111889

NUS CORPORATION

GANNETT FLEMING, INC.
BALTIMORE, MARYLAND

FINAL

FOCUSED FEASIBILITY STUDY

VOLUME 2

HELEVA LANDFILL SITE
LEHIGH COUNTY, PENNSYLVANIA

EPA WORK ASSIGNMENT
NUMBER 37-05-3L59.0
CONTRACT NUMBER 68-W8-0037

NUS PROJECT NUMBER 0222

JULY 1990

AR303136

APPENDIX D

REPORT ON THE RESULTS OF THE VACUUM EXTRACTION

TREATABILITY STUDY

REPORT ON THE RESULTS OF THE VAPOR EXTRACTION TREATABILITY STUDY

AT THE

HELEVA LANDFILL SITE
LEHIGH COUNTY, PENNSYLVANIA
CONTRACT NUMBER 68-W8-0037

PREPARED FOR:

NUS CORPORATION
ONE DEVON SQUARE, SUITE 222
724 WEST LANCASTER AVENUE
WAYNE, PA 19087

AND

GANNETT FLEMING, INC.
EAST QUADRANGLE, THE VILLAGE OF CROSS KEYS
BALTIMORE, MD 21210

PREPARED BY:

VAPEX ENVIRONMENTAL TECHNOLOGIES, INC.
480 NEPONSET STREET
CANTON, MA 02021

VAPEX PROJECT NO. 89-100
NUS PROJECT NO. 0222
GANNETT FLEMING PROJECT NO. 26056.001

MAY 1990

EXECUTIVE SUMMARY

This report presents the results of the soil vapor extraction (or vacuum extraction) treatability study conducted by Vapex Environmental Technologies, Inc. (*VAPEX*) at the Heleva Landfill Superfund site in Lehigh County, Pennsylvania. The work was performed by *VAPEX* under contract to NUS Corporation (NUS) as part of the ARCS III Program.

The primary objective of the treatability study was to evaluate the effectiveness of vacuum extraction to remediate specific VOCs from the vadose zone soils at the site. The evaluation was based on specific physical and chemical criteria which include:

- Range of Influence - a determination of the range of influence of vacuum pressure in various soil units at the site.

- Operating Parameters - an evaluation of the effects of key operating parameters on system performance, including vapor extraction rate and vacuum pressure.

- System Configuration - an evaluation of the effects of various system components and configurations on system performance.

- Remediation Time - an estimation of the length of time required to remediate the contaminated soils to the cleanup criteria specified in the contract documents.

To achieve the treatability study objectives, *VAPEX* installed a pilot scale soil vapor extraction system and monitored physical and chemical performance characteristics of the system over an approximately two week operating period between February 27 and March 13, 1990. The pilot scale system included two vacuum extraction wells and 13 vapor probe monitoring points and was operated at air flow rates of from 5 to 13 cfm. As expected, trichloroethylene (TCE) was the primary constituent in the vapor discharge, although a wide variety of chlorinated and aromatic hydrocarbons were detected in the discharge from the pilot scale system.

VAPEX used the pilot scale test data in proprietary air flow and contaminant transport models to evaluate vadose zone soil/air flow parameters and to simulate full scale vapor extraction system performance. Pilot test and modelling results indicate that soil air flow characteristics vary significantly within two identified vadose zone soil units.

It was determined that vertical vacuum extraction wells in the shallow strata (from ground surface to a depth of approximately 25 feet) would be capable of achieving an effective radius of influence of approximately 50 feet at an optimal vapor extraction rate of 100 cfm and a corresponding well head vacuum pressure of 15 inches of mercury. The maximum initial VOC removal rates from the shallow wells would be approximately 100 pounds per day. Vertical vacuum extraction wells in the deep strata (from a depth of 25 to 45 feet below ground surface) would be capable of achieving an effective radius of influence of approximately 10 feet at an optimal vapor extraction rate of 7 cfm and a corresponding well head vacuum pressure of 15 inches of mercury. The maximum initial VOC removal rates from the deep wells would be approximately 20 pounds per day. It is estimated that if the saturated zone soils above the bedrock (from a depth of 45 to 65 feet below ground surface) were dewatered, they would display air flow and chemical removal characteristics similar to the deep vadose zone soils.

A conceptual design for a full scale vapor extraction system was developed for each of the three soil zones.

Assuming a shallow zone remediation area of approximately 62,500 square feet, the full scale system for the shallow zone would consist of 11 vertical vacuum extraction wells spaced at 100 feet on center. Based on an estimated total of 2,750 pounds of VOCs present in the vadose zone soils within this area, the estimated remediation time to achieve soil clean up goals would be one year. The net present value of the estimated cost for the shallow zone system is approximately $991,000, or $17 per yard of soil.

Assuming a remediation area of approximately 65,500 square feet, the full scale system for the deep zone would consist of 156 vertical vacuum extraction wells spaced at 20 feet on center. Based on an estimated total of 2,570 pounds of VOCs present in the vadose zone soils within this area, the estimated remediation time to achieve soil clean up goals would be two years. The net present value of the estimated costs for the deep zone system is approximately $8,254,000, or $88 per yard of soil.

Assuming a remediation area of approximately 122,500 square feet, the full scale system for the soils above the bedrock zone would consist of 306 vertical vacuum extraction wells spaced at 20 feet on center. Based on an estimated total of 5,544 pounds of VOCs present in the zone soils within this area, the estimated remediation time to achieve soil clean up goals would be three to five years. The net present value of the estimated costs for the system to treat the soil above the bedrock (excluding ground water drawdown and treatment costs), is approximately $9,826,000, or $108 per yard of soil.

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1.0 INTRODUCTION

On February 1, 1990, Vapex Environmental Technologies, Inc. (*VAPEX*) was awarded the contract (ARCS III Program, EPA Contract Number 68-W8-0037) for the vacuum extraction treatability study at the Heleva Landfill Superfund Site in Lehigh County, Pennsylvania. The study was performed by *VAPEX* under contract to NUS Corporation (NUS). *VAPEX* prepared the following report which presents the results of the treatability study.

1.1 Site History

The Heleva Landfill Site is an inactive, 20 acre landfill constructed in a former quarry, located in North Whitehall Township; Lehigh County, Pennsylvania. Figures 1-1 and 1-2 designate the approximate study area. The site began operating as a sanitary landfill in 1967 receiving both municipal and industrial waste. These wastes were believed to include chlorinated solvents, in general, and trichloroethylene (TCE), in particular.

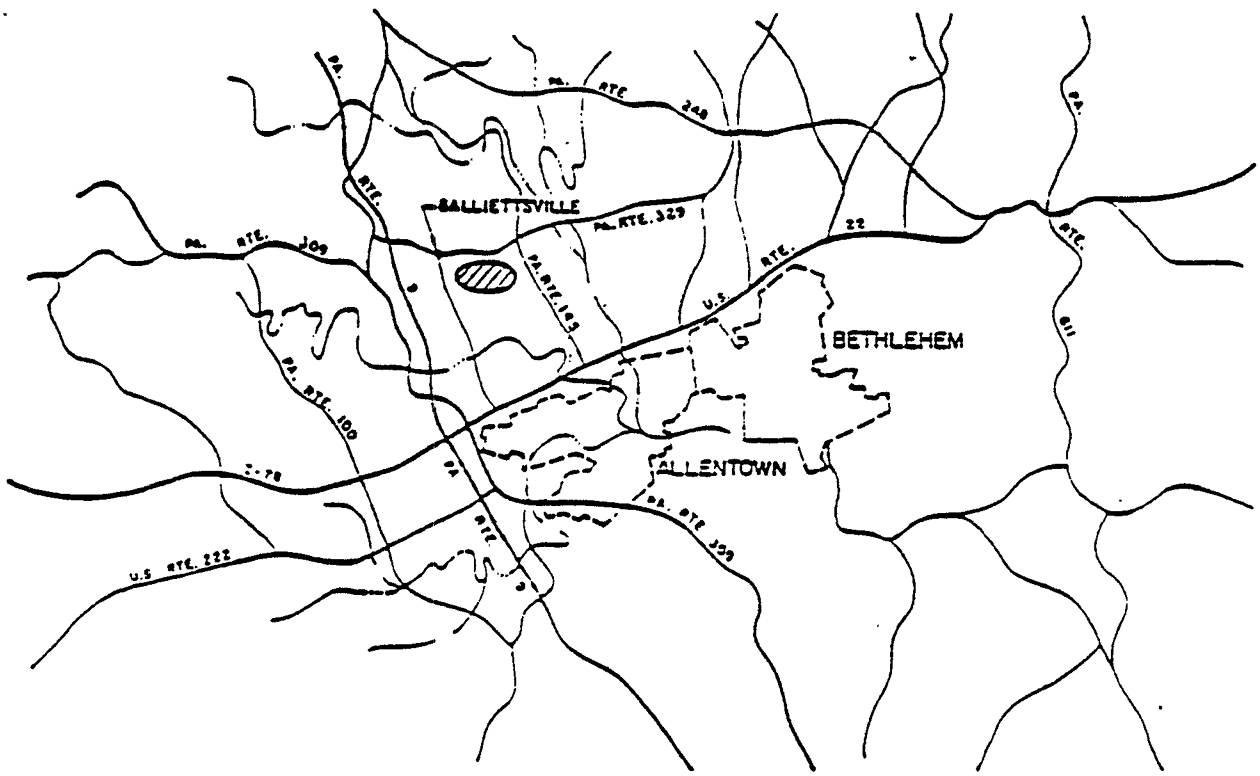
On November 15, 1979, the site was listed as potentially hazardous by the Pennsylvania Department of Environmental Resources (PADER) and the United States Environmental Protection Agency (EPA). Site closure was ordered in 1981 by PADER. On August 4, 1982, the site was placed on the National Priority List (NPL) for hazardous waste sites in accordance with the Comprehensive Environmental Response Compensation and Liability Act (CERCLA).

1.2 Technology Description

Vapor (or vacuum) extraction removes volatile organic compounds (VOCs) from soil above the water table (soil in the unsaturated or vadose zone) by applying a vacuum to the contaminated soil mass. Extraction wells (or manifold in trenches or soil piles) connected to vacuum pumps provide the means for extracting contaminated soil vapors. Vacuum pumps draw air through the soil, upsetting the physical/chemical equilibrium conditions that exist between the contaminants and the soil system. The moving air entrains and removes contaminants that exist in the vapor phase, causing further volatilization of contaminants from the liquid phase. Continuation of this process results in essentially complete removal of the VOC contamination from the soil.

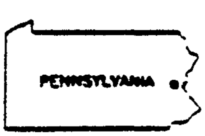
There are three basic factors that govern the successful application of vapor extraction: 1) the physical-chemical properties of the contaminants of concern (i.e., are they sufficiently volatile?), 2) the ability to establish a significant vapor flow rate through the affected unsaturated soils (i.e., are the soils permeable enough?), and 3) the ability to establish an air flow path in close proximity to the contaminant source location (i.e., can you get air to the contaminant?).

VAPEX utilizes proprietary air flow and contaminant transport computer models to evaluate vadose zone soil/air flow parameters and to simulate vapor extraction system performance. Computer modeling allows *VAPEX* to determine overall system feasibility, to establish optimal vapor extraction system configurations and operating parameters, and to estimate the time required to remediate the soils to specified target contaminant closure levels.



Base Drawing Source Gannett Fleming, Inc., 1989

JOB	TITLE
89-100	Site Location Plan
DATE 4/3/90	SITE HELEVA LANDFILL SITE LEHIGH COUNTY, PA.
SCALE 1"=10mi	VAPEX ENVIRONMENTAL TECHNOLOGIES 480 NEPONSET STREET CANTON, MA 02021
DRAWN HP	
CHECKED BC	TEL 617 821-5560 FAX 617 821-4987

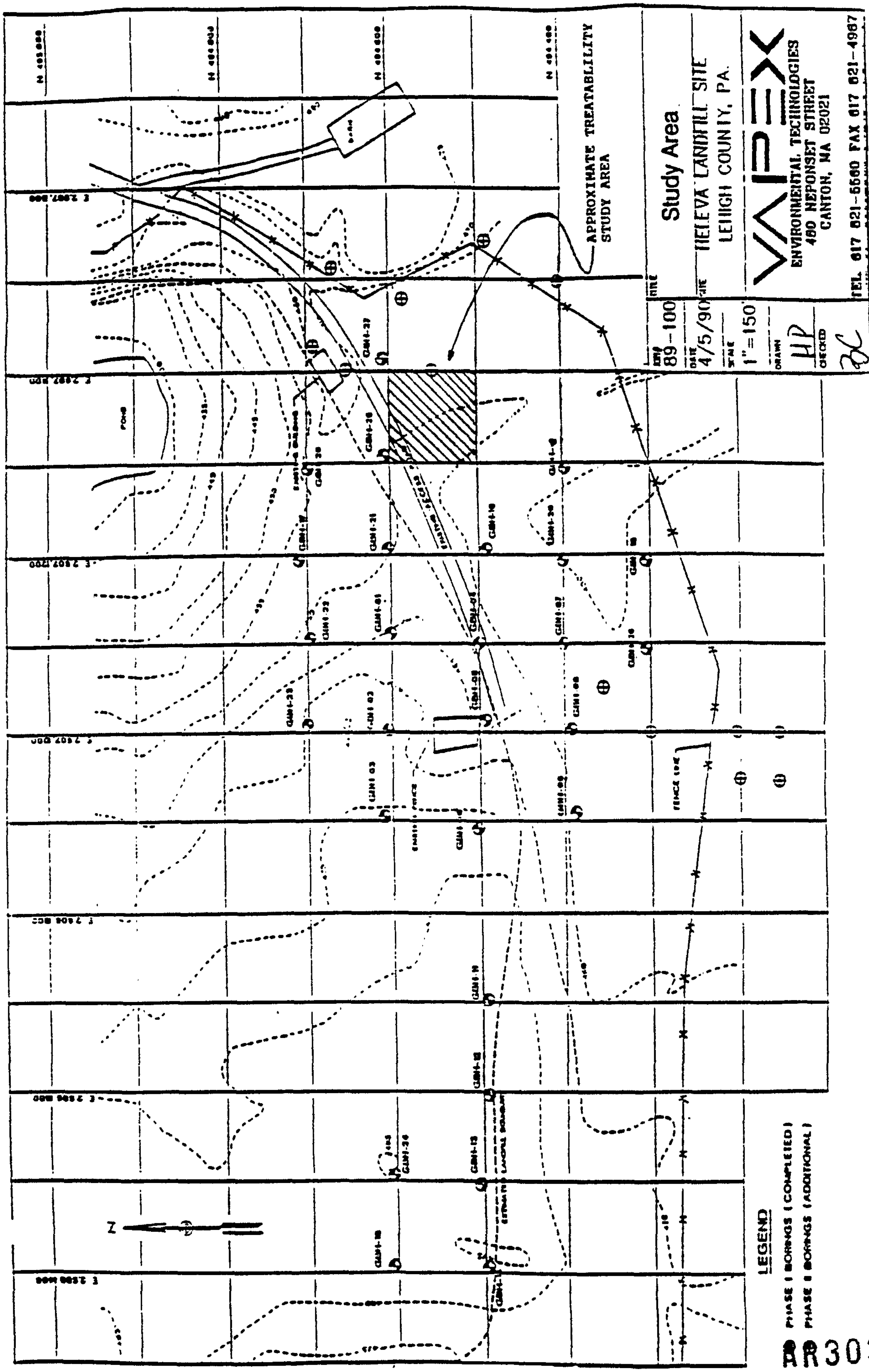


QUADRANGLE LOCATION

STUDY AREA

Figure 1

D-10



Base Drawing Source Gannett Fleming, Inc., 1989

Figure 1-2

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1.3 Treatability Study and Objectives

The primary objective of this treatability study was to evaluate the effectiveness of vacuum extraction to remediate specific VOCs from the vadose zone soils at the site. The evaluation was based on specific physical and chemical criteria which include:

- Range of influence - a determination of the range of influence of vacuum pressure in various soil units at the site.

- Operating parameters - an evaluation of the effects of key operating parameters on system performance, including vapor extraction rate and vacuum pressure.

- System configuration - an evaluation of the effects of various system components and configurations on system performance.

- Remediation time - an estimation of the length of time required to remediate the contaminated soils to the cleanup criteria specified in the contract documents.

2.0 METHODS

This section presents the methodologies and equipment used throughout the soil vacuum extraction feasibility study at the Heleva Landfill Site. A chronology covering the vapor probe and vacuum well installation, pilot test system installation, and pilot test operation is presented. Physical and chemical modelling techniques that were utilized for the interpretation of treatability study data and the evaluation of vacuum extraction feasibility, are presented as well.

2.1 Vacuum Well and Vapor Probe Installation

2.1.1 Overview

Background information provided by NUS and Gannett Fleming, Inc. (GF) indicated that vadose zone soils at the Heleva Landfill site consist primarily of silt and clay occasionally interspersed with varying amounts of sand, clay, and fine gravel. The water table is located approximately 50 to 70 feet below ground surface, although perched water conditions have been encountered in some areas at depths ranging from 15 to 25 feet.

Recent exploratory borings indicated that vadose zone soils at the site in the vicinity of the study area consist primarily of silts and clays with varying amounts of sand. A distinct sand layer was encountered at a depth of 20 to 25 feet below ground surface. Soil moisture was visually classified as "moist to wet" from a depth of 10 to 25 feet, and a noticeable decrease in soil moisture was observed below 25 feet. The water table was encountered at a depth of approximately 50 to 55 feet.

Based on this information, *VAPEX* recommended a vacuum well/vapor probe network that consisted of two vertical vacuum extraction wells nested in a single borehole, and 13 vapor probe monitoring points nested in four additional boreholes.

TABLE 1-1
SOIL CLEANUP CRITERIA
HELEVA LANDFILL SITE

Contaminant	Range of Concentration in Soil	Soil Cleanup Goal
Acetone	15-1,400,000	9,500
2-Butanone (MEK)	47-9,000	9,800
Chloroform	3.7-3,700	230
cis-1,2-Dichloroethene	0.7-35,000	4,200
trans-1,2-Dichloroethene	(Total)	7,300
Methylene Chloride	6-14,000	54
Trichloroethene	0.5-330,000	780

Note: Units are ug/kg

The nested vacuum well configuration consists of one vacuum well screened over a relatively shallow interval (approximately 5 feet to 18 feet below grade) and a second vacuum extraction well screened over a deeper interval (approximately 30 feet to 45 feet below grade). A bentonite seal is installed between the two well screens over the entire depth of the sand layer to isolate the two wells. This configuration allows for the separate evaluation of the upper and lower soil units of the vadose zone. The vacuum extraction wells, when each are manifolded to a vacuum source, allow flexibility in operation for the extraction of soil vapors from the soil mass.

The *VAPEX* vapor probes are permanently installed to allow measurement of pressure and soil vapor contaminant concentrations. These measurements are utilized in the monitoring and assessment of the system over the duration of the pilot test remediation project. The probes are positioned at varying depths and areal location in order to collect data needed to determine the air flow characteristics of the individual soil units (e.g., the horizontal and vertical air permeabilities).

The general location for the installation of the vacuum well/vapor probe network was designated by GF. Vacuum well and vapor probes were installed by Empire Soils Investigations, Inc., under the supervision of a GF geologist. A *VAPEX* geologist was on site during installation activities to provide instructions on specific component positioning and on installation details, based upon conditions encountered in each borehole.

2.1.2 Test Boring and Sampling Procedures

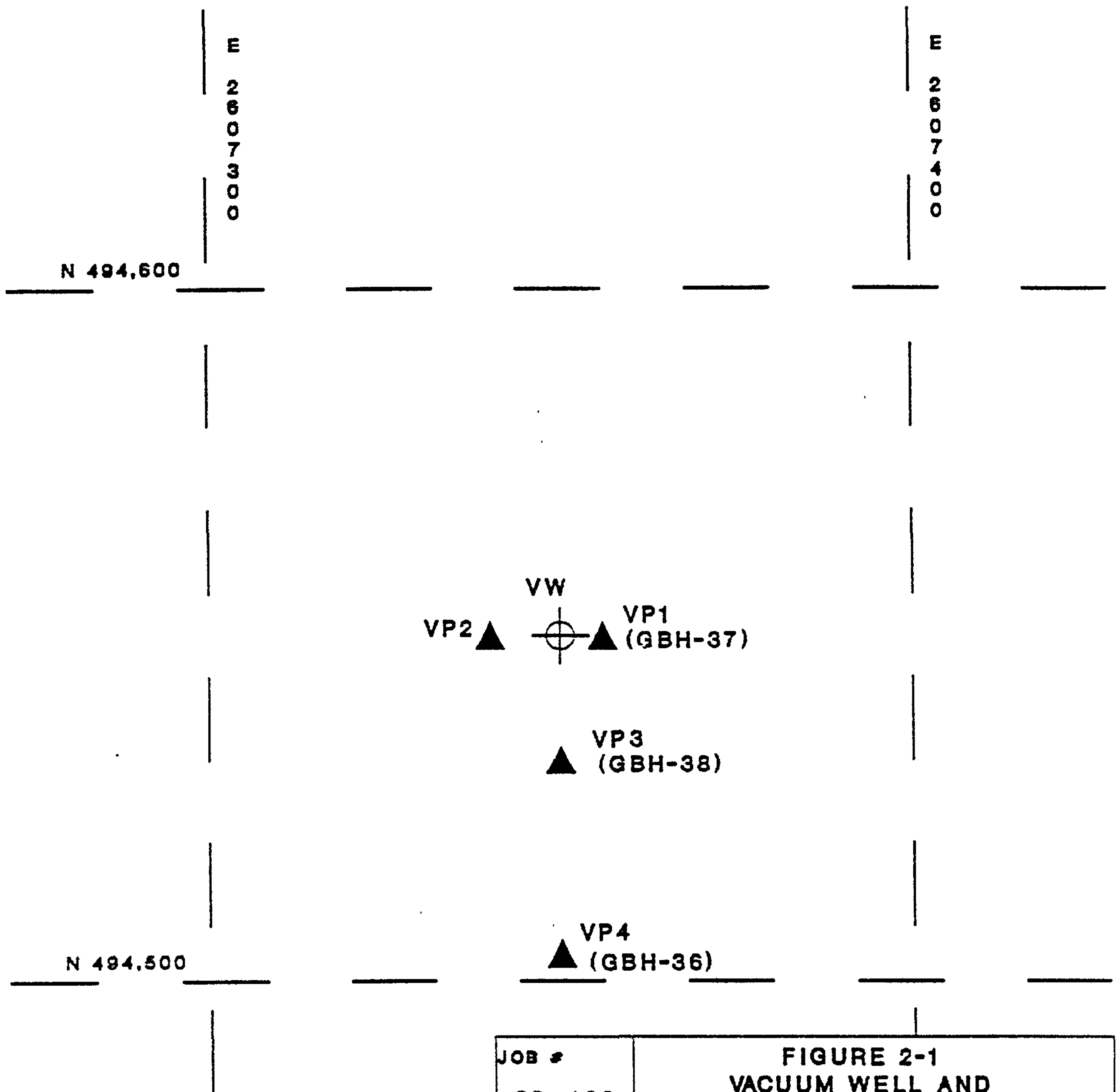
In order to further identify vadose zone soil characteristics in the study area, test borings were performed prior to installation of vacuum wells and vapor probes. Each test boring consisted of advancing hollow stem augers (4 1/4" ID) and obtaining subsurface samples at five foot intervals using a three inch diameter split barrel sampler driven with a 300 pound hammer. Split barrel samples were visually and texturally characterized in the field by GF geologists for color, density, moisture content, and classification. Figure 2-1 presents a plan showing the investigatory borings, vacuum well and vapor probe locations.

2.1.3 Chronology

The following is a chronological record of the sequence of events contributing to the decisions made regarding the placement and installation of vacuum wells and vapor probes:

2/6/90 GF performs a shallow soil gas survey using a field gas chromatograph. The survey indicated high soil vapor hydrocarbon concentrations near GBH-25 which steadily decreased in an easterly direction (away from the landfill). Test boring GBH-36 is started. Soil gas survey indicated that this location was possibly on the edge of a hydrocarbon plume.

2/7/90 *VAPEX* geologist arrives at site. *VAPEX* and GF decide that due to non-detectable jar headspace readings in upper vadose zone soils at GBH-36, the vacuum well location should be moved as close to the landfill as possible. GBH-36 was designated as a potential vapor probe location. Test boring was initiated at GBH-37, jar



LEGEND

▲ = VAPOR PROBE NUMBER 2

⌖ = VACUUM WELL

(GBH-38) = GF BORING DESIGNATION

JOB # 89-100	FIGURE 2-1 VACUUM WELL AND VAPOR PROBE LOCATIONS
DATE 5/11/90	HELEVA LANDFILL LEHIGH COUNTY, PA
SCALE 1"=25'	VAPEX ENVIRONMENTAL TECHNOLOGIES 480 NEPONSET STREET CANTON, MA. 02021 TEL: 617 821-5560 FAX: 617 821-4967
DRAWN MW	
CHECKED BC	

headspace concentrations were relatively high, this location was designated as a potential location for a vapor probe nest to be located adjacent to the vacuum well. The physical and chemical conditions at this location would determine placement of vacuum wells and thus all vapor probes. Test boring completed at GBH-36 and GBH-37 by end of day. Augers remained capped in the boreholes overnight to allow review of field data prior to determining well and probe placement.

2/8/90 *VAPEX* personnel determine potential configuration of vacuum wells and vapor probes. Two vapor probes installed in GBH-36, and five vapor probes installed in GBH-37. Test boring GBH-38 started at location 15 feet from proposed vacuum well location.

2/9/90 Three vapor probes installed in GBH-38. Vacuum wells installed using 8 1/4" ID augers at location five feet from GBH-37. No sampling was performed at this location. *VAPEX* geologist leaves site.

2/10/90 Three vapor probes installed at location eight feet from vacuum wells under supervision of GF personnel per written instructions left by *VAPEX* geologist. No sampling was performed at this location.

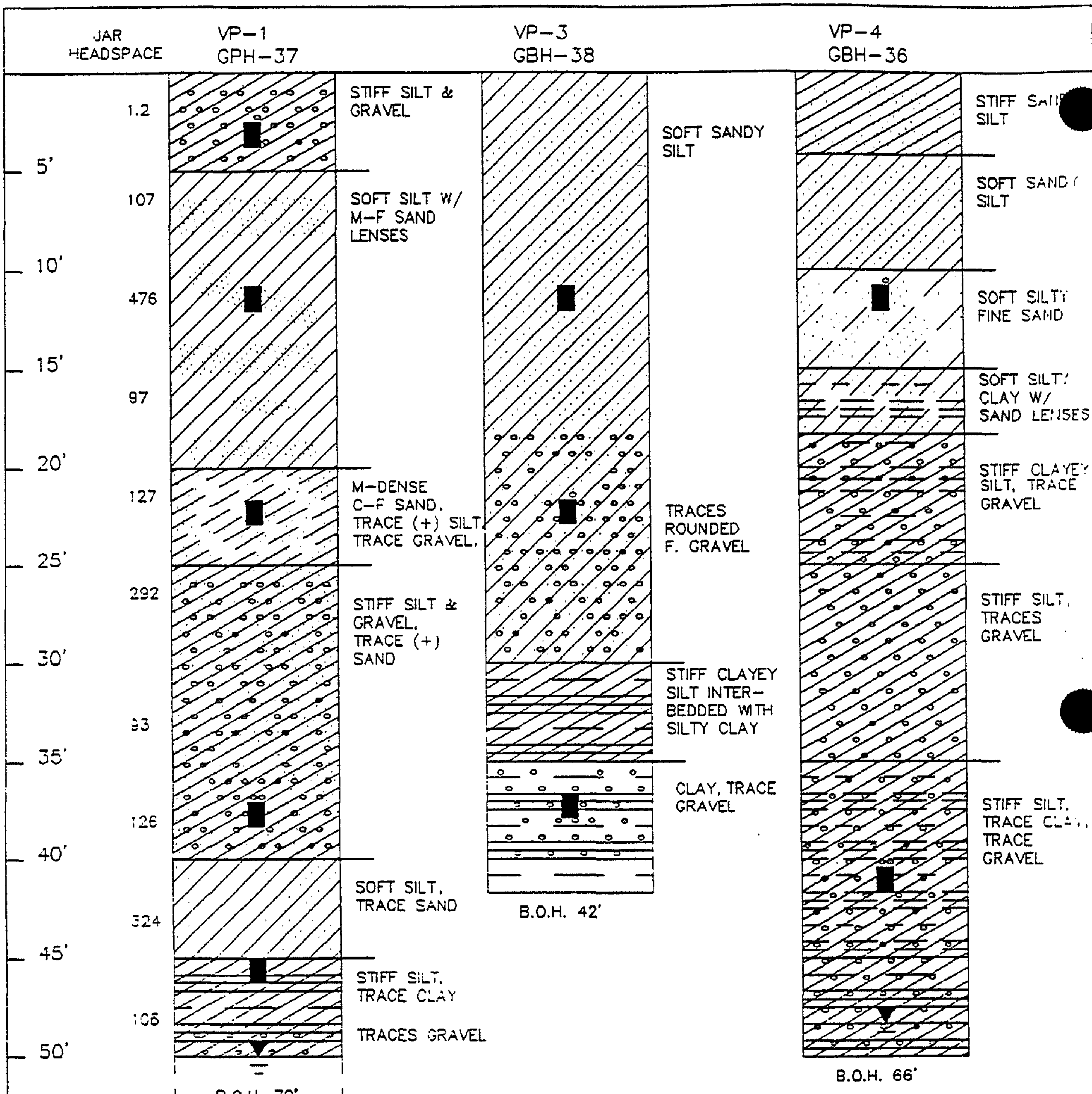
2.1.4 Vacuum Well Installation Details

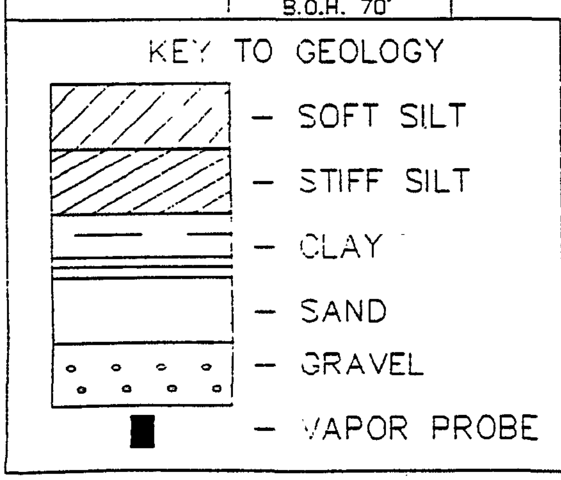
Stratigraphic columns, representing the vadose zone soils at GBH-36, 37, and 38 based on field characterization of split spoon samples, are presented in Figure 2-2. The stratigraphy at GBH-37 was used to determine the screened interval for the shallow and deep vacuum wells, which were located approximately five feet from GBH-37.

Soils encountered at GBH-37 consisted primarily of soft to stiff silt with varying amounts of gravel and sand. Trace amounts of clay were encountered only in the lowest vadose zone unit. Most of the materials above twenty feet were classified as soft (according to sampler blow counts). Soils below twenty feet were generally stiff to medium dense. A relatively coarse layer of slightly silty, medium-dense, coarse to fine sand was encountered between twenty and twenty-five feet.

The presence of the coarse to fine sand layer was a primary factor in determining the screen intervals for the vacuum wells. Due to the potential for short circuiting of air through the more permeable sand layer during vapor extraction operations, it was decided that this coarse layer be isolated by sealing the annular space over that region with bentonite and that the deep vacuum wells be screened in the stiff, dense soils below the sand layer and the shallow vacuum well be screened in the relatively soft soil above the coarser sand. Figure 2-3 is an installation diagram showing the vacuum well and vapor probe cross sections.

The vacuum wells were constructed of two inch PVC 10 slot screen and riser. Prior to installation of the vacuum wells, a 5 foot thick bentonite seal was placed at the bottom of the borehole such that it intersected the ground water table, thereby preventing a direct path for water uptake during the pilot study. This lower bentonite seal extends over a depth of approximately 52 to 47 feet below ground surface (BGS).





JOB# 89100	TITLE FIGURE 2-2 BORING LOG STRATIGRAPHIC COLUMNS
DATE 3/90	SITE HELEVA LANDFILL LEHIGH COUNTY, PA
SCALE NTS	VAPEX
DRAWN HP	ENVIRONMENTAL TECHNOLOGIES 480 NEPONSET STREET CANTON, MA 02021
CHECKED	TEL 617 821-5560 FAX 617 821-4967

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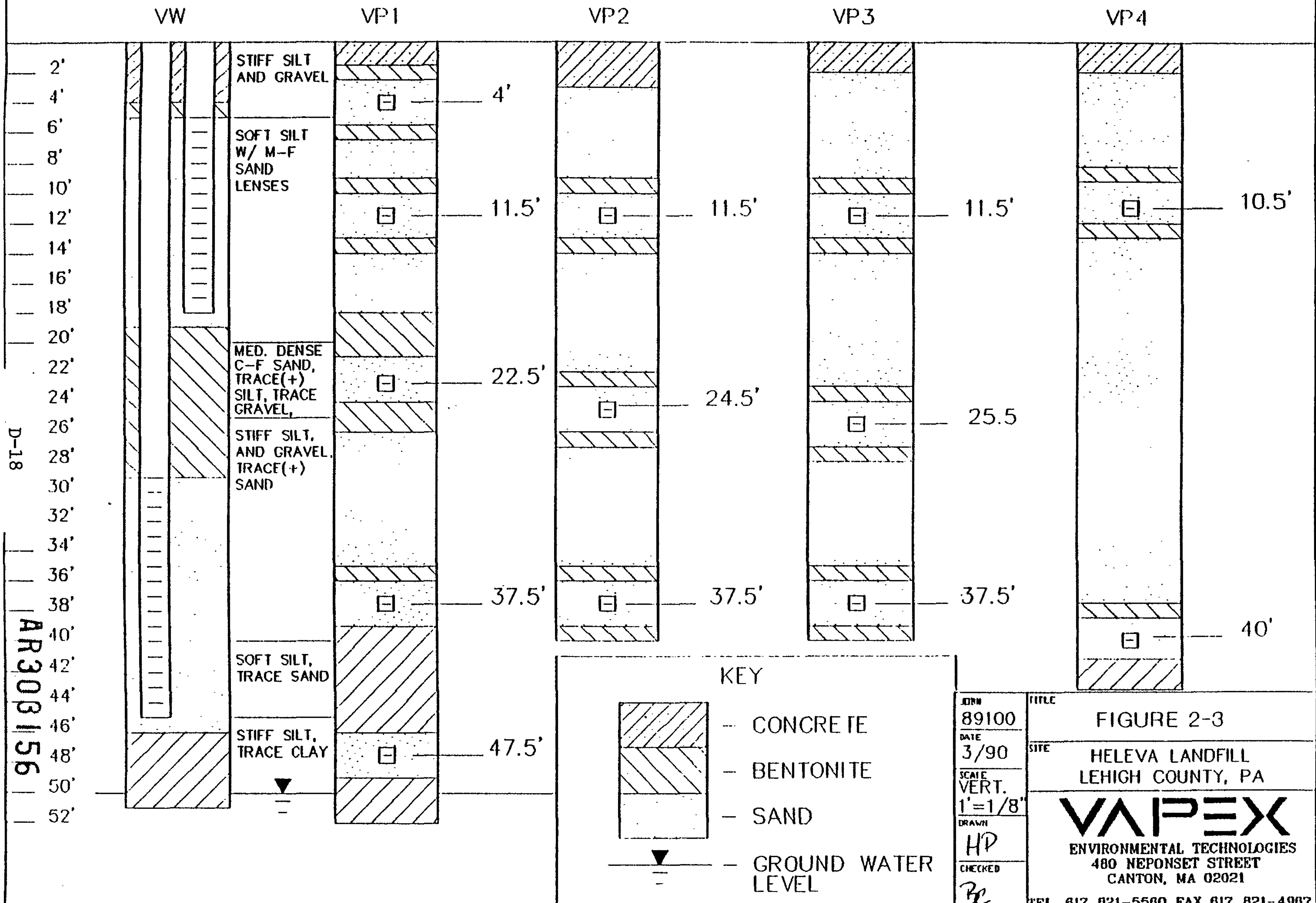
VAPOR EXTRACTION WELL AND VAPOR PROBE CROSS SECTIONS - HELEVA LANDFILL

VERTICAL SCALE: 1' = 0.125" HORIZONTAL IS NOT TO SCALE



JOB# 89100	TITLE FIGURE 2-3
DATE 3/90	SITE HELEVA LANDFILL LEHIGH COUNTY, PA
SCALE VERT. 1'=1/8"	VAPEX ENVIRONMENTAL TECHNOLOGIES 480 NEPONSET STREET CANTON, MA 02021
DRAWN HP	
CHECKED Bc	TEL. 617 821-5560 FAX 617 821-4967

The deep well was installed with a fifteen foot screened section extending from a depth of 45 to 30 feet BGS. The shallow well was installed with a 13 foot screened section extending from a depth of 18 feet to 5 feet. The annular space around each well screen was backfilled with silica sand which extended one foot below and one foot above each screened interval.

An approximately 10 foot thick bentonite seal was installed in the annular space between the two well screens to isolate the two wells from each other and isolate each well screen from the sandy layer at the 20 feet to 25 feet interval.

2.1.5 Vapor Probe Installation Details

A total of 13 *VAPEX* vapor probes were installed in four boreholes in the vicinity of the vacuum wells. Vapor probes were nested at varying depths in each borehole to provide dedicated monitoring points for the upper and lower wells and for each soil unit. Vapor probe locations were numbered VP1 through VP4 with VP1 closest and VP4 furthest from the vacuum wells. Measured vapor probe distances from the vacuum well are as follows: VP1, 4.75 feet; VP2, 8 feet; VP3, 15 feet; VP4, 47 feet. Probes nested at a particular location were numbered with increasing depth BGS, e.g., VP1-1 is at four feet BGS, VP1-2 is at 11.5 feet BGS, etc. Vapor probe and vacuum well installation configurations are summarized in Table 2-1.

Vapor probes were isolated utilizing thick bentonite seals 1.5 feet above and below the center line of the probe with the following exceptions: a) additional bentonite was required to isolate a probe installed at 22.5 feet BGS at VP1 in the coarse layer, and b) probes installed at 47.5 feet and 37.5 feet BGS at VP1 required a thick bentonite seal to isolate the probes from a soft silt layer in order to allow determination of vacuum influence in the relatively tighter soils within which each probe was screened. The specific nesting of vapor probes at VP1 is required in determining the vertical components of the air flow parameters of each soil unit.

VAPEX's soil vapor probes are constructed of Teflon and PVC. The vapor probe consists of screened Schedule 40 PVC pipe, 1.5 inches in diameter, 8 inches long and slotted over 4 inches of the probe. Filter fabric is placed along the inside diameter of the probe to minimize the aspiration of silt and clay size particles during sampling. The probes are capped at both ends to form an air tight seal for the placement of an 1/8 inch Teflon tube which runs from the probe to ground surface in a 1/2 inch Schedule 40 PVC pipe. A diagram of a typical vapor probe is presented in Figure 2-4.

2.2 Pilot Scale Test System Installation

2.2.1 Mobilization

The majority of the equipment, services, and materials required for the treatability study were delivered to the site during the week of February 19, 1990. A mobile office trailer was delivered to the site by a local supplier. Electrical contracting services were provided by GC Electrical Contractors. Carbon cannisters for the air emission control system were shipped directly to the site from Carbtrol Corporation.

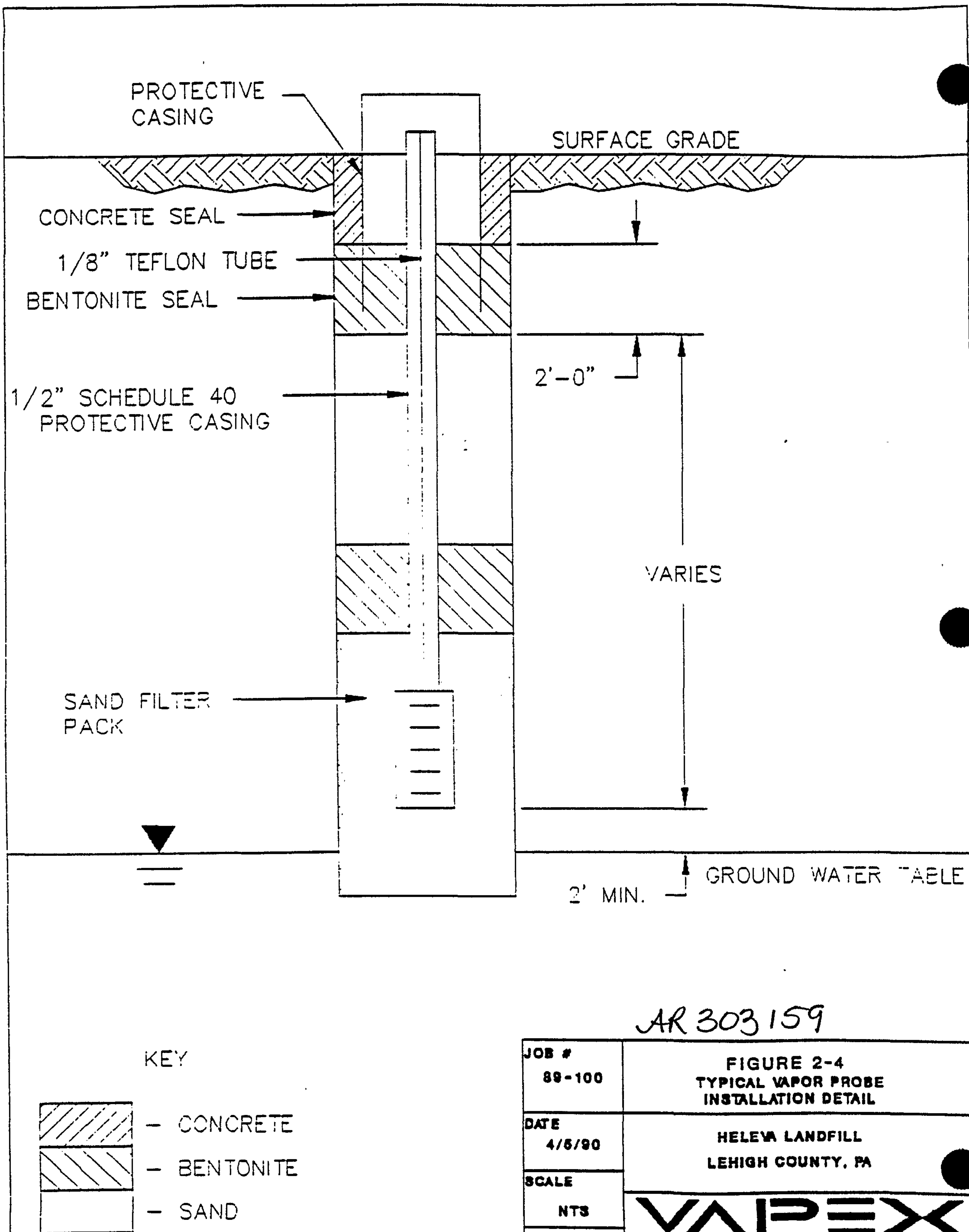
TABLE 2-1

VACUUM WELL/VAPOR PROBE INSTALLATION DETAILS
VAPOR EXTRACTION TREATABILITY TEST
HELEVA LANDFILL SITE

LOCATION	DEPTH TO TOP OF SCREENED INTERVAL	DEPTH TO BOTTOM OF SCREENED INTERVAL	DISTANCE FROM VACUUM WELL
VW-S	5'	19'	NA
VW-D	29'	46'	NA
VP1-1	2.5'	5.5'	4.75'
VP1-2	10'	13'	
VP1-3	21'	24'	
VP1-4	36'	39'	
VP1-5	46'	49'	
VP2-1	10'	13'	8'
VP2-2	22'	25'	
VP2-3	36'	39'	
VP3-1	10'	13'	15'
VP3-2	24'	27'	
VP3-3	36'	39'	
VP4-1	9'	12'	47'
VP4-2	38.5'	41.5'	

ALL DEPTH MEASUREMENTS WERE MADE FROM GROUND SURFACE

ALL DISTANCE MEASUREMENTS WERE MADE FROM WELL CENTER TO WELL CENTER



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JOB # 89-100	FIGURE 2-4 TYPICAL VAPOR PROBE INSTALLATION DETAIL
DATE 4/6/90	HELEVA LANDFILL LEHIGH COUNTY, PA
SCALE NTS	VAPEX ENVIRONMENTAL TECHNOLOGIES 480 NEPONSET STREET CANTON, MA 02021 TEL: 617 821-5560 FAX: 617 821-4967
DRAWN HP	
CHECKED JC	

2.2.2 Equipment Setup

The system was assembled and installed adjacent to the vacuum extraction well during February 21 to 23 and 26 to 27. The pilot test system included a 15 cfm liquid ring vacuum pump, a 10 cfm rotary vane oil-less vacuum pump, two air/water separator drums, and associated meters, gauges, valves, fittings, and piping. All equipment was placed on plywood platforms for the duration of the treatability study.

2.2.3 System Schematic

A schematic diagram of the pilot scale vacuum extraction test system is presented in Figure 2-5. The following text provides more detailed information on the major components of the system:

Vacuum Pump: The primary vacuum pump utilized for the pilot scale test was a 15 cfm maximum air flow capacity liquid ring vacuum pump. The vacuum pump, which featured all bronze construction, was close coupled to a 1.5 HP, single phase motor mounted on a steel baseplate with a galvanized steel water reservoir tank. The pump utilizes a water seal within the pump casing to reduce system wear and to produce a unique vacuum-flow performance curve. The reservoir tank was equipped with a low level shut off switch, a high level drain switch and valve, sight glass, inlet check valve, Y strainer, and a seal water make up valve located on the suction side of the pump.

In addition to the liquid ring vacuum pump, which was used for the majority of the test, a rotary vane vacuum pump with a 0.75 HP motor and 10 cfm maximum air flow capacity was utilized for the low flow pump test on the shallow well. The 10 cfm rotary vane pump was installed parallel to the liquid ring pump to provide a backup source of vacuum.

Air/Water Separator Drums: Two air/water separator drums were placed in line between the vacuum pump and the vacuum extraction well. The air water/separator drums were standard DOT 55 gallon steel drums with threaded inlet and outlet fittings on the top of each drum. The drums were piped in a parallel configuration and valved such that the drums could be utilized simultaneously or individually. The parallel configuration allowed sampling of water, and if necessary, replacement of full drums while maintaining system operation.

Piping, Valves, and Fittings: All piping and fittings between the vacuum pump system and the vacuum extraction well consisted of standard Schedule 40 PVC pipe. Pipe diameters varied between 3/4 to 2 inches depending on the specific application. PVC and brass ball valves were used to control and direct flow. One quarter inch brass ball valves with hose connectors were used for all vapor sampling ports. Galvanized steel pipe was used at the inlet to, and the outlet from, the liquid ring vacuum pump. Manifold pipe was insulated and heat traced to prevent freeze ups.

Air Emission Control System: The air emission control system consisted of multiple Carbtrol Corporation Model G-1 vapor phase carbon cannisters. Each cannister contained 200 pounds of vapor phase carbon. Initially, two sets of three cannisters were provided in a parallel configuration to allow continual operation of the system during cannister replacement. Two additional canisters were required

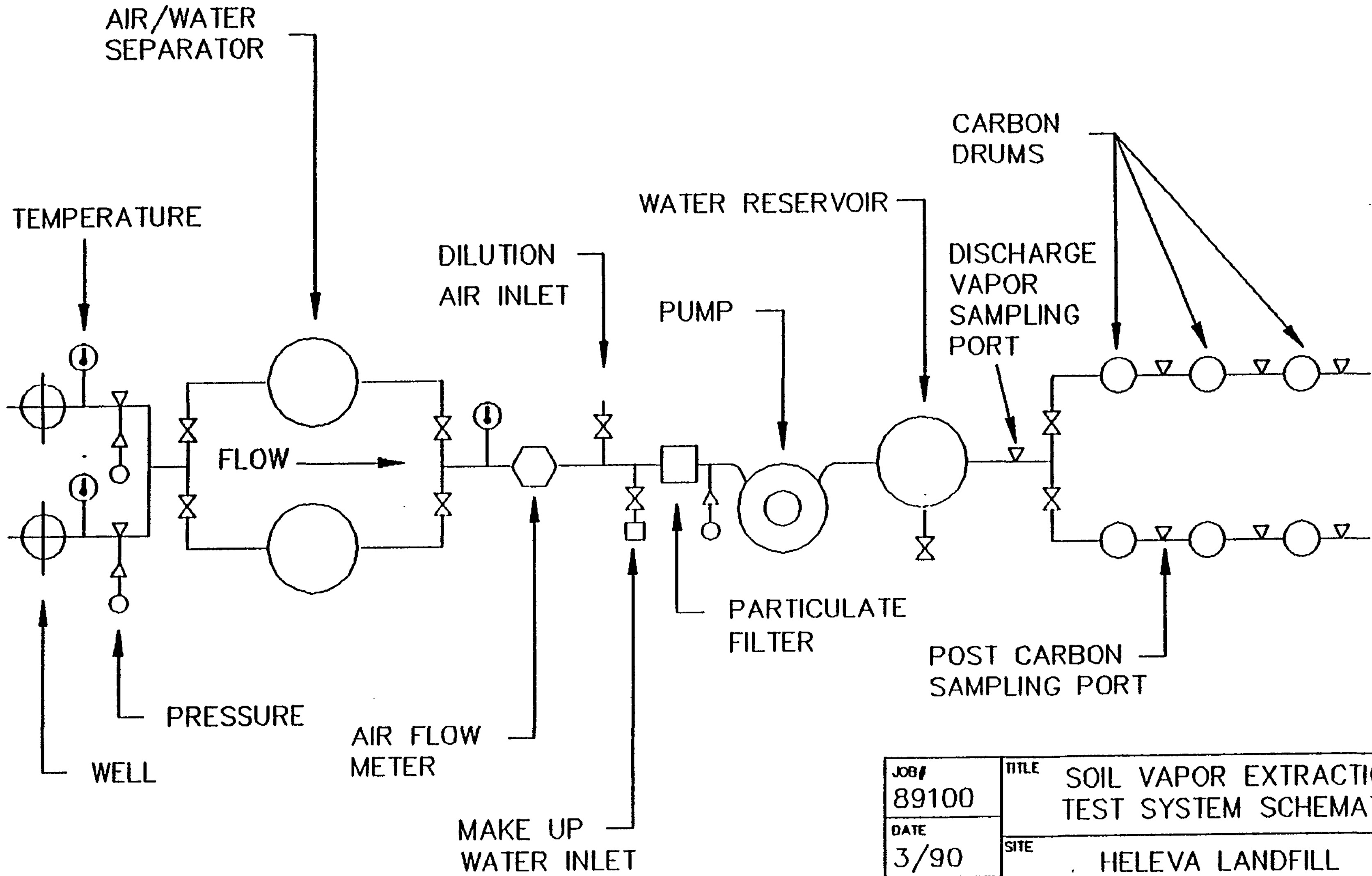


FIGURE 2-5

JOB# 89100	TITLE SOIL VAPOR EXTRACTION TEST SYSTEM SCHEMATIC
DATE 3/90	SITE HELEVA LANDFILL LEHIGH COUNTY, PA
SCALE NTS	VAPEX ENVIRONMENTAL TECHNOLOGIES 480 NEPONSET STREET CANTON, MA 02021
DRAWN HP	
CHECKED BC	TEL. 617 821-5560 FAX 617 821-4967

during the test; thus, the total amount of carbon provided for the emission control system was 1,600 pounds. The configuration of the carbon cannisters was changed throughout the pilot testing to maximize carbon efficiency. The various configurations utilized during each phase of the test are depicted in Figure 2-6.

Meters and Gauges: An Erdco, Inc. Model 0412-06T5 Orifice Plate Flow Meter was installed in line immediately before the vacuum pump. This meter was factory calibrated to provide a direct reading of flow between 5 cfm and 20 cfm, in 0.5 cfm increments.

Thermometers were installed at each wellhead and immediately upstream of the flow meter. The thermometers were manufactured by Ashcroft, Inc. and provided direct readings of the well vapors traveling through the vacuum portion of the system over a temperature range of -20 to 120 degrees F in 1 degree increments.

Vacuum pressures were measured with both Dwyer, Inc. Magnahelic differential pressure gauges and Ashcroft vacuum gauges. A series of Magnahelic gauges were used, each providing a specific range of pressure measurement. Cumulatively, the Magnahelic gauges were capable of measuring vacuum pressures over a range of from 0.005 to 150 inches of water. The Ashcroft vacuum gauges were capable of measuring over a range of one to thirty inches of mercury.

2.3 Pilot Test Procedures

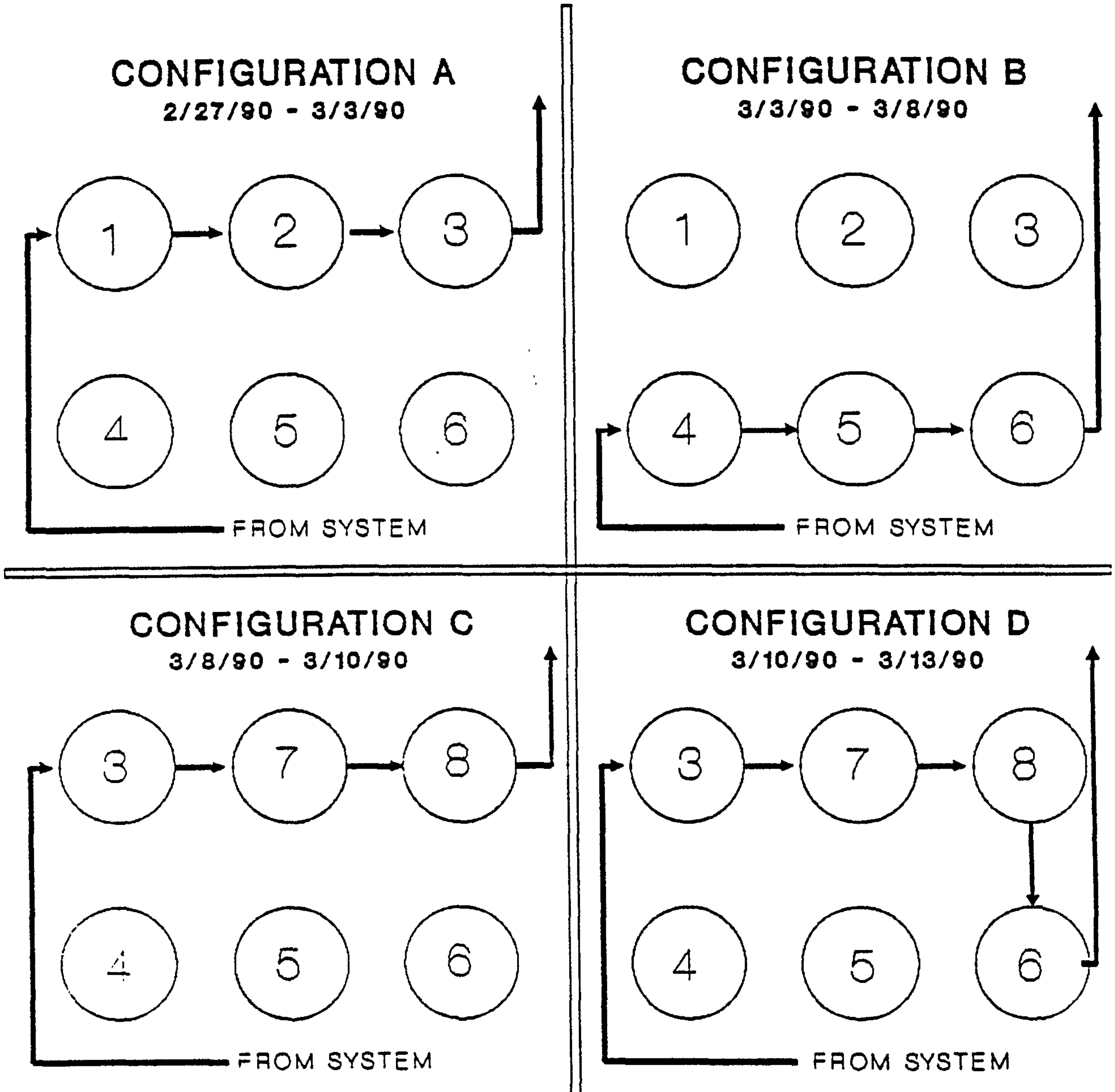
2.3.1 Overview

Following assembly and installation, the pilot test system was activated and operated over a fourteen day period. Initially, a preliminary pump test was performed on each well in order to select the well to be used as the first portion of the study. The performance of the preliminary pump test resulted in the selection of the shallow well as the primary test well since it displayed both a high VOC discharge concentration and a relatively low operating vacuum. A relatively shorter secondary test was performed on the deep well at the completion of the primary test. Both the primary and secondary wells were tested at two different air flow rates over the duration of the study. Detailed descriptions of the test objectives and procedures are presented in the following sections. A chronological summary of field pilot test events is presented in Table 2-2.

2.3.2 Preliminary Vacuum Well Testing

Following completion of the equipment setup, *VAPEX* performed a short term preliminary pump test on each vacuum extraction well using the liquid ring pump. The purpose of these tests was to assess the initial performance characteristics (discharge VOC concentration and wellhead vacuum and flow characteristics) of each well such that the primary test well could be selected for use in the extended treatability study. For each test, the 15 cfm liquid ring vacuum pump was valved to the vacuum well and operated without the use of dilution air for a duration of from thirty to sixty minutes. The discharge from the 15 cfm pump was piped through the air emission control system described above.

During each short term preliminary test, *VAPEX* measured vacuum levels at the wellhead and collected pump discharge vapor samples for VOC analysis using the on site gas chromatograph (GC). Two vapor samples were collected and



JOB # 89-100

FIGURE 2-6
SEQUENCE OF CARBON CANISTER CONFIGURATIONS

DATE 4/7/90

HELEVA LANDFILL
LEHIGH COUNTY, PA

SCALE NTS

DRAWN MW

CHECKED GC

VAPEX
ENVIRONMENTAL TECHNOLOGIES
480 NEPONSET STREET
CANTON, MA. 02021
TEL: 617 821-5560 FAX: 617 821-4967

TABLE 2-2

FIELD PILOT TESTING CHRONOLOGY
VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

TEST	DATE	TIME	SYSTEM STATUS
PRELIMINARY TESTING	2/27	10:36AM	LIQUID RING PUMP ON – BEGIN TESTING SHALLOW WELL FOR QUICK DETERMINATION OF OPERATING PARAMETERS.
2.5 HOURS		11:15AM	PUMP OFF – VALVE SYSTEM TO DEEP WELL.
		12:25PM	LIQUID RING PUMP ON – BEGIN TESTING DEEP WELL FOR QUICK DETERMINATION OF OPERATING PARAMETERS.
		12:52PM	PUMP OFF – PRELIMINARY TESTING COMPLETED. PREPARE SYSTEM FOR PRIMARY TEST.
PRIMARY TEST	2/27	3:40PM	ROTARY VANE PUMP ON – BEGIN PRIMARY TEST AT SHALLOW WELL. 4 HOURS AT LOW FLOW
10 DAYS		8:30PM	ROTARY VANE PUMP OFF – LIQUID RING PUMP ON. BEGIN NINE DAY HIGH FLOW TEST AT SHALLOW WELL
	3/8	5:00PM	OPEN INTAKE DILUTION VALVE. BEGIN 18 HOUR LOW FLOW TEST.
	3/9	1:00PM	SYSTEM OFF. PRIMARY TEST COMPLETED. VALVE SYSTEM TO DEEP WELL.
SECONDARY TEST	3/9	2:00PM	SECONDARY TEST PHASE BEGINS. THREE HOUR LOW FLOW TEST INITIATED AT DEEP WELL TO DETERMINE POTENTIAL FOR WATER UPTAKE.
4 DAYS		5:50PM	SYSTEM OFF OVERNIGHT TO ALLOW REEQUILIBRATION OF TEST AREA TO STATIC CONDITIONS.
	3/10	12:07PM	BEGIN 48 HOUR LOW FLOW TEST AT DEEP WELL. INTAKE DILUTION VALVE OPEN.
	3/12	1:30PM	CLOSE DILUTION VALVE– BEGIN 18 HOUR HIGH FLOW TEST.
	3/13	9:15AM	SECONDARY TEST COMPLETED. INTAKE DILUTION VALVE OPENED COMPLETELY. WELL VALVES CLOSED COMPLETELY.

analyzed during each test; the first was used to determine the GC detector input range, the second was used for contaminant quantification and qualification. Vapor samples were also screened for total hydrocarbon content using a Thermo Electron Model 580A total organic vapor meter equipped with photoionization detector and 11.8 eV lamp (hand held 580A). At least two vacuum measurements were made at the wellhead during each short term test.

Since the intent of the extended duration primary test was to assess the contaminant removal characteristics of the system, the initial VOC concentration in the discharge vapors, was to be the main criteria by which the primary well would be selected. Vacuum at the wellhead and the potential for the withdrawal of water were also factors that were to be considered in the selection of the primary test well. Generally, the higher the wellhead vacuum, the more likely it is that water will be withdrawn during vacuum extraction operations.

Although relatively significant VOC concentrations were observed at both extraction wells, the shallow vacuum well was chosen for the primary test since it produced a significantly lower operating vacuum. Vacuum at the shallow well measured at 17 inches of water and vacuum at the deep well was measured at 14.2 inches of mercury at air flow rates of 13 cfm and 7 cfm, respectively.

2.3.3 Primary/Secondary Test Procedures

Following the preliminary vacuum well testing, the pilot scale vapor extraction system was started up and operated over a fourteen day period from February 27 to March 13. The primary test on the shallow well was conducted over the first ten days and the secondary test on the deep well was conducted over the final four days of the study period.

Two air flow rates were utilized during the conduct of each test to allow collection of the physical data required for the calibration and verification of *VAPEX's* air flow models. The primary test started on February 27 using the 10 cfm rotary vane vacuum pump previously described. The 10 cfm pump was utilized for a period of approximately four hours at a flow rate of 10 to 11 cfm after which time the system was changed over to utilize the 15 cfm liquid ring vacuum pump. The 15 cfm rated liquid ring pump was utilized for the remainder of the primary test, which ran continuously through March 8, at a flow rate of from 12.5 to 13 cfm.

The system was also operated at an additional flow rate (7 cfm) in order to collect additional low flow operating data. This began on March 8 and was conducted over an 18 hour period terminating on March 9.

The secondary test was conducted on the deep vacuum well over a four day period from March 9 to March 13. Initially, a three hour test, at a wellhead air flow rate of four to five cfm was performed to evaluate the potential for water uptake by the vacuum extraction system. When it was determined that water uptake would not likely present a problem, the system was shut down overnight to allow re-equilibration of vacuum pressures in the vadose zone prior to initiation of the continuous secondary test.

On the morning of March 10, the system was reactivated at the deep well and operated for approximately 48 hours at a wellhead air flow rate of 5 to 5.5 cfm.

The dilution valve was then closed for the final 18 hours of the test which was conducted at a wellhead air flow rate of 7 to 7.3 cfm.

2.3.4 Monitoring of Physical Parameters

Vacuum extraction system operating parameters were recorded on a daily basis during the primary and secondary tests. The following parameters were monitored: wellhead vacuum, wellhead flow rate, flow meter temperature, wellhead temperature, and vacuum at the pump. To measure system vacuum levels during the primary test, a Dwyer Magnahelic Differential Pressure gauge was attached by tygon tubing to a hose barb on a 1/4 inch brass ball valve at the wellhead and at the vacuum pump intake. During the secondary test, which operated under significantly higher vacuum, Ashcroft pressure/vacuum gauges were used in a similar fashion, in place of the Magnahelic gauges.

Vacuum readings were taken at each vapor probe location at least once per day during the Primary and Secondary tests. Dwyer Magnahelic Differential Pressure gauges were used to perform this task. The gauge displaying the appropriate vacuum range was zeroed to atmospheric pressure and attached to the 1/8 inch OD, 1/16 inch ID Teflon tubing at each probe with tygon tubing and the vacuum (or pressure) was recorded when the gauge produced a stable reading. A stable reading was typically observed after approximately five minutes.

2.3.5 Sampling and Analysis

a. Sampling Plan

Samples were collected for VOC analysis from the following locations during the course of the feasibility test: i) vapor probe soil gas, ii) wellhead soil vapor discharge, iii) carbon cannister vapor discharge, and iv) air/water separator drain water. Sampling frequencies, collection techniques and analytical techniques are summarized in Table 2-3. Analysis of chemical parameters was conducted in accordance with *VAPEX's* Quality Assurance/Quality Control (QA/QC) Plan and Work Plan for the Heleva Landfill site.

b. Field and Laboratory Test Procedures

An HNU Model 321 Gas Chromatograph equipped with an 11.7 eV photoionization lamp (GC/PID) was used for the on site analysis of vapor samples from vapor probes, wellhead discharge, and carbon cannister discharge for the target and other VOCs present. Identification and quantification of field-generated, chromatographic peaks were determined by correlation with external standards. All GC/PID results are reported in parts per million (ppm) on a volume per volume (vol/vol) basis. The analytical procedures and data analysis techniques for the GC/PID are included in Appendix A of the QA/QC Plan.

VAPEX utilized a portable Thermo Environmental Instruments Model 580A OVA total organic vapor analyzer equipped with an 11.8 eV lamp (hand held 580A) to screen soil vapor samples from the vapor probes, the wellhead discharge and carbon cannister. The analytical procedures and data analysis techniques for the hand held 580A are presented in the Appendix A of the QA/QC Plan. All hand held 580A measurements are reported as parts per million on a volume/volume (vol/vol) basis as perchloroethylene (PCE).

TABLE 2-3

SAMPLING AND ANALYSIS PLAN
VAPOR EXTRACTION TREATABILITY STUDY
HELEVA LANDFILL SITE

SAMPLE LOCATION	ANALYSIS	ANALYST	INSTRUMENT/ CONTAINER	TEST DAY(S)	SAMPLE FREQUENCY	ADDITIONAL SAMPLES
VAPOR PROBES	TH	VAPEX/FIELD	TECO 580A	—	PRIOR TO TEST	—
	VOAv	VAPEX/FIELD	GC/PID	—	PRIOR TO TEST	—
	VOA	MDS/Laboratory	TENAX & BAG	—	PRIOR TO TEST (selected probes)	—
	VOAv	VAPEX/FIELD	GC/PID	—	POST TEST (selected probes)	—
DISCHARGE PRIMARY TEST DAYS 1-10	TH	VAPEX/FIELD	TECO 580A	ALL	Every 2 hrs., 4 per day	—
	VOAv	VAPEX/FIELD	GC/PID	Day 1	0-12 hrs.: every 2 hrs.	—
	VOAv	VAPEX/FIELD	GC/PID	Day 1	12-24 hrs.: every 4 hrs.	—
	VOA	MDS/Laboratory	BAG	Day 1	3 Per Day	D,T
	VOA	MDS/Laboratory	BAG	Day 2	1 Per Day	D,T,F
	VOAv	VAPEX/FIELD	GC/PID	Day 2-9	4 Per Day	—
	VOA	MDS/Laboratory	BAG	Day 8	1 Per Day	T,F
	VOAv	VAPEX/FIELD	GC/PID	Day 10	1 Per Day	—
DISCHARGE SECONDARY TEST DAYS 11-14	TH	VAPEX/FIELD	TECO 580A	ALL	Every 2 hrs., 4 per day	—
	VOAv	VAPEX/FIELD	GC/PID	Day 11-13	4 Per Day	—
	VOAv	VAPEX/FIELD	GC/PID	Day 14	1 Per Day	—
	VOA	MDS/Laboratory	BAG	Day 14	1 Per Day	T
POST CARBON PRIMARY TEST	TH	VAPEX/FIELD	TECO 580A	ALL	Every 2 hrs., 4 per day	—
	VOAv	VAPEX/FIELD	GC/PID	Day 1-9	1 Per Day	—
	VOAv	VAPEX/FIELD	GC/PID	Day 10	2 Per Day	—
	VOA	MDS/Laboratory	BAG	Day 1-2	1 Per Day	—
	VOA	MDS/Laboratory	BAG	Day 8	1 Per Day	—
SECONDARY TEST	VOA	MDS/Laboratory	BAG	Day 14	1 Per Day	—
LIQUID RING PUMP WATER	VOAw	MDS/Laboratory	40 mL VIAL	Day 1	1 Per Day	T,F
	VOAw	MDS/Laboratory	40 mL VIAL	Day 14	1 Per Day	T

TH TOTAL HYDROCARBONS
VOAv VOLATILE ORGANIC ANALYSIS by VAPEX
VOA VOLATILE ORGANIC ANALYSIS by MDS Laboratories
VOAw VOLATILE ORGANIC ANALYSIS
D DUPLICATE
T TRIP BLANK
F FIELD BLANK
TECO 580A Thermo Electron 580A OVM
BAG 2L TEFLON BAG SAMPLE

Vapor samples for laboratory analysis were collected in Teflon gas sampling bags and shipped to MDS Laboratories in Reading, PA for laboratory analysis by EPA Methods TO1/TO2. Water samples taken from the separator drain were collected in 40 mL VOA glass vials and transported to MDS Laboratories in Reading, PA for laboratory analysis by EPA Methods 601/602. Analytical procedures are included in the QA/QC Plan.

All field sampling and measurements were performed in accordance with *VAPEX's* Standard Operating Procedures (SOPs) which are presented in Appendix B.

c. Quality Assurance/Quality Control

All field measurements and analyses were conducted in accordance with *VAPEX's* QA/QC Plan. The field QA/QC techniques are summarized below:

c.1 Hand Held 580A

Hand Held 580A calibration was checked on a daily basis by evaluation with a known standard of perchloroethylene (PCE). The hand held 580A was recalibrated to PCE if performance against the standard indicated significant statistical deviation from previous calibration.

c.2 GC/PID

QA/QC for the GC/PID consisted of the routine analysis of field blanks, standards and duplicate samples in order to monitor GC/PID performance. Specific frequencies are summarized below:

Blanks - blanks were run between every six field samples or as needed (if less than every six field samples) to quantify/qualify background and/or cross contamination from prior samples.

Standards - A fresh vapor standard was prepared at the beginning of each day. Replicate injections of the standard were analyzed for deviations in instrument behavior and to track instrument response over the course of field activities.

Duplicates - Duplicates of field samples were run at varying frequencies as a quality control check on GC/PID performance.

2.4 Health and Safety Procedures

Health and safety procedures were followed according to *VAPEX's* Health and Safety Plan for the site. At a minimum, Level D personal protective equipment (PPE) was worn in the field at all times. Latex gloves were worn during all vapor sampling and system monitoring procedures. Level B PPE was used for the following tasks where exposure to vapors was possible: a) during all connections and disconnections of system piping directly to or from the wells, b) during all connections, modifications, and disconnections to or from the carbon canisters, c) during draining, rinsing, and cleaning of the liquid ring pump and d) during the transfer of contaminated pump, rinse, or separator water from one container to another in the demobilization phase of the project.

2.5 Airflow and Contaminant Transport Modeling

VAPEX utilized proprietary air flow and contaminant transport models to evaluate vadose zone soil/air flow parameters and to simulate vapor extraction system performance. Modeling allows *VAPEX* to determine overall system feasibility, to establish optimal vapor extraction system configurations and operating parameters, and to estimate the time required to remediate the soils to specified target contaminant closure levels.

2.5.1 Physical Modeling

Physical characteristics of the site such as soil type(s), soil heterogeneity and anisotropy, surface cover, underground trenches, etc. are required data input to the airflow models utilized in the analysis and evaluation of a specific site.

The physical characteristics of each vacuum well/vapor probe system, the vacuum pressure data, and the air flow rates recorded during the field pilot testing were used as additional input into *VAPEX's* proprietary two-dimensional (2-D), radially symmetric air flow model in porous media.

The 2-D model was utilized to determine the permeability tensor of the soil strata through which the air flow occurs. The intrinsic air permeability tensor is the matrix of soil air permeability values along specified areas, e.g., in the x, y, and z direction in a Cartesian coordinate system. Values for the relative horizontal intrinsic permeability and the relative vertical intrinsic permeability were determined for each strata of concern, and the equivalent relative vertical intrinsic permeability was determined for the surface boundary and the intermediate soil lens (the wet sand strata existing between the upper and lower well screens).

The operation of the field pilot/air permeability test at more than one air flow rate allowed for both the initial calibration (i.e., parameter evaluation using field data) and verification of the model (i.e., the model is set to simulate the system for the second air flow rate using the parameters established in the calibration mode; a comparison is made between the model predicted pressure distribution, and the actual pressure data measured at the well/probes at the second air flow rate).

Following calibration and verification, *VAPEX's* air flow model was used in the simulation mode to obtain the pressure distributions associated with a variety of extraction/injection system configurations. This allowed determination of the expected air flow paths, air flow rates, and the achievable effective radius of influence of the simulated vacuum well system.

2.5.2 Chemical Modeling

VAPEX analyzed the contaminant-related data in order to estimate the time required for full scale cleanup. The estimate was based on equilibrium partitioning concepts, initial contaminant concentrations in the pilot system discharge, final extraction system design (determined according to optimal *in-situ* air flow characteristics), the chemical data provided by GF quantifying the contaminants present in the unsaturated zone, *VAPEX's* prior experience, and the soil clean up goals specified in Attachment IV of the RFP.

In general, remediation of a contaminated site using vapor extraction can be represented by an exponentially decaying plot of extraction system off-gas contaminant concentration versus time. The length of the tail associated with this decay curve is the major element which dictates the length of time until site closure. The tail is generally associated with mass transfer limiting mechanisms, which are highly dependent on the vapor extraction system design, the contaminant distribution, and the soil structure.

VAPEX utilized its proprietary, semi-empirical contaminant transport code to aid in the prediction of vapor extraction system performance with respect to achievable contaminant removal rates and the time required to achieve target clean up levels. The model is based on equilibrium partitioning theory in conjunction with empirical equations derived from the data collected during the conduct of the pilot test and from *VAPEX's* historical data base. The model also provides a theoretical estimate of the mass of each individual contaminant present in the soils within the zone of influence of the test system. The *VAPEX* derived empirical model was used to extrapolate system performance, predicting contaminant removal rates and time to achieve target compound closure levels.

The *VAPEX* developed contaminant transport model was utilized to predict a curve of discharge concentration vs. time of vapor extraction system operation. The vapor extraction system discharge data obtained during the pilot test was plotted on the same graph as the model-predicted test curve for comparison and validation purposes. Extrapolation of the model test curve provides an estimate of the time required to meet the compound specific closure limit.

It is assumed that the test curve developed reflects overall site conditions and hence the full scale system will perform in a similar manner to the test system.

It should be noted that an accurate estimation of the time required to remediate a contaminated site utilizing vapor extraction is not a simple task. The estimate is highly dependent of a number of factors, including:

a) contaminant type (physical, chemical properties);
b) contaminant distribution;
c) soil structure (heterogeneity, anisotropy, composition, moisture content);
d) vapor extraction system design, including:
    - air flow rates,
    - screen positioning,
    - air flow paths,
    - vacuum paths,
e) other remediation activities ongoing or previously implemented at the site;
f) seasonal water table fluctuations, and
g) designated clean up levels for the site.

Generally, the parameters that influence the accurate estimation of time to cleanup are not well defined prior to or during the full scale installation of a vapor extraction system. Estimates of the time required to reach specific clean up levels should therefore be treated with the appropriate degree of uncertainty.

3.0 RESULTS

3.1 Physical Monitoring Results

3.1.1 Primary Test (Shallow Well)

The operating conditions of the pilot scale system during the primary test are summarized in Table 3-1. Operating conditions are summarized according to the wellhead air flow rates that were tested.

During the initial low flow test using the rotary vane vacuum pump with no dilution air, the system operated at an air flow rate from the wellhead of from 10 to 11.25 cfm. Vacuum levels observed at the wellhead over the approximately three hour duration of this phase of the testing fluctuated between 12 and 13.5 inches of water.

During the extended higher air flow test using the liquid ring vacuum pump with no dilution air, the system operated at an air flow rate from the wellhead that fluctuated between 12.5 and 14 cfm, with an observed average of 13 cfm. Vacuum levels observed at the wellhead over the nine day duration of this phase of the testing fluctuated between 17 and 21 inches of water.

During the lower air flow test using the liquid ring vacuum pump with the dilution air inlet between the wellhead and the pump open, the system operated at an air flow rate from the wellhead of 7 cfm. Vacuum levels observed at the wellhead over the approximately eighteen hour duration of this phase of the testing fluctuated between 8.75 and 10 inches of water.

Vacuum measurements at the vapor probes during the primary test are summarized in Table 3-2. Vacuum readings at the vapor probes were inconsistent over the first several days of the primary test. On the sixth day of operation (March 6), the vapor probe tubing was cleared by injecting three volumes of a 50 mL glass/Teflon/aluminum syringe into the tubing thirty minutes prior to measuring vacuum at each of the probes. Readings taken after clearing the tubing were generally more stable and consistent than those observed prior to clearing the Teflon lines. It is likely that the line clearing removed condensation in the Teflon lines which may have been blocking the lines and interfering with vacuum readings over the initial days of the test. Subsequent to this finding, vapor probe sampling tubes were cleared approximately thirty minutes prior to each vacuum measurement. Vacuum was observed in at least one vapor probe at each boring location over the duration of the test at levels ranging from 0.005 to 3.1 inches of water. The highest vacuum was consistently observed at probe VP2-1. Vacuum was consistently not detectable at several probes, throughout the operation, most notably VP1-1 and VP1-2.

3.1.2 Secondary Test (Deep Well)

The operating conditions of the pilot scale system during the secondary test are presented in Table 3-3. Wellhead operating vacuum for the deep well was significantly higher than that observed during the testing of the shallow well.

During the initial low air flow test, the system operated at an air flow rate from the wellhead of from 5 to 5.5 cfm. Vacuum levels observed at the wellhead over the duration of this phase of the testing ranged from 9.1 to 9.5 inches of mercury.

TABLE 3-1

EXTRACTION SYSTEM OPERATING CONDITIONS
PRIMARY TEST
VAPOR EXTRACTION TREATABILITY STUDY

HELEVA HELEVA LANDFILL SITE

SYSTEM STATUS	DATE	TIME	WELL TEMP.	WELL HEAD VACCUM (IN. WATER)	FLOW METER TEMP.	FLOW RATE (cfm)	VACUUM AT PUMP (IN. WATER)	OPERATOR INITIALS
BEGIN LOW	2/27	3:40pm	39	12	32	10	73	MTW
FLOW TEST		4:05pm	40	13	32	11.1	40	MTW
R.V. PUMP		5:15pm	41	13.5	32	11	40	MTW
		7:00pm	41.5	13.25	32	11.25	40	MTW
BEGIN HIGH	2/27	8:30pm	40	17.2	33	14	30	MTW
FLOW TEST								
L.R. PUMP	2/28	12:30am	42	17	36	13	28.5	MTW
		5:40am	42	18	36	13	30	MTW
		9:15am	43	17.7	40	13	29.5	MTW
	3/1	12:00pm	43	18.25	45	13	30	RJC
	3/2	6:00pm	43	20	55	12.5	32.5	RJC
	3/3	9:00am	46	19	56	12.5-13	30	RJC
	3/4	2:00pm	44	21	44	13	35	RJC
	3/5	2:30pm	46	20	62	13	32	RJC
	3/6	6:20pm	42	21	34	13	34	MTW
	3/7	3:35pm	46	20	53	13	23.5	MTW
	3/8	1:30pm	47	19.3	62	12.5-13	30	MTW
BEGIN LOW	3/8	5:00pm	NR	10	NR	7	NR	MTW
FLOW TEST								
L.R. PUMP	3/9	8:15am	42	9	39	7	16	MTW
	3/9	12:50pm	46	8.75	55	7	15.5	MTW

ALL VACUUM MEASUREMENTS WERE MADE USING DWYER MAGNIHELIC DIFFERENTIAL PRESSURE GAUGES

ALL TEMPERATURE MEASUREMENTS WERE MADE USING ASHCROFT MODEL 30EI60R040 TEMPERATURE GAUGES INSTALLED IN LINE, TEMPERATURES IN FARENHEIT

FLOW RATE WAS MEASURED USING AN ERDCO SEE-FLO FLOW METER, MODEL 0412-06T5

NR NO READING TAKEN

L.R. PUMP 15 CFM LIQUID RING VACUUM PUMP

R.V. PUMP 10 CFM OIL-LESS ROTARY VANE PUMP

TABLE 3-2

VAPOR PROBE VACUUM MEASUREMENTS
VAPOR EXTRACTION TREATABILITY STUDY
HELEVA LANDFILL SITE

	DATE	TIME	INITIALS	VP1-1	VP1-2	VP1-3	VP1-4	VP1-5	VP2-1	VP2-2	VP2-3	VP3-1	VP3-2	VP3-3	VP4-1	VP4-2	BAROMETER
				PRIMARY TEST													
LOW FLOW	2/27	5:00PM	MTW	ND	ND	0.0075	ND	ND	ND	0.035	ND	ND	0.005	ND	0.2	0.19	NR
		7:00PM	RJC	ND	ND	0.005	ND	ND	ND	0.012	ND	ND	0.005	ND	0.145	0.1	NR
HIGH FLOW	2/28	10:15AM	MTW	ND	ND	0.075	0.01	ND	2.2	0.125	0.03	ND	ND	ND	0.165	0.13	NR
	3/1	3:40PM	RJC	ND	ND	0.085	0.01	ND	3.25	0.125	ND	ND	ND	ND	0.2	0.15	NR
	3/2	2:30PM	RJC	ND	ND	0.08	ND	0.005	ND	0.12	(+)	(+)	ND	ND	0.175	0.12	NR
	3/3	1:30PM	RJC	ND	(+)	0.0375	0.005	ND	ND	0.1	(+)	(+)	ND	ND	0.25	0.16	NR
	3/4	2:00PM	RJC	ND	ND	0.045	ND	ND	ND	0.095	(+)	(+)	ND	ND	0.185	0.15	NR
	3/5	2:30PM	RJC	0.005	ND	0.05	0.005	ND	2.8	0.09	ND	(+)	(+)	(+)	0.185	0.1425	NR
	3/6	6:30PM	MTW	ND	0.015	0.19	ND	ND	3.1	0.165	ND	0.035	0.02	0.03	0.24	0.18	30.09
	3/7	4:00PM	MTW	ND	0.005	0.075	ND	ND	2.8	0.105	(+)	0.6	0.45	0.005	0.185	0.11	30.31
	3/8	3:30PM	MTW	ND	ND	0.085	ND	ND	2.8	0.06	ND	0.6	0.45	(+)	0.2	0.1	30.15
LOW FLOW	3/9	9:00AM	MTW	ND	ND	0.05	ND	ND	1.35	0.09	(+)	0.29	0.21	(+)	0.075	0.055	29.77
		12:50PM	MTW	ND	ND	ND	0.005	ND	1.35	0.04	(+)	0.29	0.2	(+)	0.07	0.045	29.73
				SECONDARY TEST													
QUICK TEST	3/9	5:00PM	MTW	NR	NR	0.25	0.01	ND	0.05	0.3	(+)	ND	ND	ND	0.02	0.02	29.74
SYSTEM OFF	3/10	8:20AM	MTW	ND	ND	0.005	ND	ND	ND	0.01	ND	0.01	ND	ND	0.01	0.01	29.80
LOW FLOW	3/11	11:30AM	MTW	ND	ND	0.2	0.01	ND	0.05	0.3	ND	0.01	ND	ND	0.01	0.01	29.75
	3/12	1:00pm	MTW	ND	ND	0.22	0.01	0.005	ND	0.34	ND	(+)	ND	ND	ND	ND	29.69
HIGH FLOW	3/12	5:00PM	MTW	ND	ND	0.3	0.03	ND	0.035	0.45	ND	0.02	0.035	0.005	0.04	0.03	29.70
	3/13	8:20AM	MTW	ND	ND	0.42	0.04	ND	0.1	0.45	ND	0.045	0.03	0.01	0.035	0.025	NA

ALL VACUUM MEASUREMENTS ARE IN INCHES OF WATER ANDS WERE MADE USING DWYER MAGNIHELIC DIFFERENTIAL PRESSURE GAUGES

ND NO VACUUM DETECTED, I.E.; LESS THAN 0.005" WATER

NR READING NOT RECORDED

TABLE 3-3

EXTRACTION SYSTEM OPERATING CONDITIONS
SECONDARY TEST
VAPOR EXTRACTION TREATABILITY STUDY
HELEVA HELEVA LANDFILL SITE

SYSTEM STATUS	DATE	TIME	WELL TEMP.	WELL HEAD VACCUM (IN. Hg)	FLOW METER TEMP.	FLOW RATE (cfm)	VACUUM AT PUMP (IN. Hg)	OPERATOR INITIALS
BEGIN QUICK TEST	3/9	2:00PM	NR	10	NR	4 - 5	NR	MTW
		5:00PM	48	9.9	56	5	NR	MTW
L.R. PUMP OFF		5:50PM	NR	NR	NR	NR	NR	MTW
BEGIN LOW FLOW TEST L.R. PUMP ON	3/10	12:07PM	NR	NR	NR	NR	NR	MTW
		6:00PM	50	9.1	59	5	10	MTW
	3/11	1:00PM	59	9.5	78	5 - 5.5	NR	MTW
START HIGH FLOW TEST L.R. PUMP	3/12	1:30PM	NR	15-15.4	NR	7.3	NR	MTW
	3/13	8:20AM	56	15-15.2	66	7	NR	MTW

ALL VACUUM MEASUREMENTS WERE MADE USING AN ASHCROFT DURAGAUGE, MODEL Q-8643

ALL TEMPERATURE MEASUREMENTS WERE MADE USING ASHCROFT MODEL 30EI60R040 TEMPERATURE GAUGES INSTALLED IN LINE, TEMPERATURES IN FARENHEIT

FLOW RATE WAS MEASURED USING AN ERDCO SEE-FLO FLOW METER, MODEL 0412-06T5

L.R. PUMP 15 CFM LIQUID RING VACUUM PUMP

During the higher air flow test, the system operated at an air flow rate from the wellhead fluctuating between 7 and 7.3 cfm. Vacuum levels observed at the wellhead over the approximately eighteen hour duration of this phase of the testing fluctuated between 15 and 15.4 inches of mercury.

Vacuum readings observed at the vapor probes during the secondary test are summarized in Table 3-2. Readings were taken in the same manner as described above after clearing out the vapor probe tubing. During the low flow test vacuum was consistently detectable at VP1-3, VP1-4, and VP2-2, ranging from 0.01 to 0.34 inches of water. Vacuum was not detected at any of the remaining vapor probes. During the high flow test vacuum was observed in at least one probe from each boring location over a range of 0.005 to 0.45 inches of water. The highest reading was consistently observed at VP2-2. Vacuum was not detected at VP1-1, VP1-2, VP1-5 and VP2-3.

3.2 Results of Chemical Analysis

3.2.1 Vapor Probe Sampling and Analysis

a. Pretest Sampling and Analysis

Soil vapor sampling and analysis was performed prior to the vapor extraction feasibility test to quantify and qualify VOCs in the soil vapor in the vicinity of each probe. This sampling was conducted during the period of February 22 through 23, 1990. Samples were collected from each vapor probe with the exception of probes VP1-4 and VP1-5. No samples were collected from probes VP1-4 or VP1-5 due to the inability to draw vapor samples from the sampling tube using either the sampling pump or 10 ml airtight syringes. It is likely that these sampling techniques were ineffective due to the inability to overcome the relatively high head loss associated with the lengths of the sampling tube, and/or the blockage of vapor transport to the probe due to the smearing of the borehole. Section 4.1.1.a discusses the impact of borehole smearing in more detail.

Prior to the sampling of vapor probes with the GC/PID, each vapor probe was screened with the hand held 580A as outlined in *VAPEX's* QA/QC Plan. Results of hand held 580A screening of vapor probes are presented in Table 3-4. Hand held 580A readings ranged from a high of 397 ppm v/v at VP1-2 to a low of 31 ppm v/v at VP4-1 with the highest readings generally observed at VP1, VP2, and VP3.

Following the hand held 580A screening, samples were collected for GC/PID analysis. Samples were collected from nine vapor probes at the VP1, VP2, and VP3 locations. Samples were not collected from the VP4 probes since they had displayed significantly less VOCs during the hand held 580A screening. Vapor probes were sampled and analyzed in accordance with *VAPEX's* Standard Operating Procedures (SOPs) which are included in Appendix B. Results of GC/PID chromatographic analyses are summarized in Table 3-5. Copies of the chromatograms are presented in Appendix C. The correlation between hand held 580A screening results and field GC/PID analytical results is discussed in Section 4.1.2.b.1.

Elevated concentrations of VOCs (Table 3-5) were detected in all vapor probe samples. The GC/PID analyses indicated that total target VOC concentrations

TABLE 3-4

VAPOR PROBE PRETEST TOTAL PID ANALYSES

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

VAPOR PROBES	SAMPLE	GC FILENAME	DATE	580A PID READING (ppm v/v)
VP1	VP1-1	<VP1-1>	02/22/90	211
	VP1-2	<VP1-2>	02/22/90	397
	VP1-3	<VP1-3>	02/22/90	171
	VP1-4	NA		NR
	VP1-5	NA		NR
VP2	VP2-1	<VP2-1>	02/22/90	183
	VP2-2	<VP2-2>	02/22/90	194
	VP2-3	<VP2-3>	02/23/90	360
VP3	VP3-1	<VP3-1>	02/23/90	198
	VP3-2	<VP3-2>	02/23/90	287
	VP3-3	<VP3-3>	02/23/90	255
VP4	VP4-1	NA		31
	VP4-2	NA		76

@ Samples analyzed using a Thermo Electron Model 580 Organic Vapor Meter (OVM) equipped with an 11.8 eV photoionization lamp (PID). All samples reported in parts-per-million (ppm) on a volume/volume (vol/vol basis as perchloroethylene (PCE).

NR No reading obtained.

NA Not applicable.

TABLE 3-5

VAPOR PROBE GC/PID ANALYTICAL RESULTS

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

Sample#	Filename	Depth (ft)	Date	TCA	cis-DCE	TCE*	PCE	HCCl3	Tol	Ethyl Benzene	Total Xylenes	Total
				--------- PRETEST ---------								
VP1-1	VP1-1	3	2-22-90	29	223	763	1	ND	ND	ND	ND	1016
VP1-2	VP1-2	11.5	thru	85	251	2657	2	ND	ND	28	ND	3023
VP1-3	VP1-3	23	2-23-90	5	100	522	ND	ND	ND	ND	ND	627
VP2-1	VP2-1	12		684	1113	3994	30	269	45	255	1022	7412
VP2-2	VP2-2	25		77	265	1350	3	250	5	26	65	2041
VP2-3	VP2-3	38		177	725	3628	3	410	9	30	101	5083
												0
VP3-1	VP3-1	11.5		31	48	1910	2	ND	ND	ND	ND	1991
VP3-2	VP3-2	26		285	285	3898	8	146	ND	29	52	4703
VP3-3	VP3-3	38		318	431	3595	8	56	ND	14	25	4447
				--------- POST TEST ---------								
VP1-1	VP1-1	3	3-10-90	16	109	298	ND	ND	ND	ND	ND	423
	Change			13	114	465	1	0	0	0	0	593
	% Reduction			45%	51%	61%	100%	N/A	N/A	N/A	N/A	58%
VP1-2	VP1-2B	11.5		46	115	854	ND	ND	ND	ND	ND	1015
	Change			39	136	1803	2	0	0	28	0	2008
	% Reduction			46%	54%	68%	100%	N/A	N/A	100%	N/A	66%
VP2-1	VP2-1	12		427	442	1238	3	272	ND	ND	ND	2382
	Change			257	671	2756	27	-3	45	255	1022	5030
	% Reduction			38%	60%	69%	90%	-1%	100%	100%	100%	68%
VP1-2	VP1-2	11.5	3-13-90	42	107	754	2	ND	ND	ND	ND	905
	Change			43	144	1903	0	0	0	28	0	2118
	% Reduction			51%	57%	72%	0%	N/A	N/A	100%	N/A	70%
VP1-3	VP1-3	23		3	33	202	ND	ND	ND	ND	ND	238
	Change			2	67	320	0	0	0	0	0	389
	% Reduction			40%	67%	61%	N/A	N/A	N/A	N/A	N/A	62%
VP3-1	VP3-1	11.5		38	29	858	ND	ND	ND	ND	ND	925
	Change			-7	19	1052	2	0	0	0	0	1066
	% Reduction			-23%	40%	55%	100%	N/A	N/A	N/A	N/A	54%

@	Samples analyzed using an HNU Model 321 Gas Chromatograph, equipped with an 11.7 eV photoionization detector. All samples reported in parts-per-million (ppm) on a volume/volume (vol/vol) basis.
TCA	1,1,1-trichloroethane
cis-DCE	cis-1,2-dichloroethylene
TCE	trichloroethylene
PCE	perchloroethylene/tetrachloroethylene
HCCl3	Chloroform
Tol	Toluene
Xylene	Reported as total xylenes (o-, m-, and p- isomers) based on m-xylene
*	This peak may include a second compound partially enveloped in TCE peak
ND	Not detectable
N/A	Not applicable
^	Acetone was not detected

ranged from 7,412 ppm v/v at VP2-1 to 627 ppm v/v at VP1-3. As expected, TCE was the most prominent VOC detected in all probes at concentrations ranging from 3,994 ppm v/v at VP2-1 to 522 ppm v/v at VP1-3. Relatively high concentrations of cis-DCE and TCA were also detected in all vapor probe samples. The concentration of cis-DCE ranged from 1,113 ppm v/v at VP2-1 to 48 ppm v/v at VP3-1. TCA concentrations ranged from 684 ppm v/v at VP2-1 to 5 ppm v/v at VP1-3.

b. Post Test Sampling and Analysis

At the conclusion of the soil vapor extraction feasibility test, following an equilibration period of 2 to 12 hours, soil vapor samples from selected probes were collected and analyzed. The sampling and analysis was limited to six probes which were selected based on the requirement to: 1) verify that vacuum influence had been achieved and 2) determine the effects of vacuum influence on local soil vapor composition and concentrations at these specific locations.

Post-test measurements of soil vapor VOC concentrations were not obtained with the hand held 580A since screening of probes prior to testing was sufficient to determine the proper GC/PID attenuation settings. Results of vapor probe analyses obtained at the conclusion of the test along with pre-test/post-test comparisons can be found in Table 3-5 along with pre-test vapor probe data. Copies of the chromatograms are presented in Appendix C.

Elevated concentrations of VOCs were detected in all vapor probe samples. However, the VOC concentrations were significantly lower than those obtained prior to testing. Total target VOC concentrations ranged from 2,382 ppm v/v at VP2-1 to 238 ppm v/v at VP1-3. This represents decreases of 68 and 62 per cent, respectively, from pre-test concentrations.

TCE was again the most prominent VOC detected in all probes at concentrations ranging from 1,238 ppm v/v at VP2-1 to 202 ppm v/v at VP1-3, which represented decreases of 69 and 61 per cent respectively. Similar concentration decreases were observed for other target VOCs with the exception of chloroform which remained relatively unchanged at a concentration of 272 ppm v/v in the VP2-1 sample.

3.2.2 Field Analysis of Wellhead Soil Vapor Discharge

a. Preliminary Testing

Wellhead soil vapor discharge was analyzed with the hand held 580A prior to and in association with GC/PID analysis during the preliminary testing of each vacuum well. Wellhead soil vapor discharge samples from the shallow vacuum well (VW-S) and the deep vacuum well (VW-D) measured 172 ppm v/v and 187 ppm v/v respectively, using the hand held 580A during preliminary testing.

Results of GC/PID chromatographic analyses of the preliminary tests of VW-S and VW-D wellhead discharge are presented in Table 3-6. Elevated concentrations of VOCs were detected in the discharge sample from each well. The total concentration levels for all target compounds were 8,511 ppm v/v at VW-S and 9,056 ppm v/v at VW-D. The primary constituent from both wells was TCE at concentrations of 5,913 ppm v/v and 6,013 ppm v/v for VW-S and VW-D, respectively. Relatively high concentrations of 111-TCA, cis-DCE and total

TABLE 3-6

PRELIMINARY TEST WELLHEAD VAPOR DISCHARGE ANALYSES @^

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

Sample #	Vacuum Well	Filename	Descr.	Date	Time	580A#	trans-DCE	TCA	cis-DCE	TCE*	PCE	HCCL3	Tol	Ethyl-Benzene	Xylenes	Total
1	VW-S	VW-S1/2	Exhaust (M4/M8)	26-Feb	11:00 AM	172	<1	572	1373	5913	22	ND	25	116	489	8511
2	VW-D	VW-D1/2	Exhaust (M4/M8)	26-Feb	12:40 PM	187	ND	367	1604	6013	14	571	23	95	369	9056

@ Samples analyzed using an HNU Model 321 Gas Chromatograph, equipped with an 11.7 eV photoionization detector. All samples reported in parts-per-million (ppm) on a volume/volume (vol/vol) basis

\# Samples analyzed using a Thermo Electron Model 580A Organic Vapor Analyzer (OVM) equipped with an 11.8 eV photoionization detector (PID). All samples reported in parts-per-million (ppm) on a volume/volume (vol/vol) basis as perchloroethylene (PCE). Samples have been adjusted for field calibration.

trans-DCE trans-1,2-dichloroethylene

TCA 1,1,1-trichloroethane

cis-DCE cis-1,2-dichloroethylene

TCE trichloroethylene

PCE perchloroethylene/tetrachloroethylene

HCCl3 Chloroform

Tol Toluene

Xylene Reported as total xylenes (o-, m-, and p- isomers) based on m-xylene

* This peak may include a second compound partially enveloped in TCE peak

M4/M8 GC/PID attenuation settings

ND Not detectable

^ Acetone was not detected

xylenes were also detected in the discharge sample from each well.

b. Primary Test at VW-S

Wellhead soil vapor discharge was analyzed with the hand held 580A prior to and in association with GC/PID analysis throughout the duration of the Primary Test. The results of all hand held 580A analyses of VW-S wellhead discharge are presented in Table 3-7. Over the period of the test, VW-S wellhead discharge hand held 580A readings ranged from a maximum of 470 ppm v/v on the fourth day of the test to a minimum of 93 ppm v/v on the second day of the test. The initial and final readings were 187 ppm v/v and 388 ppm v/v, respectively.

Results of GC/PID chromatographic analyses of VW-S wellhead vapor discharge throughout the Primary Test are presented in Table 3-8. Relatively high concentrations of VOCs were detected in each VW-S discharge vapor sample analyzed throughout the duration of the test. The total target VOC concentrations ranged from a maximum of 11,787 ppm v/v on the fifth day of the test to a minimum of 3,082 ppm v/v on the ninth (final) day of the test. A graphic representation of GC/PID analytical results for VW-S wellhead vapor discharge is presented in Figure 3-1.

The primary constituent in each VW-S wellhead discharge vapor sample was TCE, which ranged in concentration from a maximum of 7,318 ppm v/v on Day 5 to a minimum of 2,474 ppm v/v on the final day of the test. The other prominent target VOCs and their maximum and minimum concentrations were: cis-DCE ranging from 1,760 ppm v/v to 266 ppm v/v; total xylenes ranging from 1,173 ppm v/v to 192 ppm v/v; TCA ranging from 661 ppm v/v to 102 ppm v/v; chloroform ranging from 517 ppm v/v to non-detected; and, ethyl benzene ranging from 292 ppm v/v to 49 ppm v/v. PCE was detected at concentrations ranging from a maximum of 27 ppm v/v to a minimum of non detectable in several samples. Toluene was detected at a maximum concentration of 67 ppm v/v during the initial days of the test and was detected in only three samples after the second day of operations.

Copies of chromatograms for the VW-S wellhead vapor discharge analyses are presented in Appendix C.

c. Secondary Test at VW-D

Wellhead soil vapor discharge was analyzed with the hand held 580A prior to and in association with GC/PID analysis throughout the duration of the secondary test. The results of all hand held 580A analyses of VW-D wellhead discharge are presented in Table 3-9. Over the period of the test, VW-D wellhead discharge hand held 580A readings ranged from a maximum of 299 ppm v/v at the start of the test to a minimum of 68 ppm v/v at the completion of the test.

Results of GC/PID chromatographic analyses of VW-D wellhead vapor discharge throughout the secondary test are presented in Table 3-10. Elevated concentrations of VOCs were detected in each VW-D discharge vapor sample analyzed throughout the duration of the test. The total target VOC concentrations ranged from a maximum of 9,072 ppm v/v at the start of the test to a minimum of 4,073 ppm v/v at the completion of the test. A graphic representation of GC/PID analytical results for VW-D wellhead vapor discharge is presented in Figure 3-2.

TABLE 3-7

PRIMARY TEST WELLHEAD VAPOR DISCHARGE 580A TOTAL PID ANALYSES@

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

SAMPLE#	GC FILENAME	DATE	TIME	580A PID READING (ppm v/v)
VW-S#1	<VW-S-3>	02/27/90	04:10 PM	187
2	<VW-S-5>	02/27/90	06:41 PM	187
3	<VW-S-7>	02/27/90	08:45 PM	187
4	<VW-S-9>	02/27/90	10:18 PM	282
5	<VW-S-10>	02/28/90	12:05 AM	235
6	<VW-S-11>	02/28/90	02:00 AM	206
7	<VW-S-12>	02/28/90	05:10 AM	269
8	<VW-S-13>	02/28/90	08:47 AM	121
9	<VW-S-14>	02/28/90	01:13 PM	204
10	<VW-S-15>	02/28/90	03:58 PM	248
11	<VW-S-16>	02/28/90	06:00 PM	206
12	<VW-S-17>	03/01/90	07:58 AM	233
13	<VW-S-18>	03/01/90	10:00 AM	250
14	<VW-S-19>	03/01/90	11:05 AM	239
15	<VW-S-20>	03/01/90	11:11 AM	224
16	<VW-S-21>	03/01/90	01:05 PM	105
17	<VW-S-22>	03/01/90	02:25 PM	93
18	<VW-S-24>	03/01/90	04:58 PM	95
19	<VW-S-25>	03/02/90	10:25 AM	173
20	<VW-S-26>	03/02/90	12:20 PM	173
21	<VW-S-27>	03/02/90	01:38 PM	275
22	<VW-S-29>	03/03/90	09:30 AM	342
23	<VW-S-30>	03/03/90	11:40 AM	470
24	<VW-S-31>	03/03/90	01:24 PM	353
25	<VW-S-32>	03/03/90	03:40 PM	398
26	<VW-S-34>	03/04/90	07:59 AM	373
27	<VW-S-35>	03/04/90	10:00 AM	261
28	<VW-S-36>	03/04/90	12:04 PM	238
29	<VW-S-37>	03/04/90	02:00 PM	254
30	<VW-S-39>	03/05/90	09:37 AM	255
31	<VW-S-40>	03/05/90	11:38 AM	197
32	<VW-S-41>	03/05/90	01:35 PM	214
33	<VW-S-43>	03/05/90	03:33 PM	213
34	<VW-S-44>	03/06/90	07:45 AM	206
35	<VW-S-45>	03/06/90	01:00 PM	291
36	<VW-S-46>	03/06/90	03:53 PM	233
37	<VW-S-48>	03/06/90	06:10 PM	208
38	<VW-S-49>	03/07/90	10:23 AM	240
39	<VW-S-50>	03/07/90	12:30 PM	277
40	<VW-S-51>	03/07/90	02:00 PM	250
41	<VW-S-53>	03/07/90	04:10 PM	200
42	<VW-S-54>	03/08/90	09:30 AM	250
43	<VW-S-55>	03/08/90	11:35 AM	189
44	<VW-S-57>	03/08/90	02:55 PM	305
45	<VW-S-60>	03/08/90	05:00 PM	238
46	<VW-S-61>	03/09/90	11:40 AM	388

@ Samples analyzed using a Thermo Electron Model 580A Organic Vapor Meter (OVM) equipped with an 11.8 eV photoionization lamp (PID). All samples reported in parts-per-million (ppm) on a volume/volume (vol/vol) basis as perchloroethylene (PCE)

TABLE 3-8

PRIMARY TEST WELLHEAD VAPOR DISCHARGE GC/PID ANALYSES@

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

Sample #	Filename	Descr.	Date	Sample Time	Run Time (hrs)	Run Time (days)	Flowrate	TCA	cis-DCE	TCE*	PCE	HCCl3	Tol	Ethyl-Benzene	Xylenes	Total
VW-S#1	VW-S-3/4	Exhaust (M4/M8)	27-Feb	04:10 PM	0.73	0.03	High/	523	1642	5903	27	ND	34	171	745	9044
2	VW-S-5/6	Exhaust (M4/M8)	27-Feb	06:41 PM	3.25	0.14	13 cfm	320	814	OR	10	ND	15	79	328	OR
3	VW-S-7/8	Exhaust (M4/M8)	27-Feb	08:45 PM	5.32	0.22		387	1260	4146	17	62	25	126	540	6564
4	VW-S-9	" (M8)	27-Feb	10:16 PM	6.83	0.28		594	1678	4467	24	236	34	197	822	8051
5	VW-S-10	" (M8)	28-Feb	12:05 AM	8.65	0.36		502	1465	4035	20	161	28	174	738	7123
6	VW-S-11	" (M8)	28-Feb	02:00 AM	10.57	0.44		559	1595	4477	26	244	33	194	831	7959
7	VW-S-12	" (M8)	28-Feb	05:10 AM	13.73	0.57		526	1536	4408	22	294	33	195	825	7838
8	VW-S-13	" (M8)	28-Feb	08:47 AM	17.35	0.72		554	1551	4233	22	328	36	202	859	7785
9	VW-S-14	" (M8)	28-Feb	01:13 PM	21.78	0.91		413	1214	3709	19	264	30	159	661	6468
10	VW-S-15	" (M8)	28-Feb	03:58 PM	24.53	1.02		435	1206	4631	19	139	67	139	567	7204
11	VW-S-16	" (M8)	28-Feb	06:00 PM	26.57	1.11		475	1448	4466	19	367	27	154	643	7599
12	VW-S-17	" (M8)	28-Feb	07:58 PM	28.53	1.19		493	1325	4658	19	215	27	166	694	7597
13	VW-S-18	" (M8)	28-Feb	10:00 PM	30.57	1.27		531	1366	4653	19	376	40	141	560	7686
14	VW-S-19	" (M8)	28-Feb	11:05 PM	31.65	1.32		468	1203	4714	15	258	ND	103	401	7163
15	VW-S-20	" (M8)	01-Mar	11:11 AM	43.75	1.82		331	936	3322	14	163	ND	108	444	5318
16	VW-S-21	" (M8)	01-Mar	01:05 PM	45.65	1.90		349	840	3494	12	182	ND	114	466	5456
17	VW-S-22	" (M4)	01-Mar	03:40 PM	48.23	2.01		323	888	4061	13	213	24	113	454	6089
17	VW-S-23	Duplicate (M8)	01-Mar	03:40 PM	48.23	2.01		357	1093	4932	13	110	ND	131	541	7178
18	VW-S-24	Exhaust (M8)	01-Mar	04:58 PM	49.53	2.06		507	1430	4856	21	331	ND	181	735	8062
19	VW-S-25	" (M8)	02-Mar	10:25 AM	66.98	2.79		242	736	2881	ND	ND	ND	68	247	4174
20	VW-S-26	" (M8)	02-Mar	12:20 PM	68.90	2.87		289	781	2999	8	197	ND	97	397	4767
21	VW-S-27	" (M8)	02-Mar	02:05 PM	70.65	2.94		328	905	3205	13	239	ND	121	483	5295
21	VW-S-28	Duplicate (M8)	02-Mar	02:05 PM	70.65	2.94		242	641	2736	ND	210	ND	76	278	4183
22	VW-S-29	Exhaust (M8)	02-Mar	04:10 PM	72.73	3.03		411	1095	4336	11	318	ND	142	579	6893
23	VW-S-30	" (M8)	03-Mar	09:30 AM	90.07	3.75		315	876	4470	ND	ND	ND	84	307	6051
24	VW-S-31	" (M8)	03-Mar	11:40 AM	92.23	3.84		437	1146	5165	19	326	ND	130	541	7766
25	VW-S-32	" (M8)	03-Mar	01:24 PM	93.97	3.92		503	1297	5639	19	380	ND	176	717	8732
25	VW-S-33	Duplicate (M8)	03-Mar	01:24 PM	93.97	3.92		449	1134	5361	11	330	ND	150	602	8038
26	VW-S-34	Exhaust (M8)	03-Mar	03:40 PM	96.23	4.01		476	1258	5419	15	292	ND	173	712	8345

Continued on following page.

TABLE 3-8 (continued)

PRIMARY TEST WELLHEAD VAPOR DISCHARGE GC/PID ANALYSES@

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

Sample#	Filename	Descr.	Date	Sample Time	Run Time (hrs)	Run Time (days)	Flowrate	TCA	cis-DCE	TCE*	PCE	HCCl3	Tol	Ethyl-Benzene	Xylenes	Total
27	VW-S-35	" (M8)	04-Mar	07:59 AM	112.55	4.69	High/	535	1348	6121	15	450	ND	125	439	9034
28	VW-S-36	" (M8)	04-Mar	10:00 AM	114.57	4.77	13 cfm	627	1615	7111	25	439	ND	236	945	10999
29	VW-S-37	" (M8)	04-Mar	12:04 PM	116.63	4.86		661	1760	7318	25	517	41	292	1173	11787
29	VW-S-38	Duplicate (M8)	04-Mar	12:04 PM	116.63	4.86		565	1450	6981	22	417	ND	232	926	10594
30	VW-S-39	Exhaust (M8)	04-Mar	02:00 PM	118.57	4.94		587	1544	7009	25	472	ND	247	1004	10889
31	VW-S-40	" (M8)	05-Mar	09:37 AM	138.18	5.76		503	1215	6846	20	435	40	230	913	10202
32	VW-S-41	" (M8)	05-Mar	11:38 AM	140.20	5.84		520	1209	6921	20	370	ND	225	873	10138
32	VW-S-42	Duplicate (M8)	05-Mar	11:38 AM	140.20	5.84		427	1007	6416	15	347	ND	171	671	9053
33	VW-S-43	Exhaust (M8)	05-Mar	01:35 PM	142.15	5.92		495	1193	6901	23	415	37	225	898	10187
34	VW-S-44	" (M8)	05-Mar	03:33 PM	144.12	6.00		361	961	4533	18	319	ND	155	610	6958
35	VW-S-45	" (M8)	06-Mar	07:45 AM	160.32	6.68		378	989	4722	14	296	ND	157	620	7174
36	VW-S-46	" (M8)	06-Mar	02:20 PM	166.90	6.95		270	745	3559	11	235	ND	136	551	5508
36	VW-S-47	Duplicate (M8)	06-Mar	02:20 PM	166.90	6.95		211	555	3042	7	185	ND	99	394	4493
37	VW-S-48	Exhaust (M8)	06-Mar	03:23 PM	167.95	7.00		289	693	3895	14	286	ND	149	594	5919
38	VW-S-49	" (M8)	06-Mar	06:10 PM	170.73	7.11		257	600	3832	ND	213	ND	95	338	5334
39	VW-S-50	" (M8)	07-Mar	10:23 AM	186.95	7.79		302	723	4301	14	265	ND	165	664	6434
40	VW-S-51	" (M8)	07-Mar	12:30 PM	189.07	7.88		289	698	4273	14	257	ND	157	643	6329
40	VW-S-52	Duplicate (M8)	07-Mar	12:30 PM	189.07	7.88		186	448	3764	ND	ND	ND	97	354	4848
41	VW-S-53	Exhaust (M8)	07-Mar	03:00 PM	191.57	7.98		284	688	4156	11	254	ND	162	651	6204
42	VW-S-54	" (M8)	07-Mar	05:08 PM	193.70	8.07		258	665	3822	10	227	ND	151	615	5748
43	VW-S-55	" (M8)	08-Mar	09:30 AM	210.07	8.75		255	668	3978	10	230	ND	130	521	5792
43	VW-S-56	Duplicate (M8)	08-Mar	09:30 AM	210.07	8.75		202	483	3458	ND	184	ND	92	363	4781
44	VW-S-58	Duplicate (M8)	08-Mar	11:35 AM	212.15	8.84		204	316	3409	ND	163	ND	97	396	4585
44	VW-S-59	Duplicate #2(M8)	08-Mar	11:35 AM	212.15	8.84		102	266	2474	ND	ND	ND	49	192	3082
45	VW-S-60	Exhaust (M8)	08-Mar	02:55 PM	215.48	8.98		225	597	3420	10	220	ND	148	605	5224

@ Samples analyzed using an HNU Model 321 Gas Chromatograph, equipped with an 11.7 eV photoionization detector.
All samples reported in parts-per-million (ppm) on a volume/volume (vol/vol) basis.
TCA 1,1,1-trichloroethane
cis-DCE cis-1,2-dichloroethylene
TCE trichloroethylene
PCE perchloroethylene/tetrachloroethylene
HCCl3 Chloroform
Tol Toluene
Xylene Reported as total xylenes (o-, m-, and p- isomers) based on m-xylene
* This peak may include a second compound partially enveloped in TCE peak
M4/M8 GC/PID attenuation settings
OR Peak was over range/off scale of integration
ND Not detectable
^ Acetone was not detected

TABLE 3-9

SECONDARY TEST WELLHEAD VAPOR DISCHARGE 580A TOTAL PID ANALYSES@

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

SAMPLE	GC FILENAME	DATE	TIME	580A PID READING (ppm v/v)
VW-D#1	<VW-D-1>	03/09/90	05:10 PM	299
2	<VW-D-2>	03/10/90	12:40 PM	222
3	<VW-D-3>	03/10/90	03:27 PM	189
4	<VW-D-5>	03/10/90	05:03 PM	233
5	<VW-D-6>	03/10/90	07:06 PM	288
6	<VW-D-7>	03/11/90	08:14 AM	192
7	<VW-D-8>	03/11/90	10:22 AM	166
8	<VW-D-9>	03/11/90	12:12 PM	133
9	VW-D-10>	03/11/90	02:39 PM	150
10	VW-D-12>	03/12/90	08:53 AM	78
11	VW-D-14>	03/12/90	12:20 PM	133
12	VW-D-15>	03/12/90	01:56 PM	145
13	VW-D-16>	03/12/90	03:30 PM	138
14	VW-D-17>	03/12/90	05:35 PM	135
15	VW-D-18>	03/13/90	08:33 AM	68

@ Samples analyzed using a Thermo Electron Model 580A Organic Vapor Meter (OVM) equipped with an 11.8 eV photoionization lamp (PID). All samples reported in parts-per-million (ppm) on a volume/volume (vol/vol) basis as perchloroethylene (PCE)

TABLE 3-10

SECONDARY TEST WELLHEAD VAPOR DISCHARGE@

VAPOR EXTRACTION TREATABILITY TEST

HELEVA LANDFILL

Sample #	Filename	Descr.	Date	Time	Run Time (Days)	Run Time (hrs)	Flowrate	Dilution Factor	TCA	cis-DCE	TCE*	PCE	HCCL3	Tol	Ethyl-Benzene	Xylenes	Total
1	VW-D-2	Exhaust (M8)	10-Mar	12:40 PM	0	1	Low/5cfm	2.15	266	1246	7374	ND	<300	ND	ND	186	9072
2	VW-D-3	Exhaust (M8)	10-Mar	03:27 PM	0	3			264	1191	6354	ND	404	ND	ND	166	8381
3	VW-D-4	Exhaust (M8)	10-Mar	03:52 PM	0	4			205	893	4635	ND	283	ND	ND	114	6130
4	VW-D-5	Exhaust (M4)	10-Mar	05:03 PM	0	5			170	751	4263	ND	269	ND	41	158	5653
5	VW-D-6	Exhaust (M4)	10-Mar	07:06 PM	0	7			185	821	4513	ND	291	ND	47	183	6041
6	VW-D-7	Exhaust (M4)	11-Mar	08:14 AM	1	20			214	855	5126	6	334	ND	49	195	6778
7	VW-D-8	Exhaust (M4)	11-Mar	10:22 AM	1	22			184	677	4444	7	291	ND	48	178	5829
8	VW-D-9	Exhaust (M4)	11-Mar	12:12 PM	1	24			208	754	4894	9	320	ND	56	195	6437
9	VW-D-10	Exhaust (M8)	11-Mar	02:39 PM	1	27			196	687	4431	6	305	ND	41	122	5787
10	VW-D-11	Exhaust (M4)	11-Mar	03:28 PM	1	27			160	514	3751	8	203	ND	ND	88	4724
11	VW-D-12	Exhaust (M4)	12-Mar	08:53 AM	2	45			179	686	4192	6	293	ND	51	180	5585
12	VW-D-13	Exhaust (M4)	12-Mar	09:26 AM	2	45			153	580	3929	7	231	ND	39	152	5091
13	VW-D-14	Exhaust (M4)	12-Mar	12:20 PM	2	48			188	698	4234	6	321	101	45	163	5755
14	VW-D-15	Exhaust (M4)	12-Mar	01:56 PM	2	50	High/7cfm	N/A	185	650	2799	14	287	ND	69	231	4225
15	VW-D-16	Exhaust (M4)	12-Mar	03:30 PM	2	51			192	696	2862	7	321	ND	59	231	4369
16	VW-D-17	Exhaust (M4)	12-Mar	05:35 PM	2	53			190	667	2794	7	295	62	51	197	4262
17	VW-D-18	Exhaust (M4)	13-Mar	08:33 AM	3	68			171	581	2773	6	290	ND	53	199	4073

@	Samples analyzed using an HNU Model 321 Gas Chromatograph, equipped with an 11.7 eV photoionization detector. All samples reported in parts-per-million (ppm) on a volume/volume (vol/vol) basis
TCA	1,1,1-trichloroethane
cis-DCE	cis-1,2-dichloroethylene
TCE	trichloroethylene
PCE	perchloroethylene/tetrachloroethylene
HCCl3	Chloroform
Tol	Toluene
Xylene	Reported as total xylenes (o-, m-, and p- isomers) based on m-xylene
*	This peak may include a second compound partially enveloped in TCE peak
M4/M8	GC/PID attenuation settings
ND	Not detectable
^	Acetone was not detected

GC/PID ANALYSIS OF VW-S DISCHARGE

HELEVA LANDFILL

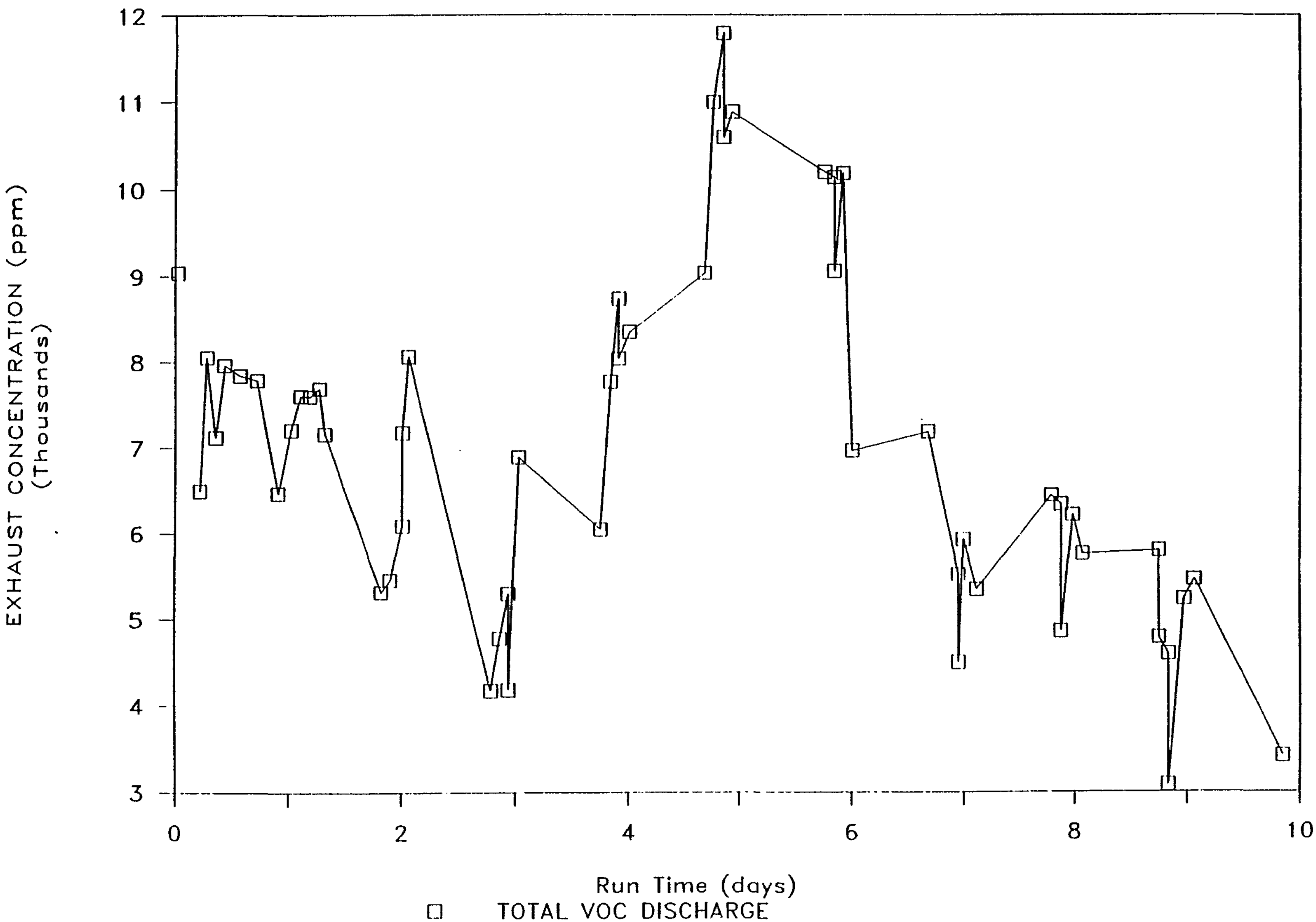
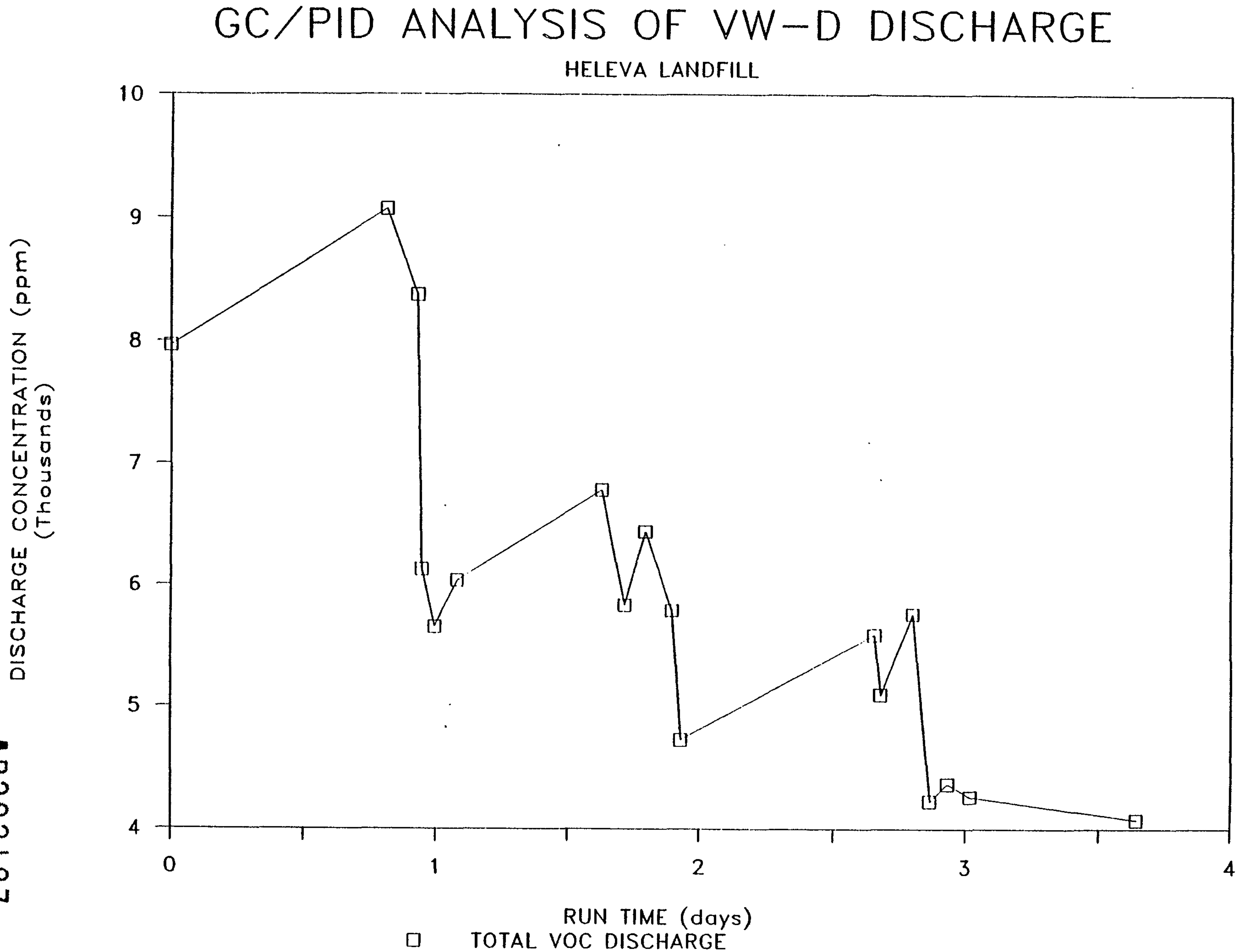


FIGURE 3-1



GC/PID ANALYSIS OF VW–D DISCHARGE
HELEVA LANDFILL
DISCHARGE CONCENTRATION (ppm)
(Thousands)
10
9
8
7
6
5
4
0
1
2
3
4
RUN TIME (days)
TOTAL VOC DISCHARGE

FIGURE 3-2

The primary constituent in each wellhead discharge vapor sample was TCE which ranged in concentration from a maximum of 7,374 ppm v/v at the start of the test to a minimum of 2,773 ppm v/v at the completion of the test. The other prominent target VOCs and their maximum and minimum concentrations were: cis-DCE ranging from 1,246 ppm v/v to 514 ppm v/v; chloroform ranging from 404 ppm v/v to 203 ppm v/v; TCA ranging from 266 ppm v/v to 160 ppm v/v; total xylenes ranging from 231 ppm v/v to 88 ppm v/v; and, ethyl benzene ranging from 59 ppm v/v to non detectable. PCE was detected at concentrations ranging from a maximum of 14 ppm v/v to a minimum of non detectable in several samples. Toluene was detected in only two samples at concentrations of 101 ppm v/v and 62 ppm v/v.

Copies of chromatograms for the VW-D wellhead vapor discharge analyses are presented in Appendix C.

3.2.3 Field Analyses of Carbon Cannister Discharge
The soil vapor discharge from the carbon cannisters was analyzed with the hand held 580A and the GC/PID on a daily basis throughout the duration of both the primary and secondary tests. The hand held 580A was used to analyze vapor samples at the interior sampling points within the carbon cannister systems, while the GC/PID was used to monitor discharge from the final cannister only. Table 3-11 presents a summary of these sampling events.

When breakthrough of the second carbon can in each of the two series of three carbon cans was detected, the system was switched over to a fresh series of carbon cans so as to prevent the breakthrough and exhaust of VOCs into the surrounding breathing space. Breakthrough of VOCs into the atmosphere was never detected. Copies of chromatograms from the analysis of outlet/postcarbon vapor can be found in Appendix C.

3.2.4 Laboratory Analyses of Wellhead Vapor Discharge
A total of five wellhead vapor discharge samples from the primary test and one sample from the secondary test were collected for laboratory analysis. Samples for laboratory analysis were collected in accordance with SOP Vapor-2, using Teflon bags which were sent to MDS Labs, Inc. for analysis by EPA Method TO1/TO2 within 48 hours of collection. The results of these laboratory chromatographic analyses are summarized in Table 3-12.

Elevated concentrations of VOCs were detected in all samples analyzed in the laboratory by EPA Method T01/T02. Total VOCs detected in the laboratory analyses of the wellhead vapor discharge from VW-S during the primary test ranged from a maximum of 2,725 ppm v/v on the second day of the test to a minimum of 783 ppm v/v on the first day of the test. TCE was the most prominent VOC that was detected, ranging from a maximum of 1,480 ppm v/v to a minimum of 452 ppm v/v. The other prominent target VOCs and their maximum and minimum concentrations were: cis-DCE ranging from 373 ppm v/v to 52 ppm v/v; TCA ranging from 364 ppm v/v to 71 ppm v/v; chloroform ranging from 362 ppm v/v to 13 ppm v/v; total xylenes ranging from 24 ppm v/v to 8 ppm v/v; and, ethyl benzene ranging from 19 ppm v/v to 6 ppm v/v. PCE and toluene, along with several other non target VOCs were detected at relatively low concentrations in most of the samples. Vinyl chloride was detected at concentrations ranging from

TABLE 3-11

CARBON CANISTER DISCHARGE ANALYSES
VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL SITE

DATE	TIME	TEST CONFIG.	CANISTER CONFIG.	CANISTER NO.	INSTRUMENT	RESULTS	GC FILENAME	LABORATORY SAMPLE NAME
2/27	10:40 AM	PRIMARY	A	1	580A	ND		
	12:50 PM	PRIMARY	A	1	580A	ND		
	5:45 PM	PRIMARY	A	1	580A	ND		
	6:40 PM	PRIMARY	A	1	580A	ND		
	8:35 PM	PRIMARY	A	1	580A	ND		
	10:06 PM	PRIMARY	A	1	580A	ND		
2/28	12:00 AM	PRIMARY	A	1	580A	ND		
	1:57 AM	PRIMARY	A	1	580A	ND		
	4:55 AM	PRIMARY	A	1	580A	ND		
	8:45 AM	PRIMARY	A	1	580A	ND		
	9:30 AM	PRIMARY	A	1	LAB	**		PC-C1-1
	12:15 PM	PRIMARY	A	3	580A	ND		
	12:15 PM	PRIMARY	A	3	GC/PID	ND●	OUTLET1	
	12:15 PM	PRIMARY	A	1	580A	ND		
	12:15 PM	PRIMARY	A	1	GC/PID	ND●	PC-C1-1/2	
	1:10 PM	PRIMARY	A	1	580A	ND		
	6:00 PM	PRIMARY	A	1	580A	ND		
	7:58 PM	PRIMARY	A	1	580A	ND		
	10:00 PM	PRIMARY	A	1	580A	ND		
	11:00 PM	PRIMARY	A	1	580A	ND		
3/1	8:00 AM	PRIMARY	A	1	580A	62 ppm		
	8:30 AM	PRIMARY	A	3	LAB	**		PC-C3-1
	9:30 AM	PRIMARY	A	3	GC/PID	ND●	OUTLET2	
	10:00 AM	PRIMARY	A	1	580A	62 ppm		
	10:00 AM	PRIMARY	A	1	GC/PID	3701 ppm	PC-C1-3/4	
	11:00 AM	PRIMARY	A	3	580A	ND		
	11:00 AM	PRIMARY	A	1	580A	61 ppm		
	1:05 PM	PRIMARY	A	3	580A	ND		
	1:05 PM	PRIMARY	A	1	580A	86 ppm		
	3:30 PM	PRIMARY	A	3	580A	ND		
	3:30 PM	PRIMARY	A	1	580A	86ppm		
	5:00 PM	PRIMARY	A	3	580A	ND		
	5:00 PM	PRIMARY	A	1	580A	86ppm		
	6:05 PM	PRIMARY	A	3	GC/PID	ND●	OUTLET4/5	
	6:30 PM	PRIMARY	A	3	GC/PID	ND●	OUTLET6	
3/2	9:30 AM	PRIMARY	A	3	GC/PID	ND●	OUTLET7/8	
	9:30 AM	PRIMARY	A	2	580A	ND		
	9:30 AM	PRIMARY	A	1	580A	170 ppm		
	12:20 PM	PRIMARY	A	3	580A	ND		
	12:20 PM	PRIMARY	A	2	580A	ND		
	12:20 PM	PRIMARY	A	1	580A	186 ppm		

	2:00 PM	PRIMARY	A	3	580A	ND		
	2:00 PM	PRIMARY	A	2	580A	ND		
	2:00 PM	PRIMARY	A	1	580A	274 ppm		
	4:10 PM	PRIMARY	A	3	580A	ND		
	4:10 PM	PRIMARY	A	2	580A	ND		
	4:10 PM	PRIMARY	A	1	580A	302 ppm		
3/3	8:00 AM	PRIMARY	A	3	GC/PID	ND●	OUTLETS	
	8:00 AM	PRIMARY	A	3	580A	ND		
	8:45 AM	PRIMARY	A	2	580A	111 ppm		
	8:45 AM	PRIMARY	A	1	580A	460 ppm		
	11:40 AM	PRIMARY	B	4	580A	ND		
	1:30 PM	PRIMARY	B	4	580A	ND		
	3:45 PM	PRIMARY	B	4	580A	ND		
3/4	7:30 AM	PRIMARY	B	4	580A	ND		
	7:30 AM	PRIMARY	B	4	GC/PID		CAN4-1	
	10:00 AM	PRIMARY	B	4	580A	ND		
	12:00 PM	PRIMARY	B	4	580A	ND		
	2:00 PM	PRIMARY	B	4	580A	ND		
3/5	7:45 AM	PRIMARY	B	4	580A	101 ppm		
	8:10 AM	PRIMARY	B	5	580A	ND		
	9:10 AM	PRIMARY	B	5	GC/PID	ND●	CAN6-1	
	11:40 AM	PRIMARY	B	5	580A	ND		
	1:30 AM	PRIMARY	B	5	580A	ND		
	3:40 AM	PRIMARY	B	5	580A	ND		
3/6	7:30 AM	PRIMARY	B	5	580A	ND		
	7:30 AM	PRIMARY	B	5	GC/PID	ND●	CAN6-2	
	8:00 AM	PRIMARY	B	5	LAB	**		PC-C5-1
	1:00 PM	PRIMARY	B	5	580A	ND		
	3:50 PM	PRIMARY	B	5	580A	ND		
	6:10 PM	PRIMARY	B	5	580A	ND		
3/7	8:34 AM	PRIMARY	B	5	580A	ND		
	8:34 AM	PRIMARY	B	5	GC/PID	ND●	CAN6-3	
	12:30 PM	PRIMARY	B	5	580A	7 ppm		
	3:00 PM	PRIMARY	B	6	580A	ND		
	5:00 PM	PRIMARY	B	6	580A	ND		
3/8	8:30 AM	PRIMARY	C	3	580A	ND		
	8:30 AM	PRIMARY	C	3	GC/PID	ND●	CAN38-1	
	11:35 AM	PRIMARY	C	3	580A	ND		
	2:35 PM	PRIMARY	C	3	580A	ND		
	5:00 PM	PRIMARY	C	3	580A	ND		
3/9	8:40 AM	PRIMARY	C	3	580A	7.5 ppm		
	8:40 AM	PRIMARY	C	3	GC/PID	ND●	CAN3828	
	10:50 AM	PRIMARY	C	7	GC/PID	ND●	PC-C7-1	
	11:40 AM	PRIMARY	C	7	580A	ND		
	5:10 PM	SECONDARY	C	7	580A	ND		
3/10	12:40 PM	SECONDARY	C	7	580A	ND		
	3:00 PM	SECONDARY	D	6	GC/PID	ND●	PC-C6-1	

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	3:00 PM	SECONDARY	D	6	580A	ND		
	5:05 PM	SECONDARY	D	6	580A	ND		
	7:00 PM	SECONDARY	D	7	580A	ND		
3/11	7:47 AM	SECONDARY	D	7	580A	ND		
	7:47 AM	SECONDARY	D	7	GC/PID	ND@	PC-C7-2	
	10:10 AM	SECONDARY	D	7	580A	ND		
	12:13 PM	SECONDARY	D	7	580A	ND		
	2:40 PM	SECONDARY	D	7	580A	ND		
3/12	8:05 AM	SECONDARY	D	7	GC/PID	ND@	PC-C7-3	
	8:05 AM	SECONDARY	D	7	580A	ND		
	8:25 AM	SECONDARY	D	6	GC/PID	ND@	PC-C6-2	
	12:20 PM	SECONDARY	D	7	580A	ND		
	1:50 PM	SECONDARY	D	7	580A	ND		
	3:30 PM	SECONDARY	D	7	580A	ND		
	5:30 PM	SECONDARY	D	7	580A	ND		
3/13	8:00 AM	SECONDARY	D	7	580A	ND		
	8:00 AM	SECONDARY	D	6	LAB	**		PC-C6-1
	8:00 AM	SECONDARY	D	7	GC/PID	ND@	PC-C7-4	
	8:15 AM	SECONDARY	D	6	580A	ND		
	8:15 AM	SECONDARY	D	6	GC/PID	ND@	PC-C6-3	

@ Peaks on chromatograms are results of residual contamination from previous run(s)

** Laboratory results indicate all parameters at concentrations less-than 0.1 uL/L (ppm)

Shaded areas within Table indicate initial detection of breakthrough

TABLE 3-12

WELLHEAD VAPOR DISCHARGE LABORATORY ANALYSES

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

ALL RESULTS EXPRESSED IN ul/L (PPM V/V)

Parameter	VW-S-1	VW-S-Lab2	VW-S-Lab3	VW-S-Lab4	VW-S-Lab5	VW-D-Lab1
Total VOCs	1327.33	782.72	1875.15	2724.75	1482.75	1195.55
1 Vinyl Chloride	393.00	119.00	42.60	56.10	<0.10	<0.10
2 Cis-1,2-DCE	140.00	51.90	272.00	373.00	72.20	125.00
3 Trans-1,2-DCE	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
4 Trichloroethylene	452.00	457.00	1180.00	1480.00	1240.00	892.00
5 Acetone	-----	-----	-----	-----	-----	-----
6 1,1,1-TCA	161.00	120.00	246.00	364.00	71.50	107.00
7 Tetrachlorethylene	7.54	1.29	1.67	<0.10	1.69	1.99
8 Benzene	3.11	<0.10	<0.10	<0.10	<0.10	<0.10
9 Toluene	5.52	<0.10	4.83	5.08	4.01	<0.10
10 Ethylbenzene	19.30	6.45	14.60	14.10	10.80	3.32
11 Xylene (s)	23.90	8.06	16.10	14.90	12.50	3.32
12 Cumene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
13 Chloroform	86.30	13.20	70.60	362.00	37.50	55.80
14 Carbon Tetrachloride	4.24	<0.10	<0.10	<0.10	9.65	<0.10
15 Chlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
16 Bromobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
17 Bromoform	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
18 Methylene Chloride	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
19 1,2-Dichloroethane	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
20 1,2-Dichloropropane	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
21 1,3-Dichloropropane	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
22 Ethylene Dibromide	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
23 Acrylonitrile	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
24 Vinylidene Chloride	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
25 Allyl Chloride	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
26 N-Heptane	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
27 I-Heptane	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
28 1,1-dichloroethylene	13.60	4.29	21.70	40.80	22.90	7.12
29 1,1-dichloroethane	4.72	<0.10	0.51	7.38	<0.10	NA
30 Trichloro-flouromethane	13.10	1.53	4.54	7.39	<0.10	NA

Chain-of-Custody Reference:
VW-S-1 ---> Form #001
VW-S-Lab2 ---> Form #001
VW-S-Lab3 ---> Form #002
VW-S-Lab4 ---> Form #003
VW-S-Lab5 ---> Form #004

@ Samples collected in Teflon Gas Sampling Bags and transported by courier to MDS Laboratories in Reading, PA. for analysis by EPA Methods TO1/TO2.

NA Not analyzed

393 ppm v/v on the first day of testing to below detection limits (i.e., <0.10 ppm v/v) on the eighth day of testing.

Similar results were observed in the wellhead discharge vapor sample from the secondary test which was collected on the final day of the secondary test and analyzed in the laboratory by EPA Method T01/T02. The sample contained total VOCs at a concentration of 1,196 ppm v/v. TCE was the most prominent constituent at a concentration of 892 ppm v/v. Cis-DCE, TCA, and chloroform were the other prominent target VOCs at concentrations of 125 ppm v/v, 107 ppm v/v, and 56 ppm v/v, respectively. Vinyl chloride was not detected in the VW-D wellhead discharge sample.

Laboratory analytical reports and chain of custody documentation are included in Appendix D. A discussion regarding the comparison between laboratory analytical results and field GC/PID analytical results is presented in Section 4.1.2.b.3.

3.2.5 Laboratory Analyses of Carbon Cannister Discharge

A total of three carbon cannister vapor discharge samples from the primary test and one sample from the secondary test were collected for laboratory analysis. Samples for laboratory analysis were collected in accordance with SOP Vapor 2, using Teflon bags which were sent to MDS Labs, Inc., in Reading, PA for analysis by EPA Method TO1/TO2 within 48 hours of collection. No VOCs were detected above the laboratory detectable limit of 0.1 ppm v/v in any of the samples. The results of these analyses are summarized in Table 3-11 and are included in Appendix D.

3.2.6 Pump Water Laboratory Analysis

The original work plan called for the analysis of water samples collected from the air/water separator. Since no significant amount of water was observed in the air/water separator over the duration of both tests, water samples were collected for analysis from the reservoir tank of the liquid ring pump. Pump/water samples were collected on Day 2 of the primary test and at the conclusion of the Secondary Test. Samples were collected using 40 mL VOA vials and transported to MDS Labs for analysis by EPA Methods 601/602. Elevated concentrations of VOCs were detected in both samples. Total VOCs were detected at concentrations of 8,455 ug/L and 19,715 ug/L in the two samples. TCE, cis-DCE, and TCA were the most prominent constituents in each sample. Copies of laboratory results and chain of custody documentation are included in Appendix D.

3.2.7 Quality Assurance/Quality Control

The QA/QC procedures specified in *VAPEX's* QA/QC Plan were implemented in all stages over the duration of the treatability study at the site.

The hand held 580A and GC/PID response fluctuated over the period of the test as determined by analysis of QA/QC standards. Implementation of the QA/QC procedures insured that the performance of the analytical equipment and data analysis was maintained within the specified confidence limits. A detailed discussion of the fluctuation in performance of the analytical equipment and the QA/QC procedures that were applied to all data is provided in Appendix D. All hand held 580A and GC/PID data presented in this report has been adjusted to reflect the changes in hand held 580A and/or GC/PID response and is reported in validated form.

3.3 Modelling Results

3.3.1 Physical Modeling

VAPEX utilized its 2-D, radially symmetric air flow model to evaluate the air flow characteristics of the individual soil units existing in the vadose zone at the Heleva site. Three distinguishable soil units were identified at the test location; a soft, sandy silt unit extending to a depth of approximately 20 feet, a discontinuous five foot thick sand unit at a depth of between 20 and 25 feet, and a stiff silt unit extending from a depth of 25 feet to below the water table level (approximately 50 feet), see Figure 2-2. Due to the discontinuous nature of the intermediate lens, and due to the recorded perched water throughout the site at this level, the pilot test system was implemented and the site was modeled as a two layer system with an intermediate boundary or lens.. The data from the VP-1 monitoring probe cluster was not used in the physical modeling, Section 4.1.1.a explains this decision in more detail.

a. Upper Unit Soft Silt

a.1 Relative Intrinsic Permeability Values

The steady state air flow and vacuum data (an arithmetic average of the data collected during the last three days of the pilot study in the upper soil unit) from the high flow (13 cfm) portion of the primary test using VW-S was used as input to the air flow model. The relative horizontal intrinsic permeability (K_r) for the vadose zone soils of this unit was calculated to be 2.29×10^{-8} cm^2. The relative intrinsic vertical permeability of the upper unit and the surface boundary condition were both calculated to be 1.0×10^{-8} cm^2.

a.2 Flow Rate Versus Vacuum and Radius of Influence

The calibrated air flow model was used in the simulation mode to predict the effective radius of influence and the vacuum levels that would be observed at the vacuum well under a variety of system conditions. Simulations were run at the low flow condition performed as part of the Primary Test for model verification, and over a larger range of achievable air flow rates. Figures 3-3 and 3-4 present the model calibration and verification curves for the upper silt unit. Figure 3-5 presents the predicted vacuum levels and radii of influence that would be observed at the wellhead over the range of achievable air flow rates.

b. Intermediate Unit

b.1 Relative Intrinsic Permeability Values

The steady state air flow and vacuum data from both the primary test of VW-S and the secondary test of VW-D were used as input to the air flow model. The relative intrinsic vertical permeability of the intermediate unit was calculated to be 4.5×10^{-8} cm^2.

c. Lower Unit Stiff Silt

c.1 Relative Intrinsic Permeability Values

The steady state air flow and vacuum data (an arithmetic average) from the high

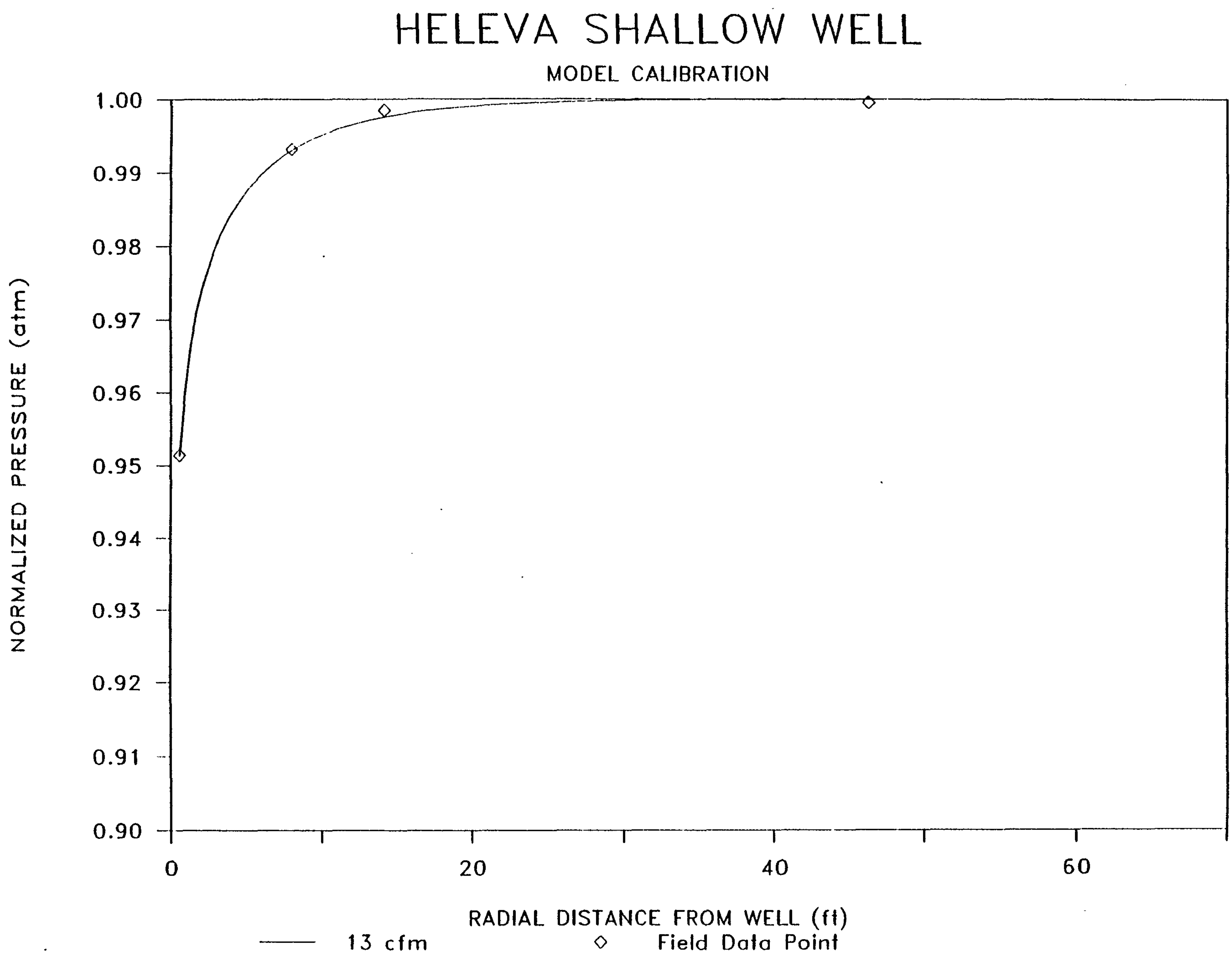
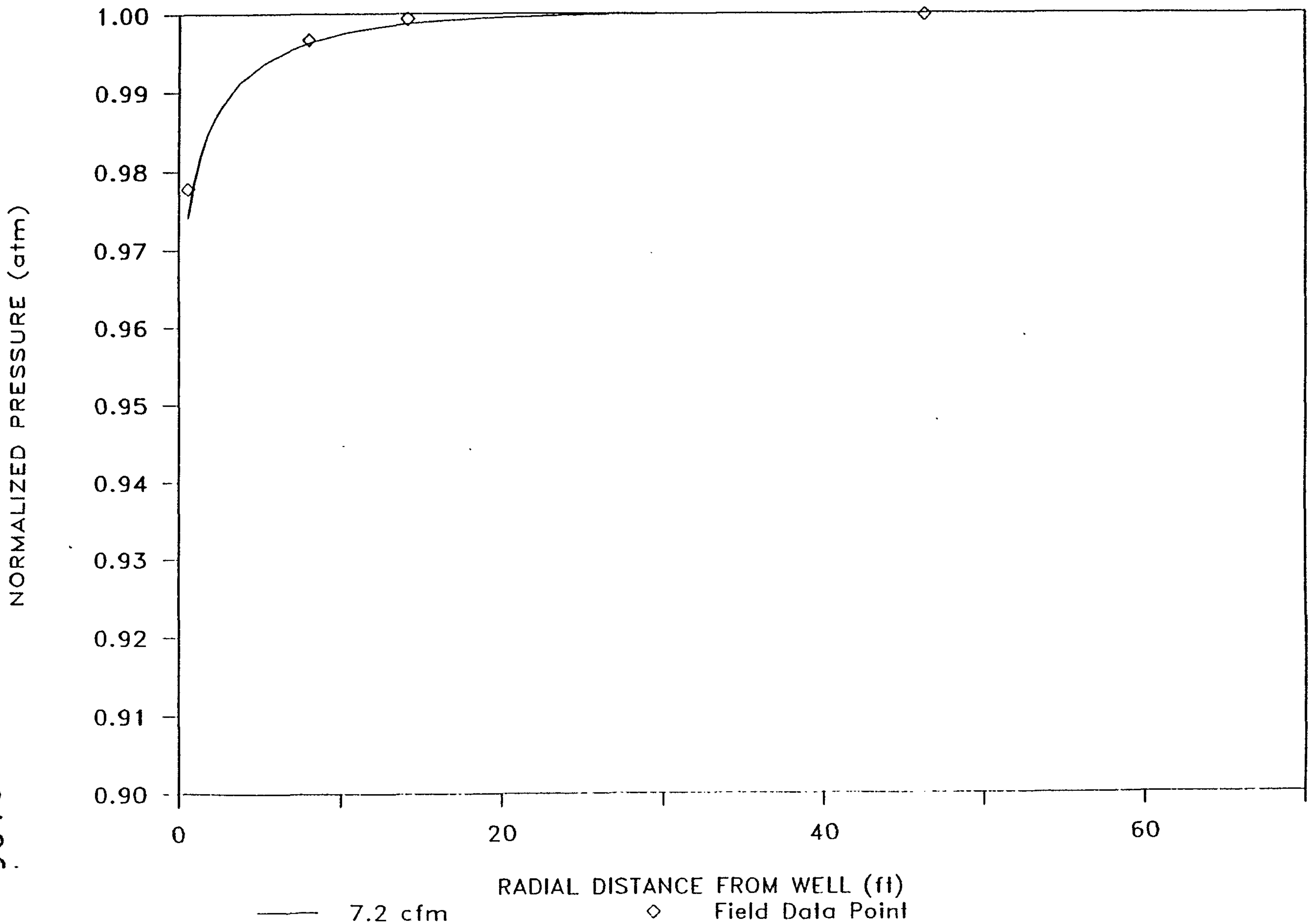

HELEVA SHALLOW WELL
MODEL CALIBRATION
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.90
NORMALIZED PRESSURE (atm)
0
20
40
60
RADIAL DISTANCE FROM WELL (ft)
13 cfm
Field Data Point

FIGURE 3-3

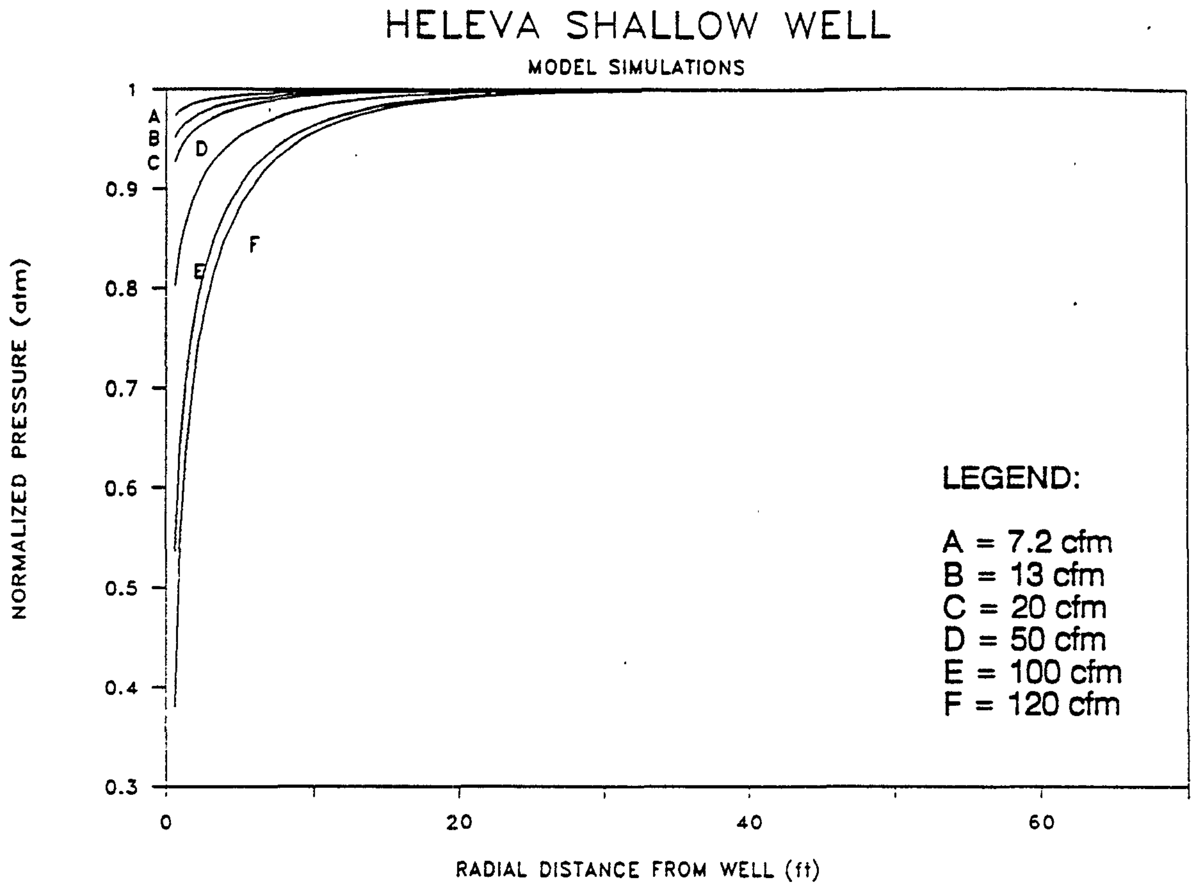
HELEVA SHALLOW WELL

MODEL VERIFICATION



FIGUR -4

AR303196


HELEVA SHALLOW WELL
MODEL SIMULATIONS
NORMALIZED PRESSURE (atm)
RADIAL DISTANCE FROM WELL (ft)
LEGEND:
A = 7.2 cfm
B = 13 cfm
C = 20 cfm
D = 50 cfm
E = 100 cfm
F = 120 cfm

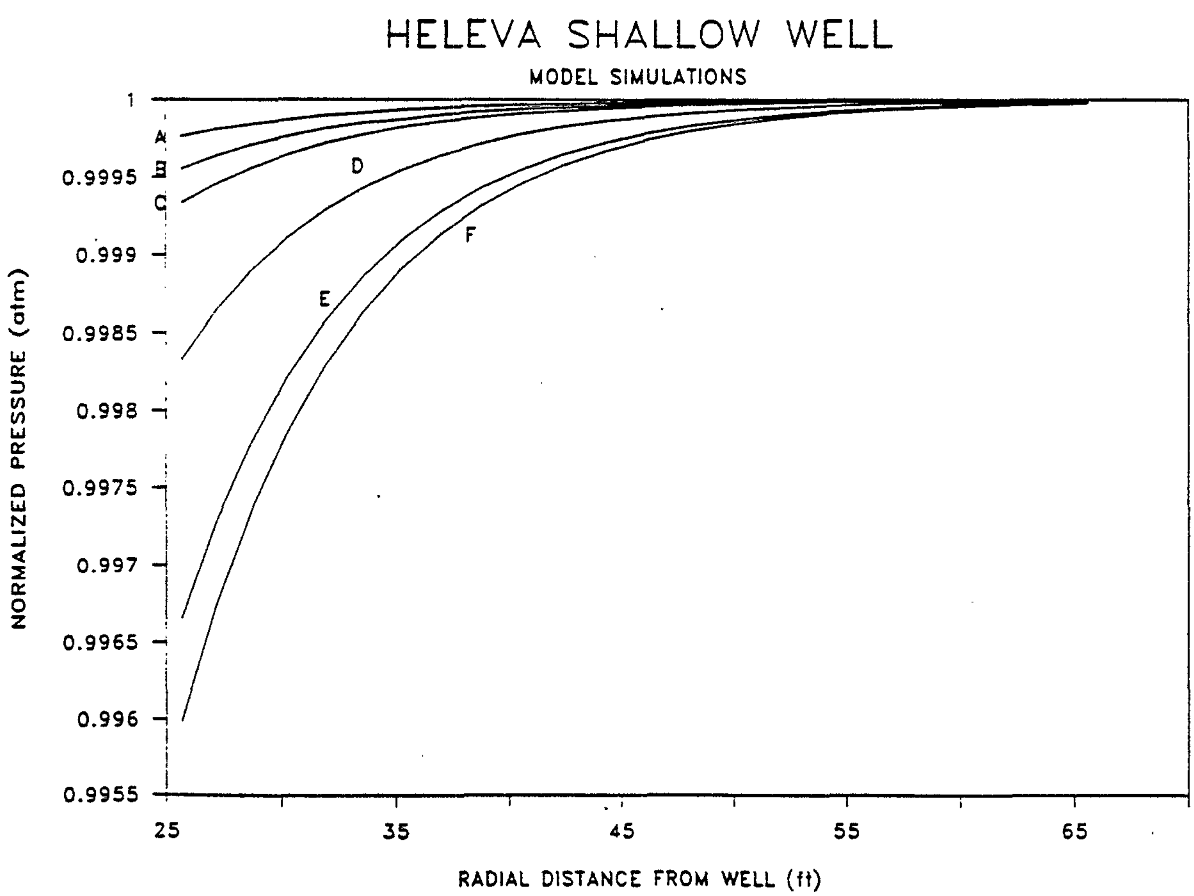

HELEVA SHALLOW WELL
MODEL SIMULATIONS
NORMALIZED PRESSURE (atm)
RADIAL DISTANCE FROM WELL (ft)

FIGURE 3-5

flow (7.2 cfm) portion of the Secondary Test using VW-D was used as input to the air flow model. The relative horizontal intrinsic permeability (K_r) for the vadose zone soils of this unit was calculated to be 3.9 x 10^{-10} cm^2. The relative intrinsic vertical permeability of the lower unit was calculated to be 1.0 x 10^{-10} cm^2.

c.2 Flow Rate Versus Vacuum and Radius of Influence

The calibrated air flow model was used in the simulation mode to predict the effective radius of influence and the vacuum levels that would be observed at the vacuum well under a variety of system conditions. Simulations were run at the low flow condition performed as part of the secondary test for model verification, and over a larger range of achievable air flow rates. Figures 3-6 and 3-7 present the model calibration and verification curves for the lower silt unit. Figure 3-8 presents the predicted vacuum levels and radii of influence that would be observed at the test well head over the range of achievable air flow rates.

3.3.2 Chemical Modeling

VAPEX utilized its semi-empirical contaminant transport model to evaluate the individual soil units existing in the vadose zone at the site with regard to contaminant removal characteristics.

a. Upper Unit Soft Silt

The contaminant discharge data as displayed in Figure 3-1 presents a curve which is atypical of a standard vapor extraction system discharge plot. This type curve is generally associated with the misalignment of the vapor extraction well with the center of mass of the contaminants within the well's zone of influence. The existence of a second peak at approximately five days into the test run represents the lag time for transport of the vapors from the center of contaminant mass to the extraction well. In predicting the removal of the contaminants from the upper zone, the initial four days of data was ignored since the data from the second peak forward will be more representative of the behavior of the full scale system and the four day period will represent an insignificant time period in the prediction of the total time to achieve the specified individual contaminant closure limits. Based on the assumptions described above, the chemical data derived from the pilot study on the upper soil unit from Day 5 forward was used to develop the semi-empirical model. In the fit of the chemical model to the pilot test data, the individual and total contaminant masses present within the zone of influence of the pilot test extraction well are theoretically derived. The derived individual contaminant masses are presented in Table 3-13 under subheading "Model" for the shallow well influence area. To provide a realistic estimate of the variation in the time to remediation of localized areas within the Heleva site, *VAPEX* also utilized maximum expected individual contaminant masses within the zone of influence of an extraction well as derived from concentration data provided by GF in the RFP. This data is presented in Table 3-13 under sub-heading "maximum" for the shallow well influence area.

The applicability of the transport model was demonstrated by the good correlation between the predicted total and individual contaminant discharge concentrations and the measured contaminant discharge concentrations over the duration of the pilot test. Figure 3-9 presents the comparison of the theoretical and measured total contaminant discharge concentrations over the test period. Figures 3-10 and 3-11 show comparisons of the theoretical and measured discharge concentrations of TCE and DCE over the test period.

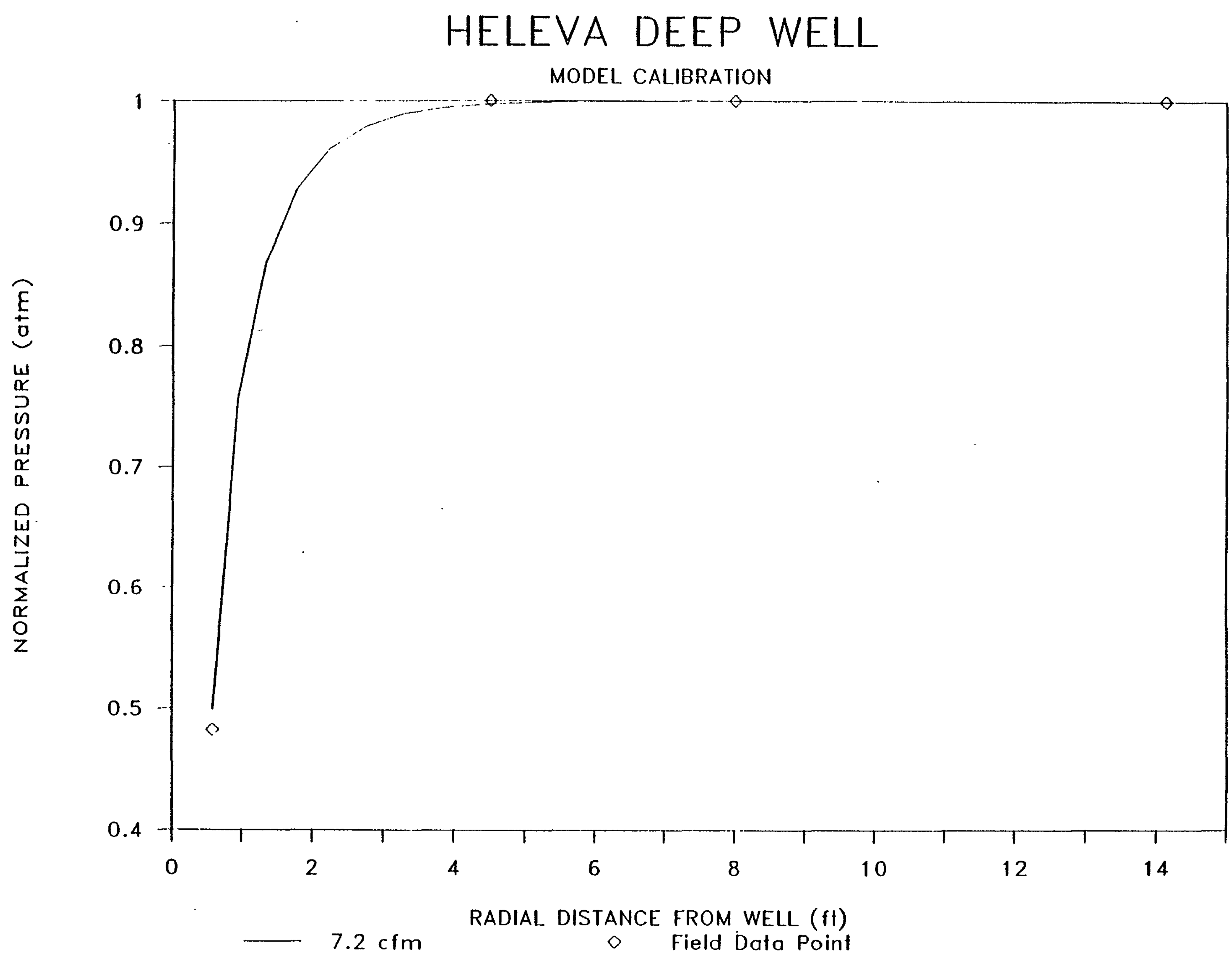

HELEVA DEEP WELL
MODEL CALIBRATION
NORMALIZED PRESSURE (atm)
1
0.9
0.8
0.7
0.6
0.5
0.4
0
2
4
6
8
10
12
14
RADIAL DISTANCE FROM WELL (ft)
7.2 cfm
Field Data Point

FIGURE 3-6

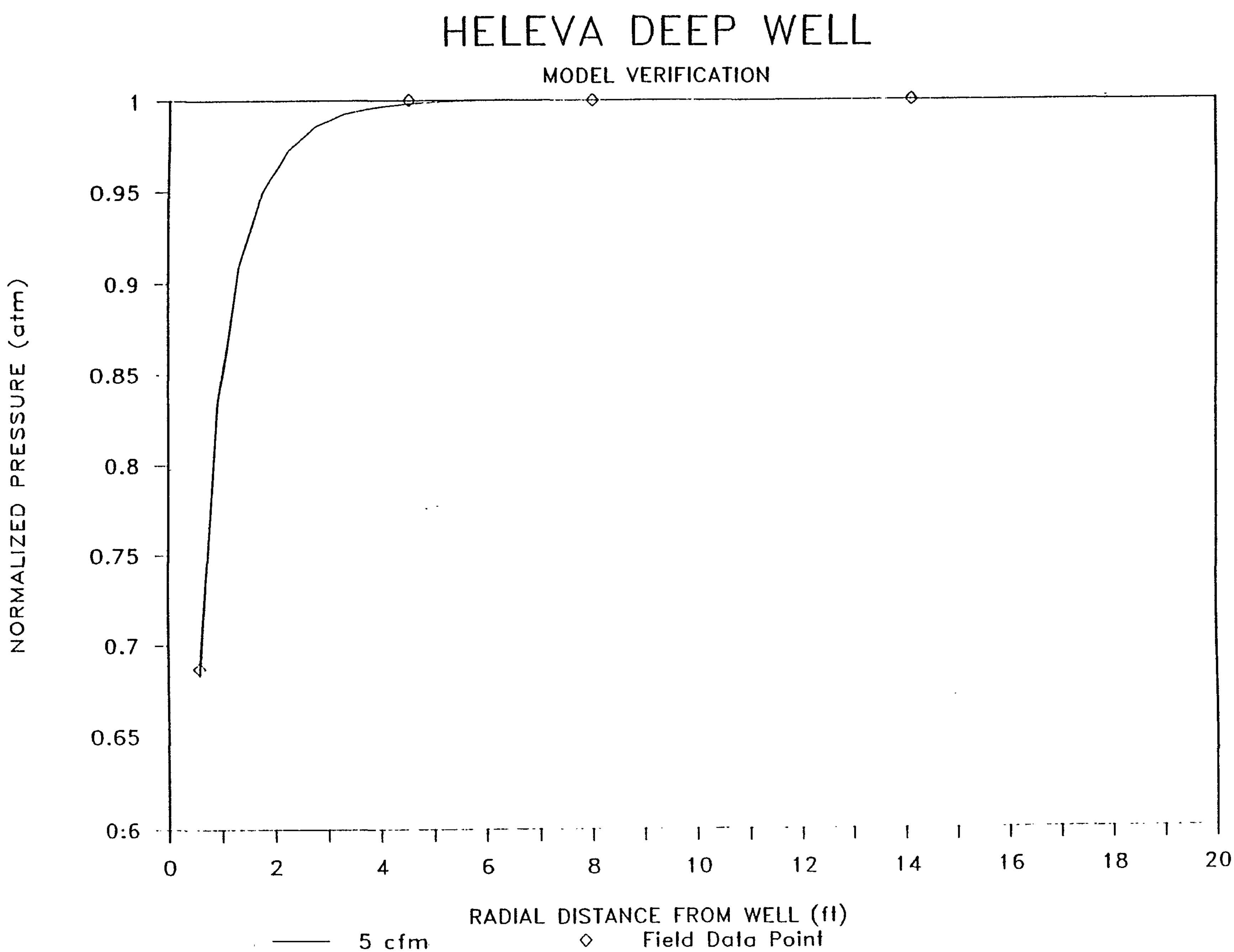
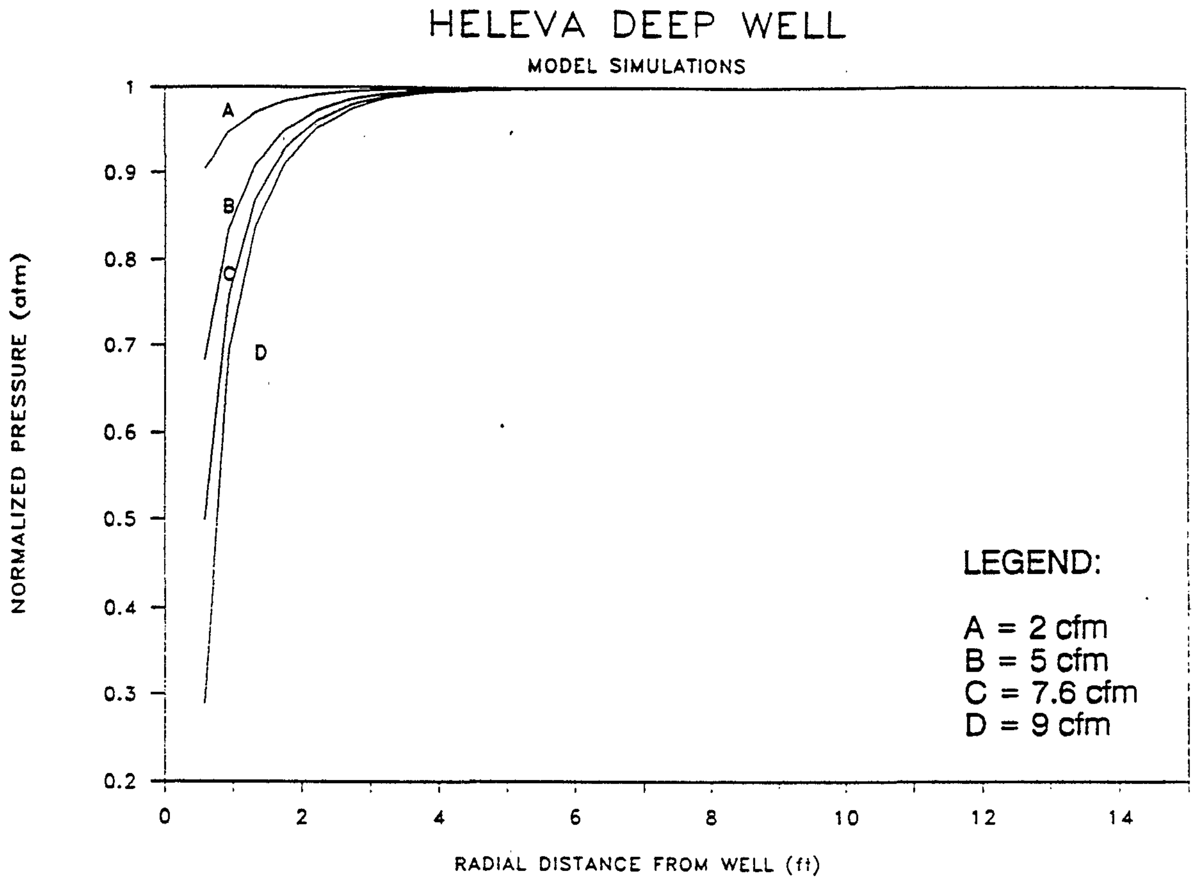

HELEVA DEEP WELL
MODEL VERIFICATION
NORMALIZED PRESSURE (atm)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0:6
0
2
4
6
8
10
12
14
16
18
20
RADIAL DISTANCE FROM WELL (ft)
5 cfm
Field Data Point

FIGURE 3-7



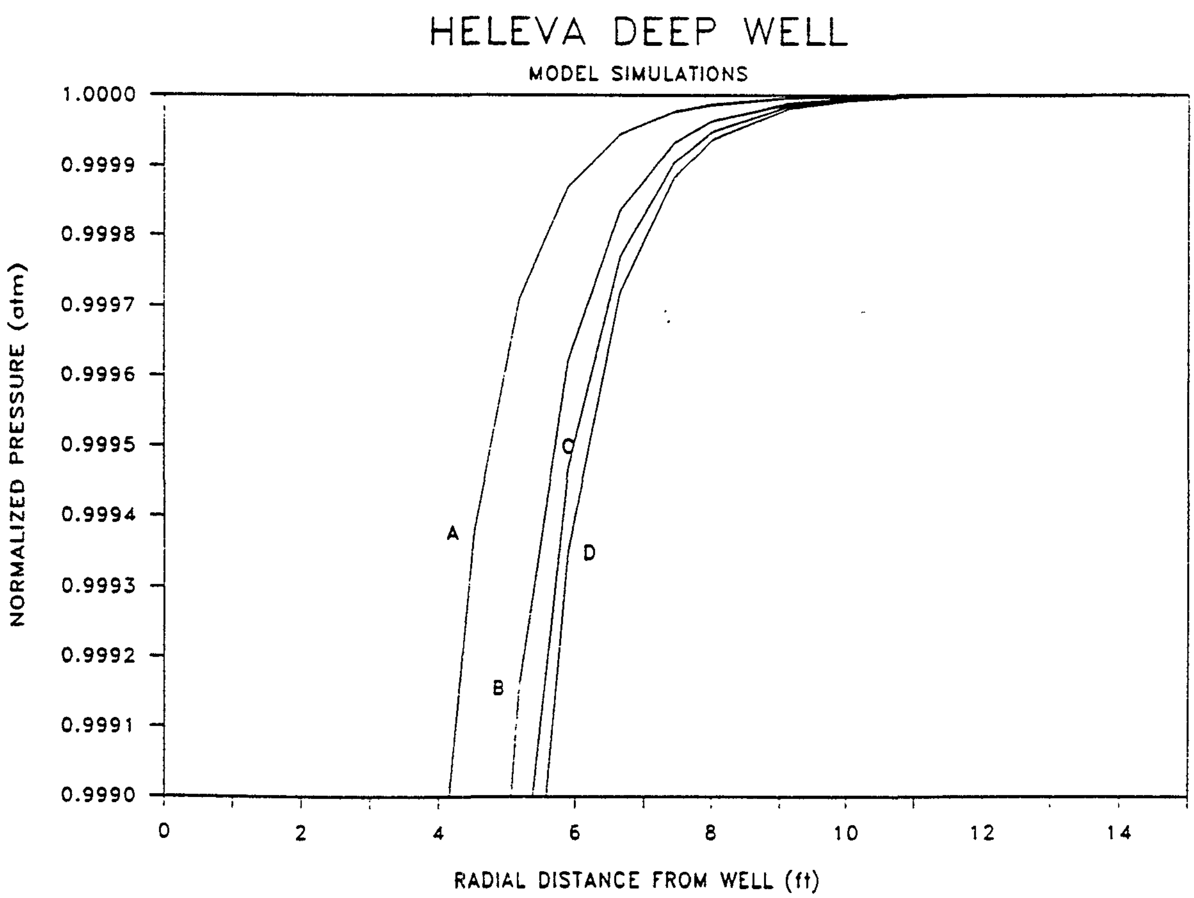


FIGURE 3-8

AR303201

TABLE 3-13

SUMMARY OF ESTIMATED COMPOUND QUANTITIES
HELEVA LANDFILL

COMPOUND	SHALLOW WELL INFLUENCE AREA			DEEP WELL INFLUENCE AREA		
	TEST	MAXIMUM	TARGET	TEST	MAXIMUM	TARGET
ACETONE	ND	NA	172	ND	NA	7
2-BUTANONE	ND	NA	177	ND	NA	8
CHLOROFORM	15	67	4	1	3	0.2
TOTAL DCE	40	632	76	3	25	3
METHYLENE CHLORIDE	0.1	253	1	ND	10	0.04
TRICHLOROETHENE	660	5958	14	71	238	0.6
TETRACHLOROETHENE	12.5	125	NCG	1	10	NCG
TOLUENE	6	60	NCG	2	20	NCG
1,1,1 TRICHLOROETHANE	33.5	335	NCG	1	10	NCG
VINYL CHLORIDE	1	10	NCG	ND	ND	NCG
ETHYL BENZENE	190	190	NCG	3	30	NCG
TOTAL XYLENES	1040	1040	NCG	18	180	NCG

All quantities were calculated using the mass of the soil within the influence zone established by each well.
The shallow well influence zone is 100 feet in diameter and 20 feet deep.
The deep well influence zone is 20 feet in diameter and 20 feet deep.
All quantities presented in units of pounds.

TOTAL DCE Combined cis and trans-1,2 Dichloroethene
TEST Quantities determined by pilot test discharge chemical model.
MAXIMUM Quantities determined by maximum concentrations identified by GF.
MAXIMUM Quantities determined are relative to chemical model values.
TARGET Allowable remaining quantity, determined by cleanup goals established by GF.
[ ] Compounds with cleanup goal criteria.
ND Not detected during pilot test.
NA Not applicable to the pilot test chemical model.
NCG No cleanup goals established for this project.

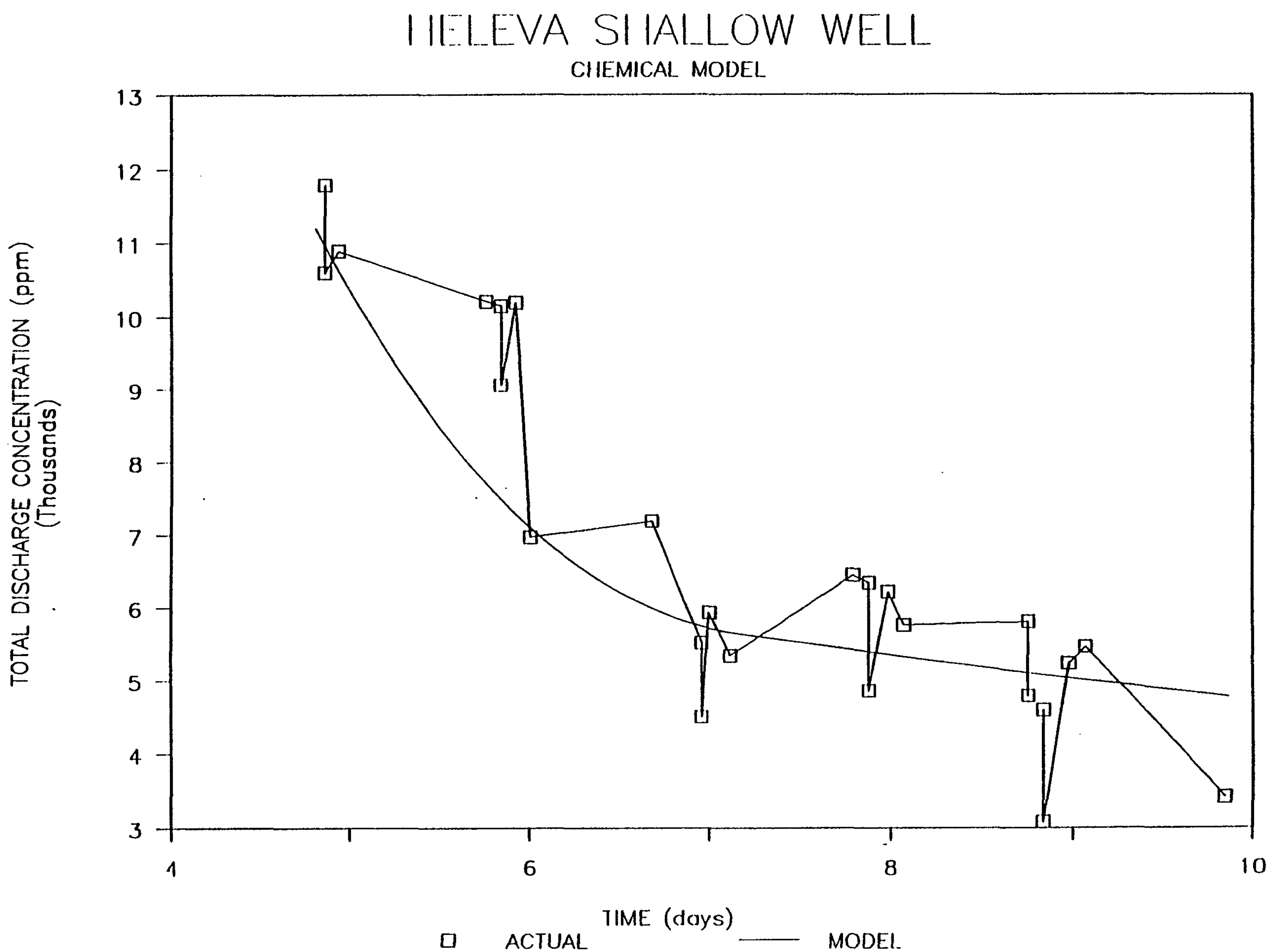

HELEVA SHALLOW WELL
CHEMICAL MODEL
TOTAL DISCHARGE CONCENTRATION (ppm)
(Thousands)
13
12
11
10
9
8
7
6
5
4
3
4
6
8
10
TIME (days)
ACTUAL
MODEL

FIGURE 3-9

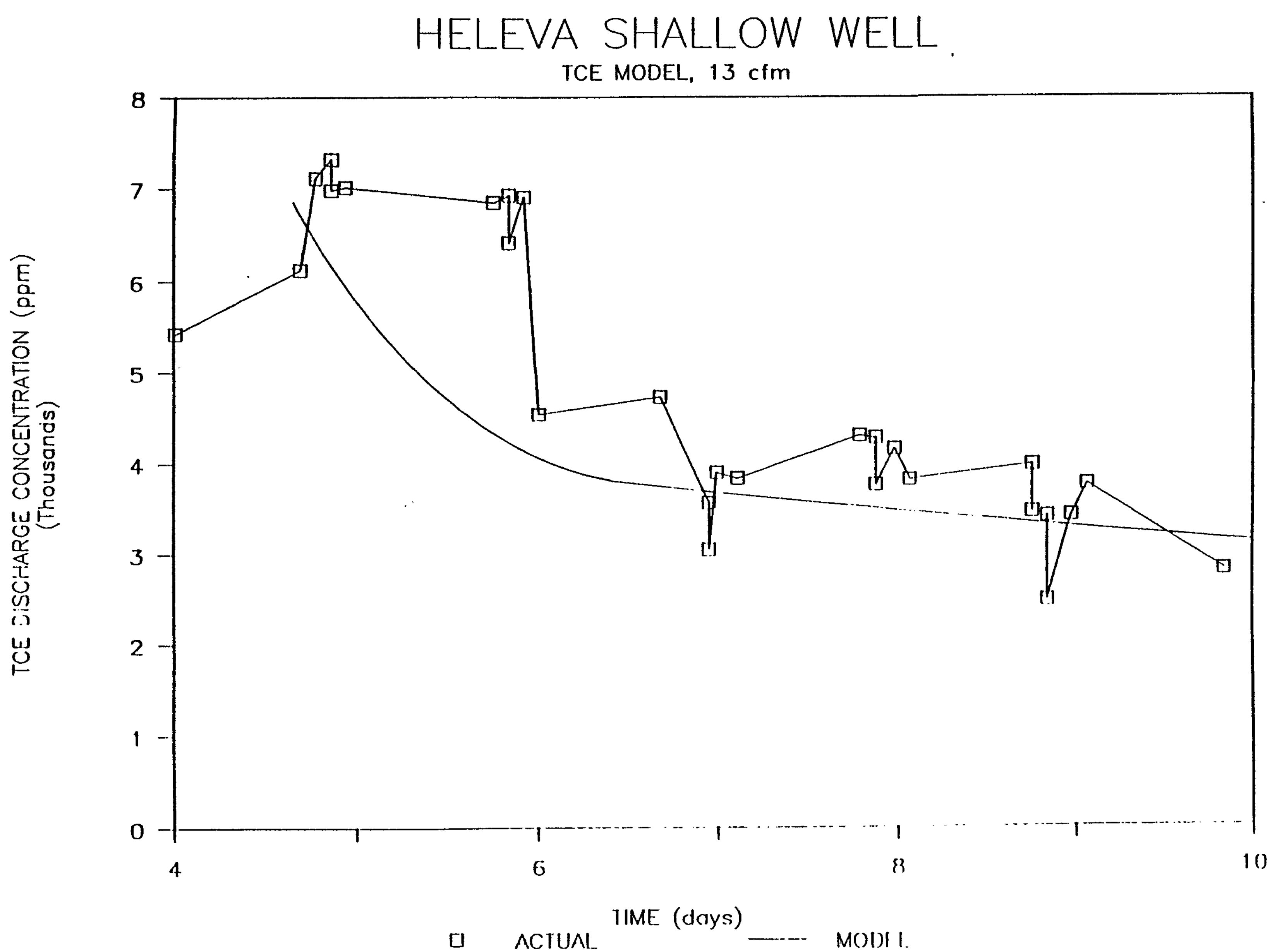

HELEVA SHALLOW WELL
TCE MODEL, 13 cfm
TCE DISCHARGE CONCENTRATION (ppm)
(Thousands)
8
7
6
5
4
3
2
1
0
4
6
8
10
TIME (days)
ACTUAL
MODEL

FIGURE 3-10

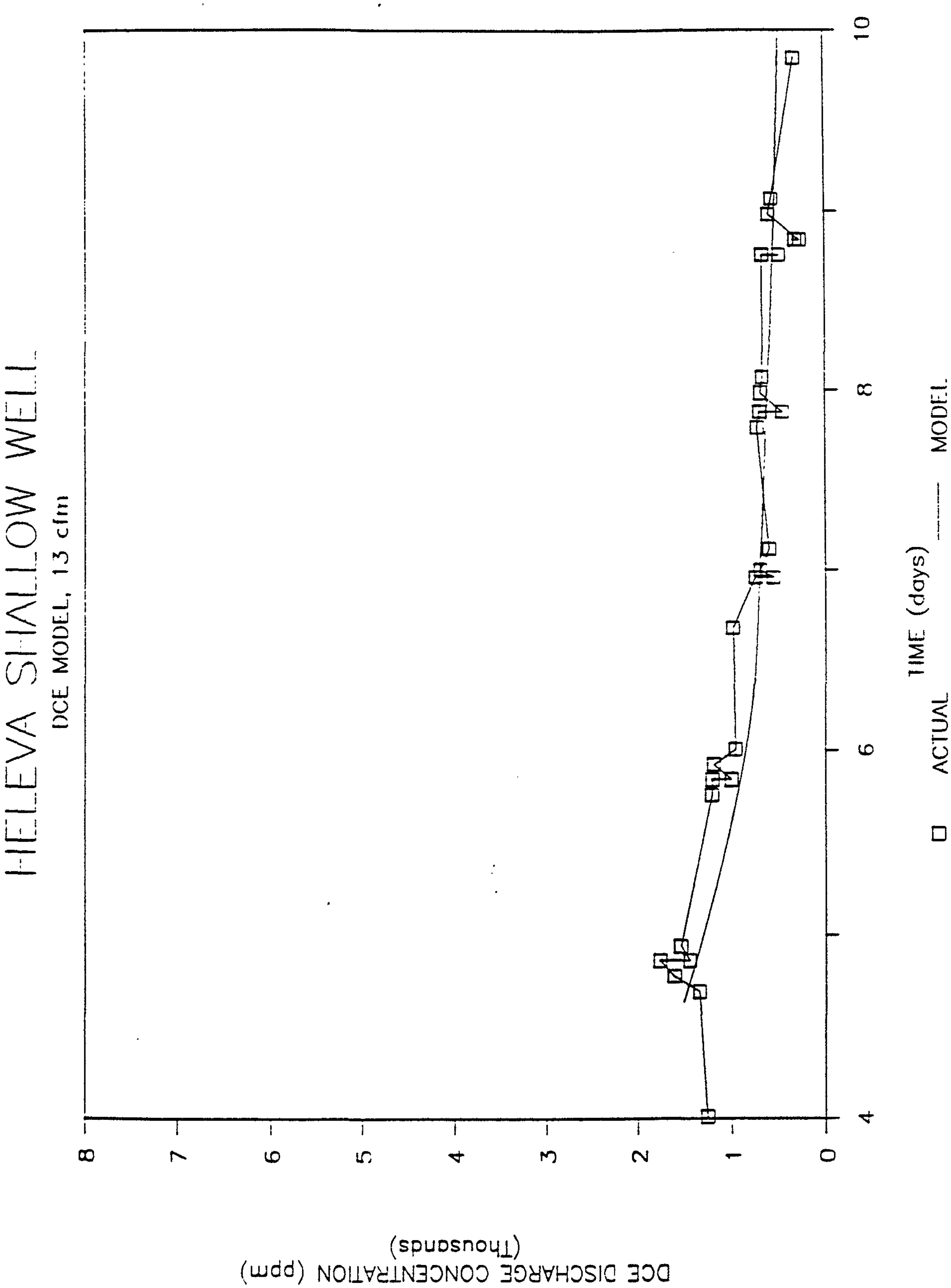

HELEVA SHALLOW WELL
DCE MODEL, 13 cfm
DCE DISCHARGE CONCENTRATION (ppm)
(Thousands)
0
1
2
3
4
5
6
7
8
4
6
8
10
TIME (days)
ACTUAL
MODEL

FIGURE 3-11

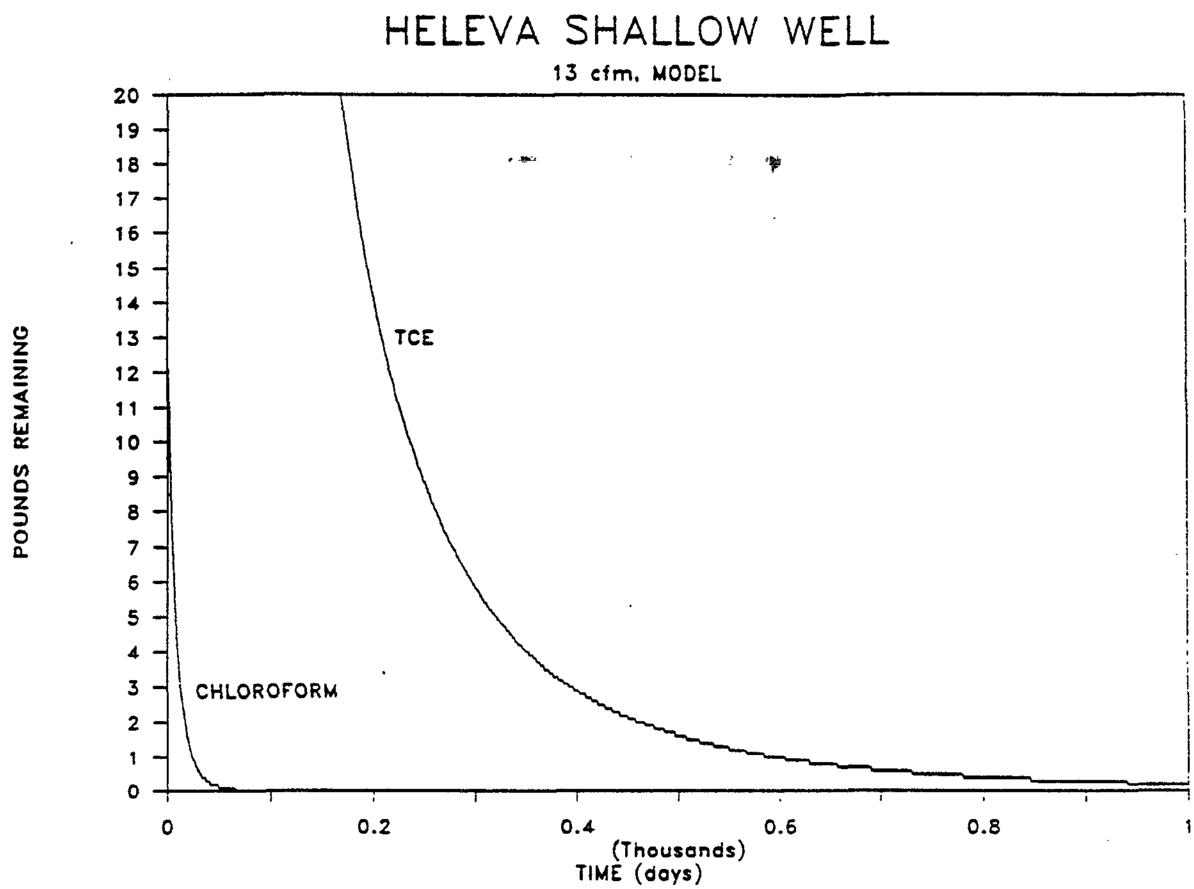
The model was utilized to extrapolate the "test" curve to estimate the time required to achieve the target contaminants specific closure limits (in accordance with the limits documented in the RFP) utilizing the initial contaminant masses as derived above and as presented in Table 3-13. Figure 3-12 presents a plot of the predicted total and individual target compound mass remaining in the soil system, (within the zone of influence of the test well) utilizing the pilot test air flow rate of 13 cfm and the mass of each contaminant as derived by the model. Figure 3-13 presents a theoretical plot of contaminant removal at a design air flow rate of 100 cfm, utilizing the initial mass of each compound as derived by the theoretical model. Figure 3-14 presents a theoretical plot of time versus contaminant removal at a design air flow rate of 100 cfm utilizing the initial mass of each compound as derived from the maximum concentration levels within the study area as specified by GF in the RFP.

b. Lower Unit Stiff Silt

The chemical data developed during the pilot test on the lower soil unit was used as input to *VAPEX's* semi-empirical chemical transport model. Within the development of the model for this location, the theoretical estimate of the initial mass of each compound present within the zone of influence of the test well as measured in the pilot system discharge was derived. This data is presented in Table 3-13 under subheading "model" for the deep well influence area. Also presented in Table 3-13 are the estimated maximum masses of the target compounds in the soil within the zone of influence of an extraction well as derived from the concentration levels specified by GF in the RFP.

The applicability of the transport model was demonstrated by the good correlation between the predicted total and individual contaminant discharge concentrations with the measured contaminant discharge concentrations, over the duration of the pilot test. Figure 3-15 presents the comparison of the theoretical and measured total contaminant discharge concentrations over the test period. Figures 3-16 and 3-17 show a comparison of the theoretical and measured discharge concentrations of TCE and DCE over the test period.

The model was utilized to extrapolate the model predicted "test" curve to estimate the time required to achieve the target contaminants specific closure limits (in accordance with the limits documented in the RFP). Figure 3-18 presents a plot of the predicted total and individual target compound mass remaining in the soil system versus time (within the zone of influence of the test well under the pilot test air flow rate of 7 cfm) utilizing the initial mass of each compound as derived by the *VAPEX* transport model. Figure 3-19 presents a theoretical plot of time versus pounds remaining within the zone of influence of an extraction well at the pilot test air flow rate (7 cfm), utilizing the initial mass of each compound derived from the maximum soil concentrations specified by GF in the RFP.


HELEVA SHALLOW WELL
13 cfm, MODEL
POUNDS REMAINING
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
TCE
CHLOROFORM
0
0.2
0.4
0.6
0.8
1
(Thousands)
TIME (days)

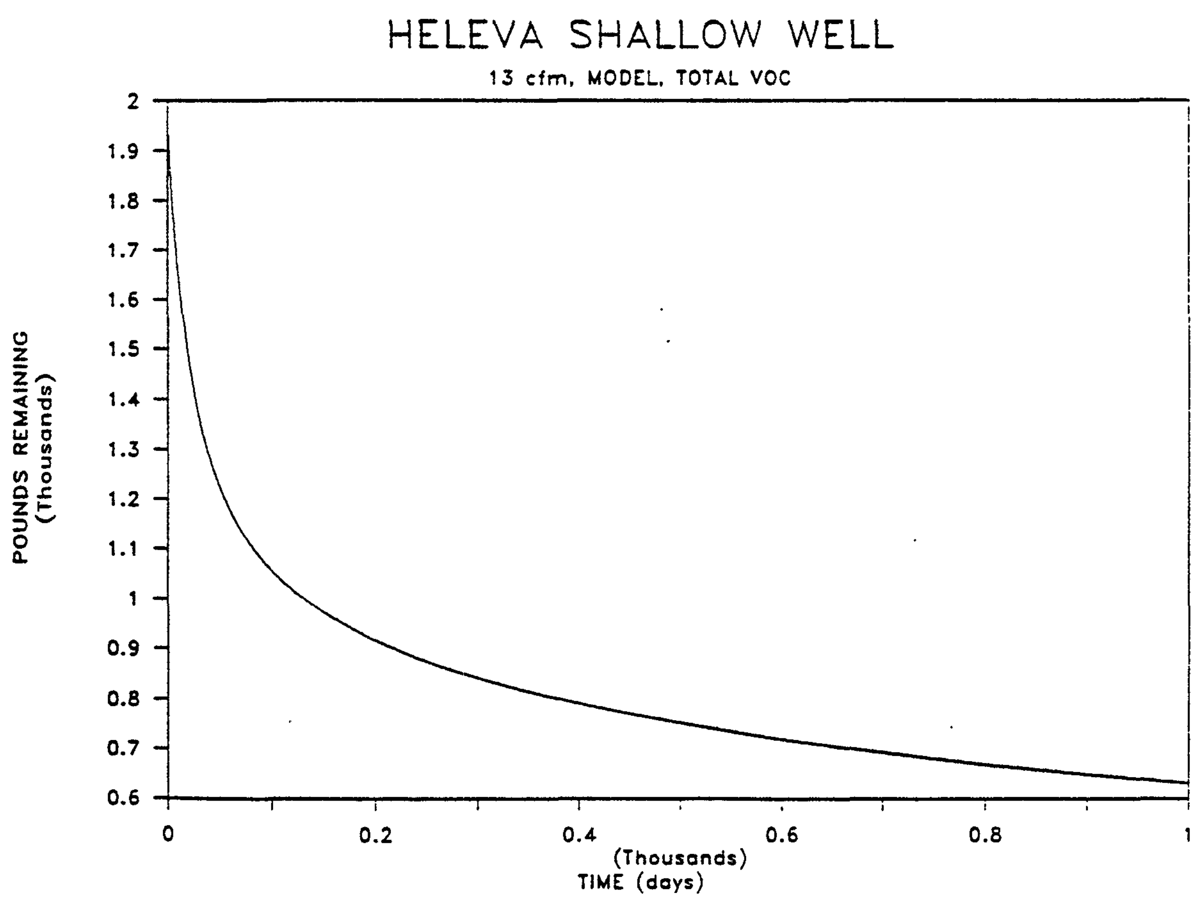
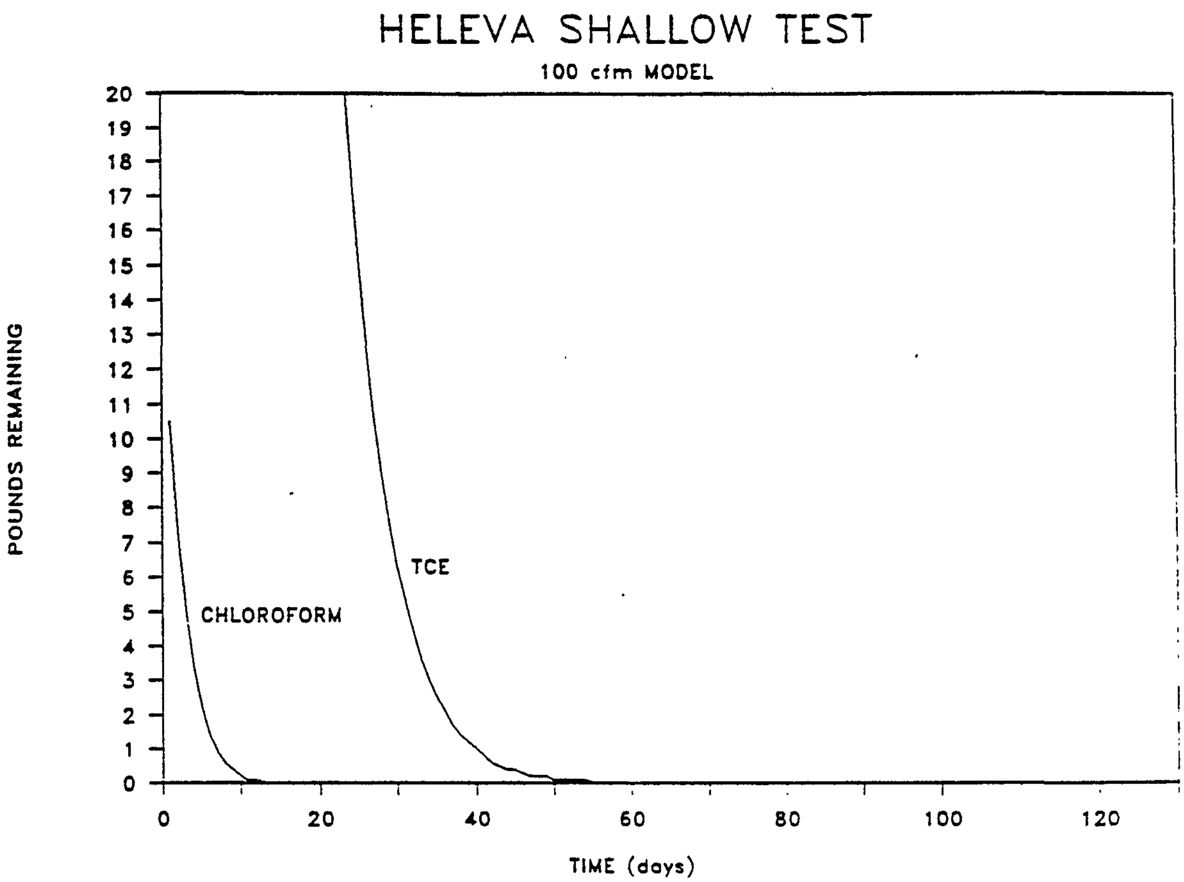
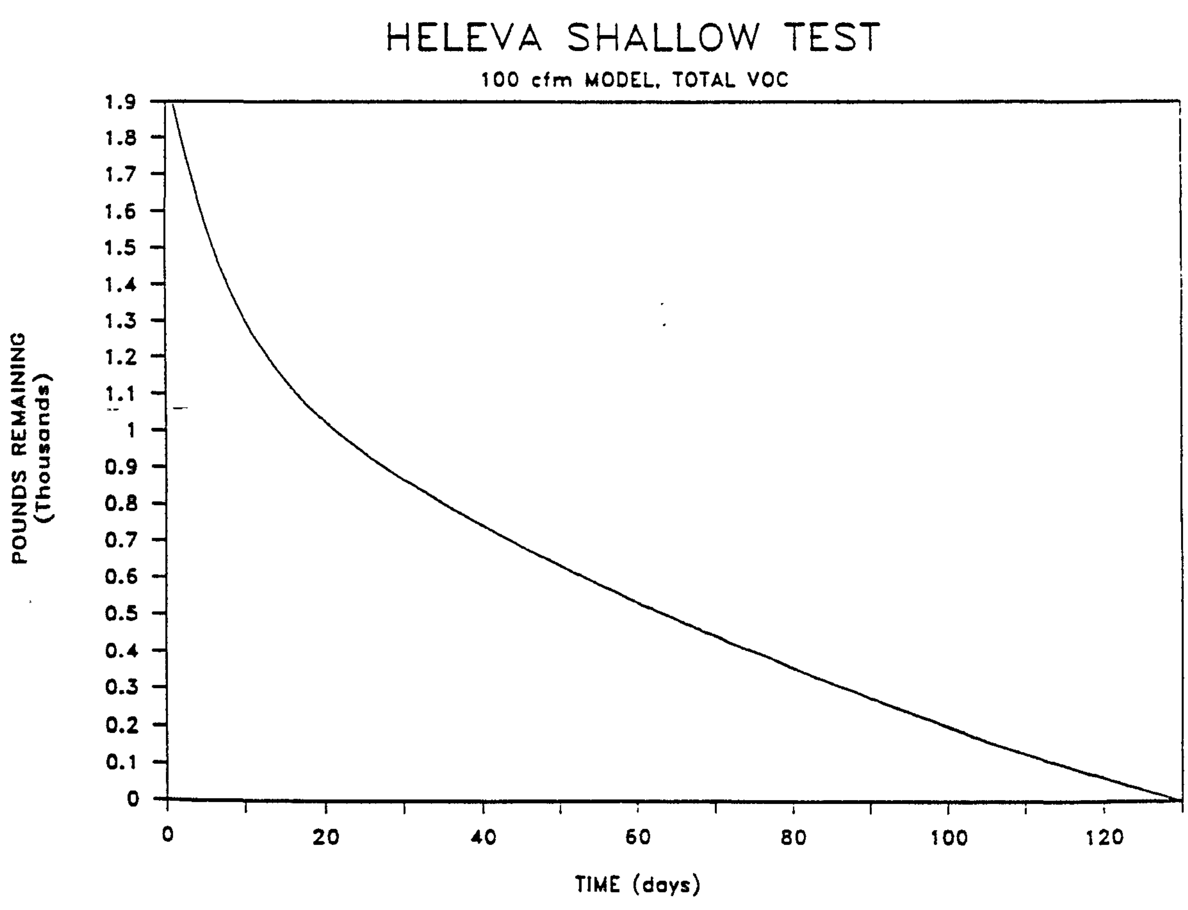

HELEVA SHALLOW WELL
13 cfm, MODEL, TOTAL VOC
POUNDS REMAINING
(Thousands)
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0
0.2
0.4
0.6
0.8
1
(Thousands)
TIME (days)

FIGURE 3-12

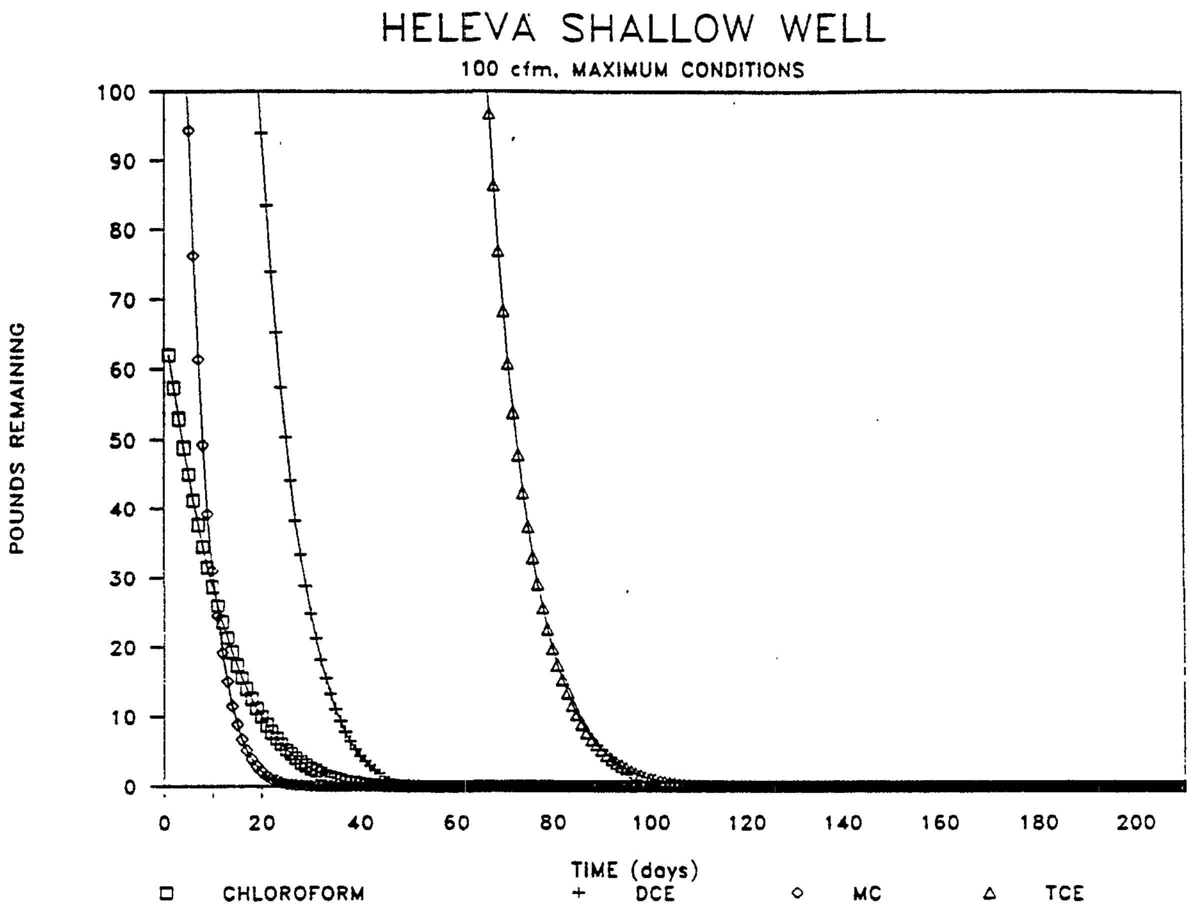


HELEVA SHALLOW TEST
100 cfm MODEL
POUNDS REMAINING
TIME (days)
CHLOROFORM
TCE
0
20
40
60
80
100
120
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20



HELEVA SHALLOW TEST
100 cfm MODEL, TOTAL VOC
POUNDS REMAINING
(Thousands)
TIME (days)
0
20
40
60
80
100
120
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9

FIGURE 3-13


HELEVA SHALLOW WELL
100 cfm, MAXIMUM CONDITIONS
POUNDS REMAINING
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180
200
TIME (days)
CHLOROFORM
DCE
MC
TCE

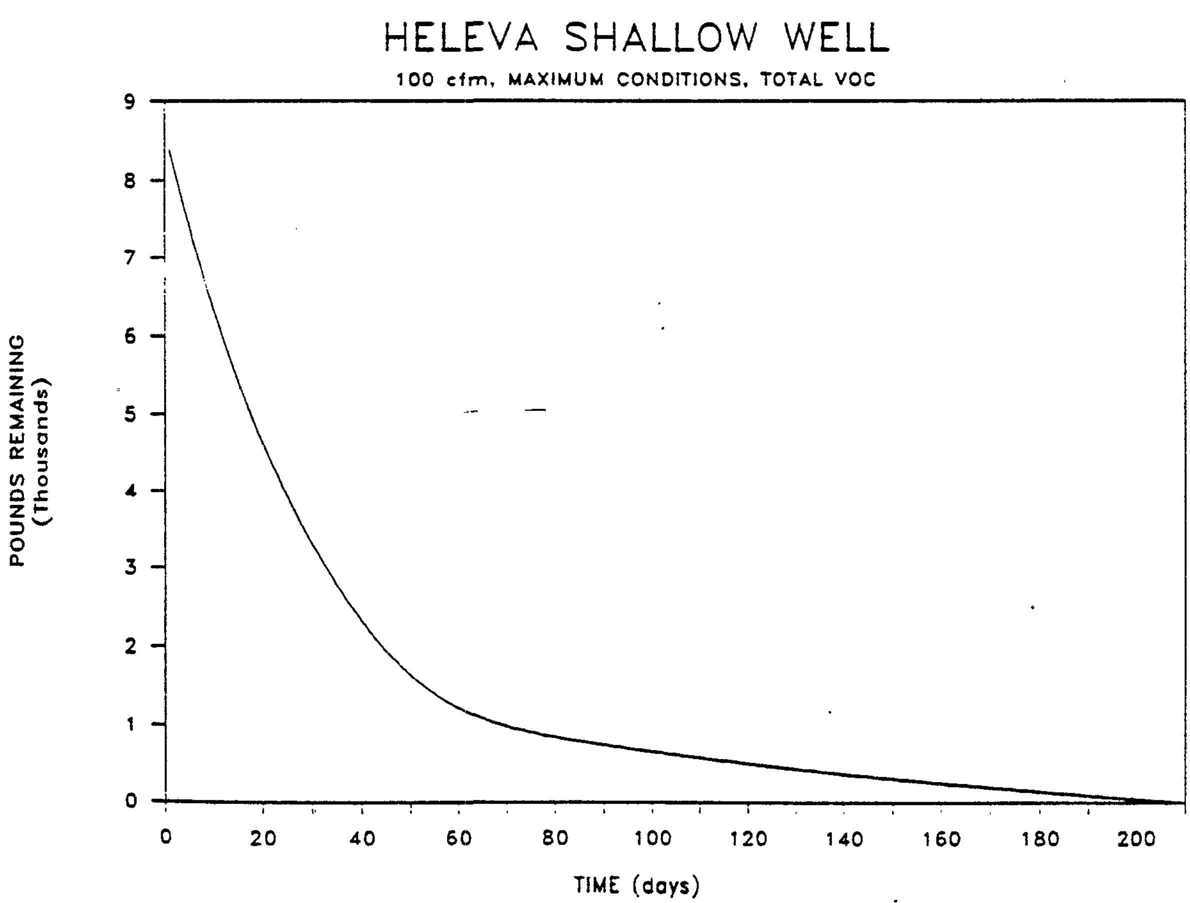

HELEVA SHALLOW WELL
100 cfm, MAXIMUM CONDITIONS, TOTAL VOC
POUNDS REMAINING
(Thousands)
9
8
7
6
5
4
3
2
1
0
0
20
40
60
80
100
120
140
160
180
200
TIME (days)

FIGURE 3-14

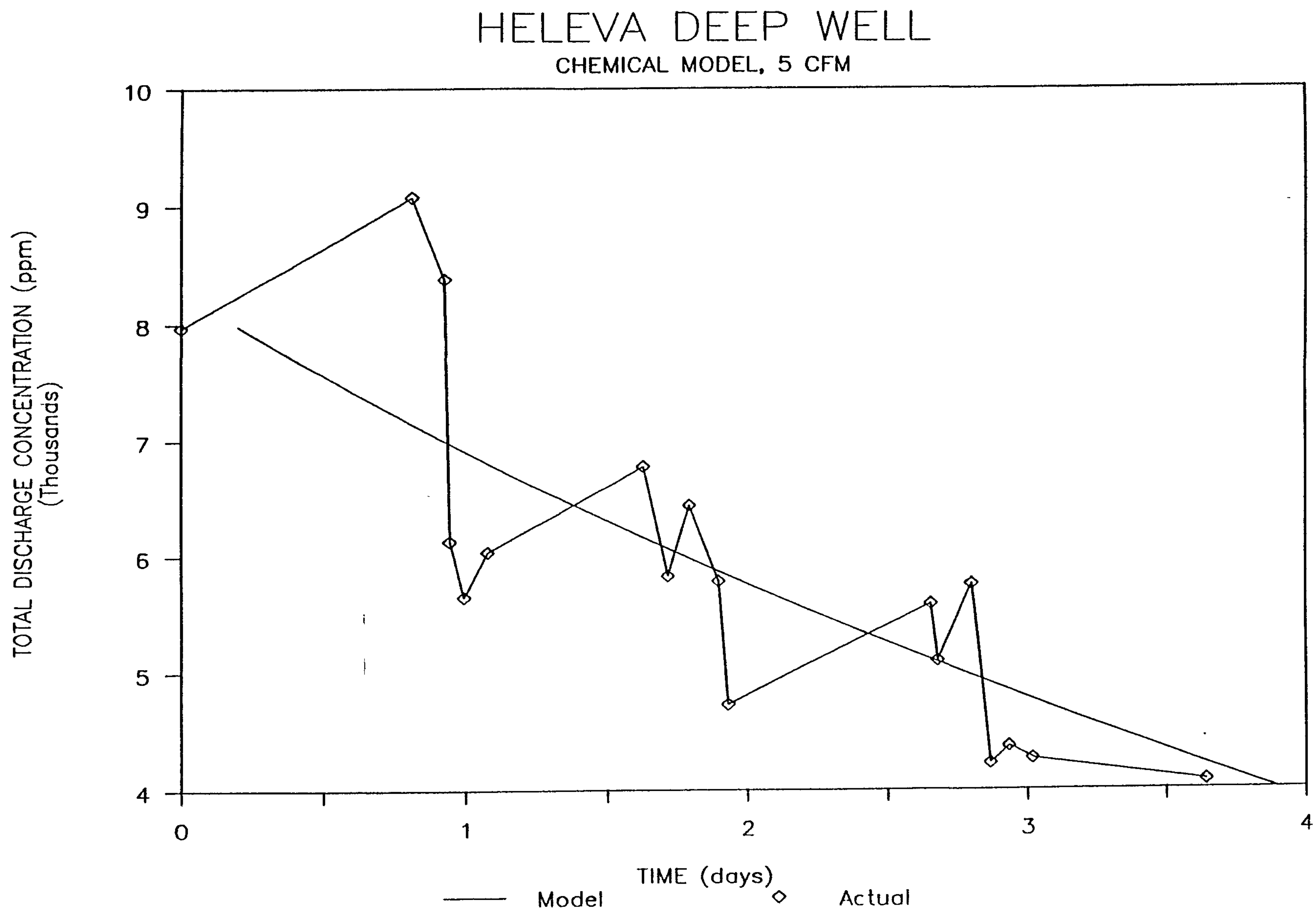

HELEVA DEEP WELL
CHEMICAL MODEL, 5 CFM
TOTAL DISCHARGE CONCENTRATION (ppm)
(Thousands)
10
9
8
7
6
5
4
0
1
2
3
4
TIME (days)
Model
Actual

FIGURE 3-15

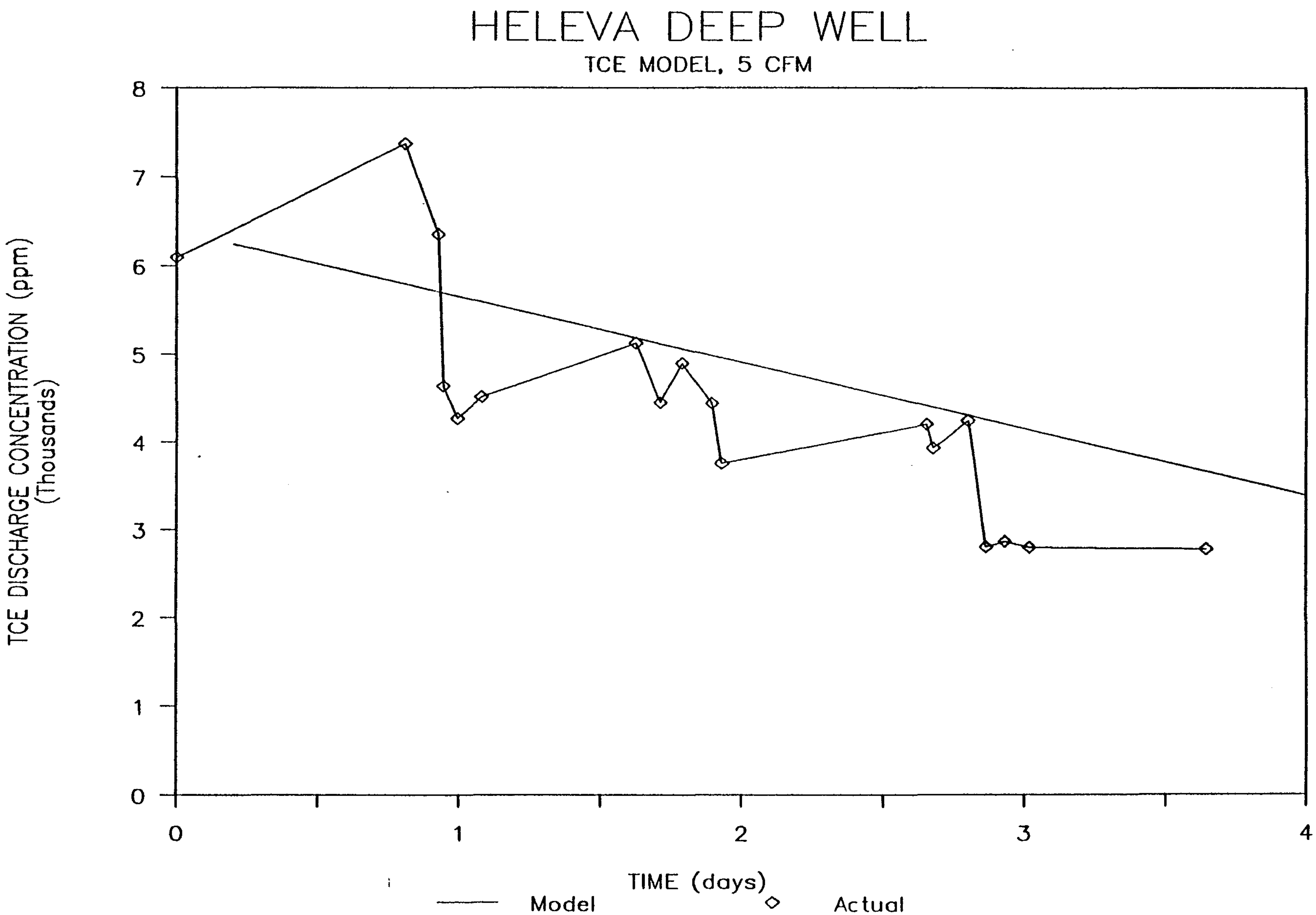

HELEVA DEEP WELL
TCE MODEL, 5 CFM
TCE DISCHARGE CONCENTRATION (ppm)
(Thousands)
8
7
6
5
4
3
2
1
0
0
1
2
3
4
TIME (days)
Model
Actual

FIGURE 3-16

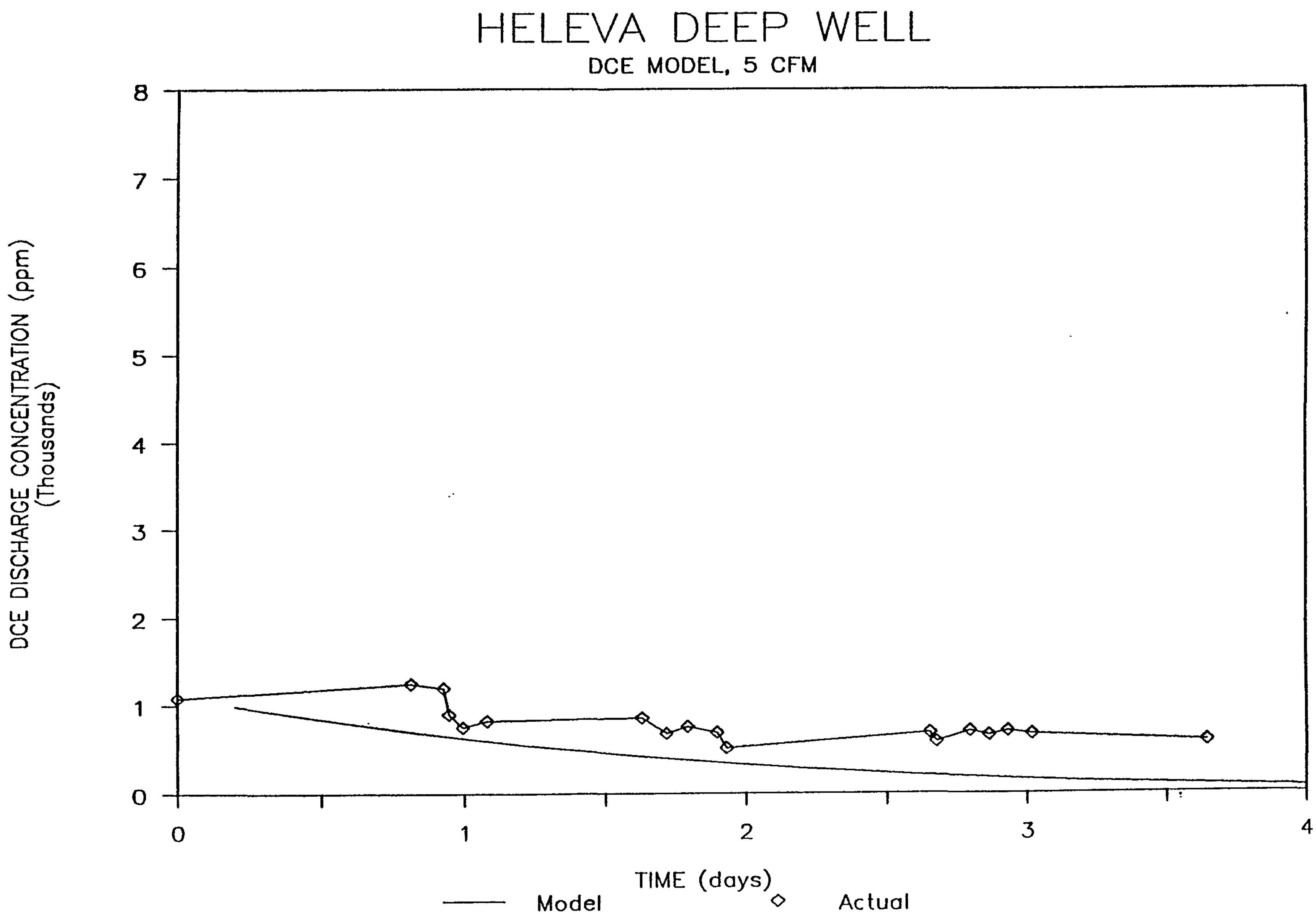
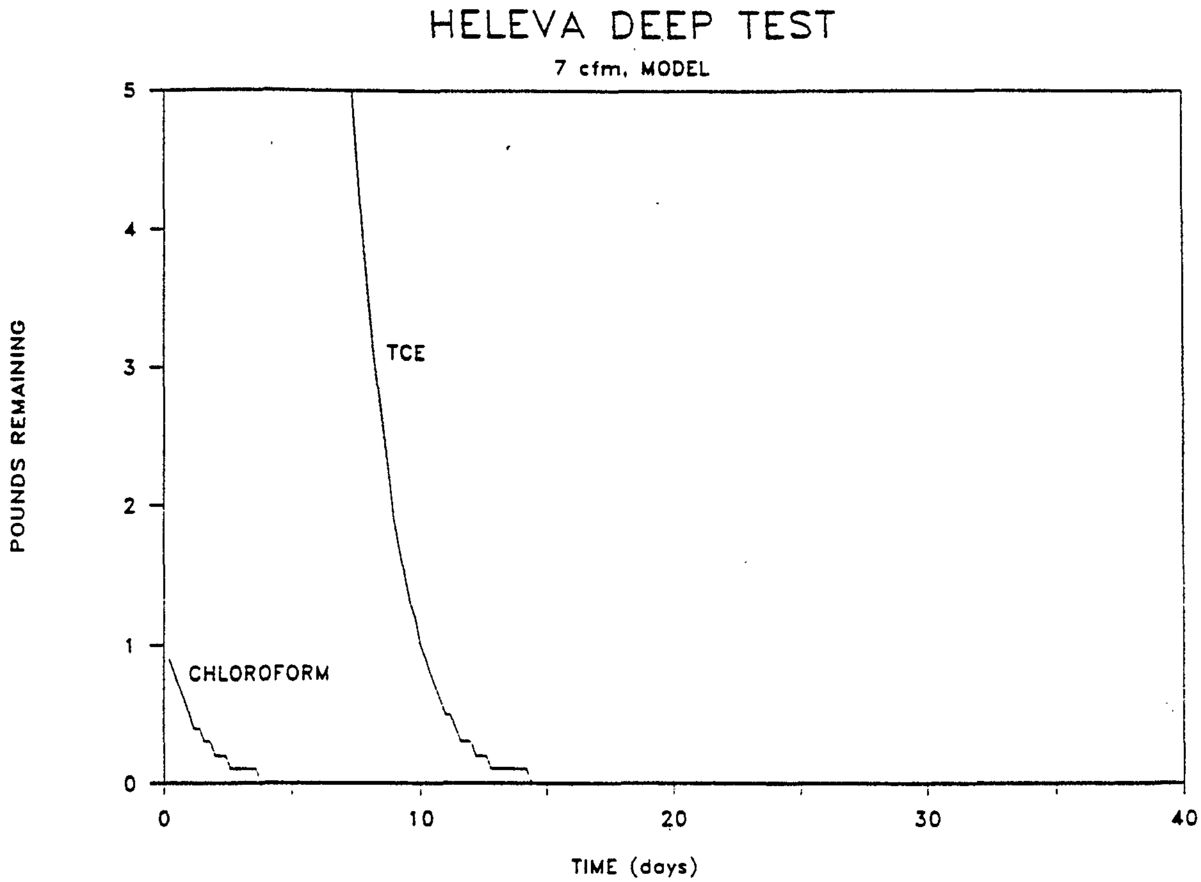

HELEVA DEEP WELL
DCE MODEL, 5 CFM
DCE DISCHARGE CONCENTRATION (ppm)
(Thousands)
0
1
2
3
4
5
6
7
8
TIME (days)
Model
Actual

FIGURE 3-17



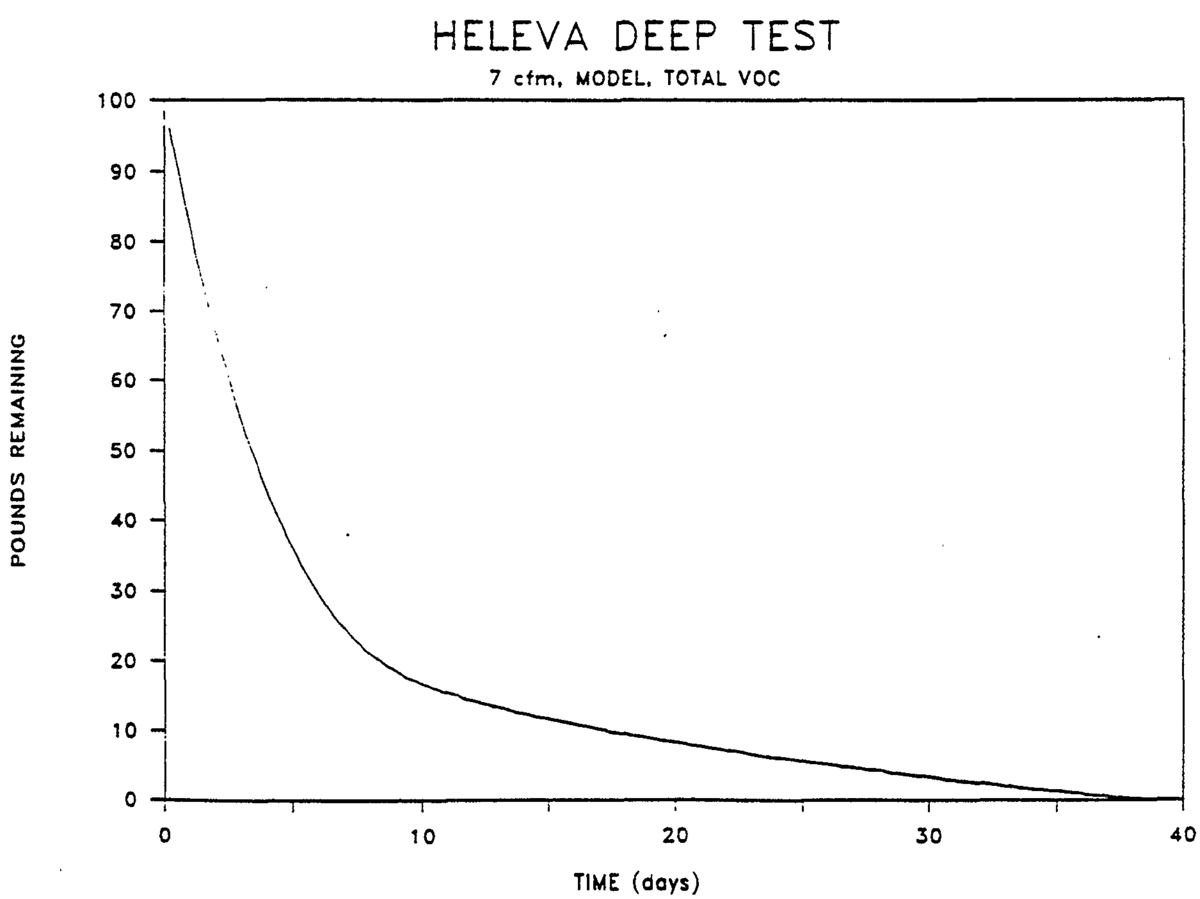
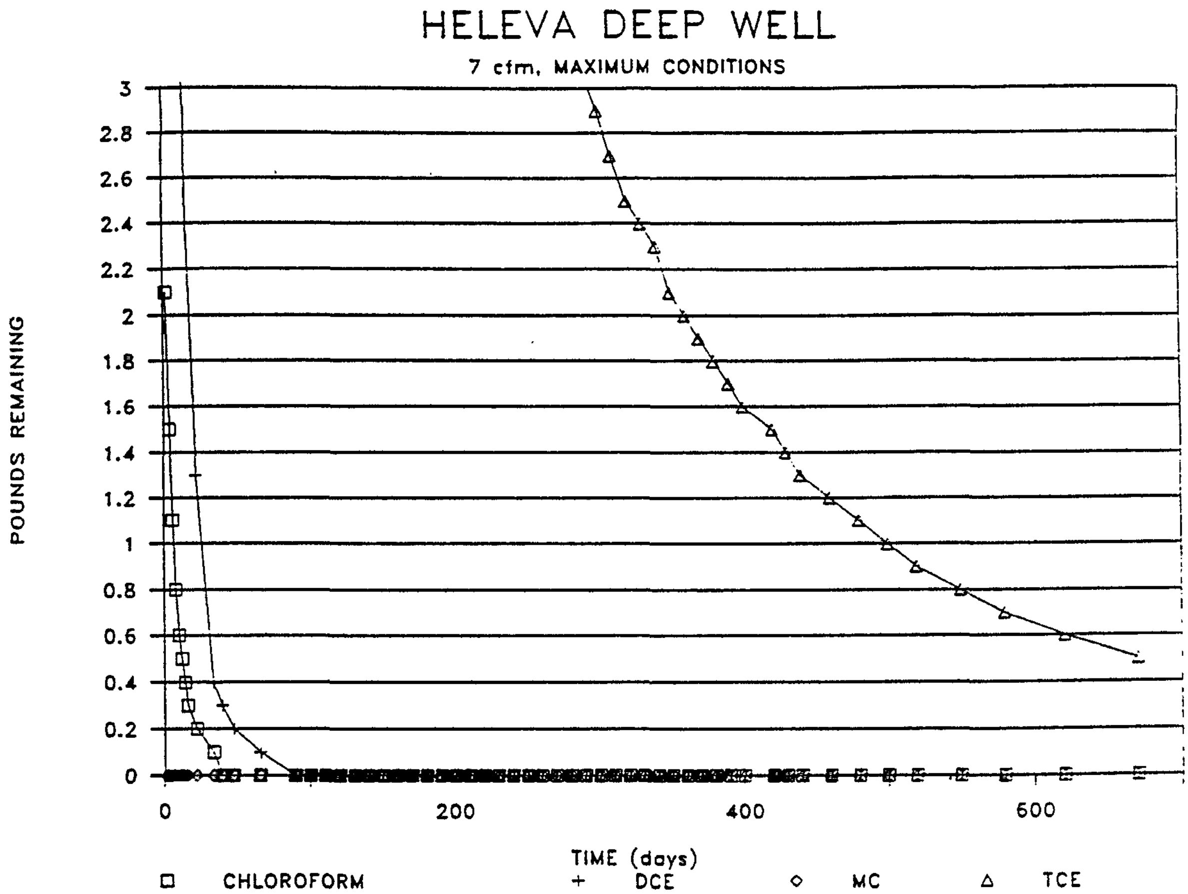


FIGURE 3-18

AR303213


HELEVA DEEP WELL
7 cfm, MAXIMUM CONDITIONS
POUNDS REMAINING
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
200
400
600
TIME (days)
CHLOROFORM
DCE
MC
TCE

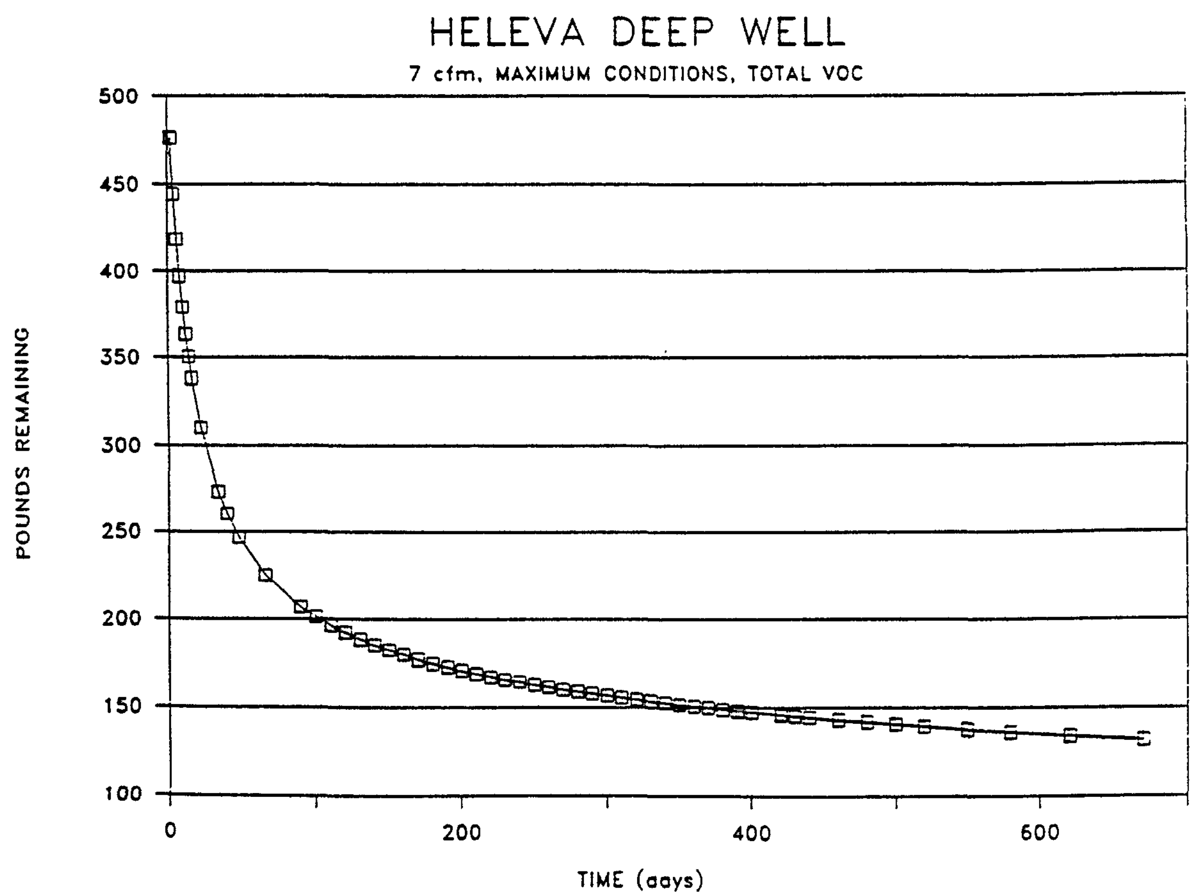

HELEVA DEEP WELL
7 cfm, MAXIMUM CONDITIONS, TOTAL VOC
POUNDS REMAINING
500
450
400
350
300
250
200
150
100
0
200
400
600
TIME (days)

FIGURE 3-19

4.0 DISCUSSION

4.1 General

4.1.1 Physical Properties

a. Performance of VP-1

The nested vapor probe system VP-1 is located approximately 5 feet from the vacuum wells (VW-S, VW-D). Over the duration of the feasibility test, vacuum was essentially non-detectable at these vapor probes. Based on the vacuum levels measured at the wellhead, the vacuum levels measured at VP-2 and the soils description from the borehole logs, *VAPEX* considers that the nested probe VP-1 was not functioning correctly. Accordingly, physical monitoring data from the VP-1
monitoring probes were not used in the evaluation of the physical properties of the soil system.

During the conduct of the test, the integrity of the connection of the Teflon lines from the main probe unit to the surface was verified. On review with *VAPEX's* field geologist, it was recorded that during the installation of VP-1, the borehole was extended approximately twenty feet beyond the water table level, through a clayey material. It is *VAPEX's* opinion that the removal of the augers from the borehole resulted in a "smearing" of the borehole walls with the wet, clayey material. As a result, VP-1 may have become isolated from the test soil unit(s) resulting in the observed vacuum level measurements.

The soil vapor contaminant concentration decrease observed at VP-1 at the conclusion of the test may also be explained, by considering the finite volume of soil gas available for evacuation, thereby resulting in a dilution of the soil gas contaminant level following each sampling event.

b. Intermediate Soil Unit

VAPEX considers that the presence of the 5 feet thick sand unit encountered at VP-1 and VP-2 at 20 to 25 feet depth should not be considered of paramount importance in the review of the vapor extraction feasibility assessment. The data from the boring logs and historical records indicate that this unit is both discontinuous and normally associated with the presence of a perched water zone. Based on these properties, the intermediate unit is unlikely to be an essential factor in the design of the full scale site remediation system.

c. Water Movement

The high operating vacuum utilized in the secondary test on VW-D is normally associated with the presence and transport of soil moisture/water into the vacuum well and out through the manifold system. At the site, negligible quantities of water were removed from the subsurface during the tests on VW-D.

Boring logs indicate the presence of stiff clayey materials at the water table level in the test area. *VAPEX* considers that it was the presence of the clay that reduced the localized ground water table mounding and the production of water expected at the vacuum well. In the full scale system operation, where more permeable materials may exist at the water table level, water removal through the vapor extraction system may be observed.

4.1.2 Chemical Parameters

a. Performance of Test on VW-S

In general, remediation of a contaminated site by vapor extraction is represented by an exponentially decaying plot of vacuum extraction well total contaminant discharge concentration with time. Figure 3-1 presents the total contaminant concentration levels measured in the discharge from VW-S over the primary test. It can be observed that the plot does not reflect the expected function as described above. *VAPEX* has observed this type of curve at other sites where vapor extraction is being utilized as the primary remediation technology. This type of curve is generally associated with the misplacement of the vacuum well with respect to the center of mass of the local contaminant source. When the vacuum system is activated, a lag period exists during which the more contaminated vapors from the center of the contaminant source are being transported to the vacuum well. As described in Section 3.2.2.a, the chemical data obtained prior to the observation of the second peak was ignored in the development of the chemical model used in the prediction of time to achieve the specified closure limits.

b. Performance of Analytical Instruments and Techniques

b.1 Correlation between Hand Held 580A and Field GC/PID

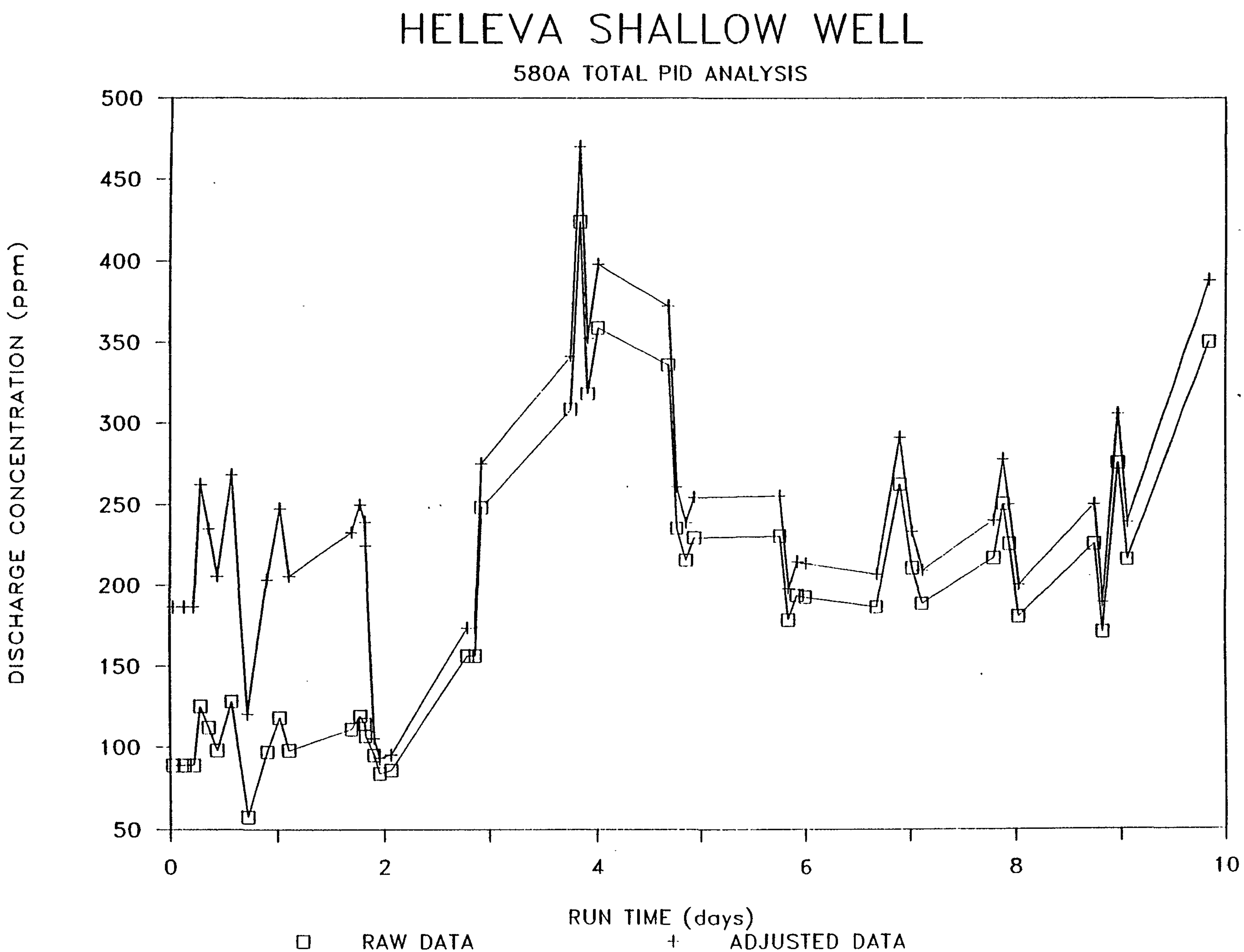
A comparison of the results of measurements of VW-S and VW-D wellhead soil vapor discharge by hand held 580A as compared to the results of GC/PID analysis can be made by visual analysis of Figures 3-1, 3-2, and E-1, E-2.

Although absolute values measured by the hand held 580A and GC/PID differ substantially, trends in total system discharge concentration as measured by hand held 580A reflect similar trends in total system discharge concentration as generated by GC/PID analysis. This validates the use of the hand held 580A as an effective screening tool to allow accurate setting of the GC/PID operating parameters.

b.2 GC/PID Response

As discussed in Appendix E, GC/PID response fluctuated over the course of the test as determined by analysis of daily QA/QC standards. In order to evaluate how the raw field data should be corrected to reflect the fluctuations in sensitivity, Relative and Average Relative Response factors (RRF and AVG RRF, respectively), as described in Appendix E, were generated. The response factors were applied retroactively to generate the corrected GC/PID field data.

In order to justify application of the corrections to field data, an understanding of the nature of these relative response factors is necessary. Analysis of the changes in GC/PID response for the individual components (cis-1,2-DCE, TCE and PCE) indicates similar response factor variation over the duration of the test. This relationship between individual constituents of the given standards is depicted visually in Figures E-3, E-4, and E-5 and is substantiated statistically by calculation of standard deviations on corresponding groups as seen in Table E-5 through E-8. These results indicate that changes in GC/PID sensitivity did occur, were accounted for, and that operator error was not a major factor in GC/PID performance.



HELEVA SHALLOW WELL
580A TOTAL PID ANALYSIS
DISCHARGE CONCENTRATION (ppm)
500
450
400
350
300
250
200
150
100
50
0
2
4
6
8
10
RUN TIME (days)
RAW DATA
ADJUSTED DATA

FIGURE E-1

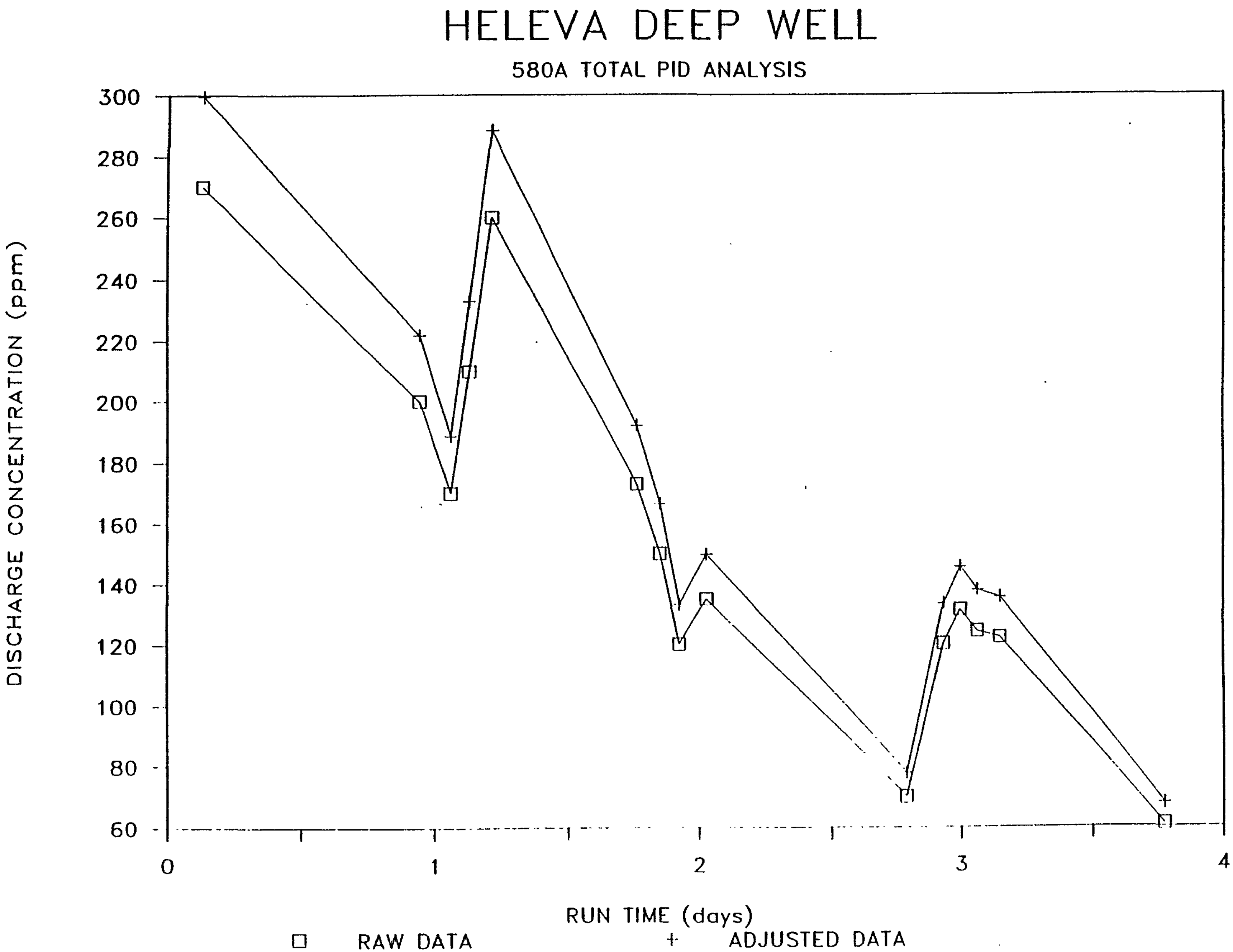

HELEVA DEEP WELL
580A TOTAL PID ANALYSIS
DISCHARGE CONCENTRATION (ppm)
300
280
260
240
220
200
180
160
140
120
100
80
60
0
1
2
3
4
RUN TIME (days)
RAW DATA
ADJUSTED DATA

FIGURE E-2

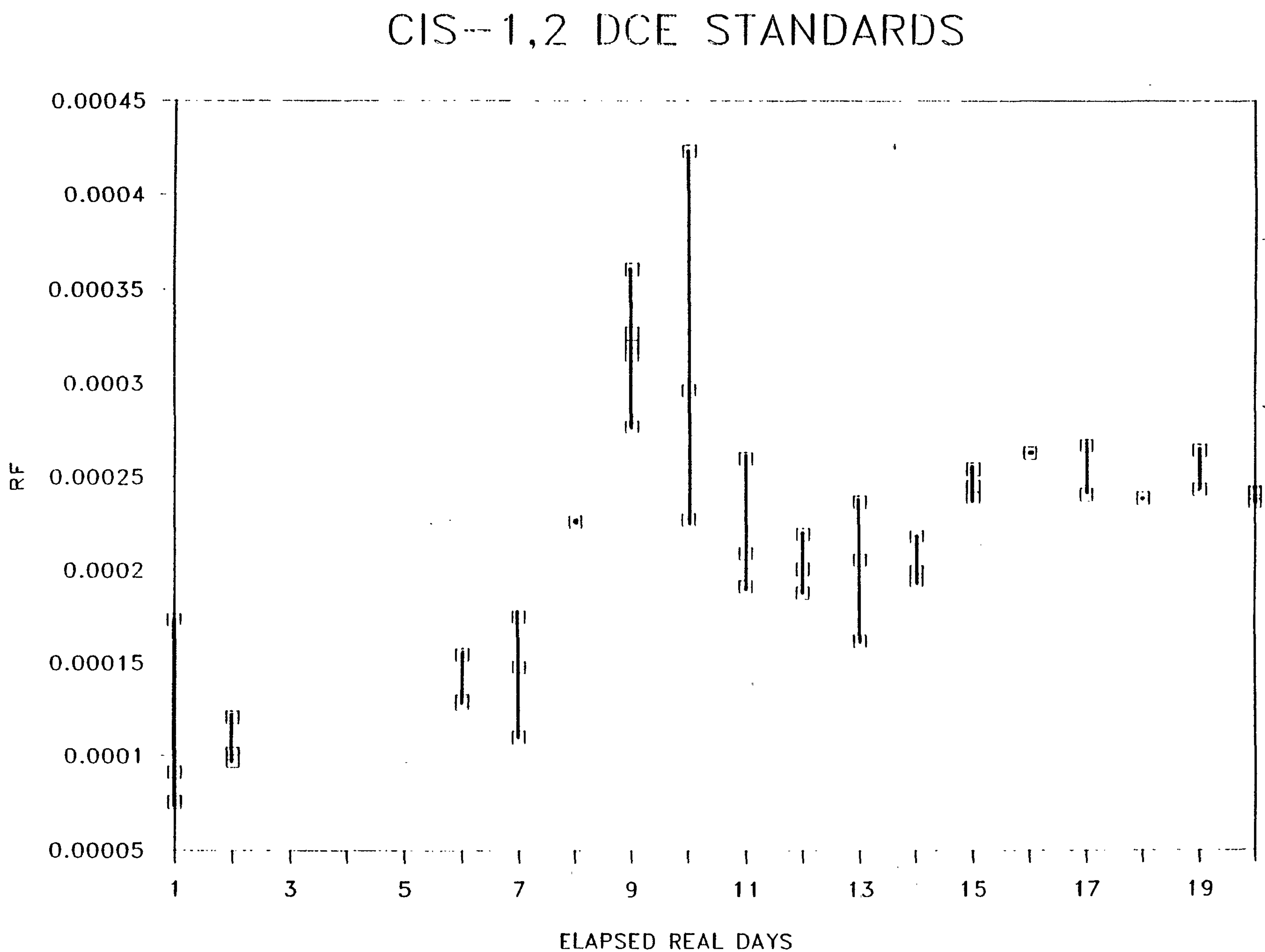

CIS-1,2 DCE STANDARDS
RF
0.00045
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
1
3
5
7
9
11
13
15
17
19
ELAPSED REAL DAYS

FIGURE E-3

TCE STANDARDS

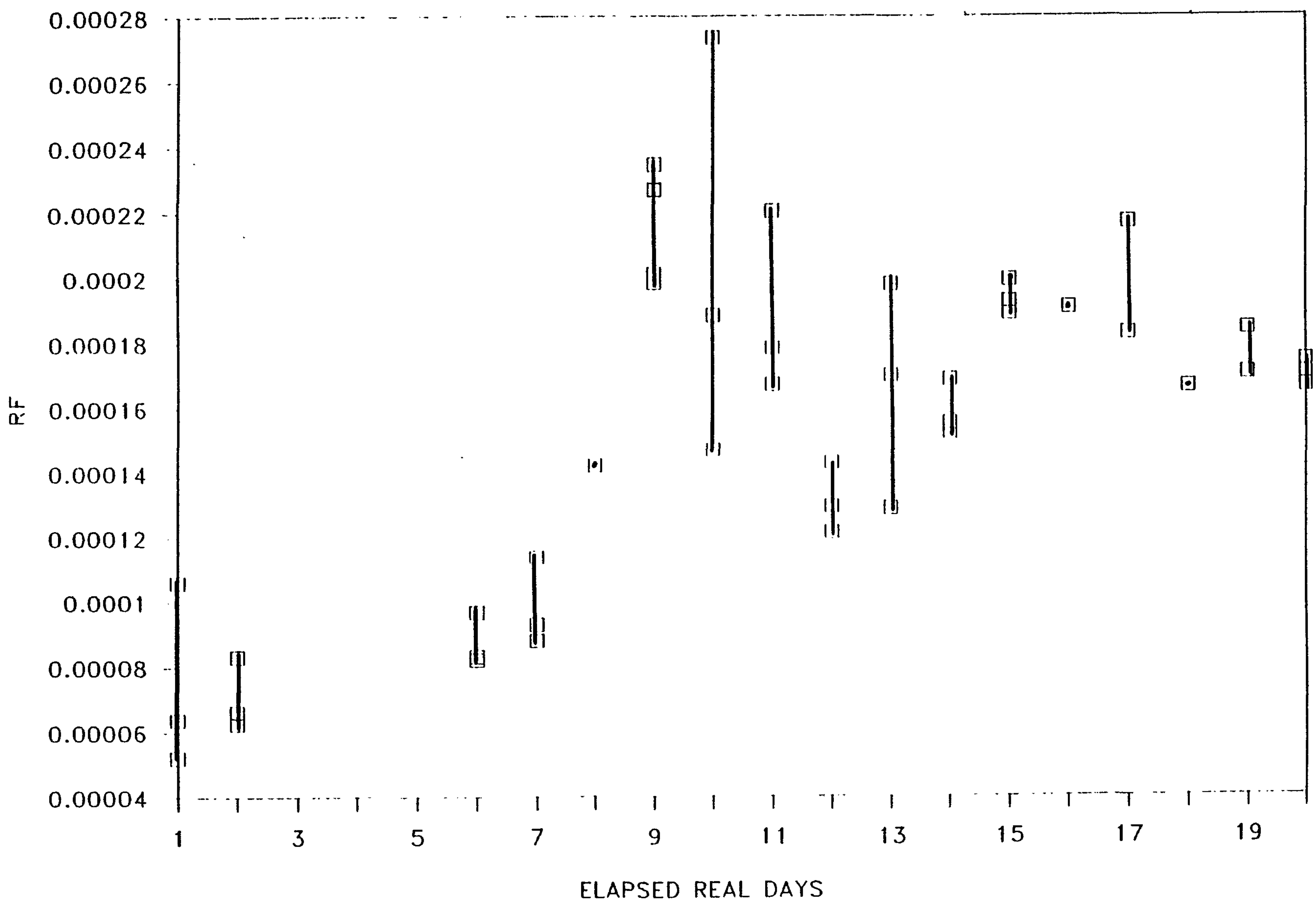


FIGURE E-4

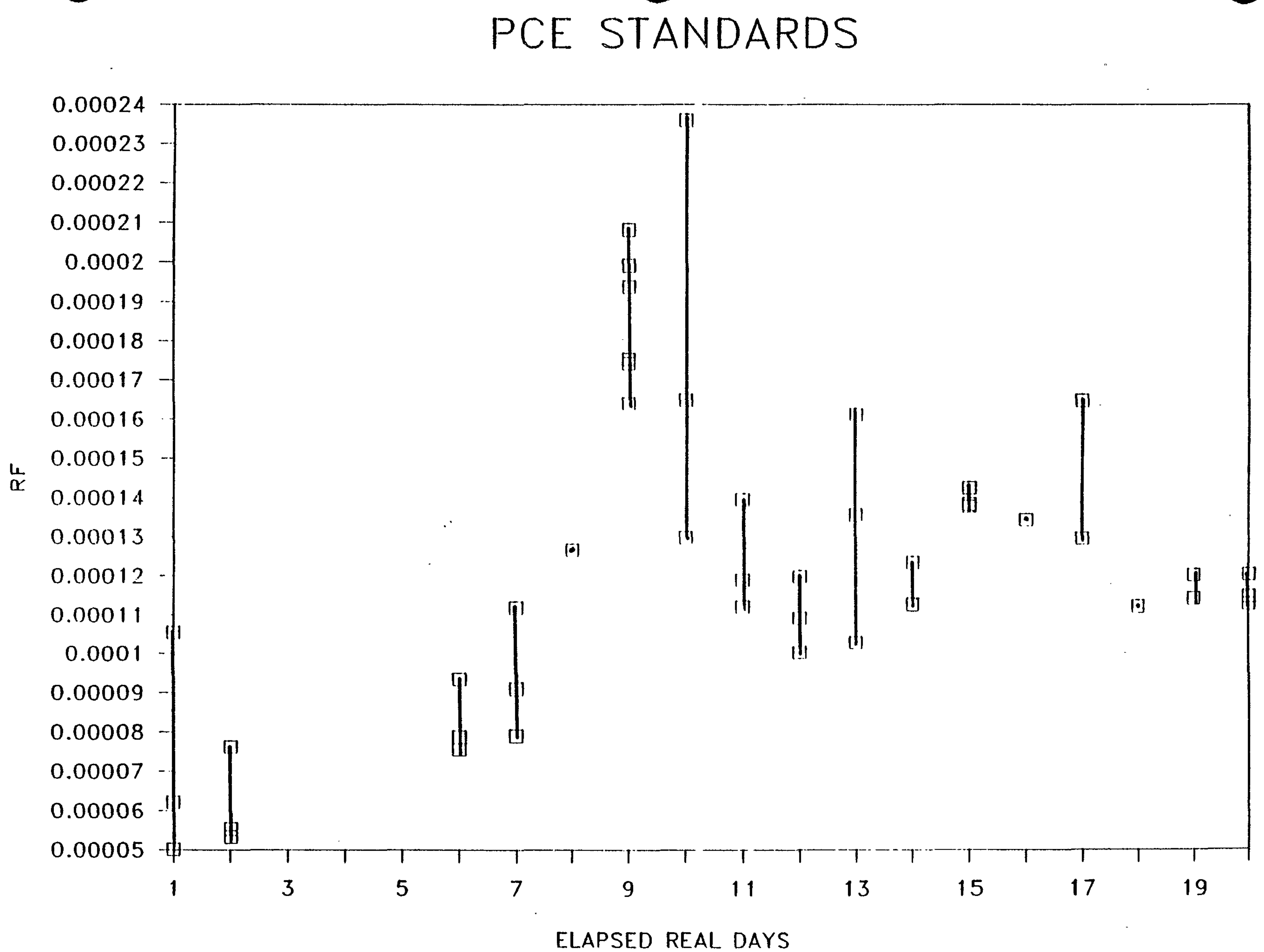
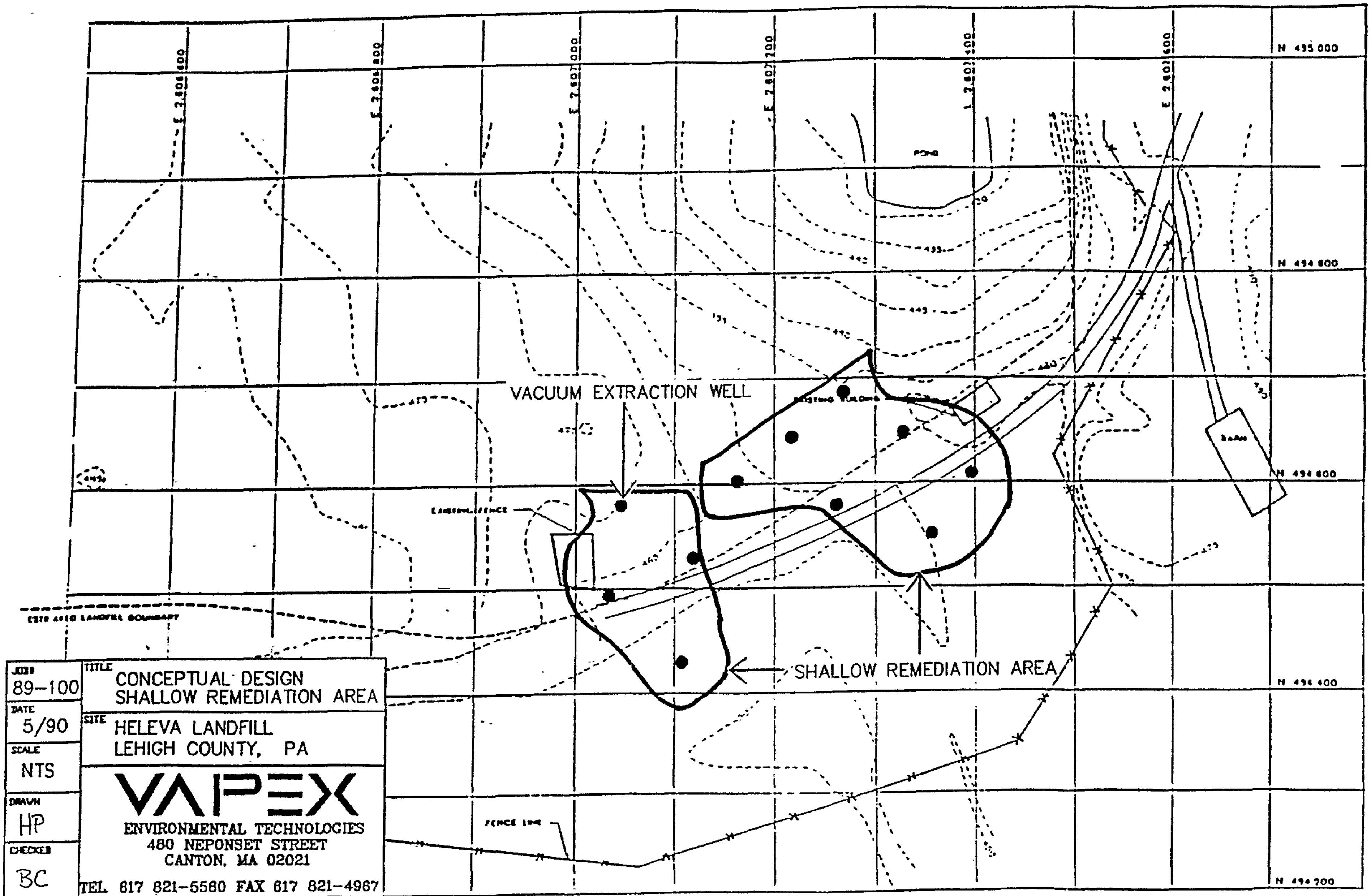

PCE STANDARDS
RF
0.00024
0.00023
0.00022
0.00021
0.0002
0.00019
0.00018
0.00017
0.00016
0.00015
0.00014
0.00013
0.00012
0.00011
0.0001
0.00009
0.00008
0.00007
0.00006
0.00005
1
3
5
7
9
11
13
15
17
19
ELAPSED REAL DAYS

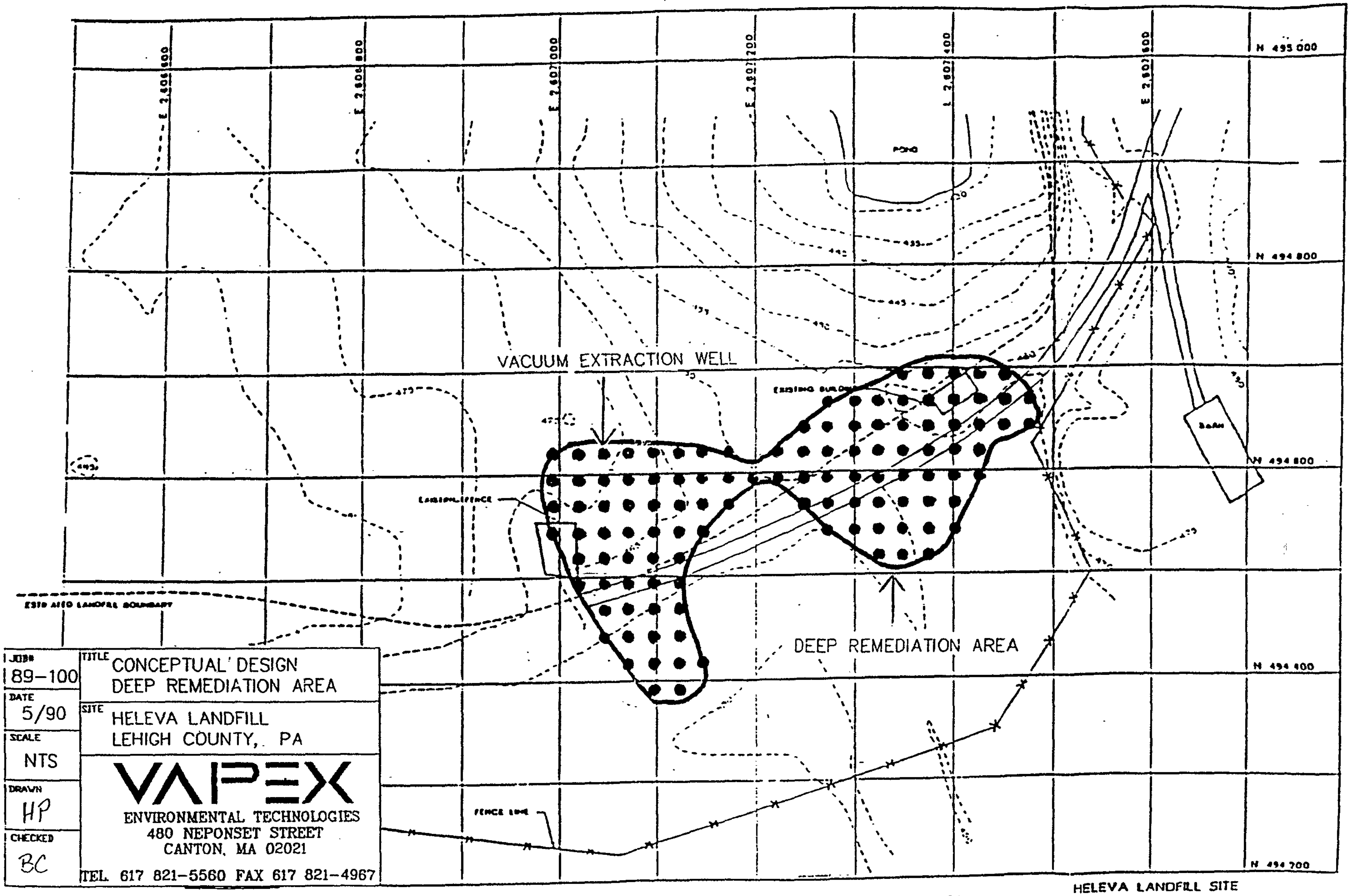
FIGURE E-5



BASE DRAWING SOURCE GANNETT FLEMING, INC. 1989

HELEVA LANDFILL SITE
LEHIGH COUNTY, PA.

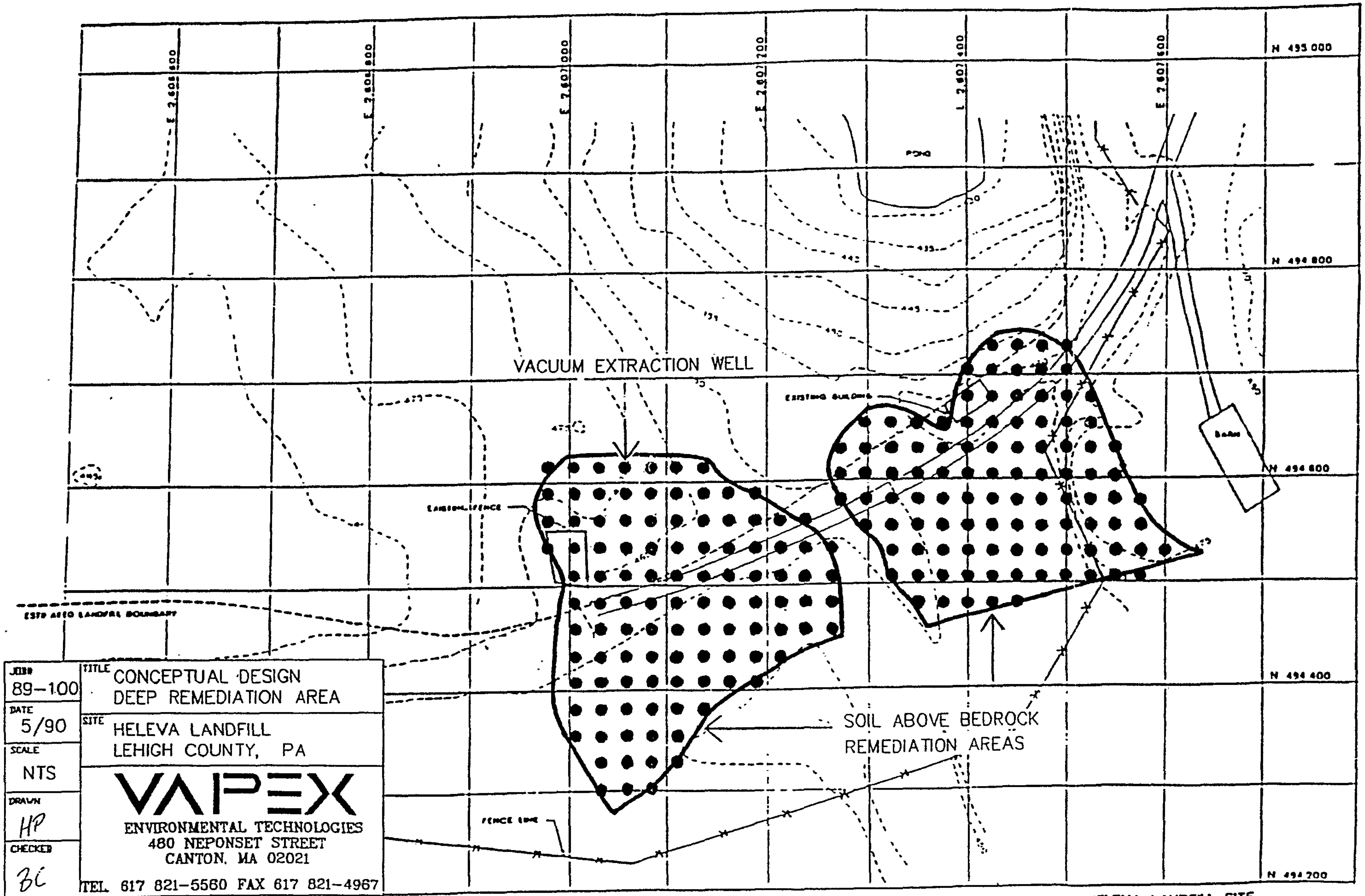
FIGURE 4-4



BASE DRAWING SOURCE GANNETT FLEMING, INC. 1989

HELEVA LANDFILL SITE
LEHIGH COUNTY, PA.

FIGURE 4-5



BASE DRAWING SOURCE GANNETT FLEMING, INC. 1989

HELEVA LANDFILL SITE
LEHIGH COUNTY, PA.

FIGURE 4-6

TABLE E-1

GC/PID DUPLICATE ANALYSIS@

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

Sample #	Filename	Descr.#	Test Day	TCA	cis-DCE	TCE*	Xylenes
17	VW-S-22	" (M4)	3	323	888	4061	454
17	VW-S-23	Duplicate (M8)		357	1093	4932	541
		%DIFFERENCE		-11	-23	-21	-19
21	VW-S-27	" (M8)	4	328	905	3205	483
21	VW-S-28	Duplicate (M8)		242	641	2736	278
		%DIFFERENCE		26	29	15	42
25	VW-S-32	" (M8)	5	503	1297	5639	717
25	VW-S-33	Duplicate (M8)		449	1134	5361	602
		%DIFFERENCE		11	13	5	16
29	VW-S-37	" (M8)	6	661	1760	7318	1173
29	VW-S-38	Duplicate (M8)		565	1450	6981	926
		%DIFFERENCE		15	18	5	21
32	VW-S-41	" (M8)	7	520	1209	6921	873
32	VW-S-42	Duplicate (M8)		427	1007	6416	671
		%DIFFERENCE		18	17	7	23
36	VW-S-46	" (M8)	8	270	745	3559	551
36	VW-S-47	Duplicate (M8)		211	555	3042	394
		%DIFFERENCE		22	26	15	29
40	VW-S-51	" (M8)	9	289	698	4273	643
40	VW-S-52	Duplicate (M8)		186	448	3764	354
		%DIFFERENCE		36	36	12	45
43	VW-S-55	" (M8)	10	255	668	3978	521
43	VW-S-56	Duplicate (M8)		202	483	3458	363
		%DIFFERENCE		21	28	13	30
44	VW-S-58	Duplicate (M8)	10	204	316	3409	396
44	VW-S-59	Duplicate #2(M8)		102	266	2474	192
		%DIFFERENCE		50	16	27	52
3	VW-D-3	Exhaust (M8)		264	1191	6354	168
3	VW-D-4	Duplicate		205	893	4635	114
		%DIFFERENCE		22	25	27	32
9	VW-D-10	Exhaust (M8)		196	687	4431	122
9	VW-D-11	Duplicate		160	514	3751	88
		%DIFFERENCE		19	25	15	28
10	VW-D-12	Exhaust (M4)		179	685	4192	180
10	VW-D-13	Duplicate		153	580	3929	152
		%DIFFERENCE		15	15	6	16

@ Samples analyzed using an HNU Model 321 Gas Chromatograph, equipped with an 11.7 eV photoionization detector (PID). All samples reported in parts-per-million (ppm) on a volume/volume (vol/vol) basis

TCA 1,1,1-trichloroethane

cis-DCE cis-1,2-dichloroethylene

TCE trichloroethylene

* This peak may include a second compound partially enveloped in TCE peak

\# %difference defined as: ((ppm sample-ppm dupl.)/ppm sample)*100

TABLE E-2

MATRIX OPERATIONS ON %DIFFERENCES AS OBTAINED FROM TABLE E-1

SOIL VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

			Percent Diff. Between Sample and Duplicate				SAMPLE ANALYSIS					
	Sample#	Filename	TCA	cis-DCE	TCE	Xylenes	AVG	S-Dev	Rel. S-Dev	Max	Min	Range
V	17	W-S-22/2	-11	-23	-21	-19	-19	6	-0.3	-11	-23	13
O	21	W-S-28/2	28	29	15	42	28	11	0.4	42	15	28
C	25	W-S-32/3	11	13	5	16	11	5	0.4	16	5	11
	29	W-S-37/3	15	18	5	21	14	7	0.5	21	5	16
A	32	W-S-41/4	18	17	7	23	16	7	0.4	23	7	16
N	36	W-S-46/4	22	26	15	29	23	6	0.3	29	15	14
A	40	W-S-51/5	35	36	12	45	32	14	0.4	45	12	33
L	43	W-S-55/5	21	28	13	30	23	8	0.3	30	13	17
Y	44	W-S-58/5	50	16	27	52	36	17	0.5	52	16	36
S	3	VW-D-3/4	22	25	27	32	27	4	0.2	32	22	10
I	9	VW-D-10/	19	25	15	28	22	6	0.3	28	15	12
S	10	VW-D-12/	15	15	6	16	13	4	0.3	16	6	9
		Avg	20	19	10	26						
		S	14	15	13	18						
		Rel S-Dev	0.7	0.8	1.2	0.7						
		Max	50	36	27	52						
		Min	-11	-23	-21	-19						
		Range	61	59	49	71						

	VOC X-double-bar					
	AVG	S-Dev	Rel. S-Dev	Max	Min	Range
	19	2	0.1	26	10	16
	15	1	0.0	18	13	6
	1	0	0.1	1	1	1
	41	3	0.1	52	27	24
	-19	1	-0.1	-11	-23	13
	60	2	0.0	71	49	22
	SAMPLE X-double-bar					
Avg	19	8	0.3	27	9	18
S	14	4	0.2	16	11	9
Rel S-Dev	0.7	0.5	0.7	0.6	1.3	0.5
Max	36	17	0.5	52	22	36
Min	-19	4	-0.3	-11	-23	9
Range	55	13	0.8	62	45	26

MATRIX KEY

Sample Analysis: Analysis by row/sample
VOC Analysis: Analysis by column/VOC

VOC X-double-bar: Statistical Anal.
on the results of VOC Analysis
The "average" of each "VOC average"

Sample X-double-bar: Statistical Analysis
on the results of Sample analysis
The "average" of all the "sample averages"

TCA has been highlighted as an example

TABLE E-3

ANALYSIS OF LABORATORY DUPLICATES FOR WELLHEAD SOIL VAPOR SAMPLES@

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

	--- VW-S-Lab3 ---			--- VW-S-Lab4 ---		
Parameter	VW-S-Lab3	Duplicate	%Diff*	VW-S-Lab4	Duplicate	%Diff*
1 Vinyl Chloride	42.60	35.70	16.2	56.10	40.20	28.3
2 Cis-1,2-DCE	272.00	150.00	44.9	373.00	514.00	-37.8
3 Trichloroethylene	1180.00	990.00	16.1	1480.00	1490.00	-0.7
4 1,1,1-TCA	246.00	141.00	42.7	364.00	418.00	-14.8
5 Toluene	4.83	2.86	40.8	5.08	3.09	39.2
6 Ethylbenzene	14.60	7.73	47.1	14.10	7.99	43.3
7 Xylene (s)	16.10	9.23	42.7	14.90	9.53	36.0
8 Chloroform	70.60	39.50	44.1	362.00	66.60	81.6
9 1,1-dichloroethylene	21.70	4.15	80.9	40.80	70.90	-73.8
		Avg	41.7		Avg	11.3
		S-Dev	19.0		S-Dev	47.6
		Rel S-Dev	0.5		Rel S-Dev	4.2
Chain-of-Custody Reference:		Max	80.9		Max	81.6
VW-S-Lab3 ---> Form #002		Min	16.1		Min	-73.8
VW-S-Lab4 ---> Form #003		Range	64.8		Range	155.4

@ Samples collected in Teflon Gas Sampling Bags and transported by courier to MDS Laboratories in Reading, PA. for analysis by EPA Methods TO1/TO2. All samples reported in uL/L (ppm)

* Percent Difference defined as: ((Sample ppm - Dupl. ppm)/Sample ppm)*100

TABLE E-4

SUMMATION OF RETENTION TIME PERFORMANCE ANALYSIS: FIELD GC/PID STANDARDS A THROUGH Q

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

STANDARD	REAL DAY	FPT DAY	COMPOUND	True Rt. (min)	X-bar (min)	S-Dev (min)	Max (min)	Min (min)	Range (min)	n	t-variate (90% C.L.)	Within 90% C.L.? (Y/N)	Within 95% C.L.? (Y/N)	Within 90% C.L.? (Y/N)	Average Accuracy (min)
A	1	0	cis-1,2-DCE	4.635	4.500	0.043	4.550	4.475	0.075	3	2.920	N	N	Y	0.135
			TCE	5.410	5.328	0.050	5.375	5.275	0.100	3	2.920	N	Y	Y	0.082
			PCE	9.281	9.203	0.041	9.250	9.175	0.075	3	2.920	N	Y	Y	0.078
B	2	0	cis-1,2-DCE	4.635	4.717	0.094	4.783	4.650	0.133	3	2.920	Y			0.071
			TCE	5.410	5.497	0.102	5.608	5.408	0.200	3	2.920	Y			0.088
			PCE	9.281	9.386	0.063	9.450	9.325	0.125	3	2.920	Y			0.105
C	6	1	cis-1,2-DCE	4.635	4.592	0.088	4.675	4.500	0.175	3	2.920	Y			0.070
			TCE	5.410	5.408	0.096	5.500	5.308	0.192	3	2.920	Y			0.066
			PCE	9.281	9.333	0.092	9.425	9.241	0.184	3	2.920	Y			0.780
D	7	2	cis-1,2-DCE	4.635	4.677	0.092	4.783	4.616	0.167	3	2.920	Y			0.056
			TCE	5.410	5.486	0.107	5.608	5.410	0.198	3	2.920	Y			0.076
			PCE	9.281	9.403	0.131	9.550	9.300	0.250	3	2.920	Y			0.121
F	9	4	cis-1,2-DCE	4.635	4.647	0.013	4.658	4.633	0.025	3	2.920	Y	Y	Y	0.013
			TCE	5.410	5.475	0.017	5.491	5.458	0.033	3	2.920	N	N	Y	0.064
			PCE	9.281	9.444	0.035	9.483	9.416	0.067	3	2.920	N	N	Y	0.163
G	9	4	cis-1,2-DCE	4.635	4.630	0.084	4.725	4.566	0.159	3	2.920	Y			0.064
			TCE	5.410	5.464	0.098	5.575	5.391	0.184	3	2.920	Y			0.066
			PCE	9.281	9.400	0.116	9.533	9.325	0.208	3	2.920	Y			0.118
H	10	5	cis-1,2-DCE	4.635	4.686	0.024	4.700	4.658	0.042	3	2.920	Y	Y		0.051
			TCE	5.410	5.508	0.025	5.533	5.483	0.050	3	2.920	Y	Y		0.098
			PCE	9.281	9.416	0.067	9.483	9.350	0.133	3	2.920	N	Y		0.135
I	11	6	cis-1,2-DCE	4.635	4.625	0.262	4.916	4.408	0.508	3	2.920	Y			0.197
			TCE	5.410	5.438	0.272	5.741	5.216	0.525	3	2.920	Y			0.192
			PCE	9.281	9.350	0.198	9.575	9.200	0.375	3	2.920	Y			0.127
J	12	7	cis-1,2-DCE	4.635	4.580	0.251	4.841	4.341	0.500	3	2.920	Y			0.192
			TCE	5.410	5.397	0.251	5.658	5.158	0.500	3	2.920	Y			0.178
			PCE	9.281	9.319	0.175	9.500	9.150	0.350	3	2.920	Y			0.125
K	13	8	cis-1,2-DCE	4.635	4.483	0.076	4.566	4.416	0.150	3	2.920	N	Y		0.152
			TCE	5.410	5.291	0.085	5.383	5.216	0.167	3	2.920	Y	Y		0.118
			PCE	9.281	9.205	0.075	9.291	9.150	0.141	3	2.920	Y	Y		0.082
L	14	9	cis-1,2-DCE	4.635	4.069	0.538	4.425	3.450	0.975	3	2.920	N	Y		0.565
			TCE	5.410	4.819	0.611	5.225	4.116	1.109	3	2.920	Y	Y		0.591
			PCE	9.281	8.714	0.599	9.116	8.025	1.091	3	2.920	Y	Y		0.567
M	15	10	cis-1,2-DCE	4.635	4.514	0.027	4.533	4.483	0.050	3	2.920	N	N	Y	0.121
			TCE	5.410	5.322	0.027	5.341	5.291	0.050	3	2.920	N	N	Y	0.088
			PCE	9.281	9.200	0.009	9.208	9.191	0.017	3	2.920	N	N	N	0.081
N	16	11	cis-1,2-DCE	4.635	4.658	0.247	4.833	4.483	0.350	2	6.314	Y			0.175
			TCE	5.410	5.467	0.235	5.633	5.300	0.333	2	6.314	Y			0.166
			PCE	9.281	9.337	0.147	9.441	9.233	0.208	2	6.314	Y			0.104
O	17	12	cis-1,2-DCE	4.635	4.550	0.012	4.558	4.541	0.017	2	6.314	N	Y		0.085
			TCE	5.410	5.371	0.006	5.375	5.366	0.009	2	6.314	N	Y		0.039
			PCE	9.281	9.288	0.018	9.300	9.275	0.025	2	6.314	Y	Y		0.013
P	18-19	13	cis-1,2-DCE	4.635	4.591	0.035	4.616	4.566	0.050	2	6.314	Y			0.044
			TCE	5.410	5.433	0.047	5.466	5.400	0.066	2	6.314	Y			0.033
			PCE	9.281	9.358	0.059	9.400	9.316	0.084	2	6.314	Y			0.077
Q	20	14	cis-1,2-DCE	4.635	4.686	0.051	4.741	4.641	0.100	3	2.920	Y	Y		0.050
			TCE	5.410	5.533	0.050	5.583	5.483	0.100	3	2.920	N	Y		0.123
			PCE	9.281	9.405	0.067	9.466	9.333	0.133	3	2.920	N	Y		0.124

AR303228

TABLE E-5

RELATIVE RESPONSE FACTORS (RRF): cis-1,2-DCE

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

Std. Run	Compound	Std #	Real Day	FPT Day	AC	Conc.	RF	RFI	% change	RRF RF/RFI	AVG RRF	RRF S-Dev	RRF Range
1	cis-1,2-DCE	A #1	1	0	1295422	97.65	0.0000753	0.0000804	-6.25	0.9374560			
4	cis-1,2-DCE	A #2	1	0	1069624	97.65	0.0000912	0.0000804	13.54	1.1353533			
7	cis-1,2-DCE	A #3	1	0	563761.5	97.65	0.0001732	0.0000804	115.41	2.1541045	1.41	0.65	1.22
10	cis-1,2-DCE	B #1	2	0	4107688	496.13	0.0001207	0.0000804	50.20	1.5019892			
13	cis-1,2-DCE	B #2	2	0	5091308	496.13	0.0000974	0.0000804	21.19	1.2118700			
19	cis-1,2-DCE	B #4	2	0	4888584	496.13	0.0001014	0.0000804	26.21	1.2621249	1.33	0.16	0.29
25	cis-1,2-DCE	C #1	6	1	3887010	504.00	0.0001296	0.0000804	61.25	1.6125189			
28	cis-1,2-DCE	C #2	6	1	3933827	504.00	0.0001281	0.0000804	59.33	1.5933281			
31	cis-1,2-DCE	C #3	6	1	3266097	504.00	0.0001543	0.0000804	91.91	1.9190725	1.71	0.18	0.33
34	cis-1,2-DCE	D #1	7	2	4581285	504.00	0.0001100	0.0000804	36.81	1.3681482			
37	cis-1,2-DCE	D #2	7	2	2888386	504.00	0.0001744	0.0000804	117.00	2.1700275			
40	cis-1,2-DCE	D #3	7	2	3416982	504.00	0.0001474	0.0000804	83.43	1.8343313	1.79	0.40	0.80
43	cis-1,2-DCE	E #1	8	3	2232824	504.00	0.0002257	0.0000804	180.72	2.8071523	2.81		
46	cis-1,2-DCE	F #1	9	4	1397708	504.00	0.0003605	0.0000804	348.44	4.4843966			
49	cis-1,2-DCE	F #2	9	4	1577096	504.00	0.0003195	0.0000804	297.43	3.9743155			
52	cis-1,2-DCE	F #3	9	4	1598746	504.00	0.0003152	0.0000804	292.05	3.9204958			
55	cis-1,2-DCE	G #1	9	4	1608892	514.24	0.0003196	0.0000804	297.49	3.9749246			
58	cis-1,2-DCE	G #2	9	4	1574008	514.24	0.0003267	0.0000804	306.30	4.0630190			
64	cis-1,2-DCE	G #3	9	4	1860999	514.24	0.0002763	0.0000804	243.64	3.4364470	3.98	0.33	1.05
70	cis-1,2-DCE	H #1	10	5	1191689	504.00	0.0004229	0.0000804	425.97	5.2596584			
73	cis-1,2-DCE	H #2	10	5	1701925	504.00	0.0002961	0.0000804	268.28	3.6828162			
79	cis-1,2-DCE	H #3	10	5	2221650	504.00	0.0002268	0.0000804	182.13	2.8212711	3.92	1.24	2.44
85	cis-1,2-DCE	I #1	11	6	1944610	504.00	0.0002591	0.0000804	222.32	3.2232052			
88	cis-1,2-DCE	I #2	11	6	2415075	504.00	0.0002086	0.0000804	159.53	2.5953136			
91	cis-1,2-DCE	I #3	11	6	2641542	504.00	0.0001907	0.0000804	137.28	2.3728099	2.73	0.44	0.85
94	cis-1,2-DCE	J #1	12	7	2220621	485.76	0.0002187	0.0000804	172.04	2.7204280			
97	cis-1,2-DCE	J #2	12	7	2427341	485.76	0.0002001	0.0000804	148.87	2.4887478			
100	cis-1,2-DCE	J #3	12	7	2594613	485.76	0.0001872	0.0000804	132.83	2.3283008	2.51	0.20	0.39
103	cis-1,2-DCE	K #1	13	8	2507853	405.00	0.0001614	0.0000804	100.84	2.0083661			
106	cis-1,2-DCE	K #2	13	8	1713481	405.00	0.0002363	0.0000804	193.94	2.9394472			
109	cis-1,2-DCE	K #3	13	8	1975726	405.00	0.0002049	0.0000804	154.93	2.5492841	2.50	0.47	0.93
112	cis-1,2-DCE	L #1	14	9	2088103	405.00	0.0001939	0.0000804	141.21	2.4120874			
118	cis-1,2-DCE	L #2	14	9	2037852	405.00	0.0001987	0.0000804	147.16	2.4715666			
121	cis-1,2-DCE	L #3	14	9	1862639	405.00	0.0002174	0.0000804	170.41	2.7040596	2.53	0.15	0.29
124	cis-1,2-DCE	M #1	15	10	1697883	405.00	0.0002385	0.0000804	196.65	2.9664511			
127	cis-1,2-DCE	M #2	15	10	1656883	405.00	0.0002444	0.0000804	203.99	3.0398567			
130	cis-1,2-DCE	M #3	15	10	1597474	405.00	0.0002535	0.0000804	215.29	3.1529070	3.05	0.09	0.19
133	cis-1,2-DCE	N #1	16	11	1545545	405.00	0.0002620	0.0000804	225.88	3.2588420	3.26		
139	cis-1,2-DCE	O #1 DUP	17	12	1522849	405.00	0.0002659	0.0000804	230.74	3.3074106			
142	cis-1,2-DCE	O #2	17	12	1688430	405.00	0.0002398	0.0000804	198.31	2.9830593	3.15	0.23	0.32
145	cis-1,2-DCE	P #1	18	13	1702345	405.00	0.0002379	0.0000804	195.87	2.9586758			
148	cis-1,2-DCE	P #2	19	13	1669992	405.00	0.0002425	0.0000804	201.60	3.0159946			
151	cis-1,2-DCE	P #3	19	13	1538089	405.00	0.0002633	0.0000804	227.46	3.2746394	3.08	0.17	0.32
154	cis-1,2-DCE	Q #1	20	14	1687446	405.00	0.0002400	0.0000804	198.48	2.9847989			
157	cis-1,2-DCE	Q #2	20	14	1681677	405.00	0.0002408	0.0000804	199.50	2.9950382			
160	cis-1,2-DCE	Q #3	20	14	1715630	405.00	0.0002360	0.0000804	193.58	2.9357652	2.97	0.03	0.06

TABLE E-6

RELATIVE RESPONSE FACTORS (RRF): TCE

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

Std. Run	Compound	Std #	Real Day	FPT Day	AC	Conc.	RF	RFI	% change	RRF RF/RFI	AVG RRF	RRF S-Dev	RRF Range
2	TCE	A #1	1	0	1508518	78.84	0.0000522	0.0000578	-9.672978	0.9032702			
5	TCE	A #2	1	0	1235337	78.84	0.0000638	0.0000578	10.301834	1.1030183			
8	TCE	A #3	1	0	743067.5	78.84	0.0001061	0.0000578	83.374812	1.8337481	1.28	0.49	0.93
11	TCE	B #1	2	0	5955822	495.38	0.0000831	0.0000578	43.758295	1.4375829			
14	TCE	B #2	2	0	7811243	495.38	0.0000626	0.0000578	8.2219400	1.0822194			
20	TCE	B #4	2	0	7470320	495.38	0.0000663	0.0000578	14.808556	1.1480855	1.22	0.19	0.36
26	TCE	C #1	6	1	6003735	499.32	0.0000831	0.0000578	43.740455	1.4374045			
29	TCE	C #2	6	1	6088894	499.32	0.0000820	0.0000578	41.730108	1.4173010			
32	TCE	C #3	6	1	5168517	499.32	0.0000966	0.0000578	66.966514	1.6696651	1.51	0.14	0.25
35	TCE	D #1	7	2	5685161	499.32	0.0000878	0.0000578	51.795104	1.5179510			
38	TCE	D #2	7	2	4391018	499.32	0.0001137	0.0000578	96.532923	1.9653292			
41	TCE	D #3	7	2	5377864	499.32	0.0000928	0.0000578	60.466841	1.6046684	1.70	0.24	0.45
44	TCE	E #1	8	3	3514990	499.32	0.0001420	0.0000578	145.51409	2.4551409	2.46		
47	TCE	F #1	9	4	2202704	499.32	0.0002266	0.0000578	291.78192	3.9178192			
50	TCE	F #2	9	4	2482444	499.32	0.0002011	0.0000578	247.83306	3.4783306			
53	TCE	F #3	9	4	2517374	499.32	0.0001983	0.0000578	242.80945	3.4280945			
56	TCE	G #1	9	4	2256657	512.2	0.0002269	0.0000578	292.27948	3.9227948			
59	TCE	G #2	9	4	2183653	512.2	0.0002345	0.0000578	305.39418	4.0539418			
65	TCE	G #3	9	4	2582712	512.2	0.0001983	0.0000578	242.75807	3.4275807	3.70	0.29	0.63
71	TCE	H #1	10	5	1825734	499.32	0.0002734	0.0000578	372.51987	4.7251987			
74	TCE	H #2	10	5	2651104	499.32	0.0001883	0.0000578	225.51706	3.2551706			
80	TCE	H #3	10	5	3387365	499.32	0.0001468	0.0000578	154.01439	2.5401439	3.51	1.11	2.19
86	TCE	I #1	11	6	2266375	499.32	0.0002203	0.0000578	280.77529	3.8077529			
89	TCE	I #2	11	6	2802063	499.32	0.0001781	0.0000578	207.98008	3.0798008			
92	TCE	I #3	11	6	2991976	499.32	0.0001668	0.0000578	188.43132	2.8843132	3.26	0.49	0.92
95	TCE	J #1	12	7	3497529	499.32	0.0001427	0.0000578	146.7396	2.467396			
98	TCE	J #2	12	7	3862339	499.32	0.0001292	0.0000578	123.43445	2.2343445			
101	TCE	J #3	12	7	4116357	499.32	0.0001213	0.0000578	109.84644	2.0984644	2.27	0.19	0.37
104	TCE	K #1	13	8	3880517	499.32	0.0001286	0.0000578	122.38779	2.2238779			
107	TCE	K #2	13	8	2524268	499.32	0.0001978	0.0000578	241.87321	3.4187321			
110	TCE	K #3	13	8	2943595	499.32	0.0001696	0.0000578	193.17199	2.9317199	2.86	0.60	1.19
113	TCE	L #1	14	9	3288260	499.32	0.0001518	0.0000578	162.44263	2.6244263			
116	TCE	L #2	14	9	3225123	499.32	0.0001548	0.0000578	167.58037	2.6758037			
122	TCE	L #3	14	9	2967966	499.32	0.0001682	0.0000578	190.76269	2.9076269	2.74	0.15	0.28
125	TCE	M #1	15	10	2647621	499.32	0.0001885	0.0000578	225.94529	3.2594529			
128	TCE	M #2	15	10	2596116	499.32	0.0001923	0.0000578	232.41180	3.3241180			
131	TCE	M #3	15	10	2510311	499.32	0.0001989	0.0000578	243.77398	3.4377398	3.34	0.09	0.18
134	TCE	N #1	16	11	2621246	499.32	0.0001904	0.0000578	229.22495	3.2922495	3.29		
140	TCE	O #1 DUP	17	12	2302942	499.32	0.0002168	0.0000578	274.72919	3.7472919			
143	TCE	O #2	17	12	2735372	499.32	0.0001825	0.0000578	215.48603	3.1548603	3.45	0.42	0.59
146	TCE	P #1	18	13	3009829	499.32	0.0001659	0.0000578	186.72047	2.8672047			
149	TCE	P #2	19	13	2935057	499.32	0.0001701	0.0000578	194.02481	2.9402481			
152	TCE	P #3	19	13	2718515	499.32	0.0001836	0.0000578	217.67894	3.1767894	2.99	0.16	0.31
155	TCE	Q #1	20	14	2932455	499.32	0.0001702	0.0000578	194.28571	2.9428571			
158	TCE	Q #2	20	14	2871644	499.32	0.0001739	0.0000578	200.51761	3.0051761			
161	TCE	Q #3	20	14	3010119	499.32	0.0001658	0.0000578	186.69265	2.8669265	2.94	0.07	0.14

TABLE E-7

RELATIVE RESPONSE FACTORS (RRF): PCE

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

Std. Run	Compound	Std #	Real Day	FPT Day	AC	Conc.	RF	RFI	% change	RRF RF/RFI	AVG RRF	RRF S-Dev	RRF Range
3	PCE	A #1	1	0	1548967	77.88	0.0000501	0.0000485	3.3358624	1.0333586			
6	PCE	A #2	1	0	1251816	77.88	0.0000620	0.0000485	27.886865	1.2788686			
9	PCE	A #3	1	0	737029.3	77.88	0.0001053	0.0000485	117.17717	2.1717717	1.49	0.60	1.14
12	PCE	B #1	2	0	6267666	478.04	0.0000762	0.0000485	57.162150	1.5716215			
15	PCE	B #2	2	0	8958494	478.04	0.0000533	0.0000485	9.9560016	1.0995600			
21	PCE	B #4	2	0	8639270	478.04	0.0000553	0.0000485	14.018913	1.1401891	1.27	0.26	0.47
27	PCE	C #1	6	1	6644337	501.95	0.0000755	0.0000485	55.667702	1.5566770			
30	PCE	C #2	6	1	6374574	501.95	0.0000787	0.0000485	62.255340	1.6225534			
33	PCE	C #3	6	1	5376119	501.95	0.0000933	0.0000485	92.389468	1.9238946	1.70	0.20	0.37
36	PCE	D #1	7	2	6358455	501.95	0.0000789	0.0000485	62.666665	1.6266666			
39	PCE	D #2	7	2	4494256	501.95	0.0001116	0.0000485	130.14013	2.3014013			
42	PCE	D #3	7	2	5521987	501.95	0.0000909	0.0000485	87.307336	1.8730733	1.93	0.34	0.67
45	PCE	E #1	8	3	3968837	501.95	0.0001264	0.0000485	160.60749	2.6060749	2.61		
48	PCE	F #1	9	4	2519662	501.95	0.0001992	0.0000485	310.49500	4.1049500			
51	PCE	F #2	9	4	2862963	501.95	0.0001753	0.0000485	261.26958	3.6126958			
54	PCE	F #3	9	4	2880682	501.95	0.0001742	0.0000485	259.04993	3.5904993			
57	PCE	G #1	9	4	2477494	480.12	0.0001937	0.0000485	299.32536	3.9932536			
60	PCE	G #2	9	4	2307697	480.12	0.0002080	0.0000485	328.70714	4.2870714			
66	PCE	G #3	9	4	2928354	480.12	0.0001639	0.0000485	237.84378	3.3784378	3.83	0.35	0.91
72	PCE	H #1	10	5	2127407	501.95	0.0002359	0.0000485	386.18279	4.8618279			
75	PCE	H #2	10	5	3048527	501.95	0.0001647	0.0000485	239.50418	3.3950418			
78	PCE	H #3	10	5	3872934	501.95	0.0001296	0.0000485	167.06075	2.6706075	3.64	1.12	2.19
87	PCE	I #1	11	6	3604484	501.95	0.0001392	0.0000485	186.95055	2.8695055			
90	PCE	I #2	11	6	4226414	501.95	0.0001187	0.0000485	144.72488	2.4472488			
93	PCE	I #3	11	6	4486903	501.95	0.0001118	0.0000485	130.41457	2.3041457	2.54	0.29	0.57
96	PCE	J #1	12	7	4196797	501.95	0.0001196	0.0000485	146.45191	2.4645191			
99	PCE	J #2	12	7	4606322	501.95	0.0001089	0.0000485	124.44366	2.2444366			
102	PCE	J #3	12	7	5018682	501.95	0.0001000	0.0000485	106.09169	2.0609169	2.26	0.20	0.40
105	PCE	K #1	13	8	4889165	501.95	0.0001026	0.0000485	111.55119	2.1155119			
108	PCE	K #2	13	8	3118665	501.95	0.0001609	0.0000485	231.65109	3.3165109			
111	PCE	K #3	13	8	3711533	501.95	0.0001352	0.0000485	178.67424	2.7867424	2.74	0.60	1.20
114	PCE	L #1	14	9	4470768	501.95	0.0001122	0.0000485	131.34921	2.3134921			
120	PCE	L #2	14	9	4459313	501.95	0.0001125	0.0000485	131.94350	2.3194350			
123	PCE	L #3	14	9	4078443	501.95	0.0001230	0.0000485	153.60380	2.5360380	2.39	0.13	0.22
126	PCE	M #1	15	10	3650078	501.95	0.0001375	0.0000485	183.36618	2.8336618			
129	PCE	M #2	15	10	3636304	501.95	0.0001380	0.0000485	184.43955	2.8443955			
132	PCE	M #3	15	10	3529663	501.95	0.0001422	0.0000485	193.03326	2.9303326	2.87	0.05	0.10
135	PCE	N #1	16	11	3746695	501.95	0.0001339	0.0000485	176.05894	2.7605894	2.76		
141	PCE	O #1 DUP	17	12	3050616	501.95	0.0001645	0.0000485	239.04912	3.3904912			
144	PCE	O #2	17	12	3885813	501.95	0.0001291	0.0000485	166.17561	2.6617561	3.03	0.52	0.73
147	PCE	P #1	18	13	4490371	501.95	0.0001117	0.0000485	130.33924	2.3033924			
150	PCE	P #2	19	13	4407564	501.95	0.0001138	0.0000485	134.66673	2.3466673			
153	PCE	P #3	19	13	4189545	501.95	0.0001198	0.0000485	146.87852	2.4687852	2.37	0.09	0.17
156	PCE	Q #1	20	14	4391010	501.95	0.0001143	0.0000485	135.55142	2.3555142			
159	PCE	Q #2	20	14	4186262	501.95	0.0001199	0.0000485	147.07213	2.4707213			
162	PCE	Q #3	20	14	4467738	501.95	0.0001123	0.0000485	131.50611	2.3150611	2.38	0.08	0.16

TABLE E-8

AVERAGE RELATIVE RESPONSE FACTORS (RRF): AS GENERATED FROM cis-1,2-DCE, TCE and PCE for the QUANTIFICATION OF TARGET COMPOUNDS

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

Std #	Real Day	FPT Day	cis-1,2-DCE RRFs	TCE RRFs	PCE RRFs	AVG RRF	AVG RRF S-Dev
A	1	0	1.41	1.28	1.49	1.39	0.36
B	2	0	1.33	1.22	1.27	1.27	0.25
C	6	1	1.71	1.51	1.70	1.64	0.37
D	7	2	1.79	1.70	1.93	1.81	0.38
E	8	3	2.81	2.46	2.61	2.62	0.47
F,G	9	4	3.98	3.70	3.83	3.84	0.41
H	10	5	3.92	3.51	3.64	3.69	0.51
I	11	6	2.73	3.26	2.54	2.84	0.67
J	12	7	2.51	2.27	2.26	2.35	0.42
K	13	8	2.50	2.86	2.74	2.70	0.47
L	14	9	2.53	2.74	2.39	2.55	0.46
M	15	10	3.05	3.34	2.87	3.09	0.54
N	16	11	3.26	3.29	2.76	3.10	0.60
O	17	12	3.15	3.45	3.03	3.21	0.52
P	19	13	3.08	2.99	2.37	2.82	0.69
Q	20	14	2.97	2.94	2.38	2.76	0.64

It is likely that the changes in GC/PID sensitivity detected are due to the effects of the high levels of VOCs on the GC/PID detector over the duration of the test. Specifically, operation of the 11.7 eV PID lamp dictated GC/PID operating parameters such that detector temperature was set at a value below the final column ramp temperature utilized to achieve an operable sample run time for the purging of higher molecular weight compounds (toluene, PCE, xylenes). As a result, residual concentrations of these higher molecular weight compounds likely fouled the detector chamber causing the fluctuations in response which were observed in the field. However, *VAPEX* considers that the implementation of the procedures as specified above and as described in *VAPEX's* QA/QC plan and in Appendix E, ensured that the required level of Quality Assurance/Quality Control was achieved and that the corrected field data reflects the true parameter values that exist at the site.

b.3 Field GC/PID versus Laboratory Data Analysis
Significant differences were observed between the analytical data generated on site (with the GC/PID) and the data generated in the laboratory analysis off site.

A corresponding field GC/PID analysis was run for every VW-S and VW-D wellhead vapor discharge sample sent to the laboratory as a quality control check and in order to determine correlation between laboratory and field methods. Analysis of the laboratory and corresponding field GC/PID samples is presented in Table 4-1 for three major VOC constituents: 1,1,1-TCA, cis-DCE and TCE. Graphic representation of Table 4-1 is demonstrated in Figure 4-1.

As compared to field GC/PID analysis, the laboratory analysis detected the same predominant chemical compounds. However, the laboratory analysis demonstrated consistently lower quantification of the VOC constituents. For the three VOCs listed above, differences between field and laboratory results ranged from 10 percent to 76 percent for 1,1,1-TCA, 60 to 96 percent for cis-DCE and 55 to 92 percent for TCE.

VAPEX considers that the operation of the field GC/PID fulfilled the objectives of the project and that the data observed is of higher integrity than the laboratory data. The following factors support the use of the field GC/PID data.

-Sample integrity: Loss of sample during GC/PID sample transfer was minimized. *VAPEX* considers that this was the main reason for the consistently lower VOC levels detected in the laboratory analysis.

-Rapid turnaround time: GC/PID Results were obtained and quantified in minutes.

-Duplicates: Duplicates were analyzed quickly and cheaply.

All other GC/PID operating parameters were consistent with volatile organic analysis (VOA) such as found in EPA Methods 601/602 and 8010/8020.

b.4 Detection of Acetone, MEK, and Vinyl Chloride
VAPEX calibrated the field GC/PID for the detection of acetone. Although the acetone did not elute from the chromatographic column as a defined peak; its

TABLE 4-1

COMPARISON OF LABORATORY AND FIELD GC/PID RESULTS@
FOR THREE MAJOR VOC CONSTITUENTS IN VACUUM WELLHEAD
SOIL VAPOR DISCHARGE

VAPOR EXTRACTION TREATABILITY STUDY

HELEVA LANDFILL

Field Sample Name	Lab Sample Name	--- 111-TCA --- Field	Lab	% Diff*	--- cis-DCE --- Field	Lab	% Diff*	--- TCE --- Field	Lab	% Diff*
VW-S-3	VW-S-1	523	161	69	1642	140	91	5903	452	92
VW-S-10	VW-S-LAB2	502	120	76	1465	52	96	4035	457	89
VW-S-13	VW-S-LAB3	554	246	56	1551	272	82	4233	1180	72
VW-S-20	VW-S-LAB4	331	364	-10	936	373	60	3322	1480	55
VW-S-47	VW-S-LAB5	211	71.5	66	555	72	87	3042	1240	59
VW-D-18	VW-D-LAB1	171	107	37	581	125	78	2773	892	68
			Avg	49		Avg	83		Avg	73
			S-Dev	32		S-Dev	13		S-Dev	15
			Max	76		Max	96		Max	92
			Min	-10		Min	60		Min	55
			Range	86		Range	36		Range	37

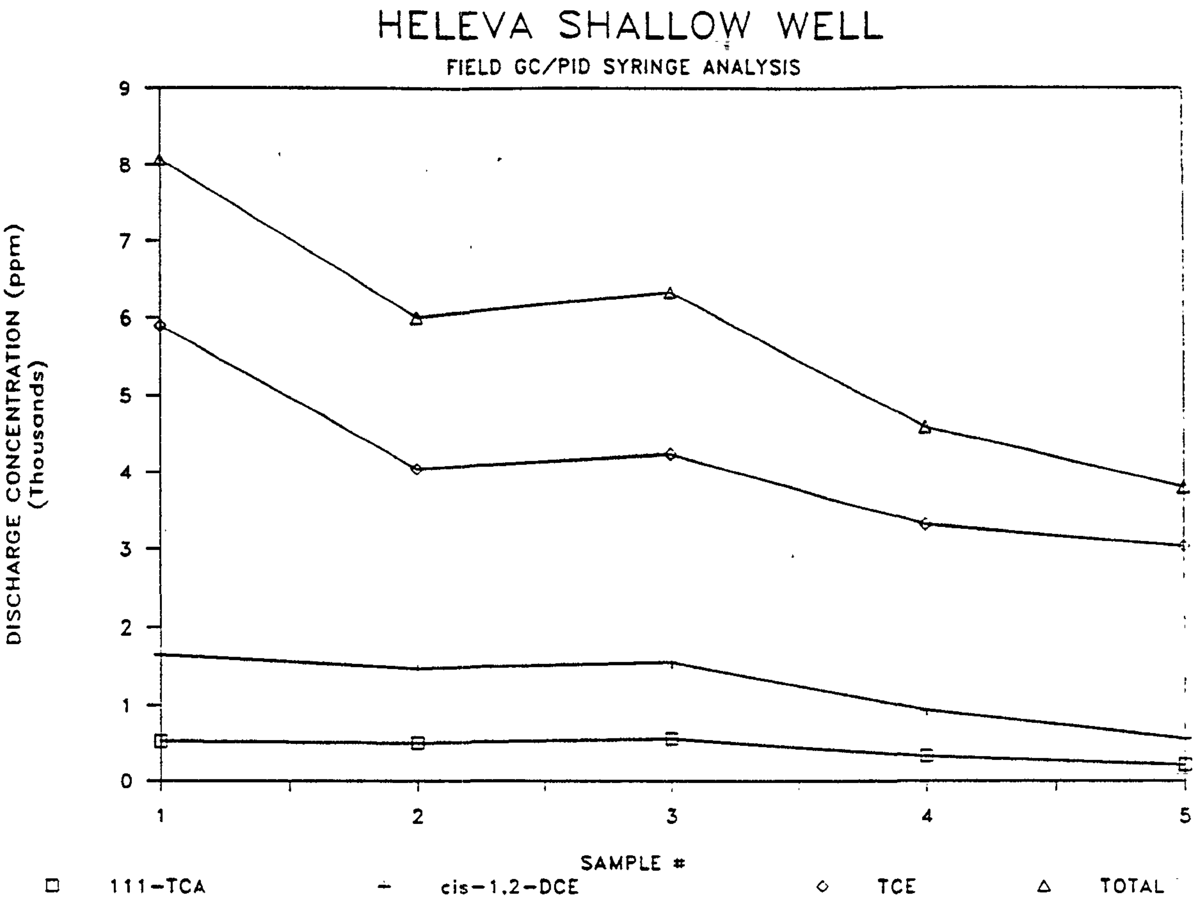
@ Samples analyzed with an HNU Model 321 Gas Chromatograph, equipped with an 11.7 eV photoionization detector (PID). All values reported in parts per million (ppm) on a volume per volume (vol/vol) basis

* Percent Difference defined as: ((field-lab)/field)x100

111-TCA 1,1,1-trichloroethane

cis-DCE cis-1,2-dichloroethylene

TCE trichloroethylene



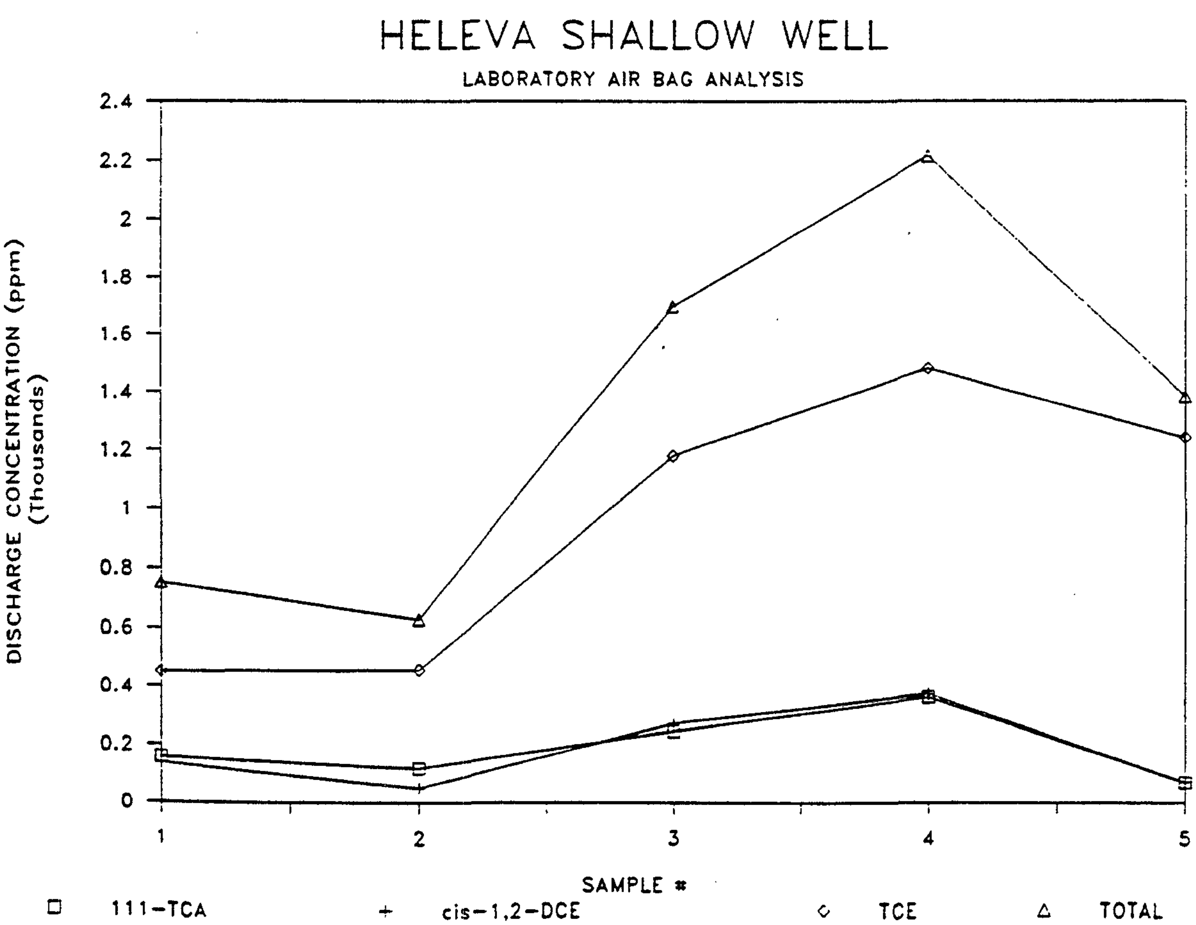


FIGURE 4-1

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presence was detectable.

MEK was not one of the VOCs targeted for standardization; however, *VAPEX* has detected and quantified MEK utilizing the GC/PID under similar operating conditions, at other sites.

Neither acetone nor MEK was detected in the soil gas discharge from VW-S and VW-D over the duration of the pilot test, within the GC/PID analysis. Although both acetone and MEK were detected in the soil samples analyzed by GF (MEK being present at levels below the specified closure limits) their absence from the soil gas is not unexpected. Acetone is miscible with water and MEK has a solubility in water of 353 grams per liter (at 10°C). This is reflected in the extremely low Henry's constant of both compounds of 3.97×10^{-5} Atm · m^3/mol (at 25°C) and 4.66×10^{-5} atm · m^3 /mol (at 25° C), respectively. Based on these physical/chemical properties, it would be expected that unless present in free phase, both acetone and MEK would be absent as a contaminant in the soil gas phase. Accordingly, removal of acetone and MEK, where present in a non free-phase form, will require the application of groundwater extraction and treatment techniques.

Vinyl chloride was detected in the laboratory analysis of soil gas samples from the test on VW-S (further qualification utilizing the GC/PID is ongoing, results will be included in the final report). Concentrations decreased from 393 ppm at the onset of the test to less than 0.1 ppm, 8 days into the test. Vinyl chloride is a gaseous compound and therefore its rapid loss from the system is expected.

4.1.3 Carbon Treatment/Usage

GC/PID and laboratory analysis of vapor samples taken from the outlet of the carbon treatment system indicated that no contaminant discharge to the atmosphere occurred. Based on an integration of the curves of contaminant discharge concentration over the duration of the project and on the treatment system configuration, it is estimated that carbon breakthrough and saturation capacities occur at approximately 10 percent and 20 percent by weight of contaminant loading, respectively.

4.2 DATA ANALYSIS AND MODELLING

4.2.1 Physical Conditions

a. Upper Soil Unit

a.1 Relative Intrinsic Permeability Values

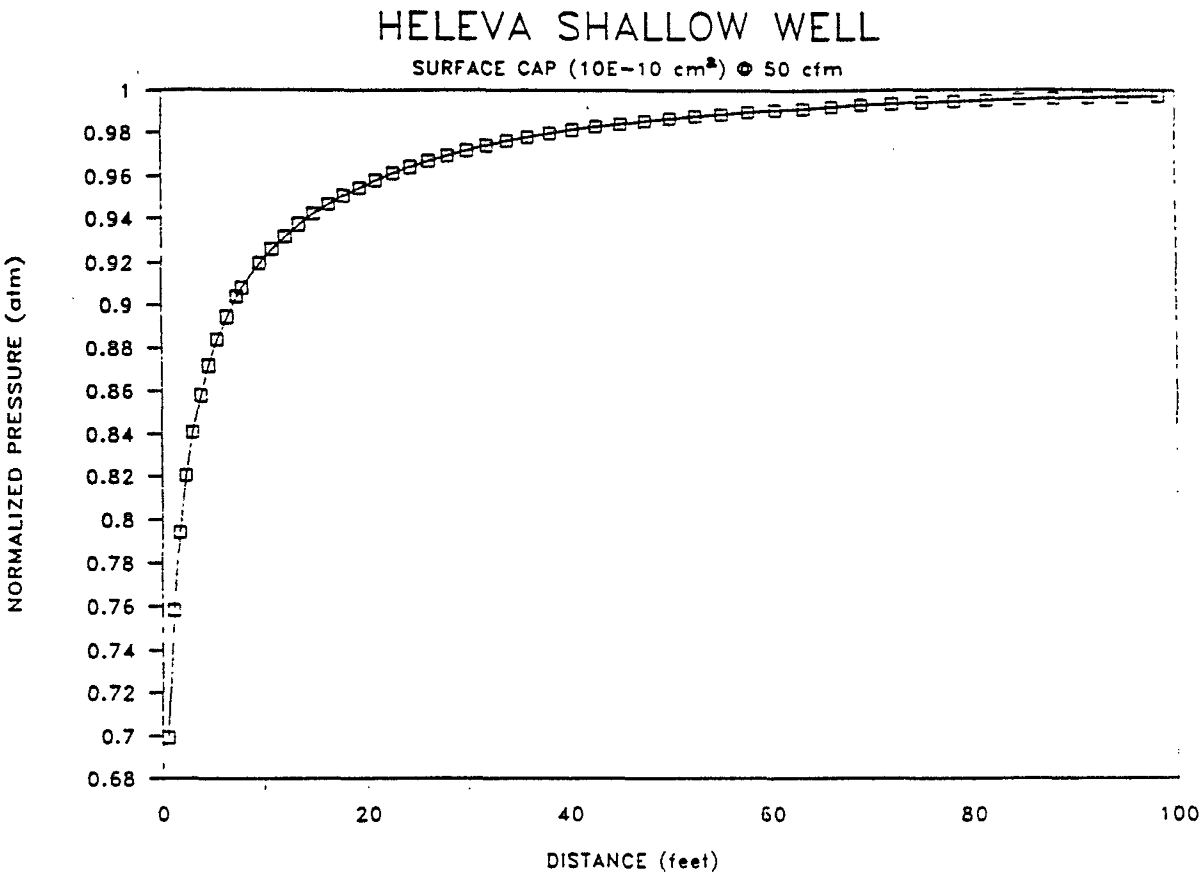
Calibration of the 2-D, radially symmetric form of the air flow equations with the steady state physical data obtained during the pilot tests, allowed determination of the horizontal (kr) and vertical (kv) intrinsic permeabilities for the upper soil unit at the test area; the calculated values were 2.29×10^{-8} cm^2 and 1.0×10^{-8} cm^2, respectively. Soils displaying an intrinsic air permeability value in this range are considered to be moderately permeable. In addition, the model provided an evaluation of the equivalent vertical intrinsic permeability of the boundary at the soil surface, the calculated value was 1.0×10^{-8} cm^2. The surface boundary condition is an important parameter in that it significantly influences the achievable radius of vacuum influence and the vacuum developed at the well. The value of the permeability of the surface boundary condition calculated for this test area indicates that the surface is relatively permeable and that significant air flow to the well from the atmosphere occurs within the near field of the well. Figures 3-3 and 3-4 present the calibration and verification plots comparing the model predictions of the vacuum pressure distribution with the measured field vacuum data, under the test flow conditions. The air flow modeling approach is validated by the positive correlation that exists between the measured and predicted vacuum distributions.

a.2 System Operating Parameters

The calibrated/verified air flow model was used to simulate system performance over the achievable range of air flow rates within the upper soil unit. The upper plot in Figure 3-5 presents the predicted vacuum pressure distribution over the range of flows from 7 cfm to 120 cfm. From the plot, it may be observed that at the maximum air flow rate of 120 cfm, the operating vacuum at the well is in excess of 18 inches of mercury; by reducing the design flow to 100 cfm, a more readily operable vacuum of less than 15 inches of mercury is predicted. Due to the significant mass of contaminants distributed within the upper soil unit, the most cost effective and highest practical flow rate is desirable; a 100 cfm design flow per well is therefore recommended. The lower plot in Figure 3-5 presents a blow-up of the pressure distribution curves in the region of the 1 atmosphere level. An effective radius of influence is defined based on client-specified objectives (cost, time to clean up, etc.), however, as a rule of thumb, a vacuum of approximately 0.9998-0.9999 may be used. From the lower plot in Figure 3-5 it can be observed that the effective radius of influence of the vacuum extraction well in the upper soil unit is in excess of 30 feet for the simulated air flow rates. An effective radius of influence of 50 feet at an air flow rate of 100 cfm is assumed in the full scale conceptual design.

As previously stated, the surface boundary condition can have a significant influence on the achievable air flow rates and on the effective radius of influence of a vacuum well. A decrease in the permeability of the surface boundary (e.g., capping) would increase the radius of influence; however, there would be a significant decease in the air flow rate from the well under the same operating vacuum.

Figure 4-2 presents plots of the predicted operating vacuum and pressure distribution for an extraction well in the upper soil unit under an operating air flow rate of 50 cfm, where the surface boundary is simulated as being capped. The upper and lower plots represent the operating conditions for caps having equivalent vertical intrinsic air permeabilities of 1.0×10^{-10} cm^2 and 1.0×10^{-12} cm^2, respectively. The plots demonstrate, as expected, the significant increase in the operating vacuum from 0.8 atm (uncapped) to 0.53 atm (1.0×10^{-12} cm^2 cap) and the significant increase in the effective radius of influence from 45 feet (uncapped) to greater than 100 feet (capped). The plots in Figure 4-2 end at a radial distance from the well of 100 feet. *VAPEX* considers that, in general, spacing extraction wells in excess of 200 feet on center has the potential to introduce significant reductions in remediation efficiency due to the potential of having significant variations in soil properties outside of this distance scale.


HELEVA SHALLOW WELL
SURFACE CAP (10E-10 cm²) @ 50 cfm
NORMALIZED PRESSURE (atm)
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
0.8
0.78
0.76
0.74
0.72
0.7
0.68
0
20
40
60
80
100
DISTANCE (feet)

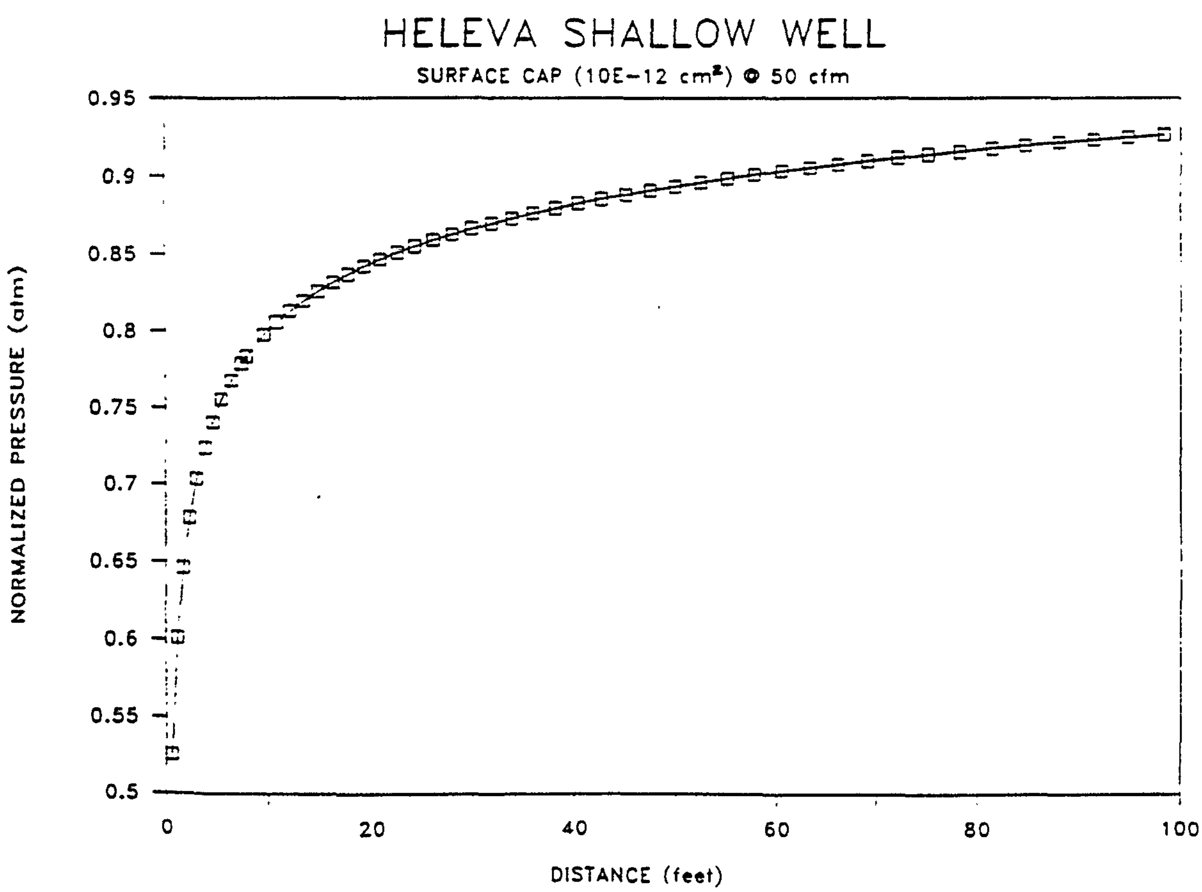

HELEVA SHALLOW WELL
SURFACE CAP (10E-12 cm²) @ 50 cfm
NORMALIZED PRESSURE (atm)
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0
20
40
60
80
100
DISTANCE (feet)

FIGURE 4-2

a.3 System Configurations
The configuration utilized in the pilot test in the upper soil unit represents a flexible and effective operating system. A significant effective radius of influence can be achieved at manageable air flow rates and operating vacuums. The significant permeability difference which exists between the upper and lower soil units necessitates the separate vacuum extraction well screen interval in the upper unit. Nesting of screen intervals within a soil unit allows an additional degree of flexibility in system performance. Section 4.4 provides further discussion of this issue.

The installation of passive and/or active air injection wells within the design of a vapor extraction system is more prevalent in low permeability soils or in a soil system which possesses a shallow vadose zone or a surface boundary which is significantly less permeable than the bulk of the soil unit. *VAPEX* considers that air injection will not effectively enhance overall vapor extraction system performance in the upper soil unit at this site.

b. Lower Soil Unit

b.1 Relative Intrinsic Permeability Values
Calibration of *VAPEX's* 2-D, radially symmetric form of the air flow equations with the steady state physical data obtained during the pilot tests allowed the determination of the horizontal (kr) and vertical (kv) intrinsic permeabilities for the lower soil unit at the test area; the calculated values were 3.9×10^{-10} cm^2 and 1.0×10^{-10} cm^2, respectively. Soils displaying an intrinsic air permeability value in this range are considered to have a low permeability approaching the limits considered effective for the application of vapor extraction technology. In addition, the model allowed determination of the equivalent vertical intrinsic permeability of the intermediate discontinuous boundary lens; the calculated value was 4.5×10^{-8} cm^2. Since the boundary lens appears discontinuous, it is important not to lend to great an emphasis on its significance. The value of the permeability of the boundary lens calculated for this test area indicates that the lens is relatively permeable and that significant air flow to the test well occurs within the near field of the well. Figures 3-6 and 3-7 present the calibration and verification plots comparing the model predictions of the vacuum pressure distribution with the measured field vacuum data under the test flow conditions. The air flow modeling approach is validated by the positive correlation that exists between the measured and predicted vacuum distributions.

b.2 System Operating Parameters
The calibrated/verified air flow model was used to simulate system performance over the achievable range of air flow rates within the lower soil unit. The upper plot in Figure 3-8 presents the predicted vacuum distribution over the range of flows from 2 cfm to 9 cfm. From the plot, it may be observed that at the maximum air flow rate of 9 cfm the operating vacuum at the well is in excess of 21 inches of mercury, by reducing the design flow to 7 cfm (the pilot test air flow rate) a more readily operable vacuum of less than 15 inches of mercury is predicted. Due to the significant mass of contaminants distributed within the lower soil unit, the most cost effective and highest practical air flow rate is desirable. Therefore, a 7 cfm design flow is recommended. The lower plot in Figure 3-8 presents a blow-up of the pressure distribution curves in the region of the 1 atmosphere level. An effective radius of influence is defined based on client specific objectives (cost,

time to clean up, etc.) however, as a rule of thumb, a vacuum of approximately 0.9998 to 0.9999 may be used. From the lower plot in Figure 3-8, it can be observed that the effective radius of vacuum influence does not change significantly with an increase in the air flow rate from the well. The effective radius of influence of the vacuum extraction well in the lower soil unit is 8 to 10 feet.

As previously stated the boundary conditions can have significant influence on achievable air flow rates and on effective radius of influence, however, capping of the ground surface would not have a significant impact on the lower soil unit due to the significant soil strata that exists between the lower unit and the ground surface.

b.3 System Configurations

Based on the limited achievable radius of influence and the significant levels of contaminants in the lower soil unit, air injection was considered as part of the full scale design. Simulations were performed to predict the operating pressures and pressure distribution in the lower soil unit under a range of air injection rates, as demonstrated in Figure 4-3. The upper plot in Figure 4-3 presents the predicted pressure distribution in the lower soil unit over a range of air injection rates from 20 to 70 cfm. From the plot, it may be observed that an operating pressure of up to 2.9 atm is predicted at the well. The lower plot in Figure 4-3 presents a blow-up of the pressure distribution curve in the region of the 1 atmosphere level. From this plot, a radius of influence of up to 13 feet is observed. Although the radius of influence is not substantially increased over the vacuum extraction case, the achievable air flow rates and hence contaminant removal potential is enhanced. If a configuration of wells in the deep soil unit consisting of alternating injection and extraction wells with the flexibility for reversal in well operation (i.e., extraction well may be used as injection wells and visa-versa) is assumed, an effective radius of influence of 12 to 13 feet at air flow rates of 7 cfm (extraction) and up to 70 cfm (injection) is achievable.

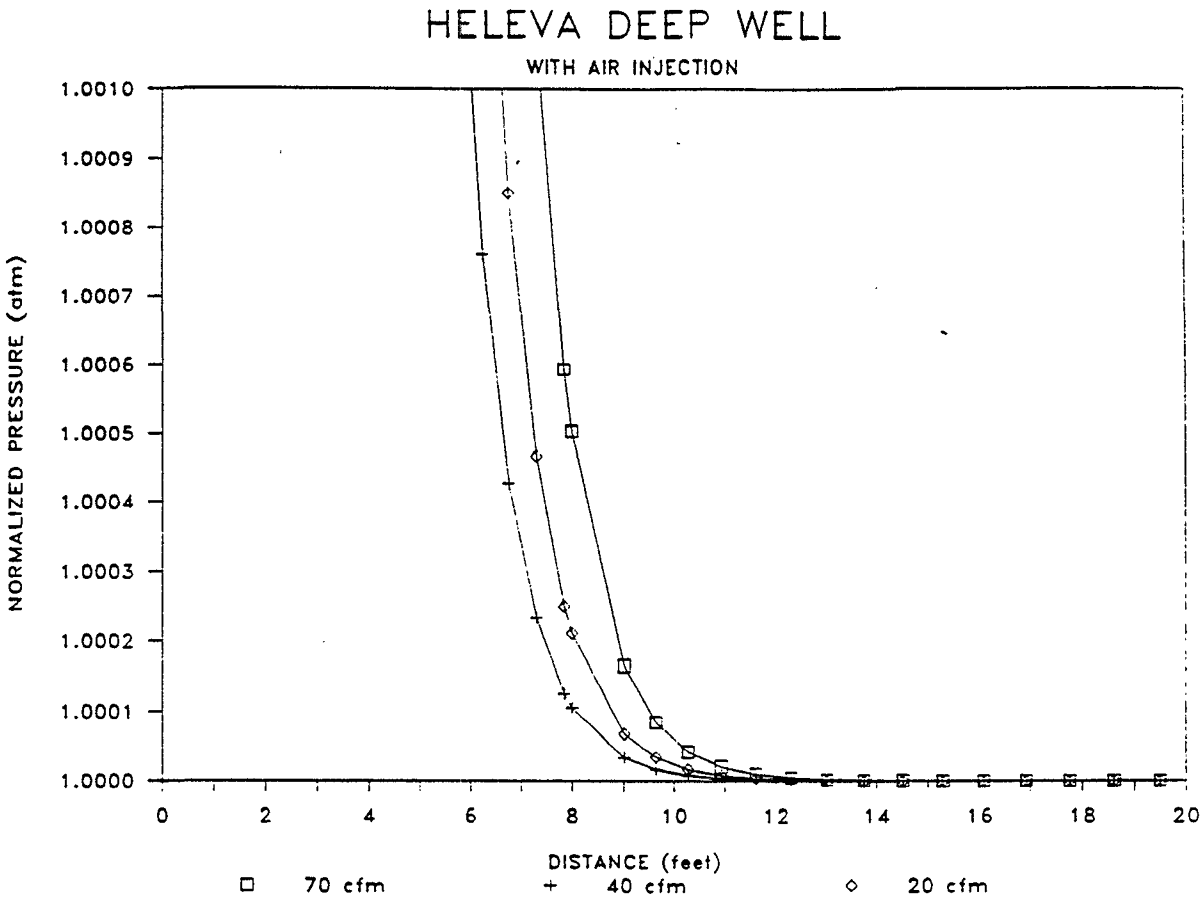
The significant permeability difference which exists between the upper and lower soil units necessitates the separate vacuum extraction well screen interval in the lower unit, further, nesting of screen intervals within a soil unit will allow an additional degree of flexibility in system performance. Section 4.4 provides further discussion of this issue.

4.2.2 Chemical Conditions

a. Shallow Well Test

As previously discussed, the change in contaminant discharge concentration levels recorded over the duration of the test on VW-S does not reflect the typical discharge curve recorded during the operation of a vapor extraction system. The discontinuity in the typical exponential decay (concentration peak) which occurs after approximately four days of operation is associated with the misplacement of the vacuum well with respect to the center of the local contaminant source.

For purposes of chemical modeling, *VAPEX* used the data from the occurrence of this concentration peak, to the conclusion of the test. Based on the chemical modeling techniques as discussed in Section 2.5.2, a theoretical plot was developed of total discharge concentration versus time, utilizing the pilot test air flow rate. This theoretical discharge plot represents the summation of the



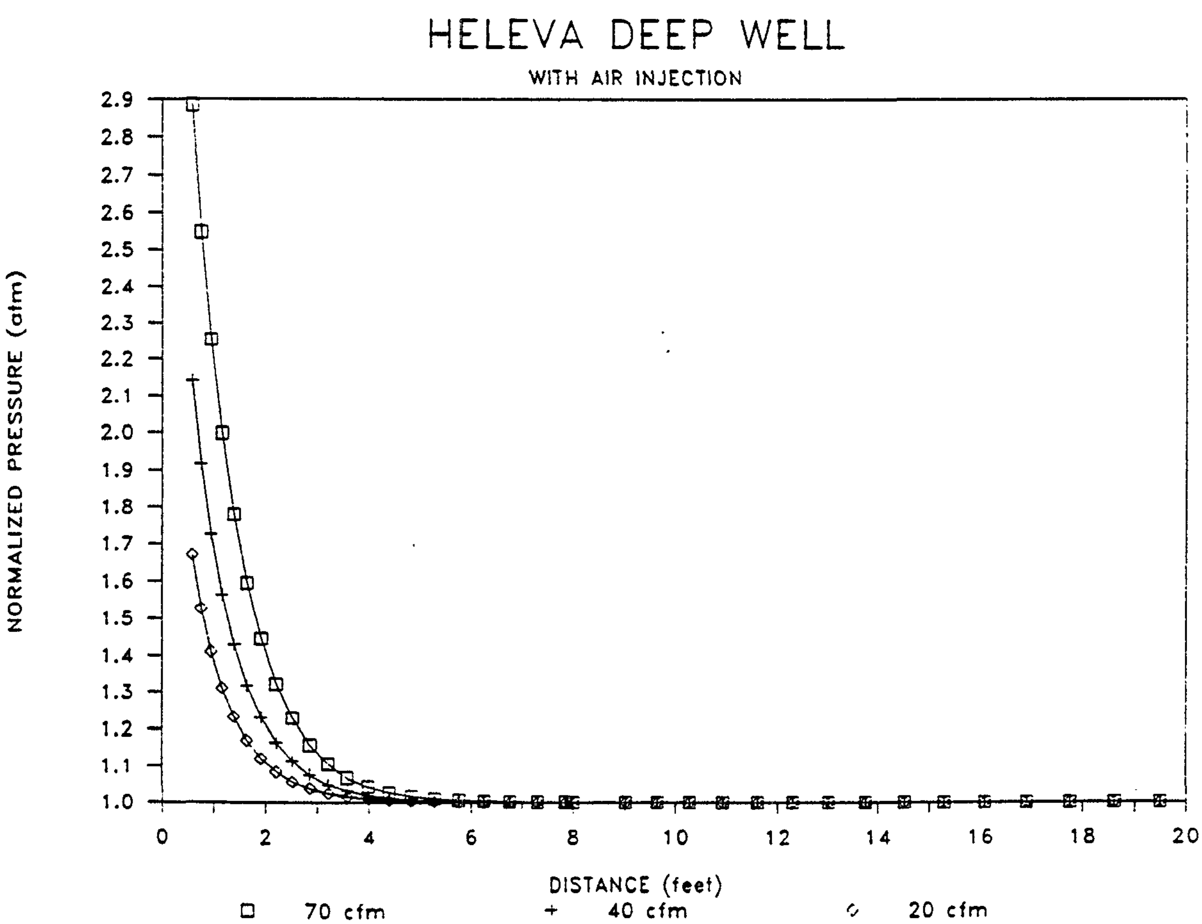


FIGURE 4-3

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discharge of ten individual compounds detected by GC/PID analysis during the test. The chemical data measured in the field was plotted on the same graph as the theoretical curve, Figure 3-9. The applicability of the chemical modeling approach is demonstrated by the positive correlation that exists between the measured and predicted discharge concentrations. To further demonstrate the applicability of the chemical model, the field recorded discharge concentrations of TCE and DCE where plotted on their respective theoretical discharge curves, Figures 3-10 and 3-11, respectively. The correlation observed between the measured and theoretical discharge concentration for TCE and DCE is good.

As described in Section 3.2.2.a, within the development of the theoretical model estimates of the initial mass of each compound present within the zone of influence of the test well were obtained. This mass of each compound present and the maximum mass of each compound allowed in the soil under the specified closure criteria are presented in Table 3-13. The quantities generated by the model generally agree with the concentrations derived from the analysis of the soil samples taken during the installation of the vacuum wells and vapor probes. The one exception is the 1,040 pound quantity of total xylenes predicted by the model, this may be due to the theoretical estimation method or simply the xylenes may not have been detected during the sampling analysis event.

The theoretical model was utilized in conjunction with both the model derived contaminant mass and the maximum expected contaminant mass (as derived from the GF data) to simulate the performance of the vapor extraction system in order to predict a range of times required to achieve the individual contaminant closure criteria as specified in the RFP. Three model simulations were performed; the first run simulated system performance (total and individual contaminant masses remaining, within the zone of influence of the test well, as a function of run duration) assuming an air flow rate of 13 cfm and the initial contaminant masses present as predicted by the model, the second run simulated system performance, utilizing the initial contaminant masses as predicted by the model, assuming the design air flow rate of 100 cfm, and the third run simulated system performance, utilizing the contaminant mass derived from the maximum contaminant concentrations in the soil as specified by GF, assuming the design air flow rate of 100 cfm. Figures 3-12, 3-13, and 3-14 present the theoretical plots of pounds of total contaminant and target contaminants remaining within the zone of influence of the test well as a function of time, for the three simulations described above. By comparison of the target individual closure limits as presented in Table 3-13 with the theoretical curves generated in Figures 3-12 through 3-14, an estimate of the range of time required to achieve the specified closure limits is obtainable. Table 4-2 presents the derived time required to reach the specified closure limits for both estimates of the initial pounds of contaminant present within the zone of influence of the test well, at the design air flow rate of 100 cfm.

At the pilot test air flow rate of 13 cfm, the target compounds chloroform and TCE are predicted to achieve closure criteria in approximately 30 and 200 days, respectively. As discussed previously, acetone and MEK are not expected to be removed in the soil gas. Theoretical estimates of the initial masses of total DCE and MC present were below the cleanup goal criteria as specified in Table 3-13. It should be noted that after 1,000 days of operation, 600 pounds of total VOC (non-target) are predicted to be remaining within the zone of influence of the test well.

TABLE 4-2

TIME TO REMEDIATE
VAPOR EXTRACTION TREATABILITY STUDY
HELEVA LANDFILL

WELL	FLOW	COMPOUND	REMEDIATION TIME	
			TEST	MAXIMUM
SHALLOW	100 cfm	ACETONE	NA	NA
	100 cfm	MEK	NA	NA
	100 cfm	CHLOROFORM	5	25
	100 cfm	TOTAL DCE	BRG	25
	100 cfm	MC	BRG	25
	100 cfm	TCE	30	80
	100 cfm	OTHER	130	210
DEEP	7 cfm	ACETONE	NA	NA
	7 cfm	MEK	NA	NA
	7 cfm	CHLOROFORM	3	30
	7 cfm	TOTAL DCE	BRG	20
	7 cfm	MC	BRG	10
	7 cfm	TCE	10	700
	7 cfm	OTHER	40	700+

REMEDIATION TIME IS IN UNITS OF DAYS

TEST — Remediation time based on chemical model derived quantities.

MAXIMUM — Remediation time based on GF maximum concentrations.

NA — Not applicable to chemical model derived from pilot test.

BRG — Chemical model quantified this compound below the remediation goal.

OTHER — Non-target VOC compounds identified during the test.

700+ — At 700 days 130 pounds of the other identified VOC compounds will be remaining.

MEK — 2-Butanone

TOTAL DCE — Combined cis and trans-1,2 Dichloroethene

MC — Methylene Chloride

TCE — Trichloroethene

At the design air flow rate of 100 cfm, the model predicted that the time to achieve the cleanup criteria for chloroform and TCE (utilizing model predicted initial masses) would be approximately 5 and 30 days, respectively. The remaining target compounds (with the exception of acetone and MEK) were predicted to be below the cleanup goal criteria as specified in Table 3-13. It should be noted that after approximately 130 days of operation the model predicts that, with the exception of acetone and MEK, the soil system within the zone of influence of the test well would be remediated.

At the design air flow rate of 100 cfm, utilizing the initial contaminant masses as specified in the RFP, the model predicted that the approximate time of cleanup for chloroform, DCE, and MC was within 25 days. The time to achieve the cleanup goal for TCE is predicted to be approximately 80 days. It should be noted that after approximately 210 days of operation, the model predicts that with the exception of acetone and MEK, remediation of the soil within the zone of influence of the test well should have been achieved.

b. Deep Well Test

Based on the chemical modeling techniques as discussed in Section 2.5.2, a theoretical plot was developed of total discharge concentration versus time utilizing the pilot test air flow rate. This theoretical discharge plot represents the summation of the discharge concentration of ten individual compounds detected by GC/PID analysis during the test. The chemical data measured in the field was plotted on the same graph as the theoretical curve, Figure 3-15. The applicability of the chemical modeling approach is demonstrated by the positive correlation that exists between the measured and predicted discharge concentrations. As a further demonstration of the applicability of the chemical model, the field recorded discharge concentrations of TCE and DCE where plotted on their respective theoretical discharge curves, Figures 3-16 and 3-17, respectively. The correlation observed between the measured and theoretical discharge concentration for TCE is good, while the theoretical discharge curve for DCE is considered to reflect the measured field data within an acceptable range.

As described in Section 3.2.2.a, within the development of the theoretical model estimates of the initial mass of each compound present within the zone of influence of the test well were estimated. Further, the maximum expected contaminant masses as derived from the concentration levels in the lower soil unit was provided by GF in the RFP. The mass of each compound present and the maximum mass of each compound allowed in the soil under the specified closure criteria are presented in Table 3-13. The quantities generated by the model generally agree with the concentrations derived from the analysis of the soil samples taken during the installation of the vacuum wells and vapor probes.

The theoretical model was utilized to extrapolate the performance of the vapor extraction system to predict the range of times required to achieve the closure criteria as specified in the RFP. Two model simulations were performed; the first run simulated system performance (total and individual contaminant masses remaining, within the zone of influence of the test well, as a function of run duration) assuming an air flow rate of 7 cfm and the initial contaminant masses present as predicted by the model, and the second run simulated system performance, utilizing the contaminant mass derived from the maximum contaminant concentrations in the soil as specified by GF, assuming the design air flow rate of 7 cfm. Figures 3-18, 3-19 present the theoretical plots of pounds of total contaminant and target contaminants remaining within the zone of influence of the test well as a function of time, for the two simulations described above. By comparison of the target individual closure limits, as presented in Table 3-13, with the theoretical curves generated in Figures 3-18 and 3-19, an estimate of the range of time required to achieve the specified closure limits is obtainable. Table 4-2 presents the derived time required to reach the specified closure limits for both estimates of the initial pounds of contaminant present within the zone of influence of the test well, at the design air flow rate of 7 cfm.

At the pilot test air flow rate of 7 cfm, utilizing the initial masses as predicted by the theoretical model, the target compounds chloroform and TCE would achieve closure criteria in approximately 3 and 10 days, respectively. As discussed previously, acetone and MEK are not expected to be removed in the soil gas. Theoretical estimates of the initial masses of total DCE and MC present were below the cleanup goal criteria as specified in Table 3-13. It should be noted that after 40 days of operation, total VOCs (with the exception of acetone and MEK) are predicted to be removed from within the zone of influence of the test well.

At the design air flow rate of 7 cfm, utilizing the initial contaminant masses as specified in the RFP, the model predicted that the approximate time of cleanup for chloroform, DCE, and MC was within 30 days. The time to achieve the cleanup goal for TCE is predicted to be 700 days. It should be noted that after approximately 700 days of operation, the model predicts that (with the exception of acetone and MEK), approximately 130 pounds of non-target VOC would remain within the zone of influence of the test well.

4.3 Vacuum Extraction Effectiveness

Based on analysis of the data developed during the conduct of the vapor extraction treatability study at the Heleva Landfill site, *VAPEX* considers that vacuum extraction is a feasible and effective remediation technology for the remediation of VOC contaminants (with the exception of acetone and MEK) from the subsurface vadose zone soils. During the conduct of the ten day pilot test on VW-S approximately 450 pounds of total VOC (predominantly TCE) was removed from the shallow soil zone. During the four day pilot test on VW-D approximately 50 pounds of total VOC (predominantly TCE) was removed from the deep soil zone.

The soil types in the study area ranged from loose silty gravels to dense silts. A review of the available boring logs outside of the study area indicate that the soils on the remainder of the site display similar physical characteristics and are likely to behave, with respect to vapor extraction, in a manner similar to that observed during the treatability study.

Within the landfill, vacuum extraction is expected to be an effective remediation technology due to the more permeable nature of typical landfilled material. However, achievable air flow rates, zones of influence and air flow paths will vary significantly depending on the nature of the landfilled material, the landfill cell configuration, and cover material characteristics.

Soils presently located below the water table level may have significant sorbed concentrations of VOCs which would be difficult and costly to remediate utilizing standard groundwater treatment methodologies. However, it is likely that focused dewatering can expose these contaminated soils allowing the potential application of vacuum extraction technology.

4.4 Full Scale Conceptual Design

The full scale conceptual design is presented under the assumption that the soil properties and contaminant composition and distribution are relatively homogeneous throughout the areas of the Heleva Landfill Site designated for remediation, as specified by GF. It is more realistic to assume that within the designated remediation areas, localized high level and low level contamination areas and varying soil conditions will exist. Where these conditions are observed in the field, it is important to consider diverging from the conceptual design with particular respect to the spacing of the wells, the use of air injection points, and the prediction for time to achieve the specified closure limits.

Utilization of air injection wells within the deeper soil units at the Heleva Site would tend to increase the effective radius of influence of the well point (as presented in Section 4.2) and enhance VOC removal through the higher air flow rates achievable within the soil system. However, preliminary estimates indicate that the relative costs associated with the air injection are significant. Further, the application of air injection will act to transfer the deep soil unit contaminants into the capture zone of the shallow soil unit vapor extraction wells and would act to prolong the period of operation of the shallow wells. Assuming field observations made during the full scale installation will demonstrate variations in soil properties and contaminant composition and distribution, it is expected that the utilization of air injection points, within localized areas, may be warranted to enhance the remediation of the deeper soil units.

In the presence of relatively small scale heterogeneity in soils (as displayed at the Heleva Site), it is good practice to use extraction wells with maximum screened intervals in the order of ten feet. This requires nesting of screened intervals within each soil unit at the Heleva Site. Maintaining a maximum screen length of approximately ten feet will maximize clean up efficiency by maximizing the flexibility in system operation and by minimizing the short circuiting effects of local, higher permeability lens.

Groundwater drawdown of the deep soils overlying the bedrock will be required to achieve effective operation of vapor extraction technology in this zone. From a review of the boring logs, it is anticipated that the vapor extraction system will operate under similar conditions to the overlying deep soil unit tested during the treatability study. Cost savings may be achieved in the full scale installation and operation by incorporating into the system design the flexibility to utilize the deep wells in an air injection, vacuum extraction and/or dewatering mode. It is expected that dewatering efficiency will be enhanced under vacuum conditions and reduced under pressure conditions.

In general, the treatability test demonstrated that the physical performance of vacuum extraction within the study area varied significantly depending on the physical properties of each soil unit. This performance variation points out the need for strata specific vacuum extraction wells. Thus, the conceptual design is presented in terms of a shallow system, a deep system, and a "soils above bedrock" system. The shallow system covers the soil interval from the ground surface to a depth of approximately 25 feet below ground surface. The deep system covers the soil interval from a depth of approximately 25 feet to 45 feet below ground surface. The soils above bedrock system covers a depth of approximately 45 feet to 65 feet below ground surface under the assumption that soil dewatering will occur.

The remediation area for each system was established from a series of TCE isoconcentration maps (using 10 foot depth intervals) for subsurface soils prepared by GF. As directed by GF, the extent of the remediation area was assumed to be defined by the 1,000 ppb TCE contour. The remediation area for each system incorporates the maximum combined area within the 1,000 ppb TCE contours for each of the isoconcentration maps within the appropriate depth interval. The assumed remediation areas for the three systems are depicted in Figures 4-4, 4-5, and 4--6, respectively.

4.4.1 Shallow System

The full scale shallow vacuum extraction well system will be installed in a similar manner to the shallow test well (VW-S). The predicted effective radius of influence for a shallow well is 50 feet, hence the well spacing will be 100 feet on center. The shallow system remediation area covers an area of approximately 62,500 square feet. A total of 11 shallow extraction wells will be required to remediate the shallow vadose zone of the specified area. Figure 4-4 presents a conceptual configuration of the vacuum wells within the designated remediation area.

The system hardware required for the shallow well system will be similar to that used during the pilot study. The vacuum pump system will be required to produce an air flow rate of 100 cfm at an operating vacuum of 15 inches of mercury at each extraction well.

4.4.2 Deep System

The full scale deep vacuum extraction well system will be installed in a similar manner to the deep test well (VW-D). The predicted effective radius of influence for a deep extraction well is 8 to 10, hence the well spacing will be approximately 20 feet on center. The deep system remediation area covers an area of approximately 65,500 square feet. A total of 156 deep extraction wells will be required to remediate the deep vadose zone of the specified area. Figure 4-5 presents a conceptual configuration of vacuum wells within the designated remediation area.

In observed high level contamination areas, to focus air flow and to enhance remediation, a system of additional injection wells should be considered. Air injection wells would be expected to have an effective radius of influence of approximately 10 to 12 feet in the deep soils. As described above, each well should be constructed such that it may operate as either an injection or extraction well.

The system hardware required for the deep well system will be similar to that used during the pilot study. The vacuum pump system will be required to produce an air flow rate of 7 cfm at an operating vacuum of 15 inches of mercury at each extraction well. The air injection equipment (if required) for each deep well must be capable of providing up to 70 cfm cfm air flow at a pressure of 50 psi.

4.4.3 Soils Above Bedrock System

The full scale soils above bedrock vacuum extraction well system will be installed in a similar manner to the test wells with the exception that it will be screened over a deeper interval. The predicted effective radius of influence for an extraction well in dewatered soils is 8 to 10 feet, hence the well spacing will be approximately 20 feet on center. The soils above bedrock system remediation area covers an area of approximately 122,500 square feet. A total of 306 extraction wells will be required to remediate the soils above bedrock (following dewatering) in the specified areas. Figure 4-6 presents a conceptual configuration of vacuum wells within the designated remediation area.

In observed high level contamination areas, to focus air flow and to enhance remediation, a system of additional injection wells should be considered. Air injection wells would be expected to have an effective radius of influence of 10 to 12 feet in the dewatered soils. As described above, each well should be constructed such that it may operate as either an injection or extraction well.

The system hardware required for the soils above bedrock system will be similar to that used during the pilot study. The vacuum pump system will be required to produce an air flow rate of 7 cfm at an operating vacuum of 15 inches of mercury at each extraction well. The air injection equipment (if required) for each well must be capable of providing up to 70 cfm air flow at a pressure of 50 psi.

4.4.4 Air Controls

It is anticipated that, in accordance with PADER requirements, air control equipment will be required for treatment of the vapor discharge from each of the vacuum extraction systems. During the treatability study, vapor phase carbon was found to be effective in providing air emission controls for all of the VOCs identified during the test. The amount of carbon required for the full scale systems will be directly related to the amount of VOC to be removed by each system.

Quantities of VOC in the soil within each remediation area were estimated by GF by extrapolation of the TCE isoconcentration maps discussed in Section 4.4. The GF estimates of the total amount of VOC present within each remediation area are 2,750 pounds in the shallow system area, 2,570 pounds in the deep system area, and 5,544 pounds in the soils above bedrock remediation area

Based on these VOC quantities, it is estimated that the total amount of carbon required for the shallow system will be approximately 27,500 pounds, based on an adsorption capacity of 10% by weight. The total amount of carbon required for the deep system and the soils above bedrock system will be approximately 25,700 and 55,440 pounds, respectively. It is anticipated that carbon requirements of this magnitude will warrant the consideration of the application of on-site regeneration techniques as opposed to off site regeneration and/or disposal.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Effectiveness

5.1.1 Shallow Zone
Vacuum extraction is an effective remediation technology for VOC removal within the shallow vadose zone (0 to 25 feet below grade) at the test area. Over the duration of the pilot test the total VOC removal rate ranged from approximately 70 pounds per day at the beginning of the test to 20 pounds per day at the end of the test. Target compounds Acetone and MEK were not detected in the discharge soil gas and are not expected to be effectively remediated utilizing vapor extraction technology.

5.1.2 Deep Zone
Vacuum extraction is an effective remediation technology for VOC removal within the deep vadose zone (25 to 45 feet below grade) of the test area. Over the duration of the pilot test, the total VOC removal rate ranged from approximately 20 pounds per day at the beginning of the test to 10 pounds per day at the end of the test. A total of 50 pounds of VOCs were removed over the four day test period. Target compounds Acetone and MEK were not detected in the discharge soil gas and are not expected to be effectively remediated utilizing vapor extraction technology.

5.1.3 Soils Above Bedrock (45 to 65 feet)
Based on the pilot tests performed by *VAPEX* in the study area and on a review of soil data from other locations within the Heleva site, vacuum extraction is considered to be an effective technology for the remediation of contaminated soils overlying the bedrock throughout the Heleva landfill site. Vacuum extraction coupled with ground water dewatering would also be effective at removing VOC adsorbed onto the soils presently below the water table level.

5.2 Effective Radius of Influence

5.2.1 Shallow Zone
In the study area, the shallow vacuum extraction well has an effective radius of vacuum influence of approximately 50 feet at the assumed design air flow rate of 100 cfm.

5.2.2 Deep Zone
In the study area, the deep vacuum extraction well has an effective radius of vacuum influence of approximately 8 to 10 feet at the assumed design air flow rate of 7 cfm. An effective radius of influence of 10 to 12 feet under air injection conditions is assumed at air injection rates of up to 70 cfm.

5.2.3 Soils Above Bedrock (45 to 65 feet)
Based on the pilot tests performed by *VAPEX* in the study area, and a review of soil data from other locations within the Heleva site, an effective radius of influence of the same magnitude as displayed in the deep zone is anticipated for the soils above the bedrock.

5.3 Operating Parameters

5.3.1 Shallow Zone

A shallow vertical vacuum extraction well (nested) installed to a depth of 25 feet is expected to remediate a volume of soil 100 feet in diameter over the 25 foot depth. The shallow vadose zone well should be capable of operating at an extraction rate of 100 cfm, at an operating vacuum of 15 inches of mercury. The maximum total discharge rate expected is 100 pounds of VOC per day.

5.3.2 Deep Zone

A deep vertical vacuum extraction well (nested) installed from a depth of 25 to 45 feet is expected to remediate a volume of soil 16 to 20 feet in diameter over a 20 foot depth. The deep vadose zone well should be capable of operating at an extraction rate of 7 cfm, at an operating vacuum of 15 inches of mercury. The maximum total discharge rate expected is 20 pounds of VOC per day. Where applicable, an air injection rate of up to 70 cfm at 50 psi pressure is warranted.

5.3.3 Soils Above Bedrock (45 to 65 feet)

Based on the pilot tests performed by *VAPEX* in the study area and a review of soil data from other locations within the Heleva site, it is expected that vacuum extraction systems can be installed and operated in the soils overlying the bedrock throughout the site at flow rates and configurations as described for the deep zone above.

5.4 Full Scale System Configuration

5.4.1 Shallow Zone

The conceptual full scale vapor extraction system for the shallow zone should consist of nested vertical extraction wells installed to a 25 foot depth spaced at 100 foot on center. Eleven shallow extraction wells will be required to achieve vacuum influence over the shallow zone of the remediation area identified by GF (approximately 57,870 cubic yards of soil). A total extraction air flow rate of 1,100 cfm will be required at an expected operating vacuum of 15 inches of mercury.

5.4.2 Deep Zone

The conceptual full scale vapor extraction system for the deep zone should consist of vertical extraction wells (nested) screened over an interval between 25 and 45 feet below surface grade or to within three feet of the water table. The wells should be spaced 20 feet on center. A total of 156 extraction wells will be required to achieve vacuum influence over the deep zone remediation area identified by GF (approximately 48,519 cubic yards of soil). Each well may be designed to allow operation under both extraction and injection conditions. A total extraction air flow rate of approximately 1,100 cfm at an anticipated operating vacuum of approximately 15 inches of mercury will be required. Where applicable, an injection air flow rate of approximately 70 cfm at an operating pressure of 50 psi will be required at each designated injection well point.

5.4.3 Soils Above Bedrock Zone

The conceptual full scale vapor extraction system for the soils above bedrock zone should consist of vertical extraction wells (nested) screened over an interval between 45 and 65 feet below surface grade or to within three feet of the depressed water table. The wells should be spaced 20 feet on center. A total of 306 extraction wells will be required to achieve vacuum influence over the soils above bedrock zone remediation area identified by GF (approximately 90,741 cubic yards of soil). Each well may be designed to allow operation under both extraction and injection conditions. A total extraction air flow rate of approximately 2,150 cfm at an anticipated operating vacuum of approximately 15 inches of mercury will be required. Where applicable, an injection air flow rate of approximately 70 cfm at an operating pressure of 50 psi will be required at each designated injection well point.

5.4.4 Air Controls

Activated vapor phase carbon was demonstrated to be effective in removing all VOCs detected during the conduct of the pilot test. Based on total VOC quantities determined by GF, it is estimated that a total of 27,500 pounds of carbon will be required for the shallow system, 25,700 pounds will be required for the deep system, and 55,440 pounds of carbon will be required for the soils above bedrock system.

5.5 Remediation Time

5.5.1 Shallow Zone

It is estimated that the time to achieve the closure criteria in the soils in the shallow zone will vary from 130 to 210 days based on the chemical modeling in the test area. Based on the uncertainty associated with the estimation techniques and in consideration of the uncertainty as to the actual quantities and distribution of VOCs in vadose zone soils, a reasonable estimate for the time to achieve the closure criteria in the shallow vadose zone in the areas designated by GF is one year.

5.5.2 Deep Zone

It is estimated that the time to achieve the closure criteria in the soils in the deep zone will vary from 40 to 700 days based on the chemical modeling in the test area. Based on the uncertainty associated with the estimation techniques and in consideration of the uncertainty as to the actual quantities and distribution of VOCs in vadose zone soils, a reasonable estimate for the time to achieve the closure criteria in the deep vadose zone in the areas designated by GF is two years. The remediation time may be vary substantially in those areas within the designated cleanup area where contamination is present at significantly different levels than those utilized in the modelling process.

5.5.3 Soils Above Bedrock Zone

Due the difficulty and unpredictability of dewatering the soils in the zone overlying the bedrock, an estimate of the time to cleanup of three to five years is warranted for this zone.

5.6 Estimated Costs

The estimated costs to install and operate a full scale vapor extraction system for the shallow, deep, and soil above bedrock zones are summarized below. Separate costs are presented for each area. It may be possible to achieve economies by combining certain aspects of each system. It is assumed that all manifold piping will be installed above grade. A detailed breakdown of the cost estimates for each system, including assumptions and unit prices, is provided in Appendix F.

5.6.1 Shallow System

Capital and Equipment Costs

A.	**Vacuum Extraction System**		
	Vacuum Well Installation	$94,230	
	Well Manifolding	$60,029	
	Vacuum Equipment	$132,480	
	Equipment Staging Areas	$100,000	
	Sub Total Capital Costs	$386,739	
B.	**Air Control Equipment**		
	Carbon With Offsite Regen	$192,500	
	Cannisters	$40,000	
	Sub Total Air Controls	$232,500	
	Sub Total Capital and Equipment	$619,239	
	Contingency at 20%	$123,848	
Total Capital and Equipment			$743,086
C.	**Operation and Maintenance**		
Monthly Costs			
	Electric	$5,569	
	Operator/Maintenance	$7,900	
	Analytical	$3,000	
	Reporting/Oversight	$1,300	
		$17,769	
	Sub Total Annual O & M	$213,225	
	Contingency @ 20%	$41,645	
Total Annual O & M			$255,870
D.	**Demobilization**		
	Allowance	$50,000	
Total Demobilization			$50,000
NET PRESENT VALUE assuming 1 year of O&M and 5% discount rate			$991,613
Estimated Cost Per Cubic Yard			$17 per yard

5.6.2 Deep System

Capital and Equipment Costs

A.	**Vacuum Extraction System**		
	Vacuum Well Installation	$1,836,207	
	Well Manifolding	$1,001,490	
	Vacuum Equipment	$255,280	
	Equipment Staging Areas	$200,000	
	Sub Total Capital Costs	$3,292,977	
B.	**Air Control Equipment**		
	Carbon With Offsite Regen	$179,900	
	Cannisters	$40,000	
	Sub Total Air Controls	$219,900	
	Sub Total Capital and Equipment	$3,512,877	
	Contingency at 20%	$702,575	
Total Capital and Equipment			$4,215,453

C.	**Operation and Maintenance**		
Monthly Costs			
	Electric	$5,528	
	Operator/Maintenance	$7,900	
	Analytical	$3,000	
	Reporting/Oversight	$1,300	
		$17,728	
	Sub Total Annual O & M	$212,736	
	Contingency @ 20%	$42,547	
Total Annual O & M			$255,283
D.	**Demobilization**		
	Allowance	$100,000	
Total Demobilization			$100,000
NET PRESENT VALUE assuming 2 year of O&M and 5% discount rate			$4,254,091
Estimated Cost Per Cubic Yard			$88 per yard

5.6.3 Soils Above Bedrock System

Capital and Equipment Costs

A.	**Vacuum Extraction System**	
	Vacuum Well Installation	$4,293,516

Well Manifolding	$1,954,365	
Vacuum Equipment	$462,280	
Equipment Staging Areas	$200,000	
Sub Total Capital Costs	$6,910,161	
B. Air Control Equipment		
Carbon With Offsite Regen	$388,080	
Cannisters	$40,000	
Sub Total Air Controls	$428,080	
Sub Total Capital and Equipment	$7,338,241	
Contingency at 20%	$1,467,648	
Total Capital and Equipment		$8,805,889
C. Operation and Maintenance		
Monthly Costs		
Electric	$10,844	
Operator/Maintenance	$7,900	
Analytical	$3,000	
Reporting/Oversight	$1,300	
	$23,044	
Sub Total Annual O & M	$276,528	
Contingency @ 20%	$55,306	
Total Annual O & M		$331,834
D. Demobilization		
Allowance	$100,000	
Total Demobilization		$100,000
NET PRESENT VALUE assuming 5 year of O&M and 5% discount rate		$9,825,875
Estimated Cost Per Cubic Yard		$108 per yard

5.7 Recommendations

Based on the findings of this report and *VAPEX's* experience, the following recommendations are made:

1. Vacuum extraction should be utilized as a remediation technology to remediate VOCs from vadose zone soils at the Heleva Landfill site.

2. The shallow vacuum extraction system should be installed and operated prior to the installation and operation of the deep and soil above bedrock system for the following reasons. First, the installation and operation of the shallow system will allow for identification of the more highly contaminated areas and for debugging of the full scale system operating parameters. Second, the shallow soils are projected to achieve closure criteria within one year, whereas the deep soils and soils above bedrock may require two to five years, hence the overall project may be extended by only one year while valuable operating knowledge is gained. Third, the operating equipment used for both the shallow and the deep systems are similar and savings in capital costs could be achieved by utilizing the same equipment for the shallow and the deep systems.

3. Vapor extraction under dewatering conditions is not as yet a widely applied remediation technique. *VAPEX* considers that should a combined dewatering vapor extraction system be considered as an option at the Heleva site, a pilot test on this system configuration should be performed in order to develop full scale design criteria.

6.0 REPORT PREPARATION AND REVIEW

The report presented above was prepared and reviewed by *VAPEX*. The report was prepared by Peter E. Nangeroni, Michael C. Marley, and Bruce L. Cliff.

VAPEX ENVIRONMENTAL TECHNOLOGIES, INC.

Peter E. Nangeroni
Project Manager

Michael C. Marley
Project Technical Director

Bruce L. Cliff, P.E.
Senior Project Engineer

AR303257

APPENDIX E

REPORT ON THE RESULTS OF THE VACUUM

EXTRACTION TREATABILITY STUDY--APPENDICES

APPENDIX E

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REPORT ON THE RESULTS OF THE
VACUUM EXTRACTION TREATABILITY STUDY--APPENDICES

APPENDIX A

BORING LOGS

Gannett Fleming ENGINEERS AND PLANNERS

BORING LOG

PROJECT/LOCATION	Heleva Landfill
GEOLOGIST/ENGINEER	Rynearson / Lewis
DRILLING CONTRACTOR	Empire Soils Investigations, Inc.
DRILLER	Paul Keeney
RIG TYPE	Acker AD-2
DRILLING METHOD	4¼" ID HS Auger
SURFACE ELEVATION	460
TOTAL DEPTH OF HOLE	
GROUNDWATER OBSERVATIONS (Date, Time, Level)	
BORING NO.	GBH-36
PROJECT NO.	26056
DATE STARTED	2/06/90
DATE FINISHED	

DEPTH	SAMPLE NO. & TYPE	BLOWS OR RQD	% RECOVERY	LEGEND	DESCRIPTION OF MATERIALS (Density, Consistency or Rock Hardness; Color; Classification; etc. . . .)	USCS	PID FID	REMARKS
	1	6-5 4-3	100		Stiff light brown Sandy SILT, wet.		0	2 VOA's collected GBH36-00
	2	1-2 1-1	100				0	
10	3	3/2.0'	80		sample is silty fine SAND		0	2 VOA's collected GBH36-10
	4	1-1 1-4	100		Soft tan silty CLAY with Sand lenses, wet		0	
	SHELBY NO. 1	350 psi	80				0	SHELBY collected GBH36-17.
20	5	4-6 7-10	100		Stiff tan Clayey SILT and coarse to fine angular rock fragments, moist.		0	2 VOA's collected GBH36-20.
	6	5-7 6-10	100		no CLAY.		0	6 Bag samples collected, GBH36-25
30	7	5-4 4-6	80		no CLAY		0	2 VOA's collected, GBH36-30

GENERAL REMARKS All spoon samples collected with 3-inch ϕ decontaminated split barrel sampler, driven with a 300-lb hammer.

AR303261

BORING NO. GBH36

Gannett Fleming
ENGINEERS AND PLANNERS

BORING LOG

PROJECT/LOCATION	HELENA LANDFILL
GEOLOGIST/ENGINEER	LEWIS
DRILLING CONTRACTOR	EMPIRE SOILS INVESTIGATIONS
DRILLER	PAUL KEENEY
RIG TYPE	ACKER AD-2
DRILLING METHOD	4 1/4" ID HSAugers
SURFACE ELEVATION	
TOTAL DEPTH OF HOLE	66
GROUNDWATER OBSERVATIONS (Date, Time, Level)	47.8 Ft (2/7/90)(1115) : 49.5 Ft (2/7/90)(1430)
BORING NO.	GBH-36
PROJECT NO.	26056
DATE STARTED	2/6/90
DATE FINISHED	2/7/90

DEPTH	SAMPLE NO. & TYPE	BLOWS OR RQD	% RECOVERY	LEGEND	DESCRIPTION OF MATERIALS (Density, Consistency or Rock Hardness; Color; Classification; etc. . .)	USCS	PID FID	REMARKS
35	8	6-7 8-12	100%		Tan to orange brown Clayey SILT trace rock fragments moist		10.1	
40	9	9-8 10-13	100%		same, except more plastic, moist		28.4	2 VOA's collected GBH36-40
45	10	6-5 7-8	100%		Same, except occ. black staining, moist		4.3	~~2 VOA's collected GBH36~~ - PJL 2/7/90
50	11	4-6 7-6	100%		Same, except and coarse to fine rock fragments, moist		4.6	2 VOA's COLLECTED GBH36-50
55	12	3-4 4-5	100%		Same, moist		5.1	
60	13	6/2"	100%		Tan fine sand and silt (4" lense of medium to fine rock fragments) wet		10.3	2 VOA's collected GBH36-60 3-8OZ JARS COLLECTED
65								
66					AUGER REFUSAL AT 66 FT			

GENERAL REMARKS
~~Drove~~ ~~from~~ Installed drive pt. from 62 to 66 Ft
water elev. = 47.8 Ft Purged 1 well volume and sampled.
groundwater Removal of ... indicated
severe damage, Top ... approx. 66

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AR303262

BORING NO. GBH-36

Gannett Fleming ENGINEERS AND PLANNERS

BORING LOG

BORING NO.	GBH-37
PROJECT NO.	26056
DATE STARTED	2/7/90
DATE FINISHED	2/8/90

PROJECT/LOCATION	HELENA LANDFILL
GEOLOGIST/ENGINEER	CARI HOFFMAN
DRILLING CONTRACTOR	EMPIRE SOILS INVESTIGATION, INC.
DRILLER	SCOTT ALBERALLA
RIG TYPE	CME 850
DRILLING METHOD	4 1/2" ID HS AUGER
SURFACE ELEVATION	
TOTAL DEPTH OF HOLE	77.0'
GROUNDWATER OBSERVATIONS (Date, Time, Level)	2/8/90 - 0839 - 51.5' depth

DEPTH	SAMPLE NO. & TYPE	BLOWS OR RQD	% RECOVERY	LEGEND	DESCRIPTION OF MATERIALS (Density, Consistency or Rock Hardness; Color; Classification; etc. . . .)	USCS	PID FID	REMARKS
0	1	3.5 9.11	40		Brown SILT, 30-40% Coarse to Fine Gravel, Moist, Stiff	ML	1.2	collected 2 VOA'S GBH37-00
5	2	1-WOH WOH-1	100		Orange Brown SILT, with medium to Fine Sand Lenses, Moist, trace organic Fibers, Very Soft	ML	107	
10	3	1-WOH WOH-1	100		Same		476	collected 2 VOA'S & 3-8oz Samples GBH37-10
15	4	1-WOH WOH-1	100		Same		97	
20	5	6-11 8-5	70		Brown Coarse to Fine SAND, 0-20% SILT, 0-10% Medium to Fine Gravel, Moist, Medium Dense	SM	127	collected 2 VOA'S GBH37-20
25	6	4-7 6-8	95		Brown SILT, 30-50% Coarse to Fine Gravel, 0-20% Coarse to Fine Sand, Moist, Stiff	ML	292	
30	7	3-6 7-7	85		Same		93	collected 2 VOA'S GBH37-30
35								

GENERAL REMARKS All split spoons taken with 3-inch ø deco[n] spoons & driven with a 300 lb. hammer. Boring backfilled to meet requirements of Vapor Probe-1 as per Matt Walsh of VAPEX.

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BORING NO. GBH-37

SHEET 1 OF 3

Gannett Fleming
ENGINEERS AND PLANNERS

BORING LOG

BORING NO.	GBH-37
PROJECT NO.	
DATE STARTED	
DATE FINISHED	
PROJECT/LOCATION	ELEVA LANDFILL
GEOLOGIST/ENGINEER	
DRILLING CONTRACTOR	
DRILLER	
RIG TYPE	
DRILLING METHOD	
SURFACE ELEVATION	
TOTAL DEPTH OF HOLE	
GROUNDWATER OBSERVATIONS (Date, Time, Level)	

DEPTH	SAMPLE NO. & TYPE	BLOWS OR RQD	% RECOVERY	LEGEND	DESCRIPTION OF MATERIALS (Density, Consistency or Rock Hardness; Color; Classification; etc. . .)	USCS	PID FID	REMARKS
	8	2-3 3-5	90		same		126	
40	9	2-2 2-4	100		Tan SILT, trace Coarse to Fine Sand, Moist, Soft	ML	324	collected 2VOA's GBH37-40
45	10	3-4 7-9	100		Brown, Tan & Black Mottled SILT, trace Clay, Moist, Stiff	ML	106	collected 3-8oz samples GBH37-45
50	11	3-7 7-6	55	▼	same, also 0-20% Coarse to Fine Gravel, wet		52.3	collected 2VOA's GBH37-50
55	12	2-2 3-6	100		same, except No Gravel, but also trace weathered Rock Frags, Wet		116	
60	13	1-2 2-2	100		same		43	collected 2VOA's GBH37-60
65	14	2-2 4-4	100		same		17	
70								

GENERAL REMARKS

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BORING NO. GBH-37
SHEET 2 OF 3

Gannett Fleming
ENGINEERS AND PLANNERS

BORING LOG

PROJECT/LOCATION	HELENA LANDFILL
GEOLOGIST/ENGINEER	
DRILLING CONTRACTOR	
DRILLER	
RIG TYPE	DRILLING METHOD
SURFACE ELEVATION	TOTAL DEPTH OF HOLE
GROUNDWATER OBSERVATIONS (Date, Time, Level)	

BORING NO.	GBH-37
PROJECT NO.	
DATE STARTED	
DATE FINISHED	

DEPTH	SAMPLE NO. & TYPE	BLOWS OR RQD	% RECOVERY	LEGEND	DESCRIPTION OF MATERIALS (Density, Consistency or Rock Hardness; Color; Classification; etc. . . .)	USCS	PID FID	REMARKS
	15	2-3 3-5	100		Same		40	collected 2VOA'S GBH 37-70
75	16	4-9 6-100	40		Same, also 0-20% coarse to fine Gravel		31	
					END BORING @ 77'			
80					AUGER REFUSAL @ 77' DEPTH			

GENERAL REMARKS

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BORING NO. GBH-37
SHEET 3 OF 3

Gannett Fleming
ENGINEERS AND PLANNERS

BORING LOG

PROJECT/LOCATION	Heleva Landfill
GEOLOGIST/ENGINEER	Gary Rynearson
DRILLING CONTRACTOR	Empire Soils Investigation Inc
DRILLER	Paul Keeney
RIG TYPE	Acker AD-2
DRILLING METHOD	4¼" ID HS Auger
SURFACE ELEVATION	
TOTAL DEPTH OF HOLE	42 feet
GROUNDWATER OBSERVATIONS (Date, Time, Level)	no groundwater in hole.
BORING NO.	GBH-38
PROJECT NO.	26056
DATE STARTED	2/8/90
DATE FINISHED	2/9/90

DEPTH	SAMPLE NO. & TYPE	BLOWS OR RQD	% RECOVERY	LEGEND	DESCRIPTION OF MATERIALS (Density, Consistency or Rock Hardness; Color; Classification; etc. . . .)	USCS	PID FID	REMARKS
					Very soft, light brown to tan Sandy SILT, wet			
10	1	5/2.0'	5		Very soft light brown to tan fine Sandy SILT, wet.		7.5	2 VOA's collected GBH38-10
	2	3/2.0'	100				15.8	5 8oz samples and 2 VOA's collected. GBH38-15
20	3	1-2 3-5	40		traces rounded fine Gravel		33	2 VOA's collected GBH38-20.
	4	2-3 5-5	100				30.2	3 8oz samples collected, GBH38-25
30	5	3-4 5-5	100		stiff light brown to tan Clayey SILT interbedded with light brown to tan silty CLAY, moist		24	2 VOA's collected, GBH38-30.

GENERAL REMARKS All spoon samples collected with 3 inch Ø decontaminated split barrel samplers, driven with a 300 lb hammer.

Gannett Fleming ENGINEERS AND PLANNERS

BORING LOG

PROJECT/LOCATION	Helena Landfill
GEOLOGIST/ENGINEER	Gary Rupenrson
DRILLING CONTRACTOR	Empire Soils Investigations Inc.
DRILLER	Paul Keeney
RIG TYPE	Acker AD-2
DRILLING METHOD	4¼" ID HS Auger
SURFACE ELEVATION	
TOTAL DEPTH OF HOLE	42 feet
GROUNDWATER OBSERVATIONS (Date, Time, Level)	no groundwater in hole.
BORING NO.	GBH-38
PROJECT NO.	26056
DATE STARTED	2/8/90
DATE FINISHED	2/9/90

DEPTH	SAMPLE NO. & TYPE	BLOWS OR RQD	% RECOVERY	LEGEND	DESCRIPTION OF MATERIALS (Density, Consistency or Rock Hardness; Color; Classification; etc. . . .)	USCS	PID FID	REMARKS
	6	3-5 7-4	100		Medium stiff to stiff light brown and redish-orange CLAY, with 20% rounded fine and coarse Gravel, some black mottling, moist.		90	3 8 oz samples collected, GBH38-35
40	7	2-2 5-5	100				L4	2 VOA's collected GBH38-40.
					Boring terminated at 42.0 feet			

GENERAL REMARKS All spoon samples collected with 3 inch ⌀ decontaminated split barrel samplers, driven with a 300-lb. hammer.

AR303267

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BORING NO. GBH-38

SHEET 2 OF 2

APPENDIX B

STANDARD OPERATING PROCEDURES

VAPEX ENVIRONMENTAL TECHNOLOGIES, INC.

STANDARD OPERATING PROCEDURES (SOP)

HNU MODEL 321 GAS CHROMATOGRAPH FIELD SETUP AND OPERATION

VAPEX SOP#: GC-OP

Purpose: To document specific procedures for the operation of the HNU Gas Chromatograph.

Objectives: To outline procedures for setup and operation of the HNU Model 321 Gas Chromatograph and associated equipment. Setup and operation includes:

- o Setup of the GC and equipment
- o Procedures for establishment of a GC baseline
- o The preparation, injection and analysis of a field vapor standard
- o The injection and analysis of field samples
- o Procedures for shutting down the GC

Required Associated SOPs: *VAPEX* SOP Nos: GC-QAQC-I and GC-QAQC-II.

Definitions:

carrier gas - medium which moves sample through the GC column. This is typically an inert gas such as nitrogen (N2) or helium (H2). Synonym = "mobile phase."

baseline - chart recorder/integrator/computer baseline. This is the established level of chromatograph response and sensitivity which corresponds to levels which are below the detection limit.

sample blank - usually ambient air which is drawn into a Hamilton gas-tight glass syringe and injected into the GC/PID to establish the baseline and determine the existence and quantity of background contamination or column residual (if any). It is also used to establish the extent of baseline drift caused by temperature gradient program.

temperature gradient program - a program by which the temperature of the GC oven is varied with time. The temperature gradient program greatly increases the separation efficiency of the GC column as a result of an increase in molecular/column interactions.

attenuation - the level of GC/PID response/sensitivity which can be adjusted by the user in response to changes in sample concentration.

GC/PID - Gas Chromatograph with Photoionization detector. GC/PID is equipped with 1 ml gas sampling loop, which ensures repetitive sample volume injection.

Equipment Description: Equipment used in the operation of the GC/PID are listed below:

1. Hamilton 1 ul and 5 ul syringes
2. Two liter (2L) volumetric static dilution flask
3. HNU Model 321 GC/PID Controller
4. HNU Model 321 GC/PID: 1/8" stainless steel packed column, 5 percent SP-1200/1.75 percent Benton 34 on 100/120 Supelcoport (1-2134). Column temp: 5 min. at 70 ^{o}C, then to 160 ^{o}C @ 5^{o}C/min. Flow rate: 23 ml/min., N2. 10.2/11.7 eV photoionization detector (PID).
5. Nelson Analytical A/D Interface
6. Toshiba T1200 laptop computer, equipped with P.E. Nelson Model 2100 PC Integrator Chromatography Software, Revision 5.0.
7. Formatted 3.5" floppy diskettes.
8. Extension cord equipped with a voltage surge protector and a Ground Fault Interrupter (GFI).
9. Nitrogen tank equipped w/ swagelok fittings and copper tubing for hook-up w/ GC.
10. Hamilton 10 ml syringe ("BLANK" syringe)
11. Equimolar standard solution (benzene, TCE and PCE - typically) of known ppm concentration which is prepared in the field by the GC operator as described below in "Standard Preparation".
12. Supply of sample syringes (10 mL) Hamilton Gastight equipped with Teflon Minivert valves.
13. Heat gun.

Health and Safety: VITON or equivalent gloves will be used when handling chemicals. Work with chemicals must not be conducted in a closed/contained space.

1.0 PROCEDURE: PHASE I/SET UP

1. Unload all GC equipment.
2. Set up equipment in configuration illustrated below:
3. Make all necessary connections/communication lines between equipment.
4. Connect the Nitrogen (N2) to the GC.
5. Turn on N2. Record N2 tank and regulator psi.
6. After 2-3 min., turn on GC (do not turn on the detector).
7. After GC is on for 2-3 min., turn on the controller.
8. Program #1: Note that all program entries must be followed by an "ENTER" (the "down arrow" on the controller is the "enter").

   i. Enter "**1**" for "Temp only".
   ii. Ambient mode? **YES**
   iii. Inj./Det temp? **95** (11.7eV PID)/**250** (10.2eV PID)
   iv. Oven temp ramp? **No**

Note: a "NO" was programmed so as to bake the GC column for a period of time prior to use (usually 0.5 hr.).

v. Final oven temp? **160** ^{O}C
vi. Just hit **enter** for question #'s 10 and 11.
vii. Press "**enter**" again to start the temperature control.
viii. Turn on the **NELSON.**
ix. While the GC warms up, format a 3.5" floppy diskette on the computer and download all appropriate GC Software methods onto the diskette.
x. Continue preparing by establishing an entry in the **GC FIELD NOTEBOOK** and recording all GC operating parameters as shown in the example in Figure 2.
xi. Once the GC warms up to the programmed parameters, allow the GC to stabilize at these settings for 30-60 min.

END PHASE I

2.0 PHASE II/TEMPERATURE RAMP

Program the controller for the following temperature ramp.

1. Press the "UP" arrow on the controller to get back to the start of the program.

2. Program as above in Steps 4i-4iii until the controller prompts for an oven temperature ramp. Enter "**YES**".

Continue the temperature program as follows:

Initial temperature (^{O}C):	**70**
Hold time (**seconds**/units = 5 mins):	**500**
Ramp (^{O}C/min):	**5**
Second temperature (^{O}C):	**160**
Second hold time (**sec.**/ units=10 min.):	**1000**
Second ramp (^{O}C/min):	**ENTER**
Final Temperature (^{O}C):	**160**
#10, #11, #12:	**ENTER**

4. After you start the temperature program, open the cover on the GC to facilitate cooling.

5. When controller lets you know it is ready, hit "enter" to start a run - EXCEPT, press "**STOP**" immediately after this.

Because the GC was allowed to warm up to 160 ^{O}C, the short amount of time you allowed for cooling was not enough. So, because the controller thinks it is ready, it will try to maintain a 70 ^{O}C oven temp while the GC cover is open. Were you to close the lid without further cooling, the temp would immediately jump past 70 ^{O}C.

6. When temp reaches approx. 48 ^{O}C, close the GC cover, and press "**ENTER**" to start the temperature program.

7. Turn on the detector - check to see that it is on (purple glow).

END PHASE II

3.0 PHASE III/ESTABLISH BASELINE

1. Get into the main menu of the Nelson GC software by typing at the **C:>** prompt:

    GC, enter
    MENU, enter

2. Get into the GC Polling menu (hit enter = **0** on main menu). Press **F2** to get into method downloading, and load the appropriate preprogrammed data method (*.MET) file which should already be on A:\ (if not, copy it from C:\ to A:\).

Enter an appropriate file name and a description including the attenuation you expect to shoot the sample on: for example "BLANK, atten. = H1". Download to NELSON.

3. Inject three volumes of ambient air through the GC sample loop with the blank syringe to purge any hydrocarbon vapors remaining in the loop.

4. Simultaneously; **INJECT** the sample, press **ENTER** on the controller to start the run and press **START** on the NELSON to begin data sampling.

    Note: If NELSON shows "Under Range" past 1.25 min., hit the "auto zero" on the GC till baseline stabilizes and Nelson remains in "Sampling" mode.

    Also, if residuals are detected, let the chromatogram continue to elute for approximately 25 minutes, then:

    1. Heat the sample loop with the heat gun while the injector is in the sample position (up).
    2. Blow 10 volumes of air through loop with the "blank" syringe.
    3. Cool the loop down with the heat gun on "cool" position.
    4. Shoot another blank.
    5. Press "**STOP**" on controller to end the run and "**STOP**" on NELSON to begin downloading the data into the computer. Open the GC cover to facilitate cooling.
    6. When the Controller has cooled, it will print a small menu. At this point, close the GC cover and press **ENTER** on the Controller to start the temperature program.
    7. When the GC has reached starting temperature (70 ^{o}C), the Controller will print a "Ready" menu.
    8. Repeat steps 2-7 for each consecutive blank injection.

END PHASE III

4.0 PHASE IV/STANDARD ANALYSIS

Once a steady baseline is established, a standard prepared in the field is injected. The standard is usually a equimolar mixture of at least three specified/target compounds which are expected to be detected in the field. The standard is prepared as follows:

Standard Preparation:

i. *A microliter (typically, 1 uL) syringe is rinsed with methanol (MeOH) and allowed to dry.*

ii. *A 2 liter static dilution flask is cleaned/heated with a heat gun (approx. 2-3 minutes) until it is free of any contamination. The flask is allowed to cool. The flask is tested with a Foxboro Century Model 128 Organic Vapor Analyzer (OVA) or an HNU Model HW-101 Portable Ionization Analyzer (PID: 10.2/11.7 eV) to ensure the flask is free of contamination. This step is repeated if necessary.*

iii. *A 3-5 mL vial of liquid/neat benzene is taken from storage *.*

iv. *The microliter syringe (1.0 uL) is introduced into the benzene through the septum of the sample vial. This is done to minimize contact with the benzene and/or vaporization of the chemical into the air.*

v. *While holding the needle of the syringe in the liquid and holding the syringe and vial up into the light, a small amount of liquid is slowly extracted into the syringe. This initial volume is expelled into the liquid and careful attention is paid to notice any small bubbles which may elute (even the tiniest bubble can have a dramatic effect on the resultant concentration of the final standard solution). This procedure is repeated until no bubbles are observed. At this point, a small (pre-calculated) volume is once again extracted up into the syringe. The syringe is carefully, but quickly, taken out of the liquid and vial and introduced into the static dilution flask where the sample is expelled. Note that the use of larger volume syringes (5, 10, 25 uL) would require procedural modifications, such as the incorporation of a volume of head space (air or methanol) prior to the extraction of sample into the syringe to 1) ensure accurate sample measurement, and 2) to provide a mechanism for the removal of all sample from the needle volume. However, the construction of the 1.0 uL syringe coupled with experimental analytical data for standards prepared with the 1.0 uL syringe indicate that consistently accurate standards can be generated without the addition of a headspace volume - these results are a function of a perfected analytical technique.*

vi. *The sample is allowed to evaporate off the needle and equilibrate.*

vii. *Steps iii through vi are repeated for trichloroethylene (TCE) and perchloroethylene (PCE) and/or any other chemicals of interest.*

viii. *Since the resultant mixture of standard components will be nonhomogeneous, the flask should be maintained at a constant temperature (70 ^{O}F) and agitated prior to use to ensure homogeneous mixing.*

In summary, the composition of the prepared standard sample should be characteristic of the expected field contaminant(s) and is designed to test the response of the detector and column over the effective range characteristic of the expected levels of the contaminant.

1. The GC Temperature Controller, the Nelson and the computer are reset to accept another run.

2. Flush the sample loop with three volumes of ambient air with the blank syringe.

3. Standards for injection are extracted from the two liter volumetric dilution flask via a 5 ml gastight syringe. Care is taken to avoid standard/sample dilution due to needle head space. The valve on the syringe is closed.

4. The syringe is attached to the loop; the syringe valve is opened and a portion of the standard in injected into the loop.

5. Simultaneously: **INJECT** the sample, hit the **ENTER** (down arrow) on the GC Temperature Controller and hit the **START** button on the Nelson Interface to start recording the run.

6. Allow the run to elute until it is certain that no other peaks may elute, then: hit the **STOP** button on the Controller to stop the run and the **STOP** button on the Nelson to begin the downloading process to the computer.

7. Open the cover of the GC to facilitate cooling and reset the GC for the next run as described above in Section 3.0.

Area counts (AC) and retention times (Rt) are calculated for each injection of standard and compared to assure statistical guidelines are met (briefly, both AC and Rt must be within at least 10 percent of known laboratory values for 90 percent confidence). Failure to meet these criteria might be caused by 1) an old and degrading column, 2) a leak in the mobile phase, or 3) an unexpected change in carrier gas pressure. These and other possibilities should be investigated to determine the cause of the Rt discrepancy before continuing. Duplicate injections should be run if necessary.
b. Area Counts (AC) for each peak are compared to expected values by correlation with the computer-resident, programmed external standards. Deviation greater than 10% may indicate error in sample preparation or suggest that the GC/PID may need recalibration. A newly prepared sample may help to determine the cause. *NOTE: The preparation of standards which contain hydrocarbon vapor at very low concentrations is difficult to prepare. The comparison of peak Rt may serve as a better evaluation of GC/PID performance at lower concentrations ($x < 100$ ppm).*

8. If standard response is within quality assurance performance criteria, then a field sample may be collected and injected as described below. Note that a blank and a standard will be injected 1) after six field samples have been run 2) after a reattenuation has resulted in a change from a less sensitive (high concentration) GC/PID attenuation setting to that of a more sensitive (lower concentration) GC/PID attenuation setting.

* *Liquid/heat chemical standards are kept in 3-5 mL brown, open-faced sample vials equipped with teflon-faced silicon septa. These sample vials are stored in a resealable plastic bag which is stored in a small container of carbon.*

5.0 PHASE V/SAMPLE ANALYSIS:

1. Collect field samples for GC/PID analysis as specified in VAPEX SOP No.GC-S.
2. Reset the GC/PID, controller, Nelson and computer for the next sample.
3. Flush the sample loop with three (3) volumes of ambient air with the blank syringe.
4. Attach the sample syringe to the loop, open the syringe valve and inject a portion of the 10 mL syringe sample into the 1 mL sampling loop. *A portion of the sample can be saved for duplicate analysis by closing the valve to ensure that no sample leaks from the syringe.*
5. As described above, simultaneously: **INJECT** the sample, hit the **ENTER** (down arrow) on the GC Temperature Controller and hit the **START** button on the Nelson Interface to start recording the run.
6. Allow the run to elute until it is certain that no other peaks may elute, then: hit the **STOP** button on the Controller to stop the run and the **STOP** button on the Nelson to begin the downloading process to the computer.
7. Open the cover of the GC to facilitate cooling and reset the equipment for the next run.

Note 1: By screening the contaminated area(s) with a total hydrocarbon PID/FID, it is possible to approach the GC sampling round so that sampling locations of similar contamination concentrations can be grouped together. This is advantageous in that it reduces the frequency of GC attenuation adjustments. Furthermore, in regards to column dynamics, sampling strategy assumes that samples are selected in increasing concentration.

Note 2: Sample syringes will be sterilized with heat gun after use and checked with a total organic vapor analyzer (TOVA) for residual contamination before repeated use.

6.0 PHASE VI/BREAKDOWN

After all field analyses have been completed, the equipment must be broken down for transportation back to the lab.

1. Turn off detector.
2. Turn off computer.
3. Turn off Nelson.
4. Turn off Controller.
5. With GC cover up, make sure the GC oven temp is below 30 ^{o}C and the injector temperature is below 100 ^{o}C. Then, turn off the GC.
6. Turn off N2 and unhook the N2 line from the GC.

REFERENCES:

1. HNU Model 321 Gas Chromatograph Operator's Manual, Ver. 1.0; HNU Systems, Inc., Newton, Massachusetts.

2. P.E. Nelson 900 Series Intelligent Interface Operator's Manual; Perkin Elmer Nelson Systems, Inc., Cupertino, California.

3. P.E. Nelson PC Integrator User's Manual, Revision 5.0; Perkin Elmer Nelson Systems, Inc., Cupertino, California.

4. The Merck Index, 9th Ed.; Merck & Co., Inc., Rahway, New Jersey.

VAPEX ENVIRONMENTAL TECHNOLOGIES, INC.

STANDARD QA/QC OPERATING PROCEDURES (SOP)

STANDARDIZATION/CALIBRATION OF HNU MODEL 321 GAS CHROMATOGRAPH

VAPEX SOP NO: GC-QAQC-I

Purpose: To document specific procedures for the Standardization/Calibration of an HNU Model 321 Gas Chromatograph equipped with an 11.7 eV photoionization detector (GC/PID).

Objectives: Describe the procedures/techniques used in the calibration of the Gas Chromatograph for chlorinated and non-chlorinated hydrocarbons.

Required Associated SOPs: GC-OP and GC-QAQC-II

Definitions:

1. carrier gas - medium which moves sample through the GC column. This is typically an inert gas such as nitrogen (N2) or helium (H2). Synonym = "mobile phase."

2. baseline - chart recorder/integrator/computer baseline. This is the established level of chromatograph response and sensitivity which corresponds to levels which are below the detection limit.

3. sample blank - usually ambient air which is drawn into a Hamilton gas-tight glass syringe and injected into the GC/PID to establish the baseline and determine the existence and quantity of background contamination or column residual (if any). It is also used to establish the extent of baseline drift caused by temperature gradient program.

4. temperature gradient program - a program by which the temperature of the GC oven is varied with time. The temperature gradient program greatly increases the separation efficiency of the GC column as a result of an increase in molecular/column interactions.

5. attenuation - the level of GC/PID response/sensitivity which can be adjusted by the user in response to changes in sample concentration.

7. VOC's - Volatile Organic Compounds

8. GC/PID - Gas Chromatograph with Photoionization detector. GC/PID is

equipped with 1 ml gas sampling loop, which ensures repetitive sample volume injection.

Equipment Description: Equipment used in the standardization/calibration of GC -

1. Hamilton 1 ul and 5 ul syringes
2. Three volumetric (2 liter) static dilution flasks
3. HNU Model 321 GC/PID Controller
4. HNU Model 321 GC/PID: 1/8" stainless steel packed column, 5% SP-1200/1.75% Benton 34 on 100/120 Supelcoport (1-2134). Column temp: 5 min. @ 70 °C, then to 160 °C @ 5 °C/min. Flow rate: 23 ml/min., N2. Det.: Photoionization detector (PID) (11.7 eV).
5. Nelson Model 950 Intelligent Interface
6. Toshiba T1200 laptop computer (280K MS DOS), equipped with P.E. Nelson Model 2100 PC Integrator Chromatography Software, Revision 5.0.
7. Formatted 3.5" floppy diskettes.
8. Extension cord equipped with a voltage surge protector.
9. Nitrogen tank equipped with compression fittings and copper tubing for hook-up w/ GC.
10. Equimolar standard solutions (benzene, TCE and PCE - typically) or selected compounds which are expected to be encountered in the field.) The preparation of these standards can be found in the section entitled "Standard Preparation" in *VAPEX* SOP No. QA/QC-IIIA.
11. Hamilton 5 mL Gastight Syringe equipped with a teflon mininert valve and a removable needle.

Procedure:

1. The Gas Chromatograph is set up in the lab according to the procedure described in *VAPEX* SOP No. GC-OP; Sections 1 through 3.

2. The GC attenuation is set to the target level.

3. Three vapor standards (of known concentration) containing the selected compounds are prepared in static dilution flasks as described in *VAPEX* SOP No. GC-OP Section 3. The three standards are designed to allow calibration the GC over the linear range of the desired attenuation. The constituent concentration levels should reflect the lower, higher and intermediate values detectable within the given attenuation range. The concentrations of each standard is calculated in units of ppm, volume per volume.

4. Three samples of the least concentrated standard are injected and run on the GC as described below:

   i. Because chlorinated solvents are heavier than air, the flask should be agitated to assure that the standard/sample is homogeneous and that a representative sample can be withdrawn. Additionally, the sample flask is kept at room temperature, 70 °F.

ii. A small aliquot of sample is withdrawn into the 5 mL Hamilton gastight syringe from the dilution flask (approx. 0.5-1 mL) and expelled into the hood. This is to purge the head volume of the needle with sample so as to prevent sample dilution.

iii. The syringe is once again inserted into the flask and a sample is withdrawn (approx. 1.5-3 mL).

iv. The needle is removed, and the sample is injected into the GC via the 1 mL sample loop.

v. Steps i-v are repeated for three (3) separate injections.

5. Step 4 is repeated for each standard in increasing concentration until all three standards (for a total of nine injections) have been run. Note: a blank may be injected after each standard/mixture to assure that component residuals do not adversely effect peak quantification.

6. Results of each sample analysis are downloaded by the Nelson Intelligent Interface into the computer and stored on the 3.5" floppy diskette.

7. Data analysis is performed as specified in *VAPEX's* Standard Operating Procedure No. GC-QA/QC-II.

References:

1. HNU Model 321 Gas Chromatograph Operator's Manual, Ver. 1.0; HNU Systems, Inc., Newton, Massachusetts.

2. P.E. Nelson 900 Series Intelligent Interface Operator's Manual; Perkin Elmer Nelson Systems, Inc., Cupertino, California.

3. P.E. Nelson PC Integrator User's Manual, Revision 5.0; Perkin Elmer Nelson Systems, Inc., Cupertino, California.

4. The Merck Index, 9th Ed.; Merck & Co., Inc., Rahway, New Jersey.

VAPEX ENVIRONMENTAL TECHNOLOGIES, INC.

STANDARD QA/QC OPERATING PROCEDURES (SOP)

DATA ANALYSIS AND STATISTICAL TREATMENT: AS APPLIED TO THE LABORATORY STANDARDIZATION OF HNU GAS CHROMATOGRAPH AND FIELD GENERATED DATA

VAPEX SOP NO. GC-QAQC-II

Purpose: To document a specific procedure for the analysis and statistical treatment of data generated by HNU Model 321 Gas Chromatograph during the laboratory and/or field standardization/calibration of the instrument.

Objectives: Describe the procedures and statistical methods of analysis used in the treatment of data as generated by the HNU Model 321 Gas Chromatograph. Procedures described here apply to both laboratory standardization and field-generated data. Also included is standard field QA/QC protocol.

Required Associated SOPs: Vapex SOP Nos. GC-OP and GC-QA/QC-I

Definitions:

1. area count (AC) - a measure of the area under a chromatographic peak as calculated by the PC Integrator. Area is directly proportional to molecular concentration.

2. Retention time (Rt) - the time it takes a compound to elute from the column and be detected. Each compound has a characteristic Rt and this Rt is used in identifying each compound.

Equipment Description: Equipment used in the analysis of GC data:

1. Toshiba T1200 laptop computer (280K MS DOS), equipped with P.E. Nelson Model 2100 PC Integrator Chromatography Software, Revision 5.0.
2. Computer data files from field and/or standardization of Gas Chromatograph.

Procedure: Laboratory

1. Consecutive injections of a given concentration are analyzed to assure that peak response parameters for each compound are statistically consistent: Area Counts (AC) and Retention times (Rt) are compared to see that response remains within 95 percent confidence level as defined as plus (+) or minus (-) two standard deviations as determined by a Student's T-test on replicate analyses.

2. The area counts for each calibration level (ppm concentration) within a given GC attenuation are averaged. The retention times for each component (Rt is not a function of the calibration level, but is an intrinsic property characteristic of each component) are averaged.

3. The averaged AC and Rt for each component are entered into the Nelson Chromatographic software along with other chromatographic parameters unique to the particular method being generated.

4. Once requirements in Step 1 are satisfied, the Nelson chromatographic software is used to generate calibration curves from which vapor concentrations from field data is calculated.

5. The linearity of the calibration curve is tested via linear regression. The calibration curve is rejected if the R-squared value is less than 95 percent.

6. Quality control standards are analyzed periodically and accepted if the relative standard deviation of the response factors is less than 10 percent of the anticipated value(s). New calibration curves are prepared when quality control limits are exceeded.

Procedure: Field

1. As described in *VAPEX* GC-OP, blanks are injected and analyzed at the start of each GC field round and no less frequently then every six field samples. Field duplicates are integrated into the sampling protocol - at least two duplicates per sampling round.

2. As described in Step 6 above, standards are injected at the beginning of each sampling round and periodically throughout a single day's operation.

Specific:

Further calibration in the field may be necessary if it is determined that: 1) detected field concentrations are outside the linear range of the established laboratory calibration curve for the given GC attenuation, and 2) will have an adverse effect on peak quantification. In this case, a new set of vapor standards must be prepared for the new expected range. Data analysis and generation of new calibration curve follow before analysis of field samples can resume.

References:

1. P.E. Nelson PC Integrator User's Manual, Revision 5.0; Perkin Elmer Nelson Systems, Inc., Cupertino, California.

2. Young, R., Lee, C., Statistical Methods of Analysis, 3rd. Ed., MacGraw-Hill, Inc., New York.

VAPEX ENVIRONMENTAL TECHNOLOGIES, INC.

STANDARD OPERATING PROCEDURES (SOP)

SOIL VAPOR PROBE SAMPLING PROCEDURES FOR ON-SITE GC/PID ANALYSIS

VAPEX SOP NO.: GC-S-I

Purpose: To document the procedure for the sampling of VOC's from vadose zone soil vapor probes.

Objectives: To establish and clarify specific guidelines for obtaining soil vapor samples from vapor probes, soil vapor extraction systems and carbon cannister vapor discharge. These samples are collected in Hamilton gastight syringes for analysis by GC/PID.

Definitions:

1. Vapor Probe - Designed by *VAPEX*, vapor probes are vadose zone soil vapor "sampling ports." They are installed to enable the sampling of soil gas for periodic screening/monitoring activities.

2. VOC's - Volatile Organic Compounds.

Equipment Description: Equipment used in the sampling of vapor probes for GC/PID are listed below:

1. Vapor Probe - see illustration in Appendix A
2. Head volume extraction syringe ("Hamilton Gastight" glass syringe with teflon mininert stopcock valve - 50 ml).
3. Sample extraction syringe ("Hamilton Gastight" glass syringe with teflon mininert stopcock valve- 10 ml).

Procedure:

1. The vapor probe sample tube is accessed by opening the protective street box as required.

2. The Head Volume Extraction syringe is connected to the teflon 1/8 inch vapor probe sample tubing by means of a small piece of Tygon tubing and a 50 ml. volume is extracted. The Tygon tubing is pinched tight thereby maintaining the isolation of the soil vapor from the atmosphere; the syringe is removed; and the volume of gas expelled.

3. The syringe is connected to the Teflon sample tubing and Step 2 is repeated so that a total head volume of three syringe volumes or approximately 150 ml has been extracted and expelled from the vapor probe. The purpose of this is to assure that a sample representative of the equilibrated soil vapor surrounding the vapor probe is now ready for extraction.

4. The 10 ml Hamilton gastight syringe is now attached to the Teflon sampling tube and a 10 ml sample is withdrawn. The syringe stopcock is closed and the syringe is removed.

5. The Teflon tubing is placed back within the protective casing; the box is closed; and the sample is brought back to the GC/PID for immediate analysis (*VAPEX* SOP-IIIA).

6. The syringe is decontaminated with a heat gun and tested with a portable total FID before it is used again.

Procedure: Soil Vapor Extraction System Discharge and/or Carbon Cannister Vapor Discharge

1. The sample syringe is connected to the discharge port of the soil gas vapor extraction system.

2. The discharge/sample port is open and a sample is withdrawn.

3. The sample port is closed and the sample is expelled so as to minimize the effects of syringe head volume dilution.

4. The sampling syringe is reattached and the sample port open. A new, fresh sample is withdrawn and the stopcock on the syringe is closed to seal the sample in the syringe for immediate transport back to the GC/PID. The sample port is closed and the syringe and tygon tube disassembled. Note: fresh tygon tube should be used each time so as to eliminate the possibility of residual cross contamination - unless the tube is first screened with a TOVA.

5. The syringe is decontaminated with a heat gun and tested with a portable total FID before it is used again.

VAPEX ENVIRONMENTAL TECHNOLOGIES, INC.

STANDARD OPERATING PROCEDURES (SOP)

SOIL VAPOR SAMPLING PROCEDURES FOR TOTAL ORGANIC VAPOR ANALYZER

VAPEX SOP NO: VAPOR-1

Purpose: To establish the sampling procedure for the sampling of soil gas from subsurface soils and to analyze the samples for total organic vapor concentration.

Objectives: To describe procedures used to analyze soil gas samples obtained from soil vapor probes, soil vapor extraction system discharge and/or carbon cannister vapor discharge using a portable total organic vapor analyzer (TOVA).

This procedure is applicable for the use of several portable total organic vapor analyzers, including the following:

Thermo Electron Instruments Model 712 Total Hydrocarbon Analyzer (712).

Foxboro Century Model 128 Organic Vapor Analyzer (OVA).

Thermo Environmental Model 580A (PID)

The 712 and OVA are equipped with a flame ionization detector (FID). The PID is equipped with an 11.7 eV photoionization detector (PID).

Definitions:

1. Vapor Probe - Designed by *VAPEX*, vapor probes are vadose zone soil vapor "sampling ports". They are installed to enable the sampling of soil gas for periodic screening/monitoring activities.

PROCEDURE 1: Vapor Probe

Required Equipment/Materials:

1. Streetbox key (to open street boxes covering vapor probes).
2. TOVA: 712, OVA, or PID.
3. FID Carrier: equipped with a personal sampling pump, a flow meter (cc/min) and battery. The pump is capable of withdrawing approximately two to three liters of air per minute.
4. Two sections, two feet in length of 1/4 inch Teflon tubing, attached to the inlet and outlet of the sampling pump.
5. 1.5 Liter Teflon Sample Bag

Procedure:

1. The soil vapor probe sampling tube is accessed by removing the streetbox cover with the streetbox key.
2. Prior to connecting the sampling system to the probe, the pump is used to flush ambient air through the bag. The TOVA is then used to sample the ambient air in the bag to ensure that no contamination exists in the sampling system.
3. Following confirmation that the system is not contaminated, the tygon tubing from the sampling pump inlet is attached to the 1/8 inch Teflon tubing extending to the ground surface from the soil vapor probe.
4. After filling the deflated sample bag with soil gas, the tip of the TOVA sampling probe is connected to the bag and the bag's valve is opened. When a steady reading is observed, the total hydrocarbon concentration measurement is recorded.
5. Following the measurement, the sampling system is disconnected from the probe and allowed to flush ambient air until contaminant levels in the bag are no longer detected.

PROCEDURE 2: Soil Vapor Extraction System Discharge and Carbon Cannister Vapor Discharge

Required Equipment/Materials:

1. A 1/4" Apollo brass ball valve with sampling port attached to the discharge of the soil vapor extraction system pump/blower.
2. TOVA: 712, OVA, or PID.
3. 1.5 liter Teflon air sampling bag.
4. A section of Tygon tubing which is long enough to reach from the discharge sampling port to the sampling bag.

Procedure:

1. The TOVA is used to test the air sampling bag to ensure that no residual contamination exists.
2. The tygon tubing is connected to the discharge port of the system exhaust.
3. The exhaust/discharge port is opened and system vapor is allowed to fill the bag.
4. The nozzle of the TOVA is connected to the bag and the TOVA response is recorded.

VAPEX ENVIRONMENTAL TECHNOLOGIES, INC.

STANDARD QA/QC OPERATING PROCEDURES (SOP)

PORTABLE TOTAL ORGANIC VAPOR ANALYZER CALIBRATION

VAPEX SOP NO.: TOVA-QAQC-I

Purpose: To establish an operating procedure for the calibration of the portable total organic vapor analyzers (TOVA) with prepared or pre-prepared standard samples of gaseous volatile organic compounds (VOC's).

Objectives: To outline techniques for the laboratory and field calibration of TOVAs and discuss methods for the assessment of instrument performance

This procedure is applicable to several portable total organic vapor analyzers, including the following:

- Thermo Electron Instruments Model 712 Total Hydrocarbon Analyzer (712).
- Foxboro Century Model 128 Organic Vapor Analyzer (OVA).
- Thermo Environmental Model 580A (PID).

The 712 and OVA are equipped with a flame ionization detector (FID). The PID is equipped with an 11.7 eV photoionization detector (PID).

PROCEDURE 1: Laboratory Calibration

Materials:
1. Three to five, 2 Liter Teflon sampling bags, each equipped with a stainless steel sampling nozzle and gastight septum.
2. Sampling pump equipped with fresh tygon tubing.
3. 1, 5, 10 and 25 uL Hamilton syringes.
4. A sample of liquid benzene (FID) or perchloroethylene (PCE).
5. A 500 mL Hamilton gastight syringe.
6. Tygon tubing for attachment from bag to instrument.
7. TOVA
8. Computer with Lotus 123.

Procedure:
1. Line up all the Teflon bags on a clean table with the septa and nozzles closest to you. (Each Teflon bag is dedicated to one sample gas concentration level.)
2. Use the positive pressure from the sampling pump to fill each bag with clean air (test the quality of the air from the pump with an instrument to verify that the air is free of residual contamination). Use the vacuum side of

the pump to flush the air out of the bag. Repeat this procedure a minimum of three times for each bag or until N/D in gas is flushed from bag.

3. Establish the number of calibration points (concentration) you expect to have (at least three, five to six is recommended). Target calibration concentration levels to test the instrument response over the range of the instrument and/or the range of each attenuation on the instrument.
4. Calculate the number of microliters of sample which is necessary for the first bag.
5. Use the pump to pull a vacuum on the bag to completely empty the bag of any residual air - close the nozzle.
6. Fill the 500 mL Hamilton syringe with 500 mL of zero grade air.
7. Hook up the charged syringe to the bag.
8. Open the bag nozzle and expel the 500 mL of air into the bag. With the syringe still hooked up to the bag, close the bag nozzle.
9. Carefully extract the required liquid (standard) aliquot into the syringe (for information on the techniques used for sampling of liquid samples with Hamilton syringes, see VAPEX SOP No. GC-OP, Section 3: Sample Preparation); carefully and quickly insert the needle into the bag thru the septa and inject the sample.
10. Allow the sample to equilibrate for a period of 5-10 minutes.
11. While the bag equilibrates, turn on the TOVA and allow it to warm up.
12. Add another 500 mL of air to the bag as described above.
13. Let the bag equilibrate for another 5 minutes.
14. Hook up the bag directly to the TOVA, open the bag nozzle and sample the air with the TOVA - record the instrument's response.
15. Repeat steps 4-13 for each calibration concentration level.
16. Flush out all the bags as described in 1 and 2 above and store them away.
17. Clean up all other materials.
18. Use Lotus 123 to generate a calibration curve and equation. Because TOVA's operate over a wide range of concentration, the resultant curve may not exactly conform linearly. This may be a result of the instrument's attenuation settings. Therefore, to attain linearity and to allow for a linear regression analysis, it may be necessary to analyze the data between attenuation settings and generate calibration curves for each attenuation. This is particularly relevant to the PID because of the effects of concentration on PID response as defined by Beer's law.
19. To verify the calibration curve, a test sample of known concentration is prepared and sampled by the instrument and its response is recorded and compared to the calibration curve. If the response does not agree with the calibration curve, repeat. If response discrepancies continue, the calibration curve or the instrument may be suspect. A new calibration curve should be generated.
20. The calibration data and data analysis should be recorded in the *Total Instrument Calibration Notebook* with a copy of the curve(s) and resultant equations stored in an envelope in the instruments case (for field reference).

PROCEDURE 2: Field Calibration

The field calibration is designed to allow a rapid, yet controlled, QA evaluation of the response of the instrument; the response is evaluated for statistically consistency with the laboratory calibration. For instruments being calibrated to benzene (OVA 712), liquid benzene or pre-prepared Calgaz benzene standards may be used. For instruments being calibrated to PCE (PID), liquid PCE is the available alternative. Note: Analysis by GC of Calgaz standards have determined Calgaz concentrations to be as much as 44 percent off the stated concentration. Therefore, if Calgaz is to be used, it must first be analyzed by GC to determine the correct concentration. Generally, unless the GC is already set up, it is easier to use liquid benzene.

1. Use the worksheet form in Figure 1 as a template to record all calculations and measurements. The worksheet has information on each of the chemicals on the back of the sheet to assist in calculations.

2. Determine the type of calibration procedure to apply (Calgaz or liquid sample). If liquid sample, refer to the procedure above for materials and explanations. For calibration with Calgaz, you will need the following materials:

1. Two, 2-4 liter Tedlar gas sampling bags with valves
2. Two feet of 1/4 inch Tygon tubing
3. One cannister of 99.4 ppm benzene gas
4. One cannister of 1,020 ppm benzene gas
5. TOVA: 712, OVA, or PID.
6. Notebook

Procedure: Calgaz (benzene)

1. Using a short section (approximately three to six inches) of Tygon tubing, connect the 99.4 ppm benzene standard cannister to the on/off valve of the Tedlar bag.
2. Fill the clean Tedlar bag with approximately one liter of the gas standard. Disconnect the cannister from the on/off valve.
3. Connect the sampling probe of the TOVA to the Tedlar bag on/off valve using a short section of Tygon tubing.
4. Record the total hydrocarbon reading from the instrument once a steady reading is observed.
5. Repeat the above procedure using the 1,020 ppm benzene standard.
6. Compare the instrument's response to the calibration curve. Does it agree? Follow the statistical analysis procedures outlined on the Field Calibration Worksheet to determine the statistical agreement.
7. If the response is in agreement, clean up materials and place a copy of the worksheet in the instrument calibration folder. If not, perform another calibration point to verify the previous results. If this new calibration point is consistent with the prior sample, then a new calibration curve will need to be generated.

VAPEX ENVIRONMENTAL TECHNOLOGIES, INC.

STANDARD QA/QC OPERATING PROCEDURES (SOP)

VAPOR SAMPLING PROCEDURES FOR THE COLLECTION OF VOC CONTAMINATED VAPOR FROM A SOIL VAPOR EXTRACTION SYSTEM

VAPEX SOP NO.: VAPOR-2

Purpose: To document a procedure for the collection of vapor samples from a soil vapor extraction system.

Objectives: To outline procedures for the field collection of VOC contaminated vapors from a soil vapor extraction system. Vapor samples will be collected in 1.5 liter Teflon air sample bags for laboratory analysis via EPA Method T01/T02.

Materials:

1. A 1/4" Apollo brass ball valve with sampling port attached to the discharge of the soil vapor extraction system pump/blower.
2. 1.5 liter Teflon air sample bags with a barb valve.
3. A section of Tygon tubing which is long enough to reach from the discharge sampling port to the sampling bag.
4. Latex and VITON gloves.
5. Field Notebook with pen.
6. Sample bag labels.
7. Chain-of-Custody Report Forms.
8. *VAPEX* Laboratory Sample Data Form.

Procedure:

1. Put VITON gloves over Latex gloves.
2. Fill out sample vial label.
3. The tygon tubing is connected to the discharge port of the system exhaust.
4. The exhaust/discharge port is opened and system vapor is allowed to fill the bag.
5. Close the sampling valve on the sample port, close the barb valve and detach from the sample port.

5\. Store all vapor samples in a cooler with an ice pack.

6\. At the end of the sampling round, fill out a Chain-of-Custody report in DUPLICATE.

7\. When the samples are to be picked up or delivered to a laboratory for laboratory analysis, have both copies of the Chain-of-Custody report form signed by the responsible party - one copy will go to the laboratory with the samples. File the other copy in the Chain-of-Custody Report Form Binder which is to be kept on site in a secure and safe location.

VAPEX ENVIRONMENTAL TECHNOLOGIES, INC.

STANDARD QA/QC OPERATING PROCEDURES (SOP)

WATER SAMPLING PROCEDURES FOR THE COLLECTION OF VOC CONTAMINATED DRAIN WATER FROM AIR/WATER SEPARATORS

VAPEX SOP NO.: WATER-1

Purpose: To document a procedure for the collection of drain water samples from air/water separators.

Objectives: To outline procedures for the field collection of VOC contaminated drain water from air/water separators. Drain water samples will be collected in EPA 40 mL VOA vials for laboratory analysis via EPA Method 601/602.

Materials:
1. EPA 40 mL VOA vials.
2. Latex and VITON gloves.
3. Field Notebook with pen.
4. Sample bottle labels.
5. Chain-of-Custody Report Form.
6. *VAPEX* Laboratory Sample Data Form and a Chain-of-Custody Form.

Procedure:
1. Put VITON gloves over Latex gloves.
2. Fill out sample vial label.
3. Open stopcock on the bottom of the air/water separator tank and fill up a VOA vial. Make sure the vial is completely filled so that when the vial is capped there are **NO** air bubbles. If an air bubble is apparent, the sample must be discarded and a new one prepared.
4. Cap the vial and record all information pertinent to the sample in the field notebook and on the *VAPEX* Laboratory Sample Data Form.
5. Store all water samples in a cooler with an ice pack.
6. At the end of the sampling round, fill out a Chain-of-Custody report in DUPLICATE.
7. When the samples are to be picked up or delivered to a laboratory for laboratory analysis, have both copies of the Chain-of-Custody report form signed by the responsible party - one copy will go to the laboratory with the samples. File the other copy in the Chain-of-Custody Report Form Binder which is to be kept on site in a secure and safe location.

APPENDIX C

GAS CHROMATOGRAMS

CHROMATOGRAM INDEX

1. **FIELD CHROMATOGRAM SEQUENTIAL LISTING**
   This is a listing of chromatograms as they were obtained in the field so that the sequence of chromatographic events may be followed.

2. **CHROMATOGRAMS**
   a. Vapor Probes - Pretest
   b. Vapor Probes - Post Test
   c. Preliminary Tests = VW-S and VW-D.
   d. Vacuum Well - Shallow (VW-S) Well Head Discharge.
   e. Vacuum Well - Deep (VW-D) Well Head Discharge
   f. Outlet Gas of Vapor Extraction System (VW-S and VW-D). Includes: Outlet, Can and Postcarbon Chromatograms
   g. Standards - Vapor Probes
   h. Standards - Vacuum Wells
   i. Blanks - Vapor Probes
   j. Blanks - Vacuum Wells

RETENTION TIME (Rt) INDEX

	COMPOUND	ABBREVIATION	Rt (min)
1.	trans-1,2-dichloroethylene	trans-1,2-DCE trans-DCE	2.444
2.	1,1,1-trichloroethane	111-TCA	3.570
3.	chloroform	HCCl3	3.840
4.	cis-1,2-dichloroethylene	cis-1,2-DCE cis-DCE	4.635
5.	trichloroethylene	TCE	5.410
6.	toluene	Tol	8.788
7.	perchloroethylene	PCE	9.281
8.	ethylbenzene	ethylbenzene	12.703
9.	m-xylene	xylene(s)	13.855

FIELD CHROMATOGRAM SEQUENCIAL LISTING

VAPOR PROBES

Pre-Test

Heleva Landfill

RUN#	SAMPLE	ATTEN.	FILE	DATE	TIME
1	BLANK#1	M4	<BLK1>	22-Feb	09:07 AM
2	STANDARD#1	M4	<STD1>	22-Feb	09:48 AM
3	STANDARD#2	M4	<STD2>	22-Feb	09:48 AM
4	VP1-1	M4	<VP1-1>	22-Feb	10:39 AM
5	VP1-2	M4	<VP1-2>	22-Feb	11:02 AM
6	VP1-2	M4	<VP1-2B>	22-Feb	11:17 AM
7	VP1-3	M8	<VP1-3>	22-Feb	11:54 AM
8	VP2-1	M4	<VP2-1>	22-Feb	01:00 PM
9	VP2-1	M8	<VP2-1B>	22-Feb	01:33 PM
10	BLANK#2	M4	<BLK2>	22-Feb	02:10 PM
11	BLANK#3	M4	<BLK3>	22-Feb	02:25 PM
12	STANDARD#3	M4	<STD3>	22-Feb	02:45 PM
13	VP2-2	M4	<VP2-2>	22-Feb	03:10 PM
1	BLANK#4	M4	<BLK4>	23-Feb	07:30 AM
2	STANDARD B#1	M4	<STD4>	23-Feb	09:25 AM
3	BLANK#5	M4	<BLK5>	23-Feb	09:47 AM
4	VP2-3	M4	<VP2-3>	23-Feb	09:57 AM
5	VP2-3	M8	<VP2-3B>	23-Feb	10:38 AM
6	BLANK#6	M4	<BLK6>	23-Feb	11:00 AM
7	VP3-1	M4	<VP3-1>	23-Feb	11:20 AM
8	VP3-1	M8	<VP3-1B>	23-Feb	11:44 AM
9	BLANK#7	M4	<BLK7>	23-Feb	11:44 AM
10	VP3-2	M8	<VP3-2>	23-Feb	12:15 PM
11	VP3-3	M8	<VP3-3>	23-Feb	12:39 PM
12	BLANK#3	M4	<BLK8>	23-Feb	01:02 PM
13	BLANK#4	M4	<BLK9>	23-Feb	01:14 PM
14	STANDARD B#2	M4	<STD5>	23-Feb	01:24 PM
15	STANDARD B#3	M8	<STD6>	23-Feb	01:40 PM
16	BLANK#10	M4	<BLK10>	23-Feb	01:51 PM
17	STANDARD B#4	M4	<STD7>	23-Feb	02:05 PM
18	STANDARD B#5	M8	<STD8>	23-Feb	02:17 PM

FIELD CHROMATOGRAM SEQUENCIAL LISTING (Cont.)

VAPOR EXTRACTION SYSTEM TESTING

Heleva Landfill

RUN#	SAMPLE	ATTEN.	FILE	DATE	TIME
1	BLANK#1	M4	<BLK1>	27-Feb	08:43 AM
2	STANDARD C#1	M4	<STD1>	27-Feb	09:10 AM
3	SYSTEM LINE	H4	<S-LINE1>	27-Feb	09:30 AM
4	SYSTEM LINE#2	H4	<S-LINE2>	27-Feb	09:47 AM
4	VW-S DISCHARGE	M4	<VW-S1>	27-Feb	11:00 AM
5	VW-S DISCHARGE	M8	<VW-S2>	27-Feb	11:18 AM
6	VW-D DISCHARGE	M4	<VW-D1>	27-Feb	12:40 PM
7	VW-D	M8	<VW-D2>	27-Feb	01:01 PM
8	VW-S #1	M8	<VW-S-4>	27-Feb	04:30 PM
9	BLANK#2	M4	<BLK2>	27-Feb	04:53 PM
10	BLANK#3	M4	<BLK3>	27-Feb	05:38 PM
11	STANDARD C#2	M4	<STD2>	27-Feb	06:12 PM
12	VW-S DISCHARGE#2	M4	<VW-S-5>	27-Feb	06:41 PM
13	VW-S DISCHARGE#2	M4	<VW-S-6>	27-Feb	07:13 PM
14	VW-S#3	M4	<VW-S-7>	27-Feb	08:45 PM
15	VW-S#3	M8	<VW-S-8>	27-Feb	09:50 PM
16	VW-S#4	M8	<VW-S-4>	27-Feb	10:16 PM
17	VW-S#5	M8	<VW-S-10>	28-Feb	12:05 AM
18	BLANK#4	M8	<BLK4>	28-Feb	12:25 AM
19	BLANK#5	M8	<BLK5>	28-Feb	12:42 AM
20	STANDARD C#3	M4	<STD3>	28-Feb	01:00 AM
21	VW-S#6	M8	<VW-S-11>	28-Feb	02:00 AM
22	VW-S#7	M8	<VW-S-12>	28-Feb	05:10 AM
23	VW-S#8	M8	<VW-S-13>	28-Feb	08:47 AM
24	BLANK#6	M4	<BLK6>	28-Feb	09:30 AM
25	BLANK#7	H4	<BLK7>	28-Feb	09:50 AM
26	BLANK#8	H1	<BLK8>	28-Feb	10:10 AM
27	BLANK#9	H1	<BLK9>	28-Feb	10:25 AM
28	BLANK#10	H1	<BLK10>	28-Feb	10:37 AM
29	BLANK#11	H1	<BLK11>	28-Feb	10:45 AM
30	BLANK#12	H1	<BLK12>	28-Feb	11:03 AM
31	BLANK#13	H1	<BLK13>	28-Feb	11:47 AM
32	BLANK#14	H1	<BLK14>	28-Feb	11:55 AM
33	OUTLET GAS	H1	<OUTLET1>	28-Feb	12:14 PM
34	POSTCARBON CAN#1	H1	<PC-C1-1>	28-Feb	12:33 PM
35	POSTCARBON CAN#1	H1	<PC-C1-2>	28-Feb	12:44 PM
36	VW-S#9	M8	<VW-S-14>	28-Feb	01:13 PM
37	STANDARD D#1	M4	<STD4>	28-Feb	03:27 PM
38	VW-S#10	M8	<VW-S-15>	28-Feb	03:58 PM
39	VW-S#11	M8	<VW-S-16>	28-Feb	06:00 PM
40	VW-S#12	M8	<VW-S-17>	01-Mar	07:58 AM
41	STANDARD D#2	M4	<STD5>	01-Mar	09:20 AM
42	VW-S#13	M8	<VW-S-18>	01-Mar	10:00 AM
43	STANDARD D#13	M4	<STD6>	01-Mar	10:45 AM
44	VW-S#14	M8	<VW-S-19>	01-Mar	11:05 AM
45	BLANK#15	H1	<BLK15>	01-Mar	08:30 AM
46	BLANK#16	H1	<BLK16>	01-Mar	08:50 AM

47	BLANK#17	H1	<BLK17>	01-Mar	09:27 AM
48	OUTLET GAS (CAN3)#2	H1	<OUTLET2>	01-Mar	09:10 AM
49	OUTLET GAS (CAN3)#2	H1	<OUTLET3>	01-Mar	09:48 AM
50	POSTCARBON1 #3	H4	<PC-C1-3>	01-Mar	10:08 AM
51	POSTCARBON1 #4	M4	<PC-C1-4>	01-Mar	10:25 AM
52	VW-S#15	M8	<VW-S-20>	01-Mar	11:11 AM
53	VW-S#16	M8	<VW-S-21>	01-Mar	01:05 PM
54	BLANK#18	M8	<BLK18>	01-Mar	02:10 PM
55	BLANK#19	M4	<BLK19>	01-Mar	02:25 PM
56	STANDARD E#1	M4	<STD7>	01-Mar	02:25 PM
57	VW-S#17	M4	<VW-S-22>	01-Mar	02:25 PM
58	VW-S#17	M8	<VW-S-23>	01-Mar	03:57 PM
59	BLANK#20	M8	<BLK20>	01-Mar	04:26 PM
60	VW-S#18	M8	<VW-S-24>	01-Mar	04:58 PM
61	BLANK#21	M8	BLANK#24>	01-Mar	05:25 PM
62	BLANK#22	M8	<BLK22>	01-Mar	05:40 PM
63	BLANK#23	H1	<BLK23>	01-Mar	05:50 PM
64	OUTLET GAS (CAN3)#3	H1	<OUTLET4>	01-Mar	06:10 PM
65	OUTLET GAS (CAN3)#3	H1	<OUTLET5>	01-Mar	06:22 PM
66	OUTLET GAS (CAN3)#4	H1	<OUTLET6>	01-Mar	06:38 PM
67	BLANK#24	H1	<BLK24>	02-Mar	08:30 AM
68	OUTLET GAS #5	HI	<OUTLET7>	02-Mar	09:05 AM
69	OUTLET GAS #5 (DUP.)	HI	<OUTLET8>	02-Mar	09:30 AM
70	VW-S#19	M8	<VW-S-25>	02-Mar	10:25 AM
71	BLANK#25	M8	<BLK25	02-Mar	11:10 AM
72	STANDARD E#1	M8	<STD8>	02-Mar	11:23 AM
73	STANDARD E#1	M8	<STD9>	02-Mar	11:47 AM
74	VW-S#20	M8	<VW-S-26>	02-Mar	12:20 PM
75	BLANK#26	M8	<BLK26>	02-Mar	12:45 PM
76	STANDARD F#3	M4	<STD40>	02-Mar	01:15 PM
77	VW-S-21	M8	<STD11>	02-Mar	01:38 PM
78	BLANK#27	M8	<VW-S-27>	02-Mar	02:05 PM
79	VW-S-21 (DUP.)	M8	<BLK27>	02-Mar	02:25 PM
80	BLANK#28	M8	<VW-S-28>	02-Mar	03:30 PM
81	VW-S#22	M8	<BLK28>	02-Mar	03:53 PM
82	VW-S-29	M4	<VW-S-29>	02-Mar	04:10 PM
83	BLANK#29	M4	<BLK29>	02-Mar	04:30 PM
84	STANDARD G#2	M4	<STD12>	02-Mar	04:57 PM
85	STANDARD G#2	M8	<STD13>	02-Mar	05:11 PM
86	STANDARD G#3	M4	<STD14>	02-Mar	05:25 PM
87	STANDARD G#3	M8	<STD15>	02-Mar	05:40 PM
88	BLANK#30	H4	<BLK30>	02-Mar	05:55 PM
89	BLANK#31	H1	<BLK31>	03-Mar	07:40 AM
90	OUTLET GAS (CAN3)#6	H1	<OUTLET9>	03-Mar	08:04 AM
91	STANDARD H#1	M4	<STD16>	03-Mar	08:40 AM
92	VW-S#23	M8	<VW-S-30>	03-Mar	09:30 AM
93	BLANK#32	M8	<BLK32>	03-Mar	10:07 AM
94	STANDARD H#2	M4	<STD17>	03-Mar	10:35 AM
95	STANDARD H#2	M8	<STD18>	03-Mar	10:50 AM
96	VW-S#24	M8	<VW-S-31>	03-Mar	11:40 AM
97	BLANK#33	M8	<BLK33>	03-Mar	12:15 PM
98	VW-S#25	M8	<VW-S-32>	03-Mar	01:24 PM
99	BLANK#34	M8	<BLK34>	03-Mar	01:55 PM
100	VW-S#25(DUP.)	M8	<VW-S-34>	03-Mar	02:10 PM
101	BLANK#35	M8	<BLK35>	03-Mar	02:27 PM

102	VW-S#26	M8	<VW-S-34>	03-Mar	03:40 PM
103	BLANK#36	M8	<BLK36>	03-Mar	03:58 PM
104	STANDARD H#3(M4)	M4	<STD19>	03-Mar	04:06 PM
105	STANDARD H#3(M8)	M8	<STD20>	03-Mar	04:23 PM
106	BLANK#37	H4	<BLK37>	03-Mar	04:34 PM
107	BLANK#38	H4	<BLK38>	04-Mar	07:10 AM
108	POSTCARBON CAN4	H1	<CAN4-1>	04-Mar	07:30 AM
109	VW-S#27	M8	<VW-S-35>	04-Mar	07:59 AM
110	BLANK#39	M8	<BLK39>	04-Mar	08:38 AM
111	STANDARD I(M4)#1	M4	<STD21>	04-Mar	08:50 AM
112	VW-S#28	M8	<VW-S-36>	04-Mar	10:00 AM
113	BLANK#40	M8	<BLK40>	04-Mar	10:30 AM
114	STANDARD I(M4)#2	M4	<STD22>	04-Mar	10:50 AM
115	VW-S#29	M8	<VW-S-37>	04-Mar	12:04 PM
116	BLANK#41	M8	<BLK41>	04-Mar	12:24 PM
117	VW-S#29(DUP.)	M8	<VW-S-38>	04-Mar	12:45 PM
118	BLANK#42	M8	<BLK42>	04-Mar	01:20 PM
119	VW-S#30	M8	<VW-S-39>	04-Mar	02:00 PM
120	BLANK#43	M8	<BLK43>	04-Mar	02:18 PM
121	STANDARD I#3	M4	<STD23>	04-Mar	02:30 PM
122	BLANK#44	H4	<BLK44>	04-Mar	02:45 PM
123	BLANK#45	H1	<BLK45>	05-Mar	07:30 AM
124	POSTCARBON CAN#4	H1	<CAN4-2>	05-Mar	09:10 AM
124	POSTCARBON CAN#5	H1	<CAN5-1>	05-Mar	09:37 AM
125	VW-S#31	M8	<VW-S#31>	05-Mar	09:37 AM
126	BLANK#46	M8	<BLK46>	05-Mar	10:00 AM
127	STANDARD J#1	M4	<STD24>	05-Mar	10:15 AM
128	VW-S#32	M8	<VW-S-41>	05-Mar	11:38 AM
129	BLANK#47	M8	<BLK47>	05-Mar	11:57 AM
130	VW-S#32(DUP.)	M8	<STD25>	05-Mar	12:20 PM
131	BLANK#48	M8	<BLK#48>	05-Mar	12:40 PM
132	STANDARD J#2	M4	<STD#25>	05-Mar	01:03 PM
133	VW-S#33	M8	<VW-S-43>	05-Mar	01:35 PM
134	BLANK#49	M8	<BLK49>	05-Mar	01:55 PM
135	STANDARD J#3	M4	<STD26>	05-Mar	02:22 PM
136	VW-S#34	M8	<VW-S-44>	05-Mar	03:33 PM
137	BLANK#50	M8	<BLK50>	05-Mar	03:55 PM
138	BLANK#51	M8	<BLK51>	05-Mar	04:10 PM
139	BLANK#52	H1	<BLK52>	06-Mar	07:15 AM
140	POSTCARBON (CAN5)#2	H1	<CAN5-2>	06-Mar	07:25 AM
141	VW-S#35	M8	<VW-S-45>	06-Mar	07:45 AM
142	BLANK#53	M8	<BLK53>	06-Mar	09:00 AM
143	STANDARDK#1	M4	<STD27>	06-Mar	09:14 AM
144	STANDARDK#2	M4	<STD28>	06-Mar	10:55 AM
144	VW-S#36	M8	<VW-S-46>	06-Mar	01:00 PM
145	BLANK#54	M8	<BLK54>	06-Mar	01:06 PM
146	VW-S#36	M8	<VW-S-47>	06-Mar	01:20 PM
147	BLANK#55	M8	<BLK55>	06-Mar	03:23 PM
148	VW-S#37	M8	<VW-S-48>	06-Mar	03:53 PM
149	BLANK#56	M8	<BLK56>	06-Mar	03:53 PM
150	STANDARD K#3	M8	<STD29>	06-Mar	03:53 PM
151	VW-S#38	M4	<VW-S-49>	06-Mar	06:10 PM
152	BLANK#57	M8	<BLK57>	06-Mar	07:10 PM
153	BLANK#58	H4	<BLK58>	06-Mar	07:35 PM
154	BLANK#59	H1	<BLK59>	07-Mar	09:05 AM

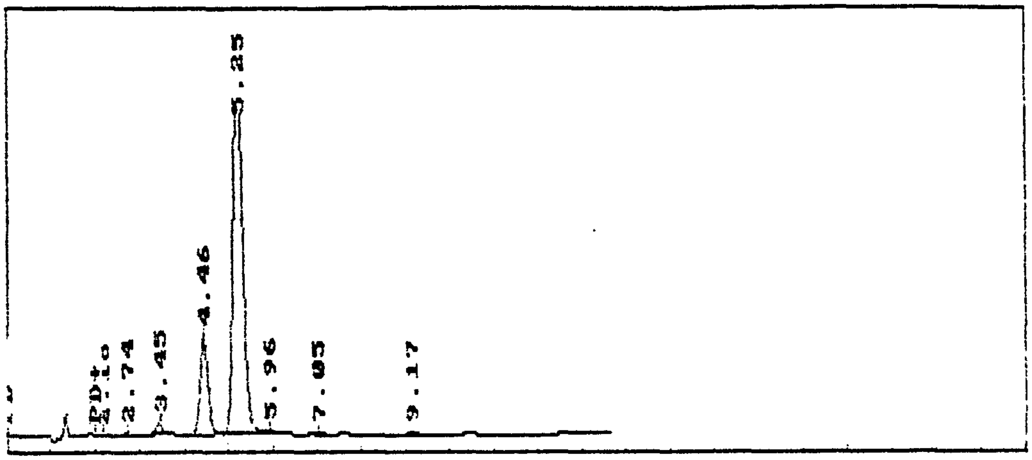
155	POSTCARBON CAN#5	H1	<CAN5-3>	07-Mar	09:34 AM
157	VW-S#39	M8	<VW-S-50>	07-Mar	10:23 AM
158	BLANK#60	M4	<BLK60>	07-Mar	10:55 AM
159	STANDARD L#1	M4	<STD30>	07-Mar	11:20 AM
160	STANDARD L#1	M8	<STD31>	07-Mar	11:40 AM
161	BLANK#61	M8	<BLK61>	07-Mar	12:00 PM
162	VW-S#40	M8	<VW-S-51>	07-Mar	12:30 PM
163	BLANK#62	M8	<BLK62>	07-Mar	12:40 PM
164	VW-S#40(DUP.)	M8	<VW-S-52>	07-Mar	01:15 PM
165	BLANK#63	M8	<BLK63>	07-Mar	01:37 AM
166	VW-S#41	M8	<VW-S-53>	07-Mar	02:00 PM
167	BLANK#64	M8	<BLK64>	07-Mar	03:27 PM
168	STANDARD L#2	M4	<STD32>	07-Mar	03:49 PM
169	BLANK#65	M8	<BLK65>	07-Mar	04:10 PM
170	VW-S#42	M8	<VW-S-54>	07-Mar	04:10 PM
171	BLANK#66	M8	<BLK66>	07-Mar	05:08 PM
172	STANDARD L#3	M4	<STD33>	07-Mar	06:05 PM
173	BLANK#67	H4	<BLK67>	07-Mar	07:00 PM
174	BLANK#68	H1	<BLK68>	08-Mar	07:40 AM
175	POSTCARBON CAN 3B#1	H1	<CAN3B-1>	08-Mar	08:30 AM
176	BLANK#69	M8	<BLK69>	08-Mar	09:00 AM
177	VW-S#43	M8	<VW-S-55>	08-Mar	09:30 AM
178	BLANK#70	M8	<BLK70>	08-Mar	09:55 AM
179	VW-S#43(DUP.)	M8	<VW-S-56>	08-Mar	10:26 AM
180	BLANK#71	M8	<BLK71>	08-Mar	11:02 AM
181	VW-S#44	M8	<VW-S-57>	08-Mar	11:35 AM
182	VW-S#44(2ND RUN)	M8	<VW-S-58>	08-Mar	12:00 PM
183	BLANK#72	H4	<BLK#72>	08-Mar	12:40 PM
184	VW-S#44(3RD RUN)	M8	<VW-S-59>	08-Mar	01:10 PM
185	BLANK#73	M8	<BLK#73>	08-Mar	01:57 PM
186	STANDARD M#1	M4	<STD33>	08-Mar	02:18 PM
187	BLANK#74	M4	<BLK74>	08-Mar	02:32 PM
188	VW-S#45	M8	<VW-S-60>	08-Mar	02:55 PM
189	BLANK#75	M8	<BLK75>	08-Mar	04:00 PM
190	STANDARD M#2	M4	<STD34>	08-Mar	04:25 PM
191	VW-S-46	M8	<VW-S-61>	08-Mar	05:00 PM
192	BLANK#76	M8	<BLK76>	08-Mar	05:30 PM
193	STANDARD M#3	M4	<STD35>	08-Mar	06:00 PM
194	BLANK#77	H4	<BLK77>	08-Mar	06:30 PM
195	BLANK#78	H1	<BLK78>	09-Mar	07:55 AM
196	POSTCARBON CAN3B#2	H4	<CAN3B-2>	09-Mar	08:40 AM
197	POSTCARBON CAN3B#2	H1	<CAN3B2B>	09-Mar	09:15 AM
198	BLANK#79	H1	<BLK79>	09-Mar	10:00 AM
199	POSTCARBON CAN#7	H1	<PC-C7-1>	09-Mar	10:50 AM
200	VW-S#47	M8	<VW-S-62>	09-Mar	11:40 AM
201	BLANK#80	M8	<BLK80>	09-Mar	12:07 PM
202	STANDARD N#1	M4	<STD36>	09-Mar	04:14 PM
203	STANDARD N#1(DUP.)	M8	<STD37>	09-Mar	04:45 PM
204	VW-D#1	M8	<VW-D-1>	09-Mar	05:10 PM
205	BLANK#81	M8	<BLK81>	09-Mar	05:55 PM
206	VP1-2	M8	<VP1-2B>	10-Mar	08:20 AM
207	BLANK#82	M8	<BLK82>	10-Mar	08:40 AM
208	VP1-1	M8	<VP1-1B>	10-Mar	09:05 AM
209	STANDARD O#1	M4	<STD38>	10-Mar	11:40 AM
210	STD O#1(DUP.)	M4	<STD39>	10-Mar	12:00 PM

211	STANDARD O#2	M4	<STD40>	10-Mar	12:20 PM
213	VP2-1(2ND)	M8	<VP2-1B>	10-Mar	12:40 PM
214	VP3-1(2ND)	M8	<VP3-1B>	10-Mar	11:40 AM
215	BLANK#83	H4	<BLK83>	10-Mar	12:00 PM
216	SYSTEM BACKGROUND	H4	<SYSBACK>	10-Mar	12:20 PM
217	VPD-2#2	M8	<VP-D-2>	10-Mar	12:40 PM
218	BLANK#84	H1	<BLK84>	10-Mar	04:40 PM
219	BLANK#85	H1	<BLK85>	10-Mar	04:44 PM
220	POSTCARBON CAN#6	M8	<PC-C6-1>	10-Mar	03:00 PM
221	VW-D#3	M8	<VW-D-3>	10-Mar	03:29 PM
222	BLANK#86	M8	<VW-D-4>	10-Mar	03:53 PM
223	VW-D#3(DUP.)	M8	<BLK86>	10-Mar	04:13 PM
224	STANDARD O#3	M4	<STD41>	10-Mar	04:40 PM
225	VW-D#4	M8	<VW-D-5>	10-Mar	05:05 PM
226	BLANK#87	M4	<BLK87>	10-Mar	05:29 PM
227	VW-D#5	M4	<VW-D-6>	10-Mar	07:10 PM
228	BLANK#88	H4	<BLK88>	11-Mar	07:35 AM
229	BLANK#89	H1	<BLK89>	11-Mar	07:25 AM
230	POSTCARBON CAN#7	H1	<PC-C7-2>	11-Mar	07:47 AM
231	VW-D#6	M4	<VW-D-7>	11-Mar	08:15 AM
232	BLANK#90	M4	<BLK90>	11-Mar	08:40 AM
233	PID CALIB. STD.	M4	<PIDCAL>	11-Mar	08:59 AM
234	BLANK#91	M4	<BLK91>	11-Mar	09:23 AM
235	VW-D#7	M4	<VW-D-8>	11-Mar	10:22 AM
236	BLANK#92	M4	<BLK92>	11-Mar	10:45 AM
237	STANDARD P#1	M4	<STD42>	11-Mar	11:16 AM
238	BLANK#93	M4	<BLK93>	11-Mar	11:40 AM
239	VW-D#8	M4	<VW-D-9>	11-Mar	12:13 PM
240	BLANK#94	M4	<BLK94>	11-Mar	12:30 PM
241	STANDARD P#2	M4	<STD43>	11-Mar	01:08 PM
242	BLANK#95	M4	<BLK95>	11-Mar	01:30 PM
243	VW-D#9	M4	<VW-D-10>	11-Mar	02:40 PM
244	VW-D#9(DUP.)	M4	<VW-D-11>	11-Mar	03:30 PM
245	BLANK#96	M4	<BLK96>	11-Mar	04:18 PM
246	STANDARD P#3	M4	<STD44>	11-Mar	04:45 PM
247	BLANK#97	H1	<BLK97>	12-Mar	07:45 AM
248	POSTCARBON CAN#7	H1	<PC-C7-3>	12-Mar	08:05 AM
249	POSTCARBON CAN#6	H1	<PC-C6-2>	12-Mar	08:27 AM
250	VW-D#10	M4	<VW-D-12>	12-Mar	08:55 AM
251	VW-D#10(DUP.)	M4	<VW-D-13>	12-Mar	09:26 AM
252	BLANK#98	M4	<BLK98>	12-Mar	10:05 AM
253	STANDARD Q#1	M4	<STD45>	12-Mar	10:29 AM
254	VW-D#11	M4	<VW-D-14>	12-Mar	12:20 PM
255	BLANK#99	M4	<BLK99>	12-Mar	12:50 PM
256	STANDARD Q#2	M4	<STD46>	12-Mar	01:15 PM
257	VW-D#12	M4	<VW-D-15>	12-Mar	01:50 PM
258	BLANK#100	M4	<BLK100>	12-Mar	02:17 PM
259	VW-D#13	M4	<VW-D-16>	12-Mar	03:30 PM
260	BLANK#101	M4	<BLK101>	12-Mar	03:52 PM
261	STANDARD Q#3	M4	<STD47>	12-Mar	04:00 PM
262	VW-D-#14	M4	<VW-D-17>	12-Mar	05:30 PM
263	BLANK#102	H1	<BLK102>	13-Mar	07:30 AM
264	POSTCARBON CAN7#4	H1	<PC-C7-1>	13-Mar	08:00 AM
265	STCARBON OUTLET CAN#6	H1	<PC-C6-3>	13-Mar	08:15 AM
266	VW-D#15	M4	<VW-D-18>	13-Mar	08:35 AM

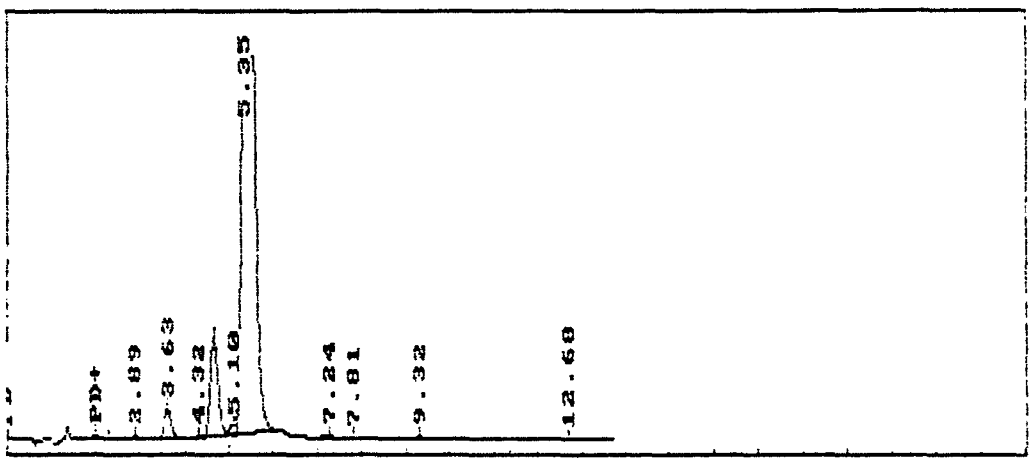
267	BLANK#103	M4	<BLK103>	13-Mar	09:30 AM
268	FIELD CAL1#1	M4	<FCAL1-1>	13-Mar	10:15 AM
269	FIELD CAL1#2	M4	<FCAL1-2>	13-Mar	10:25 AM
270	FIELD CAL1#3	M4	<FCAL1-3>	13-Mar	10:35 AM
271	VP1-2	M4	<VP1-2>	13-Mar	10:55 AM
272	BLANK#104	M4	<BLK104>	13-Mar	11:25 AM
273	VP1-3	M4	<VP1-3>	13-Mar	11:38 AM
274	VP2-3	M4	<VP2-3>	13-Mar	12:25 PM
275	FIELD CAL STD2#1	M4	<FCAL2-1>	13-Mar	01:40 PM
276	FIELD CAL STD2#2	M4	<FCAL2-2>	13-Mar	01:55 PM
277	FIELD CAL STD2#3	M4	<FCAL2-3>	13-Mar	01:05 PM

VAPOR PROBES
PRE-TEST

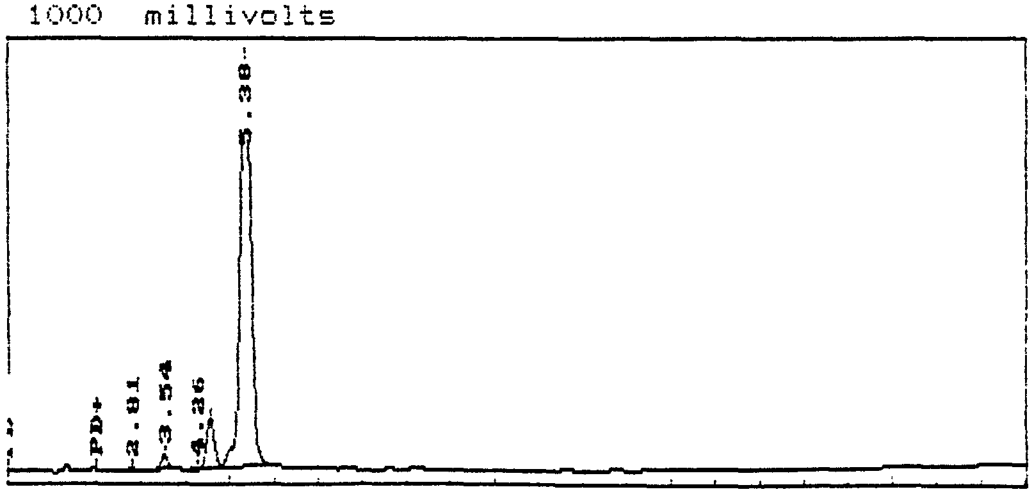
Data File = A:VP1-1.PTS Printed on 03-19-1990 at 09:28:40
Start time: 0.00 min. Stop time: 23.02 min. Offset: 20 mv.
Full Range: 1000 millivolts



Data File = A:VP1-2.PTS Printed on 03-19-1990 at 09:29:58
Start time: 0.00 min. Stop time: 23.02 min. Offset: 20 mv.
Full Range: 1100 millivolts

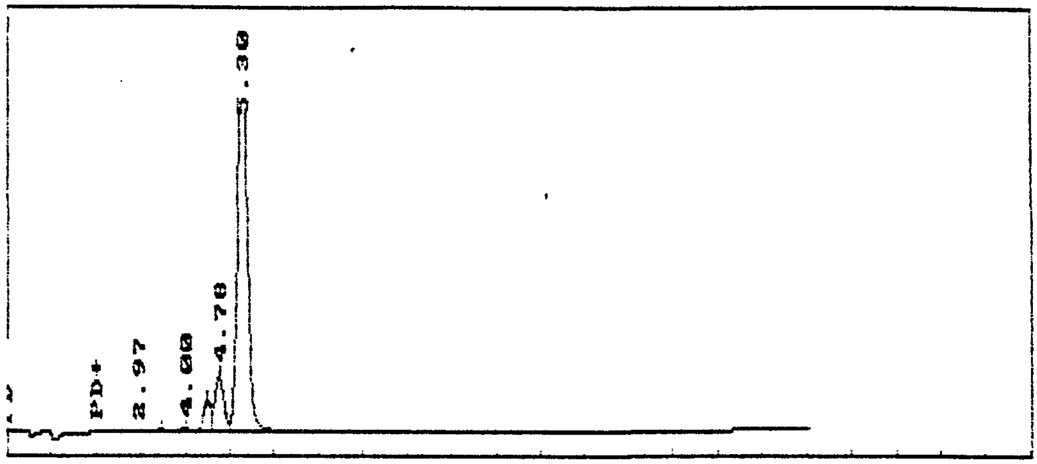


Data File = A:VP1-2B.PTS Printed on 03-19-1990 at 09:31:08
Start time: 0.00 min. Stop time: 23.02 min. Offset: 20 mv.
Full Range: 1000 millivolts

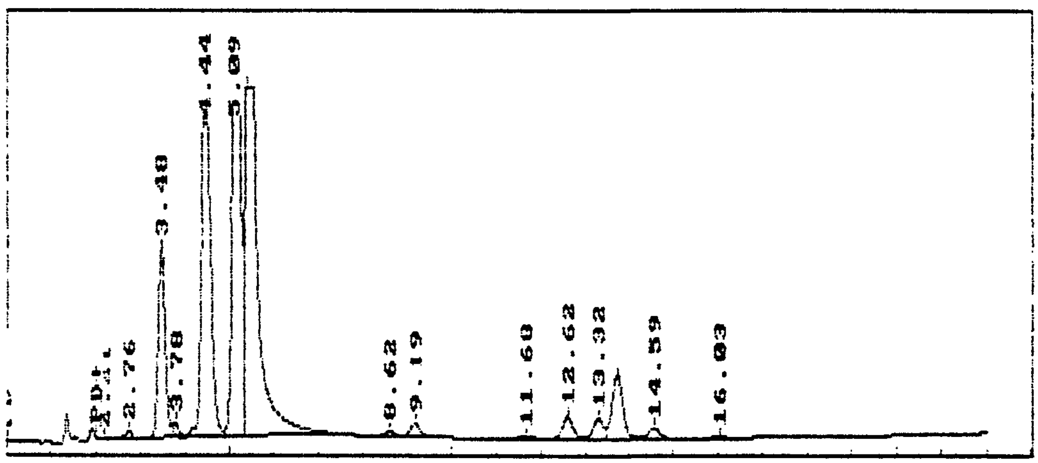


AR303301

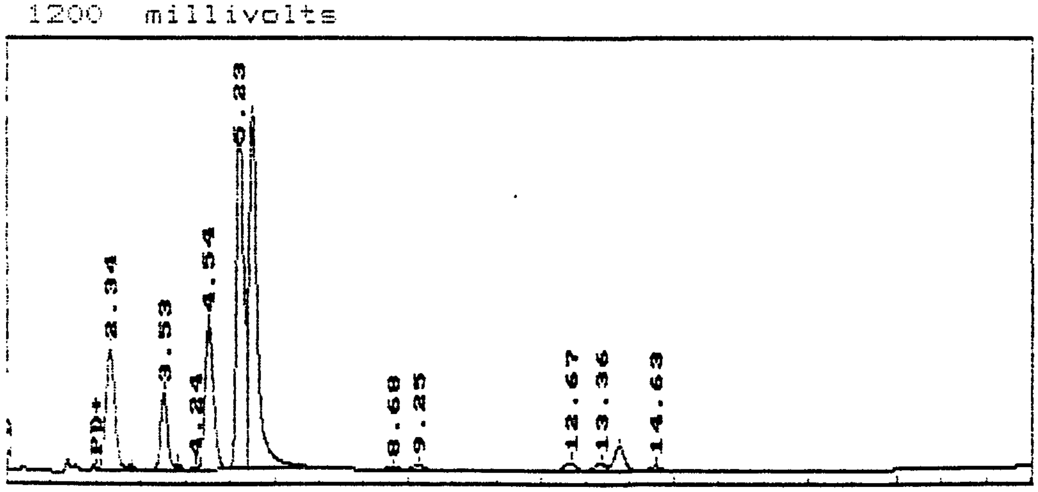
Data File = A:VP1-3.PTS Printed on 03-19-1990 at 09:33:12
Start time: 0.00 min. Stop time: 23.03 min. Offset: 20 mv.
Full Range: 700 millivolts



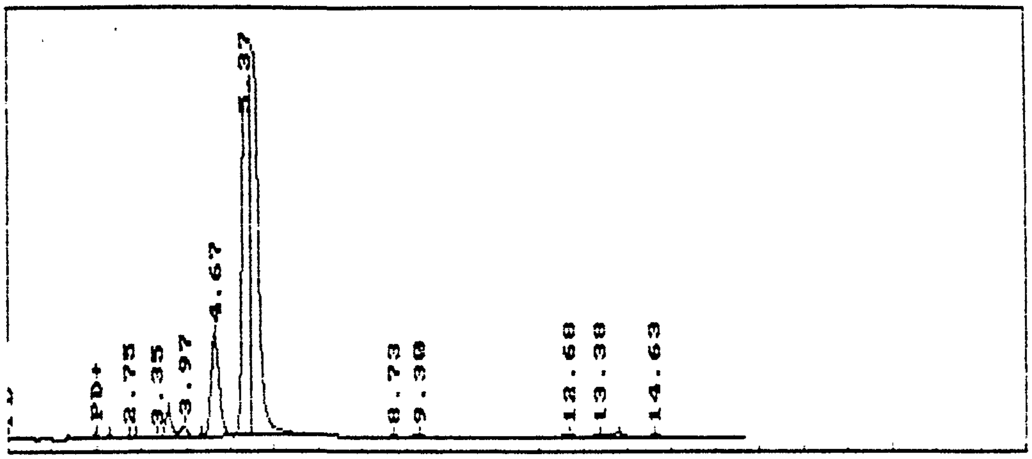
Data File = A:VP2-1.PTS Printed on 03-19-1990 at 09:36:20
Start time: 0.00 min. Stop time: 23.02 min. Offset: 20 mv.
Full Range: 1200 millivolts



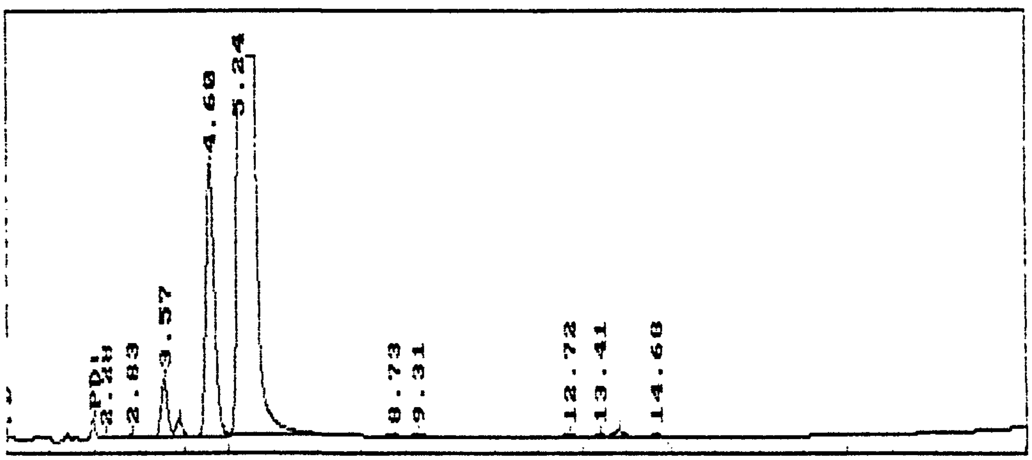
Data File = A:VP2-1B.PTS Printed on 03-19-1990 at 09:37:36
Start time: 0.00 min. Stop time: 23.02 min. Offset: 20 mv.
Full Range: 1200 millivolts



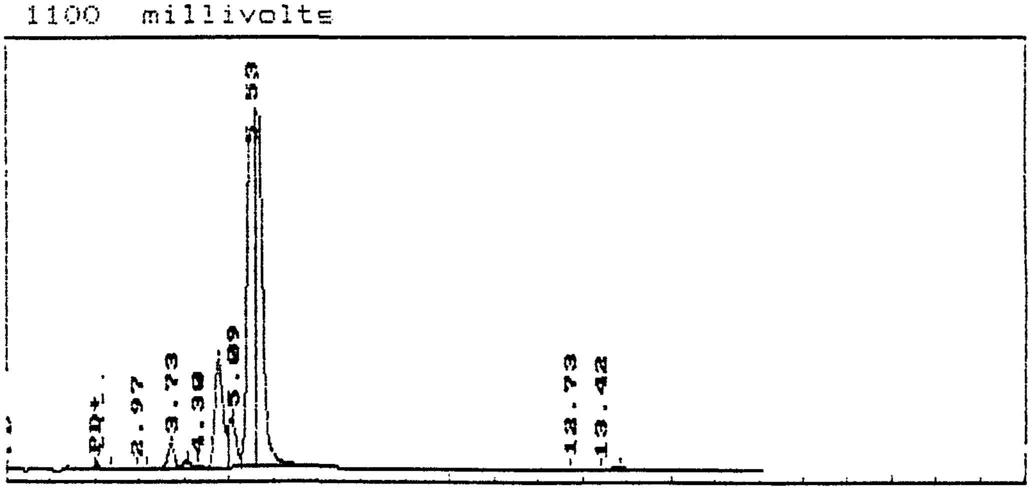
Data File = A:VP2-2.PTS   Printed on 03-19-1990 at 09:39:23
Start time: 0.00 min.   Stop time: 23.02 min.   Offset: 20 mv.
Full Range: 1100 millivolts



Data File = A:VP2-3.PTS   Printed on 03-19-1990 at 09:41:06
Start time: 0.00 min.   Stop time: 23.02 min.   Offset: 20 mv.
Full Range: 1100 millivolts

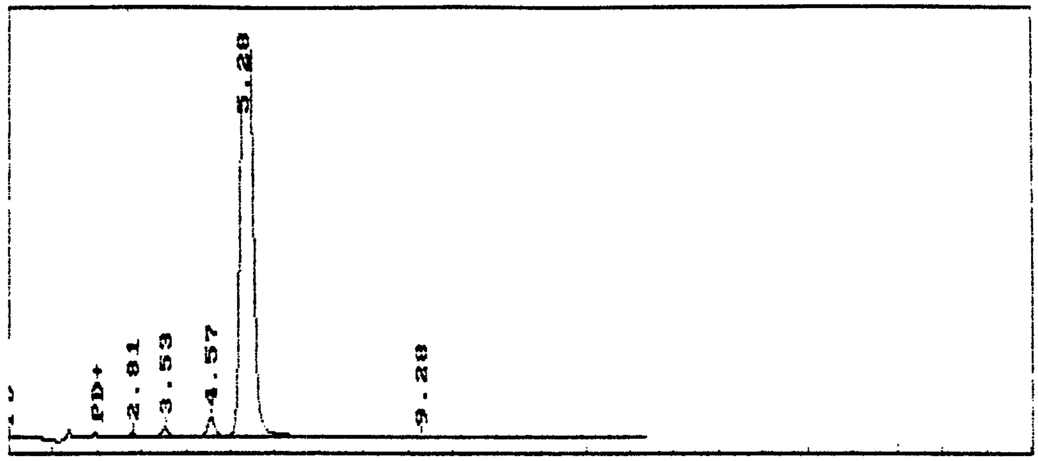


Data File = A:VP2-3B.PTS   Printed on 03-19-1990 at 09:43:56
Start time: 0.00 min.   Stop time: 23.02 min.   Offset: 20 mv.
Full Range: 1100 millivolts

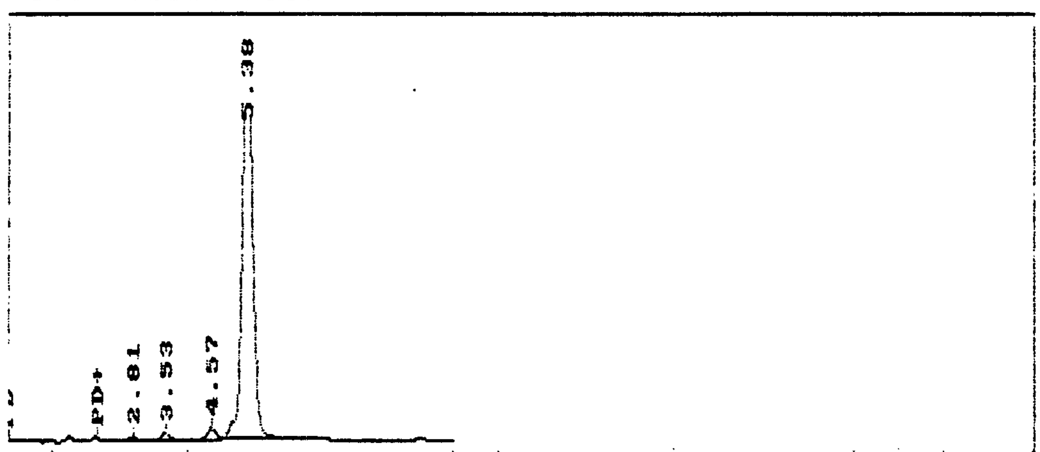


AR303303

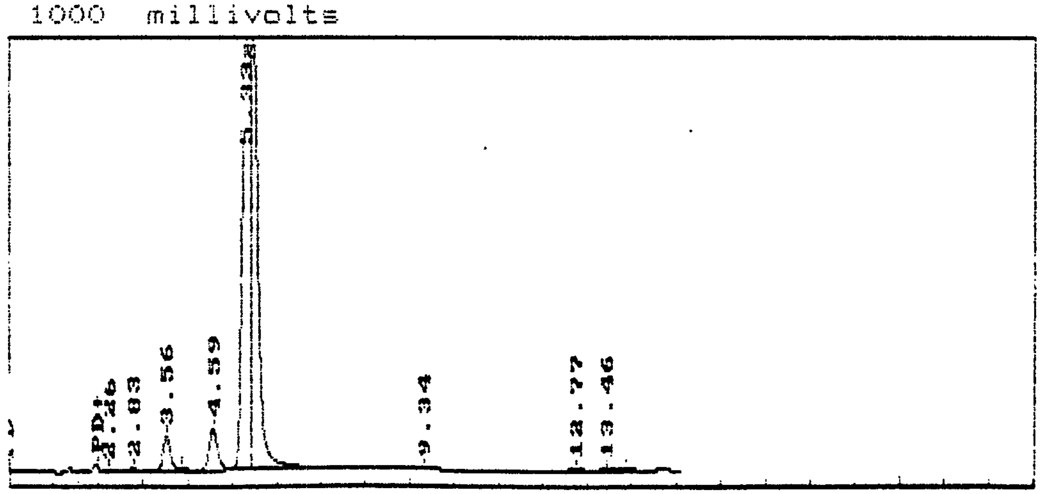
Data File = A:VP3-1.PTS Printed on 03-19-1990 at 09:46:36
Start time: 0.00 min. Stop time: 23.02 min. Offset: 20 mv.
Full Range: 1100 millivolts



Data File = A:VP3-1B.PTS Printed on 03-19-1990 at 09:48:30
Start time: 0.00 min. Stop time: 23.03 min. Offset: 20 mv.
Full Range: 800 millivolts

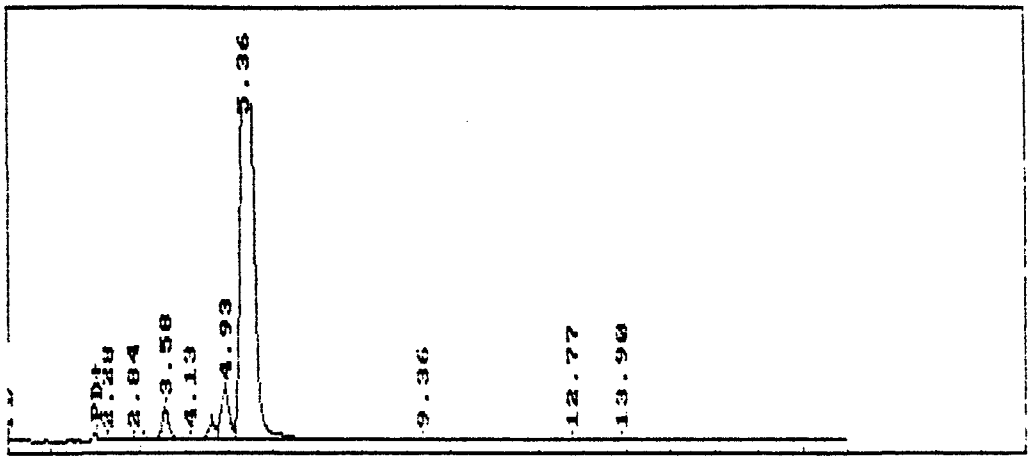


Data File = A:VP3-2.PTS Printed on 03-19-1990 at 09:50:15
Start time: 0.00 min. Stop time: 23.02 min. Offset: 20 mv.
Full Range: 1000 millivolts



AR303304

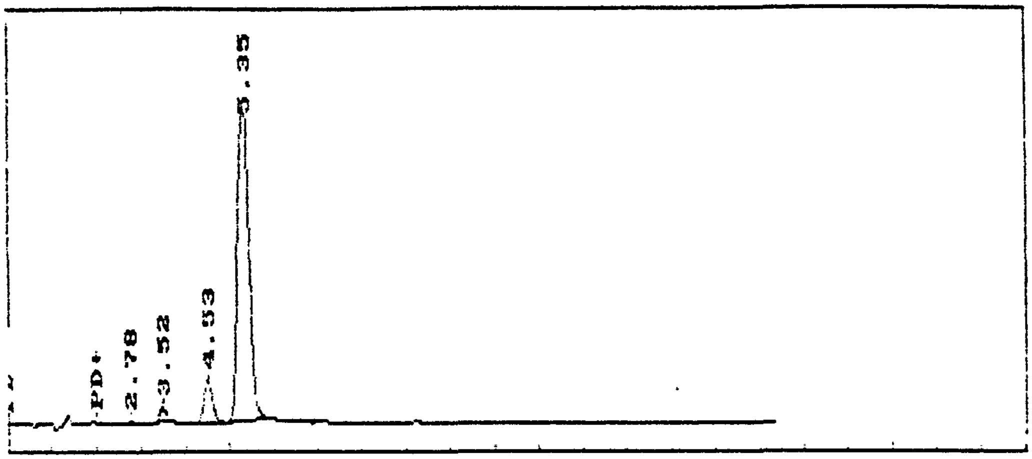
Data File = A:VP3-3.PTS Printed on 03-19-1990 at 09:52:13
Start time: 0.00 min. Stop time: 23.02 min. Offset: 20 mv.
Full Range: 1200 millivolts



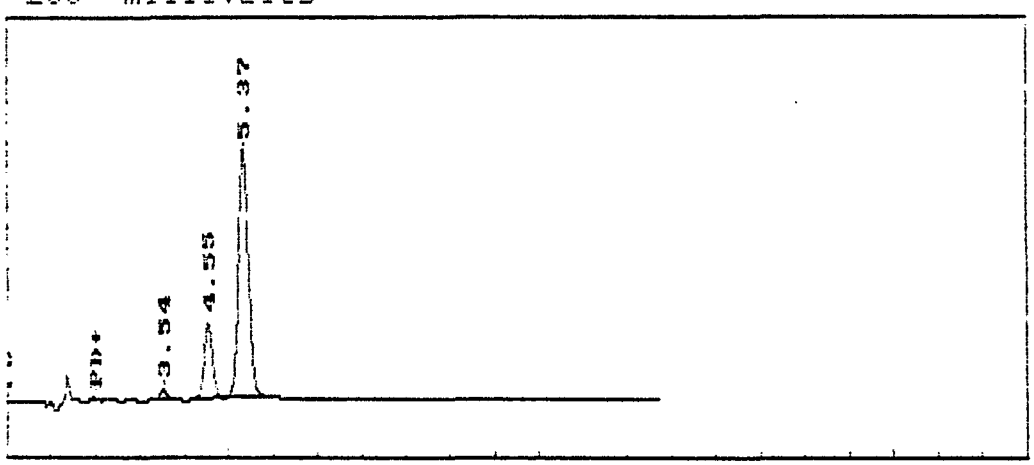
AR303305

VAPOR PROBES
POST TEST

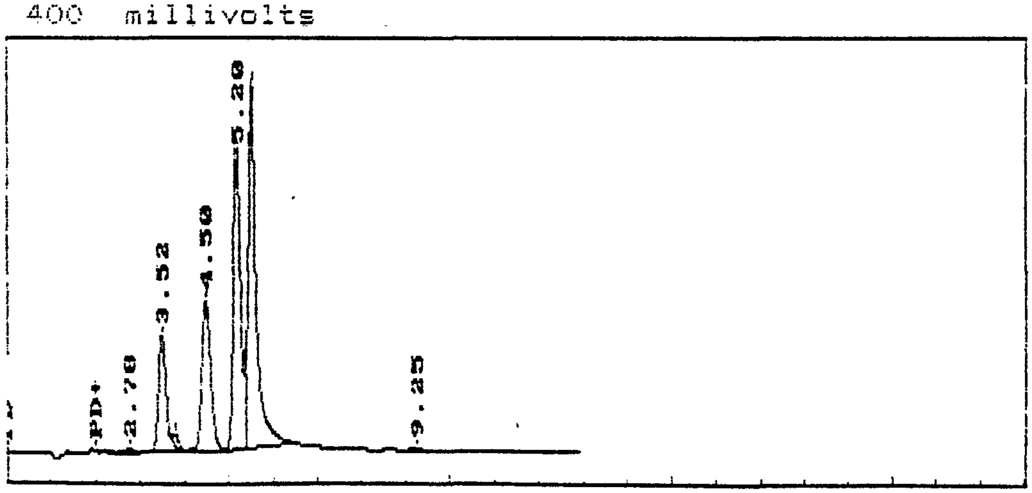
Data File = A:VP1-2B.FTS Printed on 03-19-1990 at 09:57:15
Start time: 0.00 min. Stop time: 23.02 min. Offset: 20 mv.
Full Range: 400 millivolts



Data File = A:VP1-1C.FTS Printed on 03-19-1990 at 10:00:07
Start time: 0.00 min. Stop time: 23.01 min. Offset: 20 mv.
Full Range: 200 millivolts

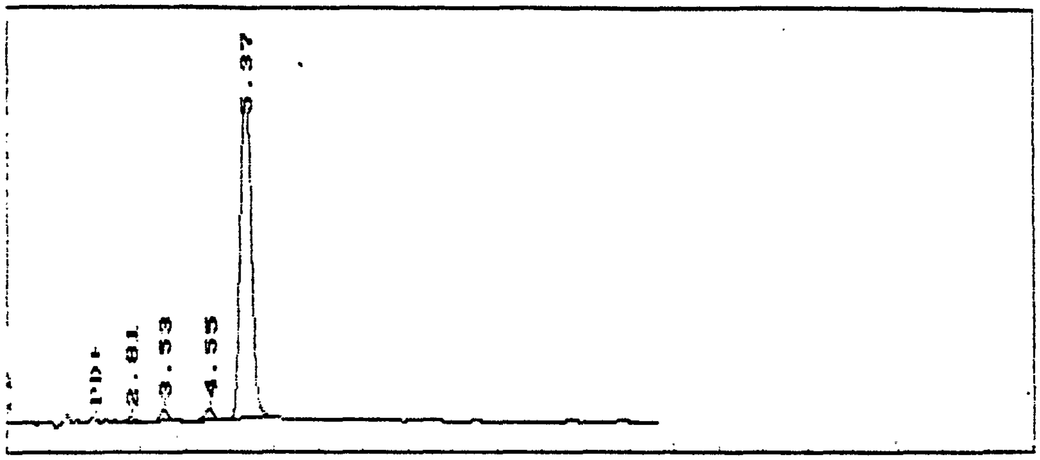


Data File = A:VP2-1B.FTS Printed on 03-19-1990 at 10:01:34
Start time: 0.00 min. Stop time: 23.02 min. Offset: 20 mv.
Full Range: 400 millivolts

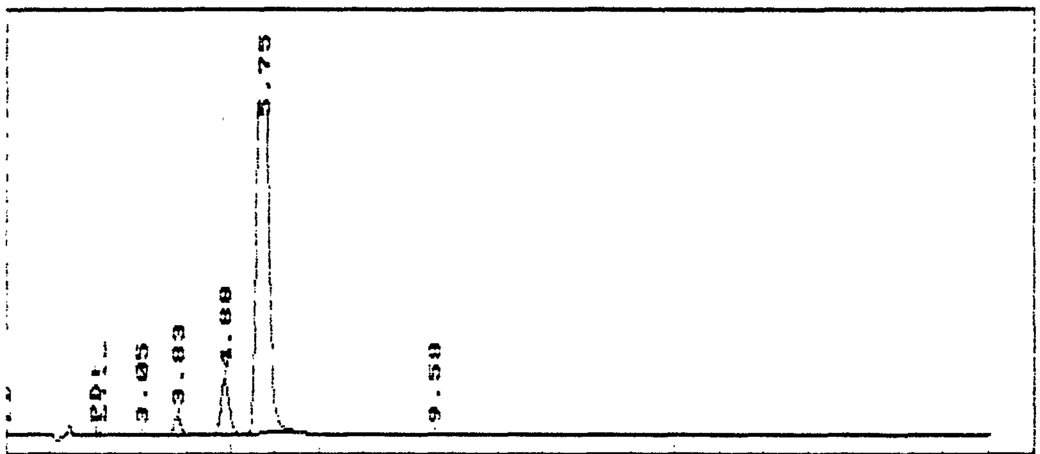


AR303307

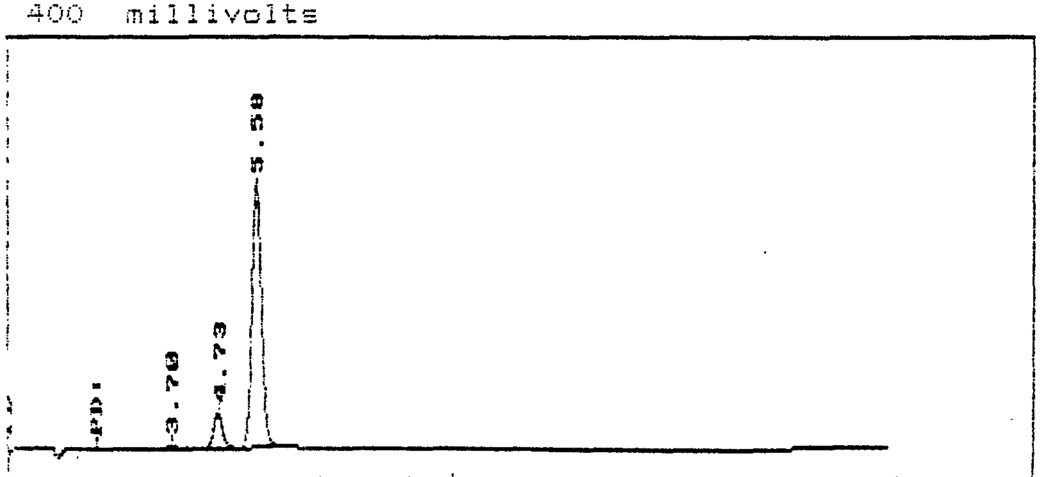
Data File = A:VP3-18.PTS Printed on 03-19-1990 at 10:03:25
Start time: 0.00 min. Stop time: 23.02 min. Offset: 20 mv.
Full Range: 400 millivolts



Data File = A:VP1-2.PTS Printed on 03-19-1990 at 10:05:02
Start time: 0.00 min. Stop time: 23.02 min. Offset: 20 mv.
Full Range: 800 millivolts

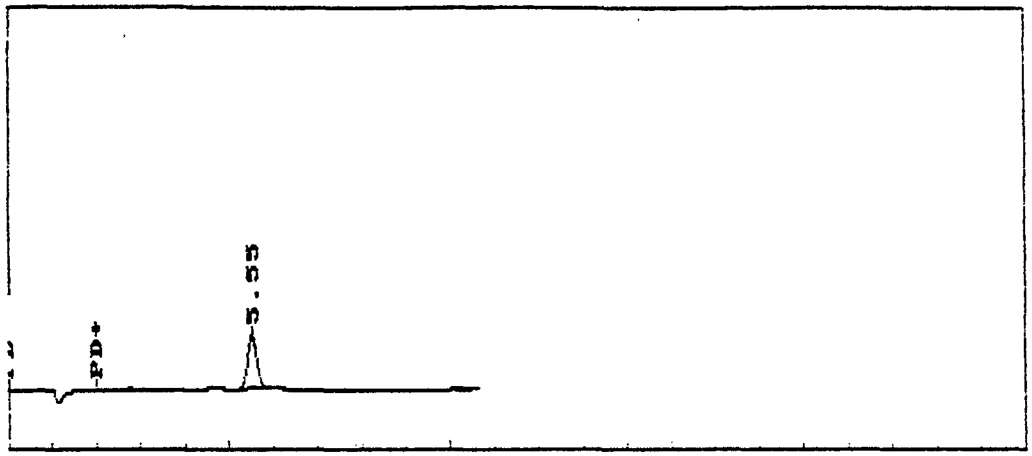


Data File = A:VP1-3.PTS Printed on 03-19-1990 at 10:06:16
Start time: 0.00 min. Stop time: 23.01 min. Offset: 20 mv.
Full Range: 400 millivolts



AR303308

Data File = A:VP2-3.PTS Printed on 03-19-1990 at 10:07:41
Start time: 0.00 min. Stop time: 23.01 min. Offset: 20 mv.
Full Range: 200 millivolts



AR303309