PILOT STUDY REPORT

WORK ASSIGNMENT D003825-29

CHEM-CORE
CITY OF BUFFALO (C)

SITE NO. 9-15-176
ERIE COUNTY (C), NY

Prepared for:
NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
625 Broadway, Albany, New York

Erin M. Crotty, Commissioner

DIVISION OF ENVIRONMENTAL REMEDIATION

URS Corporation Group Consultants
282 Delaware Avenue
Buffalo, New York 14202

Final
July 2002

G3250H

SVE PILOT TEST REPORT

CHEM-CORE SITE

SITE #9-15-176

BUFFALO, NEW YORK

Prepared For:

NYS DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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FINAL

Prepared By:

URS CORPORATION

282 DELAWARE AVENUE

BUFFALO, NEW YORK 14202

JUNE 2002

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1.0 INTRODUCTION

This report summarizes results of a SVE pilot test performed on March 27, 28, and 29, 2002 at the Chem-Core Site (Site No. 9-15-176) in Buffalo, Erie County, New York (Figure 1). In accordance with the scope of work for WA D003825-29, this report summarizes the results of the pilot test and discusses the feasibility of full-scale implementation of SVE at the site.

2.0 SOIL VAPOR EXTRACTION PILOT TEST

2.1 SVE Well Installation

Between March 4 and March 11, 2002, Nothnagle Drilling installed one SVE well (SVE-1) and four vacuum observation wells (VO-1 through VO-4) under subcontract to Buffalo Drilling Company. The SVE well and vacuum observation wells were installed inside the Chem-Core building as shown in Figure 2. The wells were constructed by advancing hollow stem augers to bedrock and then installed by incrementally removing the auger as silica sand pack was placed around the well screens. Each well was sealed with 2 to 3 foot of bentonite pellets. The wells were fitted with flush-mount curb boxes cemented into the concrete floor. SVE and vacuum observation well construction details are presented in Appendix A.

2.2 SVE Pilot Test Equipment

Soil vapor extraction and treatment was conducted with a skid-mounted dual-phase vacuum extraction unit. The blower unit is rated at 100 cubic feet per minute (cfm) and a maximum vacuum of 29.5 inches of mercury. The unit was equipped with a knockout tank and transfer pump for extracted groundwater. The unit was rented from Product Recovery Management (PRM) in North Carolina. A 55-gallon drum of vapor-phase carbon was connected in series to the blower discharge to treat soil gas prior to discharge to the atmosphere. Electrical power was supplied from a commercial 25,000-watt trailer-mounted diesel generator rented from a local vendor. The SVE unit required three-phase 230v electrical power. The SVE unit specifications are included in Appendix B.

2.3 SVE Pilot Test

URS mobilized to the site on Wednesday, March 27, 2002. The SVE test equipment was set up adjacent to SVE-1. The test was performed in two phases: 1) a stepped-rate test to evaluate capacity of the extraction well (SVE-1), and; 2) a constant-rate test to evaluate soil air permeability, radius of influence, and contaminant removal rates.

2.3.1 Stepped-Rate Test

The stepped-rate test was started at 1200 hours on March 28, 2002. Four steps were conducted. The steps were achieved by varying the amount of bypass air; and no bypass air for the final step. Step 1 was performed at a vacuum of 10-inches of mercury for 30 minutes. Step 2 was performed at a vacuum of 15-inches of mercury for 30 minutes. Step 3 was performed at a vacuum of 20-inches of mercury for 30 minutes. Step 4 was performed at a vacuum of 23-inches of mercury for 3 hours. The vacuum rate decreased to 21 inches of mercury at the end of the 3-hour test. During each step, the soil gas was monitored with a total vapor analyzer equipped with both a photoionization detector and flame ionization detector to measure VOC constituents in both the untreated air stream and discharge. Air flow and temperature at the extraction well and after the blower were recorded at 10 to 15 minute intervals. Vacuum response in the vacuum observations was measured using a magnehelic pressure gauge at each well. Data recorded during all of the steps are summarized in Appendix C. A schematic of the SVE system is shown in Figure 2. Figure 3 presents the relationship of the soil gas flow rate and the vacuum pressure at SVE-1 during the stepped-rated test. Based upon the very low response in the vacuum observation wells at maximum vacuum, URS determined that the constant-rate test would be conducted at maximum vacuum (i.e., approximately 23 inches of mercury).

2.3.2 Constant-Rate Test

The constant-rate test was started at 07:48 and ended at 15:50 on March 29. During the test, readings from the indicators on the SVE pilot unit and on the vacuum extraction wells locations were periodically recorded. These readings are shown on the field records in Appendix D. The constant-rate test started at a vacuum and soil gas flow close to the maximum achievable with the SVE unit under the step-test conditions as determined by the step test. The initial vacuum pressure was 21.75 in. mercury and the soil gas flow rate was 36.82 cubic feet per minute (cfm). At 15:50, when the test ended, the vacuum had decreased to 16.50 in. mercury vacuum pressure, and the flow rate had increased to 81 cfm soil gas flow rate. The values of the observed vacuum during the whole test were low (0.1 inch of water or less) at all four monitoring locations. Table 1 summarizes data recorded during the constant-rate test.

2.3.2.1 Radius of Influence

The radius of influence is generally the furthest distance from an extraction well that soil can effectively be treated by SVE. The radius of influence is determined by placing a vacuum on an extraction well, measuring the vacuum that is achieved in nearby monitoring points, and then projecting the distance where the well no longer has an influence. An average vacuum of 19.92 inches of mercury was placed on well SVE-1 by the blower unit. Vacuum was monitored at four locations during the pilot test, VO-1 (5 feet from SVE-1), VO-2 (15 feet from SVE-1), VO-3 (10 feet from SVE-1), and VO-4 (20 feet from SVE-1).

The vacuum measured at all monitoring locations was low (less than 0.1 inch of water column). Based on the evaluation presented in Appendix F, the estimated radius of influence for SVE-1 was 5 feet. This relatively small radius of influence may be attributable to the heterogeneity of the unsaturated zone. In particular, the upper one foot of the unsaturated zone, consisting of fill with sandy silt and traces of gravel, is believed to have a significantly higher permeability than other lithologic layers in the unsaturated zone. Because of the higher permeability in the upper zone, it is believed that most air was extracted from the upper zone during the pilot test. This zone is above the screen of the observation wells, so significant vacuum was not recorded in the observation wells. This preferential high flow in a more highly permeable zone is called short circuiting. As a result of this short circuiting, it would be necessary to use additional engineering measures, e.g., air inlet wells screened in less permeable zones, to ensure that air flows and is extracted in the less permeable lower portion of the unsaturated zones.

2.3.2.2 Intrinsic Permeability

Intrinsic permeability (k) is the measure of a soil's ability to transmit fluids, i.e. groundwater and air, and is typically used as an indicator for the effectiveness of SVE remediation (intrinsic permeability (k) is a function of soil properties only, whereas hydraulic conductivity (K) is a function of both soil and fluid properties). Based on the data obtained from the pilot test, the k value for the site soil was determined. As shown in Appendix F, the intrinsic permeability was calculated to be approximately 1×10^{-8} square centimeters (cm^2). This corresponds to the permeability expected for the fill, sand, and sandy silt that are in the upper layer of soil near the concrete floor.

The calculated permeability supports the conclusion that most flow occurred in the more permeable soil near the surface.

2.3.2.3 VOC Mass Removal Rate

VOC removal rates were estimated, both semi-quantitatively and quantitatively, during the SVE pilot test. Semi-quantitative measurements of VOCs in the extracted soil gas were made periodically with a PID instrument. Based on PID measurements, VOC concentrations in the extracted, untreated soil gas averaged 294 ppmv during the constant-rate test (Table 1).

A soil gas sample for quantitative analysis of VOC concentrations was collected through a one-hour flow controller into a Summa canister at the start of the constant-rate test. The sample was collected from the suction side of the SVE blower on March 29, 2002 and was shipped to Severn Trent Laboratories, Knoxville, Tennessee, for analysis by Method EPA-19 TO 14. The analytical data sheet for the soil gas analysis appears in Appendix E.

VOC constituents detected in the soil gas sample and the relative percent of the total quantified VOC concentration are summarized as follows:

• 1,1-Dichloroethene	16,000 ppbv	(1%)
• Methylene Chloride	610,000 ppbv	(21%)
• Tetrachloroethene (PCE)	2,200,000 ppbv	(76%)
• 1,1,1-Trichloroethane	35,000 ppbv	(1%)
• Trichloroethene (TCE)	38,000 ppbv	(1%)
Total Quantified VOCs	2,889,000 ppbv	100%

VOC mass removal rate estimates are summarized on Table 2. The estimate shows approximately 57.7 pounds of VOCs would be removed per extraction well during the first day of operation. Removal rates would then decrease over time.

3.0 TECHNOLOGY FEASIBILITY

SVE is a feasible technology in that it should be evaluated in the FS for the site. However, the pilot test shows that SVE will likely not be the best choice for remediation of onsite soil because of the following:

- Because of the small radius of influence (i.e., 5 feet or less) well spacing will be very tight, thereby increasing the cost of remediation.
- Flow seems to travel mainly in permeable zones of contamination so that relatively impermeable zones that are highly contaminated will be remediated only if air inlet wells are installed in less permeable zones, which also increases the cost of remediation.

TABLE 1

SVE PILOT TEST SUMMARY

CHEM CORE SITE

Parameter	Units	Time											Average
		7:48	8:10	8:30	8:50	9:10	9:30	9:50	10:10	10:30	10:50	11:10	Values
Well SVE-1 Casing Vacuum Pressure (P)	in Hg	21.75	20.5	20.5	20.25	20	19.9	19.5	19.5	19.5	19	18.75	19.92
Soil Gas Flow Rate	SCFM	28.05	24.83	23.05	31.59	31.2	32.77	33.81	40.57	41.41	40.51	42.26	34
Blower Inlet Flow Rate	ACFM	36.82	34.36	31.91	44.18	44.18	46.63	49.09	58.9	60.13	60.38	63.81	48
Blower Discharge Flow Rate	ACFM	78.54	66.27	63.81	61.36	68.72	73.63	73.63	76.09	76.09	74.86	78.54	72
Blower Inlet Vacuum Temperature (T)	° F	36	33	33	32	32	32	32	32	32	32	32	33
Blower Discharge Temperature	° F	56	72	79	85	87	87	88	89	96	91	91	84
Untreated Soil Gas-PID reading	ppmv	335	390	365	279	280	287	282	266	264	250	233	294
Soil Gas after Activated Carbon-PID reading	ppmv	0	0.02	0.03	0.12	0.14	0.15	0.07	0.06	0.04	0.11	0.05	0.07

NOTES:

in WC = inches water column

SCFM = standard cubic feet per minute

SCFM = ACFM x (P/14.7) x [(460+60)/(460+T)]

Soil gas flow rate is corrected for temperature and pressure

Untreated soil gas contaminants were measured after passing through the blower

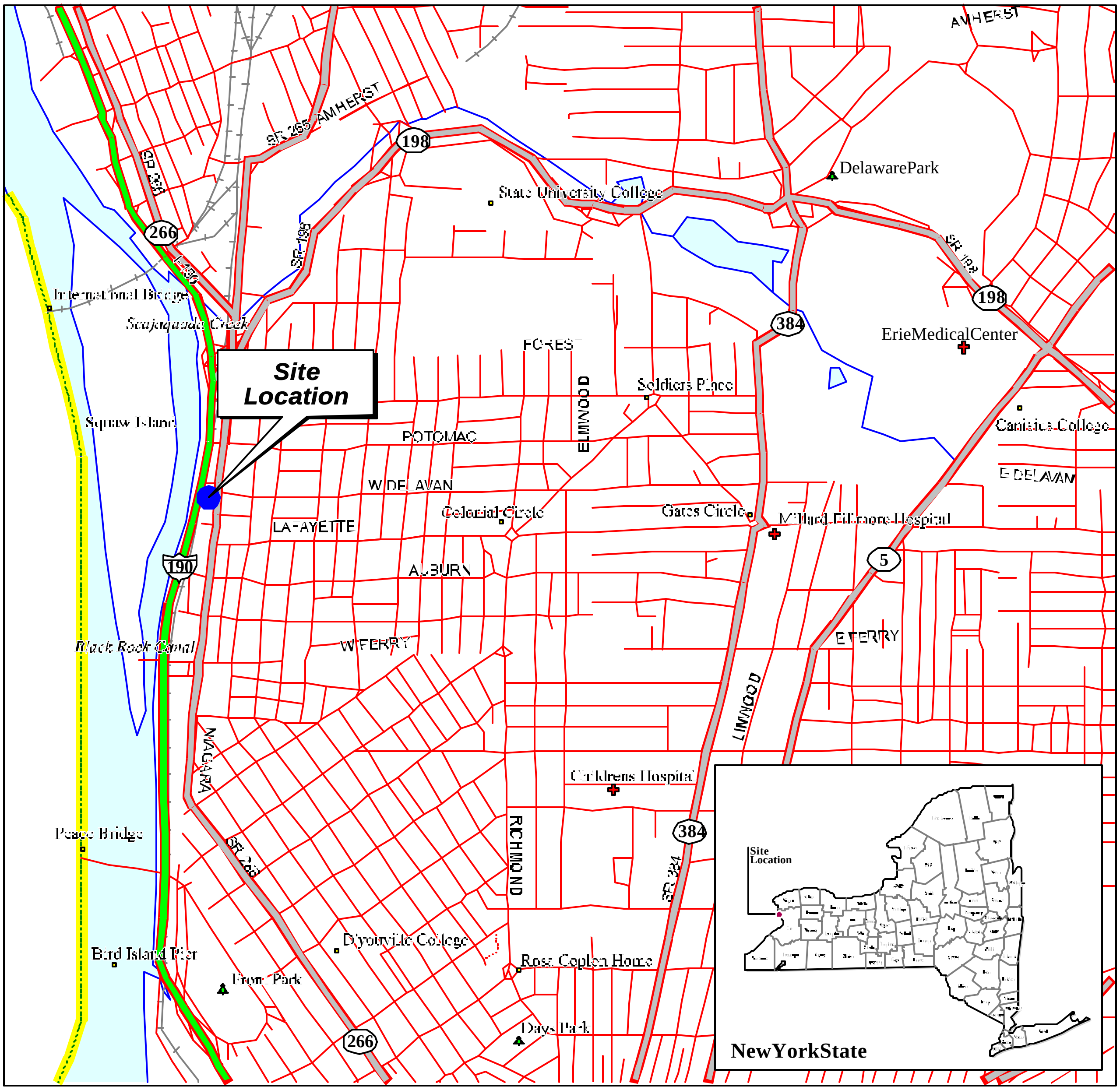
TABLE 2
VOC MASS RECOVERY RATE
SVE PILOT TEST
CHEM CORE SITE

Compound	Molecular Weight g/mol	Vapor Pressure mm Hg	Boiling Point °C	Vapor Phase Concentration ppbv	Mass Recovery Rate lb/day
1,1-Dichloroethene	97	495	31.56	16,000	0.210
Methylene Chloride	85	362	39.8	600,000	6.886
Tetrachloroethene	166	15.8	121	2,200,000	49.306
1,1,1-Trichloroethane	133.4	100	74.1	35,000	0.630
Trichloroethene	131.4	56.8	87.2	38,000	0.674
Total Volatile Organics				2,889,000	57.706

Based on 24 hours of continuous operation at a flowrate of 34 SCFM.

Mass Recovery Rate (lb/day) =

= (ppbv / 10^9) x (Molecular Weight / 22,400cm$^{3/mol}$) x (SCFM x 60 min/hr x 24 hr/day) x (30.48^3 cm^3/ft^3) / (453.59 g/lb)



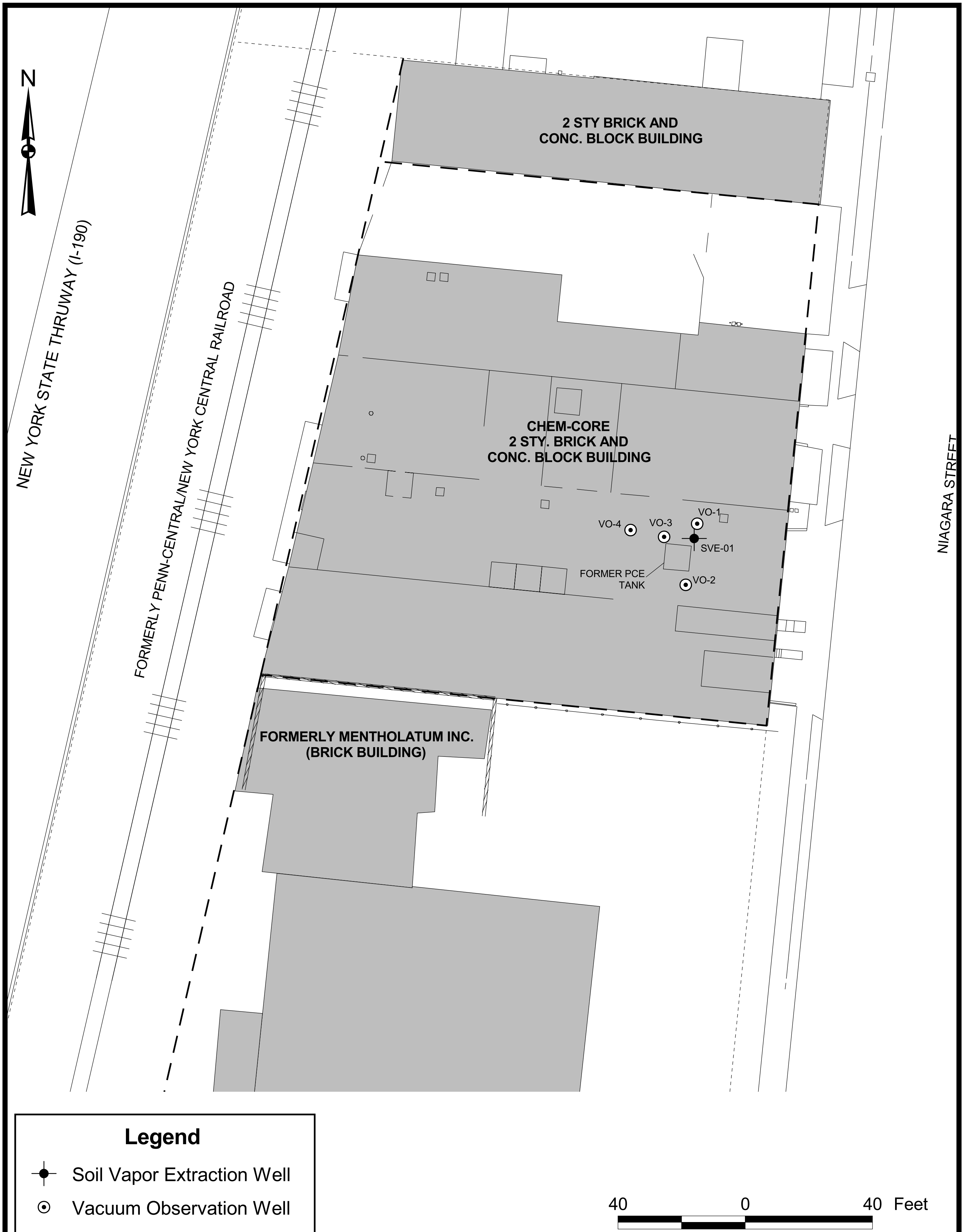
APPROXIMATE SCALE IN FEET

2500 0 2500

URS

CHEM-CORE FACILITY
SITE LOCATION MAP

FIGURE 1



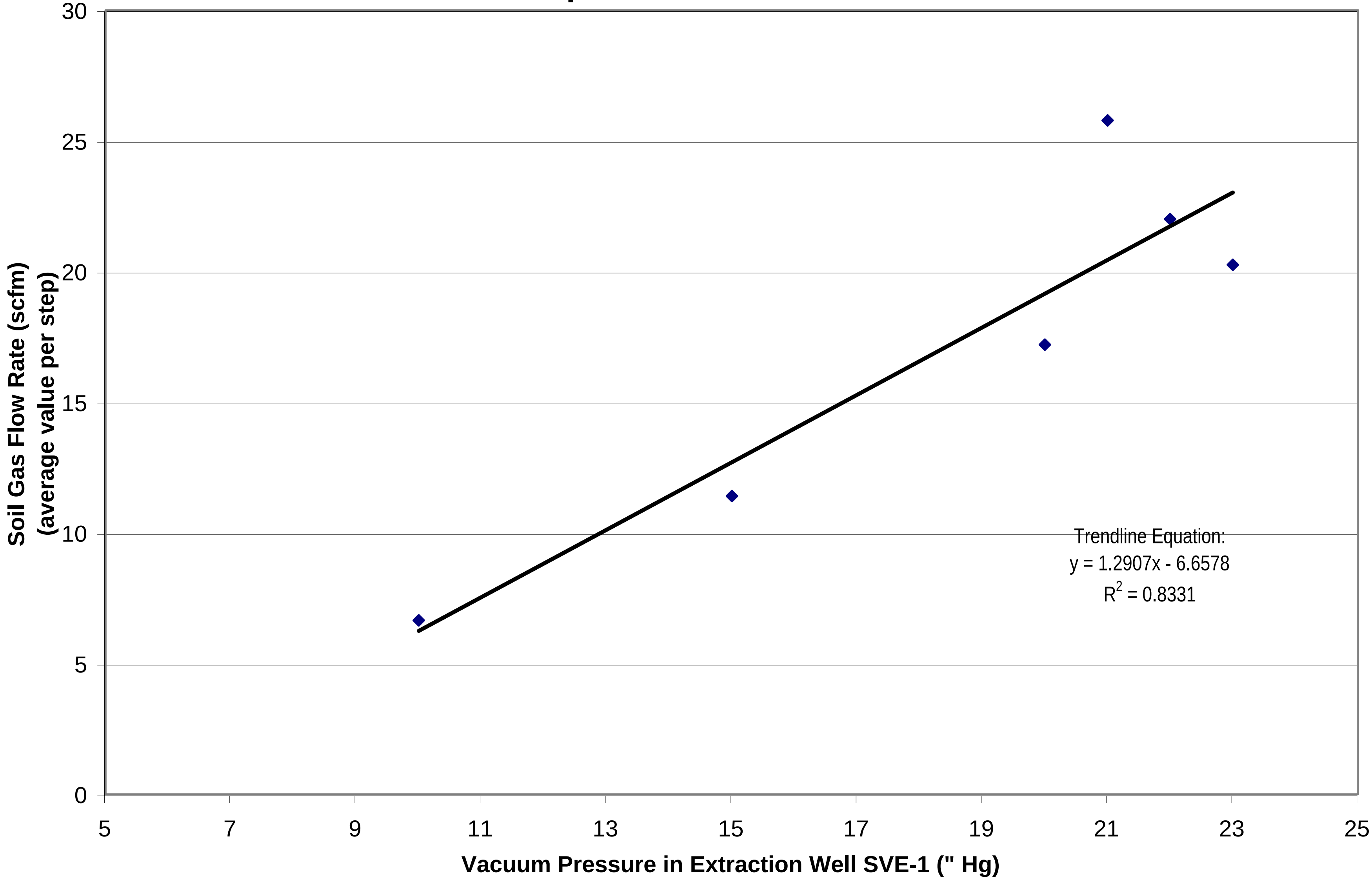
J:\35890.00\GIS\geology.apr SOIL VAPOR EXTRACTION SYSTEM
4/23/2002

URS

CHEM CORE
SVE/VACUUM OBSERVATION WELL LOCATIONS

FIGURE 2

Figure 3
Extraction Well Performance Evaluation
Step Test Observed Data



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7/15/02\10:57 AM

APPENDIX A

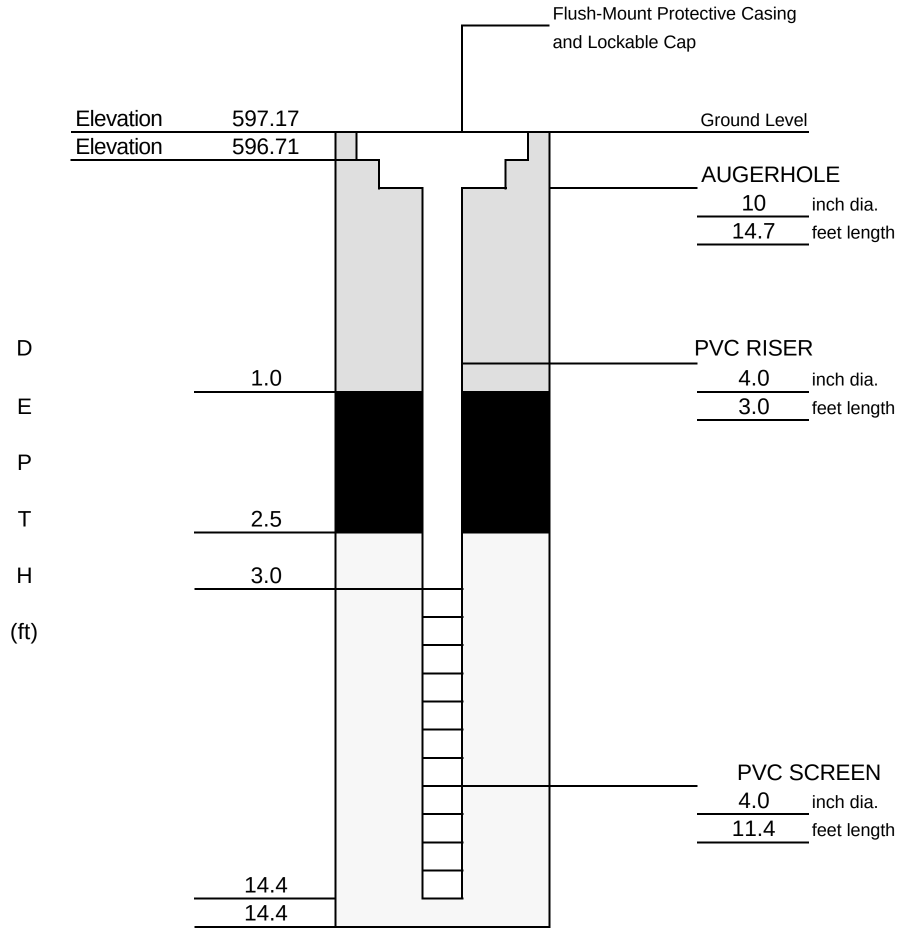
SVE WELL/VACUUM OBSERVATION WELL CONSTRUCTION DATA

DRILLING SUMMARY

Geologist:	Scott McCabe
Drilling Company:	Buffalo Drilling Co.
Driller:	Kevin Bush
Rig Make/Model:	Mite-E-Mite
Date:	3/5/02

GEOLOGIC LOG

Depth(ft.)	Description
0-14.4	See SB-2 for lithologic description.



Not to Scale

WELL DESIGN

CASING MATERIAL		*SCREEN MATERIAL*		*FILTER MATERIAL*
Surface:	8-inch steel flush-mount	Type:	4" Schedule 40 PVC	Type: NSF #2 sand Setting: 2.5-14.4'
Monitor:	4" Schedule 40 PVC	Slot Size:	.010 -inch	*SEAL MATERIAL* Type: Bentonite Chips Setting: 1.0-2.5'

COMMENTS:

LEGEND

Cement/Bentonite Grout

Bentonite Seal

Sand Pack

Client: NYSDEC	**Location:** **Chem Core**	**Project No.:** **05-00035890.04**
URS Corporation	**BEDROCK MONITORING WELL CONSTRUCTION DETAILS**	**Well Number:** **SVE-1**

DRILLING SUMMARY

Geologist:
Scott McCabe

Drilling Company:
Buffalo Drilling Co.

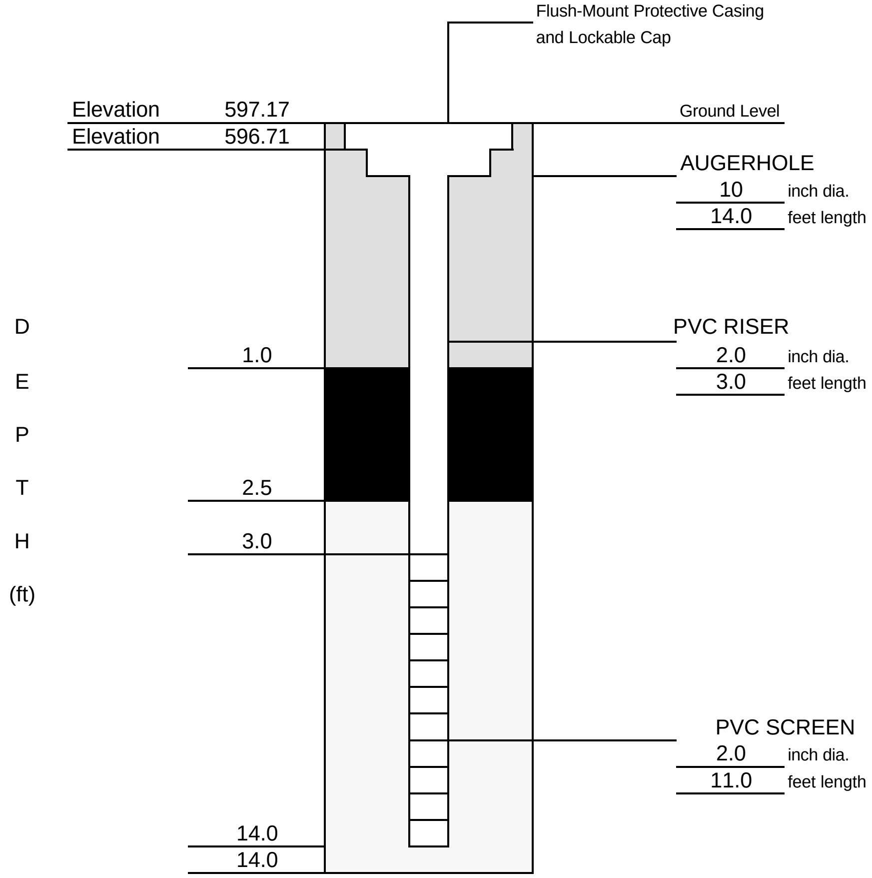
Driller:
Kevin Bush

Rig Make/Model:
Mite-E-Mite

Date:
3/5/02

GEOLOGIC LOG

Depth(ft.)	Description
0-14.0	See SB-2 for lithologic description.



Not to Scale

WELL DESIGN

CASING MATERIAL		*SCREEN MATERIAL*		*FILTER MATERIAL*
Surface:	8-inch steel flush-mount	Type:	2" Schedule 40 PVC	Type: NSF #2 sand Setting: 2.5-14.0'
Monitor:	2" Schedule 40 PVC	Slot Size:	.010 -inch	*SEAL MATERIAL* Type: Bentonite Chips Setting: 1.0-2.5'

COMMENTS:

LEGEND

- Cement/Bentonite Grout
- Bentonite Seal
- Sand Pack

Client: NYSDEC	**Location:** **Chem Core**	**Project No.:** **05-00035890.04**
URS Corporation	**BEDROCK MONITORING WELL CONSTRUCTION DETAILS**	**Well Number:** **VO-1**

DRILLING SUMMARY

Geologist:
Scott McCabe

Drilling Company:
Buffalo Drilling Co.

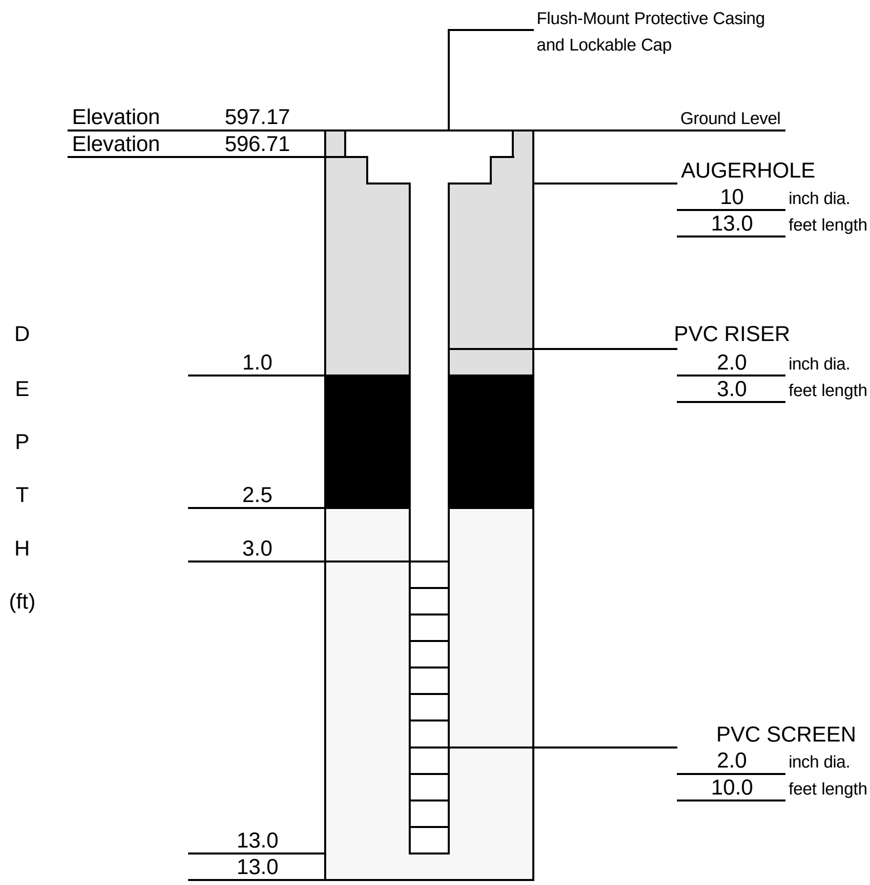
Driller:
Kevin Bush

Rig Make/Model:
Mite-E-Mite

Date:
3/7/02

GEOLOGIC LOG

Depth(ft.)	Description
0-13.0	See GB-13 for lithologic description.



WELL DESIGN

Not to Scale

CASING MATERIAL	*SCREEN MATERIAL*	*FILTER MATERIAL*
Surface: 8-inch steel flush-mount	Type: 2" Schedule 40 PVC	Type: NSF #2 sand Setting: 2.5-13.0'
Monitor: 2" Schedule 40 PVC	Slot Size: .010 -inch	*SEAL MATERIAL* Type: Bentonite Chips Setting: 1.0-2.5'

COMMENTS:

LEGEND

Cement/Bentonite Grout

Bentonite Seal

Sand Pack

Client: NYSDEC	**Location: Chem Core**	**Project No.: 05-00035890.04**
URS Corporation	**BEDROCK MONITORING WELL CONSTRUCTION DETAILS**	**Well Number: VO-2**

DRILLING SUMMARY

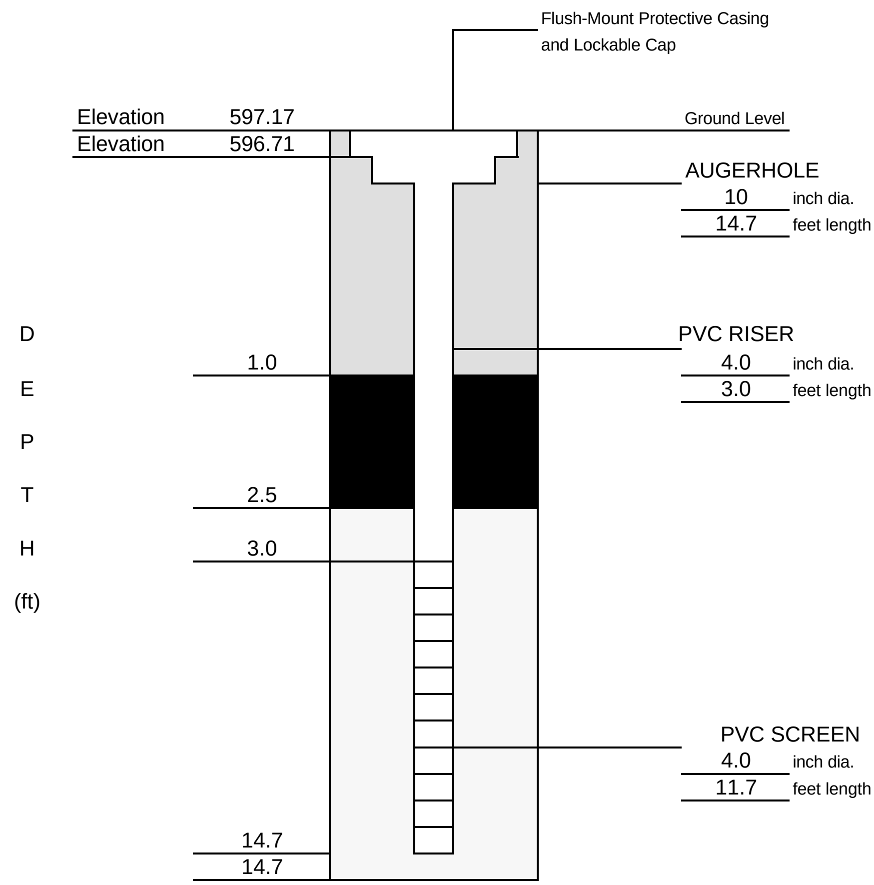
Geologist:
Scott McCabe

Drilling Company:
Buffalo Drilling Co.

Driller:
Kevin Bush

Rig Make/Model:
Mite-E-Mite

Date:
3/7/02



GEOLOGIC LOG

Depth(ft.)	Description
0-14.7	See SB-2 for lithologic description.

WELL DESIGN

Not to Scale

CASING MATERIAL		*SCREEN MATERIAL*		*FILTER MATERIAL*
Surface:	8-inch steel flush-mount	Type:	4" Schedule 40 PVC	Type: NSF #2 sand Setting: 2.5-14.7'
Monitor:	4" Schedule 40 PVC	Slot Size:	.010 -inch	*SEAL MATERIAL* Type: Bentonite Chips Setting: 1.0-2.5'

COMMENTS:

LEGEND

Cement/Bentonite Grout

Bentonite Seal

Sand Pack

Client: NYSDEC	**Location: Chem Core**	**Project No.: 05-00035890.04**
URS Corporation	**BEDROCK MONITORING WELL CONSTRUCTION DETAILS**	**Well Number: VO-3**

DRILLING SUMMARY

Geologist:
Scott McCabe

Drilling Company:
Buffalo Drilling Co.

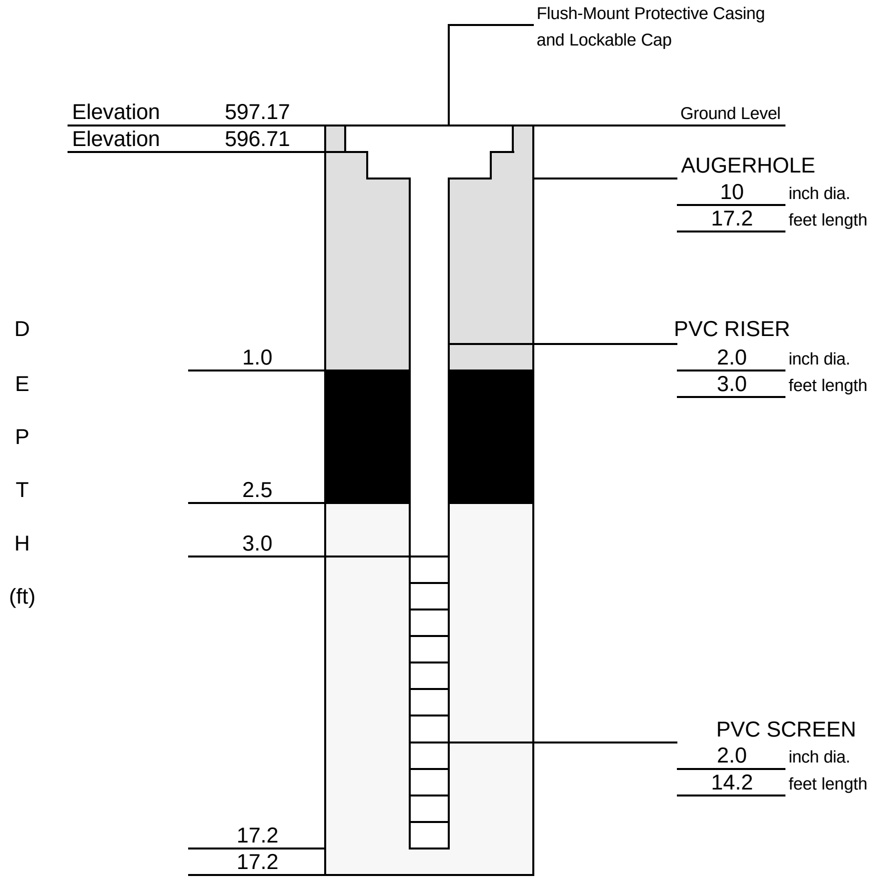
Driller:
Kevin Bush

Rig Make/Model:
Mite-E-Mite

Date:
3/6/02

GEOLOGIC LOG

Depth(ft.)	Description
0-17.2	See SB-2 for lithologic description.



Not to Scale

WELL DESIGN

CASING MATERIAL		*SCREEN MATERIAL*		*FILTER MATERIAL*
Surface:	8-inch steel flush-mount	Type:	2" Schedule 40 PVC	Type: NSF #2 sand Setting: 2.5-17.2'
				SEAL MATERIAL
Monitor:	2" Schedule 40 PVC	Slot Size:	.010 -inch	Type: Bentonite Chips Setting: 1.0-2.5'

COMMENTS:

LEGEND

Cement/Bentonite Grout

Bentonite Seal

Sand Pack

Client: NYSDEC	**Location: Chem Core**	**Project No.: 05-00035890.04**
URS Corporation	**BEDROCK MONITORING WELL CONSTRUCTION DETAILS**	**Well Number: VO-4**

APPENDIX B

SVE UNIT SPECIFICATIONS

DVT

DEKKER VACUUM TECHNOLOGIES, INC.

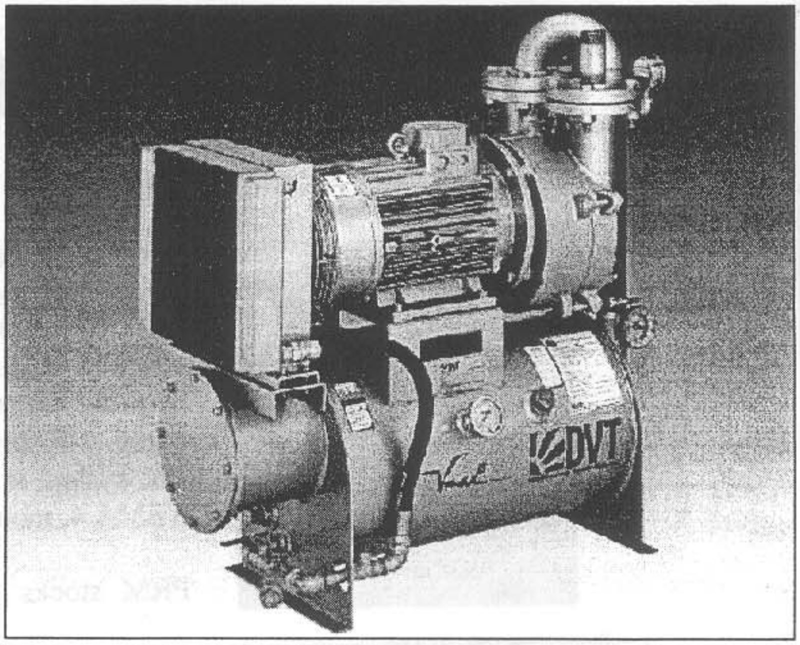
10. VMAX SYSTEMS

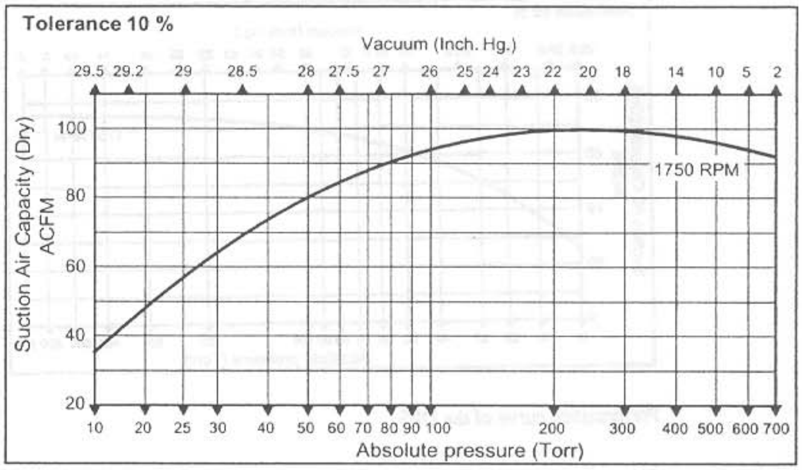
Vmax[LT] oil-sealed vacuum pump system (motor-mounted)

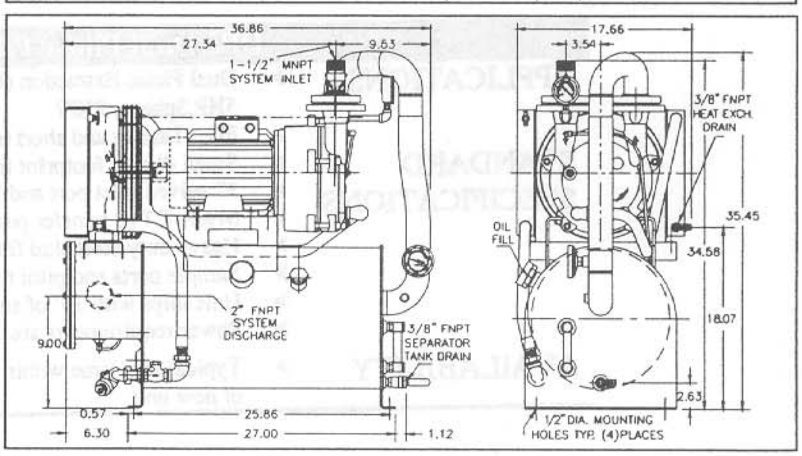
VMX0102M

Why more and more customers are switching to the Vmax[LT] system:

- √ The only system on the market with a **full 3-year warranty!**
- √ **Compact design** with all the **Vmax advantages** at the **cost of** a similar capacity **rotary vane pump.**
- √ New, patented, **high-efficiency DX-5 separator** eliminates oil carry-over concerns.
- √ Rugged, **high-quality, industrial system**, offering years of **trouble free operation**.
- √ **Extended-life seal-fluid** is not used as a lubricant. Change interval is not critical, resulting in a minimum of **10,000 hours of continuous operation.**
- √ **Motor-mounted design** eliminates the use of V-belts or couplings, resulting in very **low maintenance and zero downtime.**
- √ **Extremely low operating noise** level makes this system desirable in today's workplace.
- √ **Continuous operation over the full vacuum range** without overheating.
- √ **Carry-over** of soft solids and/or minimal amounts of liquid **does not cause damage** to the internal parts of the pump.
- √ **Air-cooled design** is **standard** with water-cooling available at no extra charge.





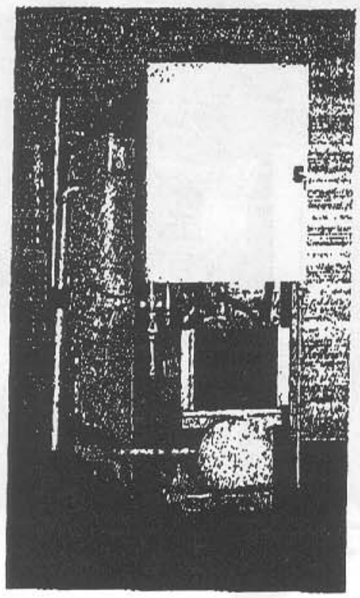


Performance Characteristics	
Nominal capacity:	100CFM
Motor:	7.5HP
Speed:	1750RPM
Maximum vacuum:	29.5"Hg
Weight (approximate):	540Lbs
Maximum gas inlet temperature:	212°F/100°C
Maximum noise level (at 3 feet):	76dBA
Oil capacity (approximate):	6 GAL
Performance based on atmospheric pressure equal to 29.92"Hg	

Information contained in this document is for reference only. Subject to change without notice.

PRODUCT RECOVERY
MANAGEMENT®

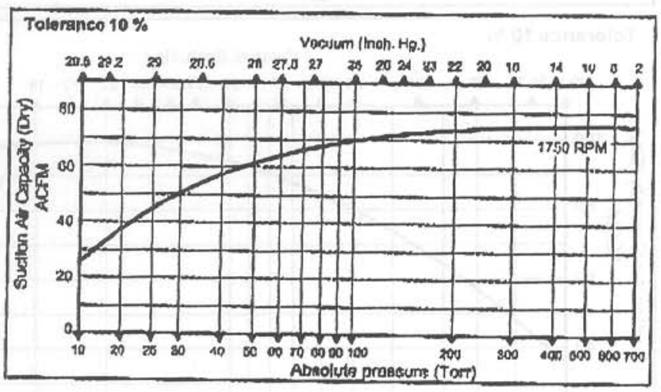
"If you lose your PRODUCT, we can MANAGE to RECOVER it."



DUAL PHASE PILOT UNIT
MODEL DP5

The PRM model DP5 Dual Phase Pilot unit is perfect for pilot testing and short term remediation. The unit pull 75acfm@20"Hg and will pull all the way up to >29"Hg. The system is rated to pump up to 20gpm from the moisture separator with a centrifugal transfer pump. Integral contols are mounted to the system. The system is wired Class I, Div. II and the panel is NEMA 4, mounted out of the Class II area.

PRM stocks the unit in inventory for immediate rental.



Performance curve of the DP5

Many state agencies are requiring alternatives to Adcanced Fluid Vapor Recovery (AFVR) or vacuum trucks that are expensive. The DP5 can easily be mobilized to the project site and ran for a week or a month at a fraction of the cost of a vacuum truck.

DP5 Dual Phase Pilot Unit

APPLICATIONS
- Dual Phase Extraction (DPE), Dekker Model VMX0082M. 5HP,3phase, 230V
- Pilot Testing and short term remediation

STANDARD SPECIFICATIONS
- Small 4' x 4' footprint for ease of shipping and handling
- 3" valved inlet port and 2" discharge stack with integral extension.
- Myers CT10 transfer pump, 1HP, 230V, 3phase
- Heavy duty steel skid frame
- Sample ports and pitot tube for air flow measurements
- Unit ships with 20' of suction and discharge hose
- Power requirements are 120/230V, 3phase power, 40Amp circuit

AVAILABILITY
- Typical ship time within 1 day for rental, 6-10 weeks for purchase of new unit

Product Recovery Management
1705 New Raleigh Rd. * Durham, NC 27703 * (919) 957-8890 * Fax (919) 957-7230
Toll Free: NC 1-888-PRM-Will FL 1-888-Treat-It KS 1-866-PRM-CENTral

APPENDIX C

STEP TEST FIELD DATA SUMMARY SHEETS

1235 [illegible]

#1	10" Hg	Start [illegible]	Stop [illegible]
#2	15" Hg	Start 1230	Stop! 1300
#3	20" Hg	Start: 1300	Stop! 1330
#4	23" Hg	Start! 1330	Stop! 1630
#5		Start:	Stop!
#6		Start!	Stop:

Chem Core - SVE Pilot Test

Well: SVE-1
Date: 3/28/02
Personnel: SCM, ST, MG

Page 1

Time	Flow Rates			Vacuum/Pressures					PID Readings			Temperature	
	At Extraction Well	Before Blower	After Blower	Extraction Well SVE-1	5 At VO-1	15 At VO-2	10 At VO-3	20 At VO-4	At Blower Direct Read PID/FID	Before Carbon PID/FID	After Carbon PID/FID	Before Blower	After Blower
Units	FPM		FPM	in Hg	in H_2O	→	→	→				°F	°F
1200	350		3500	10"	.05	.02	.05	.03		200/700	2/40	47	78
1211	375		2900	10"	.15	0	.15	.025		200/700	21/32	40	83
1225	450		2800	10"	.15	0	.09	0		135/415	.04/26	40	100
1235	525		1850	15"	0	0	0	0		[illegible]/825	.50/53	39	97
1245	350		2250	15"	.15	.05	.10	.10		187/536	.53/46	39	99
1255	400		2000	15"	.05	.05	.05	0		183/395	.32/40	39	99
1305	400		1250	20"	.02	.06	.06	.01		327/885	.27/91	38	90
1315	550		1200	20"	.04	.01	.05	.01		347/738	.28/69	36	87
1325													

VALVE ACW THRE WAY CLOSED < MAX VACUUM > #~ ~"Hg ~Start 130 S~~ ...0

#4 23" Hg Start 1330 Stop

#5 Start Stop

Chem Core - SVE Pilot Test

Well: SVE-1

Date: 3/28/02

Personnel: SM, ST, MG

Time	Flow Rates			Vacuum/Pressures					PID Readings			Temperature	
	At Extraction Well	Before Blower	After Blower	Extraction Well SVE-1	5' At VO-1	15' At VO-2	10' At VO-3	20' At VO-4	At Blower Direct Read PID/FID	Before Carbon PID/FID	After Carbon PID/FID	Before Blower	After Blower
Units	FPM		FPM	In Hg	In H_2O →			→		(ppm)	(ppm)	°F	°F
1325	550		1300	20"	.04	.009	.05	.01		353/800	.24/71	34	87
1335	520		800	23"	.05	.009	.04	.01		400/1058	.48/111	33	80
1400	500		700	23"	.05	.02	.05	.04		485/1180	.24/96	31	77
1430	510		850	22.7"	.04	.04	.04	.02		471/1160	.15/83	31	76
1500	525		900	22.1	.05	0	.04	.01		434/1070	.14/76	30	80
1530	625		1000	21.9	.03	0	.03	.01		409/880	.08/64	30	82
1550	650		1150	21.2	.05	0	.03	.03		366/9[illegible]0	.03/[illegible]	30	83
1610	660		1100	21.0	.05	0	.02	.02		364/831	.17/58	30	84
1630	800		1200	21.0	.02	0	.02	.01		368/800	.18/58	30	85

J:\35890.02\Excel\[SVE-test.xls]Sheet1

* NOTE: OUT OF Hydrogen

APPENDIX D

CONSTANT-RATE TEST FIELD DATA

SUMMARY SHEET

Chem Core - SVE Pilot Test

Well: SVE-1
Date: 3/29/02
Personnel: S / MG

#2
#3
#4
#5

Time	Flow Rates			Vacuum/Pressures					PID Readings			Temperature	
	At Extraction Well	Before Blower	After Blower	Extraction Well SVE-1	At VO-1	At VO-2	At VO-3	At VO-4	At Blower Direct Read PID/FID	Before Carbon PID/FID	After Carbon PID/FID	Before Blower	After Blower
Units	FPM		FPM	in Hg	in-H2O	→	→	→		ppm	ppm	°F	°F
0748	750		1600	21.75	.07	.02	.05	.04		335/1200	0/112	36	56
0810	700		1250	20.50	.05	.02	.04	.03		390/1270	.02/99	33	72
0830	650		1300	20.50	.05	.01	.06	.02		365/1073	.03/80	33	79
0850	900		1250	20.25	.07	.02	.07	.05		279/685	.12/56	32	85
0910	900		1400	20.0	0	0	0	.04		280/680	.14/50	32	87
0930	950		1500	19.9	.02	.02	.02	.04		287/628	.15/47	32	87
0950	1000		1500	19.5	.02	.009	.03	.03		282/585	.07/38	32	88
1010	1200		1550	19.5	.02	.01	.02	.04		266/554	.06/38	32	89
1030	1225		1550	19.5	.02	0	.01	.03		204/550	.09/40	32	96
1050	1230		1525	19.0	.02	.01	.01	.04		250/515	.11/46	32	91
1110	1300		1600	18.85	.01	.005	.03	.01		233/491	.05/38	32	91
1130	1500		1800	18.75	.01	0	.01	.03		260/500	.14/36	32	93
1150	1490		1750	18.50	.01	0	.02	.02		237/513	.05/37	32	93
1210	1600		1750	18.25	0	0	0	.01		233/465	.10/40	33	94
1230	1490		1750	18.10	0	0	0	.01		228/450	.09/37	33	95
1250	1490		1825	18.00	.01	0	.01	.02		226/413	.07/31	33	96
1310	1600?		1650	17.50	0	0	0	.01		223/425	.08/28	33	97
1330	1500		1700	17.50	0	0	0	.01		209/399	.08/29	33	98
1350	1600?		1750	17.00	.01	0	0	.01		225/384	.06/28	33	99
1410	1500		1750	17.00	.01	0	0	.02		221/317	.09/28		

J:\35890.02\Excel\[SVE-test.xls]Sheet1

START SAMPLE 0755 — 0855
SUMMA CANISTER

J/35890.02/EXCEL/SVE-test

stop test @ 1550

Chem Core - SVE Pilot Test

Well: SVE-1
Date: 3/29/02
Personnel:

Time	Flow Rates			Vacuum/Pressures					PID Readings			Temperature	
	At Extraction Well	Before Blower	After Blower	Extraction Well SVE-1	At VO-1	At VO-2	At VO-3	At VO-4	At Blower Direct Read PID/FID	Before Carbon PID/FID	After Carbon PID/FID	Before Blower	After Blower
Units	FPM		FPM	IN Hg	IN H_2O	→	→	→		ppm	ppm	°F	°F
1430	1550		1900	16.75	0	0	0	.01		194/470	.04/30	33	99
1450	1500		1700	16.75	0	0	.01	.02		199/360	.05/26	34	100
1510	1500		1900	16.75	.01	0	.02	.04		190/343	.06/25	34	100
1530	1550		2000	16.75	.02	.03	.06	.03		189/317	.05/24	34	100
1550	1650		2000	16.50	.10	.02	.05	.04		180/324	.06/24	34	100

APPENDIX E

SOIL GAS LABORATORY ANALYSIS DATA SHEET

URS

Client Sample ID: SVE-1

GC/MS Volatiles

Lot-Sample #...: H2D010119-001 Work Order #...: EW72Q1AA Matrix.........: AIR
Date Sampled...: 03/29/02 Date Received..: 04/01/02
Prep Date......: 04/06/02 Analysis Date..: 04/06/02
Prep Batch #...: 2097097
Dilution Factor: 120100 Method.........: EPA-19 TO-14

PARAMETER	RESULT	REPORTING LIMIT	UNITS
Acetone	ND UJ	600000	ppb(v/v)
Benzene	ND	24000	ppb(v/v)
Bromodichloromethane	ND	24000	ppb(v/v)
Bromoform	ND	24000	ppb(v/v)
Bromomethane	ND	24000	ppb(v/v)
Carbon disulfide	ND	24000	ppb(v/v)
Carbon tetrachloride	ND	24000	ppb(v/v)
Chlorobenzene	ND	24000	ppb(v/v)
Dibromochloromethane	ND	24000	ppb(v/v)
Chloroethane	ND	24000	ppb(v/v)
Chloroform	ND	24000	ppb(v/v)
Chloromethane	ND	60000	ppb(v/v)
1,1-Dichloroethane	ND	24000	ppb(v/v)
1,2-Dichloroethane	ND	24000	ppb(v/v)
1,1-Dichloroethene	**16000 J**	**24000**	**ppb(v/v)**
cis-1,2-Dichloroethene	ND	24000	ppb(v/v)
trans-1,2-Dichloroethene	ND	24000	ppb(v/v)
1,2-Dichloropropane	ND	24000	ppb(v/v)
cis-1,3-Dichloropropene	ND	24000	ppb(v/v)
trans-1,3-Dichloropropene	ND	24000	ppb(v/v)
Ethylbenzene	ND	24000	ppb(v/v)
2-Hexanone	ND UJ	60000	ppb(v/v)
Methylene chloride	**610000 ~~B~~**	**24000**	**ppb(v/v)**
Styrene	ND	24000	ppb(v/v)
1,1,2,2-Tetrachloroethane	ND	24000	ppb(v/v)
Tetrachloroethene	**2200000**	**24000**	**ppb(v/v)**
Toluene	ND	24000	ppb(v/v)
1,1,1-Trichloroethane	**35000**	**24000**	**ppb(v/v)**
1,1,2-Trichloroethane	ND	24000	ppb(v/v)
Trichloroethene	**38000**	**24000**	**ppb(v/v)**
Vinyl chloride	ND	24000	ppb(v/v)
o-Xylene	ND	24000	ppb(v/v)
m-Xylene & p-Xylene	ND	24000	ppb(v/v)
2-Butanone (MEK)	ND UJ	60000	ppb(v/v)
4-Methyl-2-pentanone (MIBK)	ND UJ	60000	ppb(v/v)

SURROGATE	PERCENT RECOVERY	RECOVERY LIMITS
1,2-Dichloroethane-d4	101	(70 - 130)
Toluene-d8	103	(70 - 130)
4-Bromofluorobenzene	93	(70 - 130)

w 5/6/02

APPENDIX F

SVE PILOT TEST CALCULATIONS

CALCULATION COVER SHEET

Client: NYSDEC Project Name: Chem Core

Project/Calculation Number: 05.00035890.02

Title: SVE Pilot Test Calculations

Total Number of Pages (including cover sheet): ____________

Total Number of Computer Runs: ____________

Prepared by: DEMETRA PAPADEMETRIOU Date: 4/25/02

Checked by: Donald A. McCall DAM Date: 4-25-02

Description and Purpose:

Design Basis/References/Assumptions

Remarks/Conclusions/Results:

Calculation Approved by: [signature] / 6/12/2002
Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

Project Manager/Date

URS Corp

JOB NO.: 05.35890.04
MADE BY: D. Papademetriou DATE: 4/25/02
CHECKED BY: DAS DATE: 4.25.02

PROJECT: **Chem Core Facility**
SUBJECT: **SVE Pilot Test Calculations**

Problem: Determine the site-specific characteristics (radius of influence and permeability) based on the results of a pilot test conducted at the Chem Core site.

References:

1. *Practical Design Calculations for Groundwater and Soil Remediation*, Jeff Kuo, 1999.

2. *A Practical Approach to the Design, Operation and Monitoring of In Situ Soil-Venting Systems*, Groundwater, Spring 1990.

3. Blower Performance curve for Dekker Vacuum Technologies VMX0102M blower.

4. *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites*, USEPA, May 1995.

Assumptions:

1. The length of exposed screen in the extraction well will be based on the water level in the well prior to the initiation of the pilot test. Due to the short duration of the test, any water rise caused by the vacuum on the well is assumed to be minimal.

2. The subsurface conditions in the fill area are assumed to be relatively homogenous between the extraction well and the pressure monitoring locations.

CALCULATIONS

1. Radius of Influence

Reference 1 (p. 148) presents the following equation to determine the radius of influence for a soil venting well by using pressure drawdown data:

$$P_r^2 - P_w^2 = (P_{RI}^2 - P_w^2)\frac{\ln(r / R_w)}{\ln(R_I / R_w)}$$

Where:

- P_r = pressure at a radial distance *r* from the vapor extraction well, [abs pressure]
- P_w = pressure at the vapor extraction well, [abs pressure]
- P_{RI} = pressure at the radius of influence (=atmospheric pressure, or other preset value), [abs pressure]
- r = radial distance from the extraction well, [feet]
- R_I = radius of influence where pressure is equal to a preset value, [feet]
- R_w = well radius of the vapor extraction well, [feet]

Using the data from the pilot study, the equation will be solved for R_I at the four locations where vacuum was monitored (VO-1, VO-2, VO-3, and VO-4). All data used in the following calculations is the average of the values measured between 7:48 AM and 11:10 AM as summarized on Table 5.

Example for VO-1:

P_r: the steady state vacuum at VO-1 was 0.027 " water column for 19.92" mercury (271 " water column) vacuum at the extraction well. Converting to atmospheres (atm): 0.027 "wc (1 atm/406.92 "wc) = 0.000067 atm of vacuum on the well. Converting to absolute pressure: 1 atm - 0.000067 = 0.99993 atm.

P_w: the vacuum at the extraction well was maintained at 19.92 " Hg (271 " wc) for this step. Converting to atm = 0.666 atm. Converting to absolute pressure = 0.334

P_{RI}: is assumed to be atmospheric pressure, 1 atm.

r: the distance from the extraction well (SVE-1) to VO-1 is 5 feet.

R_w: SVE-1 is 4 inches in diameter, therefore the radius is approximately 2 inch or 0.167 foot.

Substituting the values into the equation:

$$0.99993^2 - 0.334^2 = (1^2 - 0.334^2)\frac{\ln(5/0.167)}{\ln(R_I/0.167)}$$

R_I is calculated to be 5 feet based on the data for VO-1.

Table F-1 shows the radius of influence calculated from the data for all monitored locations. As it can be seen, the calculated radius of influence at each monitoring location is approximately equal to its distance from the extraction well. This is due to the fact that very small vacuums were observed at the monitoring locations.

According to USEPA guidance (Ref. 4), as a rule of thumb, the radius of influence is often considered to be the distance from the extraction well at which a vacuum of at least 0.1 inches of water is observed. According to this criteria, the radius of influence is 5 feet or less. A vacuum of 0.1 inches of water was achieved at VO-1 (5 feet from the extraction well) at the end of the constant rate test. The average vacuum at VO-1 during the pilot test was about 0.03 inches of water.

PROJECT: Chem Core Facility
SUBJECT: SVE Pilot Test Calculations

Based on the data from the pilot test, the radius of influence is estimated to be 5 feet.

2. Soil Permeability to Air Flow

Knowing the radius of influence and flow rate achieved from the extraction well, the soil permeability to air flow or *k* can be determined. The *k* can be estimated from the following equation as presented in Reference 2, Equation 5:

$$\frac{Q}{H_o} = \pi \frac{k}{\mu} P_w \frac{[1-(P_{atm}/P_w)^2]}{\ln(R_w/R_I)}$$

Where:

- H_o = Thickness of the screened well section, [cm]
- k = Soil permeability to air flow, [cm^2]
- R_I = Extraction well's radius of influence, [cm]
- R_W = Radius of the extraction well, [cm]
- P_W = Absolute pressure in the well, [$g/cm\ s^2$]
- P_A = Absolute ambient pressure ($1.01 \times 10^6\ g/cm\ s^2$) or 1 atmosphere;
- μ = Viscosity of air ($1.8 \times 10^{-4}\ g/cm\ s$)
- Q = Air flow from the well, [cm^3/s]

The absolute pressure at the soil vapor extraction well is calculated by subtracting the actual vacuum at the well from the atmospheric pressure (1 atmosphere or 33.9 feet of water). The values used in the equation are as follows:

JOB NO.: 05.35890.04
MADE BY: D. Papademetriou DATE: 4/25/02
CHECKED BY: DWF DATE: 4.25.02

PROJECT: Chem Core Facility
SUBJECT: SVE Pilot Test Calculations

PARAMETER	VALUE
H_o	The construction log for SVE-1 shows the depth to bottom of the SVE-1 well from top of riser was 13.85 feet and the screen length is 11.4 feet. Based on the round of water levels collected on 3/29/02, the depth to water from top of riser was 12.43 feet. Therefore, the length of the exposed screen during the test was 11.4-(13.85-12.43) = 10 feet = 120 inches = 305 cm
R_I	As calculated above, the radius of influence is assumed to be 5 feet = 60 inches = 152.5 cm
R_W	The radius of SVE-01 = 2 inch = 5.08 cm
P_W	The vacuum at the extraction well was maintained at 19.92 " Hg =270.95 "wc = 0.666 atm = 0.334 atm absolute pressure. 1 atm = $1.01x10^6$ g/cm s^2, so the pressure = 337,290 g/cm s^2
μ	1.8×10^{-4} g/cm s
P_A	1.01×10^6 g/cm s^2
Q	The average flow rate from the well during the test was determined to be 34 scfm. Converting to cm^3/s: 34 ft^3/min x (1 min/60 sec) x ($1.728x10^3$ in^3/ft^3) x (2.54 cm/in)^3 = 16,046 cm^3/s.

Substituting the values into the equation:

$$\frac{16{,}046 cm^3/s}{305 cm} = \pi \frac{k}{1.8x10^{-4}} (337{,}290 g/cm \cdot s^2) \frac{[1-(1.01x10^6/337{,}290)^2]}{\ln(5.08/152.5)}$$

Solving for k = $3.8x10^{-9}$ cm^2

JOB NO.: 05.35890.04
MADE BY: D. Papademetriou DATE: 4/25/02
CHECKED BY: TMP DATE: 4.25.02

PROJECT: Chem Core Facility
SUBJECT: SVE Pilot Test Calculations

Based on the results of the RI, the soils at the site are comprised of fill, stratified clayey silt and silty clay, mixed with sand and sandy silt seams. The intrinsic permeability of these units varies widely. The intrinsic permeability of fill and sand, and sandy silt is estimated to be on the order of 1×10^{-6} to 1×10^{-10} cm^2 (Reference 4). The intrinsic permeability of the clayey silt and silty clay is estimated to range between 1×10^{-10} to 1×10^{-14} cm^2 (Reference 4).

The calculated permeability from the pilot test is in the range of the fill, sand and sandy silt. These materials are generally nearer the surface (under the concrete floor) at the site. This data indicates that flow into the extraction well occurs mainly in the upper layer of soil or in sandy seams. Because of this preferential pathway, the radius of influence in the entire formation (which includes clayey silt and silty clay at lower depths) is small.

Table F-1
Chem Core Site
Calculation of Radius of Influence

Monitoring Location	P_r		P_w			P_{RI}	r	R_w	$P_{RI}^2 - P_w^2$	$P_r^2 - P_w^2$	$\ln(r/R_w)$	Calculated R_I
	(in. H_2O)	(atm)	(in. Hg)	(in. H_2O)	(atm)	(atm)	(feet)	(feet)				(feet)
VO-1	0.0273	0.999933	19.92	270.95	0.334	1	5	0.167	0.8885	0.8883	3.40	5.00
VO-2	0.0113	0.999972	19.92	270.95	0.334	1	15	0.167	0.8885	0.8884	4.50	15.00
VO-3	0.0309	0.999924	19.92	270.95	0.334	1	10	0.167	0.8885	0.8883	4.09	10.01
VO-4	0.0336	0.999917	19.92	270.95	0.334	1	20	0.167	0.8885	0.8883	4.79	20.02

Calculation: $P_r^2 - P_w^2 = (P_{RI}^2 - P_w^2)\ [\ln(r/R_w)]\ /\ [\ln(R_I/R_w)]$

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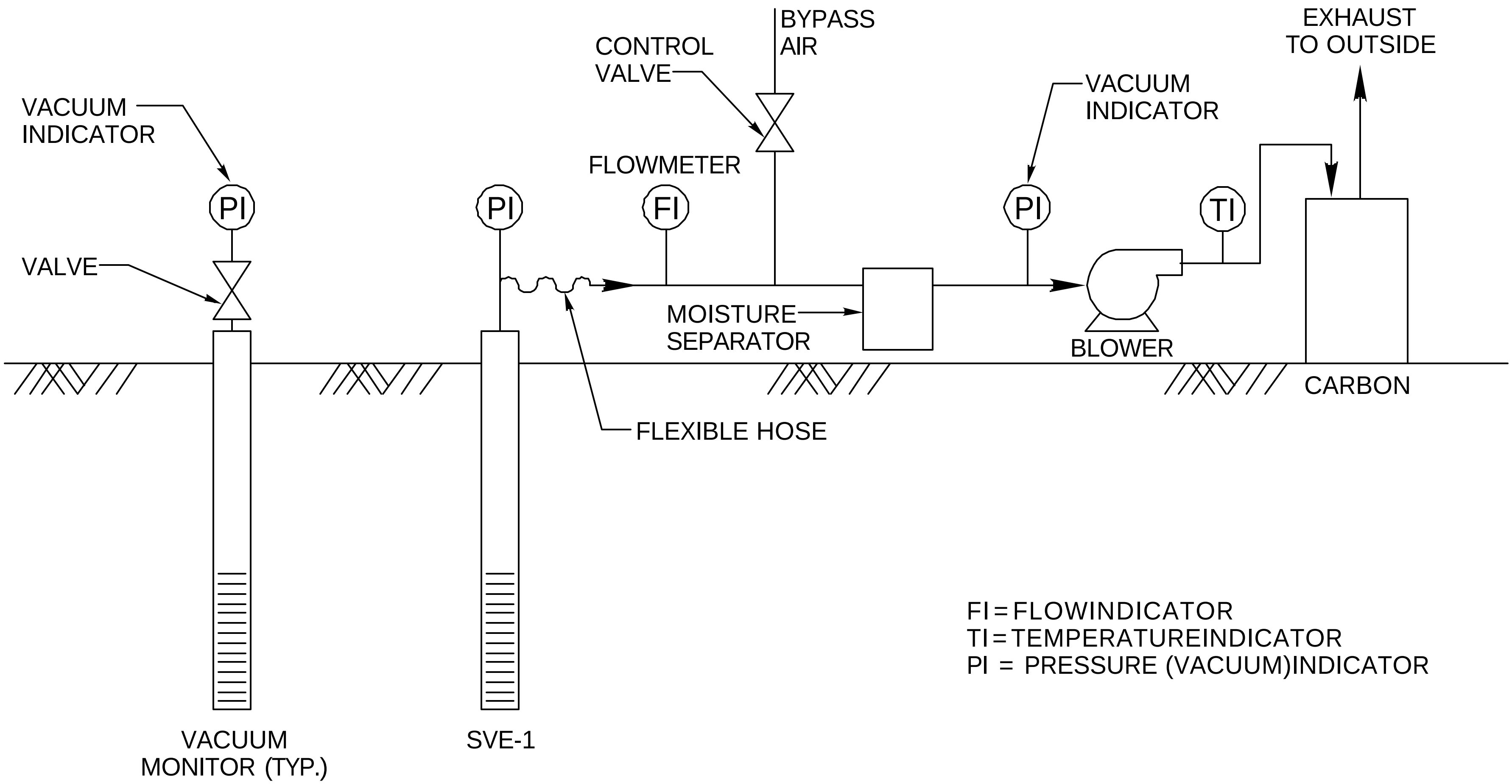

URS

SVE PILOT TEST SYSTEM SCHEMATIC

FIGURE 1

Chem Core - SVE Pilot Test

Well: SVE-1 (STEP TEST)

Date: 3/28/02

Personnel: BCM, ST, MG

STEP # 1	10" Hg	START 1200	STOP 1230
# 2	15" Hg	START 1230	STOP! 1300
# 3	20" Hg	START: 1300	STOP!
# 4		START!	STOP!
# 5		START!	STOP!
# 6		START!	STOP!

Page 1

Time	Flow Rates			Vacuum/Pressures					PID Readings			Temperature	
	At Extraction Well	Before Blower	After Blower	Extraction Well SVE-1	5 At VO-1	15 At VO-2	10 At VO-3	20 At VO-4	At Blower Direct Read PID/FID	Before Carbon PID/FID	After Carbon PID/FID	Before Blower	After Blower
Units	FPM		FPM	IN Hg	IN H_2O							°F	°F
1200	350		3500	10"	.05	.02	.05	.03		200/700	2/40	47	78
1211	325		2900	10"	.15	0	.15	.025		200/700	<1/32	40	83
1225	450		2600	10"	.15	0	.09	0		135/415	.04/26	40	100
1235	525		1850	15"	0	0	0	0		112/825	.50/53	39	97
1245	350		2250	15"	.015	.05	.10	.10		187/536	.53/146	39	99
1255	460		2000	15"	.05	.05	.05	0		183/395	.32/40	39	99
1305	400		1250	20"	.02	.06	.06	.01		327/885	.27/91	38	90
1315	550		1200	20"	.04	.01	.05	.01		347/738	.28/69	36	87
1325													

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Valve ACB THE WAY CLOSED < MAX VACUUM → #3 20" Hg START 1300 STOP 1330

#4 23" Hg START 1330 STOP

#5 START STOP

Chem Core - SVE Pilot Test

STEP TEST

Page 2

Well: SVE-1

Date: 3/28/02

Personnel: SM, ST, MG

Time	Flow Rates			Vacuum/Pressures					PID Readings			Temperature	
	At Extraction Well	Before Blower	After Blower	Extraction Well SVE-1	5' At VO-1	15' At VO-2	10' At VO-3	20' At VO-4	At Blower Direct Read PID/FID	Before Carbon PID/FID	After Carbon PID/FID	Before Blower	After Blower
Units	FPM		FPM	In Hg	In H2O					(ppm)	(ppm)	°F	°F
1325	550		1300	20"	.04	.009	.05	.01		353/800	.24/71	34	87
1335	520		800	23"	.05	.009	.04	.01		400/1058	.48/111	33	80
1400	500		700	23"	.05	.02	.05	.01		485/1180	.24/96	31	77
1430	510		850	22.7"	.04	.04	.04	.02		471/1160	.15/83	31	76
1500	525		900	22.1	.05	0	.04	.01		434/1070	.14/76	30	80
1530	625		1000	21.9	.03	0	.03	.01		409/880	.08/64	30	82
1550	650		1150	21.2	.05	0	.03	.03		366/9[illegible]0	.03/[illegible]1	30	83
1610	660		1100	21.0	.05	0	.02	.02		364/831	.17/58	30	84
1630	800		1200	21.0	.02	0	.02	.01		368/800	.18/58	30	85

J:\35890.02\Excel\[SVE-test.xls]Sheet1

A NOTE: OUT OF Hydrogen

755 start summa canister
0855 finish

STEP #1 .1.7
#2
#3
#4
#5

Chem Core - SVE Pilot Test

Well: SVE-1 CONSTANT-RATE TEST

Date: 3/24/02

Personnel: [illegible]

Time	Flow Rates			Vacuum/Pressures					PID Readings			Temperature	
	At Extraction Well	Before Blower	After Blower	Extraction Well SVE-1	At VO-1	At VO-2	At VO-3	At VO-4	At Blower Direct Read PID/FID	Before Carbon PID/FID	After Carbon PID/FID	Before Blower	After Blower
Units	FPM		FPM	in Hg	in H2O	→	→	→		ppm	ppm	°F	°F
0748	750		1600	21.75	.07	.02	.05	.04		335/1200	.02/112	36	56
0810	700		1350	20.50	.05	.02	.04	.03		390/1270	.02/99	33	72
0830	650		1300	20.50	.05	.01	.06	.02		365/1073	.03/80	33	79
0850	800		1250	20.25	.02	.02	.07	.05		279/685	.12/56	32	85
0910	900		1400	20.0	0	0	0	.04		280/680	.14/50	32	87
0930	950		1500	19.9	.02	.02	.02	.04		287/628	.15/44	32	87
0950	1000		1500	19.5	.02	.009	.03	.03		282/585	.07/38	32	88
1010	1200		1550	19.5	.02	.01	.02	.04		266/554	.06/38	32	89
1030	1225		1550	19.5	.02	0	.01	.03		264/550	.09/40	32	96
1050	1230		1525	19.0	.02	.01	.01	.04		250/515	.11/46	32	91
1110	1300		1600	18.75	.01	.005	.03	.01		233/491	.05/38	32	91
1130	1500		1800	18.75	.01	0	.01	.03		260/500	.14/36	32	93
1150	1490		1750	18.50	.01	0	.02	.02		237/513	.05/37	32	93
1210	1500		1750	18.25	0	0	0	.01		233/465	.10/40	33	94
1230	1490		1750	18.10	0	0	0	.01		228/450	.09/37	33	95
1250	1490		1825	18.00	.01	0	.01	.02		226/413	.07/31	33	96
1310	1600?		1650	17.50	0	0	0	.01		223/425	.08/28	33	97
1330	1500		1700	17.50	0	0	0	.01		209/399	.08/29	33	98
1350	1600?		1750	17.00	.01	0	0	.01		225/384	.06/28	33	99
1410	1500		1750	17.00	.01	0	0	.02		221/376	.09/28		

J:\35890.02\Excel\[SVE-test.xls]Sheet1

[illegible] 1700 [illegible]

START SAMPLE 0755 — 0855
SUMMA CANISTER

STOP TEST @ 1600

Chem Core - SVE Pilot Test

Well: SVE-1 CONSTANT RATE TEST

Date: 3/29/02

Personnel:

Time	Flow Rates			Vacuum/Pressures					PID Readings			Temperature	
	At Extraction Well	Before Blower	After Blower	Extraction Well SVE-1	At VO-1	At VO-2	At VO-3	At VO-4	At Blower Direct Read PID/FID	Before Carbon PID/FID	After Carbon PID/FID	Before Blower	After Blower
Units	FPM		FPM	IN Hg	IN H_2O	→	→	→		PPM	PPM	°F	°F
1430	1550		1900	16.75	0	0	0	.01		194/430	.04/30	33	99
1450	1500		1700	16.75	0	0	.01	.02		199/350	.05/26	34	100
1510	1500		1900	16.75	.01	0	.02	.04		190/343	.06/25	34	100
1530	1550		2000	16.75	.02	.03	.06	.03		189/317	.05/24	34	100
1550	1650		2000	16.50	.10	.02	.05	.04		160/324	.06/24	34	100

Reference 1

PRACTICAL DESIGN CALCULATIONS

for Groundwater and Soil Remediation

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LEWIS PUBLISHERS
Boca Raton London New York Washington, D.C.

Discussion. The actual concentration of the extracted vapor would be lower than 13,200 ppmV due to the fact that not all the air flows through the contaminated zone and that limitations of mass transfer were not considered in the above calculations.

V.1.3 *Radius of influence and pressure profile*

Selecting the number and locations of vapor extraction wells is one of the major tasks in design of in situ soil vapor extraction systems. The decisions are typically based on the radius of influence (R_I), which can be defined as the distance from the extraction well where the pressure drawdown is very small (P @ $R_I \sim 1$ atm). The most accurate and site-specific R_I values should be determined from steady-state pilot testing. The pressure drawdown data at the extraction well and the observation wells can be plotted as a function of the radial distance from the extraction well on a semilog plot to determine the R_I of that well. The approach is similar to the distance-drawdown method for aquifer tests, as described in Section II.3.3. The R_I is commonly chosen to be the distance where the pressure drawdown is less than 1% of the vacuum in the extraction well.

The field test data can also be analyzed by using the flow equations, which describe the subsurface air flow. The subsurface is usually heterogeneous, and the air flow through it can be very complex. As a simplified approximation, a flow equation was derived for a fully confined radial gas flow system in a permeable formation having uniform and constant properties.[3-6] References 3 through 6 are the basis for most of the sections on soil venting.

For the steady-state radial flow subject to the boundary conditions ($P = P_w$ @ $r = R_w$ and $P = P_{atm}$ @ $r = R_I$), the pressure distribution in the subsurface can be derived as

$$P_r^2 - P_w^2 = (P_{RI}^2 - P_w^2)\frac{\ln(r/R_w)}{\ln(R_I/R_w)} \qquad \text{[Eq. V.1.2]}$$

P_r = pressure at a radial distance r from the vapor extraction well
P_w = pressure at the vapor extraction well
P_{RI} = pressure at the radius of influence (= atmospheric pressure or a preset value)
r = radial distance from the vapor extraction well
R_I = radius of influence where pressure is equal to a preset value
R_w = well radius of the vapor extraction well

Eq. V.1.2 can be used to determine the R_I of a vapor extraction well if the pressure drawdown data of the extraction well and a monitoring well (or data of two monitoring wells) are known. As shown, the flow rate and the permeability of the formation are not included in this equation. The R_I

Reference 2

tities accidentally released to the environment. There are more sophisticated equations for predicting vapor concentrations in soil systems based on equilibrium partitioning arguments, but these require more detailed information (organic carbon content, soil moisture) than is normally available. If a site is chosen for remediation, the residual total hydrocarbons in soil typically exceed 500 mg/kg. In this residual concentration range most of the hydrocarbons will be present as a separate or "free" phase, the contaminant vapor concentrations become independent of residual concentration (but still depend on composition), and Equation 1 is applicable (Johnson et al. 1988). In any case, it should be noted that these are estimates only for vapor concentrations at the start of venting, which is when the removal rates are generally greatest. Contaminant concentrations in the extracted vapors will decline with time due to changes in composition, residual levels, or increased diffusional resistances. These topics will be discussed in more detail.

Under Ideal Vapor Flow Conditions (i.e., 100 – 1000 scfm Vapor Flow Rates), Is This Concentration Great Enough to Yield Acceptable Removal Rates?

Question 2 is answered by multiplying the concentration estimate C_{est}, by a range of reasonable flow rates, Q:

$$R_{est} = C_{est}\,\dot{Q} \qquad (2)$$

Here R_{est} denotes the estimated removal rate, and C_{est} and Q must be expressed in consistent units. For reference, documented venting operations at service station sites typically report vapor flow rates in the 10 – 100 scfm range (Hutzler et al. 1988), although 100 – 1000 scfm flow rates are achievable for sandy soils or large numbers of extraction wells. At this point in the decision process what is still being neglected is that vapor concentrations decrease during venting due to compositional changes and mass transfer resistances. Figure 4 presents calculated removal rates R_{est} [kg/d] for a range of C_{est} and Q values. C_{est} values are presented in [mg/L] and [ppm_{CH_4}] units, where [ppm_{CH_4}] represents methane-equivalent parts-per-million volume/volume (ppm_v) units. The [ppm_{CH_4}] units are used because field analytical tools that report [ppm_v] values are often calibrated with methane. The [mg/L] and [ppm_{CH_4}] units are related by:

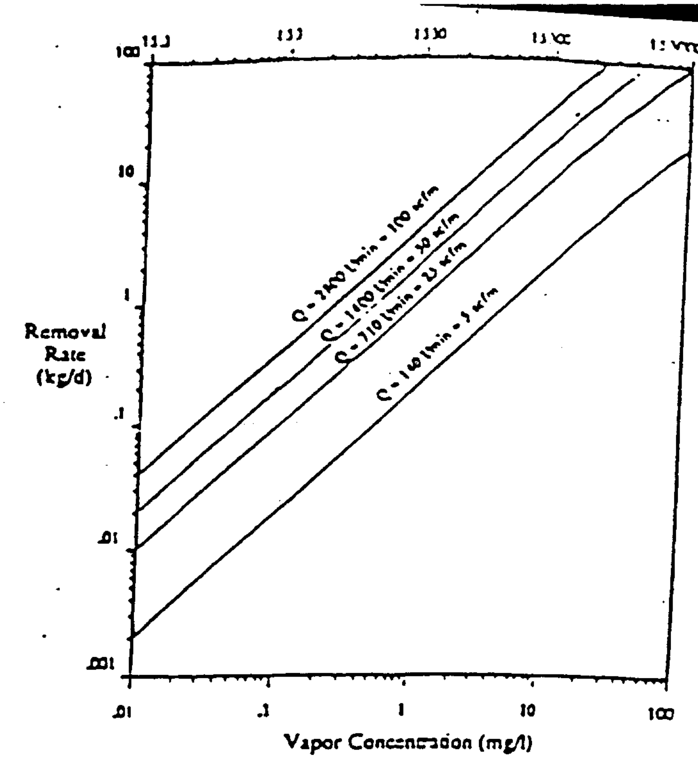
$$[mg/L] = \frac{[ppm_{CH_4}] \cdot 16000\ mg\text{-}CH_4/mole\text{-}CH_4 \cdot 10^{-6}}{(0.0821\ l\text{-}atm/°K\text{-}mole) \cdot (298\ K)} \qquad (3)$$

For field instruments calibrated with other compounds (i.e., butane, propane), [ppm_v] values are converted to [mg/L] by replacing the molecular weight of CH_4 in Equation 3 by the molecular weight [mg/mole] of the calibration compound.

Acceptable or desirable removal rates $R_{acceptable}$, can be determined by dividing the estimated spill mass M_{spill}, by the maximum acceptable cleanup time τ:

$$R_{acceptable} = M_{spill}/\tau \qquad (4)$$

For example, if 1500kg (~500 gal) of gasoline had been spilled at a service station and it was wished to



• (ppm_{CH_4}) - concentration in methane-equivalent ppm (vol./vol.) units

Figure 4. In situ soil-venting removal rate dependence on vapor extraction rate and vapor concentration.

complete the cleanup within eight months, then $R_{acceptable}$ = 6.3 kg/d. Based on Figure 4, therefore, C_{est} would have to average >1.5 mg/L (2400 ppm_{CH_4}) for Q=2800 l/min (100 cfm) if venting is to be an acceptable option. Generally, removal rates <1 kg/d will be unacceptable for most releases, so soils contaminated with compounds (mixtures) having saturated vapor concentrations less than 0.3 mg/L (450 ppm_{CH_4}) will not be good candidates for venting, unless vapor flow rates exceed 100 scfm. Judging from the compounds listed in Table 1, this corresponds to compounds with boiling points (T_b)>150 C, or pure component vapor pressures <0.0001 atm evaluated at the subsurface temperature.

What Range of Vapor Flow Rates Can Realistically Be Achieved?

Question 3 requires that realistic vapor flow rates for the site-specific conditions be estimated. Equation 5, which predicts the flow rate per unit thickness of well screen Q/H [cm³/s], can be used for this purpose:

$$\frac{Q}{H} = \pi \frac{k}{\mu} P_w \frac{[1 - (P_{Atm}/P_w)^2]}{\ln(R_w/R_I)} \qquad (5)$$

where:

k = soil permeability to air flow [cm²] or [darcy]
μ = viscosity of air = 1.8 x 10⁻⁴ g/cm-s or 0.018 cp
P_w = absolute pressure at extraction well [g/cm-s²] or [atm]
P_{Atm} = absolute ambient pressure ~ 1.01 x 10⁶ g/cm-s² or 1 atm
R_w = radius of vapor extraction well [cm]
R_I = radius of influence of vapor extraction well [cm].

Reference 3

DEKKER VACUUM TECHNOLOGIES, INC.

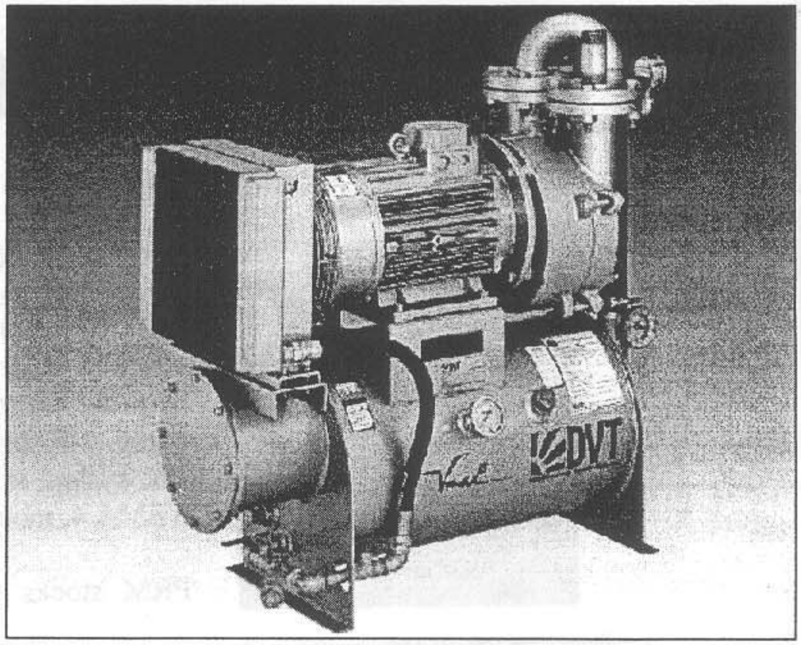
10. VMAX SYSTEMS

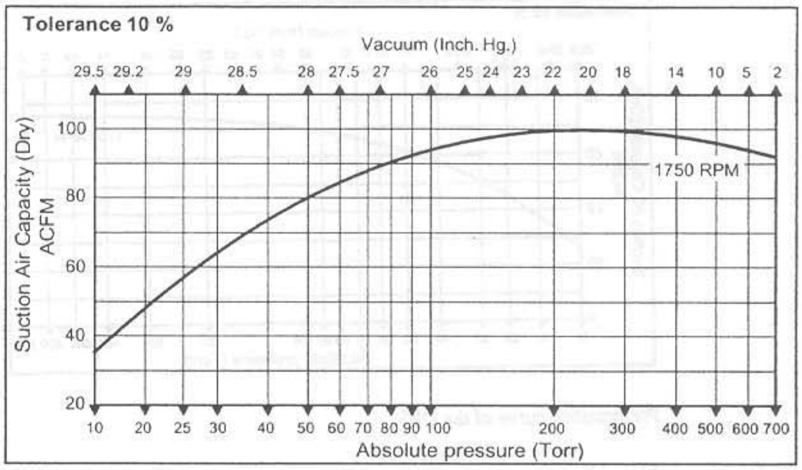
Vmax[LT] oil-sealed vacuum pump system (motor-mounted)

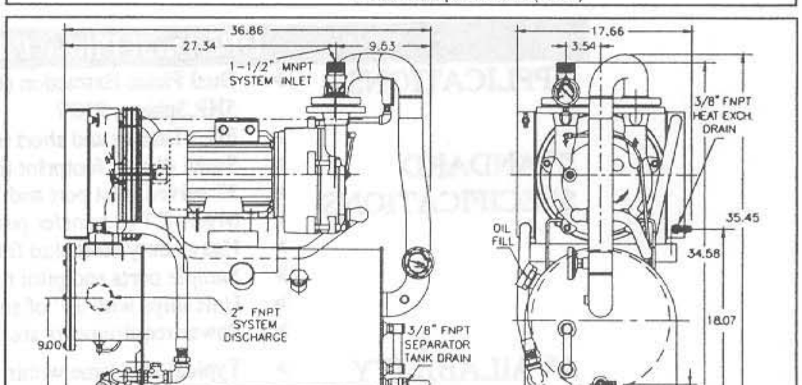
VMX0102M

Why more and more customers are switching to the Vmax[LT] system:

- √ The only system on the market with a **full 3-year warranty!**
- √ **Compact design** with all the **Vmax advantages** at the **cost of** a similar capacity **rotary vane pump.**
- √ New, patented, **high-efficiency DX-5 separator** eliminates oil carry-over concerns.
- √ Rugged, **high-quality, industrial system**, offering years of **trouble free operation**.
- √ **Extended-life seal-fluid** is not used as a lubricant. Change interval is not critical, resulting in a minimum of **10,000 hours of continuous operation.**
- √ **Motor-mounted design** eliminates the use of V-belts or couplings, resulting in very **low maintenance and zero downtime.**
- √ **Extremely low operating noise** level makes this system desirable in today's workplace.
- √ **Continuous operation over the full vacuum range** without overheating.
- √ **Carry-over** of soft solids and/or minimal amounts of liquid **does not cause damage** to the internal parts of the pump.
- √ **Air-cooled design** is **standard** with water-cooling available at no extra charge.







Performance Characteristics	
Nominal capacity:	100CFM
Motor:	7.5HP
Speed:	1750RPM
Maximum vacuum:	29.5"Hg
Weight (approximate):	540Lbs
Maximum gas inlet temperature:	212°F/100°C
Maximum noise level (at 3 feet):	76dBA
Oil capacity (approximate):	6 GAL

Performance based on atmospheric pressure equal to 29.92"Hg

Information contained in this document is for reference only. Subject to change without notice.

Reference 4

United States
Environmental Protection
Agency

Emergency Response
5403W

May 1995

McCALL

PA

How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites

A Guide for Corrective Action Plan Reviewers

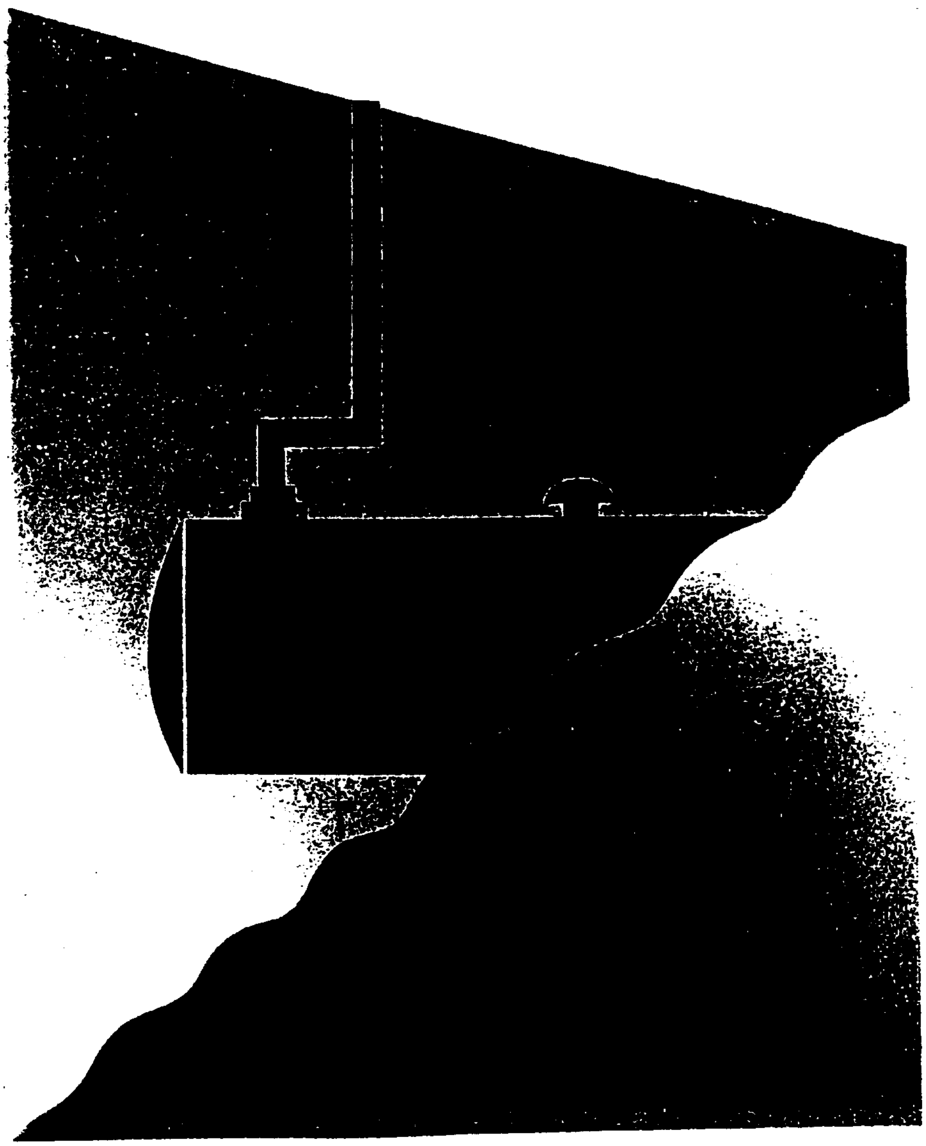


Exhibit II-6
Intrinsic Permeability And SVE Effectiveness

Intrinsic Permeability (k)	SVE Effectiveness
$k \geq 10^{-8}\ cm^2$	Generally effective.
$10^{-8} \geq k \geq 10^{-10}\ cm^2$	May be effective; needs further evaluation.
$k < 10^{-10}\ cm^2$	Marginal effectiveness to ineffective.

At sites where the soils in the saturated zone are similar to those within the unsaturated zone, hydraulic conductivity of the soils may be used to estimate the permeability of the soils. Hydraulic conductivity is a measure of the ability of soils to transmit water. Hydraulic conductivity can be determined from aquifer tests, including slug tests and pumping tests. You can convert hydraulic conductivity to intrinsic permeability using the following equation:

$$k = K\ (\mu\ /\ \rho g)$$

where:
- k = intrinsic permeability (cm^2)
- K = hydraulic conductivity (cm/sec)
- μ = water viscosity (g/cm · sec)
- ρ = water density (g/cm^3)
- g = acceleration due to gravity (cm/sec^2)

At 20°C: $\mu/\rho g = 1.02 \cdot 10^{-5}$ cm/sec

To convert k from cm^2 to darcy, multiply by 10^8

Soil Structure And Stratification

Soil structure and stratification are important to SVE effectiveness because they can affect how and where soil vapors will flow within the soil matrix under extraction conditions. Structural characteristics such as microfracturing can result in higher permeabilities than expected for certain soil components (e.g., clays). However, the increased flow availability will be confined within the fractures but not in the unfractured media. This preferential flow behavior can lead to ineffective or significantly extended remedial times. Stratification of soils with different permeabilities can increase the lateral flow of soil vapors in the more permeable stratum while dramatically reducing the soil vapor flow through the less permeable stratum.