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6025100

FINAL REPORT
FEASIBILITY STUDY

ACS NPL SITE
GRIFFITH, INDIANA

JUNE 1992

PREPARED FOR:
STEERING COMMITTEE
ACS PRP GROUP

...

PREPARED BY:
WARZYN INC.
ADDISON, ILLINOIS

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WARZYN INC.
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GRIFFITH, INDIANA
FEASIBILITY STUDY
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FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES NPL SITE
GRIFFITH, INDIANA

SECTION 1.0
INTRODUCTION

1.1 Authorization, Purpose, and Scope

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), has established a fund for the investigation and clean-up associated with uncontrolled hazardous waste sites. CERCLA requires the United States Environmental Protection Agency (U.S. EPA) to evaluate remedial activities, to determine the appropriate extent of the activities, and to determine that remedial measures are cost-effective. Such remedial measures must, to the extent practicable, be in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

The U.S. EPA has authority and responsibility for carrying out these requirements under CERCLA as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). The provisions for enacting the requirements of CERCLA appear in the NCP (40 CFR 300).

After discovery of a possible uncontrolled Site, a preliminary determination is made as to whether the Site presents or may present a threat to the public health or the environment. If additional action is determined to be warranted, the U.S. EPA may place the Site on the National Priorities List (NPL) of hazardous waste sites. Additional work may then be undertaken to better define potential problems, to develop and evaluate possible solutions (remedies) and to select an action based on the study results. This process for selection of remedial measures consists of the following three major elements:

- Remedial Investigation (RI)--During the RI, data is collected to define Site conditions, including the extent of releases from the Site and the character of source materials. Data on releases are evaluated to assess the potential effects of releases on public health and the environment.

- Feasibility Study (FS)--In the FS, a number of potential remedial alternatives are developed, evaluated against a range of factors, and compared against one another.

- Selection of Remedy--The U.S. EPA, in consultation with the State of Indiana, will indicate a preference for a particular remedial alternative, and prepare a Proposed Plan for the Site. This Plan, together with the RI and FS reports and other documents, are placed in the administrative record for review and comment by the public. The U.S. EPA makes a final selection of the remedy for the Site after the comments are reviewed, considered, and addressed.

This Remedial Investigation/Feasibility Study is being conducted by Warzyn Inc. (Warzyn) of Chicago, Illinois under contract with certain of the Potentially Responsible Parties (PRPs) to perform RI/FS activities for the American Chemical Services (ACS) Site. The Remedial Investigation element of the process has been completed. This Feasibility Study presents and evaluates alternatives for remedial action at the Site.

1.1.1 Report Organization

This report is organized in five sections. Section 1 is an introduction and summary of work conducted during the Remedial Investigation. Remedial action objectives are defined, and remedial action technologies are identified and screened in Section 2. Section 3 presents a preliminary screening of remedial action alternatives. The alternatives that are carried forward in Section 3 are evaluated in detail in Section 4. Section 5 presents a comparative analysis of the alternatives evaluated in Section 4.

1.1.2 Site Description

The American Chemical Services (ACS) NPL Site (Site) is located at and near 420 South Colfax Avenue in Griffith, Indiana. The Site is located in the northeast one-quarter of the southeast one-quarter, Section 2, Township 35 North, Range 9 West, Lake County, Indiana (Figure 1-1). Although the Site name is ACS, the United States Environmental Protection Agency (U.S. EPA) has defined the Site as including the ACS property (19 acres) the Pazmey Corporation property (2 acres; formerly Kapica Drum, Inc.) and the inactive portion of the Griffith Municipal Landfill (about 15 acres).

Six areas of probable waste disposal have been identified at the Site, based on preliminary reports and the review of aerial photographs. These six areas have been assigned the following designations by U.S. EPA and ACS management: the On-Site Containment Area, the Still Bottoms Area, Treatment Lagoon #1, the Off-Site Containment Area, the Kapica/Pazmey Area, and the Griffith Municipal Landfill. These designations will be used throughout this report to facilitate discussions about the Site. The location of each area is illustrated in Figure 1-2.

1.1.3 History of Site Operations

ACS began operations as a solvent recovery facility in May 1955, and according to ACS personnel, solvent reclamation was the only operation performed on-Site until the late 1960s. Solvent recovery remained the principal operation at ACS throughout its history. Small batches of specialty chemicals were first manufactured at ACS in the late 1960's and early 1970's. These early manufacturing operations included treating rope with a fungicide, bromination, and treating ski cable.

ACS installed its first incinerator in 1966, and a second in 1969. The incinerators were used to burn still bottoms and non-reclaimable materials generated at the Site, and off-Site wastes. The incinerators were located on the eastern side of the ACS compound, south of the On-Site Containment Area and west of Colfax Avenue. The incinerators were removed from the Site in 1970, when their operation was discontinued.

Between 1970 and 1975, the batch manufacturing processes were expanded. A lard oil process which utilized tallow and animal rendering was used to manufacture a lubricant product. In 1971, an additive manufacturing area was built. Various detergents, lubricants, and chemical additives were manufactured, in addition to soldering flux. An epoxidation plant was constructed in 1974. The epoxidation process creates a plasticizer.

The ACS facility ceased to perform solvent recycling in September, 1990. Until that time it operated under RCRA interim status. A closure plan has been prepared for the final closure of the Site. The nature and extent of actions required of the owner and operator in respect to the RCRA closure has not been finally determined.

The Griffith Municipal Landfill has been an active solid waste disposal facility since the 1950's. Kapica Drum, Inc. began operations in 1951. Operations at Kapica Drum, Inc. consisted of drum reconditioning. Kapica Drum was sold to Pazmey Corporation in February 1980. The Pazmey Corporation property was sold to Darija Djurovic in March 1987.

1.1.4 History of Site Disposal Practices

Still bottoms from the solvent recovery process were originally disposed of in the Still Bottoms Pond and Treatment Lagoon #1. The Still Bottoms Pond and Treatment Lagoon #1 were taken out of service in 1972. At this time, these two areas were drained and filled in with drums partially full of sludge materials.

Between 1958 and 1975, the Off-Site Containment Area was utilized as a waste disposal area. A variety of wastes were disposed of in this area, including the still bottoms from the Still Bottoms Pond and Treatment Lagoon #1. Between 1968 and 1970, wastes from on-Site incinerators were disposed of in this area. General refuse, drums, and a tank truck partially full of solidified paint were also repeatedly disposed of in the Off-Site Containment Area. It has been reported that the drums were punctured prior to disposal.

Use of the Off-Site Containment Area was discontinued in 1972, and the area was reportedly capped with 2 to 3 feet of soil.

During the mid-1960's, landfilling of drums was performed in the On-Site Containment Area (See Figure 1-2). Approximately 400 drums containing sludge and semi-solids of unknown types were reportedly disposed of in the On-Site Containment Area.

The incinerators previously mentioned operated between about 1966 or 1968 and 1970. Over this time period, approximately 2 million gallons of on-Site and off-Site waste were reportedly burned per year in the incinerators.

As part of the November 1989 environmental audit of the ACS facility by Warzyn, ACS's Part B permit application and records of past compliance inspections by IDEM were reviewed. The audit report, presented in Appendix B of the RI, describes several potential sources and possible documented occurrences of spills at the ACS Site which occurred after 1975. ACS reported that it did not have knowledge of any spills occurring after 1975.

1.1.5 Previous Investigations

The first documented regulatory agency concern for the ACS facility was apparently expressed by the Indiana State Board of Health (ISBH) on April 12, 1972.

U.S. EPA activities involving ACS began in February of 1980. At this time, U.S. EPA Region V made an Identification and Preliminary Assessment of ACS as a potential hazardous site (CDM, 3/26/85).

The first sampling at ACS by U.S. EPA was performed in May 1980 by the U.S. EPA Environmental Emergency and Investigation Branch. This sampling event centered on the Off-Site Containment Area and the Griffith Landfill. Samples were obtained of soil, leachate and surface water (USEPA, 5/8/80). A variety of organic compounds were found present in the samples analyzed, including phenol, isophorone, naphthalene, fluorene, phenanthrene, anthracene, bis (2-chloroethyl) ether, and phthalates (CDM, 3/26/85 and Weston, 10/23/89).

On September 9, 1980 an on-Site inspection/investigation was performed by the U.S. EPA Field Investigation Team (FIT). Noted during this investigation were a leachate spring along the northeast side of the Off-Site Containment Area, vegetation damage, and partially exposed drums (Ecology and Environment, 9/11/80).

In July, 1982, the U.S. EPA FIT installed four monitoring wells near the Off-Site Containment Area and the Griffith Landfill. Sampling of these wells indicated the presence of several volatile organic compounds, including chloroethane, benzene, and vinyl chloride (Weston, 12/84).

In June, 1983, an HRS score was assigned to the ACS Site. This score consisted of: Groundwater Route Score, 59.86; Surface Water Route Score, 8.89; Air Route Score, 0.00; Overall Average Score, 34.98.

On November 29, 1984, a site assessment of the ACS Site was performed by the U.S. EPA Technical Assistance Team (TAT). This site assessment centered on the Off-Site Containment Area and Treatment Lagoon #1.

In 1984, ATEC Associates, Inc. (ATEC) performed a Preliminary Hydrogeologic Site Assessment for ACS. This investigation consisted of the installation of soil borings, monitoring wells, groundwater sampling and analysis, water level measurements, and a site geophysical survey. Organic chemicals detected in the groundwater monitoring wells included benzene, ethylbenzene, toluene, and other acid/base/neutral compounds (ATEC, 1/14/85).

On June 1, 1989, the U.S. EPA TAT conducted sampling at the Griffith Landfill. Two surface water samples, and one soil sample were collected. Numerous VOCs were detected in the samples, but were also detected in the blanks. Acid/base/neutral compounds were detected in one of the water samples (Weston, 10/23/89).

An RI was conducted by Warzyn beginning in 1989. The investigation included drilling soil borings, installing monitoring wells and piezometers, excavating test pits, and collecting samples of surface water, groundwater, surface soil, sediments, buried waste and subsurface soil. Samples were also collected from domestic wells located in the vicinity of the Site. Sampling locations from the RI are shown in Figures 1-3 to 1-6.

A RCRA Closure Plan for ACS's current tank farms covered under its Interim Status Permit was submitted to the IDEM in October of 1990. The proposed Closure Plan included the emptying and cleaning of all storage tanks and ancillary piping and equipment covered under the Interim Status permit. It did not include any subsurface soil or groundwater sampling. The proposed Closure Plan also did not address other pre or post-1975 areas of the Site that could also be defined as solid waste management units (SWMUs) under RCRA. It is not known if a final closure plan has been approved by the

IDEM. The "Solids Mixing Area" located on the northern portion of the Site has been undergoing closure under a separate Closure Plan. The status of the "Solids Mixing Area" closure is not known.

1.2 Physical Setting

1.2.1 Regional Geology

The ACS Site is located in northwestern Indiana within the Calumet Lacustrine Plain, a subdivision of the Northern Moraine and Lake Region (Hartke, et al., 1975). A variety of unconsolidated materials are found within the limits of the Calumet Lacustrine Plain. These materials include fine lake silts and clays, paludal muck and peat, beach and dune sands, sand and gravel outwash, and glacial tills.

The glacial deposits in the immediate Site vicinity are approximately 130 feet thick. These deposits have been subdivided into four units: an upper sand and gravel unit, an intermediate clay unit, a lower sand and gravel unit, and a lower clay till unit which directly overlies bedrock. The uppermost bedrock in the Site vicinity consists of the Devonian Detroit River and Traverse Formations, composed of limestone with some karst (CDM, 3/26/85).

1.2.2 Site Geology

Three geologic units have been identified within the glacial deposits at the ACS Site. These units are: an upper sand and gravel unit, an intermediate silty clay unit, and a lower sand and gravel unit. The stratigraphic relationships among these units are illustrated in Figures 1-7 through 1-10, which are cross-sections of the ACS Site (Figure 1-11 is the cross-section location map).

The Upper Sand and Gravel Unit at the Site generally consists of a brown to dark gray, fine to coarse sand with trace to little fine to coarse gravel, trace clay, and trace silt. In the Site monitoring wells, the Upper Sand and Gravel Unit ranged in thickness from about 13 to 32 feet, with an average thickness of about 17 feet.

The clay layer found underlying the Upper Sand and Gravel Unit at the Site has been classified as a gray silty to lean clay with trace to some fine to medium sand and trace fine to coarse gravel. The silty clay layer was found to range in thickness from an estimated minimum of 2.5 feet at boring CB-1 to a maximum thickness of 18.1 feet at monitoring well MW-7.

The Lower Sand and Gravel Unit at the Site consists of a brown to dark gray fine to coarse sand with trace to some gravel and trace silt and pebbles. The full thickness of this unit was not penetrated in any of the borings performed for the RI. However, the driller's log for an on-Site water supply well indicates that this unit extends to bedrock at the Site. Bedrock was not encountered in any of the borings performed for the Remedial Investigation.

1.2.3 Regional Surface Water Hydrology

Regional information suggests that the ACS Site is located on a surface water divide. To the north, the runoff flows into Lake Michigan; runoff from the other directions flows into tributaries of the Mississippi River. Site data indicate that the ACS Site lies entirely within the southern drainage basin.

The U.S. Geological Survey topographic map of the region indicates that the local surface drainage is from the north to the southwest. The elevation of the ground surface is greater than 635 feet north of the Site, and slopes generally down to 630 feet west and south of the Site. The natural drainage appears to have been into a wetland located a mile south of the Site. Turkey Creek, which flows west to east approximately one mile south of the Site, is adjacent to the southern border of the wetland and these wetlands and Turkey Creek are hydrologically connected.. There appears to be no direct surface water connection between the Site and local streams or lakes. However, groundwater does discharge to the wetlands south of the Site, and those wetlands are drained by Turkey Creek one half to a mile further to the south.

1.2.4 Site Specific Hydrology

Data collected for this investigation also indicates that surface water runoff is toward the west and south. Determination of surface water runoff patterns is based on measurements at ten staff gages placed across the Site.

Surface water flows past the Site from north to south. A drainage ditch flows into the Site at the northern boundary directly north of the western ACS fence line, flows west along the northern Site boundary and into the drainage ditch cut north to south through the marsh west of the Site. In the current Site configuration, there is no indication of surface water runoff from the Site as a whole. All surface water runoff appears to be contained within the Site boundaries in the form of internal drainage or infiltration. The wetlands, groundwater and surface water may be interconnected and provide for the minor off-site release of contaminants.

1.2.5 Regional Hydrogeology

Three hydrostratigraphic units have been identified in the glacial deposits in the Site vicinity. These units include, in descending order, an uppermost aquifer (Calumet Aquifer), a clay confining layer and a lower aquifer (Valparaiso Aquifer).

The uppermost aquifer in the Site area is the Calumet Aquifer. Based on regional information (Hartke, et al., 1975), this aquifer is composed of sand and gravel, ranges in thickness from 5 to 75 feet and exhibits an average thickness of about 20 feet. Regional flow in the Calumet Aquifer is to the north or to streams or drainageways which intersect the aquifer.

Beneath the Calumet Aquifer is a clay till. The clay till ranges in thickness from negligible to about 50 feet in others. Where present, the clay till is regarded as an aquitard, separating the shallow Calumet Aquifer from the underlying Valparaiso Aquifer.

The lower aquifer in the Site area is the Valparaiso Aquifer. The Valparaiso Aquifer is composed of sand and gravel, and, ranges from about 10 to about 90 feet in thickness, (based on regional information (Hartke et al., 1975)). Water well logs indicate that the

lower aquifer may be in excess of 50 feet thick in the Site vicinity. Regional flow in the lower aquifer is to the north beneath the Site.

The majority of the private wells in the immediate Site vicinity draw water from the lower aquifer.

Limestones, dolomites, and shales of Silurian and Devonian age compose the shallow bedrock aquifer in the Site area. Private well logs indicate that the shallow bedrock aquifer is encountered at a depth of about 130 feet at the Site.

1.2.6 Site Specific Hydrogeology

Monitoring wells, piezometers, leachate headwells, and surface water staff gages were installed at the ACS Site to investigate the hydrogeologic setting. The locations of these devices are illustrated in Figure 1-5.

Upper Aquifer. Grain size analysis performed on upper aquifer samples indicated that the samples were more than 80 percent sand, with the exception of one sample from MW-5 which consisted of 43 percent gravel. Little gravel was found in the other samples, and only trace amounts of clay and silt.

In-situ hydraulic conductivity (permeability) tests were conducted at monitoring wells constructed for this investigation. Average permeability values (K) calculated for the upper aquifer material are:

Geometric Mean: $K = 7.9 \times 10^{-3}$ ft/min
4.0×10^{-3} cm/sec

Two distinct ranges of permeability are evident when the data from the in-situ hydraulic conductivity testing is plotted on a site base map. The permeability appears to be significantly greater along the eastern part of the Site than in the monitoring wells along the western part. Based on the in-situ aquifer tests, the average values for the

permeability in the upper aquifer on the east and west side are as follows:

East side Mean: $K = 1.5 \times 10^{-2}$ ft/min
7.6×10^{-3} cm/sec

West side Mean: $K = 2.9 \times 10^{-3}$ ft/min
1.5×10^{-3} cm/sec

This permeability difference is supported by permeability calculations made with the Hazen equation, as detailed in the RI Report, and by observation of coarser grained upper aquifer materials in the soil borings made on the east side of the Site.

Water level measurements were made on numerous occasions during the course of the remedial investigation. Figure 1-12 presents a groundwater table map constructed for the upper aquifer at the Site.

There are four primary hydraulic controls in the upper aquifer flow pattern which are superimposed to create the observed potentiometric surface: 1) the regional gradient; 2) discharge to drainage ditches; 3) de-watering activities at the landfill; and 4), recharge which occurs primarily at the cleared and filled areas. A fifth minor control, is a ditch which extends northward from staff gage SG-1 for several hundred feet and discharges into a marshy area having an elevation below 630 feet.

In all the watertable maps for this investigation, the fire pond has consistently exhibited the highest water elevation, and the potentiometric contour lines decline with distance from the pond. This pattern indicates that the primary groundwater flow at the Site is radially outward from the fire pond. There are minor seasonal differences in the flow pattern. However, a similar radial pattern is observed, both during the wet season and during the dry season.

Groundwater flow in the upper aquifer can be represented by the five flow paths identified on Figure 1-13. Radial groundwater flow from the fire pond mound is represented by three "spokes" extending outward. Two supplemental flow paths are also shown. Groundwater flow path #1 is from the On-Site Containment area, northwest

toward the drainage ditch in the vicinity of staff gage SG-5. Groundwater flow path #2 flows from the fire pond mound west toward discharge in the landfill excavation. Groundwater flow path #3 begins in the still bottoms area and flows southwest towards the landfill excavation. Groundwater flow path #4 begins beneath the fenced ACS facility, curves beneath the Off-Site Containment Area, and discharges to the small drainage ditch and the landfill excavation. Groundwater flow path #5 is to the east, outside the influence of the Fire Pond mound. It represents the regional flow which is diverted to the south by the groundwater mounding.

Calculations of groundwater seepage velocity in the upper aquifer have been made along each flow path.These calculations indicate that groundwater flow rates at the Site vary from about 20 feet/year to about 250 feet/year in the upper aquifer.

Lower Aquifer. Eight monitoring wells have been installed in the lower aquifer at the ACS Site. Groundwater elevations measured in these wells on several occasions illustrate a consistent north trending gradient. The potentiometric surface of the lower aquifer is illustrated in Figure 1-14.

In situ hydraulic conductivity (permeability) tests were conducted at four lower aquifer monitoring wells. The permeability (K) values of the lower aquifer material ranged from 4.2×10^{-2} ft/min at MW-9 to 4.6×10^{-3} ft/min at MW-7 and MW-10. The geometric mean value for the four tests is:

Geometric Mean: $K = 4.4 \times 10^{-2}$ ft/min
3.2×10^{-2} cm/sec

Assuming a horizontal hydraulic gradient of 0.00063 and a hydraulic conductivity value of 4.4×10^{-2} ft/min, a groundwater seepage velocity of 73 ft/year was calculated for the lower aquifer.

Vertical Gradients. Differences in groundwater elevation between the upper and lower aquifer of 9 to 13 feet were measured in the Site monitoring wells. Downward vertical gradients were calculated between the upper and lower aquifer across the clay confining layer. These calculations assume that head loss occurs only across the thickness of the

clay. The vertical gradients calculated vary from 0.71 to 1.43, with an average downward gradient of approximately 1.

Potential Leakage across the Clay Confining Layer. Estimates of potential vertical leakage across the clay confining layer were calculated using a hydraulic conductivity value of 4.8×10^{-8} cm/sec, the vertical gradient for each lower monitoring well location, and an effective porosity of 0.15. With these assumptions, it was calculated that the vertical seepage rate for groundwater between the upper and lower aquifer is between 0.24 ft/yr at MW-7 to 0.46 ft/yr at MW-10, where the clay layer is thinner. This represents the potential seepage rate for water through the clay. The calculation of a potential seepage rate for water through the clay may overstate the actual seepage and explain the lesser and slower migration of contaminants from the sources than hypothesized by calculations. Migration of contaminants has been inhibited by many other factors as demonstrated by the absence in the lower aquifer of most contaminants found at sources on the site.

1.3 Nature and Extent of Contamination

The data which were used to define the characteristics and extent of contaminated zones were collected in three phases and a Supplemental Technical Investigation (STI) during the course of the RI. The locations of sampling points for the remedial investigation are illustrated in Figures 1-3 to 1-6. Data was collected through the installation of 24 monitoring wells, 41 piezometers, 10 staff gages, 5 leachate wells, 3 soil area samples, 83 auger probes, 73 soil borings, 2 test pits, 5 surface water samples, 11 sediment samples, and 10 private well samples.

The general purpose of Phase I was to identify each zone of contamination. The purpose of Phase II, the STI, and Phase III was to document the horizontal and vertical extent of contamination and identify the homogeneity or variety of chemical constituents within each zone. Section 5 of the RI Report provides a detailed description of the contaminants found at the ACS Site, and their horizontal and vertical extent.

Sampling was conducted in the following media during the field investigation: soil/waste, groundwater, surface water, and sediment. Samples from the various media were analyzed for U.S. EPA Target Compound List (TCL) organics and Target Analyte List (TAL) metals and cyanide. Groundwater, surface water and private well samples were also analyzed for water quality indicator parameters.

Due to the relatively large number of waste constituents detected at the Site, compounds were grouped together, where appropriate, to assist in evaluating contaminant distribution. The specific compound groupings which were used are discussed below:

- BETX Compounds - Partially water soluble products from gasoline, oil and/or hydrocarbon products (i.e., benzene, ethyl benzene, toluene, xylene);

- Total Chlorinated Benzenes - Used as solvents and reagents from a variety of chemical manufacturing processes. Compounds in this group include chlorobenzene, hexachlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichlorobenzene, and 1,2,4-trichlorobenzene;

- Total Chlorinated Ethenes - Chlorinated ethenes, including tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE) and vinyl chloride. These compounds represent a potential degradation sequence, and are common industrial compounds;

- Total Chlorinated Ethanes - Chlorinated ethanes, including 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane, 1,1,1-trichloroethane, 1,2-dichloroethane, 1,1-dichloroethane, and chloroethane. These compounds represent a potential degradation sequence and are common industrial solvents;

- Ketones - Compounds found in resins, paint removers, cement adhesives and cleaning fluids (e.g., acetone, 2-butanone, 2-hexanone, 4-methyl-2-pentanone, isophorone);

- Plasticizers - Compounds associated with plastics and plastic making processes (e.g., phthalates);

- PCBs - Mixtures of chlorinated biphenyls identified as Aroclors, formerly used extensively in industrial applications.

- Polycyclic Aromatic Hydrocarbons (PAH) - A group of compounds associated with and derived from coal and oil, and the incomplete combustion of carbonaceous materials;

- Phenols - A group of chemicals of similar composition used in adhesives, epoxies, plastics and a variety of synthetic fibers and dyes. Compounds in the group include chlorinated, methylated, and nitrified phenols. Benzoic acid is also included with the phenols, because it may be a degradation product of the phenols.

Table 5-1 in the RI Report provides a listing of specific compounds placed in the above groupings. Note that the compounds listed in the table do not contain all compounds detected in the various media, nor were all listed compounds detected in each media sampled. Summaries of individual compounds detected in each sample are contained in Appendices Q and R of the RI Report.

1.3.1 Phase I Results

Results of the Phase I investigation identified three general source areas of contamination at the ACS Site (Figure 1-2).

- the On-Site Containment Area;
- the Still Bottoms/Treatment Lagoon and adjacent areas; and
- the Off-Site Containment Area and Kapica/Pazmey Area.

While the concentrations and distribution of the organic contaminant groupings varied between and within the three source areas, the organic compounds present were generally the same, with the exception of the PCBs. For example, while the BETX group generally represented the highest concentration of organic contaminants in the waste areas, elevated concentrations of BETX were closely correlated to elevated concentrations of chlorinated ethenes, chlorinated ethanes, etc. (see Figure 5-1 and 5-2 of the RI Report). However, correlation between BETX and PCBs did not exist (Figure 5-3, RI Report). Therefore, for the purpose of describing the nature and extent of organic contaminants with respect to remediation, two categories of organic contaminants can be developed:

- Organic contaminants without PCBs; and
- Organic contaminants with PCBs.

The metals data from the Phase I waste samples were evaluated in the context of the U.S. EPA Publication, Trace Chemical Element Content of Natural Soils (1983). Of the twelve metals detected in excess of the U.S. EPA "common range", total chromium and lead were the most prevalent. As shown in Figure 5-5 in the RI Report, a logarithmic plot of Phase I lead concentrations versus total chromium concentrations indicate a strong correlation in the occurrence of these two elements. Therefore, lead concentrations were selected as an indicator of TAL metals distribution in the source areas.

The phases of investigation performed after Phase I were designed to delineate vertical and horizontal extent of contamination in the source areas. The contamination encountered in each area is discussed in detail in Section 5 of the RI Report. A brief discussion of each area is presented below.

1.3.2 Landfill Area

Leachate samples were collected during Phase I from the Griffith Municipal Landfill, at leachate wells LW01 through LW04 (Figure 1-5). The TCL organics and tentatively identified compounds (TICs) detected in the leachate samples tended to be highest in samples from LW03 and LW04 located in the newer area of the landfill The six organic groupings detected in the leachate well samples included BETX, Chlorinated benzenes, Ketones, Phthalates, PAHs, and Phenols.

Concentration ranges for each organic contaminant grouping detected in the leachate well samples were as follows:

- BETX — 2.0 ug/L (LW02) to 244 ug/L (LW04)
- Chlorinated benzenes — 8.0 ug/L (LW03) to 53 ug/L (LW04)
- Ketones — 251 ug/L (LW04) to 1740 ug/L (LW03)
- Phthalates — 5.0 ug/L (LW04) to 42 ug/L (LW03)
- PAHs — 3.0 ug/L (LW04) to 43 ug/L (LW03)
- Phenols — 7.0 ug/L (LW01) to 831 ug/L (LW03)

Typically, landfill leachates have a high inorganic component due to the breakdown of the waste material. Concentrations of most TAL metals, including cyanide, in leachate samples from the Griffith Municipal Landfill were highest at LW02. The exceptions were cadmium, selenium and silver at LW03, and arsenic, potassium and thallium at LW04.

Concentration ranges for selected inorganic constituents were as follows:

- Chromium 41.2 ug/l(LW01) to 288 ug/l(LW02)
- Lead 130 ug/l(LW01) to 1370 ug/l(LW02)

Analytical results for the leachate wells are summarized in Appendix R of the RI Report.

1.3.3 Sediment and Surface Water

Sediment and surface water sample locations are shown in Figure 1-6. Sediment samples were analyzed for TCL organics and TAL inorganics.

Seven general sediment areas were sampled. The following briefly summarizes the analytical results in each of the seven general sediment sampling areas:

- ACS facility - Four of the nine organic contaminant groups were detected in SD01 and SD02. Phthalates and PCBs were detected in both samples at somewhat elevated levels, BETX and total phenols were detected in SD02 at relatively low concentrations. Lead levels at SD02 appeared slightly elevated.

- Wetlands north and west of ACS - Eight of the nine contaminant groups were detected in one or more of the six samples representing sediments in this area. With the exception of PCBs and phthalates at SD16, and total PAHs at SD10, most concentrations were relatively low. Lead and chromium levels were also somewhat elevated at SD16.

- Drainage ditch west of ACS - Three contaminant groups were detected in the two samples from this area. Total PAHs and phthalates were detected at low to moderate concentration in both SD07A and SD07B, total phenols were detected in SD07B only.

- Drainage ditch north of Landfill - Phthalates and PCBs were detected in SD07C.

- Wetland west of Landfill - Total phenols, PAHs, phthalates and ketones were detected in one or more samples from this area.

- Wetland east of Landfill - BETX, phenols, PAHs and phthalates were detected in one or both samples from this area.

- Drainage from Off-Site Containment - BETX, phenols, PAHs and phthalates were detected at relatively high concentrations at SD05 immediately west of the Off-Site Containment.

Five surface water samples were collected; two were internal to the Site, and three were on the perimeter of the Site. The following is a summary of the sampling results from each area:

- ACS facility - Trace amounts of 1,2-dichloroethene and 1,1-dichloroethane, both of which were detected in nearby soils were detected in the ACS Fire Pond (SW01). Aroclor 1248 was also reported at the detection limit at both SW01 and SW02, and is likely related to suspended solids in the surface water.

- Drainage from Off-Site Containment - Historical review indicates a ditch was cut between the Off-Site Containment area and the landfill, apparently to drain surface water toward the west. Over the years, sections of the ditch have become filled in so it is no longer a continuous surface water flow route. The surface water samples collected from this ditch (SW05) contained the highest concentrations of VOCs of the surface waters sampled with BETX (508 ug/L) and ketones (574 ug/L), as well as lower levels of chlorinated ethenes and ethanes. All the VOCs detected in SW05 were present in soils from the Off-Site Containment Area and groundwater. No pesticides or PCBs were detected in this sample.

- Ditch west of ACS - SW07A, contained chloroethane at 14 ug/L as the only detected organic target compound.

- Wetlands east of Landfill - SW08 contained toluene at 8 ug/L, and total phenols at 635 ug/L.

1.3.4 Waste/Soils

A relatively large number of compounds were detected in the waste areas. As was previously discussed, the extent of contaminated waste and soils was evaluated based on the three indicator groupings (total VOCs, total PCBs and lead). Visual observations

and HNu readings obtained from subsurface auger probes were also considered in the determination of horizontal and vertical waste extent.

Six contaminant-extent base maps were developed for the RI Report (Figures 5-6 through 5-11 of the RI Report). A series of overlays were developed for each base map for discrete sampling depths (labeled as Figure 5-6a, 5-6b, etc.). Detailed discussion of these overlay maps, and the individual waste areas at the ACS Site are presented in Section 5 of the RI Report. The following discussion provides a general summary of each waste area.

On-Site Containment Area. The On-Site Containment Area is a rectangular shaped area, approximately 250 feet north to south and 450 feet west to east, located in the northern third of the fenced ACS facility (Figure 1-2). Historical information and subsurface investigations during the RI indicate that drums are buried beneath at least a portion of this area. The buried drums are found in an area approximately 50 feet by 50 feet in size, and appeared to be stacked three high in the test pit excavation. It is possible that the drums represent the major source of potential contaminants in this area.

With the exception of a few localized areas in the western half of the On-Site Containment Area, most of the contaminants are non-PCB containing organic waste.

All nine organic-compound groups were detected in the On-Site Containment Area. Generally the highest concentrations were detected in samples from test pit TP02, which showed buried drums. Concentration ranges for the organic compound groups (with the exception of PCBs) in the remaining subsurface soil samples are as follows:

· BEXT	11 ug/kg to 3,002,000 ug/kg
· Chlorinated Benzenes	2 ug/kg to 10,790 ug/kg
· Chlorinated Ethenes	2 ug/kg to 1,110,000 ug/kg
· Chlorinated Ethanes	1 ug/kg to 11,000 ug/kg
· Ketones	4 ug/kg to 7,400 ug/kg
· Phthalates	39 ug/kg to 15,086 ug/kg
· PAHs	50 ug/kg to 121,338 ug/kg
· Phenols	93 ug/kg to 2270 ug/kg

PCB contaminated wastes were detected only in the western half of the On-Site Containment Area, and were relatively localized horizontally. Total PCB concentrations in the On-Site Containment Area samples ranged from 130 ug/kg to 26,000 ug/kg.

Elevated metals in the On-Site Containment Area appear to be limited to near surface soils in the western half of the Area.

Still Bottoms/Treatment Lagoon Area. The Still Bottoms Area is an oval area approximately 100 feet in diameter in the central portion of the fenced ACS facility. The Treatment Lagoon Area is an oval area approximately 200 feet by 100 feet located between the ACS Fire Pond and the Still Bottoms Area (Figure 1-2).

As with the On-Site Containment Area, most of the contaminants detected in the Still Bottoms/Treatment Lagoon are non-PCB containing organics. Localized areas of PCB containing wastes were detected in the Still Bottoms and some metals were detected in both areas.

All nine organic compound groups were detected in the Still Bottoms and Treatment Lagoon Areas, and for the most part, highest concentrations were detected in samples from test pits which encountered buried drums. Concentration ranges for the organic compound groups (with the exception of PCBs) in subsurface soil samples including test pits are as follows:

- BEXT - 66 - 34,670,000 ug/kg
- Chlorinated Benzenes - 45 - 62,500 ug/kg
- Chlorinated Ethenes - 31 - 2,000,000 ug/kg
- Chlorinated Ethanes - 8 - 21,000,000 ug/kg
- Ketones - 55 - 4,100,00 ug/kg
- Phthalates - 456 - 4,694,000 ug/kg
- PAHs - 351 - 1,057,900 ug/kg
- Phenols - 429 - 194,00 ug/kg

PCBs were not detected in the Treatment Lagoon Area. Total PCB concentrations in the Still Bottoms Area samples ranged from 330 ug/kg to 74,000 ug/kg.

Chromium and lead were the primary inorganic constituents detected. Total chromium ranged from 8.7-1410 mg/kg, and lead ranged from 21.9-6300 mg/kg. Antimony, cadmium, copper, magnesium, mercury, selenium, and zinc were also detected.

Area West of Fire Pond. An area of contaminated subsurface soils was discovered west of the existing ACS Fire Pond during the RI. One soil boring, SB20, was conducted in this area, and a sample of the contaminated soil collected.

Concentrations of the organic compound groups for this location were similar to those east of the Fire Pond, with all nine compound groups being detected. Metals concentrations were not elevated in this area.

Former Incinerator Area. The former incinerator area is a square 50 by 50 foot area located along the eastern portion of the fenced ACS facility. Total indicator contaminant concentrations in surface soils (SA03) from the former incinerator location were considerably less than in the waste disposal areas of the fenced ACS facility.

Total VOC concentration in SA03 was 980 ug/kg, with BETX as the only VOC group detected. Total PAHs were detected at 50 ug/kg, and total phthalates at 2600 ug/kg. The remaining organic compound groups, including PCBs, were not detected in SA03. TAL metal concentrations were not elevated at this location.

Off-Site Containment Area. The Off-Site Containment Area is located south of the fenced ACS facility. It is an approximately 300 by 400 foot area formerly used by ACS as a disposal area for drums of waste materials and still-bottom sludges. The greatest volume of wastes detected in this area are non-PCB organics. However, PCBs and metals were detected primarily in one localized area at depth in the northern portion, as well as at a number of small areas in the southern portion of the Off-Site Area.

The following concentration ranges of each organic contaminant group (with the exception of PCBs) were detected in the Off-Site Containment area samples:

· BEXT	17 - 254,500,000 ug/kg
· Chlorinated Benzenes	3 - 1,000,000 ug/kg
· Chlorinated Ethenes	44 - 65,000,000 ug/kg
· Chlorinated Ethanes	8 - 151,330,000 ug/kg
· Ketones	52 - 197,600,000 ug/kg
· Phthalates	54 - 19,136,000 ug/kg
· PAHs	273 - 3,487,700 ug/kg
· Phenols	180 - 1,054,000 ug/kg

PCB concentrations in the soil and wastes in the Off-Site Containment Area are, for the most part, found at concentrations of less than 50 ppm. These levels of PCBs occur in scattered, localized areas at various depths between the Kapica building and a surficial waste seep near the southwest corner of the off-Site area. Actual total PCB concentrations in the Off-Site Containment Area samples ranged from 96 ug/kg to 1,400,000 ug/kg.

The distribution of wastes/soils in the Off-Site Containment potentially contaminated with metals is similar to that of the PCB wastes, but to a lesser extent.

Kapica-Pazmey Area. The Kapica Drum recycling area is located in the far southeastern corner of the Off-Site Containment Area. The Kapica Area was used to recycle and clean drums for the ACS facility, as well as other non related customers. Observations in this area and results of the RI indicate that much of the waste was apparently disposed of directly on the ground surface.

All nine organic contaminant groups are present in the Kapica/Pazmey Area. Concentration ranges of each organic contaminant group with the exception of PCBs were as follows:

· BEXT	1 - 46,300,000 ug/kg
· Chlorinated Benzenes	18 - 27,000 ug/kg
· Chlorinated Ethenes	2 - 960,000 ug/kg
· Chlorinated Ethanes	5 - 1350 ug/kg
· Ketones	2 - 367,000 ug/kg

• Phthalates	177 - 698,100 ug/kg
• PAHs	54 - 157,300 ug/kg
• Phenols	280 - 34,300 ug/kg

Soils containing PCBs at levels in excess of 1 ppm are found primarily in an area north of the Kapica building. Actual PCB concentrations in the Kapica area ranged from 4,200 ug/kg to 280,000 ug/kg.

Metals contaminated soils in the Kapica area are primarily found to the west and north of the Kapica building.

1.3.5 Groundwater

Twenty-four groundwater monitoring wells (MW01 through MW24) were installed during the Site RI (Figure 1-5). Eight of the 24 monitoring wells (MW07, MW08, MW09, MW10, MW21, MW22, MW23, and MW24) are screened in the lower aquifer. The remaining 16 wells are water table wells.

The following discussion reviews the organic and inorganic character of the groundwater in the upper and lower-aquifers, and presents a comparison among the potential contaminant source areas.

Upper Aquifer. The occurrence, concentration and distribution of contaminants in the upper aquifer reflects the groundwater flow paths previously described. As groundwater flows from the Fire Pond toward the Griffith Municipal Landfill dewatering pit, some of the relatively soluble, and therefore more mobile, organic constituents associated with source areas are detected downgradient.

As with the buried wastes, the BETX group of organic compounds was widely distributed in the upper aquifer and was present at the highest concentration relative to other contaminants detected in the upper aquifer monitoring well samples. Figure 1-15 shows that the distribution of BETX contamination in the upper aquifer well samples and aquifer matrix samples occurs in essentially two contaminant plumes. The highest total BETX concentrations were detected at MW03 (106,000 ug/L - Round 2). This well is located downgradient of the On-Site Containment Area under steady state groundwater

flow conditions as were present during the second sampling round conducted in May 1990. Benzene, for the most part, was the predominant constituent compound detected within the BETX grouping.

Chlorinated ethanes were as widespread in the upper aquifer samples as the BETX group, however, overall concentrations were generally lower, with the plume centered downgradient of the Off-Site Containment Area (Figure 1-16).

The highest concentrations of chlorinated ethanes were detected at MW16 (4,000 ug/L - Round 2); at this location the predominant constituent compound was 1,1-dichloroethane (2,400 ug/L, with chloroethane at 1,600 ug/L). MW16 is located immediately downgradient of the Still Bottoms and Off-Site Containment Area. Both of these areas contained elevated concentrations of the heavier chlorinated ethanes.

The remaining organic contaminant groupings were considerably less widespread than the BETX and chlorinated ethanes and, with exception of the ketones, were at considerably lower concentrations.

Ten trace metals were detected in one or more upper aquifer well samples at concentrations at least five times the background well (MW11). Iron and potassium were also detected at concentrations that may be at least partially attributable to ACS wastes or the Griffith Municipal Landfill, rather than aquifer geochemistry. Apparently, elevated trace metal concentrations occurred most frequently in samples from MW03 and MW04 adjacent to the On-Site Containment Area, and MW06 adjacent to the Off-Site Containment area. Trace metals detected include: arsenic, barium, cadmium, total chromium, manganese, mercury, nickel, potassium, selenium, vanadium, and zinc.

Lower Aquifer. Lower aquifer contamination relative to the upper aquifer is limited, both with respect to nature of compounds detected and the extent. Considerable attenuation of contaminant levels downgradient of the impacted area is apparent.

The only TCL organics detected in lower aquifer monitoring wells were: chloroethane, bis(2-Chloroethyl)ether, and 4-Methyl-2-pentanone. Trace metal concentrations greater than five times background were not detected in the lower aquifer wells.

Private Wells. Private well sampling was performed at eight locations during Phase II of the RI, and 2 locations during Phase III. TCL volatiles, semivolatiles and pesticide/PCBs were not detected in the private well samples. Trace metals detected in private well samples included barium, cadmium, lead, and zinc. These elements were not elevated in the lower aquifer sample collected at the Site and the latter three may be attributable to the water distribution system.

1.4 Contaminant Fate and Migration

Groundwater provides a primary migration pathway by which contaminant transport may occur. This section describes the potential behavior of the identified chemical contaminants within the groundwater system.

The fate and migration of organic contaminants in the subsurface environment can be affected by a number of chemical and physical reactions including hydrolysis, oxidation, reduction, volatilization, adsorption and biodegradation. The major reactions effecting chemical transport in groundwater, however, are sorption (adsorption plus absorption) and biodegradation (Olsen and Davis, 1990).

Through application of the distribution coefficient (K) to saturated zone contaminant transport, a contaminant's retardation factor (R) can be estimated. The retardation factor describes the affect of sorption in decreasing the rate of contaminant transport in the liquid phase relative to a conservative or nonreactive species (R = 1). For example, if R = 10, the contaminant chemical moves at one-tenth the velocity of the groundwater.

Distribution coefficients were calculated for several representative contaminant compounds (Table 6-2, RI Report) based on total organic carbon (TOC) concentrations for aquifer soils obtained during Phase II drilling and from the compound specific organic carbon partitioning coefficient K, (U.S. EPA, 1986).

Retardation factors were calculated based on the calculated K values, the aquifer porosity (n) and bulk density (P). Values representative of upper and lower aquifer soils along the eastern (MW07) and western (MW09) portion of the Site are summarized in Table 6-2 of the RI Report. Retardation factors ranged from 1.26 (acetone) to 62,693 (PCBs) for the confining layer at MW07 and 1.15 (acetone) to 36,955 (PCBs) at MW09.

Transport velocities for the upper aquifer organic contaminants were calculated using the calculated range of vertical seepage rates and retardation factors. Theoretical transport velocities across the confining layer range from 0 ft/yr (essentially immobile) for PCBs across the entire Site, to 0.399 ft/yr for acetone in the vicinity of MW09, assuming a seepage rate of 0.46 ft/yr. Therefore, assuming the thickness of clay beneath areas of contaminated groundwater in the upper aquifer to range from 6 ft to 15 ft, potential acetone migration across the confining layer would take approximately 15 to 37 years. Given the capacity of the confining layer to attenuate the migration of organic contaminants, it is not surprising that only minor contamination has been detected in the lower aquifer.

Theoretical contaminant transport velocities were also calculated along the five upper aquifer groundwater flow paths illustrated in Figure 1-13. Calculated retardation factors, based on upper aquifer soils at MW07 were used to generate theoretical transport velocities along Flow Path #5. Calculations along the remaining flow paths were based on upper aquifer soils at MW09.

Potential acetone migration ranged from approximately 19 ft/yr along Flow Path #3 to 128 ft/yr along Flow Path #2. However, acetone was not as prevalent in waste and groundwater samples as BETX, chlorinated ethenes and chlorinated ethanes and so does not accurately represent the overall plume movement from identified source areas.

Benzene is the most mobile of the BETX compounds. Transport velocities for benzene range from approximately 7 ft/yr along Flow Path #5 to 54 ft/yr along Flow Path #2. Based on these transport velocities, it would take approximately 25 to 190 years for benzene to migrate one-quarter mile downgradient, assuming adsorption is the only

attenuation mechanism. Ethylbenzene, toluene and xylene transport velocities are less than half those of benzene. This difference is probably a contributing factor to the higher occurrence of benzene in downgradient groundwater samples, in comparison to other BETX constituents.

1,1-Dichloroethene is the most mobile constituent of the chlorinated ethene group. Transport velocities for this compound range from 13 ft/yr along Flow Path #3 to 88 ft/yr along Flow Path #2. The least mobile constituent of the group is tetrachloroethene. Velocities for this compound range from 1.7 ft/yr along Flow Path #5 to 18 ft/yr along Flow Path #2. 1,1-Dichloroethene was the most widely detected of the chlorinated ethenes which is consistent with its relative mobility. However, the chlorinated ethenes as a group were considerably less widespread than either the BETXs or chloroethane, which, may suggest other mechanisms (e.g., biodegradation) as the primary attenuating factor for this group.

Chloroethane was the predominant chlorinated ethane detected in the upper aquifer. 1,1-Dichloroethane was also detected, but considerably less frequently. The calculated transport velocity for 1,1-dichloroethane ranges from 16 ft/yr along Flow Path #3 to 107 ft/yr along Flow Path #2, which is more than two times those for chloroethane; 5 ft/yr (Flow Path #5) to 44 ft/yr (Flow Path #2).

The calculated horizontal seepage rate in the lower aquifer is 73 ft/yr. The theoretical transport velocity for chloroethane in the lower aquifer was calculated as 22.3 ft/yr compared to 57.3 ft/yr for bis(2-chloroethyl)ether. Based on the above values, it would take approximately 60 years for chloroethane and 23 years for bis(2-chloroethyl)ether to migrate one-quarter mile downgradient. These estimated migration times assume no other attenuating mechanisms.

Migration of contaminants has not occurred at the rate or rates calculated. Apparently, a combination of factors, indigenous to the Site, have served to retard migration, with the result that the bulk of contaminants of concern remain near source locations.

Evidence of reductive dechlorination at the Site is apparent. Chlorinated ethenes and chlorinated ethanes are present with a non-halogenated carbon source (BETX, ketones, etc.) under anoxic conditions. While high concentrations of trichloroethene and trichloroethanes were detected in the waste areas, chloroethane, a probable degradation product was the predominant chlorinated constituent in the downgradient groundwater.

The biodegradation of BETXs has also been documented (Barker and Patrick, 1987; Borden et al., 1986), however these investigations show oxygen is the primary electron acceptor. Therefore, these compounds appear to degrade more readily under aerobic conditions (Bouwer and McCarty, 1981). Aerobic degradation of BETX, likely is significant in the vadose and at the water table. In addition periodic fluctuations in groundwater levels would facilitate oxygenation of the upper aquifer. Evidence of anoxic conditions in groundwater immediately adjacent to the Site, however, may in part be responsible for the predominance of BETX in the upper aquifer (see Section 5.5 of the RI Report). As dissolved oxygen concentrations increase further downgradient of the Site, natural aerobic biodegradation may be the major mechanism for BETX mass decrease.

Contamination of surface water and sediment occurs primarily through overland transport of contaminated soils through erosion and/or discharge of contaminated groundwater. The majority of wastes at the Site were buried and therefore are not currently subject to surface erosion. However, two areas of surface soil contamination were identified during the RI; the former incinerator area located in the ACS facility; and the Kapica/Pazmey Area (see Figure 1-2).

Surface topography, vegetative cover and soil composition vary between these two locations. The former incinerator area is covered in gravel, as is most of the ACS facility. While runoff from the gravel may occur in areas of compaction, slope within the facility is relatively flat and potential for erosion of gravel and contaminated soil would be low. When runoff does occur, it likely follows the facility drainage system toward the ACS Firepond.

Surface soils in the vicinity of the Kapica/Pazmey Area are mostly vegetated. Topography in this area generally slopes to the north and west toward the low area between Off-Site Containment Area and the Griffith Municipal Landfill. Surface water and sediment samples (SW05 and SD05) collected in this low area generally contained the highest concentrations of contaminants detected. This would indicate runoff has or continues to occur in this area.

Discharge of contaminated groundwater to the surface wetlands may occur along western portions of the Site. Two predominant zones of upper aquifer contamination were identified during the RI west of the ACS facility and west of the Off-Site Containment Area. BETXs and chloroethane were the predominant contaminants detected.

BETXs and chloroethane (and to a lesser extent ketones) were detected in hydraulically connected downgradient (west) sediment and surface water samples. Discharge of contaminated groundwater may be a contributing factor to contamination in these areas.

1.6 Summary of Baseline Risk Assessment

The purpose of the baseline risk assessment is to evaluate the potential health risks of the Site with regard to a variety of exposure scenarios. If no risks are calculated for the exposure scenarios examined, then the no action alternative may be appropriate. If risks are calculated for certain scenarios, (such as direct contact with contaminated soils by future Site trespassers), then remedial actions are warranted to prevent the risks (such as covering the soils to prevent direct contact).

It is emphasized that the risk factors developed in the Baseline Risk assessment may not represent the actual risks at the Site. The calculated risks are only applicable to the extent that the exposure scenario is recognized. For instance, although the baseline risk assessment calculates risk for ingestion of contaminated groundwater, there are no current groundwater users that have been impacted by the Site.

The following sections provide a general summary of the results of the baseline risk assessment. Detailed results and interpretations are presented in the Baseline Risk Assessment, Volumes 1, 2 and 3 September 1991.

The Baseline Risk assessment was performed consistent with the Risk Assessment Guidance for Superfund (RAGS, U.S. EPA 1989) in coordination with the U.S. EPA RPM and Technical Support Group.

1.6.1 Uncertainties in the Risk Assessment Process

The risk assessment process incorporates numerous assumptions and is therefore associated with some degree of uncertainty. Calculated risk estimates are based upon reasonable worst case scenarios, and may or may not be realized at the Site. Proper interpretation of health risk values requires consideration of the uncertainties and assumptions involved in the risk assessment calculations. In addition, the risk assessment uses hypothetical scenarios and conservative assumptions to quantify potential risks for current and future land uses which may or may not reflect actual risks.

1.6.2 Quantification of Potential Risk

Non-cancer health effect risks were estimated by calculation of hazard quotients (HQ). For a given exposure pathway, the hazard quotients for all chemicals of concern are added to arrive at a total. This total value is referred to as the hazard index (HI) for the exposure pathway. A HI or HQ in excess of unity (1) may represent a potential health risk associated with exposure via a particular pathway or chemical.

The cancer risk value is an estimate of an individual's lifetime likelihood of developing cancer over and above the existing background chance of developing cancer. A cancer risk of 1×10^{-6}, for example, may be interpreted as an increased risk of one in one million of developing cancer over a person's lifetime. This risk may also be interpreted on a population basis, to predict that one additional case of cancer may occur in a population of one million people. For known or suspected carcinogens, the 1×10^{-6} risk

level is used by U.S. EPA as a "point of departure". Cancer risks which are between 1 x 10^{-6} and 1 x 10^{-4} may or may not warrant remediation, depending on other risk management factors.

1.6.3 Potential Health Risks Based on Current Land Use

The current land use scenario is a reasonable worst case situation that could occur if the Site is left unchecked and unremediated with no action taken to minimize any migration from, or direct exposure to, contaminants at the Site. Current land use health risks associated with exposure to contaminated Site media were evaluated for off-Site residents, trespassers, and on-Site workers at the ACS facility. The assumed degree of exposure to populations from the pathways in the risk assessment is based upon common assumptions which probably result in risk assessments that are conservative.

Off-Site residents were considered to be exposed to contaminants released to groundwater and air under current land use conditions. Although these exposures were created hypothetically for this report, it is not inconceivable that these conditions may be realized in the future given current land use conditions. Risk to adults and children was considered separately, as was exposure to groundwater from the lower and upper aquifers. Risks to off-Site residents which might occur if off-Site residents were actually exposed under this scenario included:

- A non-cancer hazard index (HI) greater than 1 for children primarily as a result of dermal exposure to 4-methyl-2 pentanone (54% of the risk).
- A total cancer risk to children exposed to groundwater from the upper aquifer of 1.7 x 10^{-2}, attributed mainly to dermal exposure to benzene.
- A total pathway HI for off-Site residents exposed to contaminants in air and groundwater of 2.1.
- A total cancer risk for off-Site adults of 4.5 x 10^{-4}, attributable mainly to ingestion of arsenic and bis(2-chloroethyl) ether from groundwater.

Site trespassers were assumed to be exposed to contaminants from surface soils, surface water, sediments, and fugitive dusts and volatiles. Quantified risks for this scenario included:

- A total HI for all pathways of $1.9 \times 10^{+1}$, due mainly to ingestion and dermal absorption of surface soils at Kapica-Pazmey.
- A total cancer risk for all pathways of 6.3×10^{-3}, attributed mainly to dermal contact with benzene, inhalation of volatiles, and exposure to PCBs.

ACS facility workers were assumed to be exposed hypothetically via inhalation of fugitive dusts from Kapica-Pazmey and volatiles released from buried waste. Risks for this hypothetical scenario included:

- A HI of 9.9, due mainly to VOC emissions from buried wastes.
- A cancer risk of 1.6×10^{-3}, due mainly to inhalation of VOCs (primarily 1,1-dichlorethene, chloroform, and carbon tetrachloride).

1.6.4 Potential Health Risks Based On Future Land Use

Future land-use health risks were based on exposure to contaminated Site media by residents living on-Site. This is assumed to be the reasonable worst case scenario. Residents were assumed to be exposed to soils at specific parts of the Site independent of the other areas, e.g., the Off-Site Containment area exclusively. The only difference in risk associated with each specific portion of the Site came from soil exposure, since exposure to groundwater and surface water was assumed to be the same throughout the Site. Risks associated with this future land use scenario included:

- The non-cancer hazard index for exposure to contaminated groundwater from the upper aquifer was estimated at $3.3 \times 10^{+2}$, due primarily to dermal exposure to 2-butanone. The cancer risk was approximately 8.7×10^{-2}, due mainly to benzene exposure.
- The non-cancer hazard quotients for surface water and sediments are less than unity. The cancer risk due to surface water exposure was 1.6×10^{-4}, attributed mainly to dermal exposure to PCBs. Sediment cancer risk was 2.2×10^{-4}, as a result of exposure to carcinogenic PAHs and PCBs.

- The non-cancer hazard index for inhalation of VOCs was $1.6 \times 10^{+1}$, due primarily to exposure to n-chain alkanes. The cancer hazard risk was 2.7×10^{-3}, as a result of possible exposure to 1,1-dichloroethene, carbon tetrachloride, and chloroform.

- Non-cancer HI values in excess of unity and cancer risk estimates associated with exposure to soils in the various Site areas were due to the presence of various volatile organics and metals. Among the chemicals of concern were tetrachloroethene, PCBs, carbon tetrachloride, and PAHs.

- The non-cancer hazard quotient and cancer risk appeared greatest for a resident residing at the Off-Site Containment Area ($1.0 \times 10^{+3}$ and 1.5×10^{-1}, respectively).

1.6.5 Summary of Ecological Assessment

Warzyn completed a draft of an ecological assessment for the site. U.S. EPA commented on the draft, but consensus could not be reached on resolution of the comments. Therefore, a consultant for the U.S. EPA prepared the final ecological assessment for the Site under U.S. EPA direction. The results of the ecological assessment performed by the U.S. EPA indicate that there may be possible ecological risks at the Site based on conservative worst case assumptions, but they are difficult to quantify. The U.S. EPA ecological assessment shows that:

- Contaminants of potential ecological concern in water at the ACS Site may include lead, iron, zinc, cadmium, mercury, cyanide, PCBs, chlorobenzene, benzene, diethyl phthalate, and bis (2-ethylhexyl) phthalate.

- Contaminants of potential ecological concern in soils and sediments at the ACS Site may include arsenic, cadmium, chromium, copper, lead, mercury, zinc, PCBs, benzene, toluene, ethylbenzene, xylene, bis (2-ethylhexyl) phthalate, heptachlor epoxide and PAHs.

- The major risk to burrowing rodents appears to be from exposure to PCBs resulting from potential exposure to browse grown in contaminated soil and incidental ingestion of contaminated sediments.

- Upland, wetland, and aquatic receptors may be adversely affected by contaminants present in the environmental media within the ACS Site watershed. The contaminants posing the greatest ecological risk include PCBs and lead. In addition, various metals, bis (2-ethylhexyl) phthalate and heptachlor epoxide pose a potential risk to aquatic receptors and mink.[1]

1. Mink have not been observed in the area.

Calculated exposure levels from the BRA were used to establish potential maximum soil design concentrations. Potential minimum soil design concentrations were established by calculating weighted arithmetic averages for individual contaminants based on a ratio of the number of detects to the total number of soil samples collected from each area. Tables 4-8 through 4-12 present potential minimum and maximum soil design concentrations by chemical grouping for each area. An example of the calculation used in determining the weighted average soil concentrations is presented as an Addendum to Table 4-8. Potential minimum soil design concentrations were used, where applicable, in design calculations and preparation of the primary cost estimate for each alternative.

Chemical groupings for TICs established in the BRA were used in the calculation of groundwater and soil design concentrations. Chemical groupings for TICs were incorporated into previously established chemical groups for the FS based on chemical similarities. Table 4-13 shows the placement of TICs into chemical groupings for incorporation into the FS. Calculated exposure levels from the BRA for each TIC chemical grouping were treated as constants and used in the calculation of both minimum and maximum soil and groundwater concentrations.

A total VOC level of 10 parts per million (ppm) was the criteria used to delineate areas and depths to be included in the calculation of the soil volume requiring treatment for the purpose of evaluating soil treatment process options. This delineation was based on total VOCs only since data from the RI shows a direct correlation between the concentrations of VOCs and SVOCs detected in the source areas. A 10 ppm total VOC level was used as the criteria for soil volume delineation since it encompasses all of the source areas where elevated contaminant concentrations were detected, and was considered to be an appropriate level for the successful implementation of soil treatment process options retained for detailed analysis. A uniform depth of VOC-contaminated soil presence using surface areas depicted in Figure 4-2 was not assumed in the calculation of volume. The depth requiring treatment for each cross-sectional area was assumed to be the maximum depth meeting the criteria outlined above based on sampling intervals used during the RI. Cross-sectional drawings delineating defined areas of VOC-contaminated soils would have to be prepared during the final design.

At the request of the U.S. EPA, an attempt was made to delineate areas where SVOC concentrations in soils currently exceed acceptable risk levels in the RI for potential future site use scenarios. The purpose of the delineation was to determine the additional soil volume that would have to be removed in order to meet acceptable risk levels for potential future site use scenarios involving alternatives using soil treatment process options that are more effective at removing VOCs than SVOCs. It is noted that the only exposure scenario that presents a concern is potential direct contact with contaminated soils that may be excavated in the future. Groundwater exposure would not be a concern because the SVOC contaminants have not migrated significantly to groundwater. Direct contact with contaminated surface soils would be prevented by providing a soil cover. Results of the evaluation showed that areas and depths of SVOC concentrations currently in excess of acceptable health risk levels for potential future site use scenarios encompass the entire soil volume delineated by the criteria of 10 ppm total VOC level. It is noted that the majority of samples collected from the On-Site Containment Area were not analyzed for SVOCs. Because the concentrations of SVOCs can be correlated to VOCs in samples collected from other source areas, SVOC concentrations in the On-Site Containment Area are expected to be in excess of acceptable risk levels for future site use scenarios.

All of the treatment technologies that are being considered would treat some SVOCs to some degree. Therefore, it is not possible to predict what the calculated risk levels for individual SVOCs would be in the site soils after treatment. If it is assumed that no SVOCs would be removed with the VOCs, then the volume of soil that would have to be removed in order to meet acceptable SVOC risk levels for future site use scenarios would essentially be equal to the entire soil volume using the above-mentioned criteria. Since Alternatives 7 and 8 involve the removal of the entire soil volume for above-ground treatment using process options capable of treating both VOCs and SVOCs, the delineation of SVOC concentrations in excess of currently acceptable risk levels for future site use scenarios was not presented in the FS. Alternatives 2, 3, 4, 5, and 6 would leave some volume of SVOCs in the ground after treatment of VOCs.

4.1.3 Criteria Definitions

The detailed evaluation process used in this Feasibility Study was developed on the basis of the U.S. EPA Interim Final "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA" (October, 1988). The Interim Final Guidance was developed based on the statutory requirements of CERCLA, program initiatives promulgated in the revised National Contingency Plan, and experience gained in the Superfund program.

Nine criteria serve as the basis for conducting the alternative screening and detailed analysis during the Feasibility Study and for subsequently selecting an appropriate remedial action. The evaluation criteria are as follows:

- Overall protection of human health and the environment;
- Compliance with applicable or relevant and appropriate requirements (ARARs);
- Short-term effectiveness;
- Long-term effectiveness;
- Reduction of toxicity, mobility, and volume;
- Implementability;
- Cost;
- State acceptance; and
- Community acceptance.

Assessments of the first two criteria, overall protection of human health and the environment and compliance with ARARs, relate directly to statutory findings that must ultimately be made in the Record of Decision. Therefore, these criteria must be met by each alternative. The next five criteria represent the primary criteria upon which the screening or evaluation is based. State acceptance of the preferred alternative will be addressed subsequent to the public comment period on the Feasibility Study and proposed plan. Community acceptance will be fully addressed subsequent to the public comment period and review of the proposed plan.

Each of the nine evaluation criteria have been further divided into specific factors to allow a thorough analysis of the alternatives. These factors are discussed in the following subsections.

Overall Protection of Human Health and the Environment

This criterion gives an assessment of whether each alternative provides adequate protection of human health and the environment. The overall assessment takes into account the assessments conducted under all other evaluation criteria, especially long- and short-term effectiveness and compliance with ARARs. The assessment of overall protection should focus on whether an alternative achieves adequate protection, and describe how Site risks are reduced, controlled or eliminated by the implementation of that alternative.

Compliance with ARARs

This criterion is used to determine how each remedial alternative complies with applicable or relevant and appropriate Federal and State Requirements (ARARs), as defined in CERCLA Section 121(d). The three general categories of ARARs are chemical-, location- and action-specific. Section 3.2 describes the process used to perform the ARARs evaluation and initially identifies potential ARARs for the Site. The potential ARARs for the ACS Site are listed in Tables 3-2, 3-3 and 3-4.

Long-Term Effectiveness and Permanence

This criterion addresses the extent of residual risk remaining at the Site after the remedial objectives have been met. The following factors are addressed by this criterion:

- Magnitude of total residual risk: this factor assesses the long-term risk associated with exposure to treatment residuals and untreated residual contamination.

- Adequacy and suitability of controls: this factor addresses the type and degree of long-term management, monitoring, and operation and maintenance functions that must be performed. This factor also addresses the ability of technologies to meet the required process efficiencies or performance specifications.

- Reliability of controls over time: this element assesses the adequacy and suitability of controls, if any, that are used to manage treatment residuals or untreated wastes that remain on-Site. It includes the assessment of potential exposure and the associated risks should the remedial action need replacement.

Reduction of Toxicity, Mobility or Volume Through Treatment

This criterion addresses the preference stated in CERCLA Section 121 that remedial alternatives which employ technologies that permanently and significantly reduce the toxicity, mobility or volume of contaminants be selected. This preference is satisfied when treatment is used to reduce the principal threats at a Site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media. The following specific factors are taken into consideration for each particular remedial alternative by this criterion:

- Treatment process: the effectiveness of the treatment process at minimizing the toxicity, mobility and volume of contaminants, as well as any special requirements for the treatment process are addressed by this factor.

- Amount of hazardous material destroyed or treated: this factor evaluates the mass and volume of contaminated material destroyed or treated. Also evaluated are the type and quantity of treatment residuals produced, as well as the irreversibility of the treatment itself.

- Whether the alternative would satisfy the statutory preference for treatment as a principal element.

Short-Term Effectiveness

This criterion addresses the effects of each alternative during the implementation phase until the remedial objectives have been attained. The following factors of this criterion are addressed for each remedial alternative:

- Potential impacts on the community during remedial action implementation: this factor addresses risk that results from the implementation of the remedial action, such as air pollutant emissions that might affect community health.

- Potential impacts on workers during remedial action: this aspect of short-term effectiveness addresses threats that might be posed to workers during the implementation of a remedial action, as well as the effectiveness and reliability of protective measures that could be taken on-Site to mitigate those threats.

- Potential environmental impacts: this factor addresses the potential adverse effects on the environment resulting from the implementation of an alternative, and the effectiveness and reliability of measures that may be taken to mitigate the adverse effects.

- Time until protection is achieved: this factor includes an estimate of the time required to achieve remedial objectives on-Site.

Implementability

The implementability criterion addresses the technical and administrative feasibility of implementing an alternative, as well as the availability of services and materials required for its implementation. The following factors are analyzed by this criterion:

- Technical feasibility: this factor addresses the difficulties and unknowns associated with the remedial technologies proposed in each alternative as well as their reliability. Most alternatives will require some level of pre-design testing. Substantial bench-scale and pilot testing may be required for technologies which have not been proven feasible. Future remedial actions that might be required and their ease of implementability are also evaluated.

- Administrative feasibility: the level of agency activity needed to coordinate the implementation of the alternative is evaluated.

- Availability of services and materials: this factor involves the examination of the availability of adequate treatment, storage or disposal facilities, the existence of multiple vendors, and the availability of needed equipment and specialists required for implementation of each alternative.

Cost

The application of cost estimates to alternatives evaluation is addressed by the following factors:

- Capital: The direct and indirect capital costs associated with each remedial alternative are evaluated. Direct capital costs may include construction, equipment, land and Site development, buildings and services and waste disposal costs. Indirect capital cost may include engineering expenses, legal fees, license or permit costs, start-up costs and contingency allowances.

- Operation and Maintenance: Operation and maintenance (O&M) costs are post-construction costs necessary to maintain the future effectiveness of a remedial action. These costs include maintenance, materials and labor costs, operating labor costs, energy, disposal of residues, insurance, taxes, costs of periodic Site reviews and licensing.

- Present Worth: Present worth analysis allows the evaluation of future expenditures for each remedial alternative relative to a common base year. It is a combination of capital costs and the present worth of operation and maintenance costs over the life of the remedy.

The cost estimates developed for this analysis are relative. Costs reflect planning-level estimates and may vary from -30 to +50 percent. For initial cost development, a 5% discount rate over the operational period was assumed for each alternative based on U.S. EPA "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (October 1988)."

State Acceptance

This assessment evaluates the technical and administrative issues and concerns that the State of Indiana may have regarding each of the alternatives. The analysis will include formal comments from meetings, agency reviews, and the transmittal of comments between agencies. State acceptance of the preferred alternative will be addressed subsequent to the public comment period on the Feasibility Study and proposed plan. Therefore, no discussion is included in this report.

Community Acceptance

This criterion incorporates public comments which have been provided to Federal and State agencies during the Remedial Investigation/Feasibility Study process. The analysis will address those alternatives which the community formally supports, has reservations about, or opposes. Community input regarding the Feasibility Study will be solicited during the public comment period, during which time the Feasibility Study report will be available for public review. A responsiveness summary will be prepared to address comments received during the public comment period. The public comments and responsiveness summary will be made a part of the Record of Decision. In general, there will not be a discussion of potential community acceptance in the following sections. However, representatives of the Town of Griffith have already expressed concern relative to the use of on-Site incineration as a treatment method at the Site. Therefore, these comments will be factored into the implementability sections of appropriate alternatives.

4.2 Detailed Analysis of Independent and Medium-Specific Process Options

4.2.1 Groundwater and Surface Water Institutional Measures

Description

Deed restrictions, well closures, and long-term monitoring are discussed in detail in Section 3.3.1.

4.2.2 Groundwater Vertical Barriers

Description

A soil-bentonite slurry wall system is under consideration for the Site as described in Section 3.3.2. Slurry walls are being considered as a part of containment alternatives, as well as an aid in groundwater dewatering. Refer to Section 3.3.3 for a comparison of Site dewatering pumping rates based on preliminary groundwater modeling both with and without use of a slurry wall. A slurry wall system can also be used to prevent dewatering of the surrounding wetlands during groundwater extraction activities. The slurry wall approaches shown on Figure 3-2a and Figure 3-2b are under consideration for both containment and dewatering alternatives. In lieu of a slurry wall system, groundwater extraction wells or pipe and media drains could be placed downgradient of the ACS Site to serve as the method of off-Site containment of contaminants migrating off-Site in the

groundwater. A cost/benefit analysis for use of a slurry wall system to reduce groundwater pumping rates for alternatives involving Site dewatering would have to be performed during the design phase.

Long-Term Effectiveness and Permanence

A slurry wall utilized for containment will greatly reduce the flow of contaminated groundwater off-Site as described in Section 3.3.2. Long-term monitoring of a slurry wall is simply conducted by measuring groundwater levels from inside and outside the wall. A 5 year review would be appropriate to confirm the containment provided. Long-term effectiveness and permanence does not apply for a slurry wall utilized simply to aid upper aquifer dewatering.

Implementability

The implementability issues associated with slurry walls are described in Section 3.3.2. The choice of slurry wall option is dependant on the intended purpose (i.e., containment or dewatering), as well as the consequences of removing and possibly replacing the railroad tracks between the ACS facility and the off-Site areas. The feasibility of removing the railroad tracks is dependent upon the future operations of ACS. If ACS's future operations do not require use of the railroad tracks, they can easily be removed without concern for replacing them. If ACS continues to require use of the railroad tracks, an alternative slurry-wall configuration (Figure 3-2b) or alternative ways of handling the railroad tracks may be appropriate (i.e., installing a concrete cap over the slurry wall at the railroad track crossing for replacement of the railroad tracks). At the present time, ACS's continuing chemical manufacturing operations will require future use of the railroad tracks. An analysis of the Site dewatering requirements will be necessary during remedial design, as a part of groundwater pump testing.

4.2.3 Groundwater Extraction/Collection

Description

Based on results of the groundwater modeling, the upper aquifer could be dewatered to within four to five feet of the clay confining layer using the extraction scenario presented in the modeling assumptions and pumping at an initial rate of 200 gpm; the pumping rate

would reduce to 80 gpm after one year of pumping. Additional extraction locations (e.g., well points) would likely have to be added after initial dewatering has begun to dewater the source areas down to the depth of the clay confining layer. Contaminants were detected down to the depth of the clay confining layer in all source areas. Site dewatering and off-Site groundwater collection for containment purposes could be accomplished using a series of sixteen to twenty groundwater extraction groupings as shown on Figure 4-3. Each extraction grouping would consist of one to four pumps capable of extracting 10 gallons per minute (gpm) maximum total flow. The pumps may be placed in 4-inch diameter extraction wells or pipe and media drains (refer to Section 3.3.3 for a description of extraction wells and pipe and media drain construction). This configuration will create the best conditions for efficient dewatering of the Site and groundwater containment. This configuration was chosen based upon groundwater modeling presented in Appendix A. Groundwater pump testing will be necessary to determine the exact number and spacing of extraction wells or drains. The groundwater extraction pumps will be manifolded together and piped to the treatment area shown on Figure 4-3.

Phase III sampling was performed as part of the RI in order to define the extent of impact to the lower aquifer. It appears that the lower aquifer may be impacted by low levels of organics (primarily chloroethane and bis (2-chloroethyl) ether). If it is determined that the risk levels associated with these levels of contamination in the lower aquifer warrant remedial action, groundwater modeling and pump testing would have to be performed in order to design the lower aquifer extraction system and determine the increase in the groundwater pumping rate.

Since the 200 gpm groundwater pumping rate established to dewater the Site without a slurry wall system is only required for the first few months of operation, excess capacity will then exist within the treatment system. Based on preliminary groundwater modeling results (refer to Section 3.3.3), approximately 80 gpm would be required to keep the Site dewatered during source treatment activities and an additional 10 gpm to contain off-Site groundwater migration to the northwest of the ACS Site (refer to Supplement to

Appendix A). Initial modeling suggests that a lower aquifer extraction system would add approximately 100 gpm to the pumping rate.

Two options for incorporating lower aquifer extraction into the groundwater pumping and treatment system include:

- design of the groundwater treatment system for 300 gpm with commencement of lower aquifer extraction at the beginning of source treatment activities; or
- design of the groundwater treatment system for 200 gpm with commencement of lower aquifer extraction at the completion of source treatment activities.

Based on the Phase III lower aquifer sampling results, there does not appear to be a major breach in the clay confining layer between the upper and lower aquifers. Groundwater flow in the lower aquifer is from south to north across the Site. VOCs were detected in a single on-Site monitoring well (MW-09) located downgradient of the source areas. Monitoring wells located further downgradient of MW-09 were not impacted. Additional sampling of the lower aquifer within the source areas is not proposed at this time because of the potential to create a breach in the clay confining layer by drilling through it.

The VOCs detected in MW-09 included chloroethane and bis (2-chloroethyl) ether. Because of their relatively high solubilities in water and low soil adsorption coefficients, chloroethane and bis (2-chloroethyl) ether are the most mobile of the VOCs detected at the ACS Site. Chloroethane is a biological degradation product of the reductive dehalogenation of chlorinated ethenes (including vinyl chloride). The presence of low levels of only mobile VOCs, one of which is a potential degradation product, at a single monitoring well would indicate that a major breach in the clay confining layer between the upper and lower aquifers has not occurred.

All of the alternatives described in the following sections focus on preventing the off-Site migration of contaminants in the upper aquifer quickly and then reducing the concentrations of source material over time. As discussed above, there is no off-Site

migration of contaminants in the lower aquifer. Concentrations of contaminants in the lower aquifer are several orders of magnitude less than in the upper aquifer and there does not appear to be a significant source of contamination in the lower aquifer. Therefore, groundwater in the lower aquifer can be addressed by continued monitoring while groundwater in the upper aquifer is extracted and treated.

There are various uncertainties associated with the lower aquifer contamination. Limited action risks the possibility that contamination may disperse further into the lower aquifer, thus increasing remediation costs at a later date. Another uncertainty involves the fact that the lower aquifer monitoring wells were only screened in the first five to ten feet of the lower aquifer. Chloroethane, the primary VOC detected in the lower aquifer, has a density greater than water and could be present at depths below the screening interval. At the present time, contamination has only been detected in one lower aquifer well. Zones of higher contamination could exist in the lower aquifer that have yet to be detected by the current monitoring system.

If monitoring of the lower aquifer shows that contaminant levels are increasing above acceptable levels or contaminants are migrating from the Site, the need for extraction of groundwater from the lower aquifer can be considered. It is possible that after groundwater and source treatment have reduced contaminant levels in the upper aquifer, the contaminant levels in the lower aquifer will diminish over time.

For purposes of the detailed analysis of alternatives and groundwater treatment cost estimates in Section 4.0, it has been assumed that the groundwater treatment system would be operated at 200 gpm. Monitoring of off-Site contaminant migration within the lower aquifer would continue during source treatment activities. Lower aquifer pumping and treatment could be added to the surplus capacity that would exist for the groundwater treatment system following the completion of source treatment and Site dewatering activities.

Implementability

Groundwater extraction/collection is a standard, proven technology for removal of contaminated groundwater and construction Site dewatering. Based on the results of the groundwater modeling presented in Appendix A, the Site could be sufficiently dewatered without a slurry wall if well points within the source areas provide any additional dewatering that may be required. Groundwater pump testing would be required to determine the optimal extraction well configuration and exact flow rates and influent contaminant concentrations. The effect of Site dewatering on the structural integrity of existing buildings and tank farm foundations would have to be evaluated.

Because of the predominantly sandy soils in the upper aquifer at the Site, extraction wells and pipe and media drains should be equally effective for dewatering of the upper aquifer. Multiple extraction wells with pumps at an extraction grouping will remove water across an area similar to the effect of placing perforated pipe in a trench leading to a single pump. However, there are tradeoffs between extraction wells and pipe and media drains.

Extraction wells have a greater potential to become clogged by suspended solids in the groundwater. Repeated start-up and shut-down of a multiple well dewatering system over a potentially long period of time could stir up fine grained soils and other small particles in the groundwater. Grain size analyses at the Site performed during the RI indicate that the upper aquifer sand layer contains between approximately four percent and 10 percent total silt and clay. A properly designed sand pack around the well screen would help to filter out suspended solids in the groundwater. Pipe and media drains have a larger volume of well graded granular material around the collection point which will generally screen suspended solids from the groundwater better than an extraction well. In addition, because there are fewer pumps with media drains, operation and maintenance costs are lower.

Because the dewatering system is to be installed across portions of the Site that contain contaminated soils and buried waste, drill cuttings from extraction wells and trench spoils from pipe and media drains may have to be added to the soil volume requiring treatment. The volume of soil removed is much greater for pipe and media drains than for extraction wells. In addition, extraction wells can be located to avoid contaminated

areas more easily than trenches, which would reduce the likelihood that extraction well drill cuttings would have to be treated or disposed of as hazardous wastes.

Another potential disadvantage of pipe and media drains is that the trenches would likely cave in during excavation due to the saturated sandy soil conditions. In order to dewater the Site to the clay confining layer, pipe and media drains would have to be installed at a depth of approximately 20 feet. Extensive shoring and bracing would be required to prevent collapse, and to allow installation of the drain system. Unlike extraction wells which can be turned off and taken out of service when remedial action activities are completed, pipe and media drains could cause permanent impacts and disturbances to surrounding wetlands.

A pilot scale test to examine the cost effectiveness of extraction wells versus media drains could be conducted during final design.

4.2.4 Treated Water Discharge

4.2.4.1 Off-Site Discharge

Description

Treated groundwater and process wastewaters, such as backwash water from ion exchange operations or condensate from in-situ steam stripping operations, may be discharged to the local POTW, Hammond Sanitary District, as described in Section 3.3.4.1. Figure 4-3 shows a possible lateral connection location for the potential discharge of treated groundwater and process wastewaters. The potential effectiveness of POTW discharges is described in Section 3.4.2.

Implementability

Mr. Jeffrey Massey, Pretreatment Coordinator for the Hammond Sanitary District, indicates that a discharge to the sanitary sewer would be acceptable as long as industrial waste discharge requirements are met. The most stringent of criteria listed in the City of Hammond, Indiana Industrial Waste Ordinance No. 4996 (Ord. No. 4996) and the U.S. EPA pretreatment standards would be applicable. Ord. No. 4996 currently exists in two forms, existing and proposed. The proposed ordinance is expected to go into effect

pending approval by the Hammond City Council. When the proposed Ord. No. 4996 goes into effect, ACS's existing permit will be modified to reflect the changes. Mr. Massey has specified that 40 CFR 414 Subpart H (Effluent Guidelines and Standards for Specialty Organic Chemicals) would represent pretreatment criteria for a discharge from a groundwater treatment system at the ACS Site. 40 CFR 414 Subpart H regulates process wastewater discharges resulting from the manufacture of specialty organic chemicals and organic chemical groups.

Since ACS also operates chemical manufacturing processes, the pretreatment regulations presented in 40 CFR 414 Subpart H would directly apply to those operations. However, 40 CFR 414 Subpart H should not directly apply to a groundwater treatment system operated on the ACS Site independent of ACS's chemical manufacturing operations. Mr. Massey did indicate, though, that the Hammond POTW would apply the specialty organic chemical pretreatment standards to the groundwater treatment system as well. Table 4-14 lists pretreatment criteria for ACS's existing permit, proposed Ord. No. 4996 and 40 CFR 414 Subpart H.

4.2.4.2 On-Site Discharge

Description

Four potential options exist for on-Site treated water discharge in accordance with NPDES requirements. These options could either be exercised individually or in combination. The optimum pump and treat approach to this Site would likely involve a combination of these discharge options. The first option involves piping treated groundwater to the drainage ditch north of the ACS facility to the location shown on Figure 4-3. The second option involves piping treated groundwater to Turkey Creek or one of its tributaries. Turkey Creek is approximately 4,000 feet southeast of the Site. The third option involves reinjection of treated groundwater, which could be done in conjunction with in-situ biological treatment to enhance the removal efficiency of the pump and treat system. The fourth involves discharge to wetlands west of the Site.

Implementability

According to Joe Krueger, IDEM Division of Water Management, discharge to a stream or ditch is potentially viable depending upon Site circumstances. Discharge requirements for NPDES type discharges are generally well established and administratively feasible. However, specific levels for discharge are determined on a case by case basis. Table 4-14 lists MCLs, water quality criteria and RCRA corrective action levels for contaminants of concern. These concentrations were used as effluent discharge criteria for initial design purposes in order to evaluate the relative effectiveness and prepare the primary cost estimate for each groundwater treatment technology. They should not be considered cleanup criteria.

Discharge to the ditch north of the ACS facility, subject to approval by the IDEM, provides a mechanism for recharging the wetlands that may draw down due to dewatering. Discharge to Turkey Creek provides an option if the ditch is shown to be inappropriate for discharge. The lengthy piping run that would be required to discharge to Turkey Creek could cause disturbances and have an adverse impact on the surrounding wetlands. Discharge of water to the wetlands provides several benefits. The discharge of treated water would prevent dewatering of the wetlands. In addition, the discharge water could be used to flush residual levels of contaminants from sediments in the wetland.

It is likely that a combination of the discharge options would be used. For instance, some portion of the treated water could be used to recharge the wetlands and flush contaminants from wetland sediments, while another portion could be reinjected on-Site to enhance the removal efficiency of the pump and treat system. Flushing of wetland sediments would not likely be effective at removing adsorbed hydrophobic contaminants. A more detailed analysis of the impact of flows to the wetlands, drainage ditch or creek would have to be conducted during final design.

A more aggressive pump and treat approach, which could include in-situ biological treatment, may be performed if initial groundwater pump and treat techniques are not effective at remediating the upper and/or lower aquifers. If in-situ biological treatment of groundwater is performed, treated groundwater would be reinjected into areas of aquifer contamination to enhance contaminant removal achievable by groundwater

bibliography in Appendix D, the following removal efficiencies and final effluent concentrations have been achieved by activated carbon adsorption for the groundwater chemicals of concern at influent concentrations of 0 to 1000 ug/l (i.e., activated carbon adsorption to be used strictly as a secondary treatment process option):

Volatile Ketones (primarily acetone, methyl ethyl ketone and methyl isobutyl ketone): Removal efficiencies range between >86% and >92.8% with a final effluent concentration between <10 ppb and <54 ppb.

BEXT Compounds (primarily benzene): Removal efficiencies range between >80% and 99% with a final effluent concentration between 0.1 ppb and <10 ppb.

Chlorinated Methanes (primarily methylene chloride): Removal efficiencies range between 67% and 99% with a final effluent concentration between <1.0 ppb to 85 ppb.

Chlorinated Ethenes (primarily vinyl chloride and tetrachloroethene): Removal efficiencies range between 68% and 99.7% with a final effluent concentration between 0.1 ppb and 32 ppb. Vinyl chloride is not amenable to activated carbon adsorption treatment.

Ethers (primarily bis(2-chloroethyl) ether): Removal efficiencies range between 49% and >97.7% with a final effluent concentration between <10 ppb and 23 ppb.

PNAs (primarily naphthalene and its derivatives): Removal efficiencies range between >73% and 99.97% with a final effluent concentration of <10 ppb.

Even though the following chemical groups are not included among the groundwater chemicals of concern, they have been included in the detailed analysis since they could be affected by potential groundwater discharge ARARs:

Chlorinated Ethanes (primarily chloroethane and 1,1-dichloroethane): Removal efficiencies range between 58% and >99.35% with a final effluent concentration between <1.0 ppb and <10 ppb.

Isophorone - Removal efficiencies range between 57% and >98.9% with a final effluent concentration between <10 ppb and 23 ppb.

Phenols (primarily 4-methylphenol and phenol): Removal efficiencies range between >63% and 99% with a final effluent concentration of <10 ppb.

Chlorinated Benzenes (primarily chlorobenzene and 1,2-dichlorobenzene): Removal efficiencies range between 91.3% and 99.7% with a final effluent concentration between 0.01 ppb and <10 ppb.

Phthalates (primarily bis(2-ethylhexyl) phthalate): Removal efficiencies range between 18% and 99% with a final effluent concentration between 0.1 ppb and 220 ppb.

PCBs: Removal efficiencies exceed 99% with a final effluent concentration below analytical detection limits.

Based on the above removal efficiencies and final effluent levels, and the selected discharge standards in Table 4-14, it is feasible that the NPDES and POTW discharge standards can be met for all of the chemical groups of concern by using activated carbon adsorption as a secondary treatment process option. Vinyl chloride is not amenable to activated carbon adsorption treatment, and would have to be treated to the appropriate discharge standards by the primary organics treatment process option. Some metals, ketones and chlorinated ethanes may also require treatment to acceptable discharge levels by a pretreatment process option and the primary organics treatment process option.

It may not be feasible to treat bis(2-ethylhexyl) phthalate to its maximum contaminant level (MCL) of 4.0 ppb for discharge under an NPDES permit using activated carbon adsorption unless significant reduction is achieved during the primary treatment process option. The calculated maximum phthalate concentration in groundwater was only 20 ppb.

Implementability

Activated carbon adsorption is a proven technology for the treatment of contaminated groundwater. It would only be used as a secondary treatment process option as part of a treatment train, with air stripping or biological treatment as the primary process option, if additional treatment is necessary to achieve applicable discharge standards. Vendors

for activated carbon adsorption equipment are readily available. Only periodic operator attention is necessary to monitor carbon canisters for breakthrough. Spent carbon would have to be handled as a RCRA hazardous waste and sent off-Site for regeneration. Complex metal ions present in groundwater would be removed by the primary treatment process options and would not be expected to interfere with a carbon adsorption polishing step.

Cost

Costs associated with activated carbon treatment are included in the cost estimates for air stripping and biological treatment.

4.2.7.2. Biological Treatment

Description

A description for the biological treatment of groundwater is presented in Section 3.4.1.1. Figure 4-4 presents a schematic process flow diagram and preliminary design information for a biological treatment system.

Reduction in Toxicity, Mobility or Volume Through Treatment

Biological treatment of groundwater reduces the toxicity and volume of organic contaminants by converting them to non-toxic compounds. Metals are not amenable to biological treatment. Eckenfelder (1989) presents a comparison of removal mechanisms for various priority pollutants in activated sludge treatment systems. Volatilization is believed to be the predominant removal mechanism for chlorinated compounds such as 1,1,1-trichloroethane, trichloroethene and tetrachloroethene. Approximately 5% to 50% of the total removal can be attributed to volatilization for compounds such as BEXT compounds, methylene chloride, chloroform and carbon tetrachloride. Volatilization of VOCs from aerobic treatment systems does not represent a reduction in their toxicity as a result of treatment.

One and two carbon chlorinated compounds have been degraded most effectively anaerobically. However, vinyl chloride can be degraded aerobically. Reductive dehalogenation under anaerobic conditions is the primary mechanism for the biological degradation of one and two carbon chlorinated compounds. BEXT compounds can be degraded either aerobically or anaerobically.

The following approaches are potentially applicable to effectively biologically treat the compounds present in the groundwater at the ACS Site which are either refractory to biological treatment or are amenable only to anaerobic treatment:

- Recent research (Nelson, 1987 as referenced in Thomas, 1989) has shown the potential for aerobic degradation of trichloroethene and other compounds by an aromatic pathway in the presence of phenol, toluene or cresol (i.e., cometabolism). These aromatic compounds are present in the groundwater at the ACS Site. Cometabolism is the biological degradation of an organic substance by a microbe that cannot use the compound for growth and must rely on other compounds for carbon and energy. Thomas and Ward (1989) also report that certain chlorinated solvents can be cometabolized in the presence of methane and selected methanotrophs (methane-utilizing organisms). All of the chlorinated methanes, ethanes and ethenes were reportedly amenable to cometabolism in the presence of methane;

- It may be feasible to operate only an aerobic treatment process and allow for a certain level of volatilization to occur without violating applicable air emission ARARs or posing a threat to human health in the vicinity of the ACS Site. The primary groundwater contaminants, BEXT compounds and ketones, are amenable to aerobic biological treatment. Most of the chlorinated solvents most likely to volatilize from an aerobic treatment system have calculated maximum concentrations less than 1.0 ppm. The calculated maximum concentration for chloroethane is approximately 2.0 ppm;

- A powdered activated carbon treatment (PACT) system can be employed. PACT systems incorporate powdered activated carbon into conventional activated sludge systems. A combination of physical adsorption with biological treatment can be effective in treating compounds which are potentially toxic to biological growth. Use of activated carbon in bioreactors allows more rapid initial removal and greater removal of slowly degradable refractory compounds. Upon reactor startups, the activated carbon concentrates materials on the carbon surface. With microbial growth, enhanced biodegradation occurs which enhances the life of the carbon. PACT systems also reduce the volatilization of adsorbable compounds.

- A series operation of aerobic and anaerobic fluidized bed or membrane bioreactors could be installed (i.e., sequence batch reactors). Vendors for combination aerobic and anaerobic treatment units are readily available;

- White rot fungus has been found to aerobically degrade several refractory compounds such as PNAs with more than two to three benzene rings, PCBs and chlorinated phenols;

- Engineered or acclimated microorganisms can be used to degrade refractory compounds in either an aerobic or anaerobic treatment system. Studies have shown that properly selected microbial populations and maintenance of environmental conditions most favorable to their metabolic activity can degrade significant quantities of organic materials; and

- A secondary treatment process option(s), such as air stripping, carbon adsorption or UV/oxidation, capable of removing refractory compounds could be installed after the biological treatment system.

Based upon a review of the U.S. EPA's WERL treatability database and other references presented in the Section 4.0 bibliography in Appendix D, the following removal efficiencies and final effluent concentrations have been achieved by activated sludge and PACT systems for the groundwater chemicals of concern. The activated sludge removal efficiencies include both degradation and volatilization.

- Volatile Ketones (primarily acetone, methyl ethyl ketone and methyl isobutyl ketone): Activated sludge removal efficiencies range between 99.09% and 99.79% with a final effluent concentration between 0.9 ppb and 500 ppb for a volatile ketones concentration ranging between 100 ppm and 300 ppm; while PACT removal efficiencies are approximately 99.4% with a final effluent concentration of approximately 14 ppb.

- BEXT Compounds (primarily benzene): Activated sludge removal efficiencies range between 49% and 99.9% with a final effluent concentration between <0.1 ppb and 4,100 ppb for a BEXT influent concentration ranging between 30 ppm and 100 ppm; PACT removal efficiencies range between 95% and 99.7% with a final effluent concentration between 0.3 ppb and 1500 ppb.

- Chlorinated Methanes (primarily methylene chloride): Activated sludge removal efficiencies range between 38% and 98.4% with a final effluent concentration between 1.3 ppb and 59 ppb for a chlorinated methane influent concentration of approximately 200 ppb; PACT removal efficiencies range between >70% and >99.9% with a final effluent concentration between 9.0 ppb and <20 ppb.

- Chlorinated Ethenes (primarily vinyl chloride and tetrachloroethene): Activated sludge removal efficiencies range between 30% and 99% with a final effluent concentration between <0.6 ppb and 100 ppb for a chlorinated ethene influent concentration of approximately 200 ppb; PACT removal efficiencies range between 88% and >99.7% with a final effluent concentration between <1.0 ppb and <10.0 ppb.

- Ethers (primarily bis(2-chloroethyl) ether): Activated sludge removal efficiencies range between 67% and 98.3% with a final effluent concentration between <13 ppb and 29 ppb for an ether influent concentration of approximately 2.0 ppm; PACT removal efficiencies are approximately 53% with a final effluent concentration of 44 ppb.

- PNAs (primarily naphthalene and its derivatives): Activated sludge removal efficiencies range between 35% and >99.09% with a final effluent concentration between <0.7 ppb and 42 ppb for a PNA influent concentration of approximately 100 ppb; PACT removal efficiencies range between >90% to >99.5% with a final effluent concentration between <1 ppb and <10 ppb.

Even though the following chemical groups are not included among the groundwater chemicals of concern, they have been included in the detailed analysis since they could be affected by potential groundwater discharge ARARs:

- Chlorinated Ethanes (primarily chloroethane and 1,1-dichloroethane): Activated sludge removal efficiencies range between 39% and 99.7% with a final effluent concentration between <0.3 ppb and 30 ppb for a chlorinated ethane influent concentration between 1.0 ppm and 3.5 ppm; PACT removal efficiencies range between 71% and 99.7% with a final effluent concentration between <1.0 ppb and 25 ppb.

- Isophorone - Activated sludge removal efficiencies range between >56% and >98.2% with a final effluent concentration between 3.0 ppb and <10 ppb for an isophorone influent concentration of approximately 9.0 ppb; PACT removal efficiencies are approximately 97.5% with a final effluent concentration of <1.0 ppb.

- Phenols (primarily 4-methylphenol and phenol): Activated sludge removal efficiencies range between 68% and >79% with a final effluent concentration between <1.0 ppb and 1300 ppb for a phenol influent concentration of approximately 4.0 ppm; PACT removal efficiencies are approximately 96% with a final effluent concentration of approximately 160 ppb.

- Chlorinated Benzenes (primarily chlorobenzene and 1,2-dichlorobenzene): Activated sludge removal efficiencies range between 37% and 99.3% with a final effluent concentration between <2.0 ppb and 270 ppb for a chlorinated benzene influent concentration of approximately 300 ppb; PACT removal efficiencies range between 90% and >99% with a final effluent concentration between 3.0 ppb and 30 ppb.

- Phthalates (primarily bis(2-ethylhexyl) phthalate): Activated sludge removal efficiencies range between 37% and 99% with a final effluent concentration between <1.0 ppb and <15 ppb for a phthalate influent concentration of approximately 20 ppb; PACT removal efficiencies range between 67% and 99.5% with a final effluent concentration of <2.0 ppb to 22 ppb.

- PCBs - Activated sludge removal efficiencies range between 44% and 79% with a final effluent concentration between 0.2 ppb and 0.5 ppb for a PCB influent concentration of approximately 2.0 ppb. No data was available for PACT treatment.

Based on the above removal efficiencies and final effluent levels, and the selected discharge standards in Table 4-14, neither the NPDES nor POTW discharge standards appear likely to be met using conventional aerobic treatment systems for the BETX compounds, chlorinated methanes, chlorinated ethanes, chlorinated ethenes, chlorinated benzenes and phenols. Either a modified biological treatment system (e.g., PACT system) or a secondary treatment process option (e.g., air stripping, activated carbon adsorption or UV/oxidation) would be required to meet the applicable discharge standards. All POTW discharge standards appear likely to be met if a PACT system, or equivalent, is employed. However, NPDES discharge standards for benzene and various chlorinated compounds are still not likely to be met without the use of a secondary treatment process option.

Implementability

Aerobic and anaerobic biological treatment are proven technologies for industrial wastewaters and contaminated groundwater, and have been selected as a groundwater treatment technology in numerous CERCLA Records of Decision (RODs).

If in-situ biological treatment of groundwater is selected, treated groundwater from the above-ground biological treatment system could be reinjected, instead of discharged. This could decrease the operational costs for in-situ biological treatment (e.g., nutrient addition, etc.). Biological treatment is applicable to contaminant levels up to approximately 4,000 ppm. The total maximum VOC and SVOC groundwater concentration determined from data presented in Table 4-7 is approximately 400 ppm. Since monitoring wells were not located within the areas of buried wastes and soil contamination, initial contaminant influent concentrations may be significantly higher. Biological treatment is better capable of handling both higher, as well as fluctuating, influent contaminant concentrations than the other groundwater treatment process options.

Treatability and pilot studies would be required to evaluate a range of design conditions and treatment processes in order to optimize the removal efficiencies and degradation rates for the organic contaminant matrix present in the groundwater at the ACS Site. Both a treatment mechanism and the type of biological system would have to be selected. Various forms of fluidized and fixed bed bioreactors, activated sludge systems, rotating biological disks and trickling filters may be applicable. Rotating biological contractors are often used at hazardous waste sites because they are compact, can handle large flow variations and organic shock loads and do not require use of aeration equipment.

Daily operator attention is required, but is limited to approximately two hours per day. Biological treatment sludge would require off-Site disposal and would likely qualify as a RCRA hazardous waste. If a PACT system is used, spent carbon would require either off-Site regeneration or disposal as a RCRA hazardous waste. Vendors for aerobic and anaerobic biological treatment equipment are readily available.

Cost - Capital and annual O&M costs for a groundwater pumping rate of 200 gpm are presented in Table 4-15. Design assumptions for purposes of the cost estimate are presented in Figure 4-4.

4.2.7.3 UV/Oxidation

Description

A description for the UV/oxidation treatment of groundwater is presented in 3.4.1.3. Figure 4-5 presents a schematic process flow diagram and preliminary design information for a UV/oxidation system.

Reduction of Toxicity, Mobility and Volume Through Treatment

UV/oxidation reduces the volume and toxicity of organic contaminants by converting them to non-toxic compounds. Based on a review of vendor literature, all of the groundwater chemicals of concern are potentially amenable to UV/oxidation treatment. Metals are not amenable to UV/oxidation treatment. Organic compounds with double bonds (e.g. chlorinated ethenes, aromatics, ketones) are more amenable to oxidation. Compounds without double bonds, but high Henry's Law constants, are more likely to be stripped out of the groundwater by the ozone gas. Significant percentages of VOCs (5% to 75%) which are less susceptible to oxidation have been measured to be stripped out of the groundwater by the ozone and transferred to the vapor phase. During the March 1989 field demonstration of the Ultrox International UV/oxidation unit as part of the U.S. EPA SITE Program, ozone and VOC off-gas destruction efficiencies for the catalytic treatment unit were measured to be greater than 99.99%.

Results of the SITE demonstration (U.S. EPA September 1990) showed minimal reductions in groundwater TOC following treatment, suggesting that incomplete oxidation of organic compounds had occurred. However, contaminants comprised only 2% of the TOC, thus making a statistical comparison difficult. Other Superfund Target Compound List VOC and SVOC compounds were not detected as possible degradation products following treatment. Data regarding degradation product evaluation is not available for review. An evaluation of potential degradation products and their corresponding toxicities may have to be performed as part of a treatability or pilot study.

The following potential removal efficiencies for the groundwater chemicals of concern were identified based on a review of U.S. EPA (September 1990), available vendor literature and the U.S. EPA WERL treatability database:

- Ketones (primarily acetone, methyl ethyl ketone and methyl isobutyl ketone): Data was not available for these compounds.

- BEXT Compounds (primarily benzene): Removal efficiencies range between 99% and 99.9% with a final effluent concentration below analytical detection limits for a BEXT influent concentration ranging between 30 ppm and 100 ppm.

- Chlorinated Methanes (primarily methylene chloride): Removal efficiencies range between 99% and 99.9% with a final effluent concentration between below analytical detection limits and 3.0 ppb for a chlorinated methane influent concentration of approximately 200 ppb.

- Chlorinated Ethenes (primarily vinyl chloride and tetrachloroethene): Removal efficiencies range from 86% to 99.9% with final effluent concentrations between below analytical detection limits and 4.0 ppb for a chlorinated ethene influent concentration of approximately 200 ppb.

- Ethers (primarily bis(2-chloroethyl) ether): Removal efficiency of approximately 99.7% with a final effluent concentration of <6.0 ppb for an ether influent concentration of approximately 2.0 ppm.

- PNAs (primarily naphthalene and its derivatives): Removal efficiency of >88% with a final effluent concentration of <2.0 ppb for a PNA influent concentration of approximately 100 ppb.

Even though the following chemical groups are not included among the groundwater chemicals of concern, they have been included in the detailed analysis since they could be affected by potential groundwater discharge ARARs:

- Chlorinated Ethanes (primarily chloroethane and 1,1-dichloroethane): Removal efficiencies range from 40% to 85%. No representative effluent concentrations were reported for a chlorinated ethane influent concentrations ranging between 1.0 and 3.5 ppm.

- Phenols (primarily 4-methylphenol and phenol): Removal efficiency of approximately 98% with a final effluent concentration of less than 100 ppb for a phenol influent concentration ranging between 3.0 and 4.0 ppm.

- Chlorinated Benzene (primarily chlorobenzene and 1,2-dichlorobenzene): Data was not available for these compounds.

- Phthalate (primarily bis(2-ethylhexyl) phthalate): Removal efficiency of approximately >87% with a final effluent concentration of <3.0 ppb for a phthalate influent concentration of approximately 20 ppb.

- PCBs: Removal efficiencies range between 99.6% and 99.9% with final effluent concentrations between below analytical detection limits and 0.2 ppb for a PCB influent concentration of approximately 2.0 ppb.

Based on the above removal efficiencies and final effluent levels, and the selected discharge standards in Table 4-14, it is feasible that the NPDES and POTW discharge standards can be met for all of the chemical groups of concern by UV/oxidation treatment. A secondary treatment process option (e.g. carbon adsorption) would not be required.

Implementability

Based on a review of vendor literature, UV/oxidation is applicable to contaminant levels up to 1,000 ppm and total organic carbon levels of 20,000 ppm. The total maximum VOC and SVOC groundwater concentration determined from data presented in Table 4-7 is approximately 400 ppm. As mentioned earlier, monitoring wells were not located within the areas of buried wastes and soil contamination. If actual concentrations are significantly higher during initial dewatering, UV/oxidation of groundwater may not be feasible as the primary method of treatment. Dilution of influent groundwater from off-Site or lower aquifer pumping, however, may occur since contaminant concentrations in these areas are significantly lower. UV/oxidation could still be used as a secondary treatment process option instead of carbon adsorption following biological treatment or air stripping.

UV/oxidation has been used on full scale groundwater cleanups at a limited number of sites in the last few years. Groundwater contaminant matrices similar to the ACS Site have been reported to be successfully treated using UV/oxidation based on vendor case studies. UV/oxidation treatment of groundwater has been selected as the remedial action alternative in two recent CERCLA RODs; one involving treatment of chlorinated ethenes and the other wood-treating phenols. The chlorinated ethene ROD was for the same site where the SITE program demonstration was performed. Vendor availability for UV/oxidation systems is limited.

High metals and suspended solids concentrations in the groundwater can foul a UV/oxidation system, thus requiring pretreatment. These conditions exist in the groundwater samples collected at the ACS Site. A metals pretreatment system would be required. Adjustments to groundwater pH based on alkalinity levels may be required to optimize treatment efficiency. Maintenance of the ozonation system, UV/lamp assembly, ozone decomposition unit and other miscellaneous system parts is required. Daily operator attention and sampling is required, but is limited to approximately two hours per day.

A treatability and/or pilot study is required to optimize ozone, hydrogen peroxide and UV combinations and dosages. It is likely that follow-up testing would be required to alter these dosages as groundwater contaminant concentrations decrease with time. The gas to liquid ratio can be used to control the amount of contaminant stripping that occurs.

Cost - Capital and annual O&M costs for a groundwater pumping rate of 200 gpm are presented in Table 4-15. Design assumptions for purposes of the cost estimate are presented in Figure 4-5.

4.2.7.4 Air Stripping

Description

A description for the air stripping of groundwater is presented in Section 3.4.1.4. Figure 4-6 presents a schematic process flow diagram and preliminary design information for an air stripping system.

Reduction of Toxicity, Mobility or Volume Through Treatment

Air stripping of groundwater transfers organic compounds to the air phase. If vapor phase treatment is used, the destruction of organics as a result of thermal treatment or spent carbon regeneration would result in an overall toxicity and volume reduction of contaminants in the groundwater. Metals are not amenable to air stripping treatment. Based on a review of the U.S. EPA's WERL treatability database and other references presented in the Section 4.0 bibliography in Appendix D, the following removal efficiencies and final effluent concentrations have been achieved by air stripping for the groundwater chemicals of concern:

- Volatile Ketones (primarily acetone, methyl ethyl ketone and methyl isobutyl ketone): Removal efficiency is approximately 91.5% with a final effluent concentration of approximately 10 ppm for a volatile ketone influent concentration ranging between 100 ppm and 300 ppm.

- BEXT Compounds (primarily benzene): Removal efficiencies range between 73% and 99.3% with a final effluent concentration between 52 ppb and 9300 ppb for a BEXT influent concentration ranging between 30 ppm and 100 ppm.

- Chlorinated Methanes (primarily methylene chloride): Removal efficiencies range between 96.9% and 99.9% with a final effluent concentration between <0.1 ppb and 18 ppb for a chlorinated methane influent concentration of approximately 200 ppb.

- Chlorinated Ethenes (primarily vinyl chloride and tetrachloroethene): Removal efficiencies range from 72% to 99.9% with a final effluent concentration between 0.2 ppb and 57 ppb for a chlorinated ethene influent concentration of approximately 200 ppb.

- Ethers (primarily bis(2-chloroethyl) ether): No data is available for these compounds. Based on their Henry's law constants and an influent concentration of approximately 2.0 ppm, ethers would not be expected to be amenable to air stripping.

- PNAs (primarily naphthalene and its derivatives): Removal efficiencies range from 10% to 91% with a final effluent concentration of 37 ppb to 100 ppb for a PNA influent concentration of approximately 100 ppb.

Even though the following chemical groups are not included among the groundwater chemicals of concern, they have been included in the detailed analysis since they could be affected by potential groundwater discharge ARARs:

- Chlorinated Ethanes (primarily chloroethane and 1,1-dichloroethane): Removal efficiencies range from 89% to 99.7% with a final effluent concentration ranging between 0.2 ppb and 140 ppb for a chlorinated ethane influent concentration ranging between 1.0 ppm and 3.5 ppm.

- Isophorone - Removal efficiency is approximately 33% with a final effluent concentration of approximately 6.0 ppb for an isophorone influent concentration of approximately 9.0 ppb.

- Phenols (primarily 4-methylphenol and phenol): No data are available for these compounds. Based on their Henry's law constants and an influent concentration ranging between 3.0 to 4.0 ppm, phenols would not be expected to be amenable to air stripping.

- Chlorinated Benzenes (primarily chlorobenzene and 1,2-dichlorobenzene): Removal efficiencies range between >83% and 97% with a final effluent concentration between 0.18 ppb and <23 ppb for a chlorinated benzene influent concentration of approximately 300 ppb.

- Phthalates (primarily bis(2-ethylhexyl) phthalate): No data is available for these compounds. Based on their Henry's law constants and a phthalate influent concentration of approximately 20 ppb, phthalates would not be expected to be amenable to air stripping.

- PCBs: No data is available for these compounds.

Based on the above removal efficiencies and final effluent levels, and the selected discharge standards in Table 4-14, a secondary treatment process option may be required after the air stripping operation to meet both the NPDES and POTW discharge standards. Secondary treatment of benzene may be required. Similarly, although potential discharge standards could not be identified for the ketones, their high influent concentrations and relatively low air stripping treatment efficiencies would likely require secondary treatment to meet discharge standards that would be established by the responsible Agencies.

Other chemical groups that may not meet either NPDES or POTW discharge standards using air stripping without secondary treatment are the phenols and PCBs. The phthalates would be expected to meet the POTW, but not the NPDES, discharge standards. Of the chemical groups not amenable to air stripping, the calculated maximum influent concentrations for the ethers, PNAs and isophorone are below the selected NPDES and POTW discharge standards and, thus, may not require treatment.

Implementability

Air stripping is a proven technology for the treatment of contaminated groundwater, and is the most frequently selected groundwater treatment technology in CERCLA RODs to date. Air stripping is usually cost effective for contaminant influent concentrations up to approximately 100 ppm. The total maximum VOC and SVOC groundwater concentration determined from data presented in Table 4-7 is approximately 400 ppm. Since monitoring wells were not located within the source areas of buried wastes and soil contamination, initial contaminant concentrations may be significantly higher. Air stripping alone may not be sufficiently flexible to effectively treat influent concentrations at these levels in a cost effective manner. Dilution of influent groundwater from off-Site or lower aquifer pumping, however, may occur since contaminant concentrations in these areas are significantly lower.

The air stripping tower would require periodic operator attention and maintenance, as would an activated carbon adsorption secondary treatment process option (refer to Section 4.2.7.1). A metals and suspended solids pretreatment system may be required based on groundwater samples collected at the ACS Site. A pilot study would be required to determine the influent contaminant concentrations and optimize the operation of the air stripping tower. It is likely that follow-up adjustments to the air/water ratio would be required as groundwater contaminant concentrations decrease with time and with the inclusion of lower aquifer extraction. Periodic maintenance would also include backflushing the system to remove buildup of iron and bacteria sludge. Vendors for air stripping towers are readily available.

As mentioned earlier, ketones are not readily strippable under normal operating conditions. Ketones also have high carbon usage requirements if a carbon adsorption secondary treatment process option is added. It is also possible that benzene levels will not meet applicable discharge ARARs following air stripping because of its potentially high influent concentrations.

An option to improve the removal efficiencies for the ketones and benzene is to preheat the influent groundwater. Case studies (Halvorsen and Ohneck and U.S. EPA, 1988) have shown dramatic improvement in the removal efficiencies of methyl ethyl ketone by preheating the influent groundwater. Henry's Law constants are temperature dependent. Increasing the temperature of the groundwater increases the Henry's Law constants (i.e., strippability) of the contaminants by decreasing solubility in water and increasing vapor pressure. If thermal treatment of off-gases from the air stripping tower is employed in order to meet VOC emission ARARs, waste heat from the unit can be used to preheat the influent groundwater.

The discharge of heated groundwater effluent on-Site to receiving bodies discussed in Section 4.2.4.2 may be subject to Indiana Water Quality Standards ARARs. Heat (i.e., temperature) is considered a potential pollutant, which can be subject to NPDES permit conditions and Indiana Water Quality Standards. IAC 2-1-6 prohibits the discharge of water at temperatures which would either adversely impact the aquatic biota, microorganism or wildlife species, or cause a rise at any time or place above natural temperatures of 5°F or more. If the temperature of treated groundwater violates Indiana Water Quality Standards ARARs, a heat exchanger would have to be placed after the air stripping tower in order to cool the effluent to an acceptable temperature. Cooling water for the heat exchanger would likely be supplied by installing a cooling tower as part of the treatment system. This would result in an increase in the capital (approximately $40,000) and O & M costs for the air stripping process option. These cost increases would not be significant in relation to the total cost of a groundwater treatment system.

Because the Site is located in a current U.S. EPA non-attainment area for ozone, treatment of off-gas from the stripper will probably be required. It has been assumed that a thermal treatment unit would be used for off-gas treatment for the purpose of the cost estimates. Heat from the unit can also be used to preheat groundwater prior to stripping.

Cost - Capital and O&M costs for a groundwater pumping rate of 200 gpm are presented in Table 4-15. Design assumptions for purposes of the cost estimate are presented in Figure 4-6.

4.2.7.5 Ion Exchange

Description

A description for the ion exchange treatment of groundwater is presented in Section 3.4.1.7. Ion exchange preliminary design information is presented in the corresponding figures for the primary treatment process options.

Reduction of Toxicity, Mobility or Volume Through Treatment

Ion exchange is potentially applicable for removing all of the inorganic metals detected in the groundwater at the ACS Site, thus reducing the volume of metals present in the groundwater. Patterson (1985) discusses the expected ion exchange removal efficiencies for several of the metals present in the ACS Site's groundwater. Ion exchange removal efficiencies range from 75% to 99% for dilute inorganic influent concentrations up to approximately 4,000 mg/l. The calculated maximum total metals influent concentration determined from data presented in Table 4-7 is 1,000 ppm. Patterson reports an ion exchange removal efficiency for arsenic of 77% based on a maximum arsenic influent concentration of 20 ppb. Based on the calculated maximum influent concentrations and selected discharge standards in Table 4-14, all of the influent concentrations for the metals are below the selected NPDES and POTW discharge standards and, thus, may not require treatment.

Implementability

For the most part, ion exchange is not capable of selectively removing specified metals. It may prove difficult to treat specified metals to applicable discharge standards if other metals present in high concentrations use up available ion exchange capacity. As mentioned earlier, it may not be necessary to treat any metals in order to meet NPDES

or POTW discharge standards. If this is the case, ion exchange could still be used as a metals pretreatment process option in order to prevent interference with the primary organics treatment process option.

Ion exchange is a proven technology for metals removal from industrial wastewaters and contaminated groundwater. Vendors for ion exchange units are readily available. Only periodic operator attention is necessary to backwash the ion exchange unit when its capacity has been spent. A pilot study would be required to evaluate the influent metals concentrations, removal efficiencies and regeneration requirements.

Cost

Capital and annual O&M costs for a groundwater pumping rate of 200 gpm are presented in Table 4-15. Design assumptions for purposes of the cost estimate are presented in Figure 4-6 and Appendix C.

4.2.8 Thermal Treatment of Buried Waste and/or Soils

4.2.8.1 On-Site Incineration

Description

A description of thermal treatment techniques for buried wastes and soil is presented in Section 2.5.2.2. Figures 4-8 presents a schematic process flow diagram and preliminary design information for on-Site incineration.

Reduction of Toxicity, Mobility or Volume Through Treatment

Incineration of buried wastes and/or soil reduces the toxicity and volume of organic contaminants by destroying them. Metals are not amenable to incineration treatment, but would be immobilized if fixation of the resulting ash is performed. Combustion products include carbon dioxide, water and other off-gases of incomplete combustion. These off-gases are typically treated using appropriate scrubber systems. Excluding the inorganic metals, all of the chemical groups of concern are amenable to incineration technologies. Incineration treatment efficiencies typically exceed 99.99%.

Implementability

Incineration is a proven technology for the treatment of wastes and soil, and is a frequently selected waste and soils treatment technology in CERCLA RODs. Even though vendor availability for mobile on-Site incineration is somewhat limited, there are more potential vendors than for low temperature thermal treatment. Since all organic matter in soil is destroyed during the incineration process, the volume of destroyed organics would have to be replaced with clean fill materials. Because the water consists of high concentrations of organics, a significant amount of backfill may be required in the waste areas. A pilot test burn would be required to optimize the incineration operating parameters. There is likely be significant public concern relative to placing an incinerator at the Site.

Cost - Refer to Section 4.3.7

4.2.8.2 On-Site Low Temperature Thermal Treatment

Description

A description of thermal treatment technologies is presented in Section 2.5.2.2. Figure 4-9 presents a schematic process flow diagram and preliminary design information for on-Site low temperature thermal treatment.

Reduction in Toxicity, Mobility and Volume Through Treatment

Low temperature thermal treatment reduces the toxicity and volume of organic contaminants by destroying them in a catalytic afterburner. Metals are not amenable to low temperature thermal treatment, but would be immobilized if fixation of the soil is performed. Off-gases for low temperature thermal treatment are significantly less than incineration, and would also be treated using appropriate scrubbing systems. BEXT compounds, chlorinated methanes, chlorinated ethanes, chlorinated ethenes and volatile ketones are amenable to low temperature thermal treatment. Since low temperature thermal treatment has been limited, to date, to the remediation of VOC- and petroleum-contaminated soils, a pilot study would be required to ascertain the treatability of the SVOCs, which include PCBs, phthalates, PNAs, phenols, ethers, organic acids, chlorinated benzenes, and isophorone.

Based on a review of the U.S. EPA WERL treatability database, a pilot study which included bis(2-ethylhexyl) phthalate resulted in a treatment efficiency of 64% at 350°F and >99% at 550°F. This data suggests that the SVOCs are amenable to low temperature thermal treatment at operating temperatures between 500°F and 600°F. A pilot study which included tetrachloroethane resulted in a treatment efficiency of 98.8% at 350°F and 99.99% at an operating temperature of 550°F. Removal efficiencies for BEXT compounds have exceeded 99%. Pilot study data presented in Fox and Alperin reported successful treatment of PNAs, as well as reductions of PCB levels in soils from feed concentrations ranging between 200 ppm and 40,000 ppm to a final concentration of less than 2.0 ppm at treatment temperatures of approximately 600°F to 1000°F. Based on bench and pilot scale studies presented in U.S. EPA (December 1990) and Chemical Waste Management (February 1990), removal efficiencies in excess of 99.5% are attainable for PNAs, chlorinated benzenes and PCBs, with final concentrations ranging from approximately 2.0 mg/kg for individual compounds to below analytical detection limits for operating temperatures of 500°F or greater.

Implementability

Low temperature thermal treatment has been used on full scale soil remediations at a limited number of sites in the last few years. Its applications, to date, have been limited to simple contaminant matrices and petroleum derivative compounds. Low temperature thermal treatment has been mentioned in five recent CERCLA RODs as being a possible technology for treating soils with a similar contaminant matrix as the ACS Site. Pilot studies are being proposed for each of these sites.

Low temperature thermal treatment units are designed to treat soils or sludges containing less than 10% total organics. The total weighted average VOC and SVOC buried wastes and soil level for the Off-Site Containment Area is 3.3% (i.e., 33,000 ppm). This would be within the capabilities of low temperature thermal treatment.

The total maximum VOC and SVOC buried waste level for the Off-Site Containment Area based on BRA exposure levels is 85% (i.e., 850,000 ppm). Even though this level is expected to be significantly higher than what is actually encountered, the total organics

level in the buried waste would be expected to exceed 10%. Some mixing of waste with less contaminated soil may be required to bring the mixture within the range of the equipment.

Both a pilot study and test burn would be required to evaluate the ability of low temperature thermal treatment to handle the organic contaminant matrix of concern, as well as to optimize the operational parameters. Since soil is not destroyed during the treatment process, it is feasible to place it back onto the ACS Site and eliminate the requirement for backfill material. A variance from the RCRA land-ban requirements may have to be obtained in order to place treated soils back on-Site. There may be significant public concern relative to placing a low temperature unit at the Site.

Cost - Refer to Section 4.3.7

4.2.9 Biological Treatment of Buried Wastes and Soil

4.2.9.1 Land Farming

Description

A description of the biological treatment of buried wastes and soil is presented in Section 3.5.1.1. Figure 4-11 presents a schematic process flow diagram and preliminary design information for land farming treatment.

Implementability

Land farming is a proven method of biological treatment for soils, and is the most frequently selected method of biological treatment in CERCLA RODs. A very large area would be required to construct land farm treatment cells because of the volume of buried waste and soils requiring treatment, and the relatively slow biodegradation rates experienced under land farm conditions. Some of ACS's chemical manufacturing operations may be impacted by the need to provide sufficient surface area.

Compounds either not amenable or refractory to aerobic degradation are likely to volatilize during treatment and would not be degraded. Off-gases would have to be collected and treated if applicable air emission ARARs are exceeded, or the VOC emissions pose a threat to human health in the vicinity of the ACS Site. It is not feasible

to conduct both aerobic and anaerobic biological treatment under land farm conditions. It would also be difficult to introduce cometabolized and/or engineered microorganisms in a homogeneous manner to land farm treatment cells.

Material handling requirements for land farming are much less than for slurry-phase bioreactor treatment, thus reducing the potential for volatilization during material handling activities. Construction of land farm treatment cells is relatively simple if off-gas collection and treatment is not required. Laborers would only be required to be on-Site on a periodic basis to monitor and maintain the land farm treatment cells. Maintenance would include periodic mixing of the waste with tilling equipment to enhance and ensure that proper decomposition is occurring in the treatment zone.

Cost - Refer to Section 4.3.8

4.2.9.2 Slurry-Phase Bioreactor

Description

A description of the biological treatment of buried wastes and soil is presented in Section 3.5.1.1. Figure 4-12 presents a schematic process flow diagram and preliminary design information for slurry-phase bioreactor treatment.

Implementability

Slurry-phase bioreactors have been used on full scale soil cleanups at a limited number of sites in the last few years. There are no known CERCLA Sites where slurry-phase bioreactor systems are being used on a full scale. Pilot studies are currently being conducted at several CERCLA Sites in order to evaluate the feasibility of using slurry-phase bioreactors on large-scale remedial action projects. Slurry-phase bioreactor treatment can be implemented over a smaller area than land farm treatment because of faster biodegradation rates which are achievable. Because of the volume of soil requiring treatment, however, multiple bioreactor units would have to be simultaneously operated to provide sufficient treatment capacity.

Increased contact time between microorganisms and contaminants yield faster biodegradation rates and higher and more consistent removal efficiencies. Greater process control and removal capabilities are potentially achievable in a slurry-phase biological treatment system. A series operation of aerobic and anaerobic bioreactors can be installed to degrade all of the chemicals of concern and minimize VOC emissions due to volatilization. Introduction of cometabolites and engineered microorganisms can be accomplished in a more controlled homogeneous manner in a slurry-phase bioreactor system. Recycling of acclimated microorganisms also yields higher removal efficiencies than is achievable in a land farm treatment system. Since extracted groundwater can be incorporated into a slurry-phase bioreactor treatment, the volume of groundwater required to be treated by the on-Site groundwater treatment system could be reduced once buried waste and soils treatment begins.

Material handling requirements for slurry-phase bioreactors are much greater than for land farming, thus increasing the potential for volatilization during material handling activities. Wastewater generated during the final slurry separation process would either have to be discharged under an NPDES or POTW permit, or added to the on-Site groundwater treatment system. Laborers would be required on a continuous basis to operate the slurry-phase bioreactor system.

Cost - Refer to Section 4.3.8

4.3 Detailed Analysis of Remedial Action Alternatives

4.3.1 Alternative 1 - No Action Alternative

Description

The no action alternative is required by the (revised) NCP to be carried forward for detailed evaluation. It is a no cost alternative that is retained to provide a baseline comparison to the other alternatives. Continued monitoring may be required as part of the no action alternative.

Overall Protection of Human Health and the Environment

The current levels of risk presented in the BRA would not be reduced by the no action alternative except through natural attenuation mechanisms. The presence of buried wastes below the water table, as well as contaminants which are soluble in water, would

provide a continuing source of upper and lower aquifer impact. Since the surrounding wetlands serve as a localized area for groundwater discharge, they would likely be impacted by contaminants migrating in groundwater. Downgradient residential water wells used for non-drinking purposes could also be impacted by contaminants in the groundwater.

Compliance with ARARs

None of the ARARs presented in Tables 3-2 through 3-4 are directly applicable to the no action alternative. SDWA MCLs and non-zero MCLGs could be considered relevant and appropriate ARARs. Contaminants identified in individual groundwater samples exceed corresponding SDWA MCLs and non-zero MCLGs.

Long-Term Effectiveness and Permanence

The current levels of risk or contaminant concentrations would not be reduced by the no action alternative except through natural attenuation mechanisms. The no action alternative does not include institutional controls to reduce the potential for future human exposure.

Reduction of Toxicity, Mobility or Volume Through Treatment

The no action alternative would not reduce the toxicity, mobility or volume of contaminants through treatment except by natural attenuation mechanisms.

Short-Term Effectiveness

The presence of buried waste below the water table, and contaminants which are soluble in water, would provide a continuing source of groundwater impact. On-Site workers at the ACS Site and nearby residents would potentially be exposed to VOCs released into the ambient air.

Implementability

The no action alternative does not pose any implementability issues.

Cost

There are no costs associated with the no action alternative.

4.3.2 Alternative 2 - Containment With Slurry Wall; On-Site Gradient Control; Off-Site Groundwater Pumping and Treatment; Treated Water Discharge to Wetlands; and Capping Contaminated Surface Soils

Description

A soil-bentonite slurry wall system would be constructed around the entire Site to minimize off-Site contamination migration and impede groundwater flow into the Site. Pumping from within the slurry wall would be conducted to maintain inward gradients. A discussion of potential slurry wall options is presented in Section 4.2.2. Contaminated surface soils would be capped with a RCRA multimedia cap to prevent dermal contact and minimize rainwater infiltration. In operational areas of the ACS facility, cover could be provided by asphalt or concrete. Groundwater pumping and treatment would be performed to treat off-Site contaminant migration. Groundwater treatment process options which have been retained for detailed analysis include air stripping, UV/oxidation and biological treatment. At least some of the treated groundwater would be discharged or reinjected to the wetlands west of the Site. Discharging treated groundwater would prevent dewatering of the wetlands from groundwater pumping. It is possible that some discharge water would also be used to flush contaminants from waste areas within the slurry wall.

Soil-bentonite slurry wall trenches are excavated under a slurry of bentonite and water, and the trench is backfilled with soil materials mixed with a slurry of bentonite and water. For the ACS Site, slurry walls would be keyed into the clay confining layer with an average depth of about 25 feet. Deed restrictions, fencing and well closures would be required to reduce the potential for human exposure.

Except for the former natural drainage system which received runoff from the Off-Site Containment Area (i.e., sample SD05 in the RI), elevated levels of VOCs and SVOCs were not detected in the remaining drainage ditch and wetlands sediment samples. Low levels of PAHs and phthalates were the predominant contaminants detected in the sediment samples. The levels of detected phthalates were within a range which is often typical of naturally occurring background conditions, while the levels of detected PAHs were within a range which is typical of areas proximate to vehicular traffic. Surficial

presence of PAHs is often associated with petroleum fuel-containing surface runoff from vehicular traffic sources or leaching from asphalt-based surfaces, such as the roads that bound the Site on the east.

Because of the adverse impacts to the wetlands that would result, the excavation of wetlands and drainage ditch sediments containing these levels of phthalates and PAHs has not been included as part of this alternative. Containment by the slurry wall and soil cap would minimize any potential future migration of phthalates and PAHs to the wetlands and drainage ditch sediments as a result of adsorption onto surface runoff soils. Flushing sediments over time with treated groundwater, or incorporation of in-situ biological treatment, may further reduce the phthalates and PAHs below their present low levels. Because of their strong affinity for adsorbing onto soils, phthalates and PAHs are not expected to migrate either off-Site or to the upper aquifer from wetlands and drainage ditch sediments.

The sediment sample collected from the former drainage system adjacent to the Off-Site Containment Area was the only sample which exceeds the 10 ppm total VOC criteria used to delineate contaminated soils. Sediments from this area would be contained within the slurry wall area. None of the sediment samples exceeded the 50 ppm total PCBs criteria used to delineate PCB-contaminated soils. Only one sample, SB02 taken from the ACS Site, exceeded 10 ppm total PCBs (22 ppm). This area would be contained within the slurry wall area.

Overall Protection of Human Health and the Environment

The current levels of risk associated with the on-Site exposure scenarios presented in the BRA would be reduced by preventing contact with contaminated waste and soils. On-Site levels of contaminants in soil, surface water and groundwater would not be reduced except by natural attenuation mechanisms. This could be enhanced by flushing waste and soil within the slurry wall with treated groundwater. The continued migration of contaminants in the groundwater off-Site would be reduced, which should mitigate future impact to downgradient wetlands, Turkey Creek and residential water wells. Since the source of contamination would still be present, the potential for lower aquifer impact would not be reduced. Capping the contaminated surface soils at the Site would reduce

the potential for erosion and transport of contaminated surface soils. It would also minimize the potential for the volatilization of VOCs into the ambient air, eliminate the generation of airborne contaminants, and prevent dermal contact and ingestion of surface soils if used in conjunction with deed restriction controls.

Compliance with ARARs

Most of the ARARs presented in Tables 3-2 through 3-4 are not directly applicable to Alternative 2. SDWA MCLs could be considered relevant and appropriate ARARs. Contaminants identified in individual groundwater samples exceed corresponding SDWA MCLs. Excavated soil generated during the construction of the slurry wall may qualify as RCRA hazardous wastes, and may have to be handled in accordance with RCRA storage and treatment ARARs if included in the soil volume to be treated. 40 CFR 264 Subparts F and G, pertaining to releases from Solid Waste Management Units (SWMUs) and closure and post-closure of RCRA landfills, could be considered ARARs for untreated contaminants which remain on-Site.

Long-Term Effectiveness and Permanence

The current levels of risk associated with the on-Site exposure scenarios presented in the BRA would be reduced by preventing contact with contaminated soil and waste. Contaminant concentrations would be reduced through natural attenuation of contaminants from the waste and soil with subsequent treatment of the groundwater. This could be enhanced by flushing contaminates within the slurry wall with treated groundwater. The continued migration of contaminants in the groundwater off-Site would be reduced, which would mitigate future impact to downgradient wetlands, Turkey Creek and residential water wells. Capping the contaminated soils and waste at the Site would reduce the potential for erosion and transport of contaminated surface soils. It would also minimize the potential for the volatilization of VOCs into the ambient air, eliminate the generation of airborne contaminants, and prevent dermal contact and ingestion of surface soils if used in conjunction with deed restriction controls. Institutional controls would be used to control the use of contaminated groundwater and access to the ACS Site.

Groundwater pumping and treatment may not be capable of achieving established ARARs in a 30 year time period. The groundwater pump and treat system would be optimized to determine the most efficient means to remediate the aquifer. Groundwater remediation approaches could include in-situ biological treatment or the placement of injection and withdrawal wells to more aggressively pump and treat groundwater. Consistent with current U.S. EPA guidance, it may also consist of pumping to contain the continued migration of contaminants combined with long term pumping and treatment. Based on data collected to date, it appears that the two primary flow paths for off-Site contaminant migration appear to be accumulation within the wetlands west of the Site, and to the southwest into the Griffith Landfill's dewatering system. Neither of these flow paths represent potential groundwater exposures to human receptors. The Griffith Landfill dewatering system appears to be acting as a current method of containment for off-Site contaminant migration. The Griffith Landfill's dewatering system should only be considered as a temporary method of containment since its time frame for future operation is uncertain. Two potential flow paths for off-Site contaminant migration which would not be contained by the slurry wall system, wetlands or Griffith Landfill dewatering system appear to be to the north across the railroad tracks (i.e., towards MW-13) and to the southeast (i.e., towards MW-6 and MW-17). They would be addressed by the groundwater pump and treat system.

Slurry walls used for containment may be susceptible to chemical attack and destabilization over time. Degradation of the slurry wall is likely to occur at individual points as opposed to large surface areas. However, contaminants within the groundwater would not migrate off-Site because pumping from the interior of the wall will be conducted. A small amount of pumping would maintain inward horizontal gradients. However, the strong downward vertical gradients would not be reversed by small scale pumping. Continued operations at the ACS Site would require increased maintenance to prevent deterioration of the RCRA, asphalt, or concrete caps which may be placed over portions of the Site.

Reduction of Toxicity, Mobility or Volume Through Treatment

Alternative 2 would reduce the toxicity and volume of contaminants through treatment by the operation of the groundwater pump and treat system. In the long term, some reduction in the toxicity and volume of contaminants in the waste and soils would be achieved by natural flushing and subsequent treatment of the groundwater. This could be enhanced by flushing waste and soil within the slurry wall with treated groundwater discharge. The mobility of contaminants would be greatly reduced by the slurry wall and groundwater pump and treat system.

Short-Term Effectiveness

Installation of the groundwater pump and treat system would almost immediately prevent further migration of contaminants from the Site. Therefore, the primary exposure route would be cut off. If the RCRA, asphalt and concrete caps are properly maintained, both ACS workers and nearby residents would be protected from exposure to VOCs which volatilize into the ambient air, as well as airborne contaminants. Continued chemical manufacturing operations at the ACS Site could cause maintenance problems for any RCRA, asphalt, or concrete caps which are placed over the areas of contamination. Slurry wall construction workers would be exposed to contaminated soils during the excavation process. A health and safety program which requires the use of personal protective equipment for remediation workers should minimize short-term risks to workers during implementation of Alternative 2. The time frame required to complete the construction of Alternative 2 is estimated to be one year. Operation and maintenance would continue for 30 years.

Implementability

Slurry wall systems are proven methods for containing contaminated groundwater. Vendors capable of installing slurry wall systems are readily available. The coarse grained sand present at the ACS Site may cause construction problems and slowdowns. The construction techniques used in the installation of soil-bentonite slurry wall systems should be capable of overcoming the potential problems associated with the soil conditions at the ACS Site. Issues associated with ACS's continued use of the railroad tracks which divide the on- and off-Site areas can be resolved so that an appropriate

slurry wall configuration can be selected. At the present time, ACSs continuing chemical manufacturing operations will require future use of the railroad tracks.

Cost - Capital, annual operation and maintenance (O&M) and net present worth costs are presented in Table 4-16 and Appendix B. Design assumptions for purposes of the cost estimates are presented in Figure 3-2 and the itemized cost estimated for Alternative 2 presented in Appendix B.

4.3.3 Alternative 3A - Dewatering of On-site Areas; Excavation and On-site Incineration of Buried Waste; Groundwater Pumping and Treatment; and Treated Water Discharge to Wetlands

Alternative 3B - Same as Alternative 3A Except Waste Would be Treated with Low Temperature Thermal Treatment

Description

The Site would be dewatered using an extraction system described in Section 4.2.3 so that areas defined as buried waste and PCB-contaminated soils can be excavated for on-Site thermal treatment. Initially, the groundwater pumping and treatment system would operate at 200 gpm to lower the water level at the Site to elevation 725. Once the groundwater level is lowered, the pumping rate would be reduced to about 80 gpm to maintain the lowered level. Excavation would then begin in one of the waste areas until groundwater is encountered. A well point system would then be used around the excavation area to further lower the water table to the top of clay in the immediate vicinity of the excavation. Excavation would then continue to the top of clay. For Alternative 3A, the excavated waste would be treated with an on-Site incinerator. Waste would be treated with a low temperature thermal treatment unit for Alternative 3B. Treated waste would be placed back into the excavation. After the waste from each area is removed, treated and backfilled, the well point system would be removed. Excavation of waste would then begin in a new area of the Site until all waste is removed and treated.

Groundwater pumping and treatment would be conducted in off-Site areas. At least some of the treated groundwater would be discharged to the wetlands west of the Site. Discharging treated groundwater would prevent dewatering of the wetlands from groundwater pumping. It is anticipated that the groundwater pump and treat system would operate for 30 years.

Treatment of contaminated soils would be accomplished by flushing of contaminants to the water table by means of both rainfall infiltration and reinjection of treated groundwater. Contaminants flushed from the soils would then be treated in the groundwater pump and treat system. An infiltration basin would have be constructed in each of the source areas in order to use treated groundwater to flush contaminants from the unsaturated zone. Following removal of the buried waste and their treatment on-Site, the groundwater pump and treat system would be optimized to determine the most efficient means to remediate the aquifer. Groundwater remediation approaches could include in-situ biological treatment or the placement of injection and withdrawal wells to more aggressively pump and treat the groundwater. Consistent with current U.S. EPA guidance, it may consist of pumping enough to prevent the further migration of contaminants with long term pumping and treatment. Deed restrictions, fencing and well closures would be required to reduce the potential for human exposure. Groundwater treatment process options which have been retained for detailed analysis include air stripping, biological treatment and UV/oxidation. A comparison of groundwater and surface water treatment process options is presented in Section 4.2.7.

For the purposes of generating a cost estimate for this alternative, buried waste volumes for each source area were determined incorporating both visual observations of buried drum and free waste presence during site investigation activities, as well as a delineation of areas at each sample depth interval with total VOCs in excess of 1% based on data generated during the RI. A cut-off point of 1% VOCs was selected for buried waste determination since this level is expected to represent the presence of "free waste/liquids" and offered a discernible level for the differentiation of the RI data. The maximum volume determined using either approach was used to calculate the buried waste volume for this alternative. Based on these determinations, approximately 65,000

cubic yards (approximately 96,000 tons) would require on-Site thermal treatment. A delineation of areas defined as buried waste is depicted in Figure 4-1. Using 50 ppm total PCBs as the criteria for delineation, approximately 1,000 cubic yards of PCB-contaminated soils would be excavated for thermal treatment. A uniform depth of buried waste and PCB presence using surface areas depicted in Figure 4-1 was not assumed in the calculation of volume. The depth requiring excavation for each cross-sectional area was assumed to be the maximum depth meeting one of the buried waste or PCB-contaminated soils criteria outlined above based on sampling intervals used during the RI. Cross-sectional drawings delineating defined areas of buried waste and PCB-contaminated soils at depth will have to be prepared during the final design.

Low temperature thermal treatment and incineration have been retained as potential thermal treatment technologies. ACS's intention to continue its chemical manufacturing operations would have to be considered in locating an on-Site thermal treatment unit. The mobile thermal treatment unit and soil staging area would have to be located adjacent to the off-Site Containment Area depicted in Figure 4-7 to avoid interfering with ACS' operations. A comparison of these process options has been made in Section 4.2.7. Figures 4-8 and 4-9 present schematic process flow diagrams and preliminary design information for these process options. Off-gases from the low temperature thermal treatment unit would likely be treated using a thermal or catalytic incinerator.

On-Site thermal treatment would be performed using either a mobile low temperature thermal treatment unit or mobile rotary kiln incinerator. Excavated materials from the areas located on the ACS portion of the Site would have to be transported to the off-Site staging area. Tank farms located on top of the Still Bottoms and Treatment Lagoon Areas would either have to be dismantled or relocated before excavation could begin in those areas.

None of the sediment samples collected exceeded the 1% total VOC criteria used to delineate buried waste. Except for the former natural drainage system which received runoff from the Off-Site Containment Area (i.e., sample SD05 in the RI), elevated levels

of VOCs and SVOCs were not detected in the remaining drainage ditch and wetlands sediment samples. Low levels of PAHs and phthalates were the predominant contaminants detected in the sediment samples. The levels of detected phthalates were within a range which is often typical of naturally occurring background conditions, while the levels of detected PAHs were within a range which is typical of areas proximate to vehicular traffic. Surficial presence of PAHs is often associated with petroleum fuel-containing surface runoff from vehicular traffic sources or leaching from asphalt-based surfaces, such as the roads that bound the Site to the east.

Because of the adverse impacts to the wetlands that would result, the excavation of wetlands and drainage ditch sediments containing these levels of phthalates and PAHs has not been included as part of this alternative. Source removal resulting from the excavation and thermal treatment of buried waste of soils and soil covering would reduce the future migration of phthalates and PAHs to the wetlands and drainage ditch sediments as a result of adsorption onto surface runoff soils. Flushing sediments over time with treated groundwater, or incorporation of in-situ biological treatment, may further reduce the phthalates and PAHs below their present low levels. Because of their strong affinity for adsorbing onto soils, phthalates and PAHs are not expected to migrate either off-Site or to the upper aquifer from wetlands and drainage ditch sediments.

None of the sediment samples exceeded the 50 ppm total PCBs criteria used to delineate PCB-contaminated soils. Only one sample, SB02 taken from the ACS Site, exceeded 10 ppm total PCBs (22 ppm). This area could either have a soil cover placed over it to prevent dermal contact, or excavated for thermal treatment along with other PCB-contaminated soil areas.

The largest mobile incinerator and low temperature thermal units currently available are capable of processing 30 to 50 tons of soil per hour. A typical mobile thermal treatment unit processes 10 tons of soil per hour. Pretreatment in the form of mixing and screening of the buried waste would be necessary to provide a more homogeneous feedstock. Assuming a one year time frame to complete dewatering activities, and 24 hours per day operation of the thermal treatment unit, the estimated time frame to complete source

treatment activities for Alternative 3 is 3 years. Treated waste would be backfilled into the excavations; however, some soil volume would have to be made up with clean fill materials. Fixation of metals present in the incinerator ash soil residuals from low temperature thermal treatment may have to be performed prior to placement back onto the Site.

Overall Protection of Human Health and the Environment

On-Site thermal treatment of buried wastes would reduce the overall risk by treating the areas of highest contamination. However, residual levels of contaminants in soil would remain. Contaminated groundwater would be treated. The continued migration of contaminants in the groundwater off-Site would be reduced, which should mitigate future impact to downgradient wetlands, Turkey Creek and residential water wells. The potential for lower aquifer impact would be reduced by a significant reduction in the volume of source material. Well closures, and possibly institutional controls pertaining to access restrictions to the Site, may be required to reduce the potential for human exposure to contaminated groundwater and residual contaminants which remain on-Site.

Compliance with ARARs

A description of potential ARARs for the ACS Site is presented in Tables 3-2 thru 3-4. It is anticipated that all ARARs would be met by Alternative 3. SDWA MCLs could be considered relevant and appropriate chemical-specific ARARs for groundwater, while proposed RCRA Corrective Action regulations could be considered as chemical- and action-specific ARARs or TBCs for groundwater. Contaminants identified in individual groundwater samples exceed corresponding SWDA MCLs. Chemical location and action-specific ARARs would apply to the discharge or reinjection of treated groundwater and surface water to either the POTW, Turkey Creek, the drainage ditch which recharges the surrounding wetlands or directly to the wetlands or other portions of the Site or upper aquifer. Action-specific ARARs would apply to the operation of the on-Site thermal treatment unit. 40 CFR 264 Subparts F and G, pertaining to releases from SWMUs and closure and post-closure of RCRA landfills, could be considered ARARs for untreated contaminants which remain on-Site.

The operation of the on-Site thermal treatment unit would have to meet RCRA hazardous waste and TSCA PCB storage and treatment regulations. Generated incinerator ash and groundwater treatment system residuals (e.g. ion exchange backflushing) storage and off-Site disposal would have to comply with RCRA hazardous waste generator regulations. A treatability variance from the RCRA LDRs may have to be obtained to redeposit thermally treated soils on-Site. It is expected that the LDRs can be met since incineration and immobilization are the BDATS for most of the organic compounds and metals detected at the Site. Refer to Section 3.5.1 for a discussion on obtaining a treatability variance for CERCLA response actions. The alternative action levels specified in Section 3.5.1 are also applicable to incineration and low temperature thermal treatment.

Air emissions (e.g. particulates) from the thermal treatment operation would have to comply with IDEM air emission requirements. IDEM VOC emission requirements would be applicable to the operation of the low temperature thermal stripping operation, as well as the air stripping of groundwater if employed. If air stripping is selected as the groundwater treatment option, a vapor phase carbon adsorption or thermal treatment unit would have to be added to the air stripping tower if VOC emission levels are exceeded. Current IDEM VOC emission requirements for new facilities contained in 326 IAC 8-6-6 require best available control technology (BACT) for sources which have potential emissions of 25 tons per year or greater (i.e., approximately 6.0 pounds per hour for continuous operations). The emission requirements would cover total VOC emissions from all remedial action processes.

Long-Term Effectiveness and Permanence

The current levels of risk associated with the on-Site exposure scenarios presented in the BRA (e.g. on-Site resident) would be reduced with the removal of contaminated groundwater and excavation of buried wastes. The dewatering of the Site would reduce groundwater and contaminant migration from the Site. Residual levels of contaminants in the soil would remain. Remaining residual soil contaminants would either be naturally attenuated into infiltrating groundwater and be treated with the groundwater pump and treat system or removed by a more aggressive groundwater pump and treat

system. The levels of remaining residual soil contaminants could impact the lower aquifer where they would be pumped and treated. Institutional controls would be used to control the use of contaminated groundwater and access to the ACS Site. Refer to Section 4.3.2 for a discussion pertaining to the long-term effectiveness of groundwater pumping and treatment.

Reduction of Toxicity, Mobility or Volume Through Treatment

A discussion of reduction of toxicity, mobility or volume through treatment is presented in Section 4.2.8 for on-Site low temperature thermal treatment and incineration.

Short-Term Effectiveness

Completion of Site dewatering would be completed in approximately one year. Both horizontal and vertical migration of contaminants in the groundwater from the Site would be mitigated upon completion of this task. The estimated time frame to complete source treatment activities for Alternative 3 is 3 years. It is assumed for purposes of the cost estimates that groundwater treatment would continue for a 30 year period. A more aggressive pump and treat approach would likely reduce the time frame to reach the maximum achievable level of aquifer contaminant removal.

Nearby residents, ACS workers and remediation contractor workers could be exposed to airborne particulates or volatilized VOCs during excavation and material handling activities. Ambient air monitoring may be required to evaluate potential VOC exposures. Small quantities of contaminated materials could be spilled over the surface of the Site during transfer to the soil staging area located adjacent to the Off-Site Containment Area. ACS workers and remediation contractor workers would be exposed to contaminated soil during excavation and material handling activities. A health and safety program which requires the use of personal protection equipment for on-Site workers should minimize short-term risk during implementation of Alternative 3.

Implementability

A discussion of implementability is presented in Section 4.2.8 for on-Site thermal treatment and incineration. A RCRA Part B treatment permit would not be required for operation of the thermal treatment unit since this is a CERCLA Site. IDEM air

emission ARARs would have to be met in order to construct and operate the thermal treatment unit. Appropriate approvals and/or permits would have to be obtained in order to discharge treated groundwater. Tank farms located on top of the Still Bottoms and Treatment Lagoon Areas would either have to be dismantled or relocated before excavation could begin in those areas. Utility lines and product and water lines are also located in the area of the tank farms. These lines would either have to be moved or replaced. The continuation of ACS's chemical manufacturing operations could interfere with excavation and material handling activities. An access road and entrance road to the Site, both adjacent to the On-Site Containment Areas, may be blocked by excavation activities. Temporary access roads may have to be constructed. A full time shift of workers would have to be present on-Site to operate the thermal treatment system on a 24-hour basis. If infiltration basins are used in each of the source areas to use reinjected groundwater to flush contaminants from the unsaturated zone, they would have to be constructed over very large surface areas. Because of the significant surface areas to be covered, the construction of infiltration basins over each of the source areas may not prove either feasible or practical.

Cost - Capital, annual O&M and net present worth costs are presented in Table 4-15 and Appendix B. Design assumptions for purposes of the cost estimates are presented in Figures 4-12, 4-13 and 4-14 and the itemized cost estimates for Alternatives 3A and 3B presented in Appendix B.

4.3.4 Alternative 4 - In-Situ Steam Stripping of Buried Waste, Soils and Groundwater; Groundwater Pumping and Treatment; and Treated Water Discharge to Wetlands

Description

PCB-contaminated surficial soils (i.e., depths of 0 to 3 feet) exceeding 50 ppm total PCBs would be immobilized in-situ by natural attenuation processes or fixation techniques or excavated for Off-Site landfilling. In-situ steam stripping would be used to simultaneously treat buried wastes, soil and on-Site groundwater in place. Approximately 135,000 cubic yards (200,000 tons) of buried waste and soils would require in-situ steam stripping treatment (refer to Sections 4.1.2 and 4.3.6 for basis of buried waste and soil volume calculations). Deed restrictions, fencing and well closures would be required to reduce the potential for human exposure. Delineations of areas

would be required to reduce the potential for human exposure. Delineations of areas requiring in-situ steam stripping treatment are depicted in Figures 4-1 and 4-2.

Groundwater pumping and treatment would be performed to contain off-Site contaminant migration. The groundwater pump and treat system would be optimized to determine the most efficient means to remediate the aquifer. Groundwater remediation approaches could include in-situ biological treatment or the placement of injection and withdrawal wells to more aggressively pump and treat groundwater. Consistent with current U.S. EPA guidance, it may also consist of pumping to contain the continued migration of contaminants combined with long term pumping and treatment. At least some of the treated groundwater would be discharged to the wetlands west of the Site. Discharge of treated groundwater would prevent dewatering of the wetlands. Groundwater treatment process options which have been retained for detailed analysis included air stripping, UV/oxidation and biological treatment.

Figure 4-13 presents a schematic process flow diagram and preliminary design information for in-situ steam stripping. Steam stripping involves the use of steam and hot air to strip VOCs from contaminated soil and/or groundwater. Present in-situ steam stripping processes involve the injection of steam through specially designed hollow stem augers which are moved vertically through the unsaturated and saturated zones. The auger injection unit is mobile, and is capable of treating approximately 3.3 square yards of surface area at a time. Each of the areas to be treated would be sectioned into individual grids. Steam at 400°F and compressed air at 275°F are piped through the augers to nozzles located on the cutter blades. The air is filtered and recycled to the soil by a compressor. Steam is condensed and processed through a batch distillation system prior to being treated for soluble organics removal and recycled through a cooling tower. Organic vapors are condensed, collected following a water separation process, and shipped off-Site for disposal via incineration or a secondary fuel blending program.

Treatment times for each block of soil vary depending on the soil type and contaminant concentrations. The average treatment times per block for the SITE Program demonstration of in-situ steam stripping was 24 hours (de Percin, June 1990) for a treatment depth of 5 feet. Assuming a 36 hour treatment time for soil and groundwater to a depth of 20 feet (including set up time for each block), a treatment surface area of 35,000 square feet, continuous operation for 250 days per year and simultaneous operation of four to eight auger injection units, the estimated time frame to complete source treatment activities for Alternative 4 is 10 to 20 years. The treatment time frame could be proportionately reduced with the inclusion of additional mobile auger injection units operating simultaneously at different locations of the Site. It is anticipated that the groundwater pump and treat program would continue for 30 years.

Except for the former natural drainage system which received runoff from the Off-Site Containment Area (i.e., sample SD05 in the RI), elevated levels of VOCs and SVOCs were not detected in the remaining drainage ditch and wetlands sediment samples. Low levels of PAHs and phthalates were the predominant contaminants detected in the sediment samples. The levels of detected phthalates were within a range which is often typical of naturally occurring background conditions, while the levels of detected PAHs were within a range which is typical of areas proximate to vehicular traffic. Surficial presence of PAHs is often associated with petroleum fuel-containing surface runoff from vehicular traffic sources or leaching from asphalt-based surfaces, such as the roads that bound the Site to the east.

Because of the adverse impacts to the wetlands that would result, the excavation of wetlands and drainage ditch sediments containing these levels of phthalates and PAHs has not been included as part of this alternative. Source removal resulting from the in-situ steam stripping treatment of buried waste and soils and soil covering would minimize the future migration of phthalates and PAHs to the wetlands and drainage ditch sediments as a result of adsorption onto surface runoff soils. Flushing sediments over time with treated groundwater, or incorporation of in-situ biological treatment, may further reduce the phthalates and PAHs below their present low levels. Because of their strong affinity for adsorbing onto soils, phthalates and PAHs are not expected to migrate either off-Site or to the upper aquifer from wetlands and drainage ditch sediments.

The sediment sample collected from the former drainage system adjacent to the Off-Site Containment Area was the only sample which exceeds the 10 ppm total VOC criteria used to delineate contaminated soils. Sediments from this area would either be excavated for off-Site disposal or treated by in-situ steam stripping. None of the sediment samples exceeded the 50 ppm total PCBs criteria used to delineate PCB-contaminated soils. Only one sample, SB02 taken from the ACS Site, exceeded 10 ppm total PCBs (22 ppm). This area could either have a soil cover placed over it to prevent dermal contact, or excavated for off-Site landfilling or treated in-situ along with other PCB-contaminated soil areas.

Overall Protection of Human Health and the Environment

In-situ steam stripping would significantly reduce the VOCs and some of the SVOCs present in the soils. If biological degradation of the remaining SVOCs occurs in conjunction with steam stripping treatment, additional reductions could occur. Because of its limited history in treating VOCs and SVOCs at concentrations similar to those detected at the ACS Site, it is not known if steam stripping is capable of achieving adequate removal efficiency for all of the organic compounds of concern. Deed restrictions, fencing and the placement of a soil cover may have to be instituted to prevent exposure to remaining residual soil contaminants.

At the completion of the remedial action activities, contaminated soil and groundwater would be treated, and the continuing source of groundwater contamination significantly reduced. This could mitigate future impact to downgradient wetlands, Turkey Creek, residential water wells, as well as the lower aquifer. Well closures, and possibly institutional controls pertaining to access restrictions and capping of the Site, would be required to reduce the potential for human exposure to contaminated groundwater and residual contaminants which remain on-Site.

Compliance With ARARs

Refer to Section 4.3.3 for a discussion of Site ARARs in general, as well as ARARs applicable to VOC air emissions. It is anticipated that all ARARs would be met by Alternative 4. Based on high VOC contaminant levels present in the buried wastes and

soil, VOC emissions would exceed the 6 pound/hr limit established by the IDEM. Vapor phase treatment (most likely condensation) would be required if in-situ steam stripping is employed. Condensed organics storage and off-Site disposal would have to comply with RCRA hazardous waste generation regulations. 40 CFR 264 Subparts F and G, pertaining to releases from SWMUs and closure and post-closure of RCRA landfills, could be considered ARARs for untreated contaminants which remain on-Site.

Long-Term Effectiveness and Permanence

Based on risk levels presented in the BRA for various on-Site exposure scenarios (e.g. on-Site resident), a significant reduction of the identified chemicals of concern would have to be achieved. It is not known if in-situ steam stripping would adequately remove the SVOCs identified at the Site. SVOCs not amenable to in-situ steam stripping treatment that may remain as residual soil contamination tend to be insoluble in water and have high soil adsorption coefficients. These compounds would not be expected to be mobile in groundwater systems (identified groundwater contaminants at the ACS Site are presently limited to VOCs and SVOCs with high water solubilities such as benzene, acetone, methyl ethyl ketone and bis(2-chloroethyl) ether). Because of its limited history in treating VOCs at concentrations similar to those detected at the ACS Site, it is not known if steam stripping is capable of achieving such a removal efficiency for all of the organic compounds of concern. In-situ fixation of metals and PCBs may also have to be performed on soils.

At the completion of remedial action activities, contaminated groundwater would be treated. The continuing source of groundwater contamination would be significantly reduced. This could mitigate future impact to downgradient wetlands, Turkey Creek, residential water wells, as well as the lower aquifer. Remaining residual soil contaminants would either be naturally attenuated by infiltrating groundwater and treated with the pump and treat system or removed by a more aggressive pump and treat system (refer to "Description" subsection).

Institutional controls would be used to control the use of contaminated groundwater and access to the Site. Refer to Section 4.3.2 for a discussion pertaining to the long term effectiveness of groundwater pumping and treatment. During the treatment process, the possibility exists that contaminated groundwater from untreated areas could migrate into the saturated zones of areas which have already been treated. This would increase the levels of residual contamination following the completion of treatment activities. A significant concern with steam stripping is the potential that the augers will penetrate the clay confining layer under the Site. If that were to occur, very high levels of contamination would be introduced into the lower aquifer. In addition, the steam stripping operation will mix highly contaminated waste with less contaminated surrounding soils. If for any reason the steam stripping system does not work, a much larger volume of contaminated soil would need to be addressed.

Reduction of Toxicity, Mobility or Volume Through Treatment

In-situ steam stripping of buried waste, soils and groundwater transfers organic compounds to the air phase. If thermal treatment is used or condensed organics shipped off-Site to a secondary fuel blending program, the destruction of organic compounds would result in an overall toxicity and volume reduction of contaminants in the buried waste, soils and groundwater. Compounds with boiling points less than 150°C are generally amenable to steam stripping. Based on this criteria and the boiling points for the target compounds presented in Table 3-1, BETX compounds, chlorinated methanes, chlorinated ethanes, chlorinated ethenes and volatile ketones would be amenable to steam stripping. Chlorinated benzenes, carcinogenic PNAs, naphthalene and its derivatives, PCBs, phthalates, phenols, ethers, organic acids, isophorone and inorganic metals may not be amenable to steam stripping. According to U.S. EPA (September 1988), all of the chemical groups of concern except PCBs and inorganic metals are potentially amenable to steam stripping.

Limited data presently exists to evaluate removal efficiencies for in-situ steam stripping. The only case study available to date is the U.S. EPA SITE program demonstration performed by Toxic Treatment (USA) Inc. at a Superfund Site located in San Pedro, California (de Percin, June 1990). The contaminant matrix and soil conditions at that

Site are analogous to those present at the ACS Site. Trichlorothene, tetrachloroethene and chlorobenzene were the primary contaminants of concern. Average total VOC concentrations present in soils prior to treatment were approximately 500 ppm, significantly lower than contaminant concentrations present at the ACS Site. Based on tests run on twelve separate soil blocks, an average total VOC removal efficiency of 85% was achieved. Substantial removal efficiency variations occurred between soil blocks. Downward migration of contaminants to below the treatment zone appeared to be insignificant. SVOCs were reduced by an average of 55%, but their final disposition could not be determined.

Of the chemical groups that may not be amenable to in-situ steam stripping, phenols were not identified as a target compound group for soils in any of the areas based on the BRA. Phenols, organic acids and isophorone were not identified as target compounds in the upper aquifer. Phthalates, carcinogenic PNAs, PCBs and inorganic metals have high soil adsorption coefficients and were not identified as a target compound group in the upper aquifer. If left untreated, phthalates, carcinogenic PNAs, PCBs and inorganic metals would be expected to be immobilized in the soil matrix and not pose a potential migration threat to either the upper aquifer or ambient air.

Ethers and naphthalene and its derivatives are the only chemical groups that may not be amenable to in-situ steam stripping identified as target compound groups in both the soil matrix and upper aquifer. Both of these target compound groups, as well as other SVOCs and residual VOCs, can be biologically degraded under aerobic conditions (refer to Section 4.2.7.2). If required, in-situ fixation of soils would reduce the mobility of metals, SVOCs and/or PCBs. Figure 4-14 presents a schematic process flow diagram and preliminary design information for in-situ fixation. Refer to Section 3.6.2.5 for a discussion of in-situ fixation. The fixation of metals is a proven technology, but the effectiveness of immobilizing PCBs and SVOCs by fixation technologies has yet to be adequately demonstrated. SVOCs, PCBs, and metals would, therefore, be immobilized by either natural attenuation processes or fixation techniques.

Short-Term Effectiveness

Sampling performed during the SITE program demonstration showed fugitive organic emissions to be very low during processing. On-Site workers or neighboring residents would not be exposed to airborne contaminants or contaminated soil during remedial action activities. The estimated time frame to complete source treatment activities for Alternative 4 is 10 to 20 years. It is assumed for purposes of the cost estimates that groundwater treatment would continue for a 30 year period. A more aggressive pump and treat approach would likely reduce the time frame to reach the maximum achievable level of aquifer contaminant removal.

Implementability

In-situ steam stripping has yet to be demonstrated on full scale soil and waste cleanups. To date, its application at CERCLA Sites has been limited to a single pilot study as part of the SITE demonstration program. A pilot study would be required to determine the feasibility of treating the contaminant matrix present in the buried waste, soils and groundwater of the ACS Site. There is one known vendor at the present time for this technology.

The primary attribute of in-situ steam stripping is its potential ability to concurrently treat buried waste, soils and groundwater at the ACS Site without the need to dewater the Site or excavate and treat the buried waste separately. However, the possibility exists that contaminated groundwater from untreated areas could migrate into the saturated zones of areas which have already been treated. The zone of influence for in-situ steam stripping is not sufficient to treat contamination underneath the tank farms located over the Still Bottoms/Treatment Lagoon Area. Therefore, the tank farms would have to be dismantled or relocated if ACS continues its chemical manufacturing operations. Utility lines and product and water lines are also located in the area of the tank farms. These lines would either have to be moved or replaced. Results of the SITE program demonstration found that physical properties of the soil were not affected by the treatment. Since dewatering is not involved, and the technology is primarily self-contained, there would be minimal requirements to abandon wells or dismantle process equipment and piping following completion of the remedial action remedy.

Because of the extensive surface area requiring in-situ treatment, a single auger injection unit would not be capable of remediating the Site in an acceptable time frame. Multiple units would have to be operated simultaneously at different locations of the Site. Workers would have to be on-Site a minimum of one 8-hour shift per day to move and operate the mobile auger injection units. In order to support multiple auger units, a centralized steam supply system would likely have to be constructed. Soil and groundwater sampling would have to be performed at the completion of in-situ steam stripping to verify its effectiveness.

Two significant concerns with steam stripping are the potential for penetrating the clay confining layer and the large volume of soil that would have to be treated if the system does not work.

Treatability and pilot studies would be required if in-situ fixation is required for soils and sediments following in-situ steam stripping treatment.

Cost - Capital, annual O&M and net present worth costs are presented in Table 4-16 and Appendix B. Design assumptions for purposes of the cost estimate are presented in Figure 4-18 and itemized cost estimate for Alternative 4 presented in Appendix B.

4.3.5 Alternative 5 - Off-Site Incineration of Buried Drums; Off-Site Disposal of Miscellaneous Debris; In-Situ Vapor Extraction of Buried Waste and Soils; Groundwater Pumping and Treatment; and Treated Water Discharge to Wetlands

Description

The Site would be dewatered using an extraction system described in Section 4.2.3 so that intact buried drums and miscellaneous debris can be excavated. Intact buried drums in the On-site Containment Area and miscellaneous debris would be excavated prior to installation of the vapor extraction treatment system. Intact drums would be incinerated off-Site and miscellaneous debris would be landfilled off-Site. PCB-contaminated surficial soils (i.e., depths of 0 to 3 feet) exceeding 50 ppm total PCBs would be

immobilized in-situ by natural attenuation processes or fixation techniques or excavated for off-Site landfilling. Initially, a groundwater pumping and treatment system would operate at 200 gpm to lower the water level at the Site to elevation 725. Once the groundwater level is lowered across the Site, the pumping rate would be reduced to about 80 gpm to maintain the lowered level. Additional wells would be installed around the waste areas to lower the water level to the top of the clay confining layer.

An in-situ vapor extraction system would be installed in order to treat both soils and buried waste. Partial installation of a vapor extraction system could begin following the completion of Site dewatering in areas which are not impacted by buried drum excavation activities. Refer to Sections 4.1.2 and 4.3.6 for a discussion of the criteria used to delineate areas and depths of soils and buried waste requiring treatment. Approximately 135,000 cubic yards (200,000 tons) of soils and buried waste would require vapor extraction treatment. A delineation of areas requiring vapor extraction treatment is presented in Figures 4-1 and 4-2. A uniform depth of buried waste, PCB and VOC presence using surface areas depicted in Figures 4-1 and 4-2 was not assumed in the calculation of total volume requiring treatment. The depth requiring treatment for each cross-sectional area was assumed to be the maximum depth meeting either the buried waste or VOC- or PCB-contaminated soils criteria based on sampling intervals used during the RI. Cross-sectional drawings delineating defined areas of buried waste and VOC- and PCB-contaminated soils at depth will have to be prepared during the final design.

Because of the large waste and soil volumes requiring treatment, and the significant distances between each of the areas, it has been assumed for cost estimating purposes that four separate vapor extraction systems would be installed. Separate systems would be located in the On-Site Containment Area, the Still Bottoms/Treatment Lagoon Areas, the Off-Site Containment Area and the Kapica-Pazmey Area. Figure 4-15 presents a layout of the proposed extraction system, while Figure 4-16 presents a schematic process flow diagram and preliminary design information for a vapor extraction system.

Design parameters presented in the case study for the Verona Well Field Superfund Site (Verona Site) located in Battle Creek, Michigan (U.S. EPA, July 1989) serve as the basis for the treatment time frame estimate and extraction well spacings for the ACS Site. The soil conditions and VOC contaminant matrix at the Verona Site were similar to the ACS Site. Maximum individual VOC soil concentrations at the Verona Site ranged up to 1800 ppm (U.S. EPA, July 1989). Approximately 28,000 pounds of VOCs were extracted in 55 days of operation (i.e., an average of approximately 500 pounds/day). Actual design parameters for a vapor extraction system would be determined following the completion of a pilot study.

A grid system of extraction wells, spaced at 75-foot intervals, would be installed in the four areas described above. A 75-foot well spacing would allow each of the wells to serve as either extraction or passive inlet wells in order to provide for maximum operational flexibility. Well placement and screening depths are dependent on the zones of contamination to be treated and localized soil conditions. The extraction well system would be manifolded to a building or shelter housing the vacuum pump and vapor treatment system. Each pump would operate at a vacuum of approximately 5-inches of mercury. Depending on the actual level of vapor emissions and potential implementability issues, the vapor treatment system would either consist of separate carbon adsorption units, separate portable thermal or catalytic treatment units or a larger, centralized thermal or catalytic treatment unit. Since the vapor extraction system would be operated under winter conditions, insulation and heat tracing would have to be provided for portions of the air manifold system installed above the freeze line.

Except for the former natural drainage system which received runoff from the Off-Site Containment Area (i.e., sample SD05 in the RI), elevated levels of VOCs and SVOCs were not detected in the remaining drainage ditch and wetlands sediment samples. Low levels of PAHs and phthalates were the predominant contaminants detected in the sediment samples. The levels of detected phthalates were within a range which is often typical of naturally occurring background conditions, while the levels of detected PAHs were within a range which is typical of areas proximate to vehicular traffic. Surficial presence of PAHs is often associated with petroleum fuel-containing surface runoff from vehicular traffic sources or leaching from asphalt-based surfaces, such as the roads that bound the Site to the east.

Because of the adverse impacts to the wetlands that would result, the excavation of wetlands and drainage ditch sediments containing these levels of phthalates and PAHs has not been included as part of this alternative. Source removal resulting from vapor extraction treatment of buried waste and soils and soil covering would minimize the future migration of phthalates and PAHs to the wetlands and drainage ditch sediments as a result of adsorption onto surface runoff soils. Flushing sediments over time with treated groundwater, or incorporation of in-situ biological treatment, may further reduce the phthalates and PAHs below their present low levels. Because of their strong affinity for adsorbing onto soils, phthalates and PAHs are not expected to migrate either off-Site or to the upper aquifer from wetlands and drainage ditch sediments.

The sediment sample collected from the former drainage system adjacent to the Off-Site Containment Area was the only sample which exceeds the 10 ppm total VOC criteria used to delineate contaminated soils. Sediments from this area would either be excavated for off-Site disposal or treated by vapor extraction since the area will be dewatered. None of the sediment samples exceeded the 50 ppm total PCBs criteria used to delineate PCB-contaminated soils. Only one sample, SB02 taken from the ACS Site, exceeded 10 ppm total PCBs (22 ppm). This area could either have a soil cover placed over it to prevent dermal contact, or excavated for off-Site landfilling or treated in-situ along with other PCB-contaminated soil areas.

A cover could be placed over unpaved surfaces in the areas to be treated in order to prevent the short-circuiting of air from the surface, which reduces the radius of influence of individual extraction wells. A cover would also reduce rainwater infiltration which could adversely impact vapor extraction treatment efficiencies. Either a plastic liner or soil cover could serve this purpose.

The treatment time frame estimate is based on an assumed average VOC soil concentration in the Off-Site Containment Area of 24,000 ppm (2.4%), and an average VOC removal rate between 500 pounds per day and 3500 pounds per day (extrapolated based on the ratio of total VOC concentrations in the Off-Site Containment Area versus

the Verona Well Field Superfund Site) for the Off-Site Containment Area only. The Off-Site Containment Area was used as the basis for the treatment time frame calculations since the highest average total VOC concentrations were found in this area. Based on these VOC removal rates, the estimated time frame to complete Alternative 5 is 5 to 20 years.

Groundwater pumping and treatment would be performed to contain off-Site contaminant migration. After dewatering is achieved, buried drums would be excavated and taken off-Site for incineration. The groundwater pump and treat system would then be optimized to determine the most efficient means to remediate the aquifer. Groundwater remediation approaches could include in-situ biological treatment or the placement of injection and withdrawal wells to more aggressively pump and treat the groundwater. Consistent with current U.S. EPA guidance, it may consist of pumping enough to prevent the further migration of contaminants with long term pumping and treating. At least some of the treated groundwater would be discharged to the wetlands west of the Site. Discharging treated groundwater would prevent dewatering of the wetlands from groundwater pumping. It is anticipated that the groundwater pump and treat system would operate for 30 years.

Overall Protection of Human Health and the Environment

The primary exposure pathway from the site is the migration of contaminants in groundwater. The installation of a groundwater extraction system eliminates this pathway. Treatment of extracted groundwater has the effect of reducing the volume of source material over time.

Vapor extraction is a proven technology for the treatment of VOC-contaminated soils. It is most effective in homogeneous, permeable soil conditions, such as those at the ACS Site. Dewatering of the site prior to the installation of the vapor extraction system should reduce the water content of the Site soils to the optimum treatment range. Vapor extraction is less effective in the treatment of some SVOC compounds and metals. However, these compounds are relatively immobile in the environment and pose little potential for migration.

Vapor extraction is expected to be effective in lowering the concentrations of contaminants in waste materials. A major advantage of this system is that extraction is conducted in-situ under controlled conditions so that the short term risks associated with excavating highly contaminated materials are eliminated. Vapor extraction treatment may not adequately remove SVOCs from soils to the level necessary to eliminate the potential risk to future Site users.

A pilot scale test would be conducted to demonstrate its overall effectiveness because it has not been proven in materials with contaminant concentrations as high as those at the ACS Site. However, even if final removal efficiencies cannot be achieved, it is anticipated that very large reductions in contaminant levels would be accomplished. Therefore, the volume of waste which may require additional treatment in the future would be significantly reduced. Because VOCs, which have the greatest potential for airborne migration if excavated, would be greatly reduced, the risks of future excavation, if required, would be minimized.

Compliance With ARARs

Refer to Section 4.3.3 for a discussion of Site ARARs in general, as well as ARARs applicable to the discharge of treated groundwater and VOC air emissions. It is anticipated that all ARARs would be met by Alternative 5. Groundwater treatment system residuals (e.g., ion exchange backflushing) storage and off-Site disposal would have to comply with RCRA hazardous waste generator regulations. Based on a weighted average approach using the previously mentioned VOC removal rates for the Off-Site Containment Area and the average VOC concentrations throughout the remainder of the Site (i.e., On-Site Containment, Treatment Lagoon and Kopica-Pazney Areas), VOC emissions would range from 80 pounds/hr to 400 pounds/hr, which would exceed the 25 tons per year limit established by the IDEM. Vapor phase treatment is likely to be required if vapor extraction is employed. 40 CFR 264 Subparts F and G, pertaining to releases from SWMUs and closure and post-closure of RCRA landfills, could be considered ARARs for untreated contaminants which remain on-Site.

Long-Term Effectiveness

Based on the risk levels presented in the BRA for various on-Site exposure scenarios, a significant reduction of the identified chemicals of concern would have to be achieved. It is not known if vapor extraction would adequately remove the SVOCs identified at the Site. SVOCs not amenable to vapor extraction treatment that may remain as residual soil contamination tend to be insoluble in water and have high soil adsorption coefficients. These compounds would not be expected to be mobile in groundwater systems (identified groundwater contaminants at the ACS Site are presently limited to VOCs and SVOCs with high water solubilities such as benzene, acetone, methyl ethyl ketone and bis (2-chloroethyl) ether). At the completion of remedial action activities, contaminated soil and groundwater would be treated. Institutional controls would be used to prevent the use of contaminated groundwater and access to the Site.

The continuing source of groundwater contamination would be significantly reduced. Refer to Section 4.3.2 for a discussion pertaining to the long-term effectiveness of groundwater pumping and treating. Remaining residual contaminants would either be naturally attenuated into infiltrating groundwater and treated with the pump and treat system or removed by a more aggressive groundwater pump and treat system (refer to "Description" subsection).

Some areas of buried waste may not be treatable by vapor extraction if adequate soil porosity is not available to allow for continuous air contact. However, the volume of waste that may require additional treatment would be significantly reduced by the operation of the vapor extraction system. In addition, the reduction of VOCs in the waste would significantly reduce potential risks should additional treatment be required in the future.

Reduction of Toxicity, Mobility or Volume Through Treatment

Vapor extraction of soil and waste transfers organic compounds to the air phase. If vapor phase treatment is used, the destruction of organics as a result of thermal treatment or spent carbon regeneration would result in an overall toxicity and volume reduction of contaminants in the soil. Based on Henry's Law constants (refer to Section 3.6.1.6), the BETX compounds, chlorinated methanes, chlorinated ethanes, chlorinated

ethenes, chlorinated benzenes and naphthalene and its derivatives are amenable to vapor extraction. The volatile ketones are potentially amenable to vapor extraction. PNAs, phthalates, ethers, phenols, isophorone, organic acids and inorganic metals would not be expected to be amenable to vapor extraction. However, these compounds are less mobile in the environment then VOCs. Because of its soil adsorption characteristics, PCBs would also not be expected to be amenable to vapor extraction; however, they have a low mobility in soil.

A pilot scale study would be conducted to evaluate the overall removal efficiencies of the vapor extraction system. Most applications of vapor extraction, to date, involve the remediation of chlorinated solvents, BEXT compounds and light end petroleum products. Based on case studies presented in Hutzler et al. (June, 1989) and U.S. EPA (July, 1989), the following soil treatment levels were reported:

- Tetrachloroethane was remediated to less than 1 ppm;
- Trichloroethene was remediated to less than 5 ppb;
- Carbon tetrachloride was remediated to below analytical detection limits;
- 99.2% hydrocarbon reduction was achieved for a jet fuel spill; and
- Benzene levels of less than 1 ppb were achieved for one gasoline spill cleanup, while total hydrocarbons were reduced to below analytical detection limits for a second gasoline cleanup.

Based on the case study data presented above, 99%+ removal efficiencies appear to be obtainable for VOCs amenable to vapor extraction. None of the sites presented in the case studies, however, had a contaminant matrix analogous to the ACS Site. Most of the sites had total VOC concentrations less than 1,000 ppm. One site reported maximum VOC concentrations of 5,600 ppm, while one of the sites involving remediation of fuel contamination reported total hydrocarbon levels of 6,200 ppm. VOC removal rates are the highest during initial startup and decrease with time as mass transfer of contaminants

into the vapor phase becomes rate limiting. Final removal efficiencies are also a function of the time frame the vapor extraction system is allowed to operate.

Of the chemical groups not expected to be amenable to vapor extraction, phenols were not identified as a target compound group for soils in any of the areas based on the BRA. Phenols, organic acids and isophorone were not identified as target compounds in the upper aquifer. Phthalates, carcinogenic PNAs, PCBs and inorganic metals are relatively immobile because they have high soil adsorption coefficients. They were not identified as a target compound group in the upper aquifer. If left untreated, phthalates, carcinogenic PNAs, PCBs and inorganic metals would not be expected to migrate to either the upper aquifer or ambient air.

Ethers are the only chemical group not amenable to vapor extraction treatment which has been identified as a target compound group in both the soil matrix and upper aquifer. Ethers, as well as other SVOCs and residual VOCs, can be biologically degraded under aerobic conditions (refer to Section 4.2.7.2). Hinchee et. al. and Downee et. al. report enhanced biodegradation in the soil matrix as a result of aeration introduced during vapor extraction treatment. Both studies involved the remediation of jet fuel spills at Air Force bases. Levels of carbon dioxide measured during vapor extraction were consistently an order-of-magnitude higher than in the atmosphere, suggesting that significant biological activity was occurring in the subsurface soils. Therefore, biodegradation of SVOCs and residual VOCs could occur as a result of soil vapor extraction.

If required in the future based on monitoring of the performance of the system, in-situ fixation of soils would reduce the mobility of metals. Figure 4-14 presents a schematic process flow diagram and preliminary design information for in-situ fixation. Refer to Section 3.6.2.5 for a discussion of in-situ fixation that shows that the fixation of metals is a proven technology. SVOCs and PCBs are immobilized in soils by natural attenuation processes.

Short-Term Effectiveness

The installation of the groundwater extraction and treatment system would eliminate the migration of contaminants from the Site. As discussed above, VOC removal rates with a vapor extraction system are highest during startup so that a rapid reduction in contaminants in waste and soils would be achieved. The estimated time frame to complete source treatment activities for Alternative 5 is 5 to 20 years. It is assumed for purposes of the cost estimates that groundwater treatment would continue for a 30 year period. A more aggressive pump and treat approach would likely reduce the time frame to reach the maximum achievable level of aquifer contaminant removal.

A significant advantage to vapor extraction of both buried waste and soils is that excavation of waste and soils are not required. Because of the high levels of VOC in both the buried waste and soils, there is the potential for significant volatilization and airborne migration of VOC during excavation activities. This would be exacerbated during hot weather conditions in the summer. These potential problems would not occur with vapor extraction because VOCs are removed in situ and treated under controlled conditions.

Implementability

Vapor extraction is a proven technology for the treatment of VOC-contaminated soils, and was the selected remedy specified in approximately 17 CERCLA RODs issued during 1989. Systems are already operational on at least two Superfund sites. The soil conditions at the ACS Site would appear to be conducive to vapor extraction.

Based on the levels of contaminants detected in soil samples collected beneath the depth of the water table (and the presence of buried drums), a separate "free waste" phase (i.e., free liquids that are not dissolved in, or floating on top of, groundwater) is expected to exist in the buried waste and other source areas. Sufficient air permeability may not exist through these "free waste" zones to allow sufficient air contact necessary to effectively extract VOCs contained in the buried waste and other source areas. A separate pilot study would be required for the buried waste areas. Soil moisture content and depth to groundwater are also a potential hindrance to vapor extraction. Soil sampling for moisture content, as well as a pilot study, would be required to determine the effectiveness of vapor extraction following Site dewatering.

Pilot testing would be conducted to define the design parameters for vapor extraction systems. The pilot study would be designed to evaluate the following:

- the optimum vacuum and flow rate necessary to size the vacuum pump or blower system in order to maximize contaminant removal while minimizing the energy requirements (i.e., horsepower requirements for the vacuum pump or blower);
- the radius of influence of each individual recovery well;
- contaminant removal rates in order to estimate the remediation time frame and design air treatment systems that may be required by IDEM permit conditions for VOC emissions;
- the effects of using passive injection wells on air flow patterns and contaminant removal rates;
- the effects of covering the surface on the radius of influence of individual wells, soil moisture levels and contaminant removal rates; and
- the effects of varying individual recovery well flow rates, including complete shutdown, on the contaminant removal rates and energy requirements of the system.

Because of the size of the areas requiring treatment, the complicated contaminant matrix of concern and non-homogeneous soil conditions and contaminant distributions across the entire Site, extensive labor requirements are typically required to optimize the startup and operation of the vapor extraction system. Periodic monitoring and adjustments are required to the operation of the system. Workers would not have to be on-Site full time, however. It is expected that at least two additional phases of soil sampling would be required to monitor the progress, and verify the completion, of vapor extraction treatment. Tank farms located over the Still/Bottoms Treatment Lagoon Area would not likely have to be relocated or dismantled.

Cost

Capital, annual O&M and net present worth costs are presented in Table 4-16 and Appendix B. Design assumptions for purposes of the cost estimates are presented in Figures 4-12, 4-13, 4-20, and 4-21 and the itemized cost estimates for Alternative 5 presented in Appendix A.

4.3.6 Alternative 6A - On-Site Incineration of Buried Drums; Off-Site Disposal of Miscellaneous Debris; On-Site Incineration of Waste; In-Situ Vapor Extraction of Soils; Groundwater Pumping and Treatment; and Treated Water Discharge to Wetlands
Alternative 6B - Same as Alternative 6A Except Waste Would be Treated with Low Temperature Thermal Treatment and Buried Drums Would be Treated Off-Site by Incineration

Description

The Site would be dewatered using an extraction system described in Section 4.2.3 so that areas defined as buried waste can be excavated for on-Site thermal treatment (refer to Section 4.3.3). Initially, the groundwater pumping and treatment system would operate at 200 gpm to lower the water level of the Site to elevation 725. Intact buried drums would first be excavated for either on- or off-Site incineration. Miscellaneous debris would be taken off-Site for landfilling. Areas designated as buried waste and PCB-contaminated soils would be excavated for on-Site thermal treatment. Refer to Section 4.3.3 for discussions pertaining to the thermal treatment of buried waste. It is assumed for Alternative 6 that only solid or liquid waste materials would be excavated for on-Site thermal treatment. Soils surrounding the waste or intermixed with the waste would be left in place and treated with the vapor extraction system.

For the purposes of generating a cost estimate for this alternative, buried waste volumes for each source area were determined incorporating both visual observations of buried drum and free waste presence during site investigation activities, as well as a delineation of areas at each sample depth interval with total VOCs in excess of 1% based on data generated during the RI (Refer to "Description" subsection of 4.3.3 for discussion of rationale.) Based on these determinations, approximately 35,000 cubic yards to 65,000

cubic yards (approximately 52,000 tons to 98,000 tons) would require on-Site thermal treatment. An approximate delineation of areas defined as buried waste is depicted in Figure 4-1. Using 50 ppm total PCBs as the criteria for delineation, approximately 1,000 cubic yards of PCB-contaminated soils would be excavated for thermal treatment. A uniform depth of buried waste presence using surface areas depicted in Figure 4-1 was not assumed in the calculation of volume. The depth requiring excavation for each cross-sectional area was assumed to be the maximum depth meeting one of the buried waste or PCB-contaminated soils criteria outlined above based on sampling intervals used during the RI. Cross-sectional drawings delineating defined areas of buried waste and PCB-contaminated soils at depth will have to be prepared during the final design.

Deed restrictions, fencing and well closures would be required to reduce the potential for human exposure. Long-term monitoring of off-Site contamination migration would also be instituted. Refer to Section 4.3.3 for discussions pertaining to thermal treatment of buried waste.

Groundwater pumping and treatment would be performed to contain off-Site contaminant migration. After dewatering is achieved, buried waste would be removed and treated on-Site. Buried drums would be removed and treated on-Site with the buried waste (Alternative 6A) or treated off-Site by incineration (Alternative 6B). The groundwater pump and treat system would then be optimized to determine the most efficient means to remediate the aquifer. Groundwater remediation approaches could include in-situ biological treatment or the placement of injection and withdrawal wells to more aggressively pump and treat the groundwater. Consistent with current U.S. EPA guidance, it may consist of pumping enough to prevent the further migration of contaminants with long term pumping and treating. Groundwater treatment process options which have been retained for detailed analysis include air stripping, biological treatment and UV/oxidation. A comparison of groundwater and surface water treatment process options is presented in Section 4.2.7. At least some of the treated groundwater would be discharged to the wetlands west of the Site or reinjected. Treated groundwater would be discharged to the wetlands if required to prevent dewatering of the wetlands from groundwater pumping. It is anticipated that the groundwater pump and treat system would operate for 30 years.

An in-situ vapor extraction system would be installed following completion of thermal treatment activities. Partial installation of a vapor extraction system could begin following the completion of Site dewatering in areas which are not impacted by buried waste excavation activities. A delineation of areas requiring vapor extraction treatment is depicted in Figure 4-2. Approximately 100,000 cubic yards (150,000 tons) of soil would require on-Site vapor extraction treatment (refer to Section 4.1.2 for basis of soil volume calculation). Refer to Section 4.3.5 for a more detailed discussion of the vapor extraction system.

Because of the large waste and soil volumes requiring treatment, and the significant distances between each of the areas, it has been assumed for cost estimating purposes that four separate vapor extraction systems would be installed. Separate systems would be located in the On-Site Containment Area, the Still Bottoms/Treatment Lagoon Areas, the Off-Site Containment Area and the Kapica-Pazmey Area. Figure 4-15 presents a layout of the proposed extraction system, while Figure 4-16 presents a schematic process flow diagram and preliminary design information for a vapor extraction system.

It may be possible to reduce the aerial extent of the vapor extraction system (and number of vapor extraction systems) by consolidating contaminated soils into one area. The materials handling plan would consist of:

- excavating waste from the off-Site buried waste areas shown in Figure 4-1, thermally treating it and stockpiling the treated material;
- excavating waste from the on-Site buried waste areas shown in Figure 4-1, thermally treating it and stockpiling the treated material;
- excavating contaminated soil from the on-Site areas shown in Figure 4-2 and placing the soil in the buried waste excavation in the off-Site area; and
- backfilling the on-Site waste and contaminated soil excavations with the stockpiled treated material.

The effect of the above is that all contaminated materials from the on-Site areas would be removed or treated so that the on-Site areas will be "clean". All of the contaminated soil would be consolidated in the off-Site areas so that vapor extraction would only need to be conducted off-Site. Contaminated soils from the on-Site and off-Site areas would be treated as a single area of contamination off-Site.

Design parameters presented in the case study for the Verona Well Field Superfund Site (Verona Site) located in Battle Creek, Michigan (U.S. EPA, July 1989) serve as the basis for the treatment time frame estimate and extraction well spacings for the ACS Site. The soil conditions and VOC contaminant matrix at the Verona Site were similar to the ACS Site. Maximum individual VOC soil concentrations at the Verona Site ranged up to 1800 ppm (U.S. EPA, July 1989). Approximately 28,000 pounds of VOCs were extracted in 55 days of operation (i.e., an average of approximately 500 pounds/day). Actual design parameters for a vapor extraction system would be determined following the completion of a pilot study.

A grid system of extraction wells, spaced at 75-foot intervals, would be installed in the four areas described above. A 75-foot well spacing would allow each of the wells to serve as either extraction or passive inlet wells in order to provide for maximum operational flexibility. Well placement and screening depths are dependent on the zones of contamination to be treated and localized soil conditions. The extraction well system would be manifolded to a building or shelter housing the vacuum pump and vapor treatment system. Each pump would operate at a vacuum of approximately 5-inches of mercury. Depending on the actual level of vapor emissions and potential implementability issues, the vapor treatment system would either consist of separate carbon adsorption units, separate portable thermal or catalytic treatment units or a larger, centralized thermal or catalytic treatment unit. Since the vapor extraction system would be operated under winter conditions, insulation and heat tracing would have to be provided for portions of the air manifold system installed above the freeze line.

A cover may be placed over unpaved surfaces in the areas to be treated in order to prevent the short-circuiting of air from the surface, which reduces the radius of influence of individual extraction wells. A cover would also reduce rainwater infiltration which could adversely impact vapor extraction treatment efficiencies. Either a plastic liner or soil cover could serve this purpose.

The treatment time frame estimate is based on an assumed average VOC soil concentration of 5,000 ppm (0.5%) following the removal of buried wastes, and an average VOC removal rate of 500 pounds per day (pounds/day) for each area to be treated (i.e., average VOC removal rate reported in Verona case study). A maximum VOC removal rate of 3,500 pounds/day for each treatment area was used to estimate the minimum treatment time frame (refer to Section 4.3.5 for explanation). Based on these VOC removal rates, the estimated time frame to complete source treatment activities for Alternative 6 is 5 to 8 years. This includes a three year time frame to complete dewatering activities and thermal treatment of buried wastes,

Except for the former natural drainage system which received runoff from the Off-Site Containment Area (i.e., sample SD05 in the RI), elevated levels of VOCs and SVOCs were not detected in the remaining drainage ditch and wetlands sediment samples. Low levels of PAHs and phthalates were the predominant contaminants detected in the sediment samples. Other contaminants detected include 2-butanone, manganese, bis (2-ethylhexyl) phthalate, and mercury. The levels of detected phthalates were within a range which is often typical of naturally occurring background conditions, while the levels of detected PAHs were within a range which is typical of areas proximate to vehicular traffic. Surficial presence of PAHs is often associated with petroleum fuel-containing surface runoff from vehicular traffic sources or leaching from asphalt-based surfaces, such as the roads that bound the Site to the east.

Because of the adverse impacts to the wetlands that would result, the excavation of wetlands and drainage ditch sediments containing these levels of phthalates and PAHs has not been included as part of this alternative. Source removal resulting from the excavation and thermal treatment of buried waste and vapor extraction treatment of soils and soil covering would minimize the future migration of phthalates and PAHs to the

wetlands and drainage ditch sediments as a result of adsorption onto surface runoff soils. Flushing sediments over time with treated groundwater, or incorporation of in-situ biological treatment, may further reduce the phthalates and PAHs below their present low levels. Because of their strong affinity for adsorbing onto soils, phthalates and PAHs are not expected to migrate either off-Site or to the upper aquifer from wetlands and drainage ditch sediments.

The sediment sample collected from the former drainage system adjacent to the Off-Site Containment Area was the only sample which exceeded the 10 ppm total VOC criteria used to delineate contaminated soils. Sediments from this area would either be excavated for on-Site thermal treatment along with the buried waste or treated by vapor extraction since the area will be dewatered. None of the sediment samples exceeded the 50 ppm total PCBs criteria used to delineate PCB-contaminated soils. Only one sample, SB02 taken from the ACS Site, exceeded 10 ppm total PCBs (22 ppm). This area could either have a soil cover placed over it to prevent dermal contact, or excavated for thermal treatment along with other PCB-contaminated soil areas.

Overall Protection of Human Health and the Environment

Excavation and thermal treatment of waste would eliminate the risk of waste at the Site. In-situ vapor extraction would significantly reduce the VOCs and some of the SVOCs present in the soils. Vapor extraction treatment may not adequately remove SVOCs from soils, which may not eliminate the dermal risk to future Site users. These contaminants would not be expected to migrate to groundwater. Refer to Section 4.3.5 for a more detailed discussion of the overall protection provided by the vapor extraction system. Deed restrictions and fencing would be instituted to prevent any potential exposure to remaining residual soil contaminants.

At the completion of the remedial action activities, contaminated soil and groundwater would be treated, and the continuing source of groundwater contamination eliminated or drastically reduced. This would mitigate future impact to downgradient wetlands, Turkey Creek, residential water wells, as well as the lower aquifer. Institutional controls

pertaining to access restrictions and use of groundwater in the vicinity of the Site, would further reduce the potential for human exposure to contaminated groundwater and residual contaminants which remain on-Site during the treatment period.

Compliance With ARARs

Refer to Section 4.3.3 for a discussion of Site ARARs in general, as well as ARARs applicable to the discharge of treated groundwater, thermal treatment of buried waste and VOC air emissions. It is anticipated that all ARARs would be met by Alternative 6. Groundwater treatment system residuals (e.g. ion exchange backflushing) storage and off-Site disposal would have to comply with RCRA hazardous waste generator regulations. Based on the discussion presented in Section 4.3.5, VOC emissions would range from 80 pounds/hr to 400 pounds/hr, which would exceed the 25 tons/year limit established by the IDEM. Vapor phase treatment is likely to be required if vapor extraction is employed. 40 CFR 264 Subparts F and G, pertaining to releases from SWMUs and closure and post-closure of RCRA landfills, could be considered ARARs for untreated contaminants which remain on-Site.

A treatability variance from the RCRA LDRs may have to be obtained to redeposit thermally treated soils on-Site. It is expected that the LDRs can be met since incineration and immobilization are the BDATs for most of the organic compounds and metals detected at the Site. Refer to Section 3.5.1 for a discussion on obtaining a treatability variance for CERCLA response actions. The alternative action levels specified in Section 3.5.1 are also applicable to incineration and low temperature thermal treatment.

Long-Term Effectiveness and Permanence

Based on the risk levels presented in the BRA for various on-Site exposure scenarios, a significant reduction of the identified chemicals of concern would have to be achieved. It is not known if vapor extraction would adequately remove the SVOCs identified at the Site. SVOCs not amenable to vapor extraction treatment that may remain as residual soil contamination tend to be insoluble in water and have high soil adsorption coefficients. These compounds would not be expected to be mobile in groundwater systems (identified groundwater contaminants at the ACS Site are presently limited to

VOCs and SVOCs with high water solubilities such as benzene, acetone, methyl ethyl ketone and bis (2-chloroethyl) ether). At the completion of remedial action activities, contaminated soil and groundwater would be treated. Institutional controls would be used to prevent the use of contaminated groundwater and access to the Site.

The continuing source of groundwater contamination would be significantly reduced. Refer to Section 4.3.2 for a discussion pertaining to the long-term effectiveness of groundwater pumping and treating. Remaining residual contaminants would either be naturally attenuated into infiltrating groundwater and treated with the pump and treat system or removed by a more aggressive groundwater pump and treat system (refer to "Description" subsection).

Reduction of Toxicity, Mobility or Volume Through Treatment

Refer to Section 4.2.8 for discussions pertaining to the thermal treatment of buried waste. Refer to Section 4.3.5 for a discussion of vapor extraction of contaminated soil.

Short-Term Effectiveness

Completion of Site dewatering and thermal treatment of buried waste would be completed in approximately three years. Both horizontal and vertical migration of contaminants in the groundwater from the Site would be mitigated upon completion of these tasks. The dewatering of the Site would serve to reduce groundwater migration from the Site during the course of remedial action activities. The estimated time frame to complete source treatment activities for Alternative 6 is 5 to 8 years. It is assumed for purposes of the cost estimates that groundwater treatment would continue for a 30 year period. A more aggressive pump and treat approach would likely reduce the time frame to reach the maximum achievable level of aquifer contaminant removal. Short-term effectiveness discussions in Section 4.3.3 pertaining to wetlands dewatering are also applicable to Alternative 6. Remediation contractor workers would be exposed to contaminated soil during installation of the vapor extraction system. A health and safety program which requires the use of personal protection equipment for remediation contractor workers should minimize short-term risk during implementation of Alternative 6.

Nearby residents, ACS workers and remediation contractor workers could be exposed to airborne particulates or volatilized VOCs during excavation and material handling activities. Ambient air monitoring may be required to evaluate potential VOC exposures. Small quantities of contaminated materials could be spilled over the surface of the Site during transfer to the soil staging area located adjacent to the Off-Site Containment Area. ACS workers and remediation contractor workers would be exposed to contaminated soil during excavation and material handling activities. A health and safety program which requires the use of personal protection equipment for on-Site workers should minimize short-term risk during implementation of Alternative 6.

Implementability

Implementability issues associated with the thermal treatment of buried wastes are presented in Section 4.3.3. Implementability issues associated with vapor extraction of contaminated soils are presented in Section 4.5.3.

Appropriate approvals and/or permits would have to be obtained in order to discharge treated groundwater. Treatability and pilot studies would be required if in-situ fixation is required for soils and sediments following vapor extraction treatment.

There is likely to be strong public opposition to on-Site incineration of waste. It is possible that implementation of the plan could be delayed significantly while public concerns are allayed and approvals to construct the system are obtained.

Cost - Capital, annual O&M and net present worth costs are presented in Table 4-16 and Appendix B. Design assumptions for purposes of the cost estimates are presented in Figures 4-12, 4-13, 4-20 and 4-21 and the itemized cost estimates for Alternatives 6A and 6B presented in Appendix B.

4.3.7 Alternative 7A - Incineration of Buried Drums; Off-Site Disposal of Miscellaneous Debris; On-Site Incineration of Buried Waste and Soils; Groundwater Pumping and Treatment; and Treated Water Discharge to Wetlands

Alternative 7B - Same as Alternative 7A Except that Waste and Soils Would be Treated with Low Temperature Thermal Treatment

Description

The Site would be dewatered using an extraction system described in Section 4.2.3 so that designated areas of buried waste and PCB- and VOC-contaminated soils can be excavated for on-Site thermal treatment. Initially, the groundwater pumping and treatment system would operate at 200 gpm to lower the water level at the Site to elevation 725. Intact buried drums would first be excavated for either on- or off-Site incineration. Miscellaneous debris would be taken for off-Site landfilling. Delineations of areas requiring excavation for on-Site thermal treatment are depicted in Figures 4-1 and 4-2. Approximately 135,000 cubic yards (200,000 tons) of buried waste and soils would require on-Site thermal treatment (refer to Sections 4.1.2 and 4.3.6 for basis of buried waste and soil volume calculations). Well closures would be required to reduce the potential for human exposure to contaminated groundwater. Long-term monitoring of off-Site contamination migration would also be instituted.

Groundwater pumping and treatment would be conducted in off-Site areas. Following removal of the buried waste and their treatment on-Site, the groundwater pump and treat system would be optimized to determine the most efficient means to remediate the aquifer. Groundwater remediation approaches could include in-situ biological treatment or the placement of injection and withdrawal wells to more aggressively pump and treat the groundwater. Consistent with current U.S. EPA guidance, it may consist of pumping enough to prevent the further migration of contaminants with long term pumping and treatment. At least some of the treated groundwater would be discharged to the wetlands west of the Site. Discharging treated groundwater would prevent dewatering of the wetlands from groundwater pumping. It is anticipated that the groundwater pump and treat system would operate for 30 years.

Low temperature thermal treatment and incineration have been retained as potential thermal treatment technologies. A comparison of these process options has been made in Section 4.2.7. Figures 4-8 and 4-9 present schematic process flow diagrams and preliminary design information for these process options. Off-gases from the low temperature thermal treatment unit would be treated using a thermal or catalytic incinerator. Groundwater pumping and treatment would be performed to contain off-Site contaminant migration. Groundwater treatment process options which have been retained for detailed analysis include air stripping, biological treatment and UV/oxidation. A comparison of groundwater and surface water treatment process options is presented in Section 4.2.7.

On-Site thermal treatment would be performed using either a mobile low temperature thermal treatment unit or mobile rotary kiln incinerator. ACS's intention to continue its chemical manufacturing operations may dictate, or interfere with, the location of an on-Site thermal treatment unit. The mobile thermal treatment unit and soil staging area would have to be located adjacent to the Off-Site Containment Area depicted on Figure 4-7. Excavated materials from the active portions of the Site would have to be transported to the staging area. Tank farms located on top of the Still Bottoms/Treatment Lagoon Area would either have to be dismantled or relocated before excavation could begin in those areas.

The largest mobile incinerator and low temperature thermal treatment units currently available are capable of processing 30 to 50 tons of soil per hour. A typical mobile thermal treatment unit processes 10 tons of soil per hour. Pretreatment in the form of mixing and screening of the buried wastes and soil would be necessary to provide a more homogeneous feedstock. Assuming a one year time frame to complete dewatering activities, and continuous operation of the thermal treatment unit for 250 days per year, the estimated time frame to complete source treatment activities for Alternative 7 is 2 to 6 years. Treated soil would be deposited back into the excavations. Because thermal treatment will destroy the organics in the waste and soil, some volume would have to be made up with clean fill materials. Fixation of metals present in some of the incinerator ash may have to be performed prior to backfilling.

Except for the former natural drainage system which received runoff from the Off-Site Containment Area (i.e., sample SD05 in the RI), elevated levels of VOCs and SVOCs were not detected in the remaining drainage ditch and wetlands sediment samples. Low levels of PAHs and phthalates were the predominant contaminants detected in the sediment samples. The levels of detected phthalates were within a range which is often typical of naturally occurring background conditions, while the levels of detected PAHs were within a range which is typical of areas proximate to vehicular traffic. Surficial presence of PAHs is often associated with petroleum fuel-containing surface runoff from vehicular traffic sources or leaching from asphalt-based surfaces, such as the roads that bound the Site to the east.

Because of the adverse impacts to the wetlands that would result, the excavation of wetlands and drainage ditch sediments containing these levels of phthalates and PAHs has not been included as part of this alternative. Source removal resulting from the excavation and thermal treatment of buried waste and soils and soil covering would minimize the future migration of phthalates and PAHs to the wetlands and drainage ditch sediments as a result of adsorption onto surface runoff soils. Flushing sediments over time with treated groundwater, or incorporation of in-situ biological treatment, may further reduce the phthalates and PAHs below their present low levels. Because of their strong affinity for adsorbing onto soils, phthalates and PAHs are not expected to migrate either off-Site or to the upper aquifer from wetlands and drainage ditch sediments.

The sediment sample collected from the former drainage system adjacent to the Off-Site Containment Area was the only sample which exceeds the 10 ppm total VOC criteria used to delineate contaminated soils. Sediments from this area would be excavated for on-Site thermal treatment since the area will be dewatered. None of the sediment samples exceeded the 50 ppm total PCBs criteria used to delineate PCB-contaminated soils. Only one sample, SB02 taken from the ACS Site, exceeded 10 ppm total PCBs (22 ppm). This area could either have a soil cover placed over it to prevent dermal contact, or excavated for thermal treatment along with other PCB-contaminated soil areas.

Overall Protection of Human Health and the Environment

On-Site incineration of buried wastes and contaminated soils is capable of achieving appropriate cleanup levels. Based on available pilot study data, low temperature thermal treatment is also capable of achieving appropriate removal efficiencies for all of the organic compounds of concern. Deed restrictions and fencing will be instituted to prevent potential exposure to remaining residual soil contaminants redeposited back onto the Site.

At the completion of remedial action activities, contaminated groundwater and soils would be treated, and the continuing source of groundwater contamination significantly reduced. This should mitigate future impact to downgradient wetlands, Turkey Creek, residential water wells, as well as the lower aquifer. Institutional controls pertaining to access restrictions to the Site will be instituted to reduce the potential for human exposure to contaminated groundwater and residual contaminants which remain on-Site during the treatment process.

Compliance with ARARs

Refer to Section 4.3.3. It is anticipated that all ARARs would be met by Alternative 7. If all residual contaminants are thermally treated to establish health-based cleanup objectives, 40 CFR 264 Subparts F and G, pertaining to releases from SWMUs and closure and post-closure of RCRA landfills, would not qualify as ARARs. A treatability variance from the RCRA LDRs may have to be obtained to redeposit treated soils on-Site. It is expected that the LDRs can be met since incineration and immobilization are the BDATs for most of the organic compounds and metals detected at the Site. Refer to Section 3.5.1 for a discussion on obtaining a treatability variance for CERCLA response actions. The alternative action levels specified in Section 3.5.1 are also applicable to incineration and low temperature thermal treatment.

Long-Term Effectiveness and Permanence

Based on risk levels presented in the BRA for various on-Site exposure scenarios (e.g. on-Site resident), significant removal of the identified chemicals of concern would have to be achieved. On-Site incineration is capable of achieving appropriate risk reduction without the requirement of deed restrictions, fencing or capping. Based on available pilot study data, it appears that low temperature thermal treatment is also capable of

achieving appropriate removal efficiencies for all of the organic compounds of concern. If low temperature thermal treatment is used, deed restrictions and fencing will be instituted, if necessary, to prevent exposure to any remaining residual soil contaminants redeposited back onto the Site. Above-ground fixation of metals may also have to be performed on soils that are redeposited back onto the Site following low temperature thermal treatment in order to achieve acceptable risk levels.

At the completion of remedial action activities, contaminated groundwater would be treated. The continuing source of groundwater contamination would be significantly reduced if incineration or low temperature thermal treatment is used. Institutional controls would be used to control the use of contaminated groundwater and access to the ACS Site. Refer to Section 4.3.2 for a discussion pertaining to the long-term effectiveness of groundwater pumping and treatment.

Reduction of Toxicity, Mobility or Volume Through Treatment

A discussion of reduction of toxicity, mobility or volume through treatment is presented in Section 4.2.8 for on-Site low temperature thermal treatment and incineration. If required, above-ground fixation of soils following low temperature thermal treatment would reduce the mobility of metals prior to their being redeposited back onto the Site. The fixation of metals is a proven technology. Inorganic metals have high soil adsorption coefficients and were not identified as target compound groups in the upper aquifer. If left untreated, inorganic metals would be expected to be immobilized in the soil matrix based on their high affinity for adsorption to soils, and not pose a potential threat to either the upper aquifer or ambient air. Metals would, therefore, be immobilized in soils by either natural attenuation processes or fixation techniques.

Short-Term Effectiveness

Short-term effectiveness discussions in Section 4.3.3 pertaining to material handling activities and wetlands dewatering are also applicable to Alternative 7. The completion of Site dewatering would be completed in approximately one year. Both horizontal and vertical migration of contaminants in the groundwater from the Site would be mitigated upon completion of this task. The potential for contamination migration to the lower

aquifer would be mitigated as a result of ongoing Site dewatering activities. The dewatering of the Site would serve to reduce groundwater migration from the Site during the course of remedial action activities. The estimated time frame to complete source treatment activities for Alternative 7 is 2 to 6 years. It is assumed for purposes of the cost estimate that groundwater treatment would continue for a 30 year period. A more aggressive pump and treat approach would likely reduce the time frame to reach the maximum achievable level of aquifer contaminant removal.

Nearby residents, ACS workers and remediation contractor workers could be exposed to airborne particulates or volatilized VOCs during excavation and material handling activities. Ambient air monitoring may be required to evaluate potential VOC exposures. Small quantities of contaminated materials could be spilled over the surface of the Site during transfer to the soil staging area located adjacent to the Off-Site Containment Area. ACS workers and remediation contractor workers would be exposed to contaminated soil during excavation and material handling activities. A health and safety program which requires the use of personal protection equipment for on-Site workers should minimize short-term risk during implementation of Alternative 7.

Implementability

Refer to Section 4.3.3. Treatability and pilot studies would be required if above-ground fixation is required for soils following thermal treatment.

There is likely to be strong public opposition to on-Site incineration of buried waste and soils. It is possible that implementation of the plan could be delayed significantly while public concerns are allayed and approvals to construct the system are obtained.

Cost - Capital, annual O&M and net present worth costs are presented in Table 4-16 and Appendix B. Design assumptions for the purposes of the cost estimates are presented in Figures 4-12, 4-13 and 4-14 and the itemized cost estimates for Alternatives 6A and 6B presented in Appendix B.

4.3.8 Alternative 8A - Off-Site Incineration of Buried Drums; Off-Site Disposal of Miscellaneous Debris; Landfarming of Buried Waste and Soils; Groundwater Pumping and Treatment; and Treated Water Discharge to Wetlands

Alternative 8B - Same as Alternative 8A Except Waste and Soils Treated with a Slurry-Phase Bioreactor

Description

The Site would be dewatered using an extraction system described in Section 4.2.3 so that areas defined as buried waste and contaminated soils can be excavated for biological treatment. Initially, the groundwater pumping and treatment system would operate at 200 gpm to lower the water level at the Site to elevation 725. Intact buried drums would first be excavated for off-Site incineration. Miscellaneous debris would be taken off-Site for landfilling. Delineations of areas requiring excavation for on-Site biological treatment are depicted in Figures 4-1 and 4-2. Approximately 135,000 cubic yards (200,000 tons) of buried waste and soils would require on-Site biological treatment (refer to Sections 4.1.2 and 4.3.6 for basis of buried waste and soil volume calculations). Deed restrictions, fencing and well closures would be required to reduce the potential for human exposure.

Groundwater pumping and treatment would be conducted in off-Site areas. Following removal of the buried waste and their treatment on-Site, the groundwater pump and treat system would be optimized to determine the most efficient means to remediate the aquifer. Groundwater remediation approaches could include in-situ biological treatment or the placement of injection and withdrawal wells to more aggressively pump and treat the groundwater. Consistent with current U.S. EPA guidance, it may consist of pumping enough to prevent the further migration of contaminants with long term pumping and treating. At least some of the treated groundwater would be discharged to the wetlands west of the Site. Discharging treated groundwater would prevent dewatering of the wetlands from groundwater pumping. Groundwater treatment process options which have been retained for detailed analysis include air stripping, biological treatment and UV/oxidation. A comparison of groundwater and surface water treatment process options is presented in Section 4.2.7.

Land farming (Alternative 8A) and slurry-phase bioreactors (Alternative 8B) have been retained as potential solid-phase biological treatment approaches. A comparison of these approaches has been made in Section 4.2.9. Figures 4-11 and 4-12 present schematic process flow diagrams and preliminary design information for these biological systems.

Since it is ACS's intention to continue its chemical manufacturing operations, the biological treatment system would have to be located adjacent to the Off-Site Containment Area depicted on Figure 4-10. Excavated materials from the active portions of the Site would have to be transported to the staging area. Tank farms located on top of the Still Bottoms/Treatment Lagoon Area would either have to be dismantled or relocated before excavation could begin in those areas.

Approximately 80,000 square feet are available for the construction of land-farm treatment cells adjacent to the Off-Site Containment Area. If it is assumed that soil is placed within each treatment cell to a depth of three feet, and that sufficient biological treatment is achieved in six months, the estimated time frame to complete source treatment activities for Alternative 8A is 8 to 15 years. This assumes a one year time frame to complete dewatering activities. For Alternative 8B, either multiple bioreactors or construction of a large treatment pond would be required to provide the capacity necessary to achieve a 5 year time frame for slurry-phase biological treatment. The actual number of bioreactors required would depend on degradation rates determined during the treatability and pilot studies. Treated soil would be deposited back into the excavations.

Except for the former natural drainage system which received runoff from the Off-Site Containment Area (i.e., sample SD05 in the RI), elevated levels of VOCs and SVOCs were not detected in the remaining drainage ditch and wetlands sediment samples. Low levels of PAHs and phthalates were the predominant contaminants detected in the sediment samples. The levels of detected phthalates were within a range which is often typical of naturally occurring background conditions, while the levels of detected PAHs were within a range which is typical of areas proximate to vehicular traffic. Surficial presence of PAHs is often associated with petroleum fuel-containing surface runoff from vehicular traffic sources or leaching from asphalt-based surfaces, such as the roads that bound the Site to the east.

Because of the adverse impacts to the wetlands that would result, the excavation of wetlands and drainage ditch sediments containing these levels of phthalates and PAHs has not been included as part of this alternative. Source removal resulting from the excavation and biological treatment of buried waste and soils and soil covering would minimize the future migration of phthalates and PAHs to the wetlands and drainage ditch sediments as a result of adsorption onto surface runoff soils. Flushing sediments over time with treated groundwater, or incorporation of in-situ biological treatment, may further reduce the phthalates and PAHs below their present low levels. Because of their strong affinity for adsorbing onto soils, phthalates and PAHs are not expected to migrate either off-Site or to the upper aquifer from wetlands and drainage ditch sediments.

The sediment sample collected from the former drainage system adjacent to the Off-Site Containment Area was the only sample which exceeds the 10 ppm total VOC criteria used to delineate contaminated soils. Sediments from this area would be excavated for on-Site biological treatment since the area will be dewatered. None of the sediment samples exceeded the 50 ppm total PCBs criteria used to delineate PCB-contaminated soils. Only one sample, SB02 taken from the ACS Site, exceeded 10 ppm total PCBs (22 ppm). This area could either have a soil cover placed over it to prevent dermal contact, or excavated for biological treatment along with other PCB-contaminated soil areas.

Overall Protection of Human Health and the Environment

There are no documented cases of biological treatment being used on Sites where either the wide range of contaminants or the high concentrations of contaminants approach those at the ACS Site. Biological treatment has been shown to be very effective in treating simple contaminant matrices, such as petroleum hydrocarbons or some types of VOCs. It has also been shown to be effective in significantly reducing concentrations of some SVOCs such as creosote compounds. Because of the wide range of compounds at the ACS Site, it is possible that the time to conduct biological treatment will be longer than anticipated and hence the cost will be greater than estimated. Extensive bench and

pilot scale treatability studies would have to be conducted to examine the feasibility of biological treatment. It is not known if biological treatment would achieve appropriate removals for all compounds.

At the completion of remedial action activities, contaminated groundwater would be treated and the continuing source of groundwater contamination significantly reduced. This should mitigate future impact to downgradient wetlands, Turkey Creek, residential water wells, as well as the lower aquifer. Well closures and institutional controls pertaining to access restrictions would be instituted to reduce the potential for human exposure to contaminated groundwater and residual contaminants which remain on-Site.

Compliance with ARARs

Refer to Section 4.3.3 for a discussion of Site ARARs in general, as well as ARARs applicable to the discharge of treated groundwater and VOC air emissions. It is anticipated that all ARARs would be met by Alternative 8. The operation of the biological treatment system would have to meet RCRA hazardous waste and TSCA PCB storage and treatment regulations. Since landfarming would be performed in engineered treatment cells within the current Area of Contamination designed to meet RCRA ARARs for waste piles (refer to Figure 4-11), the RCRA land-ban standards should not apply to the placement of soil into the treatment cells. Generated biological treatment sludge and groundwater treatment system residuals (e.g. ion exchange backflushing) storage and off-Site disposal would have to comply with RCRA hazardous waste generator regulations. If VOC emissions exceed IDEM requirements, off-gas capture and treatment systems would have to be incorporated into the biological treatment process. In the case of land farming, a dome would have to be constructed over the treatment cells, and a vacuum placed on the entire system. Exhaust from the system would be directed to a vapor phase treatment system (i.e., vapor carbon adsorption or thermal treatment). 40 CFR 264 Subparts F and G, pertaining to releases from SWMUs and closure and post-closure of RCRA landfills, could be considered ARARs for untreated contaminants which remain on-Site.

A treatability variance from the RCRA LDRs would most likely have to be obtained to redeposit biologically treated soils on-Site. A treatability variance appears warranted for the ACS Site based on the complicated contaminant matrix and elevated concentrations that were found. Refer to Section 3.5.1 for a discussion on obtaining a treatability variance for CERCLA response actions.

Long-Term Effectiveness and Permanence

Based on risk levels presented in the BRA for various on-Site exposure scenarios (e.g. on-Site resident), significant removal of the identified chemicals of concern would have to be achieved. As discussed above, it is not known if biological treatment would achieve appropriate removals for all compounds. It is likely that volatilization of VOCs would occur during material handling and treatment activities, which would also contribute to the overall removal efficiency. Above-ground fixation of metals may also have to be performed on soils that are redeposited back onto the Site following biological treatment in order to achieve acceptable risk levels.

At the completion of remedial action activities, contaminated groundwater would be treated. The continuing source of groundwater contamination would be significantly reduced. Remaining residual soil contaminants would either be naturally attenuated into infiltrating groundwater and treated with the pump and treat system or removed by a more aggressive groundwater pump and treat system (refer to "Description" subsection). Refer to Section 4.3.5 or 4.3.6 for a discussion of SVOC mobility in soils. Institutional controls would be used to control the use of contaminated groundwater and access to the ACS Site. Refer to Section 4.3.2 for a discussion pertaining to the long-term effectiveness of groundwater pumping and treatment.

Reduction of Toxicity, Mobility or Volume Through Treatment

A discussion of reduction of toxicity, mobility or volume through treatment is presented in Sections 3.4.1.1 and 4.2.7.2 for biological treatment. The potential approaches to biological treatment, as well as treatability potential, that were presented for groundwater can also be applied to soils. All of the chemical groups of concern for the soils and buried waste were also included in the groundwater discussion. It is likely that volatilization of VOCs would occur during material handling and treatment activities, which would also contribute to the overall removal efficiency.

Figure 3-3 presents a summary of organic groups subject to biodegradation (U.S. EPA, 1985), while Figure 3-4 presents BOD5/COD ratios for various organic compounds (Lyman, 1982). Ratios of BOD5/COD have been used as an indicator of potential aerobic degradation. Excluding the inorganic metals, chlorinated methanes, chlorinated ethanes and chlorinated ethenes, the remaining chemical groups of concern are potentially amenable to aerobic biological treatment. The BETX compounds, chlorinated benzenes, chlorinated methanes, chlorinated ethanes and chlorinated ethenes are potentially amenable to anaerobic biological treatment. Recent research (Nelson, 1987 as referenced in Thomas, 1989) has shown the potential for aerobic degradation of trichloroethene and other chlorinated compounds by an aromatic pathway in the presence of phenol, toluene or cresol.

Removal efficiencies and degradation rates for individual compounds are dependent on the chemical matrix and concentrations, as well as the design parameters of the biological treatment system. The use of properly selected or engineered microbial populations, maintained under environmental conditions most conducive to their metabolic activity (e.g., oxygen concentration, nutrient addition, etc.), can be an important means of biologically degrading refractory compounds. Biological degradation is often enhanced through acclimation of the microbial population to the chemical matrix to be treated or by cometabolism mechanisms. Most of the potential approaches to the biological treatment of groundwater discussed in Section 4.2.7.2 (e.g., cometabolism in the presence of methane or aromatics, sequence batch reactors, white rot fungus, etc.) can also be utilized in solid phase biological treatment applications.

If required, above-ground fixation of soils following biological treatment would reduce the mobility of metals prior to their being redeposited back on-Site. The fixation of metals is a proven technology. Inorganic metals have high soil adsorption coefficients and were not identified as a target compound group in the upper aquifer. If left untreated, inorganic metals would be expected to be immobilized in the soil matrix and not pose a potential threat to either the upper aquifer on ambient air. Metals would, therefore, be immobilized in soils by either natural attenuation processes or fixation techniques.

Short-Term Effectiveness

The completion of Site dewatering would be completed in approximately one year. Both horizontal and vertical migration of contaminants in the groundwater from the Site would be mitigated upon completion of this task. The estimated time frame to complete source treatment activities for Alternative 8 is 5 to 10 years. It is assumed for purposes of the cost estimates that groundwater treatment would occur for a 30 year period. A more aggressive pump and treat system would likely reduce the time frame to reach the maximum achievable level of aquifer contaminant removal. Short-term effectiveness discussions in Section 4.3.3 pertaining to material handling activities and wetlands dewatering are also applicable to Alternative 8.

Nearby residents, ACS workers and remediation contractor workers could be exposed to airborne particulates or volatilized VOCs during excavation and material handling activities. Ambient air monitoring may be required to evaluate potential VOC exposures. Small quantities of contaminated materials could be spilled over the surface of the Site during transfer to the soil staging area located adjacent to the Off-Site Containment Area. ACS workers and remediation contractor workers would be exposed to contaminated soil during excavation and material handling activities. A health and safety program which requires the use of personal protection equipment for on-Site workers should minimize short-term risk during implementation of Alternative 8.

Implementability

Refer to Section 4.2.8. Treatability studies would be required to evaluate a range of design conditions and treatment processes in order to optimize the removal efficiencies and degradation rates for the organic contaminant matrix present in the soil at the ACS Site. A pilot test would also be required if slurry-phase bioreactors are used. If biological treatment of groundwater is also employed, the treatability studies for both soil and groundwater may be able to be combined and incorporated into a single overall biological treatment approach to the contaminant matrix present at the ACS Site.

A RCRA Part B treatment permit would not be required for operation of the biological treatment system since this is a CERCLA Site. Appropriate approvals and/or permits would have to be obtained in order to discharge treated groundwater. Tank farms located on top of the Still Bottoms and Treatment Lagoon Areas would either have to be dismantled or relocated before excavation could begin in those area. Utility lines and product and water lines are also located in the areas of the tank farms. These lines would either have to be moved or replaced. The continuation of ACS's chemical manufacturing operations could interfere with excavation and material handling activities. An access road and entrance road to the Site, both adjacent to the On Site Containment Area, may be blocked by excavation activities. Temporary access roads may have to be constructed. A full time shift of workers would have to be present on-Site to operate the slurry-phase biological treatment system on a 24-hour basis. Workers would only have to be on-Site on a periodic basis to monitor and control a land farm treatment system.

Treatability and pilot studies would be required if above-ground fixation is required for soils following biological treatment.

Cost - Capital, annual O&M and net present worth costs are presented in Table 4-16 and Appendix B. Design assumptions for the purposes of the cost estimates are presented in Figures 4-15, 4-16 and 4-17 and the itemized cost estimates for Alternatives 7A and 7B presented in Appendix B.

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SECTION 2.0
IDENTIFICATION AND SCREENING OF TECHNOLOGIES

The primary objective of the technology screening process is to identify a manageable number of remedial technologies which can then be assembled into remedial action alternatives. For the ACS Site, this process consists of four steps:

- Develop remedial action objectives;
- Develop general response actions;
- Identify and screen remedial technologies; and
- Summarize the technologies array.

The following subsections contain a discussion of each of the steps.

2.1 Remedial Action Objectives

In this step, the remedial action objectives, which are the goals for protecting human health and the environment, are developed. Considering the general long-term goals of protecting public health and the environment, and the Site-specific goals of reducing the release of contaminants to the air, surface water and groundwater, a number of specific remedial action objectives were developed. As the Feasibility Study proceeds, it may or may not be appropriate to consider that the ACS facility is an operating RCRA facility initiating closure. Remedial alternative development will consider the coordination between proper closure activities and the appropriate evaluated remedial alternatives. These objectives are as follows:

Groundwater

- Provide adequate protection against human consumption of water containing carcinogens in excess of maximum contaminant levels (MCLs) and a total cancer risk for all carcinogens of greater than 10^{-4} to 10^{-6}, with a point of departure of 10^{-6}.

- Provide adequate protection against human consumption of water containing non-carcinogens in excess of MCLs and a total hazard index based on reference doses for all contaminants of greater than 1.0.

- Restore groundwater quality to applicable ARARs.

- Prevent migration of contaminated groundwater to surrounding wetlands, as well as potential migration to neighboring wells and the waters and sediments of tributaries of Turkey Creek consistent with risk levels defined in the ecological assessment.

- Reduce or eliminate migration of subsurface soil contaminants to the groundwater.

Soils

- Provide adequate protection against human contact, consumption or inhalation of soils which have a total cancer risk for all carcinogens of greater than 10^{-4} to 10^{-6}, with a point of departure of 10^{-6}.

- Provide adequate protection against human contact, consumption or inhalation of soils which have a total hazard index based on reference doses for all contaminants of greater than 1.0.

- Reduce potential for erosion and transport of contaminated surface and subsurface soils from the Site.

Buried Drums/Liquid Wastes/Sludges

- Minimize or eliminate continuing source of contaminants to subsurface soils and groundwater.

- Provide adequate protection against human contact, consumption or inhalation with wastes which have a total cancer risk for all carcinogens greater than 10^{-4} to 10^{-6}, with a point of departure of 10^{-6}.

- Provide adequate protection against human contact, consumption or inhalation with wastes which have a total hazard index based on reference doses for all contaminants greater than 1.0.

Surface Water and Sediments

- Reduce potential for erosion and transport of contaminated sediments and surface soils surrounding drainage ditches, wetlands and tributaries of Turkey Creek.

- Reduce to acceptable levels releases of contaminants from sediments and groundwater discharge that would cause applicable ARARs to be exceeded in surrounding drainage ditches and tributaries of Turkey Creek.

- Reduce or eliminate exposure of wetland organisms and human populations to contaminated sediments and surface water.

Landfill

- Provide adequate protection against human contact, consumption or inhalation of leachate, contaminated soils, sediments, surface water, and groundwater which has a total cancer risk for all carcinogens of greater than 10^{-4} to 10^{-6}, with a point of departure of 10^{-6}.

- Provide adequate protection against human contact, consumption or inhalation of leachate, contaminated soils, sediments, surface water, and groundwater which have a total hazard index based on reference doses for all contaminants greater than 1.0.

2.2 General Response Actions

In this step, the general response actions that will satisfy the remedial action objectives are developed. To satisfy the remedial action objectives, general response actions have been developed for probable sources of health risks. General response actions, associated technology groups and process options identified for consideration are presented in Figure 2-1.

2.3 Identification and Screening of Remedial Technologies

In this step, the universe of potentially applicable technologies and process options are identified and then subsequently reduced by screening (evaluating) the options. Technologies and process options were identified in consideration of the types of contaminants identified during the Remedial Investigation.

The purpose of the screening process is to select a limited number of promising technologies for consideration in assembling remedial action alternatives. A decision is made whether to retain an identified technology or process option for use in developing alternatives or to eliminate it from further consideration. Criteria used for screening of the options include effectiveness, implementability, and cost.

Effectiveness is the primary criterion used to screen options at this point. Effectiveness is evaluated considering end results; i.e., the ability of the technology to meet the remedial action objectives.

Implementability is evaluated considering the technical and institutional feasibility of implementing the technology. Technical implementability considers a range of factors relevant to obtaining, installing, and using a particular technology. Some remedial technologies are proven and readily available, while others are in the research and development stages. Insufficiently developed technologies are generally screened out. Site conditions must be compatible with the feasible range of a given technology's capability, considering for example, depth to bedrock, depth to groundwater, space requirements, etc.. Institutional implementability considers a range of factors relevant to the testing, review, approval, or permitting of a particular technology.

Cost plays a limited role in the screening of options at this point. Cost is evaluated relative to capital and operation and maintenance costs.

Potentially applicable remedial action technologies that have been identified for ACS are listed in Figure 2-1. The Figure briefly describes the technologies, indicates the applicability of each technology, and presents the remedial technologies retained for further consideration. The screening of potentially applicable technologies considered for the Site is summarized in the following sections.

2.4 Groundwater and Surface Water Remedial Technologies

Technologies addressing contaminated groundwater would apply to both the upper and lower aquifers at the Site. The screening of potentially applicable groundwater and surface water technologies is presented below.

2.4.1 Groundwater Institutional Measures

Access restrictions may be taken as part of an overall Site remedy. Deed restrictions would be appropriate for properties within potentially contaminated areas. The feasibility of this depends on whether the U.S. EPA/State/City has this authority and is willing to impose restrictions. Both of these institutional measures will be retained for alternatives development.

2.4.2 Groundwater Containment

Groundwater control methods fall into two categories: physical barriers and hydraulic gradient control. Physical barriers can be effective in controlling the movement of groundwater and its associated contaminants by placement of low permeability barriers to reduce flow from one area to another. Hydraulic gradient control is used to modify local groundwater flow patterns. This is accomplished using water injection, groundwater extraction, or a combination of the two.

2.4.2.1 Barriers. Both horizontal and vertical barriers are under consideration for the Site. Low permeability cut-off walls or diversions are installed below ground to contain, capture, or redirect groundwater flow in the vicinity of the Site. Slurry walls are the most common subsurface barriers because they are a relatively inexpensive means of vastly reducing groundwater flow in unconsolidated earth materials. An engineered soil mixture is blended with the bentonite slurry and placed in a vertical trench to form a soil-bentonite slurry wall. In some cases, the trench is excavated under a slurry of portland cement, bentonite, and water, and this mixture is left in the trench to harden into a cement-bentonite slurry wall. At the ACS Site, the depth to the clay aquitard is conducive to the implementation of slurry walls as a vertical barrier to prevent off-Site groundwater flow in the upper aquifer. Slurry walls keyed into the low permeability clay aquitard at a depth of approximately 25 feet would also be effective in reducing quantities of water to be pumped as a part of a pump and treat alternative. Slurry walls will be retained for alternatives development.

Grout curtains are subsurface barriers created in unconsolidated materials by pressure injection. Grout barriers can be many times more costly than slurry walls and are generally incapable of attaining truly low permeabilities in unconsolidated materials. The vibrating beam method places grout so as to generate a wall. As it is difficult to ensure the integrity of a grout curtain or a vibrating beam wall, these technologies will not be retained for alternatives development.

In addition to slurry wall and grouted cut-offs, sheet piling can be used to form a groundwater barrier. Sheet piles can be made of wood, pre-cast concrete, or steel. Wood is an ineffective water barrier, however, and concrete is used primarily where great strength is required. Steel is often the most effective form of groundwater cut-off. Interlocks between barrier material may be difficult to seal. This technology is not retained because of high associated costs and unpredictable wall integrity.

Bottom sealing refers to techniques used to place a horizontal barrier beneath an existing Site to act as a floor and prevent downward migration of contaminants. Both block displacement and grout injection bottom sealing process options involve variations of the grouting techniques as described above. These technologies are not retained for alternative development due to the difficulties with assuring the integrity of such barriers and because the Site already has an effective clay layer beneath it.

2.4.2.2 Gradient Control. Injection is used to develop a hydraulic barrier by creating a mound in the water table. Water can be injected into the aquifer using wells, trenches, or seepage basins. The high permeability of Site soils would make this technology difficult to implement. A high volume of water would be required for injection, and it is likely that the injected water would discharge directly to the surrounding wetlands as opposed to mounding. Injection of clean water to the aquifer as a method of gradient control is not considered viable, and is not retained for alternative development. Reinjection of treated groundwater, however, could be used as a form of groundwater flushing to both enhance aquifer cleanup and minimize the dewatering of Site wetlands.

2.4.2.3 Extraction/Collection. Groundwater extraction is a method of controlling groundwater movement, while removing contaminants. Wells and trenches are most commonly used to collect groundwater. Trenches are most effective for low permeability soils, but are also used in higher permeability sandy soils. If wells are used, the high permeability of the Site soils suggests that an array of shallow wells placed so that their zones of influence overlap would provide an effective extraction system. Both systems will be retained for alternatives development because they are the most generally effective and readily implemented groundwater extraction devices for this Site.

A well point and header system could also potentially be used. This would provide flexibility in operation of a multiwell system while limiting maintenance on pumps. The effective depth of such a system may limit its viability at this Site.

2.4.3 Direct Groundwater and Surface Water Treatment

VOCs, SVOCs and metals were detected in groundwater samples. Groundwater treatment methods can be divided into three categories: biological, chemical, and physical. Some level of treatment will probably be required prior to any discharge, in order to attain effluent limitations. Treated effluent from the processes described in the following sections may be discharged via recharge wells to the upper aquifer, to Turkey Creek via conventional pipeline and outfall, to the wetlands west of the Site, or to a publicly-owned treatment works (POTW). Discharge to the POTW may require pretreatment. All four methods are appropriate options for consideration for groundwater treatment systems, and will be retained for alternatives development.

Discharge to the POTW would result in an increase in hydraulic loading on the local plant. Volatilization would be the major fate of VOCs at the POTW, and substantial removal efficiencies may be obtained, even though the plant was not specifically designed for VOC removal. Although discharge to the POTW may not be appropriate because of high hydraulic loadings and elevated VOC concentrations, it may become feasible if water quantities and VOC levels are lowered in time. Therefore, this discharge option is retained for consideration.

2.4.3.1 Biological Methods. Aerobic biological degradation is potentially applicable to treatment of BETX compounds, as well as numerous other organic compounds, found at this Site. Metals are not treated using biological processes. Aerobic degradation of these compounds by methanotrophic bacteria has been demonstrated. Reaction rates and microbial growth kinetics have not been well defined for aerobic degradation processes. Reactor configurations are being developed and assessed, including a fixed-film gas-permeable membrane system (Woods, Williamson and Strand, 1989), a concurrent flow, packed bed, gas-phase continuous reactor (Huffman et. al., 1989), and a center downflow, annular space upflow column (Pritchard, 1989). Laboratory and pilot scale studies would have to be conducted to determine removal rates, biological growth kinetics and nutrient requirements.

Anaerobic treatment can also be used to reduce contaminants in Site groundwater. Anaerobic degradation pathways have been published for aromatic and chlorinated solvents. The mechanism for anaerobic transformation of the compounds of concern is not well understood. Studies where transformation and degradation have been demonstrated all were conducted under conditions where another carbon and energy source was available (e.g., ethanol, acetate or naturally-occurring sediment organic matter). Therefore, a carbon/energy source and nutrients would have to be provided. Both aerobic and anaerobic treatment have been retained because of their degradation capabilities and potential applicability to Site contaminants.

2.4.3.2 Chemical Methods. Conventional chemical treatment methods such as coagulation, precipitation, or reduction would not be effective in VOC removal, but may be necessary as a pretreatment step for metals prior to VOC treatment. Chemical precipitation involves the addition of chemicals to adjust pH to precipitate inorganic metals from solution. Prior to the settling of precipitated solids, it is often necessary to add a coagulating agent in order to flocculate solids which are suspended in solution. As part of the precipitation process, it is often necessary to add a reducing agent which alters the valence state of certain metals (e.g., chromium) in order to make them more amenable to precipitation. For this reason, these technologies have been retained as treatment alternatives because of their potential pretreatment applications.

Photolysis/Oxidation. Oxidation using ozone and/or hydrogen peroxide is a promising chemical treatment technology. In this process, ozone and/or hydrogen peroxide are contacted with contaminated water in a reactor. Ozone decomposes in water to form hydroxyl radicals, which react with various organic compounds. Chemical doses and overall reaction rates must be determined experimentally for a particular effluent water, because of competing oxidation and free radical reactions. The oxidation process can be followed by photolysis, the photodegradation of contaminants using ultraviolet radiation or polar solvents, to further remove organic compounds. Metals are not treated by this process. Both the oxidation and photolysis technologies are retained due to their demonstrated effectiveness in contaminant destruction.

2.4.3.3 Physical Methods. Physical methods to be evaluated include freeze technologies, screening/filtration, air/steam stripping, activated carbon adsorption, reverse osmosis, ion exchange and spray evaporation.

Freezing Technologies. Freeze crystallization operates on the principal that when water freezes, the ice crystal structure that forms naturally excludes all contaminants from the water molecule matrix. A version of freeze crystallization that directly injects the refrigerant into the waste has been developed. The process occurs within a crystallization column. The separated slurry liquid is removed from the system for disposal. This technology is theoretically applicable to both organic and inorganic contaminants present in aqueous waste streams. This technology has not been retained since its ability to effectively treat groundwater containing the matrix and concentrations of VOCs and SVOCs at the ACS Site has not been demonstrated at either the laboratory or field scale. It does not offer any advantages over proven technologies which have been retained since contaminants would only be transferred from one medium to another and not destroyed.

Screening/Filtration

Conventional physical treatment methods such as screening, filtration, or settling would not treat VOCs and are therefore not considered viable as a complete treatment technology. This alternative has been retained as a method of pretreatment for suspended solids.

Air/Steam Stripping. VOCs are conventionally stripped from water using air or steam in a packed column. Water is pumped to the top of a tower packed with a high surface area, high void volume, and inert packing material. Water trickles over the packing and is discharged at the bottom of the tower. The stripping gas is typically introduced at the bottom of the tower. Volatile contaminants are transferred from the water to the stripping gas. For solutes as volatile and readily strippable as the VOCs detected at the Site, at the concentrations anticipated, ambient temperature stripping with air is generally used. Air pollution controls may be required. The effectiveness of this technology has been well demonstrated at numerous other Sites. Air stripping would not treat metals or PCBs. This technology is retained due primarily to its potentially acceptable effectiveness and low cost. Steam stripping may be more cost effective than air stripping due to the potentially high VOC influent concentrations that may be encountered (i.e. in excess of approximately 10 mg/l).

Activated Carbon Adsorption. Activated carbon adsorption is also commonly used to remove organics from water. Most frequently, granular activated carbon beds are used. Contaminated water flows through the carbon bed and contaminants are adsorbed on the carbon. The process is capable of reducing VOCs and many SVOCs to less than detectable levels. When the capacity of the carbon is exhausted, the bed is taken out of service. The spent carbon is usually either regenerated, disposed of in a landfill, or incinerated. The choice of carbon handling methods depends largely on the types and concentration of contaminants and the economics of regeneration versus disposal or destruction. The effectiveness of this technology for VOC removal has been demonstrated at several Sites, and the technology is thus retained. Carbon adsorption may also treat metals and PCBs present in the groundwater.

Reverse Osmosis. Reverse osmosis (hyperfiltration) is potentially applicable for the removal of VOCs. A semi-permeable membrane is used to effect a separation of solvent (water, in this case) and solute (e.g., TCE or benzene, in this case). The pore size in the membrane is such that water passes through more readily than the contaminant. Contaminated water is pumped under high pressure to membrane-holding cartridges. Water with low contaminant levels passes through the membrane (permeate stream) and

a concentrated aqueous VOC solution (concentrate stream) remains on the pressurized side of the membrane. A concentrated reject stream must therefore be managed. The relative proportions of permeate and concentrate depend on solute properties, membrane properties, flow rates, operating pressures and the configuration and number of units used in the process. No reports of full scale use of membrane separation for VOC removal have been identified. A major unknown is membrane material compatibility with the contaminants. The energy needed to operate a high pressure system and the need for permanent treatment would likely make this a costly process. This technology has not been retained since its ability to effectively treat groundwater containing the matrix and concentrations of VOCs and SVOCs at the ACS Site has not been demonstrated at either the laboratory or field scale. Alternative proven technologies have been retained, instead.

Ion Exchange. Ion exchange involves the reversible interchange of ions between a liquid and solid. Ion exchange is often used to remove dissolved metal ions, cyanide, and other inorganic compounds from solution. It is not applicable to the removal of VOCs or PCBs. Materials such as natural and synthetic zeolites and organic resins are used as ion exchange surfaces. This alternative has been retained as a method of inorganics removal prior to VOC treatment operations.

Spray Evaporation. Spray evaporation, a process in which contaminated groundwater is sprayed into the air, volatilizing VOCs to the atmosphere, is difficult to control. Complete volatilization of some constituents is unlikely. Once airborne, contaminants may be carried off-Site. Therefore, spray evaporation is not considered viable for alternative development.

2.4.3.4 Thermal Treatment. Several different thermal destruction methods are applicable to treating organic compounds present in the groundwater. Groundwater and surface water treated by thermal treatment technologies would be evaporated as part of the process. Section 2.5.2.2 discusses the principles of thermal treatment technologies, in general, and incineration technologies in particular. The principles of wet air oxidation are discussed in Section 2.5.2.4. Because of the energy intensive nature involved with

using thermal destruction technologies to evaporate groundwater and surface water, the costs of using these technologies would be prohibitive. Since equally effective methods of groundwater and surface water treatment are available, thermal destruction has not been retained as an alternative.

2.4.4 Offsite Treatment

The same technologies that were discussed for direct treatment on-Site in Section 2.4.3 are also applicable as off-Site treatment alternatives. Extracted groundwater would be collected and transported to an off-Site treatment facility. Off-Site treatment alternatives include discharge to the POTW and transportation to a commercial treatment facility.

2.4.4.1 Biological. Collected groundwater would be discharged to the POTW for biological treatment. Section 2.4.3.1 discusses the principles of aerobic and anaerobic degradation. Discharge to the POTW would result in an increase in hydraulic loading on the local plant. Volatilization would be the major fate of VOCs at the POTW, and substantial removal efficiencies may be obtained, even though the plant was not specifically designed for VOC removal. Although discharge to the POTW may not be appropriate because of high hydraulic loadings and elevated VOC concentrations, it may become feasible if water quantities and VOC levels are lowered in time. Therefore, this treatment option is retained for consideration.

2.4.4.2 Chemical, Physical, Thermal. Collected groundwater would be transported to a commercial facility for off-Site treatment. Due to the types and levels of contaminants present in the groundwater, as well as the large volumes of extracted groundwater that would require treatment, this alternative would be cost prohibitive. Off-Site commercial treatment has not been retained as a treatment alternative.

2.4.5 In-Situ Groundwater Treatment Methods

In-place treatment of contaminated groundwater is potentially viable for the physical conditions and contaminants identified at the ACS Site. As with aboveground processes, the technologies can be categorized as biological, chemical or physical methods.

2.4.5.1 Biological In-Situ Methods

Biological degradation of the primary contaminants (e.g. BETX compounds, the PCBs, and chlorinated solvents) occurs either aerobically or anaerobically. Section 2.4.3.1 discusses the principles of aerobic and anaerobic degradation. Physically, an in-situ bioreclamation system would involve feeding nutrients, an organic substrate, and possibly a terminal electron acceptor into water from extraction wells and then reinjecting the water into the aquifer. The goal of this system would be to maintain suitable environmental conditions throughout the aquifer section of interest to support the growth of desired microorganisms to enhance aerobic or anaerobic degradation of contaminants. The major difficulty associated with this treatment is that in some cases, neither the mechanisms responsible for specific compound degradation nor optimum growth conditions have been identified. Therefore, the ability to maintain suitable conditions is difficult to assess at this stage. Because of the high permeability of soils present at the ACS Site, both aerobic and anaerobic treatment will be retained.

2.4.5.2 Physical In-Situ Methods.

Permeable Treatment Beds. Permeable treatment beds are essentially excavated trenches placed perpendicular to groundwater flow and filled with an appropriate material to treat the plume as it flows through the material. Some of the materials that may be used in the treatment bed are limestone, crushed shells, activated carbon, glauconitic green sands, and synthetic ion exchange resins. Permeable treatment beds have the potential to reduce the quantities of contaminants present in leachate plumes. The system is applicable to relatively shallow groundwater tables containing a plume.

Potentially numerous problems exist in using a permeable treatment bed. These include saturation of bed material, plugging of the bed with precipitates, and short life of treatment materials. Therefore, permeable treatment should be considered as a temporary remedial action rather than a permanent one. This technology would ultimately only slow, not prevent, migration of contaminants. This technology is eliminated from further consideration because of its limited effectiveness and implementability limitations.

Steam Stripping. Steam stripping involves the use of steam and hot air to strip VOCs from contaminated soil. Metals or PCBs would not be treated by steam stripping. Present in-situ steam stripping processes involve the injection of steam through specially designed hollow augers which are moved vertically through the soil. It may be applied to depths of approximately 30 feet. The auger injection system is mobile, so larger sites can be treated by sectioning into individual treatment cells. Off-gases of the steam stripping process are collected for treatment using a collection hood and blower. In-situ steam stripping has been retained for future consideration because of its potential to simultaneously treat VOCs present in both soil and groundwater.

2.4.5.3 Chemical In-Situ Methods. Ozone and hydrogen peroxide can be used to chemically destroy organic compounds in water in a reaction vessel. In principle, these chemicals could be injected into the aquifer to effect volatile destruction. Because the desired reactions would take place in the porous medium of the aquifer instead of in a tank, many other competing reactions could be anticipated. The system would involve feeding chemicals in aqueous solution into water from groundwater extraction wells, and reinjecting the water into the aquifer. Materials of construction (pumps, piping, wells, etc.) must be resistant to the oxidants used.

No reports of chemical oxidation of the contaminants of concern in an aquifer or in soils have been identified, so this technology would require extensive testing. This technology is not considered adequately developed for use at the Site, and is therefore eliminated from consideration due to effectiveness and implementability concerns.

2.4.6 Treated Water Discharge

A method of discharging the treated groundwater must be determined. Both on- and off-Site methods of discharge are available.

2.4.6.1 Off-Site Discharge. Discharge of the treated groundwater to the POTW is the primary off-Site alternative available. Discharge to the POTW would result in an increase in hydraulic loading on the local plant. The groundwater would be treated to contaminant levels acceptable to the POTW. Further information pertaining to the

POTW's discharge requirements applicable to the treated groundwater must be obtained. This discharge option is retained for consideration.

2.4.6.2 On-Site Discharge. Various on-Site discharge alternatives are also available. Treated groundwater can be discharged to proximate surface water bodies such as stormwater collection ditches or tributaries of Turkey Creek. All of the surface water discharge options would require obtaining a National Pollution Discharge Elimination System (NPDES) permit. Treated groundwater may also be reinjected back into the upper or lower aquifer using recharge wells. Some of the available treatment alternatives (e.g., biological) work more efficiently if treated groundwater is reinjected. The use of recharge wells may require obtaining a State injection well permit. Treated groundwater can also be discharged to the wetlands located west of the Site. Discharge to the wetlands would prevent them from being dewatered by groundwater pump and treat systems. In addition, the treated groundwater could be used to flush residual levels of contaminants from wetland sediments.

Both on- and off-Site discharge alternatives have been retained for future consideration.

2.5 Waste and Soil Remedial Technologies

Waste is considered to be actual waste materials that were deposited at the Site. It would include drums, contents of drums, drum residues and free product that was dumped or pumped onto the ground surface or into excavations. Soil refers to any Site soils which contain residual levels of contaminants. VOCs, SVOCs and metals were detected in soil samples collected from all areas excluding the Inactive Landfill. The following sections present a screening of the technologies available for treating waste and soil at the Site. If a technology is only appropriate for just waste or just soil, it is noted.

2.5.1 Waste and Soil Access Restrictions

Access restrictions may be used as part of an overall Site remedy. Deed restrictions would be appropriate for properties within contaminated areas. The feasibility of this depends on whether the U.S. EPA/State/City has this authority and is willing to impose

restrictions. Fencing designated areas of contamination would aid in reducing the incidences of trespassing, thus decreasing the risk associated with dermal contact of contaminants. Each of these alternatives has been retained for consideration.

2.5.2 Waste and Soil Removal

Removal of contaminated materials at the source areas would be a technically feasible means of minimizing the additional release of contaminants to groundwater, surface water, soil, and air. Options for managing these materials include treatment (on-Site or off-Site) and disposal (on-Site or off-Site). On-Site technologies considered for alternative development can be divided into four categories: biological, chemical and physical treatment; and thermal destruction.

Candidate areas for removal include VOC contaminated soils from all of the areas. Intact buried drums are believed to be present in the On-Site Containment Area. Drum waste and drum carcasses are present in the Off-Site Containment Area and the Still Bottoms/Treatment Lagoon Area. Excavation of contaminated soils and buried drums would be effective as a source control measure and would eliminate or reduce further contaminant migration associated with the soils. Field screening during excavation activities would be required to provide the necessary data to accurately define the areal extent of contamination and to determine when target cleanup levels have been achieved.

2.5.2.1 Biological Treatment

Section 2.4.3.1 discusses the principles of aerobic and anaerobic degradation. Biological treatment is potentially viable for removal of Site contaminants, and could be more readily controlled above-ground using landfarming or bioreactor methods. Metals are not treated using biological processes. Degradation of the primary Site contaminants can be accomplished either aerobically or anaerobically. Biological treatment could be accomplished in a moving bed or rotary drum contactor, which may also promote volatilization. Slurry-type reactors could be used, but this would produce an aqueous waste stream requiring treatment and disposal. Pilot testing would be required. Biological treatment is retained for the development of alternatives for soil and waste.

2.5.2.2 Thermal Treatment

Several different process options were considered for thermal treatment. Incineration can be performed either on-Site or off-Site. Mobile incinerators have been developed for on-Site use that operate as effectively as off-Site facilities. Mobile incinerators can be used to reduce or eliminate organic compound contamination in soils, wastes and water. A mobile incinerator treatment system requires several tractor- trailer units to transport the necessary equipment to the Site. The capacity of commercially available mobile incinerators varies depending on the size and the type of unit that is utilized. Utilities needed for the operation for a mobile unit include electric power, auxiliary fuel, and clean water. The residue remaining after incineration would be disposed of on-Site or at an off-Site landfill. Air emission scrubbers required to reduce air pollution potential will generate waste effluent and particulates that must be properly treated and disposed. The efficiency and ability of the incinerator will have to be tested to determine its ability to destroy the organic contaminants to compliance levels. The volume of soil potentially requiring treatment would dictate that above-ground incineration be performed in stages. Considerable material handling activities would be required. Incineration would not treat metals. There may be some public opposition to the implementation of the on-Site incineration alternative. The three process options retained for alternative development, rotary kiln, infrared incineration, and low temperature thermal treatment are described below.

Rotary Kiln Incineration

Rotary kiln incinerators are cylindrical, refractory-lined shells. They are fueled by natural gas, oil, or pulverized coal. Most of the heating of the waste is due to heat transfer with the combustion product gases and the walls of the kiln.

Wastes are injected into the kiln at the higher end and are passed through the combustion zone as the kiln rotates. The rotation creates turbulence and improves combustion. Rotary kilns often employ afterburners to ensure complete combustion. Most rotary kilns are equipped with wet scrubber emission controls.

The residence time and temperature depend upon combustion characteristics of the waste. Residence times can range from a few seconds to an hour or more for bulk solids. Combustion temperatures range from 1500°F to 3000°F. Because the primary contaminants in the soil are VOCs, it may be possible to utilize much lower temperatures to release the VOCs.

Infrared Incineration

Infrared incineration systems destroy organic compounds in soils and wastes, through thermal oxidation, using infrared energy as the primary heat source. Wastes are carried through the primary furnace on a conveyor belt that is gently sifted to ensure mixing and combustion. Electrically infrared rods located above the conveyor heat the furnace to approximately 1800°F. The residence time varies from 10-180 minutes depending on the waste type. Ash residue from the furnace is discharged into a hopper, and is then conveyed to a collection system for containment, testing, and subsequent disposal in an appropriate on-Site or off-Site landfill.

The organic vapor generated in the primary furnace is exhausted to a secondary combustion chamber, which is heated to 2300°F using propane burners. A residence time of several seconds ensures destruction of any remaining organics. Exhaust gases from the secondary chamber pass through air pollution control equipment prior to discharge.

Low Temperature Thermal Treatment

Low temperature thermal treatment is a separation process to remove VOCs and SVOCs from a solid matrix. The system consists of a dryer and gas treatment system. The dryer heats the materials and volatilizes the water and organic contents. Its operation temperature and energy requirements are much less than incineration. Operating temperatures typically range between 450° and 850°F. The gas treatment system condenses and collects the volatilized compounds for disposal. It also serves as the air pollution control portion of the system. The applicability of low temperature thermal treatment to the destruction of PCBs has yet to be determined.

2.5.2.3 Physical Treatment

Physical treatment methods considered for alternative development include the following: solvent and vapor extraction, soil flushing and fixation.

Vapor Extraction

Vapor extraction at ambient temperatures would address the VOC, and possibly SVOC, contamination at the Site. A vacuum is applied at some collection point or series of collection points. Steam may also be injected in order to elevate soil temperatures and increase removal efficiencies. Soil gases and contaminant vapors migrate toward the collection points. The gases may require treatment prior to discharge. This is typically accomplished using an adsorbent bed, a catalytic combustion device or a fume incinerator. Vapor extraction would not treat metals or PCBs. Operating conditions are better controlled in above-ground applications. Above-ground operation of vapor extraction would not be inhibited by the shallow groundwater conditions present at the Site. The volume of soil that potentially requires treatment would dictate that above-ground treatment be performed in stages. Considerable material handling activities would be involved. This treatment alternative will be retained for both soil and waste.

Solvent Extraction

Solvent extraction utilizes liquified gases and other organic solvents to extract organics from sludges and soils. The extraction process occurs in a batch reactor unit. The solvent flows upward through the material and extracts organic compounds that have been adsorbed. The extracted mixture goes to a separator where the solvent is vaporized and recycled. The recovered organics are drawn off from the separator for disposal. Solvent extraction is potentially applicable to the organic compounds present at the Site, but has not been proven under field conditions. PCB-contaminated harbor sediments have been successfully treated using solvent extraction. Even though metals are not treatable by solvent extraction, an analogous soil flushing method could be used for metals removal. The volume of soil which potentially requires treatment would dictate that above-ground treatment be performed in stages. Considerable material handling activities would be involved. Even though this technology has not been field tested for the contaminants present at the Site, it has been retained for soil because of its potential ability to treat most of the primary contaminants. It will not be retained for waste

because of the very high levels of contaminants in the waste. Solvent extraction is typically used to separate organics from soils (i.e. solids) or perform phase separation of oils, water and solids in the case of refinery waste. The waste materials, which would exist predominantly in liquid, sludge and slurry forms, would not present a matrix amenable to phase separation by solvent extraction.

Fixation

Fixation methods are designed to immobilize contaminants and thereby prevent their leaching. Once the mixture hardens, contaminants become fixated within the structure and leaching is minimized or eliminated. These methods have particular application to metals contaminated soils. However, their ability to immobilize organic compounds and PCBs have yet to be adequately proven. The addition of materials, as well as operating conditions, are better controlled in above-ground applications. This treatment technology will be retained for soil since it may be applicable to potential treatment residues (e.g. incinerator ash) resulting from other treatment methods.

Soil Washing

Above-ground soil washing utilizes an aqueous-based flushing solution and mechanical separation methods to extract organic and inorganic contaminants from the adsorbed soil phase. The extracted mixture is then separated from the solid soil phase and either recovered or disposed of in a proper manner. Depending on the soil type and contaminant matrix, repeated flushing/washing cycles may be required to effectively remove organic contaminants adsorbed onto soils. Soil washing is most effective in removing contaminants which are readily soluble in water and are not strongly adsorbed onto soils. Surfactants are typically used in the removal of less soluble, hydrophobic organic compounds. No technology currently exists to separate surfactants from extracted organics.

Case studies involving the use of surfactants to extract organic contaminants have been limited to pilot studies involving wood treating and petroleum sites (U.S. EPA 1989). Reported removal efficiencies for aromatic VOCs do not document their final disposition. Significant volatilization of VOCs during the separation and mixing

operation would likely occur, which would increase the potential exposure risk for ACS workers and nearby residents. The use of surfactants in the extraction of hydrophobic organic contaminants is chemical specific and effective only for simple contaminant matrices (U.S. EPA, September 1988).

This process option has not been retained for alternatives development for both soils and buried waste because of the complex organic contaminant matrix present in these media, as well as the hydrophobic nature and high soil adsorption affinity of most of the detected VOCs and SVOCs. Because of the high organic concentrations, aqueous-based solutions would not be effective in extracting organics which would likely remain preferentially dissolved in the oil phase.

2.5.2.4 Chemical Treatment

Chemical treatment methods considered include oxidation/reduction, dechlorination, and wet air oxidation.

Oxidation/Reduction

The oxidation process for soils is similar to that described for groundwater in Section 2.4.3.2. The process of reduction involves mixing a reducing agent with the contaminated soils in a contactor to reduce chlorinated organics. The cost of both oxidation and reduction are likely to be prohibitive due to the large volume of materials involved; therefore, they are not retained for alternative development.

Dechlorination

Dechlorination is a process that involves the addition of an alkali metal and polyethylene glycol (PEG) reagent to remove chlorine atoms from chlorinated organic compounds. Dechlorination processes have been commercially developed primarily for the treatment of PCB's in electric transformer fluids. However, the process may be applicable to soils contaminated with PCB's, dioxins, pesticides, and other chlorinated hydrocarbons. Residues from the process include chloride salts, polymers, and occasionally heavy metals. The heavy metals may require treatment before disposal. A dechlorination process applicable to soils has yet to be developed. Dechlorination treatment is not

applicable to non-chlorinated VOCs and SVOCs also present in areas of PCB-containing soils. This process option has not been retained since there is presently no means of applying it to soils, and alternative technologies have been retained which have the capability of treating VOCs and SVOCs also present in PCB-containing soils at the Site.

Wet Air Oxidation

Wet air oxidation involves aqueous phase oxidation of dissolved or suspended organic substances at elevated temperatures and pressures. The temperature of the process is relatively low, 350-650°F, and the pressure varies between 300-3000 PSI. The waste is pumped into the system by the high pressure pump and mixed with air from the air compressor. The mixture passes through a heat exchanger, and then into the reactor where oxygen in the air reacts with organic matter in the waste. The oxidation is accompanied by a temperature rise. The gas and liquid phases are separated after the reactor, and the liquid passes through the heat exchanger, heating the incoming material. The gas and liquid streams are discharged from the system through control valves. The degree of oxidation is primarily a function of reaction temperature and residence time.

Wet air oxidation is used primarily to treat concentrated aqueous waste streams containing organic and oxidizable inorganic wastes. It is generally selected for treating or pretreating a waste stream which has a high COD/BOD ratio and is not readily amenable to biological treatment. It is also selected where it is determined to be more cost-effective than incineration of aqueous wastes. Waste streams for which wet air oxidation is particularly applicable include concentrated streams containing pesticides, herbicides or other complex organics which are not readily biodegradable. This technology has not been retained for alternatives development since it is only applicable to aqueous waste streams, and not to solid, sludge or slurry-phase waste matrixes represented by the buried waste and soils.

2.5.2.5 Land Disposal. Disposal of excavated soils can be implemented off-Site in an existing RCRA-permitted landfill. Off-Site disposal involves excavation of soils contaminated in excess of the target criteria and transportation to an approved RCRA-permitted hazardous waste disposal facility. Since the wastes contained in the buried drums are not expected to meet the RCRA land disposal requirements, this technology will not be retained for alternative development for wastes. It will be retained for soil and for the disposal of potential residues (e.g., incinerator ash).

On-Site disposal of excavated soils necessitates the construction of a secure hazardous waste landfill at the Site. Elements of such a Site must meet the applicable RCRA requirements and regulations (40 CFR 264.300 - 264.317), as well as State requirements, unless a variance is allowed. Because of the reasons described above, on-Site disposal will not be retained for the removal of wastes, but will be retained for the disposal of soils and potential treatment residues.

2.5.3 In-Situ Waste and Soil Treatment

A variety of process options exist for treating the contaminated soils in-situ. They can be classified as biological, chemical and physical.

2.5.3.1 Biological In-Situ Treatment. Biological degradation of the primary contaminants (e.g. BETX compounds, PCBs, chlorinated solvents) can occur either aerobically or anaerobically. Section 2.4.3.1 discusses the principles of aerobic and anaerobic degradation. In-situ biological treatment of soils is often done in conjunction with in-situ vapor extraction or biological treatment of groundwater. The activity of organisms responsible for contaminant destruction is controlled by several factors, notably nutrients, water and electron receptor availability, temperature and pH. In addition, activities can be inhibited by the presence of toxic organic compounds, metals or high salt contents. During the microbial growth process, available nutrients, such as nitrogen and phosphorus, must be maintained to ensure that only the contaminant is the limiting nutrient. Control of the physical environment may be utilized to enhance organism growth by maintaining adequate moisture and optimum pH and temperature. The higher the temperature (within organism limits) the faster the degradation. Biological treatment does not degrade metals.

In-situ treatment typically involves the biodegradation of contaminants which are adsorbed onto soils within a saturated zone. The process involves the addition of small amounts of nutrients and, for aerobic processes, large quantities of an oxygen source. This is accomplished by injecting nutrient-enriched solutions into the contaminated zone through a series of wells or trenches, and recovering groundwater downgradient. In order for the process to be effective, the injection/recovery system must provide for the transport of nutrients through the contaminated region. This is particularly difficult where the geology is highly irregular.

The engineering parameters associated with this process are highly dependent on soil permeability, which becomes the rate-limiting step for mass transfer of oxygen to the organisms. In-situ bioreclamation has been used in some instances for treatment in unsaturated soils at shallow depths and above zones of contaminated water. These treatment systems are difficult to control, and rely on introducing nutrient-rich water to the soil through percolation or pressure injection. Air is then drawn through the soil to enhance the air exchange in the soil matrix.

Because of the high permeability of soils present at the ACS Site, both anaerobic and aerobic technologies will be retained for both soil and waste.

Bioharvesting. Bioharvesting involves the use of plants to accumulate contaminants in the tissues. Plant roots absorb contaminants present in the soil. The plants are then harvested for disposal. This treatment alternative has not been retained for either soils or buried wastes because of the depths and levels of contaminants present at the Site.

2.5.3.2 Chemical In-Situ Treatment. Available chemical treatment methods for in-situ treatment of chlorinated VOCs and semi-volatiles in unsaturated soils are limited. Chemical treatment methods include oxidation, reduction and photolysis. These technologies are described in Section 2.4.3.2. As discussed, chemical doses and overall reaction rates must be determined experimentally because of competing reactions. This can be difficult even under controlled conditions. It would be much more difficult, if not

impossible, to monitor and adjust the system if the process were conducted in-situ. Therefore, due to the implementability limitations and uncertainties regarding effectiveness of applying these technologies in-situ, they have not been retained for future consideration for either soils or buried wastes.

2.5.3.3 Physical In-Situ Treatment. Physical in-situ treatment methods include vapor extraction, vitrification, injection grouting, solvent extraction, soil flushing, fixation and radio frequency. The technologies available for in-situ treatment are generally the same for removal and treatment described in Section 2.5.2.3.

Steam Stripping. Section 2.4.5.2 discusses the principles of steam stripping. In-situ steam stripping has been retained for future considerations for remediating soil because of its potential to simultaneously treat VOCs present in the buried waste, soil and groundwater.

Vapor Extraction

Vapor extraction at ambient temperatures would address the VOC, and possibly SVOC, contamination at the Site. A vacuum is applied at some collection point or series of collection points, which may be either wells or perforated pipe laid in trenches. Steam may also be injected in order to elevate soil temperatures and increase removal efficiencies. Soil gases and contaminant vapors migrate toward the collection points. The gases may require treatment prior to discharge. This is typically accomplished using an adsorbent bed, a catalytic combustion device or a fume incinerator. With well-placed extraction wells and/or trenches and by controlling pressure within the unsaturated zone, contaminant vaporization can be controlled to effect contaminant removal from extensive areas and from under structures. Excessive moisture levels due to the shallow groundwater conditions at the Site may inhibit vapor extraction unless the affected areas are dewatered first. Vapor extraction would not treat metals, PCBs, and some SVOCs. However, although the vapor extraction technology may not treat all of the SVOCs, recent studies have shown that the process can enhance biological activity in the soil which may help to reduce the remaining SVOCs. This technology is retained for use in developing alternatives for soil and waste based on implementability and effectiveness considerations.

Vitrification

In-situ vitrification is accomplished by installing electrodes in boreholes around an area, applying a high voltage and heating the soil/waste mass as a result of the electrical resistance of the mass. Soils are melted at the high temperatures developed. A hood is erected over the area to be vitrified to collect off-gases, which are then treated. Vitrification results in organic contaminant destruction and melting of the heated mass, which then cools to a glassy solid, immobilizing residual contaminants. This technology is best applied where very high temperatures are required for contaminant destruction, and where the glassy solid product is beneficial in immobilizing inorganic contaminants that are not destroyed during processing. It is applicable to a depth of approximately 30 feet. The shallow groundwater conditions at the Site will drastically increase the energy requirements if affected areas are not dewatered first. The process is relatively expensive and energy intensive. This technology will be retained because of its ability to address all of the contaminants at the Site.

Injection Grouting. This technology involves the injection of grout into the ground through well points in order to stabilize contaminated material. Injection grouting may be effective if the Site soils are homogeneous, the types of contaminants and distribution of contaminants are relatively consistent throughout the soil and the depths of contamination are known. If this were the case, it may be possible to develop an effective leach and pilot scale test. However, at the ACS Site, the concentration of contaminants range from low part per billion to several percent within a relatively small area. In addition, the vertical distribution of contaminants varies significantly. Therefore, it would be difficult, if not impossible, to develop a pilot scale test that would model the potential behavior of the remainder of the Site. This technology has not been retained for future considerations.

Solvent Extraction. Section 2.5.2.3 discusses the principles of solvent extraction. The ability to uniformly distribute and collect solvents in-situ has yet to be demonstrated. Effective solvent extraction requires agitation and other mechanical means in order to

provide sufficient contact time between the solvent and contaminant. These conditions would not exist for an in-situ application which would result in ineffective removal. Most extraction solvents are toxic, themselves, which could result in further impact to groundwater if an adequate collection and separation system can not be developed. Due to the implementability limitations and uncertainties regarding effectiveness of applying this technology in-situ, it has not been retained for future consideration for either soils or buried wastes.

Soil Washing

In-situ soil flushing involves the flooding of contaminated soils in the vadose zone with an aqueous-based solution. The resulting leachate is then collected for above-ground treatment using either a series of extraction wells, shallow wellpoints or subsurface drains. Soil washing is most effective in removing contaminants which are readily soluble in water and are not strongly adsorbed onto soils. Surfactants are typically used in the removal of less soluble, hydrophobic organic compounds. Since surfactants are often toxic and cannot be separated from the recovered groundwater matrix, they must also be treated in the groundwater treatment system. The use of surfactants in the extraction of hydrophobic organic contaminants is chemical specific and effective only for simple contaminant matrices (U.S. EPA, September 1988).

Results of a pilot study demonstration of in-situ soil washing using various surfactants performed jointly by the U.S. EPA and the Air Force at the Volk Field fire training pit did not show any appreciable decrease in organic contaminant concentrations in soils following seven days of continuous flushing (Kostecki and Calabrese). The contaminants of concern involved various chlorinated and aromatic VOCs. It was concluded that in-situ soil flushing would be ineffective for contaminants with a high affinity for soil adsorption.

This process option has not been retained as a primary method of treatment for alternatives development for both soils and buried waste because of the complex organic contaminant matrix present in the soils and buried waste, as well as the hydrophobic nature and high soil adsorption affinity of most of the detected VOCs and SVOCs.

Because of the high organic concentrations, aqueous-based solutions would not be effective in extracting organics which would likely remain preferentially dissolved in the oil phase. Since treated groundwater may be reinjected on-Site, in-situ soil flushing could be used in conjunction with a primary treatment method to further enhance the removal of contaminants from the vadose zone.

Fixation

Fixation methods are designed to immobilize contaminants and thereby prevent leaching of the contaminants. Special auger technologies are used to mix materials such as sulfides, lime fly ash and numerous other materials into soil in-situ. Once the mixture hardens, contaminants become fixated within the structure and leaching is reduced or eliminated. These methods have particular application to metals contaminated soils. However, their ability to immobilize organic compounds and PCBs have yet to be adequately proven. The shallow water table condition present at the Site may also inhibit in-situ fixation. This alternative has been retained because of its potential to be used in conjunction with an in-situ treatment technology for VOCs and SVOCs in areas which have been impacted by PCBs and metals. High levels of organic content typically inhibit the binding and setup reactions involved in current fixation technologies. Because of its inability to immobilize high concentrations of VOCs, and the inhibition of the fixation process by high levels of organic content, it has not been retained for alternative development as a waste or primary soil treatment alternative.

Radio Frequency

The in-situ radio frequency process uses electromagnetic energy in the range of 2 to 45 megahertz to heat soil. VOCs and SVOCs are volatilized and migrate to the soil surface. A vapor containment cover is placed over the treatment zone to capture the released VOCs and SVOCs. The collected vapors are treated by thermal treatment or carbon adsorption. The process has been used successfully to heat the sands at depths of more than 1000 feet to enhance oil recovery. However, it has not been tested on contaminants present at the Site at a laboratory of field scale. Radio frequency would not treat metals, and may not treat PCBs. This treatment technology has been retained for soil because of its potential ability to treat most of the primary contaminants. It will

not be retained for waste because of the exorbitant energy requirements that would be associated with volatilizing areas of concentrated wastes. A health and safety risk would be posed by the uncontrolled emission of large quantities of VOCs by the process which could either escape the capture system or create a potentially explosive gas stream.

2.5.4 Waste and Soil Containment

Containment technologies consist of two general response actions: capping and surface stabilization. They are discussed below.

2.5.4.1 Capping

Capping is a process used to cover buried waste materials to prevent their release to either the air or groundwater. The designs of caps usually conform to the performance standards in 40 CFR 264.310, which addresses RCRA landfill closure requirements. These standards include minimum liquid migration through the wastes, low cover maintenance requirements, sufficient Site drainage, high resistance to damage by settling or subsidence, and a permeability lower than or equal to the underlying liner system or natural soils.

There are a variety of cap designs and capping materials available. Most cap designs are multi-layered to conform with the above-mentioned design standards; however, single-layered designs are also used for special purposes. The design of multi-layered caps generally conforms to EPA's guidance under RCRA, which recommends a three-layered system consisting of an upper vegetative layer, underlain by a drainage layer over a low permeability layer. The vegetative layer consists of topsoil; the drainage layer is composed of sand; and the low permeability layer is formed by a combined synthetic and soil liner system. The cap functions by diverting infiltration liquids from the vegetative layer through the drainage layer and away from the underlying waste materials. The cap design and selection of capping materials is influenced by specific factors such as local availability and costs of cover materials, desired functions of cover materials, the nature of the wastes being covered, local climate and hydrogeology, and projected future use of the Site.

The main disadvantages of capping are the need for long-term maintenance and uncertain design life. Caps will need to be periodically inspected for settlement, ponding of liquids, erosion, and naturally occurring invasion by deep-rooted vegetation. In addition, the groundwater monitoring wells, often associated with caps, need to be periodically sampled and maintained. However, these long-term maintenance requirements usually are considerably more economical than excavation and removal of the wastes.

The design life of a cap is uncertain because of the uncertain life of synthetic liner materials (if one is used in the cap), the uncertain amounts of annual rainfall which will infiltrate the cap, and the uncertain rate of waste migration which would result from any infiltrating rainwater. This uncertainty may necessitate the strategic placement of monitoring wells at a Site to detect any waste migration, thus signaling the need to replace the cap. Caps generally have a minimum design life of 20 years. Capping of the entire Site will not be retained for analysis. Capping of some areas such as areas of waste will be retained for alternative development for both waste and soil.

Rigid covers such as concrete and asphalt are vulnerable to cracking because of settlement of wastes and chemical deterioration. Concrete covers may have a design life of about 50 years, except when applied to chemically severe or physically unstable environments. The area to be covered at the Site is large, thus increasing the probability of cracking and breaking of rigid covers. Therefore, rigid covers will not be retained as a method of containment for alternative development. Asphalt and concrete covers will be retained as a method of preventing dermal contact.

A soil cover provides basic prevention from contacts with surface soils and groundwater. It also prevents migration of contaminants to the extent that migration is via erosion. It is less effective in reducing migration of contaminants to the water table, because it only provides minimal reduction of surface water infiltration. It is most effective in situations where contaminants are not migrating to the water table. Since continuing migration of contaminants to groundwater is a concern, it will not be retained for alternative

development. It will be retained as a part of some alternatives where preventing direct contact with contaminated materials is desired, but natural flushing through rainfall infiltration will be used to reduce contaminant levels in soil and waste.

2.5.4.2 Surface Stabilization. Surface stabilization technologies considered for the Site include grading, revegetation, and dust control. Grading is the general term for techniques used to reshape the surface of the land in order to manage surface water infiltration and run-off while controlling erosion. The spreading and compaction steps used in grading are techniques practiced routinely at sanitary landfills. The equipment and methods used in grading are essentially the same for all surfaces, but applications of grading technology will vary by Site. Grading is often performed in conjunction with surface sealing practices and revegetation as part of an integrated landfill closure plan. Regrading is a relatively inexpensive remedial action component when suitable cover materials are available on-Site or close to the disposal Site. Periodic regrading and future Site maintenance may be necessary to eliminate depressions formed through differential settlement and compaction, or to repair slopes that have slumped or become badly eroded.

The establishment of a vegetative cover is a cost-effective method to stabilize the surface of hazardous waste disposal sites, especially when preceded by capping and grading. Revegetation decreases erosion by wind and water and contributes to the development of a naturally fertile and stable surface environment. Also, the technique can be used to upgrade the appearance of disposal sites that are being considered for various re-use options. Short-term vegetative stabilization (i.e., on a semi-annual or seasonal basis) can also be used as a remedial technique for disposal sites.

Commonly used measures for controlling fugitive dusts from inactive waste piles and active cleanup sites include use of chemical dust suppressants, wind screens, water spraying and other dust control measures commonly used during construction. Dust suppressants include a wide range of natural and synthetic waste materials which strengthen bonds between soil particles and hold this strengthened condition for an appreciable period of time.

Use of dust suppressant provides an effective means for temporary control of fugitive dust emissions, but must be periodically reapplied to provide long-term fugitive dust control.

Wind fences offer a low cost method of reducing fugitive dust emissions. A wind fence is a porous screen which takes up or deflects a sufficient amount of wind so that the wind velocity is lowered below the threshold required for initiation of soil movement. Wind screens are typically 4 to 10 feet high and are composed of polyester or other high strength material. The fences can be easily transported and set-up for application in various work areas. However, they are, at best, only partially effective in controlling inhalable particulates.

The most commonly used method for control of dust emissions is to spray water on the exposed surface areas. This method is mainly used to reduce fugitive dusts along active travel paths, excavation areas, and from truck boxes loaded with soils. Active travel areas dry quickly and water must be reapplied frequently (about every 2 hours) to maintain effectiveness. Water is applied to the unpaved road surface with a water wagon or spray bar. The quantity will vary with the road surface material, sunlight, humidity, and traffic level.

The above surface stabilization technologies are considered short-term solutions which do not provide future reductions of contaminant migration. Therefore, these technologies will not be considered as stand-alone alternatives. They may be used in conjunction with other technologies during alternative development.

2.6 Process Options Passing Technology Screening

Table 2-1 lists the process options which were retained for consideration in developing alternatives based on the Site and contaminant characteristics and remedial action objectives. Figure 2-1 presents a description and applicability discussion for both the process options which were retained and those which were rejected.

2.7 Alternatives to be Screened

To maintain the necessary flexibility throughout the alternatives screening process, alternatives were developed based on general response actions, as opposed to remedial technologies and process options. Individual process options will be evaluated for each identified media of concern during the alternatives screening stage of the FS process. One to two remedial technologies and/or process options will be selected for each identified media of concern following the completion of the alternatives screening stage. The selected remedial technologies and/or process options will be carried over into the detailed alternatives stage along with their respective alternatives. A list of the alternatives to be screened is presented in Table 2-2.

Since identified remedial technologies and process options are not necessarily applicable to all of the media and potential contaminants of concern, it is necessary to identify media of concern and evaluate the applicability of each alternative to each media separately. Structuring the analysis in this manner will allow for maximum flexibility in selecting the best remedial action technologies to address the media and contaminants of concern at the Site. VOCs and SVOCs were detected uniformly across all of the areas sampled. PCBs and metals, however, were detected in discrete areas and were not uniformly present across the entire Site. Because of the contaminant distribution and presence of buried waste, the following media of concern were established in order to evaluate process options in the matrix of alternatives:

- groundwater;
- buried wastes as defined in Section 2.5;
- soils and sediments requiring the remediation of VOCs and SVOCs;
- soils and sediments requiring the remediation of VOCs, SVOCs and PCBs; and
- soils and sediments requiring the remediation of VOCs, SVOCs, PCBs and metals;

Table 2-3 presents a matrix of alternatives versus media of concern. It also presents the specific process options associated with each alternative that would be applicable to a given media of concern.

SECTION 3.0
DEVELOPMENT AND SCREENING OF ALTERNATIVES

3.1 Development of Alternatives

3.1.1 Introduction

Alternatives based on general response actions were presented in Section 2.7. Individual process options which are applicable to each general response action alternative will be evaluated for each identified media of concern as part of the preliminary screening process in this chapter. A representative number of process options will be retained and combined into more specific alternatives for detailed evaluation in Section 4.0. The final alternatives to be evaluated in Section 4.0 will be identified at the end of this section. A preliminary screening of the general response action alternatives based on the evaluation of individual process options is presented at the end of this section. A general response action alternative presented in Section 2.0 will be eliminated from further analysis in Section 4.0 if all of the corresponding process options applicable to that alternative are eliminated during the preliminary screening process in this section.

The selection of process options to be retained in the final alternatives will allow for necessary flexibility to meet acceptable health-based risk levels and chemical-specific cleanup objectives. Modifications to the process options retained in the final alternatives may be necessary. Modifications to the final alternative would likely involve the elimination or addition of secondary process options which are part of an overall "treatment train" designed to treat contaminants either not amenable to treatment by the primary process option, or where contaminants are in a great enough concentrations that the efficiency of the primary system cannot treat or remove the contamination to the required performance standard.

To maintain the necessary flexibility throughout the alternative screening process, three to four groundwater pumping and treatment process options will be selected for detailed evaluation at the beginning of Section 4.0. These groundwater pumping and treatment options will be evaluated prior to the detailed analysis of the final alternatives. This approach is feasible since the evaluation of groundwater pumping and treatment process options is, for the most part, independent of the evaluation of source treatment (i.e., buried waste and soil) process options.

3.1.2 Screening of Alternatives

The purpose of the preliminary screening is to reduce the number of process options that will be combined into the final alternatives for detailed analysis. Defined alternatives are evaluated against the short- and long-term aspects of three broad criteria: effectiveness, implementability and cost. The references used in Section 3.0 to evaluate process options and develop preliminary cost estimates are presented in the bibliography in Appendix D.

The preliminary screening of process options which are independent of the general response action alternatives (e.g., institutional measures, slurry wall) is presented in Section 3.3. The analysis of independent process options is presented separate from the process options which will comprise the final alternatives. Independent process options which will be retained for detailed analysis will be designated in this chapter. The on- and off-Site landfilling, above-ground fixation, coagulation/flocculation, reduction and screening/filtration process options will not be discussed separately in Sections 3.0 or 4.0. These process options were retained in Section 2.0 because of their potential applications as pretreatment or residual treatment alternatives.

Aspects of effectiveness considered include the ability of the alternative to protect human health and the environment, the reduction of the toxicity, mobility, or volume of the contaminants present at the Site, and the reliability of the alternative. Protectiveness was assessed by considering pathways addressed, determining whether ARARs would be attained, considering the time until protection is achieved, and considering long-term management needs.

The implementability of each alternative was assessed by considering the overall technical and administrative feasibility of constructing, operating and maintaining the remedial action alternative. The availability of the technologies which comprise the alternative was also evaluated by considering commercial availability, use at other sites, near-commercial availability for promising but unproven technologies or the existence of permitted facilities in or near the region.

Cost was considered when comparing alternatives providing similar protection. Readily available unit costs were used for comparison purposes where appropriate. Both capital and annual operation and maintenance costs were considered. A qualitative assessment of cost was made when comparing variations of similar technologies (e.g. slurry walls). The cost comparisons presented in this chapter are preliminary estimates and do not include costs which are common to all of the alternatives and/or process options.

The following assumptions were made in the development of the preliminary cost estimates:

- controls will be required to collect air emissions from air stripping, vapor extraction, vitrification and in-situ steam stripping operations; and
- groundwater extraction and treatment systems will have to achieve potential ARARS prior to discharge under a NPDES permit.

Due to the relatively large number of waste constituents detected, compounds were grouped together, where applicable, to assist in the preliminary screening process. Organic compounds have been grouped together based on similar chemical characteristics. One or two target compounds have been designated from each chemical grouping as being representative of that group for purposes of determining treatability potential. The selected target compounds represent primary contaminants detected at the Site based on either total concentrations found in soils or groundwater or contribution to overall health risk based on the Baseline Risk Assessment (BRA). More than one target compound was selected from a respective chemical group if significant differences in physical properties used to evaluate treatability (e.g., vapor pressure, solubility, Henry's Law constant, etc.) were evident. Table 3-1 presents physical parameters for the target compounds relevant to the preliminary screening process. The specific chemical groupings and designated target compounds are discussed below.

- <u>BETX Compounds</u> - BETX is an acronym representing the compounds benzene, ethyl benzene, toluene and xylene. BETX compounds are typically used as solvents and are derived from oil and/or hydrocarbon products. Benzene and toluene have been designated as being representative of this group for use in evaluating treatability potential.

- Chlorinated Methanes - The chlorinated methanes detected at the ACS Site include chloromethane, methylene chloride, chloroform and carbon tetrachloride. These compounds are used as solvents and degreasing agents. Chloroform has been designated as being representative of this group for use in evaluating treatability potential.

- Chlorinated Ethanes - Chlorinated ethanes detected at the ACS Site include 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane, 1,1,1-trichloroethane, 1,1- and 1,2-dichloroethane and chloroethane. These compounds are used as solvents and degreasing agents and may also represent an anaerobic biodegradation sequence. Chloroethane and 1,1,1-trichloroethane have been designated as being representative of this group for use in evaluating treatability potential.

- Chlorinated Ethenes - Chlorinated ethenes detected at the ACS Site include trichloroethene, tetrachloroethene, cis- and trans-dichloroethene and vinyl chloride. Trichloroethene and tetrachloroethene are used as solvents and degreasing agents, while dichloroethene and vinyl chloride usually represent anaerobic biodegradation products of other chlorinated compounds. Vinyl chloride is also used as a monomer in the manufacture of plastics. Tetrachloroethene and vinyl chloride have been designated as being representative of this group for use in evaluating treatability potential.

- Ketones - Ketones detected at the ACS Site include acetone, methyl ethyl ketone, methyl isobutyl ketone and isophorone. These compounds are used as solvents and as intermediates in the production of other organic chemicals. Methyl ethyl ketone and isophorone have been designated as being representative of this group for use in evaluating treatability potential.

- Chlorinated Propanes - Chlorinated propanes detected at the ACS Site include 1,2-dichloropropane. Since 1,2-dichloropropane was not a predominant contaminant detected at the ACS Site, it has not been included in the target compound list.

- Chlorinated Benzenes - Chlorinated benzenes detected at the ACS Site include chlorobenzene and 1,2- and 1,4-dichlorobenzene. These compounds are used as raw materials in the manufacture of fumigants, pesticides and dyes. 1,2-dichlorobenzene has been designated as being representative of this group for use in evaluating treatability potential.

- Phthalates - Phthalates detected at the ACS Site include diethylphthalate, dibutyl phthalate, butylbenzylphthalate, bis (2-ethylhexyl) phthalate, dioctylphthalate and dimethylphthalate. Phthalates are used as plasticizing agents, and also may be naturally occurring. Dibutylphthalate and bis (2-ethylhexyl) phthalate have been designated as being representative of this group for use in evaluating treatability potential.

- Polynuclear Aromatic Hydrocarbons (PNAs) - PNAs detected at the ACS Site include naphthalene, 2-methylnaphthalene, acenophthene, phenanthrene, fluorene, anthracene, fluoranthene, pyrene, benzo (a) pyrene, ideno (1,2,3-cd) pyrene, dibenzo (a,h) anthracene and benzo (g,h,i) perylene. PNA compounds are derived from coal tars, oils and other petroleum products. Naphthalene and 2-methylnaphthalene were the only PNAs that were predominant among the contaminants detected at the ACS Site. Naphthalene has been designated as being representative of this group for use in evaluating treatability potential.

- Phenols - Phenols detected at the ACS Site include phenol, 2- and 4-methylphenol, 2,4-dimethylphenol and pentachlorophenol. These compounds are used as raw materials and intermediates in the production of various organic chemicals and compounds. 4-methylphenol has been designated as being representative of this group for use in evaluating treatability potential.

- Miscellaneous Organic Compounds - Miscellaneous organic compounds detected at the ACS Site which have not been placed in one of the above chemical groups include benzoic acid, bis (2-chloroethyl) ether, bis (2-chloroisopropyl) ether, dibenzofuran and hexachlorobenzene. Benzoic acid and bis (2-chloroethyl) ether are the only predominant compounds from this group detected at the ACS Site and have been designated as target compounds for use in evaluating treatability potential.

- PCBs - PCBs are high molecular weight variably chlorinated biphenyls which were present in dielectric fluids formerly used in electrical equipment (e.g., capacitors, transformers) and hydraulic oils. Treatability potential for PCBs will be evaluated as a group as opposed to individually (e.g., Arochlor 1248).

- Tentatively Identified Compounds (TICs) - It is assumed that all of the TICs detected at the ACS Site will be represented by one of the chemical groups already designated. TICs will not be included in the evaluation of treatability potential.

- Inorganic Metals - Inorganic metals detected at the ACS Site include, aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, thallium, vanadium, zinc and total cyanides. Inorganic metals may be present in raw materials used in the waste streams disposed of at the ACS Site (e.g., pigments present in paint and ink sludges) or may be naturally occurring. Barium, arsenic, lead, iron and zinc have been designated as being representative of this group for use in evaluating treatability potential.

3.2 Applicable or Relevant and Appropriate Requirements

3.2.1 ARARs Overview

The 1985 NCP revisions required selected remedies to attain or exceed applicable or relevant and appropriate Federal public health and environmental requirements (ARARs). In addition, the 1985 NCP required consideration of other pertinent Federal criteria, advisories and guidance, as well as State standards. In 1986, the Superfund Amendments and Reauthorization Act (SARA) Section 121(d) codified and expanded the ARARs concept. Under Section 121(d)(2)(A) of SARA, remedial actions must attain a level or standard of control which attains any standard, requirement, criteria or limitation under any Federal environmental law, including but not limited to, the Resource Conservation and Recovery Act, the Toxic Substances Control Act, the Safe Drinking Water Act, the Clean Air Act, the Marine Protection, Research and Sanctuaries Act, and the Solid Waste Disposal Act, which are determined to be legally applicable or relevant and appropriate.

SARA also requires remedial actions to achieve a level or standard of control which attains any promulgated standard, requirement, criteria, or limitation under a State environmental or facility siting law that is more stringent than any Federal standard, requirement, criteria, or limitation and is legally applicable or relevant and appropriate.

SARA Part 121(d)(4) of SARA provides for waivers of ARARs under six (6) different types of circumstances. These include:

- where the remedial action is an interim measure and where the final remedy will attain the ARAR upon completion;
- where compliance will result in greater risk to human health and the environment than other options;
- where compliance is technically impractical;
- where an alternative remedial action will attain the equivalent of the ARAR;
- for State requirements, where the State has not consistently applied the State requirement in similar circumstances; and

- for Section 104 remedial actions, where compliance with the ARAR will not provide a balance between protecting public health, welfare, and the environment at the Site with the availability of Superfund money for response at other sites (fund-balancing).

SARA Part 121(e) states that no Federal, State, or local permit shall be required for the portion of any remedial action conducted entirely on-Site. On-Site is defined to include the areal extent of contamination and all suitable areas in proximity to the contamination necessary for implementation of the response action. This exemption only applies to the administrative requirements of the permit. On-Site actions must still comply with the substantive requirements that permits enforce.

Substantive requirements pertain directly to actions or conditions in the environment. Health- or risk-based restrictions (e.g. MCLs), technology-based requirements (e.g., incinerator standards), and location restrictions (e.g. wetlands) are examples of substantive requirements. Administrative requirements are those mechanisms that facilitate the implementation of the substantive requirements of a statute or regulation. These include approval and issuance of permits, documentation, reporting, and recordkeeping.

3.2.2 Definition of ARARs and TBCs

The NCP identifies two categories of remedial action requirements:

- ARARs; and
- Other criteria, advisories, guidance and proposed standards To-Be- Considered (TBCs)

An ARAR can be either "applicable" or "relevant and appropriate" to a remedial action. Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations, promulgated under Federal or State law. These requirements specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a Site. Relevant and appropriate requirements are those clean-up standards, standards of control or other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law which are not applicable to

circumstances at a Site, but do address problems or situations sufficiently similar to those encountered at the Site. TBCs are other Federal and State criteria, advisories, guidance, and proposed standards that are not legally binding, but may provide useful information or recommended procedures. For example, TBCs may be used to set clean-up levels where no ARARs exist for a particular situation, or existing ARARs do not ensure protectiveness. TBCs generally fall within four (4) categories:

- health effects information;
- technical information;
- policy; and
- proposed rules and regulations.

3.2.3 Identification of Potential ARARs

The potential ARARs for the ACS Site are listed in Tables 3-2, 3-3 and 3-4 and are divided into three (3) categories, as defined in the NCP:

- Chemical-specific requirements;
- Location-specific requirements; and
- Action-specific requirements.

Chemical-specific ARARs are usually health- or risk-based requirements often expressed as numerical values, which when applied to Site-specific conditions establish the acceptable amount of a chemical that may be found in, or discharged to, the ambient environment. Currently, there are only a limited number of chemical-specific requirements. Location-specific ARARs are requirements which place restrictions either on the concentration of hazardous substances or the conduct of activities solely because they are in specific locations (i.e., wetlands, floodplains, historic places, etc.). Action-specific ARARs are usually technology- or activity-based requirements which are triggered by the particular remedial activities that are selected to accomplish a remedy (i.e., capping, incineration, air stripping, etc.).

3.3 Evaluation of Independent Process Options

3.3.1 Groundwater and Surface Water Institutional Measures

Description. Deed restrictions for property development and new well development on and adjacent to the Site would be implemented during remedial action. Deed restrictions would be appropriate for every alternative except no action.

Wells on and adjacent to the Site which could potentially be impacted by contaminated groundwater may need to be properly abandoned to minimize potential exposure pathways. Further monitoring of the impacts of Site contamination at adjacent wells would be required to determine which wells, if any, would require closure. Replacement of abandoned wells as necessary to prevent contact with contaminated water is assumed to be part of well closure. Well closure would be utilized as a part of every alternative except no action.

Monitoring will be necessary to assess remediation effectiveness and to maintain an understanding of contaminant distributions in relation to water supply wells. Future groundwater monitoring will include use of existing wells and piezometers and any additional monitoring wells as warranted. Monitoring will be used as a part of every remedial alternative including no action. Monitoring includes collecting samples for analysis in a laboratory and water level measurements.

Effectiveness. Deed restrictions and well closures reduce the risk of dermal contact and ingestion through drinking or bathing with contaminated groundwater. Deed restrictions also reduce the risk of dermal contact and incidental ingestion with potentially contaminated surface water and soil. Monitoring alone does not provide protection of human health and the environment. Long term monitoring would help to maintain an understanding of contaminant distributions on and adjacent to the Site.

Implementability. Implementing deed restrictions and well closures is dependant upon the willingness and authority of the U.S. EPA/State/City to impose such restrictions. Monitoring is easily implementable both technically and administratively, and will be necessary to assess remediation effectiveness.

Cost. The cost of implementing deed restrictions, if any, would be limited to minimal administrative charges by the authority imposing restrictions. Well closure costs include the cost of grouting the contaminated well, and costs associated with installing replacement wells, if required. The cost of replacement wells is dependant upon the depth and location required. Monitoring costs include collecting samples, taking water level measurements, laboratory analyses costs, and validation and review of data.

Screening Status. Deed restrictions will be utilized during remedial action because of their effectiveness in preventing dermal contact and ingestion with contaminated groundwater and surface water. Well closure will be retained as a potential remedy for contaminated wells on, and adjacent to, the Site. Monitoring will be retained to assess remediation effectiveness and maintain an understanding of future contaminant distributions on, and adjacent to, the Site.

3.3.2 Groundwater Vertical Barriers

Description. Soil-bentonite and cement-bentonite slurry walls are under consideration for the Site. Soil-bentonite slurry wall trenches are excavated under a slurry of bentonite and water, and the trench is backfilled with soil materials mixed with a slurry of bentonite and water. Cement-bentonite slurry wall trenches are excavated under a slurry of Portland cement, bentonite, and water. The cement-bentonite mixture is left in the trench to harden.

For the ACS Site, slurry walls would be keyed into the clay confining layer with an average depth of approximately 25 ft. The proposed slurry wall approaches are shown on Figure 3-2 and discussed in the effectiveness, implementability, and cost subsections of this section. Slurry walls could be used to impede groundwater flow into the Site to reduce the volumes of water to be pumped and the time required for pumping in dewatering efforts, and to allow dewatering of the contaminated source areas without lowering the water level in the wetland areas west of the Site.

Effectiveness. Slurry walls are the most common subsurface barriers because they are a relatively inexpensive means of vastly reducing groundwater flow in unconsolidated earth materials. The trench is excavated under a slurry which shores the trench to prevent collapse, and forms a filter cake on the trench walls to prevent high fluid losses into the surrounding ground. The filter cake also may provide additional reduction in permeability of the wall. Slurry walls are effective for Site dewatering and groundwater containment.

For the Site alternatives utilizing groundwater dewatering, a slurry wall could aid in dewatering efforts by reducing the volume of water entering the contaminated zone. The slurry wall could also help to prevent dewatering the wetlands while the groundwater pumping system is in operation. Preliminary groundwater modeling indicates that about 10 ft vertical drawdown of the upper aquifer may be achievable without a slurry wall and without lowering the water table in the wetland areas (see Section 3.3.3 for more details pertaining to groundwater modeling at the ACS Site).

The permeability of a soil-bentonite slurry wall is typically around 10^{-7} to 10^{-8} centimeters per second (cm/sec), and is capable of achieving 10^{-9} cm/sec. The permeability of a cement-bentonite slurry wall is normally around 10^{-6} cm/sec. However, both types of slurry walls are subject to installation limitations, and higher permeabilities are sometimes found in the field. Permeabilities of 10^{-6} cm/sec, 4×10^{-6} cm/sec and 10^{-5} cm/sec were used for groundwater modeling. Cement-bentonite slurry walls are more susceptible to chemical attack than most soil-bentonite mixtures. However, both types of slurry walls should be able to withstand chemical attack for the types and levels of contamination found at the Site.

Implementability. Slurry walls are proven for containing contaminated groundwater and are therefore administratively feasible. Both types of slurry walls are technically feasible for the Site. Relatively flat topography at the Site is conducive to placement of soil-bentonite slurry walls which remain fluid after placement until the water content of the soil-bentonite backfill comes to equilibrium with the surrounding soil. Sandy soils at the Site would require bringing some clay materials to the Site for use in the soil-bentonite backfill. Cement-bentonite walls do not require backfill, and set up relatively quickly due to the Portland cement.

Based on potential implementability issues, as well as the preliminary results of the groundwater modeling performed for the Site, four slurry wall construction alternatives are being considered which would either reduce the flow rates necessary to dewater the Site and contain the upper aquifer groundwater plume, or serve as containment for the residual contaminants in the source areas following treatment:

- constructing a single slurry wall system around the entire perimeter of the contaminated areas to be treated (Figure 3-2a);

- constructing two separate slurry wall systems; one around the perimeter of the On-Site areas, and the second around the Off-Site areas. The existing railroad tracks that run along the southern border of the ACS Site would be the dividing line between the two slurry wall systems (Figure 3-2b);

- constructing three separate slurry wall systems, one around the perimeter of the On-Site Containment Area, a second around the Treatment Lagoon and Still Bottoms Areas, and the third around the Off-Site Containment and Kapica-Pazmey Areas (Figure 3-2c); and

- constructing a single slurry wall system dividing the Off-Site Containment Area from the Griffith Landfill (Figure 3-2d).

The slurry wall system would not be built into the wetland areas, and would be constructed adjacent to the landfill.

One slurry wall or two separate slurry walls could be utilized depending upon the feasibility of removing the railroad tracks between the on- and off-Site areas. One continuous slurry wall would be constructed around the entire area shown on Figure 3-2 as a probable slurry wall area if groundwater modeling shows that the slurry wall would significantly reduce the flow rates needed to dewater the entire area, and it is feasible to remove the railroad tracks. Replacing the railroad tracks would be possible by constructing a concrete cap where the slurry wall would cross the tracks. Two separate slurry walls surrounding the on- and off-Site areas shown on Figure 3-2 would be constructed if it is not feasible to remove the railroad tracks. Groundwater pumping rates should not be affected by the use of a two slurry wall or one continuous slurry wall system. ACS has indicated that it would need the railroad tracks for its continuing chemical manufacturing operations. The third slurry wall option would be used strictly to contain significant levels of residual contamination or buried waste in the source areas following treatment. It would not reduce the flow rates necessary to dewater the Site, nor contain the upper aquifer groundwater plume. Constructing a slurry wall between the Off-Site Containment Area and the Griffith Landfill would serve to hydraulically separate the two areas, and prevent the drawing of landfill leachate into the groundwater treatment system.

Cost. Total costs for slurry walls are determined by the depth and length of the wall, and by the materials of construction for the wall. The depth and ease of excavation play a large part in the cost of the wall. For the Site, the wall would be about 25 ft deep in relatively easy excavation conditions due to sandy soils with few boulders. Because the length of the two walled option is significantly greater than the length of the one wall option, it will be more cost effective to build one wall. It is assumed that the potential problems with removing and replacing the railroad tracks can be overcome. For cost estimating purposes, the single wall option will be carried forward for the containment alternative. Constructing a slurry wall around the source areas or between the Off-Site Containment Area and the Griffith Landfill are independent options for alternatives that do not involve containment. The selection of these slurry wall options would be made independent of cost. Cement-bentonite slurry walls average over 30 percent higher in cost than soil-bentonite walls due to the cost of Portland cement. However, a soil-bentonite slurry wall at the Site would require clay materials from off-Site for use in the backfill reducing the cost difference between the two types of slurry walls.

Screening Status. A soil-bentonite slurry wall system will be retained for detailed analysis in Section 4.0 because it offers the lowest permeability and the lowest installation cost of the types considered. Assessments relative to the feasibility of removing the railroad tracks and groundwater pumping are necessary to determine the best configuration of the wall at the Site.

3.3.3 Groundwater Extraction/Collection

Description. Extraction/collection of contaminated groundwater by extraction wells or pipe and media drains is under consideration for the Site. Extraction wells are used to pump groundwater collecting at individual points. Pipe and media drains consist of trenches backfilled with permeable material to allow accumulation of water in the trench. Perforated pipe laid in the trenches leading to a pump allows dewatering of the trench. Since the Fire Pond is actually a part of the upper aquifer system, it would also be dewatered by the extraction well system. Following dewatering, the Fire Pond would

then be backfilled with clean fill materials. A replacement water tank for fire fighting purposes would have to be provided. Extraction wells would be installed in the lower aquifer if a groundwater pump and treat system is required to treat contaminated groundwater from the lower aquifer.

Computer modeling of groundwater extraction at the Site was conducted to determine potential pumping rates and dewatering capabilities in the upper aquifer, as well as the effect of constructing a slurry wall system on pumping rates and dewatering capabilities. The sensitivity of pumping rates and dewatering capabilities on input parameters such as aquifer and slurry wall permeabilities was also evaluated during the groundwater process. Appendix A contains a discussion of the model implementation. Extracted groundwater would be manifolded together and transferred to an on-Site treatment system or off-Site for treatment at the POTW. Additional data would need to be collected during the design phase to determine the volumes of water that would need to be pumped to prevent migration of contaminants within the lower aquifer. If pumping of the lower aquifer is required, it may be that the size of the treatment system may have to be increased.

Effectiveness. Groundwater extraction effectively reduces the mobility of contaminants by eliminating the potential migration of Site contaminants. Treatment of source areas and contaminated groundwater further reduces mobility and also reduces toxicity of contaminants.

Implementability. Groundwater extraction/collection is a proven method for dewatering. Technically, groundwater extraction/collection appears to be feasible based upon the results of computer modeling presented in Appendix A. Modeling results indicate that a slurry wall around the Site reduces pumping rates and allows a greater lowering in the upper aquifer water level than without a slurry wall. Slight lowering of the wetlands may occur if a slurry wall is not used. For the modeling, permeabilities of 10^{-6} cm/sec, 4×10^{-6} cm/sec, and 10^{-5} cm/sec were used to represent the slurry wall permeability. Fifteen to twenty fully screened extraction well groupings would be necessary to extract groundwater.

The aquifer zone containing contaminants requiring remediation includes the ACS facility, the Off-Site Containment Area, the Kapica Area and areas downgradient of each of these areas (refer to Figure 3-1 for approximate locations of these areas). Groundwater modeling provided preliminary estimations of pumping rates and dewatering capabilities under various scenarios. With a slurry wall around these areas, and using the assumed permeabilities and operating parameters discussed in Appendix A, the initial total pumping rate would be approximately 175 gallons per minute. After one year, the saturated thickness of the aquifer would be reduced from 10 ft to about 4 ft, and the extraction rate would be reduced to approximately 20 gpm. Without a slurry wall, the initial total pumping rate would be approximately 200 gpm. After one year, the saturated thickness of the aquifer would be reduced from 10 feet to about 5 feet, and the extraction rate would be reduced to approximately 80 gpm.

Preliminary groundwater modeling was conducted to estimate the potential pumping rates from the lower aquifer. Initial estimates are that 100 gpm would be required to contain groundwater in the lower aquifer.

Cost. Pipe and media drains are considerably more expensive than extraction wells due to the need for excavation and backfill of a trench, as well as costs associated with the treatment of contaminated soils from the trench excavation.

Screening Status. Both extraction wells and pipe and media drains will be retained for detailed analysis due to their effectiveness and implementability.

3.3.4 Treated Water Discharge

3.3.4.1 Off-Site Discharge

Description. For this option, treated groundwater would be piped to the sanitary sewer for transmittal to the local POTW. Process wastewaters, such as backwash water from ion exchange operations or condensate from steam stripping operations, may also be discharged to the sanitary sewer system. The local POTW, Hammond Sanitary District, utilizes a conventional activated sludge treatment process. A 12-inch sewer line apparently runs by the Site with lateral connections from ACS process and domestic waste streams.

Effectiveness. Discharge to the POTW is effective in preventing potential on-Site impact of contaminants remaining after treatment of contaminated groundwater. Some additional treatment of contaminants remaining in the treated groundwater is likely at the POTW. Conventional activated sludge treatment has been shown to remove a variety of contaminants found at the Site, including BETX, chloroethanes, and phthalates. Refer to Section 3.4.3 for more details pertaining to typical municipal POTW effectiveness. According to the U.S. EPA, the Hammond Sanitary District has a history of problems associated with its pre- and post-treatment programs. This could impact the ability to have this accepted as an option.

Implementability. Preliminary correspondence with Mr. Jeffrey Massey, Pretreatment Coordinator for the Hammond Sanitary District, indicates that they would be willing to accept the discharge from a groundwater pump and treat system provided contaminant levels meet or exceed existing industrial waste discharge requirements. The Hammond POTW has sufficient capacity to accept the additional hydraulic loading. ACS is currently regulated under the Categorical Standards for Specialty Organic Chemicals, 40 CFR 414(H), and has been granted an Industrial Waste Discharge Permit by the City of Hammond with specific limitations for pH (5.0-11.5) phenols (0.5 mg/L), toluene (0.074 mg/L), and 1,2-dichloroethane (0.574 mg/L). Mr. Massey has indicated that a groundwater pump and treat system at the Site would be subject to the most stringent of criteria listed in the City of Hammond, Indiana Industrial Waste Ordinance No. 4996 and the U.S. EPA pretreatment standards. If sufficient hydraulic capacity is not available in ACS's existing main sanitary sewer lines, additional 12-inch piping runs would have to be installed to handle effluent from the groundwater treatment system.

Cost. Discharge to the POTW offers the lowest capital cost of available discharge options at the Site. Capital costs include piping and connection to the existing sanitary sewer, and potential permitting costs. Operation and maintenance costs are higher for discharge to the POTW than for the other alternatives due to charges for flow volume. Other operation and maintenance costs include monitoring.

Based on a preliminary correspondence with the Hammond Sanitary District, the following users fees would apply to discharge to the sanitary sewer system:

- $1,000 per year annual permitting fee;
- $1.20 per thousand gallons users fee. An annual users fee of approximately $126,000 would be required if a continuous flow rate of 200 gpm is assumed;
- $4.71 per 100 pounds of biological oxygen demand (BOD) over 220 mg/L. Effluent from an on-Site groundwater treatment system would not be expected to exceed this level; and
- $5.88 per 100 pounds of total suspended solids (TSS) over 260 mg/L. Effluent from an on-Site groundwater treatment system would not be expected to exceed this level.

Screening Status. Discharge to the POTW is retained for detailed analysis due to its effectiveness and apparent implementability feasibility.

3.3.4.2 On-Site Discharge

Description. Four potential on-Site discharge options appear feasible for the Site. All of the discharge options result in ultimate discharge of treated groundwater to Turkey Creek. The first option involves piping the treated groundwater to the drainage ditch north of the Site. The second option involves piping the treated groundwater directly to Turkey Creek or one of its Tributaries. The third option involves reinjection of treated groundwater in conjunction with in-situ biological treatment or as part of an aggressive pump and treat system to reduce the timeframe for operation of the groundwater system. The fourth involves discharge of treated groundwater to the wetlands west of the Site.

Effectiveness. The first two on-Site discharge options effectively convey the treated groundwater away from the contaminant source. The first option involves discharge to an intermittent ditch that flows through the wetland areas west of the Site and eventually discharges to Turkey Creek. This may be desirable to allow reinfiltration of treated groundwater into the wetland areas to minimize impact to the wetland areas. Some of

the available treatment alternatives (e.g., biological) work more efficiently if treated groundwater is allowed to reinfiltrate into the upper aquifer. The second alternative carries treated groundwater away from the wetland areas directly to a flowing body of water. If in-situ biological treatment of groundwater is performed or an aggressive approach to groundwater pump and treat is taken, treated groundwater would be reinjected into areas of aquifer contamination to enhance contaminant removal achievable by groundwater flushing. Reinjection of treated groundwater could enhance the flushing of adsorbed contaminants from either the vadose zone or upper aquifer, as well as serve as a means to minimize damage to Site wetlands due to direct surface discharge or dewatering.

Discharge of treated groundwater to the wetlands has several potential advantages. Discharge to the wetlands would prevent dewatering of the wetlands by pump and treat systems. Also, the discharge of treated water could be used to flush residual levels of contaminants from sediments in the wetlands and along the drainage ditches to Turkey Creek. Hydrophobic or pH dependent contaminants (e.g., Phthalates) may not be flushed from wetland and Turkey Creek sediments as a result of discharging treated groundwater. Discharge of treated water could also enhance biological activity in the wetlands to further reduce potential residual levels of contaminants. Discharge of treated groundwater to the wetlands could be potentially detrimental if the hydrologic balance is radically altered. This might result in many species of plants and animals being eliminated or stressed by introducing a current or increasing water volume. Discharge would therefore have to be carefully controlled to prevent impacting existing plants and animals. Groundwater extraction associated with the pump and treat system would not be expected to affect wetlands hydrology based on modeling results presented in Appendix A.

Implementability. Preliminary correspondence with IDEM indicates that the first two and fourth discharge options are implementable depending upon the circumstances and available options. An NPDES permit would be required for these options. NPDES permitting requirements are well established and administratively feasible. Applicable ARARs would have to be met in order to reinject treated groundwater.

Cost. The first and fourth options involve capital costs for piping to the discharge point and minimal operation and maintenance costs. Discharge to the northern drainage ditch would require less piping than discharge directly to Turkey Creek because the location of discharge is in much closer proximity to any potential location of a treatment system. Operation and maintenance costs would be limited to monitoring for compliance. Reinjection would involve significantly higher capital and O&M costs since injection wells and/or infiltration galleries would have to be installed.

Screening Status. All four of the on-Site discharge options will be retained for detailed analysis due to their effectiveness and implementability feasibility.

3.3.5 Buried Waste and Soil Access Restrictions

Description. Access restrictions include deed restrictions and fencing. Deed restrictions were described in Section 3.3, so the discussion here (including effectiveness, implementability, cost, and screening status) will only include fencing. Warning signs could be included as a method of access restriction to the wetlands area where fencing may be difficult.

Fencing could potentially be included as a part of every alternative except no action. The on-Site portions of ACS are currently enclosed by a fence, and the perimeter of the off-Site areas is vegetated with trees and brush; therefore, additional fencing would be necessary to provide further restriction of the Site. Containment alternatives would utilize fencing as a primary mechanism for preventing contact with contaminated source areas. Additional fencing would be constructed around the off-Site contaminant source areas as part of containment alternatives. Other alternatives would utilize fencing as a secondary measure to contain treatment system equipment.

Effectiveness. Fencing designated areas would aid in reducing the incidences of trespassing, thus decreasing the risk associated with dermal contact of contaminants. The quality of fence plays a direct role in the reduction of risk attainable.

Implementability. Fencing is easily implementable administratively and technically. If practical, fences would be placed before any other remedial action takes place. Otherwise, they would be installed as soon as remediation progressed to the point that fencing would not interfere with the remedy.

Cost. The primary costs of fencing are dependant upon the height, type and length of fence installed. Substantially increasing the cost of a fence may not equally increase the effectiveness in preventing trespassers.

Screening Status. Fencing will be retained for detailed analysis due to its ability to prevent trespassers from directly contacting contaminants.

3.3.6 Buried Waste and Soil Containment

3.3.6.1 Capping

Description. A multimedia RCRA cap, a clay-soil cap, and an asphalt cap are under consideration for the Site. See Section 2.5.4.1 for a description of the construction of the different types of caps. Use of a cap for the Site would be based on the need to prevent precipitation infiltration as part of the treatment alternative. In most areas, caps are not appropriate because rainfall infiltration is used as part of the treatment of contaminated soils or waste. In such cases, a permeable soil cover would be provided to prevent direct contact with contaminated soils or waste.

Effectiveness. A multimedia RCRA cap provides the greatest reduction of infiltration due to the flexible membrane liner and sand drainage layer. The quality of installation (i.e., sealing seams, preventing punctures) of the virtually impermeable flexible membrane liner is the limiting factor of the multimedia RCRA type cap. Asphaltic concrete typically exhibits low permeabilities and is capable of achieving a permeability less than 10^{-9} cm/sec when sealed. Asphalt caps are most commonly used for areas requiring vehicular traffic. Soil-clay caps can achieve permeabilities as low as 10^{-6} cm/sec depending upon the type of clay and degree of compaction. The effectiveness of all caps is dependant upon proper upkeep and care. Clay-soil and multimedia covered with a natural shallow rooted type of vegetation provide an additional reduction in infiltration because of evapotranspiration.

Implementability. All three of the caps under consideration for the Site are both technically and administratively feasible. Capping is a proven technology for reducing infiltration into contaminated areas. Capping of some areas of the Site could be implemented as part of every alternative except in-situ treatment of buried waste, soil, and groundwater and excavation and treatment of buried waste and soil (see Table 2-3). The operating portion of the ACS facility would require an asphalt cap because a clay-soil or multimedia cap would be too thick and difficult to install around existing buildings and tank farms. Any type of cap could be placed over the Off-Site areas.

Cost. Multimedia caps are significantly more expensive than asphalt or clay-soil caps because of the synthetic membrane and increased volumes of materials required.

Screening Status. A multimedia and asphalt cap combination is retained for use in the containment alternative due to its reduction in infiltration to the contaminated soils. Either asphalt or clay-soil capping may be utilized for alternatives where treatment will be employed because of the high costs associated with a multimedia cap. Asphalt would be utilized in areas within the ACS facility where manufacturing operations are expected to continue. Clay-soil caps would be used in all other areas. The selection of a capping approach will be dependent on specified ARARs for the Site.

3.3.6.2 Surface Stabilization

Description. As discussed in Section 2.0, surface stabilization will be considered in conjunction with other technologies as a short-term solution. Grading and regrading will be used during remedial action and for future Site maintenance to control the landscape and prevent erosion. Vegetative cover will be established and maintained over any areas receiving a clay-soil cap or a multimedia cap. Dust control methods will be considered during remedial action when the potential for dust emissions is substantially increased.

Effectiveness. Grading and regrading when necessary would eliminate depressions formed through differential settlement and compaction, and can be used to repair slumped or badly eroded slopes. Vegetative cover reduces the potential for erosion, and can be used to upgrade the appearance of the Site. Vegetative cover reduces infiltration of water through evapotranspiration. Dust control measures provide an effective means for temporary control of fugitive dust emissions.

Implementability. Surface stabilization measures are easily implementable both technically and administratively. Dust control and grading would be implemented during remedial action, and vegetative support would be implemented after remedial action is complete. Maintenance of the Site would include use of surface stabilization technologies.

Cost. Surface stabilization measures are generally low cost methods of preventing erosion and dust emissions.

Screening Status. Surface stabilization will be retained for detailed analysis due to their low cost and effectiveness.

3.4 Groundwater and Surface Water Remedial Technologies

3.4.1 Direct Treatment On-Site

3.4.1.1 Biological Treatment.

Description - A brief discussion of aerobic and anaerobic biological degradation is presented in Section 2.4.3.1. The function of biological treatment is to remove organic matter from the waste stream through microbial degradation. Microbial metabolic activity can be classified into three main categories: aerobic respiration, in which oxygen is required as a terminal electron acceptor; anaerobic respiration, in which carbon dioxide, sulfate or nitrate serves as the terminal electron acceptor; and fermentation, in which the microorganism rids itself of excess electrons by exuding reduced organic compounds. Aerobic biological treatment is presently more prevalent than anaerobic. A number of biological treatment processes exist which may be applicable to the treatment of aqueous wastes, including conventional activated sludge, various modifications of activated sludge, rotating biological disks and trickling filters.

Effectiveness - Biological treatment of groundwater reduces the toxicity of organic contaminants by converting them to non-toxic compounds. Volatilization is believed to be the primary removal mechanism for chlorinated compounds such as 1,1,1-trichloroethane, trichloroethene and 1,2-dichloroethanes in typical aerobic treatment systems, which does not represent a reduction in toxicity as a result of treatment.

Figure 3-3 presents a summary of organic groups subject to biodegradation (U.S. EPA, 1985), while Figure 3-4 presents BOD/COD ratios for various organic compounds (Lyman, 1982). Ratios of BOD/COD have been used as an indicator of potential aerobic degradation. Excluding the inorganic metals, chlorinated methanes, chlorinated ethanes and chlorinated ethenes, the remaining chemical groups of concern are potentially amenable to aerobic biological treatment. The BETX compounds, chlorinated benzenes, chlorinated methanes, chlorinated ethanes and chlorinated ethenes are potentially amenable to anaerobic biological treatment. Recent research (Nelson, 1987 as referenced in Thomas, 1989) has shown the potential for aerobic degradation of trichloroethene and other chlorinated compounds by an aromatic pathway in the presence of phenol, toluene or cresol. White rot fungus has been found to aerobically degrade several refractory compounds such as PNAs with more than two to three benzene rings, PCBs and chlorinated phenols. Inorganic metals would not be amenable to biological treatment.

Removal efficiencies and degradation rates for individual compounds are dependent on the chemical matrix and concentrations, as well as the design parameters of the biological treatment system. The use of properly selected or engineered microbial populations, maintained under environmental conditions most conducive to their metabolic activity (e.g., oxygen concentration, nutrient addition, etc.), can be an important means of biologically degrading refractory compounds. Biological degradation is often enhanced through acclimation of the microbial population to the chemical matrix to be treated or by cometabolism mechanisms.

Implementability - Aerobic and anaerobic biological treatment are proven technologies for industrial wastewaters and contaminated groundwater. Biological treatment is applicable to aqueous wastes up to approximately 4,000 mg/l. Based on existing groundwater data for the ACS Site, organic contaminant concentrations should be well below this level and, therefore, not toxic to microorganisms used in biological treatment. Aerobic degradation processes are used more often than anaerobic because the degradation process is generally more rapid and complete. As mentioned previously, several chlorinated compounds present in the groundwater at the ACS Site may not be amenable to aerobic treatment, and would subsequently be volatilized to the atmosphere during the treatment process.

The complexity of the organic contaminant matrix present at the ACS Site would likely require either the biological treatment system to include both aerobic and anaerobic treatment reactors, the development of a cometabolism mechanism that would effectively treat the entire matrix, or the use of a carbon adsorption secondary treatment process option to remove contaminants not amenable to aerobic biological treatment. Even though most of the organic compounds are amenable to some form of biological treatment, the design conditions for optimal removal efficiencies and degradation rates for individual compounds would be different. Because of this, the degree of treatment for individual compounds would vary depending on the design conditions of a given treatment system. Treatability studies would be required to evaluate a range of design conditions and treatment processes in order to optimize the removal efficiencies and degradation rates for the organic contaminant matrix present in the groundwater at the ACS Site.

Biological treatment has significant operator supervision requirements. The handling and disposal of wastewater treatment sludge would also be required.

Cost - Order-of-magnitude capital and operational costs for biological treatment are presented in Table 3-5. Biological treatment costs are not significantly greater or less than other relevant groundwater treatment methods.

Screening Status - Because of its ability to convert organic compounds to non-toxic compounds, as well as its potential applicability for treating all of the organic chemical groups of concern, the biological treatment process option has been retained for alternatives development and detailed analysis.

3.4.1.2 Chemical Precipitation.

Description - Chemical precipitation is a pH adjustment process where acid or base is added to a solution to adjust the pH to a point where the constituents to be removed have their lowest solubility. Metals may be precipitated from solution as hydroxides, sulfides, carbonates or other insoluble salts. Hydroxide precipitation with lime is most common, while sodium sulfide is sometimes used to achieve lower effluent metal concentrations. Solids separation is achieved using standard flocculation/coagulation techniques.

Effectiveness - Chemical precipitation is potentially applicable for removing all of the inorganic metals detected in the groundwater at the ACS Site. For the most part, chemical precipitation is not capable of selectively removing specified metals. Since chemical precipitation is not capable of treating any organic compounds, it would be used strictly as a pretreatment step in conjunction with a primary organic treatment process option.

Implementability - Chemical precipitation is a proven technology for metals removal from industrial wastewaters and contaminated groundwater. One of the limitations of chemical precipitation is the fact that all metals do not have a common pH at which they precipitate. A multi-stage removal process at varying pH levels would most likely be required to treat the groundwater at the ACS Site. Chemical precipitation is typically used to treat wastewaters with metal levels significantly higher than those detected in the groundwater at the ACS Site. Treatability studies would be required to optimize the removal efficiencies of the inorganic metals matrix present in the groundwater at the ACS Site.

Chemical precipitation has significant operator supervision requirements. The handling and disposal of generated wastewater treatment sludge may trigger RCRA ARARs for hazardous waste generation and storage.

Cost - Order-of-magnitude capital and operational costs for chemical precipitation are presented in Table 3-5. Because of the costs associated with chemical usage and sludge disposal, chemical precipitation operational costs are significantly higher than operational costs associated with ion exchange.

Screening Status - Based on the ACS groundwater data, chemical precipitation is not expected to be a cost effective treatment option. Ion exchange offers comparable treatment effectiveness and significantly lower operational costs. Chemical precipitation has not been retained as a pretreatment alternative or for detailed analysis. It would only be retained if ion exchange is proven incapable of adequately treating the metals levels present in the groundwater.

3.4.1.3 UV/Oxidation.

Description - A brief discussion of UV/oxidation is presented in Section 2.4.3.2. UV light enhances oxidation of organic contaminants in water. Many organic contaminants undergo a change in chemical structure or become more reactive to chemical oxidants by absorbing UV light. Ozone or hydrogen peroxide are typically used as oxidizing agents. The end products of the complete oxidation of organic compounds are typically carbon dioxide and water.

Effectiveness - UV/oxidation of groundwater reduces the toxicity of organic contaminants by converting them to non-toxic compounds. Based on a review of available vendor literature, all of the organic chemical compound groups of concern are potentially amenable to UV/oxidation treatment. Inorganic metals would not be amenable to UV/oxidation treatment. Significant percentages of VOCs (5 to 75%) which are less susceptible to oxidation have been found to be stripped out of the groundwater by ozone and transferred into the vapor phase. Present data indicates that stripped VOCs are thermally destroyed as part of the ozone off-gas treatment system which can be included with UV/oxidation units (U.S. EPA, November 1989).

Results of a March 1989 U.S. EPA Superfund Innovative Technology Evaluation (SITE) demonstration showed minimal reductions in groundwater total organic carbon (TOC) levels following treatment by UV/oxidation. The TOC results would suggest that incomplete oxidation of the organic compounds had occurred. However, contaminants comprised only 2% of the TOC, thus making a statistical comparison difficult. Incomplete oxidation could result in the generation of intermediate compounds that are as toxic, or more toxic, than the corresponding parent compounds.

Implementability - UV/oxidation has been used on full scale groundwater cleanups at a limited number of sites in the last few years. Groundwater contaminant matrices similar to the ACS Site have been reported to be successfully treated using UV/oxidation based on vendor case studies. To date, it has only been used on pilot scale studies at CERCLA Sites as part of the SITE program. Vendor availability of UV/oxidation is limited.

Because of its recent development for use in full scale groundwater remediations, limited data exists to evaluate the applicability of treating the organic compound matrix present in groundwater at the ACS Site. Pilot studies would be required to evaluate the treatment potential of UV/oxidation, as well as to optimize the necessary design parameters (e.g., influent concentrations, UV and peroxide or ozone dosages). A carbon adsorption secondary treatment system may be required following the UV/oxidation operation in order to remove organic compounds not amenable to UV/oxidation treatment.

Cost - Order-of-magnitude capital and operational costs for UV/oxidation are presented in Table 3-5. UV/oxidation costs are not significantly greater or less than other relevant groundwater treatment methods.

Screening Status - Because of its ability to convert organic compounds to non-toxic compounds, as well as its potential applicability for treating all of the organic chemical groups of concern, the UV/oxidation treatment process option has been retained for alternatives development and detailed analysis.

3.4.1.4 Air Stripping.

Description - A brief discussion of air stripping is presented in Section 2.4.3.3. Air stripping is usually accomplished in a packed tower equipped with an air blower. The packed tower works on the principle of countercurrent flow. The water stream flows down through the packing, while the air stream flows upward. Volatile components have an affinity for the gas phase and tend to diffuse from the liquid phase to the gas phase. Factors important in the removal of organics from wastewater via air stripping include temperature, pressure, air to water ratio and surface area available for mass transfer. Air to water volumetric ratios typically range from 10:1 up to 300:1.

Effectiveness - Air stripping of groundwater transfers organic compounds to the air phase. The toxicity of organic compounds is reduced by dilution in clean air. If vapor phase treatment is used, however, the destruction of organics as a result of treatment or the spent carbon regeneration process would result in an overall toxicity reduction of contaminants present in the groundwater.

Compounds with dimensionless Henry's Law constants in excess of 0.003 (.0001 atm-m^3/mole) are amenable to air stripping. Based on this criteria and the Henry's Law constants for the target compounds presented in Table 3-1, the BETX compounds, chlorinated methanes, chlorinated ethanes, chlorinated ethenes, chlorinated benzenes, naphthalene and its derivatives and PCBs are amenable to air stripping. The phthalates, ketones, phenols, ethers, benzoic acid and inorganic metals would not be amenable to air stripping. Desired removal efficiencies are achieved by either increasing the column height or the air to water ratio of the stripping column.

Implementability - Air stripping is a proven technology for the treatment of contaminated groundwater. It is applicable to aqueous waste streams up to approximately 100 mg/l. If VOC concentrations exceed approximately 100 mg/l, steam stripping is usually more cost effective. Based on the present groundwater data for the ACS Site, influent organic compound concentrations would be expected to exceed 100 mg/l. Therefore, air stripping alone may not be able to achieve the desired removal

efficiencies in a cost effective manner. Dilution of influent groundwater from off-Site or lower aquifer pumping, however, may occur since contaminant concentrations in these areas are significantly lower.

A carbon adsorption secondary treatment system would likely be required following the air stripping operation to remove the organic compounds not amenable to air stripping. A pilot study would be necessary to more accurately determine influent concentrations and contaminant removal efficiencies. A vapor phase treatment system would be required if VOC air emission ARARs are exceeded.

Cost - Order-of-magnitude capital and operational costs for air stripping are presented in Table 3-5. Air stripping costs are not significantly greater or less than other relevant groundwater treatment methods.

Screening Status - Because of its proven effectiveness in full scale groundwater remediations at both CERCLA and non-CERCLA Sites, as well as its relative cost effectiveness, the air stripping process option has been retained for alternatives development and detailed analysis.

3.4.1.5 Steam Stripping.

Description - Steam stripping uses steam to evaporate organic compounds from aqueous wastes. It is essentially a continuous fractional distillation process carried out in a packed or tray tower. The formation of minimum boiling azeotropes between steam and numerous organic compounds reduces the energy requirements of the separation process. The organic vapor/steam mixture is condensed. This concentrated mixture can be further separated, if necessary, prior to reuse or disposal.

Effectiveness - Steam stripping of groundwater concentrates the organic contamination for off-Site disposal. The toxicity of the contaminants would be reduced if a destructive treatment method (e.g., incineration, secondary fuel blending) is utilized for the off-Site disposal of the condensate waste stream.

Compounds with boiling points less than 150°C are generally amenable to steam stripping. Based on this criteria and the boiling points for the target compounds presented in Table 3-1, BETX compounds, chlorinated methanes, chlorinated ethanes, chlorinated ethenes and volatile ketones would be amenable to steam stripping. Chlorinated benzenes, naphthalene and its derivatives, PCB, phthalates, phenols, ethers, benzoic acid, isophorone and inorganic metals would not be amenable to steam stripping. Desired removal efficiencies are achieved by increasing the column height of the stripping column.

Implementability - Steam stripping is a proven technology for industrial wastewaters and contaminated groundwater. It is applicable to aqueous waste streams ranging from less than 100 mg/l to about 10% organics. Based on the present groundwater data for the ACS Site, influent organic compound concentrations would be expected to exceed 100 mg/l. If these maximum VOC concentrations are encountered in influent water, steam stripping may be more cost effective than air stripping with vapor phase carbon adsorption. A pilot study would be required to more accurately determine influent concentrations. A carbon adsorption secondary treatment system would likely be required following the steam stripping operation in order to remove organic compounds not amenable to steam stripping.

Utilization of a steam stripping system would most likely require the construction and installation of a steam supply source (e.g., boiler). Even though ACS operates on-Site boilers for use in its processes, it cannot be assumed that this steam supply source would be available to future remedial action activities. Since the resulting condensate would require off-Site disposal, this process option would trigger relevant RCRA hazardous waste generator and storage ARARs.

Cost - Order-of-magnitude capital and operational costs for steam stripping are presented in Table 3-5. Because of the need to construct and install a steam supply source, the capital cost for steam stripping is significantly greater than that for other relevant groundwater treatment methods.

Screening Status - Because other groundwater treatment process options offer comparable treatment effectiveness at lower capital costs, the steam stripping process option has not been retained for alternative development and detailed analysis.

3.4.1.6 Activated Carbon Adsorption.

Description - A brief discussion of activated carbon adsorption is presented in Section 2.4.3.3. Activated carbon adsorption is typically used to to treat dilute single phase aqueous organic wastes containing compounds with high molecular weights and boiling points and low solubilities and polarities.

Effectiveness - The destruction of organics as a result of the spent carbon regeneration process would result in an overall toxicity reduction of contaminants present in the groundwater. All of the organic compounds detected at the ACS Site, as well as some of the inorganic metals, are amenable to activated carbon adsorption. Adsorbability of a compound is usually favored by the following:

- increasing molecular weight;
- decreasing solubility and polarity;
- decreasing carbon branching; and
- increasing aromaticity.

Limitations to the use of activated carbon adsorption are usually related to the economics associated with carbon usage. Table 3-1 presents various physical parameters for the target compounds that can be used to evaluate adsorbability potential and carbon usage requirements. These parameters include molecular weight, solubility, octanol/water coefficient (log Kow) and activated carbon/water distribution coefficient (log Pac). The log Pac is defined as follows:

$$\log Pac = \log (x/m)/c \quad \text{(Verscheuren, 1983)}$$

where: x/m = mg contaminant/kg activated carbon
c = unadsorbed concentration of substance left in solution

Based on the above criteria, the chlorinated benzenes, phthalates, PCBs, naphthalene and its derivatives and tetrachloroethene would be the most amenable to carbon adsorption and require the least carbon usage. The BETX compounds, chloroethanes, chloroethenes, phenols, ethers, chloroform and benzoic acid would be less amenable to activated carbon adsorption with moderate carbon usage requirements. The ketones, chloromethanes and vinyl chloride would be the least amenable to activated carbon adsorption and have high carbon usage requirements. Desired removal efficiencies are achieved by operating multiple carbon adsorption units in series.

Implementability - Activated carbon adsorption is a proven technology for the treatment of contaminated groundwater. It is applicable to aqueous waste streams with TOC concentrations up to 10,000 mg/l with suspended solids less than 50 mg/l. Based on the present groundwater data for the ACS Site, influent organic compound concentrations and suspended solids would be expected to be below these levels. A pilot study would be required to more accurately determine influent concentrations. Since inorganic metals can compete for activated carbon sites and increase carbon usage requirements, a metal removal pretreatment step would likely be required. The handling of spent carbon would trigger relevant RCRA hazardous waste generator and storage ARARs.

Cost - Order-of-magnitude capital and operational costs for activated carbon adsorption are presented in Table 3-5. The operational costs for activated carbon adsorption are significantly greater than those for other relevant groundwater treatment methods.

Screening Status - Since other groundwater treatment process options offer comparable treatment effectiveness at lower operational costs, the activated carbon adsorption process option has not been retained for alternatives development and detailed analysis. It will be retained as a secondary process option for other primary organic compound treatment process options as part of a treatment train because of its ability to treat all of the organic chemical groups of concern, as well as some inorganic metals.

3.4.1.7 Ion Exchange.

Description - A brief discussion of ion exchange treatment is presented in Section 2.4.3.3. After a critical relative concentration of recoverable ion to exchanged ion is exceeded, the exchange resin becomes spent and must be regenerated by backflushing with a concentrated acid, base or brine solution. Spent resin and regenerating solution require either recycling or disposal.

Effectiveness - Ion exchange is potentially applicable for removing all of the inorganic metals detected in the groundwater at the ACS Site. For the most part, ion exchange is not capable of selectively removing specified metals. Since ion exchange is not capable of treating organic compounds, it would be used strictly as a secondary pretreatment step prior to a primary organic compound treatment process option.

Implementability - Ion exchange is a proven technology for metals removal from industrial wastewaters and contaminated groundwater. Concentrated waste streams with removable metal levels in excess of approximately 25,000 mg/l are usually treated in a more cost effective manner by chemical precipitation. Based on the present groundwater data, the levels of removable metals would be expected to be amenable to ion exchange treatment. However, as mentioned above, ion exchange is not selective in its removal of metals. If inorganic metals not requiring treatment interfere with the ion exchange process, the total inorganic metals levels may be high enough where chemical precipitation would become more cost effective. A pilot study would be required to evaluate the influent inorganic metal concentrations, removal efficiencies and regeneration requirements. Hazardous waste generation and storage ARARs may be applicable to the off-Site disposal of regenerating solution.

Cost - Order-of-magnitude capital and operational costs for ion exchange treatment are presented in Table 3-5. Ion exchange operational costs are significantly lower than operational costs associated with chemical precipitation.

Screening Status - Because of its lower operational costs than chemical precipitation based on present groundwater data, the ion exchange treatment process option has been retained for use as a pretreatment alternative and for detailed analysis.

3.4.2 Off-Site Treatment

Description - Off-Site treatment would consist of the collection and conveyance of groundwater and surface water to the Hammond POTW for treatment in its municipal sewage treatment plant operation. A description of the Hammond POTW's treatment system is presented in Section 3.3.4.1.

Effectiveness - Eckenfelder (1989) presents a comparison of removal mechanisms for various priority pollutants in activated sludge treatment systems. While BETX compounds, methylene chloride, chloroform and carbon tetrachloride have reported removal efficiencies in excess of 95% by activated sludge treatment systems typical of municipal POTWs, 5% to 50% removal can be attributed to volatilization as opposed to aerobic degradation. Volatilization is believed to be the predominant removal mechanism for chlorinated compounds such as 1,1,1-trichloroethane, trichloroethene, 1,2-dichloropropane, 1,2-dichloroethane, trichloroethane, 1,2-dichloropropane, 1,2-dichloroethane and 1,1,2,2-tetrachloroethane treated within activated sludge systems typical of municipal POTWs. Volatilization of VOCs from municipal POTW treatment systems does not represent a reduction in their toxicity as a result of treatment.

Implementability - The feasibility of discharging contaminated groundwater and surface water from the ACS Site to the Hammond POTW was discussed with the pretreatment coordinator for the Hammond POTW. Even though the increased hydraulic loading does not appear to be an issue, it is not likely that the organic contaminant levels would meet any pretreatment standards imposed by the POTW. It is likely that approval to discharge to the POTW would require prior treatment operations. A more detailed discussion of the Hammond POTW's pretreatment requirements is presented in Section 3.3.4.1.

Cost - Users fees associated with the direct discharge of groundwater to the Hammond POTW would be less than capital and O&M costs associated with on-Site treatment.

Screening Status - Because of the likelihood that organic compound levels in groundwater at the ACS Site would exceed pretreatment standards imposed by the Hammond POTW, off-Site disposal of groundwater and surface water has not been retained for alternative development and detailed analysis. It has been retained previously as a discharge alternative for groundwater treated on-Site.

3.4.3 In-Situ Treatment

3.4.3.1 In-Situ Biological Treatment.

Description - Brief discussions of aerobic and anaerobic biological degradation are presented in Sections 2.4.3.1 and 3.4.1.1. In-situ biological treatment of contaminated soils and groundwater involves treatment without soil excavation or the off-Site discharge of treated groundwater. These systems typically use aerobic processes and involve the addition of oxygen and inorganic nutrients to stimulate naturally occurring microorganisms to degrade the organic contaminants. Oxygen is usually added in the form of air, pure oxygen or hydrogen peroxide. Hydrogen peroxide addition has been found to be the most effective at providing required oxygen concentrations in a cost effective manner. Oxygen and nutrients can be provided to the groundwater through the use of injection wells, or added to groundwater extracted from downgradient recovery wells at the surface for subsequent reinjection upgradient. Soil in the unsaturated zone can be treated by using recharge trenches at the surface to reinject treated groundwater.

Effectiveness - A discussion of the effectiveness with respect to contaminants present in the groundwater and surface water at the ACS Site is presented in Section 3.4.1.1. Incomplete degradation of organic contaminants could result in the generation of transformation products that are as toxic, or more toxic, than the parent compounds.

Implementability - In-situ biological treatment has been used on full scale groundwater cleanups at a limited number of sites in the last few years. To date, its application at CERCLA Sites has been limited to simple contaminant matrices and petroleum derivative compounds. As mentioned previously, several of the chlorinated compounds may not be amenable to aerobic treatment. The complexity of the organic contaminant matrix present at the ACS Site would likely require treatment to occur under both

aerobic and anaerobic (i.e., reduction potential -250 mv or less) environments in order to effectively treat the entire contaminant matrix. Anaerobic conditions can be created by flooding without oxygen injection or the addition of excessive amounts of easily biodegradable organic matter to use up available oxygen. Creating anaerobic aquifer environments has not been achieved in a full scale groundwater cleanup to date.

Another implementability issue with in-situ biological treatment has been the ability to uniformly distribute oxygen and nutrients to the subsurface environment. Permeability of the soils in the unsaturated and/or saturated zone must be sufficient to allow adequate distribution of oxygen and nutrients. Formations with hydraulic conductivities of 10^{-4} cm/sec or greater are most amenable to in-situ biological treatment. The soils present at the ACS Site appear to be permeable enough to consider in-situ biological treatment. However, non-homogeneous zones of permeability also affect distribution of oxygen and nutrients. The clogging of the aquifer, injection well, trenches or extraction wells by precipitated inorganic materials or microbial sludge has also impacted the effectiveness of in-situ biological remediation systems. Treatability studies would be required to evaluate a range of design conditions and treatment alternatives in order to optimize removal efficiencies and oxygen and nutrient delivery systems.

In addition to the contaminant matrix being a potential problem with in-situ biological treatment, the levels of contaminants present due to the buried waste are expected to be too high and prove toxic to microorganisms. There are no existing case studies of in-situ biological treatment successfully remediating a contaminant matrix analogous to the one present at the ACS Site. Based on the levels of contaminants detected beneath the water table (and the presence of buried drums), as well as their hydrophobic chemical nature, a separate "free waste phase" (i.e., free liquids that are not dissolved in, or floating on top of, groundwater) is expected to exist within the upper aquifer in the source areas. Because of the hydrophobic nature of the "free waste phase" and the limited solubilities of most of the primary contaminants in water, treated groundwater from in-situ biological treatment would not penetrate the "free waste phase" and, subsequently, would

not contact and treat "free waste phase" contaminants present in the source areas. Because of the shallow water table conditions present at the ACS Site, the source areas would have to be dewatered in order to excavate sections of buried waste and soils with contaminant levels too high to be amenable to biological treatment. The requirement to dewater the ACS Site would negate the opportunity to perform in-situ biological treatment of groundwater within the source areas.

Cost - A unit cost for in-situ biological treatment of buried waste, soils and groundwater is presented in Table 3-5. In-situ biological treatment costs are not significantly greater or less than other relevant groundwater treatment methods.

Screening Status - Because of the implementability problems associated with the ACS Site, the in-situ biological treatment process option has not been retained as a method of source treatment for alternative development and detailed analysis. It will be retained as a method of enhanced treatment of groundwater outside of the source areas, as well as contaminated groundwater which has migrated off-Site. In-situ biological treatment of groundwater could be implemented following the completion of source treatment if pump and treat flushing is found to be ineffective.

3.4.3.2 In-Situ Steam Steam Stripping

Description - A brief discussion of in-situ steam stripping is presented in Section 2.4.5.2.

Effectiveness - Refer to Section 3.5.2.3

Implementability - Refer to Section 3.5.2.3

Cost - Refer to Section 3.5.2.3

Screening Status - Because in-situ steam stripping is the only process option which could potentially treat the buried waste, soils and groundwater concurrently at the ACS Site, it has been retained for alternatives development and detailed analysis.

3.5 Buried Waste Treatment

3.5.1 Removal

3.5.1.1 Bioreactor/ Land Farming.

Description - Brief descriptions of aerobic and anaerobic biological degradation are presented in Sections 2.4.3.1 and 3.4.1.1. Biological treatment following the excavation of contaminated areas can be accomplished by landfarming or in slurry-phase biological reactors. Bioremediation rates in contaminated soils and wastes are enhanced by achieving ideal oxygen levels, moisture content, nutrient levels, pH and acclimation of appropriate microorganisms.

A lined treatment bed is typically used in landfarming applications. Lateral perforated drainage pipe in the bed collects any leachate that may be formed. If the release of VOCs are of a concern, the system can be enclosed and an air collection and treatment system added. Aeration is usually provided by tilling, and irrigation systems are used to provide necessary moisture and nutrient addition.

Slurry-phase bioreactors involve the mixing of contaminated soils and wastes with water prior to treatment. Slurry-phase bioreactor processes offer greater control over the biological treatment system than landfarming techniques. This is accomplished by increased contact time between microorganisms and contaminants, use of engineered microorganisms, decreased acclimation time and superior control over process parameters. Treated soils and waste must undergo a water separation process. The separated water containing high populations of acclimated microorganisms is recycled back to the process.

Effectiveness - Biological treatment of buried wastes and soils reduces the toxicity of organic contaminants by converting them to non-toxic compounds. The excavation and material handling requirements may result in the volatilization of untreated VOCs to the atmosphere. Organic compounds which are refractory to the selected biological treatment system may also be volatilized to the atmosphere during treatment. A discussion of the effectiveness of aerobic and anaerobic biological degradation on the contaminant matrix present in the buried waste and soil at the ACS Site is presented in Section 3.4.1.1.

Implementability - Biological treatment has been used on full scale soil and waste cleanups at a limited number of sites in the last few years. To date, its application at CERCLA Sites has been limited to simple contaminant matrices and petroleum derivative compounds. As mentioned previously, several of the chlorinated compounds may not be amenable to aerobic treatment. The complexity of the organic contaminant matrix present at the ACS Site would likely require either treatment to occur under both aerobic and anaerobic (i.e., reduction potential -250 mv or less) environments in order to effectively treat the entire contaminant matrix, or an allowance for VOC emissions to the atmosphere. For similar reasons as those discussed in Section 3.4.3.1, creating an anaerobic environment in landfarming applications has not been achievable to date. Slurry-phase bioreactors offer the most feasible approach to performing both aerobic and anaerobic treatment.

In addition to the contaminant matrix being a potential hindrance to biological treatment, the levels of contaminants present due to the buried waste may be too high and prove toxic to microorganisms. If this is the case, soils with contaminant levels too high to be amenable to biological treatment would have to be segregated for treatment by an alternative process option. Treatability studies would be required to evaluate a range of design conditions and treatment processes in order to optimize the removal efficiencies and degradation rates for the organic contaminant matrix present in the buried waste and soils at the ACS Site.

Potential ARARs associated with air emissions, RCRA storage and treatment and the RCRA land ban must be addressed by any alternative which includes biological treatment of the buried waste and soil at the ACS Site. A variance from the RCRA land ban requirements would have to be obtained in order to place treated soils back on-Site. Modified material handling procedures and the installation of air treatment equipment may be required if VOC emissions exceed specified ARARs or risk based levels.

Biological treatment would most likely require a treatability variance under 40 CFR 268.44 to meet applicable land disposal restrictions (LDRs). In the revised National Contingency Plan, the U.S. EPA recognizes that soil and debris are significantly different than industrial waste streams used to develop the LDR treatment standards. The guidelines for obtaining a soil and debris treatability variance for CERCLA response actions are presented in the Office of Solid Waste and Emergency Response Directive 9347.3-06FS titled "Obtaining a Soil and Debris Treatability Variance for Remedial Actions" (Directive).

The Directive states that, "a Treatability Variance process (40 CFR 268.44) is available to comply with LDRs when a Superfund waste differs significantly from the waste used to set the LDR treatment standards such that:

- The LDR standard cannot be met; or
- The best demonstrated available technology (BDAT) used to set the standard is inappropriate for the waste."

If a treatability variance is granted, alternative treatment levels are established based on data from actual treatment of soil, or best management practices for debris.

According to the Directive, the following information should be included in the documentation of a soil and debris treatability variance for on-site response actions:

- a statement of need and justification for the proposed action;
- description of the soil or debris waste and description of the source of the contamination;
- an explanation of why the BDAT treatment technology is inappropriate or why treatment of the waste will not be able to achieve the LDR treatment standards; and
- for each alternative for which a Treatability Variance is required, the specific treatment level range to be achieved to comply with the LDRs through a Treatability Variance.

Since it is not known at this time if biological treatment will be selected as part of the final remedy, a detailed inventory of RCRA waste codes handled by ACS has not been developed. F-listed spent solvents, characteristic ignitable solvents, and paint and ink sludges etc. are believed to be the primary waste streams that were handled at the ACS Site. The BDAT pertaining to the LDR treatment standards for these waste codes is incineration. Most of the samples collected at the ACS Site had contaminant concentrations in excess of the threshold concentrations for applicable functional groups specified in Highlight 5 of the Directive.

Biological treatment of the soils and buried waste at the ACS Site would not be expected to achieve potentially applicable LDR treatment standards based on limited available data for contaminant matrices which are both simpler and of significantly lesser concentrations than what was found at the ACS Site. There is no actual performance data involving the biological treatment of analogous contaminant matrices. A site-specific biological treatability study has not been performed. According to the Directive, "When there are no actual performance data available that indicate the LDR treatment standards can be met consistently for all soil and debris, site managers should seek a Treatability Variance". A Treatability Variance appears warranted for the ACS Site based on the complicated contaminant matrix and elevated concentrations that were found.

The following alternative treatability variance levels based on percent reduction are specified in Highlight 5 of the Directive for the biological treatment of contaminant groups identified at the ACS Site (Highlight 5 of the Directive also presents variance levels based on concentration and percent reduction for metals based on immobilization/fixation as a treatment technology):

Organic Functional Group	Percent Reduction
Halogenated and Non-Polar Aromatics	90-99.9%
PCBs	90-99.9%
Halogenated Phenols	90-99%
Halogenated Aliphatics	95-99.9%
Polynuclear Aromatics	95-99.9%
Other Polar Organics	90-99.9%

Excavation of buried waste and contaminated soil for biological treatment would involve considerable material handling. The volume of buried waste and soil requiring treatment would dictate that excavation and material handling activities be performed in stages. Because of the material handling requirements, a large area would have to be available for the construction and operation of the aboveground treatment system.

Cost - Unit costs for the biological treatment of buried waste and soil are presented in Table 3-5. Assuming treated soils can remain on-Site, biological treatment costs are not significantly greater or less than other buried waste and soil treatment methods.

Screening Status - Because of its ability to convert organic compounds to non-toxic compounds, as well as its potential applicability for treating all of the organic chemical groups of concern, the biological treatment of buried wastes has been retained for alternatives development and detailed analysis.

3.5.1.2 Off-Site Incineration.

Description - A description of thermal treatment techniques is presented in Section 2.5.2.2. Buried waste and/or soil would be excavated and staged for transportation and disposal at an off-Site RCRA Part B and/or TSCA commercial incinerator.

Effectiveness - Incineration of buried waste and/or soil reduces the toxicity of organic contaminants by destroying them. The excavation and material handling requirements may result in volatilization of untreated VOCs to the atmosphere. Resulting combustion products include carbon dioxide, water and other off-gases of incomplete combustion. These off-gases are typically treated using appropriate scrubber systems. Excluding the inorganic metals, all of the organic chemical groups of concern are amenable to incineration technologies.

Implementability - Incineration is a proven technology for wastes contaminated with organic compounds and would remediate the buried waste and/or soil in a shorter time frame than any other applicable process option. Refer to Section 3.5.1.1 for implementability issues associated with the excavation and handling of buried waste and/or soil. This process option would also be subject to RCRA hazardous waste generator ARARs. There is presently a limited commercial incinerator capacity available for soils and other solid wastes.

Cost - Unit costs for off-Site incineration of buried waste and soil are presented in Table 3-5. Off-Site incineration costs are significantly higher than disposal costs associated with on-Site incineration.

Screening Status - Because of the limited commercial incinerator capacity available for soils and other solid wastes, as well as the higher costs associated with off-Site versus on-Site incineration, off-Site incineration of buried wastes has not been retained for source treatment alternatives development and detailed analysis. It will be retained for the off-Site disposal of buried drums and miscellaneous debris, as well as for limited volumes of surficial PCB-contaminated soil disposal.

3.5.1.3 On-Site Incineration.

Description - A description of thermal treatment techniques is presented in Section 2.5.2.2. Buried waste and/or soil would be excavated and staged for on-Site incineration.

Effectiveness - Refer to Section 3.5.1.2

Implementability - Incineration is a proven technology for wastes contaminated with organic compounds. Refer to Section 3.5.1.1 for implementability issues associated with the excavation and handling of buried waste and/or soil. The resulting incinerator ash must be disposed of on- or off-Site and would be subject to the RCRA land ban ARARs. This process option would also be subject to RCRA hazardous waste generator, storage and treatment ARARs. A pilot test burn would be required to optimize the operational parameters. Vendor availability for mobile or permanent incinerators should not pose a problem.

Cost - Unit costs for on-Site incineration of buried wastes and soil are presented in Table 3-5. The unit costs take into account the capital and operation and maintenance costs associated with incinerating the volume of soil at the Site. On-Site incineration operational costs are significantly lower than disposal costs associated with off-Site incineration.

Screening Status - Because of its ability to destroy all of the organic chemical groups of concern, on-Site incineration of buried waste has been retained for alternatives development and detailed analysis.

3.5.1.4 On-Site Low Temperature Thermal Treatment

Description - A description of thermal treatment techniques is presented in Section 2.5.2.2. Buried waste and/or soil would be excavated and staged for on-Site low temperature thermal treatment.

Effectiveness - Low temperature thermal treatment of buried waste and/or soil reduces the toxicity of organic contaminants by destroying them. The excavation and material handling requirements may result in the volatilization of VOCs to the atmosphere. Resulting volatilized gases would either be further treated by secondary combustion or condensed for recovery and disposal. Excluding the inorganic metals, all of the organic chemical groups of concern are amenable to low temperature thermal treatment. Based on a review of vendor literature, high boiling point organics (e.g., PCBs) are amenable to low temperature thermal treatment. Low temperature thermal treatment can be performed at higher temperatures for compounds less amenable to this type of treatment. Pilot study demonstrations have shown that SVOCs are amenable to low temperature thermal treatment at temperatures ranging from 500°F to 600°F.

Implementability - Low temperature thermal treatment has been used on full scale soil remediations at a limited number of sites in the last few years. Its applications, to date, have been limited to simple contaminant matrices and petroleum derivative compounds. Low temperature thermal treatment units are designed to treat soils or sludges containing less than 10% total organics. Based on existing soil data for the ACS Site, organic contaminant concentrations should be below this level.

Refer to Section 3.5.1.1 for implementability issues associated with the excavation and handling of buried waste and/or soil. This process option would be subject to RCRA storage and treatment ARARs. A pilot test burn would be required to evaluate the ability of low temperature thermal treatment to handle the organic contaminant matrix of concern, as well as to optimize the operational parameters. Vendor availability for mobile or permanent low temperature thermal treatment units is limited.

Cost - Unit costs for on-Site low temperature thermal treatment of buried wastes and soil are presented in Table 3-5. On-Site thermal treatment operational costs are significantly lower than operational costs associated with on-Site incineration.

Screening Status - Because of its potential to treat the organic chemical groups of concern at significantly lower operational costs than on-Site incineration, on-Site low temperature thermal treatment of buried waste has been retained for alternatives development and detailed analysis.

3.5.1.5 Off-Site Low Temperature Thermal Treatment.

Description - A description of thermal treatment techniques is presented in Section 2.5.2.2. Buried waste and/or soil would be excavated and staged for transportation and disposal at an off-Site RCRA Part B commercial low temperature thermal treatment unit.

Effectiveness - Refer to Section 3.5.1.4

Implementability - Refer to Section 3.5.1.4. There are presently no RCRA Part B commercial low temperature thermal treatment units.

Cost - Since there are no commercial facilities presently operating, costs could not be established for this process option.

Screening Status - Since there are no commercial facilities presently available, off-Site low temperature thermal treatment of buried waste has not been retained for alternatives development or detailed analysis.

3.5.2 In-Situ Treatment

3.5.2.1 In-Situ Biological Treatment

Description - A description of in-situ biological treatment is presented in Section 3.4.3.1.

Effectiveness - Refer to Section 3.4.3.1.

Implementability - As discussed in Section 3.4.3.1., the concentrations of contaminants in the waste at the Site are too high to use in-situ biological treatment of waste. It may be possible to perform in-situ treatment of some of the contaminated soils at the Site. However, the alternatives which include excavation and treatment of waste at the Site also include dewatering as a part of the alternative. Once the Site is dewatered, in-situ biological treatment of soil is not possible. The alternatives that are capable of treating the waste in-situ are also capable of treating the soil in-situ. Therefore, there is no need to consider separate technologies for treating waste and soil in-situ.

Cost - Refer to Section 3.4.3.1.

Screening Status - Because of the implementability problems associated with the ACS Site, the in-situ biological process option has not been retained for alternatives development and detailed analysis.

3.5.2.2 In-Situ Vitrification

Description - A description of in-situ vitrification is presented in Section 2.5.3.3.

Effectiveness - In-situ vitrification of buried waste and/or soil reduces the toxicity of organic contaminants by destroying them. Off-gases resulting from either vaporization or incomplete pyrolysis of organic contaminants would be released to the atmosphere unless a collection head and air treatment system were provided. Data generated to date has not conclusively refuted the possibility that volatilized gases migrate away from the treatment zone and potentially spread contaminants to lower depths. Non-volatilized

organics and inorganics are immobilized within the resulting glass matrix. According to the treatability matrix presented in U.S. EPA (September 1988), all of the chemical groups of concern are potentially amenable to in-situ vitrification.

Implementability - In-situ vitrification has yet to be demonstrated on full scale soil and waste cleanups. To date, its application at CERCLA Sites has been limited to pilot studies involving the treatment of mixed hazardous and radioactive wastes. None of the pilot studies involved organic contaminant levels approaching those at the ACS Site. Vendor availability for in-situ vitrification is limited.

A combination of high soil permeability (less than approximately 1×10^{-5} cm/sec) and the presence of groundwater and buried drums can create technical limitations to the process. All of these conditions exist at the ACS Site. Electrical shorting may be caused by the concentrated presence of buried drums. In-situ vitrification will work with fully saturated soils; however, the water in the soil must be evaporated before the soil will begin to melt. If the soil moisture is being recharged by an aquifer, there is an additional economic impact. Since high soil permeability and water table conditions exist at the ACS Site, dewatering and capping the area before treatment by in-situ vitrification is essential. Vitrified source areas would interfere with the present groundwater flow patterns.

High organic contaminant levels could cause an overload of the off-gas treatment system. Combustible VOC off-gas emissions generated during a recent pilot study caused the fiberglass air emission capture hood which is presently employed to catch on fire (Inside EPA, March 27, 1991). A pilot study would be required to determine the feasibility of treating the contaminant matrix present in the buried waste and soils at the ACS Site using in-situ vitrification. Air emission ARARs may apply to off-gases emitted by this process.

Cost - Unit costs for in-situ vitrification of buried waste and soil are presented in Table 3-5. The operational costs associated with in-situ vitrification are significantly higher than operational costs associated with other buried waste and soil treatment process options.

Screening Status - Because of the high organic contaminant levels present in the buried wastes, in-situ vitrification of buried waste has not been retained for alternatives development and detailed analysis. On-Site incineration is proven and equally effective for treating all of the chemical groups detected at the ACS Site.

3.5.2.3 Vapor Extraction

Description - Refer to Section 3.6.2.3.

Effectiveness - Refer to Section 3.6.1.6.

Implementability - Refer to Section 3.6.2.3 for general implementability issues associated with in-situ vapor extraction. Vapor extraction has been successful in removing VOCs from soils, though there have been no case studies, where VOC contaminant levels approach those detected at the ACS Site. Based on the levels of contaminants detected in soil samples collected beneath the depth of the water table (and the presence of buried drums), a separate "free waste phase" (i.e., free liquids that are not dissolved in, or floating on top of, groundwater) is expected to exist within the upper aquifer in the buried waste and other source areas. Sufficient air permeability may not exist through these "free waste" zones to allow sufficient air contact necessary to effectively extract VOCs contained in the buried waste. A pilot scale test would have to be conducted in the buried waste areas to determine concentrations entering the vapor treatment system. It may be necessary to implement the vapor extraction system in phases to prevent overload of the off-gas system. Phasing could possibly be accomplished by installing wells around the perimeter of the waste areas and moving inward as VOC levels are reduced in the extraction air.

Screening Status - Because vapor extraction is the only proven technology which could potentially treat both buried waste and soils in-situ with minimal excavation requirements, it has been retained for alternative development and detailed analysis.

3.5.2.4 In-Situ Steam Stripping

Description - A brief discussion of in-situ steam stripping is presented in Section 2.4.5.2.

Effectiveness - Refer to Section 3.4.1.5 for a general discussion of steam stripping effectiveness. According to the treatability matrix presented in U.S. EPA (September 1988), the BETX compounds, chlorinated methanes, chlorinated ethanes, chlorinated ethenes and volatile ketones are amenable to steam stripping; while the chlorinated benzenes, phthalates, phenols, PNAs, ethers, isophorone and benzoic acid are potentially amenable to steam stripping. PCBs and inorganic metals would not be amenable to steam stripping.

The preliminary findings of a SITE program demonstration of in-situ steam stripping reported in de Percin (June 1990), showed that removal efficiencies varied between treatment cells, and the disposition of semi-volatile organic compounds that were reportedly removed could not be determined. Downward migration of contaminants to below the treatment zone appeared to be insignificant. In-situ steam stripping has the potential to treat soil and groundwater concurrently.

Implementability - In-situ steam stripping has yet to be demonstrated on full scale soil and waste cleanups. To date, its application at CERCLA Sites has been limited to pilot studies involving remediation of VOC-contaminated soils. Vendor availability for in-situ steam stripping is limited.

In-situ steam stripping should be capable of treating the organic contaminant concentrations present in the buried waste at the ACS Site since wastewater applications of steam stripping are able to handle concentrated organics. A pilot study would be required to determine the feasibility of treating the contaminant matrix present in the buried waste and soils at the ACS Site using in-situ steam stripping. Off-gases from the steam stripping process would either have to be treated or condensed for recovery or off-Site disposal. This process option would be subject to RCRA hazardous waste generator ARARs, and may also be subject to air emission ARARs.

A problem with in-situ steam stripping is that large diameter augers would be used to auger holes into the ground on a grid pattern across all of the areas of contamination. If any of the augers penetrated the clay confining layer beneath the Site, high levels of contamination would be introduced to the lower aquifer. A second potential problem with in-situ steam stripping is that the process could mix highly contaminated waste with the surrounding soil which has much lower levels of contamination. If, for any reason, the steam stripping technology does not work, the volume of contaminated waste to be dealt with would be larger.

Cost - A unit cost for in-situ steam stripping is presented in Table 3-5. In-situ steam stripping costs are not significantly greater or less than other relevant buried waste and soil treatment methods that also require soil excavation and/or concurrent groundwater treatment.

Screening Status - Because in-situ steam stripping is the only process option which could potentially treat the buried wastes, soil and groundwater concurrently at the ACS Site, it has been retained for alternatives development and detailed analysis.

3.6 Soil and Sediments Treatment

3.6.1 Removal

3.6.1.1 Bioreactor/Land Farming

Description - Refer to Section 3.5.1.1.

Implementability - Refer to Section 3.5.1.1.

Cost - Refer to Section 3.5.1.1.

Screening Status - Because of its ability to convert organic compounds to non-toxic compounds, as well as its potential applicability for treating all of the organic chemical groups of concern, the biological treatment of soils has been retained for alternatives development and detailed analysis.

3.6.1.2 Off-Site Incineration

Description - Refer to Section 3.5.1.2.

Effectiveness - Refer to Section 3.5.1.2.

Implementability - Refer to Section 3.5.1.2.

Cost - Refer to Section 3.5.1.2.

Screening Status - Because of the limited commercial incinerator capacity available for soils and other solid wastes, as well as the higher costs associated with off-Site versus on-Site incineration, off-Site incineration of soils has not been retained for alternatives development and detailed analysis.

3.6.1.3 On-Site Incineration

Description - Refer to Section 3.5.1.3.

Effectiveness - Refer to Section 3.5.1.3.

Implementability - Refer to Section 3.5.1.3.

Cost - Refer to Section 3.5.1.3.

Screening Status - Because of its ability to destroy all of the organic chemical groups of concern, on-Site incineration of soil has been retained for alternative development and detailed analysis.

3.6.1.4 On-Site Low Temperature Thermal Treatment

Description - Refer to Section 3.5.1.4.

Effectiveness - Refer to Section 3.5.1.4.

Implementability - Refer to Section 3.5.1.4.

Cost - Refer to Section 3.5.1.4.

Screening Status - Because of its potential to treat the organic chemical groups of concern at significantly lower operational costs than on-Site incineration, on-Site low temperature thermal treatment of soils has been retained for alternatives development and detailed analysis.

3.6.1.5 Off-Site Low Temperature Thermal Treatment

Description - Refer to Section 3.5.1.5.

Effectiveness - Refer to Section 3.5.1.5.

Implementability - Refer to Section 3.5.1.5.

Cost - Refer to Section 3.5.1.5.

Screening Status - Since there are no commercial facilities presently available, off-Site low temperature thermal treatment of soil has not been retained for alternatives development and detailed analysis.

3.6.1.6 Vapor Extraction

Description - A brief discussion of above-ground vapor extraction is presented in Section 2.5.2.3. Excavated soil would be staged in a lined area and covered in order to minimize leaching and volatilization. A header system is situated at the base of the soil pile. The system operates by applying a vacuum through the header system. The established vacuum draws VOC-contaminated air from the soil pores and fresh air from a recharge source. The disruption in the vapor/liquid equilibrium that is created results in diffusion of VOCs into the vapor phase and continued removal. Stripping of VOCs from the dissolved water phase into the vapor phase also occurs. The removed vapors are either discharged to the atmosphere or treated.

Effectiveness - Vapor extraction of soil transfers organic compounds to the air phase. The toxicity of organic compounds is reduced by dilution in clean air. If vapor phase thermal treatment or carbon adsorption is used, however, the destruction of organics as a result of incineration or spent carbon regeneration would result in an overall toxicity

reduction. The excavation and material handling requirements may result in the volatilization of untreated VOCs to the atmosphere.

Compounds with dimensionless Henry's Law constants in excess of .01 (.0004 atm-m^3/mole) are amenable to vapor extraction, while compounds with dimensionless Henry's Law constants in excess of .001 (.00004 atm-m^3/mole) are potentially amenable to vapor extraction. Based on this criteria and the Henry's Law constants for the target compounds presented in Table 3-1, the BETX compounds, chlorinated methanes, chlorinated ethanes, chlorinated ethenes, dichlorobenzenes, naphthalene and its derivatives and PCBs are amenable to vapor extraction. The volatile ketones are potentially amenable to vapor extraction. The phthalates, ethers, phenols, isophorone, benzoic acid and inorganic metals would not be expected to be amenable to vapor extraction. Because of its soil adsorption characteristics, PCBs would also not be expected to be amenable to vapor extraction. There are no documented case studies of vapor extraction being used to remediate PCB-contaminated sites. Removal efficiencies are determined by mass transfer relationships and site hydrogeology.

Implementability - Vapor extraction is a proven technology for the treatment of VOC-contaminated soils. Vapor extraction performed above-ground offers more control over the treatment process than vapor extraction performed in-situ. Variables which adversely impact in-situ vapor extraction such as moisture content, as well as non-homogeneous soil conditions and contaminant levels, are better controlled in above-ground applications of vapor extraction. A pilot study would have to be performed to more accurately determine VOC emissions and optimize the design parameters.

Refer to Section 3.5.1.1 for implementability issues associated with the excavation and handling of soil and the RCRA land ban ARARs associated with the placement of treated soil on-Site. Potential ARARs associated with RCRA hazardous waste storage and treatment would have to be addressed by any alternative which includes above-ground vapor extraction. A vapor phase treatment system would be required if VOC air emission ARARs are exceeded.

Cost - A unit cost for the above-ground vapor extraction of soil is not available in the literature. Operational costs for above-ground vapor extraction would be significantly higher than operational costs associated with in-situ vapor extraction because of the soil excavation requirements.

Screening Status - Since in-situ vapor extraction offers comparable treatment effectiveness at lower operational costs without the requirement of soil excavation and handling, above-ground vapor extraction of soils has not been retained for alternative development and detailed analysis.

3.6.1.7 Solvent Extraction

Description - A brief discussion of solvent extraction using critical fluids is presented in Section 2.5.2.3.

Effectiveness - Solvent extraction transfers contaminants from the solid phase to a concentrated liquid phase. The toxicity of the contaminants would be reduced if a destructive treatment method (e.g., incineration, secondary fuel blending) is utilized for the off-Site disposal of the extracted contaminants. The excavation and material handling requirements may result in the volatilization of untreated VOCs to the atmosphere.

According to the treatability matrix presented in U.S. EPA (September 1988), all of the chemical groups of concern are potentially amenable to solvent extraction. Inorganic metals would not be expected to be amenable to critical fluids extraction, but would be amenable to a separate solvent extraction or soil washing process. Critical fluids solvent extraction has been shown to be more effective when a cosolvent, such as methanol, is added.

Implementability - Solvent extraction has yet to be demonstrated on a full scale soil cleanup. To date, its application at CERCLA Sites has been limited to pilot and laboratory studies involving PCBs and petroleum-derivative wastes. Vendor availability for solvent extraction is limited.

The complexity of the organic contaminant matrix present at the ACS Site would make it difficult to identify a single solvent or mixture that could effectively solubilize and extract all of the necessary contaminants. Solvent extraction has yet to be tested on a complicated waste matrix. A pilot study would be required to determine the feasibility of treating the contaminant matrix present in the soil at the ACS Site using solvent extraction.

Refer to Section 3.5.1.1 for implementability issues associated with the excavation and handling of soil and the RCRA land ban ARARs associated with the placement of treated soil on-Site. The generated extract would require off-Site disposal. Potential ARARs associated with RCRA hazardous waste generation, storage and treatment must be addressed by any alternative which includes solvent extraction.

Cost - A unit cost for solvent extraction is presented in Table 3-5. Solvent extraction costs are not significantly greater or less than other relevant soil treatment methods.

Screening Status - Since other proven soil treatment process options offer comparable treatment effectiveness at similar costs, solvent extraction of soils has not been retained for alternatives development and detailed analysis.

3.6.2 In-Situ Treatment

3.6.2.1 In-Situ Biological Treatment

Description - Refer to Section 3.4.3.1.

Effectiveness - Refer to Section 3.4.3.1.

Implementability - Refer to Section 3.4.3.1.

Cost - Refer to Section 3.4.3.1.

Screening Status - Because of the implementability problems associated with the ACS Site, discussed in Section 3.5.2.1, the in-situ biological treatment process option has not been retained as a method of source treatment for alternatives development and detailed analysis.

3.6.2.2 In-Situ Steam Stripping

Description - A brief discussion of in-situ steam stripping is presented in Section 2.4.5.2.

Effectiveness - Refer to Section 3.5.2.3.

Implementability - Refer to Section 3.5.2.3.

Cost - Refer to Section 3.5.2.3.

Screening Status - Because in-situ steam stripping is the only process option which could potentially treat the buried waste, soils and groundwater concurrently at the ACS Site, it has been retained for alternatives development and detailed analysis.

3.6.2.3 Vapor Extraction

Description - Refer to Section 3.6.1.6 for a general discussion of vapor extraction principles. Extraction wells are installed in a grid pattern across the area(s) to be treated. The surface is often capped in order to prevent short-circuiting and enhance the radius of influence of the extraction wells. If the surface is capped, the extraction wells could also serve as passive inlet wells in order to provide a recharge source for clean air. The extractions wells are connected by a header system to one or more vacuum pumps depending on the system design requirements.

Effectiveness - Refer to Section 3.6.1.6.

Implementability - Vapor extraction is a proven technology for the treatment of VOC-contaminated soils. Even though vapor extraction is potentially applicable to all soil conditions and permeabilities, it is the most effective in homogeneous, permeable soil conditions. The soil conditions at the ACS Site would appear to be conducive to vapor extraction. Soil moisture content and depth to groundwater are also a potential hindrance to vapor extraction. Vapor extraction is most effective when the soil moisture content is less than 10%, although it can still be effective up to 30%, and the depth to

groundwater is greater than five feet. Since high soil permeability and water table conditions exist at the ACS Site, dewatering the area before treatment by in-situ vapor extraction is essential. Soil sampling for moisture content and pilot testing would be required to determine the effectiveness of vapor extraction following Site dewatering. Groundwater extraction wells could also serve a dual purpose as vapor extraction or passive inlet wells.

Since the theory of vapor extraction is not well defined, a pilot study would be required to optimize the design parameters. The start-up of vapor extraction systems for complex waste matrices can be labor intensive. Follow-up soil sampling is required to determine the effectiveness of the system in meeting established cleanup criteria. A vapor phase treatment system would be required if VOC air emission ARARs are exceeded.

Cost - A unit cost for the in-situ vapor extraction of soil is presented in Table 3-5. Operational costs for in-situ vapor extraction are significantly lower than operational costs associated with above-ground vapor extraction.

Screening Status - Because of its proven effectiveness in full scale soil remediations at both CERCLA and non-CERCLA Sites, as well as it being the only proven in-situ process option for the contaminant matrix of concern, in-situ vapor extraction has been retained for alternatives development and detailed analysis.

3.6.2.4 In-Situ Vitrification

Description - Refer to Section 3.5.2.2.

Effectiveness - Refer to Section 3.5.2.2.

Implementability - Refer to Section 3.5.2.2.

Cost - Refer to Section 3.5.2.2.

Screening Status - Since other proven soil treatment process options offer comparable treatment effectiveness at significantly lower operational costs, in-situ vitrification of soils has not been retained for alternatives development and detailed analysis.

3.6.2.5 In-Situ Fixation

Description - A brief discussion of in-situ fixation is presented in Section 2.5.3.3. Fixation methods are designed to immobilize contaminants and thereby prevent their further migration by leaching into the water phase. Mobility is reduced through the binding of hazardous constituents into a solid mass with low permeability and high ionic bonding affinity that resists leaching. Fixation processes may be cement based, pozzolanic-based, silicate-based, thermoplastic-based or organic polymer-based. Cement, pozzolanic and silicate systems are the most prevalent at the present time. Special auger technologies are used to mix materials into soil in-situ.

Effectiveness - In-situ fixation immobilizes contaminants within a solid mass. According to the treatability matrix presented in U.S. EPA (September 1988), inorganic metals are amenable to in-situ fixation. All of the organic chemical groups of concern are potentially amenable. Fixation techniques have effectively immobilized waste streams contaminated with inorganic metals and oily sludges from petrochemical manufacturing operations. Its effectiveness at immobilizing PCBs and the organic chemical groups of concern at the ACS Site has yet to be documented through case studies and SITE Program demonstrations.

Implementability - In-situ fixation has yet to be demonstrated on full scale soil cleanups. To date, its application at CERCLA Sites has been limited to pilot studies involving inorganic metals, petroleum wastes and PCBs. Fixation is a proven technology for inorganic metals and oily sludges containing organic compounds with limited leachability. Treatability studies would be required to determine the effectiveness of fixation on the contaminant matrix present at the ACS Site. Vendor availability for in-situ fixation is limited.

Cost - Costs were not developed for in-situ fixation since it is not being considered as a primary process option.

Screening Status - Since in-situ fixation of soils is not proven to be effective at treating the contaminant matrix at the ACS Site, it has not been retained for alternatives development. It has been retained for detailed analysis as a secondary treatment process option to be used in conjunction with primary process options not capable of treating inorganic metals, PCBs or certain semi-volatile organic compounds.

3.6.2.6 In-Situ Radio Frequency

Description. A brief discussion of in-situ radio frequency is presented in Section 2.5.3.3. Radio frequency has heated large volumes of soil up to 725 ^{o}F in-situ. Similar to in-situ vitrification, energy is supplied by inserting electrodes into the ground using a grid layout. When the electrode array is supplied with electromagnetic energy, an electromagnetic wave is transmitted by the exciter electrode into the target volume of soil. A vapor containment cover is placed over the treatment zone to capture VOCs for treatment by catalytic incineration or carbon adsorption.

Effectiveness - In-situ radio frequency treatment of soil transfers organic compounds to the air phase. The toxicity of organic compounds is reduced by dilution in clean air. If vapor phase thermal treatment or carbon adsorption is used, however, the destruction of organics as a result of incineration or spent carbon regeneration would result in an overall toxicity reduction.

Based on a review of vendor literature, in-situ radio frequency is applicable to compounds such as VOCs and petroleum hydrocarbons with boiling points less than 500 ^{o}F. Based on this criteria and the boiling points for the target compounds presented in Table 3-1, all of the organic chemical groups of concern, except PCBs, would be amenable to in-situ radio frequency. Inorganic metals would not be amenable to in-situ radio frequency.

Implementability - In-situ radio frequency has yet to be demonstrated on pilot or full scale soil cleanups. To date, it has only been tested on potential soil cleanup applications on a laboratory scale. This process has been used for many years to heat tar sands at depths of more than 1000 feet to enhance oil recovery operations. Vendor availability for in-situ radio frequency is limited. A pilot study to determine the effectiveness of in-situ radio frequency on treating the contaminant matrix at the ACS Site would be required. A vapor phase treatment system would be required if VOC air emission ARARs are exceeded.

Cost - A unit cost for the in-situ radio frequency treatment of soil is presented in Table 3-5. Operational costs for in-situ radio frequency are higher than operational costs associated with other relevant soil treatment process options.

Screening Status - Since in-situ radio frequency has not been demonstrated to be effective on the contaminant matrix at ACS on a pilot or full scale remediation, it has not been retained for alternatives development and detailed analysis.

3.7 Detailed Alternatives To Be Screened

The final alternatives to be evaluated in Section 4.0 have been developed in this subsection based on the preliminary screening evaluations of individual process options. The process options associated with each of the general response action alternatives are presented in Table 2-3. The process options which have been retained for detailed analysis are summarized below along with the screening status of the general response action alternatives presented in Section 2.0. A summary of the final alternatives to be evaluated in Section 4.0 is presented in Table 3-6.

3.7.1 No Action (Alternative I)

Description - No remedial action measures would be taken as part of the no action alternative. This alternative is required by the NCP to be carried forward for detailed analysis in order to provide a baseline for comparison to the other alternatives. In Section 4.0, this alternative will be designated Alternative 1.

Screening Status - The no action alternative has been retained for detailed analysis in Section 4.0.

3.7.2 Containment with Slurry Wall; On-Site Groundwater Gradient Control; Groundwater Pumping and Treatment Outside Slurry Wall (Alternative II)

Description - Alternative II involves constructing a slurry wall around the entire ACS Site. Figure 3-2 shows the proposed boundary for the slurry wall. Groundwater within the slurry wall would be pumped and treated to maintain an inward gradient. Groundwater outside the slurry wall would be pumped and treated. Contaminated soils at the ground surface would be covered to prevent contact. This will be designated as Alternative 2 in Section 4.0.

Screening Status - Alternative II has been retained for detailed analysis in Section 4.0. Air stripping, UV/oxidation and biological treatment will be evaluated as potential groundwater treatment process options.

3.7.3 Excavation and Treatment of Buried Waste; and Groundwater Pumping and Treatment (Alternative III)

Description - Alternative III is primarily a source treatment approach and involves dewatering the source areas and excavation and treatment of buried wastes only. On-Site incineration and low temperature thermal treatment are the above-ground buried wastes treatment process options which have been retained for detailed analysis. Both on-Site and off-Site groundwater pumping and treatment would be conducted.

Screening Status - Two final alternatives have been developed for analysis in Section 4.0 from applicable process options which have been retained for detailed analysis. Alternative 3A would involve dewatering the areas of contamination and excavation and on-Site incineration of buried waste. Alternative 3B would involve dewatering the areas of contamination and excavation and on-Site low temperature thermal treatment of buried waste. Air stripping, UV/oxidation and biological treatment will be evaluated as potential groundwater treatment process options for both alternatives.

3.7.4 Groundwater Pumping and Treatment (Alternative IV)

Description - Alternative IV is primarily a groundwater pumping and treatment approach. Groundwater pumping would be used to flush contaminants from the unsaturated zone. A significant volume of wastes are buried 5 to 15 feet below the existing water table at the Site.

A recent study completed by Oak Ridge National Laboratories (ORNL) supported a report published by the U.S. EPA in 1990 concerning the effectiveness of groundwater pump and treat systems. The ORNL study (Environmental Science and Technology, October 1990) and U.S. EPA report both concluded that groundwater pump and treat systems were not effective at achieving health-based cleanup objectives at hazardous waste sites.

Screening Status - Because of the high levels of contaminants present with the upper aquifer (also the presence of buried drums) at the ACS Site, groundwater pump and treat technologies would not be effective at remediating the Site in an acceptable timeframe without performing concurrent source treatment. Alternative IV has not been retained for detailed analysis in Section 4.0.

3.7.5 In-Situ Treatment of Buried Waste, Soils and Groundwater; and Groundwater Pumping and Treatment (Alternative V)

Description - Alternative V involves treating the soils, buried waste and groundwater in-situ. In-situ steam stripping is the only process option which has been retained for detailed analysis.

Screening Status - One final alternative has been developed from applicable process options which have been retained for detailed analysis. This final alternative would involve in-situ steam stripping of the buried waste, soils and groundwater. Groundwater pumping and treatment outside of the waste and contaminated soil areas would also be included. Air stripping, UV/oxidation and biological treatment will be evaluated as potential groundwater treatment process options. This alternative will be designated Alternative 4 in Section 4.0.

3.7.6 In-Situ Treatment of Buried Waste and Soils; and Groundwater Pumping and Treatment (Alternative VI)

Description - Alternative VI involves dewatering the areas of contamination and treating soils and buried waste in-situ. Vapor extraction of buried wastes and soil has been retained for detailed analysis. Groundwater pumping and treatment would be conducted in areas outside of the waste and contaminated soil area.

Screening Status - One final alternative has been developed from applicable process options which have been retained for detailed analysis. The final alternative would involve in-situ vapor extraction of buried waste and soils. Air stripping, UV/oxidation and biological treatment will be evaluated as potential groundwater treatment process options. This alternative will be designated Alternative 5 in Section 4.0.

3.7.7 Excavation and Treatment of Buried Waste; In-Situ Treatment of Soils; and Groundwater Pumping and Treatment (Alternative VII)

Description - Alternative VII involves dewatering the source areas, excavation and treatment of buried waste and in-situ treatment of soils. Based on the discussion presented in Section 3.7.3, on-Site incineration and low temperature thermal treatment are the only above-ground buried waste treatment process options which have been retained for detailed analysis. Above-ground biological treatment of buried waste has not been retained because the high organic contaminant concentrations would likely be toxic to microorganisms. The likely existence of the buried waste in a liquid, sludge or slurry state would prevent the effective implementation of either landfarming or slurry-phase biological treatment which are typically designed for treating wastes in a solid state. In-situ vapor extraction is the only soil treatment process option which has been retained for detailed analysis.

Screening Status - Two final alternatives have been developed from applicable process options which have been retained for detailed analysis. They will be designated alternatives 6A and 6B in Section 4.0. Alternative 6A would include dewatering the source areas with excavation and on-Site incineration of buried waste. Alternative 6B would include dewatering the source areas with excavation and low temperature thermal treatment of buried waste. In-situ vapor extraction of soil and groundwater pumping and treatment would be conducted outside of the areas of waste and contaminated soil. Air stripping, UV oxidation and biological treatment will be evaluated as potential groundwater treatment process options.

3.7.8 Excavation and Treatment of Buried Waste and Soils; and Groundwater Pumping and Treatment (Alternative VIII)

Description - Alternative VIII involves dewatering the areas of contamination and excavation and treatment of buried waste and soils. On-Site incineration, low temperature thermal treatment and biological treatment of buried waste and soils have been retained for detailed analysis.

Screening Status - Four final alternatives have been developed from applicable process options which have been retained for detailed analysis. All would involve dewatering the source areas and excavation and treatment of both waste and contaminated soil. They would all include groundwater pumping and treating outside of the waste and contaminated soil areas. The four alternatives would be designated alternatives 7A, 7B, 8A and 8B in Section 4.0. Air stripping, UV/oxidation and biological treatment will be evaluated as groundwater treatment process options. Alternative 7A would include excavation and incineration of both waste and soil, while Alternative 7B would consist of low temperature thermal treatment. Waste and soil would be treated biologically in a landfarm for Alternative 8A and in a slurry-phase bioreactor reactor in Alternative 8B.

SECTION 4.0
DETAILED ANALYSIS OF ALTERNATIVES

4.1 Approach to Detailed Analysis

4.1.1 Introduction

Final alternatives for detailed analysis were selected in Section 3.7. This section presents site specific descriptions and a detailed analysis of the remedial action alternatives which were retained during the preliminary screening process. Section 4.1.2 presents the nine evaluation criteria used to perform the detailed analysis of alternatives; and Sections 4.2 and 4.3 consist of the evaluation and presentation of information for each alternative relevant to the selection of a Site remedy. This approach to analyzing alternatives will provide sufficient information to adequately compare alternatives, select an appropriate Site remedy and demonstrate satisfaction of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remedy selection requirements in the Record of Decision. The initial alternatives discussed involve containment remedies, while the later alternatives involve treatment remedies. The references used in Section 4.0 to evaluate process options and develop cost estimates are presented in the *bibliography in Appendix D.*

Various independent and medium specific process options which are applicable to more than one of the final alternatives were retained for detailed analysis. Detailed analyses of these independent and medium-specific process options are presented in Section 4.2, which are separate from the detailed analyses of alternatives presented in Section 4.3. Independent and medium-specific process options discussed in Section 4.2 include groundwater extraction/collection, groundwater vertical barriers, treated water discharge, buried waste and soil access restrictions and containment, groundwater and surface water remedial technologies, thermal treatment of buried waste and soils, and biological treatment of buried waste and soils. Only potentially relevant criteria used to differentiate the process options included in more than one alternative were addressed in the detailed analyses of independent and medium-specific process options. Criteria not addressed in the detailed analyses of independent and medium-specific process options are included in the detailed analyses of applicable alternatives.

4.1.2 Parameters Used in the Detailed Analysis

Based on results of the Baseline Risk Assessment (BRA) performed during the RI, primary chemicals of concern were established for each area and medium at the ACS Site (Tables 4-1 through 4-6). The contaminants of concern are presented in this chapter solely for the purpose of evaluating the relative effectiveness of the various technologies for treating these contaminants or for evaluating potential treatment interferences caused by the contaminants of concern. Similarly, the concentration of the contaminants presented below are solely for the purpose of determining cost estimates in order to compare the relative costs of the technologies. The listing of a compound as a contaminant of concern in this chapter does not imply that the compound needs to be remediated.

Chemical groupings and target compounds from each grouping were established in Section 3.1.2. In order to facilitate the detailed analysis and design calculations, these chemical groupings and target compounds have also been retained in Section 4.0 of the FS. Minimum and maximum concentrations by chemical grouping were established for each area and medium for use in design calculations and cost estimates.

Groundwater minimum and maximum design concentrations were established based on groundwater data for monitoring wells MW-3, MW-16, MW-5 and MW-6 (i.e., monitoring wells located within the proposed area to be dewatered). Data from MW-3 and MW-16, which are located downgradient of the on- and off-Site areas, were averaged in order to establish potential maximum groundwater design contaminant levels. Data from MW-3, MW-16, MW-5 and MW-6, which also include upgradient locations, were averaged in order to establish potential minimum groundwater design contaminant levels. Potential minimum and maximum groundwater design concentrations by chemical grouping are presented in Table 4-7. Calculated exposure levels from the BRA are also presented in Table 4-7. The BRA exposure levels are a statistical representation of all of the data collected at the Site. Potential maximum groundwater design concentrations were used, where applicable, in design calculations and preparation of the primary cost estimate for each alternative.

flushing. The need for in-situ biological treatment would be evaluated during the CERCLA five year review process. In-situ biological treatment could be applied to on-Site areas outside of the source areas and off-Site areas. Applicable ARARs would have to be met in order to reinject treated groundwater.

Cost - Refer to Section 3.3.4.2.

4.2.5 Buried Waste and Soil Access Restrictions

Description

Access restrictions are described in Section 3.3.5.

Long-Term Effectiveness and Permanence

Refer to the discussion on effectiveness in Section 3.3.5.

Implementability

Refer to the discussion on implementability in Section 3.3.5.

4.2.6 Buried Waste and Soil Containment

4.2.6.1 Capping

Description

Caps, if used, would only be placed over the presently delineated areas of contamination (i.e., On- and Off-Site Contaminant Areas, Still Bottoms and Treatment Lagoon Areas and Kapica-Pazmey Area). Section 2.5.4.1 contains a description of the different types of caps. For alternatives involving treatment which requires final capping to minimize exposure to remaining residual contaminants, asphalt (concrete only if the area is located underneath an in-service tank farm) capping would be used in areas affected by ACS's continuing operations. The selection of a capping approach will be dependent on specified ARARs for the Site.

Long-Term Effectiveness and Permanence

Because the caps are used to limit direct contact and prevent rainfall infiltration, both concrete and asphalt caps would serve this function. Even if minimal cracking occurs, sealed asphaltic and concrete also have minimal infiltration. Reducing infiltration limits the leaching of contaminants that adhere to soil into groundwater.

Implementability

Capping is a standard, proven technology for containment of contaminated source areas. The design and implementation of caps are well known and available. The use of asphalt and concrete caps would be necessary for the ACS facility to remain in operation. Concrete would be placed under tank farms to provide strength to hold the weight of the tanks. Asphalt would be placed in other manufacturing areas requiring vehicular traffic or where a thicker multimedia cap would interfere with operations.

4.2.6.2 Surface Stabilization

Description

Grading, regrading, vegetative cover and dust control methods are to be used in conjunction with other technologies as described in Section 3.3.6.2.

Long-Term Effectiveness and Permanence

Refer to the discussion on effectiveness in Section 3.3.6.2. The Site will need to be graded during remedial action to redirect rainfall and control runoff. Regrading as a part of routine maintenance will be required to control runoff.

Implementability

Refer to the discussion on implementability in Section 3.3.6.2.

4.2.7 Groundwater and Surface Water Remedial Technologies

4.2.7.1 Activated Carbon Adsorption

Description

A description for the activated carbon adsorption treatment of groundwater is presented in 3.4.1.6.

Reduction in Toxicity, Mobility or Volume Through Treatment

The destruction of organics as a result of the spent carbon regeneration process would result in an overall toxicity and volume reduction of contaminants present in groundwater. Some metals are also amenable to activated carbon adsorption treatment. Based on a review of the U.S. EPA's Water Engineering Research Laboratory (WERL) treatability database (version 3.0) and other references presented in the Section 4.0

SECTION 5.0
COMPARATIVE ANALYSIS OF ALTERNATIVES

In this section, the alternatives screened in Section 3 and developed in Section 4 are compared with one another relative to the following factors as required by the National Contingency Plan:

- Overall Protection of Human Health and the Environment
- Compliance with ARARs
- Long Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility or Volume Through Treatment
- Short Term Effectiveness
- Implementability
- Cost
- Community Acceptance
- State Acceptance

5.1 Overall Protection of Human Health and the Environment

Alternative 1, the no action alternative, does not provide any protection against further migration of contaminants to the groundwater beneath the Site, nor does it prevent continued migration of contaminants away from the Site through groundwater. Therefore, although the RI does not show any current impact to groundwater wells in the vicinity of the Site, the RI's current and future land use scenarios show that the no action alternative would do nothing to prevent this from occurring sometime in the future. Alternative 1 would also do nothing to prevent future Site users from being exposed to unearthed soils resulting from future development of the Site.

Alternatives 2 thru 8 include a groundwater pump and treat system to prevent the migration of contaminants from the Site and treat contaminated groundwater over time until cleanup objectives are achieved. At least some of the treated groundwater may be

discharged to the wetlands or reinjected as part of an overall groundwater remediation system designed to prevent dewatering of the wetlands by the pump and treat system and to flush residual levels of contaminants from wetland sediments and the upper aquifer.

Waste materials buried at the Site are addressed by Alternatives 2 thru 8. Wastes are isolated within a slurry wall with Alternative 2 to prevent migration of contaminants via surface water runoff, to prevent direct contact and to reduce migration to groundwater. For alternatives 3A, 3B, 6A, 6B, 7A, 7B, 8A, and 8B, wastes are excavated and treated on-Site. Alternatives 3A, 6A, and 7A utilize high temperature thermal treatment to destroy contaminants in the waste. Low temperature thermal treatment is utilized in Alternatives 3B, 6B, and 7B. On-Site biological treatment is used in Alternatives 8A and 8B. Alternative 4 uses in-situ steam stripping to remove contaminants from buried waste materials. Alternative 5 uses in situ vapor extraction to remove contaminants from waste. Residual concentrations of contaminants in waste would remain in the ground after treatment with Alternatives 2, 4 and 5. Alternative 2 would be least effective in removing contaminants from waste. Alternative 5 would remove the majority of VOC contaminants and some SVOC contaminants. Alternative 4 would address both VOC and SVOC contaminants. Therefore, if wastes at the site were excavated under a future exposure scenario, the risks for dermal contact would be greater for Alternative 2, than Alternatives 4 and 5. There would be no risk for Alternatives 3, 6, 7 and 8 because the waste would be excavated and treated.

Contaminated soils are addressed in Alternatives 2 thru 8. Contaminated soils are isolated within a slurry wall with Alternative 2. Contaminated soils would be treated by natural flushing from rainfall infiltration with Alternatives 2 and 3. In-situ steam stripping is used in Alternative 4 to treat contaminated soils. In-situ vapor extraction is used for contaminated soils in Alternatives 5 and 6. Soils are excavated and treated with thermal and biological treatment in Alternatives 7 and 8, respectively. Residual levels of contaminants would remain in site soils after treatment for Alternatives 2, 3, 4, 5, 6 and

8. Therefore, if soils were excavated under a future exposure scenario, the risks for these alternatives would be greater than for Alternative 7.

The lowest levels of residual contaminants following source treatment would likely be achieved by Alternative 7A in which both waste and soil are excavated and incinerated. Because of its limited history, removal efficiencies for low temperature thermal treatment (Alternative 7B), if selected, cannot be determined without performing a treatability/pilot study; however, they are likely to approach those of 7A for most contaminants. Alternatives 4, 5, 6, 7, and 8 would significantly reduce the primary contaminants present in both waste and contaminated soil at the Site. By removing only buried waste, Alternative 3 would reduce the overall risk by treating the areas of highest contamination. Residual levels of contaminants in the source areas would be higher for Alternative 3 than for Alternatives 4, 5, 6, 7, and 8 because contaminated soils are only addressed by natural flushing or reinjection of groundwater in Alternative 3. Use of a slurry wall and groundwater extraction for containment purposes in Alternative 2 would reduce the migration of contaminants present in the groundwater, but would only marginally reduce the possibility of exposure to contaminated soils by future Site users.

Alternatives 2 thru 8 involve extraction to contain and treat contaminants present in the groundwater off-Site. The continued migration of contaminants in the groundwater would be reduced, which should mitigate future impact to downgradient wetlands, Turkey Creek and residential wells. The potential for lower aquifer impact would still exist for Alternatives 1, 2 and 3 since high levels of residual source contamination would remain.

5.2 Compliance with ARARs

SDWA MCLs have been identified as potential ARARs for groundwater. Contaminants identified in individual groundwater samples exceed corresponding MCLs at some parts of the Site. Alternative 1, the no action alternative, would not comply with these ARARs for the Site. Alternatives 2 thru 8 involve a groundwater pump and treat system which would be used until groundwater cleanup objectives are met.

In Section 3, several ARARs were identified for each of the Alternatives that were considered. With the exception of the no action alternative, all identified ARARs would be met by each of the alternatives.

5.3 Long-Term Effectiveness and Permanence

The RI showed that contaminants have migrated to both the upper and lower aquifers beneath the Site and are migrating away from the Site in groundwater in the upper aquifer. The RI/BRA showed that there is no imminent risk to users of groundwater in the vicinity of the Site. It is possible that there could be risk to groundwater users if the contamination at the Site is allowed to continue to migrate from the Site.

Alternative 1, the no action alternative, does nothing to prevent the continued migration of contaminants to the groundwater and away from the Site. Therefore, in the long term, conditions at the Site would be expected to deteriorate. Eventually, it is possible that contaminants from the Site would impact domestic wells in the vicinity of the Site.

The groundwater pump and treat system which is a part of Alternatives 2 thru 8 would be effective in preventing the migration of contaminants away from the Site and lowering the levels of contaminants in the groundwater over time. Each of the alternatives would be equally effective in preventing the migration of contamination away from the Site. The time required to lower the contaminant levels in on-Site groundwater is dependent on the residual concentrations of contaminants in soils and wastes. However, because off-Site migration is prevented by the groundwater pump and treat system, the length of time required to reach the groundwater cleanup objectives do not make any of the alternatives more or less effective than the others.

The buried waste at the Site does not pose a risk to human health unless there is direct contact, ingestion or inhalation of the waste. Currently, the Site is fenced or the waste is covered with soil or vegetation so there is little potential for direct contact, ingestion, or inhalation. Alternative 1, the no action alternative, does nothing additional to prevent direct contact, ingestion, or inhalation of waste. Alternative 2 provides additional cover

material over the Site, thereby reducing the potential for direct contact, ingestion, or inhalation of waste materials at the Site. The effectiveness of Alternative 2 is dependent on the cover material and slurry wall performing adequately for a long period. Proper maintenance of the cover and monitoring of groundwater outside the slurry wall would need to continue in the long term. Therefore, there is more uncertainty with this alternative than others.

Alternatives 3 thru 8 provide additional treatment of waste at the Site. In alternatives 3A, 3B, 6A, 6B, 7A, 7B, 8A, and 8B, waste is excavated and treated on-Site as described in Section 5.1. In the long term, alternatives that include removal and treatment of waste will probably result in lower residual concentrations of contaminants. Therefore, the potential for problems with long term maintenance will be lower. However, this must be compared to the short term problems of excavation and treatment of large volumes of potentially incompatible waste. Alternative 4 uses in-situ steam stripping to remove contaminants from the waste. Alternative 5 uses in-situ vapor extraction to remove contaminants from the waste. Some of the alternatives would more completely destroy certain contaminants in the waste, and the residual levels of contaminants are lower for some of the alternatives. On-Site incineration would be able to treat all of the organic contaminants in the waste. Low temperature thermal treatment, vapor extraction, landfarming and slurry phase bioreactors will also likely be effective in removing contaminants. Because these technologies have not been tested at Sites that have the wide range of contaminants and high concentrations of contaminants detected at the ACS Site, the relative effectiveness of the technologies cannot be defined without bench and pilot scale tests. A significant potential problem with Alternative 4 (steam stripping) is that the augers used to treat the waste could puncture the clay confining layer and introduce contaminants into the lower aquifer.

Residual concentrations of contaminants in waste remain in the ground after treatment with Alternatives 2, 4 and 5. Alternative 2 would be least effective in removing contaminants from waste, and long term maintenance and monitoring would be required to document long term performance. Alternative 5 would remove the majority of VOC contaminants and some SVOC contaminants. The residual contaminants that would

remain would be relatively immobile in soil and groundwater. Therefore, in the long term, there would be less uncertainty associated with Alternative 5 than Alternative 2. Alternative 4 would address both VOC and SVOC contaminants. Therefore, if wastes at the site were excavated under a future exposure scenario, the risks for dermal contact would be greater for Alternative 2 than Alternatives 4 and 5. There would be no risk for Alternatives 3, 6, 7 and 8 because the waste would be excavated and treated.

The contaminated soils at the Site do not pose a risk to human health unless there is direct contact or ingestion of the waste. Currently, the Site is fenced. In unfenced areas, most of the contaminated soil is covered with soil or vegetation so there is little potential for either direct contact or ingestion. There are a few locations across the Site where contaminated soil is exposed at the ground surface. Alternative 1, the no action alternative, does nothing additional to prevent direct contact or ingestion of contaminated soil. Alternative 2 provides additional cover material. Additional soil cover would be provided in areas where contaminated soil is exposed as a part of Alternative 3. The effectiveness of Alternative 2 is dependent on the cover material and slurry wall performing adequately for a long period. Proper maintenance of the cover and monitoring of groundwater outside the slurry wall would need to continue in the long term. Therefore, there is more uncertainty with this alternative than others.

Alternatives 4 thru 8 provide additional treatment of contaminated soils at the Site. In Alternatives 7A, 7B, 8A, and 8B, contaminated soils are excavated and treated on-Site as described in Section 5.1. In the long term, alternatives that include removal and treatment of waste will probably result in lower residual concentrations of contaminants. Therefore, the potential for problems with long term maintenance will be lower. However, this must be compared to the short term problems of excavation and treatment of large volumes of potentially incompatible waste. Alternative 4 uses in-situ steam stripping to remove contaminants from the soils and Alternative 5 uses soil vapor extraction. Some of the alternatives would more completely destroy certain contaminants in the soils, and the residual levels of contaminants are lower in some of the alternatives. Because all of the alternatives would treat the more mobile compounds

in the soil and direct contact, and ingestion is prevented by the fact that the contaminated soils are primarily subsurface, none of these alternatives are considered more effective than the others. Residual levels of contaminants would remain in site soils after treatment for Alternatives 2, 3, 4, 5, 6 and 8. Therefore, if soils were excavated under a future exposure scenario, the risks for these alternatives would be greater than for Alternative 7.

The least protective alternatives relative to potential future excavation of soil would be Alternatives 2 and 3. Alternatives 5 and 6 would be equally protective because each utilizes soil vapor extraction however, Alternative 4 may provide additional protection because this technology would be applicable to more types of contaminants.

5.4 Reduction of Toxicity, Mobility or Volume Through Treatment

Alternative 1, the no action alternative, does nothing to reduce the toxicity, mobility or volume through treatment. The mobility of contaminants is prevented in Alternatives 2 thru 8 because the groundwater pump and treat system would collect and treat any contaminants that migrate to the groundwater beneath the Site. Both the toxicity and volume of a wide range of contaminants in the groundwater would also be reduced in time as contaminants are removed with the groundwater and treated.

The toxicity and volume of contaminants in the waste at the Site are not reduced by Alternative 1, the no action alternative. Both the volume and toxicity of contaminants in the waste are reduced by Alternatives 2 thru 8. In Alternative 2, the toxicity and volume of off-Site contaminants in the upper aquifer are reduced by flushing with groundwater and treatment in the groundwater treatment system. On-Site contaminants would not be significantly reduced by this alternative. The toxicity and volume of contaminants in wastes are reduced in Alternatives 3A, 3B, 4, 5, 6A, 6B, 7A, 7B, 8A, and 8B as described in Section 5.1. The probable greatest reduction in volume would occur with high temperature incineration (3A, 6A, and 7A). The reduction in volume for low temperature thermal (3B, 6B, 7B), steam stripping (4), vapor extraction (5), landfarming (8A), and slurry-phase biological treatment (8B), would have to be determined with bench and pilot scale testing.

Low temperature thermal treatment, vapor extraction, slurry-phase biological treatment, landfarming, and steam stripping may not reduce the toxicity or volume of some semivolatile compounds. In addition, none of the alternatives reduces the toxicity or volume of heavy metals in the waste. However, both the semivolatile organic compounds and heavy metals tend to be immobilized through adsorption to soil.

The toxicity and volume of contaminants in soil are reduced in Alternatives 2 thru 8. Alternatives 2, 3A, and 3B flush contaminants below the water table as described above for waste. Alternative 4 steam strips contaminants in soil water. Vapor extraction is utilized in Alternatives 5 and 6 to reduce the volume and toxicity of contaminants in soil. The toxicity and volume of contaminants in soil are reduced in Alternatives 7A, 7B, 8A, and 8B by excavation and on-Site high temperature thermal treatment, low temperature thermal treatment, slurry-phase biological treatment and landfarming, respectively.

Alternative 2 would have the highest residual concentrations of contaminants and longest time to implement. Alternative 3 would have a significantly lower level of residual contaminants, but the implementation time is equivalent to Alternative 2. Alternatives 4 and 5 may have similar residual levels of contaminants that are lower than Alternatives 2 and 3, and similar implementation times that are shorter than Alternatives 2 and 3. Alternatives 6 and 8 have lower residual concentrations of contaminants than Alternatives 2 through 5, and a similar implementation time to Alternatives 4 and 5. Alternatives 7 has the lowest residual concentration of contaminants and shortest implementation time.

5.5 Short-Term Effectiveness

The primary migration pathway away from the Site is groundwater. The no action alternative does nothing to prevent the continued migration of contaminants from the Site. Alternatives 2 thru 8 cut off the groundwater migration pathway by the installation of a groundwater pump and treat system. Each of Alternatives 2 thru 8 would be equally effective in containing the groundwater pathway within about one to two years.

Nearby residents, ACS workers and remediation contract or workers could be exposed to airborne particulates or volatilized VOCs during excavation and material handling activities associated with Alternatives 3, 6, 7, and 8. This would be exacerbated during hot weather conditions in the summer. To prevent off-Site migration of VOCs through the air, excavation activities may have to be severely restricted during some parts of the year. Small quantities of contaminated materials could be spilled over the surface of the Site during transfer to the soil staging area. Exposures would occur over a much shorter period for Alternatives 3 and 6, which involve the excavation of buried waste only. Alternative 4 (steam stripping) and Alternative 5 (vapor extraction) are conducted in-situ so that volatilization is controlled.

5.6 Implementability

Alternatives 1 and 2, which involve no action or containment, would be the easiest to implement. Alternatives 3, 5, 6, 7, and 8 involve proven technologies which have been selected in numerous CERCLA RODs. Applications of low temperature thermal treatment (Alternatives 3B, 6B, and 7B), have been shown to be effective for a wide range of contaminant matrices. Biological treatment (Alternative 8) has yet to be demonstrated on a contaminant matrix or scale analogous to the ACS Site. Extensive treatability studies would be required to evaluate potential biological treatment mechanisms. Steam stripping (Alternative 4) has yet to be demonstrated on full scale soil and waste cleanups. There is one known vendor at the present time for in-situ steam stripping.

5.7 Cost

Capital, annual O&M and net present worth costs are presented in Table 4-16 and Appendix B.

5.8 Summary

All of the alternatives that have been considered address groundwater, the primary migration pathway from the Site, as well as waste and contaminated soils at the site. Although the residual levels of contaminants that will remain after treatment are different for the various alternatives, the majority of the remaining contaminants are semivolatile organic compounds and metals. Because these compounds do not migrate

readily, they will not result in additional groundwater contamination leaving the site. In addition, all of the alternatives include covering contaminated soils at the ground surface, so direct contact with contaminated soil or waste is prevented. Therefore, although different residual levels of contaminants would be present, in the current use scenario, all of the alternatives are effective.

Alternatives that treat waste and soil in-situ, even if they leave some residual levels of SVOCs and metals, may provide the best balance of reducing both actual and potential risk at the site. Because of the large volume of VOCs at the site, excavation of waste and soil would result in the release of VOCs to the atmosphere. In hot weather, volatilization could be very difficult to both predict and control. In addition, the drums and waste at the site were disposed of in a random fashion. Although the contaminants appear to be in an equilibrium state now, excavation could cause mixing of incompatible wastes with resulting risk to workers and residents in the area.

Alternatives 2, 3, 4, 5, 6, 7 and 8 use technologies to contain or treat waste and soils. For Alternative 2, there is little risk to workers because no excavation is involved, but it provides little reduction in contaminant levels in the long term. Alternatives 3 and 6 have more risk to workers because significant excavation occurs, but residual levels of contaminants are lower in the long term. There is a disadvantage to Alternative 4 because the augers that would be used to pump steam into the ground could puncture the clay confining layer and introduce contaminants to the lower aquifer. Therefore, although long term reductions in contaminant levels would be achieved, the short term risks may be unacceptable.

Alternative 7 provides the greatest reduction of contaminants in the long term, but the greatest potential exposure in the short term because both soils and waste are excavated. Alternative 8 also includes excavation of both soils and waste so that short term risks are higher. In addition, the treatment costs for these alternatives are also the most sensitive to increases in the volume of materials to be treated because they are directly related to material handling requirements.

Alternative 5 is considered to have an advantage because the most mobile contaminants in both the waste and soil will be removed in-situ and workers or residents would not be exposed to contaminants. Treatability studies will be needed to assess vapor extraction for wastes at the site. These can be conducted within early stages of operation as the system is used to treat contaminated soils.

Table 3-5b

Total Costs for Buried Waste and Soil Process Options

Process Option[1]	Literature Unit Cost ($)	Literature Unit Basis	Unit Cost Per Cubic Yard[7] ($/cu yd)
I. Buried Waste			
Land Farm[2]	$90	cubic yard	$90
Slurry-Phase Bioreactor[2,3]	$150	cubic yard	$150
On-Site Incineration[2,4]	$250	ton	$370
Off-Site Incineration[2]	$1500	ton	$2220
On-Site Low Temp Thermal[2]	$140	ton	$185
In-Situ Vitrification[2]	$375	ton	$555
II. In-Situ Treatment of Buried Waste, Soil and Groundwater			
Biological[2]	$130	cubic yard	$130
Steam Stripping[6]	$300	cubic yard	$300
III. Above-Ground Soil Treatment			
Land Farm[2]	$90	cubic yard	$90
Slurry-Phase Bioreactor[2,3]	$150	cubic yard	$150
On-Site Incineration[2,4]	$250	ton	$370
Off-Site Incineration[2]	$1500	ton	$2220
On-Site Low Temp Thermal[2]	$125	ton	$185
Above-ground Vapor Extraction	NA	NA	NA
Critical Fluids Extraction[2,4]	$100	cubic yard	$100
IV. In-Situ Soil Treatment			
In-Situ Vapor Extraction with Vapor Phase Carbon Adsorption[2]	$67	ton	$100
In-Situ Vitrification[2]	$375	ton	$555
In-Situ Radio Frequency[5]	$220	cubic yard	$220

NA - Unit Cost Not Available in Literature

Notes:

1. Soil excavation costs are not included in cost estimates for above-ground soil treatment process options. Unit costs include primary equipment and installation, labor, raw materials and utilities.
2. Unit cost obtained from literature. Refer to bibliography at end of Section 3.0 for a list of references used to evaluate process options and develop cost estimates.
3. Unit cost does not include costs associated with biological sludge management.
4. Unit cost does not include costs associated with residuals disposal.
5. In-situ radio frequency unit cost is based on in-situ vitrification unit cost and engineering design calculations and judgment.
6. In-situ steam stripping unit cost is estimated using similar in-situ treatment technology unit costs and engineering design calculations and judgment.
7. Unit costs converted from a per ton to per cubic yard basis by multiplying by 1.48 tons per cubic yard, an average bulk density of soil.

Table 2-1

Process Options Passing Technology Screening
American Chemical Services
Griffith, Indiana

General Response Action	Remedial Technology	Process Option
Groundwater and Surface Water		
No Action	None	None
Institutional Measures	Deed Restriction	None
	Well Closure	None
	Monitoring	None
Containment	Vertical Barriers	Soil/Bentonite Slurry Wall
		Cement/Bentonite Slurry Wall
	Extraction/Collection	Extraction Wells
		Pipe and Media Drains
Direct Treatment Onsite	Biological	Aerobic
		Anaerobic
	Chemical	Flocculation
		Precipitation
		Oxidation
		Photolysis
		Reduction
	Physical	Filtration
		Air Stripping
		Steam Stripping
		Carbon Adsorption
		Ion Exchange
Offsite Treatment	Biological	POTW
In-Situ Treatment	Biological	Aerobic
		Anaerobic
	Physical	Steam Stripping
Treated Water Discharge	Offsite Discharge	POTW
	Onsite Discharge	Recharge Wells
		Surface Water Outfall
		Discharge to Wetlands

Table 2-1 (continued)

General Response Action	Remedial Technology	Process Option
Buried Waste		
No Action	None	None
Access Restrictions	Deed Restrictions	None
	Fence	None
Removal	Biological	Bioreactor/Land Farming
	Thermal	On and Offsite Incineration
		On and Offsite Low Temperature
In-Situ Treatment	Biological	Aerobic
		Anaerobic
	Physical	Vitrification
		Vapor Extraction
Containment	Cap	Clay and Soil
		Multimedia
Soils and Sediments		
No Action	None	None
Access Restrictions	Deed Restrictions	None
	Fence	None
	Trespassing Restrictions	None
Removal	Biological	Bioreactor/Land Farming
	Thermal	On and Offsite Incineration
		On and Offsite Low Temperature
	Physical	Vapor Extraction
		Solvent Extraction
		Fixation
	Land Disposal	On and Offsite RCRA Landfill
In-Situ Treatment	Biological	Aerobic
		Anaerobic
	Physical	Vapor Extraction
		Vitrification
		Fixation
		Radio-Frequency
		Steam Stripping
Containment	Cap	Clay and Soil
		Multimedia
	Stabilization	Revegetation

Table 2-1 (continued)

General Response Action	Remedial Technology	Process Option
Landfill		
No Action	None	None
Institutional Measures	Monitoring	None
	Fence	None
	Deed Restrictions	None
Containment	Cover	Soil
	Cap	Single Layer Multi Layer
Leachate Removal and Disposal	On-Site Treatment	Same as Groundwater
	Off-Site Treatment	Discharge to POTW

Table 2-2

Alternatives To Be Screened
American Chemical Services
Griffith, Indiana

- No action;
- Slurry wall site; and groundwater pumping and treatment outside of slurry wall;
- Excavation and treatment of buried waste; and groundwater pumping and treatment;
- Groundwater pumping and treatment;
- In-situ treatment of the buried waste, soils and groundwater; and groundwater pumping and treatment;
- In-situ treatment of buried waste and soils; and groundwater pumping and treatment;
- Excavation and treatment of buried waste; in-situ treatment of soils; and groundwater pumping and treatment; and
- Excavation and treatment of buried waste and soils; and groundwater pumping and treatment.

TABLE 2-3

Alternative Development Matrix
American Chemical Services
Griffith, Indiana

Alternative	Groundwater (1)	Buried Waste (2)	Soils/Sediments with VOCs & SVOCs (3)	Soils/Sediments with VOCs, SVOCs & PCBs (4)	Soils/Sediments with VOCs, SVOCs, PCBs and Metals (5)
I. No action	No action	No action	No action	No action	No action
II. Slurry wall site; and groundwater pumping and treatment outside slurry wall	Slurry wall and a. UV oxidation, b. carbon adsorption, c. air or steam stripping, d. biological treatment, or e. off-site discharge to POTW.	Natural flushing	Natural flushing	Natural flushing, cover	Natural flushing, cover
III. Excavation and treatment of buried waste; and groundwater pumping and treatment	a. UV oxidation, b. carbon adsorption, c. air or steam stripping, d. biological treatment, or e. off-site discharge to POTW.	Excavation and f. on-site incineration, g. off-site incineration, or h. biological treatment.	Natural flushing	Natural flushing, cover	Natural flushing, cover
IV. Groundwater pumping and treatment	a. UV oxidation, b. carbon adsorption, c. air or steam stripping/carbon adsorption, d. biological treatment, or e. off-site discharge to POTW.	Natural flushing	Natural flushing	Natural flushing, cover	Natural flushing, cover

TABLE 2-3

Alternative Development Matrix
American Chemical Services
Griffith, Indiana

Alternative	Groundwater (1)	Buried Waste (2)	Soils/Sediments with VOCs & SVOCs (3)	Soils/Sediments with VOCs, SVOCs & PCBs (4)	Soils/Sediments with VOCs, SVOCs, PCBs and Metals (5)
V. In-situ treatment of buried waste, soils and groundwater; and groundwater pumping and treatment	a. Biological treatment, or b. steam stripping.	c. Biological treatment, or d. steam stripping.	e. Biological treatment, or f. steam stripping.	g. Biological treatment, or h. steam stripping.	i. Biological treatment, or j. steam stripping.
VI. In-situ treatment of buried waste and soils; and groundwater pumping and treatment	a. UV oxidation, b. carbon adsorption, c. air or steam stripping, d. biological treatment, or e. off-site discharge to POTW.	f. Vitrification, or g. vapor extraction.	h. Vitrification, or i. vapor extraction.	j. Vitrification, or k. vapor extraction.	l. Vitrification, or m. vapor extraction with fixation of metals.
VII. Excavation and treatment of buried waste; in-situ treatment of soils; and groundwater pumping and treatment	a. UV oxidation, b. carbon adsorption, c. air or steam stripping, d. biological treatment, or e. off-site discharge to POTW.	Excavation and f. on-site incineration, g. off-site incineration, or h. biological treatment.	i. Vapor extraction, j. steam stripping, k. biological treatment, l. vitrification, or m. radio frequency.	n. Vapor extraction with fixation of PCBs, o. steam stripping with fixation of PCBs, p. biological treatment with fixation of PCBs, q. vitrification, or r. radio frequency with fixation of PCBs.	s. Vapor extraction with fixation of PCBs and metals, t. stream stripping with fixation of PCBs and metals, u. biological treatment with fixation of metals, v. vitrification, or w. radio frequency with fixation of PCBs and metals.

TABLE 2-3

Alternative Development Matrix
American Chemical Services
Griffith, Indiana

Alternative	Groundwater (1)	Buried Waste (2)	Soils/Sediments with VOCs & SVOCs (3)	Soils/Sediments with VOCs, SVOCs & PCBs (4)	Soils/Sediments with VOCs, SVOCs, PCBs and Metals (5)
VIII. Excavation and treatment of buried waste and soils; and groundwater pumping and treatment	a. UV oxidation, b. carbon adsorption, c. air or steam stripping, d. biological treatment, or e. off-site discharge to POTW.	Excavation and f. on-site incineration, g. off-site incineration, or h. biological treatment.	i. On or off-site incineration, j. on or off-site low temp thermal, k. vapor extraction, l. solvent extraction, or m. biological treatment.	n. On or off-site incineration, o. vapor extraction with PCB fixation, p. solvent extraction, or q. biological treatment.	r. On or off-site incineration with fixation of metals, s. vapor/steam extraction with fixation of PCBs and metals, t. solvent extraction with fixation of metals, or u. biological treatment with fixation of metals.

Notes:

(1) Includes all areas of the site.

(2) Includes On- and Off-Site Containment Areas and Still Bottoms Pond/Treatment Lagoon Areas.

(3) Includes On- and Off-Site Containment Areas, Still Bottoms Pond/Treatment Lagoon Areas and Kapica/Pazmey Area.

(4) Includes limited soil volumes and areas within all of the locations described in Note 2 above.

(5) Includes Kapica/Pazmey Area only.

TABLE 3-1
PHYSICAL CONSTANTS FOR TARGET COMPOUNDS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Target Compound	Molecular Weight (gm/mole)[1]	Boiling Point(°C)[1]	Vapor Pressure (mmHg) [1,3]	Henry's Law [1,3] Constant (atm-m^3/mole)	Solubility (mg/l) [1,3]	Log K_{ow}[1]	Log P_{ac}[2]
Benzene	78	80	95	.00559	1,750	2.12	3.58
Benzoic Acid	122	249	.0045	7.0E-8	2,700	1.87	3.70
Bis(2-chloroethyl) ether	143	178	1.55	1.31E-7	10,200	1.50	3.30
Bis(2-ethylhexyl) phthalate	391	230	6.45E-6	1.1E-5	0.3	5.11	5.70
Chloroethane	65	12	766	.0148	5,740	1.54	2.80
Chloroform	119	62	246	.00287	8,200	1.97	3.60
1,2-Dichlorobenzene	147	181	1.47	.00193	100	3.60	4.90
Di-n-butylphthalate	278	340	1.4E-5	2.82E-7	13	5.60	5.30
Isophorone	138	214	0.38	5.8E-6	12,000	2.22	3.75
Methyl Ethyl Ketone	72	80	91	2.74E-5	268,000	0.26	2.25
4-Methylphenol	108	202	0.13	1.10E-6	31,000	1.97	NA
Naphthalene	128	218	.082	.000483	32	3.30	5.20
PCBs	328	350	4.05E-5	.00107	.0310	6.04	6.00
Tetrachloroethene	166	121	18	.0259	150	2.60	5.40
Toluene	92	111	28	.00637	535	2.73	2.88
1,1,1-Trichloroethane	133	74	124	.0144	1,500	2.50	4.20
Vinyl Chloride	63	-14	2660	.0819	2,670	1.38	NA

NA - Not available

Notes:
1. Physical constants obtained from U.S. EPA (1986) and Howard (1990)
2. Log P_{ac} data obtained from Verschueren (1983)
3. Henry's law constant, vapor pressure and solubility data based on temperatures of 20°C or 25°C.
4. Physical constants for inorganic metals target compounds have not been included since the preliminary screening analysis did not require this data.

TABLE 3-2
SELECTED LOCATION - SPECIFIC POTENTIAL, APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Location	Requirements	Prerequisites for Applicability	Citation
Within 100-year floodplain	Facility must be designed, constructed, operated, and maintained to avoid washout	RCRA hazardous waste; treatment, storage or disposal	40 CFR 264.18(b) 329 IAC 3-41-9(b)
	Landfill unit must be constructed/designed such that it is not in the 100-year floodplain. Variances may be granted based on adverse effects.	Solid or hazardous waste permit application	IDEM, OSHWU permit requirements
Within floodplain	Action to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values	Action that will occur in a floodplain, i.e., lowlands, and relatively flat areas of adjoining inland and coastal waters and other flood prone areas	Protection of floodplains (40 CFR 6, Appendix A); Fish and Wildlife Coordination Act (16 USC 661 et seq); 40 CFR 6.302
	Approval by Indiana DNR, Division of Water for plans involving construction, excavation, or fill in a floodplain.	Activities that will occur in a floodplain	IC 13-22-2
Area affecting stream or river	Action to protect fish or wildlife	Diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife	Fish and Wildlife Coordination Act (16 USC 661 et seq); 40 CFR 6.302
Effluent to stream or river	Site specific water quality standards for direct discharge of pollutants, per IDEM, OWM interpretation based on U.S. EPA Ambient Water Quality Criteria	Discharge of pollutants to the state's streams and rivers	327 IAC 2-1 327 IAC 2-1-6(b) 327 IAC 5
Underground Waters	Minimum Water Quality Conditions for all waters of the state, standards for public drinking water and water for industrial use	Activities affecting the quality of waters of the state	330 IAC 1-1-6(a) 327 IAC 2-1-7 327 IAC 2-1-6(f) 327 IAC 2-1-6(g)
Wetlands	Site specific operating permit requirements for activities which impact wetlands	Activities in wetlands	U.S. Army Corps of Engineers permit; Certification by the State Water Quality Surveillance Standards Branch; Indiana DNR Division of Water Requirements

TABLE 3-2
SELECTED LOCATION - SPECIFIC POTENTIAL, APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Location	Requirements	Prerequisites for Applicability	Citation
Area Atmosphere	Site specific operating permit requirements for emissions of VOCs	Air emissions of VOCs sufficient for state rules to apply	326 IAC 2-1 326 IAC 8-1
	Potential TBC	Public health excess lifetime cancer risk of 10E-6 exceeded	U.S. EPA requirement
		New rules developed and approved for toxic air emissions by the Air Pollution Control Board prior to applicable remedial actions	Rules as developed and approved
	PM10 portion of particulate matter must meet National Ambient Air Quality Standards	PM10 emissions may be subject to control to prevent emissions of dangerous chemicals or gases on a case-by-case basis	326 IAC 4-2
	Fugitive dust from soil handling is subject to off-site opacity limits	Fugitive dust must be controlled	326 IAC 6-4 and 6-5

TABLE 3-3
SELECTED ACTION - SPECIFIC POTENTIAL, APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Action	Requirements	Prerequisites for Applicability	Citation
Air Emissions from On-Site Treatment Operations	National primary and secondary ambient air quality standards for sulfur dioxide, particulate matter, carbon monoxide, volatile organic compounds, nitrogen dioxide, arsenic and lead are established.	Air emissions of sulfur dioxide, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead.	40 CFR 50.1 - 50.12 326 IAC 1-3-4
	Regulations listing standards for eight hazardous air pollutants, along with the monitoring, testing, reporting, and recordkeeping requirements for each.	Air emissions of asbestos, benzene, beryllium, coke oven emissions, inorganic arsenic, mercury, radionuclides, and vinyl chloride.	40 CFR 61.01 - 61.252
	Construction and operating permit requirements for a source of regulated pollutants.	Air emissions of VOCs and particulate matter	326 IAC Article 2-1 40 CFR 264 Subpart AA and BB
	BACT required for VOC treatment.	New source with VOC emissions greater than 25 tons per year.	326/IAC Article 8
Closure with Post-Closure Care	Multi-layer cap for closure; minimum 30-year groundwater monitoring and a post-closure care plan; surface water controls for water contacting active face and for any leachate	Applicable for closure in place of wastes regulated under RCRA provisions	40 CFR 264 329 IAC 3-45 and 3-46
	Potential TBC-Proposed RCRA Corrective Action rules for closure of an Interim Status facility.	May be applicable if soils and groundwater residual contamination following the completion of remedial action activities exceed established health-based cleanup objectives.	40 CFR 264 Subpart S
Closure with No Post-Closure Care (e.g., Clean Closure)	General performance standard requires elimination of need for further maintenance and control; elimination of post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products.	Applicable to land-based unit containing hazardous waste. Applicable to RCRA hazardous waste (listed or characteristic) placed at site after the effective data of the requirements or placed into another unit. Not applicable to material treated, stored, or disposed only before the effective date of the requirements, or if treated in-situ, or consolidated within areas of contamination. Designed for cleanup that will not require long-term management. Designed for cleanup to health-based standards.	40 CFR 264.111 13 IC Article 7 329 IAC 3-46
	Disposal or decontamination of equipment, structures, and soils. Removal or decontamination of all waste residues, contaminated containment system components (e.g., liners, dikes), contaminated subsoils, and structures and equipment contaminated with waste and leachate, and management of them as hazardous waste.	May apply to surface impoundments and container or tank liners and hazardous waste residues, and to contaminated soil, including soil from dredging or soil disturbed in the course of drilling or excavation, and returned to land.	40 CFR 264.111 40 CFR 264.178 40 CFR 264.197 40 CFR 264.288(o)(1) and 40 CFR 264.258
	Meet health-based levels at unit.		
	Potential TBC-Proposed RCRA Corrective Action rules for closure of an Interim Status facility.	May be applicable if soils and groundwater residual contamination following the completion of remedial action activities exceed established health-based cleanup objectives.	40 CFR 264 Subpart S

TABLE 3-3
SELECTED ACTION - SPECIFIC POTENTIAL, APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA
Page 2

Action	Requirements	Prerequisites for Applicability	Citation
Registration of Extraction Wells	Extraction wells must be registered and an alternative water supply must be provided to persons affected by the wells.	Extraction well(s) qualify as a "Significant Water Withdrawal Facility"	IC-13-2-6.1
Hazardous Waste Generation, Storage and Off-Site Disposal	Site must obtain a U.S. EPA identification number	Generation of RCRA hazardous wastes (listed or characteristic) in excess of 1000 kilograms per month which are stored on-site for less than 90 days prior to off-site disposal. Small quantity generators are not subject to the 90-day limit (40 CFR 262.34(c), (d) and (e)).	40 CFR 262.12 329 IAC 3-7-3
	Tank storage of hazardous waste must meet design and storage requirements in 40 CFR 264 listed below, excluding closure requirements.		40 CFR 262.34 329 IAC 3-9-5
	Containers of hazardous waste must meet storage requirements in 40 CFR 264 listed below, excluding secondary containment and closure requirements.		40 CFR 262.34 329 IAC 3-9-5
	Accumulation of hazardous waste can not exceed 90 days.		40 CFR 262.34 329 IAC 3-9-5
	A Uniform Hazardous Waste Manifest must be completed for all off-site hazardous waste shipments.		40 CFR 262.20 329 IAC 3-8-1
PCB Generation, Storage and Off-Site Disposal	Refer to 40 CFR 761 Subparts C and K and 761.60	Generation, storage and off-site disposal of PCB soils and debris greater than 50ppm.	40 CFR 761 Subparts C and K, and 761.60
Hazardous Waste Tank Storage	The tank material of construction must be compatible with the hazardous wastes being stored in it.	Storage of RCRA hazardous waste (listed or characteristic) not meeting small quantity generator criteria held for a temporary period greater than 90 days before treatment, disposal, or storage elsewhere (40 CFR 264.10), in a container (i.e., any portable device in which a material is stored, transported, disposed of, or handled). A generator who accumulates or stores hazardous waste on-site for 90 days or less in compliance with 40 CFR 262.34(a)(1-4) is not subject to full RCRA storage requirements.	40 CFR 264 Subpart J 329 IAC 3-49
	Incompatible wastes should not be mixed in the same tank.		
	Flammable or reactive wastes should be buffered from all potential ignition sources and comply with National Fire Protection Association buffer zone requirements		
	The tank system must have sufficient structural integrity and is acceptable for storing and treating hazardous waste. The foundation, structural support, seams, connections and pressure controls must be adequately designed, and the tank system has sufficient structural strength, compatibility with the waste to be stored or treated, and corrosion protection to ensure that it will not collapse, rupture or fail.		

TABLE 3-3
SELECTED ACTION - SPECIFIC POTENTIAL, APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Action	Requirements	Prerequisites for Applicability	Citation
	In order to prevent the release of hazardous waste into the environment, secondary containment that is designed, installed and operated to prevent any migration of waste out of the system to the surrounding environment at any time during the use of the tank system must be provided.		
	VOC emission control and monitoring for storage or treatment process vents or equipment leaks.	Storage of hazardous wastes in tanks or operation of treatment processes which vent to the atmosphere.	40 CFR 264 Subparts AA & BB
	The tank system must be provided with a leak detection system designed and operated to detect the presence of a hazardous waste release or the failure of either the primary or secondary containment structure within a 24 hour period.		
	Appropriate controls and practices must be provided to prevent spills and overflows from the tank system.		
	Daily inspections of tank system components must be documented.		
	At closure, the owner or operator must remove or decontaminate all waste residues, contaminated containment system components, contaminated soils and structures and equipment contaminated with waste.		
	Storage of banned waste must be in accordance with 40 CFR 268. When such storage occurs beyond one year, the owner/operator bears the burden of proving that such storage is solely for the purpose of accumulating sufficient quantities to allow for proper recovery, treatment, and disposal.		40 CFR 268.50
	Inclusion of new source performance standards for VOC emissions.	New tank storage with capacity in excess of 10.567 gallons storing liquids with vapor pressure greater than 0.51 psia.	326 IAC 12 40 CFR 60

TABLE 3-3
SELECTED ACTION - SPECIFIC POTENTIAL, APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Action	Requirements	Prerequisites for Applicability	Citation
Hazardous Waste Container Storage	Containers of RCRA hazardous waste must be: · Maintained in good condition; · Compatible with hazardous waste to be stored; and · Closed during storage (except to add or remove waste). Inspect container storage areas weekly for deterioration. Place containers on a sloped, crack-free base, and protect from contact with accumulated liquid. Provide containment system with a capacity of 10 percent of the volume of containers of free liquids. Remove spilled or leaked waste in a timely manner to prevent overflow of the containment system. Containment must be able to contain leaks, spills, and other liquids in the containment system. Keep containers of ignitable or reactive waste at least 50 ft from the facility's property line. Keep incompatible materials separate. Separate incompatible materials stored near each other by a dike or other barrier. Run-on or rainwater in the containment may be hazardous, and handled as a hazardous waste. At closure, remove all hazardous waste and residues from the containment system, and decontaminant or remove all containers, liners.	Storage of RCRA hazardous waste (listed or characteristic) not meeting small quantity generator criteria held for a temporary period greater than 90 days before treatment, disposal, or storage elsewhere (40 CFR 264.10), in a container (i.e., any portable device in which a material is stored, transported, disposed of, or handled). A generator who accumulates or stores hazardous waste on-site for 90 days or less in compliance with 40 CFR 262.34(a)(1-4) is not subject to full RCRA storage requirements. Small Quantity generators are not subject to the 90-day limit (40 CFR 262.34 (c), (d), and (c)).	40 CFR 264 Subpart I 329 IAC 3-48
	Storage of banned waste must be in accordance with 40 CFR 268. When such storage occurs beyond one year, the owner/operator bears the burden of proving that such storage is solely for the purpose of accumulating sufficient quantities to allow for proper recovery, treatment, and disposal.		40 CFR 268.50

TABLE 3-3
SELECTED ACTION - SPECIFIC POTENTIAL, APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Action	Requirements	Prerequisites for Applicability	Citation
PCB Container Storage	Refer to 40 CFR 761.65	Storage of PCB soil and debris greater than 50ppm in containers prior to on-site treatment or off-site disposal.	40 CFR 761.65
Construction of New Hazardous Waste and PCB Landfill On-Site	Minimum Technology Requirements		40 CFR 264 Subpart N
	Install two liners or more, a top liner that prevents waste migration into the liner, and a bottom liner that prevents waste migration through the liner.(b)	RCRA hazardous waste (listed or characteristic) and/or PCB soil and debris greater than 50 ppm being placed in a new landfill.	329 IAC 3-53
	Install leachate collection systems above and between the liners.		
	Construct run-on and run-off control systems capable of handling the peak discharge of a 25-year storm.		
	Control wind dispersal of particulates.		326 IAC 6-4
	Operation and maintenance		
	Close each cell with a final cover after the last waste has been received.		
	Establish and meet TCLPs using BAT subject to land band requirements.		40 CFR 268
	Groundwater Monitoring		
	Establish a detection monitoring program (264.98). Establish a compliance monitoring program (274.99) and corrective action monitoring program (264.100) when required by 40 CFR 264.91. All monitoring programs must meet RCRA general groundwater monitoring requirements (264.97).	Creation of a new landfill unit to treat, store, or dispose of RCRA hazardous wastes as part of a response action.	
Excavation	Movement of excavated materials to new location and placement in or on land will trigger land disposal restrictions for the excavated waste or closure requirements for the unit in which the waste is being placed.	Materials containing RCRA hazardous wastes subject to land disposal restrictions are placed in another unit.	40 CFR 268 (Subpart D) 326 IAC 6-4 and 6-5
	Area from which materials are excavated may require cleanup to levels established by closure requirements.	RCRA hazardous waste placed at site.	See "Closure" Action in this table

TABLE 3-3
SELECTED ACTION - SPECIFIC POTENTIAL, APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Action	Requirements	Prerequisites for Applicability	Citation
Incineration of Hazardous Waste and PCBs	Analyze the waste feed.	Incineration of RCRA hazardous waste and/or PCB soil and debris at a PCB concentration greater than 50 ppm.	40 CFR 264 Subpart O IAC 329 3-54
	Dispose of all hazardous waste and residues including ash, scrubber water and scrubber sludge.		
	No further requirements apply to incinerators that only burn wastes that are listed as hazardous solely by virtue of contamination with other wastes, and if the waste analysis demonstrates that no Appendix VIII constituent is present that might reasonably be expected to be present.		
	Performance standards for incinerators: · Achieve a destruction and removal efficiency of 99.99 percent for each principal organic hazardous constituent in the waste feed and 99.9999 percent for dioxins; · Reduce hydrogen chloride emissions to 1.89 kg/hr or 1 percent of the HCL in the stack gases before entering any pollution control devices; and · Not release particulate in excess of 180 mg/dscm corrected for amount of oxygen in stack gas.		
	Monitoring of various parameters during operation of the incinerator is required. These parameters include: · Combustion temperature; · Waste feed rate; · An indicator of combustion gas velocity; and · Carbon monoxide.		
	Control fugitive emissions either by: · Keeping combustion zone scaled; or · Maintaining combustion-zone pressure lower than atmosphere.		40 CFR 264.345 326 IAC 4-2
	Utilize automatic cut-off system to stop waste feed when operating conditions deviate.		

TABLE 3-3
SELECTED ACTION - SPECIFIC, POTENTIAL, APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Action	Requirements	Prerequisites for Applicability	Citation
	National primary and secondary ambient air quality standards for sulfur dioxide, particulate matter, carbon monoxide, volatile organic compounds, nitrogen dioxide, and lead are established.	Air emissions of sulfur dioxide, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead.	40 CFR 50.1 - 50.12
	Requires owners or operators of incineration facilities to monitor and test air emissions for compliance with the standard for particulate matter.		40 CFR 60.50 - 60.54
Land Treatment	Prior to land treatment, the waste must be treated to BDAT levels or meet a no migration standard.	RCRA hazardous waste being treated or placed into another unit.	40 CFR 264 Subparts K, L and M
	Ensure that hazardous constituents are degraded, transformed, or immobilized within the treatment zone.		329 IAC 3-50, 3-51 and 3-52
	Maximum depth of treatment zone must be no more than 1.5 meters (5 feet) from the initial soil surface and more than 1 meter (3 feet) above the seasonal high water table.		
	Demonstrate that hazardous constituents for each waste can be completely degraded, transformed, or immobilized in the treatment zone.		
	Minimize run-off of hazardous constituents.		
	Maintain run-on/run-off control and management system.		
	Special application conditions if foodchain crops are grown in or on treatment zone.		
	Unsaturated zone monitoring.		
	Special requirements for ignitable or reactive waste.		
	Special requirements for incompatible wastes.		
	Special testing and location requirements for certain hazardous wastes.	RCRA waste Nos. F020, F021, F022, F023, F026, F027 (dioxin-containing wastes).	

TABLE 3-3
SELECTED ACTION - SPECIFIC POTENTIAL, APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Action	Requirements	Prerequisites for Applicability	Citation
Surface Water Control	Prevent run-on and control and collect from a 24-hour 25-year storm (waste piles, land treatment facilities, landfills). Prevent over-topping of surface impoundment.	RCRA hazardous waste treated, stored, or disposed of after the effective date of the requirements.	40 CFR 264.251(c), (d) 40 CFR 254.273(c), (d) 40 CFR 264.301(c), (d) 329 IAC 3-51-2, 3-52-4 and 3-53-2 40 CFR 264.221(c)
Treatment of Hazardous Waste or PCBs (in a unit)	Design and operating standards for unit in which hazardous waste is treated. (See citation at right for design and operating requirements for specific unit.)	Treatment of hazardous waste or PCB soil and debris greater than 50 ppm in a unit.	40 CFR 264.221 and 329 IAC 3-50-2 (Surface Impoundments) 40 CFR 264.251 and 329 IAC 3-51-2 (Waste Piles) 40 CFR 264.273 and 329 IAC 3-52-4 (Land Treatment Unit) 40 CFR 264.343-.345 and 329 IAC 3-54-4 thru 3-54-6 (Incinerators) 40 CFR 264.601 (Misc. Treatment Units) 40 CFR 265.373 and 329 IAC 3-30-2 (Thermal Treatment Units) 40 CFR 761 Subpart D (PCB Storage and Disposal) 329 IAC 3-21
Placement of Hazardous Waste in Land Disposal Unit	Land Disposal Restrictions: Attain land disposal "treatment standards" before putting waste into landfill in order to comply with land ban restrictions. A treatment standard can be either: (1) a concentration level to be achieved (performance-based); or (2) a specified technology that must be used (technology-based). If the standard is performance-based, any technology can be used to achieve the standard. (See Treatment when waste will be land disposed.)	Placement of RCRA hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground mine or cave.	40 CFR 268 (Subpart D)

TABLE 3-3
SELECTED ACTION - SPECIFIC POTENTIAL, APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Action	Requirements	Prerequisites for Applicability	Citation
Discharge of Treatment System Effluent	Best Available Technology: Use of the best available technology (BAT) economically achievable is required to control toxic and nonconventional pollutants. Technology-based limitations may be determined on a case-by-case basis.	Point source discharge to waters of the United States. (i)(j)	40 CFR 122.44 327 IAC 5
	Water Quality Standards: Applicable Federally approved State water quality standards must be complied with. These standards may be in addition to or more stringent than other Federal standards under the CWA.(k)		40 CFR 122.44 327 IAC 5-2-10 40 CFR 131 40 CFR 125-Subpart A 40 CFR 122.44(c)
	Discharge limitations must be established at more stringent levels than technology-based standards for toxic pollutants.		327 IAC 5-2-9 327 IAC 2-1
	Discharge in compliance with the instructions of an on-scene coordinator or a state employee acting in a similar capacity, which does not require an NPDES permit.	Facility comes under the exclusionary provision of 327 IAC 5-2-3(a)(5)	327 IAC 5-2-3 40 CFR 1510 33 CFR 153.10(c)
	Construction permit applications for wastewater treatment	Proposed construction of wastewater treatment facility.	40 CFR 122.21 IDEM, Office of Water Management
	Best Management Practices: Develop and implement a Best Management Practices Program to prevent the release of toxic constituents to surface waters.		40 CFR 125.100
	The Best Management Practices program must:	Discharge to waters of the U.S.	40 CFR 125.104
	· Establish specific procedures for the control of toxic and hazardous pollutant spills.		
	· Include a prediction of direction, rate of flow, and total quantity of toxic pollutants where experience indicates a reasonable potential for equipment failure.		
	· Assure proper management of solid and hazardous waste in accordance with regulations promulgated under RCRA.		

TABLE 3-3
SELECTED ACTION - SPECIFIC POTENTIAL, APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Action	Requirements	Prerequisites for Applicability	Citation
	Approved test methods for waste constituent to be monitored must be followed. Detailed requirements for analytical procedures and quality control are provided.		40 CFR 136.1-136.4
	Sample preservation procedures, container materials, and maximum allowable holding times are prescribed.		
	Comply with additional substantive conditions such as: · Duty to mitigate any adverse effects of any discharge; and · proper operation and maintenance of treatment systems.		40 CFR 122.41
Discharge to Publicly Owned Treatment Works (POTW)	Discharge of pollutants that pass-through the POTW without treatment, interfere with POTW operation, contaminate POTW sludge, or endanger health/safety of POTW workers, is prohibited.	Indirect discharge to a POTW.	40 CFR 403
	Notification by the Hammond POTW to the U.S. EPA of the new introduction of pollutants into the POTW by a direct discharger.	The discharge of treated or untreated surface and/or groundwater from the ACS Site to the Hammond POTW.	40 CFR 122.42(b)
	Discharge must comply with local POTW pretreatment program, including POTW hydraulic capacities, specific pollutants, spill prevention program requirements, and reporting and monitoring requirements.		40 CFR 403.5 327 IAC 5-11 thru 5-15
	Regulatory requirements of the IDEM Office of Water Management and Office of Air Management	Pretreatment facilities construction for water and/or air emissions type facilities	326 IAC 8
	RCRA Permit-by-rule requirements (including corrective action where the NPDES permit was issued after November 8, 1984) must be complied with for discharge of RCRA hazardous wastes to POTWs.	Transport of RCRA hazardous wastes to POTWs by truck, rail, or dedicated pipe (i.e., pipe solely dedicated for hazardous waste [as defined in 40 CFR 264] which discharges from within the boundaries of the CERCLA site to within the boundaries of the POTW).	40 CFR 270.60

TABLE 3-4
SELECTED CHEMICAL-SPECIFIC POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES
GRIFFITH, INDIANA

Requirements	Citation
Establishes Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) for drinking water.	40 CFR 141
Establishes water quality standards for the State of Indiana	327 IAC 2-1
Establishes requirements for PCB spill cleanup	40 CFR 761 Subpart G
Potential TBC - RCRA health-based "action levels" for individual Appendix VIII hazardous constituents	July 27, 1990 Federal Register - Proposed RCRA Corrective Action regulations

Table 3-5a

Capital and Annual Operational Costs for Groundwater and Surface Water Process Options

Process Option [1]	Capital Cost ($)	Annual Operating Cost ($)
Biological Treatment with Carbon Adsorption[2,4,7]	$500,000	$400,000
Chemical Precipitation[3,4]	$200,000	$50,000
UV/Oxidation[2]	$600,000	$250,000
Air Stripping with Liquid and Vapor Phase Carbon Adsorption[2,7]	$350,000	$800,000
Steam Stripping with Carbon Adsorption[2,6,7]	$500,000	$650,000
Carbon Adsorption[2,7]	$200,000	$1,000,000
Ion Exchange[3,5]	$150,000	$30,000

Notes:

1. Installation costs for the dewatering system are not included in the cost estimates. Capital cost estimates include primary equipment and installation. Operational cost estimates include labor, raw materials and utilities. Cost estimates based on a groundwater pumping rate of 100 gpm.
2. Cost estimates based on preliminary engineering design calculations and judgment.
3. Cost estimates obtained from literature for similar applications and flow rates. Refer to bibliography at end of Section 3.0 for a list of references used to evaluate process options and obtain cost estimates.
4. Operational cost estimate does not include costs associated with sludge disposal.
5. Operational cost estimate does not include costs associated with the disposal of backwash residuals.
6. Capital cost estimate does not include steam source construction costs.
7. It is assumed that spent carbon would be regenerated off-site and handled as a RCRA hazardous waste.

TABLE 3-6

Final Alternatives for Detailed Analysis
American Chemical Services
Griffith, Indiana

Alternative	Groundwater (1)	Buried Waste (2)	Soils/Sediments with VOCs & SVOCs (3)	Soils/Sediments with VOCs, SVOCs & PCBs (4)	Soils/Sediments with VOCs, SVOCs, PCBs and Metals (5)
1. No action	No action	No action	No action	No action	No action
2. Slurry wall site; and groundwater pumping and treatment	Slurry wall and UV oxidation, air stripping, or biological treatment	Natural flushing	Natural flushing	Natural flushing, cover	Natural flushing, cover
3. Excavation and treatment of buried waste; and groundwater pumping and treatment	UV oxidation, air stripping, or biological treatment	On-site incineration or low temp thermal	Natural flushing	Natural flushing, cover	Natural flushing, cover
4. In-situ treatment of buried waste, soils and groundwater; and groundwater pumping and treatment	Steam stripping and UV oxidation, air stripping, or biological treatment	Steam stripping	Steam stripping	Steam stripping with in-situ fixation of PCBs	Steam stripping with in-situ fixation of PCBs and metals
5. In-situ treatment of buried waste and soils; and groundwater pumping and treatment	UV oxidation, air stripping, or biological treatment	Vapor extraction	Vapor extraction	Vapor extraction with in-situ fixation of PCBs	Vapor extraction with in-situ fixation of PCBs and metals

TABLE 3-6

Final Alternatives for Detailed Analysis
American Chemical Services
Griffith, Indiana

Alternative	Groundwater (1)	Buried Waste (2)	Soils/Sediments with VOCs & SVOCs (3)	Soils/Sediments with VOCs, SVOCs & PCBs (4)	Soils/Sediments with VOCs, SVOCs, PCBs and Metals (5)
6. Excavation and treatment of buried waste; in-situ treatment of soils; and groundwater pumping and treatment	UV oxidation, air stripping, or biological treatment	On-site incineration or low temp thermal	Vapor extraction	Vapor extraction with fixation of PCBs	Vapor extraction with in-situ fixation of PCBs and metals
7. Excavation and treatment of buried waste and soils; and groundwater pumping and treatment	UV oxidation, air stripping, or biological treatment	On-site incineration or low temp thermal	On-site incineration or low temp thermal	On-site incineration or low temp thermal	On-site incineration or low temp thermal with fixation of metals
8. Excavation and treatment of buried waste and soils; and groundwater pumping and treatment	UV oxidation, air stripping, or biological treatment	Biological treatment (Landfarming or slurry-phase bioreactor)	Biological treatment (Landfarming or slurry-phase bioreactor)	Biological treatment (Landfarming or slurry-phase bioreactor)	Biological treatment with fixation of metals (Landfarming or slurry-phase bioreactor)

Notes:

(1) Includes all areas of the site.

(2) Includes On- and Off-Site Containment Areas and Still Bottoms Pond/Treatment Lagoon Areas.

(3) Includes On- and Off-Site Containment Areas, Still Bottoms Pond/Treatment Lagoon Areas and Kapica/Pazmey Area.

(4) Includes limited soil volumes and areas within all of the locations described in Note 2 above.

(5) Includes Kapica/Pazmey Area only.

Table 4-1

American Chemical Services
Target Compounds Based on Baseline Risk Assessment

Area: Upper Aquifer/On-Site Resident

Target Compounds	Chemical Group
Acetone	Ketones
Methyl Ethyl Ketone	Ketones
Methyl Isobutyl Ketone	Ketones
Vinyl Chloride	Chlorinated Ethenes
Tetrachloroethene	Chlorinated Ethenes
Chloroethane	Chlorinated Ethanes
Methylene Chloride	Chlorinated Methanes
Benzene[2]	BEXT
Bis(2-chloroethyl)ether	Ethers
Methylated Naphthalenes (TICs)	PNAs
Arsenic	Inorganic Metals

Notes:
(1) Target compounds based on individual hazard quotient >1 or cancer risk $>10^{-5}$.
(2) Compound contributes at least 10% of the total non-carcinogenic or carcinogenic risk for this medium.

Table 4-2

American Chemical Services
Target Compounds Based on Baseline Risk Assessment

Area: Soil/On-Site Containment/On-Site Resident

Target Compounds	Chemical Group
Benzene	BEXT
Ethylbenzene[2]	BEXT
Xylene	BEXT
Toluene[2]	BEXT
1,1,1-Trichloroethane	Chlorinated Ethenes
Tetrachloroethene	Chlorinated Ethenes
1,1,2,2-Tetrachloroethane	Chlorinated Ethanes
Chloroethane	Chlorinated Ethanes
bis(2-ethylhexyl)phthalate	Phthalates
Naphthalene	PNAs
Carcinogenic PNAs	PNAs
PCBs[2]	PCBs

Notes:
(1) Target compounds based on individual hazard quotient >1 or cancer risk >10^{-5}.
(2) Compound contributes at least 10% of the total non-carcinogenic or carcinogenic risk for this medium.

Table 4-3

American Chemical Services
Target Compounds Based on Baseline Risk Assessment

Area: Soil/Still Bottoms/On-Site Resident

Target Compounds	Chemical Group
Benzene	BEXT
Ethylbenzene	BEXT
Toluene	BEXT
Propyl Benzenes (TICs)	BEXT
Propenyl Benzenes (TICs)	BEXT
Methyl Propyl Benzenes (TICs)	BEXT
Dimethyl Ethyl Benzenes (TICs)	BEXT
Nitrogenated Benzenes (TICs)	BEXT
N-Chain Alkanes (TICs)	BEXT
Branched Alkanes (TICs)	BEXT
Chloroform	Chlorinated Methanes
Carbon Tetrachloride[2]	Chlorinated Methanes
Methylene Chloride	Chlorinated Methanes
Chloroethane	Chlorinated Ethanes
1,1,1-Trichloroethane	Chlorinated Ethanes
1,2-Dichloroethane	Chlorinated Ethanes
1,1,2-Trichloroethane	Chlorinated Ethanes
Halogenated Alkanes (TICs)	Chlorinated Ethanes
Tetrachloroethene	Chlorinated Ethenes
1,2-Dichloroethene	Chlorinated Ethenes
Isophorone	Ketones
bis(2-ethylhexyl)phthalate	Phthalates
1,2-Dichloropropane	Chlorinated Propanes
Naphthalene	PNAs
Carcinogenic PNAs	PNAs
Methylated Naphthalenes (TICs)	PNAs
Styrene	Miscellaneous
bis(2-chloroethyl)Ether[2]	Ethers
Hexachlorobenzene	Miscellaneous
Hexachlorobutadiene	Miscellaneous
PCBs[2]	PCBs
Endosulfan	PCBs
4,4-DDT	PCBs
Antimony	Inorganic Metals
Cadmium	Inorganic Metals
Lead[2]	Inorganic Metals

Notes:
(1) Target compounds based on individual hazard quotient >1 or cancer risk $>10^{-5}$.
(2) Compound contributes at least 10% of the total non-carcinogenic or carcinogenic risk for this medium.

Table 4-4

American Chemical Services
Target Compounds Based on Baseline Risk Assessment

Area: Soil/Off-Site Containment/On-Site Resident

Target Compounds	Chemical Group
Benzene	BEXT
Ethylbenzene	BEXT
Xylene	BEXT
Toluene	BEXT
Propyl Benzenes (TICs)	BEXT
Propenyl Benzenes (TICs)	BEXT
Diethyl Benzenes (TICs)	BEXT
Methyl Propyl Benzenes (TICs)	BEXT
Trimethyl Benzenes (TICs)	BEXT
Dimethyl Ethyl Benzenes (TICs)	BEXT
Oxygenated Benzenes (TICs)	BEXT
Nitrogenated Benzenes (TICs)[2]	BEXT
Chloroform	Chlorinated Methanes
Methylene Chloride	Chlorinated Methanes
Chloroethane	Chlorinated Ethanes
1,1,1-Trichloroethane	Chlorinated Ethanes
1,1,2-Trichloroethane	Chlorinated Ethanes
1,2-Dichloroethane	Chlorinated Ethanes
1,1-Dichloroethene	Chlorinated Ethanes
1,2-Dichloroethene	Chlorinated Ethenes
Tetrachloroethene[2]	Chlorinated Ethenes
Vinyl Chloride	Chlorinated Ethenes
Trichloroethene	Chlorinated Ethenes
Methyl Ethyl Ketone[2]	Ketones
Acetone	Ketones
Methyl Isobutyl Ketone[2]	Ketones
Isophorone	Ketones
bis(2-ethylhexyl)phthalate[2]	Phthalates
1,4-Dichlorobenzene	Chlorinated Benzenes
Chlorobenzene	Chlorinated Benzenes
1,2-Dichloropropane	Chlorinated Propanes
Naphthalene	PNAs
Methylated Naphthalenes (TICs)	PNAs
bis(2-chloroethyl) Ether	Ethers
Hexachlorobutadiene	Miscellaneous
Styrene	Miscellaneous
2,6-Dinitrotoluene	Miscellaneous
Hexachlorobenzene	Miscellaneous
Noncyclic Acids (TICs)	Organic Acids
alpha-BHC	PCBs
beta-BHC	PCBs
Aldrin	PCBs

Table 4-4 (continued)

Area: Soil/Off-Site Containment/On-Site Resident

Target Compounds	Chemical Group
4,4-DDD	PCBs
4,4-DDT	PCBs
PCBs[2]	PCBs
Antimony	Inorganic Metals
Cadmium	Inorganic Metals

Notes:
(1) Target compounds based on individual hazard quotient >1 or cancer risk $>10^{-5}$.
(2) Compound contributes at least 10% of the total non-carcinogenic or carcinogenic risk for this medium.

Table 4-5

American Chemical Services
Target Compounds Based on Baseline Risk Assessment

Area: Soil/Kapica Surface Soil/On-Site Resident

Target Compounds	Chemical Group
Ethylbenzene	BEXT
Toluene	BEXT
Tetrachloroethene	Chlorinated Ethenes
Trichloroethene	Chlorinated Ethenes
Isophorone	Ketones
bis(2-ethylhexyl)phthalate	Phthalates
Naphthalene	PNAs
Carcinogenic PNAs[2]	PNAs
Styrene	Miscellaneous
Aldrin	PCBs
PCBs[2]	PCBs
Antimony	Inorganic Metals
Barium	Inorganic Metals
Cadmium	inorganic Metals
Chromium	Inorganic Metals
Lead[2]	Inorganic Metals

Notes:
(1) Target compounds based on individual hazard quotient >1 or cancer risk $>10^{-5}$.
(2) Compound contributes at least 10% of the total non-carcinogenic or carcinogenic risk for this medium.

Table 4-6

American Chemical Services
Target Compounds Based on Baseline Risk Assessment

Area: Soil/Kapica Subsurface Soil/On-Site Resident

Target Compounds	Chemical Group
Benzene	BEXT
Tetrachloroethene	Chlorinated Ethenes
Trichloroethene	Chlorinated Ethenes
Isophorone	Ketones
bis(2-ethylhexyl)phthalate	Phthalates
Carcinogenic PNAs[2]	PNAs
Styrene	Miscellaneous
2,4-Dinitrotoluene	Miscellaneous
PCBs[2]	PCBs
Antimony	Inorganic Metals
Barium	Inorganic Metals
Cadmium	Inorganic Metals
Lead[2]	Inorganic Metals

Notes:
(1) Target compounds based on individual hazard quotient > 1 or cancer risk > 10^{-5}.
(2) Compound contributes at least 10% of the total non-carcinogenic or carcinogenic risk for this medium.

Table 4-7

American Chemical Services
Groundwater Concentrations Used in Detailed Analysis

Chemical Group	Minimum Concentration (ug/l)[2]	Maximum Concentration (ug/l)[2]	BRA Exposure Level (ug/l)[3]
Ketones	100,000	200,000	300,000
BEXT Compounds	30,000	50,000	100,000
Chlorinated Methanes	200	200	200
Chlorinated Ethanes	1200	3200	2700
Chlorinated Ethenes	200	200	200
Phenols	2900	3600	2300
Ethers	1700	1900	1600
Organic Acids	1600	2000	1200
Chlorinated Benzenes	300	300	300
PNAs	100	100	100
Phthalates	20	20	20
PCBs	2.0	2.0	2.0
Arsenic	30	30	30
Barium	600	600	600
Lead	2.0	2.0	2.0
Mercury	0.3	0.3	0.3
Zinc	200	200	200
Total Metals	1,000,000	1,000,000	1,000,000

1. Groundwater minimum concentrations based on an average of individual chemical data from monitoring wells MW-3, MW-16, MW-5 and MW-6.
2. Groundwater maximum concentrations based on an average of individual chemical data from monitoring wells MW-3 and MW-16.
3. BRA exposure levels based on a sum of individual chemical levels using the on-site resident exposure scenario.
4. Concentrations were rounded to two significant figures.

Table 4-8

American Chemical Services
Buried Wastes and Soil Concentrations Used in Detailed Analysis

Area: On-Site Containment

Chemical Group	Weighted Average Concentration (mg/kg)[1]	BRA Exposure Level (mg/kg)[2]
Ketones	10	5.0
BEXT Compounds	6,000	114,000
Chlorinated Methanes	0.2	2.0
Chlorinated Ethanes	500	1,300
Chlorinated Ethenes	200	6,000
Phenols	5.0	10
Ethers	BDL	BDL
Organic Acids	20	200
Chlorinated Benzenes	2.0	10
PNAs	30	100
Phthalates	20	200
PCBs	25	10
Arsenic	BDL	BDL
Barium	50	100
Lead	100	No value
Mercury	1.0	1.0
Zinc	B	No value
Total Metals	5,000	13,000

Notes:
B - below background concentration
BDL - below analytical detection limit
1. Weighted average concentrations were determined by calculating a sum of the weighted arithmetic averages for individual compounds based on a ratio of the number of detects to the total number of soil samples collected from this area.
2. BRA exposure levels based on a sum of individual chemical levels using the on-site resident exposure scenario.
3. Concentrations were rounded to two significant figures.

Addendum to Table 4-8

Example of Weighted Average Soil Concentration Calculations

Example: Weighted average soil concentration calculations are shown for BEXT Compounds and Chlorinated Ethanes in the On-Site Containment Area.

Basis: Data was obtained from Table 7-4 of the BRA. The mean soil concentrations presented in Table 7-4 of the BRA were calculated only for samples where concentrations exceeded analytical detection limits. Weighted average calculations are based on a total of 42 soil samples analyzed from the On-Site Containment Area.

$$\text{WEIGHTED AVERAGE SOIL CONCENTRATION} = \text{BRA Mean Soil Concentration} \times \frac{\text{(Number of Detects)}}{\text{(Total Number of Samples)}}$$

Compound	BRA Mean Soil Concentration (mg/kg)	Number of Detects	Weighted Average Soil Concentration
Benzene	205	35	171
Ethylbenzene	194	37	171
Xylene	791	37	697
Toluene	5,293	38	4,788
TICs[1]			142
Total BEXT Compounds			**6,000[2]**
1,1,1-Trichloroethane	885	23	485
Remaining Chlorinated Ethane Compounds and TICs			1
Total Chlorinated Ethanes			**500[2]**

Notes:

1. The weighted average soil concentration calculation was performed for all of the TIC groupings shown in Table 4-13 that were categorized as BEXT Compounds. Only the total calculated weighted soil concentration for all of the TIC groupings is shown in this table.

2. The calculated weighted average soil concentration was rounded upward to one significant digit for concentrations less than 10,000 mg/kg, or two significant digits for concentrations greater than 10,000 mg/kg.

Table 4-9

American Chemical Services
Buried Wastes and Soil Concentrations Used in Detailed Analysis

Area: Still Bottoms/Treatment Lagoon

Chemical Group	Weighted Average Concentration (mg/kg)[1]	BRA Exposure Level (mg/kg)[2]
Ketones	500	5,000
BEXT Compounds	15,000	90,000
Chlorinated Methanes	400	6,000
Chlorinated Ethanes	1,000	26,000
Chlorinated Ethenes	400	4,000
Phenols	20	200
Ethers	10	100
Organic Acids	30	400
Chlorinated Benzenes	60	300
PNAs	200	1200
Phthalates	600	5,000
PCBs	25	200
Arsenic	BDL	BDL
Barium	200	100
Lead	900	6300
Mercury	B	No value
Zinc	400	2,300
Total Metals	5,000	21,000

Notes:
B - below background concentration
BDL - below analytical detection limit
1. Weighted average concentrations were determined by calculating a sum of the weighted arithmetic averages for individual compounds based on a ratio of the number of detects to the total number of soil samples collected from this area.
2. BRA exposure levels based on a sum of individual chemical levels using the on-site resident exposure scenario.
3. Concentrations were rounded to two significant figures.

Table 4-10

American Chemical Services
Buried Wastes and Soil Concentrations Used in Detailed Analysis

Area: Off-Site Containment Area

Chemical Group	Weighted Average Concentration (mg/kg)[1]	BRA Exposure Level (mg/kg)[2]
Ketones	6,000	200,000
BEXT Compounds	11,000	290,000
Chlorinated Methanes	100	3,000
Chlorinated Ethanes	4,000	160,000
Chlorinated Ethenes	3,000	65,000
Phenols	100	1,000
Ethers	30	300
Organic Acids	6,000	100,000
Chlorinated Benzenes	100	2,000
PNAs	500	5,000
Phthalates	2,000	21,000
PCBs	100	500
Arsenic	BDL	BDL
Barium	400	500
Lead	1,000	No value
Mercury	2.0	10
Zinc	500	1,300
Total Metals	3,000	6,000

Notes:
B - below background concentration
BDL - below analytical detection limit
1. Weighted average concentrations were determined by calculating a sum of the weighted arithmetic averages for individual compounds based on a ratio of the number of detects to the total number of soil samples collected from this area.
2. BRA exposure levels based on a sum of individual chemical levels using the on-site resident exposure scenario.
3. Concentrations were rounded to two significant figures.

Table 4-11

American Chemical Services
Buried Wastes and Soil Concentrations Used in Detailed Analysis

Area: Kapica-Surface Soil

Chemical Group	Weighted Average Concentration (mg/kg)[1]	BRA Exposure Level (mg/kg)[2]
Ketones	100	400
BEXT Compounds	13,000	50,000
Chlorinated Methanes	0.05	0.2
Chlorinated Ethanes	0.1	0.2
Chlorinated Ethenes	300	1,000
Phenols	20	40
Ethers	BDL	BDL
Organic Acids	30	300
Chlorinated Benzenes	2.0	10
PNAs	100	200
Phthalates	400	800
PCBs	40	300
Arsenic	BDL	BDL
Barium	2,500	5,700
Lead	8,000	16,000
Mercury	7.0	10
Zinc	8,700	16,000
Total Metals	50,000	100,000

Notes:
B - below background concentration
BDL - below analytical detection limit
1. Weighted average concentrations were determined by calculating a sum of the weighted arithmetic averages for individual compounds based on a ratio of the number of detects to the total number of soil samples collected from this area.
2. BRA exposure levels based on a sum of individual chemical levels using the on-site resident exposure scenario.
3. Concentrations were rounded to two significant figures.

Table 4-12

American Chemical Services
Buried Wastes and Soil Concentrations Used in Detailed Analysis

Area: Kapica Subsurface Soil

Chemical Group	Weighted Average Concentration (mg/kg)[1]	BRA Exposure Level (mg/kg)[2]
Ketones	20	200
BEXT Compounds	700	6,000
Chlorinated Methanes	0.0004	0.003
Chlorinated Ethanes	0.10	2.0
Chlorinated Ethenes	40	500
Phenols	6.0	20
Ethers	BDL	BDL
Organic Acids	10	100
Chlorinated Benzenes	7.0	30
PNAs	20	100
Phthalates	40	200
PCBs	10	50
Arsenic	BDL	BDL
Barium	400	1,500
Lead	1,000	4,000
Mercury	0.6	No value
Zinc	700	2,200
Total Metals	4,000	15,000

Notes:
B - below background concentration
BDL - below analytical detection limit
1. Weighted average concentrations were determined by calculating a sum of the weighted arithmetic averages for individual compounds based on a ratio of the number of detects to the total number of soil samples collected from this area.
2. BRA exposure levels based on a sum of individual chemical levels using the on-site resident exposure scenario.
3. Concentrations were rounded to two significant figures.

Table 4-13

American Chemical Services
Placement of TICs Into FS Chemical Groups

TIC Group[1]	Chemical Group
Propyl Benzenes	BEXT Compounds
Propenyl Benzenes	BEXT Compounds
Ethylmethyl Benzenes	BEXT Compounds
Diethyl Benzenes	BEXT Compounds
Methylpropyl Benzenes	BEXT Compounds
Methylethenyl Benzenes	BEXT Compounds
Methylphenyl Benzenes	BEXT Compounds
Trimethyl Benzenes	BEXT Compounds
Dimethylethyl Benzenes	BEXT Compounds
Tetramethyl Benzenes	BEXT Compounds
Oxygenated Benzenes	BEXT Compounds
Halogenated Benzenes	Chlorinated Benzenes
Nitro Benzenes	Chlorinated Benzenes
Cyclic Alkanes	BEXT Compounds
Cyclic Alkenes	BEXT Compounds
Halogenated Alkanes	Chlorinated Ethanes
Straight Chain Alkanes	BEXT Compounds
Branched Alkanes	BEXT Compounds
Branched Alkanes and Alkynes	BEXT Compounds
Ethers	Ethers
Straight Chain Alkenes and Alkynes	BEXT Compounds
Methylated Naphthalenes	PNAs
Phthalic Anhydride	Phthalates
Methylated Phenols	Phenols
Methylated Ketones	Ketones
Simple Ketones	Ketones
Cyclic Ketones	Ketones
Diols	Ketones
Simple Alcohols	Ketones
Oxygenated Alcohols	Ketones
Cyclic Alcohols	Phenols
Cyclic Acids	Organic Acids
Non-cyclic Acids	Organic Acids
Amines	Organic Acids
PCBs	PCBs
Furans	Ketones

Notes:
1. TIC chemical groups were taken from Table 7-12 of the Baseline Risk Assessment.

Table 4-14

American Chemical Services
Groundwater Treatment Design Criteria for Target Compounds

Chemical	ACS Permit[3]	Hammond POTW[4]	Pretreatment Standards[5]	SDWA MCLs[6]	CWA Water Quality Criteria[7]	RCRA Corrective Action Levels[8]
Arsenic	NA	1,000[1]	NA	50[2]	48	50
Barium	NA	NA	NA	1,000[2]	NA	1,000
Lead	NA	1,800[1]	320	50[2]	3.2	50
Mercury	NA	40[1]	NA	2.0[2]	1.2×10^{-2}	2.0
Zinc	NA	5,000[1]	1,050	5,000[2]	110	NA
Benzene	NA	3,000[1]	57	5.0[2]	5,300	NA
Benzoic Acid	NA	NA	NA	NA	NA	NA
Bis(2-chloroethyl) ether	NA	NA	NA	NA	230,000[2]	0.03
Bis(2-ethylhexyl) phthalate	NA	578[1]	NA	4.0[2]	3.0	3.0
Chloroethane	574	578[1]	110	5.0[2]	35,000	0.3
Chloroform	NA	NA	111[1]	5.0[2]	1,200	6.0
1,2- Dichlorobenzene	NA	NA	196[1]	75[2]	760	NA
Dibutylphthalate	NA	NA	NA	NA	3.0[2]	4,000
Isophorone	NA	NA	NA	NA	117,000[2]	9.0
Methyl Ethyl Ketone	NA	NA	NA	NA	NA	2,000[2]
4-Methylphenol	500[1]	NA	NA	NA	NA	2,000[2]
Naphthalene	NA	NA	NA	NA	NA	NA
PCBs	NA	0[1]	NA	0.5[2]	1.4×10^{-2}	0.005
Tetrachloroethene	NA	NA	52[1]	5.0[2]	84	0.7
Toluene	74	551[1]	28	2,000[2]	17,000	10,000
1,1,1- Trichloroethane	574	578[1]	22	200[2]	18,000	3,000
Vinyl Chloride	NA	NA	97[1]	2.0[2]	2.0	2.0
Total Cyanides	NA	10,000[1]	420	200[2]	5.2	NA

Table 4-14 (continued)

Notes:
All units in micrograms per liter.
NA - discharge standard not available
1. POTW discharge standard selected for target compound and corresponding chemical group for use in detailed analysis and design and cost calculations.
2. NPDES discharge standard selected for target compound and corresponding chemical group for use in detailed analysis and design and cost calculations.
3. Discharge standards taken from current permit issued by the Hammond POTW to ACS for ongoing operations.
4. Discharge standards taken from proposed Hammond POTW pretreatment regulations.
5. Discharge standards taken from 40CFR 414.85 (i.e., existing source pretreatment standards for specialty organic chemicals manufacturing). Hammond POTW Pretreatment Coordinator specified that these discharge standards would be considered for groundwater remedial action activities at the ACS Site.
6. Standards correspond to Safe Drinking Water Act (SDWA) Maximum Concentration Levels (MCLs).
7. Standards correspond to Clean Water Act (CWA) Water Quality Criteria for Protection of Aquatic Life (Freshwater Acute/Chronic).
8. Standards correspond to RCRA Action Levels for water ingested presented in the July 27, 1990 Federal Register.
9. Specified discharge standards may actually apply to a different compound included in the chemical group represented by the target compound. These values were substituted either if they were more stringent than standards for the target compound, or a corresponding standard does not exist for the target compound.

Table 4-15

American Chemical Services
Groundwater Treatment Cost Summary

Groundwater Treatment Process Option	Capital Cost ($x10^6)	Annual O&M ($x10^6)	Present Worth Annual O&M ($x10^6)	Net Present Worth ($x10^6)[1]
Biological Treatment	$3.30	$0.500	$7.69	$11.0
UV/Oxidation	$1.60	$0.850	$13.07	$14.7
Air Stripping with Vapor Treatment and Effluent Polishing	$0.95	$0.625	$9.61	$10.6
Ion Exchange	$0.20	$0.11	$0.92	$1.1

Notes:

1 Net present worth comparison is based on a 5% discount factor and 30 years operating period.

Table 4-16

American Chemical Services
Alternatives Cost Summary

Alternative	Capital Cost ($X10^6)	Present Worth Annual O&M ($X10^6)	Net Present Worth ($X10^6)
No Action (Alt. 1)	$0	$0	$0
Slurry Wall Site; and Groundwater Pumping and Treatment (Alt. 2)	$3.85	$8.15	$12.0
Excavation and On-Site Incineration of Buried Waste; and Groundwater Pumping and Treatment (Alt. 3a)	$38.70	$16.13	$54.8
Excavation and On-Site Low Temp Thermal Treatment of Buried Waste; and Groundwater Pumping and Treatment (Alt. 3b)	$28.95	$16.13	$45.1
In-Situ Steam Stripping of Buried Waste, Soils and Groundwater; and Groundwater Pumping and Treatment (Alt. 4)	$13.74	$37.14	$50.9
In-Situ Vapor Extraction of Buried Waste and Soils; and Groundwater Pumping and Treatment (Alt. 5)	$12.64	$20.40	$33.0
Excavation and On-Site Incineration of Buried Waste; In-Situ Vapor Extraction of Soils; and Groundwater Pumping and Treatment (Alt. 6a)[2]	$26.89 to $40.39	$16.17	$43.1 to $56.6
Excavation and On-Site Low Temp Thermal Treatment of Buried Waste; In-Situ Vapor Extraction of Soils; and Groundwater Pumping and Treatment (Alt. 6b)[2]	$21.64 to $30.64	$16.17	$37.8 to $46.8

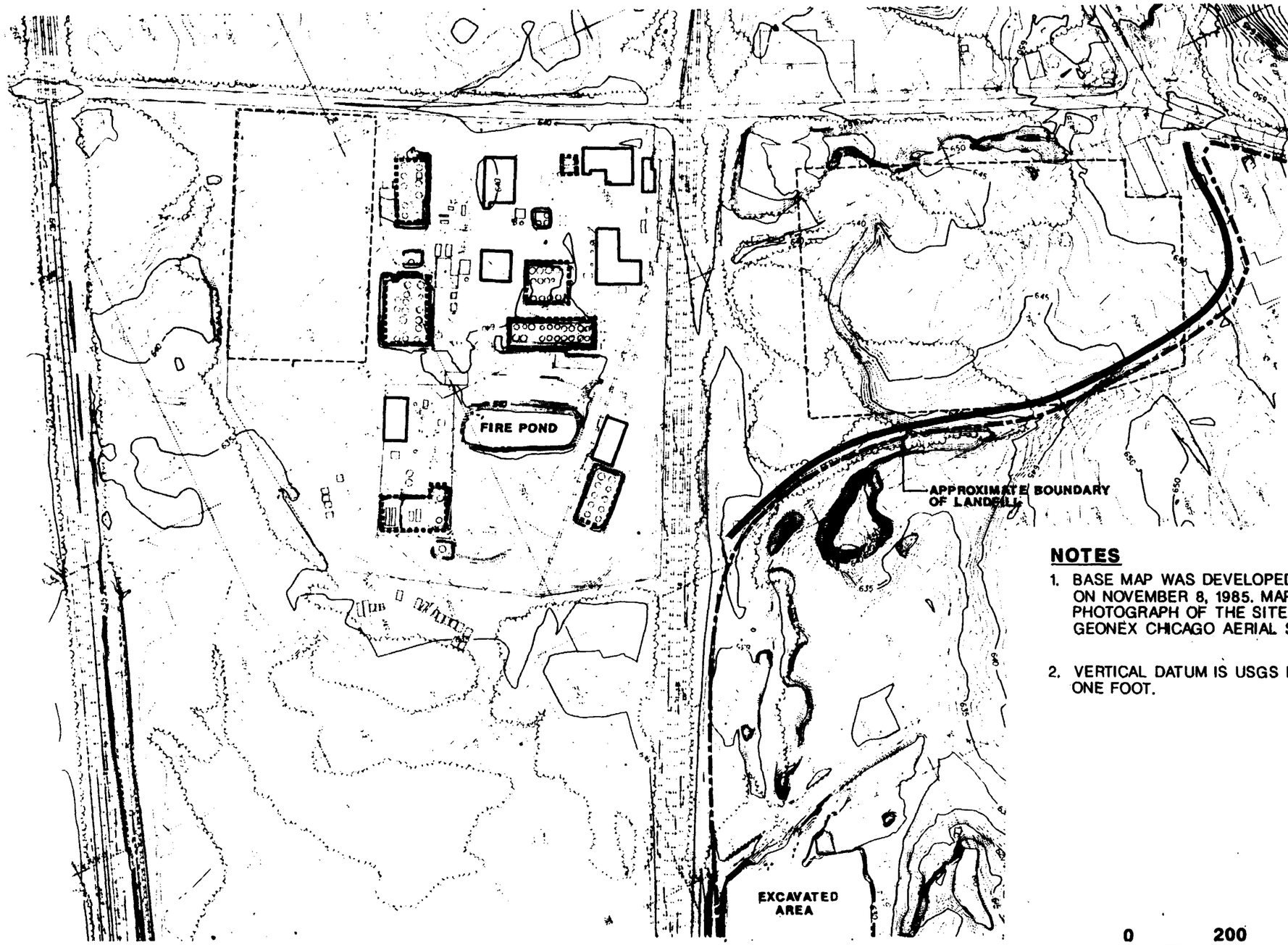
Table 4-16 (continued)

Alternative	Capital Cost ($X10^6)	Present Worth Annual O&M ($X10^6)	Net Present Worth ($X10^6)
On-Site Incineration of Buried Waste and Soils; and Groundwater Pumping and Treatment (Alt. 7a)	$70.20	$14.43	$84.6
On-Site Low Temp Thermal Treatment of Buried Waste and Soils; and Groundwater Pumping and Treatment (Alt. 7b)	$49.95	$14.43	$64.4
Excavation and Landfarming of Buried Waste and Soils; and Groundwater Pumping and Treatment (Alt. 8a)	$11.44	$22.77	$34.2
Excavation and Slurry-Phase Bioreactor Treatment of Buried Waste and Soils; and Groundwater Pumping and Treatment (Alt. 8b)	$16.63	$26.56	$43.2

Note:

1. Cost estimates for alternatives 3 thru 8 are based on a groundwater treatment capital cost of $1.2 million and first year O&M costs of $750,000. Groundwater treatment annual O&M costs were assumed to decrease with time based on decreasing influent concentrations with continuing source treatment and groundwater flushing.

2. Cost estimates for Alternative 6 are based on a potential range of buried waste requiring on-Site thermal treatment of 35,000 cubic yards to 65,000 cubic yards.



LEGEND

APPROXIMATE TANK FARM BOUNDARY

SLURRY WALL BETWEEN LANDFILL AND OFF-SITE CONTAINMENT AREA

NOTES

1. BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 8, 1985. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC.

2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.

0 200 400

SCALE IN FEET

north

FIGURE 3-2d

WARREN

PROPOSED SLURRY WALL

FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

60251B73

LEGEND

APPROXIMATE TANK FARM BOUNDARY

SLURRY WALL FOR SOURCE AREAS

NOTES

1. BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 8, 1985. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC.

2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.

0 200 400

SCALE IN FEET

north

FIGURE 3-2c

PROPOSED SLURRY WALL

FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

60251B72

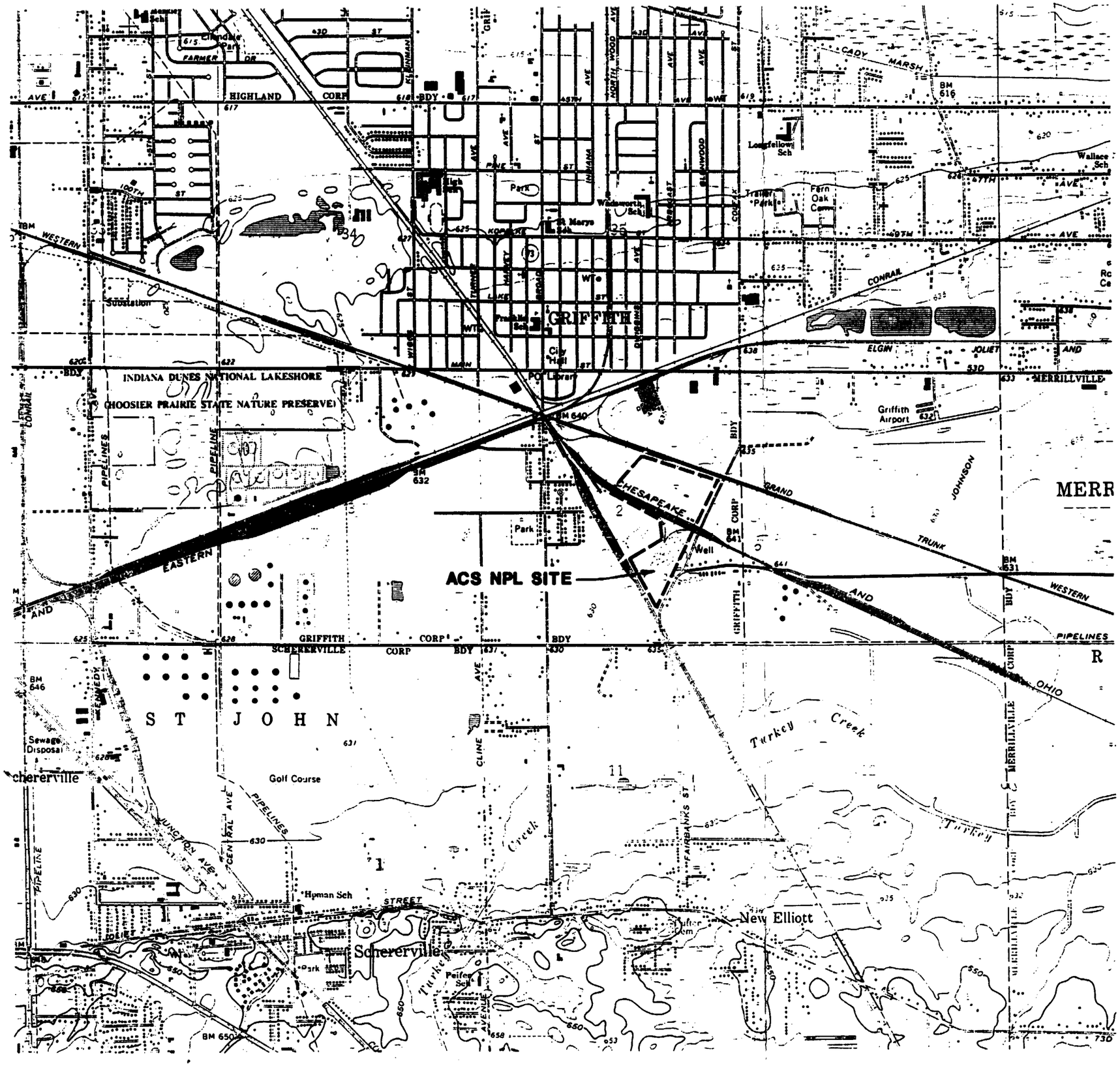
WARZYN

Drawn By: DLL

Checked By:

Approved By: MSR

Date: 10/23/91



NOTES

1. BASE MAP DEVELOPED FROM HIGHLAND & ST. JOHN, INDIANA 7.5 MINUTE USGS TOPOGRAPHIC QUADRANGLE MAPS DATED 1968 AND 1962, RESPECTIVELY, PHOTOREVISED 1980.

FIGURE 1-1

WARZYN
WARZYN ENGINEERING INC.

Drawn by D.L.L.
Checked by JHW
Date 10/23/91
Designed by
Approved by MSP

SITE LOCATION MAP
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

60251 B51

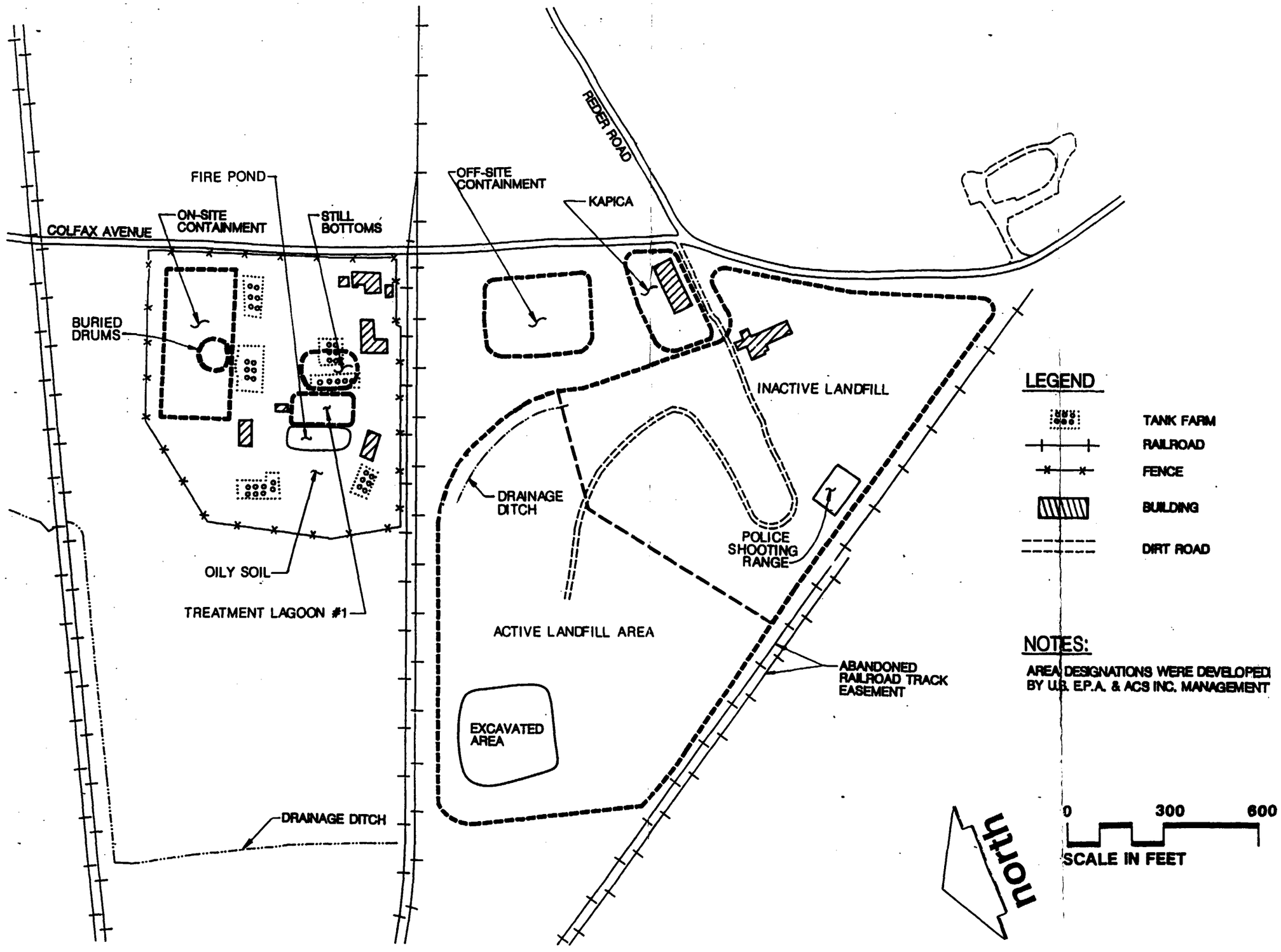


FIGURE 1-2

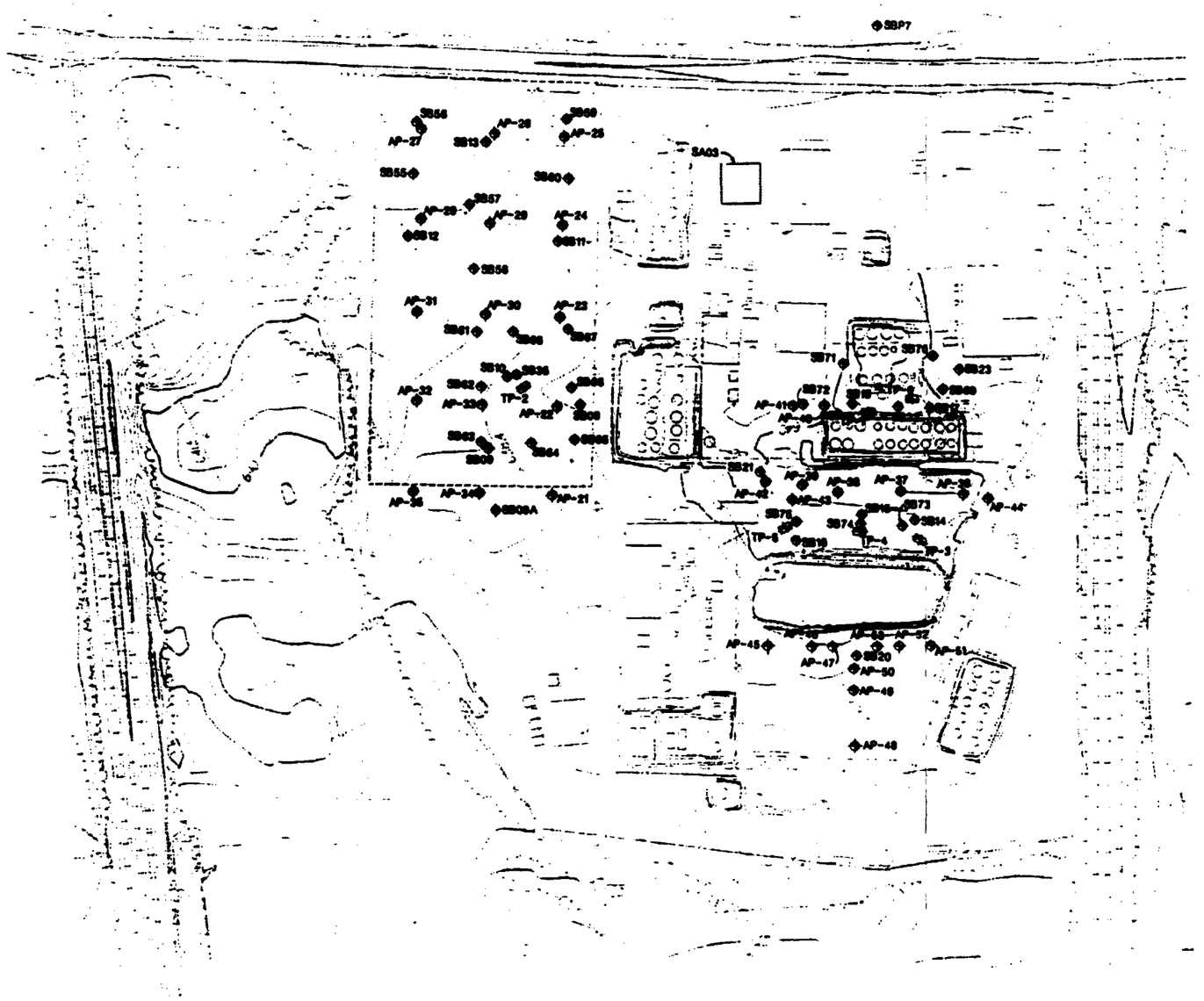
WARZYN

WASTE BURIAL AREAS

FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFITH, INDIANA

60251 B52

Designed by M/SR
Drawn by DLL, ELR
Checked by JAW
Date 10/23/91



LEGEND

----	GEOPHYSICS INVESTIGATION AREA
◆SB-01	SOIL BORING LOCATION & NUMBER
◆AP-01	AUGER PROBE LOCATION & NUMBER
TP-1	TEST PIT LOCATION & NUMBER
□SA01	SOIL AREA LOCATION & NUMBER

NOTES

1. INITIAL BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC ON NOVEMBER 4, 1988. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1988 BY GEONEX CHICAGO AERIAL SURVEY, INC. THE BASE MAP WAS UPDATED BASED ON THE AERIAL PHOTOGRAPH BY GEONEX.
2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1). ONE FOOT.
3. SOIL BORINGS SB01 TO SB18 AND AUGER PROBES AP-1 TO AP-44 FOR PHASE I WERE DRILLED BY EXPLORATION TECHNOLOGY INC. (ETI) UNDER THE SUPERVISION OF WARZYN IN AUGUST AND SEPTEMBER 1988.
4. SOIL BORINGS SB19 TO SB75 AND AUGER PROBES AP-45 TO AP-68 FOR PHASE II WERE DRILLED BY EXPLORATION TECHNOLOGY INC. (ETI) UNDER THE SUPERVISION OF WARZYN IN MAY AND JUNE 1989.
5. LOCATIONS FOR SOIL BORINGS WITH SAMPLING AND TEST PITS WERE FIELD LOCATED BY EWI ENGINEERING ASSOC. SURVEYORS.
6. LOCATIONS OF AUGER PROBES ARE APPROXIMATE.
7. SOIL BORING NUMBERS SB10 AND SB64 DO NOT EXIST.

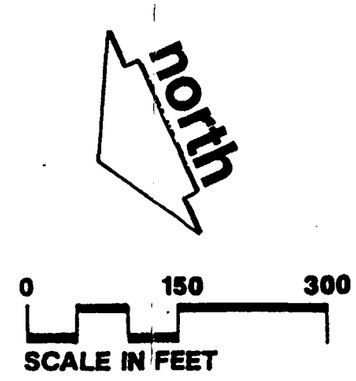


FIGURE 1-3

Designed by TJM
Drawn by D.L.L.
Checked by JAW
Approved by MSR
Date 10/23/91
Revisions

WARZYN
WARZYN ENGINEERING INC.

SOIL BORING, AUGER PROBE & TEST PIT LOCATIONS (OU-SITE)
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number 60251 B53

WARZYN

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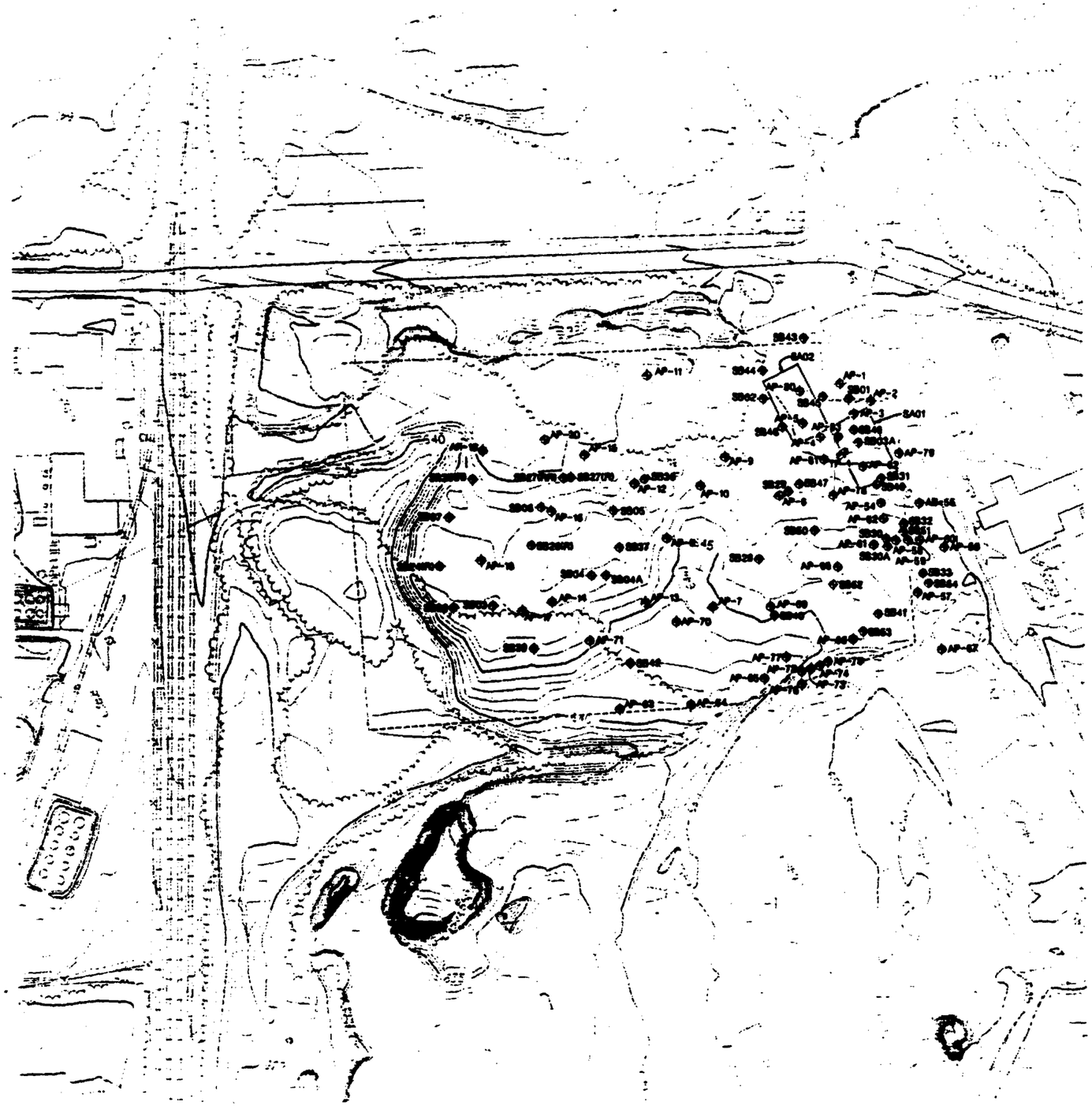


LEGEND

———	GEOPHYSICS INVESTIGATION AREA
SB-01	SOIL BORING LOCATION & NUMBER
AP-01	AUGER PROBE LOCATION & NUMBER
TP-1	TEST PIT LOCATION & NUMBER
SA01	SOIL AREA LOCATION & NUMBER

NOTES

1. INITIAL BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC ON NOVEMBER 5, 1986. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 2, 1986 BY GEONEX CHICAGO AERIAL SURVEY, INC. THE BASE MAP WAS UPDATED BASED ON THE AERIAL PHOTOGRAPH BY GEONEX.
2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.
3. SOIL BORINGS SB01 TO SB15 AND AUGER PROBES AP-1 TO AP-44 FOR PHASE I WERE DRILLED BY EXPLORATION TECHNOLOGY INC. (ETI) UNDER THE SUPERVISION OF WARZYN IN AUGUST AND SEPTEMBER 1988.
4. SOIL BORINGS SB16 TO SB75 AND AUGER PROBES AP-45 TO AP-85 FOR PHASE II WERE DRILLED BY EXPLORATION TECHNOLOGY INC. (ETI) UNDER THE SUPERVISION OF WARZYN IN MAY AND JUNE 1989.
5. LOCATIONS FOR SOIL BORINGS WITH SAMPLING AND TEST PITS WERE FIELD LOCATED BY EWI ENGINEERING ASSOC. SURVEYORS.
6. LOCATIONS OF AUGER PROBES ARE APPROXIMATE.
7. SOIL BORING NUMBERS SB19 AND SB24 DO NOT EXIST.

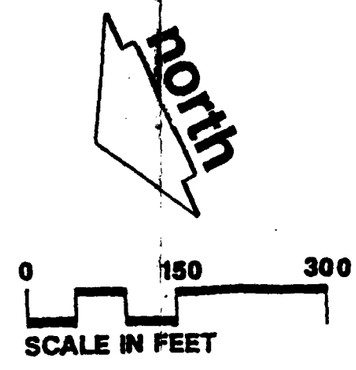


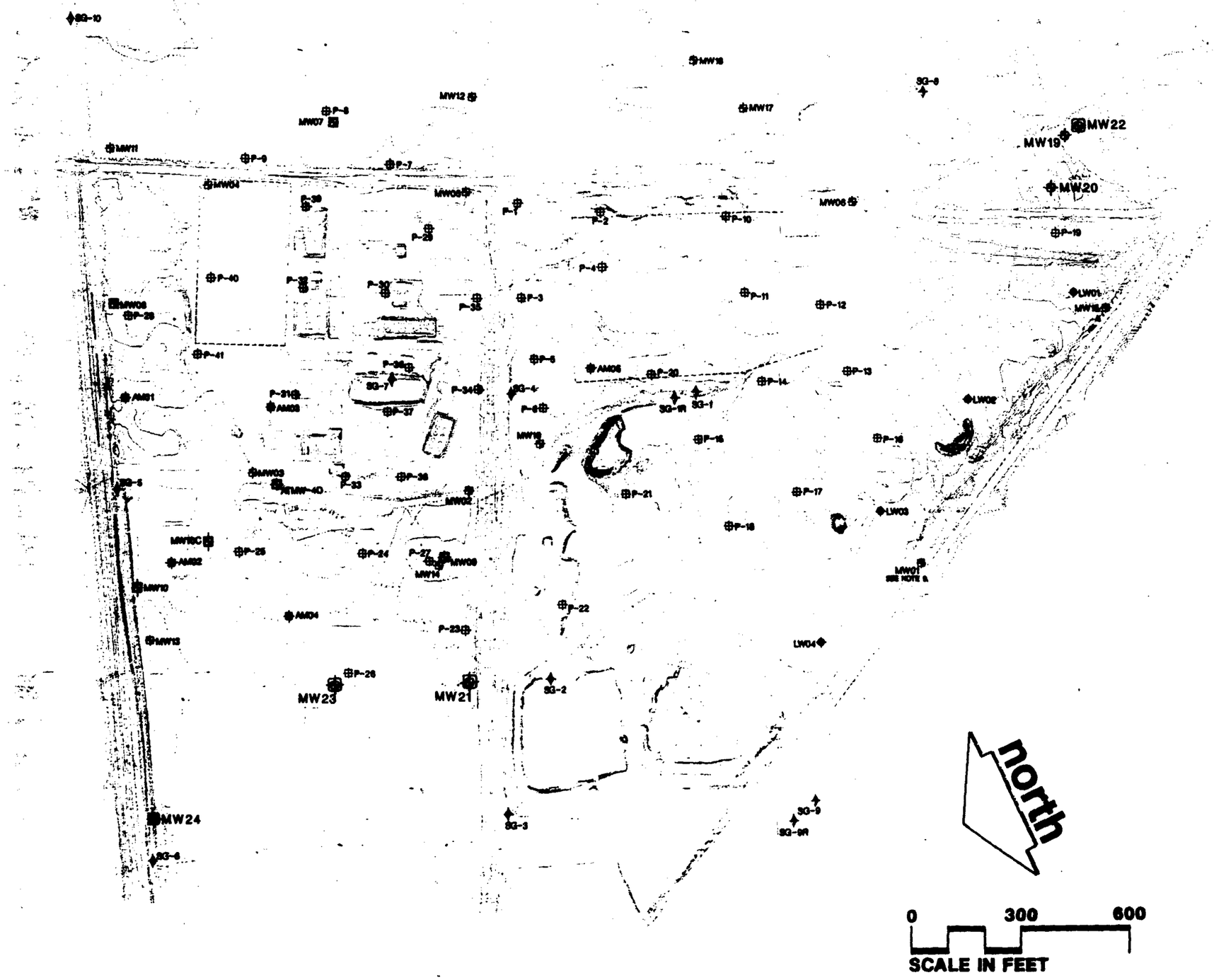
FIGURE 1-4

WARZYN

Designed by TWM
Drawn by D.L.L.
Checked by JAW
Approved by MSR
Date 10/23/91

SOIL BORING, AUGER PROBE & TEST PIT LOCATIONS (OAK SITE)
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number 60251 B54



LEGEND

—	GEOPHYSICS INVESTIGATION AREA
MW01	UPPER AQUIFER MONITORING WELL LOCATION & NUMBER
MW10	LOWER AQUIFER MONITORING WELL LOCATION & NUMBER
LW01	LEACHATE HEADWELL LOCATION & NUMBER
P-1	PIEZOMETER LOCATION & NUMBER
SG-1	STAFF GAUGE LOCATION & NUMBER
AM01	AQUIFER MATRIX SAMPLE LOCATION & NUMBER

NOTES

1. INITIAL BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 8, 1988. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF SITE FLOWN ON NOVEMBER 3, 1988 BY GEONEX CHICAGO AERIAL SURVEY, INC. THE BASE MAP WAS UPDATED BASED ON THE AERIAL PHOTOGRAPH.
2. MONITORING WELL MW01, STAFF GAUGES SG1 AND SG2 HAVE BEEN DESTROYED. STAFF GAUGES SG-1R AND SG-2R ARE THE CORRESPONDING REPLACEMENT STAFF GAUGES.
3. VERTICAL SITE DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.
4. MONITORING WELL ATIMW-4D WAS DRILLED AND INSTALLED BY ATEC ENGINEERING ASSOC. ON SEPTEMBER 27, 1988. THE LOCATION OF ATIMW-4D IS APPROXIMATE.
5. MONITORING WELL MW01 TO MW06 WERE DRILLED AND INSTALLED BY EXPLORATION TECHNOLOGY INC (ETI) UNDER THE SUPERVISION OF WARZYN DURING THE PHASE I INVESTIGATION IN JULY 1988.
6. MONITORING WELL MW07 TO MW16 WERE DRILLED AND INSTALLED BY EXPLORATION TECHNOLOGY INC (ETI) UNDER THE SUPERVISION OF WARZYN DURING THE PHASE II INVESTIGATION IN MARCH THROUGH JUNE 1989.
7. LOCATIONS OF MONITORING WELLS, PIEZOMETERS, AND SURFACE WATER STAFF GAUGES WERE FIELD LOCATED BY EIN ENGINEERING ASSOC. SURVEYORS.
8. STAFF GAUGES ARE CONSTRUCTED OF IRON POLES AND WERE INSTALLED BY WARZYN.
9. MONITORING WELL MW-01 WAS DESTROYED BY ROAD CONSTRUCTION DURING SPRING 1990.

FIGURE 1-5

Designed by TDM
Drawn by D.L.L.
Checked by JAW
Approved by MSR
Date 10/23/91
Revision

WARZYN
WARZYN ENGINEERING INC.

MONITORING WELL, PIEZOMETER & STAFF GAUGE LOCATIONS
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number 60251 B55

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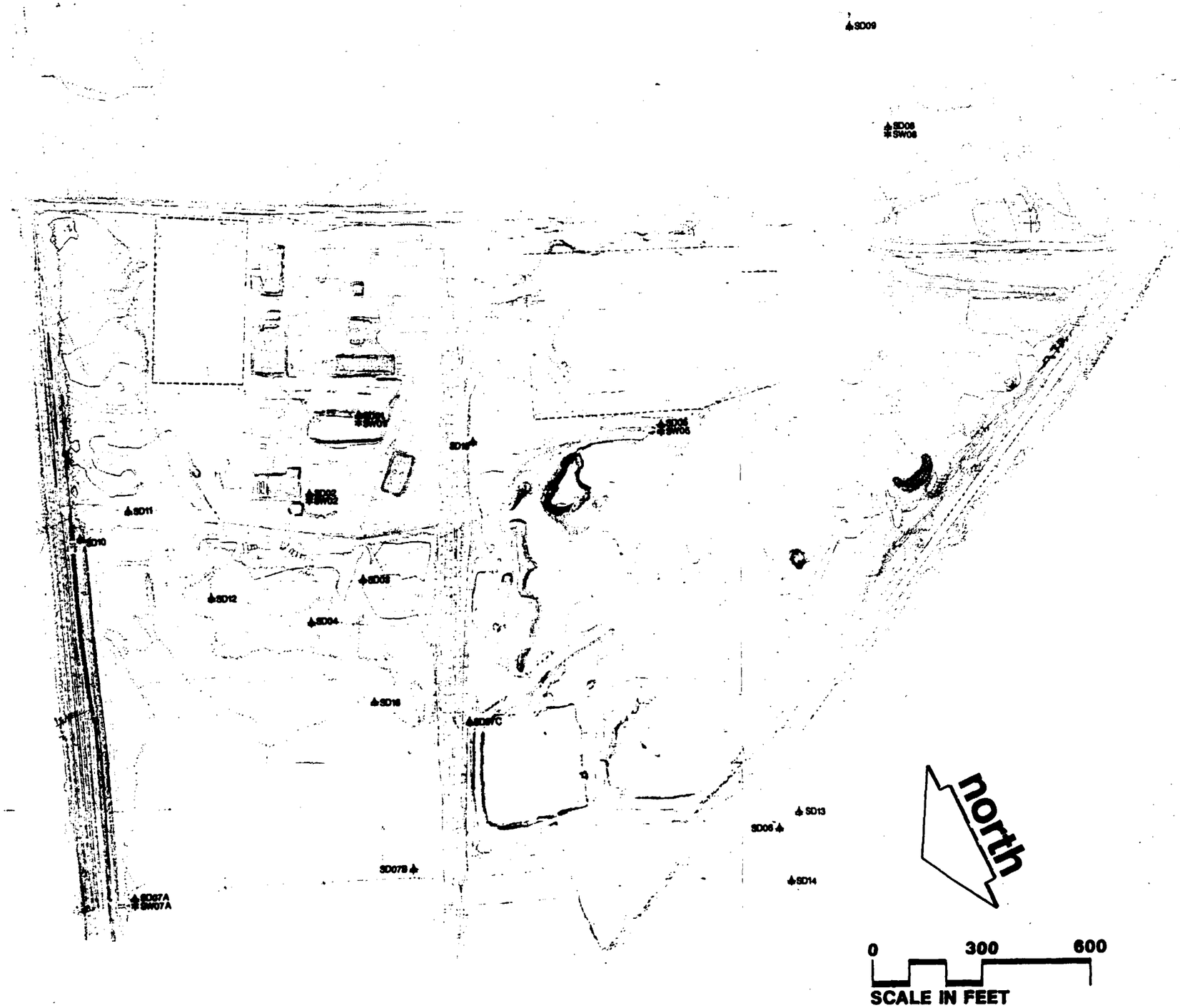

LEGEND

———	GEOPHYSICS INVESTIGATION AREA
▲ SD01	SEDIMENT SAMPLE LOCATION & NUMBER
✱ SW01	SURFACE WATER SAMPLE LOCATION & NUMBER

NOTES

1. INITIAL BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC ON NOVEMBER 6, 1985. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC. THE BASE MAP WAS UPDATED BASED ON THE AERIAL PHOTOGRAPH BY GEONEX.
2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.
3. SURFACE WATER AND SEDIMENT SAMPLES WERE COLLECTED BY WARZYN. PHASE I SAMPLES SD01 THROUGH SD09 AND SW01, SW02, SW03, SW07A AND SW08 WERE COLLECTED IN JULY 1989. PHASE II SEDIMENT SAMPLES SD10 THROUGH SD14 WERE COLLECTED ON MAY 30, 1990. PHASE II SAMPLES SD15 AND SD16 WERE COLLECTED ON JULY 3, 1990 AND RESAMPLED FOR VOCS ONLY ON JULY 30, 1990.
4. LOCATIONS OF SURFACE WATER AND SEDIMENT SAMPLES WERE FIELD LOCATED BY EWI ENGINEERING ASSOC. SURVEYORS.

FIGURE 1-6

Date 9/1/92 WARZYN WARZYN ENGINEERING INC.
Designed By TSM Drawn By D.L.L. Checked By JAW
Approved By MSR Date 10/23/91
Revisions

SURFACE WATER & SEDIMENT SAMPLING LOCATIONS
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number 60251 B56

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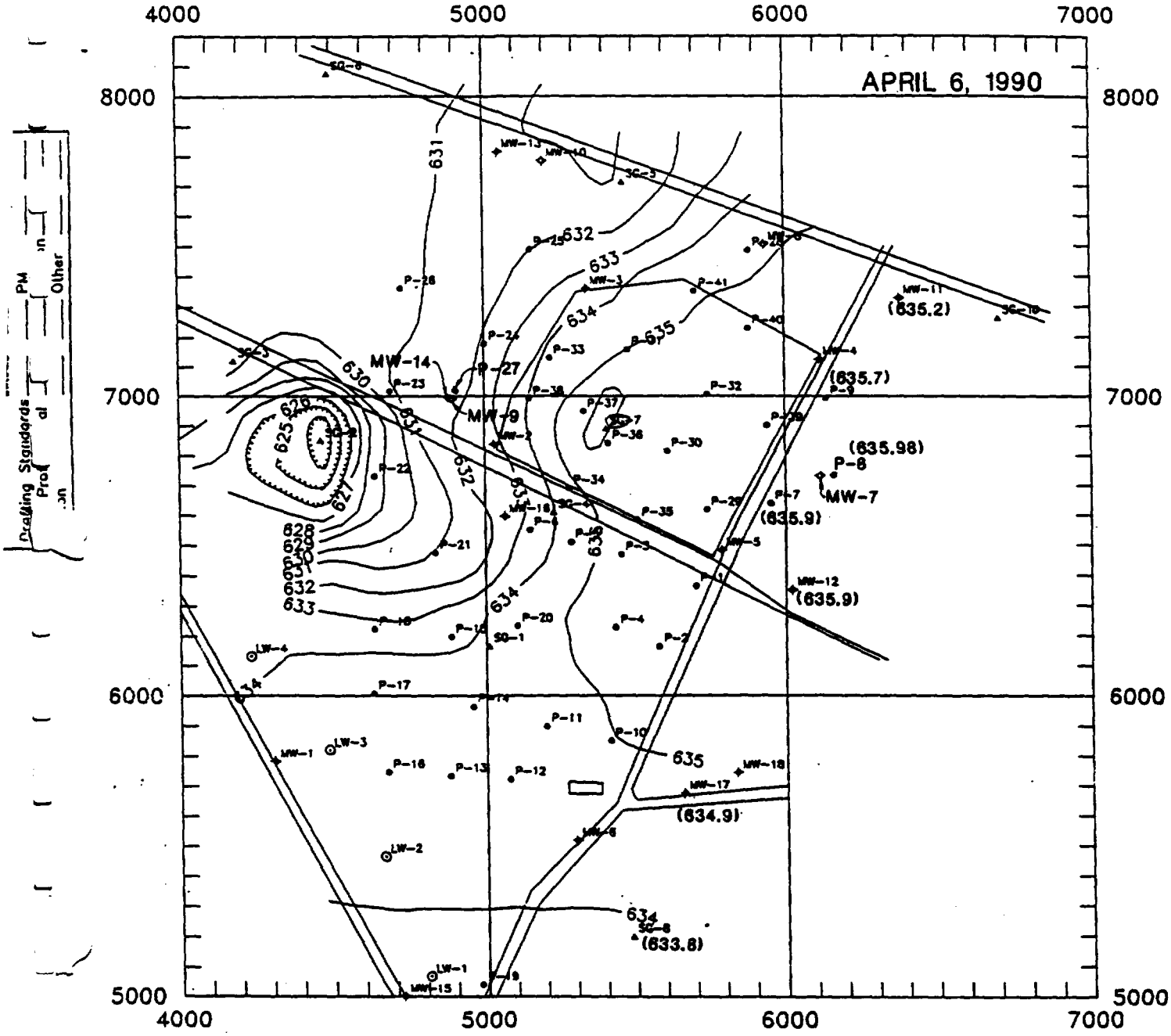


LEGEND

(632.7) GROUNDWATER ELEVATION

◆ UPPER AQUIFER MONITORING WELL LOCATION

◇ LOWER AQUIFER MONITORING WELL LOCATION

⊙ LEACHATE WELL LOCATION

● PIEZOMETER LOCATION

▲ STAFF GAUGE LOCATION

—620— WATER LEVEL CONTOUR LINE

NOTES

1. A GROUNDWATER ELEVATION FOR MW-1 WAS NOT AVAILABLE. THIS WELL WAS DESTROYED PRIOR TO WATER LEVEL MEASUREMENT.
2. THE GROUNDWATER ELEVATION AT P-18 WAS NOT USED IN MAP CONSTRUCTION. THE ELEVATION AT THIS PIEZOMETER WAS APPROXIMATELY 10 FT. HIGHER THAN ADJACENT GROUNDWATER ELEVATIONS.

0 500 1000

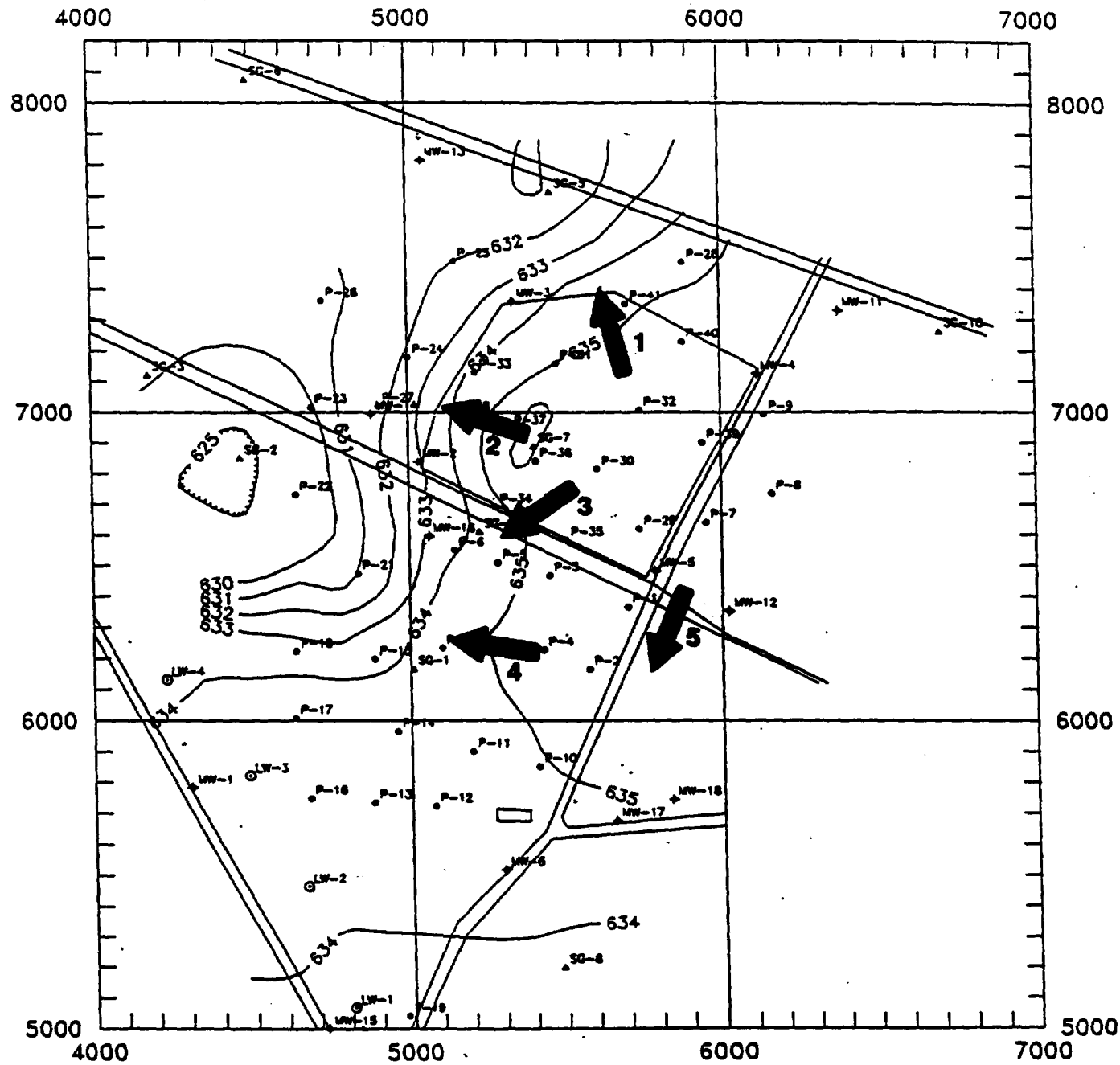
SCALE IN FEET

north

FIGURE 1-12

WARZYN	WATER TABLE CONTOUR MAP APRIL 6, 1990 FEASIBILITY STUDY AMERICAN CHEMICAL SERVICES NPL SITE GRIFFITH, INDIANA	Drawn D.L.L., T.J.M., J.A.W. Revisions	Checked JAW App'd. MSR Date 10/23/91 60251 A26

TELEDYNE POST . N40683



LEGEND

- ◆ UPPER AQUIFER MONITORING WELL LOCATION
- ⊙ LEACHATE WELL LOCATION
- ● PIEZOMETER LOCATION
- ▲ STAFF GAUGE LOCATION
- 1 ← GROUNDWATER FLOW PATH

NOTES

1. GROUNDWATER FLOW PATHS ARE DESCRIBED IN TABLE 4-5.

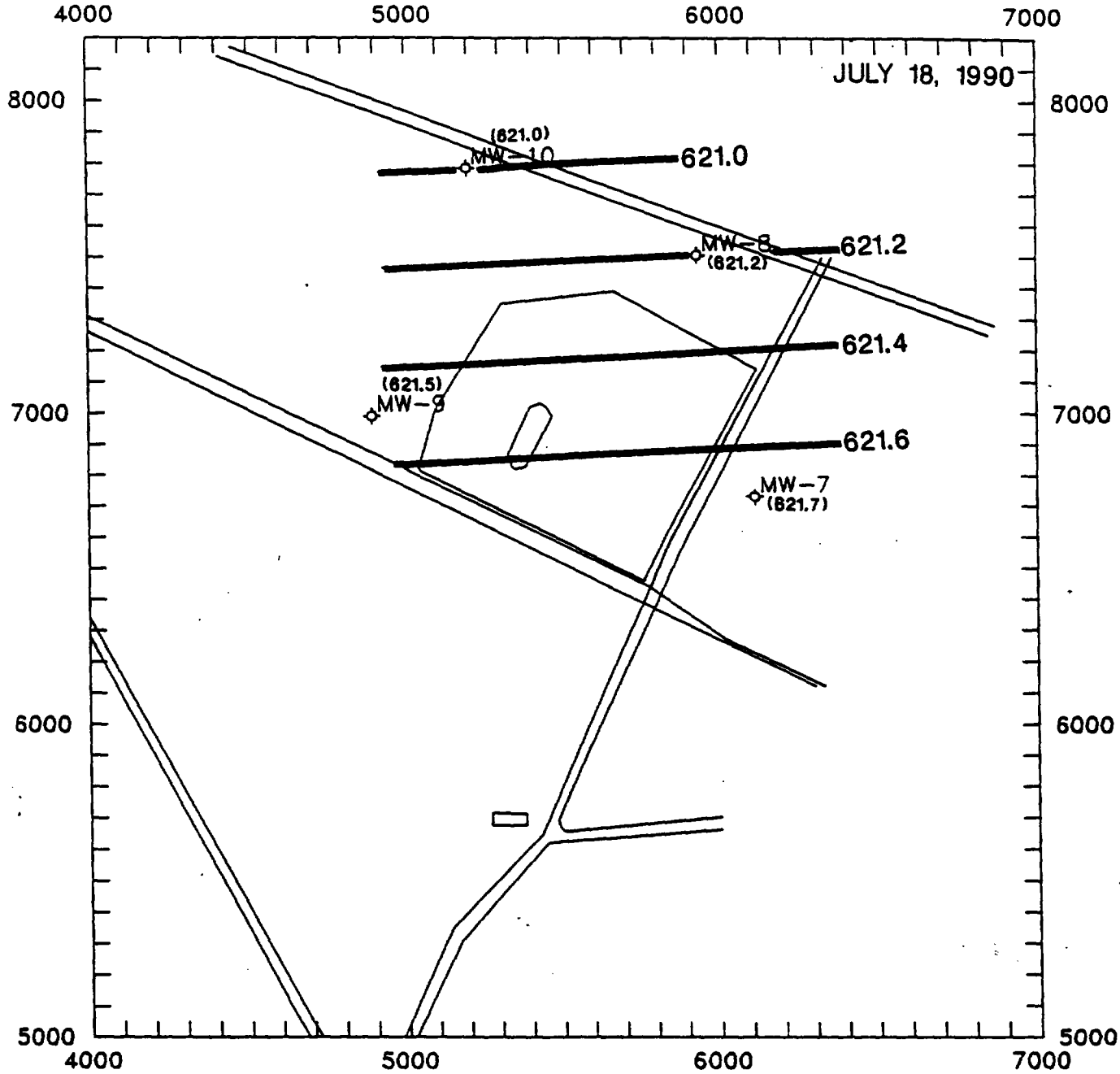
north

0 500 1000

SCALE IN FEET

FIGURE 1-13

WARZYN	UPPER AQUIFER GROUNDWATER FLOW PATHS	Drawn D.L.L., T.J.M., J.A.W.	Checked JAW	App'd. MSR
	FEASIBILITY STUDY AMERICAN CHEMICAL SERVICES NPL SITE GRIFFITH, INDIANA	Revisions		Date 10/23/91
				60251 A27



LEGEND

- ◇ LOWER AQUIFER MONITORING WELL LOCATION
- (621.5) MEASURED GROUNDWATER ELEVATION
- —— POTENTIOMETRIC SURFACE CONTOUR LINE

north

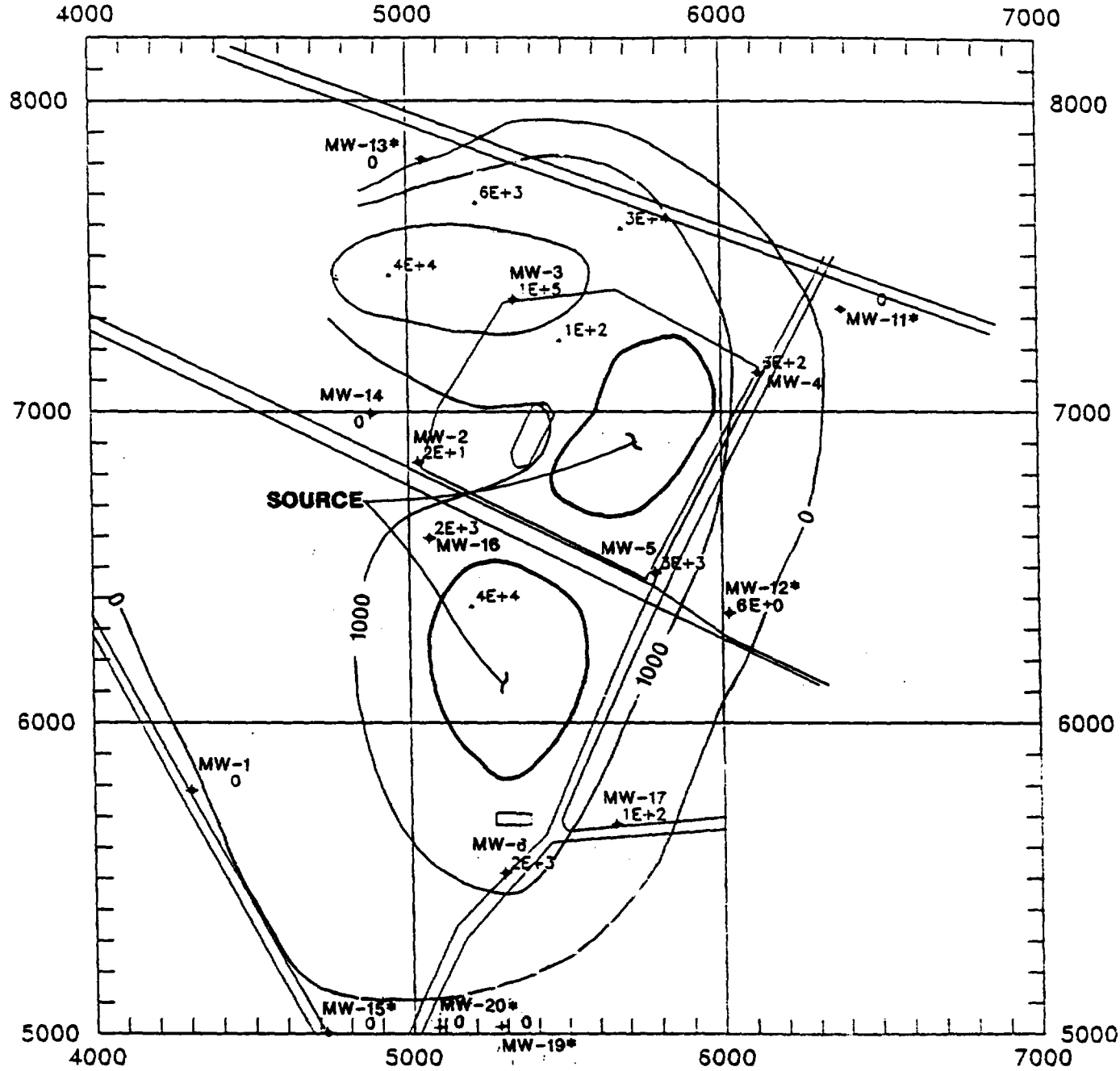
0 500 1000

SCALE IN FEET

FIGURE 1-14

WARZYN	POTENTIOMETRIC SURFACE, LOWER AQUIFER, JULY 18, 1990 FEASIBILITY STUDY AMERICAN CHEMICAL SERVICES NPL SITE GRIFFITH, INDIANA	Drawn D.L.L., T.J.M., J.A.W. Checked JAW Revisions	App'd. MSR Date 10/23/91 60251 A28

TELEDYNE POST N40683



LEGEND

- ◆ UPPER AQUIFER MONITORING WELL LOCATION
- ~ ISO-CONCENTRATION LINE
- ▲ AQUIFER MATRIX SAMPLE

NOTES

1. * INDICATES SAMPLES COLLECTED JAN. 16, 17 OR 18, 1991. ALL OTHER SAMPLES COLLECTED DURING PHASE II OF THE INVESTIGATION.

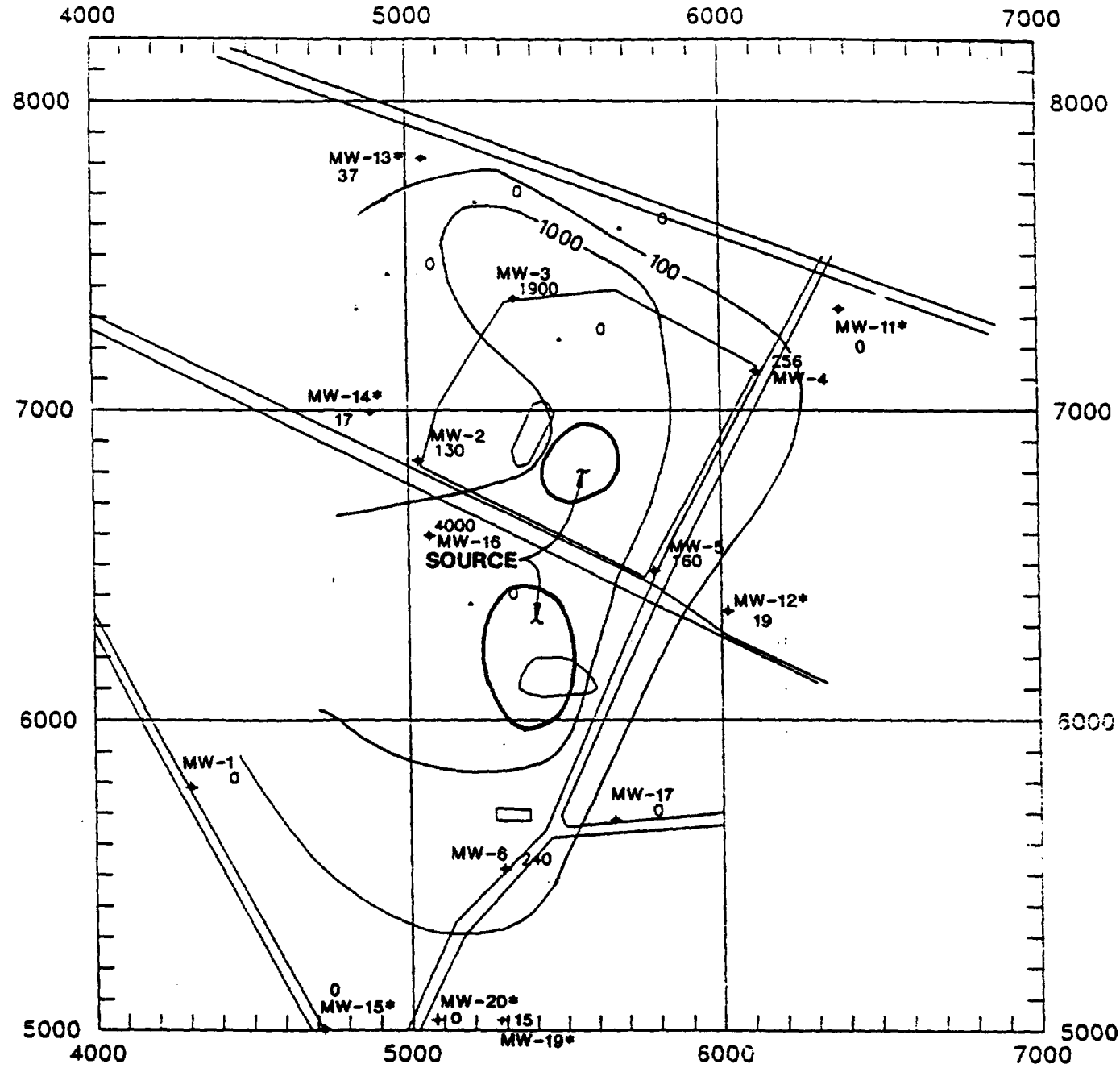
north

0 500 1000

SCALE IN FEET

FIGURE 1-15

WARZYN	UPPER AQUFER BETX DISTRIBUTION (ug/l)	Drawn DLL, TJM, JAW Checked JAW	App'd. MSR
	FEASIBILITY STUDY AMERICAN CHEMICAL SERVICES NPL SITE, GRIFFITH, INDIANA	Revisions	Date 10/23/91
			60251 A29



LEGEND

- ◆ UPPER AQUIFER MONITORING WELL LOCATION
- ~ ISO-CONCENTRATION LINE
- ▲ AQUIFER MATRIX SAMPLE

NOTES

1. * INDICATES SAMPLES COLLECTED JAN. 16, 17 OR 18, 1991. ALL OTHER SAMPLES COLLECTED DURING PHASE II OF THE INVESTIGATION.

north

0 500 1000

SCALE IN FEET

FIGURE 1-16

WARZYN	UPPER AQUFER CHLORINATED ETHANE DISTRIBUTION (ug/l)	Drawn DLL, TJM, JAW	Checked JAW	App'd. MSR
		Revisions		Date 10/23/91
	FEASIBILITY STUDY AMERICAN CHEMICAL SERVICES NPL SITE, GRIFFITH, INDIANA			60251 A30

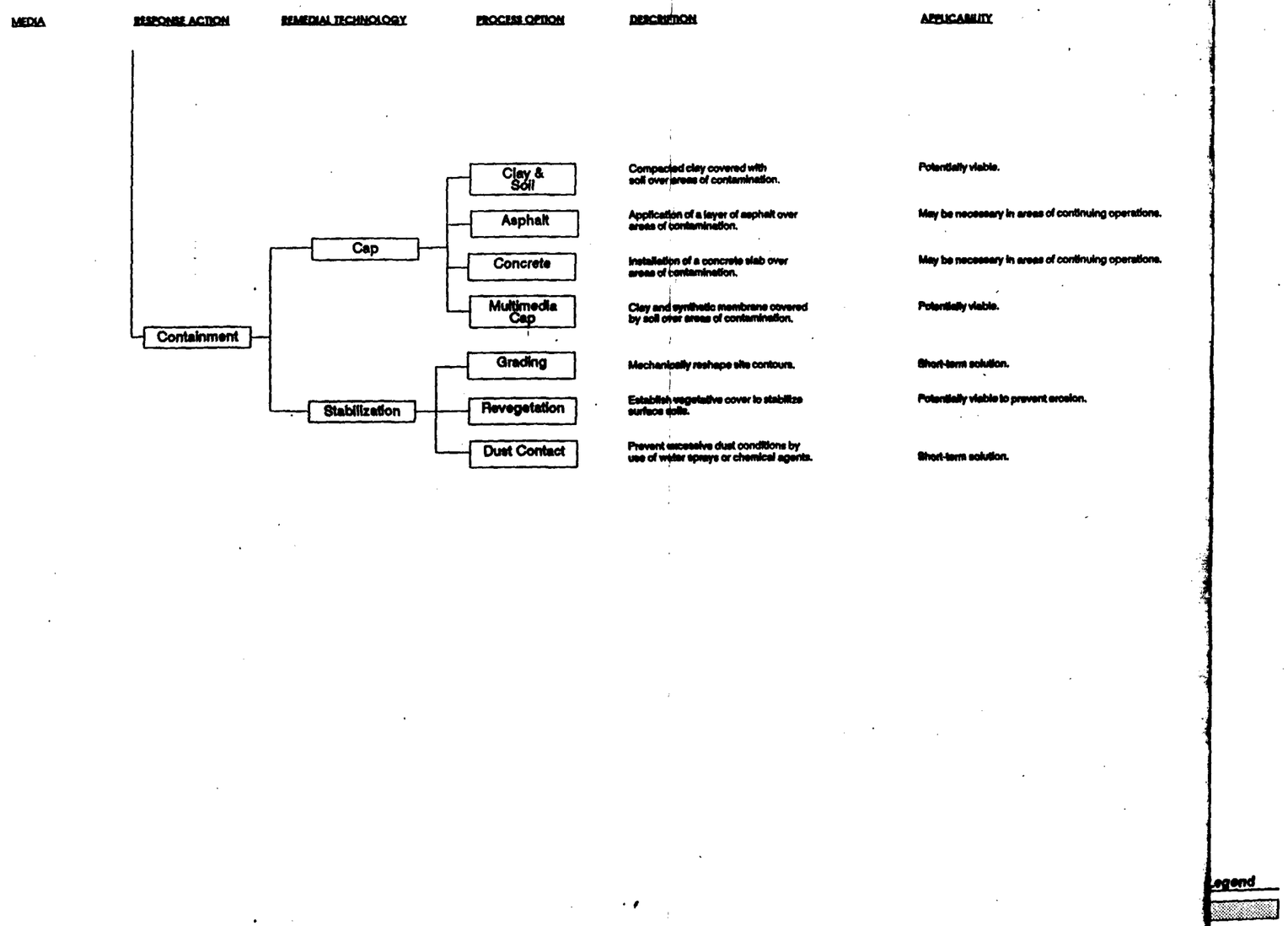


FIGURE 2-1

REMEDIAL TECHNOLOGY SCREENING (9 OF 9)

FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number 60251 B70

WARZYN

Designed By
Approved By MSR
Drawn By D.L.L.
Checked By CWB
Date 10/23/91

MASTER BLUE PRINT INC. 516246

MEDIA	RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	APPLICABILITY
Soils and Sediments	In-Situ Treatment	Land Disposal	Offsite RCRA Landfill	Permanent storage of contaminated soils at an approved RCRA-permitted.	Potentially viable for soils and treatment residues.
			Onsite RCRA Landfill	Permanent storage of contaminated soils onsite.	Potentially viable for soils and treatment residues.
		Biological Treatment	Aerobic	Soil seeded with micro-organisms and nutrients to allow biological degradation in aerobic environment.	Potentially viable for all areas. Would not treat metals.
			Anaerobic	Soil seeded with micro-organisms and nutrients to allow biological degradation in anaerobic environment.	Potentially viable for all areas. Would not treat metals.
			Bioharvesting	Use of plant and animal species to accumulate contaminants in their tissues. Species are harvested and disposed of.	Contaminant levels too high. Not proven for contaminants found.
		Chemical Treatment	Oxidation	Application via underground injection of chemicals such as ozone, hydrogen peroxide, or permanganite for degradation of organics.	Difficult to control in-situ.
			Reduction	Applicaitne via underground injection of reducing chemicals in which the oxidation state of the compound is reduced.	Difficult to control in-situ.
			Photolysis	Photodegradation of soil contaminants via solar energy and the application of solvents.	Shallow penetration depth. Soils too deep.
		Physical Treatment	Steam Stripping	Steam is injected in-situ to strip VOCs from soil to air. Vapors are collected for further treatment.	Potentially viable for all areas. Would not treat metals or PCBs.
			Vapor Extraction	Removal of VOC's by application of vacuums on soils, or injection of steam, through a system of wells.	Potentially viable for all areas. Would not treat metals or PCBs.
			Vitrification	Contaminated material is fused into glassy stable materials by heating it in place with an electric current.	Potentially viable for all areas.
			Injection Grouting	Stabilization of contaminated material by injection of grout into the ground through well points.	Not proven for types of contaminants found.
			Solvent Extraction	Application of solvent either via surface flooding or injection and collection of extract at wells followed by treatment.	Potential for migration to lower aquifer.
			Soil Washing	Application of water either via surface flooding or injection and collection of extract at wells followed by treatment.	Contamination levels too high. Not proven for types of contaminants found.
			Fixation	Immobilization of contaminants using sulfide, lime, fly ash and numerous other materials.	Potentially viable for PCBs and metals. Not likely to treat organics.
			Radio Frequency	Vaporization of contaminants using electromagnetic wave energy to heat soil.	Potentially viable for all areas. Would not treat metals.

Legend

FIGURE 2-1

REMEDIAL TECHNOLOGY SCREENING (8 OF 9)

FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number 60251B69

WARZYN

Drawn by D.L.L.
Checked by CWB
Date 10/23/91
Designed by
Approved by MSR

WARZYN ENGINEERING INC.

MASTER BLUE PRINT INC. 516246

MEDIA	RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	APPLICABILITY
Soils and Sediments	No Action	None		No Action	NCP requires no action to be carried through to detailed analysis of alternative!
	Access Restrictions	Deed Restrictions		All deeds for property within potentially contaminated areas would include restrictions.	Potentially viable.
		Fence		Fence would be installed around site.	Potentially viable.
	Removal	Biological Treatment	Bioreactor/ Land Farming	Soil is spread out over large area, aerated and treated with nutrients to allow biological degradation.	Potentially viable for all areas. Would not treat metals.
		Thermal Treatment	Offsite Incineration	Destruction of contaminants using various high temperature methods.	Potentially viable for all areas. Would not treat metals.
			Onsite Incineration	Destruction of contaminants using various high temperature methods.	Potentially viable for all areas. Would not treat metals.
			Onsite Low Temp	Volatilization of contaminants using various low temperature methods with high temperature struction of off-gases.	Potentially viable for all areas. Would not treat metals.
			Offsite Low Temp	Volatilization of contaminants using various low temperature methods with high temperature destruction of off-gases.	Potentially viable for all areas . Would not treat metals.
		Physical Treatment	Vapor Extraction	Removal of VOCs by application of vacuums on soils, or through injection of air.	Potentially viable for all areas. Would not treat metals or PCBs.
			Solvent Extraction	Application of solvents in a bath process to extract contaminants for separation and further treatment.	Potentially viable for all areas.
			Fixation	Immobilization of contaminants using sulfide, lime, fly ash and numerous other materials. Would not apply to buried drums.	Potentially viable for metals and PCBs for all areas. Not likely to treat organics.
			Soil Washing	Application of water and surfactants in a batch process to extract contaminants for separation and further treatment.	Contamination levels too high. Not proven for types of contaminants found.
		Chemical Treatment	Oxidation	Oxidizer such as ozone, hydrogen peroxide, or permanganate is introduced into a contactor where it mixes with soil and oxidation occurs.	Cost is prohibitive due to large volume.
			Dechlorination Process	Sodium reagent used to strip chlorine atoms from chlorinated hydrocarbons.	Cost is prohibitive due to large volume.
			Wet Air Oxidation	Oxidation of organics in a reactor under high temperature and pressure.	Cost is prohibitive due to large volume.
			Reduction	Reduction of chlorinated organics and hexavalent chromium.	Cost is prohibitive due to large volume.

Legend

FIGURE 2-1

REMEDIAL TECHNOLOGY SCREENING (7 OF 9)

FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

WARZYN ENGINEERING, INC.

Drawn By D.L.L.
Checked By CJB
Date 10/23/91
Designed By
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Project Number 60251B68

WARZYN

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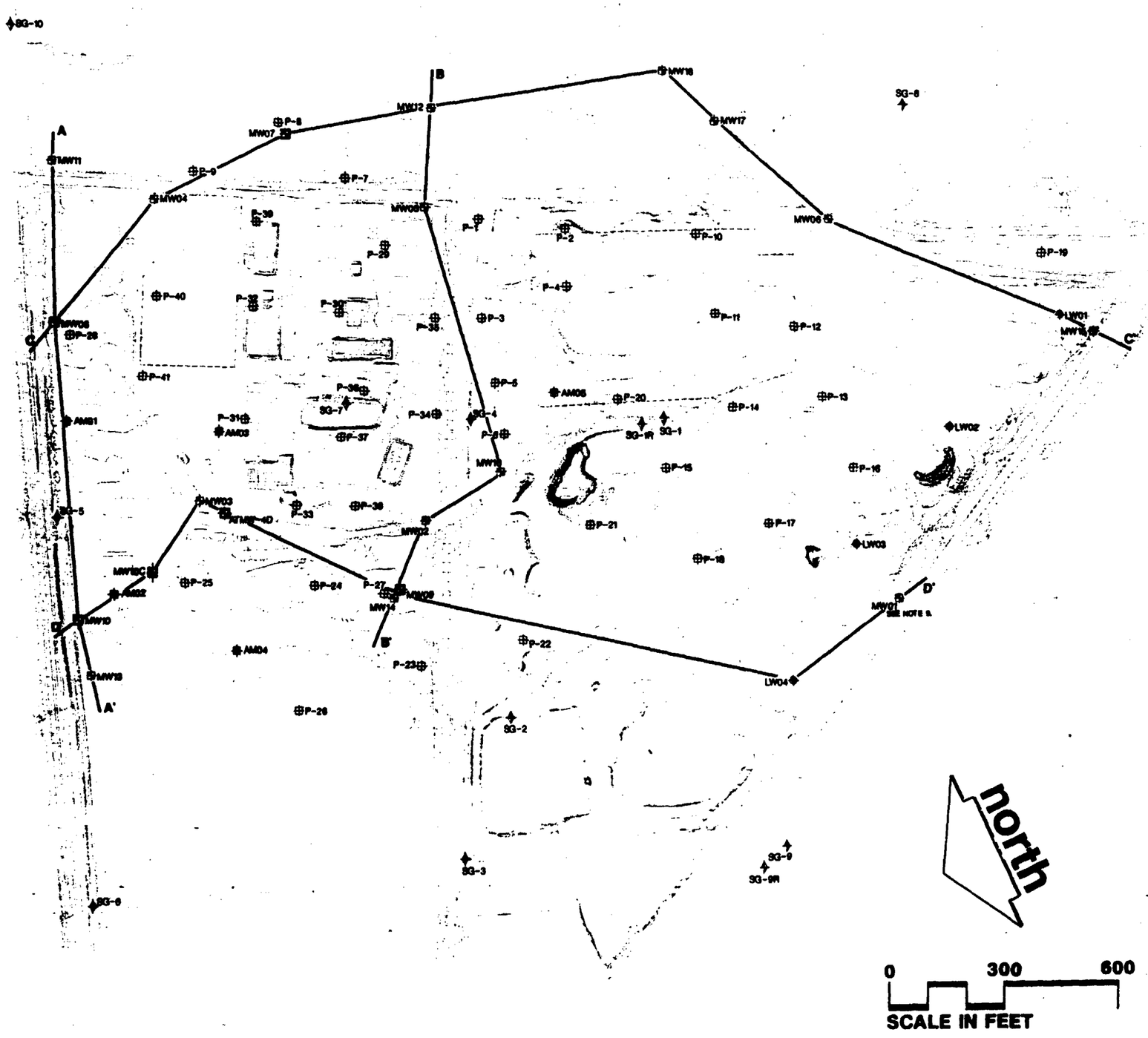

LEGEND

———	GEOPHYSICS INVESTIGATION AREA
MW01	UPPER AQUIFER MONITORING WELL LOCATION & NUMBER
MW10	LOWER AQUIFER MONITORING WELL LOCATION & NUMBER
LW01	LEACHATE HEADWELL LOCATION & NUMBER
P-1	PIEZOMETER LOCATION & NUMBER
SG-1	STAFF GAUGE LOCATION & NUMBER
AM01	AQUIFER MATRIX SAMPLE LOCATION & NUMBER
— —	GEOLOGIC CROSS-SECTION LOCATION

NOTES

1. INITIAL BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 6, 1986. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC. THE BASE MAP WAS UPDATED BASED ON THE AERIAL PHOTOGRAPH.
2. MONITORING WELL MW01, STAFF GAUGES SG1 AND SG9 HAVE BEEN DESTROYED. STAFF GAUGES SG-1R AND SG-9R ARE THE CORRESPONDING REPLACEMENT STAFF GAUGES.
3. VERTICAL SITE DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.
4. MONITORING WELL ATMW-4D WAS DRILLED AND INSTALLED BY ATEC ENGINEERING ASSOC. ON SEPTEMBER 27, 1988. THE LOCATION OF ATMW-4D IS APPROXIMATE.
5. MONITORING WELL MW01 TO MW05 WERE DRILLED AND INSTALLED BY EXPLORATION TECHNOLOGY INC (ETI) UNDER THE SUPERVISION OF WARZYN DURING THE PHASE I INVESTIGATION IN JULY 1988.
6. MONITORING WELL MW07 TO MW18 WERE DRILLED AND INSTALLED BY EXPLORATION TECHNOLOGY INC (ETI) UNDER THE SUPERVISION OF WARZYN DURING THE PHASE II INVESTIGATION IN MARCH THROUGH JUNE 1989.
7. LOCATIONS OF MONITORING WELLS, PIEZOMETERS, AND SURFACE WATER STAFF GAUGES WERE FIELD LOCATED BY EMI ENGINEERING ASSOC. SURVEYORS.
8. STAFF GAUGES ARE CONSTRUCTED OF IRON POLES AND WERE INSTALLED BY WARZYN.
9. MONITORING WELL MW-01 WAS DESTROYED BY ROAD CONSTRUCTION DURING SPRING 1990.

FIGURE 1-11

Designed by TEM
Drawn by D.L.L.
Checked by JAW
Approved by MSP
Date 10/23/91
Revisions

WARZYN
WARZYN ENGINEERING INC.

LOCATION MAP FOR SITE CROSS-SECTIONS
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number 60251 B61

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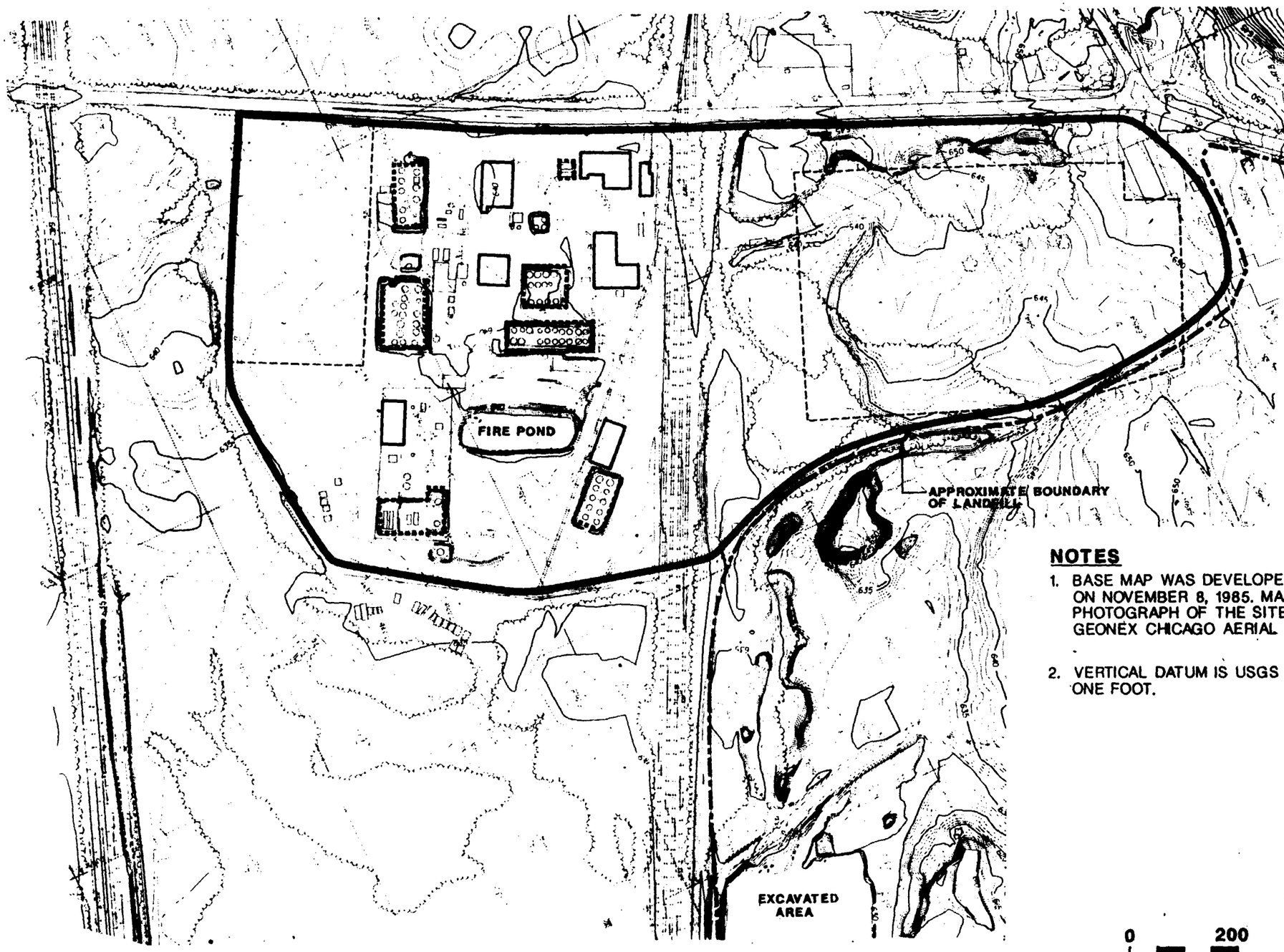


LEGEND

APPROXIMATE TANK FARM BOUNDARY

SLURRY WALL FOR SITE REMOVING RAILROAD TRACKS

NOTES

1. BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 8, 1985. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC.

2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.

0 200 400
SCALE IN FEET

north

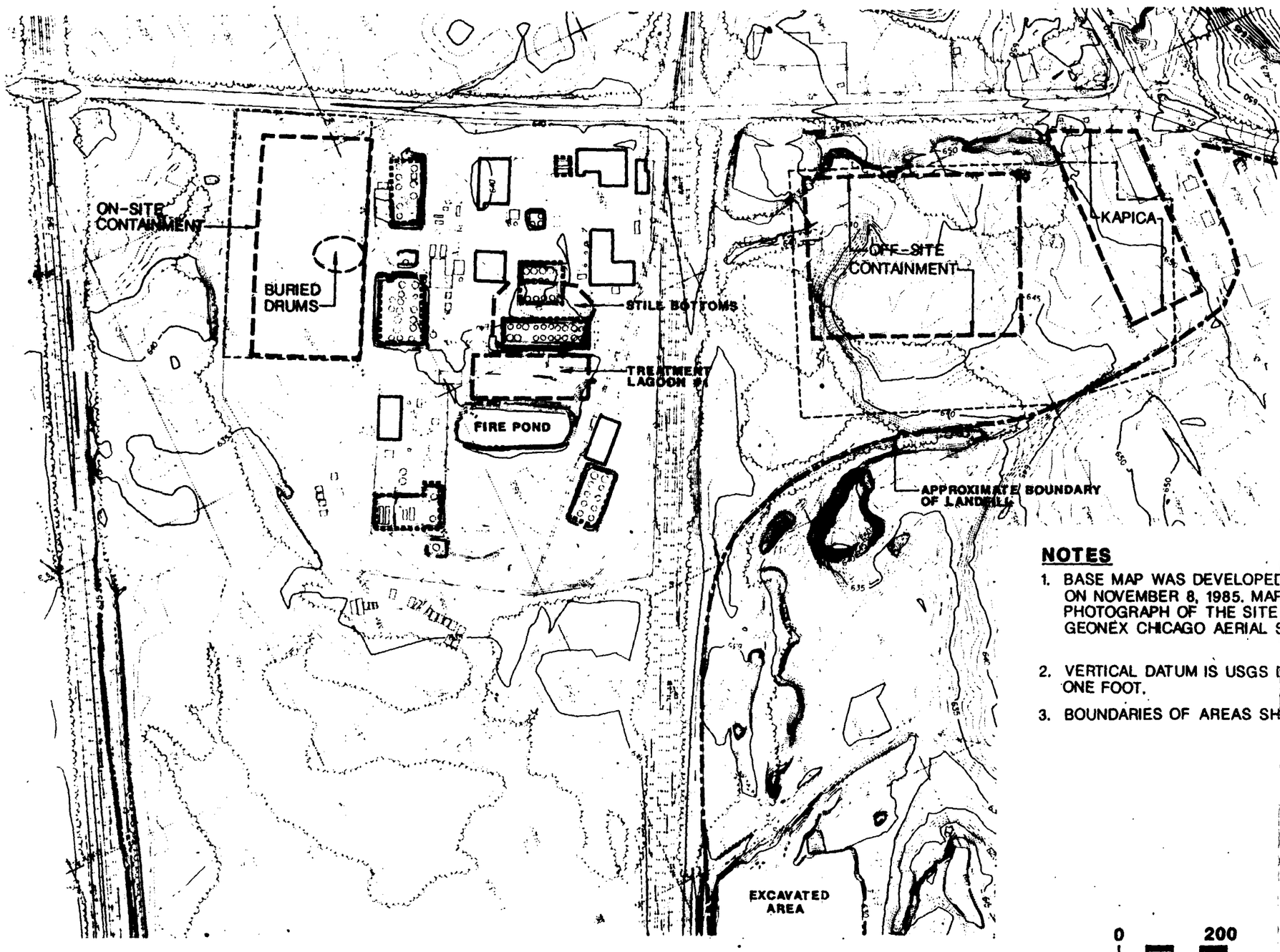
FIGURE 3-2a

WARZYN

Drawn by DLL
Checked by
Approved by MSR
Date 10/23/91
Reference
File Path:

PROPOSED SLURRY WALL
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number 60251B32



LEGEND

APPROXIMATE TANK FARM BOUNDARY

NOTES

1. BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 8, 1985. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC.
2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.
3. BOUNDARIES OF AREAS SHOWN ARE APPROXIMATE.

0 200 400
SCALE IN FEET

north

FIGURE 3-1

WARZYN

Designed by
Drawn by TLO
Checked by
Approved by ASK
Date 7/13/90
Reference
File Path:
Revisions
Date & By/Appr'd
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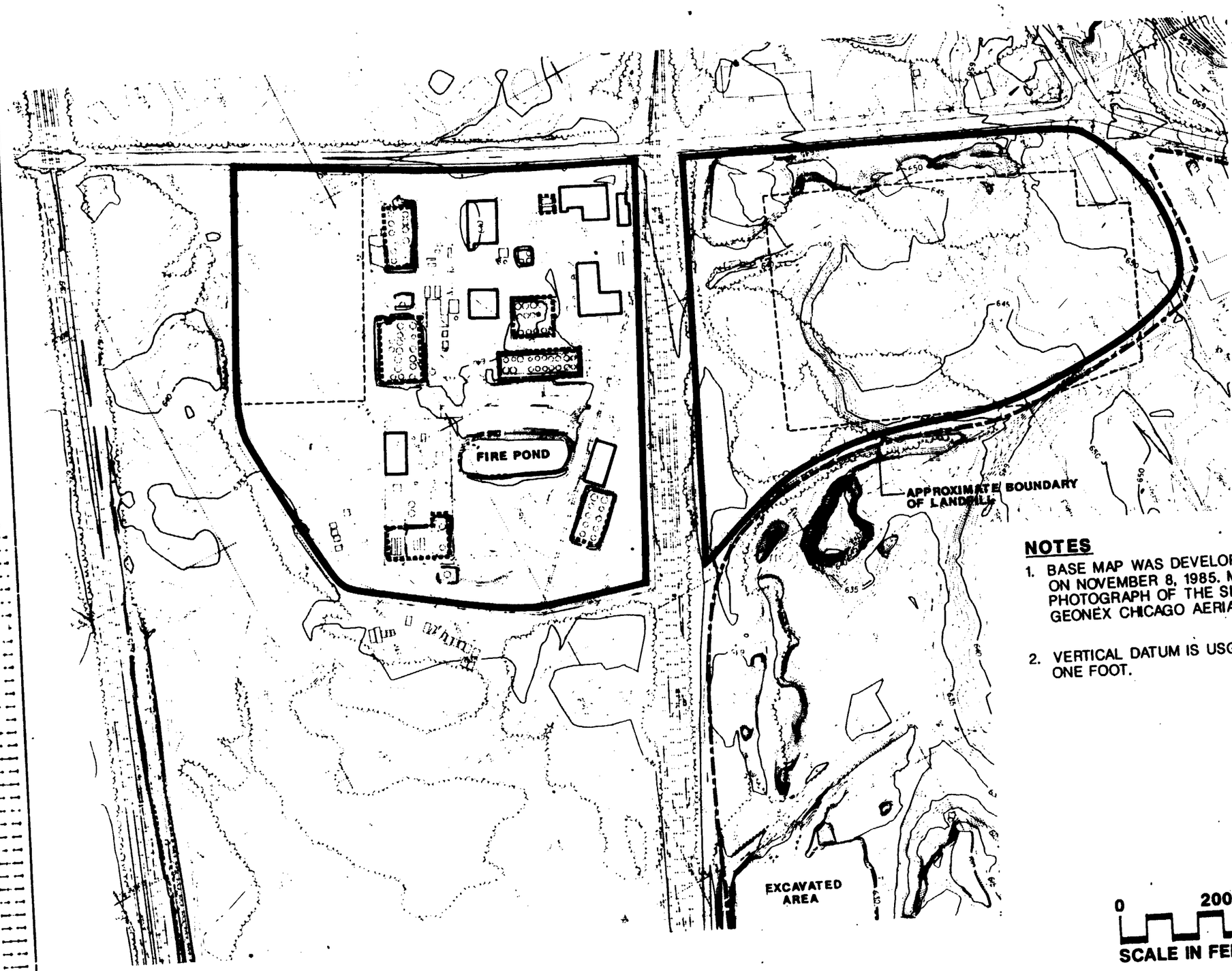
SITE LAYOUT MAP
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number
60251 B31



LEGEND

APPROXIMATE TANK FARM BOUNDARY

SLURRY WALL FOR SITE LEAVING RAILROAD TRACKS

NOTES

1. BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 8, 1985. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC.
2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.

0 200 400
SCALE IN FEET

north

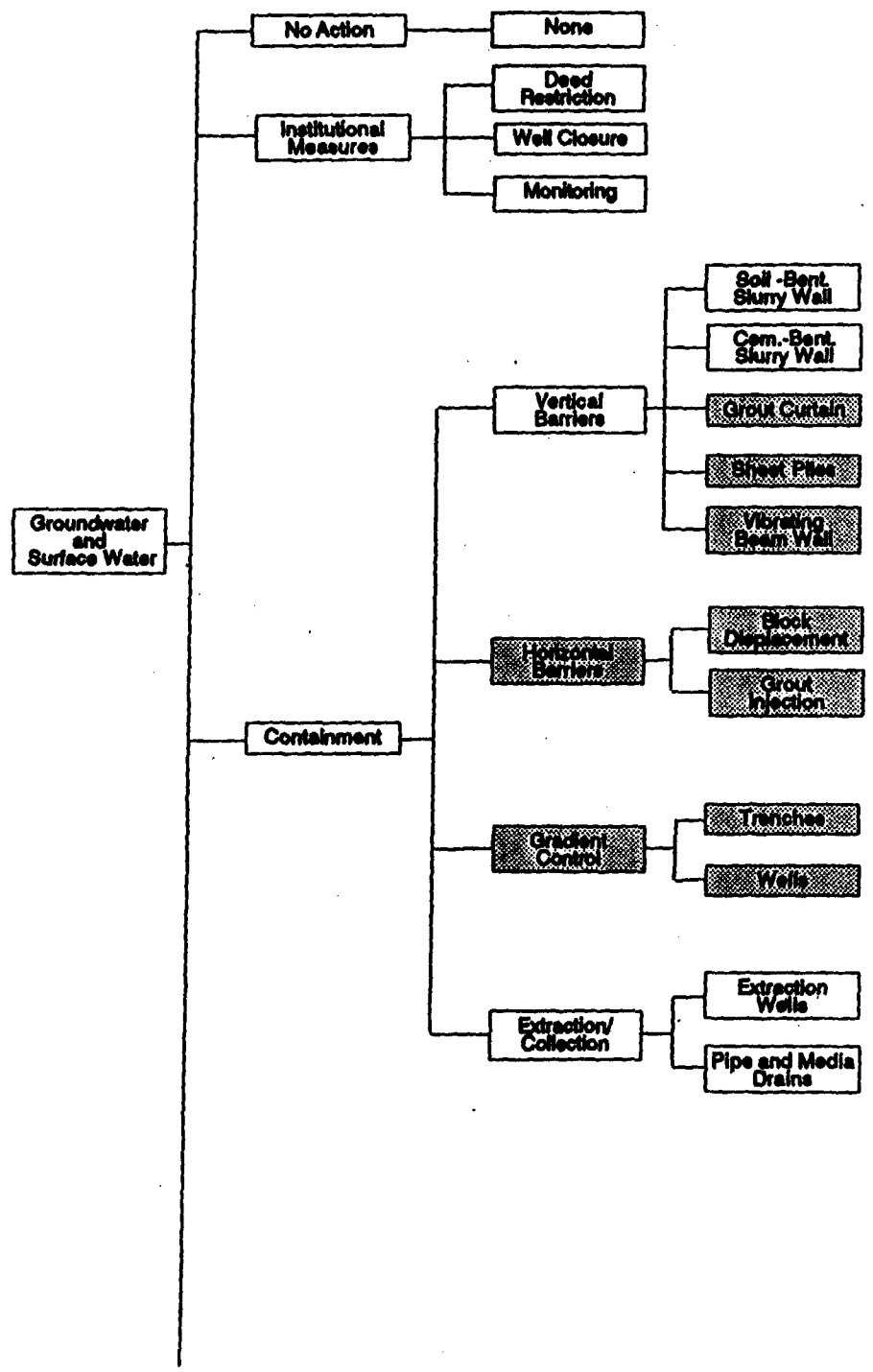
FIGURE 3-2b

PROPOSED SLURRY WALL
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

60251 B33

WARZYN

Drawn By DLT
Checked By
Date 1/16/91
Approved By
Reference
File Path



DESCRIPTION	APPLICABILITY
No Action.	NCP requires No Action to be carried through to detailed analysis of alternatives.
All deeds for property within potentially contaminated areas would include restrictions on use of property.	Potentially viable.
Closure of drinking water wells and replacement as necessary within the affected area of influence.	Potentially viable.
Periodic analysis of groundwater to evaluate remedial effectiveness.	Potentially viable.
Trench is excavated while filled with a bentonite water slurry. Trench is backfilled with a soil-bentonite mix.	Potentially viable for all areas of the site. Not viable for surface water runoff.
Trench is excavated while filled with a cement bentonite water slurry. Cement sets and forms the wall.	Potentially viable for all areas of the site. Not viable for surface water runoff.
Pressure injection of grout in a regular overlapping pattern of drilled holes.	Difficult to assure continuity of barrier. Leakage may occur.
Driven steel sheet piling.	Interlocks may be difficult to seal. Leakage may occur.
Vibratory force used to advance steel beam into ground and injection of relatively thin wall of cement or bentonite as beam is withdrawn.	Difficult to determine integrity of barrier. Leakage may occur.
Controlled injection of slurry in notched injection holes to produce horizontal barrier beneath the contaminants.	Not applicable for use at a large site.
Pressure injection of grout at depth through closely spaced drilled holes.	Not applicable for use at a large site.
Trenches used to inject water to create a hydraulic barrier or to direct the contaminated groundwater and surface water to extraction wells or collection areas.	Very large volume to pump.
Wells installed to inject water to create a hydraulic barrier or to direct the contaminated groundwater to extraction wells.	Very large volume to pump.
Series of wells to extract contaminated groundwater, for treatment or disposal.	Potentially viable for groundwater, but not surface water runoff.
System of perforated pipe laid in trenches and backfilled with permeable media to collect contaminated groundwater.	Potentially viable.

Legend

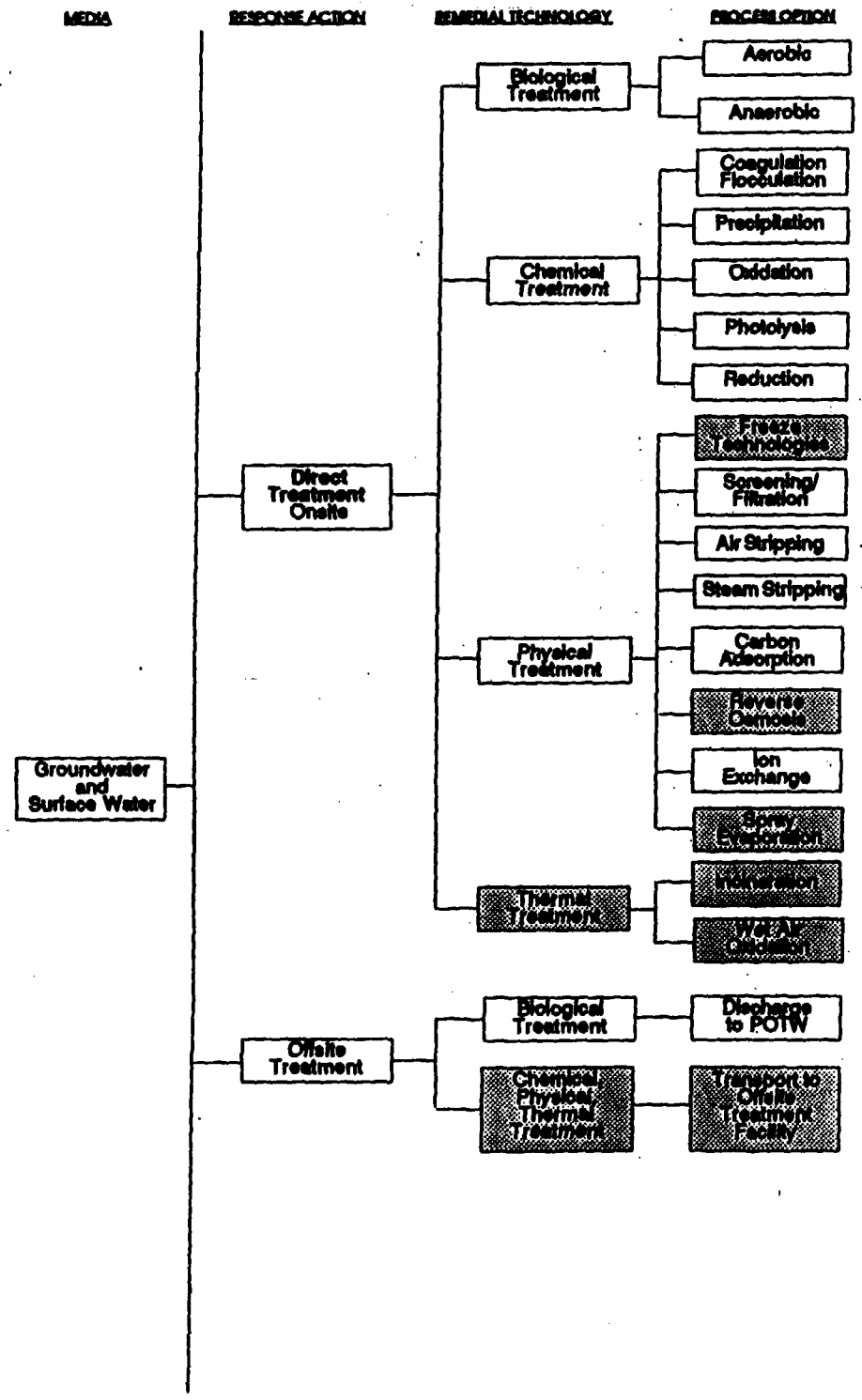
FIGURE 2-1

REMEDIAL TECHNOLOGY SCREENING (1 OF 9)
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

WARZYN ENGINEERING INC.

Project Number 60251 B62

Drawn By D.L.L. Checked By CWB
Designed By Approved By MSR Date 6/23/91



DESCRIPTION	APPLICABILITY
Use microorganisms in an aerobic environment to degrade organics.	Potentially viable. Would not treat metals.
Use microorganisms in an anaerobic environment to degrade organics.	Potentially viable. Would not treat metals
Physical/Chemical process to agglomerate particulates into a larger mass for removal.	Potentially viable for suspended materials.
Alteration of chemical equilibrium to reduce solubility of the constituent.	Potentially viable. Would only treat metals.
Chemical oxidation of groundwater contaminants using an oxidization agent such as peroxide, hypochlorite, chlorine gas or ozone.	Potentially viable. Would not treat metals.
Photodegradation of contaminants using UV radiation.	Potentially viable.
Reduction of chlorinated organics and hexavalent chromium.	Potentially viable.
Dilute solutions are frozen to separate inorganic, organic and aqueous phases.	Not proven for types of contaminants found.
Physical removal of suspended solids from a waste stream.	Potentially viable for pretreatment prior to organics removal.
Contacting of large volumes of air with water in a packed column or through diffused aeration to promote transfer of VOC's to air.	Potentially viable for organic contaminants. Would not treat metals or PCBs.
Similar to air stripping except steam is pumped into stripping column to add heat in the promotion of transfering VOC's from liquid to air.	Potentially viable for organic contaminants. Would not treat metals or PCBs.
Passage of contaminated water over columns of activated carbon where contaminants adsorb onto the carbon surfaces.	Potentially viable for organic contaminants and metals.
Use of high pressure to force clean water through a membrane leaving contaminants behind.	Cost is prohibitive. Effectiveness is unproven.
Contaminated water is passed through a bed of resin material where exchange of ions occurs between the bed and the water.	Potentially viable. Would only treat metals.
Contaminated water sprayed into the air where volatile compounds are transferred from the water. Large collection ponds receive spray water.	Process difficult to control. Once airborne, contaminants may be carried offsite. Complete volatilization of some constituents may not occur.
Thermal destruction of organic contaminants using any one of many reactor types suited to handle aqueous wastes.	Not practical for treating groundwater with low level contamination.
Oxidation of organic contaminants at elevated temperatures and pressures.	Energy Intensive. Other equally effective technologies are available.
Contaminated groundwater is pumped and discharged to POTW	Potentially viable.
Contaminated groundwater is pumped for above ground storage and trucked to offsite disposal facility.	Cost is prohibitive because of large volumes of water.

Legend

FIGURE 2-1

REMEDIAL TECHNOLOGY SCREENING (2 OF 9)

FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number 60251 B63

WARZYN

Designed by
Drawn by D.L.L.
Checked by CWB
Approved by MSR
Date 10/23/91

WARZYN ENGINEERING INC.

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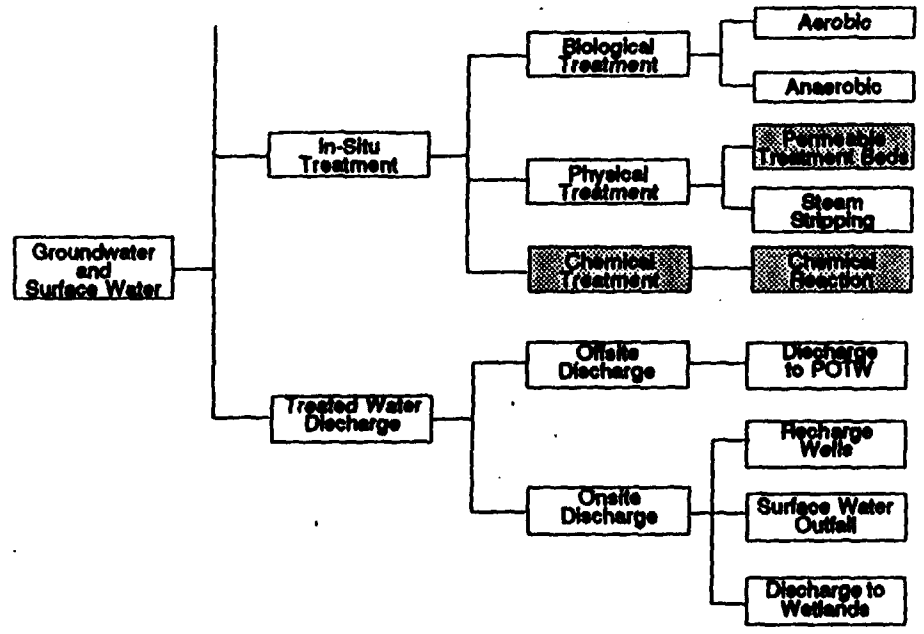

MEDIA	RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	APPLICABILITY
Groundwater and Surface Water	In-Situ Treatment	Biological Treatment	Aerobic	System of injection and extraction wells used to inject water seeded with bacteria and nutrients to biodegrade contaminants in an aerobic environment.	Potentially viable for all areas. Would not treat metals.
			Anaerobic	System of injection and extraction wells used to inject water seeded with bacteria and nutrients to biodegrade contaminants in an anaerobic environment.	Potentially viable for all areas. Would not treat metals.
		Physical Treatment	Permeable Treatment Beds	Trenches downgradient of site backfilled with activated carbon, lime, or ion exchange resins, to remove contaminants as groundwater passes through.	Difficult to determine when beds exhausted. Depth of contaminants too great.
			Steam Stripping	Steam is injected in-situ to strip VOCs from groundwater to air. Vapors are collected for further treatment.	Potentially viable for all areas. Would not treat metals or PCBs.
		Chemical Treatment	Chemical Reaction	System of injection wells used to inject oxidizers such as ozone, permanganate or hydrogen peroxide for degradation of organics.	Difficult to control in-situ. Unproven technologies.
	Treated Water Discharge	Offsite Discharge	Discharge to POTW	Treated water is pumped to the local POTW.	Potentially viable.
		Onsite Discharge	Recharge Wells	Treated water is reinjected into the upper aquifer via a series of injection wells.	Potentially viable.
			Surface Water Outfall	Treated water is discharged to a local stream.	Potentially viable.
			Discharge to Wetlands	Treated water is discharged to wetlands west of site to flush sediments and prevent dewatering.	Potentially viable.

Legend

FIGURE 2-1

REMEDIAL TECHNOLOGY SCREENING (3 OF 3)

FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

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Drawn by O.L.L.
Checked by CWB
Approved by MSR
Date 10/23/91

Project Number 60251 B64

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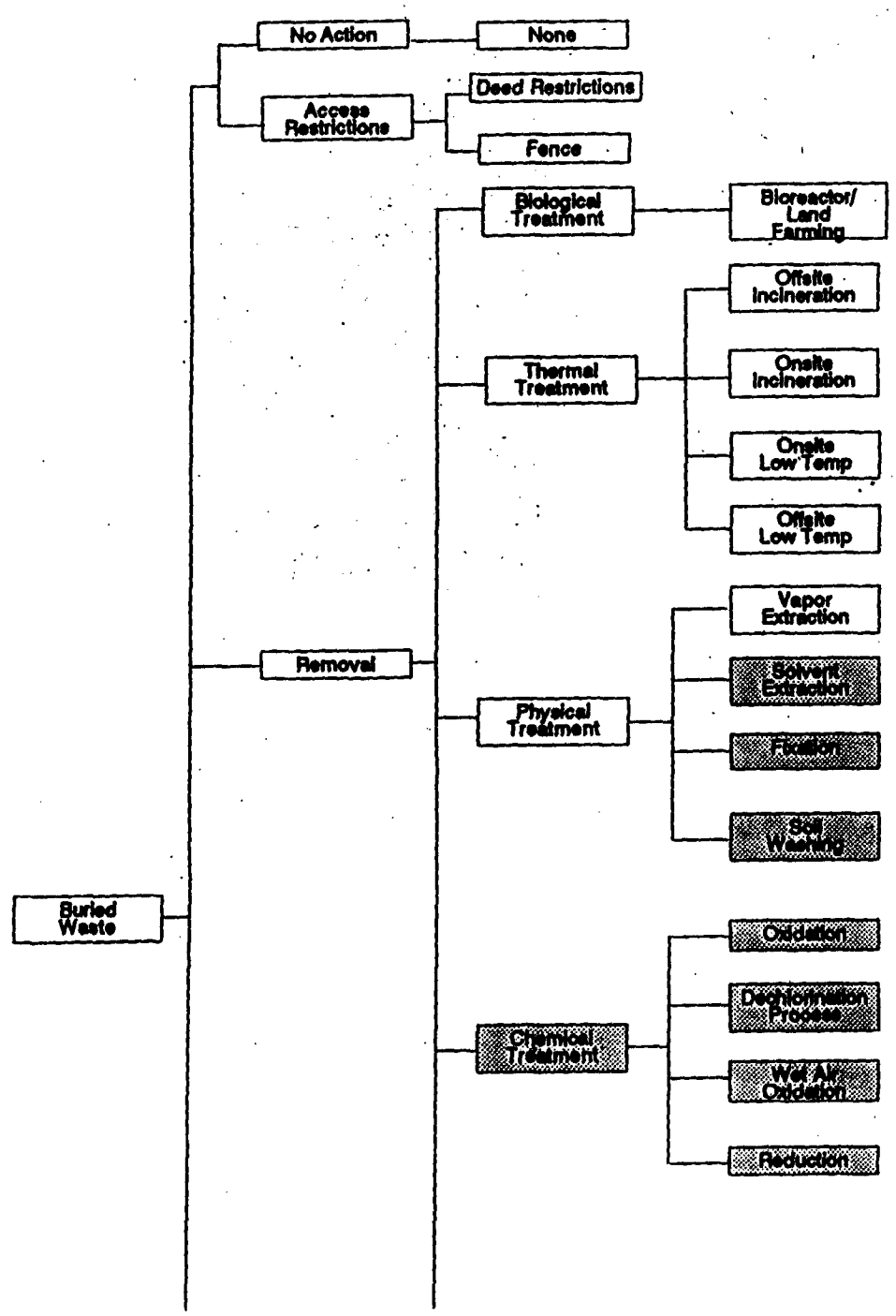

MEDIA	RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	APPLICABILITY
Buried Waste	No Action	None		No Action	NCP requires no action to be carried through to detailed analysis of alternatives
	Access Restrictions	Deed Restrictions		All deeds for property within potentially contaminated areas would include restrictions.	Potentially viable.
		Fence		Fence would be installed around site.	Potentially viable.
	Removal	Biological Treatment	Bioreactor/ Land Farming	Waste is spread out over large area, aerated and treated with nutrients to allow biological degradation.	Potentially viable for all areas. Would not treat metals.
		Thermal Treatment	Offsite Incineration	Destruction of contaminants using various high temperature methods.	Potentially viable for all areas. Would not treat metals.
			Onsite Incineration	Destruction of contaminants using various high temperature methods.	Potentially viable for all areas. Would not treat metals.
			Onsite Low Temp	Volatilization of contaminants using various low temperature methods with high temperature destruction of off-gases.	Potentially viable for all areas. Would not treat metals. Would not apply to buried drums.
			Offsite Low Temp	Volatilization of contaminants using various low temperature methods with high temperature destruction of off-gases.	Potentially viable for all areas. Would not treat metals. Would not apply to buried drums.
		Physical Treatment	Vapor Extraction	Removal of VOCs by application of vacuume on soils, or through injection of air.	Potentially viable.
			Solvent Extraction	Application of solvents in a bath process to extract contaminants for separation and further treatment.	Contaminant levels too high.
			Fixation	Immobilization of contaminants using sulfide, lime, fly ash and numerous other materials. Would not apply to buried drums.	Contaminant levles too high.
			Soil Washing	Application of water and surfactants in a batch process to extract contaminants for separation and further treatment.	Contamination levels too high. Not proven for types of contaminants found.
		Chemical Treatment	Oxidation	Oxidizer such as ozone, hydrogen peroxide, or permenganate is introduced into a contactor where it mixes with soil and oxidation occurs.	Cost is prohibitive due to large volume.
			Dechlorination Process	Sodium reagent used to strip chlorine atoms from chlorinated hydrocarbons.	Cost is prohibitive due to large volume.
			Wet Air Oxidation	Oxidation of organics in a reactor under high temperature and pressure.	Cost is prohibitive due to large volume.
			Reduction	Reduction of chlorinated organics and hexavalent chromium.	Cost is prohibitive due to large volume.

Legend

REMEDIAL TECHNOLOGY SCREENING (4 OF 9)

FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

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WARZYN ENGINEERING INC.

Designed by MSR
Drawn by D.L.L.
Checked by CWB
Date 10/23/91

Project Number 60251 B65

FIGURE 2-1

MEDIA	RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	APPLICABILITY
Buried Waste	In-Situ Treatment	Land Disposal	Offsite RCRA Landfill	Permanent storage of contaminated soils at an approved RCRA-permitted.	Would not meet RCRA regulations for land disposal.
			Onsite RCRA Landfill	Permanent storage of contaminated soils onsite.	Would not meet RCRA regulations for land disposal.
		Biological Treatment	Aerobic	Soil seeded with micro-organisms and nutrients to allow biological degradation in aerobic environment.	Potentially viable for all areas. Would not treat metals.
			Anaerobic	Soil seeded with micro-organisms and nutrients to allow biological degradation in anaerobic environment.	Potentially viable for all areas. Would not treat metals.
			Bioharvesting	Use of plant and animal species to accumulate contaminants in their tissues. Species are harvested and disposed of.	Contaminant levels too high.
		Chemical Treatment	Oxidation	Application via underground injection of chemicals such as ozone, hydrogen peroxide, or permanganate for degradation of organics.	Contaminant levels too high.
			Reduction	Application via underground injection of reducing chemicals in which the oxidation state of the compound is reduced.	Contaminant levels too high.
			Photolysis	Photodegradation of soil contaminants via solar energy and the application of solvents.	Contaminant levels too high.
		Physical Treatment	Vapor Extraction	Removal of VOC's by application of vacuums on soils, or injection of steam, through a system of wells.	Potentially viable for all areas. Would not treat metals.
			Vitrification	Contaminated material is fused into glassy stable materials by heating it in place with an electric current.	Potentially viable.
			Mineral Grouting	Stabilization of contaminated material by injection of grout into the ground through well points.	Not proven for types of contaminants found.
			Solvent Extraction	Application of solvent either via surface flooding or injection and collection of extract at wells followed by treatment.	Contaminant levels too high.
			Soil Washing	Application of water either via surface flooding or injection and collection of extract at wells followed by treatment.	Contaminant levels too high. Not proven for types of contaminants found.
			Fixation	Immobilization of contaminants using sulfide, lime, fly ash and numerous other materials.	Contaminant levels too high. Not proven for types of contaminants found.
			Radio Frequency	Vaporization of contaminants using electromagnetic wave energy to heat soil.	Contaminant levels too high. Would not treat metals.
			Steam Stripping	Steam is injected in-situ to strip VOCs from buried waste to air. Vapors are collected for further treatment.	Potentially viable for all areas. Would not treat metals.

Legend

FIGURE 2-1

REMEDIAL TECHNOLOGY SCREENING (5 OF 9)

FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number 60251B66

WARZYN

Drawn By D.L.L. Checked By CWB Date 6/23/91

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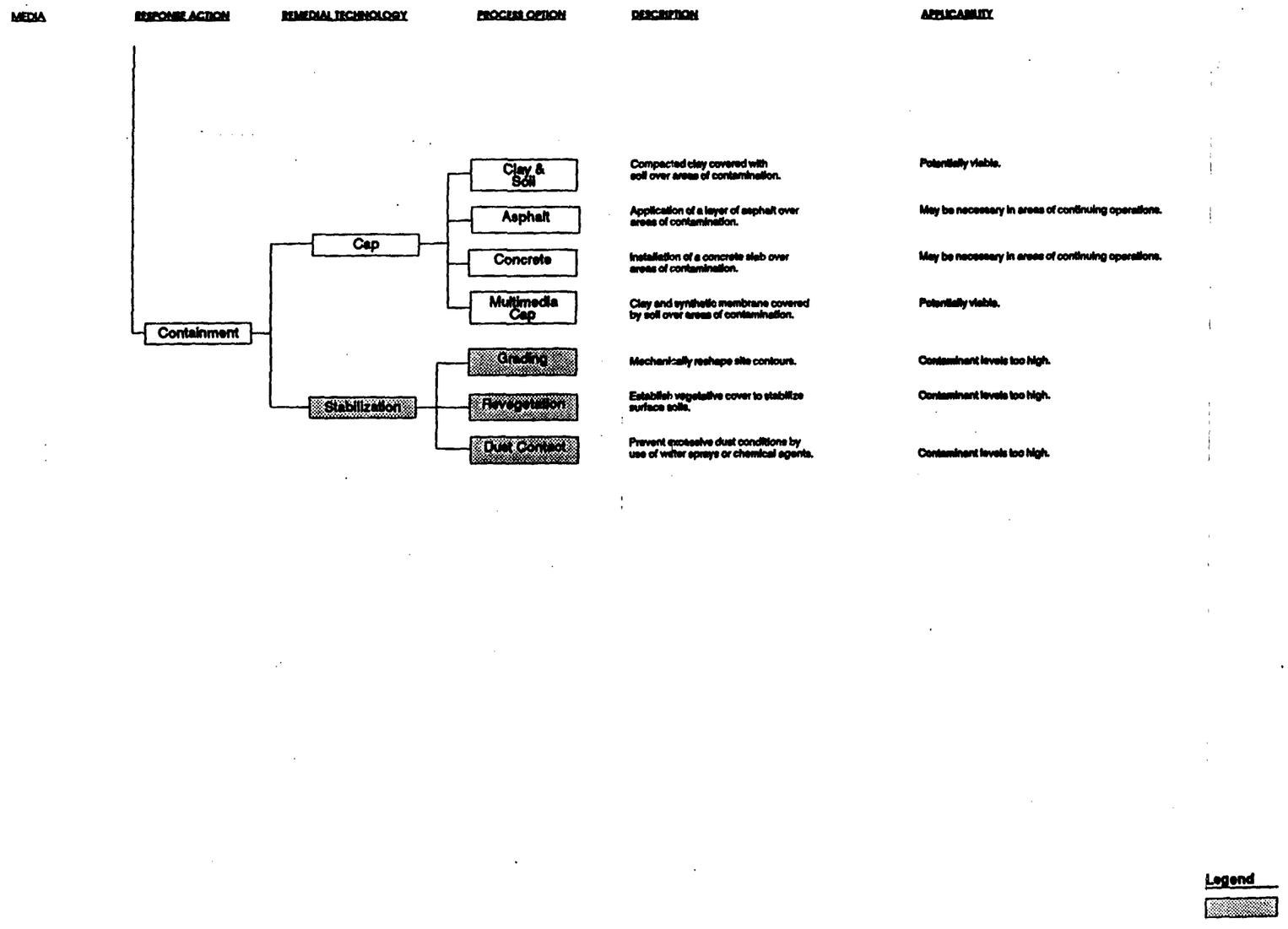

FIGURE 2-1

REMEDIAL TECHNOLOGY SCREENING (6 OF 9)

FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

WARZYN ENGINEERING INC.

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Drawn by D.L.L.
Checked by CWB
Approved by MSR
Date 10/23/91

Project Number 60251 B67

WARZYN

FIGURE 3-3 (cont'd)

Substrate Compounds	Respiration		Fermentation	Oxidation	Co-oxidation
	Aerobic	Anaerobic			
Thiols					
Cyclic Alkanes	+		+	+	+
Unhalogenated Aromatics	+	+		+	
Halogenated Aromatics	+	+		+	+
Simple Aromatic Nitro Compounds	+	+			
Aromatic Nitro Compounds With Other Functional Groups	+	+			+
Phenols	+	+	+	+	+
Halogenated Side Chain Aromatics	+		+	+	
Fused Ring Hydroxy Compounds	+				
Nitrophenols		+			
Halophenols	+			+	

(continued)

FIGURE 3-3 (cont'd)

Substrate Compounds	Respiration		Fermentation	Oxidation	Co-oxidation
	Aerobic	Anaerobic			
Phenols - Dihydrides, Polyhydrides	+			+	+
Two & Three Ring Fused Polycyclic Hydrocarbons	+			+	
Biphenyls	+				
Chlorinated Biphenyls	+				
Four Ring Fused Polycyclic Hydrocarbons	+				
Five Ring Fused Polycyclic Hydrocarbons	+				
Fused Polycyclic Hydrocarbons	+				
Organophosphates	+	+			
Pesticides and Herbicides	+	+			+

FIGURE 3-4

BOD_5/COD RATIOS FOR VARIOUS ORGANIC COMPOUNDS

Compound	Ratio
Relatively Undegradable	
Butane	~0
Butylene	~0
Carbon tetrachloride	~0
Chloroform	~0
1,4-Dioxane	~0
Ethane	~0
Heptane	~0
Hexane	~0
Isobutane	~0
Isobutylene	~0
Liquefied natural gas	~0
Liquefied petroleum gas	~0
Methane	~0
Methyl bromide	~0
Methyl chloride	~0
Monochlorodifluoromethane	~0
Nitrobenzene	~0
Propane	~0
Propylene	~0
Propylene oxide	~0
Tetrachloroethylene	~0
Tetrahydronaphthalene	~0
1-Pentene	<0.002
Ethylene dichloride	0.002
1-Octene	>0.003
Morpholine	<0.004
Ethylenediaminetetraacetic acid	0.005
Triethanolamine	<0.006
o-Xylene	<0.008
m-Xylene	<0.009
Ethylbenzene	<0.009
Moderately Degradable	
Ethyl ether	0.012
Sodium alkylbenzenesulfonates	~0.017
Monoisopropanolamine	<0.02
Gas oil (cracked)	~0.02
Gasolines (various)	~0.02
Relatively Degradable (cont'd.)	
Furfural	0.17-0.46
2-Ethyl-3-propylacrolein	<0.19
Methylethylpyridine	<0.20
Vinyl acetate	<0.20
Diethylene glycol monomethyl ether	<0.20
Naphthalene (molten)	<0.20
Dibutyl phthalate	0.20
Hexanol	~0.20
Soybean oil	~0.20
Paraformaldehyde	0.20
n-Propyl alcohol	0.20-0.63
Methyl methacrylate	<0.24
Acrylic acid	0.26
Sodium alkyl sulfates	~0.30
Triethylene glycol	0.31
Acetic acid	0.31-0.37
Acetic anhydride	>0.32
Ethylenediamine	<0.35
Formaldehyde solution	0.35
Ethyl acetate	<0.36
Octanol	0.37
Sorbitol	<0.38
Benzene	<0.39
n-Butyl alcohol	0.42-0.74
Propionaldehyde	<0.43
n-Butyraldehyde	<0.43

Compound	Ratio
Moderately Degradable (cont'd.)	
Mineral spirits	~0.02
Cyclohexanol	0.03
Acrylonitrile	0.031
Nonanol	>0.033
Undecanol	<0.04
Methylethylpyridine	0.04-0.75
1-Hexene	<0.044
Methyl isobutyl ketone	<0.044
Diethanolamine	<0.049
Formic acid	0.05
Styrene	>0.06
Heptanol	<0.07
sec-Butyl acetate	0.07-0.23
n-Butyl acetate	0.07-0.24
Methyl alcohol	0.07-0.73
Acetonitrile	0.079
Ethylene glycol	0.081
Ethylene glycol monoethyl ether	<0.09
Sodium cyanide	<0.09
Linear alcohols (12-15 carbons)	>0.09
Allyl alcohol	0.091
Dodecanol	0.097
Relatively Degradable	
Valeraldehyde	<0.10
n-Decyl alcohol	>0.10
p-Xylene	<0.11
Urea	0.11
Toluene	<0.12
Potassium cyanide	0.12
Isopropyl acetate	<0.13
Amyl acetate	0.13-0.34
Chlorobenzene	0.15
Jet fuels (various)	~0.15
Kerosene	~0.15
Range oil	~0.15
Glycerine	<0.16
Adiponitrile	0.17
Relatively Degradable (cont'd.)	
Ethyleneimine	0.46
Monoethanolamine	0.46
Pyridine	0.46-0.56
Dimethylformamide	0.48
Dextrose solution	0.50
Corn syrup	~0.50
Maleic anhydride	>0.51
Propionic acid	0.52
Acetone	0.55
Aniline	0.56
Isopropyl alcohol	0.56
n-Amyl alcohol	0.57
Isoamyl alcohol	0.57
Cresols	0.57-0.68
Crotonaldehyde	<0.58
Phthalic anhydride	0.58
Benzaldehyde	0.62
Isobutyl alcohol	0.63
2,4-Dichlorophenol	0.78
Tallow	~0.80
Phenol	0.81
Benzoic acid	0.84
Carbolic acid	0.84
Methyl ethyl ketone	0.88
Benzoyl chloride	0.94
Hydrazine	1.0
Oxalic acid	1.1

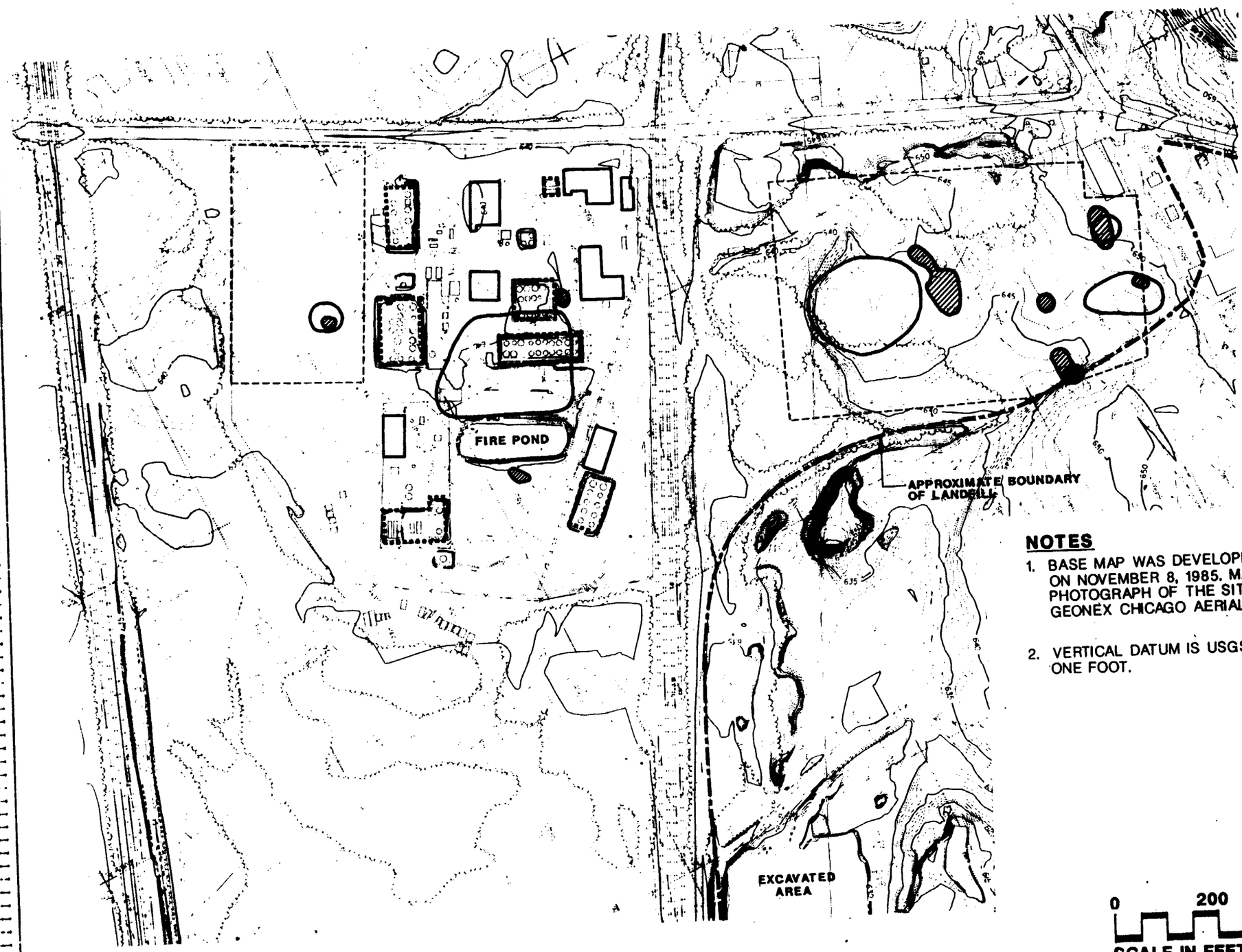
Source: Lyman, Reehl and Rosenblatt, 1982

FIGURE 3-3

SUMMARY OF ORGANIC GROUPS SUBJECT TO BIODEGRADATION

Substrate Compounds	Respiration		Fermentation	Oxidation	Co-oxidation
	Aerobic	Anaerobic			
Straight Chain Alkanes	+	+	+	+	+
Branched Alkanes	+	+	+	+	+
Saturated Aklyl Halides		+		+	+
Unsaturated Alkyl Halides		+		+	
Esters, Glycols, Epoxides	+	+	+	+	
Alcohols	+	+		+	
Aldehydes, Ketones	+	+		+	
Carboxylic Acids	+	+		+	
Amides	+	+			
Esters	+	+			
Nitriles	+	+			
Amines	+	+			
Phthalate Esters	+	+		+	
Nitrosamines		+			

(continued)



LEGEND

- APPROXIMATE TANK FARM BOUNDARY
- BURIED WASTE
- PCBs > 50 ppm

NOTES

1. BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 8, 1985. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC.
2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.

FIGURE 4-1

BURIED WASTE & PCB LOCATION MAP

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AMERICAN CHEMICAL SERVICES
NPL SITE
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WARTZN

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Approved By: MSK

Revisions

Reference:

File Prefix:

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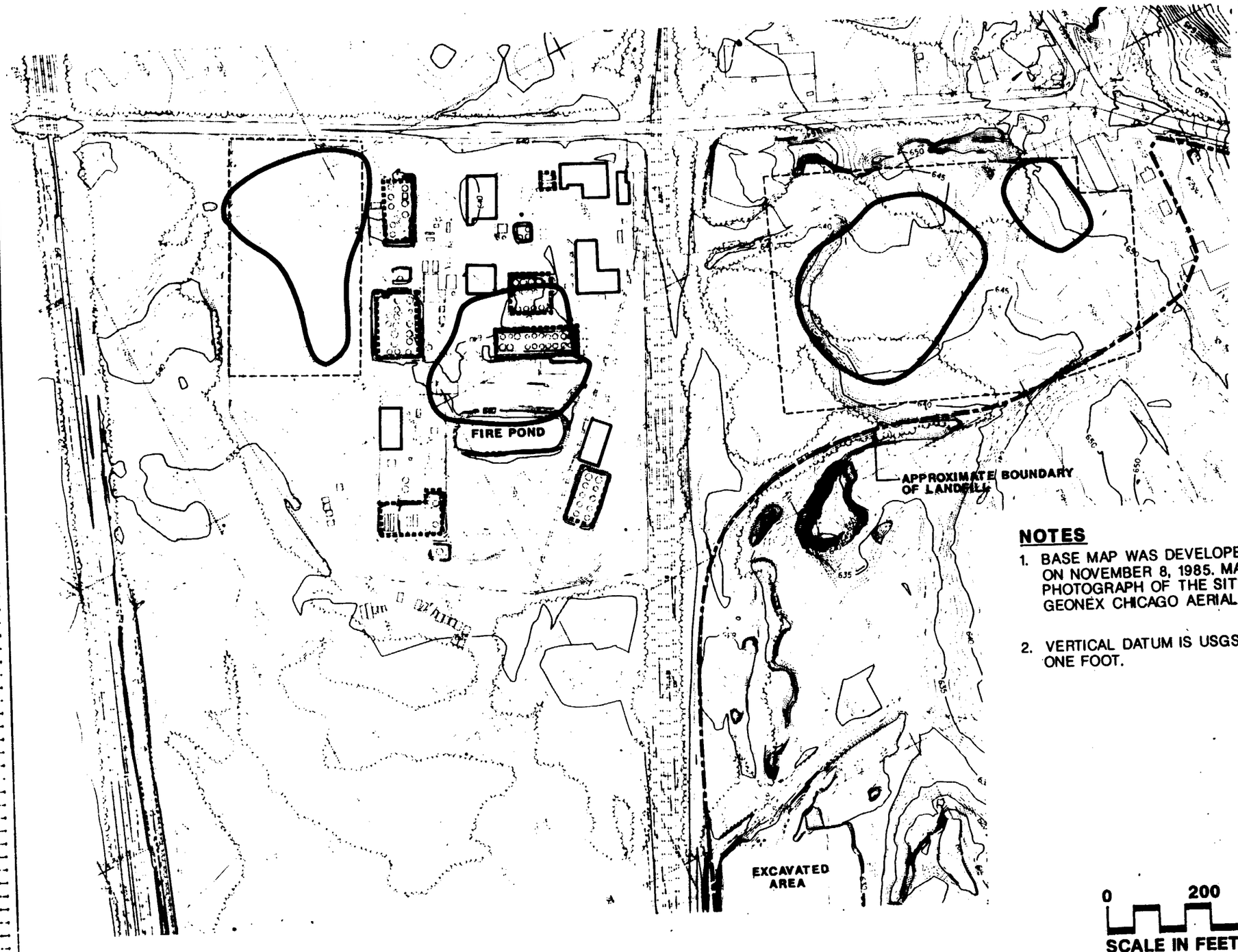

LEGEND

APPROXIMATE TANK FARM BOUNDARY

CONTAMINATED SOIL (TOTAL VOCs > 10 ppm)

NOTES

1. BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 8, 1985. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC.
2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.

0 200 400
SCALE IN FEET

north

FIGURE 4-2

CONTAMINATED SOIL LOCATION MAP
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AMERICAN CHEMICAL SERVICES
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Project Number 60251B49

WARREN

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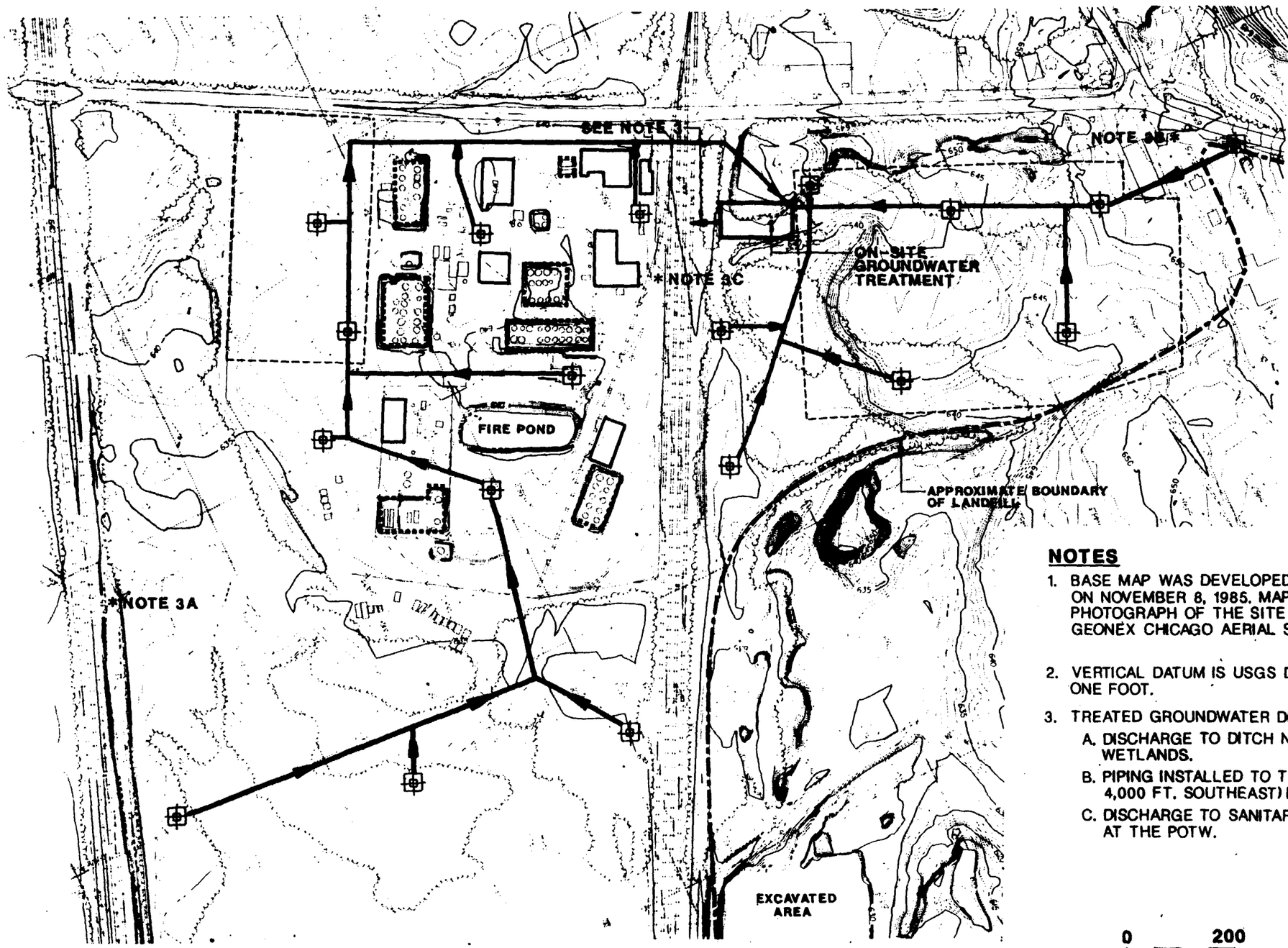


LEGEND

- APPROXIMATE TANK FARM BOUNDARY
- RECOVERY WELL GROUP
- GROUNDWATER COLLECTION PIPING

NOTES

1. BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 8, 1985. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC.
2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.
3. TREATED GROUNDWATER DISCHARGE OPTIONS:
   - A. DISCHARGE TO DITCH NORTH OF SITE TO RECHARGE WETLANDS.
   - B. PIPING INSTALLED TO TURKEY CREEK (APPROXIMATELY 4,000 FT. SOUTHEAST) FOR DISCHARGE.
   - C. DISCHARGE TO SANITARY SEWER FOR FURTHER TREATMENT AT THE POTW.

0 200 400
SCALE IN FEET

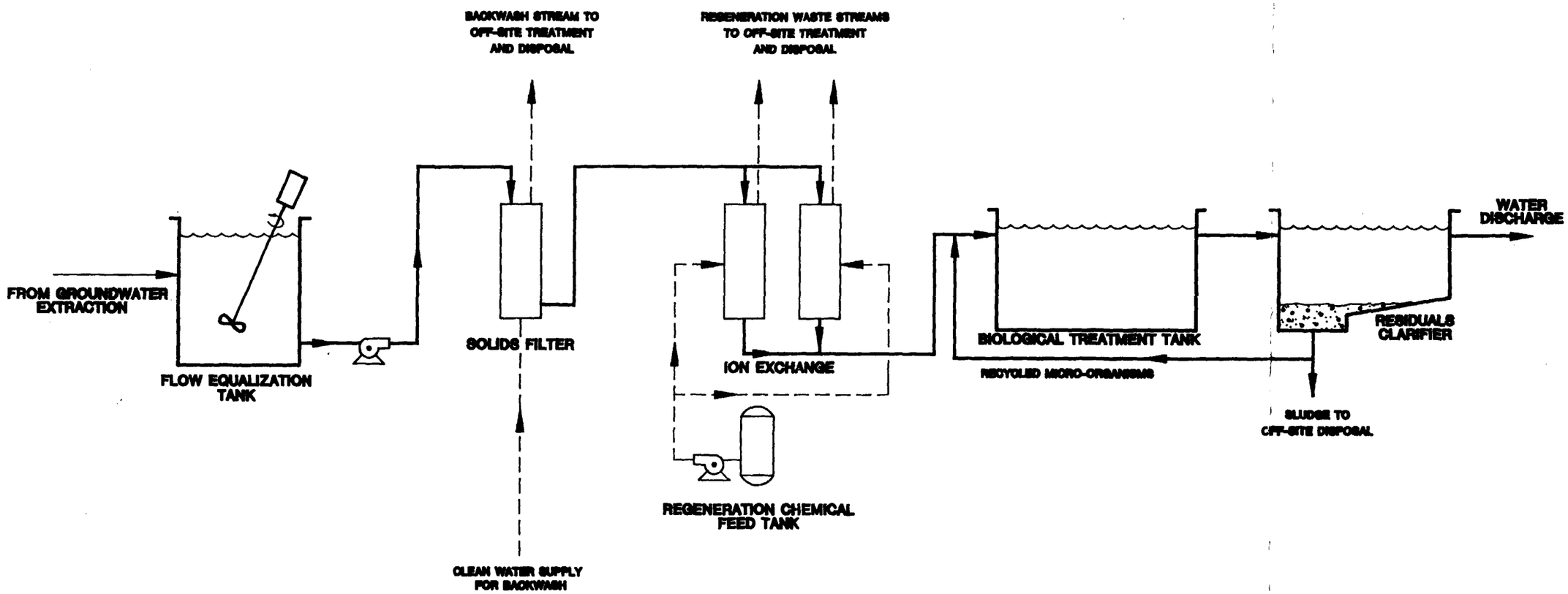
north

FIGURE 4-3

GROUNDWATER DEWATERING SYSTEM & TREATMENT AREA PLAN
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

WARZYN

60251B45



NOTES

1. THE PROCESS EQUIPMENT SHOWN WAS INCLUDED IN THE COST ESTIMATES. THE OPTIMAL TREATMENT SYSTEM CONFIGURATION WILL BE DETERMINED DURING FINAL DESIGN.
2. THE FLOW EQUALIZATION TANK, SOLIDS FILTER, AND ION EXCHANGE MAY NOT BE REQUIRED. IT IS ASSUMED THAT THIS PRETREATMENT WOULD BE NECESSARY TO PREVENT FOULING OF THE PRIMARY TREATMENT SYSTEM.
3. GROUNDWATER FLOW RATE IS 200 GALLONS PER MINUTE.
4. BIOLOGICAL TREATMENT SYSTEM INCLUDES TWO 22-FOOT DIAMETER FLUIDIZED BED REACTORS WITH 5300 CUBIC FEET OF BED VOLUME. THE SYSTEM ALSO INCLUDES 75,000 POUNDS OF GRANULAR ACTIVATED CARBON AS THE FLUIDIZING MEDIUM, PUMPS, AN AIR COMPRESSOR, AND AN OXYGEN SEPARATION UNIT.
5. COST ESTIMATE ASSUMES A BIOCHEMICAL OXYGEN DEMAND OF 650 mg/L, A CHEMICAL OXYGEN DEMAND OF 775 mg/L, AND AN OXYGEN FEED RATE OF 17 mg/L.
6. CARBON ADSORPTION USAGE RATE WOULD BE APPROXIMATELY 75,000 POUNDS PER YEAR. OFF-SITE REGENERATION OF SPENT CARBON IS ASSUMED.
7. SLUDGE WOULD BE DEWATERED BY A FILTER PRESS BEFORE OFF-SITE DISPOSAL.

FIGURE 4-4

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Project Number 60251 B35
GROUNDWATER BIOLOGICAL TREATMENT SCHEMATIC
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
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GRIFFITH, INDIANA
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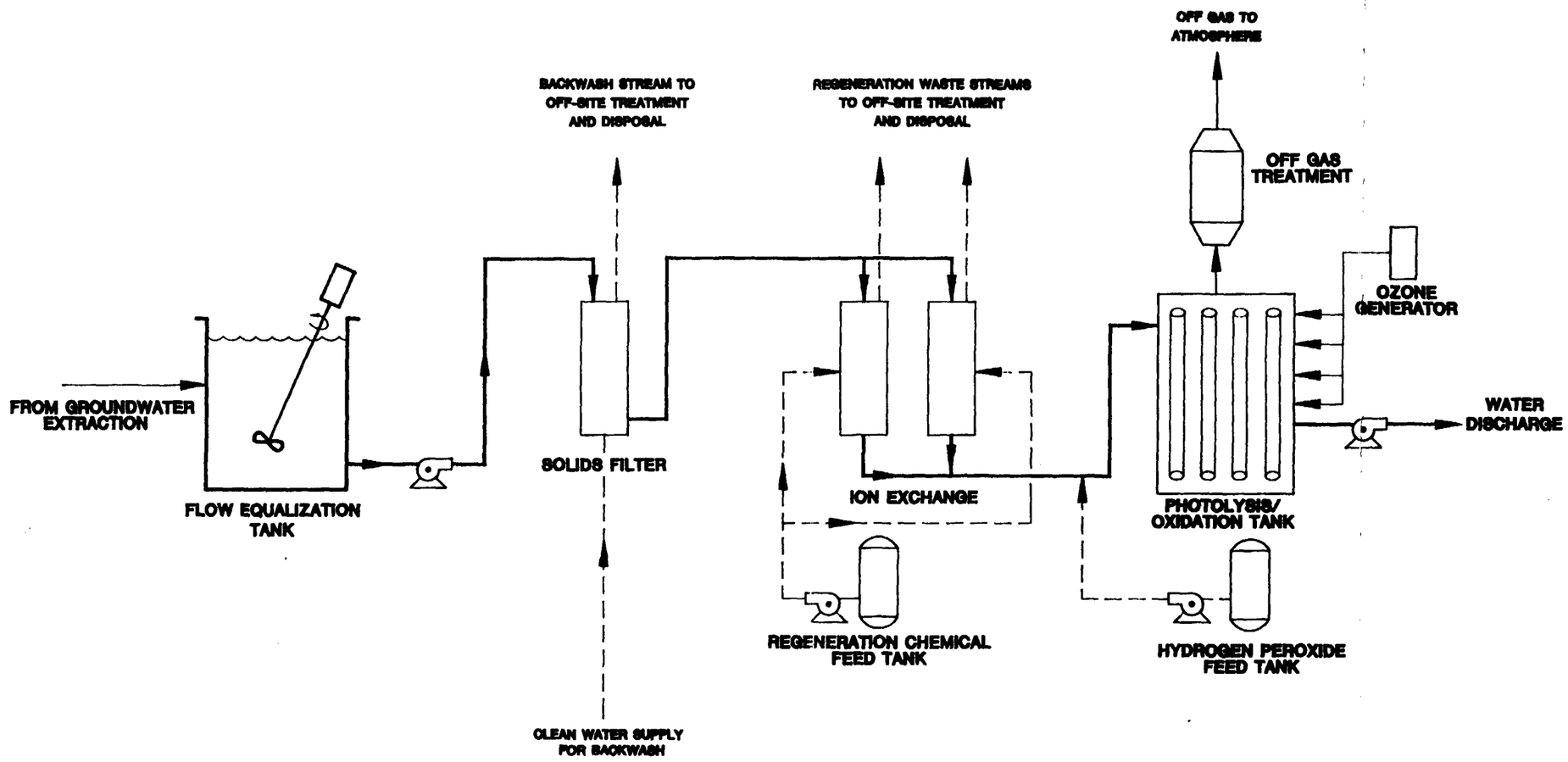

NOTES

1. THE PROCESS EQUIPMENT SHOWN WAS INCLUDED IN THE COST ESTIMATES. THE OPTIMAL TREATMENT SYSTEM CONFIGURATION WILL BE DETERMINED DURING FINAL DESIGN.
2. THE FLOW EQUALIZATION TANK, SOLIDS FILTER, AND ION EXCHANGE MAY NOT BE REQUIRED. IT IS ASSUMED THAT THIS PRETREATMENT WOULD BE NECESSARY TO PREVENT FOULING OF THE PRIMARY TREATMENT SYSTEM.
3. GROUNDWATER FLOW RATE IS 200 GALLONS PER MINUTE.
4. UV/OXIDATION TREATMENT SYSTEM INCLUDES TWO 5000-GALLON REACTORS AND ONE 1300-GALLON SECONDARY REACTOR. AN ESTIMATED RETENTION TIME OF 45 MINUTES WAS ASSUMED.
5. THE FOLLOWING ESTIMATED DOSAGE RATES WERE ASSUMED:
   - 125 mg/L OF HYDROGEN PEROXIDE
   - 375 mg/L OF OZONE
   - 150 WATTS/L OF UV LIGHT

FIGURE 4-5

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GROUNDWATER UV/OXIDATION TREATMENT SCHEMATIC
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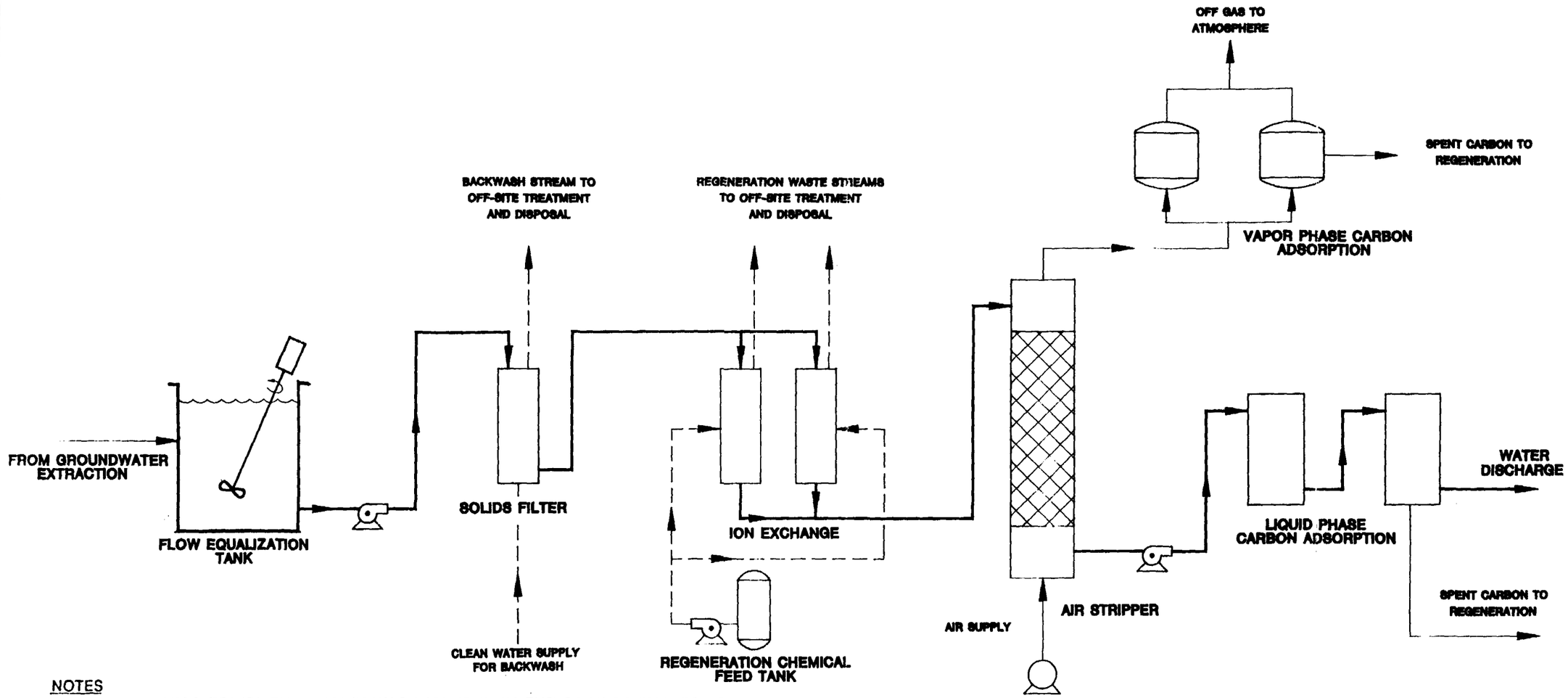

NOTES

1. THE PROCESS EQUIPMENT SHOWN WAS INCLUDED IN THE COST ESTIMATES. THE OPTIMAL TREATMENT SYSTEM CONFIGURATION WILL BE DETERMINED DURING FINAL DESIGN.
2. THE FLOW EQUALIZATION TANK, SOLIDS FILTER, AND ION EXCHANGE MAY NOT BE REQUIRED. IT IS ASSUMED THAT THIS PRETREATMENT WOULD BE NECESSARY TO PREVENT FOULING OF THE PRIMARY TREATMENT SYSTEM.
3. GROUNDWATER FLOW RATE IS 200 GALLONS PER MINUTE.
4. BASED ON THE AIR STRIPPING SIMULATIONS PRESENTED IN APPENDIX C, THE FOLLOWING TOWER PARAMETERS WERE ESTIMATED:
   - 215:1 AIR/WATER RATIO
   - 7-FOOT TOWER DIAMETER
   - 40-FOOT PACKING DEPTH
5. A 6000 CUBIC FEET PER MINUTE, 30 HORSEPOWER BLOWER WOULD BE REQUIRED TO ACHIEVE AN AIR/WATER RATIO OF 215:1.
6. AIR STRIPPER OFF-GASES WOULD BE THERMALLY TREATED.
7. INFLUENT GROUNDWATER WOULD BE HEATED TO 80 °F, USING OFF-GASES FROM THE THERMAL TREATMENT UNIT, IN ORDER TO OBTAIN THE REQUIRED REMOVAL FOR METHYL ETHYL KETONE.
8. LIQUID PHASE CARBON ADSORPTION USAGE RATE WOULD BE APPROXIMATELY 62,400 POUNDS PER YEAR. OFF-SITE REGENERATION OF SPENT CARBON IS ASSUMED.

FIGURE 4-6

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GROUNDWATER AIR STRIPPING TREATMENT SCHEMATIC
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Project Number 60251 B37
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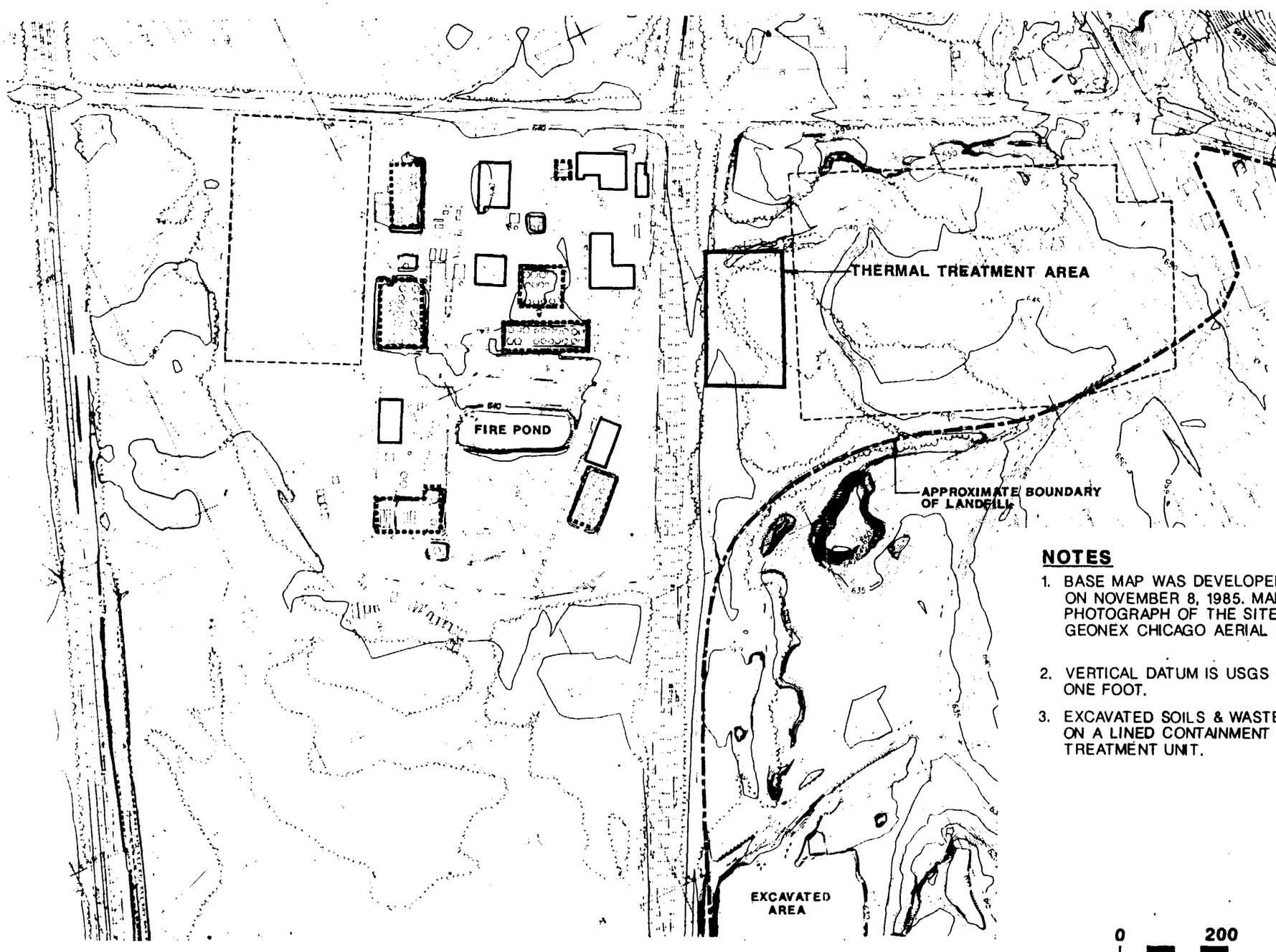

LEGEND

APPROXIMATE TANK FARM BOUNDARY

NOTES

1. BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 8, 1985. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC.
2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.
3. EXCAVATED SOILS & WASTE WOULD BE TEMPORARILY STOCKPILED ON A LINED CONTAINMENT AREA NEAR THE THERMAL TREATMENT UNIT.

0 200 400
SCALE IN FEET

north

FIGURE 4-7

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ON-SITE THERMAL TREATMENT PLAN
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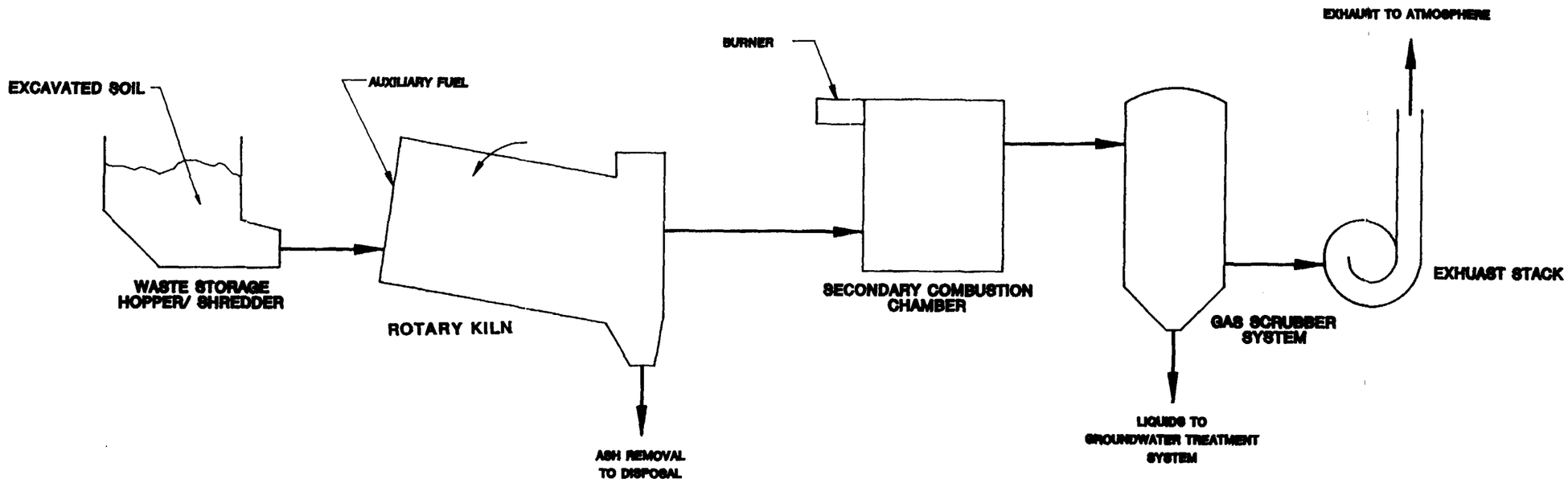
AMERICAN CHEMCAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number
60251B46



NOTES

1. THE PROCESS EQUIPMENT SHOWN WAS INCLUDED IN THE COST ESTIMATES. THE OPTIMAL TREATMENT SYSTEM CONFIGURATION WILL BE DETERMINED DURING FINAL DESIGN.
2. THERMAL TREATMENT SOIL FEED RATE IS 10 TONS PER HOUR. THE SYSTEM WOULD BE OPERATED ON A CONTINUOUS BASIS.

FIGURE 4-8

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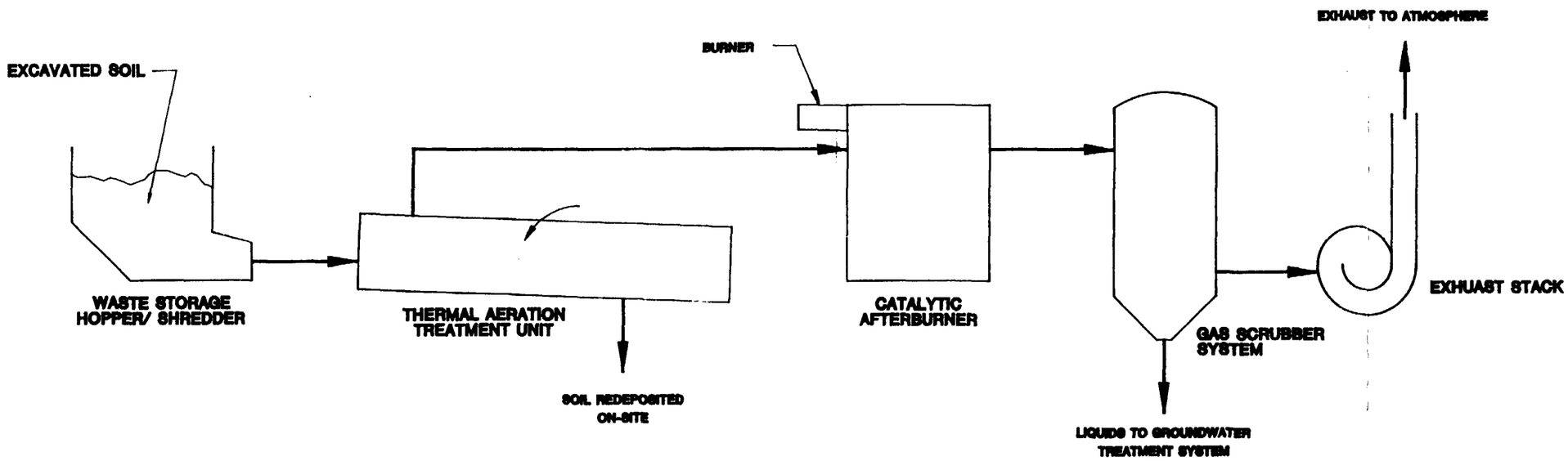
ON-SITE INCINERATION SCHEMATIC
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

Project Number
60251 B44



NOTES

1. THE PROCESS EQUIPMENT SHOWN WAS INCLUDED IN THE COST ESTIMATES. THE OPTIMAL TREATMENT SYSTEM CONFIGURATION WILL BE DETERMINED DURING FINAL DESIGN.
2. THERMAL TREATMENT SOIL FEED RATE IS 10 TONS PER HOUR. THE SYSTEM WOULD BE OPERATED ON A CONTINUOUS BASIS.

FIGURE 4-9

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Referenced

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Project Number: 60251 B43

ON-SITE LOW TEMPERATURE THERMAL TREATMENT SCHEMATIC
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

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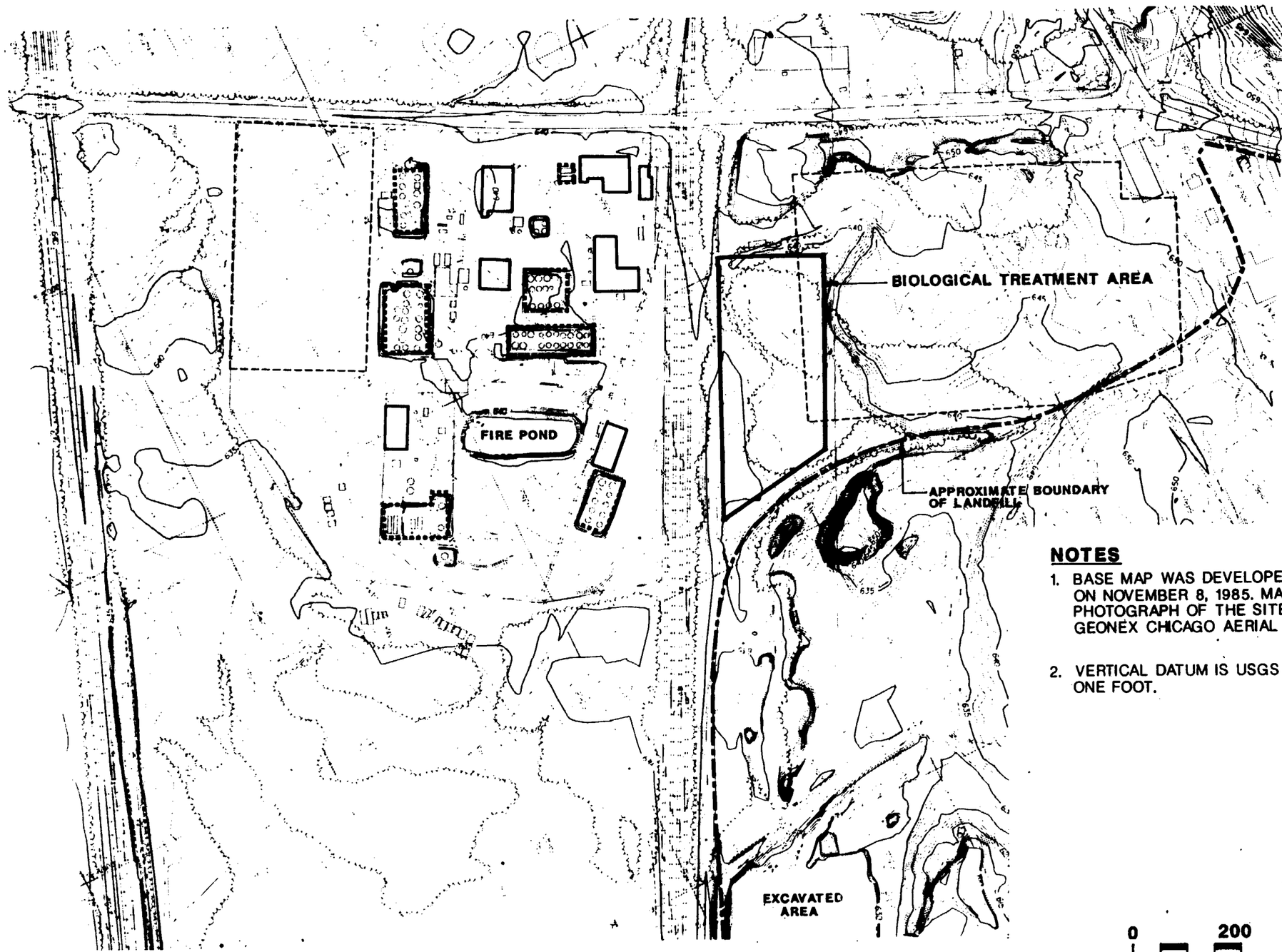

LEGEND

APPROXIMATE TANK FARM BOUNDARY

NOTES

1. BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 8, 1985. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC.

2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.

0 200 400
SCALE IN FEET

north

FIGURE 4-10

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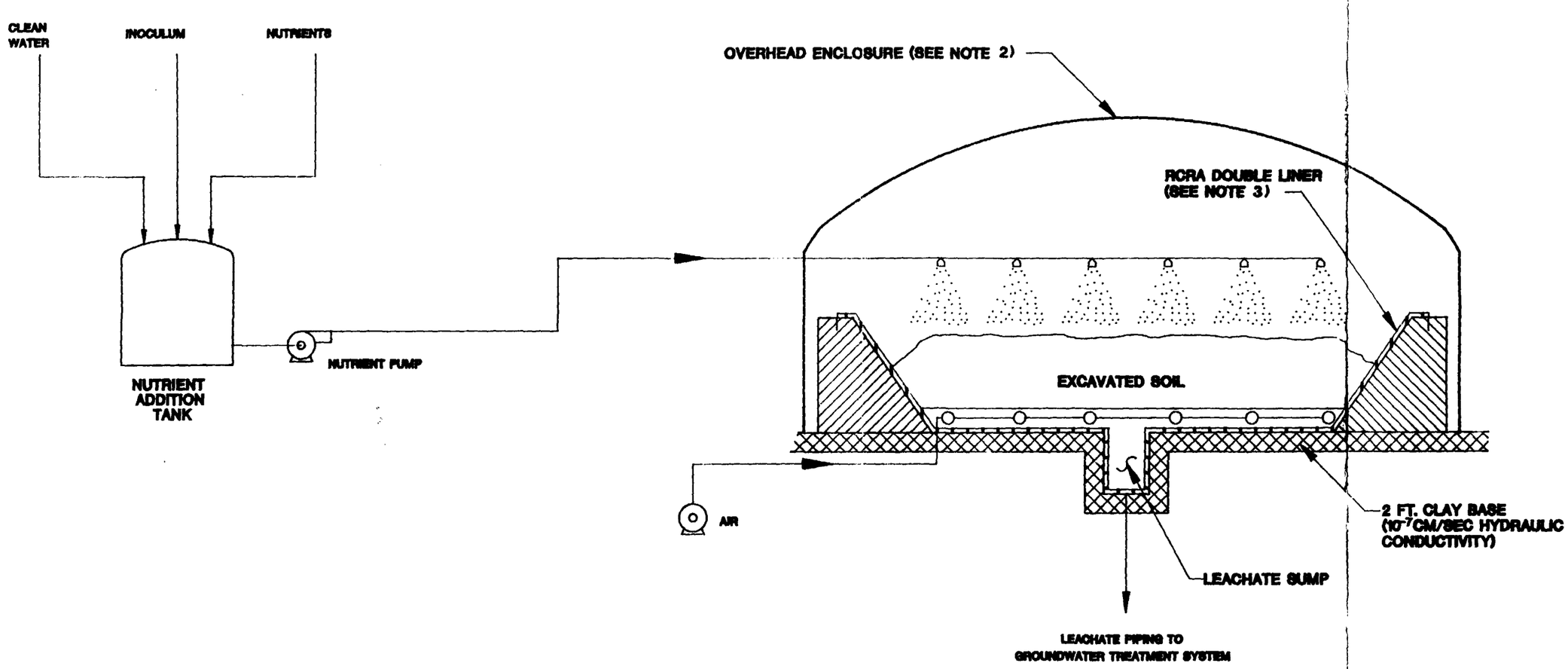
BURIED WASTE & SOIL BIOLOGICAL TREATMENT PLAN
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA
60251B47



NOTES

1. THE PROCESS EQUIPMENT SHOWN WAS INCLUDED IN THE COST ESTIMATES. THE OPTIMAL TREATMENT SYSTEM CONFIGURATION WILL BE DETERMINED DURING FINAL DESIGN.
2. THE OVERHEAD ENCLOSURE IS OPTIONAL, BUT MAY BE REQUIRED IF VOC EMISSION ARARS ARE EXCEEDED. AN AIR MANAGEMENT SYSTEM WOULD BE USED TO COLLECT AND TREAT AIRBORNE CONTAMINANTS. THE OVERHEAD ENCLOSURE AND VAPOR COLLECTION AND TREATMENT ARE INCLUDED IN THE COST ESTIMATES.
3. THE TREATMENT UNIT WOULD BE LINED WITH A RCRA COMPLIANT DOUBLE LINER SYSTEM, INCLUDING TWO 60-MIL GEOMEMBRANE LINERS, WITH 1-FOOT SAND LAYERS AND LEACHATE PIPING BETWEEN THE LINERS.
4. TREATED SOIL WOULD BE REDEPOSITED ON-SITE. SOME TREATED SOIL MAY REQUIRE FIXATION BEFORE BEING REDEPOSITED ON-SITE. FIXATION COSTS WERE NOT INCLUDED IN THE COST ESTIMATES.

FIGURE 4-11

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LANDFARMING SCHEMATIC
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
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GRIFFITH, INDIANA
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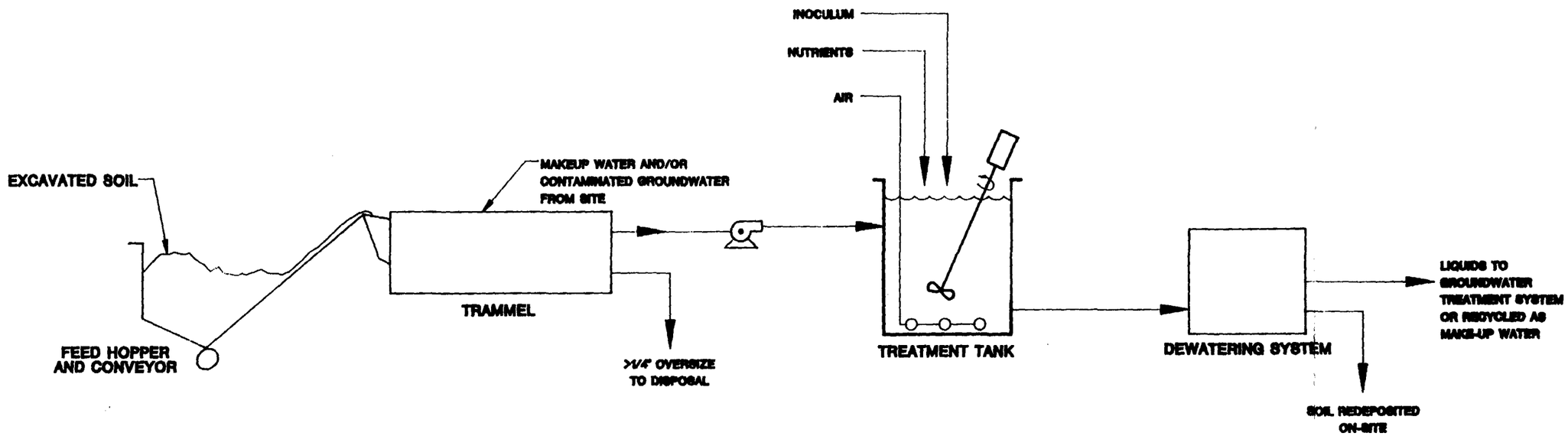

NOTES

1. THE PROCESS EQUIPMENT SHOWN WAS INCLUDED IN THE COST ESTIMATES. THE OPTIMAL TREATMENT SYSTEM CONFIGURATION WILL BE DETERMINED DURING FINAL DESIGN.
2. SOIL FEED RATE IS 10 TONS PER HOUR. THE SLURRY WOULD BE 35 PERCENT SOIL BY WEIGHT. THREE TREATMENT REACTORS IN SERIES, WITH A CAPACITY OF 300,000-GALLONS EACH, WOULD BE REQUIRED. A RETENTION TIME OF 7 DAYS WAS ASSUMED.
3. SOME TREATED SOIL MAY REQUIRE FIXATION BEFORE BEING REDEPOSITED ON-SITE. FIXATION COSTS WERE NOT INCLUDED IN THE COST ESTIMATES.

FIGURE 4-12

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SLURRY - PHASE BIOREACTOR SCHEMATIC
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
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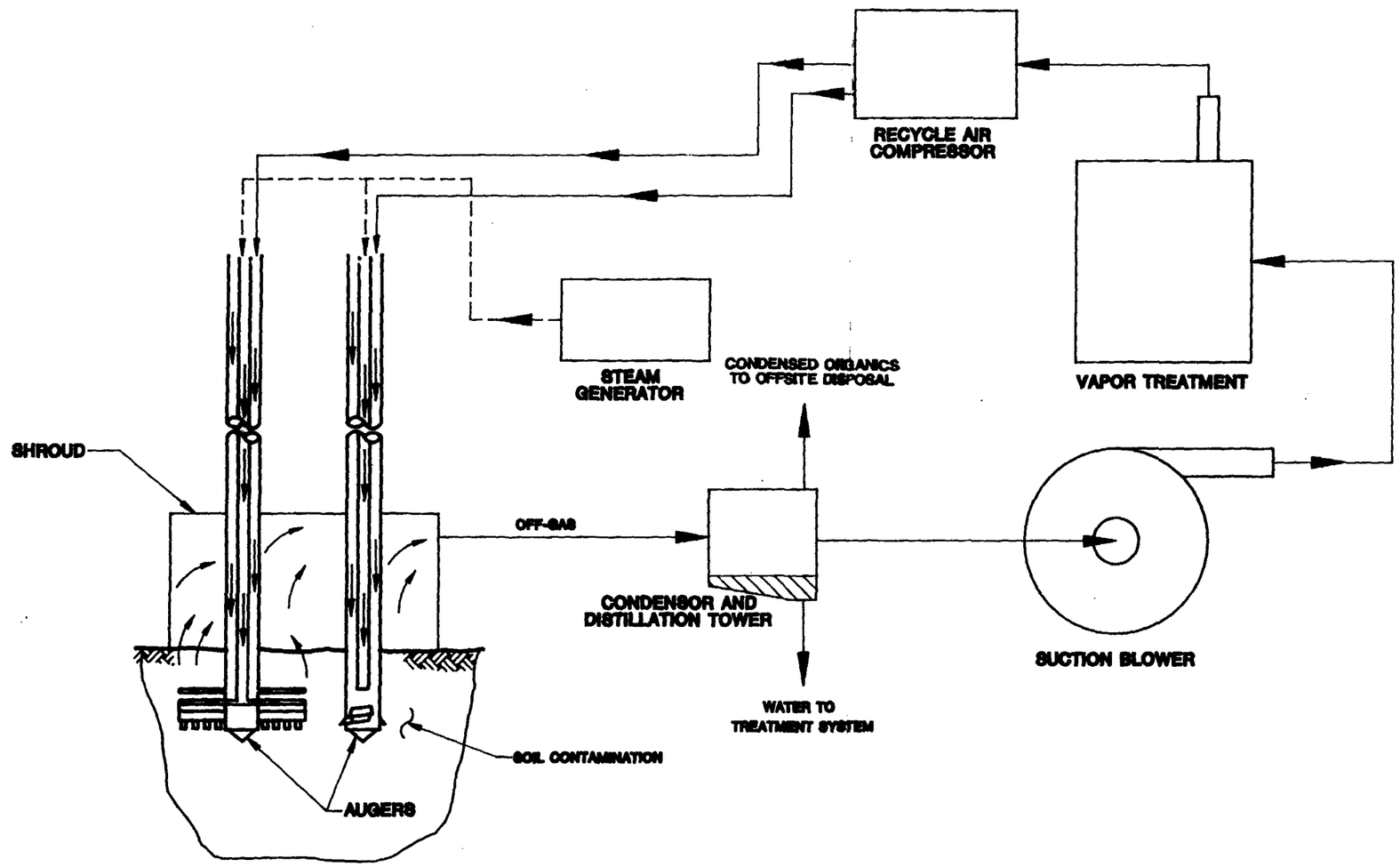

NOTES

1. THE PROCESS EQUIPMENT SHOWN WAS INCLUDED IN THE COST ESTIMATES. THE OPTIMAL TREATMENT SYSTEM CONFIGURATION WILL BE DETERMINED DURING FINAL DESIGN.
2. THE OPERATION WOULD INVOLVE EIGHT AUGER SYSTEMS OPERATED CONCURRENTLY ON A CONTINUOUS BASIS.

FIGURE 4-13

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IN-SITU STEAM STRIPPING SCHEMATIC
FEASIBILITY STUDY
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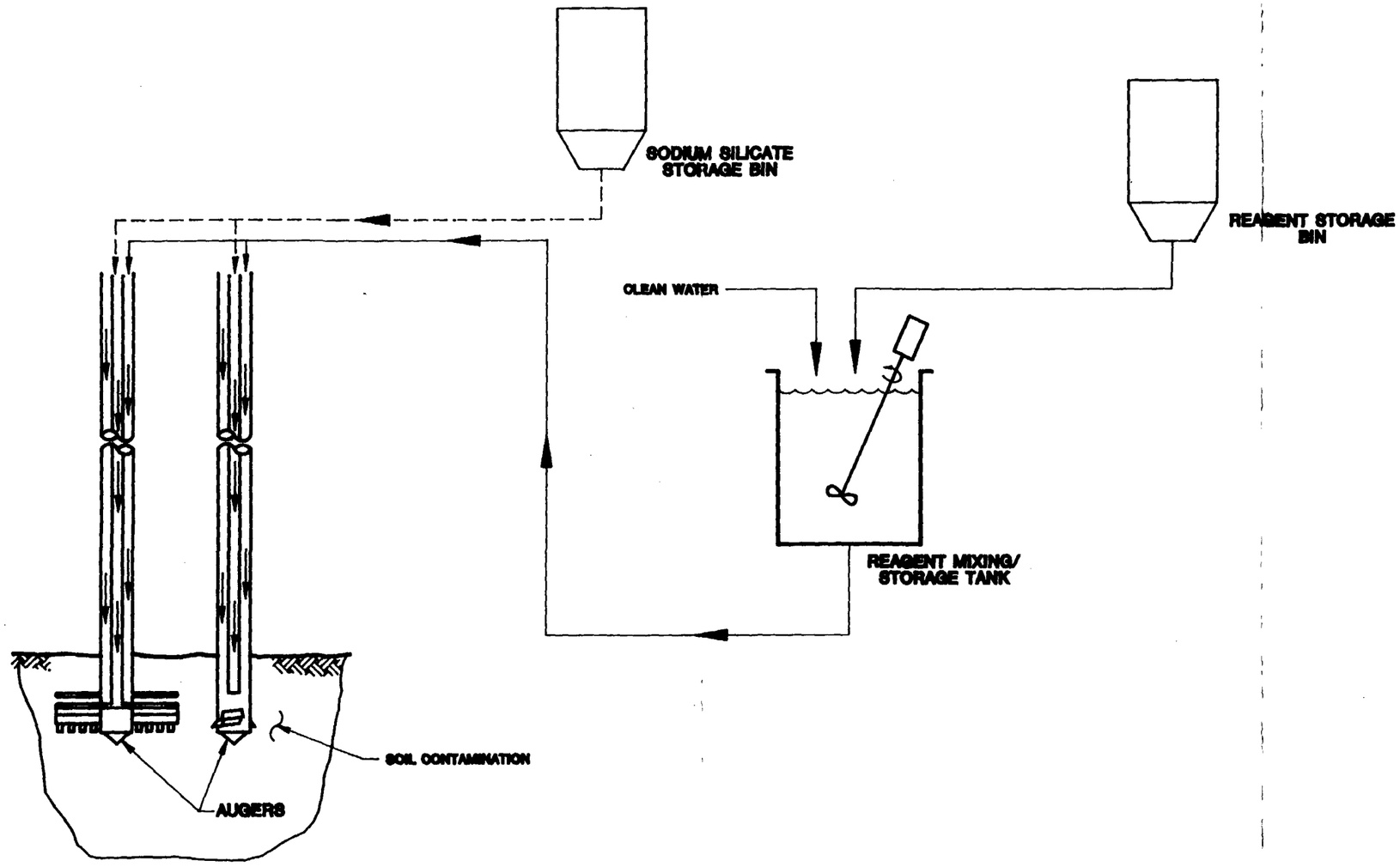

FIGURE 4-14

IN-SITU FIXATION SCHEMATIC
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

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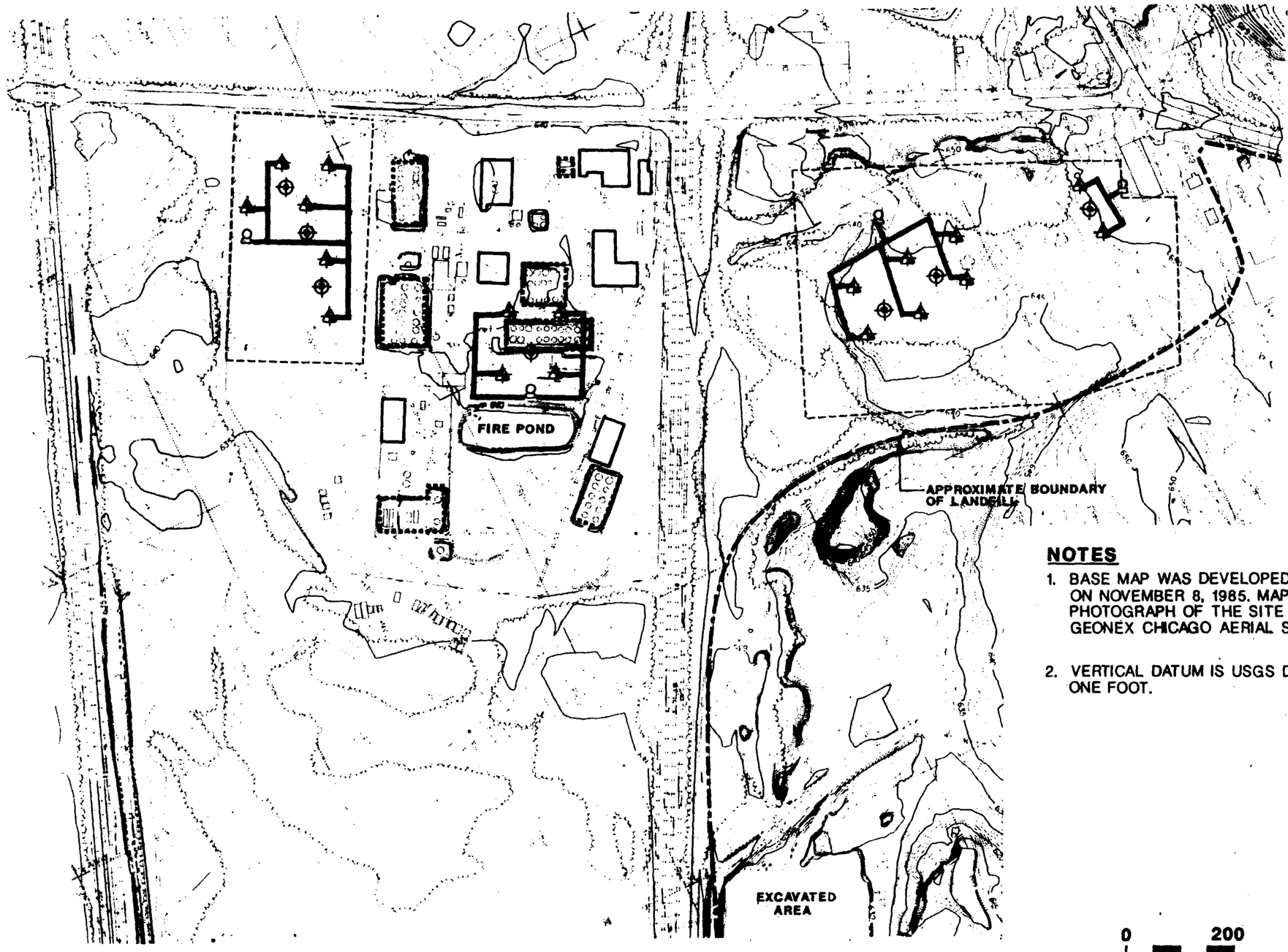

LEGEND

- APPROXIMATE TANK FARM BOUNDARY
- VAPOR EXTRACTION WELL LOCATION
- PASSIVE INLET WELL LOCATION ONLY (OPTIONAL)
- VACCUUM BLOWER

NOTES

1. BASE MAP WAS DEVELOPED FOR CAMP DRESSER & MCKEE INC. ON NOVEMBER 8, 1985. MAP HAS BEEN UPDATED FROM AN AERIAL PHOTOGRAPH OF THE SITE FLOWN ON NOVEMBER 3, 1989 BY GEONEX CHICAGO AERIAL SURVEY, INC.
2. VERTICAL DATUM IS USGS DATUM. CONTOUR INTERVAL IS (1) ONE FOOT.

0 200 400
SCALE IN FEET

north

FIGURE 4-15

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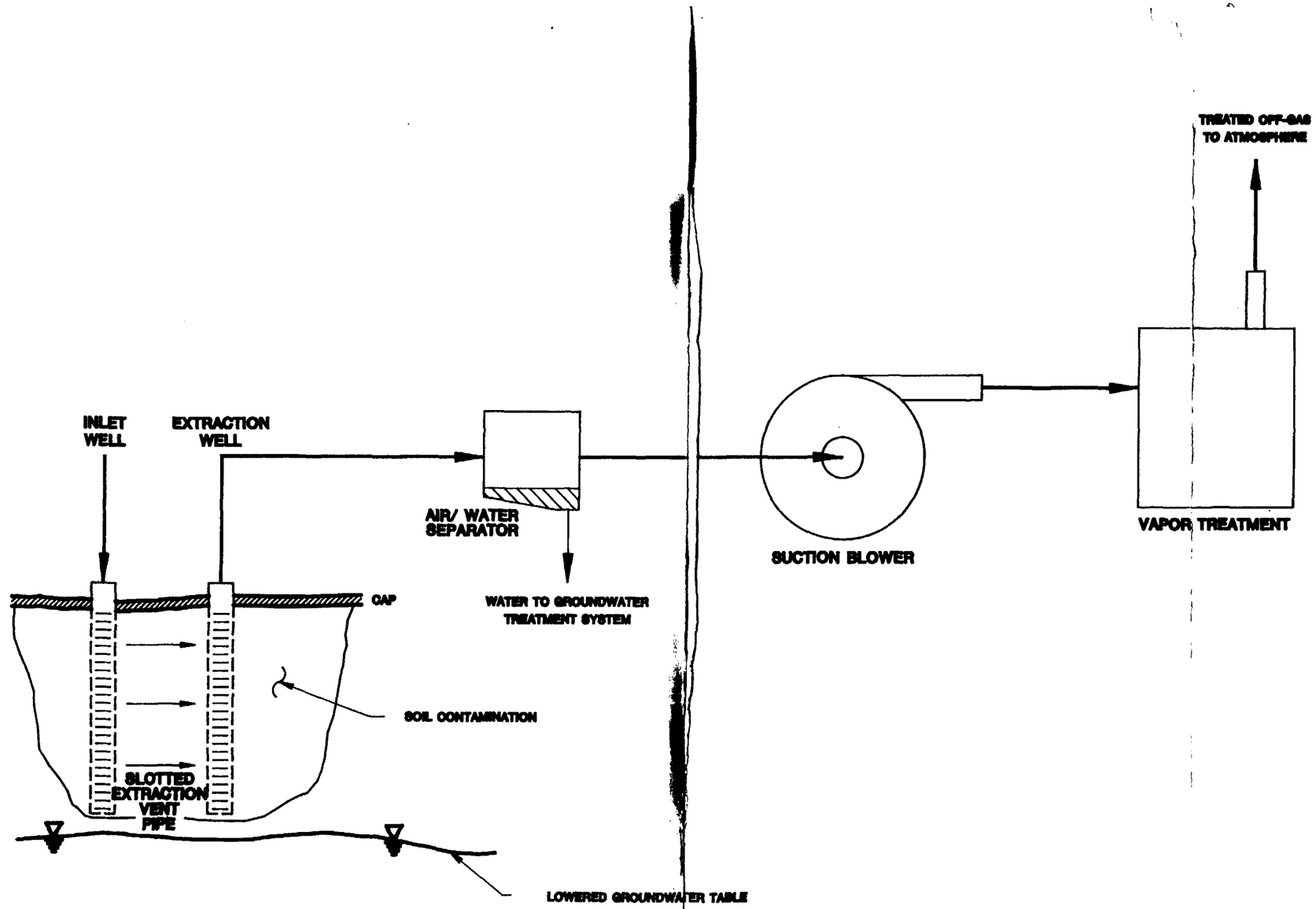
Date 10/23/91

SOIL VAPOR EXTRACTION TREATMENT SYSTEM
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA

60251B50



NOTES

1. THE PROCESS EQUIPMENT SHOWN WAS INCLUDED IN THE COST ESTIMATES. THE OPTIMAL TREATMENT SYSTEM CONFIGURATION WILL BE DETERMINED DURING FINAL DESIGN.
2. THE VAPOR EXTRACTION SYSTEM INCLUDES 18 EXTRACTION WELLS TOTAL. A PRELIMINARY FLOW RATE OF 60 CUBIC FEET PER MINUTE PER WELL WAS DETERMINED BASED ON GROUNDWATER PERMEABILITY DATA AND AN OPERATING VACUUM OF 5-INCHES OF MERCURY (SEE FIGURE 4-15).
3. 4 BLOWERS AT 5-INCHES OF MERCURY VACUUM WOULD BE OPERATED CONCURRENTLY (SEE FIGURE 4-15).
4. ALL ABOVEGROUND VAPOR COLLECTION PIPING WOULD BE HEAT TRACED.
5. VAPORS WOULD BE TREATED IN A CENTRALIZED THERMAL TREATMENT UNIT RATED AT 1100 CUBIC FEET PER MINUTE AND 1500-1600 °F OPERATING TEMPERATURE.

FIGURE 4-16

WARZYN ENGINEERING INC.

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Title: IN-SITU SOIL VAPOR EXTRACTION SCHEMATIC
FEASIBILITY STUDY
AMERICAN CHEMICAL SERVICES
NPL SITE
GRIFFITH, INDIANA
Project Number 60251 B39

[redacted]

Appendix A

Groundwater Modeling Results

U.S.G.S Modflow model was used to evaluate potential groundwater remedial systems of both the upper and lower aquifer at the ACS NPL Site in Griffith, Indiana. Separate model implementations were developed to model the upper and lower aquifer.

UPPER AQUIFER SIMULATIONS

Six pump and treat scenarios were evaluated for the upper aquifer. The following tables and figures area attached:

Tables:
- Summary of model input variables.
- Summary of model output results.

Figures:
- Finite Difference Grid for Modflow.
- Steady-State Non-Remediation Flow Conditions
- Plot of REM2 head distribution after 90 days
- Plot of REM4 head distribution after 90 days
- Graph showing summed extraction rate for REM1-REM5
- Graph of water level in de-water area for REM1-REM5

Description of Modeling Procedure

The model was implemented in a 30 column, 24 row finite difference grid, with 100 foo grid spacing. Aquifer thickness is variable because the a water table aquifer is bein modeled. The base of the aquifer is assumed to be 620 feet msl. The water tabl elevation is variable across the Site, at 630 to 634 feet msl in the ACS facility, to le than 625 feet in vicinity of the municipal landfill where de-watering occurs continuousl

The aquifer permeability values used were derived by conducting baildown tests at m of the site monitoring wells. The results suggested that the hydraulic conductivity is order of magnitude higher on the east side of the site than along the western bound of the ACS facility. Grain-size analysis of aquifer samples indicated that the aqu matrix was coarser grained at the wells along the eastern boundary. Groundwater modeling was used to history match water table configurations. It was found tha observed head distribution in the upper aquifer was most reasonably achieved i simulation where hydraulic conductivity values were 10x lower on the western si the site.

The model was calibrated to known water table elevations, measured at approxi 50 points across the site, including surface water locations, measured at four di times throughout approximately one year. Sensitivity analysis was conducted aerial recharge by infiltrating precipitation and 2) hydraulic conductivity.

Average annual precipitation in northwestern Indiana is 44 inches. Simulations were run with assumed infiltration of 4 to 20 inches (10 to 50 percent). Infiltration amounts from 4 to 12 inches gave results which were consistent with field observations. Even 20 inches provided reasonable results. In otherwords, the model was relatively insensitive to variations in total infiltration amounts.

The use of lower hydraulic conductivity values caused significant deviations from the observed water table heads. However, doubling and quadrupling the hydraulic conductivity had relatively little effect on the water table distribution.

The major control on groundwater flow regime (and associated head values) appears to be the steep gradient and interaction between recharge at ACS and de-watering in the landfill area.

SIMULATION OF UPPER AQUIFER REMEDIATION

The calibrated groundwater flow model was used to evaluate several components of a pump and treat system. The major items to test were the approximate effluent rates which could be expected, and the effect of placing a slurry wall around the pumped area.

Six simulations were conducted, REM1 through REM6. Basic assumptions and results are summarized on the attached sheets. The following were the initial assumptions/set-up parameters:

1. An approximate 24 acre area was surrounded by a 10^{-6} cm/sec slurry wall.

2. The aquifer hydraulic conductivity varies from approximately 10^{-3} cm/sec along the east side of the site, to 10^{-4} cm/sec, 800 feet to the west, along the western ACS facility boundary.

3. 12 extraction "drains" were set up spaced about 200 feet apart within the slurry-walled area. (To simulate pumps would have required assigning un-varying pumping rates. However, since the transmissivity is variable spatially, and since it will decrease as de-watering occurs, it is desirable to have variable pumping rates. Within Modflow, "drains" remove the effluent available within a given model grid for a given time step. Therefore, the "drains" represent optimal pumping rates.)

4. it was assumed that 1 foot of the annual precipitation recharges the water table each year.

The following is a brief summary of the remediation simulations:

REM1: Simulated basic permeability with 1 foot of infiltration per year with a 10^{-6} cm/sec slurry wall.

Total groundwater extraction rate started at 174 gpm, decreased to 24 gpm at the end of the first year, when the water level appeared to reach equilibrium about 4 feet above the bottom of the aquifer

REM2: Aquifer permeability was doubled, and slurry wall permeability was increased by factor of 4. To simulate no cap and excess infiltration inside the slurry wall (perhaps because of open excavations), the infiltration within the slurry-walled area was doubled to 24 inches per year.

Slightly lower heads were achievable, because of more efficient de-watering, and pumping rates were higher, starting at 210 gpm and dropping to 42 gpm at one year.

REM3: Original aquifer permeability was used, but slurry wall K value was increased to 10^{-5} cm/sec.

The achievable water level was similar to REM1, with slightly higher pumping rates: 175 gpm during first 30 days, 30 gpm after one year.

REM4: No slurry wall. The original aquifer conditions were simulated with 1 ft/yr infiltration.

De-watering was less effective. The water table was lowered less than 2/3 of the available saturated thickness, leaving more than 5 feet of water in the bottom of the aquifer.

REM5: No slurry wall. The hydraulic conductivity values were doubled.

The achievable head values were approximately the same at locations inside de-watering locations (drains), but the gradient sloped less steeply away from the de-watered area. Pumping rates to accomplish the drawdown were significantly higher.

REM6: REM1 was modeled using 10 gpm well rates. The aquifer began to de-water after 60 days.

<u>UPPER AQUIFER REMEDIATION CONCLUSIONS</u>

1. It is likely that areal recharge is in the range of 6 to 15 inches per year.

2. Hydraulic conductivity:
   - Qualitatively, it is reasonable to assume that bulk transmissivity of the aquifer decreases from east to west.
   - Quantitatively, there is uncertainty as to the actual hydraulic conductivity values at the site. The baildown tests provided an indication, but pumping tests would help to narrow the range.

LOWER AQUIFER REMEDIATION SIMULATION

The U.S.G.S Modflow model was used to evaluate potential pumping rates to hydraulically control the zone of potential contamination in the lower aquifer at the ACS NPL Site.

Modflow was configure to represent the lower aquifer with 3 layer, 30 column by 30 row model with 100 foot x and y grid spacing. The 3 layers were used to represent a 60 foot saturated thickness. A 10-foot thickness was used for the upper layer, a 20-foot thickness was used to represent the second layer, and a 30-foot thickness was used to represent the lower layer. The length and volume units used in the model were feet (i.e., grid spacing measured in feet, pumping rate measured in cubic feet). "Days" were the time unit used for the simulation.

The simulated extraction wells were located only in the upper layer, thereby simulating wells screened in just the upper 10 feet of a 60-foot thick aquifer. The hydraulic conductivity for the upper 30 feet of the aquifer (layers 1 and 2) was assigned a value of $3x10^{-2}$ cm/sec (90 feet/day). The lower 30 feet of the aquifer (layer 3) based on RI tests) was assigned a hydraulic conductivity value of $6x10^{-2}$ cm/sec (180 feet/day), to represent an aquifer increasing in permeability with depth. The cross-sectional schematic is sketched on the attached maps of drawdown.

Other model variables used to represent aquifer properties included storativity, specific yield and vertical hydraulic conductivity.

Storativity of all aquifer layers was assigned to be SF1 = 0.1. The specific yield of the upper aquifer was assigned a value of SF2 = 0.25.

Vertical Conductivity was established to be one-tenth of the horizontal conductivity. The vertical conductivity is input to represent the conductivity through the aquifer layer from top to bottom, so it is represented as the unit K-value divided by the layer thickness. Therefore, the model input values vary in each layer because of variable layer thickness, and the increasing horizontal permeability with depth. The following values were used: 1.0 per day for layer 1 and 0.5 per foot for layer 2.

The general aquifer characteristics used in the simulation included the regional hydraulic gradient and the boundary conditions. The hydraulic gradient, based on site measurements, was 0.0006 ft/ft. The boundary conditions were used to set the regional gradient, by setting the outer rows and columns to constant head values.

The groundwater extraction system was modeled by simulating 4 wells extracting groundwater from the upper 10 feet (layer 1) at locations approximately 200 feet apart, arrayed along the northern edge of the suspected source of lower aquifer contamination. The model was conducted to simulate one year of continuous pumping.

By modeling, it was found that pumping rates of 25 gallons per minute (5000 cubic feet per day) at each of the four wells, sufficiently lowered the potentiometric head within the zone of suspected contamination to result in hydraulic control. With this pumping rate, a total of 100 gpm, the hydraulic gradient occurs across at least the upper 30 feet of the lower aquifer.

Table 1.
Summary of Input Variables
Upper Aquifer Remediation Simulation
ACS NPL Site

The following are the input parameters for the Modflow Implementation of the upper aquifer at the ACS NPL Site.

Single layer, 30 column, 24 row finite difference grid. Uniform grid spacing = 100 foot.

Time Units = days, Length Units = feet
Time steps were generally 30 or 60 days. Single time step used for transient simulation.

Boundary Conditions
- Row 1 is set generally as a No-flow boundary (IBOUND=0)
- Row 2 is generally a discharge zone
- Column 1 and Row 24 are established as GHB boundaries, by input unit 27.
- Column 30 is constant head boundary (IBOUND<1)
- Initial head values were developed from steady-state solution to Run 3.

Aquifer Properties
Specific yield/storage coefficient set as 0.25
Hydraulic conductivity range
2.4 to 24 ft/day (8.5×10^{-4} to 8.5×10^{-3} cm/sec)

Aquifer thickness calculated within model
- Top elevation from head-value for node
- Bottom elevation set at 620 ft msl

Discharge Areas
- De-watering at Landfill Excavation
- In ACS.* runs, "drains" used, via module 23.
- In REM.* runs, IBOUND used to set as constant head values.
- Level set at 627 ft msl, field-measured value.
- Three river stretches set by module 24
- Creek along row 3 between column 2 and 9, set to 630 ft msl
- Creek along row 2 between column 26 and 28, set to 630 ft msl
- Ditch along north boundary simulated setting column 28, rows 3 - 15 at levels from 630 to 631
- Ditch just west of Off-Site Containment Area set at 632 ft msl,based on staff gage SG-1 history.

Table 1. (continued)
Summary of Input Variables
Upper Aquifer Remediation Simulation

Recharge Areas

- Constant heads and GBH boundaries provide lateral recharge
- Module 28, used to apply areal precipitation recharge
- Average annual precipitation for area = 40 in/yr
- Model calibrated assuming 10% infiltration (4 in/yr) ACS facility has no vegetation.
- Storm sewers from southeast drain into fire pond
- Drained area is about 20x the fire pond area.
  - Coefficient of 20 used for fire pond
  - Coefficient of 2 used for much of unvegetated area
  - Factor of 10 used in Off site area at internal drainage area north of Off-Site containment area.

Strongly Implicit Procedure (SIP) module used to solve model.

REM_SUM.WK1

Table 2
Summary of Output
Remediation Simulation
ACS NPL Site

Simulation REM1

Infiltrating precipitation 1 ft/year
7.8E+06 gal/yr for the 24 acre area
14.8 gpm " " " "

12 groundwater extraction points (drains)

Time (days)	Head	Total Pumping Rate (12 wells)
0	634.1 ft	
30	630.1 ft	174 gpm
90	626.8 ft	80 gpm
180	625.1 ft	41 gpm
365	624.2 ft	24 gpm
730	623.9 ft	18 gpm

Simulation REM2

Permeability of Aquifer doubled
Permeability of Slurry Wall Quadrupled to 4x10-6 cm/sec

Infiltrating precipitation 2 ft/year inside slurry walled a
1.6E+07 gal/yr for the 24 acre area
29.6 gpm " " " "

12 groundwater extraction points (drains)

Time (days)	Head	Total Pumping Rate (12 wells)
0	634.1 ft	
30	629.6 ft	210 gpm
90	626.1 ft	108 gpm
180	624.1 ft	62 gpm
365	623.3 ft	42 gpm
730	623.0 ft	36 gpm

Table 2 (continued)
Summary of Output
Remediation Simulation

Simulation REM3

Same as REM1, except
Permeability of Slurry Wall increase to 10e-5 cm/sec

Infiltrating precipitation 1 ft/year inside slurry walled a
7.8E+06 gal/yr for the 24 acre area
14.8 gpm " " " "

12 groundwater extraction points (drains)

Time (days)	Head	Total Pumping Rate (12 wells)
0	634.1 ft	
30	630.2 ft	175 gpm
90	626.9 ft	84 gpm
180	625.2 ft	47 gpm
365	624.3 ft	30 gpm
730	624.0 ft	25 gpm

Simulation REM4

Same as REM1, except NO Slurry Wall

Infiltrating precipitation 1 ft/year inside slurry walled a
7.8E+06 gal/yr for the 24 acre area
14.8 gpm " " " "

12 groundwater extraction points (drains)

Time (days)	Head	Total Pumping Rate (12 wells)
0	634.1 ft	
30	631.0 ft	201 gpm
90	627.4 ft	124 gpm
180	625.9 ft	93 gpm
365	625.2 ft	80 gpm
730	625.0 ft	76 gpm

Table 2 (continued)
Summary of Output
Remediation Simulation

Simulation REM5

Same as REM1, except NO Slurry Wall
and K doubled

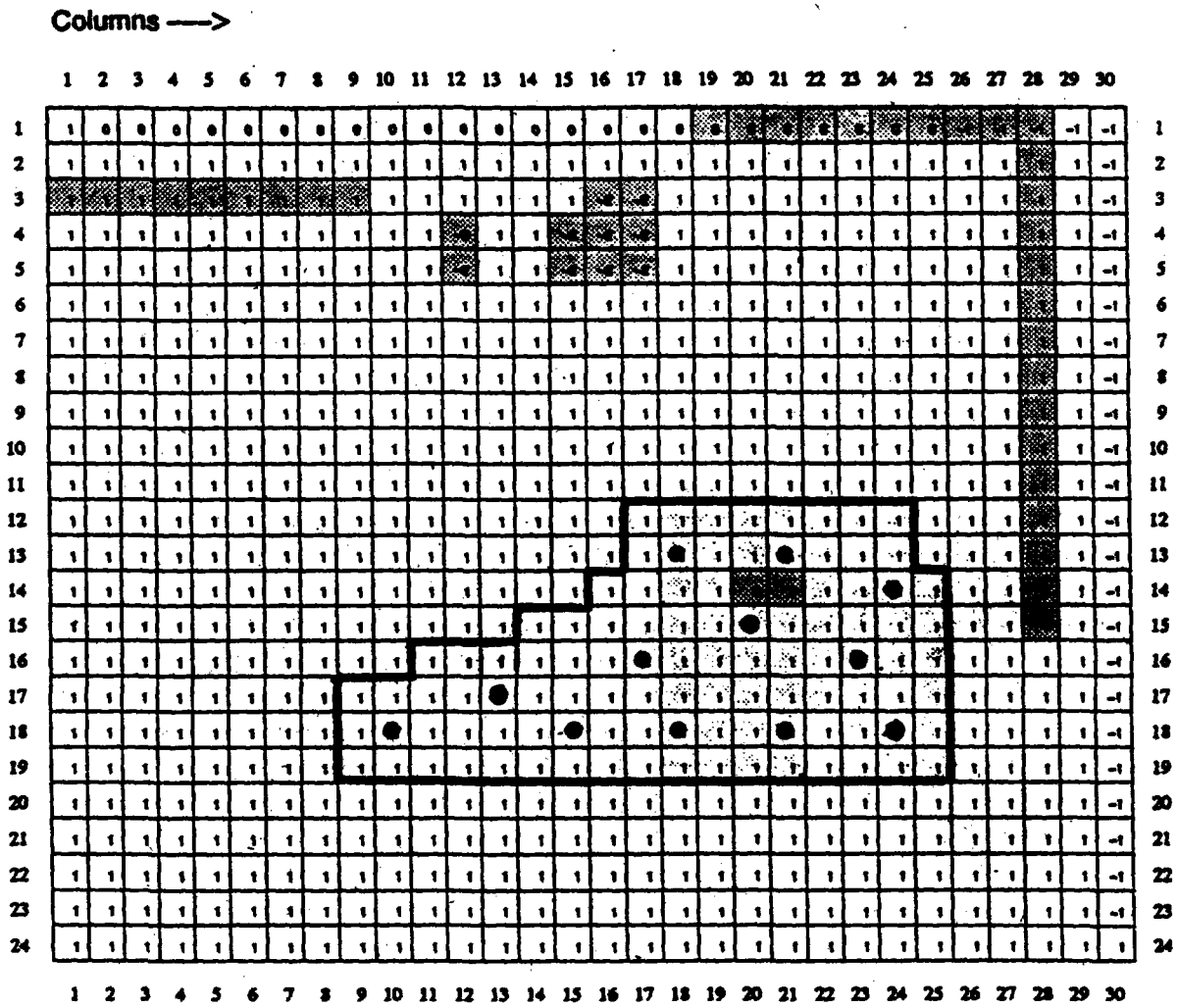
Infiltrating precipitation 1 ft/year inside slurry walled a
7.8E+06 gal/yr for the 24 acre area
14.8 gpm " " " "

12 groundwater extraction points (drains)

Time (days)	Head	Total Pumping Rate (12 wells)
0	634.1 ft	
30	630.1 ft	245 gpm
90	627.2 ft	170 gpm
180	625.9 ft	138 gpm
365	625.4 ft	124 gpm
730	625.3 ft	121 gpm

Finite Difference Grid for Modflow

ACS Remediation Simulation



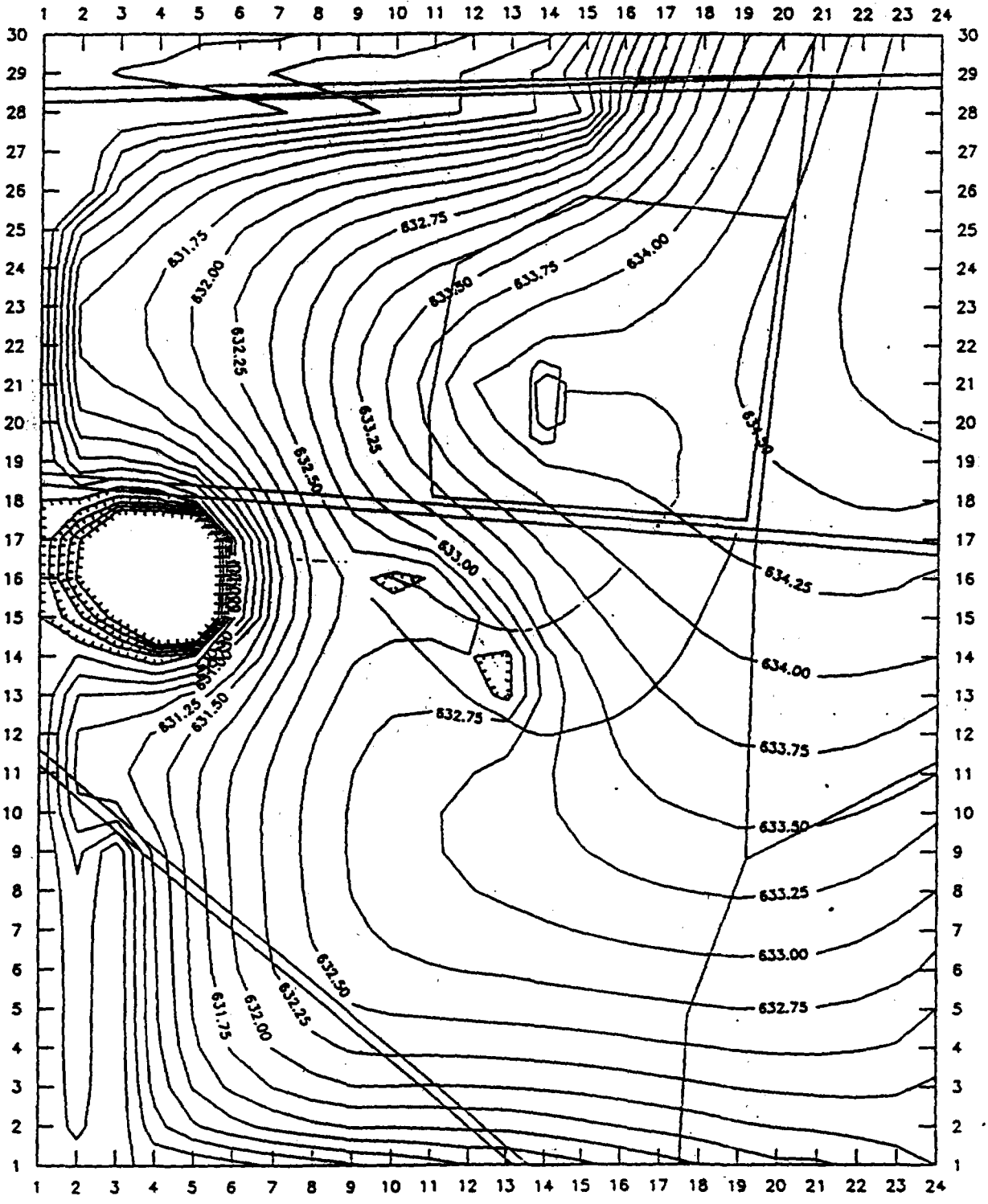
LEGEND

SLURRY WALL

EXTRACTION WELL LOCATION

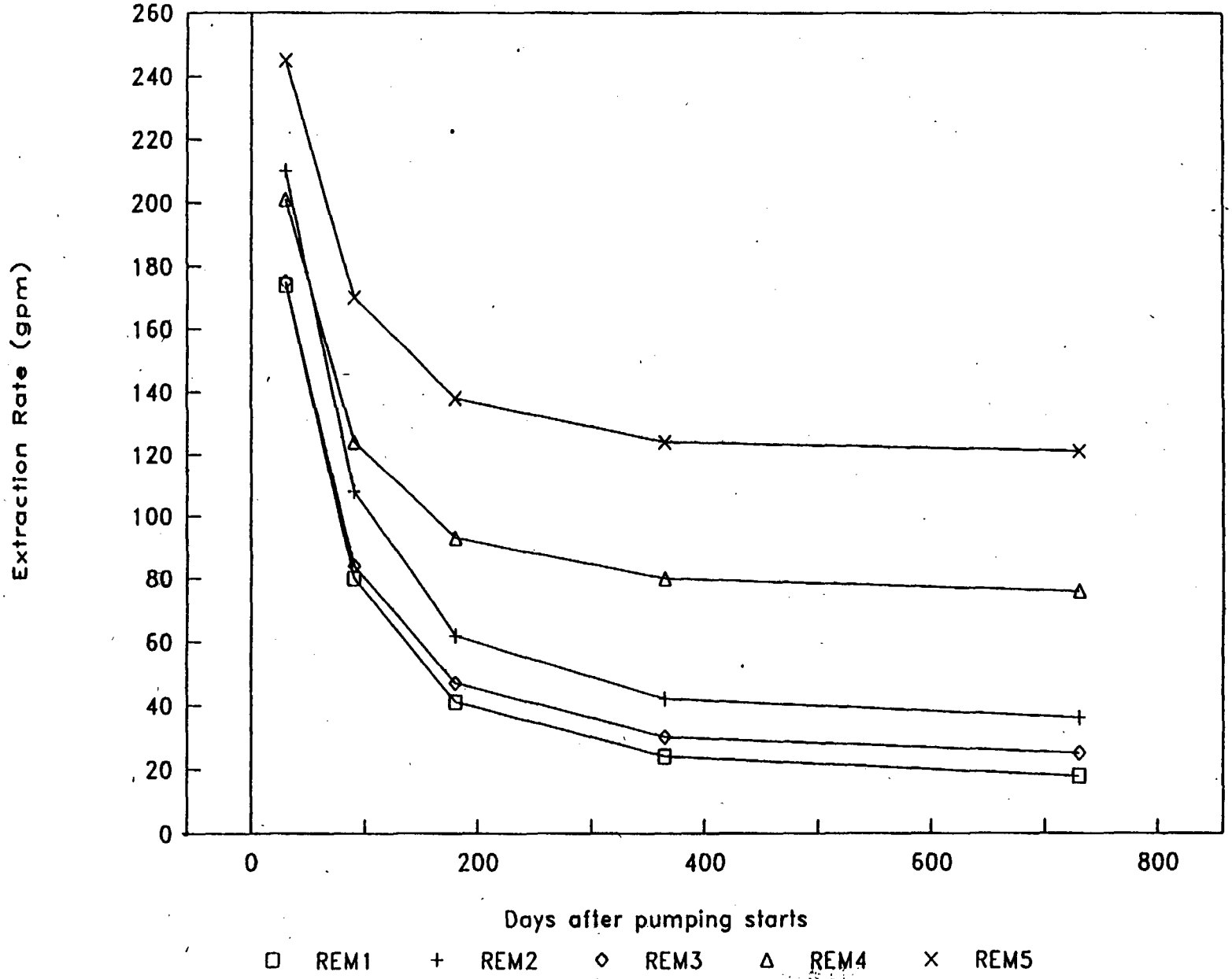
STEADY-STATE NON-REMEDIATION FLOW CONDITIONS

ACS - 4

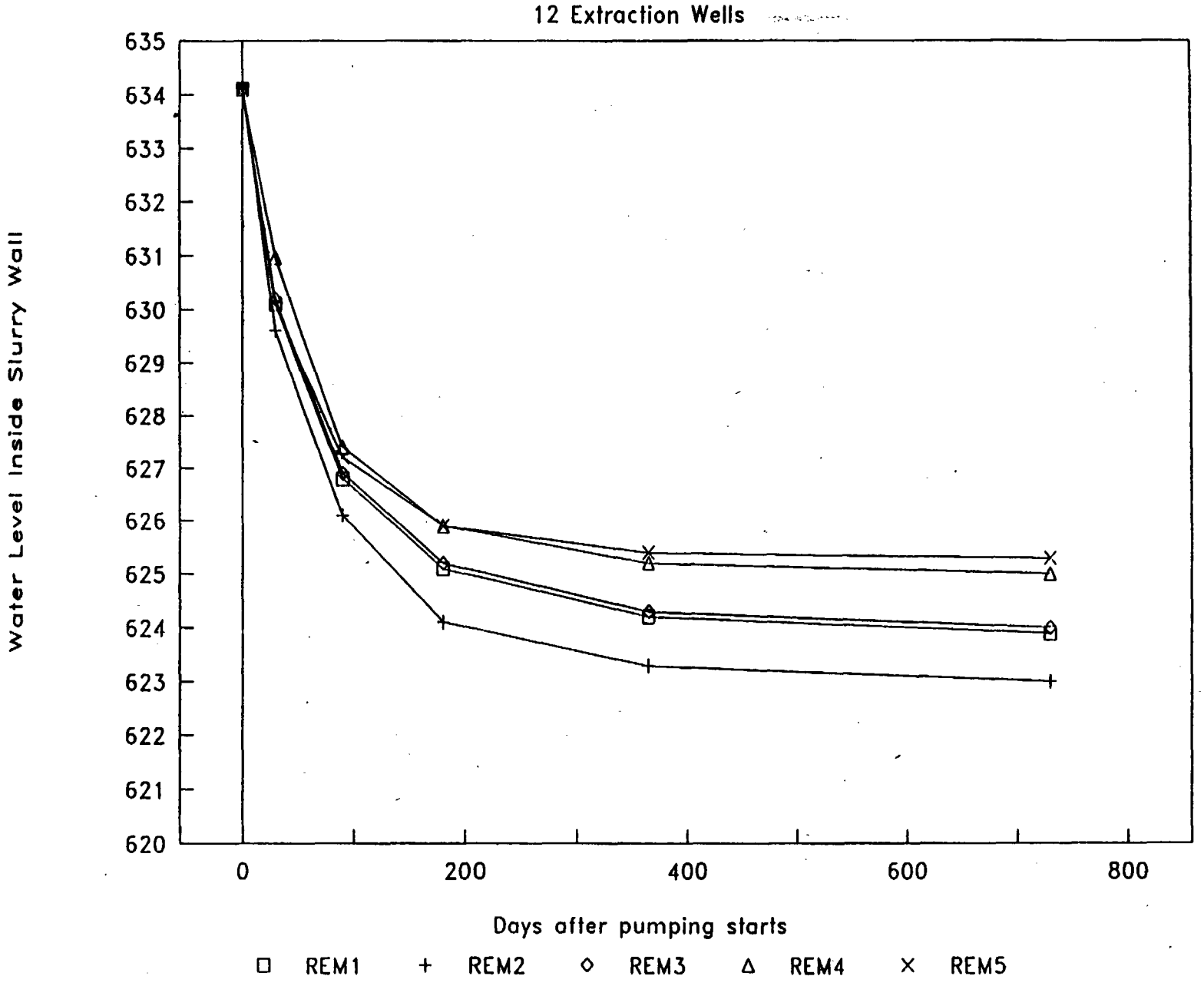


Summed Extraction Rate

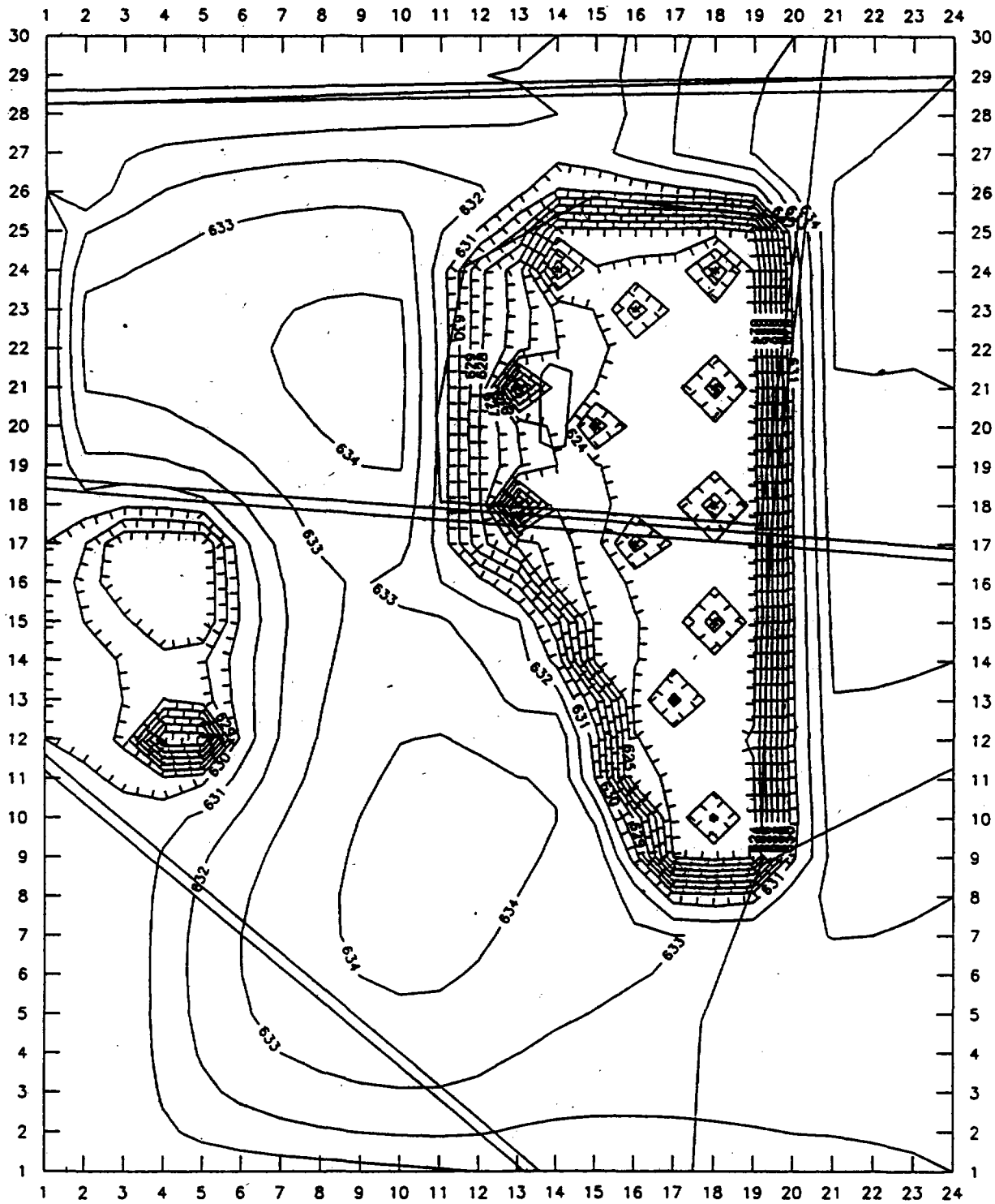
12 Extraction Wells



Water Level - Center of Dewatering Area



REM2 -- 10e-6 cm/sec Slurry Wall - 1 year



365 Days, No Slurry Wall

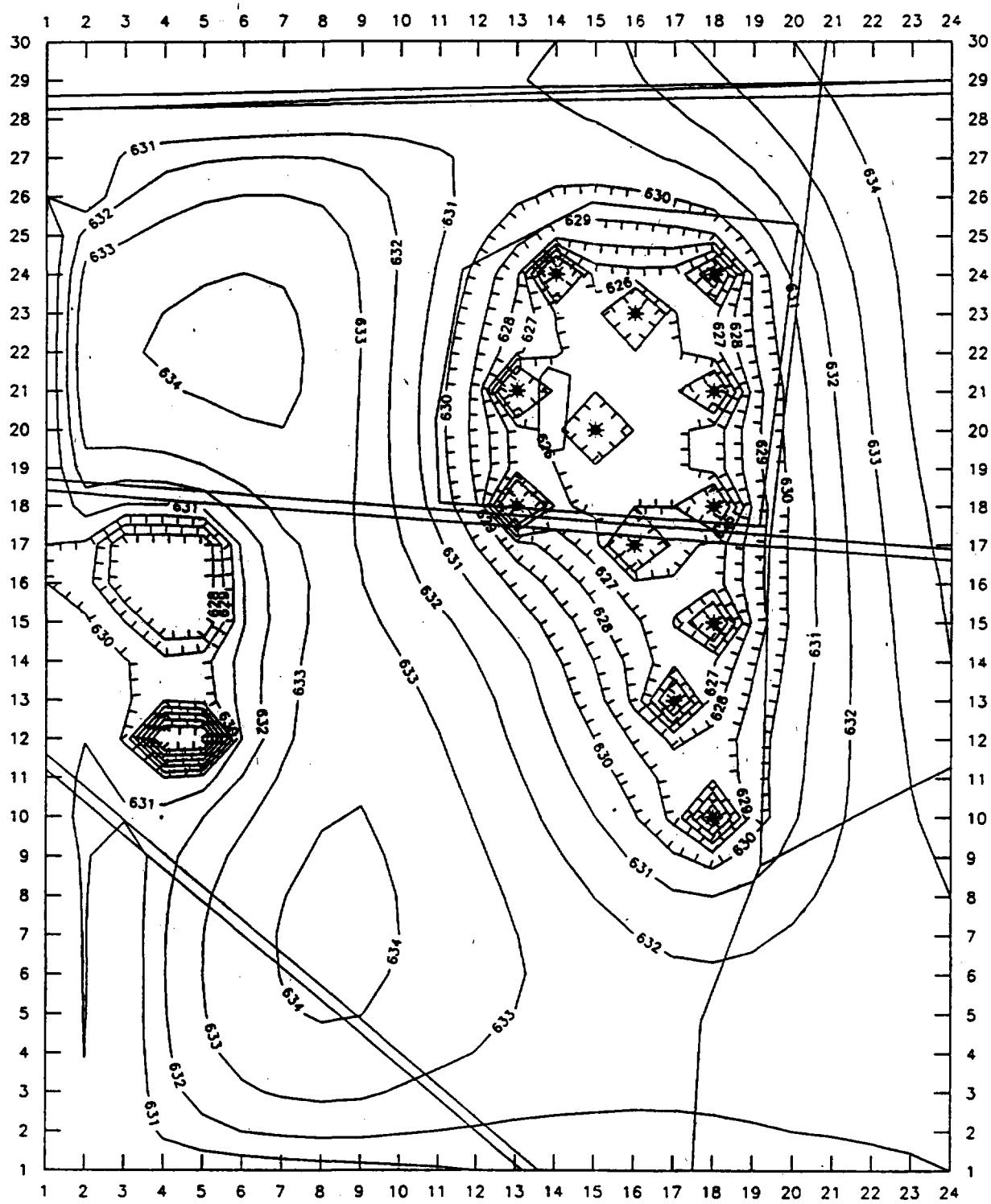
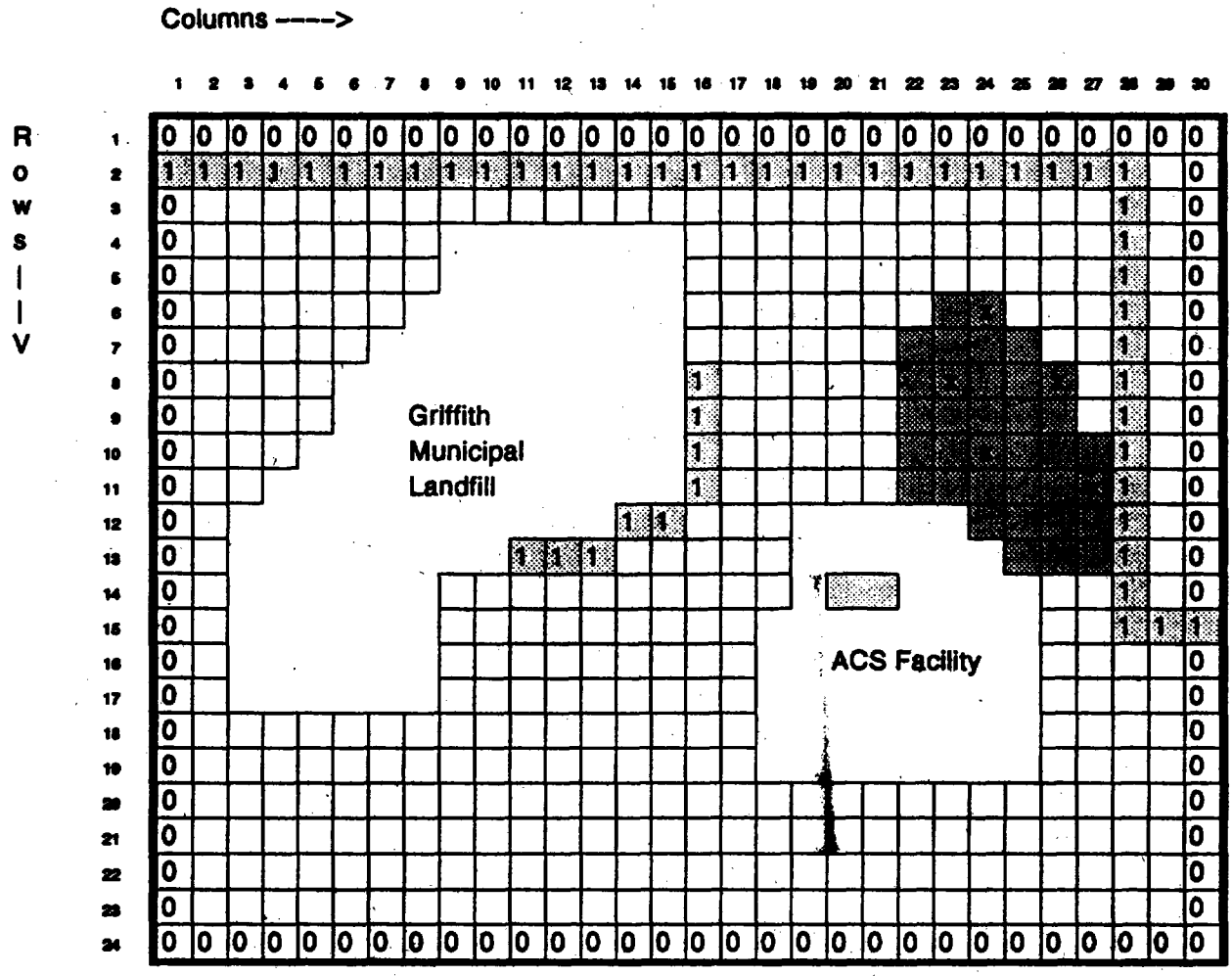


Figure A. Finite-Difference Grid, Model Node Assignments
For Northwest Area Groundwater Remediation

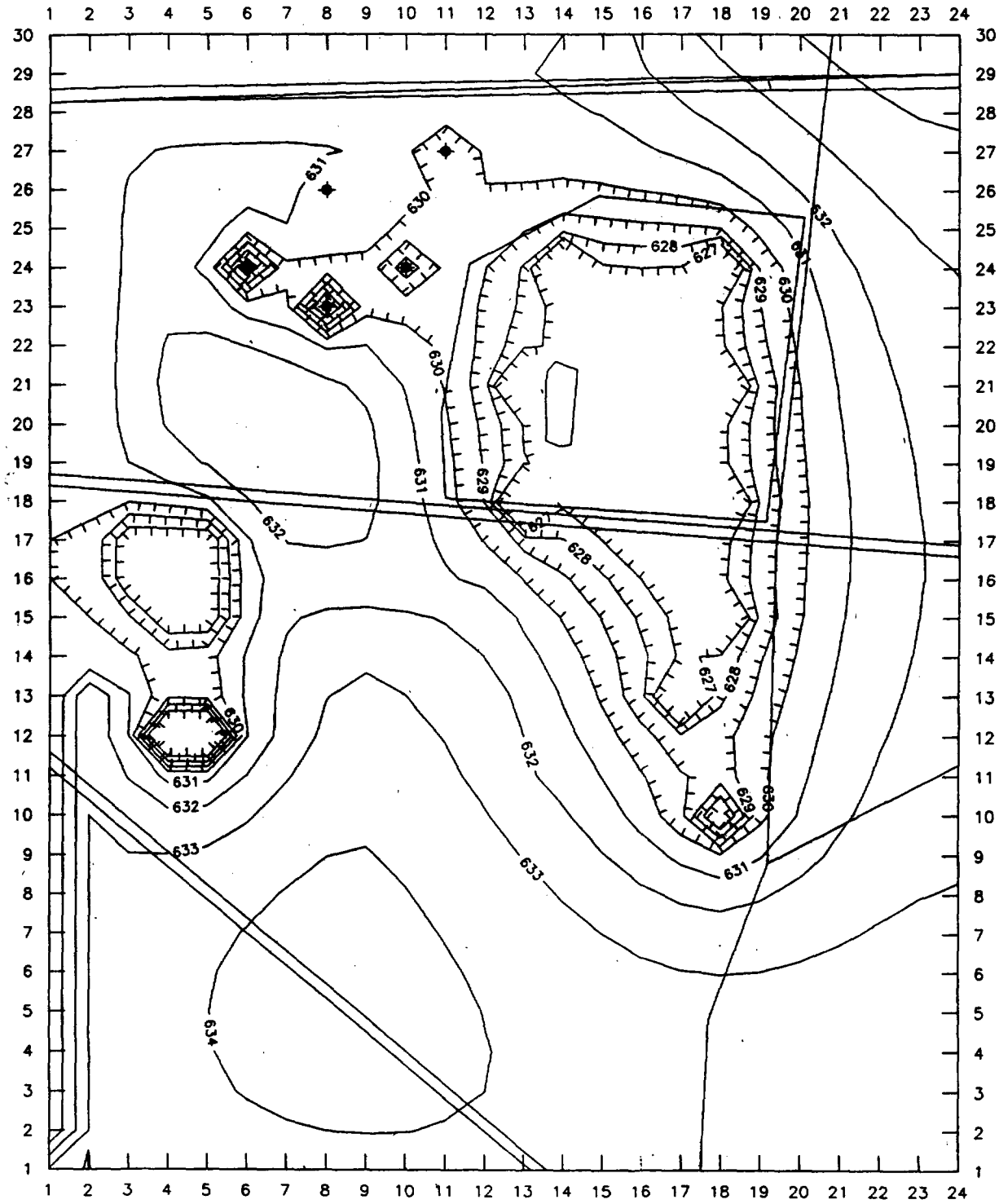


Legend:

- 0 General Head Boundary Nodes
- 1 Creek Nodes
- Upper Aquifer Groundwater Remediation Zone
- Upper Aquifer Gradient Control Wells

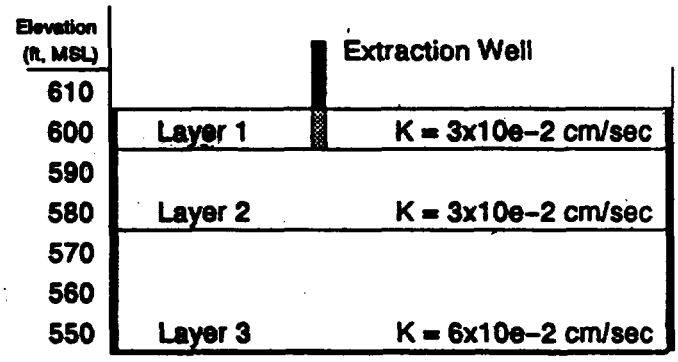
Figure B.

Gradient Control in Northwest Area, 5 2-gpm wells

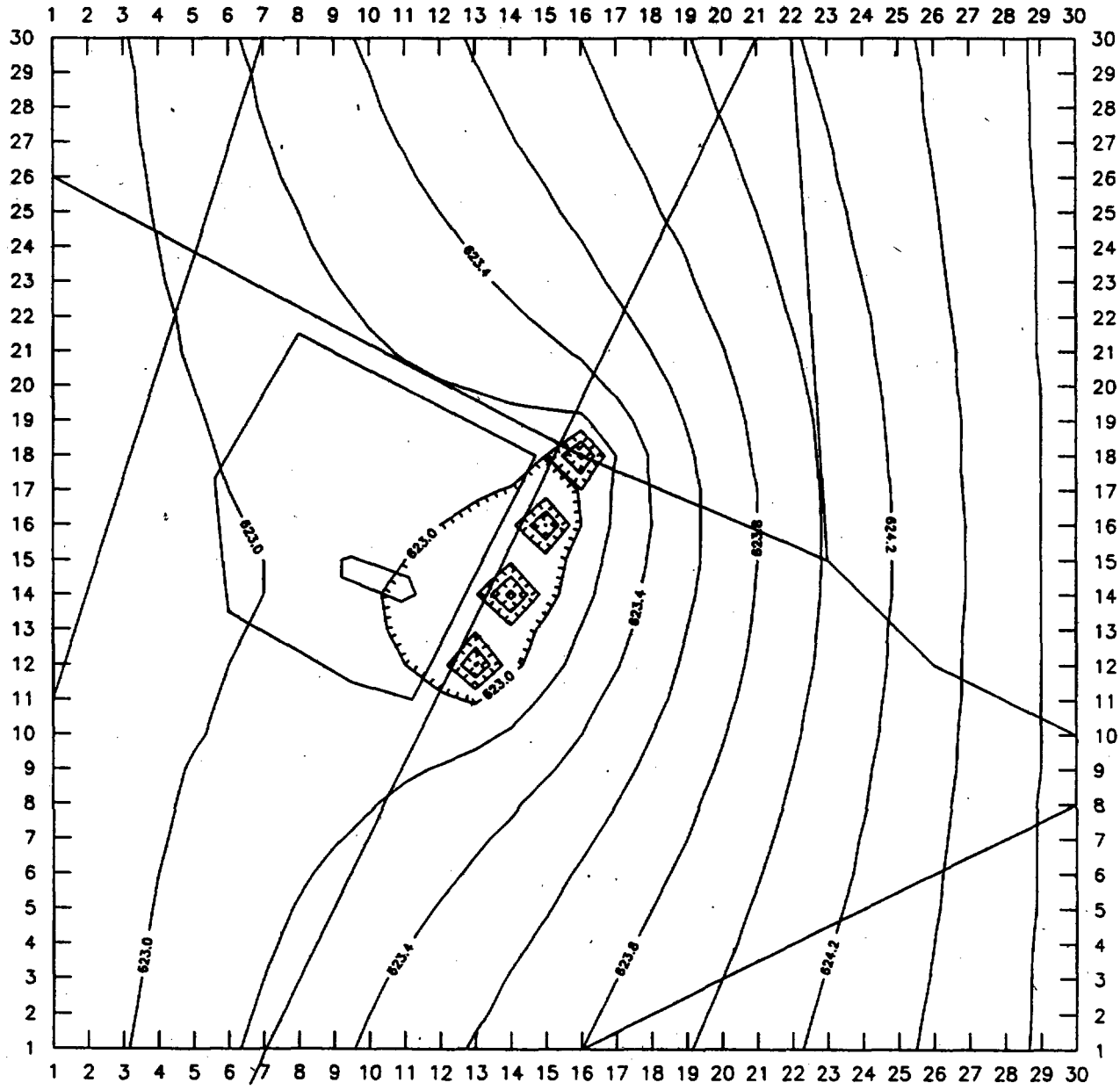


Lower Aquifer Simulation

Cross-Sectional View

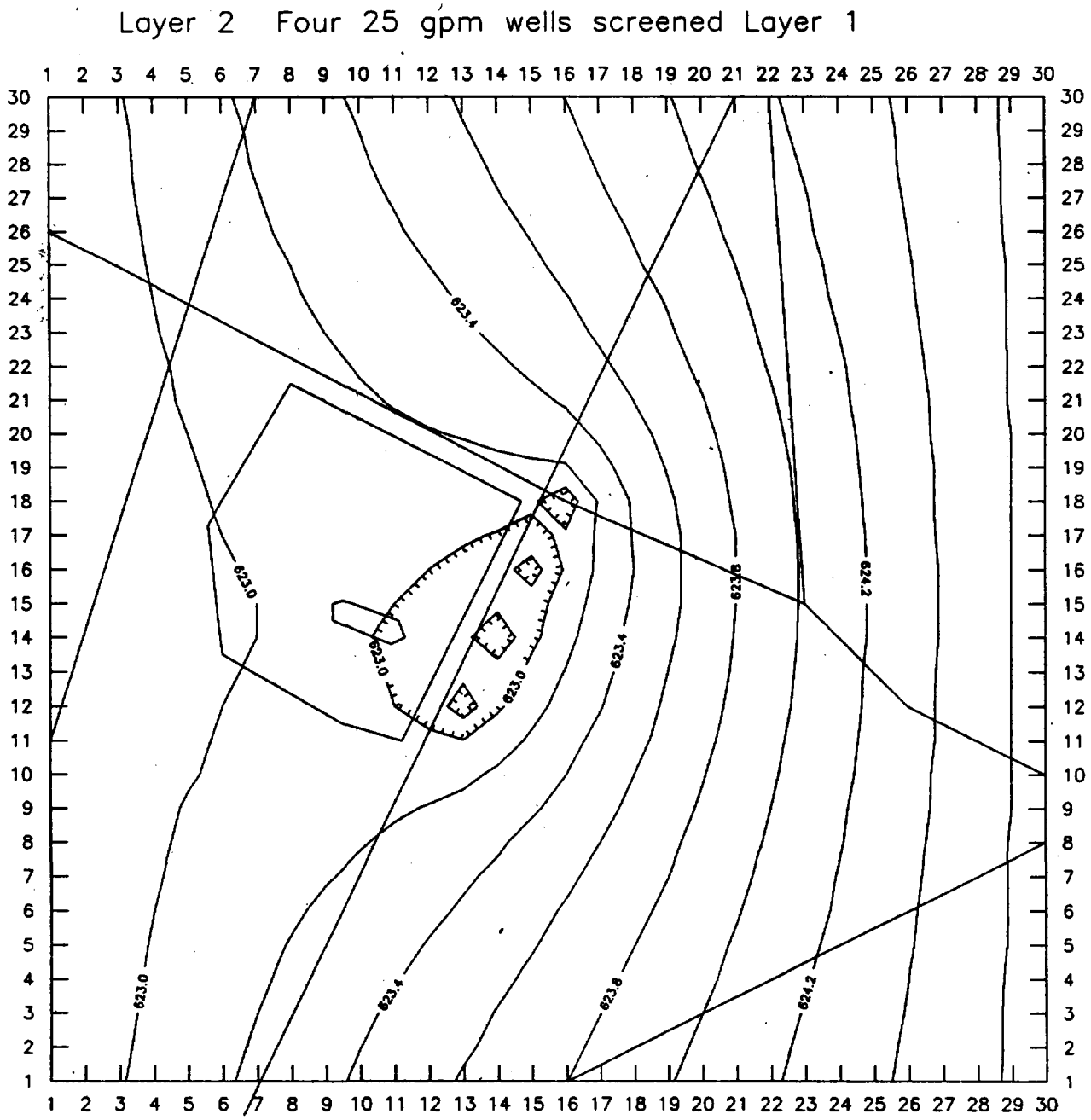


Layer 1 Four 25 gpm wells screened in upper 10'



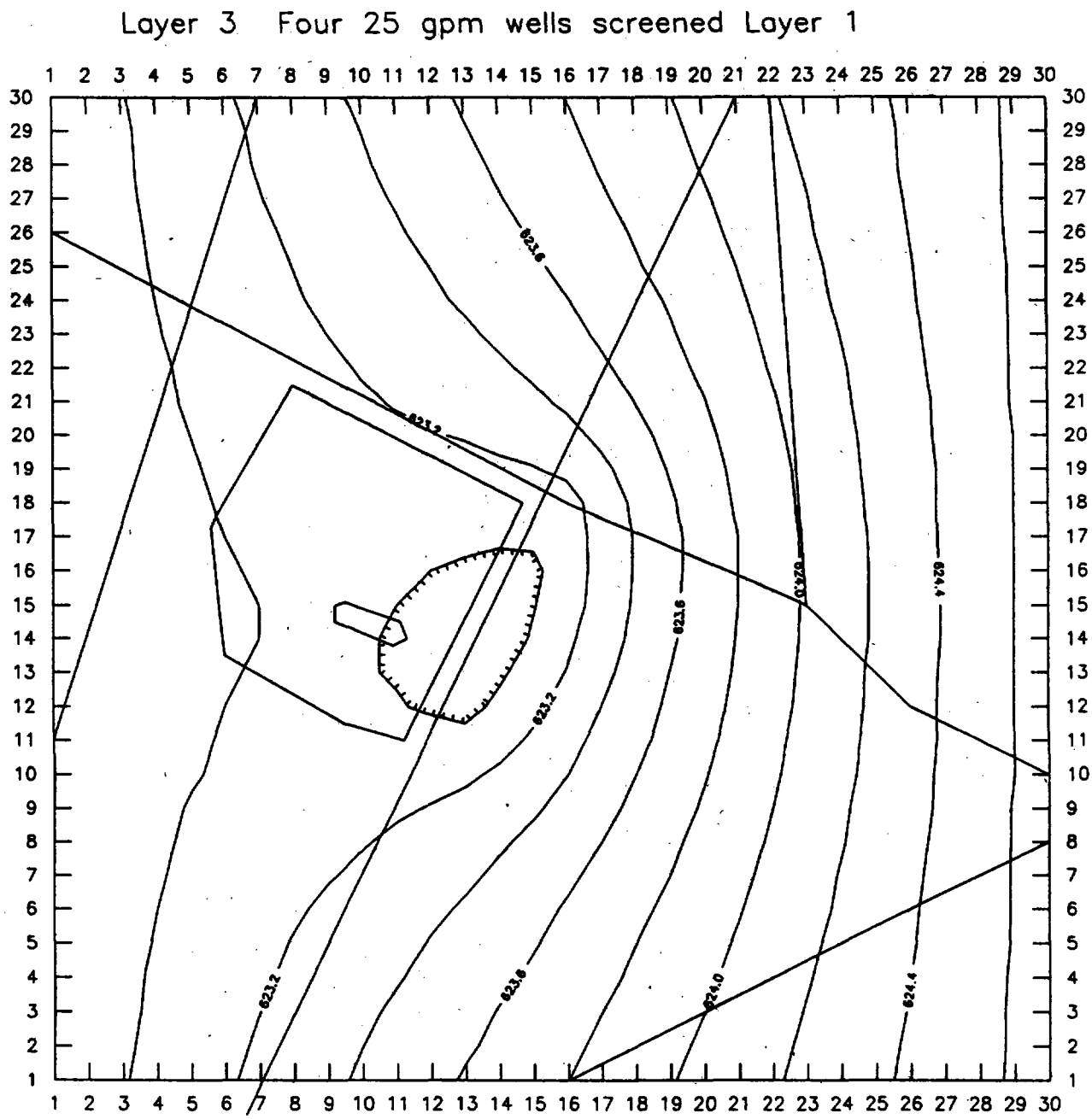
Lower Aquifer Simulation

Layer 2



Lower Aquifer Simulation

Layer 3



Supplement to Appendix A, ACS NPL Site, Feasibility Study
Groundwater Modeling -- Northwest Area

A zone of affected groundwater was identified in the upper aquifer extending 500 to 600 feet to the northwest of the ACS facility (Northwest Area). The groundwater contained levels of BETX greater than 10 ppm, and levels of chlorinated ethanes greater than 1 ppm. After the implementation of a groundwater pump and treat system to remediate the groundwater within the ACS facility and the Off-Site Containment Area, there is still the potential that groundwater gradients in the Northwest Area may still be toward the northwest, away from the Site.

Over pumping of the upper aquifer could be expected to relatively quickly de-water the upper aquifer in the Northwest Area because of the following factors: the relatively low hydraulic conductivity, the relatively thin saturated thickness, and the absence of major recharge sources (other than the drainage ditch).

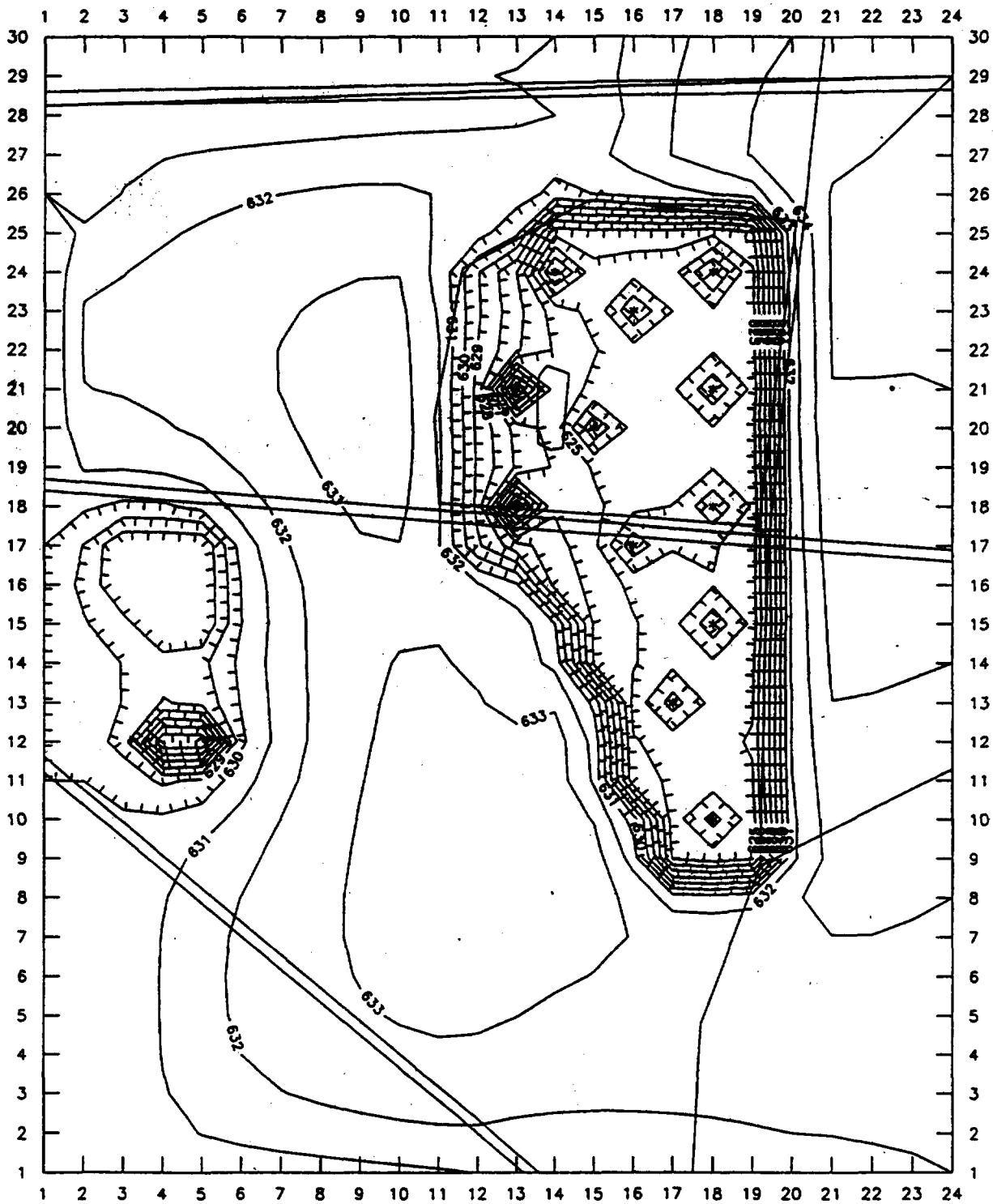
The saturated thickness of the upper aquifer in the Northwest Area is approximately 12 feet. Findings of the Remedial Investigation indicate that the hydraulic conductivity of the upper aquifer in the Northwest Area is approximately $3x10^{-3}$ ft/min ($1.5x10^{-3}$ cm/sec). In addition, remediation would be causing de-watering of the aquifer to the east, upgradient from the Northwest Area.

Groundwater flow modeling was used to evaluate the number of groundwater extraction wells, their locations and their pumping rates, to effectively control the groundwater gradient, without de-watering the upper aquifer (and wetland areas) in the Northwest Area. The groundwater model remedial implementation was used (REM4.*). Attached Figure A shows the finite-difference model grid node assignments for the model. Figure B is a plot of the modeled water table which results when five, 2 gpm extraction wells are placed in the Northwest Area to control the upper aquifer hydraulic gradient, during the remediation of the ACS facility and Off-Site Containment Area. (It should be noted that the orientation of the plot in Figure B is rotated 90 degrees counter-clockwise from Figure A). This is because the model uses a column and row coordinate system (3rd quadrant plot) and the plotting program plots uses an X-Y coordinate system (first quadrant plot).

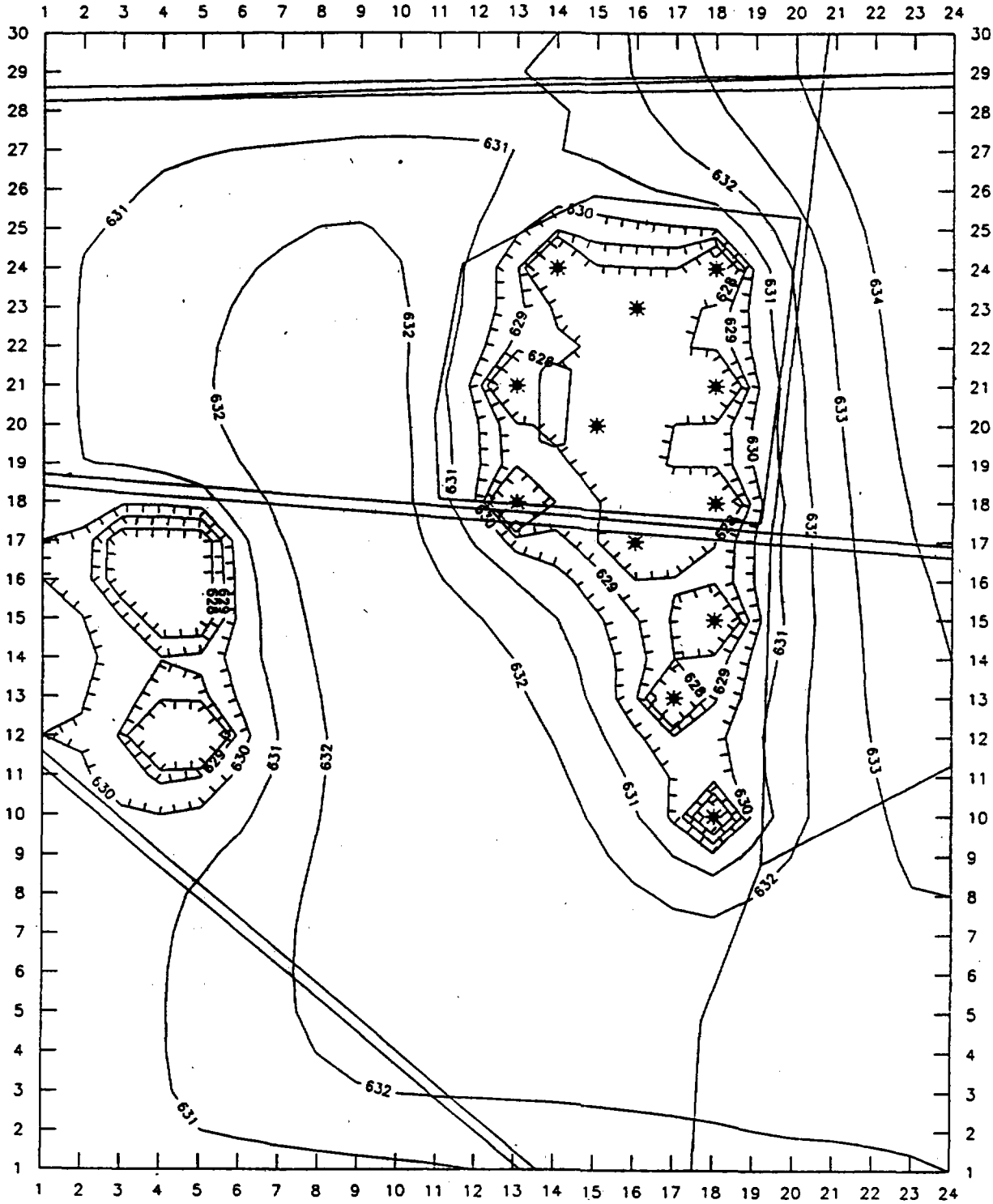
Assuming the RI estimates of hydraulic conductivity, a total groundwater extraction rate of approximately 10 gpm will control the hydraulic gradient. However, a pumping rate greater than 2 gpm at any one location is likely to de-water the aquifer in the vicinity of the well and limit pumping efficiency.

The estimated volume of affected groundwater in the Northwest area is 900,000 cubic feet (7 million gallons). The calculation is based on the following assumptions: aquifer area = 500 ft by 600 ft, saturated aquifer thickness = 12 ft, and aquifer porosity = 25%). With a continuous total groundwater extraction rate of 10 gpm, this volume of water would be extracted from the upper aquifer in approximately 500 days.

REM2 -- 10e-6 cm/sec Slurry Wall - 90 days



90 Days, No Slurry Wall



Appendix B

Detailed Cost Estimates For Final Alternatives In Section 4.0

APPENDIX B

DETAILED COST ESTIMATES

Detailed cost estimates are presented by task for each alternative discussed in Section 4.0 of the FS. Line item costs are presented for each of the primary tasks necessary to implement the alternative. Some of the individual tasks are common to the implementation of all of the alternatives (e.g., surface water diversion, site preparation). The total net present worth (i.e., the sum of the total capital costs and total present worth O&M) was calculated for each alternative for cost comparison purposes.

The cost estimates have been organized according to the following categories:

- Direct Capital Costs: includes all labor, equipment and materials costs directly associated with the acquisition and installation of source and groundwater treatment systems, as well as the implementation of necessary tasks prior to the installation of the treatment systems. These are mostly one time only costs incurred at the beginning of the project. The basis for each of the line item cost estimates is also presented (e.g., 65,000 cubic yards of soil for on-Site incineration of buried waste in Alternative 3A);

- Indirect Capital Costs: includes all labor associated with ancillary support services necessary to complete the tasks included in the direct capital costs (e.g., engineering design). These costs have been presented as a percentage of the direct capital costs. The percentages listed under "% Capital" have been adjusted accordingly if an Indirect Capital Cost line item has been assumed to be the same for more than one of the alternatives for purposes of alternative comparison. For most of the alternatives, the costs associated with the "Design Level Investigation", "Engineering Design", "Startup Costs" and "License/Permit Fees/Oversight" subcategories have been assumed to be approximately the same for most of the alternatives.

- Operation and Maintenance (O&M) Costs: includes labor, raw materials, utilities, maintenance, analytical, etc. costs associated with operating each of the components of the remedial action system. It also includes the costs associated with the administration and oversight of the remedial action alternative. These costs are incurred on an annual basis until the remedial action alternative has

been completed. The present worth was determined for each of the O&M line items based on a 5% discount rate and the number of years the O&M costs associated with that line item would be incurred.

The following is a brief description of the primary line items included in the "Direct Capital" and "O&M" categories:

DIRECT CAPITAL COSTS

Surface Water Diversion: includes the construction of a surface water runoff collection system (e.g., drainage ditches) to take the place of the Fire Pond which has been proposed to be filled in during remedial action activities.

Site Preparation: includes the clearing and grubbing of source treatment areas, the installation of additional utility lines and the construction of additional access roads etc.

Groundwater Extraction System: includes the installation of all wells, pumps and header piping associated with the upper aquifer dewatering and containment systems. It was assumed that vertical extraction wells would be installed.

Groundwater Treatment System: includes all equipment and installation costs associated with the groundwater treatment system. The capital cost is based on the use of air stripping and ion exchange as the primary treatment process options. The number of wells for Alternative 2 is assumed to be less than other treatment alternatives since only off-Site pumping would be required (i.e., Site would not be dewatered). The slurry wall system would contain on-Site groundwater. The groundwater pumping rate for Alternative 4 was assumed to be less than the remaining treatment alternatives since this alternative does not require the Site to be dewatered.

Remove ACS Tank Farms: includes the dismantling and removal of two current tank farms located on top of the Still Bottoms and Treatment Lagoon Areas.

Excavation of Drums: includes the excavation of intact buried drums located in the On-Site Containment, Still Bottoms and Treatment Lagoon Areas.

Repackaging and Off-Site Incineration of Drums: includes the placement of excavated drums into overpack drums and transportation and disposal costs associated with off-Site incineration.

Off-Site Disposal of Drum and Miscellaneous Debris: includes excavation and off-Site disposal costs for drum carcasses and remnants, free liquids and other miscellaneous debris encountered during remedial action activities which would otherwise interfere with the implementation of an alternative.

Source Treatment: includes all equipment and installation costs associated with the primary source treatment process option listed in the alternative description. The costs associated with the construction of any structures, foundations or buildings required by the treatment system would also be included in this line item.

The total costs associated with On-Site incineration and low temperature thermal treatment were presented on a unit cost basis under the "Direct Capital Costs" category. On-Site thermal treatment is typically performed by a vendor on a mobile basis (i.e., capital equipment would not be purchased). Costs would be paid on a monthly or per volume of soil treated basis. It was considered more representative to present the costs associated with thermal treatment in this manner.

O & M COSTS

Groundwater Monitoring: includes labor and analytical costs for groundwater sampling performed on a quarterly basis.

Groundwater Extraction Wells: includes utility and maintenance costs associated with operating the groundwater extraction system.

Groundwater Treatment: includes labor, raw materials, utilities, maintenance, analytical, etc. costs associated with operating the groundwater treatment system. The O&M cost is based on the use of air stripping and ion exchange as the primary treatment process options. The total annual O&M cost was split into thirds to allow for lower treatment costs with time based on decreasing influent concentrations with continuous

source treatment and groundwater flushing. "Initial Groundwater Treatment" corresponds to the time period of highest influent concentrations prior to the completion of source treatment activities; while "Intermediate Groundwater Treatment" corresponds to the time period of decreasing influent concentrations following the completion of source treatment activities; and "Final Groundwater Treatment" corresponds to the time period of lowest influent concentrations following the completion of source treatment and allowing for the effects of continuous groundwater flushing.

Insurance: includes contractor insurance costs associated with remedial action activities, and was calculated as a percentage of the direct capital cost for the primary soils and buried waste treatment process option. It was assumed that the cost for insurance would only be incurred sured over the treatment time frame for buried waste and soils.

Reserve Fund: includes funds which are set aside for the replacement of capital equipment that may become inoperable or obsolete over the course of remedial action activities and was calculated as a percentage of the direct capital cost for the primary soils and buried waste treatment process option. It was assumed that the cost for the reserve fund would only be incurred over the treatment time frame for buried waste and soils.

Administration: includes contractor oversight and client and Agency correspondences associated with remedial action activities.

Cost Sensitivity Analysis

Since the primary variable included in the cost sensitivity analysis were found to impact only the magnitude of the cost estimate and not the relative comparison of alternatives, a qualitative discussion is presented as opposed to quantitative estimates of the cost range for each alternative. Separate discussions of variables which can affect the costs of the groundwater treatment process options retained for detailed analysis are presented throughout Section 4.2.7. Presented below is a brief discussion of the primary variables which could potentially impact the magnitude of the cost estimates, as well as the alternatives most likely to be impacted by variations in the assumptions used in the preparation of the cost estimates.

- Treatment Time Frame: Variations in the assumed treatment time frames for each alternative would directly affect to the present value O & M costs for each alternative. Variations in the treatment time frame assumptions are most likely to occur for Alternatives 4, 5, 6 and 8 since time frames for these alternatives are sensitive to contaminant removal rates. Treatment time frames for Alternatives 2, 3 and 7 are more dependent on material handling operations which are less likely to vary from the assumed values.

- Buried Waste Delineation: A variation in the percentage of materials to be treated that meet the criteria of buried waste would have the most impact on costs for alternatives involving separate treatment process options for buried waste and soils. The costs for Alternatives 3 and 6, which involve thermal treatment of buried waste and alternative soils treatment, would be impacted the most by a variation in the percentage of buried waste to total materials requiring treatment.

- Soil Volume: A variation in the volume of soils requiring treatment would have the most impact on the costs of process options whose O & M costs are directly tied to material handling requirements. The costs for alternatives 4, 7 and 8, which either involve treating a specified surface area or excavating and handling soils, would be impacted the most by variations in soil volume from the assumed values. The costs for Alternatives 5 and 6 would be impacted to a lesser degree by variations in the soil volume to be treated since the installation of additional extraction wells does not represent a significant percentage of the overall costs for these alternatives. Besides some increase to the O & M costs, the remaining costs associated with vapor extraction treatment for Alternatives 5 and 6 are fixed in relation to the volume of soils to be treated.

- Average Contaminant Concentrations: A significant variation from the assumed contaminants concentrations would have the most impact on the costs of process options whose O & M costs are directly tied to the total mass of contaminants removed. The costs for Alternatives 4, 5, 6 and 8 would be impacted the most by significant variations from the assumed contaminant concentrations since O & M costs associated with air pollution control and treatment time frame would vary. Refer to the above discussion pertaining to cost sensitivity involving "Treatment Time Frame." O & M costs for Alternatives 3 and 7, which involve thermal treatment, are relatively insensitive to variations in contaminant concentrations.

- Criteria Used to Delineate Buried Waste and Soils: Variations from the assumed criteria used to delineate buried waste and soils would have a direct impact on the volumes to be treated. Refer to the above discussions pertaining to cost sensitivity involving "Buried Waste Delineation" and "Soil Volume."

- Health-Based Cleanup Criteria: The establishment of final cleanup criteria would have the most impact on the costs of process options where mass transfer relationships (e.g., desorption, diffusion) may limit the rate of contaminant removal and final residual contaminant levels which are achievable. The treatment time frames for Alternatives 4, 5, 6 and 8 (in-situ steam stripping, vapor extraction and biological treatment) may be affected by mass transfer relationships. Assumed treatment time frames for Alternatives 3 and 7, which involve thermal treatment, are insensitive to mass transfer relationships.

- Unit Costs for Treatment: Thermal treatment is the only process option for which the entire cost of treatment is based on an average of unit costs provided by multiple vendors. Since Alternative 7 involves thermal treatment exclusively, it would be the most sensitive to variations in assumed unit costs. Alternatives 3 and 6, which involve thermal treatment of buried wastes only, would be less sensitive to variations in the unit cost. The cost estimates for the remaining process options were compared against literature and vendor quoted unit costs as a method of comparing the relative accuracy of cost estimates prepared by alternative means.

- Groundwater Treatment Variables: Variables which could impact the capital and/or O & M costs for groundwater treatment include pumping rate, treatment time frame and average contaminant concentrations. Variations from assumed values would directly affect groundwater treatment costs. A detailed cost sensitivity discussion of each variable is not presented since groundwater treatment costs are relatively constant for all of the alternatives except Alternative 1 (No Action). Variations from the assumed values should impact the costs of each of the alternatives equally.

ADDENDUM TO APPENDIX B
BREAKDOWN AND BASIS OF COST ESTIMATES

ALTERNATIVE	ITEM[1,2]	TOTAL COST[3]	BASIS
I. LINE ITEMS COMMON TO MULTIPLE ALTERNATIVES			
A. Direct Capital Costs	Surface Water Diversion Site Preparation Tank Demolition	$200,000 $525,000 $150,000	Means Construction (1990), engineering estimates and past experience with similar applications
	Excavation of Drums	$50,000	$100/drum unit cost based on past experience with similar applications
	Repackaging and Off-Site Incineration of Drums	$700/drum	Vendor quote
	Off-Site Disposal of Miscellaneous Debris	$1,000,000	Engineering estimate
	Groundwater Extraction System		
	a. wells	$100,000	$4,000/well installed unit cost based on past experience with similar applications
	b. pumps	$25,000	$2,000/pump installed-Means Construction (1990)
	c. piping	$200,000	$10/linear foot installed-Means Construction (1990)
	d. electrical/heat tracing	$130,000	Engineering estimate and past experience with similar applications
B. Annual O&M Costs	Soil Excavation	$300,000	$19.00/cu.yd. total unit cost-Means Construction (1990)
	Groundwater Monitoring	$200,000	Engineering estimate and past experience with similar applications
	Groundwater Extraction	$65,000	Engineering estimate
	Administration	$200,000	Engineering estimate
II. GROUNDWATER TREATMENT PROCESS OPTIONS			
A. Air Stripping Direct Capital Costs	Equipment	$240,000	U.S. EPA (1990), Hall et al. (April 1981), Chemical Engineering (1988), vendor quotes and past experience with similar applications
	Thermal Treatment Unit	$300,000	U.S. EPA (1990) and Mullins et. al. (May 1988)
B. Air Stripping Annual O&M Costs	Effluent Carbon Regeneration	$200,000	Engineering estimate
	Thermal Treatment	$250,000	U.S. EPA (1990)
	Utilities	$55,000	Engineering estimate
C. Biological Direct Capital Costs	Equipment	$1,800,000	Vendor quote

ADDENDUM TO APPENDIX B
BREAKDOWN AND BASIS OF COST ESTIMATES

ALTERNATIVE	ITEM[1,2]	TOTAL COST[3]	BASIS
D. Biological Annual O&M Costs	Electrical, Nutrients and Oxygen	$160,000	Vendor quote
	Carbon Regeneration	$150,000	Engineering estimate
	Labor	$65,000	Engineering estimate
E. UV/Oxidation Direct Capital Costs	Equipment	$800,000	Vendor quote
F. UV/Oxidation Annual O&M Costs	Hydrogen Peroxide, Electricity, Ozone	$660,000	Vendor quote
G. Ion Exchange Capital Costs	Equipment	$200,000	U.S. EPA (January 1987)
H. Ion Exchange Annual O&M Costs	Raw Materials, Utilities, Disposal of Backwash Residues	$110,000	U.S. EPA (January 1987) and engineering estimates
III. ALTERNATIVE 2			
A. Direct Capital Costs	Slurry Wall	$1,000,000	$8.60/sq.ft. unit cost averaged from U.S. EPA (October 1987)
B. Annual O&M Costs	None		
IV. ALTERNATIVE 3 (THERMAL TREATMENT)	Incineration		$450/cu.yd. unit cost for capital and annual O&M is average of multiple vendor quotes
	Low Temperature Thermal		$300/cu.yd. unit cost for capital and annual O&M is average of multiple vendor quotes
V. ALTERNATIVE 4 (IN-SITU STEAM STRIPPING)			
A. Direct Capital Costs	Auger System	$2.3 million	Extrapolated from U.S. EPA (August 1990)
	Steam System	$700,000	Extrapolated from Cheremisnoff (March 1985), Hall, et al. (April 1982), Chemical Engineering (1988) and engineering estimates
	Vapor Treatment	$1.4 million	U.S. EPA (September 1986), Vatavuk and Neveril (November 1980 and July 1982), Hall, et al. (April 1982), vendor quotes and engineering estimates

ADDENDUM TO APPENDIX B
BREAKDOWN AND BASIS OF COST ESTIMATES

ALTERNATIVE	ITEM[1,2]	TOTAL COST[3]	BASIS
B. Annual O&M Costs	Auger System (electrical & labor)	$2.6 million	Extrapolated from U.S. EPA (August 1990)
	Steam System (electricity, fuel, chemicals)	$600,000	Extrapolated from Cheremisnoff (March 1985) and engineering estimates
	Vapor Treatment (power, liquid and carbon regeneration, disposal of condensed otganics)	$500,000	Engineering estimates
VI. ALTERNATIVES 5 and 6[4] (VAPOR EXTRACTION)			
A. Direct Capital Costs	Pumps, Piping, Heat Treating, etc.	$150,000	Means Construction (1990), vendor quotes, engineering estimates and past experience with similar applications
	Thermal Treatment Unit	$300,000	Vatavuk and Neveril (November 1980 and July 1982), U.S. EPA (September 1986)
	Extraction Wells and Manifold Piping Installation	$150,000	Means Construction (1990), vendor quotes and past experience with similar applications
B. Annual O&M Costs	Thermal Treatment Unit	$200,000	U.S. EPA (September 1986), U.S. EPA (May 1990) and engineering estimates
	Maintenance and Monitoring	$110,000	Engineering estimates and past experience with similar applications
	Electricity	$30,000	Engineering estimates
VII ALTERNATIVE 7 (THERMAL TREATMENT)			
	Incineration		$450/cu.yd. unit cost for capital and annual O&M is average of multiple vendor quotes
	Low Temp Thermal		$300/cu.yd. unit cost for capital and annual O&M is average of multiple vendor quotes
VIII ALTERNATIVE 8 (LANDFARMING)			
A. Direct Capital Costs	Install Compacted Clay	$360,000	$12.87 unit cost; Means Construction (1990) and engineering estimates
	Install Membrane/Sand	$400,000	$3.50/sq.ft. unit cost; Means Construction (1990) and engineering estimates
	Enclosure	$850,000	$6.76/sq.ft. unit cost; Means Construction (1990) and engineering estimates
	Fume Incinerator	$300,000	Vatavuk and Neveril (November 1980 and July 1982) and U.S. EPA (September 1986)
	Air Collection System	$200,000	Means Construction (1990) and engineering estimates

ADDENDUM TO APPENDIX B
BREAKDOWN AND BASIS OF COST ESTIMATES

ALTERNATIVE	ITEM[1,2]	TOTAL COST[3]	BASIS
B. Annual O&M Costs	Power, Nutrients and Water	$300,000	Engineering estimates and past experience with similar applications
	Labor	$150,000	Engineering estimates and past experience with similar applications
XI. ALTERNATIVE 8 (SLURRY-PHASE BIOREACTOR)			
A. Direct Capital Costs	Equipment	$2,800,000	Hall, et al. (April 1982), Chemical Engineering (1988), Means Construction (1990), vendor quote
B. Annual O&M Costs	Power, Nutrients, Water and Labor	$900,000	Engineering estimates

Notes:

1. Only the primary components of the direct capital and annual O&M costs are presented in this table. Therefore, total costs in this table will not be equal to the FS cost estimate presented for each alternative.
2. Installation (e.g., mechanical, electrical, etc.) and annual maintenance were assumed to be percentages of the capital costs based on engineering judgment.
3. All costs obtained from references, etc. were converted to 1991 dollars using appropriate Chemical Engineering Plant Cost Indices obtained from Chemical Engineering Magazine.
4. Refer to IV for thermal treatment cost breakdown for Alternative 6.

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ALTERNATIVE 2
SLURRY WALL SITE; AND GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	COST
DIRECT CAPITAL COSTS			
Surface Water Diversion	lump sum	1	$200,000
Groundwater Extraction Wells	wells	6	$200,000
Groundwater Treatment	gpm	100	$800,000
Slurry Wall	sq ft	116,000	$1,000,000
	TOTAL DIRECT CAPITAL COSTS		$2,200,000

INDIRECT CAPITAL COSTS

	% OF CAPITAL	
Mobilization	10%	$220,000
Health & Safety	10%	$220,000
Design Level Investigation	30%	$660,000
License/Permit Costs/Oversight	10%	$220,000
Scope Contingency	15%	$330,000
	TOTAL INDIRECT CAPITAL COSTS	$1,650,000

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$20,000	5%	30	$307,000
Groundwater Treatment	$250,000	5%	30	$3,843,000
Reserve Fund	$10,000	5%	30	$154,000
Administration	$50,000	5%	30	$769,000
	TOTAL PRESENT WORTH O&M			$8,150,000

TOTAL NET PRESENT WORTH $12,000,000

ALTERNATIVE 3A
EXCAVATION AND ON-SITE INCINERATION OF BURIED WASTE;
AND GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	UNIT COST	COST
DIRECT CAPITAL COSTS				
Surface Water Diversion	lump sum	1		$200,000
Site Preparation	lump sum	1		$525,000
Groundwater Extraction System	wells	24		$500,000
Groundwater Treatment System	gpm	200		$1,200,000
Remove ACS Tank Farms	lump sum	1		$150,000
Excavation of Drums	drums	500		$50,000
Repackaging and Off-site Incineration of Drums	drums	500		$350,000
Off-site Disposal of Drum and Miscellaneous Debris	lump sum	1		$1,000,000
Trial Burn	lump sum	1		$200,000
On-site Incineration	cu yds	65,000	$450	$29,250,000
	TOTAL DIRECT CAPITAL COSTS			$4,180,000
	TOTAL INCINERATION COSTS			$29,250,000
INDIRECT CAPITAL COSTS				
	% OF CAPITAL			
Mobilization	20%			$836,000
Health & Safety	20%			$836,000
Design Level Investigation	12%			$502,000
Engineering Design	12%			$502,000
Startup Costs	12%			$502,000
License/Permit Fees/Oversight	20%			$836,000
Scope Contingency	30%			$1,254,000
	TOTAL INDIRECT CAPITAL COSTS			$5,270,000

ALTERNATIVE 3A
EXCAVATION AND ON-SITE INCINERATION OF BURIED WASTE;
AND GROUNDWATER PUMPING AND TREATMENT

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$65,000	5%	30	$999,000
Initial Groundwater Treatment	$250,000	5%	10	$1,930,000
Intermediate Groundwater Treatment	$250,000	5%	20	$3,116,000
Final Groundwater Treatment	$250,000	5%	30	$3,843,000
Insurance	$50,000	5%	1	$48,000
Reserve Fund	$50,000	5%	1	$48,000
Administration	$200,000	5%	30	$3,074,000
	TOTAL PRESENT WORTH O&M			$16,130,000

TOTAL NET PRESENT WORTH **$54,800,000**

ALTERNATIVE 3B
EXCAVATION AND ON-SITE LOW TEMP THERMAL TREATMENT OF BURIED WASTE;
AND GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	UNIT COST	COST
DIRECT CAPITAL COSTS				
Surface Water Diversion	lump sum	1		$200,000
Site Preparation	lump sum	1		$525,000
Groundwater Extraction System	wells	24		$500,000
Groundwater Treatment System	gpm	200		$1,200,000
Remove ACS Tank Farms	lump sum	1		$150,000
Excavation of Drums	drums	500		$50,000
Repackaging and Off-site Incineration of Drums	drums	500		$350,000
Off-site Disposal of Drum and Miscellaneous Debris	lump sum	1		$1,000,000
Treatability/Pilot Study	lump sum	1		$200,000
On-site Low Temp	cu yds	65,000	$300	$19,500,000
	TOTAL DIRECT CAPITAL COSTS			$4,180,000
	TOTAL LOW TEMP COSTS			$19,500,000

INDIRECT CAPITAL COSTS	% OF CAPITAL	
Mobilization	20%	$836,000
Health & Safety	20%	$836,000
Design Level Investigation	12%	$502,000
Engineering Design	12%	$502,000
Startup Costs	12%	$502,000
License/Permit Fees/Oversight	20%	$836,000
Scope Contingency	30%	$1,254,000
	TOTAL INDIRECT CAPITAL COSTS	$5,270,000

ALTERNATIVE 3B
EXCAVATION AND ON-SITE LOW TEMP THERMAL TREATMENT OF BURIED WASTE;
AND GROUNDWATER PUMPING AND TREATMENT

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$65,000	5%	30	$999,000
Initial Groundwater Treatment	$250,000	5%	10	$1,930,000
Intermediate Groundwater Treatment	$250,000	5%	20	$3,116,000
Final Groundwater Treatment	$250,000	5%	30	$3,843,000
Insurance	$50,000	5%	1	$48,000
Reserve Fund	$50,000	5%	1	$48,000
Administration	$200,000	5%	30	$3,074,000
	TOTAL PRESENT WORTH O&M			$16,130,000

TOTAL NET PRESENT WORTH **$45,100,000**

ALTERNATIVE 4
IN-SITU STEAM STRIPPING OF BURIED WASTE, SOILS AND GROUNDWATER;
AND GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	COST
DIRECT CAPITAL COSTS			
Surface Water Diversion	lump sum	1	$200,000
Site Preparation	lump sum	1	$475,000
Groundwater Extraction System	wells	24	$500,000
Groundwater Treatment System	gpm	150	$1,000,000
Remove ACS Tank Farms	lump sum	1	$150,000
Excavation of Drums	drums	500	$50,000
Repackaging and Off-site Incineration of Drums	drums	500	$350,000
Off-site Disposal of Drum and Miscellaneous Debris	lump sum	1	$1,000,000
Pilot Study	lump sum	1	$200,000
In-Situ Steam Stripping	augers	8	$4,500,000
	TOTAL DIRECT CAPITAL COSTS		$8,430,000

INDIRECT CAPITAL COSTS	% OF CAPITAL	
Mobilization	10%	$843,000
Health & Safety	10%	$843,000
Design Level Investigation	6%	$506,000
Engineering Design	6%	$506,000
Startup Costs	6%	$506,000
License/Permit Fees/Oversight	10%	$843,000
Scope Contingency	15%	$1,265,000
	TOTAL INDIRECT CAPITAL COSTS	$5,310,000

ALTERNATIVE 4
IN-SITU STEAM STRIPPING OF BURIED WASTE, SOILS AND GROUNDWATER;
AND GROUNDWATER PUMPING AND TREATMENT

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$65,000	5%	30	$999,000
Initial Groundwater Treatment	$325,000	5%	15	$3,373,000
Final Groundwater Treatment	$325,000	5%	30	$4,996,000
In-Situ Steam Stripping	$2,700,000	5%	10	$20,849,000
Insurance	$50,000	5%	10	$386,000
Reserve Fund	$50,000	5%	10	$386,000
Administration	$200,000	5%	30	$3,074,000
	TOTAL PRESENT WORTH O&M			$37,140,000

TOTAL NET PRESENT WORTH **$50,900,000**

ALTERNATIVE 5
IN-SITU VAPOR EXTRACTION OF BURIED WASTE AND SOILS; AND GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	COST
DIRECT CAPITAL COSTS			
Surface Water Diversion	lump sum	1	$200,000
Site Preparation	lump sum	1	$525,000
Groundwater Extraction System	wells	24	$500,000
Groundwater Treatment System	gpm	200	$1,200,000
Remove ACS Tank Farms	lump sum	1	$150,000
Excavation of Drums	drums	500	$50,000
Repackaging and Off-site Incineration of Drums	drums	500	$350,000
Off-site Disposal of Drum and Miscellaneous Debris	lump sum	1	$1,000,000
Off-site Disposal of PCB Soil at RCRA/TSCA Landfill	cu yds	1000	$700,000
Treatability/Pilot Study	lump sum	1	$200,000
Vapor Extraction Pilot Study	lump sum	1	$200,000
Vapor Extraction	systems	4	$800,000
	TOTAL DIRECT CAPITAL COSTS		$5,880,000
INDIRECT CAPITAL COSTS			
	% OF CAPITAL		
Mobilization	20%		$1,176,000
Health & Safety	20%		$1,176,000
Design Level Investigation	10%		$588,000
Engineering Design	10%		$588,000
Startup Costs	10%		$588,000
License/Permit Fees/Oversight	20%		$1,176,000
Scope Contingency	25%		$1,470,000
	TOTAL INDIRECT CAPITAL COSTS		$6,760,000

ALTERNATIVE 5
IN-SITU VAPOR EXTRACTION OF BURIED WASTE AND SOILS; AND GROUNDWATER PUMPING AND TREATMENT

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$65,000	5%	30	$999,000
Initial Groundwater Treatment	$250,000	5%	10	$1,930,000
Intermediate Groundwater Treatment	$250,000	5%	20	$3,116,000
Final Groundwater Treatment	$250,000	5%	30	$3,843,000
Vapor Extraction	$400,000	5%	15	$4,152,000
Insurance	$10,000	5%	16	$108,000
Reserve Fund	$10,000	5%	16	$108,000
Administration	$200,000	5%	30	$3,074,000
	TOTAL PRESENT WORTH O&M			$20,400,000

TOTAL NET PRESENT WORTH $33,000,000

ALTERNATIVE 6A
EXCAVATION AND ON-SITE INCINERATION OF BURIED WASTE;
IN-SITU VAPOR EXTRACTION OF SOILS; AND
GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	UNIT COST	COST
DIRECT CAPITAL COSTS				
Surface Water Diversion	lump sum	1		$200,000
Site Preparation	lump sum	1		$525,000
Groundwater Extraction System	wells	24		$500,000
Groundwater Treatment System	gpm	200		$1,200,000
Remove ACS Tank Farms	lump sum	1		$150,000
Excavation of Drums	drums	500		$50,000
Repackaging and Off-site Incineration of Drums	drums	500		$350,000
Off-site Disposal of Drum and Miscellaneous Debris	lump sum	1		$1,000,000
Trial Burn	lump sum	1		$200,000
On-site Incineration	cu yds	35,000	$450	$15,750,000
Vapor Extraction Pilot Study	lump sum	1		$200,000
Vapor Extraction	systems	4		$800,000
	TOTAL DIRECT CAPITAL COSTS			$5,180,000
	TOTAL INCINERATION COSTS			$15,750,000

INDIRECT CAPITAL COSTS

	% OF CAPITAL	
Mobilization	20%	$1,036,000
Health & Safety	20%	$1,036,000
Design Level Investigation	10%	$518,000
Engineering Design	10%	$518,000
Startup Costs	10%	$518,000
License/Permit Fees/Oversight	20%	$1,036,000
Scope Contingency	25%	$1,295,000
	TOTAL INDIRECT CAPITAL COSTS	$5,960,000

ALTERNATIVE 6A
EXCAVATION AND ON-SITE INCINERATION OF BURIED WASTE;
IN-SITU VAPOR EXTRACTION OF SOILS; AND
GROUNDWATER PUMPING AND TREATMENT

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$65,000	5%	30	$999,000
Initial Groundwater Treatment	$250,000	5%	6	$1,269,000
Intermediate Groundwater Treatment	$250,000	5%	11	$2,077,000
Final Groundwater Treatment	$250,000	5%	30	$3,843,000
Vapor Extraction	$400,000	5%	5	$1,732,000
Insurance	$10,000	5%	6	$51,000
Reserve Fund	$10,000	5%	6	$51,000
Administration	$200,000	5%	30	$3,074,000
	TOTAL PRESENT WORTH O&M			$16,170,000

TOTAL NET PRESENT WORTH $43,100,000

ALTERNATIVE 6A
EXCAVATION AND ON-SITE INCINERATION OF BURIED WASTE;
IN-SITU VAPOR EXTRACTION OF SOILS; AND
GROUNDWATER PUMPING AND TREATMENT

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$65,000	5%	30	$999,000
Initial Groundwater Treatment	$250,000	5%	6	$1,269,000
Intermediate Groundwater Treatment	$250,000	5%	11	$2,077,000
Final Groundwater Treatment	$250,000	5%	30	$3,843,000
Vapor Extraction	$400,000	5%	5	$1,732,000
Insurance	$10,000	5%	6	$51,000
Reserve Fund	$10,000	5%	6	$51,000
Administration	$200,000	5%	30	$3,074,000
	TOTAL PRESENT WORTH O&M			$16,170,000

TOTAL NET PRESENT WORTH $56,600,000

ALTERNATIVE 6A
EXCAVATION AND ON-SITE INCINERATION OF BURIED WASTE;
IN-SITU VAPOR EXTRACTION OF SOILS; AND
GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	UNIT COST	COST
DIRECT CAPITAL COSTS				
Surface Water Diversion	lump sum	1		$200,000
Site Preparation	lump sum	1		$525,000
Groundwater Extraction System	wells	24		$500,000
Groundwater Treatment System	gpm	200		$1,200,000
Remove ACS Tank Farms	lump sum	1		$150,000
Excavation of Drums	drums	500		$50,000
Repackaging and Off-site Incineration of Drums	drums	500		$350,000
Off-site Disposal of Drum and Miscellaneous Debris	lump sum	1		$1,000,000
Trial Burn	lump sum			$200,000
On-site Incineration	cu yds	65,000	$450	$29,250,000
Vapor Extraction Pilot Study	lump sum	1		$200,000
Vapor Extraction	systems	4		$800,000
	TOTAL DIRECT CAPITAL COSTS			$5,180,000
	TOTAL INCINERATION COSTS			$29,250,000

INDIRECT CAPITAL COSTS

	% OF CAPITAL	
Mobilization	20%	$1,036,000
Health & Safety	20%	$1,036,000
Design Level Investigation	10%	$518,000
Engineering Design	10%	$518,000
Startup Costs	10%	$518,000
License/Permit Fees/Oversight	20%	$1,036,000
Scope Contingency	25%	$1,295,000
	TOTAL INDIRECT CAPITAL COSTS	$5,960,000

ALTERNATIVE 6B
EXCAVATION AND ON-SITE LOW TEMP THERMAL TREATMENT OF BURIED WASTE; IN-SITU VAPOR EXTRACTION OF SOILS; AND GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	UNIT COST	COST
DIRECT CAPITAL COSTS				
Surface Water Diversion	lump sum	1		$200,000
Site Preparation	lump sum	1		$525,000
Groundwater Extraction System	wells	24		$500,000
Groundwater Treatment System	gpm	200		$1,200,000
Remove ACS Tank Farms	lump sum	1		$150,000
Excavation of Drums	drums	500		$50,000
Repackaging and Off-site Incineration of Drums	drums	500		$350,000
Off-site Disposal of Drum and Miscellaneous Debris	lump sum	1		$1,000,000
Treatability/Pilot Study	lump sum	1		$200,000
On-site Low Temp	cu yds	35,000	$300	$10,500,000
Vapor Extraction Pilot Study	lump sum	1		$200,000
Vapor Extraction	systems	4		$800,000
	TOTAL DIRECT CAPITAL COSTS			$5,180,000
	TOTAL LOW TEMP COSTS			$10,500,000
INDIRECT CAPITAL COSTS				
	% OF CAPITAL			
Mobilization	20%			$1,036,000
Health & Safety	20%			$1,036,000
Design Level Investigation	10%			$518,000
Engineering Design	10%			$518,000
Startup Costs	10%			$518,000
License/Permit Fees/Oversight	20%			$1,036,000
Scope Contingency	25%			$1,295,000
	TOTAL INDIRECT CAPITAL COSTS			$5,960,000

ALTERNATIVE 6B
EXCAVATION AND ON-SITE LOW TEMP THERMAL TREATMENT OF BURIED WASTE; IN-SITU VAPOR EXTRACTION OF SOILS; AND GROUNDWATER PUMPING AND TREATMENT

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$65,000	5%	30	$999,000
Initial Groundwater Treatment	$250,000	5%	6	$1,269,000
Intermediate Groundwater Treatment	$250,000	5%	11	$2,077,000
Final Groundwater Treatment	$250,000	5%	30	$3,843,000
Vapor Extraction	$400,000	5%	5	$1,732,000
Insurance	$10,000	5%	6	$51,000
Reserve Fund	$10,000	5%	6	$51,000
Administration	$200,000	5%	30	$3,074,000
	TOTAL PRESENT WORTH O&M			$16,170,000

TOTAL NET PRESENT WORTH $37,800,000

ALTERNATIVE 6B
EXCAVATION AND ON-SITE LOW TEMP THERMAL TREATMENT OF BURIED WASTE; IN-SITU VAPOR EXTRACTION OF SOILS; AND GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	UNIT COST	COST
DIRECT CAPITAL COSTS				
Surface Water Diversion	lump sum	1		$200,000
Site Preparation	lump sum	1		$525,000
Groundwater Extraction System	wells	24		$500,000
Groundwater Treatment System	gpm	200		$1,200,000
Remove ACS Tank Farms	lump sum	1		$150,000
Excavation of Drums	drums	500		$50,000
Repackaging and Off-site Incineration of Drums	drums	500		$350,000
Off-site Disposal of Drum and Miscellaneous Debris	lump sum	1		$1,000,000
Treatability/Pilot Study	lump sum	1		$200,000
On-site Low Temp	cu yds	65,000	$300	$19,500,000
Vapor Extraction Pilot Study	lump sum	1		$200,000
Vapor Extraction	systems	4		$800,000
	TOTAL DIRECT CAPITAL COSTS			$5,180,000
	TOTAL LOW TEMP COSTS			$19,500,000
INDIRECT CAPITAL COSTS				
	% OF CAPITAL			
Mobilization	20%			$1,036,000
Health & Safety	20%			$1,036,000
Design Level Investigation	10%			$518,000
Engineering Design	10%			$518,000
Startup Costs	10%			$518,000
License/Permit Fees/Oversight	20%			$1,036,000
Scope Contingency	25%			$1,295,000
	TOTAL INDIRECT CAPITAL COSTS			$5,960,000

ALTERNATIVE 6B
EXCAVATION AND ON-SITE LOW TEMP THERMAL TREATMENT OF BURIED WASTE; IN-SITU VAPOR EXTRACTION OF SOILS; AND GROUNDWATER PUMPING AND TREATMENT

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$65,000	5%	30	$999,000
Initial Groundwater Treatment	$250,000	5%	6	$1,269,000
Intermediate Groundwater Treatment	$250,000	5%	11	$2,077,000
Final Groundwater Treatment	$250,000	5%	30	$3,843,000
Vapor Extraction	$400,000	5%	5	$1,732,000
Insurance	$10,000	5%	6	$51,000
Reserve Fund	$10,000	5%	6	$51,000
Administration	$200,000	5%	30	$3,074,000
	TOTAL PRESENT WORTH O&M			$16,170,000

TOTAL NET PRESENT WORTH **$46,800,000**

ALTERNATIVE 7A
ON-SITE INCINERATION OF BURIED WASTE AND SOILS;
AND GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	UNIT COST	COST
DIRECT CAPITAL COSTS				
Surface Water Diversion	lump sum	1		$200,000
Site Preparation	lump sum	1		$525,000
Groundwater Extraction System	wells	24		$500,000
Groundwater Treatment System	gpm	200		$1,200,000
Remove ACS Tank Farms	lump sum	1		$150,000
Excavation of Drums	drums	500		$50,000
Repackaging and Off-site Incineration of Drums	drums	500		$350,000
Off-site Disposal of Drum and Miscellaneous Debris	lump sum	1		$1,000,000
Trial Burn	lump sum	1		$200,000
On-site Incineration	cu yds	135,000	$450	$60,750,000
	TOTAL DIRECT CAPITAL COSTS			$4,180,000
	TOTAL INCINERATION COSTS			$60,750,000

INDIRECT CAPITAL COSTS

	% OF CAPITAL	
	20%	$836,000
Health & Safety	20%	$836,000
Design Level Investigation	12%	$502,000
Engineering Design	12%	$502,000
Startup Costs	12%	$502,000
License/Permit Fees/Oversight	20%	$836,000
Scope Contingency	30%	$1,254,000
	TOTAL INDIRECT CAPITAL COSTS	$5,270,000

ALTERNATIVE 7A
ON-SITE INCINERATION OF BURIED WASTE AND SOILS;
AND GROUNDWATER PUMPING AND TREATMENT

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$65,000	5%	30	$999,000
Initial Groundwater Treatment	$250,000	5%	5	$1,082,000
Intermediate Groundwater Treatment	$250,000	5%	10	$1,930,000
Final Groundwater Treatment	$250,000	5%	30	$3,843,000
Insurance	$50,000	5%	5	$216,000
Reserve Fund	$50,000	5%	5	$216,000
Administration	$200,000	5%	30	$3,074,000
	TOTAL PRESENT WORTH O&M			$14,430,000

TOTAL NET PRESENT WORTH $84,600,000

ALTERNATIVE 7B
EXCAVATION AND ON-SITE LOW TEMP THERMAL TREATMENT OF BURIED WASTE AND SOILS; AND GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	UNIT COST	COST
DIRECT CAPITAL COSTS				
Surface Water Diversion	lump sum	1		$200,000
Site Preparation	lump sum	1		$525,000
Groundwater Extraction System	wells	24		$500,000
Groundwater Treatment System	gpm	200		$1,200,000
Remove ACS Tank Farms	lump sum	1		$150,000
Excavation of Drums	drums	500		$50,000
Repackaging and Off-site Incineration of Drums	drums	500		$350,000
Off-site Disposal of Drum and Miscellaneous Debris	lump sum	1		$1,000,000
Treatability/Pilot Study	lump sum	1		$200,000
On-site Low Temp	cu yds	135,000	$300	$40,500,000
	TOTAL DIRECT CAPITAL COSTS			$4,180,000
	TOTAL LOW TEMP COSTS			$40,500,000

INDIRECT CAPITAL COSTS	% OF CAPITAL	
Mobilization	20%	$836,000
Health & Safety	20%	$836,000
Design Level Investigation	12%	$502,000
Engineering Design	12%	$502,000
Startup Costs	12%	$502,000
License/Permit Fees/Oversight	20%	$836,000
Scope Contingency	30%	$1,254,000
	TOTAL INDIRECT CAPITAL COSTS	$5,270,000

ALTERNATIVE 7B
EXCAVATION AND ON-SITE LOW TEMP THERMAL TREATMENT OF BURIED WASTE AND SOILS; AND GROUNDWATER PUMPING AND TREATMENT

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$65,000	5%	30	$999,000
Initial Groundwater Treatment	$250,000	5%	5	$1,082,000
Intermediate Groundwater Treatment	$250,000	5%	10	$1,930,000
Final Groundwater Treatment	$250,000	5%	30	$3,843,000
Insurance	$50,000	5%	5	$216,000
Reserve Fund	$50,000	5%	5	$216,000
Administration	$200,000	5%	30	$3,074,000
	TOTAL PRESENT WORTH O&M			$14,430,000

TOTAL NET PRESENT WORTH $64,400,000

ALTERNATIVE 8A
EXCAVATION AND LANDFARMING OF BURIED WASTE AND SOILS;
AND GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	COST
DIRECT CAPITAL COSTS			
Surface Water Diversion	lump sum	1	$200,000
Site Preparation	lump sum	1	$535,000
Groundwater Extraction System	wells	24	$500,000
Groundwater Treatment System	gpm	200	$1,200,000
Remove ACS Tank Farms	lump sum	1	$150,000
Excavation of Drums	drums	500	$50,000
Repackaging and Off-site Incineration of Drums	drums	500	$350,000
Off-site Disposal of Drum and Miscellaneous Debris	lump sum	1	$1,000,000
Treatability/Pilot Study	lump sum	1	$400,000
Landfarming	cu yds	135,000	$2,500,000
	TOTAL DIRECT CAPITAL COSTS		$6,890,000

	% OF CAPITAL	
INDIRECT CAPITAL COSTS		
Mobilization	10%	$689,000
Health & Safety	10%	$689,000
Design Level Investigation	7%	$482,000
Engineering Design	7%	$482,000
Startup Costs	7%	$482,000
License/Permit Fees/Oversight	10%	$689,000
Scope Contingency	15%	$1,034,000
	TOTAL INDIRECT CAPITAL COSTS	$4,550,000

ALTERNATIVE 8A
EXCAVATION AND LANDFARMING OF BURIED WASTE AND SOILS;
AND GROUNDWATER PUMPING AND TREATMENT

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$65,000	5%	30	$999,000
Initial Groundwater Treatment	$250,000	5%	10	$1,930,000
Intermediate Groundwater Treatment	$250,000	5%	15	$2,595,000
Final Groundwater Treatment	$250,000	5%	30	$3,843,000
Soil Excavation	$300,000	5%	10	$2,317,000
Landfarming	$600,000	5%	10	$4,633,000
Insurance	$20,000	5%	10	$154,000
Reserve Fund	$20,000	5%	10	$154,000
Administration	$200,000	5%	30	$3,074,000
	TOTAL PRESENT WORTH O&M			$22,770,000

TOTAL NET PRESENT WORTH $34,200,000

ALTERNATIVE 8B
EXCAVATION AND SLURRY-PHASE BIOREACTOR TREATMENT OF BURIED WASTE AND SOILS; AND GROUNDWATER PUMPING AND TREATMENT

ITEM	UNIT	QUANTITY	COST
DIRECT CAPITAL COSTS			
Surface Water Diversion	lump sum	1	$200,000
Site Preparation	lump sum	1	$535,000
Groundwater Extraction System	wells	24	$500,000
Groundwater Treatment System	gpm	200	$1,200,000
Remove ACS Tank Farms	lump sum	1	$150,000
Excavation of Drums	drums	500	$50,000
Repackaging and Off-site Incineration of Drums	drums	500	$350,000
Off-site Disposal of Drum and Miscellaneous Debris	lump sum	1	$1,000,000
Treatability/Pilot Study	lump sum	1	$400,000
Slurry-Phase Bioreactor	cu yds	135,000	$6,000,000
	TOTAL DIRECT CAPITAL COSTS		$10,390,000
INDIRECT CAPITAL COSTS			
	% OF CAPITAL		
Mobilization	10%		$1,039,000
Health & Safety	10%		$1,039,000
Design Level Investigation	5%		$520,000
Engineering Design	5%		$520,000
Startup Costs	5%		$520,000
License/Permit Fees/Oversight	10%		$1,039,000
Scope Contingency	15%		$1,559,000
	TOTAL INDIRECT CAPITAL COSTS		$6,240,000

ALTERNATIVE 8B
EXCAVATION AND SLURRY-PHASE BIOREACTOR TREATMENT OF BURIED WASTE AND SOILS; AND GROUNDWATER PUMPING AND TREATMENT

OPERATION & MAINTENANCE COSTS

	ANNUAL O&M	DISCOUNT RATE	NUMBER OF YEARS	PRESENT WORTH
Groundwater Monitoring	$200,000	5%	30	$3,074,000
Groundwater Extraction Wells	$65,000	5%	30	$999,000
Initial Groundwater Treatment	$250,000	5%	5	$1,082,000
Intermediate Groundwater Treatment	$250,000	5%	10	$1,930,000
Final Groundwater Treatment	$250,000	5%	30	$3,843,000
Soil Excavation	$600,000	5%	5	$2,598,000
Slurry-Phase Bioreactor	$2,200,000	5%	5	$9,525,000
Insurance	$50,000	5%	5	$216,000
Reserve Fund	$50,000	5%	5	$216,000
Administration	$200,000	5%	30	$3,074,000
	TOTAL PRESENT WORTH O&M			$26,560,000

TOTAL NET PRESENT WORTH $43,200,000

AIR STRIPPING SIMULATION RESULTS

C

Appendix C

Air Stripping Tower Simulations
Computer Model Results

APPENDIX C
AIR STRIPPING TOWER SIMULATIONS

Introduction

Air stripping involves transferring contaminants from a wastewater stream (i.e., contaminated groundwater) to the vapor phase. The strippability of a given compound (i.e., ability of a compound to be transferred) is controlled primarily by the Henry's Law constant and temperature. Henry's Law constants for target compounds at the Site are presented in Table 3-1. Temperature has a dramatic effect on the Henry's Law constant and the mass transfer coefficient. The lower the temperature, the slower the mass transfer at the air/water interface. The coldest expected temperature is assumed for design. If the Henry's Law constant is between 0.02 and 1.0 (0.0005 and 0.02 atm-m^3/mole at 20 ^oC), the optimum strippability can be reached by adjusting the air to water ratio. If the Henry's Law constant is higher than 1.0, then stripping will be essentially complete even at low air to water ratios. If the Henry's Law constant is less than about 0.02, the compound is not very volatile, and stripping becomes poorer as the Henry's Law constant decreases.

Air stripping tower design simulations were performed for the ACS Site groundwater using the "AIRSTRIP" computer software program (Release 1.1, Copyright 1989) developed by Johannes Haaroff and Dave Schoeller. The "AIRSTRIP" program uses the Onda correlations as its basis for estimating mass transfer rate constants in counter current packed aeration towers. The program allows the user to vary the contaminant to be stripped, the concentration of the contaminant, temperature, air/water ratio, packing type, packing depth, liquid loading rate (i.e., flow rate and tower diameter), and pressure in the tower. By varying these parameters, a stripping tower can be designed to remove specific contaminants to a desired level.

Compounds that cannot be removed effectively by air stripping can be removed by a liquid phase carbon adsorption process following the air stripping column. Vapor phase carbon adsorption or thermal or catalytic incineration can be used to treat off-gases before release to the atmosphere.

Approach and Results for the ACS Site

The majority of the organic contaminants found in Site groundwater are amenable to air stripping based on Henry's Law constants (see Table 3-1). Compounds found in Site groundwater that are not readily stripped include phenols, phthalates, organic acids, ethers, and ketones. Liquid phase carbon adsorption polishing was included to remove compounds that are not readily stripped in order to meet the potential NPDES discharge criteria identified in Table 4-14.

Table 4-7 (maximum concentration values) presents assumed groundwater influent concentrations by chemical group for the groundwater treatment system. A flow rate of 200 gallons per minute (gpm) was used for design purposes. It was assumed that the strippability (i.e., mass transfer rate coefficients) of individual contaminants would be independent of the presence of dilute concentrations of other contaminants in groundwater. Target compounds were selected to simplify the air stripping simulations. The final design parameters for the air stripping tower were selected based on the worst case simulation for each of the individual target compounds. Simulations for the remaining target compounds were then run at the selected design conditions. A safety factor is introduced into the design by using the sum of individual influent concentrations for the contaminants from a given chemical family to represent the influent concentration of the corresponding target compounds used in the design simulations. This safety factor accounts for the use of empirical correlations in the simulation.

Air stripping simulations were performed for organic chemical groups identified in Table 4-7, using the representative compounds identified in Section 3.1.2. Generally, only one of the identified representative compounds for each chemical group was used for the air stripping simulations. However, both vinyl chloride and tetrachloroethene were used to represent chlorinated ethenes in the tower simulations, because vinyl chloride has a significantly higher Henry's Law constant and a lower potential discharge criteria than other chlorinated ethenes. Air stripping simulations were not run for organic acids and ethers because of their low Henry's Law constants.

Liquid phase activated carbon polishing was assumed for the air stripper effluent because the discharge criteria for phenols was not achieved by the air stripper simulation. Carbon adsorption isotherm data was used to predict activated carbon usage rates for each of the compounds that had non-zero concentrations predicted by the tower simulations. Activated carbon usage is not selective for specific compounds. Activated carbon usage rates were calculated for the specific contaminants based on equations shown in "Carbon Adsorption Isotherms for Toxic Organics" (U.S. EPA, April 1980). The carbon usage rates were adjusted for natural organic matter found in groundwater by an empirical relation determined by activated carbon vendors. The isotherm parameters were taken from U.S. EPA (April 1980), the U.S. EPA WERL treatability database, and vendor information. For cost estimating purposes, the total activated carbon usage rate was assumed to be the sum of the individual usage rates. The activated carbon usage rate was estimated to be approximately 62,400 pounds per year.

Based on the influent concentrations presented in Table 4-7, and the removal rates predicted by the simulation, approximately 25 pounds per hour of total VOCs would be transferred to the vapor phase. Treatment of the air stripper off-gases would be required based on IDEM VOC emission limits of 25 tons per year as discussed in Section 4.3.3. Thermal treatment of the air stripper off-gases was, therefore, assumed. Heat from the thermal treatment process would be recovered and used to heat the influent groundwater to approximately 80 ^{o}F before entering the air stripping tower.

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Potential NPDES discharge criteria presented in Table 4-14 were used for design purposes in the air stripping simulations. A discharge criteria of 50 ug/L was assumed for methyl ethyl ketone based on a review of relevant case studies.

Preliminary air stripping simulations were run varying the tower diameter, height and air/water ratios to determine the optimum design parameters for each of the target contaminants. The optimum tower diameter and height were selected based on achieving the specified effluent objectives, while minimizing the air/water ratio and maintaining an optimum pressure drop (i.e., energy requirements). An optimum pressure drop across the air stripping tower of 0.06 to 0.07 inches inches of water per foot of tower height was selected for tower diameter sizing. The following design assumptions were used in the preliminary air stripping simulations:

- the type of packing used was 1.5 inch p-flexrings
- groundwater temperature of 50 ^{o}F (minimum expected)
- an operating pressure of one atmosphere

Based on the preliminary air stripping simulations, it was determined that methyl ethyl ketone and 4-methylphenol would limit tower design. Ketones are not easily adsorbed by activated carbon, and would have a very high carbon usage rate. 4-methylphenol was found to be essentially unstrippable, but phenols are adsorbed well by activated carbon. Therefore, methyl ethyl ketone was chosen as the controlling contaminant for tower design.

Methyl ethyl ketone has a relatively low Henry's Law constant, and is difficult to strip. To achieve the desired removal of methyl ethyl ketone at 50 ^{o}F, an air/water ratio in excess of 400:1 would be required. By increasing the influent water temperature to approximately 80 ^{o}F, the desired removal efficiency can be achieved with an air/water ratio of 215:1. The selected air stripping tower design parameters, based on the removal of methyl ethyl ketone, for treatment of groundwater at the ACS Site are as follows:

- 200 gpm flow rate
- 215:1 air/water ratio
- 80 ^{o}F influent groundwater temperature
- a tower diameter of 7 feet
- total packing depth of 40 feet
- a pressure drop of 0.069 inches of water per foot of packing

Final simulations were run for the remaining contaminants using the design parameters specified above. Program output for the final simulations can be found at the end of this appendix. The results of the final simulations with the selected design parameters show that the assumed effluent objectives can be met for most of the chosen compounds at the concentrations used.

The following presents the assumed influent and effluent objective concentrations used in the air stripping simulations, as well as the resulting effluent level from the air stripping simulation:

Target Compound	Represented Chemical Family	Groundwater Influent Conc.	Air Stripper Effluent Conc.	Effluent Objective
Methyl ethyl ketone	Ketones	200,000	30	50
Benzene	BEXT	50,000	0	5.0
Chloroform	Chlorinated Methanes	200	0	5.0
Chloroethane	Chlorinated Ethanes	3,200	0	5.0
Tetrachloroethene	Chlorinated Ethenes	125	0	5.0
Vinyl Chloride	Vinyl Chloride	75	0	2.0
4-Methylphenol	Phenols	3,600	3,600	2,000
1,2-Dichlorobenzene	Chlorinated Benzenes	300	0	75
Napthalene	PNAs	100	0	N.A.
Di-n-butylphthalate	Phthalates	20	4.0	3.0
PCBs	PCBs	2.0	0	0.5
bis (2-chloroethyl) ether	Ethers	1,900	1,900	230,000
Benzoic acid	Organic acids	2,000	2,000	N.A.

Notes: 1. All concentrations in micrograms per liter (ug/L).
2. N.A. = discharge criteria not available.

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Ketones DATE : 4/8/1991

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PHYSICAL CONSTANTS

Design temperature	:	80.0 degrees F.
Density of water	:	62.2 lb/ft^3
Density of air	:	0.0735 lb/ft^3
Viscosity of water	:	5.80E-04 lb/ft.s
Viscosity of air	:	1.21E-05 lb/ft.s
Surface tension of water	:	72 dyne/cm
Atmospheric pressure	:	1.00 atm

CONTAMINANT PROPERTIES

Name	:	Methyl Ethyl Ketone
Molecular weight	:	72.0 g/mol
Boiling point	:	176 degrees F.
Molal volume at boiling point	:	0.0896 L/mol
Henry's Constant	:	0.00790
Enthalpy upon dissolution in water	:	3800 cal/mol
Molecular diffusivity in air	:	1.09E-04 ft^2/s
Molecular diffusivity in water	:	1.19E-08 ft^2/s

PACKING PROPERTIES

Name	:	Flexirings
Packing Material	:	Plastic
Nominal Size	:	1.50 inch
Specific Area	:	39.9 ft^2/ft^3
Critical surface tension	:	33 dyne/cm
Packing depth	:	40.0 ft
Air friction factor	:	31

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Ketones DATE : 4/8/1991

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LOADING RATES

Water mass loading rate	:	0.7 lb/ft^2.s	*
Air mass loading rate	:	0.183 lb/ft^2.s	*
Water volumetric loading rate	:	5.20 gpm/ft^2	*
Air volumetric loading rate	:	1118 gpm/ft^2	*
Air pressure gradient .	:	0.069 " H2O/ft	#
Volumetric air/water ratio	:	215.0	
Stripping factor	:	2.4	

MASS TRANSFER PARAMETERS

Percentage of packing area wetted	:	37.4 %	
Wetted packing area	:	14.9 ft^2/ft^3	*
Transfer rate constant in water	:	0.000442 ft/s	
Transfer rate constant in air	:	0.066986 ft/s	
Overall transfer rate constant	:	0.000277 ft/s	
Overall mass transfer coefficient	:	0.0041 1/s	
NTU	:	10.1081	
HTU	:	3.9572 ft	

CONTAMINANT REMOVAL

Influent concentration	:	200.0 mg/L	
Effluent concentration	:	30.2 ug/L	
Fraction removed	:	100.0 %	
Mass of contaminant removed	:	12.47812 lb/ft^2.day	*
Concentration in airstream	:	2.44614 mg/ft^2.ft^3	

* Expressed per unit of stripping tower cross-sectional area
\# Expressed per unit of tower length

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Polychlorobiphenyls (PCBs) DATE : 4/8/1991

ENGINEER : CWB PAGE : 1/2

PHYSICAL CONSTANTS

Design temperature	:	80.0 degrees F.
Density of water	:	62.2 lb/ft^3
Density of air	:	0.0735 lb/ft^3
Viscosity of water	:	5.80E-04 lb/ft.s
Viscosity of air	:	1.21E-05 lb/ft.s
Surface tension of water	:	72 dyne/cm
Atmospheric pressure	:	1.00 atm

CONTAMINANT PROPERTIES

Name	:	PCBs (Aroclor 1242)
Molecular weight	:	266.0 g/mol
Boiling point	:	662 degrees F.
Molal volume at boiling point	:	0.2482 L/mol
Henry's Constant	:	0.02300
Enthalpy upon dissolution in water	:	3800 cal/mol
Molecular diffusivity in air	:	5.67E-05 ft^2/s
Molecular diffusivity in water	:	6.45E-09 ft^2/s

PACKING PROPERTIES

Name	:	Flexirings
Packing Material	:	Plastic
Nominal Size	:	1.50 inch
Specific Area	:	39.9 ft^2/ft^3
Critical surface tension	:	33 dyne/cm
Packing depth	:	40.0 ft
Air friction factor	:	31

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Polychlorobiphenyls (PCBs) DATE : 4/8/1991

ENGINEER : CWB PAGE : 2/2

LOADING RATES

Water mass loading rate	:	0.7 lb/ft^2.s	*
Air mass loading rate	:	0.183 lb/ft^2.s	*
Water volumetric loading rate	:	5.20 gpm/ft^2	*
Air volumetric loading rate	:	1118 gpm/ft^2	*
Air pressure gradient	:	0.069 " H2O/ft	#
Volumetric air/water ratio	:	215.0	
Stripping factor	:	6.9	

MASS TRANSFER PARAMETERS

Percentage of packing area wetted	:	37.4 %	
Wetted packing area	:	14.9 ft^2/ft^3	*
Transfer rate constant in water	:	0.000326 ft/s	
Transfer rate constant in air	:	0.043253 ft/s	
Overall transfer rate constant	:	0.000264 ft/s	
Overall mass transfer coefficient	:	0.0039 1/s	
NTU	:	13.6075	
HTU	:	2.9396 ft	

CONTAMINANT REMOVAL

Influent concentration	:	2.0 ug/L	
Effluent concentration	:	0.0 ug/L	
Fraction removed	:	100.0 %	
Mass of contaminant removed	:	0.00012 lb/ft^2.day	*
Concentration in airstream	:	0.00002 mg/ft^2.ft^3	

* Expressed per unit of stripping tower cross-sectional area
\# Expressed per unit of tower length

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Phthalates DATE : 4/8/1991

ENGINEER : CWB PAGE : 1/2

PHYSICAL CONSTANTS

Design temperature	:	80.0 degrees F.
Density of water	:	62.2 lb/ft^3
Density of air	:	0.0736 lb/ft^3
Viscosity of water	:	5.80E-04 lb/ft.s
Viscosity of air	:	1.21E-05 lb/ft.s
Surface tension of water	:	72 dyne/cm
Atmospheric pressure	:	1.00 atm

CONTAMINANT PROPERTIES

Name	:	Di-n-butylphthalate
Molecular weight	:	391.0 g/mol
Boiling point	:	446 degrees F.
Molal volume at boiling point	:	0.3736 L/mol
Henry's Constant	:	0.00300
Enthalpy upon dissolution in water	:	3800 cal/mol
Molecular diffusivity in air	:	4.86E-05 ft^2/s
Molecular diffusivity in water	:	5.05E-09 ft^2/s

PACKING PROPERTIES

Name	:	Flexirings
Packing Material	:	Plastic
Nominal Size	:	1.50 inch
Specific Area	:	39.9 ft^2/ft^3
Critical surface tension	:	33 dyne/cm
Packing depth	:	40.0 ft
Air friction factor	:	31

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Phthalates DATE : 4/8/1991

ENGINEER : CWB PAGE : 2/2

LOADING RATES

Water mass loading rate	:	0.7 lb/ft^2.s	*
Air mass loading rate	:	0.183 lb/ft^2.s	*
Water volumetric loading rate	:	5.20 gpm/ft^2	*
Air volumetric loading rate	:	1118 gpm/ft^2	*
Air pressure gradient	:	0.069 " H2O/ft	#
Volumetric air/water ratio	:	215.0	
Stripping factor	:	0.9	

MASS TRANSFER PARAMETERS

Percentage of packing area wetted	:	37.4 %	
Wetted packing area	:	14.9 ft^2/ft^3	*
Transfer rate constant in water	:	0.000288 ft/s	
Transfer rate constant in air	:	0.039023 ft/s	
Overall transfer rate constant	:	0.000104 ft/s	
Overall mass transfer coefficient	:	0.0016 1/s	
NTU	:	1.6790	
HTU	:	23.8233 ft	

CONTAMINANT REMOVAL

Influent concentration	:	20.0 ug/L	
Effluent concentration	:	4.0 ug/L	
Fraction removed	:	80.2 %	
Mass of contaminant removed	:	0.00100 lb/ft^2.day	*
Concentration in airstream	:	0.00020 mg/ft^2.ft^3	

* Expressed per unit of stripping tower cross-sectional area
\# Expressed per unit of tower length

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Chlorinated Benzenes DATE : 4/8/1991

ENGINEER : CWB PAGE : 1/2

PHYSICAL CONSTANTS

Design temperature	:	80.0 degrees F.
Density of water	:	62.2 lb/ft^3
Density of air	:	0.0735 lb/ft^3
Viscosity of water	:	5.80E-04 lb/ft.s
Viscosity of air	:	1.21E-05 lb/ft.s
Surface tension of water	:	72 dyne/cm
Atmospheric pressure	:	1.00 atm

CONTAMINANT PROPERTIES

Name	:	o-Dichlorobenzene
Molecular weight	:	147.0 g/mol
Boiling point	:	358 degrees F.
Molal volume at boiling point	:	0.1378 L/mol
Henry's Constant	:	0.08000
Enthalpy upon dissolution in water	:	3800 cal/mol
Molecular diffusivity in air	:	8.11E-05 ft^2/s
Molecular diffusivity in water	:	9.18E-09 ft^2/s

PACKING PROPERTIES

Name	:	Flexirings
Packing Material	:	Plastic
Nominal Size	:	1.50 inch
Specific Area	:	39.9 ft^2/ft^3
Critical surface tension	:	33 dyne/cm
Packing depth	:	40.0 ft
Air friction factor	:	31

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Chlorinated Benzenes DATE : 4/8/1991

ENGINEER : CWB PAGE : 2/2

LOADING RATES

Water mass loading rate	:	0.7 lb/ft^2.s	*
Air mass loading rate	:	0.183 lb/ft^2.s	*
Water volumetric loading rate	:	5.20 gpm/ft^2	*
Air volumetric loading rate	:	1118 gpm/ft^2	*
Air pressure gradient	:	0.069 " H2O/ft	#
Volumetric air/water ratio	:	215.0	
Stripping factor	:	24.0	

MASS TRANSFER PARAMETERS

Percentage of packing area wetted	:	37.4 %	
Wetted packing area	:	14.9 ft^2/ft^3	*
Transfer rate constant in water	:	0.000388 ft/s	
Transfer rate constant in air	:	0.054881 ft/s	
Overall transfer rate constant	:	0.000365 ft/s	
Overall mass transfer coefficient	:	0.0055 1/s	
NTU	:	18.8434	
HTU	:	2.1228 ft	

CONTAMINANT REMOVAL

Influent concentration	:	300.0 ug/L	
Effluent concentration	:	0.0 ug/L	
Fraction removed	:	100.0 %	
Mass of contaminant removed	:	0.01872 lb/ft^2.day	*
Concentration in airstream	:	0.00367 mg/ft^2.ft^3	

* Expressed per unit of stripping tower cross-sectional area
\# Expressed per unit of tower length

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Polynuclear Aromatics DATE : 4/8/1991

ENGINEER : CWB PAGE : 1/2

PHYSICAL CONSTANTS

Design temperature	:	80.0 degrees F.
Density of water	:	62.2 lb/ft^3
Density of air	:	0.0735 lb/ft^3
Viscosity of water	:	5.80E-04 lb/ft.s
Viscosity of air	:	1.21E-05 lb/ft.s
Surface tension of water	:	72 dyne/cm
Atmospheric pressure	:	1.00 atm

CONTAMINANT PROPERTIES

Name	:	Napthalene
Molecular weight	:	128.2 g/mol
Boiling point	:	424 degrees F.
Molal volume at boiling point	:	0.1476 L/mol
Henry's Constant	:	0.04900
Enthalpy upon dissolution in water	:	3800 cal/mol
Molecular diffusivity in air	:	7.84E-05 ft^2/s
Molecular diffusivity in water	:	8.81E-09 ft^2/s

PACKING PROPERTIES

Name	:	Flexirings
Packing Material	:	Plastic
Nominal Size	:	1.50 inch
Specific Area	:	39.9 ft^2/ft^3
Critical surface tension	:	33 dyne/cm
Packing depth	:	40.0 ft
Air friction factor	:	31

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Polynuclear Aromatics DATE : 4/8/1991

ENGINEER : CWB PAGE : 2/2

LOADING RATES

Water mass loading rate	:	0.7 lb/ft^2.s	*
Air mass loading rate	:	0.183 lb/ft^2.s	*
Water volumetric loading rate	:	5.20 gpm/ft^2	*
Air volumetric loading rate	:	1118 gpm/ft^2	*
Air pressure gradient	:	0.069 " H2O/ft	#
Volumetric air/water ratio	:	215.0	
Stripping factor	:	14.7	

MASS TRANSFER PARAMETERS

Percentage of packing area wetted	:	37.4 %	
Wetted packing area	:	14.9 ft^2/ft^3	*
Transfer rate constant in water	:	0.000380 ft/s	
Transfer rate constant in air	:	0.053665 ft/s	
Overall transfer rate constant	:	0.000345 ft/s	
Overall mass transfer coefficient	:	0.0051 1/s	
NTU	:	17.3258	
HTU	:	2.3087 ft	

CONTAMINANT REMOVAL

Influent concentration	:	100.0 ug/L	
Effluent concentration	:	0.0 ug/L	
Fraction removed	:	100.0 %	
Mass of contaminant removed	:	0.00624 lb/ft^2.day	*
Concentration in airstream	:	0.00122 mg/ft^2.ft^3	

* Expressed per unit of stripping tower cross-sectional area
\# Expressed per unit of tower length

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Vinyl Chloride DATE : 4/8/1991

ENGINEER : CWB PAGE : 1/2

PHYSICAL CONSTANTS

Design temperature	:	80.0 degrees F.
Density of water	:	62.2 lb/ft^3
Density of air	:	0.0735 lb/ft^3
Viscosity of water	:	5.80E-04 lb/ft.s
Viscosity of air	:	1.21E-05 lb/ft.s
Surface tension of water	:	72 dyne/cm
Atmospheric pressure	:	1.00 atm

CONTAMINANT PROPERTIES

Name	:	Vinylchloride
Molecular weight	:	62.5 g/mol
Boiling point	:	9 degrees F.
Molal volume at boiling point	:	0.0653 L/mol
Henry's Constant	:	3.40000
Enthalpy upon dissolution in water	:	3800 cal/mol
Molecular diffusivity in air	:	1.33E-04 ft^2/s
Molecular diffusivity in water	:	1.44E-08 ft^2/s

PACKING PROPERTIES

Name	:	Flexirings
Packing Material	:	Plastic
Nominal Size	:	1.50 inch
Specific Area	:	39.9 ft^2/ft^3
Critical surface tension	:	33 dyne/cm
Packing depth	:	40.0 ft
Air friction factor	:	31

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Vinyl Chloride DATE : 4/8/1991

ENGINEER : CWB PAGE : 2/2

LOADING RATES

Water mass loading rate	:	0.7 lb/ft^2.s	*
Air mass loading rate	:	0.183 lb/ft^2.s	*
Water volumetric loading rate	:	5.20 gpm/ft^2	*
Air volumetric loading rate	:	1118 gpm/ft^2	*
Air pressure gradient	:	0.069 " H2O/ft	#
Volumetric air/water ratio	:	215.0	
Stripping factor	:	1020.8	

MASS TRANSFER PARAMETERS

Percentage of packing area wetted	:	37.4 %	
Wetted packing area	:	14.9 ft^2/ft^3	*
Transfer rate constant in water	:	0.000486 ft/s	
Transfer rate constant in air	:	0.076417 ft/s	
Overall transfer rate constant	:	0.000485 ft/s	
Overall mass transfer coefficient	:	0.0072 1/s	
NTU	:	25.1499	
HTU	:	1.5905 ft	

CONTAMINANT REMOVAL

Influent concentration	:	75.0 ug/L	
Effluent concentration	:	0.0 ug/L	
Fraction removed	:	100.0 %	
Mass of contaminant removed	:	0.00468 lb/ft^2.day	*
Concentration in airstream	:	0.00092 mg/ft^2.ft^3	

* Expressed per unit of stripping tower cross-sectional area
\# Expressed per unit of tower length

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Phenols DATE : 4/8/1991

ENGINEER : CWB PAGE : 1/2

PHYSICAL CONSTANTS

Design temperature	:	80.0 degrees F.
Density of water	:	62.2 lb/ft^3
Density of air	:	0.0735 lb/ft^3
Viscosity of water	:	5.80E-04 lb/ft.s
Viscosity of air	:	1.21E-05 lb/ft.s
Surface tension of water	:	72 dyne/cm
Atmospheric pressure	:	1.00 atm

CONTAMINANT PROPERTIES

Name	:	4-Cresol (4-Methylphenol)
Molecular weight	:	108.0 g/mol
Boiling point	:	396 degrees F.
Molal volume at boiling point	:	0.1045 L/mol
Henry's Constant	:	0.00005
Enthalpy upon dissolution in water	:	3800 cal/mol
Molecular diffusivity in air	:	9.24E-05 ft^2/s
Molecular diffusivity in water	:	1.06E-06 ft^2/s

PACKING PROPERTIES

Name	:	Flexirings
Packing Material	:	Plastic
Nominal Size	:	1.50 inch
Specific Area	:	39.9 ft^2/ft^3
Critical surface tension	:	33 dyne/cm
Packing depth	:	40.0 ft
Air friction factor	:	31

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Phenols DATE : 4/8/1991

ENGINEER : CWB PAGE : 2/2

LOADING RATES

Water mass loading rate	:	0.7 lb/ft^2.s	*
Air mass loading rate	:	0.183 lb/ft^2.s	*
Water volumetric loading rate	:	5.20 gpm/ft^2	*
Air volumetric loading rate	:	1118 gpm/ft^2	*
Air pressure gradient	:	0.069 " H2O/ft	#
Volumetric air/water ratio	:	215.0	
Stripping factor	:	0.0	

MASS TRANSFER PARAMETERS

Percentage of packing area wetted	:	37.4 %	
Wetted packing area	:	14.9 ft^2/ft^3	*
Transfer rate constant in water	:	0.000422 ft/s	
Transfer rate constant in air	:	0.059875 ft/s	
Overall transfer rate constant	:	0.000004 ft/s	
Overall mass transfer coefficient	:	0.0001 1/s	
NTU	:	0.0139	
HTU	:	***.**** ft	

CONTAMINANT REMOVAL

Influent concentration	:	3.6 mg/L	
Effluent concentration	:	3.6 mg/L	
Fraction removed	:	1.4 %	
Mass of contaminant removed	:	0.00310 lb/ft^2.day	*
Concentration in airstream	:	0.00061 mg/ft^2.ft^3	

* Expressed per unit of stripping tower cross-sectional area
\# Expressed per unit of tower length

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : ~~BEXT~~ DATE : 4/8/1991

ENGINEER : CWB PAGE : 1/2

PHYSICAL CONSTANTS

Design temperature	:	80.0 degrees F.
Density of water	:	62.2 lb/ft^3
Density of air	:	0.0735 lb/ft^3
Viscosity of water	:	5.80E-04 lb/ft.s
Viscosity of air	:	1.21E-05 lb/ft.s
Surface tension of water	:	72 dyne/cm
Atmospheric pressure	:	1.00 atm

CONTAMINANT PROPERTIES

Name	:	Benzene
Molecular weight	:	78.1 g/mol
Boiling point	:	176 degrees F.
Molal volume at boiling point	:	0.0960 L/mol
Henry's Constant	:	0.23000
Enthalpy upon dissolution in water	:	3680 cal/mol
Molecular diffusivity in air	:	1.05E-04 ft^2/s
Molecular diffusivity in water	:	1.14E-08 ft^2/s

PACKING PROPERTIES

Name	:	Flexirings
Packing Material	:	Plastic
Nominal Size	:	1.50 inch
Specific Area	:	39.9 ft^2/ft^3
Critical surface tension	:	33 dyne/cm
Packing depth	:	40.0 ft
Air friction factor	:	31

****** A N A L Y S I S O F S T R I P P I N G T O W E R ******

PROJECT : BEXT DATE : 4/8/1991

ENGINEER : CWB PAGE : 2/2

LOADING RATES

Water mass loading rate	:	0.7 lb/ft^2.s	*
Air mass loading rate	:	0.183 lb/ft^2.s	*
Water volumetric loading rate	:	5.20 gpm/ft^2	*
Air volumetric loading rate	:	1118 gpm/ft^2	*
Air pressure gradient	:	0.069 " H2O/ft	#
Volumetric air/water ratio	:	215.0	
Stripping factor	:	68.3	

MASS TRANSFER PARAMETERS

Percentage of packing area wetted	:	37.4 %	
Wetted packing area	:	14.9 ft^2/ft^3	*
Transfer rate constant in water	:	0.000433 ft/s	
Transfer rate constant in air	:	0.065308 ft/s	
Overall transfer rate constant	:	0.000424 ft/s	
Overall mass transfer coefficient	:	0.0063 1/s	
NTU	:	36.0526	
HTU	:	1.1095 ft	

CONTAMINANT REMOVAL

Influent concentration	:	50.0 mg/L	
Effluent concentration	:	0.0 ug/L	
Fraction removed	:	100.0 %	
Mass of contaminant removed	:	3.12000 lb/ft^2.day	*
Concentration in airstream	:	0.61163 mg/ft^2.ft^3	

* Expressed per unit of stripping tower cross-sectional area
\# Expressed per unit of tower length

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Chlorinated Methanes DATE : 4/8/1991

ENGINEER : CWB PAGE : 1/2

PHYSICAL CONSTANTS

Design temperature	:	80.0 degrees F.
Density of water	:	62.2 lb/ft^3
Density of air	:	0.0735 lb/ft^3
Viscosity of water	:	5.80E-04 lb/ft.s
Viscosity of air	:	1.21E-05 lb/ft.s
Surface tension of water	:	72 dyne/cm
Atmospheric pressure	:	1.00 atm

CONTAMINANT PROPERTIES

Name	:	Chloroform
Molecular weight	:	119.4 g/mol
Boiling point	:	144 degrees F.
Molal volume at boiling point	:	0.0923 L/mol
Henry's Constant	:	0.12000
Enthalpy upon dissolution in water	:	3436 cal/mol
Molecular diffusivity in air	:	1.03E-04 ft^2/s
Molecular diffusivity in water	:	1.17E-08 ft^2/s

PACKING PROPERTIES

Name	:	Flexirings
Packing Material	:	Plastic
Nominal Size	:	1.50 inch
Specific Area	:	39.9 ft^2/ft^3
Critical surface tension	:	33 dyne/cm
Packing depth	:	40.0 ft
Air friction factor	:	31

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Chlorinated Methanes DATE : 4/8/1991

ENGINEER : CWB PAGE : 2/2

LOADING RATES

Water mass loading rate	:	0.7 lb/ft^2.s	*
Air mass loading rate	:	0.183 lb/ft^2.s	*
Water volumetric loading rate	:	5.20 gpm/ft^2	*
Air volumetric loading rate	:	1118 gpm/ft^2	*
Air pressure gradient	:	0.069 " H2O/ft	#
Volumetric air/water ratio	:	215.0	
Stripping factor	:	34.9	

MASS TRANSFER PARAMETERS

Percentage of packing area wetted	:	37.4 %	
Wetted packing area	:	14.9 ft^2/ft^3	*
Transfer rate constant in water	:	0.000438 ft/s	
Transfer rate constant in air	:	0.064397 ft/s	
Overall transfer rate constant	:	0.000420 ft/s	
Overall mass transfer coefficient	:	0.0063 1/s	
NTU	:	21.3933	
HTU	:	1.8697 ft	

CONTAMINANT REMOVAL

Influent concentration	:	200.0 ug/L	
Effluent concentration	:	0.0 ug/L	
Fraction removed	:	100.0 %	
Mass of contaminant removed	:	0.01248 lb/ft^2.day	*
Concentration in airstream	:	0.00245 mg/ft^2.ft^3	

* Expressed per unit of stripping tower cross-sectional area
\# Expressed per unit of tower length

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Chlorinated Ethanes DATE : 4/8/1991

ENGINEER : CWB PAGE : 1/2

PHYSICAL CONSTANTS

Design temperature	:	80.0 degrees F.
Density of water	:	62.2 lb/ft^3
Density of air	:	0.0735 lb/ft^3
Viscosity of water	:	5.80E-04 lb/ft.s
Viscosity of air	:	1.21E-05 lb/ft.s
Surface tension of water	:	72 dyne/cm
Atmospheric pressure	:	1.00 atm

CONTAMINANT PROPERTIES

Name	:	Chloroethane
Molecular weight	:	64.5 g/mol
Boiling point	:	54 degrees F.
Molal volume at boiling point	:	0.0727 L/mol
Henry's Constant	:	0.68000
Enthalpy upon dissolution in water	:	3800 cal/mol
Molecular diffusivity in air	:	1.25E-04 ft^2/s
Molecular diffusivity in water	:	1.35E-08 ft^2/s

PACKING PROPERTIES

Name	:	Flexirings
Packing Material	:	Plastic
Nominal Size	:	1.50 inch
Specific Area	:	39.9 ft^2/ft^3
Critical surface tension	:	33 dyne/cm
Packing depth	:	40.0 ft
Air friction factor	:	31

****** A N A L Y S I S O F S T R I P P I N G T O W E R ******

PROJECT : Chlorinated Ethanes DATE : 4/8/1991

ENGINEER : CWB PAGE : 2/2

LOADING RATES

Water mass loading rate	:	0.7 lb/ft^2.s	*
Air mass loading rate	:	0.183 lb/ft^2.s	*
Water volumetric loading rate	:	5.20 gpm/ft^2	*
Air volumetric loading rate	:	1118 gpm/ft^2	*
Air pressure gradient	:	0.069 " H2O/ft	#
Volumetric air/water ratio	:	215.0	
Stripping factor	:	198.1	

MASS TRANSFER PARAMETERS

Percentage of packing area wetted	:	37.4 %	
Wetted packing area	:	14.9 ft^2/ft^3	*
Transfer rate constant in water	:	0.000470 ft/s	
Transfer rate constant in air	:	0.073344 ft/s	
Overall transfer rate constant	:	0.000467 ft/s	
Overall mass transfer coefficient	:	0.0070 1/s	
NTU	:	24.6670	
HTU	:	1.6216 ft	

CONTAMINANT REMOVAL

Influent concentration	:	3.2 mg/L	
Effluent concentration	:	0.0 ug/L	
Fraction removed	:	100.0 %	
Mass of contaminant removed	:	0.19968 lb/ft^2.day	*
Concentration in airstream	:	0.03914 mg/ft^2.ft^3	

* Expressed per unit of stripping tower cross-sectional area
\# Expressed per unit of tower length

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Chlorinated Ethenes DATE : 4/8/1991

ENGINEER : CWB PAGE : 1/2

PHYSICAL CONSTANTS

Design temperature	:	80.0 degrees F.
Density of water	:	62.2 lb/ft^3
Density of air	:	0.0735 lb/ft^3
Viscosity of water	:	5.80E-04 lb/ft.s
Viscosity of air	:	1.21E-05 lb/ft.s
Surface tension of water	:	72 dyne/cm
Atmospheric pressure	:	1.00 atm

CONTAMINANT PROPERTIES

Name	:	Tetrachloroethylene
Molecular weight	:	165.8 g/mol
Boiling point	:	250 degrees F.
Molal volume at boiling point	:	0.1280 L/mol
Henry's Constant	:	0.59000
Enthalpy upon dissolution in water	:	3581 cal/mol
Molecular diffusivity in air	:	8.52E-05 ft^2/s
Molecular diffusivity in water	:	9.60E-09 ft^2/s

PACKING PROPERTIES

Name	:	Flexirings
Packing Material	:	Plastic
Nominal Size	:	1.50 inch
Specific Area	:	39.9 ft^2/ft^3
Critical surface tension	:	33 dyne/cm
Packing depth	:	40.0 ft
Air friction factor	:	31

******* A N A L Y S I S O F S T R I P P I N G T O W E R *******

PROJECT : Chlorinated Ethenes DATE : 4/8/1991

ENGINEER : CWB PAGE : 2/2

LOADING RATES

Water mass loading rate	:	0.7 lb/ft^2.s	*
Air mass loading rate	:	0.183 lb/ft^2.s	*
Water volumetric loading rate	:	5.20 gpm/ft^2	*
Air volumetric loading rate	:	1118 gpm/ft^2	*
Air pressure gradient	:	0.069 " H2O/ft	#
Volumetric air/water ratio	:	215.0	
Stripping factor	:	173.8	

MASS TRANSFER PARAMETERS

Percentage of packing area wetted	:	37.4 %	
Wetted packing area	:	14.9 ft^2/ft^3	*
Transfer rate constant in water	:	0.000397 ft/s	
Transfer rate constant in air	:	0.056749 ft/s	
Overall transfer rate constant	:	0.000394 ft/s	
Overall mass transfer coefficient	:	0.0059 1/s	
NTU	:	20.3090	
HTU	:	1.9696 ft	

CONTAMINANT REMOVAL

Influent concentration	:	125.0 ug/L	
Effluent concentration	:	0.0 ug/L	
Fraction removed	:	100.0 %	
Mass of contaminant removed	:	0.00780 lb/ft^2.day	*
Concentration in airstream	:	0.00153 mg/ft^2.ft^3	

* Expressed per unit of stripping tower cross-sectional area
\# Expressed per unit of tower length

Appendix D

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APPENDIX D

SECTIONS 2.0 and 3.0
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APPENDIX Y

GROUNDWATER MODEL

U.S.G.S Modflow model (Modflow) was used to simulate the groundwater flow system in the upper aquifer at the American Chemical Service NPL Site. Modflow is a three-dimensional finite-difference groundwater flow model developed by the U.S. Geological Survey. The model simulates groundwater flow within aquifers using a block-centered finite-difference approach. Multiple layers can be simulated as confined, unconfined, or a combination of both. The model can simulate external stresses including: flow to wells, areal recharge, evapotranspiration, flow to drains, flow through riverbeds, and general-head boundary conditions.

The version used for this report was compiled by S.S. Papadopulos & Associates for use with the MT3D method of characteristics solute transport simulation. Abstracts from the Modflow and MT3D model documentation are attached. The following items are also attached following this summary of the modeling procedure:

- Table summarizing input variables for the modeling.
- Figure showing Finite Difference Grid and Node Assignments
- Contour plots of the simulated water table under current conditions, and future conditions, assuming landfill closure, and closure of the ACS Firepond.
- Block diagrams of the current and future water table simulations
- Solute transport simulation results for 10 years, 20 years and 30 years to predict effects of Griffith municipal landfill in upper aquifer.
- Modflow input files for Current Conditions Simulation
- Modflow input files for Future Conditions Simulation
- MT3D input files for simulating 30 years of solute transport from the Griffith Municipal Landfill.

MODEL PARAMETERS

Modeling in this implementation was limited to the upper aquifer which is effectively isolated from lower aquifer by the clay confining layer found beneath the upper aquifer across the whole site. A single consistent set of time and space units are required for the model. The units selected for this implementation were "feet" for length units and "days" for the time unit. The following parameters resulted. Grid spacing, aquifer

thickness, and watertable elevation were reported in feet. Hydraulic conductivity units were in feet per day; transmissivity units were in feet-squared per day. Volumes of discharge and recharge were reported in cubic feet per day. The Strongly Implicit Procedure (SIP) module used to solve model.

A 30 column, 24 row finite difference grid, with 100-foot grid spacing was used for the simulation. Input variables are used in the model to define the: 1) aquifer geometry, 2) boundary conditions, 3) hydraulic characteristics of the aquifer, and 4) recharge/discharge interactions with the atmosphere and surface water bodies. The use of each of these groups of input parameters is discussed below. The attached figure, "Finite Difference Grid, Model Node Assignments," displays the orientation of the model over the modeled area, and indicates the boundary conditions used.

Aquifer Geometry

Aquifer thickness is variable because the a water table aquifer is being modeled. The base of the aquifer is assumed to be 620 feet msl. The water table elevation is variable across the Site, at 630 to 634 feet msl in the ACS facility, to less than 625 feet in vicinity of the municipal landfill where de-watering occurs continuously.

Boundary Conditions

The General Head Boundary (GHB) module was used to simulate the boundary conditions surrounding the site. GHB entries were made for each of the exterior nodes of the model. The "head" specified for each was the average groundwater elevation observed along that boundary during the RI. The conductivity value was selected to represent the transmissivity of the aquifer.

Hydraulic Properties

Aquifer characteristics are required for each layer of the model. These include: specific yield (storativity), hydraulic conductivity, and transmissivity, vertical hydraulic conductivity between model layers.

Specific Yield for the upper aquifer was assigned to be SF1 = 0.25. Since the aquifer being simulated is unconfined, it was not necessary to assign a storativity value.

Hydraulic Conductivity. Based on baildown tests conducted at the Phase I and II monitoring wells, it was determined that the hydraulic conductivity ranges from 2.4 to 24 feet/day (8.5×10^{-4} to 8.5×10^{-3} cm/sec) from west to east across the site. The model calculated the transmissivity for each node, by multiplying the value by the saturated thickness, calculated as the difference between the water table elevation and elevation of the bottom of the layer. The bottom elevation (BOT-1) was assigned as 620 feet in the BCF input file.

Recharge/Discharge

Recharge is both lateral and vertical. Lateral recharge occurs to the upper aquifer from north and east of the Site. For the simulation, lateral recharge is controlled by the General Head Boundary assignments in column 30 and row 24.

Areal recharge was applied on the basis of 6 inches per year infiltration (0.00137 feet/day), in the RCH module. Areal recharge was not applied to discharge areas, including areas of wetland observed at the site. The primary recharge occurred across the ACS facility, where there is little relief and no vegetation to promote runoff and evapotranspiration. Storm sewers drain approximately one-third of the ACS compound directly into the fire pond. The area drained is approximately 50 times greater than the fire pond surface area, so the recharge to the pond was calculated to be 50 times the annual infiltration rate.

Primary discharge from the upper aquifer occurs toward the landfill de-watering area in the southwest, and toward the drainage ditch which runs to the northwest and west of the site. These were simulated by establishing "river nodes" with assigned head values in the RIV module. Locations are shown on the attached Figure.

MODEL IMPLEMENTATION

Existing Conditions Simulation

The model was implemented with the hydraulic data developed in the Remedial Investigation of the site. Initially the model was implemented to replicate the existing conditions at the site, with surface water discharge to the ACS Firepond and groundwater discharge to the excavation area in the Griffith Municipal Landfill. The

input files are included in this appendix. The DOS extension for the files is "*.AC1". Upon obtaining a reasonable replication of the observed water table configuration, the model was used to predict the future water table configuration, assuming that the Griffith Landfill is closed, so upper aquifer de-watering is discontinued, and the ACS fire pond is no longer used to receive surface water run-off.

The aquifer permeability values used were derived by conducting baildown tests at most of the site monitoring wells. The results suggested that the hydraulic conductivity is an order of magnitude higher on the east side of the site than along the western boundary of the ACS facility. Grain-size analysis of aquifer samples indicated that the aquifer matrix was coarser grained at the wells along the eastern boundary. Groundwater flow modeling was used to history match water table configurations. It was found that the observed head distribution in the upper aquifer was most reasonably achieved in the simulation where hydraulic conductivity values were 10x lower on the western side of the site.

The model was calibrated to known water table elevations, measured at approximately 50 points across the site, including surface water locations, measured at four different times throughout approximately one year. Sensitivity analysis was conducted with 1) aerial recharge by infiltrating precipitation and 2) hydraulic conductivity.

Average annual precipitation in northwestern Indiana is 44 inches. Simulations were run with assumed infiltration of 4 to 20 inches (10 to 50 percent). Infiltration amounts from 4 to 12 inches gave results which were consistent with field observations. Even 20 inches provided reasonable results. In otherwords, the model was relatively insensitive to variations in total infiltration amounts.

The use of lower hydraulic conductivity values caused significant deviations from the observed water table heads. However, doubling and quadrupling the hydraulic conductivity had relatively little effect on the water table distribution. Six inches of annual infiltration, representing approximately 15 percent of the annual precipitation was selected as representative of the site conditions.

The major control on groundwater flow regime (and associated head values) appears to be the steep gradient and interaction between recharge at ACS and de-watering in the landfill area.

Future Conditions Simulation

Three changes were made to the current condition (*.AC1) input files to create the future condition (*.AC3):

- the "drains" which represent the de-watering at the landfill were removed;
- the high level of recharge to the fire pond was eliminated; and
- Infiltration was reduced by a factor of 10 in the Off-Site Containment area, because it is assumed that the area will be remediated and capped.

The groundwater flow simulation was run for 30 years, for use in the solute transport simulation.

SOLUTE TRANSPORT SIMULATION

Benzene was selected as the source of contamination to model. The concentration of benzene observed in the landfill ranged from 2 to 6 ug/L. A value was 5 ug/L was assigned for the entire landfill area.

The future condition water table results (*.AC3 input files) were used for the advection for the transport simulation.

Longitudinal dispersion coefficient was assigned a value of D_l = 2 feet. Transverse and vertical dispersion coefficients of $D_t = D_v = 0.4$ were used. Retardation coefficients were calculated for the upper and lower aquifer in the RI Report, Section 6 (Table 6-2 and 6-4). The value derived was $R_f = 2.47$, based on aquifer porosity of 0.25, bulk density of 1.8, and a distribution coefficient of 0.204.

SIMULATION RESULTS

The groundwater modeling shows that closure of the landfill and ACS fire pond will result in significantly reduced hydraulic gradients, but in no major change in

groundwater flow paths. The groundwater will still flow generally from the northeast, beneath the site and discharge at the ditch cut through the wetlands west of the Site.

In the current condition groundwater flow regime, all the groundwater flowing beneath the landfill, discharges to the de-watering excavations. In the future scenario, when the de-watering is discontinued, the drainage ditch will resume its function and groundwater will continue to discharge to the east.

The solute transport model shows that the the benzene level (and other landfill constituents) will migrate slowly towards the west. The upper aquifer surrounding the landfill will not be affected by leaking leachate.

GROUNDWATER MODEL DOCUMENTATION ABSTRACTS

Techniques of Water-Resources Investigations
of the United States Geological Survey

Chapter A1

A MODULAR THREE-DIMENSIONAL FINITE-DIFFERENCE GROUND-WATER FLOW MODEL

By Michael G. McDonald and
Arlen W. Harbaugh

This chapter supersedes U.S. Geological
Survey Open-File Report 83-875

Book 6

MODELING TECHNIQUES

A MODULAR THREE-DIMENSIONAL FINITE-DIFFERENCE GROUND-WATER FLOW MODEL

By Michael G. McDonald and Arlen W. Harbaugh

ABSTRACT

This report presents a finite-difference model and its associated modular computer program. The model simulates flow in three dimensions. The report includes detailed explanations of physical and mathematical concepts on which the model is based and an explanation of how those concepts are incorporated in the modular structure of the computer program. The modular structure consists of a Main Program and a series of highly independent subroutines called "modules." The modules are grouped into "packages." Each package deals with a specific feature of the hydrologic system which is to be simulated, such as flow from rivers or flow into drains, or with a specific method of solving linear equations which describe the flow system, such as the Strongly Implicit Procedure or Slice-Successive Overrelaxation.

The division of the program into modules permits the user to examine specific hydrologic features of the model independently. This also facilitates development of additional capabilities because new packages can be added to the program without modifying the existing packages. The input and output systems of the computer program are also designed to permit maximum flexibility.

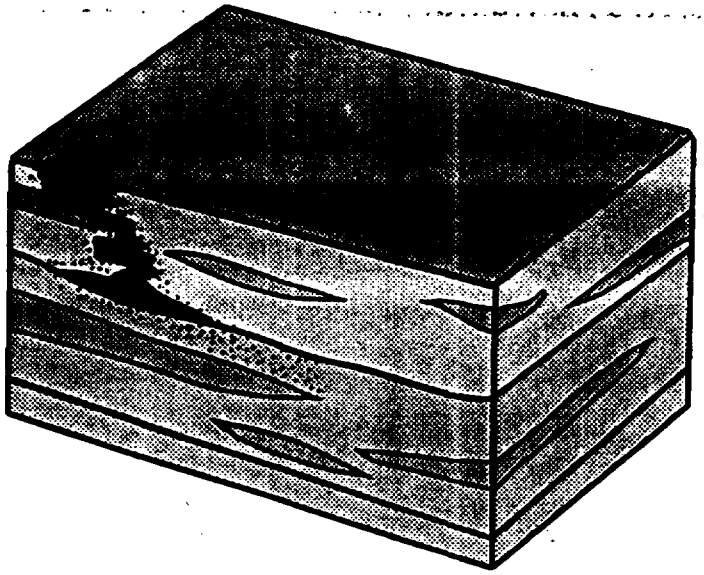
Ground-water flow within the aquifer is simulated using a block-centered finite-difference approach. Layers can be simulated as confined, unconfined, or a combination of confined and unconfined. Flow associated with external stresses, such as wells, areal recharge, evapotranspiration, drains, and streams, can also be simulated. The finite-difference equations can be solved using either the Strongly Implicit Procedure or Slice-Successive Overrelaxation.

The program is written in FORTRAN 77 and will run without modification on most computers that have a FORTRAN 77 compiler. For each program module, this report includes a narrative description, a flow chart, a list of variables, and a module listing.

M T 3 D

a modular three-dimensional transport model

User's Manual



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S.S. Papadopulos & Associates, Inc.

PREFACE

This document describes the theory and application of MT3D: a modular three-dimensional transport model for simulation of advection, dispersion and chemical reactions in groundwater systems. It includes four computer disks containing the MT3D source code, example data sets, post-processing programs, and a flow model to be used in conjunction with MT3D. A supplemental document which contains a complete listing of the MT3D source code is available if there is a need to verify the source code included in the computer disk.

The documentation for the MT3D program has been funded in part by the United States Environmental Protection Agency. However, the funding does not constitute endorsement or recommendation by the United States Environmental Protection Agency for the use of MT3D or any commercial products mentioned in the document.

To report any error in the MT3D program or to inquire about future upgrades, please call or write to

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Abstract

mt3d: a modular three-dimensional transport model

This documentation describes the theory and application of a modular three-dimensional transport model for simulation of advection, dispersion and chemical reactions of dissolved constituents in groundwater systems. The model program, referred to as MT3D, uses a modular structure similar to that implemented in MODFLOW, the U. S. Geological Survey modular three-dimensional finite-difference groundwater flow model (McDonald and Harbaugh, 1988). This modular structure makes it possible to simulate advection, dispersion, sink/source mixing, and chemical reactions independently without reserving computer memory space for unused options. New transport processes and options can be added to the model readily without having to modify the existing code.

The MT3D transport model uses a mixed Eulerian-Lagrangian approach to the solution of the three-dimensional advective-dispersive-reactive equation, in three basic options: the method of characteristics (referred to as MOC), the modified method of characteristics (referred to as MMOC), and a hybrid of these two methods (referred to as HMOC). This approach combines the strength of the method of characteristics for eliminating numerical dispersion and the computational efficiency of the modified method of characteristics. The availability of both MOC and MMOC options, and their selective use based on an automatic adaptive procedure under the HMOC option, make MT3D uniquely suitable for a wide range of field problems.

The MT3D transport model is intended to be used in conjunction with any block-centered finite-difference flow model such as MODFLOW and is based on the assumption that changes in the concentration field will not affect the flow field measurably. This allows the user to construct and calibrate a flow model independently. MT3D retrieves the hydraulic heads and the various flow and sink/source terms saved by the flow model, automatically incorporating the specified hydrologic boundary conditions. Currently, MT3D accommodates the following spatial discretization capabilities and transport boundary conditions: (1) confined, unconfined or variably confined/unconfined aquifer layers; (2) inclined model layers and variable cell thickness within the same layer; (3) specified concentration or mass flux boundaries; and (4) the solute transport effects of external sources and sinks such as wells, drains, rivers, areal recharge and evapotranspiration.

TABLE AND FIGURES

Table 1.
Summary of Input Variables
Upper Aquifer Groundwater Model
ACS NPL Site

The following are the input parameters for the Modflow Implementation of the upper aquifer at the ACS NPL Site. The general conductions used for all simulations are listed first. These are followed by a listing of the model parameters changed to simulate future conditions, and then input variables for the solute transport simulation.

Single layer, 30 column, 24 row finite difference grid. Uniform grid spacing = 100 foot.

Time Units = days, Length Units = feet

Boundary Conditions

- General Head Boundary conditions provide regional water table elevations of 635 feet msl in northeast, to 633 feet msl along south and west boundary, 635 to 634 feet msl along eastern boundary, and 635 to 633 feet msl along northern boundary.

- Groundwater elevation is essentially controlled by discharge to the creek on the northwest (column 28) and west sides (row 2).

Aquifer Properties

Specific yield/storage coefficient set as 0.25
Hydraulic conductivity range
2.4 to 24 ft/day (8.5×10^{-4} to 8.5×10^{-3} cm/sec)

Aquifer thickness calculated within model

- Top elevation from head-value for node
- Bottom elevation set at 620 ft msl

Discharge Areas

- De-watering at Landfill Excavation
- The DRN module was used to simulate de-watering to 625 feet msl in the landfill de-watering area.
- Three river stretches set by RIV module
- Creek along row 3 between column 2 and 9, set to 630 ft msl
- Creek along row 2 between column 26 and 28, set to 630 ft msl
- Ditch along north boundary simulated setting column 28, rows 3 - 15 at levels from 630 to 631
- Ditch just west of Off-Site Containment Area set at 632 ft msl,based on staff gage SG-1 history.

Table 1. (continued)
Summary of Input Variables
Upper Aquifer Groundwater Model
ACS NPL Site

Recharge Areas

- GBH boundaries provide lateral recharge from northeast area.
- RCH module used to apply areal precipitation recharge
- Average annual precipitation for area = 44 inches/year
- Model calibrated assuming 15% infiltration (6 in/yr) ACS facility has no vegetation.
- Storm sewers from southeast drain into fire pond
- Drained area is about 50x the fire pond area.
  - Coefficient of 50 used for fire pond
  - Coefficient of 2 used for much of unvegetated area
  - Factor of 2 used in Off site area at internal drainage area north of Off-Site containment area.

Time step was 5 years to represent essentially steady-state conditions.

Strongly Implicit Procedure (SIP) module used to solve model.

FUTURE CONDITION SIMULATION

Three changes were made to the current condition (*.AC1) input files to create the future condition (*.AC3):

- the "drains" which represent the de-watering at the landfill were removed;
- the high level of recharge to the fire pond was eliminated; and
- Infiltration was reduced by a factor of 10 in the Off-Site Containment area, because it is assumed that the area will be remediated and capped.

The groundwater flow simulation was run for 30 years, for use in the solute transport simulation.

SOLUTE TRANSPORT SIMULATION

Source: 5 ug/L benzene for entire landfill area.

Advection was driven by future condition water table configuration, for 30 year simulation.

Dispersion: D_l = 2.0 feet
D_t = 0.4 feet
D_v = 0.4 feet

Retardation. Benzene retardation factor = 2.47

Finite Difference Grid, Model Node Assignments

Columns ---->

Rows

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		0
3	0															2	2											1		0
4	0								4	4	4	2	4	4	2	2	2											1		0
5	0								4	4	4	2	4	4	2	2	2											1		0
6	0							4	4	4	4	4	4	4	4													1		0
7	0						4	4	4	4	4	4	4	4	4													1		0
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14	0		4	4	4	4	4	4											5	3	3	5	5	5	5			1		0
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19	0																	5	5	5	5	5	5	5	5					0
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23	0																													0
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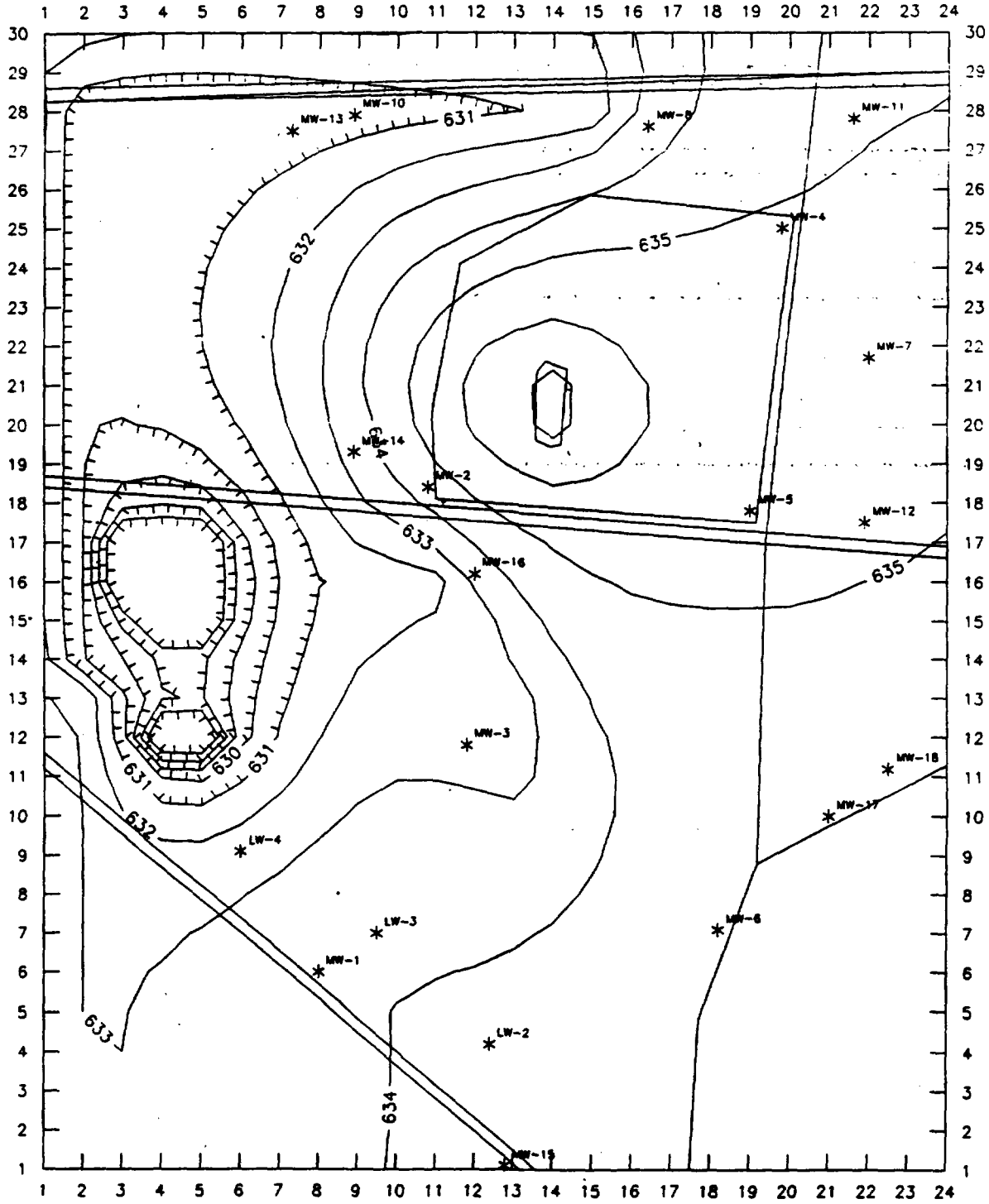
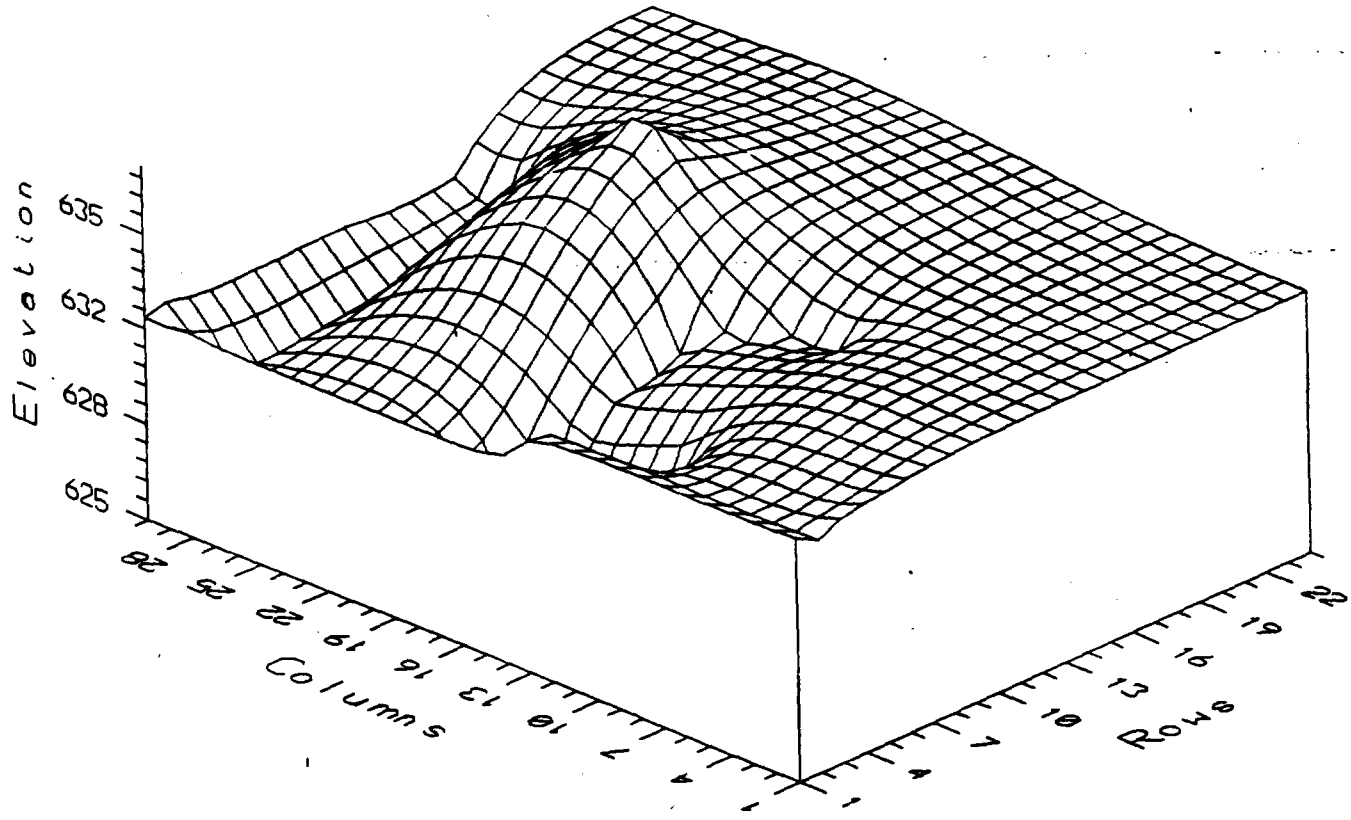
Legend:

- 0 General Head Boundary Nodes
- 1 Creek Nodes
- 2 Landfill De-Watering Areas
- 3 ACS Fire Pond Nodes
- 4 Griffith Landfill Nodes
- 5 American Chemical Service Facility

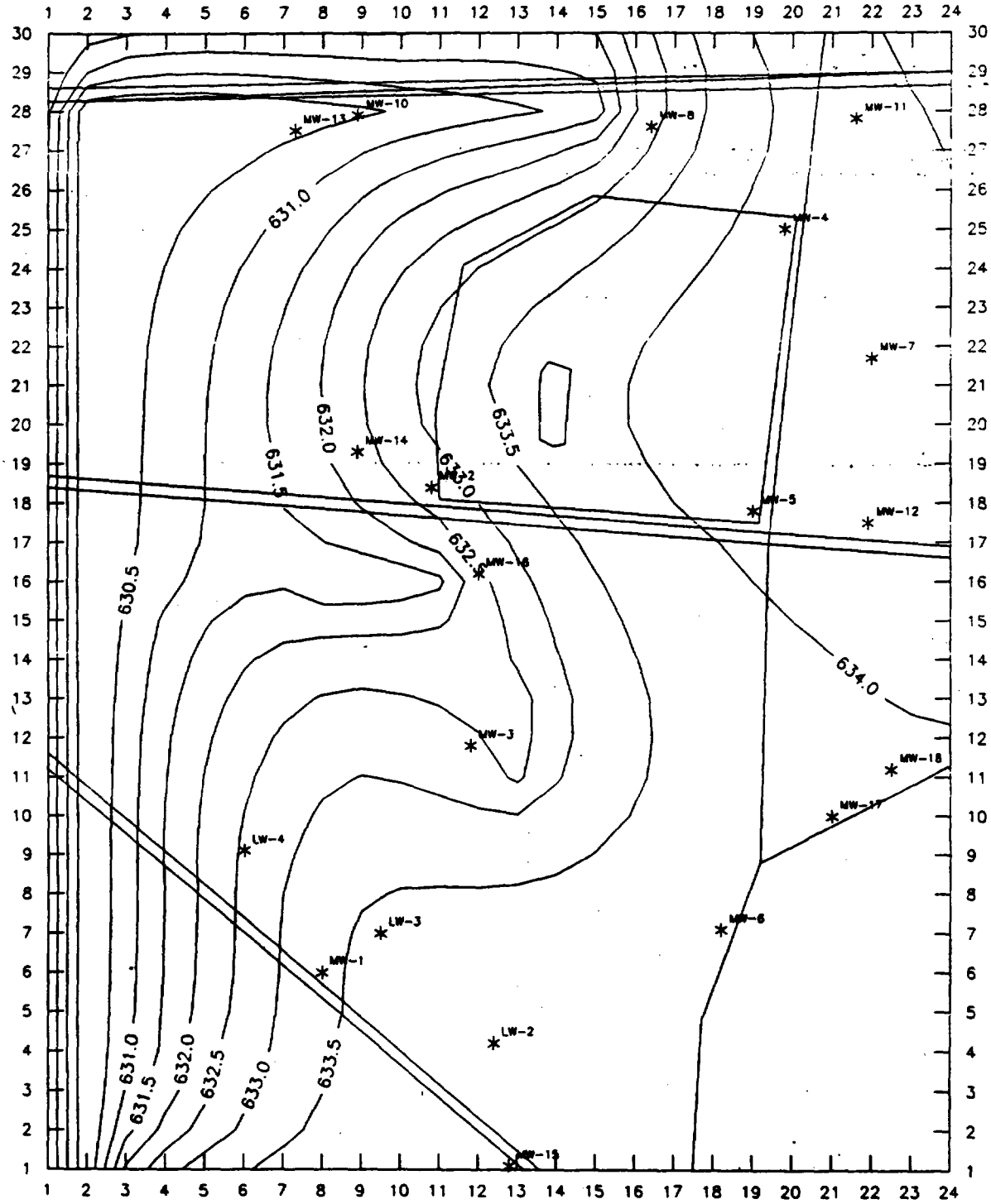
Modeled Water Table -- Current Conditions

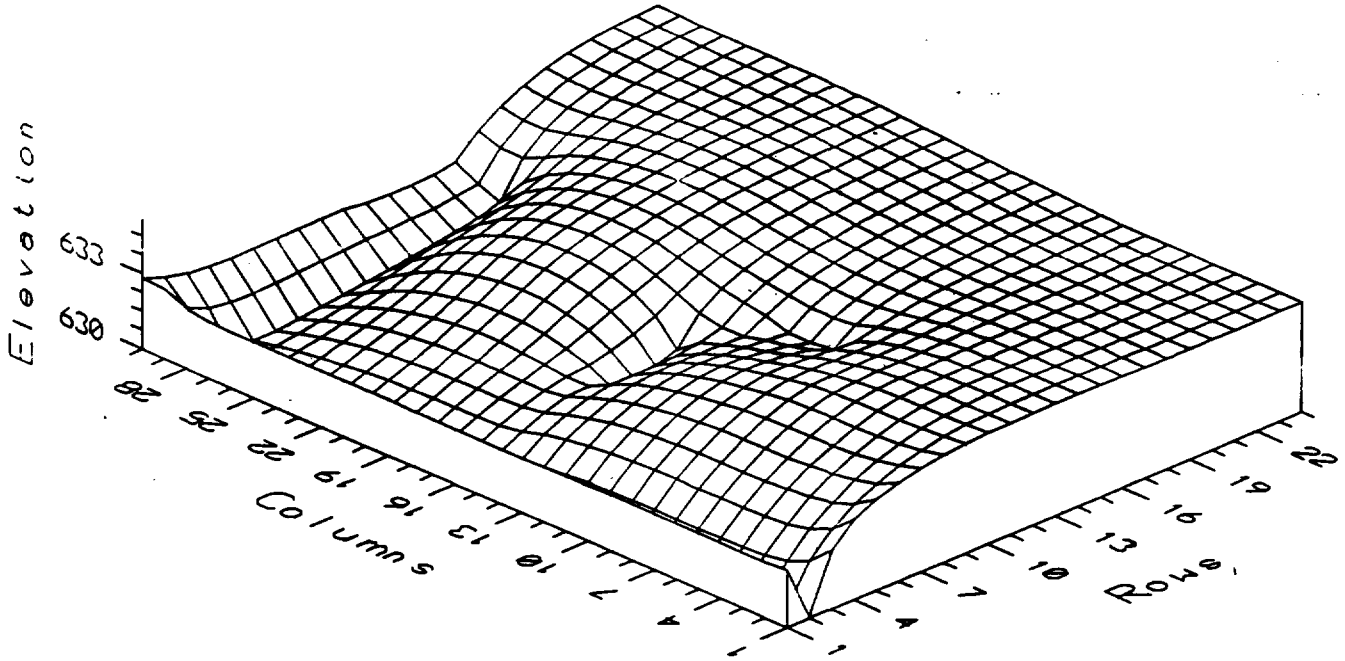




Modeled Existing Water Table

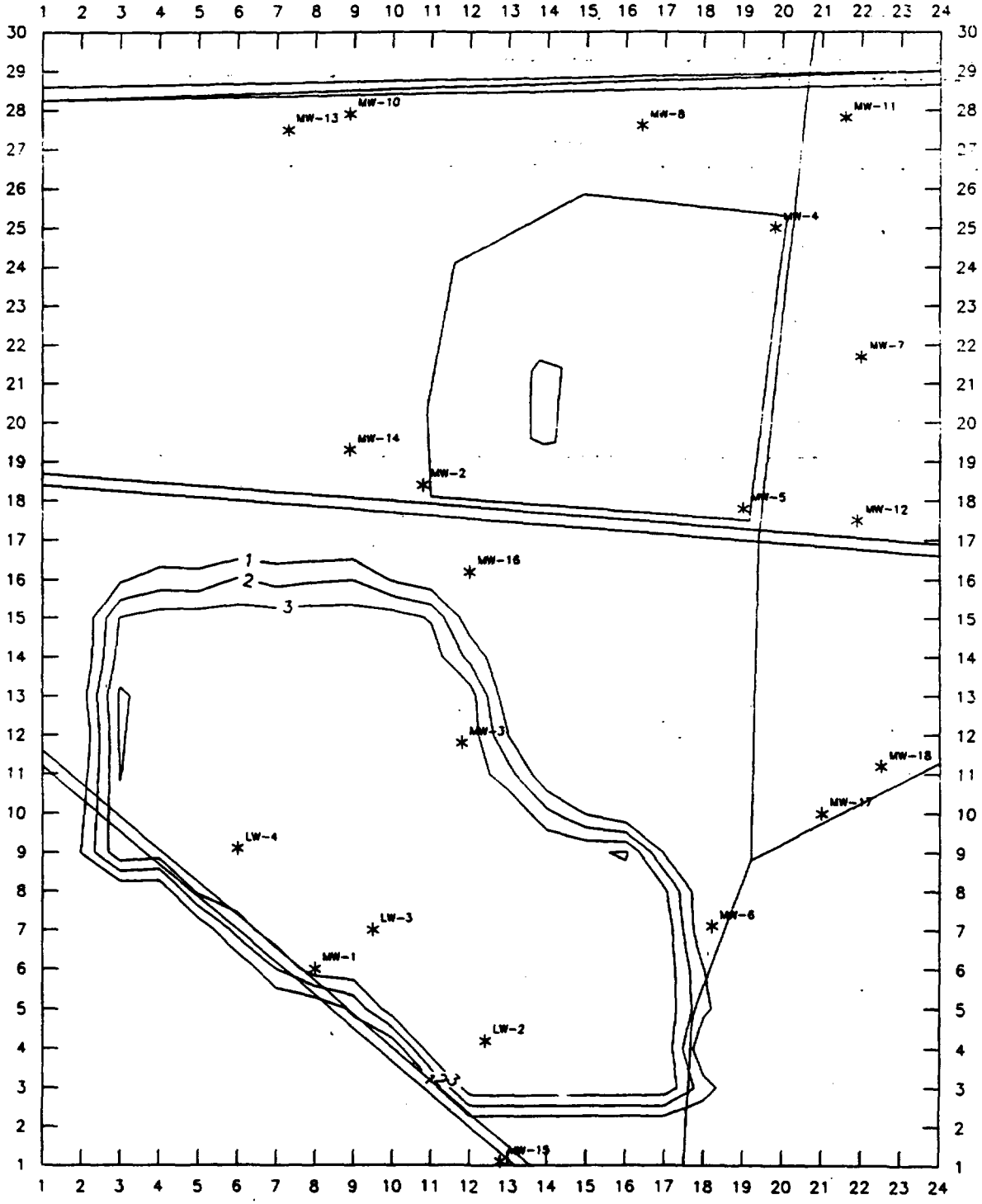
Future Conditions -- Landfill Closed. No Fire Pond



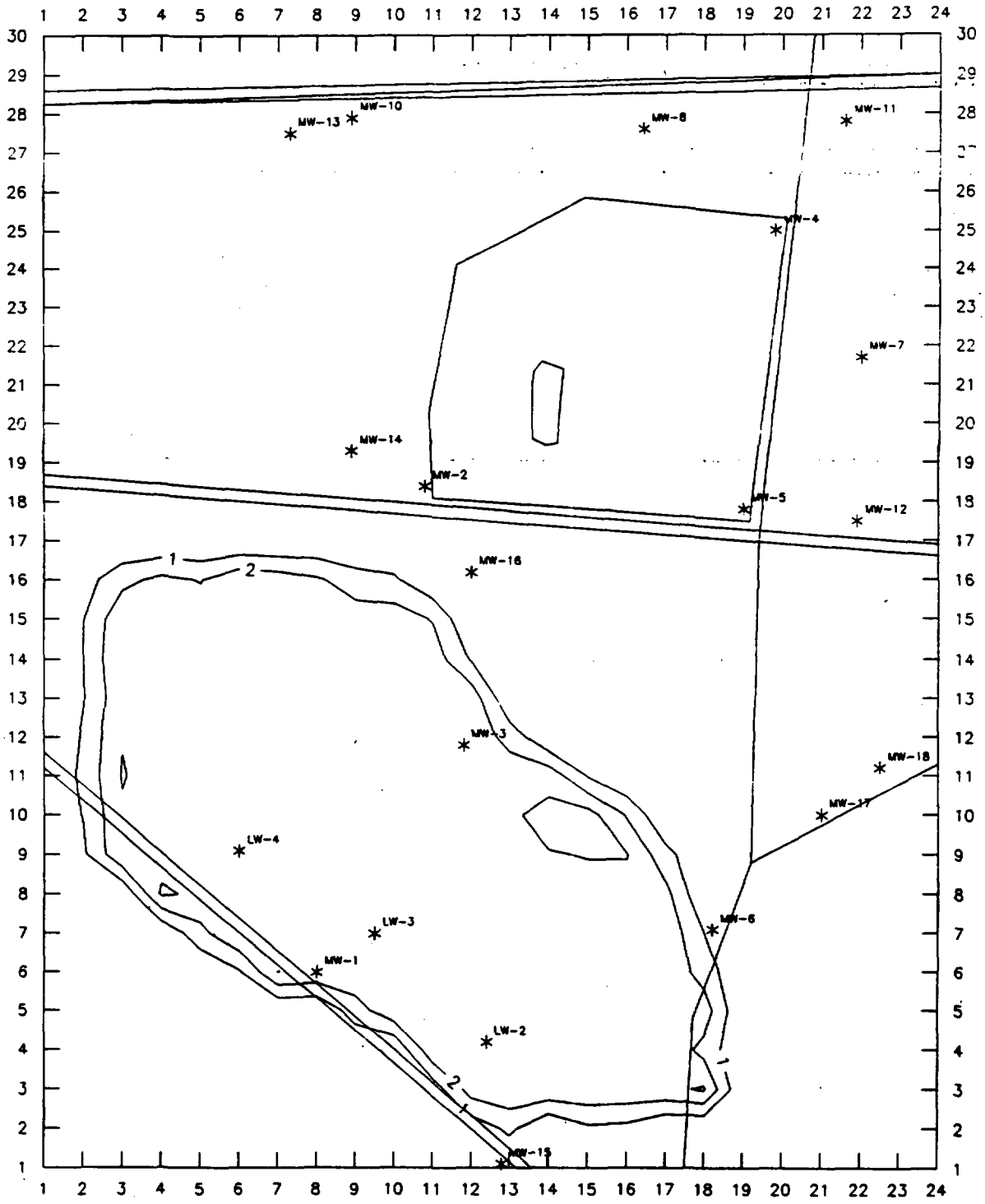


Modeled Future Water Table - Landfill Closed

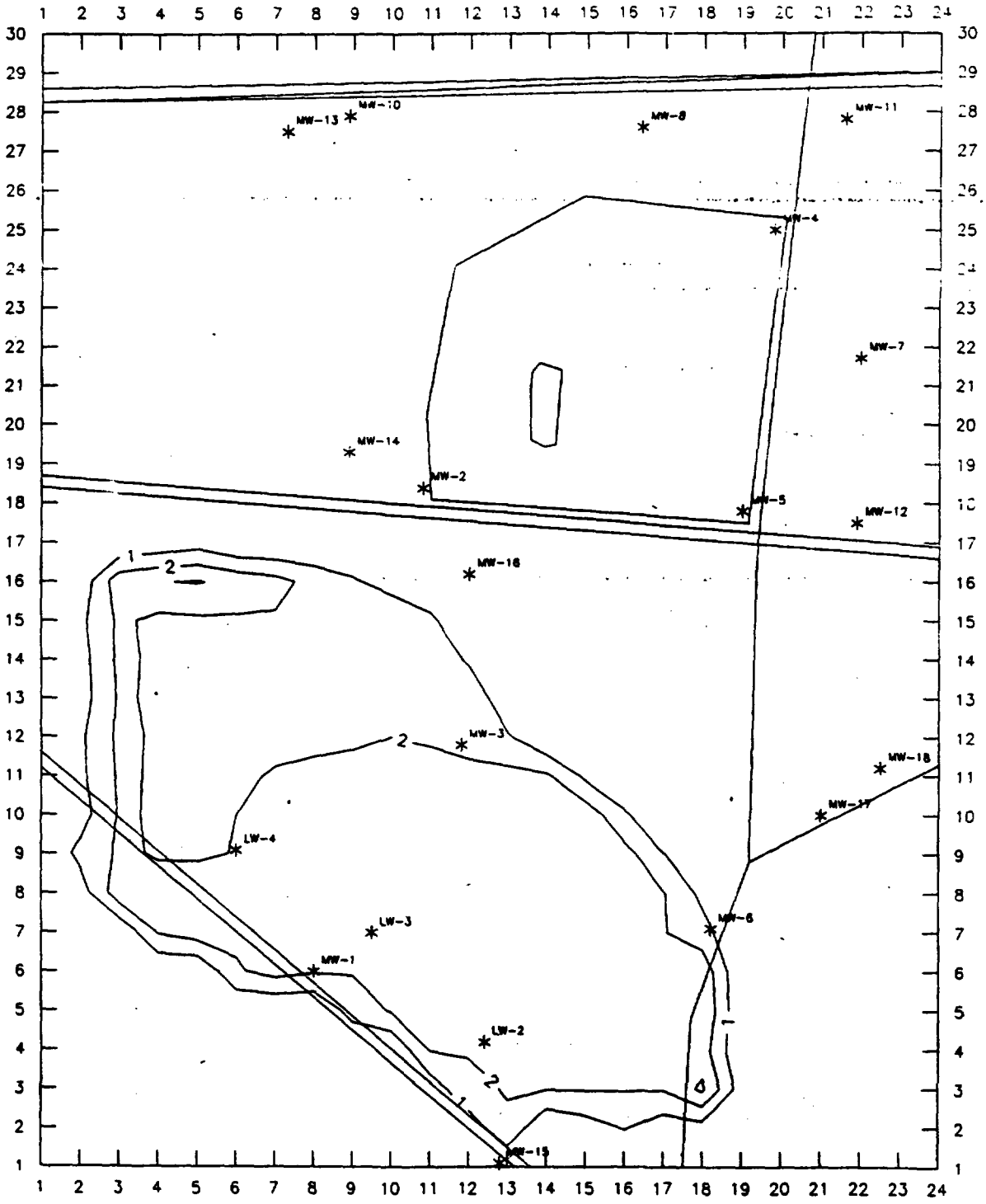
Modeled Benzene Concentration after 10 years



Modeled Benzene Concentration after 20 years



Modeled Benzene Concentration after 30 years



INPUT FILES
EXISTING CONDITION GROUNDWATER FLOW SYSTEM

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landfill drains at @[illegible] ft -- 5 year simulation
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         3         3                                         IAPART,ISTRT
         1         1  (3012)                      3          IBOUND-1
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 8  7  6  5  4
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0 620. BOT-1

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1	2	17	625.0	5000.		
1	4	12	625.0	5000.		
1	4	15	625.0	5000.		
1	4	16	625.0	5000.		
1	4	17	625.0	5000.		
1	5	12	625.0	5000.		
1	5	15	625.0	5000.		
1	5	16	625.0	5000.		
1	5	17	625.0	5000.		
-1					T-2	
-1					T-3	
-1					T-4	
-1					T-5	
-1					T-6	
-1					T-7	
-1					T-8	
-1					T-9	
-1					T-10	
-1					T-11	

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
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1	2	8	633.0	1500.	627.0	
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1	13	13	632.0	500.	628.0	
1	13	12	632.0	500.	628.0	
1	13	11	632.0	500.	628.0	
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-1						T-3
-1						T-4
-1						T-5

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INPUT FILES
FUTURE CONDITION GROUNDWATER FLOW SYSTEM

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30 year simulation, No leachate collection system, no [illegible] source

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1826.25 1 1. T-2

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7 7 6 5 4

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8 7 6 5 4

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8 7 6 5 4

0 620. BOT-1

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INPUT FILES
SOLUTE TRANSPORT SIMULATION FOR LANDFILL AREA

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        4                                                NPRS
  365.25   3652.50   7305.00   10957.5
        4                                                NOBS
        1        3        4                              Layer, Row, Col
        1        6        4
        1        9        4
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        T                                                CHKMAS
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Darcy's law, Q = -KiA was used to evaluate the groundwater flow (Q) in the vicinity of the Griffith Municipal Landfill. A mass balance method. $Q_1 \times Conc_1 = Q_2 \times Conc_2$, was used in conjunction with the groundwater flow and observed leachate quality, to evaluate the potential groundwater quality in the upper and lower aquifer in the vicinity of the landfill.

Four components were identified in the groundwater flow in the upper and lower aquifer in the vicinity of the landfill. They are shown on the attached block diagram.

- **Q_1** Areal recharge across the landfill area through existing landfill cover/cap.
- **Q_2** Horizontal groundwater flow in the upper aquifer beneath the landfill.
- **Q_3** Vertical groundwater flow through the clay confining layer between the upper and lower aquifers.
- **Q_4** Horizontal groundwater flow in the lower aquifer.

The variables and calculations for each of the four flow components are shown in the attached table. The assignment of values for each of the variables was based on field observations and data.

SELECTION OF VARIABLES

In accordance with Darcy's law Q = -KiA, the groundwater discharge (Q) in each flow component can be calculated from the field derived values for each of the variables, hydraulic conductivity (K), hydraulic gradient (i), and cross-sectional aquifer area (A). (The minus sign only indicates flow direction and therefore is not relevant to this analysis of flow volume.)

Flow Component Q_1

Q_1 represents the source of groundwater and leachate in the aquifer. Figure 4-21 shows that the landfill area of concern is approximately 1000 feet by 1000 feet, between the 634 contour lines in the northwest and southeast, and the 635 contour line in the northeast. The groundwater flow is toward the landfill de-watering area, shown by the closed 625-foot contour line. Landfill contaminants were not detected in monitoring wells MW-1 and MW-15, indicating that the groundwater discharge is toward the northwest. The numerical modeling of the Site with the U.S.G.S. Modflow model (Appendix Y) showed that groundwater flow in the upper aquifer would still be toward the west, toward the creek, even if the de-watering activities are ceased at the Site.

It is assumed that that no further covering or capping of the landfill is conducted. In this case, it is reasonable to assume that approximately 25 percent (1 foot) of the annual 48 inches of precipitation would infiltrate into the landfill to form groundwater and leachate. Assuming a 1000 by 1000 foot landfill area, this infiltration represents 1,000,000 cubic feet of water per year. Darcy's law can be inverted to test for reasonableness of this calculation.

The only unknown for the landfill is the K-value, so Darcy's law can be re-arranged in the form K = Q/iA. The hydraulic gradient from the center of the landfill (Figure 4-21) toward the west is 0.5 foot drop in 1000 feet (i = 0.0005). The cross-sectional area, A = 14 x 1000 = 14,000 ft^2. (The bottom of the upper aquifer is at elevation of 620 feet msl and the water table is approximately 634 feet msl). Solving for K, yields a value of 0.27 feet/min (1.3×10^{-1} cm/sec), which is not an unreasonable K-value for unconsolidated fill and trash.

Flow Component Q_2

Groundwater flow component Q_2 is equal to component Q_1. The discharge is currently to the landfill de-watering area. If de-watering is discontinued, it would be to the creek which now flows past the west side of the landfill.

Flow Component Q_3

The hydraulic conductivity of the clay confining layer is known from laboratory tests on several samples collected during the field investigation. The results are summarized on Table 4-7. The average value is K = 4.8×10^{-8} cm/sec. The vertical hydraulic gradient across the clay confining layer varies somewhat across the Site, but generally is in the range of unity (i = 1) (see Table 4-6). The seepage would occur across the landfill area of concern, 1000 by 1000 feet, so A = 1,000,000 square feet.

Flow Component Q_4

Groundwater flow in the lower aquifer can be calculated from the field measurements of hydraulic conductivity and hydraulic gradient. Slug tests at four lower aquifer monitoring wells indicated an average hydraulic conductivity of K = 4.4×10^{-2} ft/min for upper part of the lower aquifer (Section 4.5.3.3). Water levels were measured at the lower aquifer monitoring wells on three separate dates and the hydraulic conductivity was consistently i = 0.00063 (Figures 4-22, 4-23, and 4-23A). The width of the affected aquifer was assumed to be 1000 feet. It was assumed that the leakage through the clay confining layer would diffuse/disperse into the upper 20 feet of the lower aquifer. Therefore, A = 1000 x 20 feet = 20,000 feet.

The calculations of groundwater flow are summarized on the first page of the attached table.

POTENTIAL CONTAMINANT LOADING

The landfill leachate is the source of potential contamination. Several VOCs were detected in the leachate sampling results. Benzene. detected in each of the leachate wells, is the compound of potential concern. The results are tabulated in Appendices Q-1 and R-1. It is reasonable to assume that the impact to the upper and lower aquifer would result from the average leachate concentration detected in the landfill, which is 4.5 ug/L for benzene.

This concentration of benzene was used with the groundwater flow volumes to calculate the contaminant loading to the upper aquifer, surface water, and lower aquifer in the vicinity of the landfill. The results are summarized on the second page of the attached table.

Mass balance calculation of potential impacts to upper and lower aquifer from Griffith Municipal Landfill Leachate.

Q1 = Areal Recharge across landfill area (annual infiltrating precipitation)
Q2 = Upper Aquifer horizontal Discharge to de-watering area
Q3 = Leakage from upper to lower Aquifer
Q4 = Lower Aquifer Discharge to the north.

Q1 = Landfill Area x Infiltrating Precipitation

Area =	1,000,000	sq ft	(1000 x 1000 ft)
Infiltration =	1	ft/yr	
Q1 =	1,000,000	cu ft/yr	

Q2 = KiA Q2 = Q1
K = Q2/iA

Q2 =	1,000,000	cu ft/yr	
i =	0.0005	ft/ft	
A =	14,000	sq. ft	(14 x 1000 ft)
K =	143,000	ft/yr	
	2.7E-1	ft/min	

Q3 = K'iA K' = K/thickness Thickness = 10 ft

K' =	4.8E-8	cm/sec	
	5.0E-2	ft/yr	
i =	1	ft/ft	
A =	1,000,000	sq ft	(1000 x 1000 ft)
Q3 =	50,000	cu ft/yr	

Q4 = KiA

K =	4.40E-02	ft/min	
	23,000	ft/yr	
i =	0.00063	ft/ft	
A =	20,000	ft	(20 x 1000 ft)
Q4 =	290,000	cu ft/yr	

Mass Balance

Upper Aquifer

At the present time, Q1, the groundwater leachate flowing beneath the landfill, discharges to the landfill de-watering area. At the present time, Q2 is the discharge into the landfill de-watering area. As such it is disposed of by the City of Griffith and not released to the environment.

It cannot be assumed that landfill de-watering will continue indefinitely into the future. Numerical modeling of the upper aquifer shows that if de-water is discontinued, the groundwater/leachate flowing from the landfill (Q1) will discharge exclusively to the creek located to the west of the current de-watering area. will discharge to the creek which is currently to the west of the landfill de-watering area.

In the future, it can be assumed that Q2, dicharge along the creek will be equal from both sides of the creek. Therefore, Q1 will be equal to one-half of Q2. This does not consider further dilution which would occur by the water already flowing down the stream from upstream.

Mass Balance Calculation

Q1 x Conc1 = Q2 x Conc2

Conc2 = (Q1 x Conc1)/Q2

Q1 =	1,000,000	cu ft/yr
Conc1 =	4.5	ug/L
Q2 = 2*Q1 =	2,000,000	cu ft/yr
Conc2 =	2.3	ug/L

Leachate Analytical Results

Leachate Well	Benzene conc.	
LW-1	5.0	ug/l
LW-2	2.0	ug/l
LW-3	5.0	ug/l
LW-4	6.0	ug/l
Average:	4.5	ug/l

Lower Aquifer

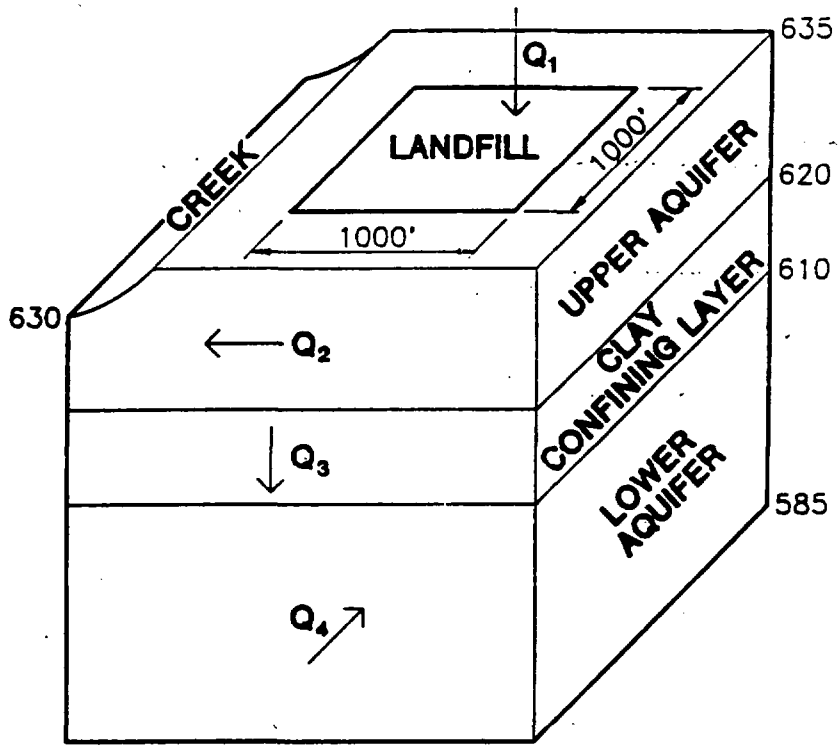
Q3 x Conc3 = Q4 x Conc4

Conc4 = (Q3 x Conc3)/Q4

Q3 =	50,000	cu ft/yr
Conc3 =	4.5	ug/L
Q4 =	290000	cu ft/yr
Conc4 =	0.78	ug/L

QUALITY CONTROL

	INITIALS	DATE
Drafting Standards	DLC	9/4/91 PM
Lead Professional	KJE	9/17/91 Division
Section		Other



LEGEND

Q_1 = INFILTRATION
Q_2 = UPPER AQUIFER DISCHARGE
Q_3 = PERCOLATION THROUGH CONFINING LAYER
Q_4 = LOWER AQUIFER DISCHARGE
635 ELEVATION (M.S.L. IN FEET)

north

NOT TO SCALE

WARZYN	INPUTS FOR GROUNDWATER MODEL	Drawn TPB	Checked
	REMEDIAL INVESTIGATION AMERICAN CHEMICAL SERVICES NPL SITE GRIFFITH, INDIANA	Revisions	

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Appendix Z

Screening Method for Estimating Inhalation Exposure to Volatile Chemicals from Domestic Water

DRAFT FEB 15 1991

SCREENING METHOD FOR ESTIMATING INHALATION EXPOSURE TO VOLATILE CHEMICALS FROM DOMESTIC WATER

1. Introduction

The following discussion has been developed to provide a screening method for estimating the indoor air concentrations of volatile chemicals from indoor water uses and the resulting human inhalation exposures, with an emphasis on showers. A computerized model titled MAVRIQ (Model for Analysis of Volatiles and Residential Indoor-Air Quality), which is under development, may also be used to refine the exposure estimates since it more accurately accounts for human behavioral and water use patterns.

This procedure evolved from research done by Julian Andelman at the Universtity of Pittsburg under funding from the Expsoure Assessment Group at US EPA in Washington, DC. The references given provide a more detailed description of these procedures and related work.

2. When is Inhalation Exposure of Concern?

In order to determine the significance of the inhalation pathway the ratio of the vapor inhalation exposure to the water ingestion exposure can be calculated. Using Henry's Law Constant to obtain the equilibrium concentration in air, and setting a ratio of < 0.1 as criteria, the equation can be derived as follow:

$$\frac{\text{max inhalation exposure}}{\text{water ingestion exposure}} < 0.1 \qquad (1)$$

$$\frac{H\,C_w \times (20{,}000\ \text{L/day})}{C_w \times (2\ \text{L/day})} < 0.1 \qquad (2)$$

$$H < 10^{-5} \qquad (3)$$

Where C_w = contaminant concentration in water (mg/L)
H = Henry's Law Constant (unitless)

The unitless Henry's Law Constant can be calculated by using the following equation.

$$H = H'/RT$$

where H' = Henry's Law Constant in atm-m^3/mol
R = gas constant in atm-m^3/mol °K
T = temperature in °K.

Assuming a typical water temperature in a shower scenario of 40°C, RT is 2.6 x 10^{-2} atm-m^3/mol.
Equation (3) suggests that for compounds with Henry's Law Constants of < 10^{-5}, the inhalation exposure would not exceed ingestion and is probably much less, therefore the inhalation pathway may not be of concern when compared to ingestion. Caution should be used when applying this criterion. If the ingestion exposure is significant, the inhalation exposure, although orders of magnitude less, may also be significant when considered separately.

3. Showering Exposure

The derivations and assumptions of the equations used to estimate exposure through the showering scenario are included in Appendix 1.

The exposure equation below accounts for the exposure during the showering time and the exposure during the period subsequent to the shower where there is a decay of the chemical concentration.

$$E_i = [C_{aAVG1}Bt_1]_{shower} + [C_{aAVG2}Bt_2]_{after\ shower} \quad (4)$$

Where: E_i = exposure [mg]
C_{aAVG1} = average air concentration during shower [mg/L]
C_{aAVG2} = average air concentration after shower [mg/L]
B = breathing rate [L/hr]
t_1 = shower period [hr]
t_2 = after shower period [hr]

C_{aAVG1} and C_{aAVG2} are estimated using equations (5) and (6) and (7) below.

$$C_{aAVG1} = C_{aMAX}/2 \quad (5)$$

$$C_{aAVG2} = C_{aMAX} \quad (6)$$

$$C_{aMAX} = \frac{C_w \times f \times F_w \times t_1}{V_a} \quad (7)$$

Where: C_{aMAX} = maximum air concentration in bathroom [mg/L]
C_w = water concentration [mg/L]
f = fraction volatilization [unitless]
F_w = water flow rate [L/hr]
V_a = bathroom size [L]

Default values for the variables in these equations are tabulated in table 1.

Using equations (4) through (7) and the average or most probable values from Table 1, one

can estimate the exposure during showering.

Example:
Assumptions

$f = .75$
$F_w = 600$ L/hr
$t_1 = 0.08$ hr
$t_2 = 0.2$ hr
$V_a = 10{,}000$ L

$$C_{aMAX} = \frac{C_w\,(0.75)(600\text{L/hr})(0.08\text{ hr})}{(10{,}000\text{ L})}$$

$$= 3.6 \times 10^{-3}\, C_w$$

$$C_{aAVG} = 1.8 \times 10^{-3}\, C_w$$

$$E_i = 1.8 \times 10^{-3}\, C_w(833\text{L/hr})(0.08\text{hr}) + 3.6 \times 10^{-3}\, C_w(833\text{L/hr})(0.2\text{hr})$$

$$= 0.72(\text{L})\, C_w$$

TABLE 1

Variable	Value or Range	Reference
Fraction Volatilization (f)	0.5 - 0.9 (typical=0.75)	1
Water Flow Rate (F_w) [L/hr]	600 - 1,800 (mean=600)	2
Shower Period (t_1) [hr]	0.08 - 0.3 (mean=0.08)	2
After Shower Period (t_2)	0.2 (typical)	1
Bathroom size (V_a) [L]	8,300 - 9,800	3
Breathing Rate (B) [L/hr]	833 ($20m^3$/day)	4

1. Andelman, J., Total Exposure to Volatile Organic Compounds in Potable Water, Chapter 20, Significance and Treatment of Volatile Organic Compounds in Water Supplies

2. U.S. Department of Housing and Urban Development, Residential Water Conservation Projects, March 1984, Contract H-5230

3. Giardino NJ, Gumerman E, Andelman JB, Wilkes CR, Small MJ, Borrazo JE, Davidson CI (1990), Real-Time Air Measurements of Trichloroethylene in Domestic Bathrooms using Contaminated Water

4. U.S. EPA Factors Handbook

4. Whole House Exposure

Similarly, a one-compartment indoor-air model may be used to describe the range of average indoor-air concentrations that are likely to be encountered from a volatile organic chemical. The equation does not address the time and space variations that will be encountered throughout the day in the home. The exposure estimates obtained using the air concentrations from equation (8) do not include those that would occur at the point of water use, such as during showering.

The air concentration can be estimated by using the equation below.

$$C_a = \frac{WHF\ C_w\ f}{HV\ ER\ MC} \qquad (8)$$

where; C_a = concentration in air (mg/m^3)
C_w = concentration in water (mg/L)
WFH = water flow rate in whole house (L/day)
HV = house volume (m^3)
ER = exchange rate (air changes/day)
MC = mixing coefficient (unitless)
f = fraction of contaminant that volatilizes (unitless)

Table 2 shows a list of the ranges of values that these variables can take. An example of the use of equation (8) is presented below.

Assumptions

WFH = 723 (L/day)
HV = 177.7 (m^3)
ER = 13.7 - 58.8 (air changes/day)
MC = 0.15 - 1.0 (unitless)
f = 0.5 - 1.0 (unitless)

$$C_a = (0.03 - 2.0\ [L/m^3])\ C_w\ [mg/L] \qquad (9)$$

TABLE 2

Variable	Value or Range	Reference
Water Flow Rate (WFH) [L/day]	723 (typical)	1
House Volume (HV) [m^3]	177.7 (typical?)	2
Exchange Rate (ER) [air changes/day]	13.7 - 58.8	3
Exchange Rate (ER) [air changes/day]	21.6 - 84.0	4
Mixing Coefficient (MC) (unitless)	0.15 - 1.0	5
Fraction Volatilization (f) [unitless]	0.5 - 1.0	6

1. U.S. Department of Housing and Urban Development (1984) Residential Water Conservation Projects

2. Axley J (1988) Progress Toward a General Analytical Method for Predicting Indoor Air Pollution in Buildings: Indoor Air Quality Modeling Phase III Report. NBSIR 88-3814

3. Grimsrud D.T., Sherman M.H., and Sonderegger R.C. (1982) Calculating infiltration: Implications for a Construction Quality Standard. Proceedings - ASHRAE/DEO Conference on Thermal Performance of the Exterior Envelopes of Buildings, Las Vegas, NV, Lawrence Berkeley Laboratory Report, LBL-9416. (refers to new houses)

4. ASHRAE (1985) Natural Ventilation and Infiltration. ASHRAE Fundamentals Handbook, Chapter 22, ASHRAE Inc., Atlanta, GA. (refers to older houses)

5. U.S. EPA (1987); Exposure to Volatilized Drinking Water Contaminants Via Inhalation - Importance Relative to Ingestion; Office of Drinking Water, Criteria and Standards Division, Health Effects Branch.

6. Cantor, K.P., Christman R.F., Ram, N.M., Significance and Treatment of Volatile Organic

Compounds in Water Supplies; Chapter 20 - Total Exposure to Volatile Organic Compounds in Potable Water; Julian B. Andelman

Note: The ranges represent the average value and the maximum value. For the range presented in reference #4, the first value represents the median. Values presented for mixing coefficients are based on judgment.

Appendix A: Derivation of Equations

Nature of Volatilization Process

To assess the potential for VOC's to volatilize from water used indoors, it is useful to consider the equilibrium and rate processes involved. The relevant relationship describing the volatilization of a chemical and its subsequent equilibrium between the air and water phases is Henry's law

$$H = C_a/C_w \tag{1}$$

where H is the dimensionless Henry's law constant, and C_a and C_w (mass/volume) are the concentrations of the volatilized chemical in the air and water phases, respectively, at equilibrium.

Table 5 is a list of H constants at 25 °C for several organic chemicals of environmental concern, along with their vapor pressures and solubilities, the values being approximate, either calculated or taken directly from the compilation by Mackay and Shiu [19]. The H constants shown there encompass a

range greater than five orders of magnitude. Their vapor pressures and water solubilities are also quite different. Since the H values are predicted fairly well by the ratio of the vapor pressure of the pure material to its aqueous solubility, compounds such as carbon tetrachloride and tetrachloroethylene, with quite different solubilities and vapor pressures, can nevertheless have similar H values. Also it is essential to recognize that even a low vapor-pressure chemical, by virtue of its low solubility in water, has the potential to volatilize to the same extent as a high vapor-pressure chemical.

The maximum extent to which a chemical may be expected to volatilize in the home from indoor water uses can be estimated by considering the average quantities of water used within a home, F_w (L/h), along with typical air flow or infiltration rates F_a (L/h). For a family of four a typical ratio of F_a/F_w may be taken as 10^4 [4]. The ratio of masses of volatilized chemicals, r, in the two phases is given by

$$r = (C_a/C_w)(V_a/V_w) \quad (2)$$

where V_a and V_w are the quantities of air and water, respectively, used in a given period of time in the home. In the steady-state one can assume that V_a/V_w equals F_a/F_w, and r_{MAX} is the maximum expected value for r when C_a/C_w equals H, such that

$$r_{MAX} = H(F_a/F_w) = 10^4 H \quad (3)$$

This indicates that in the steady-state, as water is used within the typical home and air infiltrates through it, for a chemical with an H value as low as 10^{-4}, r_{max} is unity, or about 50% volatilization will occur. Since all the chemicals in Table 5 have H values greater than 10^{-4}, in each case, assuming Henry's law equilibrium is attained, one would expect substantial volatilization to occur in the home from normal uses of contaminated water as it is exposed to the indoor air.

The H constant will increase with temperature. Munz and Roberts [20] showed that for several volatile organic chemicals the temperature effect is given by

$$\log H = A' - B'/T \qquad (4)$$

where A' and B' are constants for each chemical, and T is absolute temperature. For chloroform the measured A' and B' values were found to be 4.990 and 1729, respectively; and for carbon tetrachloride, 5.853 and 1718, respectively, the measurements being taken over the range of 10 to 30 °C. For example, using this equation for chloroform, the H values are 0.076 and 0.19 at 10 °C and 30 °C, respectively, The comparable values for carbon tetrachloride are 0.606 and 1.52. Thus the maximum extent of volatilization that can occur will increase markedly with temperature.

As discussed by Mackay and Yeun [21], the rate of volatilization of a chemical from water is dependent on its molecular-diffusivity properties. Often a two-resistance model

is used to describe the process in which the volatilizing chemical has to first diffuse across a liquid film at the air water interface, followed by diffusion across the air film. Mackay and Yeun measured volatilization rates in a wind wave tank for 11 organic compounds with varying Henry's law constants. They confirmed the validity of the two-resistance model, and showed the effects of solute diffusivity and temperature. The chemicals studied included several halogenated VOC's, including chlorobenzene, carbon tetrachloride, 1,2-dibromoethane, and 1,2-dichloropropane, as well as benzene and toluene, and several ketones and alcohols. They showed that no interactions occur when solutes volatilize simultaneously, and concluded that the mass-transfer rate was predominantly liquid-phase resistant for many of these chemicals.

The two-resistance model expressing the mass flux, F_m (mol/m^2s), can be written as

$$F_m = K(C_w - C_a/H) \quad (5)$$

where K is the overall, two-resistance mass-transfer coefficient (m/s), C_a is the solute concentration in air (mol/m^3) and C_w that in water. The overall mass transfer is a product of the flux and the surface area exposed, so that, for example, small droplets in a shower with a greater surface area would be expected to have a greater rate of volatilization per unit time than would the same mass of larger droplets with a lower surface area/mass ratio.

Mackay and Yeun concluded that the mass-transfer coefficient in either the liquid or gas phase was most likely dependent on the Schmidt number, Sc, which is the dimensionless ratio of viscosity/(density x diffusivity), in the respective phase. The two-resistance model describes the K in terms of liquid and gas phase transfer coefficients, K_L and K_G, respectively, such that

$$1/K = 1/K_L + 1/HK_G \qquad (6)$$

They showed that for their data K_L was proportional to 3.41×10^{-3} $Sc_L^{-0.5}$, while K_G was proportional to 4.62×10^{-2} $Sc_G^{-0.67}$. The Sc_G and Sc_L values for the 12 compounds did not differ greatly, ranging from 0.72-1.07 for Sc_G, and 939-1177 for Sc_L at 20 °C. However, the H values varied considerably by almost four orders of magnitude. For the smallest H-value compound, 1-butanol, the K_G term dominated to establish the overall K, while for the high H-value compounds like benzene and carbon tetrachloride, liquid-film transfer was the dominant rate-controlling step, the $1/HK_G$ term being negligible in Equation 8. The overall mass-transfer coefficients measured were thus quite different at these two extremes. For example, the ratio of mass-transfer coefficients for benzene to that of 1-butanol varied from 14 to 20. In contrast, for those compounds where K_L dominated, the K values did not vary much, as expected, since their Sc_L values were quite similar, and H no longer played a significant role in determining K. Thus, in one series of determinations of mass-transfer coefficients, Mackay and Yeun measured K values of 51.1, 51.1,

and 45.3 (10^6 m/s), respectively, for benzene, carbon tetrachloride, and 1,2-dibromoethane, their Sc_L values being 1021, 1062, and 1075, respectively.

This analysis indicates that one should be able to compare and predict the K values among compounds based on fundamental molecular properties and H values, to the extent that this two-resistance model applies to the volatilization from indoor water uses. They observed that the use of the K_L dependency on $Sc_L^{-0.5}$ predicts a 2.8% temperature increase in K per degree.

Equation 5 for the mass-transfer or flux at the water air-interface predicts that when the air concentration, C_a, is negligible, meaning a small buildup of chemical in the receiving air, then the rate of mass transfer is directly proportional to the concentration of volatilizing chemical in the water. This is of importance in that one could then extrapolate the percent volatilization at a high concentration in the feed water to predict the same fractional volatilization at a low-feed concentration. At the same time, even if the buildup in the air did occur, however, and its removal were first order in concentration, one could still extrapolate to the lower feed concentration.

There is independent evidence in laboratory studies that the mass-transfer coefficient may be reasonably constant over several orders of magnitude of concentration [22]. For 1,2-dichloroethane in the range of 1 g/L to 10 ug/L the coefficient

of variation of mass-transfer coefficient was found to be ± 6.31%; for 1,1,1-trichloroethane it was ± 5.42% over a range of concentration of 0.05 g/L to 30 ug/L.

In summary, the H constant will limit the maximum volatilization that can occur in indoor water uses. However, except for a few still-water systems in the home, such as water in a toilet bowl, many water uses are flowing or are of short-term duration in which the rate of volatilization will be limiting and equilibrium not reached. In those instances the mass-transfer coefficients become the principal controlling factor for the relative releases of different volatile and semi-volatile chemicals. Even here, however, the H constant is of importance in that it will influence the magnitude of the mass-transfer coefficient, as well as the extent to which the flux for volatilization at the water-air interface will be reduced as the air concentration builds up.

Finally, the water-air interfacial areas and temperatures of the water uses are critical determining factors in the rate of mass transfer; and certainly the H constants will increase with temperature as well. Thus, one can expect that since the various indoor water uses involve different quantities and flows of water, residence times in the water appliances and uses, degrees of mixing and turbulence, and temperatures, the extents of volatilization among the water uses, even for a given chemical, should vary.

Values for transfer efficiencies among water uses in a typical home have been determined for radon by Prichard and Gessell [10]. As shown in Table 6, the transfer efficiencies (percent volatilization) were found to vary from 30 to 90% among the water uses, the volume use-weighted mean being about 50%.

Laboratory Shower Experiments

We have performed studies on volatilization of chemicals from laboratory and full-size shower and bath systems in which chemicals have been added to the water [3-8]. In our typical laboratory shower experiments with chloroform shown in Figure 1 [23], the concentration of the chemical in the air pumped from the chamber is measured continuously as the shower water flows, and continues to be measured after the chemical injection is terminated, but with the shower still flowing. The peak concentrations shown in Figure 1 occur shortly after terminating the injection of chemical. In these studies we have also monitored the drainwater leaving the shower chamber for mass-balance purposes.

For this system the equation describing the rate of change of air concentration, C_a (mg/L), can be expressed as [6]

$$V_a(dC_a/dt) = k(C_w - C_a/H) - F_aC_a \qquad (7)$$

where V_a (L) is the volume of the shower chamber, C_w (mg/L) the concentration of the chemical in the feed water, F_a (L/min) the air flow rate through the chamber, and k (L/min) the

volatilization mass-transfer coefficient. When the feed concentration is terminated, the volatilization source term becomes zero and Equation 7 reduces to

$$V_a(dC_a/dt) = -F_aC_a \quad (8)$$

the integrated form being

$$\ln C_a = \ln C_{a,INITIAL} - (F_a/V_a)t \quad (9)$$

As expressed by Equation 7, we find that the volatilization source term $k(C_w - C_a/H)$ does indeed reduce significantly with time as C_a increases. For example, in the experiment with a chloroform feed of 1.84 mg/L shown in Figure 1, at 10, 30, and 50 min, the instantaneous fractional rate of volatilization, f, was 0.82, 0.70, and 0.62, respectively. This is consistent with our experimental observation that the C_a/C_w ratio for air and water leaving the chamber was found to be less than the H value for chloroform, but that the latter value of about 0.15 was gradually approached during the shower experiment [23], thus gradually inhibiting the volatilization rate.

We have also found in our experiments with both chloroform and trichloroethylene (TCE), that during the decay period (following the termination of the chemical in the shower feed) significant quantities of the volatilized chemical in the shower chamber air redissolves in the flowing water, as measured in the drainwater. Thus, Equations 8 and 9 are not quite accurate, since there is this additional decay route.

As shown in Figure 1 for chloroform, as expected the air concentration due to volatilization increases with temperature and concentration of the feed water in the shower experiments. Also as expected, we have found that increased air flow reduces the concentration of volatilized chemical in the chamber air and at the same time increases the rate of volatilization, since the rate of approach to Henry's law equilibrium is reduced. Rates of volatilization for chloroform and TCE ranged from about 50 to 90%, depending on temperature and other shower conditions, with chloroform volatilization typically lower than that for TCE.

Modeling Shower and Whole House Exposures

One can estimate the shower and whole house exposures by the use of simple, one-compartment modeling. For example, integrating Equation 7 and assuming that C_a/H is negligible compared to C_w, one obtains an expression for the change in C_a with time in a chamber

$$\ln (1 - C_a F_a / k C_w) = - (F_a / V_a) t \qquad (10)$$

The assumption that C_a/H is negligible implies that the rate of volatilization in the shower is constant. In that case it can be shown that k equals fF_w, where f is the fraction of chemical that volatilizes from the feedwater whose flow rate is F_w (V/t). Although, as noted above there is a gradual decrease in f values with time during the shower experiments, this will not substantially affect the estimated average values of C_a that will

be used to calculate exposures. Using Equation 10 one can calculate the maximum air concentration that will be achieved in a one-compartment shower or bath. For small values of $(F_w/V_a)t$ (the magnitude of which will be considered below), Equation 10 reduces to a simple linear form

$$C_a = ktC_w/V_a \tag{11}$$

Thus, after a given shower period, t, this is also the maximum concentration, C_{aMAX},

$$C_{aMAX} = ktC_w/V_a \tag{12}$$

Also, the average concentration, C_{aAVG}, would be $C_{aMAX}/2$ since C_a increases linearly with time

$$C_{aAVG} = ktC_w/2V_a \tag{13}$$

For the purpose of estimating possible shower exposures, it will be assumed that the concentrations during the shower period itself, as well as subsequently while a person remains in the bathroom, will be the same in the shower and bathroom. In fact, our measurements in a full-size shower show that there is indeed a difference between the two, and that the system should be more appropriately treated as a two-compartment system [24]. For precise modeling of the exposures, this difference should be considered, but as an approximation it will be neglected here.

Subsequent to the showering period there will be a decay of the air concentrations in the bathroom due to normal exchange of air. During this period the person in the bathroom will continue to be exposed to the volatilized chemicals in the air. The decay

of C_a is represented by

$$\ln (C_a/C_{aMAX}) = - (F_a/V_a)t \quad (14)$$

For small values of $(F_a/V_a)t$ this equation linearizes to

$$C_a = C_{aMAX} [1 - (F_a/V_a)t] \quad (15)$$

The average concentration during this period, C_{aAVG}, is

$$C_{aAVG} = (C_a + C_{aMAX})/2 \quad (16)$$

Combining Equations 15 and 16, one obtains

$$C_{aAVG} = C_{aMAX} [1 - F_a t/(2V_a)] \quad (17)$$

In many cases, the $F_a t/(2V_a)$ term in Equation 17 is likely to be substantially smaller than unity, so that as an approximation during the decay period one can assume that $C_{aAVG} = C_{aMAX}$, at least for the purposes of estimating the magnitude of inhalation exposures.

One can use these equations to estimate the C_{aAVG} values for various shower-water flow and bathroom characteristics. In an Australian survey of water uses, distributions of average shower-water flow rates and duration were reported for about 2,500 households [25]. The geometric mean for the shower flow rates, F_w, was about 8 L/min (about 500 L/h), and about 6 min for the shower duration, which will be specified as t_d, and typically taken as 0.1 h. These values will be utilized here to estimate C_a values using the above equations. In a study of modern houses in one heating season the geometric mean for air exchange rates was reported to be 0.53 h^{-1} [13]. This value will be used for the bathroom, along with a value for its size, V_a, of 10,000 L.

Thus, the F_a for the bathroom will be $0.53V_a$, or about 5,000 L/h. Thus, for a shower period of 0.1 h, or a decay period of 0.2 h, with $(F_a/V_a)t$ values of 0.053 and 0.115, respectively, the approximation of linearizing Equations 10 and 14 involves errors of less than one percent.

The above equations and data can be utilized to estimate the average air concentrations to which people are exposed in bathrooms during and after showering. As discussed earlier, the fractional volatilization rate in our shower experiments has been found to range from 0.5 to 0.9, depending on the specific chemical, water temperature, and other factors. For the purposes of estimating a typical value, we will use an f value of 0.75.

Using Equation 12 and the fact that k equals fF_w yields

$$C_{aMAX} = C_w f F_w t_d / V_a \tag{18}$$

One can use typical values for the variables indicated above to obtain

$$C_{aMAX} = C_w(0.75)(500)(0.1)/10^4 = 3.75\text{x}10^{-3}\ C_w \tag{19}$$

The value for C_{aAVG} would be one-half this, or $1.9\text{x}10^{-3}\ C_w$. It is interesting to note that Prichard and Gesell [10] predicted that for a five-minute shower using 75 L of water and with 65% volatilization in a 30,000 L room, the average radon air concentration would be $1.6\text{x}10^{-3}\ C_w$. Similarly, McCone [9] modeled several low molecular-weight organics volatilizing with multiple family use of a bathroom in the early morning hours and calculated typical bathroom air concentrations of $5\text{x}10^{-3}\ C_w$.

Such predicted air concentrations will be highly dependent on a variety of factors, including the nature of the volatilizing chemical, geometry and air exchange between the shower and surrounding room, water temperature, and water flow rate. Nevertheless, these can be assessed to determine the likely range of bathroom air concentrations that can be expected in homes.

It is also of interest to estimate the inhalation exposures in the shower and bathroom, and compare them to the likely ingestion exposures. Inhalation exposure, E_i (mg), can be defined as the product of C_a, the breathing rate, B (L/h), typically 1,000 L/h for an adult, and the exposure time, t.

$$E_i = C_a B t \qquad (20)$$

As an example, one can use this equation to estimate the exposures during a 0.1 h showering time, using the value of C_{aAVG} above of 1.9×10^{-3} C_w. Also as noted above, during a 0.2 h period subsequent to the shower, the decay will not be significant, so that the C_{aAVG} during this period can be taken to be C_{MAX}, namely 3.75×10^{-3} C_w. Thus, one can calculate the E_i for the combined 0.1 h shower and 0.2 h subsequent period in the bathroom as the sum of two terms using Equation 20, to give

$$E_i = [C_{aAVG} B t]_{shower} + [C_{aAVG} B t]_{decay} \qquad (21)$$

Inserting the appropriate values, one obtains

$$E_i = 1.875 \times 10^{-3}\ C_w (1000)(0.1) + 3.75 \times 10^{-3}\ C_w (1000)(0.2) \qquad (22)$$

Thus, E_i has the value $0.94 C_w$, where the units of C_w are mass/L.

This is the inhalation exposure in the bathroom during the shower and subsequent to it while the bather remains in the bathroom, and is approximately equivalent to the exposure that would occur from ingesting one liter of the water. However, several occupants of a home may take a shower during a period when the volatile chemical air concentration in a bathroom has not decayed and builds up to levels higher than one would predict for a single bather. In that instance, the exposures could be substantially higher than would be predicted by the above relationship.

Similarly, we have used a simple predictive equation, based on a one-compartment indoor-air model, to describe the range of average indoor-air concentrations that are likely to be encountered from a chemical volatilizing at an average rate of 50% from all water uses, as discussed above to be a typical value for radon. The relationship we have obtained for the expected range of indoor-air concentrations is [7]

$$C_a = (0.1 \text{ to } 5)\times10^{-4}\ C_w \qquad (23)$$

where C_a is the average indoor-air concentration (mg/L), generated by the corresponding average water concentration, C_w (mg/L). Thus, for example, a water concentration of 1 mg/L would be expected to generate between 1×10^{-5} to 5×10^{-4} mg/L average air concentration in the home. This, of course, does not address the time and space variations that will be encountered throughout the day in the home. It is interesting to note that

Nazaroff et al. [13] have similarly made estimates of the likely indoor-air concentrations of radon for U.S. homes by the water volatilization route. The geometric mean in their factor applicable to Equation 23 is 0.65×10^{-4}, within our range of predicted values. Also, their range of one standard deviation around the mean corresponds to the following equation

$$C_a = (0.23 \text{ to } 1.87) \times 10^{-4}\ C_w \qquad (24)$$

also within our predicted range. McKone [9] has similarly estimated household air concentration for several volatilizing chemicals, predicting an average C_a ranging from 2×10^{-5} to 1.2×10^{-4} mg/L in air for a C_w of 1 mg/L in water, also within the range of that predicted by Equation 23.

One can use these air concentration predictions to estimate the likely inhalation exposures, E_i, for an adult during a 24-hour residence period in a house. Combining Equations 20 and 23 one obtains

$$E_i = (0.1 \text{ to } 5)(10^{-4})(1000)(24)\ C_w = (0.2 \text{ to } 10)\ C_w \qquad (25)$$

Since the C_w units here are mass/L, a 1 mg/L water concentration corresponds to a range of inhalation exposures of 0.2 to 10 mg per day, in comparison to 2 mg per day for the ingestion of 2 liters of that water. It should be noted that these inhalation exposure estimates do not include those that would occur at the point of water use, such as during showering. As discussed above, the latter exposures can be comparable to those from direct ingestion.

There is a remarkable consistency in the above range of likely predicted average indoor-air concentrations from the totality of indoor water sources. Nevertheless, there are a number of factors to be considered in refining these estimates and developing a useful and simple predictive relationship that can be applied by those responsible for exposure assessments in specific situations. They can be categorized as follows:

a) chemical characteristics that affect the rate and extent of volatilization, including soap and detergent use

b) water use factors that affect the "source strength" and its time and location variability

c) chemical characteristics that influence the behavior and interactions of the volatilized chemicals with "sinks", typically high surface area materials in the home; also the specific nature, amounts, and locations of these sinks

d) house structure and indoor-air flow regimes that transport the volatilized chemicals throughout the home

e) personal behavior and home occupancy factors that determine an individual's exposure.

The simple indoor-air models mentioned above generally are not sufficiently specific to address all the above factors, although they can and have been evaluated for some indoor-air pollution sources other than those from water [26].

The potential interactions between surfaces in homes and organic vapors released from water into indoor air have not been

studied and need to be evaluated. For some chemicals it may be appropriate to incorporate these interactions into the volatilization, indoor-air exposure model. One study of the interaction of volatile organic chemicals with materials used in the home examined three surfaces [27]: plywood, nylon carpeting, and wool carpeting. The study focused on twenty volatile organic chemicals, including alkanes, aromatics, alcohols, esters, ketones, aldehydes, terpenes, and chlorinated hydrocarbons. They showed clear interactions between the gaseous organic chemicals and the surfaces. For example, in one experiment wool carpeting became essentially saturated with lindane within about one day.

In order to determine the role of such "sink" interactions there are three broad questions that need to be addressed:

1) Which classes of organic/surface systems demonstrate significant sorption effects?

2) What are the appropriate equilibrium and kinetic models for the sorption process for the organic/surface systems of interest?

3) How can this equilibrium and kinetic information be incorporated into a water-volatilization, indoor-air quality model?

Summary and Conclusions

VOC's have the potential for causing substantial human exposures from indoor uses of contaminated water by non-ingestion

routes, namely inhalation following volatilization from water, as well as by skin contact. The latter exposures have been estimated to be comparable to those from direct ingestion of water, although published research in this area is scanty.

Measurements in homes have shown that VOC's can be detected in indoor air following the use of contaminated water. Scaled-down and full-size laboratory bath and shower studies for such VOC's as chloroform and trichloroethylene have shown that a variety of factors can affect the extent of volatilization, found to be typically in the range of 50 to 90%. These include the nature of the volatilizing chemical, water temperature, air and water flow rates, and nature of the water use (e.g., bath versus shower).

The Henry's law equilibrium constants, H, predict that even chemicals with low vapor pressures may be expected to volatilize substantially, provided their water solubilities are also low. Thus, so-called semi-volatile organic chemicals have the potential to volatilize and cause inhalation exposures. Also, chemicals with varying H values may nevertheless volatilize at comparable rates.

Modeling and estimates of inhalation exposures to VOC's indicate that for the bather these exposures during and directly after a shower can be comparable to that from direct ingestion of the contaminated water. Also, when all water uses are considered, the inhalation exposures to all inhabitants of a home

may be substantially larger than that from direct ingestion, even without considering the inhalation exposures at the point of water use. However, additional research is required to more specifically and precisely quantify these exposures to encompass the full range of home characteristics, as well as personal water uses and occupancy factors.

Because the non-ingestion exposures to VOC's in indoor water uses are likely to be comparable to or greater than those from direct ingestion, it would be prudent to consider this in establishing regulatory limits in drinking water, as well as the need to restrict all indoor water uses when it is judged that there is a significant health risk from the direct ingestion of a contaminated water.

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Appendix B: Assumptions and Uncertainties

- Equation (4) does not account for the concentration of the chemical in the air remaining from previous showers taken by other members of the family.

- The use of Equation (4) also assumes that $(F_a/V)t$, where F_a is the air flow rate, is small compared to unity, which implies that the relationship between concentration in air and time is linear.

- Equation (4) also assumes that C_a/H during the course of the shower is small compared to C_w; which implies that the volatilization rate in the shower is constant.

- The use of Equation (6) assumes that $tF_a/2V_a$ is small compared to unity so that the concentration during the decay period after the shower, $C_{a,AVE2}$, can be approximated by C_{MAX}.

- The exchange between the air in the shower chamber and that in the bathroom is so rapid that the combined volume of these two compartments can be treated as a single chamber with a single concentration of volatilized chemical.

- Equation (4) does not account for the exchange rate that occurs when an exhaust fan is turned on. Modeling results using the Model for Analysis of Volatiles and Residential Indoor-air Quality (MAVRIQ) indicate that exposure is reduced by 20 % if exhaust fan is used.

- The range of volatilization fraction in Table 1 is based on experiments conducted with trichloroethylene, chloroform and dibromochloropropane. The relationship between these volatilization rates, Henry's Law Constant and molecular weight is not known yet. Summarized below are the experimental results for these three chemicals under approximately the same conditions.

Chemical	T (°C)	H (unitless)	% Volatilized
Trichloroethylene	46	1.14	81.8
Chloroform	42	0.35	56
Dibromochlorpropane	42	0.03	22.8

- Equation (8) treats the whole house as one compartment model.

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BY [illegible] DATE [illegible] SUBJECT [illegible] SHEET NO ____ OF ____
CHKD BY [illegible] DATE [illegible] JOB NO [illegible]

$$E_i\,(mg) = \left[\left(\frac{C_w\left(\frac{mg}{L}\right) * f\,(0.9) * F_w\left(\frac{1000\,L}{hr}\right) * t_1\,(0.08\,hr)}{Z \quad V_a\,(10{,}000\,L)}\right) * \left(B\left(\frac{[illegible]}{hr}\right) * t_1\,[illegible]\right)\right] -$$

$$\left[\left(\frac{C_w\left(\frac{mg}{L}\right) * f\,(0.9) * F_w\left(\frac{1000\,L}{hr}\right) * t_1\,(0.08\,hr)}{V_a\,(10{,}000\,L)}\right) * \left(B\left(\frac{[illegible]}{hr}\right) - t_2\,[illegible]\right)\right]$$

$$E_i\,(mg) = \left[\left(\frac{C_w\left(\frac{mg}{L}\right) * 43.2}{\frac{Z}{10{,}000}}\right)\left(\frac{[illegible]}{L}\right)\right] + \left[\left(\frac{C_w\left(\frac{mg}{L}\right) * [illegible]}{[illegible]}\right)\left(\frac{[illegible]}{L}\right)\right] -$$

$$= \left(C_w\left(\frac{mg}{L}\right) * 0.144\right) + \left(C_w\left(\frac{mg}{L}\right) * 0.71[illegible]12\right) = E_i\,\left(\frac{mg}{day}\right)$$

$f * C_w * 0.15[illegible]$

C_w = conc (mg/L)
f = Fraction Volatized (90%)
F_w = Water Flow Rate (600 L/hr)
ET < t_1 = Shower Period (0.08 hr)
t_2 = bathroom Period (0.2 hr)
V_a = bathroom Volume (10,000 L)
IR = B = breathing Rate (L/hr)

$$\text{Intake} = \frac{CA\left(\frac{mg}{m^3}\right) * IR\left(\frac{m^3}{hr}\right) * ET\left(\frac{hr}{day}\right) * EF\left(\frac{day}{year}\right) * ED\,(years)}{BW\,(kg) * At\,(days)}$$

eq 6-16 R

EF = 365 day/year
ED = 10 yrs
BW = 30 kg
At = 3650 (NC)
25,550 (C)

$$\left[\left(\frac{\left(\frac{\left(C_w\left(\frac{mg}{L}\right) * f(x) * F_w\left(\frac{400\,L}{hr}\right) * t_1(0.08\,hr)\right)}{2}\right)}{V_a\,(10{,}000\,L)}\right) * \left(B\left(\frac{83\,\%\,L}{hr}\right) * t_1(0.08\,hr)\right)\right] + \left[\left(\frac{\left(C_w\left(\frac{mg}{L}\right) * f(x) * F_w\left(\frac{400\,L}{hr}\right) * t_1(0.08\,hr)\right)}{V_a\,(10{,}000\,L)}\right) * \left(K\left(\frac{273\,L}{hr}\right) * t_1(0.08\,hr)\right)\right]$$

$$= \left(C_w\left(\frac{mg}{L}\right) * f(x) * 0.154736\right) + \left(C_w\left(\frac{mg}{L}\right) * f(x) * 0.799168\right)$$

$$= \left(C_w\left(\frac{mg}{L}\right) * f(x) * 0.959616\right) = E_1\left(\frac{mg}{day}\right)$$