DRAFT FINAL
CORRECTIVE MEASURE STUDY
T-38 TEST CELL (SS-59/SWMU 229)
AND
BUILDING 828 (SS-60/SWMU 230)

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U.S. Army Corps of Engineers
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Omaha, Nebraska

December 1994

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Appendix A Vapor Abatement Life Cycle Cost Analysis, T-38 Test Cell - SS-59/SWMU 229

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ACRONYMS USED

AFB	Air Force Base
AGE	Aerospace Ground Equipment
APCB	Air Pollution Control Bureau
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CAO	Corrective Action Objective
CFU/g	Colony Forming Units per Gram
CFR	Code of Federal Regulations
CMS	Corrective Measure Study
CUB	Contaminant-Utilizing Bacteria
EPA	United States Environmental Protection Agency
IRA	Interim Remedial Action
IRP	Installation Restoration Program
HSWA	Hazardous and Solid Waste Amendments
HVDPE	High Vacuum Dual Phase Vapor Extraction
LNAPL	Light Non-Aqueous Phase Liquids
mg/l	Milligrams per Liter
NCP	Natural Contingency Plan
NMED	New Mexico Environment Department
NPDES	National Pollutant Discharge Elimination System

ACRONYMS USED (CONTINUED)

OSHA	Occupational Safety and Health Administration
ppb	Parts per Billion
ppm	Parts per Million
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SSHP	Site Safety Health Plan
SWMU	Solid Waste Management Unit
TDS	Total Dissolved Solids
THB	Total Heterotrophic Bacteria
TPH	Total Petroleum Hydrocarbon
ug/l	Micrograms per Liter
VOC	Volatile Organic Compounds

1.0 INTRODUCTION

1.1 Purpose and Organization of Document

This Corrective Measure Study (CMS) has been prepared for the T-38 Test Cell (Building 639), and the Aerospace Ground Equipment (AGE) Fueling Station (Building 828) located on Holloman Air Force Base (AFB), New Mexico. The T-38 Test Cell is identified as Installation Restoration Program (IRP) site SS-59, and Solid Waste Management Unit (SWMU) 229. Building 828 is IRP site SS-60 and SWMU 230. The CMS evaluates corrective action alternatives and recommends the corrective measures to be taken at each site. The CMS has been prepared in accordance with the U.S. Environmental Protection Agency (EPA)-approved CMS Workplan for the sites dated 17 June 1994, and complies with the following requirements:

- RCRA Corrective Action Plan (Interim Final), EPA/530-SW-88-028 (EPA, June 1988);
- Hazardous and Solid Waste Amendments (HSWA) permit requirements;
- Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities; Proposed Rule, Federal Register, July 27, 1990, Volume 55, No. 145;
- Air Emissions of 40 CFR 254, Subpart AA (for process vents) and Subpart BB (for equipment leaks);
- Holloman AFB RCRA Part B permit; and
- As applicable to IRP sites, the National Contingency Plan (NCP) 40 CFR Part 300.

The objective of the CMS is to identify, screen, and develop alternative(s) for removal, containment, treatment and/or other remediation of contamination at the SWMUs based on the corrective action objectives identified for the sites. The alternatives are based on

information provided in the RCRA Facility Investigation (RFI) for the sites and the Interim Remedial Action (IRA) conducted at the T-38 Test Cell under a Rapid Response initiative. Due to similarities between the T-38 Test Cell and Building 828 with respect to contaminants, corrective action objectives, and site characteristics, the preliminary screening of technologies and analysis of remedial alternatives for each site have been combined.

The remainder of this document is organized in the following manner: Section 2.0 presents current conditions at the two sites, including a description of each site, nature and extent of contamination, actual or potential exposure pathways, and current site activities. In Section 3.0, site-specific Corrective Action Objectives (CAOs) are developed for the two sites based on public health and environmental criteria, data from the RFI, EPA guidance, and requirements of any applicable State, Federal and base-specific statutes and agreements. The current status of the IRA at the T-38 Test Cell is summarized in Section 4.0. Section 5.0 screens the recommended technologies and potentially applicable corrective measure technologies, including the no action alternative, identifies technologies for further evaluation, and eliminates those technologies which have limitations due to the contaminants, site-specific conditions, and inherent technology limitations. Section 6.0 develops more fully the corrective measure alternative(s) retained for further analysis, weighing preliminary/relative life-cycle costs, technical merits, human health, and environmental factors. Section 7.0 justifies and recommends the corrective measure(s) selected for each site with respect to technical, environmental, human health and institutional criteria. Section 8.0 provides a list of references. Supporting information for the CMS is presented in the attached Appendices, Tables, and Figures.

2.0 DESCRIPTION OF CURRENT CONDITIONS

2.1 T-38 Test Cell - IRP Site SS-59/SWMU 229

2.1.1 Site Description and Background

Descriptions of the site and previous investigations are provided from the RFI Report (Woodward-Clyde, June 1994). The T-38 Test Cell (Building 639) is located within the Holloman AFB airfield, northeast of Building 638 and along the northwest edge of Taxiway A (Figure 2-1). The Test Cell and the adjacent Test Cell outdoor power check pad are currently used to test the engines of T-38 planes. Other site features include a 5,000 gallon aboveground fuel tank, two oil-water separators, an abandoned water storage tank, and Building 638 which is utilized for general support and maintenance activities.

The area directly adjacent to the Test Cell (approximately 1 acre) is covered by asphalt. Both the Test Cell and power check pad are constructed on a concrete pad. The surrounding area is undeveloped with sparse vegetation. Topography slopes gently southwest with nearly level paved areas. The site is served by electricity, natural gas, and water. No sanitary sewer lines are located within a 1,500 foot radius of the site.

2.1.2 Site History

Personnel interviews, historical aerial photographs, and available plans indicate that the T-38 Test Cell was used as an F-4 trim pad from 1966-1977. During this time, an aboveground storage tank and power check pad were in place. Beginning in about 1973, F-4 engines were tested at the site. In 1977, the facility was upgraded for testing of T-38 aircraft. A temporary test cell at the concrete pad near well 229-MW4 and soil boring 229-SB21 was used for approximately 3 years in conjunction with a 1,000 gallon aboveground storage tank. In 1988, DynCorp assumed operation of the T-38 Test Cell. In 1991, after a week of non-usage, the fuel level in the 5,000 gallon aboveground JP-4 tank was checked. Approximately 2,000 gallons of JP-4 was estimated to have leaked from the underground lines leading to the Test Cell. All underground lines were subsequently replaced by aboveground lines.

2.1.3 Previous Site Investigations

In June and July 1993, pursuant to the HSWA permit for Holloman AFB, the T-38 Test Cell was investigated to confirm if a release had occurred from the Test Cell facility and to determine the nature and extent of contamination. In the Phase I investigation, conducted in June 1993, a total of 18 soil borings (229-SB1 through 229-SB18) and 5 monitor wells (229-MW1 through 229-MW5) were installed. Soil samples were analyzed for benzene, toluene, ethylbenzene, and total xylenes (BTEX), total petroleum hydrocarbons (TPH), metals, and geotechnical properties. Groundwater samples were analyzed from wells without light non-aqueous phase liquids (LNAPLs) for BTEX, metals, and general water quality parameters. Slug tests were performed on wells 229-MW2 and 229-MW5 to determine aquifer properties.

Following identification of LNAPLs in the wells installed during the Phase I investigation, 17 additional borings (229-SB19 through 229-SB35) and 7 additional wells (229-MW6 through 229-MW12) were installed in a second phase of work conducted in July 1993. Soil borings 229-SB19 through 229-SB30 were used to detect LNAPL and measure apparent thickness using temporary screens in the borings. Soil samples were analyzed for BTEX, TPH, metals, general soil quality parameters, microbial plate counts, and geotechnical properties. Groundwater samples in those wells not containing LNAPLs were analyzed for BTEX, metals, and general water quality parameters (including dissolved oxygen). Oxygen levels in the vadose zone were monitored with a combustible gas/O_2 meter at wells 229-MW3 and 229-MW6. Slug tests were performed in wells 229-MW5, MW7, MW8, MW9, and MW12. Baildown/recharge tests were performed in wells 229-MW3, MW4, MW6, and MW10 to determine representative LNAPL thickness.

2.1.4 Site Geology and Hydrogeology

Investigation results indicate that the T-38 Test Cell is underlain by 5 to 15 feet of fine silty sand or sandy silt underlain by silty clay or clayey silt with fine sand at depths of up to 25 feet. Soils are gypsiferous, and interbedded with thin, discontinuous caliche layers. Depth to water below ground surface varies from approximately 6 to 18 feet below ground surface, depending on surface topography. The water table has been depressed by LNAPL in the

area of the Test Cell by approximately 2 feet. A LNAPL mound approximately 2 feet in thickness is also present in the center of the plume. Groundwater flow is generally to the west-southwest. Seasonal water-table fluctuation at the site has not been determined. However, according to base personnel, seasonal water-table fluctuations of up to 4 feet have been observed in the past at similar areas on the base.

The soil type at the T-38 Test Cell is prevalently fine-grained. This was established by drill logs (visual observation) and confirmed by 12 sieve and/or grain-size analyses. The sieve analyses indicate that the D50 grain size (50% of material by weight) is silt-size or smaller in 75% of the samples tested. These soils have published porosity ranges of 60% to 30%, with a mid-range of 43% (Driscoll, 1986). The effective porosity of the soils at the site, or the inter-connectedness of the pores, is assumed to be less than the published porosity because of the heterogeneous (poorly-sorted) nature of the material, i.e. the less uniform the grain size, the lower the effective porosity.

Hydraulic conductivity for the T-38 Test Cell soils has been estimated using the grain-size analyses. Utilizing the D50 grain-size, a uniformity coefficient (D40÷D90), blow counts (to evaluate soil density) and published graphs (Driscoll, 1986), the hydraulic conductivity (K value) for each soil sample is estimated at less than 1×10^{-4} centimeters per second (cm/sec). This value is less than that derived from the slug tests performed during the RFI (3×10^{-3} cm/sec). However, the slug test data may reflect the influence of water recharge from the filter pack.

2.1.5 Nature and Extent of Contamination

2.1.5.1 Adsorbed Phase Hydrocarbons

Fuel-related contamination was detected in the subsurface soils at, just above, and below the water table surface. Concentrations ranged from not-detected at the perimeter of the plume to a maximum concentration of 77,000 parts per million (ppm) TPH at a depth of 6 feet in soil boring 229-SB21, in the approximate center of the LNAPL plume. Soil in excess of 1,000 ppm is present over an approximate 4.4-acre area. The average soil concentration in this area, excluding values below the detection limit of 10 ppm, is 14,400 ppm TPH.

Benzene concentrations in soil ranged from not-detected to a maximum of 170,000 parts per billion (ppb) (170 ppm), generally coinciding with the presence of LNAPL. No metals concentrations above established background levels were detected in soil. Based on soil sample analytical results and LNAPL distribution, the Test Cell tank system was confirmed as a source of hydrocarbon contamination, and the two oil-water separators were confirmed as probable sources. The extent of soil contamination is illustrated in Figure 2-2.

2.1.5.2 LNAPL and Dissolved Phase Hydrocarbons

LNAPL was detected over an approximate 10.9-acre area, over 150 feet upgradient and 500 feet downgradient of the Test Cell tank system. The areal extent of LNAPL is illustrated in Figure 2-3. Dissolved-phase contamination is estimated to extend just beyond the lateral extent of LNAPL. In July 1993, apparent LNAPL thickness ranged from 0.5 foot at the edge of the LNAPL plume to approximately 8 feet beneath the Test Cell facility. Baildown/recharge tests estimated representative LNAPL thickness of 0.5 at 229-MW10 to 4.3 feet at 229-MW3. In order to refine mass balance calculations for corrective measure evaluation, the baildown/recharge test results have been reevaluated in Section 2.1.6.1.

2.1.6 Mass Balance Calculations - T-38 Test Cell

Mass balance calculations have been made to estimate the mass of hydrocarbons in the subsurface at the T-38 Test Cell. Typically, chemical analyses of soil and groundwater and the measured or adjusted LNAPL concentrations are utilized to estimate hydrocarbon mass when the magnitude of a release is unknown. Hydrocarbon mass is used to evaluate life-cycle costs to closure for capital equipment purchases, vapor abatement equipment selection, and to guide selection of equipment for optimization of removal rates, in order to decrease overall costs to closure. Due to the inherent difficulties in estimating total mass, and the recognition that recovery of the total mass of hydrocarbons released may be technologically limited, estimates of recovered mass should not be used to determine if closure has been obtained.

2.1.6.1 Preliminary Estimate

A preliminary mass balance calculation was performed for the RFI for the T-38 Test Cell (Woodward-Clyde, June 1994). The estimate was based on an assumed zero-thickness line encompassing a 12-acre plume of LNAPL, representative thickness of LNAPL as determined by the four baildown/recharge tests, and the assumption that pore space was 100% saturated by LNAPL above, at, and below the water table surface. The thickest area of the LNAPL plume (4.5 feet) was estimated near the source, and assumed to gradually thin in all directions from the center of the plume to the zero line. The preliminary LNAPL volume calculations assumed that the LNAPL plume corresponds to the volume of soil which contains LNAPL. Pore space occupied by the LNAPL was estimated to be 33% of the volume of soil. The amount of LNAPL calculated was 1.8 million gallons.

Refinements have been made to the preliminary estimate to facilitate selection of remedial technologies and systems. The methods used to refine the estimate include:

1. More accurately estimating the areal extent of LNAPL using AutoCad™;

2. Evaluating the assumptions of pore space saturation above and below the water with respect to air to water, water to oil and oil to air saturation ratios; and

3. Utilizing average soil TPH chemical composition in the smear zone to estimate mass of hydrocarbon impacted by LNAPL and adsorbed hydrocarbons.

2.1.6.2 Calculation Considerations

Calculation of Areal Extent

The areal extent of the LNAPL plume was re-calculated using Auto-CAD.™ This calculation yielded an extent of 10.9 acres versus the preliminary 12 acre estimate (Woodward-Clyde, June 1994).

Evaluation of Baildown/Recharge Testing

Determination of LNAPL volume is difficult because the measured thickness of LNAPL in monitor wells is typically substantially more than the true LNAPL thickness in the formation at the water table. The factors which influence this "apparent thickness" include:

- Well diameter:

  The smaller the diameter of the well, the greater the exaggeration of apparent thickness.

- Permeability difference:

  The greater the difference in permeability between the filterpack and formation, the greater the apparent LNAPL thickness.

- Pore saturation volumes and effective porosity of soil:

  The greater the water saturation and the lower the effective porosity of the soil, the less LNAPL is present.

Baildown/recharge testing can be used to indicate "representative thickness" of LNAPL. In the RFI, four wells were tested using baildown/recharge recovery rates to calculate representative thickness of the LNAPL at the site. With the exception of the test conducted on well 229-MW10, analysis of the recovery data indicates that all the LNAPL may have not been removed from the well and/or the filter pack in the well annulus. Consequently, the preliminary estimates of representative LNAPL thickness may be exaggerated. In well 229-MW10, LNAPL thickness prior to testing was 1.64 feet. All but 0.01 foot of LNAPL was removed, and the calculated representative thickness was calculated to be approximately 0.5 foot, 30% of the apparent thickness. In contrast, in well 229-MW3, a representative LNAPL thickness was determined that was 73% of apparent thickness (4.3 feet versus 5.9 feet

LNAPL). During the baildown/recharge test on well 229-MW-3, over 1 foot of LNAPL was still present in the well bore prior to monitoring recovery rates.

Soil Moisture Content

Another consideration for evaluation of the mass of LNAPL is how much pore space is occupied by water. For fine-grained soils, water content in the unsaturated zone/capillary fringe may exceed 40% of the pore volume (Driscoll, 1986). In the saturated zone, 100% of the pore space is occupied by water. Therefore, in calculating the amount of LNAPL in the capillary fringe and saturated zone, consideration must be given to existing water-filled pores and how much LNAPL would be displaced above and below the water table due to the presence of water. Due to soil moisture content, typical saturation of LNAPLs (gasoline, kerosene, diesel) is 5% to 20% of actual porosity, with the soil below the water table containing 25% to 50% less LNAPL than the soil in the capillary fringe (Huntley, et al, 1994).

Chemical Data

Hydrocarbon content in soil was determined by EPA Method 418.1 on soil samples obtained in the 1993 drilling program. The areas from which samples were obtained for analysis were above, in, or below the LNAPL-impacted zone. Results of the analysis of 21 soil samples taken in the affected area (an area of 4.4 acres in the center of the plume) ranged in value from 1,400 ppm to 77,000 ppm. The average concentration was 14,400 ppm. This translates to an average of 14 pounds of hydrocarbons for every 1,000 pounds of soil, or 1.4% extractable hydrocarbon saturation by weight. Based on experience at other petroleum-contaminated sites, EPA Method 418.1 may not reflect the light-end of the hydrocarbon range (C_6 to C_8). Therefore, the 14,400 ppm average concentration may underestimate the concentration of JP-4 by as much as 20%.

2.1.6.3 Method 1: Average Hydrocarbon Content in Soil

Taking into account the factors discussed in the previous sections, two methods of mass calculation are used to refine the preliminary estimate of total hydrocarbon mass in the subsurface at the T-38 Test Cell. The first method incorporates the following assumptions, which are graphically displayed in Figure 2-4:

- Average hydrocarbon concentration (excluding non-detect or zero values) is 14,400 ppm or 1.44% of soil mass;
- Correction factor of 1.2 is applied to the average hydrocarbon concentration to account for light-end hydrocarbons (C_6 to C_8) potentially not detected by EPA Method 418.1;
- Areal extent of LNAPL is 10.9 acres;
- The average thickness of LNAPL and adsorbed hydrocarbons at and above the water table in the center of the plume (approximately 4.4 acres) is 6 feet, as determined by observations of stained soil during drilling, field headspace readings on soil samples, and soil sample analytical results;
- The average thickness of LNAPL and adsorbed hydrocarbons at and above the water table from the zero thickness line to the edge of the above area (estimated 6.5 acres) is 2 feet, as determined by observations of stained soil during drilling, field headspace readings on soil samples, and soil sample analytical results;
- Bulk density of soil is 100 lbs/ft^3 ; and
- Density of LNAPL is 6.2 lbs/gallon.

The mass is calculated as follows:

- Mass of hydrocarbons in the center of plume (internal 4.4 acres)

  = Area (ft^2) x hydrocarbon smear zone thickness (ft) x 100 lbs/ft^3 (bulk density of soil) x 1.44% hydrocarbon concentration x 1.2

  = 200,000 ft^2 x 6 ft x 100 lbs/ft^3 x 0.0144 x 1.2 = 2,073,600 lbs hydrocarbons = 334,445 gallons

- Mass of hydrocarbons in "external ring" (external 6.5 acres)

  = 270,000 ft^2 x 2 ft x 100 lbs/ft^3 x 0.0144 x 1.2 = 933,120 lbs hydrocarbons = 150,500 gallons

- Total mass from both areas = 334,445 + 150,500 ≈ 485,000 gallons

2.1.6.4 Method 2: Pore Saturation Estimate

The second method of calculation incorporates the following assumptions, which are graphically displayed in Figure 2-4:

- 20% hydrocarbon saturation (oil to air ratio) in capillary fringe;

- Initially 100% water saturated soil below the water table, with 10% pore space by volume replaced by hydrocarbons;

- 2 feet of LNAPL mounding near the source in the capillary fringe area; a cone tapering uniformly to the zero line;

- 4 feet thickness of oil and water saturated soil near the source below the water table; an inverted cone tapering uniformly to the zero line;

- 10.9 acres of LNAPL;
- 43% porosity of sediments;
- 8.4 gallons per ft^3 (conversion factor).

Mass of Hydrocarbons in Capillary Fringe (Vadose Zone)

= Area (ft^2) x height (ft) x 0.33 (area of cone) x 43% porosity x 20% saturation (oil to air)

= 470,000 ft^2 x 2 ft x 0.33 x 0.43 x 0.2 = 26,677 ft^3 hydrocarbons

26,667 ft^3 hydrocarbons x 8.4 gal/ft^3 $\approx$ 224,000 gallons hydrocarbons

Mass of Hydrocarbons in Water-Saturated Zone

= 470,000 ft^2 x 4 ft x 0.33 x 0.43 x 0.1 = 26,667 ft^3 = 224,000 gallons hydrocarbons

Total Mass = 224,000 + 224,000 = 448,000 gallons hydrocarbons

Oil to water and oil to air saturation values used are at the high end of reported saturation averages (Huntley, et al, 1994). If these values are assumed to be 5% and 10%, respectively, the calculated mass is reduced by 50% to 224,000 gallons.

2.1.7 Actual or Potential Exposure Pathways

Actual and potential exposure pathways were assessed in the RFI Report, and are summarized in Figure 2-5. Groundwater at Holloman AFB is not of drinking water quality; therefore modeling of contaminant fate and transport in groundwater was not performed due to lack of exposure pathways to potential receptors. Air modeling was performed to evaluate exposure

to volatiles for occupational and future construction workers. Excess lifetime cancer risks and hazard indexes for the child trespasser and base worker are within or below regulatory benchmarks established by the EPA. Although the hazard index benchmark of 1.0 was exceeded for the future construction worker, institutional controls should mitigate potential inhalation exposures. No complete exposure pathways exist for key receptor species identified at the site. Therefore, the contaminants of concern in the soil and groundwater pose no unacceptable ecological risks to key receptor species.

2.1.8 Current Status of Remedial Activities

In response to the identification of LNAPLs in wells during the Phase I RFI, a Rapid Response initiative for Interim Remedial Action (IRA) commenced in 1993. International Technology (IT) Corporation conducted pilot testing in November 1993 to determine the feasibility of vacuum-enhanced pumping (high vacuum dual phase extraction (HVDPE)) to address LNAPLs and potentially explosive vapor accumulation within the center one-acre area of the site corresponding to the greatest apparent thickness of LNAPL. An assessment of the IT pilot test and the proposed IRA is provided in Section 4.0. In December 1994, the Air Force designated the T-38 Test Cell as IRP site SS-59.

2.2 Building 828 - IRP Site SS-60/SWMU 230

2.2.1 Site Description and Background

The site description and background for Building 828 is provided from the RFI Report (Woodward-Clyde, June 1994). Building 828 is located in the west area of Holloman AFB, next to Buildings 821 and 827, on Bunyap Place (Figure 2-1). Building 828 is operated as part of the Aerospace Ground Equipment (AGE) maintenance facility. The facility is used for refueling, maintenance, and storage of aircraft ground support equipment. A fuel pump island is located to the south of Building 828. Three 6,000 gallon aboveground storage tanks service the fuel island. To the east of the fuel islands are located three additional underground storage tanks (USTs), which are no longer in service. Most of the area is covered by asphalt pavement. Curbs and sidewalks are concrete. The site is active, currently providing periodic maintenance and refueling of ground support equipment. The area is serviced by electricity, natural gas, and sanitary sewer.

2.2.2 Site History

As recorded in the RFI report, the site history for Building 828 has been compiled from personnel interviews and base records. The AGE facility was upgraded in 1977 to include a fuel island, USTs, concrete washrack, and an oil-water separator at adjacent Building 827. The tanks were connected to the pump island via underground lines; unleaded gasoline, JP-4 and diesel fuel were dispensed. Leaks were detected in November 1990 and 1991 in the underground diesel and JP-4 tanks, respectively, and the USTs were taken out of service. Three 6,000 gallon aboveground tanks were installed in the northwest corner of the compound and connected to the existing pumps. After one week of operation, an inventory loss of 4,700 gallons of unleaded gasoline was discovered. A faulty underground connection of the new fuel line to the unleaded pump dispenser was the suspected point of release. The connection was repaired following discovery; no other releases have been identified. In December 1992, complaints of odors were registered with the base bioenvironmental engineering unit, who subsequently completed a gas survey in the south side of the interior of Building 827. Ambient room readings taken from the floor drain in the latrine ranged from 280 ppm to 617 ppm. Readings within the commode and drain plug were 2,300 ppm and 2,500 ppm, respectively.

In January 1991, the Building 827 oil-water separator was covered with asphalt and converted for use as a sediment trap. A new oil-water separator was installed just east of the former location. According to as-built drawings, both oil-water separators connect to a sewer drain which leads to the east.

2.2.3 Previous Investigations

Pursuant to the HSWA permit for Holloman AFB, the Building 828 fuel system was identified as SWMU 230, and listed in Table III of the HSWA permit. An RFI was conducted by Woodward-Clyde in June and July 1993 to identify the extent of LNAPL and nature and extent of soil contamination at the site. In June 1993 (Phase I), a total of 18 soil borings (230-SB1 through 230-SB18) and 4 monitor wells (230-MW1 through 230-MW4) were installed. Soil samples were collected and analyzed for BTEX, TPH, metals, and geotechnical properties. Groundwater samples were analyzed for BTEX, metals, and general water quality parameters. Slug tests were conducted on wells 230-MW1, MW2, and MW4 to provide an estimate of

hydraulic conductivity at the site. In July 1993, three additional soil borings (230-SB19 through 230-SB21) were installed; soil samples were analyzed for BTEX, TPH, and metals. Soil boring 230-SB19 was used to detect LNAPL and measure apparent thickness using a temporary screen. Three additional wells (230-MW5, MW6, and MW7) were installed to define extent of LNAPLs and dissolved-phase contaminants. Soil samples were analyzed for BTEX, TPH, metals, general soil quality parameters, microbial plate counts, and geotechnical properties. Groundwater samples in non-LNAPL wells were analyzed for BTEX, metals, and general water quality parameters (including dissolved oxygen). No in situ readings of dissolved oxygen were recorded. Oxygen levels were recorded in the vadose zone using a combustible gas/O_2 meter near boring 230-SB12. Additional slug tests were conducted in wells 230-MW6 and 230-MW7. A baildown/recharge test was conducted in well 230-MW5 to determine representative LNAPL thickness.

2.2.4 Site Geology and Hydrogeology

The shallow geology beneath the Building 828 site is essentially the same as that beneath the T-38 Test Cell facility. Approximately 5 to 10 feet of fine silty sand or sandy silt is underlain by silty clay or clayey silt with fine sand extending to a depth of at least 22 feet. Soils are gypsiferous. The soil type was established by drill logs (visual observation) and confirmed by seven sieve and/or grain-size analyses. The sieve analysis indicate that the D50 grain size (50% of material by weight) is silt-size or smaller in six of the seven samples tested. These soils have published ranges in porosity from 60% to 30% (Driscoll, 1986).

The effective porosity, or the inter-connectedness of the pores, would be less than total porosity because of the heterogeneous nature of the material, i.e. the less uniform the grain-size, the lower the effective porosity. Hydraulic conductivity for the soil was estimated using the results of the grain-size analysis. Utilizing the D50 grain-size, a uniformity coefficient (D40÷D90), blow counts (to evaluate soil density) and published graphs, the hydraulic conductivity (K value) was calculated at less than 1×10^{-4} cm/sec. This value is less than that derived from the slug tests performed during the RFI (1.06×10^{3} to 2×10^{-3} cm/sec); however, the slug test data may reflect the influence of water recharge from the filter pack.

Groundwater was present beneath the site at a depth of 8 feet in July and August 1993, and had been depressed by LNAPLs in the area of the pump island. Groundwater flow is

generally to the south-southeast. An anomalous mound in the potentiometric surface was inferred near well 230-MW4.

2.2.5 Nature and Extent of Contamination

2.2.5.1 Adsorbed Phase Hydrocarbons

Fuel-related contamination was detected in the subsurface soils at, just above, and below the water table. Although the faulty connection beneath the pump island is considered the primary source of hydrocarbons in the subsurface at the site, another possible source of contamination is the Building 827 oil-water separator. Concentrations in soil ranged from not-detected at the perimeter of the plume to a maximum concentration of 9,840 ppm TPH at a depth of 9 feet in soil boring 230-SB8, in the approximate center of the LNAPL plume. The distribution of adsorbed phase hydrocarbons is illustrated in Figure 2-6. Soil in excess of 1,000 ppm is present over an approximate 0.4-acre area. The average soil concentration in this area, excluding values below the detection limit, is 4,500 ppm TPH. Benzene concentrations in soil ranged from not-detected to a maximum of 190,000 ppb (190 ppm). No metals concentrations were detected in soil above established background levels.

2.2.5.2 LNAPL and Dissolved Phase Hydrocarbons

LNAPL was detected over an approximate 8,300 square foot area (0.2 acres), directly beneath and downgradient of the fuel pump island (Figure 2-7). Dissolved-phase contamination is estimated to extend just beyond the lateral extent of LNAPL. In July 1993, apparent LNAPL thickness ranged from 0.1 feet at the edge of the LNAPL plume to approximately 2.7 feet beneath the fuel pump island. Based on baildown/recharge test results, a representative LNAPL thickness of 1.6 feet in well 230-MW5 was estimated in the RFI report (Woodward-Clyde, June 1994). Baildown/recharge test results are reevaluated in Section 2.2.6.2.

2.2.6. Mass Balance Calculations Building 828

2.2.6.1 Preliminary Estimate

A preliminary estimate of the mass of hydrocarbons in the subsurface at Building 828 was made during the RFI (Woodward-Clyde, June 1994). The areal extent of LNAPL, determined by approximating a "zero thickness" line for wells or borings in which a measurable thickness of LNAPL was detected, was estimated to be 8,350 ft^2 (0.2 acres). The areal extent of the LNAPL plume was re-calculated for this report using Auto-CAD™. This calculation yielded the same area as that estimated in the RFI report. The representative thickness of the LNAPL at various locations in the plume was calculated by use of a baildown/recharge test in well 230-MW5. The thickest part of the LNAPL, near the source, was estimated at 1.6 feet, and assumed to gradually thin in all directions to the zero line. The RFI volume calculations used the zero-line area and representative LNAPL thickness to calculate the volume of soil which contains LNAPL in soil pore space. Pore space occupied by the LNAPL was estimated to be 33% of the volume of soil (100% saturation). The amount of LNAPL calculated using this method was approximately 13,000 gallons.

2.2.6.2 Calculation Considerations

Evaluation of Baildown/Recharge Testing

Baildown/recharge testing can give indications of "representative thickness" of LNAPL. One well was tested for measuring representative thickness for the site. The baildown test for well 230-MW5 yielded a representative LNAPL thickness of 1.6 feet. However, not all LNAPL was removed from the well and filter pack (0.9 ft was left) prior to measuring recharge. The resulting test may thus have measured only the initial recharge, which then stabilized at a thickness of 1.6 feet after 130 minutes. The calculated representative LNAPL thickness was 60% of the apparent LNAPL thickness of 2.7 feet.

Chemical Data

Hydrocarbon content in soil was determined by EPA Method 418.1, on soil samples obtained in the 1993 drilling program. The areas from which samples were obtained for analysis were above, in, or below the LNAPL-impacted zone. Analytical results from four soil samples taken in the affected area ranged in value from 1,300 to 9,840 ppm. The average concentration was 4,500 ppm. Based on experience at other sites, this figure is low for soil from a zone with measurable LNAPL. Because of soil and LNAPL similarities between the two sites, the average TPH concentration of 14,400 ppm calculated for the T-38 Test Cell site is conservatively used in this report to calculate mass for the Building 828 site. This concentration represents an average of roughly 14 pounds of hydrocarbons for every 1,000 pounds of soil, or 1.4% extractable hydrocarbon saturation by weight. Based on experience for similar petroleum-contaminated sites, EPA Method 418.1 may not register the light-end hydrocarbons (C_6 to C_8). The 14,400 ppm average concentration may therefore underestimate the hydrocarbon unleaded gasoline content by as much as 20%.

2.2.6.3 Method 1: Average Hydrocarbon Content in Soil

Two methods to refine hydrocarbon mass calculations for Building 828 were utilized. The first method incorporates the following assumptions, which are graphically displayed in Figure 2-8:

- Average hydrocarbon concentration (excluding non-detect or zero values) is 14,400 ppm or 1.44% of soil mass;
- A correction factor of 1.2 is applied to the average hydrocarbon concentration to account for light-end hydrocarbons (C_6 to C_8) potentially not detected by EPA Method 418.1;
- Areal extent of LNAPL is 8,350 ft^2;
- The average thickness of LNAPL and adsorbed hydrocarbons at and above the water in the plume is 2 feet, as determined by observations of stained soil

during drilling, field headspace readings on soil samples, and soil sample analytical results;

- Bulk density of soil is 100 lbs/ft^3; and

- Density of LNAPL is 6.2 lbs/gallon.

The mass is calculated as follows:

- Mass of hydrocarbons = Area (ft^2) x hydrocarbon smear zone thickness (ft) x 100 lbs/ft^3 (bulk density of soil) x 1.44% hydrocarbon concentration x 1.2

  = 8,350 ft^2 x 2 ft x 100 lbs/ft^3 x 0.0144 HC x 1.2 = 28,858 lbs hydrocarbons

  = 4,654 gallons

2.2.6.4 Method 2: Pore Saturation Estimate

The second method of calculation incorporates the following assumptions, and is illustrated in Figure 2-8:

- 20% hydrocarbon saturation (oil to air ratio) in capillary fringe;

- Initially 100% water saturated soil below the water table, with 10% pore space by volume replaced by hydrocarbons;

- 1 foot of LNAPL mounding near the source in the capillary fringe, tapering uniformly to the zero line;

- 2 feet thickness of oil and water saturated soil near the source below the water table; an inverted cone tapering uniformly to the zero line;

- 8,350 ft^2 of LNAPL;

- 43% porosity of sediments; and
- 8.4 gallons per ft^3 (conversion factor).

Mass of Hydrocarbons in Capillary Fringe (Vadose Zone)

= Area (ft^2) x height (ft) x 0.33 (area of cone) x 43% porosity x 20% saturation (oil to air)

= 8,350 ft^2 x 1.0 ft x 0.33 x 0.43 x 0.2 = 237 ft^3 hydrocarbons

237 ft^3 hydrocarbons x 8.4 gal/ft^3 $\approx$ 1,991 gallons hydrocarbons

Mass of Hydrocarbons in Water-Saturated Zone

= 8,350 ft^2 x 2 ft x 0.33 x 0.43 x 0.1 = 237 ft^3 = 1,991 gallons hydrocarbons

Total = 1,991 + 1,991 = 3,981 gallons hydrocarbons

Oil to water and oil to air saturation values used are at the high end of reported saturation values (Huntley, et al, 1994). If these values are assumed to be 5% and 10%, respectively, the calculated mass is reduced by 50% to 1,991 gallons.

2.2.7 Actual or Potential Exposure Pathways

Actual and potential exposure pathways were assessed in the RFI Report, and are summarized in Figure 2-9. Groundwater at Holloman AFB is not of drinking water quality, therefore modeling of contaminant fate and transport in groundwater was not performed due to lack of exposure pathways to potential receptors. Air modeling was performed to evaluate exposure to volatiles for occupational and future construction workers. Excess lifetime cancer risks and hazard indexes for the child trespasser and base worker are within or below regulatory benchmarks established by the EPA. No complete exposure pathways

exist for key receptor species identified at the site. Therefore, the contaminants of concern in the soil and groundwater pose no unacceptable ecological risks to key receptor species at the site.

2.2.8 Current Status of Remedial Activities

No remedial activities are currently being conducted at Building 828. The site has been proposed as an IRP site by the Air Force, and will become Site SS-60 as soon as final approval from HQ ACC is obtained.

3.0 ESTABLISHMENT OF CORRECTIVE ACTION OBJECTIVES

In order to screen technologies and develop corrective measure alternatives, the CAOs for each site must be established. Table 3-1 identifies the regulatory framework, or applicable or relevant and appropriate requirements (ARARs) within which environmental activities at Holloman AFB must be conducted. Due to the similarity between contaminants and site conditions, CAOs for the T-38 Test Cell and Building 828 are the same.

Risk screening conducted in conjunction with the RFI at the T-38 Test Cell and Building 828 indicates that, based on risk, remediation of soil or groundwater is not necessary, with the exception of possible institutional controls for construction workers at the T-38 Test Cell site in the event of future soil disturbance. Therefore, regulatory guidance and/or base-specific agreements are the primary controls on the CAOs for the sites. Two primary CAOs have been identified for soil and groundwater. The CAOs are summarized in Table 3-2 and discussed in the following sections.

3.1 Soil CAOs

No state or federal soil remediation standards for soil exist for releases from aboveground storage tanks in New Mexico; however, Holloman AFB has adopted a base-wide remediation standard for hydrocarbon-impacted soil of 1,000 ppm TPH and 25 ppm benzene (correspondence from James Bearzi, New Mexico Environment Department (NMED) to Holloman AFB dated 2 November 1992) . Soil at the T-38 Test Cell contains maximum TPH concentrations of 77,000 ppm, and benzene concentrations of 170 ppm. Soil at Building 828 contains maximum TPH concentrations of 9,840 ppm, and benzene concentrations of 190 ppm. The NMED has proposed draft regulations which amend the New Mexico Water Quality Control Commission (NMWQCC) regulations, and introduce standards for the vadose zone (soil), vapor, and LNAPLs. Proposed Sections 3-203F and 3-203G establish criteria for demonstrating technical infeasibility, and/or demonstrating that compliance with an alternative standard is technically achievable and cost-benefit justifiable. Following adoption of the revised NMWQCC regulations, the soil CAOs for the T-38 Test Cell and Building 828 will be reevaluated to determine if alternative standards are technically feasible or justifiable.

3.2 Groundwater CAOs

Removal of measurable LNAPL on groundwater is required by the NMED. Both sites have measurable LNAPL in excess of 1 foot (apparent thickness). Removal of the LNAPLs would also decrease the likelihood of potential future occupational exposure to hydrocarbon to vapors. Due to the high total dissolved solids (TDS) content in groundwater, the groundwater is not potable, and no dissolved-phase hydrocarbon remediation to meet EPA or NMED water quality standards is required.

3.3 Other ARARs

Other ARARs considered in the CMS are summarized in Table 3-2. These include the required NMWQCC discharge standards for infiltration galleries and injection wells, discharges to the sanitary sewer, and air discharges from vapor recovery/vapor abatement equipment. The T-38 Test Cell has been added to Holloman AFB's list of IRP sites as site SS-59. Building 828 will become IRP site SS-60 as soon as final approval from HQ ACC is obtained. Because the sites are IRP sites, substantive technical compliance is required with applicable standards. However, air and groundwater discharge permits will not be required.

4.0 EXISTING CORRECTIVE MEASURES/LABORATORY OR BENCH-SCALE STUDIES

4.1 Interim Remedial Action at T-38 Test Cell - SS-59/SWMU 229

Pursuant to a Rapid Response contract, IT Corporation is currently installing a remediation system to commence an IRA at the T-38 Test Cell. The action consists of installation of a vacuum enhanced pumping (HVDPE) system and associated aboveground groundwater and vapor treatment systems. A 19-hour pilot test of an enhanced vacuum pumping system was conducted and is described in the Interim Pilot Test Report (IT Corporation, January 1994). Under an applied vacuum of 7 inches of mercury, liquid flow rates from a pilot test extraction well were 1.4 gallon per minute (gpm). Air flow rates of 30 cubic feet per minute (cfm) were attained. Vapor concentrations averaged 90,000 ppmv during the 19-hour test. Results of the pilot test indicate that an effective radius of influence of 20 feet could be achieved under 7 inches of mercury vacuum at the extraction well. Flow rates of fluids were extrapolated based on test data to predict the flow under 15 inches of mercury applied vacuum. A vacuum-enhanced pumping system consisting of 11 wells is proposed for the center 1-acre area beneath the T-38 Test Cell facility, roughly coinciding with the greatest thickness of LNAPL. Construction commenced November 1994, and startup is scheduled for January 1995.

Pilot test data was reviewed for the CMS and a different interpretation of flow rates and radius of influence is considered. First, in evaluating observed vacuum versus distance during the pilot test, a plot of log vacuum versus distance was prepared (Figure 4-1). A straight line was drawn through the points, and the distance to the point of 0.1 inch water column vacuum was determined. This is a vacuum commonly used to determine radius of influence. The radius of influence based on this plot was 31 feet. This radius of influence was observed at an applied vacuum of 7 inches of mercury vacuum. Next, the plot of water level change versus distance (Figure 4-2) was evaluated. After 16.6 hours of extraction, drawdown was 4 inches at a distance of 30 feet.

In order to achieve the desired radius of influence, the IRA design was based on an applied vacuum of 15 inches of mercury. In order to predict flow rates at this vacuum, plots of vapor and total liquid flow rate versus wellhead vacuum were constructed (Figure 4-3 and

Figure 4-4, respectively). The plot of vapor flow rate versus wellhead vacuum predicted a flow of 54 scfm at a wellhead vacuum of 15 inches of mercury. Typically, flow rates will increase with increased vacuum, until a point is reached where turbulent flow and friction loss in the soil limit flow. If the plot is re-evaluated, the point of reduced flow with increased vacuum may have been reached at about 6 inches of mercury wellhead vacuum. If so, vapor flow rate at 15 inches of mercury would be about 38 scfm, a 25% increase with a 100% increase in vacuum. The plot of liquid flow rate versus wellhead vacuum should behave similarly to the plot of vapor flow rate. If the curve is drawn through the origin (0,0), liquid flow rates level off after a wellhead vacuum of 3 inches of mercury. Liquid flow at 15 inches of mercury wellhead vacuum provide only a 21% increase with a 100% increase in wellhead vacuum.

Based on the evaluation of radius of influence and flow rates, it is anticipated that the total liquid flow rate from the IRA will be 19 gallons per minute, and the vapor flow rate will be 420 scfm. Effective radius of influence under an applied vacuum of 7 inches of mercury will be approximately 31 feet.

Under this scenario, the IRA equipment will be able to treat fluids from additional wells. As remediation progresses and dewatering takes place, liquid flow rates will decline, which will provide additional capacity for treatment.

4.2 Bacterial Enumeration Studies

Bacterial enumeration studies were conducted during the RFI to determine the density of total heterotrophic bacteria (THB) and contaminant-utilizing bacteria (CUB). Petroleum hydrocarbons, particularly BTEX compounds and low molecular weight hydrocarbons ($<C_{30}$), are inherently biodegradable. The concentration of petroleum hydrocarbons can limit biodegradation. In particular, biodegradation is usually not considered feasible within zones of LNAPL (until it is removed) or if the concentration of petroleum hydrocarbons are greater than 20,000 mg/kg. LNAPL has been confirmed at both sites and therefore, before bioremediation is considered, the LNAPL should be removed.

If the contaminant is inherently degradable, the next parameter of concern in determining the feasibility of bioremediation is whether the density of bacteria capable of degrading the contaminant is sufficient. This is usually done by measuring the density of THB, as well as the population density of CUB. These tests are qualitative in nature, as the measurement of either the THB or CUB is not considered highly accurate by researchers or practitioners. In general, population densities of THB greater than approximately 10,000 colony forming units per gram of soil (CFU/g) and CUB greater than 1,000 CFU/g are the limits below which bioremediation would be considered questionable.

Upon preliminary review, the microbial data from both sites at Holloman AFB suggest that bioremediation is not feasible. At the Building 828 site, CUB population density is < 100 CFU/g in all samples and THB population densities range from < 10,000 CFU/g to just over 30,000 CFU/g. At the T-38 Test Cell site, CUB levels range from < 100 to 3,000 CFU/g and THB levels range from < 100 to 85,000 CFU/g. However, in examining the individual samples, and comparing the microbial data with the chemical data, a preliminary correlation was made. For the Building 828 site, those samples collected in areas in which no contaminants were detected had the lowest population densities for THB. Alternatively, the sample in which there were detectable concentrations of hydrocarbons had the highest population density for THB. Population density for CUB at the Building 828 was not correlated to contaminant level. At the T-38 site, both THB and CUB populations densities appeared to positively correlate with hydrocarbon concentrations. The correlation suggests that at both sites the indigenous microbial population is limited by a carbon source and that by supplying a carbon source (i.e., the hydrocarbons) the indigenous population is able to grow and multiply. This would then suggest that bioremediation may be feasible.

Examination of the chemical data provided does not indicate that there are any major limitations to bioremediation. The pH is approaching the commonly accepted maximum (pH 8) for efficient bioremediation but is not prohibitively high. It would need to be monitored closely and possibly adjusted if bioremediation was implemented at either site.

All metal species measured were at acceptable levels for bioremediation. Total salt content may be of concern but did not appear prohibitive. Microbial nutrients (such as nitrogen and phosphorus) appeared to be adequate, although this is usually not considered

important in determining feasibility because nutrients are usually added as part of implementing bioremediation.

Based on the results of the review, in situ bioremediation at these sites is deemed to be potentially feasible. The contaminant and chemical properties of the two sites are conducive for bioremediation. However, the population densities are very low and even though there is some information to suggest that the population densities are primarily limited by the availability of a carbon source, that data is limited and inconclusive. It is therefore recommended that before further considering bioremediation, a laboratory bench feasibility study be performed to examine in detail the feasibility of using bioremediation. These tests could then be followed by field in situ respirometry tests, which more accurately measure the rate of degradation that can be expected.

5.0 SCREENING OF CORRECTIVE MEASURE TECHNOLOGIES AND IDENTIFICATION OF CORRECTIVE MEASURE ALTERNATIVES

5.1 Technology Screening

In order to screen corrective measure technologies and identify potential corrective measure alternatives, the following information should be considered:

1. Type of contaminants
2. Magnitude of contamination
3. Medium which requires corrective action
4. Levels necessary for closure (CAOs)
5. Technical feasibility of attainment of closure levels
6. Time frame for remediation
7. Costs to accomplish the remedial objective

The first three elements were determined in the RFI and are summarized in Section 2.0. The CAOs are identified in Section 3.0. The contaminants at the two sites are JP-4 at the T-38 Test Cell and unleaded gasoline at Building 828 in the dissolved, separate, and adsorbed phases. The geology is very similar for both sites (fine-grained soil from grade throughout the soil column) as well as the hydrogeology (depth to water was less than 20 feet below grade). CAOs are the same for both sites.

The major difference between the two sites was the magnitude of the releases. Preliminary estimates were 1.8 million gallons JP-4 at the T-38 Test Cell, and 13,000 gallons of unleaded fuel at Building 828. These figures have been conservatively revised to 485,000 gallons and 4,600 gallons, respectively.

Initial screening for remedial technologies was accomplished by utilizing flow charts for developing remediation strategies (Figures 5-1, 5-2, and 5-3). These charts are specific for petroleum hydrocarbon contamination, which includes both JP-4 and unleaded gasoline.

Figure 5-1 outlines the route to closure for a petroleum-contaminated site by identifying the hydrocarbon phase, the primary technology that is appropriate for addressing that phase, and the secondary technology alternatives. The technologies identified are:

- no action
- bioremediation
- excavation with treatment options
- air sparging/vapor extraction
- groundwater recovery systems (pump and treat)
- total fluid (high vacuum dual phase extraction (HVDPE))
- steam injection

These technologies were combined into potentially viable alternatives and received further evaluation and relative scoring for appropriateness in Section 6.0 of this report.

Figure 5-2 is more specific to vadose remediation using soil vapor extraction or excavation. Selection of technology is dependent on:

- depth-to-water
- quantity of soil to be remediated
- presence of LNAPL
- acceptable treatment time

Figure 5-3 is specific to the saturated zone. Critical elements for determining technology are:

- permeability/transmissivity
- presence of LNAPL
- thickness of saturated zone
- heterogeneity of geology
- remediation/containment requirements

In situ LNAPL recovery technologies are illustrated in Figure 5-4. Critical elements for LNAPL recovery are:

- permeability/transmissivity
- type of LNAPL
- rate of LNAPL recovery

Vadose zone treatment via soil vapor extraction is outlined in Figure 5-5. This chart is applicable for activities occurring following LNAPL removal.

All of the technologies listed have the capability to remediate petroleum hydrocarbons if applied in the correct hydrogeological environment. Some of the technologies are more feasible for the subject sites given the size of the LNAPL plumes, logistics at the sites (buildings are present), cost-effectiveness, and health and safety considerations.

5.2 Identification of Corrective Measure Alternatives

The following section contains a brief description of each alternative evaluated in Section 6.0. The descriptions should aid in understanding the applicability of each technology to the sites.

5.2.1 Alternative 1: No Action

This alternative has been included to provide a baseline by which to compare other alternatives as required by the CMS. Under the no action alternative, it is assumed that in order to fulfill the corrective action objectives that petroleum hydrocarbons in the soil and groundwater will naturally dissipate via attenuation, biodegradation, and dilution to the established CAOs. The exposure assessments and risk screenings performed in the RFI indicate that no remediation is necessary to protect human health or sensitive receptor species, with the exception of possible institutional controls to protect future base workers from an occupational exposure.

5.2.2 Alternative 2: High Vacuum Dual-Phase Extraction (HVDPE) or Vacuum Enhanced Pumping

HVDPE, the technology selected for the IRA at the T-38 Test Cell, is a technique whereby a vacuum is exerted on a well that is completed into an aquifer. The resultant vacuum causes groundwater, LNAPL, and soil gas to be extracted from the well. The liquids and gas are subsequently separated at the surface, and the soil gas and groundwater can then be treated, as needed. The HVDPE method results in removal of soil gas from the vadose and capillary fringe areas. Dewatering also occurs which allows for the extraction of soil gas from the previously saturated zone. HVDPE can be an effective method for soil and groundwater remediation when the contaminants to be removed are volatile organic compounds, and groundwater yield from the aquifer is low. HVDPE is also attractive at sites where groundwater fluctuations create a zone of contamination that is intermittently saturated, and thus cannot be remediated by vapor extraction alone.

HVDPE is essentially the combination of soil vapor extraction and groundwater pump and treat systems. It is a simple system, which relies on one pump to remove liquids and gases. As with soil vapor extraction, the addition of oxygen to the subsurface promotes the growth of indigenous hydrocarbon-consuming microorganisms. The movement of soil gas through the saturated zone as a result of dewatering promotes mixing, which increases the surface area of hydrocarbons exposed to vapor extraction. All of these mechanisms work together to increase mass removal rates and promote biodegradation.

HVDPE requires the application of relatively high vacuum to a well head. The vacuum required to remove liquids from the subsurface depends on the depth to groundwater and the permeability of the formation. HVDPE relies on the principles of gas lift to remove liquids. The addition of soil gas to groundwater reduces the density of the liquid, allowing it to be removed either as liquid entrained in gas, or simply by the energy of the applied vacuum. If formation permeability is too low, it may be difficult to achieve flow of soil gas, which will limit the effectiveness of HVDPE. Conversely, if formation permeability is too high, adequate vacuum may not be available to remove liquids.

A variety of well types can be employed by HVDPE, such as wells screened both above and below the water table. HVDPE can be accomplished by attaching vacuum piping directly

to the well head, or by using a drop tube inside a well. The advantages and disadvantages of different well construction and attachments depend on the particular nature of the formation and the contaminant plume. As a rule of thumb, a well should be screened across the zone of contamination.

Once both liquid and soil gas are brought to the surface, the two streams must be segregated and subsequently treated as necessary for discharge or reinjection into the surrounding environment. Typically the liquid is routed through an oil-water separator, where the LNAPL is removed. Recovered water is then treated to meet applicable discharge standards. Soil gas is routed through vapor abatement equipment, as required, prior to discharge to the atmosphere.

Because of the potential for high rates of biodegradation, the presence of high levels of carbon dioxide and low levels of oxygen must be considered when evaluating vapor abatement options. Thermal oxidation systems require adequate oxygen to completely burn the hydrocarbons. High levels of carbon dioxide can skew the readings of some hydrocarbon detection instruments. These factors must be evaluated prior to and during HVDPE operation.

5.2.3 Alternative 3: In Situ Treatment via Bioventing

This alternative considers in situ treatment of LNAPL and adsorbed hydrocarbons to levels which will achieve the remediation goals via bioventing. The alternative involves the use of common aerobic soil bacteria to degrade organic contaminants. It requires the stimulation of indigenous bacteria through the addition of essential nutrients: primarily oxygen, and possibly phosphorous and nitrogen. Organic contaminants are converted into carbon dioxide and water by bacteria. The key to successful in situ bioventing is transporting oxygen to the contaminated area. If LNAPLs are present, bioventing is not applicable. However, operation of a groundwater extraction system in conjunction with bioventing causes the LNAPLs to be absorbed to the soil column, thereby creating more surface area, and reducing the toxicity of the hydrocarbons.

The rate of biodegradation can be calculated based on oxygen uptake and carbon dioxide production data. Carbon dioxide is a direct result of the biodegradation of organic

material by microorganisms in soil and groundwater. In general, approximately 30-60% of organic carbon degraded by bacteria is released as carbon dioxide. Because of this direct relationship between biodegradation and carbon dioxide production, the monitoring of carbon dioxide can be used to determine the mass of contaminant being degraded. Also, monitoring carbon dioxide production is an effective way to assure that bioremediation is proceeding efficiently. For example, a significant reduction in carbon dioxide production can indicate an imbalance in the biological system. This imbalance can result from a lack of nutrients or oxygen, from the presence of microbial-inhibiting substances, or some other condition in the system.

As with carbon dioxide production, oxygen uptake is a direct measure of biodegradation. While more difficult to measure, respirometry tests can be conducted periodically to evaluate the rate of biodegradation. In situ respirometry tests are conducted utilizing an inert tracer, such as helium, to monitor air permeability and oxygen uptake in the subsurface.

5.2.4 Alternative 4: Excavation with Disposal at an Off-site Landfill

This alternative assumes that all soil in excess of 1,000 ppm TPH and 25 ppm benzene is excavated and hauled without further treatment to an off-site facility for disposal. Based on the conservative estimate of the volume of soil which is impacted with LNAPL, this, and all other subsequent alternatives which include soil excavation and treatment, assume a total volume of 350,000 cubic yards at the T-38 Test Cell and 20,000 cubic yards at Building 828. Soil would be excavated to a depth of 5 to 18 feet, characterized for hazardous waste constituents (flashpoint, metals, benzene), profiled, manifested and hauled to the facility located in Sunland Park, New Mexico. Clean fill would be imported to replace the disposed soil. This and all other on-site excavation alternatives conducted in conjunction with dewatering could remove LNAPLs. Excavation to meet the CAOs at the T-38 Test Cell and Building 828 cannot be performed without demolishing buildings.

No pilot testing or bench testing is necessary; however, dewatering may be required. Dewatering would require treatment and disposal of pumped water. Health and safety considerations such as vapors, open excavations, and operation of heavy machinery would be substantial.

5.2.5 Alternative 5: Excavation with On-site Treatment via Thermal Desorption

All impacted soil is excavated and treated on site via a thermal desorption unit to less than 1,000 ppm TPH in this alternative. Treated soil concentrations are verified via laboratory analysis, and soil is returned to the excavated areas. A typical thermal desorption system processes soil at an elevated temperature of 600 to 1,500°F, causing the soil contaminants to volatilize. Vaporized contaminants are condensed and captured. The water from the soil is treated and reapplied to the soil for dust control. Treated soil is typically returned to the site as clean backfill. The concentrated contaminants are collected and transferred off site for further treatment/disposal. Because the vapors are captured and recondensed, no process water or process gas is discharged, possibly eliminating the need for a water discharge or air discharge permit. The thermal desorption unit can process approximately 600 tons per day. Approximately two weeks are needed to set up the system, which requires approximately one acre for set up.

A trial burn or pilot test is recommended to determine the minimum operating temperature at which all petroleum hydrocarbons can be desorbed, and to determine if desired cleanup levels can be obtained. The same concerns regarding excavation and dewatering of the sites as stated in Alternative 4 apply to this technology. The thermal desorption unit may require a treatment permit from the NMED Air Pollution Control Bureau (APCB).

5.2.6 Alternative 6: Excavation with On-Site Aboveground Bioremediation

Under this alternative, impacted soil is excavated (in phases), aboveground bioremediation cells are constructed, and aboveground bioremediation is conducted through nutrient addition and vapor extraction to enhance oxygen content of the soil. Soil is treated to 1,000 ppm TPH and 25 ppm benzene; and treatment is verified via laboratory analysis of representative samples. Treated soil is returned to open excavations.

A bioremediation feasibility study should be conducted to determine the appropriate nutrient concentrations for effective bioremediation and to determine if the native biological populations are present to degrade the petroleum hydrocarbons. Aerobic

bioremediation in aboveground cells may not effectively treat any heavier-end hydrocarbons present; these may need to be segregated and treated and/or disposed off-site.

The same concerns with respect to excavation/dewatering apply to this technology. The time frame for remediation is most likely extended due to space limitations and the inherent length of time for effective bioremediation, which is estimated at 12 to 24 months.

5.2.7 Alternative 7: Vapor Extraction

Vapor extraction is a method of removing volatile organic contaminants from the vadose zone. It is most effective in medium to high permeability soil. Vapor extraction stimulates in situ biodegradation through the addition of oxygen to the subsurface as discussed in detail in Alternative 3 - Bioventing. Vapor extraction can be accomplished with vertical or horizontal wells. It is an applicable technology when contamination has migrated under structures, is at depths greater than those at which excavation is feasible, and when there is time to perform the remediation to desired CAOs. LNAPL removal using only vapor extraction is not as effective as combining vapor extraction with groundwater pumping or sparging, which increases surface area for volatilization of LNAPL. Off-gas treatment and air permits are usually necessitated when using vapor extraction. For extremely large sites, the operational costs associated with the vapor abatement often exceed the capital and assessment costs.

Pilot tests for determining radius of influence, well design, blower sizing and treatment equipment are recommended.

5.2.8 Alternative 8: Pump and Treat

Pump and treat, utilizing surface-mounted or submersible dual-phase recovery pumps, is historically the most common remedial technology for LNAPL and dissolved hydrocarbon contamination. This alternative is best suited to those sites where containment or dewatering is required and in medium to highly transmissive aquifers. This technology is

not appropriate for low permeability soil , such as silts and clays, because of the number of well points needed for effective capture, and because complete LNAPL recovery and removal is rarely attained. The technology is best when used in conjunction with others, like vapor extraction, reinjection of water for bioremediation, and trench systems which inhibit plume migration. The time frame for LNAPL remediation solely using pump and treat is lengthy and often technologically infeasible.

5.2.9 Alternative 9: In Situ Air Sparging/Vapor Extraction

This alternative proposes in situ treatment to remediate soil and groundwater to the proposed CAOs via combined air sparging and vapor extraction. Air sparge/vapor extraction points are placed in the center of the LNAPL plume. Air sparging is the injection of air under pressure below the water table to create a transient air-filled porosity by the displacement of water and LNAPL in the soil matrix. Air sparging enhances the physical removal of organics by direct volatile (vapor phase) extraction and stimulates biodegradation by increasing dissolved oxygen content in groundwater. Volatile compounds are carried by the air stream into the vadose zone where they can be captured by a vapor extraction system.

In order to determine design criteria and feasibility of this technology, a sparging/vapor extraction test is necessary. For this technology to be effective, the geology must be somewhat homogenous so that vapors are able to migrate vertically, and the soil must have medium to high permeability.

Because discharges from the vapor extraction system are regulated by the NMED, maximum potential vapor emissions must be determined. If concentrations are in excess of applicable NMED criteria, then emissions treatment would be necessary. The minimum depth to groundwater at which sparging is a feasible technology is 5 feet. Air sparging can result in the mobilization of contaminant plumes or vapors, and therefore is sometimes combined with some sort of containment system, such as a pump and treat system.

5.2.10 Alternative 10: Chemical Fixation/Stabilization

Under this alternative, all impacted soil at the site would be chemically treated on site to stabilize the material, and to reduce mobility of LNAPLs and dissolved-phase hydrocarbons. The process consists of in situ mixing of the soil with a soil boring/mixing tool at a rate of 400 to 1,200 cubic yards per day. In the treatment process, the slurried or stabilization mixture is injected directly into the soil at pressures up to 150 psi, and mixed in situ with the contaminated material. The entire solidification process is performed below grade. The immediate work area is covered with a fiberglass shroud to minimize the release of fugitive dust. Depth of the contaminant is a factor, along with the presence of aboveground structures. Following treatment, the property uses would most likely be limited to those which would not reverse the stabilization process.

This alternative would require a bench-scale study to determine the most efficient stabilization reagent slurry mixture for the project.

5.2.11 Alternative 11: Steam Injection

This alternative is used in conjunction with LNAPL recovery via pumping and water withdrawal technologies. The object of utilizing steam injection (or steam-sparging) is to mobilize hydrocarbons by raising the temperature of the formation. This is done by constructing a network of injection wells, which are in turn connected to a steam generation plant. A temperature of 200 °F is desirable in order to facilitate hydrocarbon movement and overcome the soil/hydrocarbon bond. Specialized equipment and wells are necessary because of the high temperatures and pressures necessary for the process. Energy requirements are high because the subsurface soils have the capability to absorb a tremendous amount of energy.

The LNAPL produced by the steam injection is recovered by pumping wells. Water must be separated from the LNAPL and treated and disposed. At the two sites, the hardness of the water and its proper disposal must be considered.

Pilot testing for feasibility and design would be required. This technology is most appropriate for heavier-chain hydrocarbons such as bunker C or motor oil, for which conventional vapor extraction/air sparging is not applicable.

6.0 EVALUATION OF CORRECTIVE MEASURE ALTERNATIVES

The corrective measure alternatives identified in the previous section are evaluated and ranked for their appropriateness in this section. The basic mechanism for the screening process is a rating system where each potential technology is assigned a numerical value with regard to the following considerations:

1) applicability to the site;

2) relative cost; and

3) treatment time acceptability.

Eleven technologies were screened for LNAPL removal, ten of which were also screened for vadose zone remediation. In addition, vapor abatement options, recovered groundwater treatment technologies, and treated groundwater discharge options were ranked. A screening matrix was used to streamline the evaluation process by organizing and recording rating scores (Tables 6-1 through 6-7).

Once each technology is rated, a simple summation enables the reviewer to eliminate those technologies that show low overall rating scores. Technologies that show high overall rating scores are retained for further consideration on a more detailed level.

A description of the rating process is provided in the following section.

6.1 Rating Process Description

Applicability to Site

The applicability of a technology to remediate contamination at any specific site is evaluated with regard to the specific advantages and disadvantages listed below. Those that are applicable are recorded on the Technology Screening Matrix in the appropriate column.

Advantages

- Mobility reduction (mred): "**mred**" is listed as an advantage when the technology significantly reduces the potential for contaminant migration.

- Destruction (dest): "**dest**" is listed as an advantage when the technology destroys, degrades or otherwise transforms the contaminant to a non-toxic form.

- Volume Reduction (vred): "**vred**" is listed as an advantage when the technology significantly reduces the amount of contamination in the contaminated matrix.

- Performance and Reliable (perf): "**perf**" is listed as an advantage if the technology has a proven track record for treating the given waste in a similar site setting.

- Implementability (i): "**i**" is listed as an advantage when the logistics of designing, obtaining, installing, and operating the technology at the given site appear to be straightforward.

- Exposure Minimization (me): "**me**" is listed if the treatment reduces human exposure to the contaminant.

Disadvantages

- Emerging Technology (et): "**et**" is listed as a disadvantage when a technology is not fully developed. Reliability of the technology is questionable for the specific site.

- Inappropriate Technology (ia): "**ia**" is listed as a disadvantage when site conditions are not technically suitable for the application of the technology.

- Not Permittable (nperm): "**nperm**" is listed as a disadvantage if permitting of the technology at the site is very difficult or impossible to obtain.

- Additional Treatment required (adtrt): "**adtrt**" is listed if technology requires additional equipment or processes to handle contaminant (e.g., off-gas control, carbon polish, etc.).

- Contaminant Not Removed (cnr): "**cnr**" is listed as a disadvantage if significant contamination remains on-site after application of the technology. This may require health risk assessment.

- Area Required (area): "**area**" is listed as a disadvantage if application of the technology would require a large area of the site surface.

- Community Impact (ci): "**ci**" is listed as a disadvantage if the technology could be perceived as negatively impacting the local community or environment.

- Inappropriate Soil Material(smat): "**smat**" is listed if the soil structure is incompatible with treatment process.

- Depth to Water (dtw): "**dtw**" is listed if depth to groundwater is inappropriate for the treatment alternative.

- Not Available (na): "**na**" is listed if the technology is not available for use at the site.

- Potential Negative Interaction (pni): "**pni**" is listed if the treatment alternative may somehow react with constituents at the site producing a negative effect.

- Potential Additional Liability (pal): "**pal**" is listed if the treatment technology may add additional liability.

- Inappropriate Groundwater Contaminant (igc): **"igc"** is listed if the treatment technology does not address the groundwater contaminant of concern.

Relative Applicability Rating

This rating gives a numerical value to the relative applicability of the technology to the specific site with regard to technical merits and the ability to permit the process. This is a subjective rating based upon the listed advantages and disadvantages of the technology applicability as well as any additional professional judgement the author may add.

Relative Costs

This rating gives a numerical value to the relative capital and operating costs incurred in implementing the technology.

- Capital Costs. Relative cost of obtaining and installing the technology at the specific site.

- Operating Costs. Relative cost of operating and maintaining the treatment system at the specific site.

Treatment Time Acceptability

This rating gives a numerical value to the potential of the treatment technology to perform the desired site remediation within an acceptable time frame.

Rating Summation

This is simply the arithmetic scoring of the columns entitled "Relative Applicability Rating (A and P)", "Relative Cost Rating (C and O)", and "Treatment Time Acceptability Rating" (T).

The formula for the Rating Summation calculation is:

Rating Summation = AxPx(C+O+T)

Retain for Consideration

A final decision on whether or not to retain a specific listed technology as a candidate for application is made based upon the relative value of the Rating Summation. Technologies with corresponding high Rating Summation values are retained for further consideration.

6.2 Results of Screening and Scoring Alternatives

6.2.1 LNAPL and Vadose Zone Alternatives

Of all the alternatives for LNAPL and vadose zone remediation, two were consistently high scoring: No Action and High Vacuum Dual-Phase Extraction. The No Action alternative will always score high because of low capital and operating costs. This is an alternative that is typically weighed against economic benefit, health and safety, environmental damage, future land use, and viability of meeting remedial objectives. For both the T-38 Test Cell and Building 828, risk screening indicates that remediation is not necessary, however CAOs of 1,000 ppm TPH and 25 ppm benzene in soil and removal of LNAPL have been established. These goals can be reached by many of the alternatives screened or a combination of alternatives.

HVDPE was ranked high because it was a technology that consistently met criteria for acceptability at these sites. These criteria include:

1) Geology/hydrogeology. HVDPE is best suited in low permeability environments. If permeability is too high, excessive water withdrawal occurs, and the radius of vacuum influence is decreased. Conversely, low permeability environments are not conducive to conventional air sparging and vapor extraction.

2) Contaminant: Volatile hydrocarbons are amendable to remediation by vapor extraction. But LNAPL cannot be readily remediated by vapor extraction alone because of the rate of removal from the LNAPL state is a function of surface area. Increasing surface area requires water table drawdown, which is accomplished by HVDPE.

3) In situ remediation: Both sites are active, with buildings, runways, utilities, etc. Excavation of the LNAPL at either site would be costly and unnecessary if in situ methods are available. If the sites were to be abandoned or if rapid closure time was a critical factor, excavation would be a viable option.

4) Pilot testing/existing equipment: The results of the pilot test for the T-38 Test Cell are very encouraging. The initial 30-day removal rate for JP-4 was 3,000 lbs/day for LNAPL, dissolved, and vapor phase hydrocarbons. This does not include removal rates via bioremediation, which will occur once oxygen is introduced into the subsurface and LNAPLs are removed. This testing adequately demonstrates the viability of HVDPE at these sites. In addition, the existing interim system at the T-38 Test Cell has excess capacity, thereby lowering the capital cost for that site when compared to other alternatives screened.

5) Combination of other alternatives: Vapor extraction combined with air sparging or groundwater pumping are other technologies that may possibly be effective. Because of the low permeability of the site sediments, air sparging with vapor extraction would require tightly-spaced sparge and vent points. Sparging with vapor extraction relies totally on volatilization of the LNAPL; alternatively, HVDPE will physically remove LNAPL. Groundwater pumping systems rely on substantial water table depression to accomplish the objective of dewatering and LNAPL recovery.

For LNAPL thicknesses greater than 0.5 foot, HVDPE is more effective for LNAPL removal than these other alternatives.

6.2.2 Vapor and Recovered Groundwater Treatment Alternatives

After technologies have been identified for remedial applicability, identification of treatment technologies for remediation by-products, such as recovered hydrocarbons, vapors, and wastewater is necessary. Corrective Measures Alternatives Screening Matrices (Table 6-3 to 6-7) list and score technology alternatives for air and water treatment and discharge for the T-38 Test Cell and Building 828 sites.

6.2.2.1 Vapor Treatment at T-38 Test Cell

Vapor treatment alternatives for the T-38 Test Cell are listed in Table 6-3. Because of the capacity to exceed 60 pounds/day and the proximity of the discharge point to workers, no action or direct discharge is not an option at this time. When concentrations of recovered vapors decrease to below the applicable health-based standards, direct discharge may be viable. Disposable and regenerative carbon systems are considered too costly to purchase and/or operate. Regenerable resin has high capital costs, few distributors, and may require high maintenance. Of the thermal systems screened, thermal oxidation scores the highest.

Thermal oxidation units are suitable for the high flow rates and high hydrocarbon vapor concentrations experienced during the pilot tests. These thermal units are available from numerous suppliers and can use both recovered LNAPL and natural gas for support fuel. As concentrations of recovered vapor decrease, these units can be changed over to catalytic oxidizers, thereby reducing the amount of support fuel.

Other thermal systems were limited by capacity (internal combustion unit, gravel bed incinerator, catalytic oxidations) or overall operating costs (flare, gravel bed incinerator).

6.2.2.2 Vapor Treatment at Building 828

The same treatment alternatives as for the T-38 Test Cell were addressed in the Technology Screening Matrix for Building 828 in Table 6-4. The scoring is different, with direct discharge (no treatment) as a possible option. This is primarily because the total volume of soil gas generated by the HVDPE system will be considerably less at the Building 828 site than at the T-38 Test Cell site due to the much smaller mass of hydrocarbons to be removed and the limited areal extent of the contamination. If direct discharge meets health-based exposure standards, this option should be considered. Thermal oxidation tops the scoring because of the capital and operating costs, the ability to convert to a catalytic mode when soil gas concentrations decline, and availability of natural gas for support fuel.

6.2.2.3 Recovered Groundwater Treatment Alternatives for the T-38 Test Cell Site

Technology alternatives for water treatment at this site must consider the high TDS in the water, treatment to 10 ppb benzene for discharge to an infiltration gallery, and the volume of water to be treated. Two options scored high: disposable carbon and air stripping with stacked trays. Pre-treatment for TDS and alkalinity should be part of either system. Costs for disposal/regeneration and transportation of a carbon system could make this system significantly more expensive to operate than tray alternatives depending upon the length of operation. Removing TDS and hydrocarbons with a tray aerator will save carbon and be more cost-effective than carbon alone during the expected lifetime operation of the remedial system. Other air stripper options are high maintenance (packed column will foul and be difficult to clean) or inefficient at removing hydrocarbons to required discharge limits (air dispersion tower). A bioreactor may be applicable depending upon flow rates and influent benzene concentrations, but pilot tests would have to be performed to determine if this is a viable option at this site. In addition, this technology is more labor intensive in its operation than other alternatives screened. UV/oxidation is a capital and operation-intensive method which is not cost effective for readily strippable compounds such as BTEX when compared to other alternatives.

6.2.2.4 Recovered Groundwater Treatment for Building 828 Site

Discharge to the sanitary sewer requires less treatment than discharge to an infiltration gallery. Therefore, a system that can reduce benzene levels to less than 500 ppb at 12 to 20 gpm is most appropriate for this site. Using this baseline for performance, an air stripper with stacked trays scored the highest of the options screened. This system requires no TDS pre-treatment as carbon or packed tower systems do, and is relatively inexpensive to purchase and operate. A bioreactor may be an option because of the low flow rates anticipated and the ability of a bioreactor to easily maintain 90% removal efficiency. Pilot testing would be necessary prior to costing and designing such a unit.

6.2.2.5 Recovered Water Disposal Alternatives

Water disposal options are screened and scored for both sites in Table 6-7. This screening considers discharge to a storm drain, sanitary sewer, and infiltration gallery. The scoring reflects the difficulty of obtaining a NPDES permit for discharge to the storm drain; the availability of and necessity of pre-treatment prior to discharge to the sanitary sewer (500 ppb benzene); and the stringent treatment standard for discharge to an infiltration gallery (10 ppb benzene). Because of the availability and the need for only partial treatment, the wastewater from Building 828 should be discharged to the sanitary sewer. At the T-38 Test Cell, no alternatives other than discharge to an infiltration gallery are available. No sanitary sewer line is present, and the lengthy NPDES process (estimated at a minimum of 2 years) negates the viability of discharge to the storm sewer in the area. To discharge to an infiltration gallery, the water will have to be treated to 10 ppb benzene. To reduce overall operational costs, the possibility of installing a flexible aboveground sanitary sewer line to the nearest existing sewer manhole (less than a one mile run) is an option which should also be pursued.

7.0 JUSTIFICATION AND RECOMMENDATION OF THE CORRECTIVE MEASURE(S)

HVDPE is the recommended corrective measures alternative for both the T-38 Test and Building 828. This alternative is recommended and justified with respect to technical, safety, environmental, human health, and institutional criteria in the following sections.

7.1 Technical Evaluation Criteria

Performance: Performance of HVDPE has been confirmed by the pilot testing at the T-38 Test Cell. The remedial objectives can be met by proper application (number of extraction points, correct size pumps, proper well design and engineering) and time (system will have to operate run a minimum of one year to meet CAOs). In addition to measuring the amount of LNAPL, dissolved and vapor-phase hydrocarbons removed, consideration should be given to the amount of biodegradation occurring as the result of adding oxygen to the formation. Measurements of CO_2 in the vadose zone and dissolved oxygen in groundwater can be helpful in estimating the rate of biodegradation.

Reliability: Conceptually, HVDPE is relatively simple. A high vacuum blower is connected to a series of wells and exerts a vacuum to remove fluids and move air through the formation. Requirements include off-gas treatment for vapors, separators to segregate LNAPL from water, and treatment of recovered water prior to disposal. Final HVDPE design will include transfer pumps, filters, safety interconnects, and a control panel for the equipment. The design and application for HVDPE is not new. Most of the equipment can be purchased as skid-mounted, pre-engineered packages, and is of industrial grade. Construction can be modular allowing rapid and inexpensive system modification during site remediation.

The vapor and water treatment equipment can be purchased pre-designed from a number of vendors. Factory warranties for moving parts are available, and factory training is provided for the technicians performing the operation and maintenance. HVDPE systems are as reliable as vapor extraction or groundwater pumping systems, and significantly more reliable than steam-injection systems. Hard water will have an impact on the equipment; pretreatment of recovered groundwater will be necessary to prevent costly maintenance.

Implementability: In situ remediation is the option best-suited for both sites. An in situ system can be constructed without adverse operational impact at either site. The HVDPE system will require a treatment compound, but there is sufficient room at both sites. Below ground piping and at grade well-heads can be constructed. Power for electrical needs is readily available along with natural gas for support fuel for the vapor treatment units. A sanitary sewer is available at the Building 828 site for water disposal, but an infiltration gallery must be constructed to accept water at the T-38 Test Cell site. LNAPL recovered during remediation will be recycled or used for supplemental fuel for the air treatment units. Permits for building and operation will not pose insurmountable problems. Duration of operation is estimated to be between one and four years at the T-38 Test Cell and considerably less at Building 828.

Safety: All operational equipment will be confined to a fenced treatment compound. Excavation hazards will consist of minor trenching runs from the extraction wells to the treatment component. Exposure to VOCs during construction activities should not be a factor because of the depth of the LNAPL. The remedial equipment will have safety interlocks to prevent exposure to untreated air or water. Explosion-proof (XP-rated) equipment will be provided per Hazard Area Classification requirements identified in the design phase. No

residences are near the sites, but on-site workers will have the potential to be exposed to vapor emissions. The treated emissions will be below occupational exposure levels for the chemicals of concern at the sites, primarily BTEX. All personnel working on or monitoring the equipment will be required to read the Site Safety and Health Plans (SSHP) and to have OSHA training if necessary.

In the event of a release from the remedial equipment, response actions per the SSHP will be enacted. Fire department emergency response crews and site personnel will be informed about the operation of the equipment and of the location of master shut-down switches. The site safety procedures will be reviewed by representatives of Holloman AFB prior to commencing additional field work, construction, or operation of the remedial systems.

7.2 Environmental Evaluation Criteria

The corrective measure is proposed as in situ systems to remove LNAPL (JP-4 and unleaded gasoline) and reduce TPH and benzene in soil to 1,000 ppm and 25 ppm, respectively. All discharges will meet substantive technical permit requirements. Recovered LNAPL will be recycled or used for fuel for the air treatment unit. The HVDPE system is the best option to meet remedial objectives in a timely fashion.

7.3 Human Health Evaluation Criteria

In situ treatment technologies are inherently more protective of human health than ex situ technologies, which require use of heavy machinery and often lead to exposure to dust and vapors from the excavations. Exposure to chemicals will be mitigated by strict adherence to OSHA standards set forth in the SSHP. Air monitoring will be conducted during all field activities, such as construction and sampling, to ensure worker safety. Fire codes will be enforced for the handling of flammable liquids. Recovered vapors and water will be discharged at or below established human health standards.

7.4 Institutional Evaluation Criteria

The selected remedial alternative, HVDPE, should be able to achieve the CAO of LNAPL removal. It is the best available technology that can remove TPH and benzene in soil to technically feasible levels. The corrective measure, as implemented at each site, will comply with the ARARS identified in Table 3-2.

7.5 Conceptual Remedial System for T-38 Test Cell Site

7.5.1 System Description

Based on a review of HVDPE pilot test data and the IRA system design, there is sufficient capacity of many components of the IRA system for use in full-scale remediation efforts. The following summarizes the IRA system design capacity, and expected usage from the interim system, illustrating the excess capacity for soil vapor and groundwater treatment.

Component	Capacity	Expected Usage
Thermal oxidizer	5,000 cfm	420 cfm
Vacuum pump	600 cfm	420 cfm
Separator	375 gal.	375 gal.
Transfer pumps	40 gpm	20 gpm
Oil-water separator	60 gpm	20 gpm
Bag filters	200 gpm	20 gpm
Tray aerator	60 gpm	20 gpm
Tray aerator pumps	40 gpm	20 gpm
Liquid phase carbon	60 gpm	20 gpm

Calculation of hydrocarbon mass remaining in the subsurface ranges from 2,000,000 to 3,000,000 pounds at the T-38 Test Cell. From the pilot test data, it is expected that soil vapor flow rates will be 38 cfm per well, and liquid flow rates will be 1.7 gpm per well under an applied vacuum of 15 inches of mercury. Radius of influence under 15 inches of mercury vacuum is expected to be 40 feet.

The area of the LNAPL plume is 10.9 acres or approximately 480,000 square feet. Assuming each extraction well has a 40-foot radius of influence, 108 wells laid out in a five-spot well formation are necessary to provide adequate coverage over the entire LNAPL plume. This is an addition of 96 wells to the IRA system. Operating 96 additional wells will add 163 gpm to the groundwater treatment system, and 3,648 cfm to the vapor treatment system, for total volumes of water and soil gas to be treated of 193 gpm and 4,068 cfm respectively. Based on this scenario, the IRA vapor treatment system can treat the soil gas, but the water treatment system would have to be expanded by adding oil-water separators and tray aerators.

It is proposed that seven vacuum pumping stations be installed at various locations over the contaminant plume. Each station would extract from up to 14 wells, and would separate the recovered liquid from vapor at the pump. The fluids would then be pumped to the central compound for treatment. A conceptual process flow diagram is provided in Figure 7-1.

In order to estimate cleanup time and cost, Groundwater Technology's Vapor Abatement Cost Analysis Program was used. Input to the program includes estimated mass of contaminant present, initial hydrocarbon concentration in extracted soil gas, and vapor abatement equipment specifications. With this data, the program calculates total time of removal of the contaminants assuming an exponential decline in hydrocarbon concentration in soil gas. Cumulative costs for vapor abatement are then calculated, incorporating both capital and support fuel costs. Several runs were made using different assumptions. All runs assumed use of a 5,000 cfm thermal oxidizer with a total flow from wells of 4,000 cfm. Results are provided in Appendix A. Assuming 3 million pounds of hydrocarbons, results of the computer modeling shows that 90% of the contaminants present could be removed within a year, with all wells open and the system 90% operational. Estimated cost would be approximately $260,000 for the thermal oxidizer and support fuel. This does not assume any recovered fuel would be used as support fuel. After two years, 99.6% of the mass would be removed, at a cost of about $760,000 for equipment and support fuel.

The system can be constructed so that the vacuum blowers can inject air into the ground at any point during the remediation in order to biovent. This may be especially useful towards the end of the project when support fuel costs are high and mass removal rates are low.

Preliminary estimated installation, capital equipment, and operation and maintenance costs are summarized in Table 7-1.

7.5.2 Process Options Considerations

In situ remediation of volatile organic compounds is a dynamic process. Over the course of remediation, conditions continually change, such as mass of contaminants, soil moisture content, and relative air permeabilities. Because of these changes, a remedial system must be able to be modified in order to cost effectively proceed towards closure. For the T-38 Test Cell, the remedial system proposed is expected to be able to meet closure criteria in a reasonable time and for a reasonable cost. In order to expedite cleanup and conserve resources, the following process options are proposed.

Since the design of the IRA system and the conceptual design of the full-scale remedial system are based on limited pilot test data, there are some uncertainties regarding actual system operation following start up. The IRA system is currently under construction and will be operational in January 1995. Operation of this system offers an excellent opportunity to gather data and determine more accurately system operating parameters. Operating data such as fluid flow rates and radius of capture at design flow rates, hydrocarbon mass removal rates, inorganic fouling and energy consumption will be evaluated from the data collected during interim system operation. These results will be incorporated into the design of the full-scale remedial system.

As HVDPE remediation progresses, the mass removal rate will decline. As this happens, support fuel usage will increase for the thermal oxidizer. When concentrations drop to less than 3,000 ppmv, it is more economical to convert the thermal oxidizer to catalytic operation by installation of a precious metal catalyst. This will allow oxidation of

hydrocarbons to occur at temperatures of 600 °F, and will reduce support fuel requirements by about 60%. As concentrations continue to decline and mass removal rates fall, at some point it will be possible to meet the NMED's direct discharge limit of 60 lbs/hr discharge without treatment. At that time, the catalytic oxidizer could be turned off and vapors discharged directly without treatment.

In addition to the physical removal of hydrocarbons by HVDPE, biological processes will biodegrade hydrocarbons in the subsurface. The addition of oxygen to the subsurface by HVDPE will enhance naturally-occurring microbial populations, which will consume hydrocarbons. When mass removal rates decrease, the extraction blowers can be reversed to inject air into the subsurface at relatively low flow rates. This will provide a cost effective method of enhancing biodegradation, and will help to remove the less volatile and less mobile hydrocarbons that are not readily extracted by HVDPE.

Because of the very high concentrations of dissolved solids, and the high alkalinity of the groundwater, fouling problems in the water treatment and reinjection system are anticipated. Data can be collected during the IRA system operation to provide an estimate of the magnitude of the problems, and this information will be used to design the final remediation system. At some point in the future, when anticipated development is completed, it may be possible to discharge treated groundwater into the sanitary sewer. This would simplify the water treatment system due to the less stringent discharge requirements, which would in turn reduce overall treatment costs.

Operation of the entire remedial system will require constant evaluation in order to maximize efficiency and minimize costs. With feedback from operation of the interim system, and during operation of the final system, decisions can be made to change vapor treatment to catalytic oxidation or direct discharge, modify water treatment to minimize fouling and maximize removal efficiencies, and change discharge points when possible. In addition, the system will be flexible to allow for segments of the HVDPE system to biovent, or direct discharge, or be turned off, while other segments are still operated in HVDPE mode.

7.6 Conceptual Remedial System for Building 828 Site

Based on an LNAPL plume of approximately 8,350 square feet, and lithology similar to that of the T-38 Test Cell, a HVDPE system is also proposed for remediation of soil and groundwater at Building 828. Installation of five extraction wells is proposed in the area of the fuel pump island, each capable of delivering 40 cfm of soil gas and 2 gpm of liquids. Vapor abatement would consist of one 250 cfm thermal oxidizer. Water treatment would consist of separation in an oil-water separator, stripping in a tray aerator to the sanitary sewer discharge criteria, and discharge to the sewer. Conceptual process flow is displayed in Figure 7-2.

Based on Groundwater Technology's Vapor Abatement Cost Analysis Program, assuming 40,000 pounds of contaminant are present, the time to remove 95% of the contaminants would be six months with the system 90% operational and all wells open, at a cost of $55,000 for vapor abatement equipment and fuel. Results are provided in Appendix B.

As with the system at the T-38 Test Cell, this system would rely on bioremediation to aid in contaminant removal. An in situ respirometry test should be conducted prior to and during remediation, along with regular monitoring of carbon dioxide production. The system is proposed to be designed so that the vacuum blowers can be reversed and air can be injected to conduct bioventing at any point during remediation. The process considerations described in Section 7.5.2 are also applicable to this site with respect to changing the vapor abatement technology to catalytic and direct discharge modes as remediation progresses. Preliminary estimated costs to design, install, and operate this system are summarized in Table 7-2.

8.0 REFERENCES

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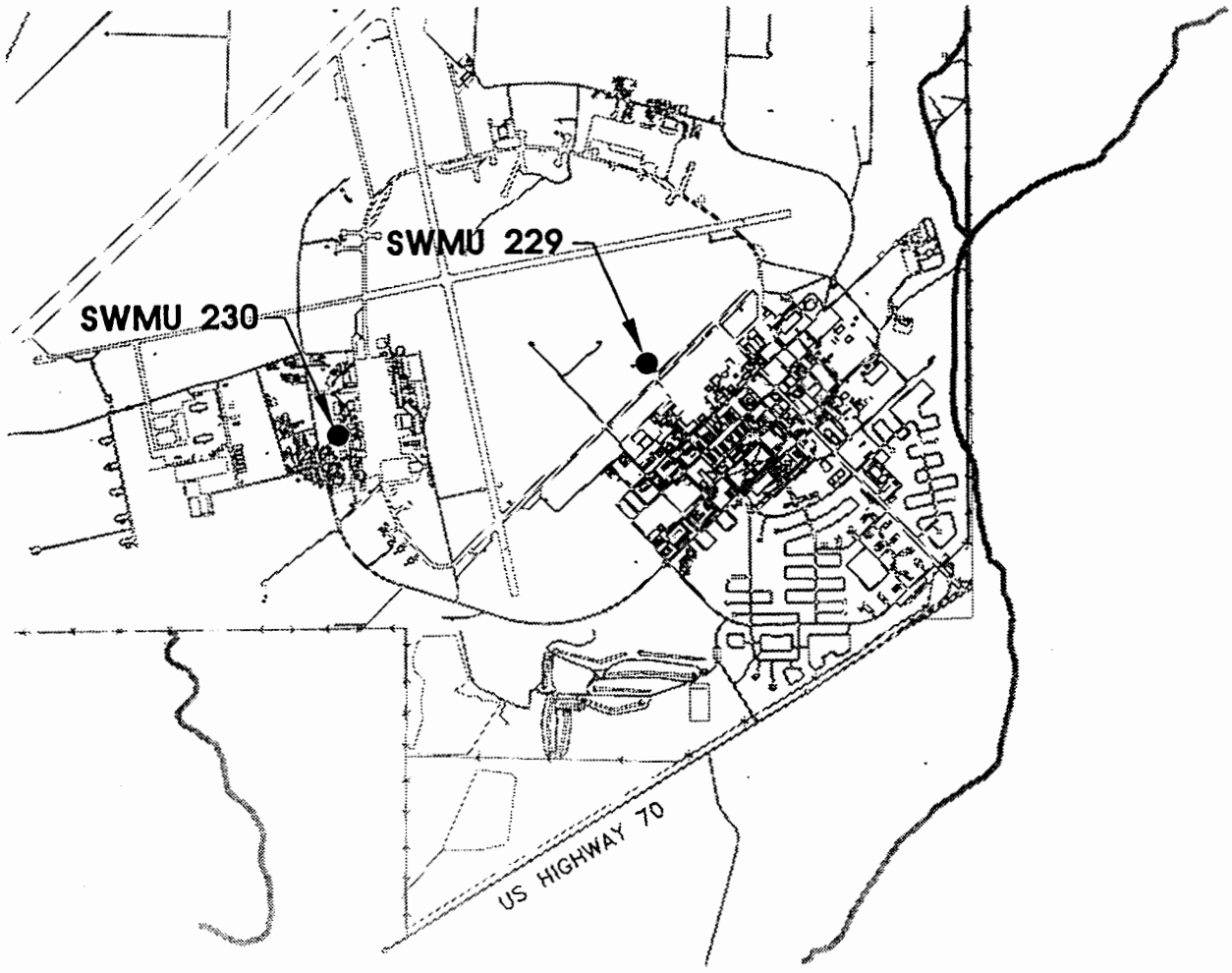
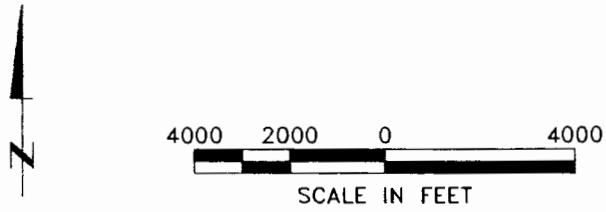




From Woodward–Clyde, June 1994

DRN BY: CJG	DATE: 10/05/93	SWMU LOCATION PLAN HOLLOMAN AIR FORCE BASE NEW MEXICO	FIGURE 2–1
CHK'D BY:	DATE:		

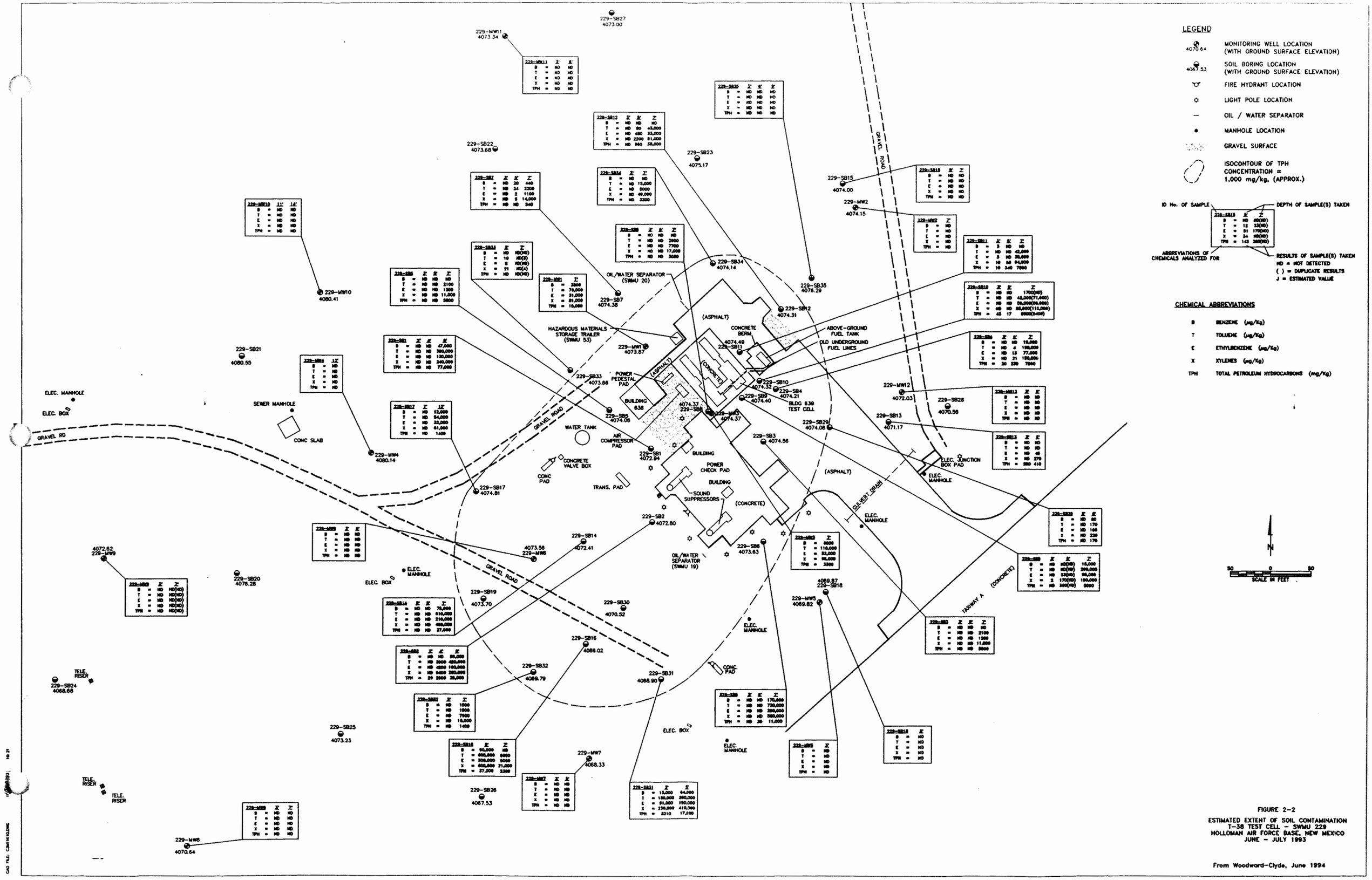


FIGURE 2-2

ESTIMATED EXTENT OF SOIL CONTAMINATION
T-38 TEST CELL - SWMU 229
HOLLOMAN AIR FORCE BASE, NEW MEXICO
JUNE - JULY 1993

From Woodward-Clyde, June 1994

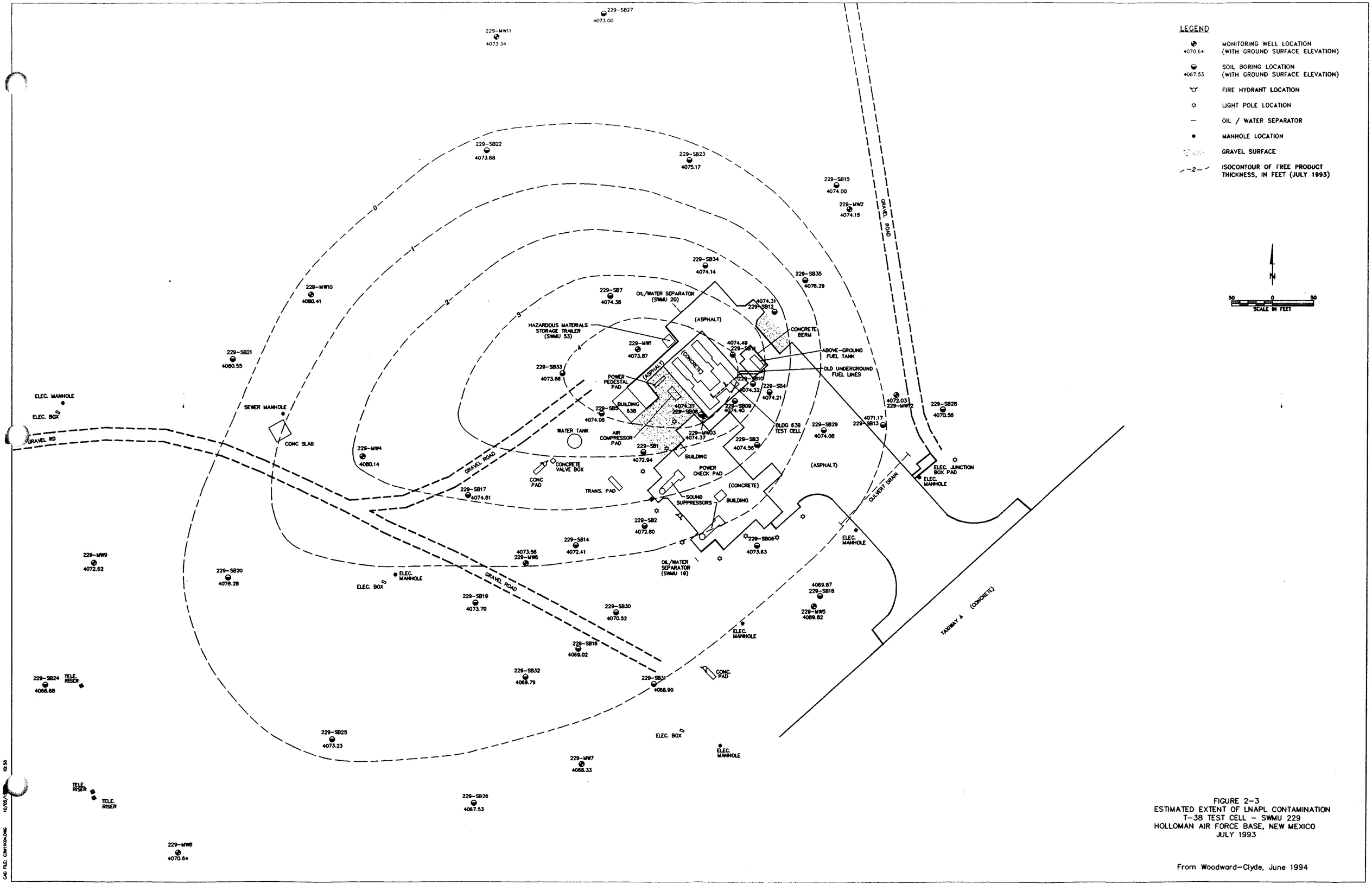
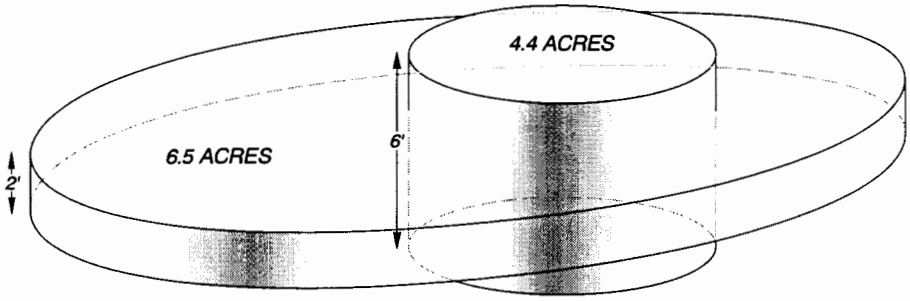


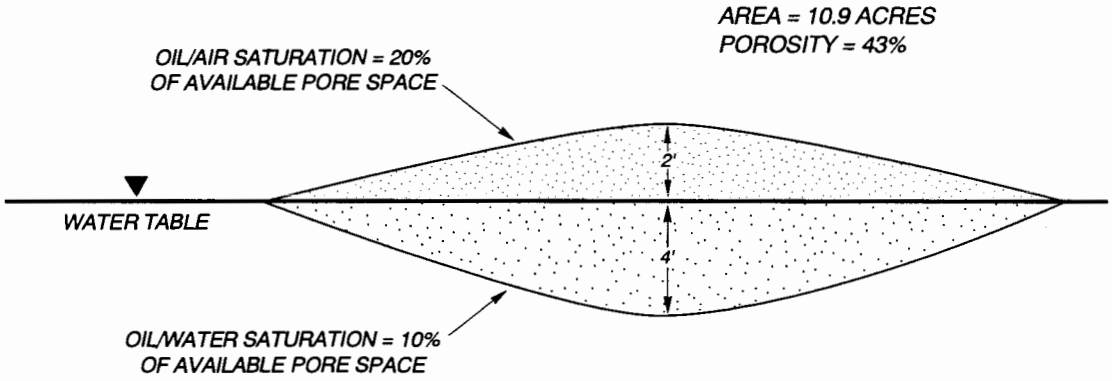
FIGURE 2-3
ESTIMATED EXTENT OF LNAPL CONTAMINATION
T-38 TEST CELL - SWMU 229
HOLLOMAN AIR FORCE BASE, NEW MEXICO
JULY 1993

From Woodward-Clyde, June 1994

METHOD 1: MASS BALANCE USING AVERAGE HYDROCARBON CONTENT IN SOIL



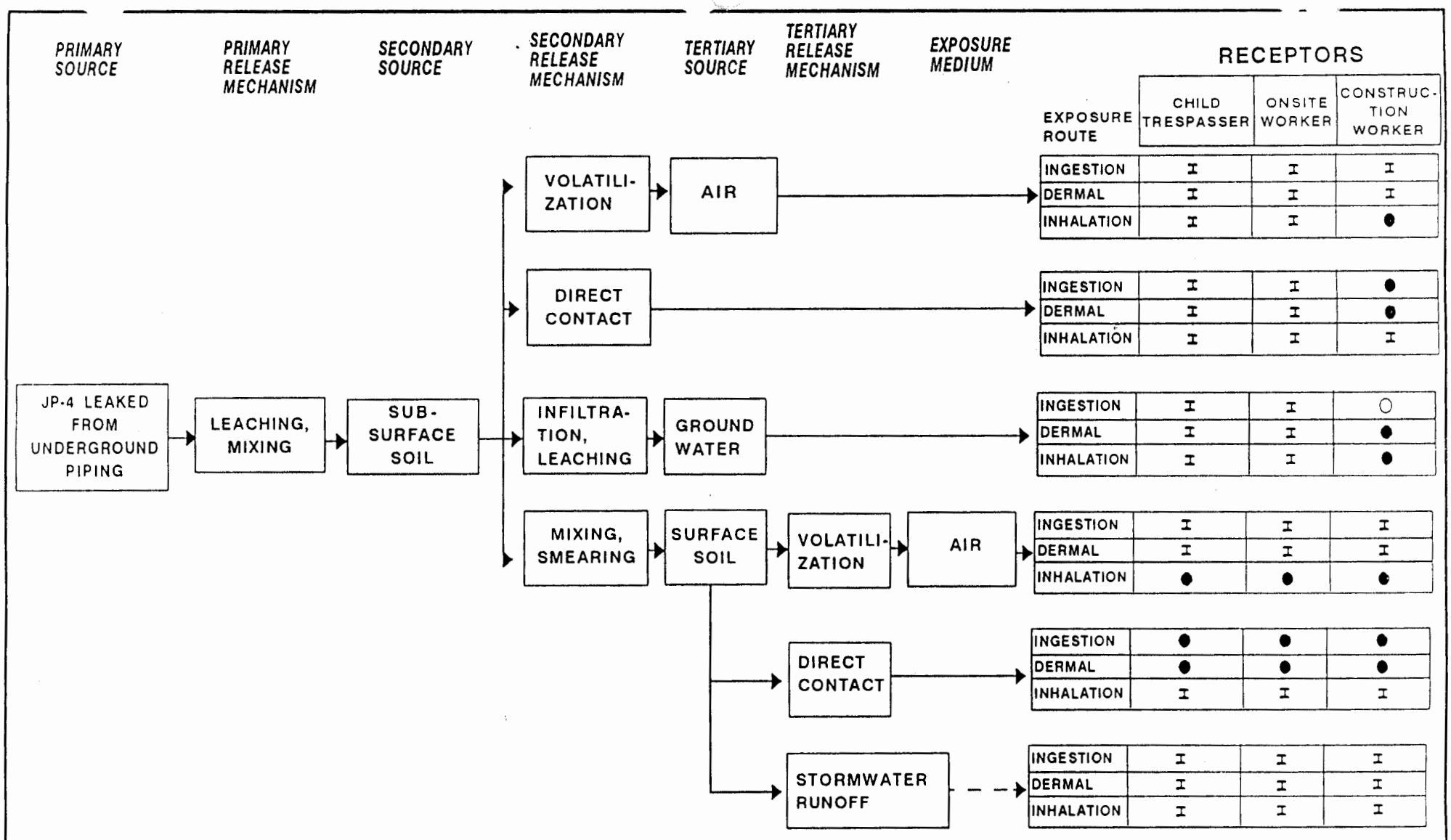
METHOD 2: MASS BALANCE USING PORE SATURATION ESTIMATE



T-38 TEST CELL – SS 59 / SWMU 229
MASS BALANCE CALCULATION METHODS
HOLLOMAN AIR FORCE BASE, N.M.

FIGURE 2-4

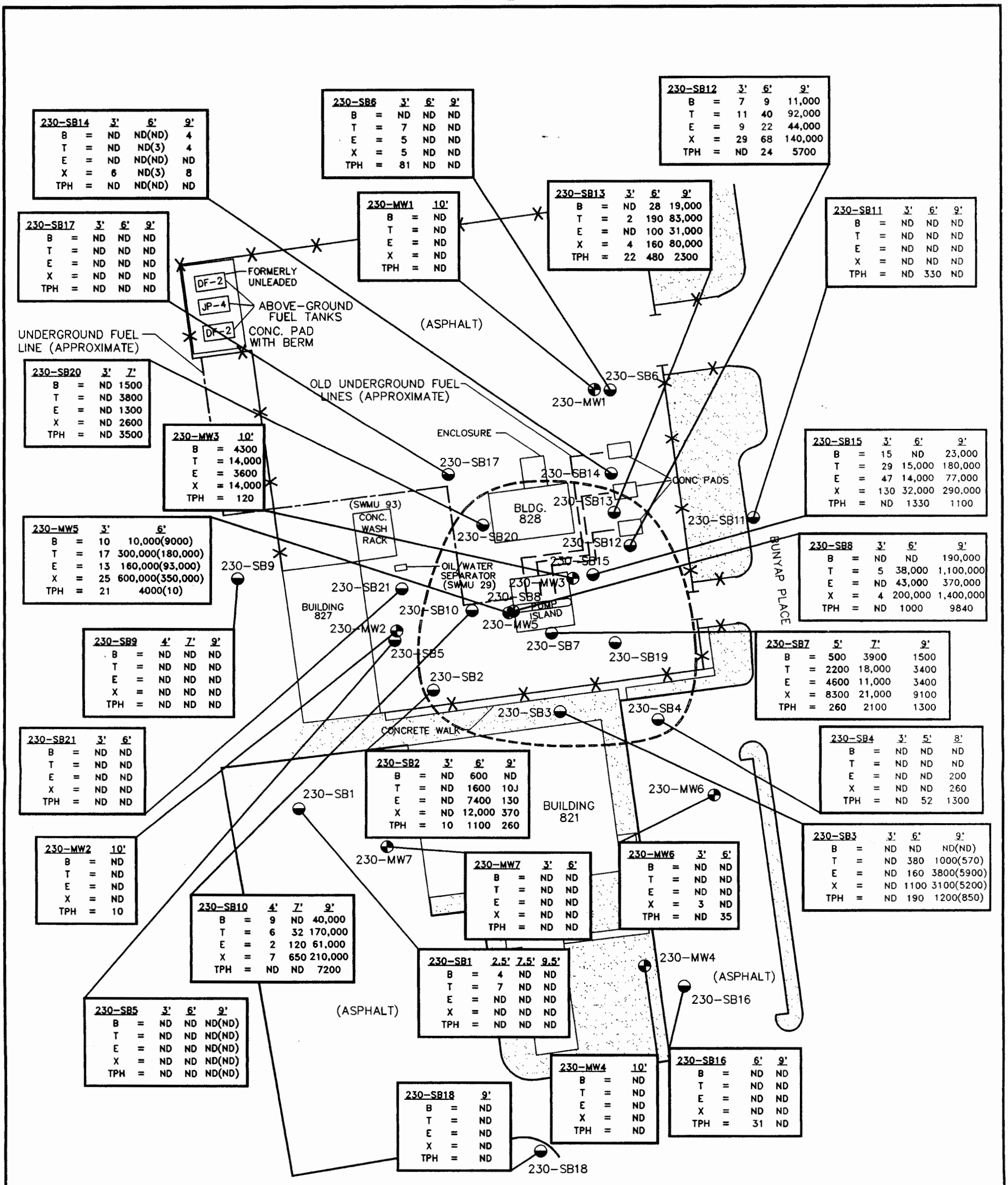
MBC 229 12/20/94



From Woodward-Clyde, June 1994

DRN. BY: JWB	DATE: 09/28/93	T-38 TEST CELL - SWMU 229 EXPOSURE PATHWAY FLOW CHART HOLLOMAN AIR FORCE BASE NEW MEXICO	FIGURE 2-5
CHK'D. BY:	REVISION: 0		

CAD FILE: C3M1[illegible]DWG 10/06/1993 16:26



LEGEND

- MONITORING WELL LOCATION
- SOIL BORING LOCATION
- GRAVEL SURFACE
- ISOCONTOUR OF TPH CONCENTRATION = 1,000 mg/Kg (APPROX.)

CHEMICAL ABBREVIATIONS

B	BENZENE (μg/Kg)
T	TOLUENE (μg/Kg)
E	ETHYLBENZENE (μg/Kg)
X	XYLENES (μg/Kg)
TPH	TOTAL PETROLEUM HYDROCARBONS (mg/Kg)

ID No. OF SAMPLE — DEPTH OF SAMPLE(S) TAKEN

230-SB15	5'	7'
B =	ND	ND(ND)
T =	12	23(ND)
E =	51	170(ND)
X =	34	ND(ND)
TPH =	143	260(ND)

ABBREVIATIONS OF CHEMICALS ANALYZED FOR

RESULTS OF SAMPLE(S) TAKEN
ND = NOT DETECTED
( ) = DUPLICATE RESULTS
J = ESTIMATED VALUE

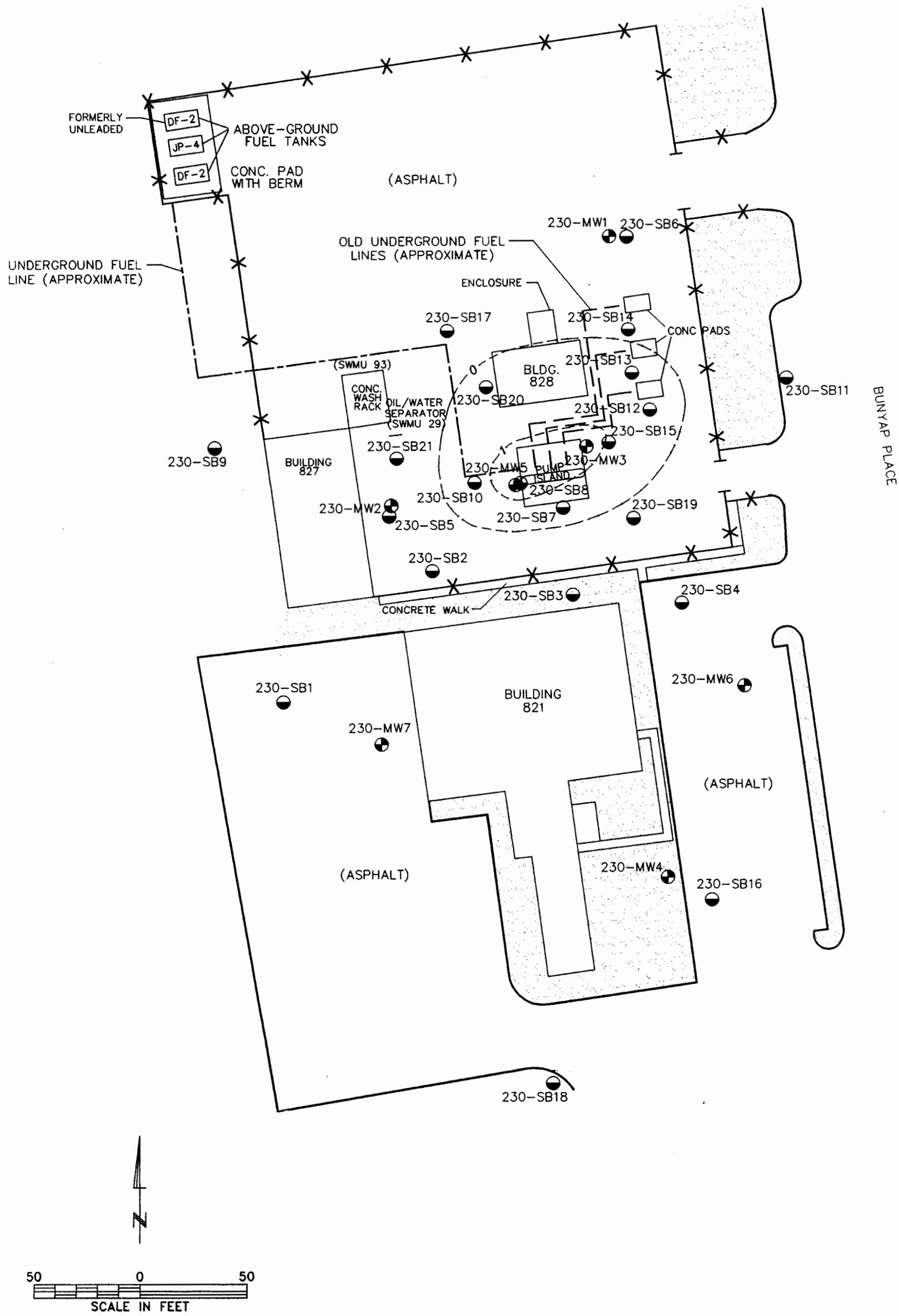
N

50 0 50
SCALE IN FEET

From Woodward-Clyde, June 1994

DRN. BY: CJG	DATE: 09/29/93	BUILDING 828 – SWMU 230 BTEX AND TPH CONCENTRATIONS IN SOIL SAMPLES HOLLOMAN AIR FORCE BASE NEW MEXICO	FIGURE 2-6
CHK'D. BY:	REVISION: 0		

CAD FILE: C3M[illegible]5.DWG 10/05/1993 13:49



LEGEND

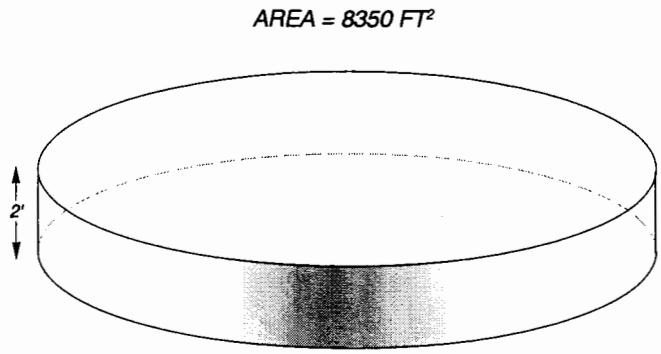
- MONITORING WELL LOCATION
- SOIL BORING LOCATION
- ISOCONTOUR OF FREE PRODUCT THICKNESS JULY 1993 (IN FEET)
- GRAVEL SURFACE

FIGURE 2-7

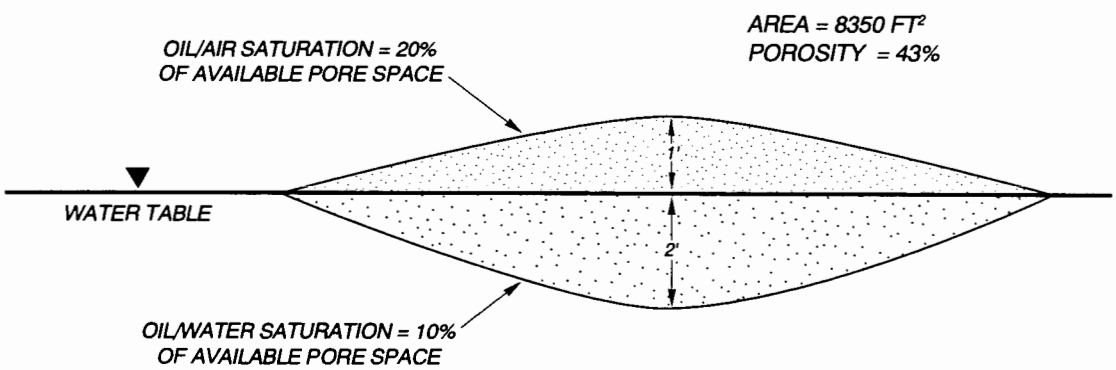
BUILDING 828 – SWMU 230
APPROXIMATE VERTICAL AND HORIZONTAL EXTENT OF FREE PRODUCT (JULY 1993)
HOLLOMAN AIR FORCE BASE NEW MEXICO

From Woodward-Clyde, June 1994

METHOD 1: MASS BALANCE USING AVERAGE HYDROCARBON CONTENT IN SOIL



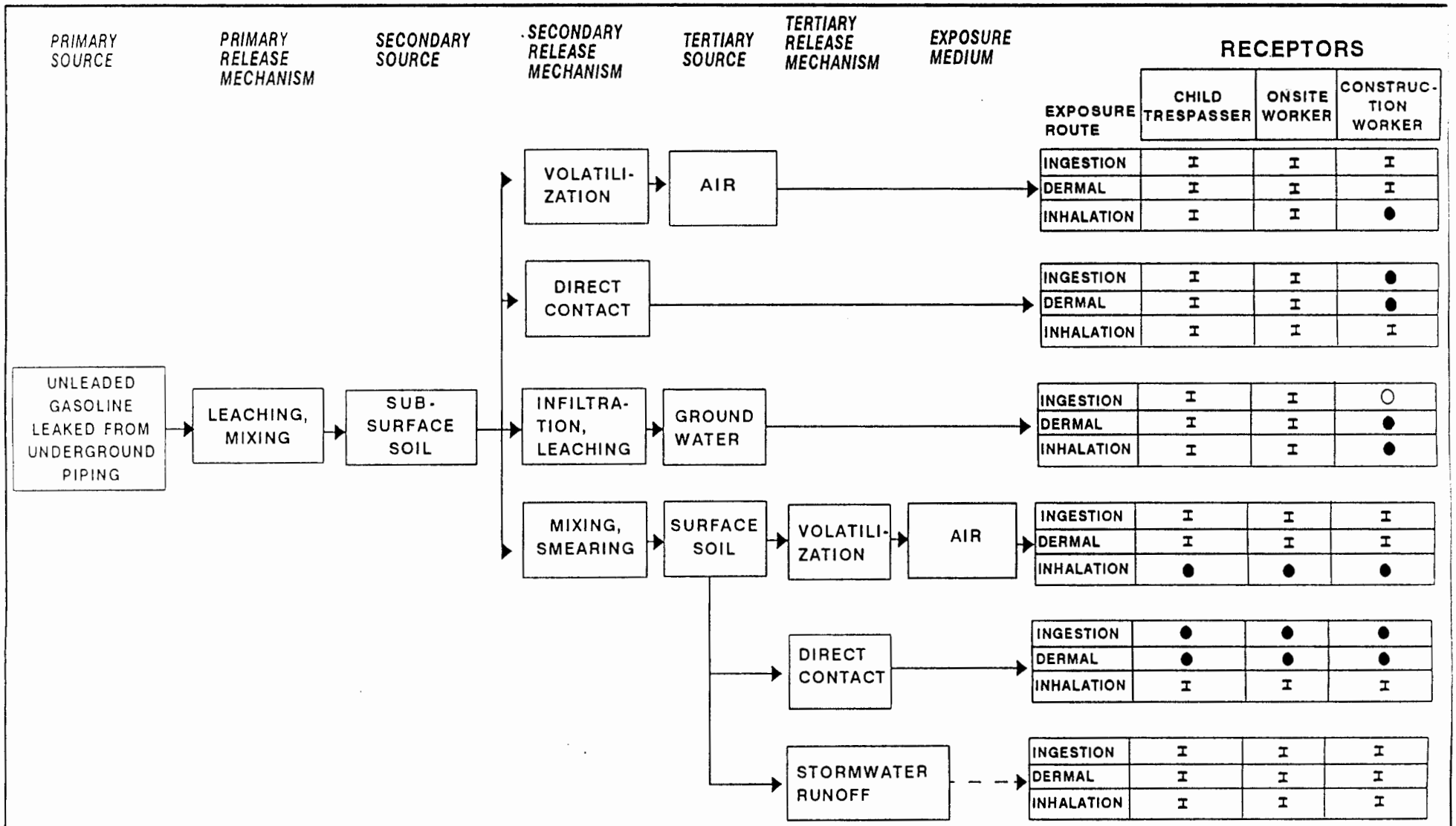
METHOD 2: MASS BALANCE USING PORE SATURATION ESTIMATE



BUILDING 828 – SS-60 / SWMU 230
MASS BALANCE CALCULATION METHODS
HOLLOMAN AIR FORCE BASE, N.M.

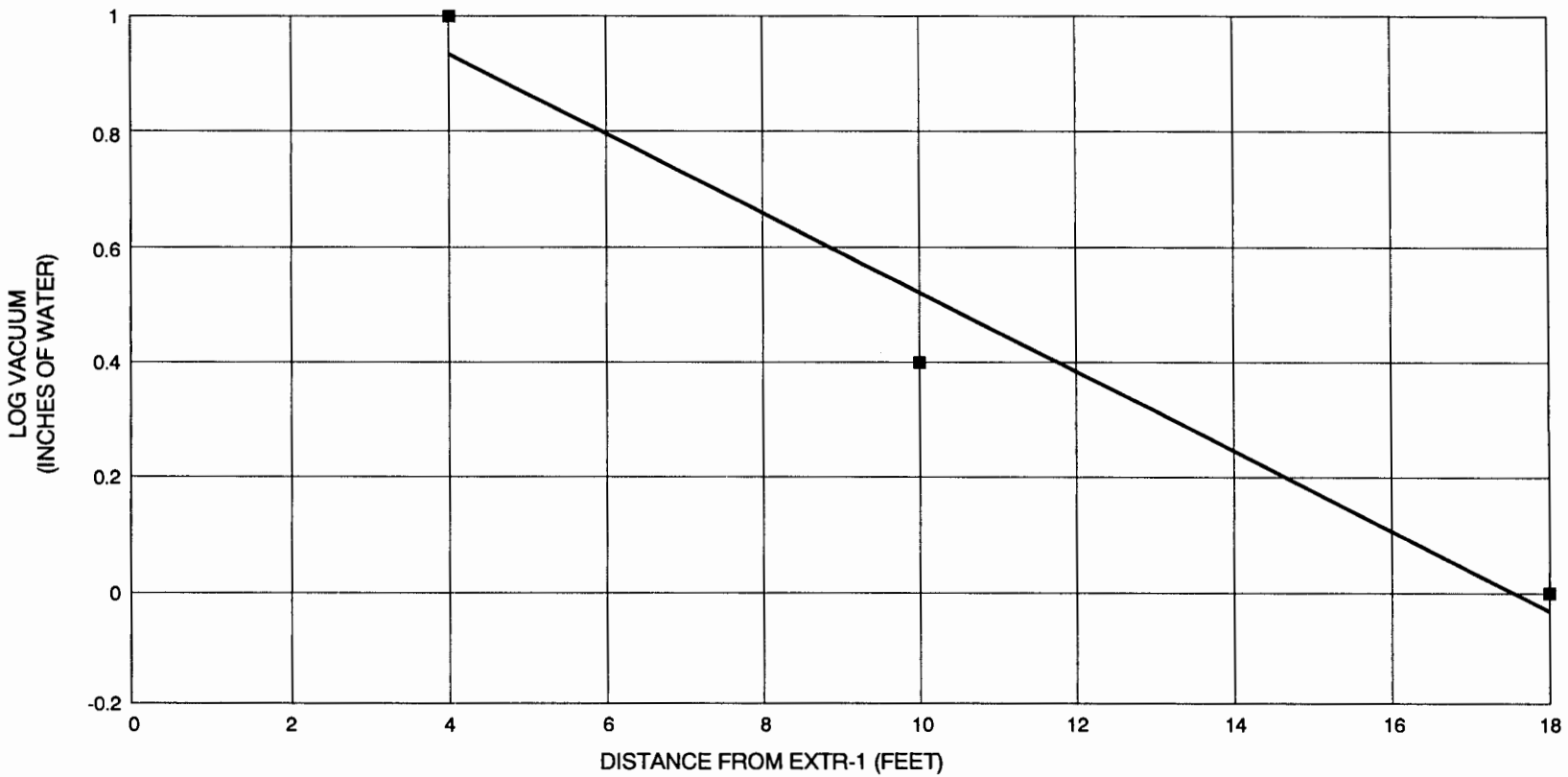
FIGURE 2-8

MBC 828 12/20/94



From Woodward-Clyde, June 1994

DRN. BY: JWB	DATE: 09/28/93	BUILDING 828 – SWMU 230 EXPOSURE PATHWAY FLOW CHART HOLLOMAN AIR FORCE BASE NEW MEXICO	FIGURE 2-9
CHK'D. BY:	REVISION: 0		



KEY

■ DATA FROM VES MONITOR POINTS

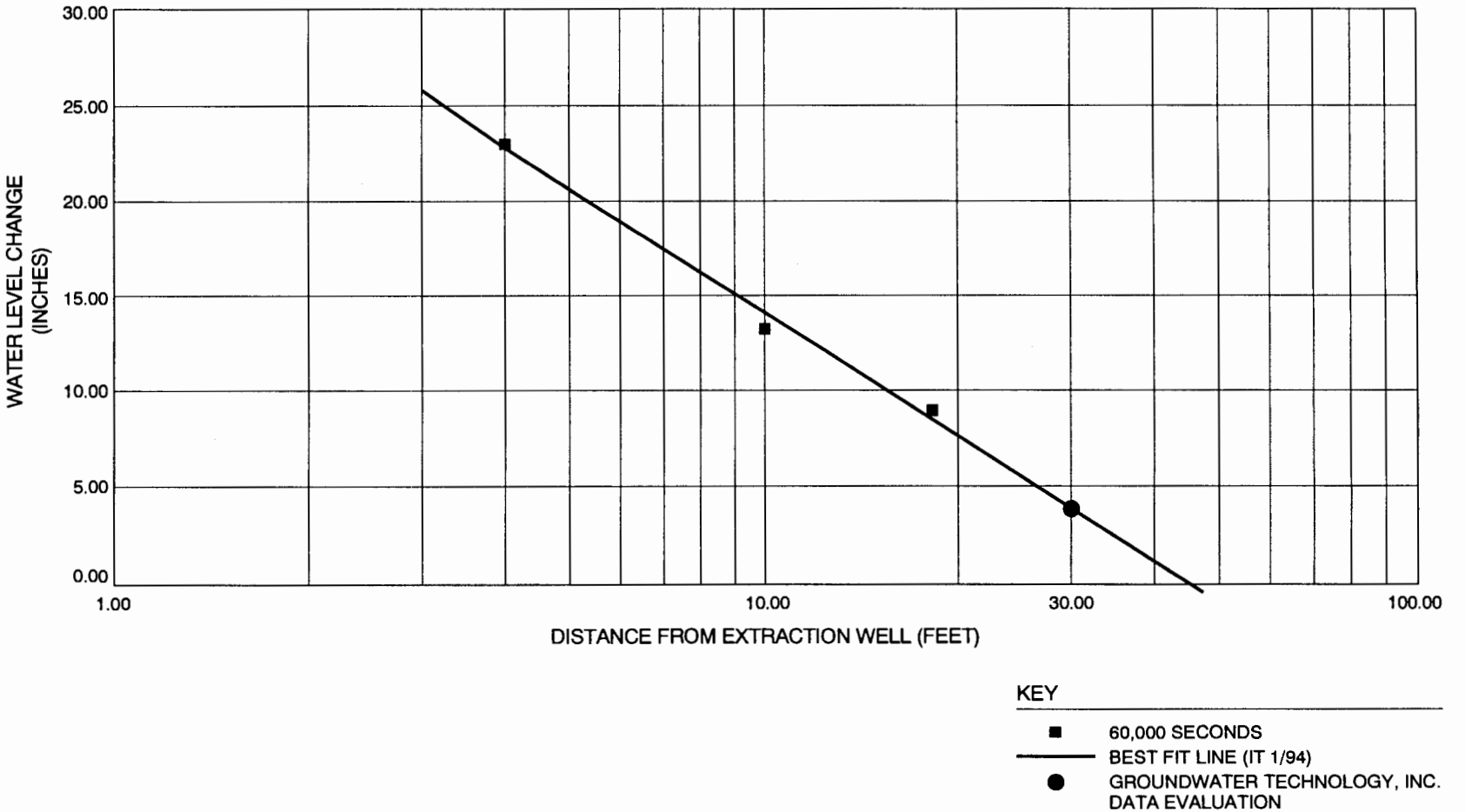
——— BEST FIT LINE

VACUUM AT EXTRACTION WELL = 7" HG

HOLLOMAN AFB/Graph 1 12/20/94

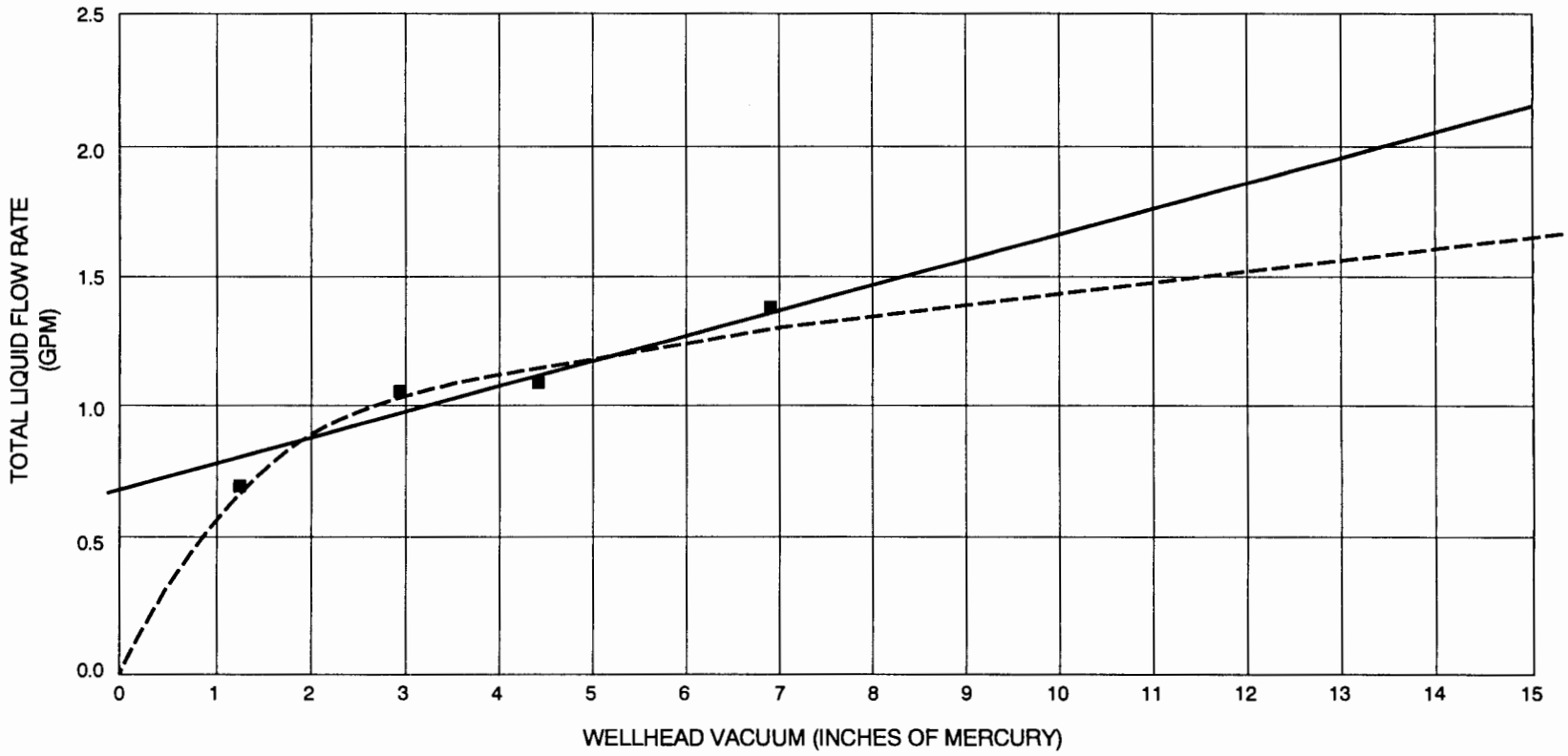
LOG OF INDUCED VACUUM VS DISTANCE
60,000 SECONDS ELAPSED,
IT PILOT TEST, NOVEMBER 1993
T-38 TEST CELL – SITE SS-59 / SWMU 229
HOLLOMAN AIR FORCE BASE, N.M.

FIGURE 4-1



NET WATER LEVEL CHANGE VS DISTANCE FROM THE EXTRACTION WELL
60,000 SECONDS ELAPSED,
IT PILOT TEST, NOVEMBER 1993
T-38 TEST CELL – SITE SS-59 / SWMU 229
HOLLOMAN AIR FORCE BASE, N.M.

FIGURE 4-2



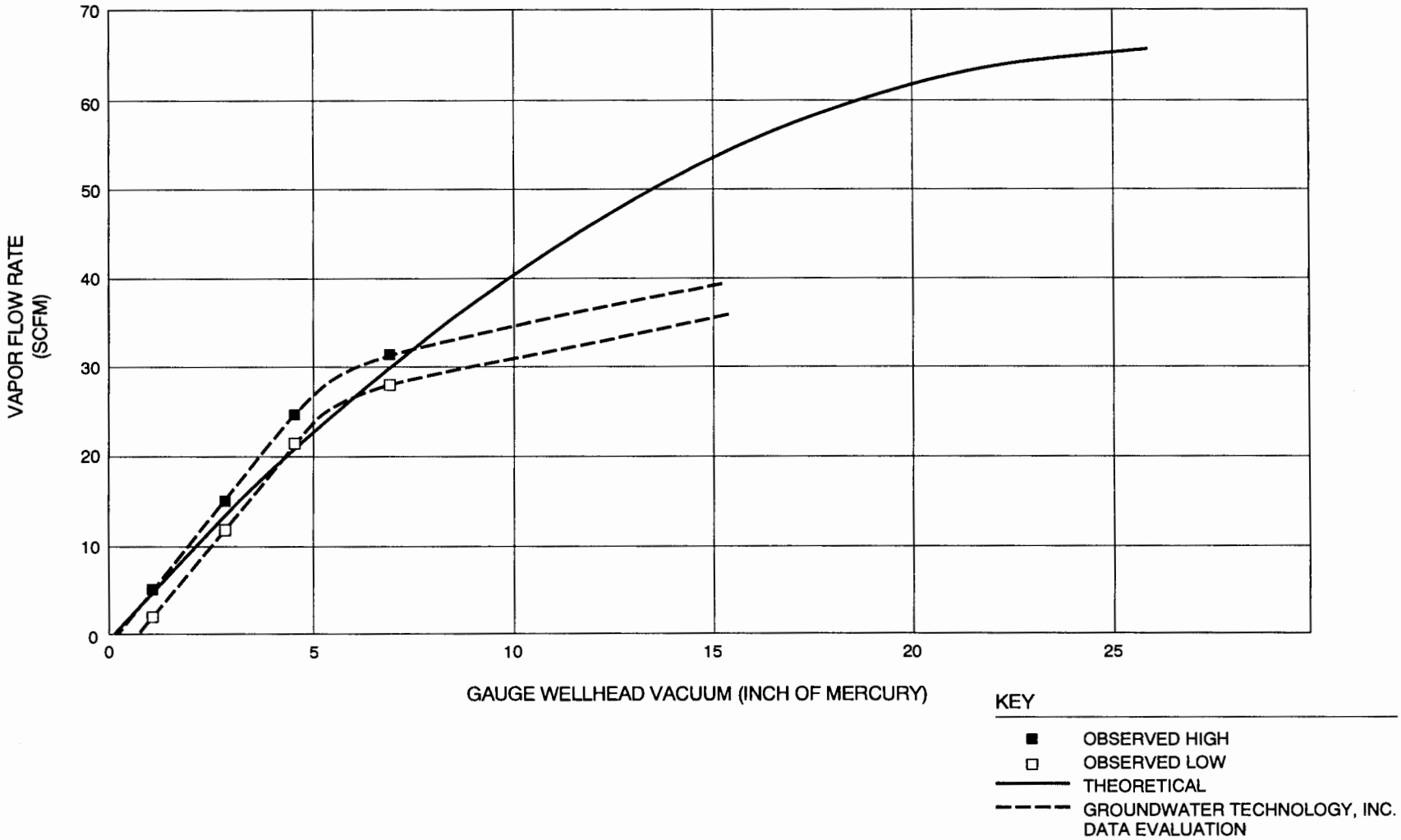
KEY

- ■ DATA
- ——— SPECIFIC CAPACITY (0.086 GPM/FT) (IT 1/94)
- – – – GROUNDWATER TECHNOLOGY, INC. DATA EVALUATION

HOLLOMAN AFB/Graph 3 12/20/94

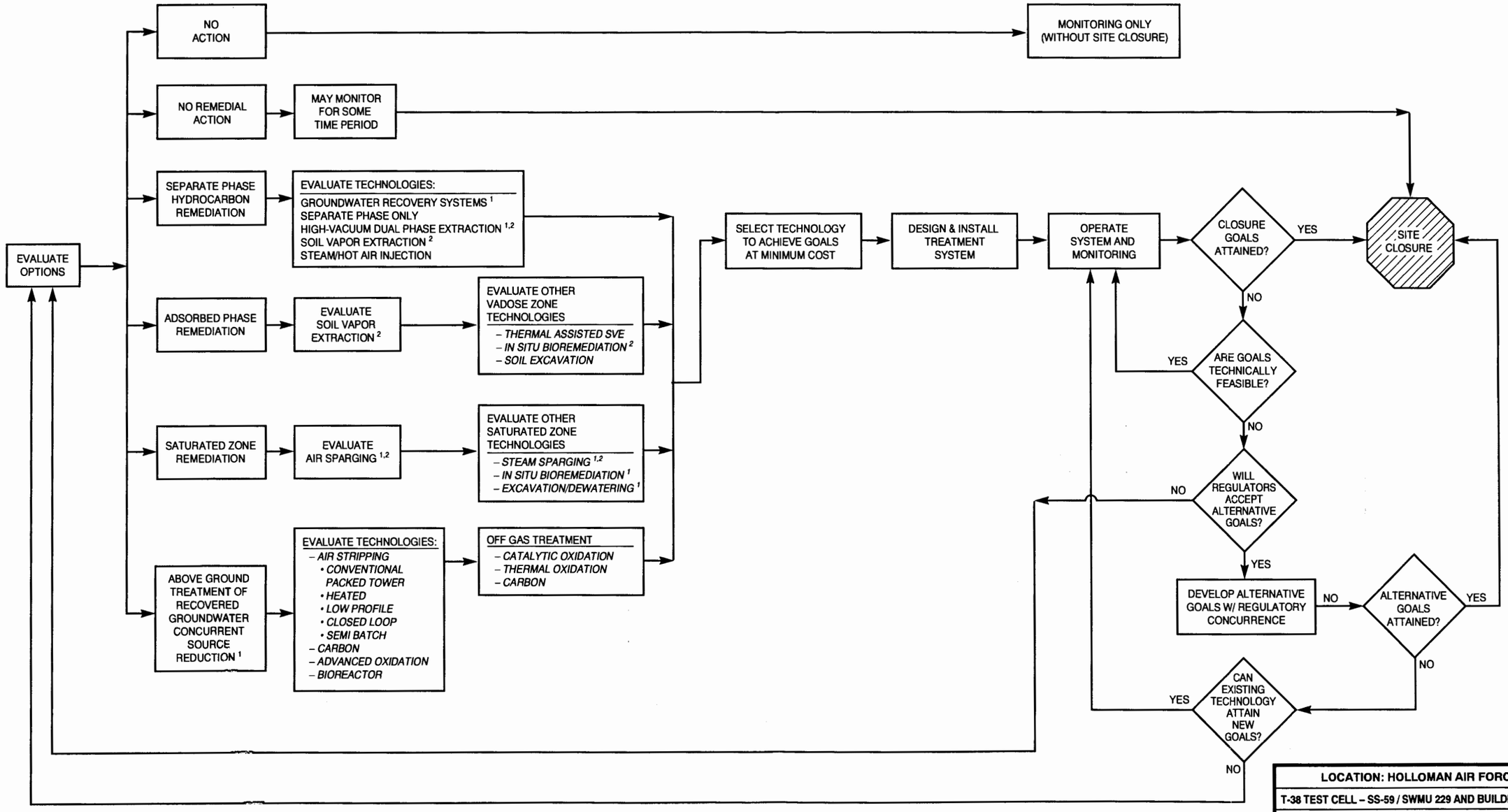
TOTAL FLOW RATE VS WELLHEAD VACUUM AT THE EXTRACTION WELL EXTR-1
(ASSUMES EXTR-1 IS FULLY DEWATERED)
IT PILOT TEST, NOVEMBER 1993
T-38 TEST CELL – SITE SS-59 / SWMU 229
HOLLOMAN AIR FORCE BASE, N.M.

FIGURE 4-3



CURVE FIT OF STEP TEST DATA TO THEORETICAL
IT PILOT TEST, NOVEMBER 1993
T-38 TEST CELL – SITE SS-59 / SWMU 229
HOLLOMAN AIR FORCE BASE, N.M.

FIGURE 4-4



[1] MAY REQUIRE CONCURRENT GROUNDWATER TREATMENT
[2] MAY REQUIRE CONCURRENT SOIL VAPOR EXTRACTION AND OFF-GAS TREATMENT
[3] CLOSURE GOALS ESTABLISHED USING ARARs, GUIDELINES AND/OR RISK ASSESSMENT

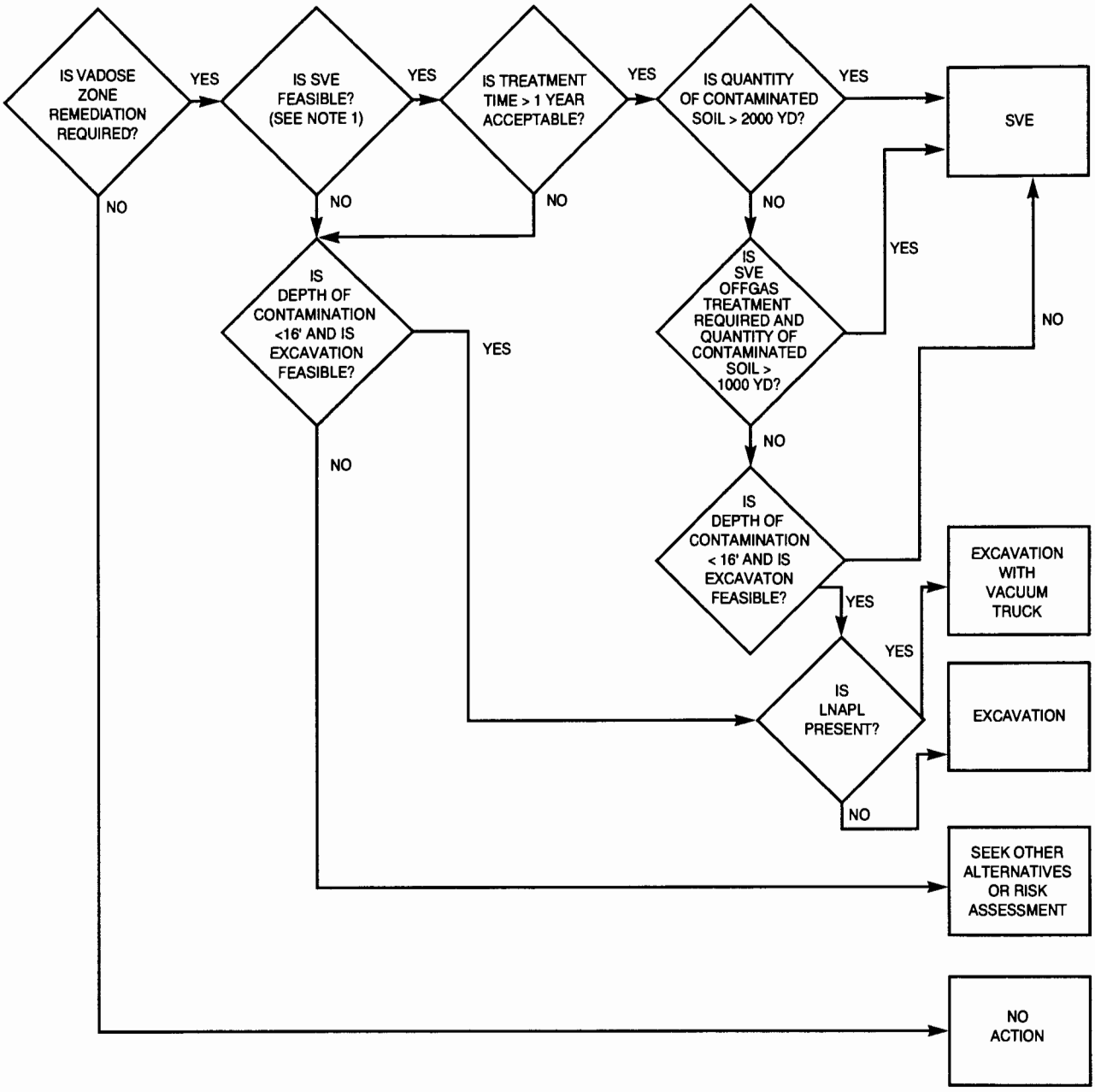
LOCATION: HOLLOMAN AIR FORCE BASE, N.M.

T-38 TEST CELL – SS-59 / SWMU 229 AND BUILDING 828 – SS-60 / SWMU 230

REMEDIATION STRATEGIES FOR PETROLEUM CONTAMINATED SITES

DRAWN BY: JU	DATE: 12/20/94	CHECKED BY:	DATE:
FOLDER: Holloman AFB		FILE: REMSTR 12/20/94	

FIGURE 5-1



NOTES:

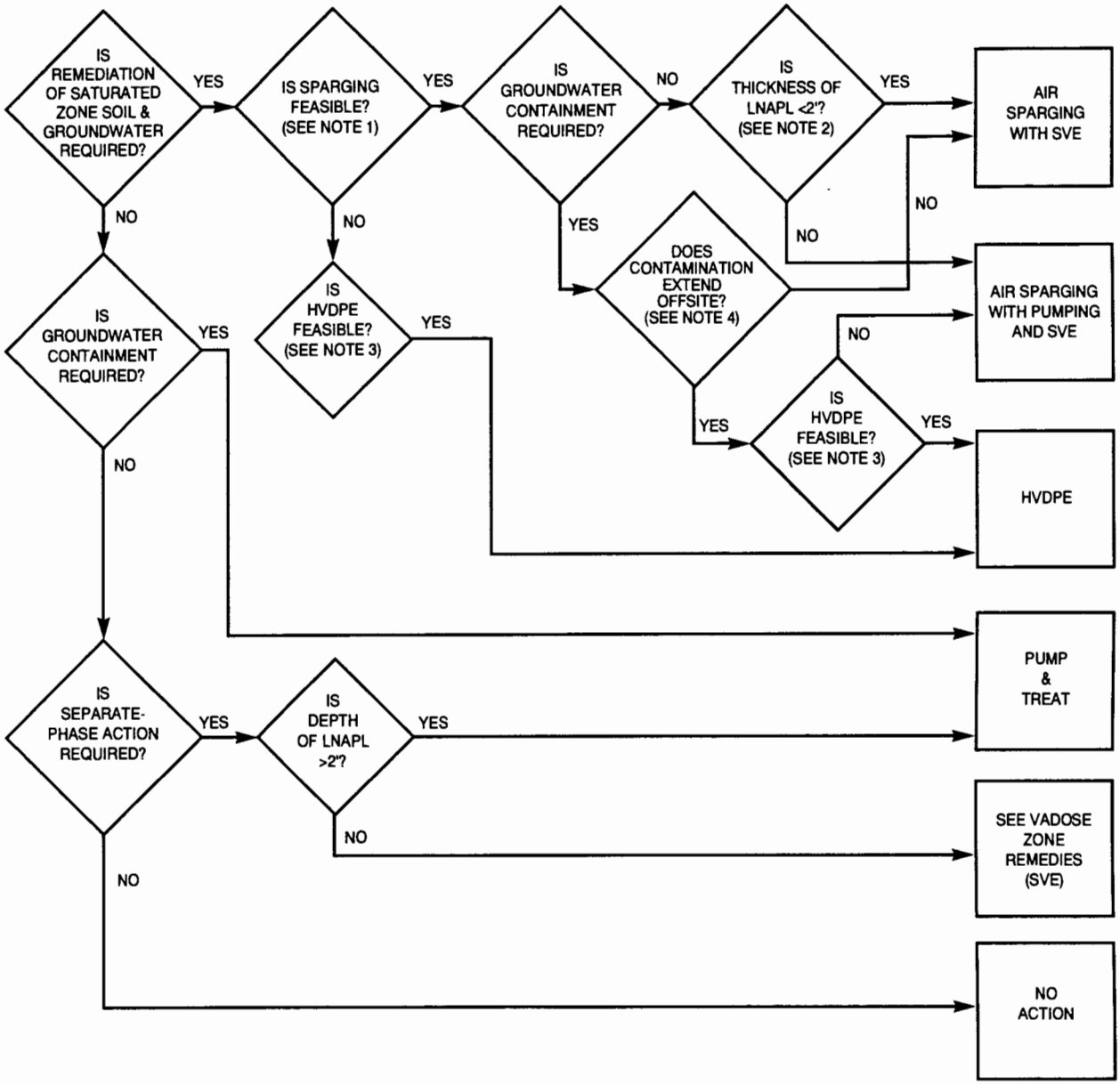
1. SVE IS FEASIBLE WHEN ALL OF THE FOLLOWING ARE SATISFIED:

- *DEPTH TO WATER >2 FEET*
- *MINIMUM FLOW AT MAXIMUM VACUUM APPLIED DURING PILOT TEST > 10 SCFM*
- *MINIMUM ROI AT MAXIMUM VACUUM APPLIED DURING PILOT TEST > 10 FEET*

PETROLEUM HYDROCARBON
REMEDIATION STRATEGY FLOWCHART FOR SVE
- VADOSE ZONE -
T-38 TEST CELL – SS 59 / SWMU 229 AND BUILDING 828 – SS-60 / SWMU 230
HOLLOMAN AIR FORCE BASE, N.M.

FIGURE 5-2

Vadzon12/20/94



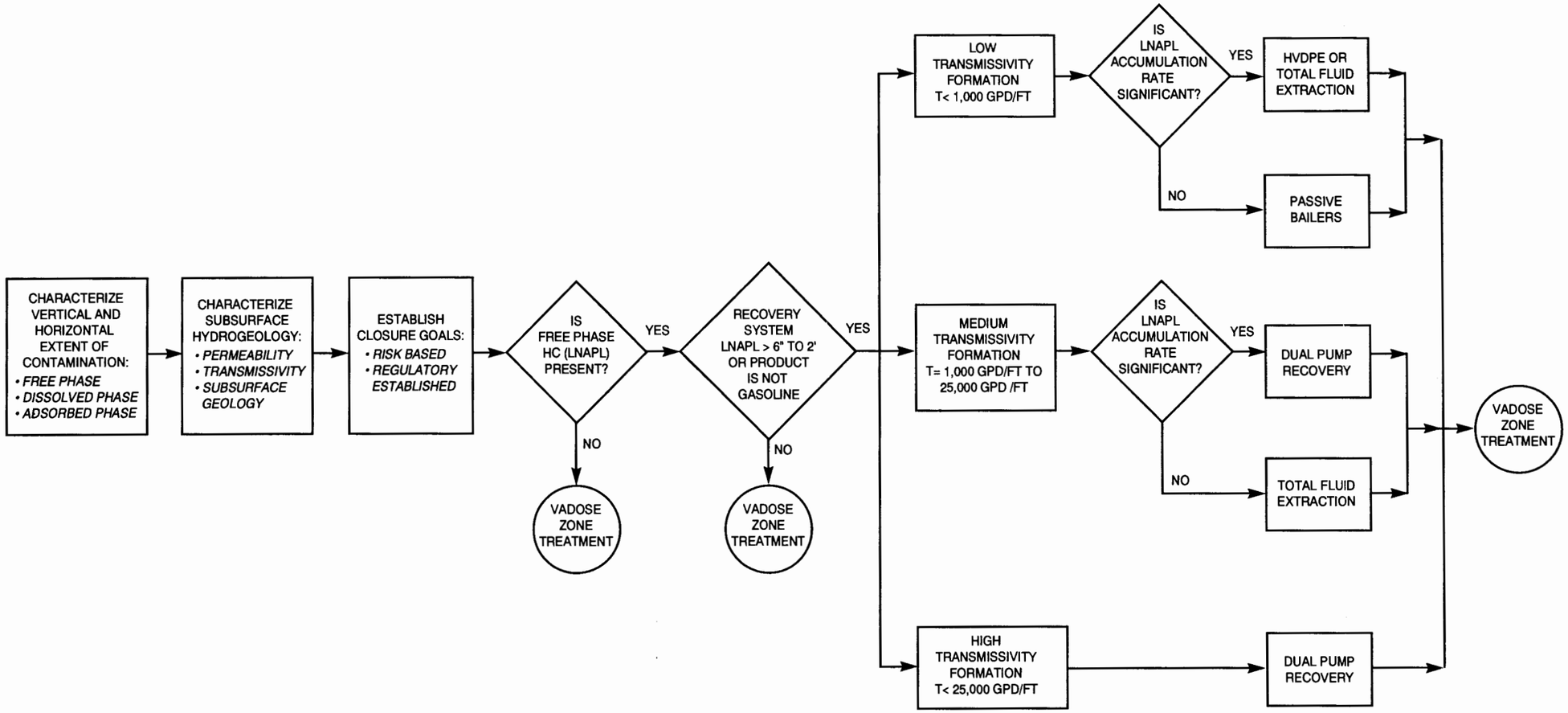
NOTES:

1. *SPARGING IS FEASIBLE WHEN ALL OF THE FOLLOWING CRITERIA ARE SATISFIED:*
   - *SATURATED ZONE THICKNESS > 5'*
   - *SPARGE AIR IS RECOVERABLE (I.E., SITE HOMOGENEOUS, MINIMAL HIGH/LOW PERMEABILITY LENSES, DEMONSTRATED PRESSURE CONTROL*
   - *SPARGING RADIUS OF INFLUENCE (ROI) > 10' BASED ON PILOT TEST*
2. *SPARGE SYSTEM SHOULD NOT BE STARTED-UP UNTIL THICKNESS OF LNAPL IS REDUCED TO < 2'*
3. *HIGH VACUUM DUAL PHASE EXTRACTION (HVDPE) IS FEASIBLE WHEN ALL OF THE FOLLOWING CRITERIA ARE SATISFIED:*
   - *AVERAGE SITE PERMEABILITY (K) < 10^{-4} CM/S BASED ON AN AQUIFER TEST*
   - *SUFFICIENT DRAWDOWN TO EXPOSE IMPACTED SATURATED SOILS IS ACHIEVABLE BASED ON HDPVE PILOT TEST*
   - *EXTRACTED VAPOR FLOW > 10 SCFM ACHIEVABLE BASED ON HVDPE OR CONVENTIONAL SVE PILOT TEST*
4. *IF DISSOLVED PHASE CONTAMINATION EXTENDS OFFSITE, THEN GROUNDWATER PUMPING IS RECOMMENDED TO AUGMENT THE SATURATED ZONE REMEDY IN ORDER TO PREVENT FURTHER OFFSITE MIGRATION*

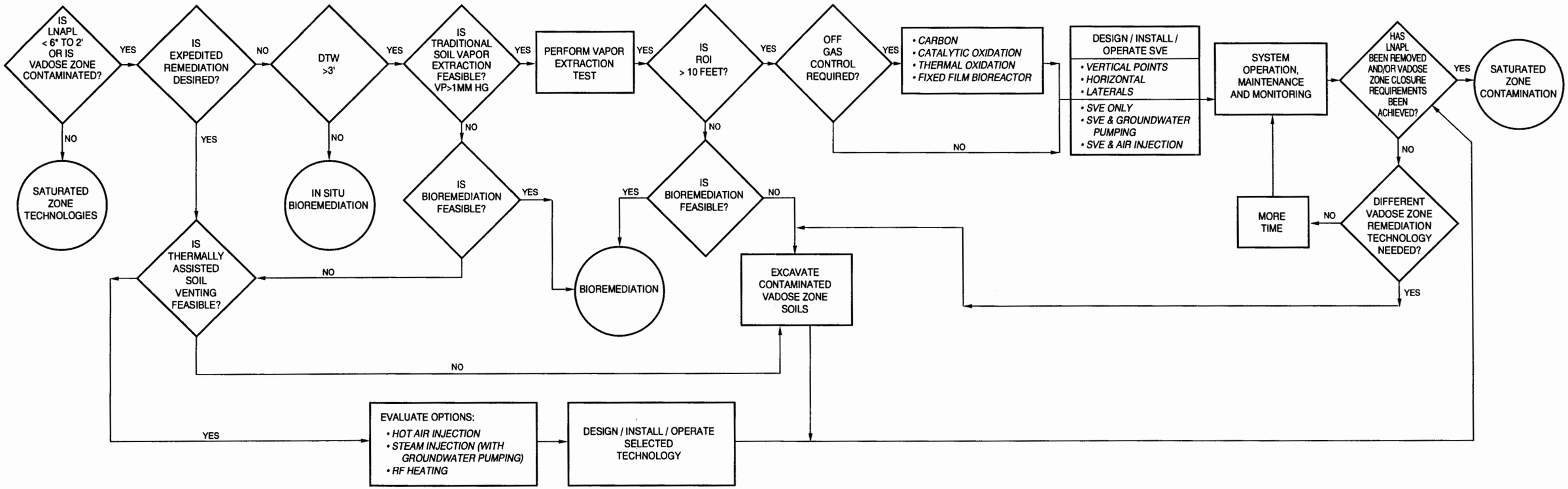
PETROLEUM HYDROCARBON
REMEDIATION STRATEGY FLOWCHART
- SATURATED ZONE -
T-38 TEST CELL – SS 59 / SWMU 229 AND BUILDING 828 – SS-60 / SWMU 230
HOLLOMAN AIR FORCE BASE, N.M.

FIGURE 5-3

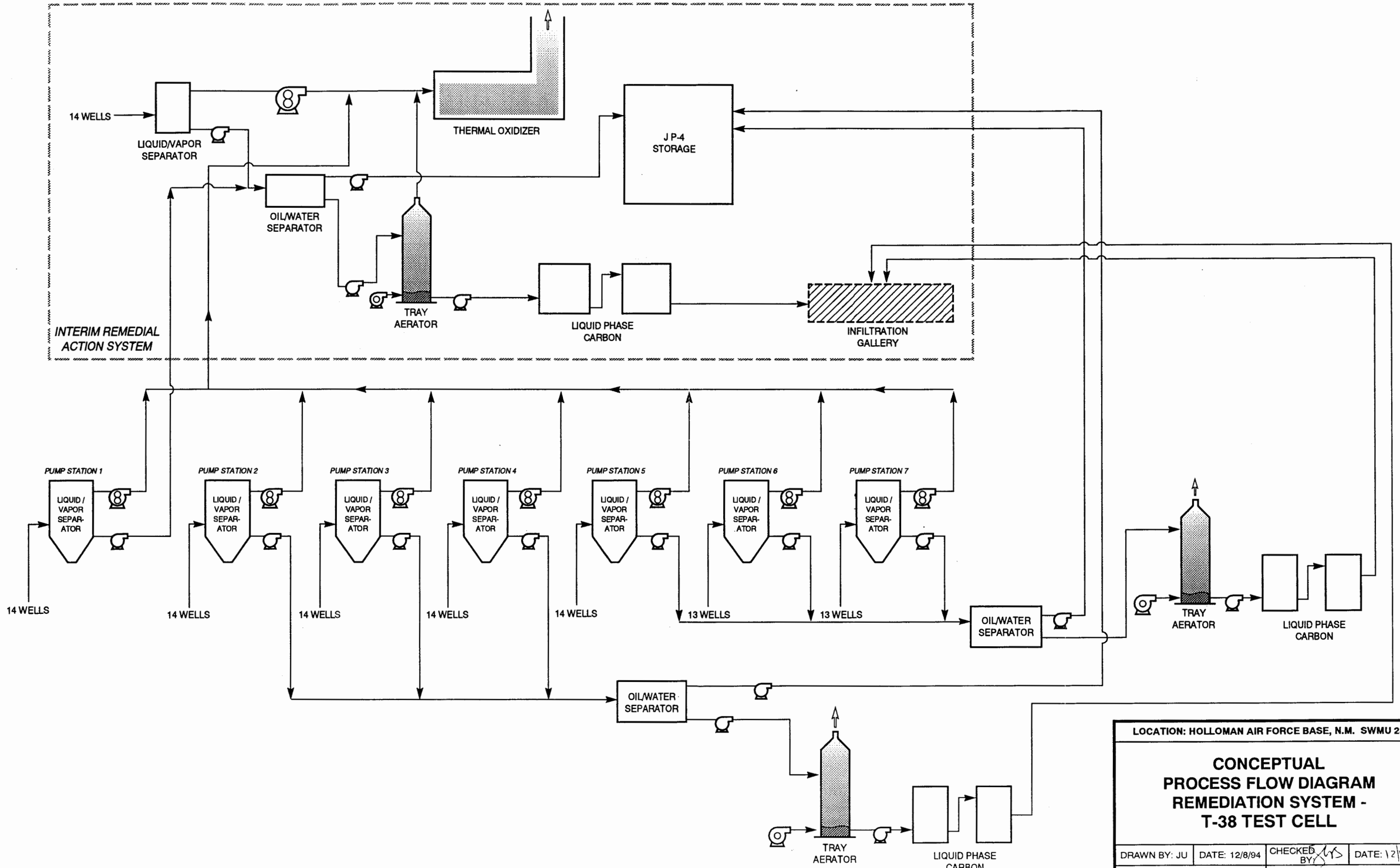
Satzon12/20/94



LOCATION: HOLLOMAN AIR FORCE BASE, N.M.			
T-38 TEST CELL – SS 59 / SWMU 229 AND BUILDING 828 – SS 60 / SWMU 230			
LNAPL REMEDIATION STRATEGY			
DRAWN BY: JU	DATE: 12/20/94	CHECKED BY:	DATE:
FOLDER: Holloman AFB		FILE: LNAPL 12/20/94	
FIGURE 5-4			



LOCATION: HOLLOMAN AIR FORCE BASE, N.M.			
T-38 TEST CELL – SS-59 / SWMU 229 AND BUILDING 828 – SS-60 / SWMU 230			
VADOSE ZONE TREATMENT SOIL VAPOR EXTRACTION			
DRAWN BY: JU	DATE: 12/20/94	CHECKED BY:	DATE:
FOLDER: Holloman AFB		FILE: SVE 12/20/94	
FIGURE 5-5			

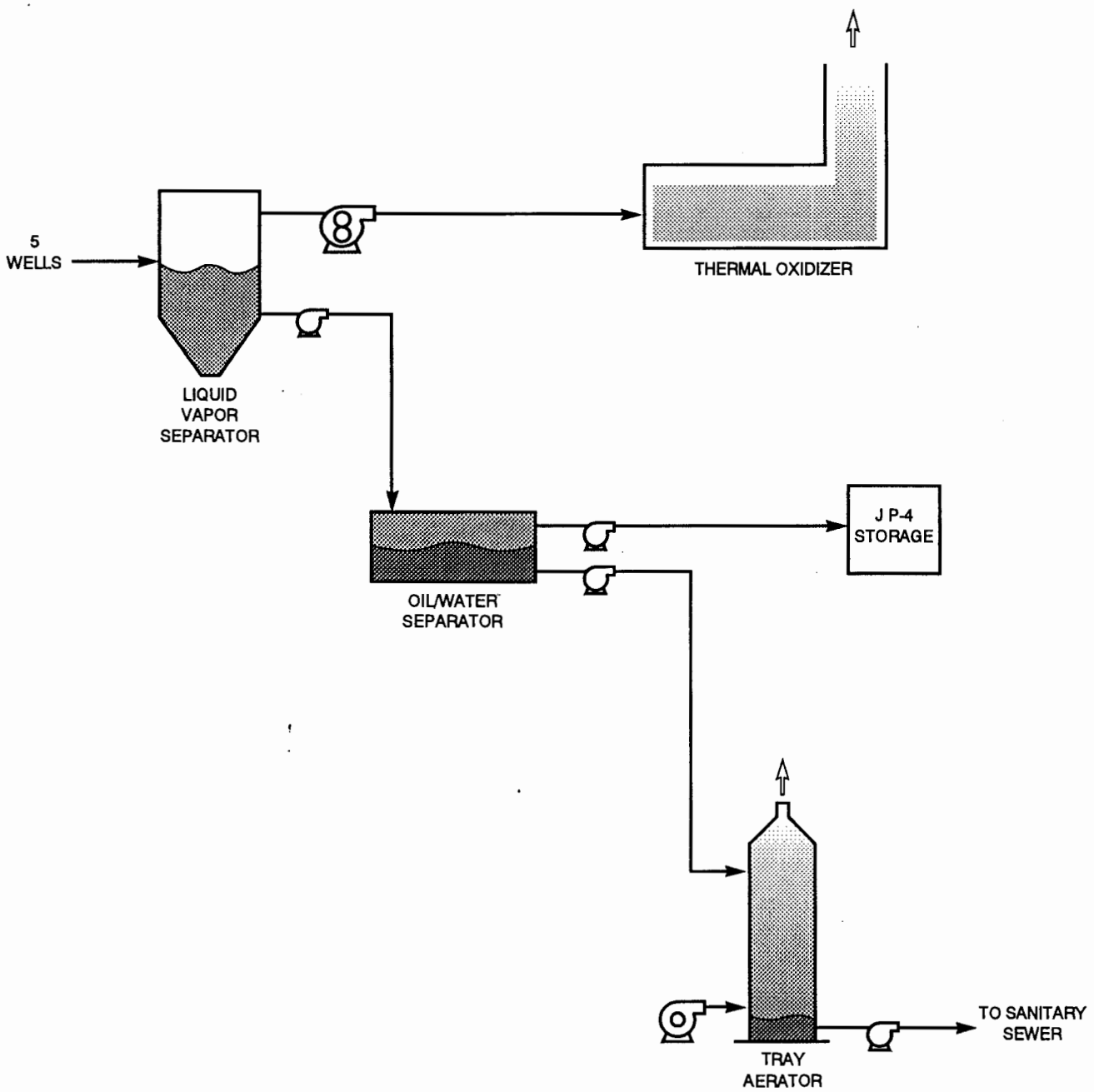


LOCATION: HOLLOMAN AIR FORCE BASE, N.M. SWMU 230

CONCEPTUAL PROCESS FLOW DIAGRAM REMEDIATION SYSTEM - T-38 TEST CELL

DRAWN BY: JU	DATE: 12/8/94	CHECKED BY: LYS	DATE: 12/11/94
FOLDER: Holloman AFB		FILE: PFDTC 12/94	

FIGURE 7-1



CONCEPTUAL PROCESS FLOW DIAGRAM
REMEDIATION SYSTEM - BUILDING 828

FIGURE 7-2

LOCATION: HOLLOMAN AIR FORCE BASE, N.M. BUILDING 828 – SWMU 230

PFD12/8/94

TABLE 3-1

SUMMARY OF REGULATORY REQUIREMENTS APPLICABLE TO CORRECTIVE ACTION AT HOLLOMAN AIR FORCE BASE, NEW MEXICO

MEDIA/ACTIVITY	REGULATORY CITATION	ENFORCING AGENCY	SUMMARY OF REGULATION
Surface and groundwater quality			
- Groundwater Quality Standards	NMWQCC Regulation Section 3-103/104 NMEIB/USTR Part XII Section 1219 (w/r to USTs)	NMED/GWPRB	- Dissolved pollutant standards apply to groundwater that has TDS levels < 10,000 mg/l.
- Surface Water Quality Standards	NMWQCC Regulations 1-100.A.	NMED/SWQB	- Establishes surface water quality standards and non-degradation policy.
Surface and groundwater discharge			
- Planned subsurface effluent discharges of non hazardous waste to infiltration galleries, injection wells, non-household septic systems, surface impoundments, etc.	NMWQCC Parts 1, 3, and 5	NMED/GWPRB	- Requires the filing of a discharge plan with specified requirements, and established discharge limits.
- Accidental releases from pipelines, above-ground storage tanks, underground storage tanks, surface spills, etc.	NMWQCC	NMED/GWPRB and/or NMED/SWQB	- Requires notification to NMED within 24 hours.
- Surface effluent discharge to surface waters (including arroyos and ephemeral streams).	CWA 40CFR122.2	EPA Region VI (issuing authority) NMED/SWQB (Review and certification authority)	- Requires NPDES permit to discharge any pollutant to navigable waters. - Exceptions include wastewater treatment systems (ponds and lagoons) and certain on-site response actions conducted under Superfund.
- Surface effluent discharge via any stormwater convalance system.	CWA 40CFR112 Stormwater NOI	EPA Region VI	- Requires permit for discharges from any stormwater system associated with an industrial activity (includes: industrial facilities, transportation facilities with vehicle maintenance, hazardous waste and TSD facilities, landfills, construction area larger than 5 acres, etc.).
- Discharge of dredged or fill material into wetlands.	CWA Wetlands Permit Section 404	EPA Region VI	- Regulates discharge of dredged or fill material to protect wetland habitats.
- Discharge of dredged material into waters of the U.S.	58 CFR 45008	USACE	- Requires permit to add or re-dispose of dredged material that destroys or degrades waters of the U.S.

TABLE 3-1 (Cont.)

SUMMARY OF REGULATORY REQUIREMENTS APPLICABLE TO CORRECTIVE ACTION AT HOLLOMAN AIR FORCE BASE, NEW MEXICO

MEDIA/ACTIVITY	REGULATORY CITATION	ENFORCING AGENCY	SUMMARY OF REGULATION
Groundwater Extraction - Extraction of groundwater associated with proposed treatment systems.	NMSEO Articles 1 through 7	NMSEO	- Requires permit to be obtained and if the majority of the extracted groundwater is not returned, water rights need to be purchased.
Underground Storage Tanks - Permit, operation, closure, and corrective action from releases.	NMEIB/USTR Parts XII and XIII	NMED/USTB	- Establishes operational standards for maintaining UST. - Specifically excludes oil-water separators, flow through process tanks, sumps, and hydraulic lifts.
- Soil, LNAPL, and Groundwater Restoration Levels and Remediation Requirements.	NMEIB/USTR Part XII Section 1209	NMED/USTB	- Specifies soil restoration levels for UST releases.
- Unable to obtain the regulatory standards with BAT.	NMEIB/USTR Part XII Section 1220	NMED/USTB	- Provides a mechanism for the UST owner/operator to petition the NMED/ USTB for less stringent cleanup standards.
Air Emissions - Air Quality Standards	NMAQCR	NMED/APCB	- TNMHCs < 0.19 ppm for 3-hour average. - Any regulated contaminant < 10 tons/year.
- Construction or operation of a stationary or portable source (e.g. vapor extraction system, air stripper, storage tanks, etc.).	NMAQCR Section 702 and 703	NMED/APCB	- Requires air permitting and registration with the State for emissions from vapor treatment systems with the potential to to emit sources > 10 lbs/hr or 25 tons/year, and/or a potential to emit any regulated contaminant < 10 tons/year.
- Emission sources of contaminants associated with remedial treatment systems.	CAA Title I	NMED/APCB	- Establishes NAAQ for individual areas.
	PSD	NMED/APCB	- Regions which meet the NAAQs may fall within the PSD program which is intended to maintain "clear air zones".
	HAP	NMED/APCB	- HAP is a federal program that applies emission standards and requires permitting for listed chemical compounds, individual compounds > 10 tons/year, combination of compounds > 25 tons/year.

TABLE 3-1 (Cont.)

SUMMARY OF REGULATORY REQUIREMENTS APPLICABLE TO CORRECTIVE ACTION AT HOLLOMAN AIR FORCE BASE, NEW MEXICO

MEDIA/ACTIVITY	REGULATORY CITATION	ENFORCING AGENCY	SUMMARY OF REGULATION
Air Emissions (Cont.)	Title V operating permits	NMED/APCB (issuing permits) EPA (notification and revisions)	- Federal Law requiring operating permits that will apply to almost all air pollution sources. - While other state and federal provisions requires permits (new source, PSD, other), Title V requires that all former permitting requirements be brought into one comprehensive document.
Hazardous Waste - Generator, storage, treatment, and disposal	HWMR Section 6	NMED/HRMB	- State program incorporates majority of RCRA subtitle C. - State of New Mexico is a RCRA-authorized state with exception for the HSWA portion.
- Generator, storage, treatment, and disposal	RCRA-HSWA 40 CFR Part 264 subpart C	EPA Region VI	- This statute is designed to provide "craddle to-grave" control of waste by imposing management requirements on generators and transporters of waste and owners of TSD facilities.
- Generator, storage, treatment, and disposal	RCRA-HSWA 40 CFR Part 264 Corrective Action Program Section 3004	EPA Region VI	- Requires TSD owners/operators to take corrective action for all releases from from SWMUs regardless of when the waste was placed in the unit or whether the unit is currently active. - SWMUs can include tanks, lagoons, waste piles, or other types of units.
- Generator, storage, treatment, and disposal	RCRA-HSWA 40 CFR Part 264 Subpart S	EPA Region VI	- Provides provisions for "voluntary" cleanup, phased RCRA facility investigations, range of cleanup levels for site-specific circumstances, and "conditional remedies".

TABLE 3-1 (Cont.)

SUMMARY OF REGULATORY REQUIREMENTS APPLICABLE TO CORRECTIVE ACTION AT HOLLOMAN AIR FORCE BASE, NEW MEXICO

MEDIA/ACTIVITY	REGULATORY CITATION	ENFORCING AGENCY	SUMMARY OF REGULATION
Hazardous Waste (Cont.)			
- Corrective Action Management Units and Treatment Units	RCRA - HSWA 40 CFR Subpart S	EPA Region VI	- CAMU and TU are designed to reduce administrative delays and encourage use of innovative remedial technologies by allowing movement of remedial waste without triggering land disposal restrictions and minimum technology requirements (e.g., double liners and leachate collection systems).
- Investigation/Remediation of Waste Sites	CERCLA/NCP Plan 40 CFR300	EPA Region VI NMED/GWPRB (DERA-IRP)	- Establishes protocol for assessment, selection of remedy and remedial actions.
Solid Waste			
- Solid Waste Management and Disposal	NMEIB/SWMR-4 (August 1994)	NMED/SWB	- Establishes operating standards, financial responsibility requirements, and closure standards for landfills. - This regulation brings the State in compliance with RCRA subtitle D requirements.
- Landfill Requirements	SWMR (August 1994)	NMED/SWB	- Sections with pertinent changes to active landfills include: permit application requirements, registration of sitings in wetlands or flood plains, methane monitoring program, groundwater monitoring requirements, etc. - Standards for remediation are less stringent (remediation required when dissolved concentrations reach corrective action levels) but more parameters need to be monitored on a regular schedule. - Recently adopted landfill requirements: bring the state program in line with federal program

TABLE 3-1 (Cont.)

SUMMARY OF REGULATORY REQUIREMENTS APPLICABLE TO CORRECTIVE ACTION AT HOLLOMAN AIR FORCE BASE, NEW MEXICO

MEDIA/ACTIVITY	REGULATORY CITATION	ENFORCING AGENCY	SUMMARY OF REGULATION
Solid waste (Cont.) - Landfill Requirements	RCRA subtitle D Section 7003	EPA Region VI	- EPA uses this regulation to prove that waste generated during investigation and implementation associated with remedial actions is not hazardous.
DOD Guidance Documents - Yearly Program Guidance	Yearly Extention Policy (4/14/94)	DUSP/ES	- This policy establishes management priortization and funding of the DoD's restoration programs. - It also sets forth performance measures that are used in monitoring the progress of the restoration program.
- Remedial Restoration Program Guidance	ACCRPM Guide	Air Force ACCRPM	- This document was developed for beginning RPMs as a primer in project management and as a reference document for experienced RPMs. - The book is based on successful restoration experiences and provides the basic outline for project execution within Air Force restoration management system.
Emergency Planning and Community Right-to-Know	- RCRA 1986: includes 40 CFR 302, 40 CFR 370, Section 313, 40 CFR 304, 40 CFR 355 - Appendices A and B - Title III of Superfund Amendments includes EO-12856	SERC LEPC	- Four major elements of EPCRA include 1) Community Emergency Planning (Section 302-303), 2) Emergency notifications; 3) Hazardous chemical reporting, and 4) Toxic chemical release inventory (TRI) reporting. - DoD prepared a guidance document called "DoD Guidance for Implementation of EO 12856 of August 3, 1993". - EPA prepared a guidance document called "EPA Interim Guidance for Implementing EO 12856".

TABLE 3-1 (Cont.)

SUMMARY OF REGULATORY REQUIREMENTS APPLICABLE TO CORRECTIVE ACTION AT HOLLOMAN AIR FORCE BASE, NEW MEXICO

MEDIA/ACTIVITY	REGULATORY CITATION	ENFORCING AGENCY	SUMMARY OF REGULATION
Pollution Prevention	EO-12856 Section 313	SERC LEPC	- States that by 1999 total releases and off-site transfers of identified toxic chemicals must be reduced 50% at a particular facility and/or agency-wide (DoD facilities) reduction of 50% must be reached. - Each facility that exceeds any EPCRA threshold needs to prepare a PPP
Proposed State Regulations - Abatement of Water Pollution	NMWQCC 3-200 Series	NMED/GWPRB	- Section 3-203A establishes standards for the vadose zone (soil), vapor, and LNAPL. - Sections 3-203F and 3-203G establish criteria for proposing that a standard is technically infeasible and allow the responsible party to petition alternative abatement standards.
Proposed Federal Regulations - Superfund	CERCLA	EPA Region VI	- Both the House of Representatives (HR 3800) and the Senate (S 1834) are preparing bills for reform of the existing regulations. - Pending measures include: elimination of pre-1987 cleanup liability, retroactive tax insurance premiums if PRPs would agree not to sue their issures, allow groundwater cleanup standards to be met only at site borders (rather than throughout site), and expand EPA's cost recovery authority to to pollutants and contaminants. - Most of the proposed changes are aimed at streamlining the remediation process and reducing the cost of cleanup.

TABLE 3-1 (Cont.)

SUMMARY OF REGULATORY REQUIREMENTS
APPLICABLE TO CORRECTIVE ACTION
AT HOLLOMAN AIR FORCE BASE, NEW MEXICO

MEDIA/ACTIVITY	REGULATORY CITATION	ENFORCING AGENCY	SUMMARY OF REGULATION
Proposed Federal Regulations (Cont.) - Air Emissions	EPA Draft Rule	EPA Region VI	- Would regulate organic air emissions from hazardous waste storage active tanks, containers, and surface impoundments (excludes: waste piles, landfills, and land treatment units). - Purpose of the regulation is to control toxic and ozone precursors that are not addressed by CAA HAP requirements. - Rule would apply to owners and operators of permitted interim status facilities and generators who store waste for greater than 90 days.
Base Specific Agreements - Base wide clean up levels	NMED letter dated 1/25/93	NMED/WWM	
- Federal Facilities Compliance Agreement (FFCA) (1988)		Signed between EPA Region VI, State of New Mexico, Holloman AFB	- Establishes closure requirements for sewage lagoons
Defense State Memorandum of Agreement (DSMOA) - DOD Funding for state oversight	DSMOA	DoD Deputy under Secretary of Defense	- Agreement establishes the DoD to set up a fund to reimburse NMED for state review of environmental permits, reports, and plans associated with DoD installation environmental restoration programs.

TABLE 3-1 (Cont.)

SUMMARY OF REGULATORY REQUIREMENTS APPLICABLE TO CORRECTIVE ACTION AT HOLLOMAN AIR FORCE BASE, NEW MEXICO

STATE ABBREVIATIONS:
NMWQCC - New Mexico Water Quality Control Commission
NMEIB/USTR - New Mexico Environmental Improvement Board/ Underground Storage Tank Regulations
NMAQCR - New Mexico Air Quality Control Regulations
HWMR - New Mexico Hazardous Waste Management Regulations
SWMR - New Mexico Solid Waste Management Regulations
NMED/GWPRB - New Mexico Environment Department Groundwater Protection and Remediation Bureau
NMED/USTB - New Mexico Environmental Department/UST Bureau
NMED/APCB - New Mexico Environmental Department/Air Pollution Control Bureau
NMED/SWQB - New Mexico Environmental Department/Surface Water Quality Bureau
NMED/HRMB - New Mexico Environmental Department/Hazardous and Radioactive Materials Bureau
NMED/SWB - New Mexico Environmental Department/Solid Waste Bureau
NMED/WWMD - New Mexico Environmental Department/Water and Waste Management Division
NMSEO - New Mexico State Engineer's Office
BAT - Best Available Technologies
ARAR - Applicable and/or Relevant and Appropriate Requirements

GENERAL ABBREVIATIONS:
TDS - Total Dissolved Solids
mg/l - milligrams per liter
ppm - parts per million
TNMHC - Total Non Methane Petroleum Hydrocarbons
LNAPLS - Light Non-Aqueous Phase Liquids

FEDERAL ABBREVIATIONS:
EPA Region VI - Regional Office for the EPA
CWA - Clean Water Act
NPDES - National Pollutant Discharge Elimination System
CFR - Code of Federal Regulations
NOI - Notice of Intent
USACE - US Army Corps of Engineers
FR - Federal Register
CAA - Clean Air Act
NAAQ - National Standards for Ambient Air Quality
PSD - Prevention of Signifiicant Deterioration
HAP - Hazardous Air Pollutants Program
RCRA - Resource Conservation and Recovery Act of 1976
HSWA - Hazardous and Solid Waste Amendments of 1984
TSD - Treatment, Storage, and Disposal
CERCLA (Superfund) - Comprehensive Environmental Response, Compensation, and Liability Act
NCP - National Contingency Plan
SWMU - Solid Waste Management Unit
CAMU - Corrective Action Management Units
TU - Temporary Units
DoD - Department of Defense
DERA-IRP - Defense Environmental Restoration Account-Installation Restoration Pr.
ACCRPM - Air Combat Command Installation Restoration Program Remedial Manager
EO - Executive Order
EPCRA -Emerg Plan. and Com Rt-to-Know
SERC - State Emergency Response Comm.D227

LEPC - Local Emergency Planning Committees
PPA - Pollution Prevention Act
PPP - Pollution Prevention Plan
PRP - Partially Responsible Party

TABLE 3-2
SUMMARY OF POTENTIALLY APPLICABLE CORRECTIVE ACTION OBJECTIVES FOR T-38 TEST CELL (SS-59/SWMU 229) AND BUILDING 828 (SS-60/SWMU 230) HOLLOMAN AIR FORCE BASE, NEW MEXICO

MEDIA OF CONCERN	APPLICABLE CORRECTIVE ACTION OBJECTIVE/ DISCHARGE LIMITS	REFERENCE
Soil	1,000 parts per million (ppm) TPH 25 ppm Benzene Alternative risk-based standards, to be developed if appropriate	Base-wide standard for POL-contaminated soil Proposed New Mexico Water Quality Control Commission Regulations (NMWQCC), Section 3-203
LNAPL	Removal of all measurable Light Non-Aqueous Phase Liquid (LNAPL)	NMED requirement for groundwater remediation at Holloman Air Force Base
Groundwater (in situ)	No Dissolved Phase Remediation Necessary	NMWQCC, Section 3-103; Total Dissolved Solids (TDS) > 10,000 ppm, therefore, no dissolved-phase groundwater remediation necessary
Discharge to Infiltration Gallery/Injection Wells	No LNAPL 10 parts per billion (ppb) Benzene 750 ppb Ethylbenzene 750 ppb Toluene 620 ppb Xylenes 30 ppb total Polynuclear Aromatic Hydrocarbons (PAHs)-Naphthalene + Monomethylnaphthalenes Toxic pollutant criteria - lifetime risk of more than one cancer per 100,000 exposed persons cannot be exceeded for the combination of contaminants or Human Health Standard of 3-103A shall apply, whichever is more stringent.	NMWQCC, Section 3-103.A NMWQCC, Section 1-101.UU
Discharge to Sanitary Sewer	No discharge of LNAPL No discharge of listed or characteristically hazardous waste, (most applicable: 500 ppb Benzene)	Discharges to Sanitary Sewer under pending NPDES permit for new treatment plant, existing Federal Facilities Compliance Agreement (FFCA) for base sewer system
Discharge to Atmosphere from vapor abatement units	60 lbs/hr Total Non-Methane Hydrocarbons (TNMHCs) in emissions 0.19 ppm TNMHCs (ambient air) in dispersed emissions (not currently enforced by NMED) 25 lbs/hr Toluene in emissions 3.75 mg/m^3 (1% of Occupational Exposure Limit (OEL)) Toluene in dispersed emissions 29 lbs/hr Ethylbenzene in emissions 4.35 mg/m^3 (1% of OEL) Ethylbenzene in dispersed emissions 29 lbs/hr Xylenes in emissions 4.35 mg/m^3 (1% of OEL) Xylenes in dispersed emissions	New Mexico Air Quality Control Regulations (NMAQCR) Part 702, Appendix A

TABLE 6-1

CORRECTIVE MEASURES ALTERNATIVES SCREENING MATRIX
LNAPL REMEDIATION
T-38 TEST CELL (SS-59/SWMU 229) AND BUILDING 828 (SS-60/SWMU 230)
HOLLOMAN AIR FORCE BASE, NEW MEXICO

TECHNOLOGY CONSIDERED	APPLICABILITY to SITE				RELATIVE COSTS		TREATMENT TIME ACCEPTABILITY	RATING SUMMATION	RETAIN YES/NO
	Advantage	Disadvantage	Relative Applicability Technical 0 - 5 A	Permits 0 - 3 P	Capital C	Operating O	Not Acceptable Acceptable T		
					High$ 1 2 3 4 5 Low$		1 2 3	A*P*(C+O+T)	
NO ACTION	i	cnr	5	3	5	5	2	180	Yes
HIGH VACUUM DUAL PHASE	i/mred/vred/perf dest	et	4	3	3	3	2	96	Yes
BIO VENTING	i/dest	ia	1	3	4	4	1	27	No
EXCAVATION/DISPOSAL	dest/perf	dtw/area/ci/pal	3	3	1	1	2	36	No
EXCAVATION/ON-SITE THERM	dest/perf	dtw/area	2	3	1	2	2	30	No
EXCAVATION ON-SITE BIO	dest/perf	dtw/area	2	3	1	2	2	30	No
VAPOR EXTRACTION	i/dest	drs/smat	3	3	3	3	1	63	Yes
PUMP & TREAT	i/mred	drs/smat	3	3	4	1	1	54	No
VAPOR EXTRACTION & SPARGE	i/mred/dest	et/smat	3	3	3	3	1	63	Yes
P&T & VAPOR EXTRACTION	i/mred/dest/perf	smat	4	3	3	2	1	84	Yes
STABILIZATION/CHEM. FIX.	mred	ia/dtw/cnr	1	3	2	2	2	18	No
STEAM STRIPPING/INJECTION	dest	ia/igc	1	3	2	1	2	15	No

LEGEND

ADVANTAGES
mred - Mobility Reduction
dest - Destruction
vred - Volume Reduction
perf - Performance & Reliable
i - Implementability
me - Exposure Minimization

DISADVANTAGES
et - Emerging Technology
ia - Inappropriate Technology
nperm - Not Permittable
cnr - Contaminant Not Removed
area - Area Required
ci - Community Impact
adtrt - Additional Treatment Required
smat = Inappropriate soil material
dtw = Depth to water
pni = Potential negative interaction
drs = Does not reach site remediation level
tna = Technology not available
pal = potential additional liability
igc = inappropriate gw contaminants

TIME LEGEND
1 > 3 years
2 > 1-3 years
3 < 1 year

PERMIT LEGEND
0 = not permittable
1 = major concern
2 = potential/slight concern
3 = not concern

COST LEGEND
1 > $500K/CY
2 $200-500K/CY
3 $100-200K/CY
4 $50-100K/CY
5 < $50K/CY

TABLE 6-2

CORRECTIVE MEASURES ALTERNATIVES SCREENING MATRIX
SOIL REMEDIATION
T-38 TEST CELL (SS-59/SWMU 229) AND BUILDING 828 (SS-60/SWMU 230)
HOLLOMAN AIR FORCE BASE, NEW MEXICO

TECHNOLOGY CONSIDERED	APPLICABILITY to SITE				RELATIVE COSTS		TREATMENT TIME ACCEPTABILITY	RATING SUMMATION	RETAIN YES/NO
	Advantage	Disadvantage	Relative Applicability Technical 0 - 5 A	Permits 0 - 3 P	Capital C	Operating O	Not Acceptable Acceptable T		
					High$ 1 2 3 4 5 Low$		1 2 3	A*P*(C+O+T)	
NO ACTION	i	cnr	5	3	5	5	1	165	Yes
HIGH VACUUM DUAL PHASE	i/mred/vred/ perf/dest	et	4	3	3	3	2	96	Yes
BIO VENTING	i/dest	smat	4	3	4	4	1	108	Yes
EXCAVATION/DISPOSAL	dest/perf	dtw/area/ci/pal	3	3	1	1	3	45	No
EXCAVATION/ON-SITE THERM	dest/perf	dtw/area	3	3	1	1	3	45	No
EXCAVATION ON-SITE BIO	dest/perf	dtw/area	3	3	1	1	3	45	No
VAPOR EXTRACTION	i/dest	smat	4	3	3	3	2	96	Yes
VAPOR EXTRACTION & SPARGE	dest	ia/smat	1	3	3	3	2	24	No
STABILIZATION/CHEM. FIX.	mred	ia/dtw/cnr	1	3	2	2	2	18	No
STEAM INJECTION	dest	ia	1	3	2	2	1	15	No

LEGEND

ADVANTAGES
mred - Mobility Reduction
dest - Destruction
vred - Volume Reduction
perf - Performance & Reliable
i - Implementability
me - Exposure Minimization

DISADVANTAGES
et - Emerging Technology
ia - Inappropriate Technology
nperm - Not Permittable
cnr - Contaminant Not Removed
area - Area Required
ci - Community Impact
adtrt - Additional Treatment Required

smat = Inappropriate soil material
dtw = Depth to water
pni = Potential negative interaction
drs = Does not reach site
remediation level
tna = Technology not available
pal = potential additional liability
igc = inappropriate gw contaminants

TIME LEGEND
1 > 3 years
2 > 1-3 years
3 < 1 year

PERMIT LEGEND
0 = not permittable
1 = major concern
2 = potential/slight concern
3 = not concern

COST LEGEND
1 > $500K/CY
2 $200-500K/CY
3 $100-200K/CY
4 $50-100K/CY
5 < $50K/CY

TABLE 6-3

CORRECTIVE MEASURES ALTERNATIVES SCREENING MATRIX
VAPOR TREATMENT AT T-38 TEST CELL (SS-59/SWMU 229)
HOLLOMAN AIR FORCE BASE, NEW MEXICO

TECHNOLOGY CONSIDERED	APPLICABILITY to SITE				RELATIVE COSTS		TREATMENT TIME ACCEPTABILITY	RATING SUMMATION	RETAIN YES/NO
	Advantage	Disadvantage	Relative Applicability Technical 0 - 5 A	Permits 0 - 3 P	Capital C	Operating O	Not Acceptable Acceptable T		
					High$ 1 2 3 4 5 Low$		1 2 3	A*P*(C+O+T)	
NO ACTION/DIRECT DISCHARGE	i/perf	ci, pal, nperm, cnr	5	1	5	5	1	55	No
CARBON (DISPOSAL)	i/perf	adtrt	3	3	4	1	2	63	No
CARBON (RESIN)	i/perf	adtrt	3	3	1	3	2	54	No
CATALYTIC OXIDATION	dest/me	--	3	2	3	4	1	48	No
THERMAL OXIDATION	dest/me	--	4	3	3	3	2	96	Yes
FLARE	dest/me	--	4	3	3	3	2	104	Yes
INTERNAL COMBUSTION	dest/i	ia	1	2	2	2	1	10	No
GRAVEL BED	dest/me/i	area	3	2	1	3	1	36	No
TR RESIN	vred/i	et	4	2	1	3	2	48	No

LEGEND

ADVANTAGES
mred - Mobility Reduction
dest - Destruction
vred - Volume Reduction
perf - Performance & Reliable
i - Implementability
me - Exposure Minimization

DISADVANTAGES
et - Emerging Technology
ia - Inappropriate Technology
nperm - Not Permittable
cnr - Contaminant Not Removed
area - Area Required
ci - Community Impact
adtrt - Additional Treatment Required
smat = Inappropriate soil material
dtw = Depth to water
pni = Potential negative interaction
drs = Does not reach site remediation level
tna = Technology not available
pal = potential additional liability
igc = inappropriate gw contaminants

TIME LEGEND
1 > 3 years
2 > 1-3 years
3 < 1 year

PERMIT LEGEND
0 = not permittable
1 = major concern
2 = potential/slight concern
3 = not concern

COST LEGEND
1 > $500K/CY
2 $200-500K/CY
3 $100-200K/CY
4 $50-100K/CY
5 < $50K/CY

TABLE 6-4

CORRECTIVE MEASURES ALTERNATIVES SCREENING MATRIX
VAPOR TREATMENT AT BUILDING 828 (SS-60/SWMU 230)
HOLLOMAN AIR FORCE BASE, NEW MEXICO

TECHNOLOGY CONSIDERED	APPLICABILITY to SITE				RELATIVE COSTS		TREATMENT TIME ACCEPTABILITY	RATING SUMMATION	RETAIN YES/NO
	Advantage	Disadvantage	Relative Applicability Technical 0 - 5 A	Permits 0 - 3 P	Capital C	Operating O	Not Acceptable Acceptable T		
					High$ 1 2 3 4 5 Low$		1 2 3	A*P*(C+O+T)	
NO ACTION/DIRECT DISCHARGE	i/perf	pal, ci, cnr	5	2	5	5	2	120	Yes
CARBON (DISPOSAL)	i/perf	adtrt	3	3	4	1	2	63	No
CARBON (RESIN)	i/perf	adtrt	4	3	2	2	2	72	No
CATALYTIC OXIDATION	dest/me	--	4	3	3	4	2	108	Yes
THERMAL OXIDATION	dest/me	--	4	3	3	3	2	96	Yes
FLARE	dest/me	--	3	3	4	2	2	72	No
INTERNAL COMBUSTION	dest/i	ia	1	2	2	2	3	14	No
GRAVEL BED	dest/me/i	area	3	2	3	4	2	54	No
TR RESIN	vred/i	et	3	2	2	2	2	48	No

LEGEND

ADVANTAGES
mred - Mobility Reduction
dest - Destruction
vred - Volume Reduction
perf - Performance & Reliable
i - Implementability
me - Exposure Minimization

DISADVANTAGES
et - Emerging Technology
ia - Inappropriate Technology
nperm - Not Permittable
cnr - Contaminant Not Removed
area - Area Required
ci - Community Impact
adtrt - Additional Treatment Required
smat = Inappropriate soil material
dtw = Depth to water
pni = Potential negative interaction
drs = Does not reach site remediation level
tna = Technology not available
pal = potential additional liability
igc = inappropriate gw contaminants

TIME LEGEND
1 > 3 years
2 > 1-3 years
3 < 1 year

PERMIT LEGEND
0 = not permittable
1 = major concern
2 = potential/slight concern
3 = not concern

COST LEGEND
1 > $500K/CY
2 $200-500K/CY
3 $100-200K/CY
4 $50-100K/CY
5 < $50K/CY

TABLE 6-5

CORRECTIVE MEASURES ALTERNATIVES SCREENING MATRIX
RECOVERED GROUNDWATER TREATMENT AT T-38 TEST CELL (SS-59/SWMU 229)
HOLLOMAN AIR FORCE BASE, NEW MEXICO

TECHNOLOGY CONSIDERED	APPLICABILITY to SITE				RELATIVE COSTS		TREATMENT TIME ACCEPTABILITY	RATING SUMMATION	RETAIN YES/NO
	Advantage	Disadvantage	Relative Applicability Technical 0 - 5 A	Permits 0 - 3 P	Capital C	Operating O	Not Acceptable Acceptable T		
					High$ 1 2 3 4 5 Low$		1 2 3	A*P*(C+O+T)	
NO ACTION/DIRECT DISCHARGE	i/perf	nperm,cnr	5	0	5	5	2	0	No
CARBON (DISPOSABLE)	i/perf	--	4	3	4	1	2	84	Yes
AIR STRIPPER - STACKED TRAYS	i/perf	adtrt	4	2	4	3	2	72	Yes
AIR STRIPPER - DISPERSION TOWER	i/perf	adtrt	3	2	4	3	2	54	Yes
AIR STRIPPER - PACKED COLUMN	i/perf	ia,adtrt	1	2	4	3	2	18	No
BIOREACTOR	dest	et,adtrt,area	3	2	3	2	2	42	No
UV PEROXIDATION	dest	et,igc	3	2	1	2	2	30	No

LEGEND

ADVANTAGES
mred - Mobility Reduction
dest - Destruction
vred - Volume Reduction
perf - Performance & Reliable
i - Implementability
me - Exposure Minimization

DISADVANTAGES
et - Emerging Technology
ia - Inappropriate Technology
nperm - Not Permittable
cnr - Contaminant Not Removed
area - Area Required
ci - Community Impact
adtrt - Additional Treatment Required
smat = Inappropriate soil material
dtw = Depth to water
pni = Potential negative interaction
drs = Does not reach site remediation level
tna = Technology not available
pal = potential additional liability
igc = inappropriate gw contaminants

TIME LEGEND
1 > 3 years
2 > 1-3 years
3 < 1 year

PERMIT LEGEND
0 = not permittable
1 = major concern
2 = potential/slight concern
3 = not concern

COST LEGEND
1 > $500K/CY
2 $200-500K/CY
3 $100-200K/CY
4 $50-100K/CY
5 < $50K/CY

TABLE 6-6

CORRECTIVE MEASURES ALTERNATIVES SCREENING MATRIX
RECOVERED GROUNDWATER TREATMENT AT BUILDING 828 (SS-60/SWMU 230)
HOLLOMAN AIR FORCE BASE, NEW MEXICO

TECHNOLOGY CONSIDERED	APPLICABILITY to SITE				RELATIVE COSTS		TREATMENT TIME ACCEPTABILITY	RATING SUMMATION	RETAIN YES/NO
	Advantage	Disadvantage	Relative Applicability Technical 0 - 5 A	Permits 0 - 3 P	Capital C	Operating O	Not Acceptable Acceptable T		
					High$ 1 2 3 4 5 Low$		1 2 3	A*P*(C+O+T)	
NO ACTION/DIRECT DISCHARGE	i/perf	nperm,cnr	5	0	5	5	2	0	No
CARBON (DISPOSABLE)	i/perf	ia	1	3	3	1	2	18	No
AIR STRIPPER - STACKED TRAYS	i/perf	--	4	2	4	4	2	80	Yes
AIR STRIPPER - DISPERSION TOWER	i/perf	--	4	2	3	3	2	64	No
AIR STRIPPER - PACKED COLUMN	i/perf	--	3	2	3	3	2	48	No
BIOREACTOR	dest	et/area	3	2	2	3	3	42	No
UV PEROXIDATION	dest	igc/et	2	2	1	2	2	20	No

LEGEND

ADVANTAGES
mred - Mobility Reduction
dest - Destruction
vred - Volume Reduction
perf - Performance & Reliable
i - Implementability
me - Exposure Minimization

DISADVANTAGES
et - Emerging Technology
ia - Inappropriate Technology
nperm - Not Permittable
cnr - Contaminant Not Removed
area - Area Required
ci - Community Impact
adtrt - Additional Treatment Required
smat = Inappropriate soil material
dtw = Depth to water
pni = Potential negative interaction
drs = Does not reach site remediation level
tna = Technology not available
pal = potential additional liability
igc = inappropriate gw contaminants

TIME LEGEND
1 > 3 years
2 > 1-3 years
3 < 1 year

PERMIT LEGEND
0 = not permittable
1 = major concern
2 = potential/slight concern
3 = not concern

COST LEGEND
1 > $500K/CY
2 $200-500K/CY
3 $100-200K/CY
4 $50-100K/CY
5 < $50K/CY

TABLE 6-7

CORRECTIVE MEASURES ALTERNATIVES SCREENING MATRIX
RECOVERED WATER DISCHARGE OPTIONS
T-38 TEST CELL (SS-59/SWMU 229) AND BUILDING 828 (SS-60/SWMU 230)
HOLLOMAN AIR FORCE BASE, NEW MEXICO

OPTIONS CONSIDERED	APPLICABILITY to SITE				RELATIVE COSTS		TREATMENT TIME ACCEPTABILITY	RATING SUMMATION	RETAIN YES/NO
	Advantage	Disadvantage	Relative Applicability Technical 0 - 5 A	Permits 0 - 3 P	Capital C	Operating O	Not Acceptable Acceptable T		
					High$ 1 2 3 4 5 Low$		1 2 3	A*P*(C+O+T)	
T-38 TEST CELL									
STORM DRAIN (NPDES)	i	adtrt/ci/nperm	3	0	4	4	NA	0	No
SANITARY SEWER	i	adtrt/tna	2	2	1	3	NA	16	Yes
INFILTRATION GALLERY	i	adtrt/area	3	1	4	2	NA	24	Yes
Building 828									
STORM DRAIN (NPDES)	i	adtrt/ci/nperm	3	0	4	4	NA	0	No
SANITARY SEWER (230)	i	adtrt	4	2	5	3	NA	64	Yes
INFILTRATION GALLERY (230)	i	adtrt/area	2	1	4	2	NA	16	No

LEGEND

ADVANTAGES
mred - Mobility Reduction
dest - Destruction
vred - Volume Reduction
perf - Performance & Reliable
i - Implementability
me - Exposure Minimization

DISADVANTAGES
et - Emerging Technology
ia - Inappropriate Technology
nperm - Not Permittable
cnr - Contaminant Not Removed
area - Area Required
ci - Community Impact
adtrt - Additional Treatment Required
smat = Inappropriate soil material
dtw = Depth to water
pni = Potential negative interaction
drs = Does not reach site remediation level
tna = Technology not available
pal = potential additional liability
igc = inappropriate gw contaminants

TIME LEGEND
1 > 3 years
2 > 1-3 years
3 < 1 year

PERMIT LEGEND
0 = not permittable
1 = major concern
2 = potential/slight concern
3 = not concern

COST LEGEND
1 > $500K/CY
2 $200-500K/CY
3 $100-200K/CY
4 $50-100K/CY
5 < $50K/CY

TABLE 7-1
PRELIMINARY ESTIMATED COSTS
FOR CORRECTIVE MEASURE IMPLEMENTATION
T-38 TEST CELL - SS-59/SWMU 229
HOLLOMAN AIR FORCE BASE, NEW MEXICO

DIRECT CAPITAL	ASSUMPTIONS	COST
	Trenching, concrete pad, fence, piping, electricity	$280,000
	96 x 4-inch diameter wells, 7 x 20hp blowers	$60,000
	2 air strippers, transfer pumps, blowers	$50,000
	2 oil-water separators	$30,000
	Land and site development	$85,000
	Building and service	$20,000
INDIRECT CAPITAL		
	Engineering expenses: In situ respirometry test Design Drafting Admin	$20,000 $60,000 $10,000 $20,000
	Legal Fees and Permits	$25,000
	Startup and shake down	$20,000
	Contingency	$75,000
OPERATION AND MAINTENANCE		
	Operating labor costs	$450,000
	Maintenance materials and labor	$50,000
	Auxiliary materials and energy	$800,000
	Purchased services	$60,000
TOTAL		**$2,115,000**

TABLE 7-2
PRELIMINARY ESTIMATED COSTS
FOR CORRECTIVE MEASURE IMPLEMENTATION
BUILDING 828 - SS-60/SWMU 230
HOLLOMAN AIR FORCE BASE, NEW MEXICO

DIRECT CAPITAL	ASSUMPTIONS	COST
	250 cfm thermal/catalytic oxidizer, stripper, oil-water separator	$80,000
	5 x 4-inch diameter wells, 12 feet deep	$5,000
	Transfer pump, blower, lines to sewer	$5,000
	Land and site development costs/abandonment of system	$8,000
	Building and service	$15,000
INDIRECT CAPITAL		
	Engineering expenses: Design Drafting Admin	$20,000 $7,000 $5,000
	Legal Fees and Permits	$10,000
	Startup and shake down	$10,000
	Contingency	$25,000
OPERATION AND MAINTENANCE		
	Operating labor costs	$50,000
	Maintenance materials and labor	$15,000
	Auxiliary materials and energy	$40,000
	Purchased services	$10,000
TOTAL		**$304,000**

Appendix A

Vapor Abatement Life Cycle Cost Analysis
T-38 Test Cell - Site 59/SWMU 229

SS-59/SWMU 229, T-38 Test Cell

Run #1 - This run assumes a mass of 3 million pounds that will be removed at a rate of 4,000 cfm at a maximum concentration of 8,000 ppmv. The run assumes a capital cost of $130,000 for equipment, and a daily maximum fuel cost of $1,543 (electricity and natural gas). This run assumes that the equipment is 90% operational.

Results show 90% mass removal after one year, at a cumulative cost of $260,000. To get to 99% removal takes another 8 months at a cumulative cost of about $600,000.

Graph 1 is a plot of mass remaining versus days of operation. Graph 2 is a blow-up of the last 10% mass removal versus time.

Run #2 - This run is identical to Run#1, except the mass is 2.79 million pounds.

Results show 90% removal after one year, at a cumulative cost of $275,000. 99% removal is achieved after another 7 months, at a cumulative cost of $560,000.

Run #3 - This run assumes a mass of 2 million pounds.

Results show 90% removal after 8.5 months, at a cumulative cost of $230,000. 99% removal is achieved after 13.3 months, at a total cost of $425,000.

GROUNDWATER TECHNOLOGY
VAPOR ABATEMENT COST ANALYSIS PROGRAM
VERSION 1.1

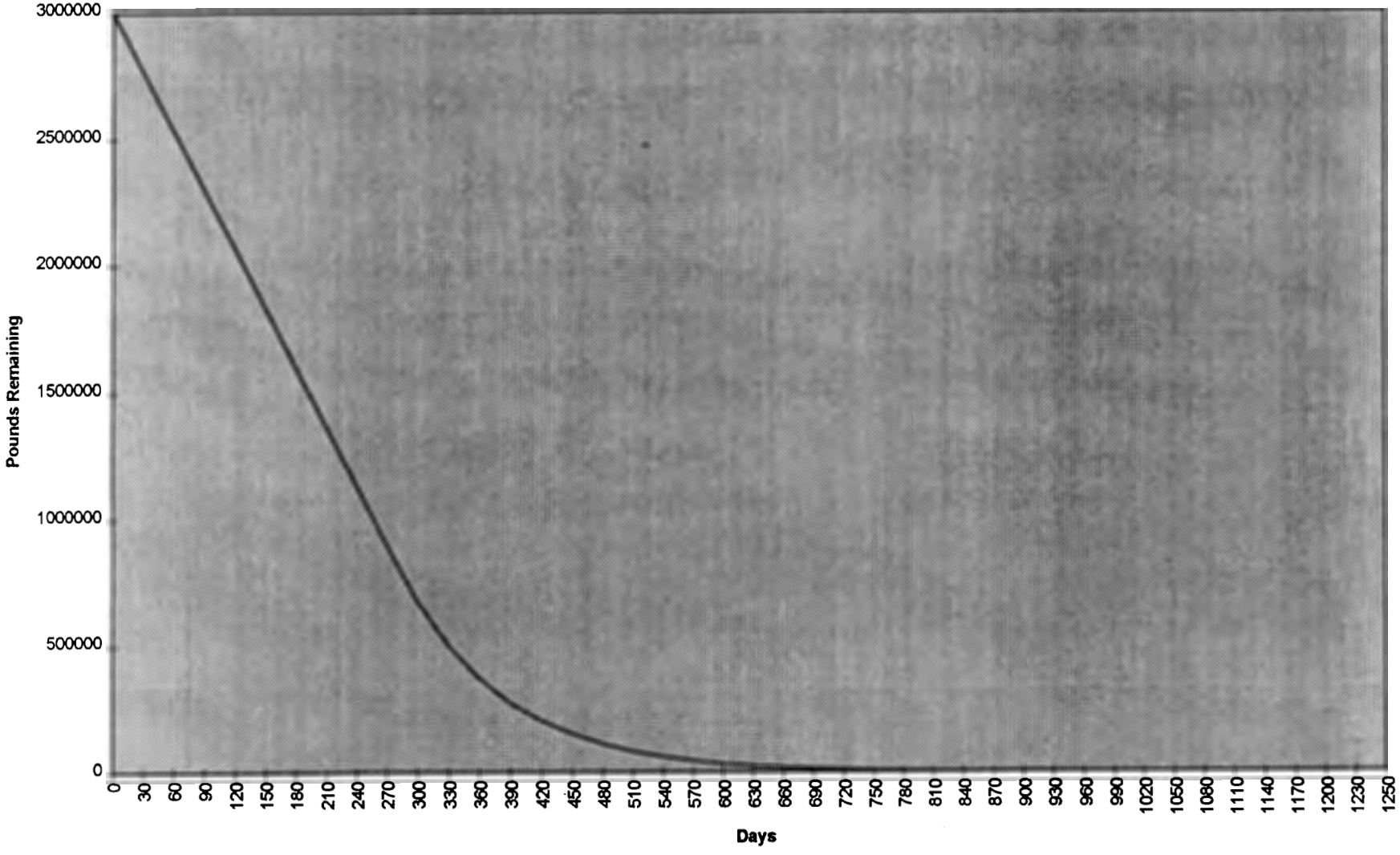
SITE NAME: Holloman T-38 test cell
SPILL SIZE (lbs): 3000000
INITIAL CONCENTRATION (ppmv): 140000
MAXIMUM EXTRACTION RATE FROM SOIL (CFM): 4000
EQUIPMENT: Thermal Oxidizer
DEVICE MAXIMUM FLOW RATE: 5000 CFM
DEVICE MAXIMUM INPUT CONCENTRATION: 8000 ppmv

REMOVAL FACTOR 0.00997357

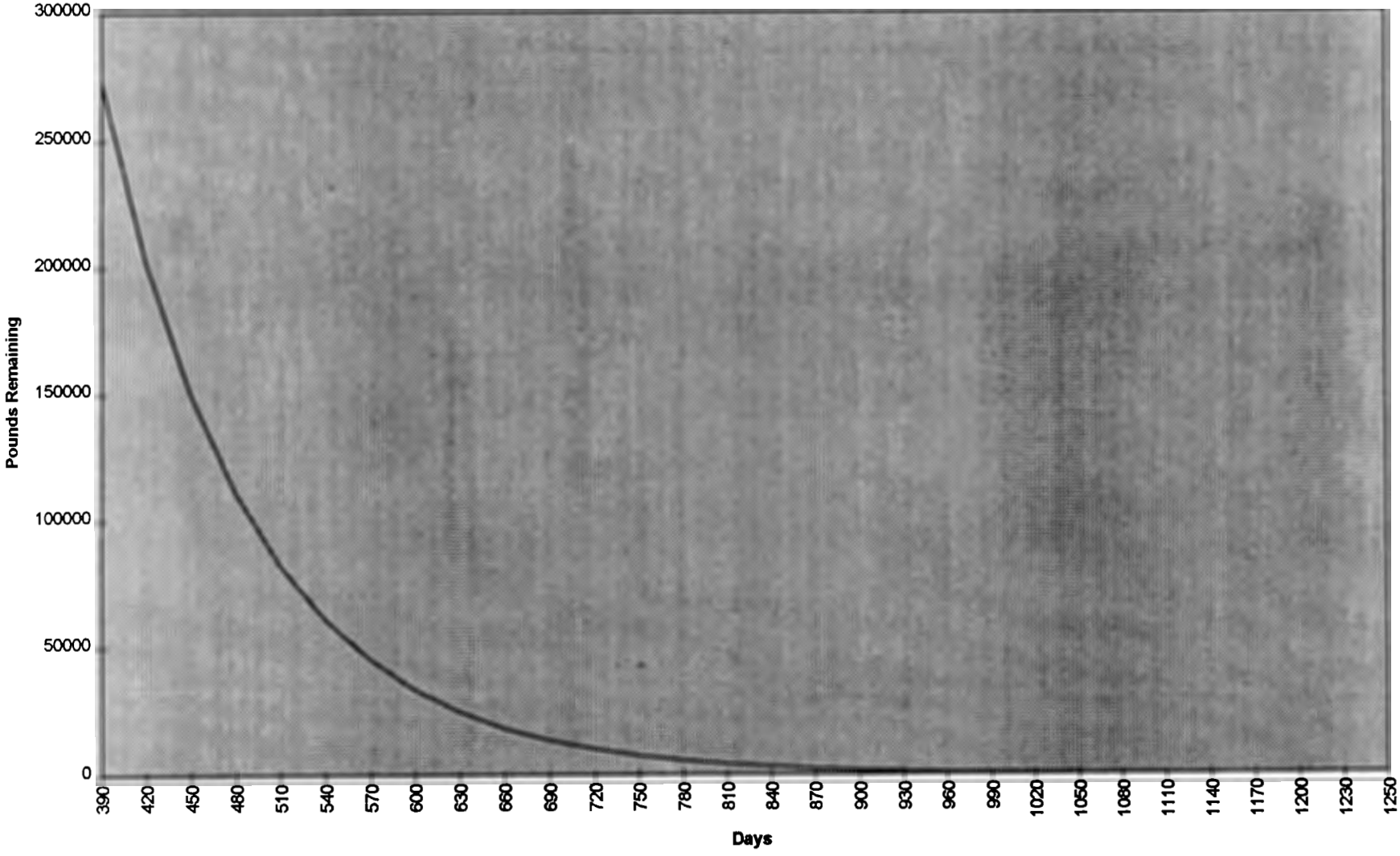
TIME (days)	CONTAMINANT LEFT (lbs)	REMOVAL (lbs/day)	DAILY FLOW (cfm)	DAILY CONCEN (ppmv)	DAILY COST ($)	CUMULATIVE COST ($)
0	3000000	0	0	140000	143	130000
30	2766720	7776	306	103641	283	138490
60	2533440	7776	413	76725	283	146980
90	2300160	7776	558	56799	283	155470
120	2066880	7776	753	42048	283	163960
150	1833600	7776	1018	31128	283	172450
180	1600320	7776	1375	23044	283	180940
210	1367040	7776	1857	17059	283	189430
240	1133760	7776	2509	12629	283	197920
270	900480	7776	3389	9349	283	206410
300	674448	6795	4000	6921	442	216074
330	499276	5030	4000	5124	728	233980
360	369598	3724	4000	3793	940	259257
390	273598	2757	4000	2808	1096	289992
420	202530	2041	4000	2079	1212	324766
450	149919	1511	4000	1539	1298	362531
480	110971	1118	4000	1139	1362	402510
510	82138	828	4000	843	1409	444128
540	60794	613	4000	624	1444	486960
570	44992	454	4000	462	1469	530689
600	33295	336	4000	342	1489	575084

630	24635	249	4000	253	1503	619971				
660	18224	184	4000	188	1513	665222				
690	13479	136	4000	139	1521	710743				
720	9965	101	4000	103	1527	756464				
750	7364	75	4000	76	1531	802332				
780	5439	55	4000	56	1534	848310				
810	4014	41	4000	42	1536	894369				
840	2959	30	4000	31	1538	940488				
870	2177	22	4000	23	1539	986652				
900	1599	17	4000	17	1540	1032848				
930	1171	12	4000	13	1541	1079069				
960	854	9	4000	9	1542	1125307				
990	620	7	4000	7	1542	1171559				
1020	446	5	4000	5	1542	1217821				
1050	317	4	4000	4	1542	1264090				
1080	222	3	4000	3	1543	1310365				
1110	152	2	4000	2	1543	1356643				
1140	99	2	4000	2	1543	1402925				
1170	61	1	4000	1	1543	1449209				
1200	32	1	4000	1	1543	1495494				
1230	11	1	4000	1	1543	1541781				
1250	0	1	4000	1	1543	1572639				
Thermal Oxidizer										
MAXIMUM FLOW RATE = 4000 CFM										
MAXIMUM INPUT CONC. = 8000 ppmv										
EFFICIENCY FACTOR = 90.0%										
INSTALLATION COST = 130000.00										
FUEL DAILY COST = 1400.00										
OTHER DAILY COST = 143.00										

Holloman T-38 Test Cell



Holloman T-38 Test Cell



GROUNDWATER TECHNOLOGY
VAPOR ABATEMENT COST ANALYSIS PROGRAM
VERSION 1.1

SITE NAME: Holloman T-38 test cell
SPILL SIZE (lbs): 2790000
INITIAL CONCENTRATION (ppmv): 140000
MAXIMUM EXTRACTION RATE FROM SOIL (CFM): 4000
EQUIPMENT: Thermal Oxidizer

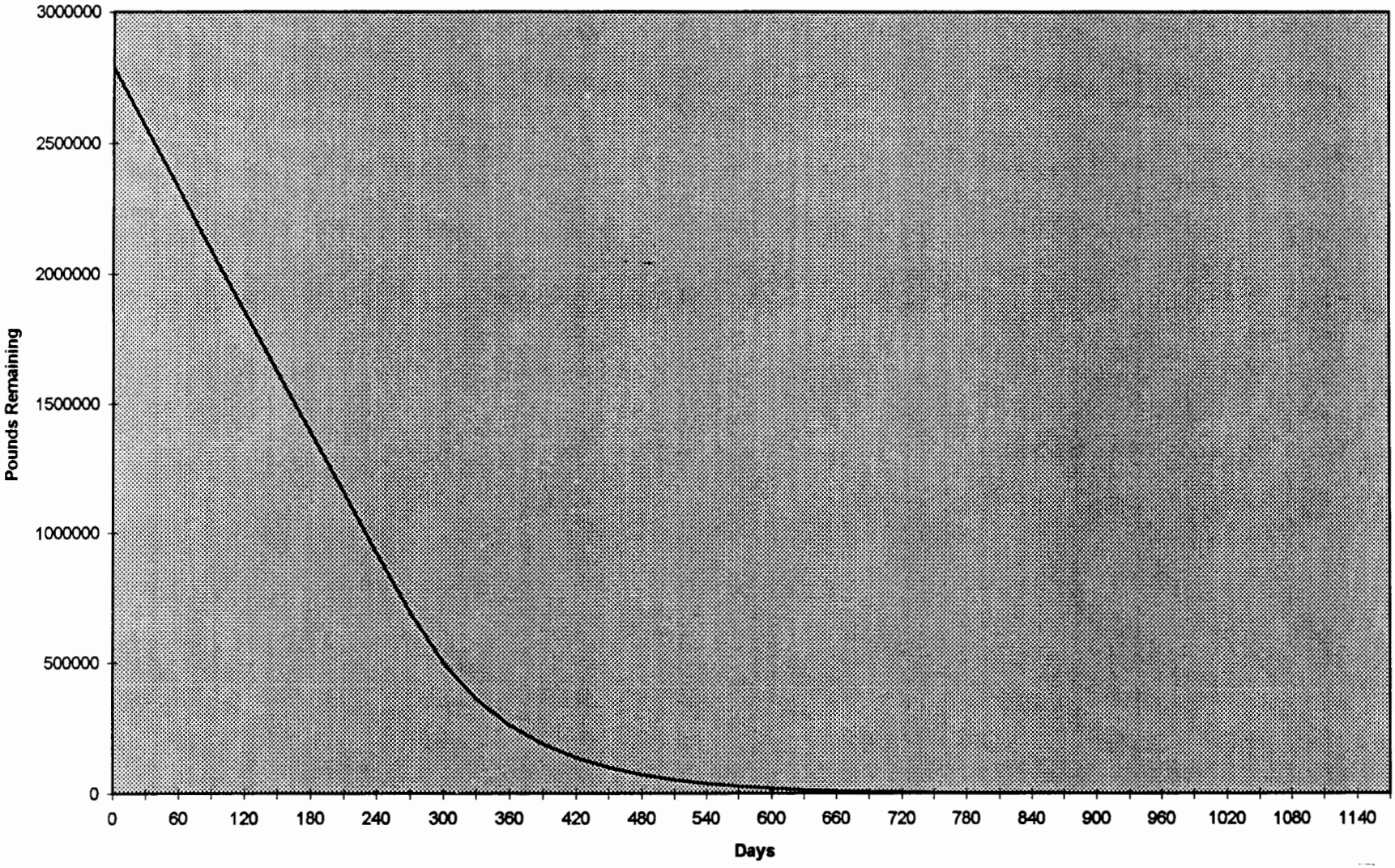
DEVICE MAXIMUM FLOW RATE: 5000 CFM
DEVICE MAXIMUM INPUT CONCENTRATION: 8000 ppmv

REMOVAL FACTOR: 0.01072127

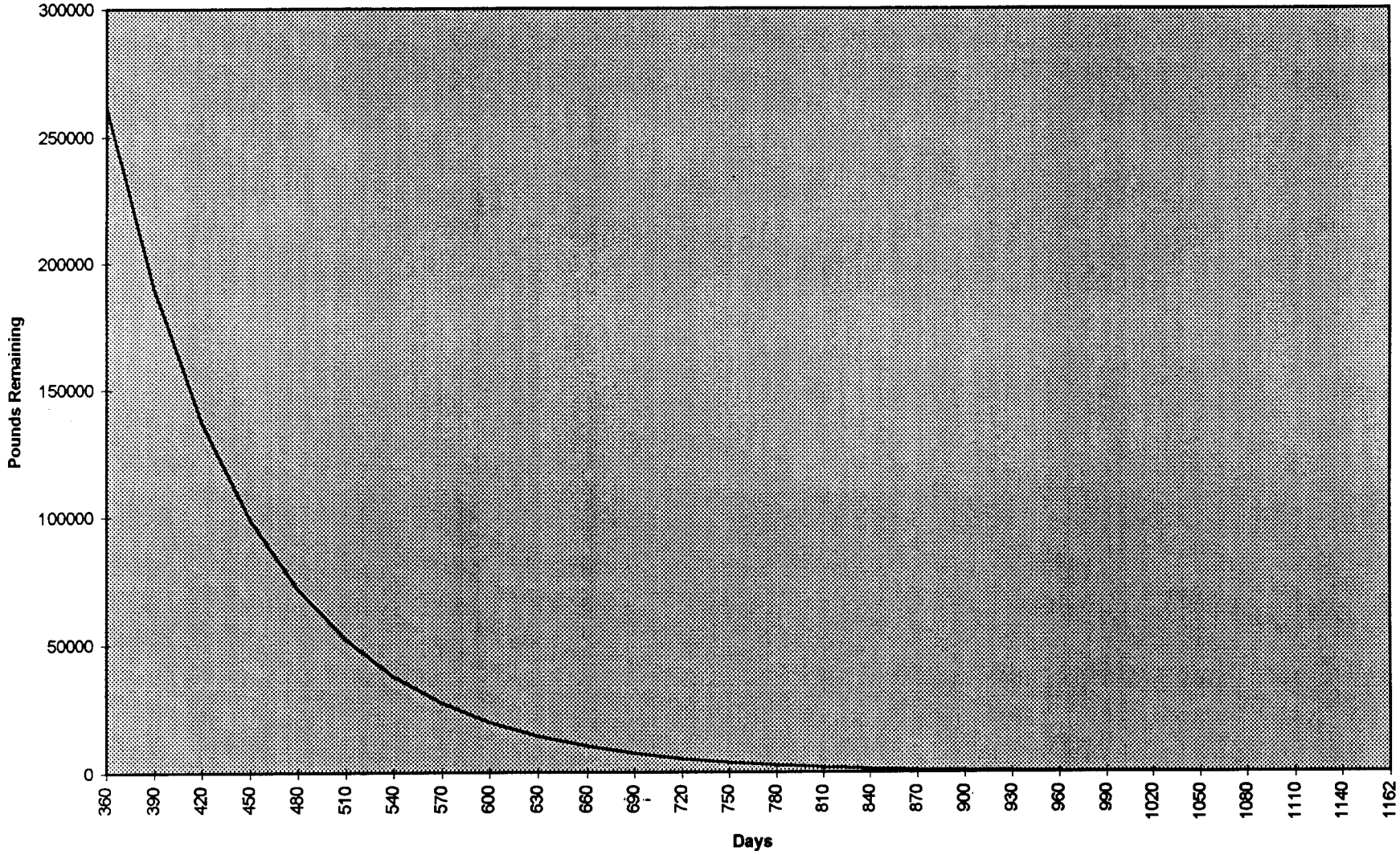
TIME (days)	CONTAMINANT LEFT (lbs)	DAILY REMOVAL (lbs/day)	DAILY FLOW (cfm)	CONCEN (ppmv)	DAILY COST ($)	CUMULATIVE COST ($)
0	2790000	0	0	140000	143	130000
30	2556720	7776	312.4	101318	283	138490
60	2323440	7776	431.7	73324	283	146980
90	2090160	7776	596.6	53065	283	155470
120	1856880	7776	824.3	38403	283	163960
150	1623600	7776	1139	27793	283	172450
180	1390320	7776	1573.9	20114	283	180940
210	1157040	7776	2174.8	14556	283	189430
240	923760	7776	3005.1	10534	283	197920
270	691131	7490.6	4000	7624	329.24	206515.48
300	500161	5421	4000	5517	664.6	221861.21
330	361955	3923.2	4000	3993	907.3	245756.75
360	261935	2839.2	4000	2890	1082.94	275839.83
390	189550	2054.7	4000	2091	1210.06	310400.84
420	137165	1487	4000	1513	1302.05	348202.53
450	99254	1076.2	4000	1095	1368.62	388349.53
480	71818	778.8	4000	793	1416.8	430193.82
510	51962	563.6	4000	574	1451.67	473266.44
540	37592	407.9	4000	415	1476.9	517228.02
570	27193	295.2	4000	300	1495.17	561832.94
600	19667	213.6	4000	217	1508.38	606903.44

630	14220	154.6	4000	157	1517.95	652310.88			
660	10279	111.9	4000	114	1524.87	697962.18			
690	7426	81	4000	82	1529.88	743789.94			
720	5361	58.6	4000	60	1533.5	789745.42			
750	3867	42.4	4000	43	1536.13	835793.33			
780	2786	30.7	4000	31	1538.03	881908.13			
810	2004	22.2	4000	23	1539.4	928071.33			
840	1437	16.1	4000	16	1540.4	974269.57			
870	1028	11.6	4000	12	1541.11	1020493.16			
900	731	8.4	4000	9	1541.64	1066735.1			
930	516	6.1	4000	6	1542.01	1112990.32			
960	361	4.4	4000	4	1542.29	1159255.15			
990	248	3.2	4000	3	1542.48	1205526.93			
1020	167	2.3	4000	2	1542.63	1251803.75			
1050	108	1.7	4000	2	1542.73	1298084.21			
1080	66	1.2	4000	1	1542.8	1344367.3			
1110	35	0.9	4000	1	1542.86	1390652.31			
1140	12	0.6	4000	1	1542.9	1436938.69			
1162	0	0.5	4000	1	1542.92	1470882.69			
Thermal Oxidizer									
MAXIMUM FLOW RATE = 4000 CFM									
MAXIMUM INPUT CONC. = 8000 ppmv									
EFFICIENCY FACTOR = 90.0%									
INSTALLATION COST = 130000.00									
FUEL DAILY COST = 1400.00									
OTHER DAILY COST = 143.00									

Holloman T-38 Test Cell



Holloman T-38 Test Cell



GROUNDWATER TECHNOLOGY

VAPOR ABATEMENT COST ANALYSIS PROGRAM

VERSION 1.1

SITE NAME: Holloman T-38 test cell

SPILL SIZE (lbs): 2000000

INITIAL CONCENTRATION (ppmv): 140000

MAXIMUM EXTRACTION RATE FROM SOIL (CFM): 4000

EQUIPMENT: Thermal Oxidizer

DEVICE MAXIMUM FLOW RATE: 5000 CFM

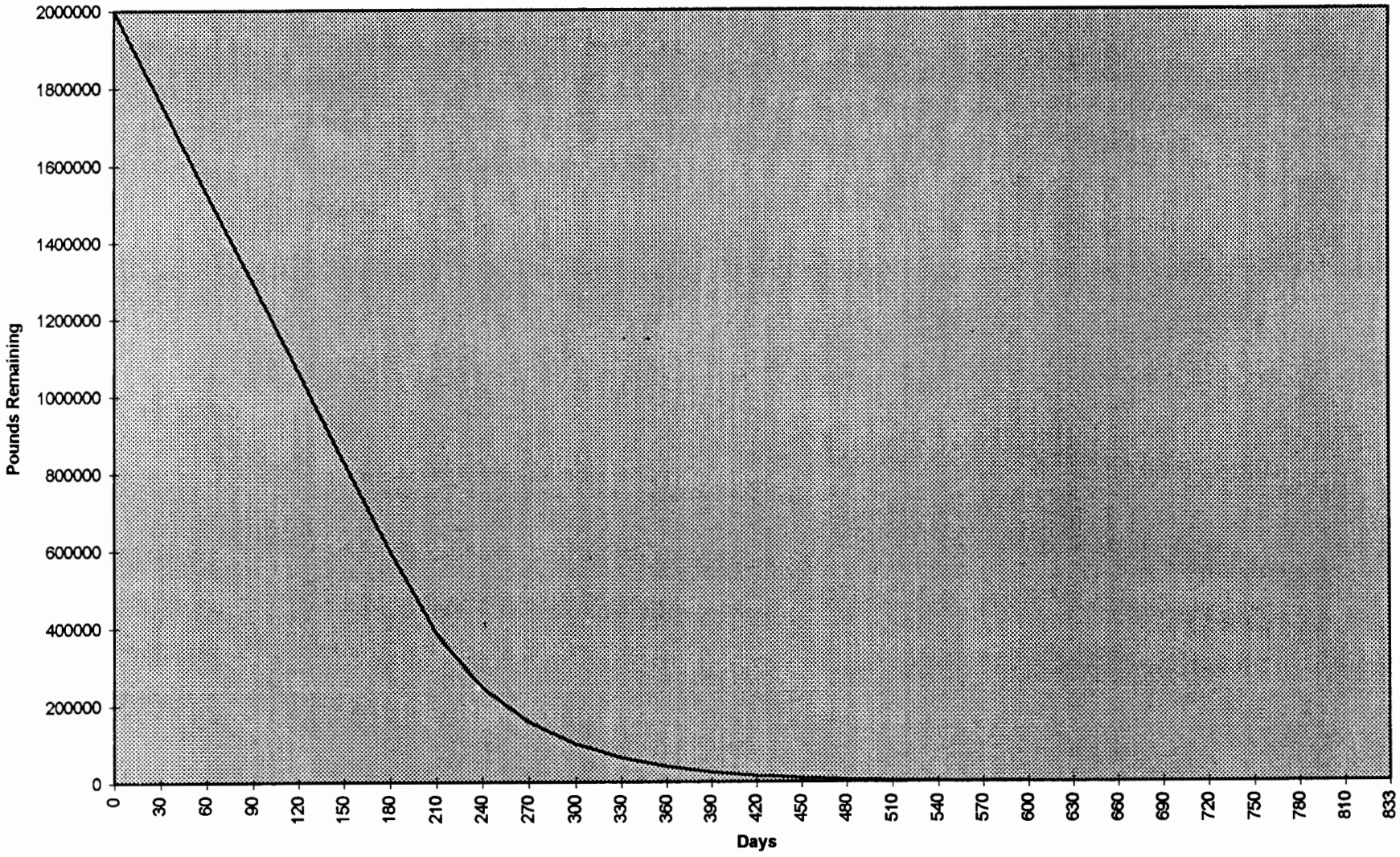
DEVICE MAXIMUM INPUT CONCENTRATION: 8000 ppmv

REMOVAL FACTOR 0.01493262

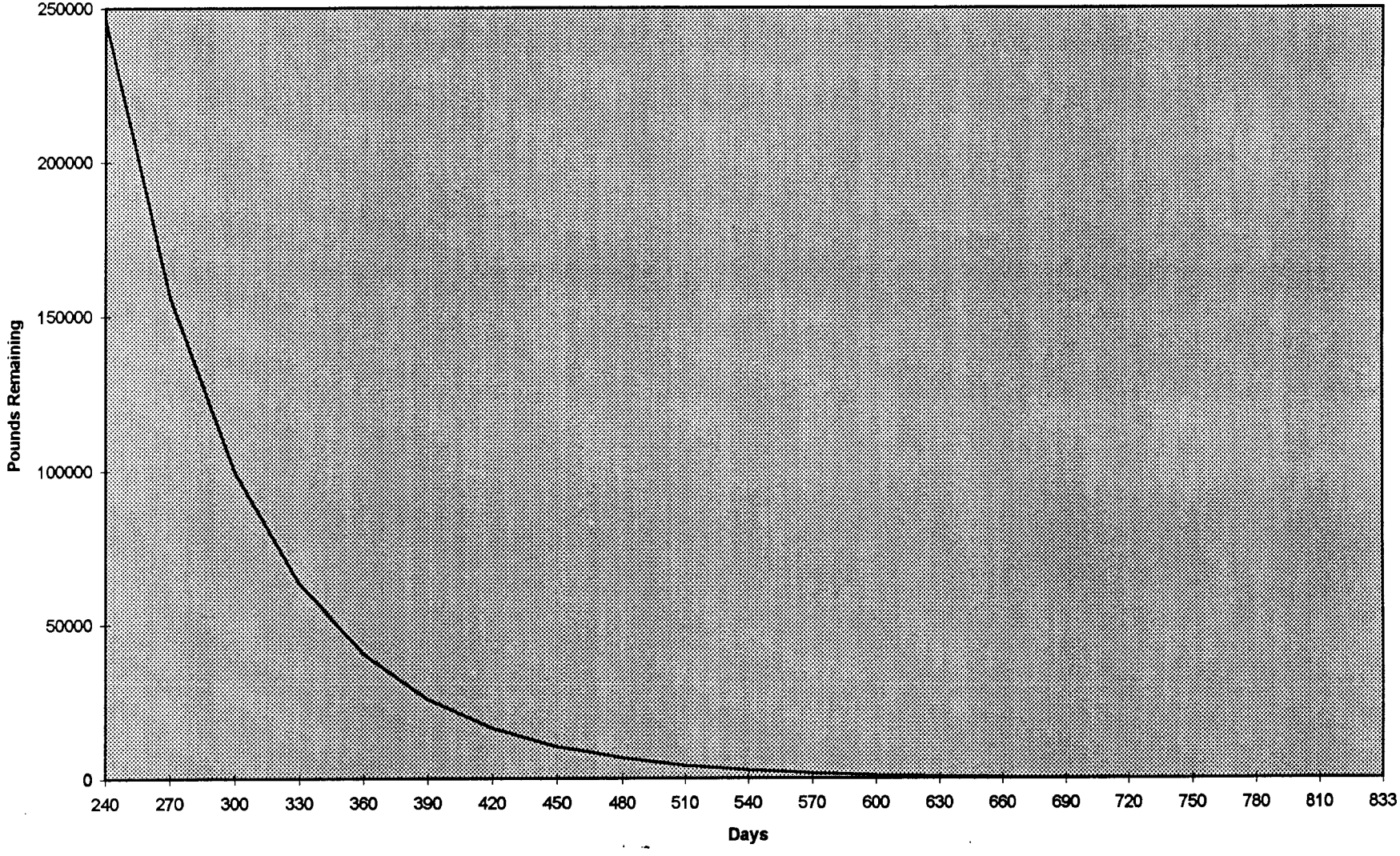
TIME (days)	CONTAMINANT LEFT (lbs)	REMOVAL (lbs/day)	DAILY FLOW (cfm)	DAILY CONCEN (ppmv)	DAILY COST ($)	CUMULATIVE COST ($)
0	2000000	0	0	140000	143	130000
30	1766720	7776	353.6	89147	283	138490
60	1533440	7776	555.3	56765	283	146980
90	1300160	7776	872.1	36146	283	155470
120	1066880	7776	1369.5	23017	283	163960
150	833600	7776	2150.8	14656	283	172450
180	600320	7776	3377.7	9332	283	180940
210	386784	5863.7	4000	5943	592.86	192629.3
240	246278	3733.8	4000	3784	937.98	216152.13
270	156809	2377.6	4000	2410	1157.75	247944.83
300	99839	1513.9	4000	1534	1297.69	285003.48
330	63562	964	4000	977	1386.79	325415.29
360	40462	613.9	4000	622	1443.53	367962.27
390	25753	390.9	4000	396	1479.66	411868.86
420	16387	248.9	4000	252	1502.67	456641.19
450	10423	158.5	4000	161	1517.32	501964.79
480	6625	100.9	4000	102	1526.65	547639.42
510	4207	64.3	4000	65	1532.59	593537.58
540	2667	40.9	4000	41	1536.37	639578.07
570	1686	26.1	4000	26	1538.78	685709.19
600	1062	16.6	4000	17	1540.31	731898.02

630	664	10.6	4000	11	1541.29	778123.6
660	411	6.7	4000	7	1541.91	824372.6
690	250	4.3	4000	4	1542.31	870636.5
720	147	2.7	4000	3	1542.56	916909.8
750	82	1.7	4000	2	1542.72	963189.2
780	41	1.1	4000	1	1542.82	1009472
810	14	0.7	4000	1	1542.89	1055758
833	0	0.5	4000	1	1542.92	1091245
Thermal Oxidizer						
MAXIMUM FLOW RATE = 4000 CFM						
MAXIMUM INPUT CONC. = 8000 ppmv						
EFFICIENCY FACTOR = 90.0%						
INSTALLATION COST = 130000.00						
FUEL DAILY COST = 1400.00						
OTHER DAILY COST = 143.00						

Holloman T-38 Test Cell



Holloman T-38 Test Cell



Appendix B

Vapor Abatement Life Cycle Cost Analysis
Building 828 - Site 60/SWMU 230

SS-60/SWMU 230, Building 828

Run #1 - This run assumes a mass of 40,000 pounds of hydrocarbons is present, removed at a rate of 200 cfm at a maximum concentration of 8,000 ppmv. Cost assumptions are $45,000 for capital, and maximum energy costs of $80 per day. 90% operation is assumed.

Results show 90% removal after 5 months, at a cumulative cost of $52,000. 99% removal is predicted after 9 months, at a total cost of $62,000.

GROUNDWATER TECHNOLOGY

VAPOR ABATEMENT COST ANALYSIS PROGRAM

VERSION 1.1

SITE NAME: Holloman SWMU 230

SPILL SIZE (lbs): 40000

INITIAL CONCENTRATION (ppmv): 14000

MAXIMUM EXTRACTION RATE FROM SOIL (CFM): 200

EQUIPMENT: Thermal Oxidizer

DEVICE MAXIMUM FLOW RATE: 250 CFM

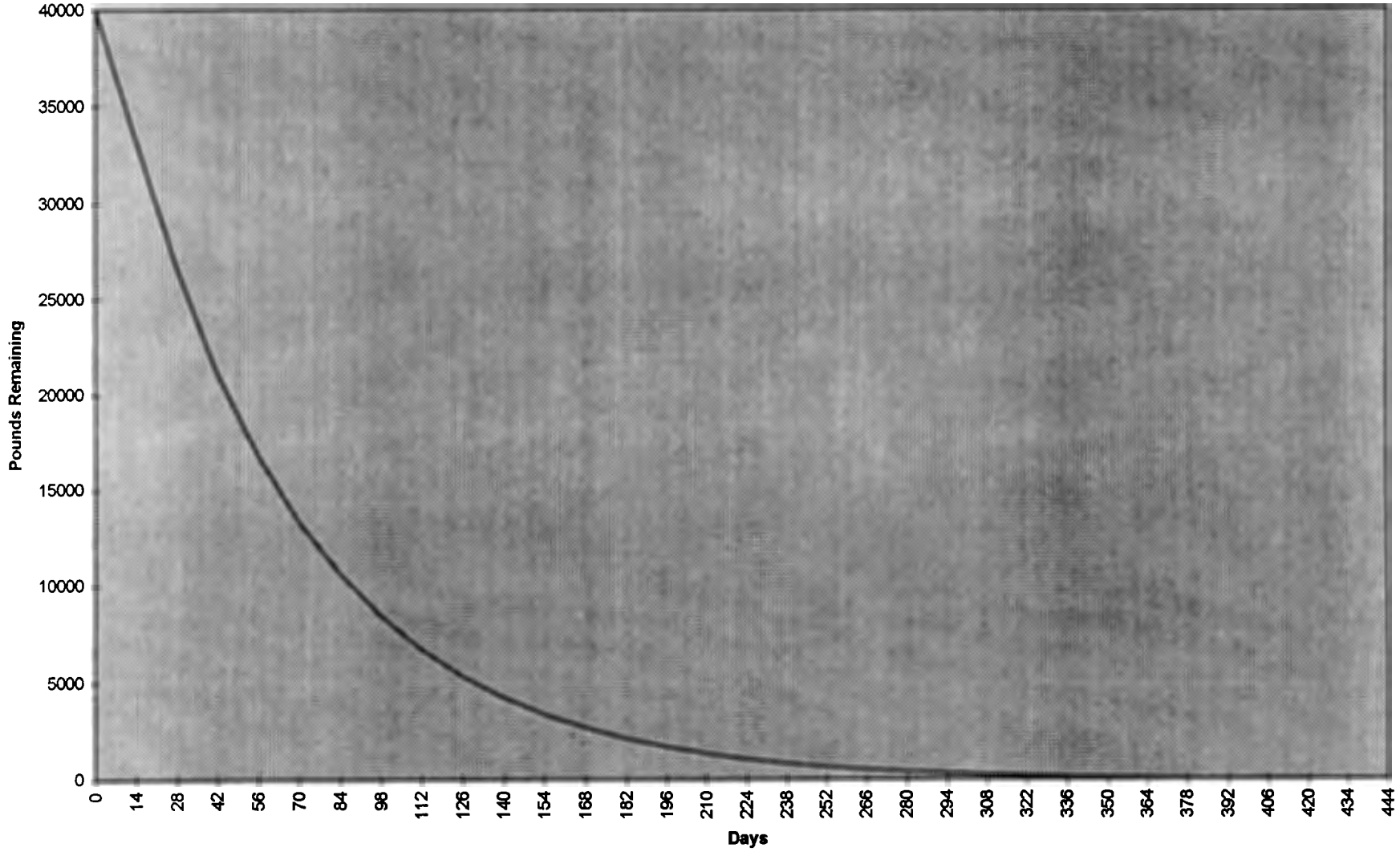
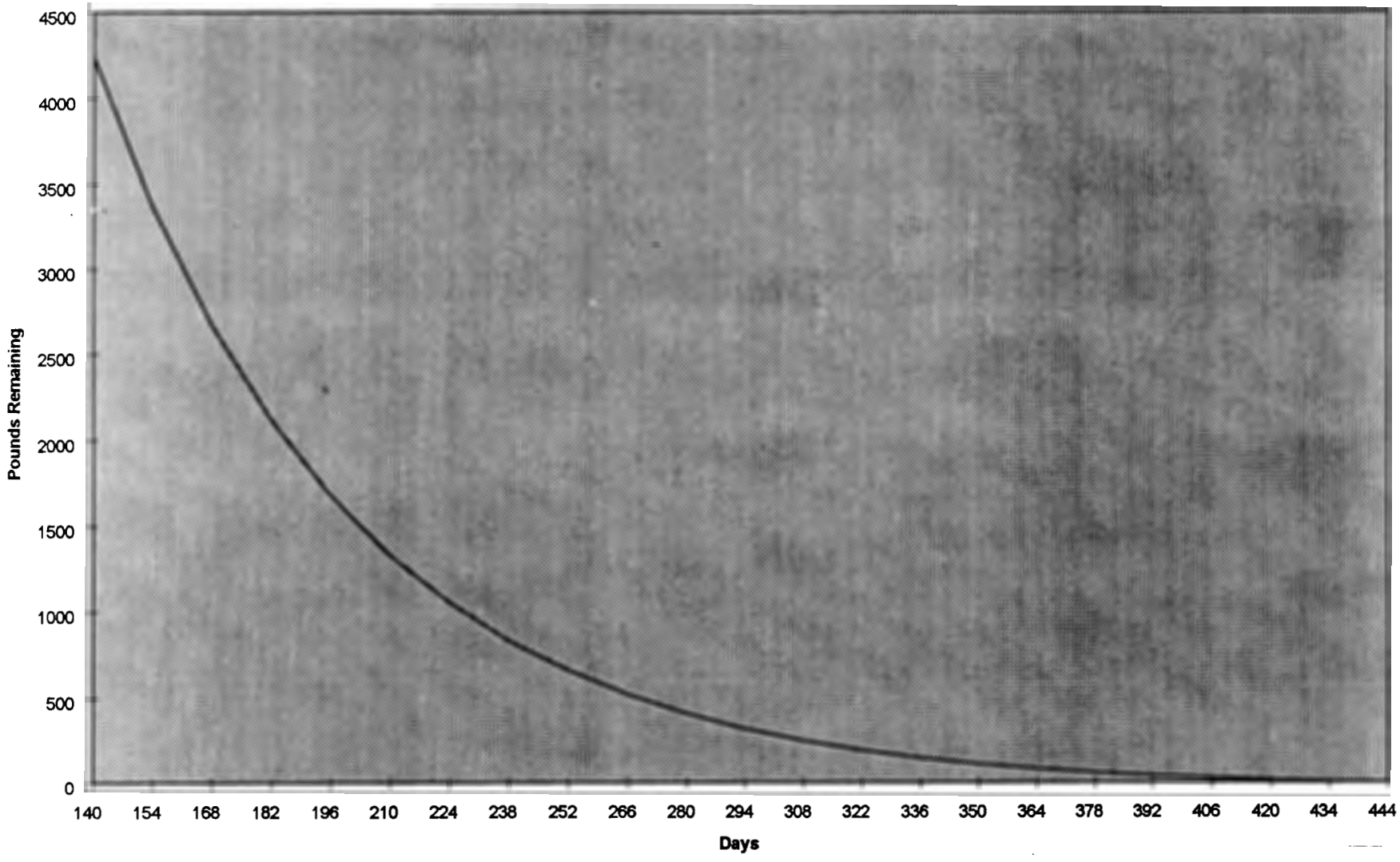
REMOVAL FACTOR

DEVICE MAXIMUM INPUT CONCENTRATION: 8000 ppmv 0.01619250

TIME (days)	CONTAMINANT LEFT (lbs)	REMOVAL (lbs/day)	DAILY FLOW (cfm)	DAILY CONCEN (ppmv)	DAILY COST ($)	CUMULATIVE COST ($)
0	40000	0	0	14000	10	45000
14	33196	486	176.6	11140	17	45238
28	26573	437.9	200	8864	23.24	45499.51
42	21138	348.4	200	7053	34.84	45914.93
56	16813	277.2	200	5612	44.06	46474.29
70	13372	220.6	200	4465	51.41	47148.21
84	10634	175.5	200	3553	57.25	47913.26
98	8455	139.7	200	2827	61.9	48750.84
112	6721	111.1	200	2249	65.6	49646.11
126	5342	88.4	200	1790	68.54	50587.31
140	4245	70.4	200	1424	70.88	51565.03
154	3371	56	200	1133	72.74	52571.82
168	2676	44.5	200	902	74.23	53601.75
182	2123	35.4	200	717	75.41	54650.08
196	1683	28.2	200	571	76.34	55713.05
210	1333	22.4	200	454	77.09	56787.67
224	1055	17.9	200	361	77.69	57871.56
238	833	14.2	200	288	78.16	58962.83
252	657	11.3	200	229	78.53	60059.97
266	517	9	200	182	78.83	61161.79
280	405	7.2	200	145	79.07	62267.31

294	316	5.7	200	115	79.26	63375.8			
308	245	4.5	200	92	79.41	64486.63			
322	189	3.6	200	73	79.53	65599.34			
336	144	2.9	200	58	79.63	66713.54			
350	109	2.3	200	46	79.7	67828.93			
364	81	1.8	200	37	79.76	68945.25			
378	58	1.4	200	29	79.81	70062.33			
392	40	1.1	200	23	79.85	71180.01			
406	26	0.9	200	19	79.88	72298.16			
420	14	0.7	200	15	79.91	73416.68			
434	5	0.6	200	12	79.92	74535.51			
444	0	0.5	200	10	79.94	75334.83			
Thermal Oxidizer									
MAXIMUM FLOW RATE = 250 CFM									
MAXIMUM INPUT CONC. = 8000 ppmv									
EFFICIENCY FACTOR = 90.0%									
INSTALLATION COST = 45000.00									
FUEL DAILY COST = 70.00									
OTHER DAILY COST = 10.00									

Holloman SWMU 230



Holloman SWMU 230