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# RUTH ASSOCIATES, INC.

VIA FEDERAL EXPRESS

June 11, 1997

Randy Sturgeon
Remedial Project Manager
Delaware/Maryland Section
U.S. Environmental Protection Agency
841 Chestnut Building
Philadelphia, PA 19107

RE: Dover Gas Light Site - Information on Soil-Vapor Extraction / Bio-Venting at another MGP

Dear Mr. Sturgeon:

The enclosed informational package has been prepared as per your request for information regarding the feasibility of soil-vapor extraction (SVE) / bio-venting at a site similar to the Dover Gas Light Site. Ruth Associates, Inc. (RAI) has successfully implemented SVE, non-aqueous phase liquid (NAPL) recovery, as well as air-sparging at another former manufactured gas plant (MGP) site on behalf of Chesapeake Utilities. This site is located in Salisbury, Maryland, and is directly underlain by the Columbia Formation, which is the same unit upon which the Dover Gas Light Site is situated, although it is somewhat sandier near Salisbury. Also, it is believed that the same gas manufacturing process (the water gas process) was employed at both the Dover and Salisbury MGPs; therefore, the characteristics of the tar and other NAPLs that may be found at these two sites are likely similar.

Several reports have been prepared through the pilot-testing, design, and operational phases of the remedial program at Salisbury. Excerpts from the following reports prepared by RAI have been enclosed for your reference:

- Remedial Design Report, dated December 1995
- Remedial Progress Report, dated March 1996
- Remedial Progress Report - Second Half of 1996

Particularly relevant portions in each report have been highlighted for ease of your review.

As general background, the Salisbury site is underlain by fine to medium grained sand with varying amounts of silt. The depth to water is approximately 22 feet below ground surface in the Former Production Area (where small amounts of

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floating NAPL have been found and recovered), and gradually reduces to about 15 feet along the downgradient property. Ground-surface in the immediate vicinity of the former production area is paved, and the southern portion of the property is grassed covered.

Soil vapor extraction rates from single well points in the former production area ranged from 20 to 85 standard cubic feet per minute (SCFM) with radii of influence varying from 75 to 90 feet. ( Remedial Progress Report, March 1996) The rate of extraction did not have a significant effect on the lateral extent of pneumatic influence.

SVE pilot testing along the downgradient property boundary showed that the optimal extraction rate was approximately 10 SCFM from a single well point with radii of influence ranging from 70 to 80 feet, similar to those observed in the former production area where extraction rates were much higher. (Remedial Design Report, December 1995) Again, increasing the extraction rate had only a small effect on the extent of lateral pneumatic influence.

Pilot testing results and observations made during full-scale operational conditions at both site areas in Salisbury support the following major conclusions:

- SVE is an effective means of removing volatile constituents from unsaturated soils, and to a lesser extent from the water table.

- SVE (or bio-venting) stimulates in-situ biodegradation of petroleum hydrocarbons by increasing the amount of available oxygen in the subsurface for bioutilization.

- Applying a vacuum near the water table where LNAPL is present enhances LNAPL recovery by mobilizing residual LNAPL that resides on top of the capillary fringe.

Based on our experience at the Salisbury site, as well as other sites not specifically discussed here, the following general conclusions can be made regarding the application of SVE for site remediation:

- SVE is effective under a very wide range of hydrogeologic conditions. RAI has successfully employed SVE at a site where soils consisted predominantly of clay, and at another site where the water table was as shallow as 4 feet below ground surface. However, certain site conditions are more amenable than others to the successful implementation of SVE.

- SVE generally works well in Coastal Plain formations like that found beneath the Dover site because the vertical permeability is typically an order-of-magnitude lower than the horizontal permeability, thus enhancing lateral pneumatic extent.

- Soils of low to moderate permeability are often better suited to SVE techniques than a coarse sand and gravel material, because lateral influence can be impeded by "short circuiting" of flow from the surface that is likely to occur if the formation is too permeable.

- The optimum SVE rate and maximum radius of pneumatic influence for a particular well point is generally dictated by factors such as: 1) the depth to water; 2) the well screen interval above the water table; and 3) the ratio of horizontal to vertical permeabilities of the formation. Well construction details such as the diameter and slot size generally play a lesser role in dictating optimal operational parameters.

- In-situ biodegradation rates stimulated by the replenishment of subsurface oxygen often greatly exceed chemical mass extraction rates in terms of contribution to total non-chlorinated hydrocarbon removal.

We hope that you find the enclosed information adequate for your purposes. If you have any questions or require additional information, please do not hesitate to call.

Sincerely,

RUTH ASSOCIATES, INC.

Michele C. Ruth

Michele C. Ruth, PE
President

Enclosures

cc: Elaine Bittner, CUC

EXCERPTS FROM

# REMEDIAL DESIGN REPORT
# FORMER SALISBURY TOWN GAS LIGHT SITE
# SALISBURY, MARYLAND

Prepared for:

**CHESAPEAKE UTILITIES CORPORATION**

**DECEMBER, 1995**

Prepared by:


**RUTH ASSOCIATES, INC.**
2017 Chesapeake Road
Annapolis, Maryland 21401

Michele C. Ruth

**Michele C. Ruth, PE**
**President**


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# 2.0 AS/SVE PILOT TEST

The effects of AS and SVE are strongly site-dependent and various hydrogeologic conditions can have a profound impact on the application of this type of remedial system. Therefore, an AS/SVE pilot test was conducted at the site prior to proceeding with the design and implementation of a full-scale system. The following provides an outline of the pilot test objectives, a description of the pilot testing methodologies employed, the results of the testing program, and an interpretation of results as they apply to the design of a full-scale system.

## 2.1 Pilot-Test Objectives

The objectives of the AS/SVE testing program were as follows:

- Demonstrate the effectiveness of the AS/SVE system for removing dissolved hydrocarbons from the ground-water; and
- Determine the design parameters for the full-scale application of AS/SVE, including the following:
  - number, spacing and depth(s) of AS-points;
  - number, spacing and depth(s) of VE-wells;
  - minimum and maximum expected air-injection rates and required pressures;
  - minimum and maximum expected flows from VE wells and required vacuum;
  - expected concentrations of contaminants in extracted air; and
  - size and type of an air emission control system.

## 2.2 Site Characteristics

The zone targeted for ground-water remediation extends between Wells MW-2 and MW-3 along the southern property boundary, downgradient of the Former Production Building. Ground water in this region contains dissolved volatile and semi-

volatile petroleum hydrocarbons ranging in total concentration from approximately 1 milligram/liter (mg/l) at MW-2 to 4 mg/l at MW-3. The depth to water ranges from approximately 23 feet (ft) below ground surface (bgs) in the vicinity of the Former Production Building, to 12.5 ft bgs along the downgradient property boundary. Soils beneath the site generally consist of fine to medium sand with occasional interbedding of siltier material.

The results of the Phase I AS/SVE Pilot Test also revealed a subtle lithologic unit of lower permeability located approximately 20 ft, bgs (or 6 ft below the water table), which effectively controlled the vertical movement of air sparged into the aquifer below this layer. Further detailed review and interpretation of boring logs for previously drilled wells and the first AS test well, AS-1, combined with the data derived from the Phase I Testing, provided additional insight into nature and extent of contamination along the southern property boundary.

It appears that, although the vast majority of the coal-tar residue that was found along the southern property has been excavated and disposed off-site, isolated amounts of coal tar residue remain. Further, it is believed that the lower permeability unit contained the vertical downward migration of the residual tar material, and that the majority of the residual tar constituents are concentrated at the top of this layer. The general vertical distribution of hydrocarbons along the southern property boundary is schematically illustrated in Figure 4. The cross-sectional location is illustrated in Figure 5, which also depicts the well network used for the pilot-testing program.

## 2.3 Pilot Testing Methodology

The AS/SVE pilot-testing program was conducted in the vicinity of the existing Monitoring Well MW-3, where the highest concentrations of dissolved contaminants have been detected in shallow ground water. The effects of AS and SVE remedial activities were evaluated separately and conjunctively during the pilot testing. Additionally, the effects of stratigraphic control on subsurface transport mechanisms was investigated via air-sparging at various depths.

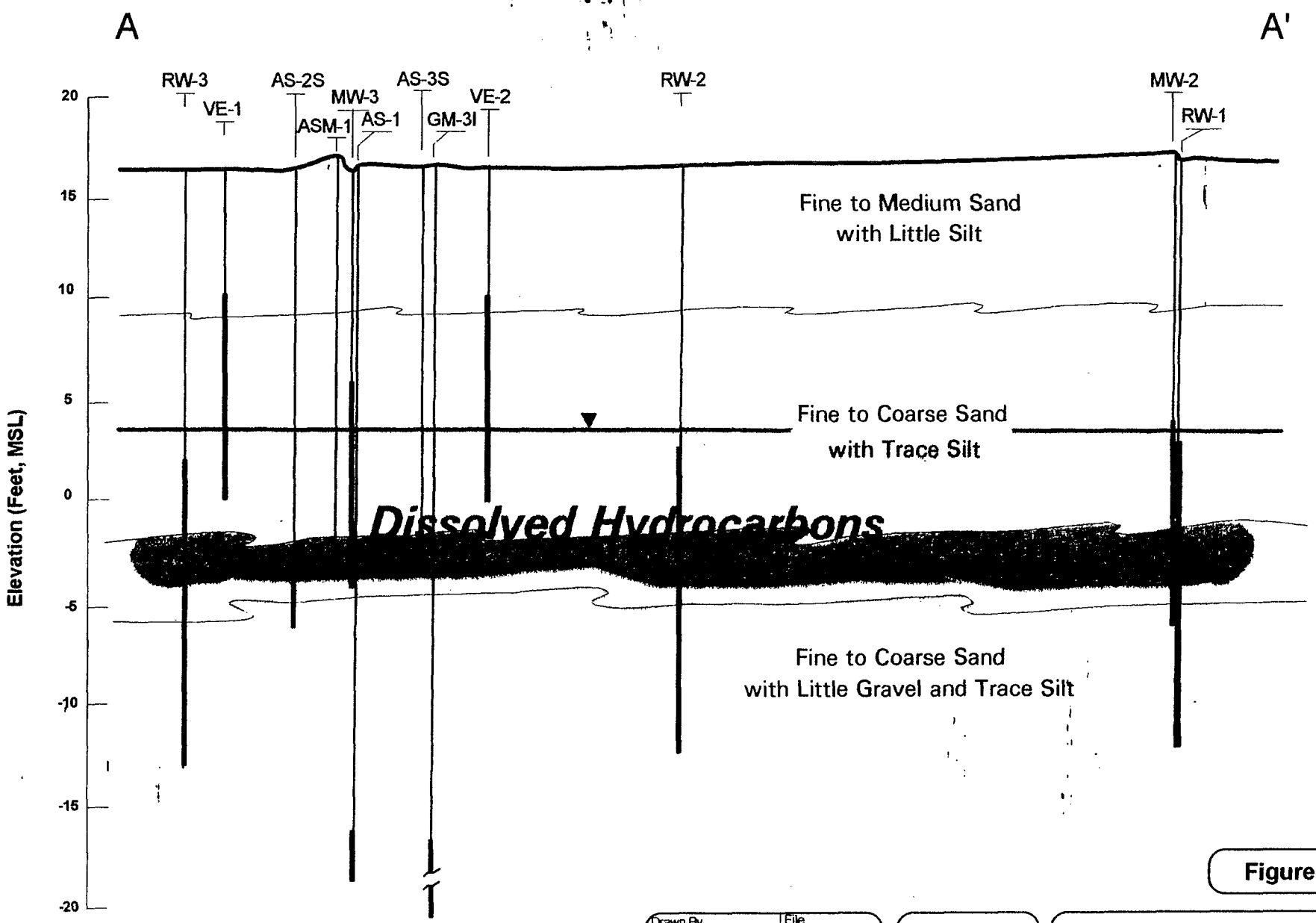


Figure 4

| | |
|---|---|
| Drawn By J Mildenberger 1/10/96 | File CUXSE2.PRE |
| Reviewed MCK | Date 1/11/96 |
| Approved MEK | Date 1/11/96 |

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Cross-Section A-A' Showing Inferred Vertical Distribution of Dissolved Hydrocarbons

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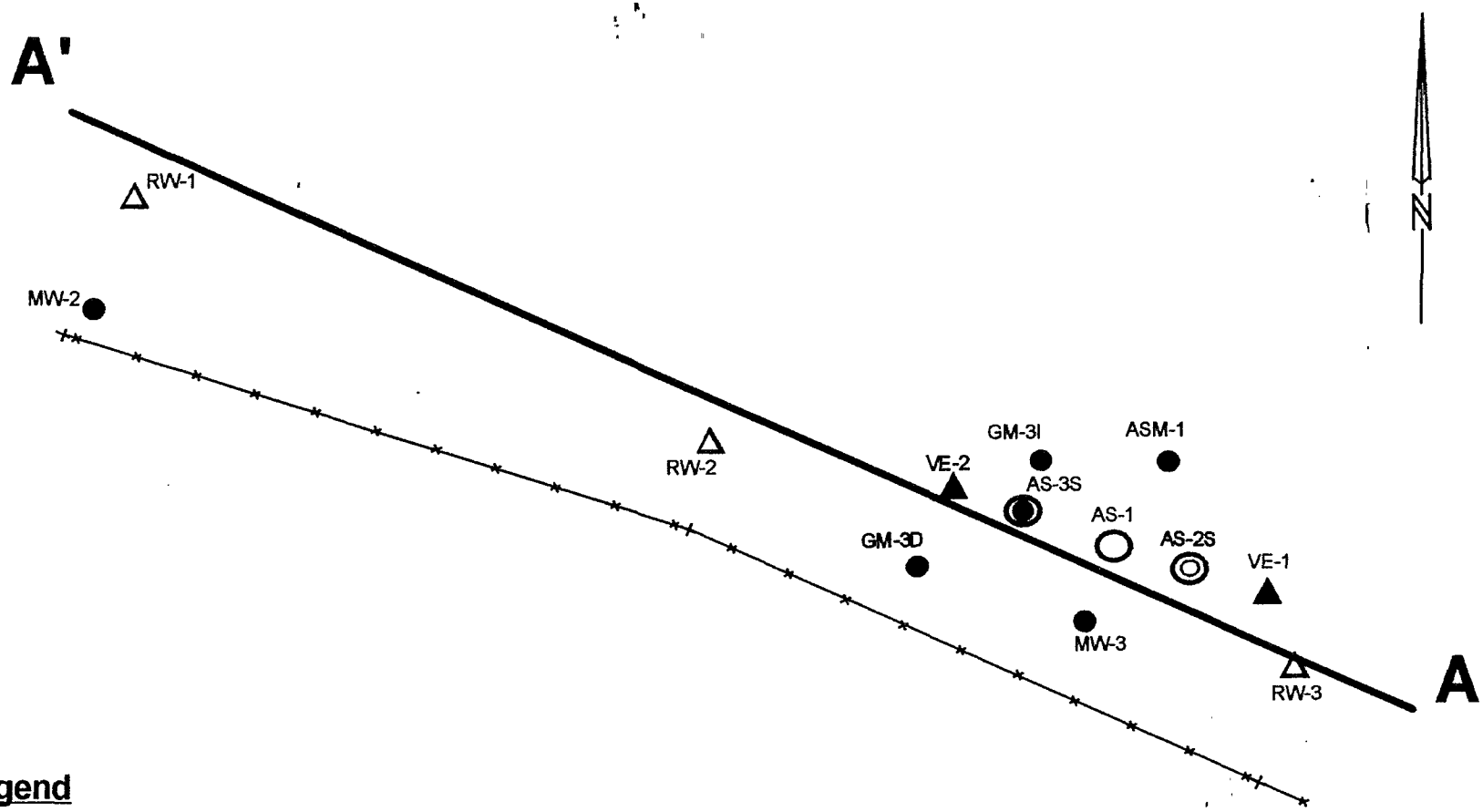


## Legend

A' — A - Line of Cross-Section

- Shallow Sparging Points
- Intermediate (Lower K) Sparging Points
- Deep Sparging Points
- Shallow Vapor Extraction Points
- Deep Vent Wells
- Ground-Water Monitoring Wells

0 15 feet

**Figure 5**

| | |
|---|---|
| Drawn By J Mildenberger 12/11/95 | File ASVEMAP3 PRE |
| Reviewed | Date 1/11/96 |
| Approved | Date 1/11/96 |

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Line of Cross-Section A-A' and the Air Sparge/Vapor Extraction System Pilot Test Network

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- water quality; and
- vapor quality.

Details of the AS/SVE testing activities and the observations made during the AS/SVE testing are summarized in Appendix B, and are discussed below. A summary of field parameter measurements collected before, during, and after the AS/SVE testing program is provided in Table 1. Laboratory results of VOC and PAH analyses of ground-water samples are presented in Tables 2 and 3, respectively. The analytical results for the vapor grab samples are presented in Table 4. The laboratory certificates of analysis for the water samples and vapor samples are included as Appendix C. The testing results provided in these tables and appendices are discussed below.

### 2.4.1 AS/SVE Testing Conditions and Physical Observations

SVE testing consisted of first extracting vapors from VE-1 only at varying rates over a total testing period of approximately 3 hours; then extracting from VE-2 only at varying rates for a period of 3-1/2 hours. After evaluating the effects of extraction vapors from the individual wells, vapors were extracted from VE-1 and VE-2 simultaneously to establish steady-state conditions.

SVE testing on VE-1 started with the extraction rate low; it was then increased in a step-wise fashion. The step-test conditions for VE-1 only were as follows:

| Extraction Rate (SCFM) | Well Vacuum (in. H20) | Minimum Radius of Influence (ft) |
|---|---|---|
| 6 | 10 | 60 |
| 9 | 12 | 60 |
| 11 | 33 | 70 |
| 13 | 44 | 80 |

TABLE 1.
WATER QUALITY FIELD PARAMETERS OBSERVED DURING THE
AIR-SPARGING/SOIL-VAPOR EXTRACTION PILOT TEST
FORMER SALISBURY TOWN GAS LIGHT SITE

| TEST CONDITIONS | ASM-1 | | | MW-2 | | | MW-3 | | | GM-3I | | | RW-1 | | | RW-2 | | | RW-3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DO | pH | SC | DO | pH | SC | DO | pH | SC | DO | pH | SC | DO | pH | SC | DO | pH | SC | DO | pH | SC |
| PHASE I TESTING -Sparge Testing at AS-1 | | | | | | | | | | | | | | | | | | | | | |
| Baseline prior to Testing | NI | NI | NI | 2.5 | NM | 467 | 1.5 | NM | 477 | 5.4 | NM | 134 | 2.3 | NM | 398 | 2.3 | NM | 360 | 1.9 | NM | 240 |
| Post SVE Only Testing | NI | NI | NI | 1.7 | 6.43 | 449 | 1.3 | 6.38 | 528 | 5.7 | 5.59 | 122 | 2.3 | 6.16 | 290 | 1.5 | 6.52 | 171 | 4.1 | 5.50 | 200 |
| Post AS/SVE Testing on AS-1 | NI | NI | NI | 2.1 | 6.49 | 402 | 1.8 | 6.17 | 380 | 6.5 | 5.62 | 144 | 2.0 | 6.46 | 453 | 8.6 | 6.52 | 198 | 8.8 | 5.88 | 241 |
| PHASE II TESTING - Sparge Testing at AS-2S and AS-3S | | | | | | | | | | | | | | | | | | | | | |
| Baseline prior to Testing | 2.2 | 6.63 | 510 | 0.9 | 6.35 | 433 | 1.6 | 6.34 | 520 | 6.2 | 5.71 | 131 | 2.0 | 6.26 | 306 | 1.7 | 6.39 | 158 | NM | 5.63 | 198 |
| Post Short-Term Sparge Tests | 2.1 | 6.63 | 509 | 0.6 | 6.42 | 415 | 5.3 | 6.62 | 323 | 5.7 | 5.66 | 130 | 1.2 | 6.39 | 382 | 6.5 | 6.60 | 237 | 1.7 | 6.01 | 292 |
| Post SVE Only Testing | 1.3 | 6.59 | 466 | 1.5 | 6.46 | 417 | 2.0 | 6.48 | 365 | 6.2 | 5.74 | 123 | 1.8 | 6.31 | 295 | 1.3 | 6.43 | 184 | 4.1 | 5.72 | 199 |
| Post AS/SVE Testing | 8.6 | 6.89 | 422 | 1.0 | 6.42 | 400 | 6.8 | 7.05 | 282 | 6.3 | 5.77 | 120 | 2 | 6.24 | 293 | 7.7 | 6.62 | 182 | 4.5 | 5.83 | 213 |

DO - Dissolved Oxygen as milligrams/liter
pH - Standard Units
SC - Specific Conductance as micromhos/centimeter
NI - Point not installed at time of monitoring
NM - Not measured

## TABLE 2.
## AIR-SPARGING/SOIL-VAPOR EXTRACTION PILOT TEST DATA
## VOLATILE ORGANIC COMPOUNDS IN GROUND WATER BEFORE AND AFTER PILOT TEST
## FORMER SALISBURY TOWN GAS LIGHT SITE

| Well I.D. | MW-3 | | VE-1 | | VE-2 | |
|---|---|---|---|---|---|---|
| Test Conditon<br>Date Sampled | Before Test<br>3/30/95 | After Test<br>4/26/95 | BeforeTest<br>3/30/95 | After Test<br>4/26/95 | Before Test<br>3/30/95 | After Test<br>4/26/95 |
| Acetone | <80 | 23 | <100 | <25 | <10 | <20 |
| Benzene | 1040 | 74 | 755 | 253 | 80 | 206 |
| Bromodichlormethane | <40 | <5 | <50 | <13 | <5 | <10 |
| Bromoform | <40 | <5 | <50 | <13 | <5 | <10 |
| Bromomethane | <80 | <10 | <100 | <25 | <10 | <20 |
| 2-Butanone | <80 | <10 | <100 | <25 | <10 | <20 |
| Carbon Disulfide | <40 | <5 | <50 | <13 | <5 | <10 |
| Carbon Tetrachloride | <40 | <5 | <50 | <13 | <5 | <10 |
| Chlorobenzene | <40 | <5 | <50 | <13 | <5 | <10 |
| Chloroethane | <80 | <10 | <100 | <25 | <10 | <20 |
| Chloroform | <40 | <5 | <50 | <13 | <5 | <10 |
| Chloromethane | <80 | <10 | <100 | <25 | <10 | <20 |
| Dibromochloromethane | <40 | <5 | <50 | <13 | <5 | <10 |
| 1,2-Dichloroethane | 32 J | 7.6 | <50 | <13 | <5 | 4.2 J |
| 1,1-Dichloroethane | <40 | <5 | <50 | <13 | <5 | <10 |
| 1,1-Dichloroethene | <40 | <5 | <50 | <13 | <5 | <10 |
| 1,2-Dichloroethene (total) | <40 | <5 | <50 | <13 | <5 | <10 |
| 1,2-Dichloropropane | <40 | <5 | <50 | <13 | <5 | <10 |
| trans-1,3-dichloropropene | <40 | <5 | <50 | <13 | <5 | <10 |
| cis-1,3-Dichloropropene | <40 | <5 | <50 | <13 | <5 | <10 |
| Ethylbenzene | 317 | 20 | 873 | 147 | 64 | 246 |
| 2-Hexanone | <80 | <10 | <100 | <25 | <10 | <20 |
| 4-Methyl-2-Pentanone | <80 | <10 | <100 | <25 | <10 | <20 |
| Methylene Chloride | <40 | <5 | <50 | <13 | <5 | <10 |
| Styrene | <40 | <5 | <50 | 50 | 74 | 107 |
| 1,1,2,2-Tetrachloroethane | <40 | <5 | <50 | <13 | <5 | <10 |
| Tetrachloroethene | <40 | <5 | <50 | <13 | <5 | <10 |
| Toluene | 38 J | 4.6J | 62 | 132 | 154 | 260 |
| 1,1,1-Trichloroethane | <40 | <5 | <50 | <13 | <5 | <10 |
| 1,1,2-Trichloroethane | <40 | <5 | <50 | <13 | <5 | <10 |
| Trichloroethene | <40 | <5 | <50 | <13 | <5 | <10 |
| Vinyl Acetate | <80 | <10 | <100 | <10 | <10 | <20 |
| Vinyl Chloride | <80 | <10 | <100 | <10 | <10 | <20 |
| Xylene | 151 | 20 | 346 | 182 | 155 | 370 |

All concentrations reported as ug/l (ppb)
J - denotes concentrations found below method quantitative detection limit

## TABLE 3.
## AIR-SPARGING/SOIL-VAPOR EXTRACTION PILOT TEST DATA
## POLYCYCLIC AROMATIC HYDROCARBONS IN GROUND WATER BEFORE AND AFTER PILOT TEST
## FORMER SALISBURY TOWN GAS LIGHT SITE

| Well I.D. | MW-3 | | VE-1 | | VE-2 | |
|---|---|---|---|---|---|---|
| Test Conditon<br>Date Sampled | Before Test<br>3/30/95 | After Test<br>4/26/95 | BeforeTest<br>3/30/95 | After Test<br>4/26/95 | Before Test<br>3/30/95 | After Test<br>4/26/95 |
| Acenaphthene | 42 | 13 | 28 J | <10 | <25 | <15 |
| Acenaphthylene | 66 | 13 | 23 J | 4.3 J | 15 J | 6.3 J |
| Anthracene | 5.5 J | <5 | <40 | <10 | <25 | <15 |
| Benzo(a)Anthracene | <10 | <5 | <40 | <10 | <25 | <15 |
| Benzo(a)Pyrene | <10 | <5 | <40 | <10 | <25 | <15 |
| Benzo(b)fluoranthene | <10 | <5 | <40 | <10 | <25 | <15 |
| Benzo(g,h,i)Perylene | <10 | <5 | <40 | <10 | <25 | <15 |
| Benzo(k)fluoranthene | <10 | <5 | <40 | <10 | <25 | <15 |
| Chrysene | <10 | <5 | <40 | <10 | <25 | <15 |
| Dibenz(a,h)Anthracene | <10 | <5 | <40 | <10 | <25 | <15 |
| Fluoranthene | <10 | <5 | <40 | <10 | <25 | <15 |
| Fluorene | 26 | 12 | 19 J | <10 | <25 | <15 |
| Indeno(1,2,3-cd)Pyrene | <10 | <5 | <40 | <10 | <25 | <15 |
| 2-Methylnaphthalene | 6.7 J | 3.6 J | 43 | 5.5 J | 94 | 54 |
| Naphthalene | 164 | 89 | 780 | 166 | 444 | 299 |
| Phenanthrene | 31 | 6.7 | 25 J | <10 | <25 | <15 |
| Pyrene | <10 | <5 | <40 | <10 | <25 | <15 |

All concentrations reported as ug/l (ppb)
J - denotes concentrations found below method quantitative detection limit

TABLE 4.
QUALITY OF VAPORS EXTRACTED DURING AIR-SPARGING/VAPOR-EXTRACTION PILOT TEST
FORMER SALISBURY TOWN GAS LIGHT SITE

| Test Conditions | Sample ID | Petroleum Constituents (ppmv, unless otherwise noted) | | | | | | | Permanent Gases (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Benzene | Toluene | Ethyl-benzene | m & p - xylenes | o - xylene | naphthalene (ug/l) | total C5-C10 | CO2 | oxygen | nitrogen | methane | CO |
| Phase I - AS-1 6 hr of SVE only | V-1 | 2.72 | 1.84 | 1.08 | 0.93 | 0.40 | <0.30 | 11.91 | 4.98 | 16.91 | 75.54 | 0.05 | <0.01 |
| 23 hr of SVE only | V-2 | 2.61 | 2.12 | 0.96 | 1.06 | 0.40 | <0.30 | 11.51 | 2.74 | 19.25 | 75.64 | 0.38 | <0.01 |
| 46 hr of SVE only | V-3 | 2.91 | 2.60 | 1.08 | 1.38 | 0.54 | <0.30 | 14.78 | 2.57 | 19.46 | 75.51 | 0.45 | <0.01 |
| 21 hr of AS/SVE | AS/SVE-1 | 2.37 | 2.15 | 0.86 | 1.01 | 0.39 | <0.30 | 10.14 | 1.69 | 20.43 | 75.27 | <0.01 | <0.01 |
| Phase II - AS-2S 21 hr of SVE only | V2-1 | 4.29 | 5.09 | 1.58 | 1.26 | 0.63 | 0.21 | 15.08 | 2.27 | 18.67 | 76.38 | <0.01 | <0.01 |
| 45 hr of SVE only | V2-2 | 5.55 | 7.38 | 1.93 | 1.59 | 0.86 | 0.57 | 19.98 | 2.31 | 18.70 | 75.95 | <0.01 | <0.01 |
| 3.5 hr of AS/SVE | V3-1 | 5.27 | 6.77 | 1.63 | 1.37 | 0.76 | 0.65 | 20.82 | 2.17 | 18.72 | 76.16 | <0.01 | <0.01 |
| 7 hr of AS/SVE | V3-2 | 4.86 | 5.95 | 1.44 | 1.17 | 0.66 | 0.31 | 16.75 | 1.67 | 19.36 | 76.17 | <0.01 | <0.01 |
| 23 hr of AS/SVE | V3-3 | 5.00 | 6.49 | 1.79 | 1.49 | 0.89 | 0.54 | 18.39 | 1.69 | 19.36 | 75.82 | <0.01 | <0.01 |
| 29 hr of AS/SVE | V3-4 | 4.42 | 5.75 | 1.48 | 1.27 | 0.74 | 0.55 | 17.93 | 1.64 | 19.49 | 76.05 | <0.01 | <0.01 |

Note: All samples collected under SVE only conditions included combined extraction from VE-1 and VE-2.

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The step-test conditions for VE-2 were similar to those for VE-1, and are summarized as follows:

| Extraction Rate (SCFM) | Well Vacuum (in. H20) | Minimum Radius of Influence (ft) |
|---|---|---|
| 2 | 8.5 | 60 |
| 3.5 | 11.5 | 60 |
| 6.5 | 22 | 70 |
| 7 | 34 | 80 |

The results of the single-well SVE testing indicated that a minimum radius of influence of approximately 60 feet can be readily achieved by extracting vapors from an individual well at a nominal rate of less than 10 SCFM, and that only a marginal increase in pneumatic influence is likely to be achieved by increasing the extraction beyond this rate.

After conducting the individual step testing on each VE-well, Phase I combined vapor extraction was performed by extracting from VE-1 and VE-2 simultaneously. The extraction rates were selected based on the results of the step testing outlined above, and with the objective of balancing the flow from the two wells. The test conditions were as follows:

Phase I - SVE Only at VE-1 and VE-2
VE-1: Extraction rate - 10 to 11 SCFM; well vacuum approx. 28 in. water
VE-2: Extraction rate - 10 to 11 SCFM; well vacuum approx. 42 in. water

Soil vapors were captured from an area of over 180 feet in length along the property boundary.

The Phase I air-sparging test was not initiated until induced vacuums and extracted vapor flow and quality approached steady-state conditions. After SVE only

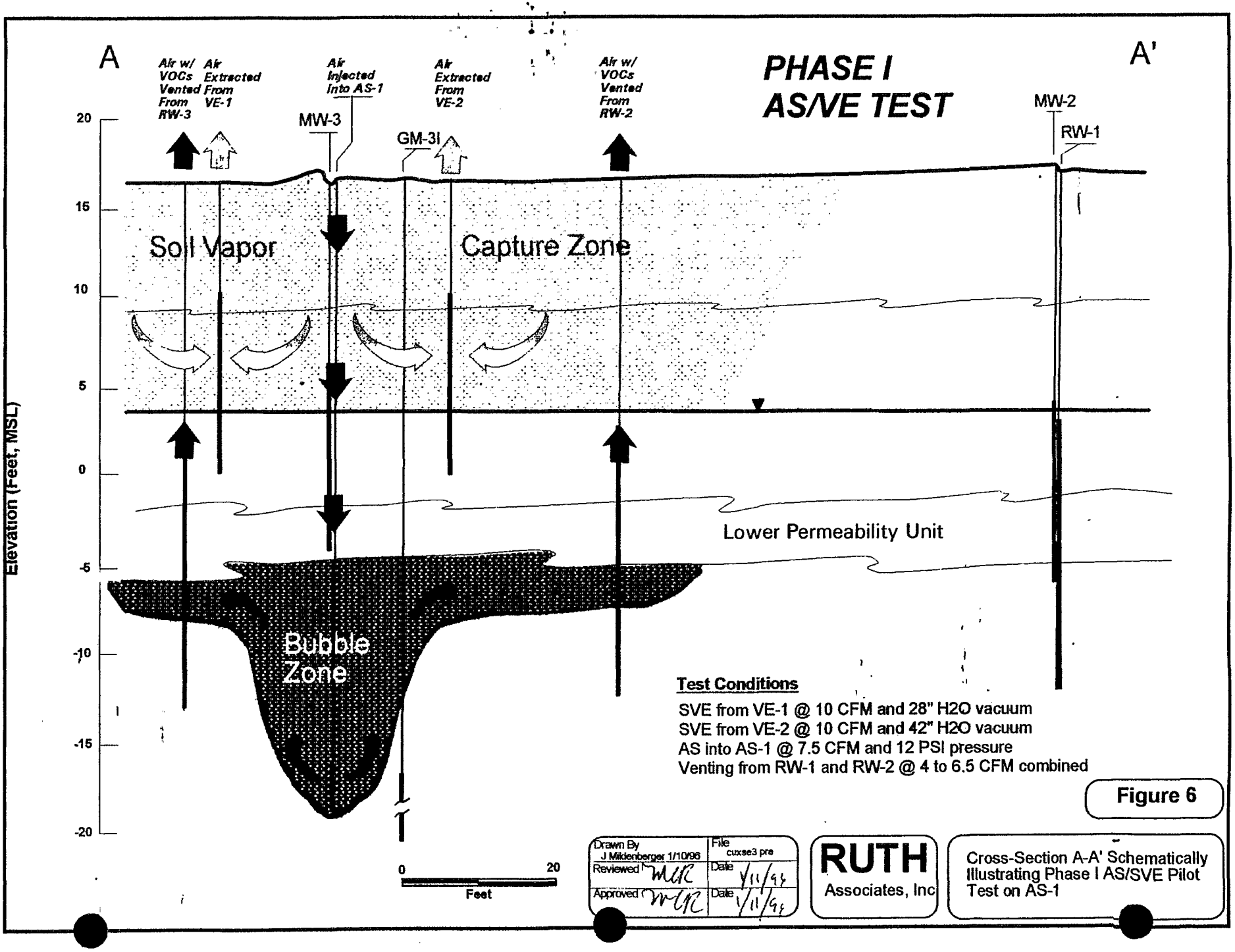
was conducted on VE-1 and VE-2 for approximately 46 hours, sparging was conducted at AS-1. The AS/SVE test conditions for this portion of the test were as follows:

Phase I - Air Injection into AS-1 w/ Deep Venting and SVE
Injected <2 SCFM air @ <10 PSI and increased up to 7.5 SCFM @ 12 PSI
SVE from VE-1 and VE-2 @ approximately 10 SCFM from each
Deep venting from RW-2 and RW-3 at a combined rate of 4 to 6.5 SCFM

The observations made during the Phase I AS/SVE testing indicated that sparging had a strong influence in the form of mechanical aeration below the lower permeability unit and at distances of at least 80 feet. Vigorous bubbling was observed at RW-2 and RW-3, with measurable flow exiting these wells when opened to the atmosphere. However, little to no sparging influence was observed at the other nearby wells, MW-3, VE-1, and VE-2, which were located closer to the AS wells but were screened at intervals that did not penetrate the lower permeability unit as do RW-2 and RW-3.

The Phase I AS/SVE test indicated that the lower permeability unit situated horizontally between the depths of RW-2 and RW-3 and the depths of the shallower wells, MW-3, VE-1 and VE-2, was restricting the vertical movement of sparged air. Sparging into the coarser materials underlying the lower permeability unit resulted in the venting of air through RW-2 and RW-3, where these wells intercepted sparge air flowing laterally beneath the horizontal flow boundary. The observations made during the Phase I AS/SVE testing are schematically illustrated in Figure 6.

Because the plume is generally restricted to the shallow portion of the aquifer extending down to the top of the lower permeability unit, and because of the flow restriction presented by this layer, sparging at the interval tested during Phase I would not be effective for plume remediation. Therefore, additional test sparge wells, AS-3S and AS-2S, were installed at shallower depths for Phase II testing. Short-term tests were run on each of the sparge wells before selecting test conditions and well(s) for the longer-term test. The following is a summary of the Phase II short-term sparge test conditions:


PHASE I
AS/VE TEST
A
A'
Air w/ VOCs Vented From RW-3
Air Extracted From VE-1
Air Injected Into AS-1
Air Extracted From VE-2
Air w/ VOCs Vented From RW-2
MW-3
GM-3I
MW-2
RW-1
Soil Vapor
Capture Zone
Lower Permeability Unit
Bubble Zone
Elevation (Feet, MSL)
20
15
10
5
0
-5
-10
-15
-20
0
20
Feet
Test Conditions
SVE from VE-1 @ 10 CFM and 28" H2O vacuum
SVE from VE-2 @ 10 CFM and 42" H2O vacuum
AS into AS-1 @ 7.5 CFM and 12 PSI pressure
Venting from RW-1 and RW-2 @ 4 to 6.5 CFM combined
Figure 6
Drawn By J Mildenberger 1/10/96
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Reviewed
Date 1/11/96
Approved
Date 1/11/96
RUTH Associates, Inc
Cross-Section A-A' Schematically Illustrating Phase I AS/SVE Pilot Test on AS-1

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Phase II - Air Injection into AS-2S Only
Injected 4 SCFM air @ 11 PSI; rose w/o adjust. to 5.5 SCFM @ 7.5 PSI

Phase II - Air Injection into AS-3S Only
Injected 3 SCFM air @ initial pressure of 13.2 PSI falling to 10.1 PSI;
Injected 5.3 SCFM air @ initial pressure of 11.9 PSI falling to 10.7 PSI

Sparging into AS-2S provided good lateral influence in the shallowest portion of the aquifer and within the lower permeability unit. Water-level rises were observed in all of the nearby shallow wells, including VE-1, VE-2, MW-3, RW-2, RW-3, AS-3S, ASM-1and GM-3I; bubbles were also observed in each of these wells, except VE-2 and GM-3I.

Sparging into AS-3S also provided good lateral influence in the shallowest portion of the aquifer, but much less of an effect was observed within the lower permeability unit. A water-level rise was observed only in RW-2. Bubbles were observed in RW-2, MW-3, and to a lesser extent in VE-1, VE-2 and RW-3. The observations from the short-term sparge test on AS-3S are schematically illustrated in Figure 7.

Because sparging into AS-2S effected ground water within the lower permeability unit to a much greater extent than AS-3S, AS-2S was selected for the longer-term AS/SVE testing. The next step was then to extract soil vapors from VE-1 and VE-2. When steady-state conditions were approached, air was injected into AS-2S. The following is a summary of the Phase II - SVE only and AS/SVE test conditions:

Phase II - SVE Only at VE-1 and VE-2
VE-1: Extraction rate - 10.5 to 14 SCFM; well vacuum approx. 32 in. water
VE-2: Extraction rate - 10 to 14 SCFM; well vacuum approx. 41 in. water

Phase II - AS/SVE with AS-2S, VE-1 and VE-2
AS-2S: Air injection rate approx. 3.5 SCFM; well pressure approx. 7.5 PSI
VE-1: Extraction rate - 11.5 to 15 SCFM; well vacuum approx. 30 in. water
VE-2: Extraction rate - 10 to 14 SCFM; well vacuum approx. 40 in. water



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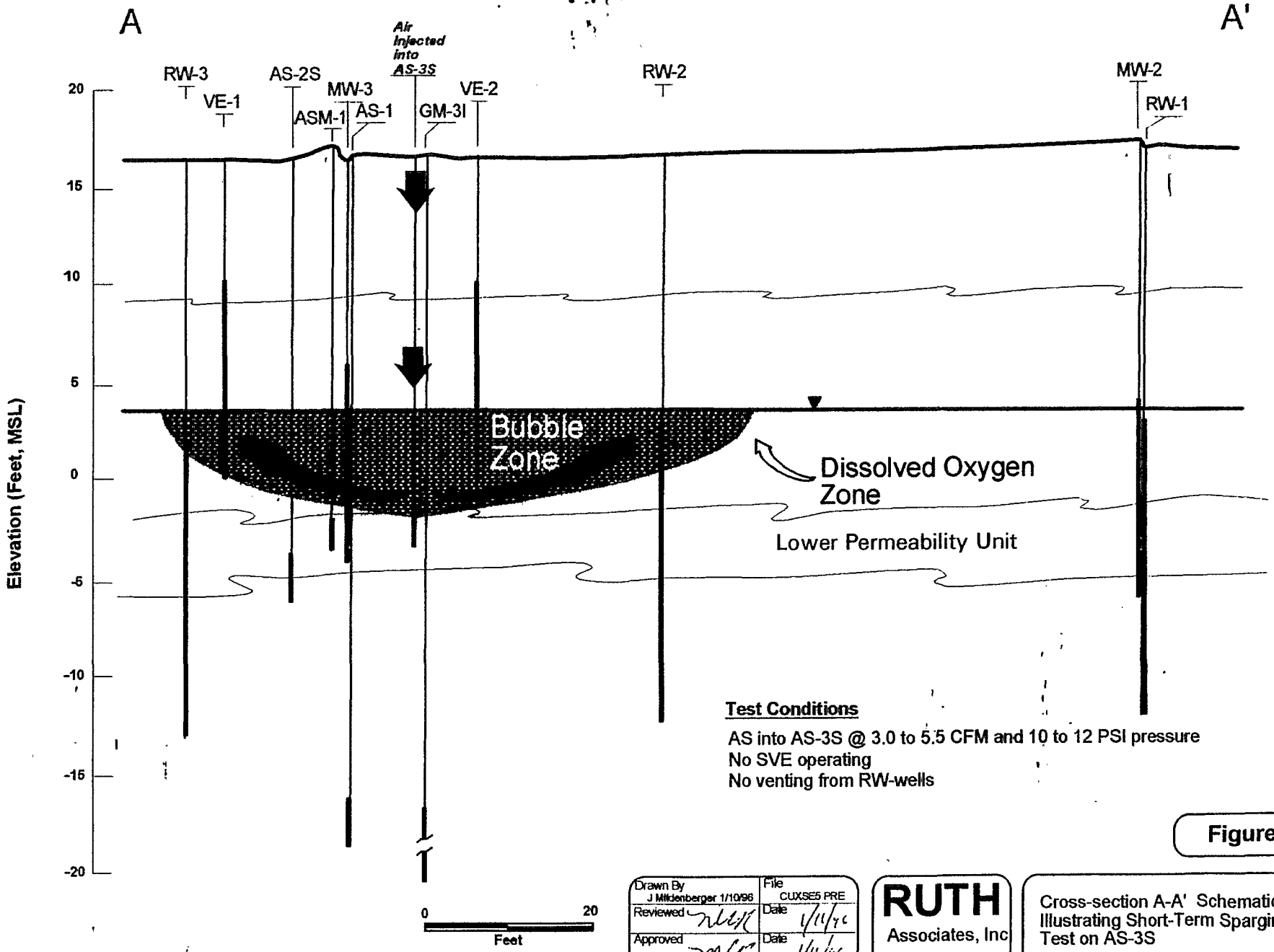


**Test Conditions**

AS into AS-3S @ 3.0 to 5.5 CFM and 10 to 12 PSI pressure
No SVE operating
No venting from RW-wells

**Figure 7**

| | |
|---|---|
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| Approved | Date 1/11/96 |

RUTH Associates, Inc

Cross-section A-A' Schematically Illustrating Short-Term Sparging Test on AS-3S

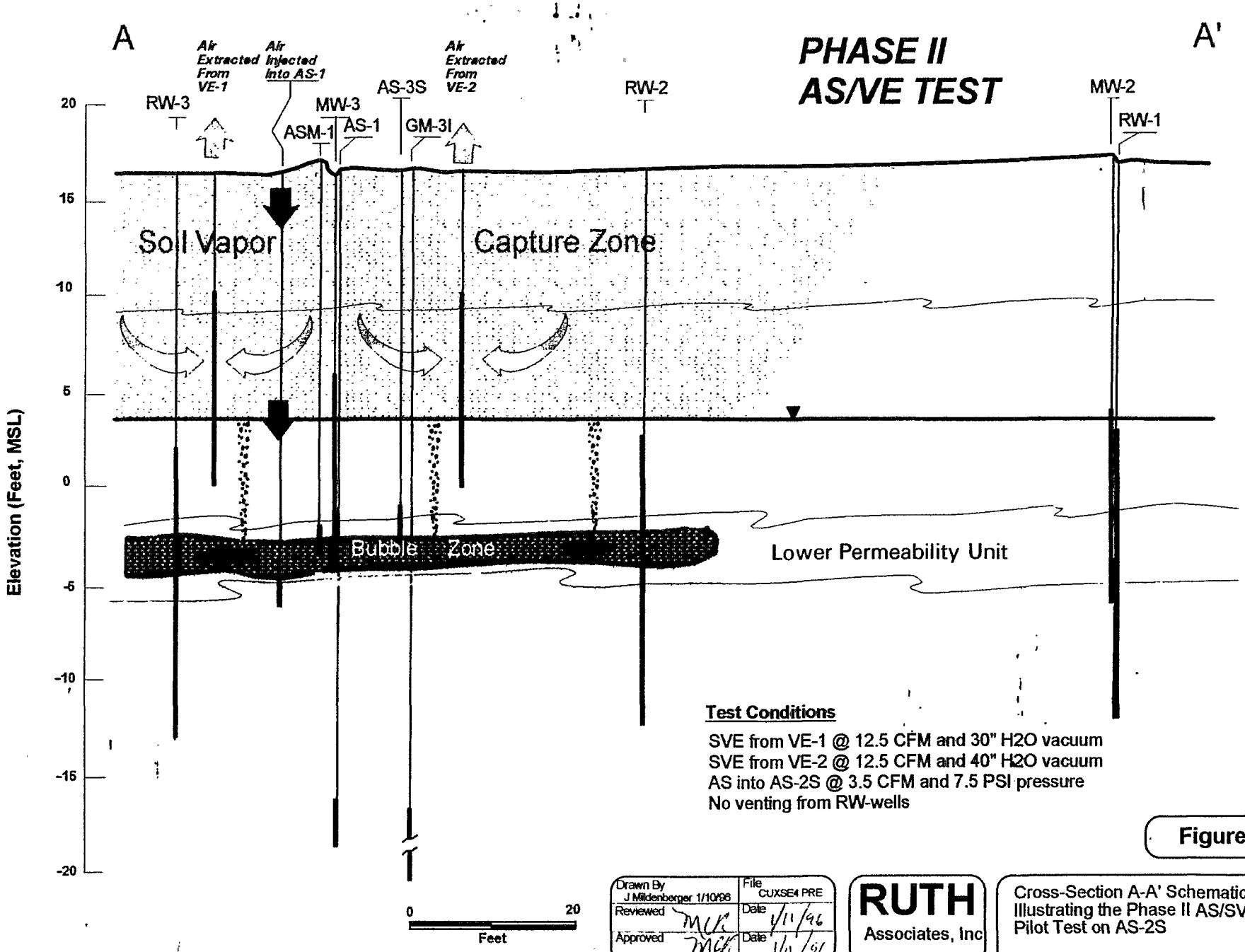
AR309752

The longer-term Phase II AS/SVE test, using AS-2S, VE-1 and VE-2, indicated that strong lateral influence in the lower permeability unit could be achieved, with bubbling observed in all of the nearby wells screened at least partially within the lower permeability unit: MW-3, ASM-1, AS-3S, RW-2 and RW-3. However, mechanical influence was not observed in the shallower wells, VE-1 and VE-2. The observations made during the Phase II AS/SVE test are schematically illustrated in Figure 8.

### 2.4.2 Ground-Water Quality

The effects of AS/SVE activities on ground-water quality conditions were evaluated. Ground-water samples were collected from MW-3, VE-1 and VE-2 on March 30, 1995, before any AS/SVE testing, and on April 26, 1995, after the AS/SVE testing was completed. The results of the laboratory analyses for VOCs and PAHs were consistent with expected ground-water quality based on data from the quarterly monitoring program, and are summarized in Tables 2 and 3, respectively. Laboratory certificates of analysis for the ground-water samples are provided as Appendix C. Ground-water samples were also collected from all of the wells in the AS/SVE test network, several times throughout the testing program, and analyzed for the field parameters, dissolved oxygen, pH, specific conductance, and temperature. The results of the field monitoring for indicator parameters are summarized in Table 1.

Baseline conditions were established prior to initiating any AS/SVE activities. Specific conductance and pH were generally consistent with values previously measured for wells in this area, with the pH being slightly acidic (i.e., less than 7.0) and specific conductance (SC) ranging from 401 to 477 micromhos-per-centimeter (umhos/cm) in the shallow wells, and decreasing with depth to 134 umhos/cm in the intermediate well, GM-3I. This was the first time that the ground water has been measured for dissolved oxygen (DO). As expected, DO concentrations were generally lowest in the wells containing the highest concentrations of hydrocarbons, ranging from 1.5 to 2.5 mg/l in the shallow wells and up to 5.4 mg/l in the intermediate well, GM-3I. This depression in DO concentrations at the water table is most likely the




**Test Conditions**

SVE from VE-1 @ 12.5 CFM and 30" H2O vacuum
SVE from VE-2 @ 12.5 CFM and 40" H2O vacuum
AS into AS-2S @ 3.5 CFM and 7.5 PSI pressure
No venting from RW-wells

**Figure 8**

| | |
|---|---|
| Drawn By J Mildenberger 1/10/96 | File CUXSE4 PRE |
| Reviewed MCK | Date 1/11/96 |
| Approved MCK | Date 1/11/96 |

**RUTH** Associates, Inc

Cross-Section A-A' Schematically Illustrating the Phase II AS/SVE Pilot Test on AS-2S

AR309754

Comparison of the analytical results for samples collected from VE-1, VE-2, and MW-3 before and after the AS/SVE testing activities indicates that both VOCs and PAHs were reduced significantly at MW-3 and VE-1; PAH concentrations decreased in VE-2, but VOC concentrations were higher in the sample collected after the testing. These results are generally consistent with the physical effects observed during the testing. Bubbling was observed in MW-3 during the short- and long-term Phase II sparging tests, but was observed in VE-1 only during the short-term Phase II tests on AS-2S and in VE-2 only during the short-term test on AS-3S.

### 2.4.3 Extracted Vapor Quality

The quality of extracted vapors was monitored to evaluate subsurface conditions prior to AS/SVE testing as well as the effects of AS/SVE activities. Field monitoring results are summarized in Appendix B, and the laboratory results for grab samples collected periodically throughout the AS/SVE testing program are provided in Table 4. The following is a discussion of the vapor-quality monitoring results.

Extracted vapor quality during the initial SVE step tests indicated conditions where soils and ground water have been impacted by readily biodegradable organic constituents. Oxygen in the extracted vapors was depressed, likely reflecting bioutilization of the oxygen associated with the degradation of the petroleum hydrocarbons. Additionally, methane was present at significant concentrations. The metabolic pathway for biodegradation of petroleum hydrocarbons typically becomes anaerobic as the available oxygen is depleted, and methane is produced as a byproduct. Because aerobic biodegradation of petroleum hydrocarbons is much faster than anaerobic biodegradation, low oxygen and high methane concentrations indicate that the rate of natural biodegradation is probably being limited by the available oxygen.

Oxygen concentrations generally were low initially, and rose with time as SVE continued. The oxygen concentrations continued to rise further after AS operations

were added to the SVE. The same general patterns were observed for both phases of testing, although baseline oxygen concentrations at the onset of the Phase II testing were significantly higher than the pre-testing conditions. Measurements of oxygen in the extracted vapors during the AS/SVE testing were as follows:

Phase I - Oxygen in Extracted Vapors
VE-1 Step Test: 2.4% rising to 15.5% (field)
VE-2 Step Test: 9.5% rising to 13% (field)
SVE Only (46 hr): 14.5% rising to 18.2% (field); 16.91% to 19.46% (lab)
AS/SVE (24 hr): 18.4% rising to 20.0% (field); 20.43% (lab)

Phase II - Oxygen in Extracted Vapors
SVE Only (45 hr): 17.0% rising to 18.5% (field); 18.67% to 18.70% (lab)
AS/SVE (30 hr): 18.5% rising to 19.5% (field); 18.7% to 19.49% (lab)

Methane was detected at high concentrations during the earliest stages of testing, and decreased dramatically as oxygen was restored to the subsurface. This dramatic decrease in methane concentrations may reflect shifting the metabolic pathway from anaerobic to aerobic biodegradation. Methane was measured directly by the laboratory in grab samples collected periodically throughout the AS/SVE test, and the analytical results are summarized in Table 4. Methane concentrations ranged from 0.05 to 0.45% during the 46 hours of the SVE-only portion of the Phase I Testing, and dropped to less than the detection limit of 0.01% after 21 hours of the Phase I AS/SVE testing. Methane was below the detection limit of 0.01% throughout the SVE-only and AS/SVE portions of the Phase II testing.

Carbon dioxide can also be an important indicator parameter because it is a byproduct of aerobic biodegradation and is generally not present at significant quantities in fresh air. Soil-vapor grab samples were therefore measured for carbon dioxide; the results are summarized in Table 4. Carbon dioxide concentrations were highest at the onset of SVE-only activities, and fell during each testing phase. These observations are likely attributable to dilution of the carbon dioxide due to the induction of fresh air into the subsurface from SVE activities and injection of air from AS activities. Carbon dioxide concentrations appeared to approach asymptotic levels,

with steady-state concentrations ranging from 1.64 to 1.69% for both the Phase I and Phase II tests.

Combustible gases, measured as a percent of the lower explosive limit (LEL), were monitored in the field using two different types of meters. One was calibrated with methane (CH4) and was sensitive to the full range of alkanes. The second instrument measured combustible gases other than methane, and was calibrated with hexane (C6H6). Combustible gases were very high (>100% of the LEL as CH4 and as high as 72% of the LEL as C6H6) during the initial Phase I SVE step tests, and then generally approached a steady-state. LEL measurements fluctuated at these lower levels throughout the Phase I AS/SVE testing. These field observations reflect the effects of purging the methane and other alkanes initially present in the soil vapors. The combustible gas measurements also indicated steady-state conditions by the end of the SVE-only portion of the Phase II test, with asymptotic levels of 3.4% of the LEL as CH4 and 12% as C6H6. However, the concentrations of combustible gases dropped further at the onset of the AS-portion of the Phase II testing, likely reflecting the effects of dilution from injecting clean air into the subsurface.

VOCs in the extracted vapor stream were semi-quantitatively measured in the field using an HNu photo-ionization detector. These readings were lowest during the initial SVE step tests, ranging from 4.6 to 16.5 parts-per-million (ppm), and increased slightly up to 23 ppm during the Phase I SVE-only test. HNu readings fluctuated between 16.4 and 23 ppm for the remainder of the Phase I test and throughout the Phase II testing. These data are generally consistent with the laboratory analysis of the vapor grab samples for the petroleum constituents, as listed in Table 4.

### 2.4.4 Estimated Chemical Mass Extraction Rates

Specific petroleum-related VOCs, including BTEX, naphthalene, and C5- to C10-hydrocarbons were also measured in the soil-vapor grab samples, and can be used to calculate the rate of chemical mass extraction by multiplying the measured constituent concentrations by the rate of total SVE extraction. The specific

constituent concentrations measured in the grab samples are provided in Table 4. The calculated extraction rates under the various testing conditions are presented in Table 5.

As shown in Table 4, the concentrations of specific chemical constituents did not reveal any significant trends during either AS/SVE testing phase. However, it does appear that the petroleum constituent concentrations were generally higher during the Phase II testing than those measured during the Phase I testing. Additionally, total SVE extraction rates were generally higher during Phase II than Phase I, as shown on Table 5, resulting in greater calculated chemical mass extraction rates for Phase II conditions.

Because no significant increase in extracted vapor concentrations was observed when AS activities were initiated, it appears likely that the principal contribution of VOCs in the extracted vapors during the pilot testing came from the soils rather than from constituents partitioned from the ground water. This would likely not be the case during full-scale operation, when more partitioning of VOCs from the shallow ground water is expected, and after the SVE operations removed the bulk of the VOCs from the soils overlying the water table.

VOC mass extraction rates, calculated based on direct measurements taken during AS/SVE pilot test, ranged from 0.048 up to 0.161 pounds-per-day (lb/day), with benzene contributing less than 0.05 lb/day in every instance (see Table 5). Using these data, estimates for chemical mass extraction for the full-scale AS/SVE system (from four SVE wells rather than the two wells used during the pilot testing) could be double those calculated for the test conditions. Chemical mass extraction rates are therefore estimated at 0.322 lb/day for VOCs, and 0.004 lb/hr for benzene.

However, it is likely that partitioning of VOCs from the ground water to the vapor phase during shallow sparging will significantly increase the VOC concentrations in the soil vapors extracted, thereby increasing the chemical mass extraction rates. Conversely, the contribution of VOCs from the unsaturated soils is likely to dissipate quickly within the first few weeks or months, thereby decreasing the chemical mass extraction rates.

## TABLE 5
## CALCULATED MASS EXTRACTION RATES FOR THE AS/SVE PILOT TEST AT THE FORMER SALISBURY TOWN GAS LIGHT SITE

| Sample ID | Flow Rate (SCFM) | Benzene (lb/day) | Toluene (lb/day) | Ethylbenzene (lb/day) | Xylenes (lb/day) | Napthalene (lb/day) | C5 - C10 Alkanes (lb/day) | Total VOCs (lb/day) | Total VOCs + Cs (lb/day) |
|---|---|---|---|---|---|---|---|---|---|
| V-1 | 20.5 | 0.018 | 0.014 | 0.010 | 0.012 | 0.000 | 0.080 | 0.053 | 0.133 |
| V-2 | 20.5 | 0.017 | 0.016 | 0.008 | 0.013 | 0.000 | 0.077 | 0.054 | 0.132 |
| V-3 | 21.5 | 0.020 | 0.021 | 0.010 | 0.018 | 0.000 | 0.104 | 0.068 | 0.173 |
| AS/SVE-1 | 19 | 0.014 | 0.015 | 0.007 | 0.011 | 0.000 | 0.063 | 0.048 | 0.111 |
| V2-1 | 21 | 0.028 | 0.040 | 0.014 | 0.017 | 0.002 | 0.104 | 0.102 | 0.206 |
| V2-2 | 21.5 | 0.038 | 0.059 | 0.018 | 0.023 | 0.006 | 0.141 | 0.144 | 0.285 |
| V3-1 | 25 | 0.042 | 0.063 | 0.018 | 0.023 | 0.008 | 0.171 | 0.154 | 0.324 |
| V3-2 | 26 | 0.040 | 0.058 | 0.016 | 0.020 | 0.004 | 0.143 | 0.138 | 0.281 |
| V3-3 | 26.5 | 0.042 | 0.064 | 0.020 | 0.027 | 0.007 | 0.160 | 0.161 | 0.321 |
| V3-4 | 24 | 0.034 | 0.051 | 0.015 | 0.021 | 0.007 | 0.141 | 0.128 | 0.269 |

Note: Total VOCs are BTEX plus naphthalene

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EXCERPTS FROM

# REMEDIAL PROGRESS REPORT - SECOND HALF OF 1996
# FORMER SALISBURY TOWN GAS LIGHT SITE
# SALISBURY, MARYLAND

Prepared for:

**CHESAPEAKE UTILITIES CORPORATION**

Prepared by:

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# 1.0 INTRODUCTION

The remedial action program to address ground-water quality at the Former Salisbury Town Gas Light Site was initiated in 1993. Principal remedial activities include soil-vapor extraction (SVE), product monitoring and recovery, air-sparging/soil-vapor extraction (AS/SVE), and ground-water monitoring.

The remedial objectives for SVE in the vicinity of the Former Production Area of removing subsurface contaminants above the water table and restoring conditions to promote natural biodegradation were achieved in late 1994. Since this time, SVE in the Former Production Area has been utilized primarily to enhance product recovery.

Product monitoring and recovery began in 1993, and is nearing completion. Only two of the three remaining product wells show any signs of floating product, and the product thicknesses and yields from these wells have decreased substantially.

Air-sparging/soil vapor extraction (AS/SVE) was initiated during the second half of 1996 to provide a treatment curtain along the downgradient property boundary. Start-up testing and ground-water monitoring demonstrate that operation of the AS/SVE system has dramatically improved ground-water quality and effectively mitigates potential off-site migration of volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) dissolved in ground water.

This report has been prepared to document the remedial actions conducted during the second half of 1996, as well as to summarize the status of the remedial program for the Former Salisbury Town Gas Light Site. The following sections provide detailed information regarding product monitoring and recovery activities, the start-up testing and initial operation of the AS/SVE system, and recent findings regarding ground-water quality at the site.

## 2.2 Air-Sparging/Soil-Vapor Extraction

The AS/SVE network is comprised of ten air sparging wells which inject air into the subsurface below the water table, and four vapor extraction wells which remove vapors from soils above the water table. The sparge and vapor extraction wells are arranged in a 120-feet long strip along the site's southwest property boundary. The AS points are installed at two different levels; six of the points are completed in the shallow sandier soils, and the four deeper points are screened within a layer of slightly lower permeability material. The configuration of the AS/SVE well network is illustrated in Figures 2, 3 and 4.

PVC air lines are manifolded from each well and routed underground to AS/SVE system hardware housed in a trailer 100 feet away. The sources of air (compressor) and vacuum (blower), system controls (control panel and computer), moisture separator, and carbon adsorption air emission controls are included in the trailer. The control panel includes a programmable logic controller (PLC) which monitors all sensors and transmitters, and controls all system functions. The PLC is interfaced with the computer and system operation software via a modem which allows for remote system monitoring. Critical alarm conditions can be reported to one or more remote stations by an automatic dialing system.

Air-sparging volatilizes organics as well as restores dissolved oxygen levels to enhance in-situ natural biodegradation. SVE is utilized to capture the constituents volatilized by the sparging as well as to remove other residual hydrocarbons that may be present in the unsaturated zone. Sparging is alternated between the shallow sparge points (SS series) and the deeper sparge points (LK series) approximately every half hour to optimize the distribution of air through the aquifer by minimizing the potential development of preferential flow pathways, or channeling. Adjustments to pressure and flow rates are made at the AS/SVE trailer and at the individual well heads to maximize system efficiency. SVE is operated continuously at a rate greater than total sparge flow to ensure capture of vapors emanating from the sparging operations.

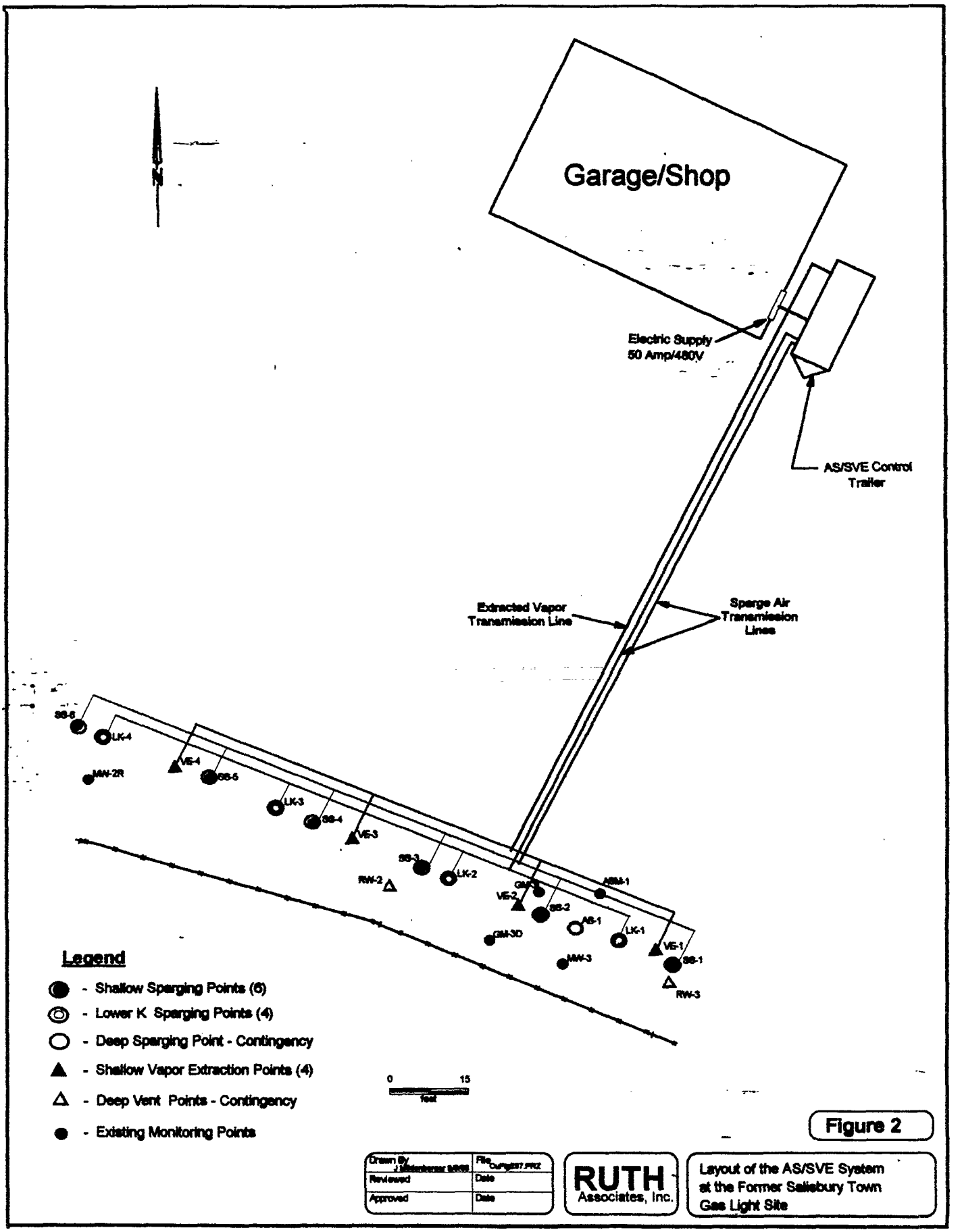


Figure 2

Layout of the AS/SVE System at the Former Salisbury Town Gas Light Site

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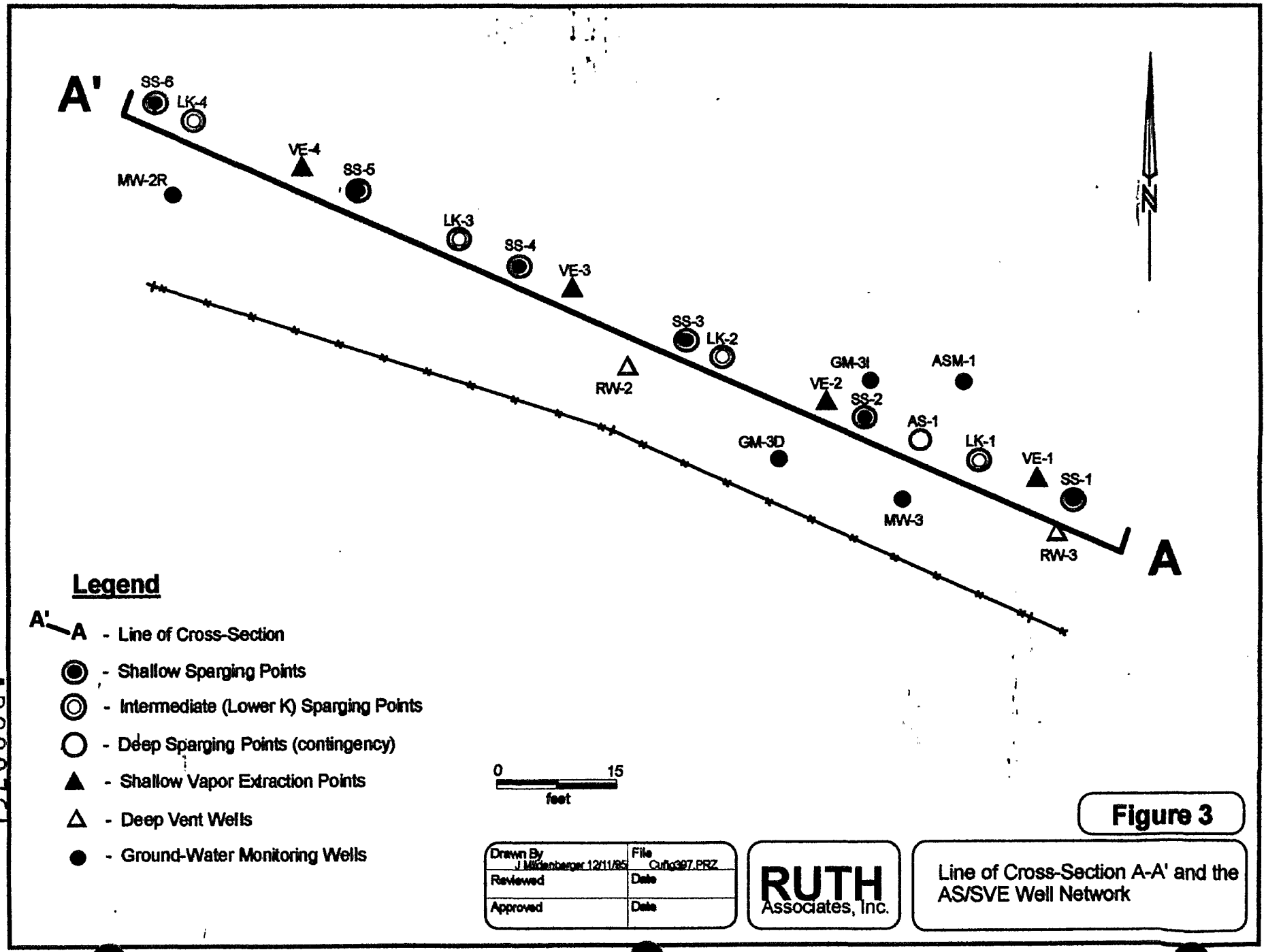


Figure 3

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Line of Cross-Section A-A' and the AS/SVE Well Network

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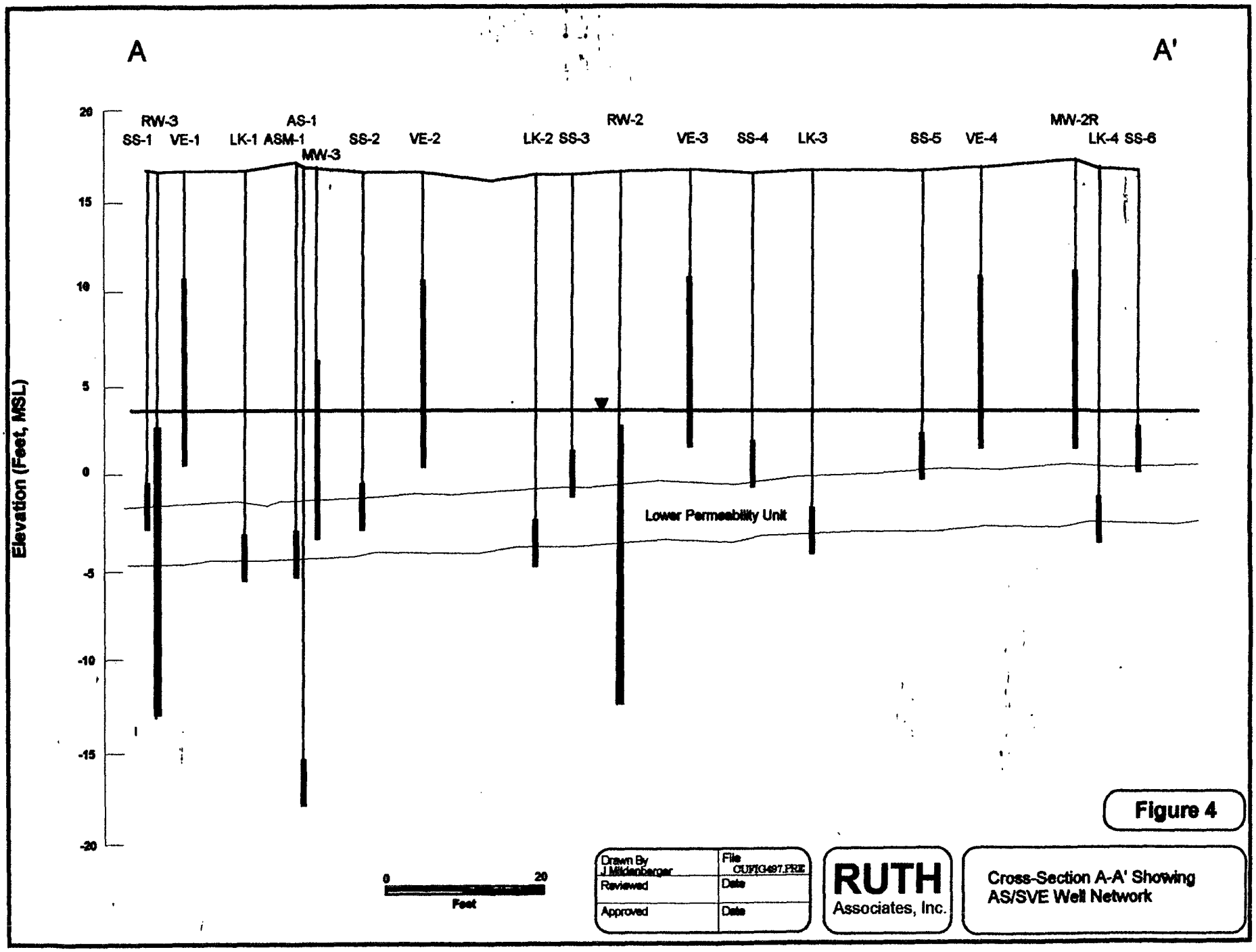


Figure 4

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less. Oxygen levels remained near atmospheric conditions at an average of 20.8%, while LEL was 0% on all but one occasion at MW-1. Field monitoring data for extracted vapor quality at Well MW-1 is given in Table 7.

### 3.2 Air-Sparging/Soil Vapor Extraction

The air transmission piping was installed from the AS and SVE well points to the planned location of the AS/SVE trailer during September 18 through 20, 1996. Each of AS and SVE well casings were trimmed to approximately 1.5-feet below grade, fitted with T-valves, air-line quick connects, and sample ports where specified. Well vaults were installed two-feet deep for frost protection at each of the well heads of the ten sparge points and the four SVE points. All non-system monitoring wells were trimmed below grade and fitted with flush-mount protective covers.

The AS/SVE trailer was delivered to the site during the week of October 7, 1996. Upon arrival, the AS/SVE trailer was installed and connected to the AS/SVE piping. Sensor calibration and testing of proper hardware functioning was also performed.

Start-up testing of the AS/SVE system was initiated during the week of October 21, 1996. Adjustments were made to balance air pressure and flow to the air-sparge points and from the vapor-extraction points, and measurements were taken to demonstrate adequate pneumatic influence from sparging and vapor-extraction activities.

Sparging operations are alternated between the shallow and deep on half-hour cycles to help prevent-injected air from channeling. Pressures and flow rates were balanced at each sparging location to evenly distribute air-injection across the treatment curtain. Total sparging rates at the shallow and deep sparging banks typically ranged from 23 to 27 standard cubic feet per minute (SCFM). Specific air-sparging operational data are given in Table 8 and summarized in Appendix A.

**TABLE 8**
**Air Sparging Operational Parameters - Field Monitoring**
**Former Salisbury Town Gas Light Site**

| Phase of Operation | Date | Tank Pressure | | Hours | Shallow Sparge Points | | Lower-K Sparge Points | |
|---|---|---|---|---|---|---|---|---|
| | | Lower | Upper | | Pressure | Flow | Pressure | Flow |
| Start-Up | 10/23/96 | 85 | 110 | 1.1 | - | - | 11 | 17 |
| | | 85 | 110 | 1.9 | - | - | 9.5 | 24 |
| | | 85 | 110 | 2.4 | - | - | 9.5 | 24 |
| | 10/24/96 | - | - | - | 6.5 | 40 | - | - |
| | | - | - | - | 22 | 14 | - | - |
| | | - | - | - | 15 | 21 | - | - |
| | | - | - | - | 7.5 | 27 | - | - |
| | | - | - | - | 7.3 | 27 | - | - |
| | 10/28/96 | 85 | 115 | 15.1 | 7.2 | 23 | - | - |
| | | 85 | 115 | 15.7 | 7 | 23 | - | - |
| | | 85 | 115 | 16 | 7 | 23 | - | - |
| | | 85 | 115 | 17 | 7.3 | 23 | - | - |
| | 10/29/96 | 85 | 115 | 31.2 | - | - | 12 | 30 |
| | | 85 | 115 | 31.5 | 7 | 23 | | |
| | | 85 | 115 | 31.8 | - | - | 12 | 30 |
| | | 85 | 115 | 32.1 | 7.5 | 23 | | |
| | 10/30/96 | 85 | 115 | 38.3 | - | - | 3.3 | 0 |
| | | 85 | 115 | 38.5 | - | - | 6 | 7 |
| | | 85 | 117 | 39.7 | - | - | 10.5 | 25 |
| | 10/31/96 | 85 | 115 | 49.5 | 7.4 | 22.5 | | |
| | 11/1/96 | 85 | 115 | 53 | - | - | 11.1 | 23 |
| | | 85 | 117 | 53.2 | 8.8 | 24 | - | - |
| | 11/2/96 | 85 | 115 | 61.1 | 9.3 | 24 | - | - |
| | | 85 | 116 | 61.4 | - | - | 13.9 | 26 |
| | 11/3/96 | - | - | 63.4 | 14 | 27.5 | - | - |
| | | - | - | 63.8 | 8.4 | 22.5 | - | - |
| | 11/4/96 | 85 | 119 | 73.9 | 8.5 | 23 | - | - |
| | | 85 | 118 | 74.1 | - | - | 11 | 23 |
| | 11/5/96 | 85 | 115 | 81.1 | - | - | 10.9 | 23 |
| | | 85 | 115 | 81.3 | 8.5 | 23 | | |
| | | 85 | 115 | 82.3 | - | - | 10.5 | 22.5 |
| | 11/6/96 | 85 | 115 | 91.9 | 8.6 | 23 | - | - |
| | 11/7/96 | 85 | 118 | 107.8 | - | - | 11 | 22.5 |
| | | 85 | 118 | 108.1 | 9.2 | 24 | - | - |
| | 11/8/96 | 85 | 115 | 122.6 | 9.2 | 23 | - | - |
| Routine | 11/12/96 | 85 | 119 | 124.3 | - | - | 11.5 | 22 |
| | | 85 | 119 | 124.6 | 9.2 | 25 | | |
| | | 80 | 112 | 126.1 | - | - | 11.2 | 23 |
| | 11/13/96 | 80 | 111 | 127.5 | 10.4 | 26 | - | - |
| | | 80 | 112 | 127.8 | - | - | 12.2 | 23 |
| | - | 80 | 111 | 128 | - | - | 11 | 23 |
| | 11/14/96 | 80 | 112 | 138.4 | - | - | 11.2 | 25 |
| | | 80 | 112 | 138.7 | 9.7 | 26.5 | - | - |
| | | 80 | 112 | 139 | 10 | 26 | - | - |
| | 11/19/96 | 80 | 112 | 182.6 | 11 | 24 | - | - |
| | | 80 | 112 | 182.9 | - | - | 13 | 22 |
| | 11/22/96 | 80 | 113 | 185.8 | 9.9 | 23 | - | - |
| | | 80 | 112 | 186.3 | - | - | 11.6 | 24 |
| | 12/4/96 | 80 | 112 | 189.6 | - | - | 12.7 | 23 |
| | | 80 | 112 | 189.9 | 10.5 | 24 | - | - |
| | 12/27/96 | - | 75 | 321.2 | - | 25 | - | - |
| | | - | 80 | 321.3 | 10.9 | 21 | - | - |
| | | 45 | 77 | 322.1 | - | - | 10 | - |
| | 12/31/96 | 50 | 100 | 323.4 | 11 | 24 | - | - |

Note: Pressures in pounds per square inch (psi), Flow in cubic feet per minute (cfm)

Extraction rates and vacuums were balanced across the four vapor extraction points, and induced vacuum was measured in nearby monitoring wells screened above the water table to verify establishment of an adequate capture zone along the treatment curtain. Total SVE rates typically ranged from 38 to 43 SCFM during the routine operational period, well above the total sparging rate of 23 to 27 SCFM. Operational data for the SVE portion of the system are summarized in Table 9 and Appendix A.

Extracted vapor quality before carbon treatment was monitored in the field using portable instruments for quantifying photo-ionizable VOCs, $\%O_2$, and %LEL. The VOC readings taken during the start-up period generally fluctuated between 10 and 20 ppm and exhibited a slight overall decline. The oxygen content of the vapors was initially 15% and rose within the first few days of operation to approximately 20%, where it hovered for the remainder of 1996. Explosive gases were highest at the beginning of the testing period (greater than 100% of the LEL), and have decreased sharply to below 1%. Field measurements of extracted vapor quality are provided in Table 9 and are depicted over time in Figure 5.

Grab samples of extracted soil-vapors prior to carbon treatment were collected daily for fourteen consecutive operating days, starting on October 22, 1996, to demonstrate compliance with air emission limits. The vapor samples were analyzed by Microseeps, Inc. for VOCs and permanent gases. The analytical results are summarized in Tables 10 and 11; laboratory certificates of analysis are provided in Appendix B.

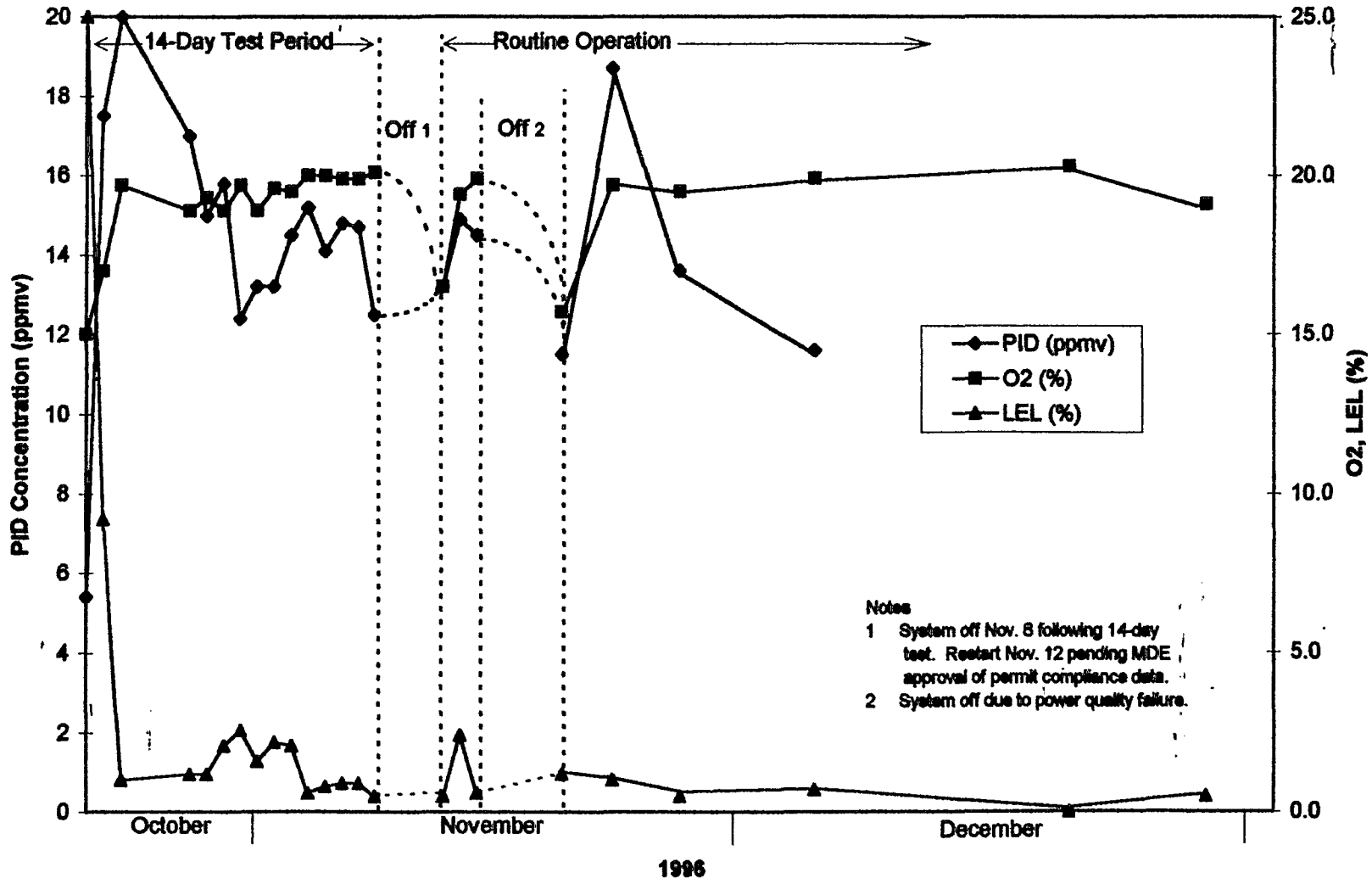
Permanent (atmospheric) gases analyzed included carbon dioxide, oxygen, nitrogen, methane and carbon monoxide. The concentrations of carbon dioxide and methane were highest at the beginning of the test period and decreased, while oxygen and nitrogen concentrations increased. Carbon monoxide was not detected in any of the vapor samples. Carbon dioxide, oxygen and methane levels for the start-up period are graphed in Figure 6, which illustrates that as oxygen is restored to the subsurface, carbon dioxide and methane concentrations decreased.

TABLE 9
SVE Operational Parameters and
Field Monitoring of Extracted Vapor Quality
Former Salisbury Town Gas Light Site

| Phase of Operation | Date | Collected Sample ID | Header Vacuum (In. of H20) | Flow Rate (SCFM) | PID ($ppm_v$) | $O_2$ (%) | LEL (%) |
|---|---|---|---|---|---|---|---|
| Start-Up | 10/22/96 | SVE-1 | 90 | 29 | 5.4 | 15.0 | Max |
| | 10/23/96 | SVE-2 | 43 | 20 | 17.5 | 17.0 | 9.2 |
| | 10/24/96 | SVE-4 | 50 | 31 | 20.0 | 19.7 | 1.0 |
| | 10/28/96 | SVE-5 | 35 | 35 | 17.0 | 18.9 | 1.2 |
| | 10/29/96 | SVE-6 | 40 | 36 | 15.0 | 19.3 | 1.2 |
| | 10/30/96 | SVE-7 | 41 | 36 | 15.8 | 18.9 | 2.1 |
| | 10/31/96 | SVE-8 | 39 | 33 | 12.4 | 19.7 | 2.6 |
| | 11/1/96 | SVE-9 | 48 | 34 | 13.2 | 18.9 | 1.6 |
| | 11/2/96 | SVE-10 | 45 | 36 | 13.2 | 19.6 | 2.2 |
| | 11/3/96 | SVE-11 | 45 | 33 | 14.5 | 19.5 | 2.1 |
| | 11/4/96 | SVE-12 | 38 | 38 | 15.2 | 20.0 | 0.6 |
| | 11/5/96 | SVE-13 | 46 | 37 | 14.1 | 20.0 | 0.8 |
| | 11/6/96 | SVE-14 | 43 | 34 | 14.8 | 19.9 | 0.9 |
| | 11/7/96 | SVE-15 | 40 | 37 | 14.7 | 19.9 | 0.9 |
| | 11/8/96 | SVE-16* | 33 | 34 | 12.5 | 20.1 | 0.5 |
| Routine | 11/12/96 | - | 32 | 42 | 13.2 | 16.5 | 0.5 |
| | 11/13/96 | - | 48 | 40 | 14.9 | 19.4 | 2.4 |
| | 11/14/96 | - | 40 | 42 | 14.5 | 19.9 | 0.6 |
| | 11/19/96 | - | 34 | 37 | 11.5 | 15.7 | 1.2 |
| | 11/22/96 | - | 45 | 40 | 18.7 | 19.7 | 1.0 |
| | 11/26/96 | - | 52 | 38 | 13.6 | 19.5 | 0.5 |
| | 12/4/96 | - | 64 | 35 | 11.6 | 19.9 | 0.7 |
| | 12/19/96 | - | 43 | 37 | - | 20.3 | 0.0 |
| | 12/27/96 | - | 42 | 38 | - | 19.1 | 0.5 |
| | 12/31/96 | - | 38 | 43 | - | - | - |

Notes:
SCFM = Standard Cubic Feet Per Minute
PID = Photo-Ionization Detector
PPMV = parts-per-million volumetric
$O_2$ = Oxygen
LEL = Lower Explosive Limit
* = Not analyzed

**Figure 5**
**SVE Extracted Vapor Quality**
**Field Monitoring Data - PID, $O_2$, LEL**



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## TABLE 10
## Summary of Start-Up Vapor Grab Sample Analytical Results for the AS/SVE System

| Date | Sample | Flow Rate | Benzene | | Toluene | | Ethyl Benzene | | o-Xylene | | m&p-xylenes | | C5-C10 | | Total VOC's | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ID | (SCFM) | ($ppm_v$) | (mg/L) | ($ppm_v$) | (mg/L) | ($ppm_v$) | (mg/L) | ($ppm_v$) | (mg/L) | ($ppm_v$) | (mg/L) | ($ppm_v$) | (mg/L) | ($ppm_v$) | (mg/L) |
| 10/22/96 | SVE-1 | 26 | 1.27 | 0.0041 | 0.21 | 0.0008 | 0.76 | 0.0034 | 0.24 | 0.0011 | 0.53 | 0.0023 | 1.31 | 0.0053 | 4.320 | 0.0170 |
| 10/23/96 | SVE-2 | 20 | 4.01 | 0.0130 | 2.26 | 0.0086 | 0.91 | 0.0040 | 0.25 | 0.0011 | 0.52 | 0.0023 | 1.10 | 0.0045 | 9.050 | 0.0335 |
| 10/23/96 | SVE-3 | 20 | 5.21 | 0.0169 | 2.33 | 0.0089 | 1.30 | 0.0057 | 0.54 | 0.0024 | 1.12 | 0.0049 | 1.32 | 0.0054 | 11.820 | 0.0442 |
| 10/24/96 | SVE-4 | 31 | 3.87 | 0.0126 | 2.19 | 0.0084 | 2.14 | 0.0094 | 1.01 | 0.0045 | 1.86 | 0.0082 | 0.53 | 0.0022 | 11.600 | 0.0452 |
| 10/28/96 | SVE-5 | 34 | 2.01 | 0.0065 | 0.76 | 0.0029 | 1.35 | 0.0060 | 0.67 | 0.0030 | 1.16 | 0.0051 | 0.32 | 0.0013 | 6.270 | 0.0248 |
| 10/29/96 | SVE-6 | 36 | 1.25 | 0.0041 | 0.40 | 0.0015 | 0.57 | 0.0025 | 0.27 | 0.0012 | 0.48 | 0.0021 | 0.32 | 0.0013 | 3.290 | 0.0127 |
| 10/30/96 | SVE-7 | 36 | 1.48 | 0.0048 | 0.70 | 0.0027 | 0.62 | 0.0027 | 0.25 | 0.0011 | 0.53 | 0.0023 | 0.40 | 0.0016 | 3.980 | 0.0153 |
| 10/31/96 | SVE-8 | 33 | 1.10 | 0.0036 | 0.64 | 0.0024 | 0.89 | 0.0039 | 0.38 | 0.0017 | 0.74 | 0.0033 | 7.53 | 0.0307 | 11.280 | 0.0456 |
| 11/1/96 | SVE-9 | 34 | 0.99 | 0.0032 | 0.71 | 0.0027 | 0.47 | 0.0021 | 0.24 | 0.0011 | 0.52 | 0.0023 | 5.07 | 0.0207 | 8.000 | 0.0320 |
| 11/2/96 | SVE-10 | 35 | 0.74 | 0.0024 | 0.52 | 0.0020 | 0.60 | 0.0026 | 0.28 | 0.0012 | 0.57 | 0.0025 | 6.30 | 0.0257 | 9.010 | 0.0365 |
| 11/3/96 | SVE-11 | 38 | 0.69 | 0.0022 | 0.36 | 0.0014 | 0.19 | 0.0008 | 0.07 | 0.0003 | 0.15 | 0.0007 | 3.10 | 0.0126 | 4.560 | 0.0181 |
| 11/4/96 | SVE-12 | 36 | 0.52 | 0.0017 | 0.25 | 0.0010 | 0.22 | 0.0010 | 0.08 | 0.0004 | 0.17 | 0.0007 | 2.37 | 0.0097 | 3.610 | 0.0144 |
| 11/5/96 | SVE-13 | 36 | 0.66 | 0.0021 | 0.30 | 0.0011 | 0.30 | 0.0013 | 0.15 | 0.0007 | 0.28 | 0.0012 | 3.04 | 0.0124 | 4.730 | 0.0189 |
| 11/6/96 | SVE-14 | 34 | 0.51 | 0.0017 | 0.32 | 0.0012 | 0.41 | 0.0018 | 0.23 | 0.0010 | 0.39 | 0.0017 | 3.59 | 0.0146 | 5.450 | 0.0221 |
| 11/7/96 | SVE-15 | 36 | 0.61 | 0.0020 | 0.29 | 0.0011 | 0.36 | 0.0016 | 0.16 | 0.0007 | 0.32 | 0.0014 | 3.32 | 0.0135 | 5.060 | 0.0203 |

SCFM = Standard cubic feet per minute  ppmv=parts per million by volume  mg/L = milligrams per liter

## TABLE 11

**Permanent Gas Concentrations from the AS/SVE System for the Start-Up Period.**

| Date | Sample ID | Flow Rate (SCFM) | $CO_2$ (%) | $CO_2$ (lbs/day) | $CO_2$ (total lbs.) | $O_2$ (%) | $O_2$ (lbs/day) | Nitrogen (%) | Nitrogen (lbs/day) | Methane (%) | Methane (lbs/day) | CO (%) | CO (lbs/day) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/22/96 | SVE-1 | 26 | 6.50 | 278 | 278 | 14.31 | 445 | 77.30 | 2102 | 1.18 | 18 | <0.01 | 0 |
| 10/23/96 | SVE-2 | 20 | 4.69 | 154 | 432 | 17.11 | 409 | 76.69 | 1604 | 0.46 | 5 | <0.01 | 0 |
| 10/23/96 | SVE-3 | 20 | 4.78 | 157 | 589 | 17.54 | 419 | 76.25 | 1595 | 0.45 | 5 | <0.01 | 0 |
| 10/24/96 | SVE-4 | 31 | 1.58 | 81 | 670 | 20.42 | 757 | 77.19 | 2503 | 0.04 | 1 | <0.01 | 0 |
| 10/28/96 | SVE-5 | 34 | 2.32 | 130 | 799 | 19.38 | 788 | 77.43 | 2754 | 0.04 | 1 | <0.01 | 0 |
| 10/29/96 | SVE-6 | 36 | 1.43 | 85 | 884 | 20.41 | 878 | 77.39 | 2914 | 0.04 | 1 | <0.01 | 0 |
| 10/30/96 | SVE-7 | 36 | 1.53 | 91 | 974 | 20.17 | 868 | 76.81 | 2893 | 0.09 | 2 | <0.01 | 0 |
| 10/31/96 | SVE-8 | 33 | 1.15 | 62 | 1,037 | 21.13 | 834 | 79.44 | 2742 | 0.11 | 2 | <0.01 | 0 |
| 11/1/96 | SVE-9 | 34 | 1.15 | 64 | 1,101 | 21.14 | 859 | 79.46 | 2826 | <0.01 | 0 | <0.01 | 0 |
| 11/2/96 | SVE-10 | 35 | 0.97 | 56 | 1,157 | 21.47 | 898 | 79.81 | 2922 | <0.01 | 0 | <0.01 | 0 |
| 11/3/96 | SVE-11 | 38 | 1.11 | 69 | 1,226 | 21.16 | 961 | 79.76 | 3170 | <0.01 | 0 | <0.01 | 0 |
| 11/4/96 | SVE-12 | 36 | 1.04 | 62 | 1,288 | 21.19 | 912 | 79.67 | 3000 | <0.01 | 0 | <0.01 | 0 |
| 11/5/96 | SVE-13 | 36 | 1.08 | 64 | 1,352 | 21.06 | 906 | 79.61 | 2998 | <0.01 | 0 | <0.01 | 0 |
| 11/6/96 | SVE-14 | 34 | 0.80 | 45 | 1,396 | 21.45 | 872 | 79.55 | 2829 | <0.01 | 0 | <0.01 | 0 |
| 11/7/96 | SVE-15 | 36 | 0.77 | 46 | 1,442 | 21.48 | 924 | 79.42 | 2991 | <0.01 | 0 | <0.01 | 0 |

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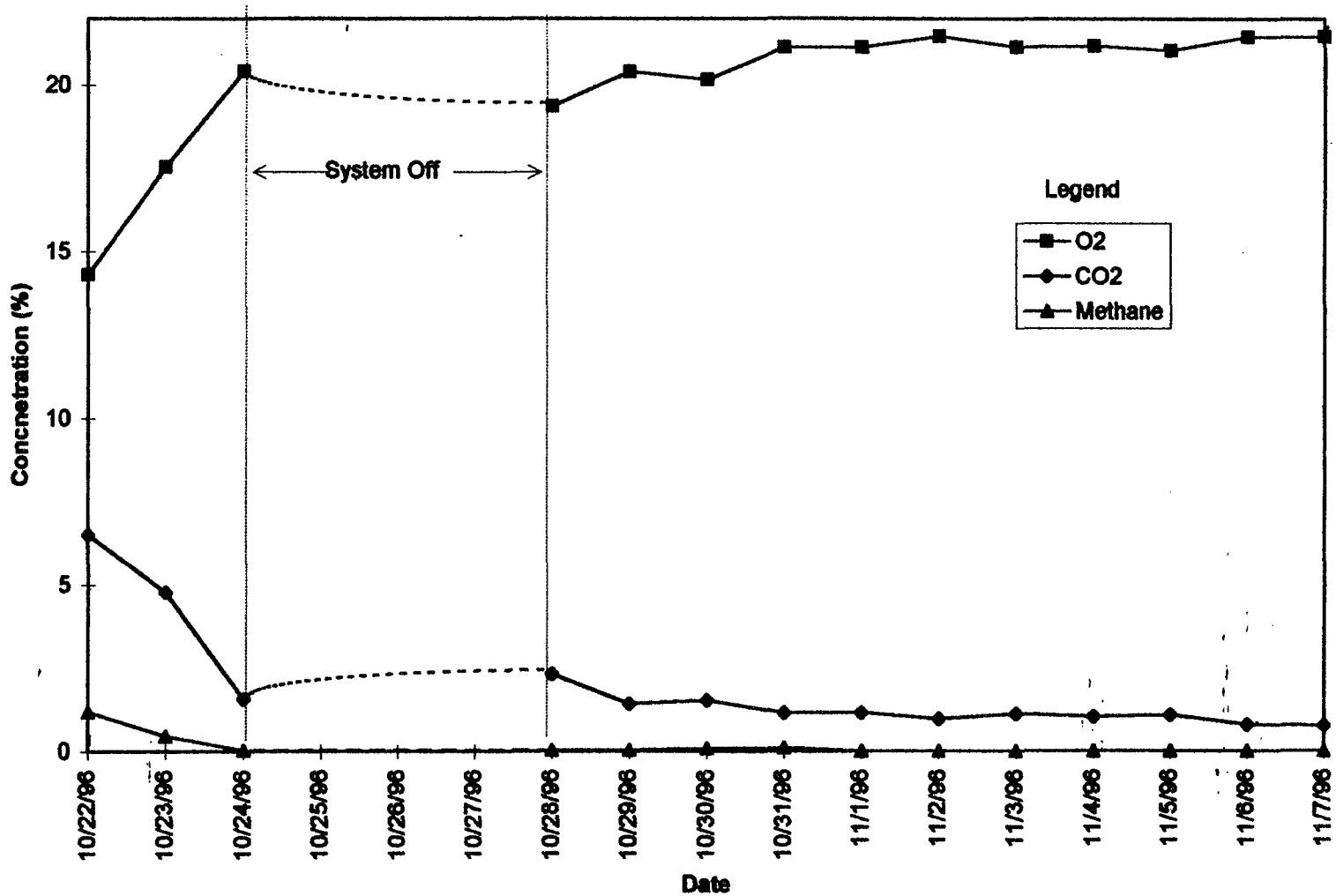
**Figure 6**
**Permanent Gas Concentrations from the AS/SVE System for the 14 Consecutive Operating Day Start-Up Period Former Salisbury Town Gas Light Site**



Chemical mass extraction rates, and therefore potential air emission rates, were calculated by multiplying VOC constituent concentrations by the rate of total SVE flow. Concentrations ~~of~~ total VOCs fluctuated during the initial demonstration period, ranging from a high of 11.8 parts-per-million volumetric (ppmv) to a low of 3.3 ppmv. Benzene concentrations in the extracted vapors ranged from a high of 5.2 ppmv down to 0.51 ppmv. With extracted vapor flow rates varying between 20 to 38 scfm, calculated mass extraction rates for benzene ranged from 0.0002 to 0.0015 lb/hr, and total VOC extraction rates ranged from 0.0397 to 0.1351 lb/day, as shown in Table 12.

Potential air emissions of total VOCs and benzene were both well below the respective permitted emission rates of 20 lb/day and 0.02 lb/hr. MDE therefore waived the daily requirement for vapor quality field measurements, and routine operation of the AS/SVE system was initiated November 12, 1997.

Mechanical troubleshooting and fine-tuning of system controls was required during the early period of routine operations. The air compressor for the AS/SVE was serviced under warranty on two occasions and adjustments were made to regulators and sparge point well head valves to balance air flow across the system. Vapor extraction well head valves, vacuum blower speed and main extraction header valve were adjusted to apply the maximum vacuum on the wells but minimize uptake of ground-water into the system's moisture separator or "knock-out" tank. On December 23, 1996 the AS/SVE system was shutdown due to compressor operational problems. Adjustments to vapor extraction vacuum and flow were made during the last two weeks of December to address accumulation of water in the SVE knock-out tank. Vapor extraction lines were flushed, the compressor was repaired under warranty, and system operation resumed on December 31, 1996.

### 3.3 Ground-Water Monitoring

The monthly monitoring program was initiated in June of 1996 to establish baseline conditions prior to the start-up of AS/SVE. A total of five baseline events were

## TABLE 12
### Hourly and Daily Chemical Mass Extraction Rates with the SVE System for the Start-Up Period.

| Date | Sample | Benzene | | Toluene | | Ethyl Benzene | | o-Xylene | | m&p-xylenes | | C5-C10 | | Total VOC's | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ID | (lbs/hr) | (lbs/day) | (lbs/hr) | (lbs/day) | (lbs/hr) | (lbs/day) | (lbs/hr) | (lbs/day) | (lbs/hr) | (lbs/day) | (lbs/hr) | (lbs/day) | (lbs/hr) | (lbs/day) |
| 10/22/96 | SVE-1 | 0.0004 | 0.0096 | 0.0001 | 0.0019 | 0.0003 | 0.0078 | 0.0001 | 0.0025 | 0.0002 | 0.0055 | 0.0005 | 0.0125 | 0.0017 | 0.0397 |
| 10/23/96 | SVE-2 | 0.0010 | 0.0234 | 0.0006 | 0.0155 | 0.0003 | 0.0072 | 0.0001 | 0.0020 | 0.0002 | 0.0041 | 0.0003 | 0.0081 | 0.0025 | 0.0603 |
| 10/23/96 | SVE-3 | 0.0013 | 0.0304 | 0.0007 | 0.0160 | 0.0004 | 0.0103 | 0.0002 | 0.0043 | 0.0004 | 0.0089 | 0.0004 | 0.0097 | 0.0033 | 0.0795 |
| 10/24/96 | SVE-4 | 0.0015 | 0.0350 | 0.0010 | 0.0233 | 0.0011 | 0.0263 | 0.0005 | 0.0124 | 0.0010 | 0.0228 | 0.0003 | 0.0060 | 0.0052 | 0.1258 |
| 10/28/96 | SVE-5 | 0.0008 | 0.0199 | 0.0004 | 0.0089 | 0.0008 | 0.0182 | 0.0004 | 0.0090 | 0.0007 | 0.0156 | 0.0002 | 0.0040 | 0.0031 | 0.0756 |
| 10/29/96 | SVE-6 | 0.0005 | 0.0131 | 0.0002 | 0.0049 | 0.0003 | 0.0081 | 0.0002 | 0.0038 | 0.0003 | 0.0068 | 0.0002 | 0.0042 | 0.0017 | 0.0411 |
| 10/30/96 | SVE-7 | 0.0006 | 0.0155 | 0.0004 | 0.0087 | 0.0004 | 0.0088 | 0.0001 | 0.0036 | 0.0003 | 0.0076 | 0.0002 | 0.0053 | 0.0021 | 0.0494 |
| 10/31/96 | SVE-8 | 0.0004 | 0.0106 | 0.0003 | 0.0073 | 0.0005 | 0.0116 | 0.0002 | 0.0050 | 0.0004 | 0.0097 | 0.0038 | 0.0910 | 0.0056 | 0.1351 |
| 11/1/96 | SVE-9 | 0.0004 | 0.0098 | 0.0003 | 0.0083 | 0.0003 | 0.0063 | 0.0001 | 0.0032 | 0.0003 | 0.0070 | 0.0026 | 0.0631 | 0.0041 | 0.0978 |
| 11/2/96 | SVE-10 | 0.0003 | 0.0075 | 0.0003 | 0.0063 | 0.0003 | 0.0083 | 0.0002 | 0.0039 | 0.0003 | 0.0079 | 0.0034 | 0.0807 | 0.0048 | 0.1146 |
| 11/3/96 | SVE-11 | 0.0003 | 0.0076 | 0.0002 | 0.0047 | 0.0001 | 0.0029 | 0.0000 | 0.0011 | 0.0001 | 0.0023 | 0.0018 | 0.0431 | 0.0026 | 0.0616 |
| 11/4/96 | SVE-12 | 0.0002 | 0.0055 | 0.0001 | 0.0031 | 0.0001 | 0.0031 | 0.0000 | 0.0011 | 0.0001 | 0.0024 | 0.0013 | 0.0312 | 0.0019 | 0.0465 |
| 11/5/96 | SVE-13 | 0.0003 | 0.0069 | 0.0002 | 0.0037 | 0.0002 | 0.0043 | 0.0001 | 0.0021 | 0.0002 | 0.0040 | 0.0017 | 0.0401 | 0.0025 | 0.0611 |
| 11/6/96 | SVE-14 | 0.0002 | 0.0051 | 0.0002 | 0.0037 | 0.0002 | 0.0055 | 0.0001 | 0.0031 | 0.0002 | 0.0053 | 0.0019 | 0.0447 | 0.0028 | 0.0673 |
| 11/7/96 | SVE-15 | 0.0003 | 0.0064 | 0.0001 | 0.0036 | 0.0002 | 0.0051 | 0.0001 | 0.0023 | 0.0002 | 0.0046 | 0.0018 | 0.0438 | 0.0027 | 0.0657 |

conducted prior to start-up of the AS/SVE system which occurred in October 1996, and two additional events were conducted in 1996 following start-up. The results for the monthly monitoring program conducted during 1996 are summarized in Table 13.

Water-quality data indicate that AS/SVE activities are replenishing dissolved oxygen (DO) in ground-water along the treatment curtain. The post-start-up data revealed that dissolved oxygen concentrations increased after the first month of AS/SVE at wells RW-3, VE-1, ASM-1 and MW-3, and all wells except RW-2 and VE-4 exhibited higher dissolved oxygen levels after two months. Baseline data generated for the five months preceding start-up of the AS/SVE system indicated an average DO level across the treatment barrier of 1.6 mg/l; the average DO level collected two months after AS/SVE start-up was 3.9 mg/l. Spatial and temporal trends in DO are depicted in Figure 7, which illustrates in cross-section the last two DO measurements before and the first two DO measurements after AS/SVE start-up.

A comparison of the October DO readings (just prior to AS/SVE) with DO concentrations measured during the December event (two months after AS/SVE start-up) are presented below in order of locations extending east to west along the treatment barrier.

Changes in Dissolved Oxygen as a Result of AS/SVE Activities

| | |
|---|---|
| RW-3 | 2.1 mg/l rose to 4.6 mg/l |
| VE-1 | 2.8 mg/l rose to 10.1 mg/l |
| ASM-1 | 1.0 mg/l rose to 5.0 mg/l |
| MW-3 | 0.6 mg/l rose to 6.2 mg/l |
| VE-2 | 1.5 mg/l rose to 3.5 mg/l |
| RW-2 | 0.6 mg/l unchanged |
| VE-3 | 1.3 mg/l rose to 2.6 mg/l |
| VE-4 | 1.8 mg/l fell to 1.1 mg/l |
| MW-2R | 0.9 mg/l rose to 1.4 mg/l |

The changes in dissolved oxygen concentrations indicated a skewed distribution, with DO concentrations increasing more dramatically at well locations situated in the eastern half of the treatment zone. This observation is likely the result of one or more of the

## TABLE 13

Monthly Ground-Water Quality Monitoring for 1996
Former Salisbury Town Gas Light Site

| Well | Date | pH (S.U.) | Specific Conductivity (uS) | Dissolved Oxygen (mg/l) | Dissolved Oxygen (% Sat.) | Eh (mV) |
|---|---|---|---|---|---|---|
| MW-2R | 6/25/96 | 6.20 | 523 | 0.3 | 4 | - |
| | 7/24/96 | 5.93 | 516 | 1.2 | 13 | - |
| | 8/20/96 | 6.07 | 541 | 1.0 | 11 | - |
| | 9/19/96 | 6.42 | 425 | 0.6 | 7 | - |
| | 10/21/96 | 6.19 | 537 | 0.9 | 9 | - |
| | 11/19/96 | 6.61 | 448 | 0.8 | 8 | - |
| | 12/19/96 | 6.61 | 409 | 1.4 | - | 26 |
| MW-3 | 6/25/96 | 6.16 | 417 | 0.2 | 3 | - |
| | 7/24/96 | 5.92 | 406 | 1.5 | 16 | - |
| | 8/20/96 | 6.05 | 438 | 1.0 | 11 | - |
| | 9/19/96 | 6.48 | 396 | 0.7 | 7 | - |
| | 10/21/96 | 6.16 | 429 | 0.6 | 6 | - |
| | 11/19/96 | 3.40 | 465 | 2.7 | 29 | - |
| | 12/19/96 | 3.28 | 408 | 6.2 | - | 453 |
| RW-2 | 6/26/96 | 6.47 | 295 | 2.2 | 24 | - |
| | 7/24/96 | 6.16 | 333 | 1.1 | 13 | - |
| | 8/20/96 | 6.20 | 327 | 0.6 | 6 | - |
| | 9/19/96 | 6.65 | 202 | 1.2 | 13 | - |
| | 10/21/96 | 6.46 | 255 | 0.6 | 6 | - |
| | 11/19/96 | 6.42 | 178 | 1.2 | 12 | - |
| | 12/19/96 | 6.36 | 137 | 0.6 | - | 47 |
| RW-3 | 6/25/96 | 6.04 | 276 | 2.1 | 24 | - |
| | 7/24/96 | 5.50 | 224 | 2.5 | 27 | - |
| | 8/20/96 | 5.70 | 226 | 2.4 | 26 | - |
| | 9/19/96 | 5.63 | 196 | 3.5 | 37 | - |
| | 10/21/96 | 5.60 | 106 | 2.1 | 21 | - |
| | 11/19/96 | 5.33 | 203 | 4.1 | 43 | - |
| | 12/19/96 | 5.28 | 167 | 4.6 | - | 212 |
| ASM-1 | 6/25/96 | 6.55 | 498 | 1.5 | 17 | - |
| | 7/24/96 | 6.27 | 493 | 2.8 | 30 | - |
| | 8/20/96 | 6.33 | 502 | 1.2 | 12 | - |
| | 9/19/96 | 6.72 | 496 | 1.0 | 11 | - |
| | 10/21/96 | 6.36 | 529 | 1.0 | 11 | - |
| | 11/19/96 | 6.17 | 416 | 4.6 | 47 | - |
| | 12/19/96 | 6.23 | 330 | 5.0 | - | 88 |

-- Not Measured

..... Indicates break between pre-AS/SVE conditions and post AS/SVE Start-up on October 24, 1996

**TABLE 13 (Continued)**

Monthly Ground-Water Quality Monitoring for 1996
Former Salisbury Town Gas Light Site

| Well | Date | pH (S.U.) | Specific Conductivity (uS) | Dissolved Oxygen (mg/l) | Dissolved Oxygen (% Sat.) | Eh (mV) |
|---|---|---|---|---|---|---|
| VE-1 | 6/25/96 | 5.75 | 337 | 0.7 | 8 | - |
| | 7/24/96 | 5.33 | 271 | 1.9 | 21 | - |
| | 8/20/96 | 5.69 | 323 | 1.4 | 16 | - |
| | 9/19/96 | 5.68 | 295 | 1.4 | 14 | - |
| | 10/21/96 | 5.07 | 225 | 2.8 | 29 | - |
| | 11/19/96 | 5.46 | 290 | 2.3 | 23 | - |
| | 12/19/96 | 5.36 | 151 | 10.1 | - | 229 |
| VE-2 | 6/25/96 | 6.12 | 419 | 1.0 | 11 | - |
| | 7/24/96 | 5.87 | 438 | 1.3 | 15 | - |
| | 8/20/96 | 6.00 | 465 | 1.8 | 21 | - |
| | 9/19/96 | 6.39 | 477 | 1.8 | 21 | - |
| | 10/21/96 | 6.13 | 497 | 1.5 | 16 | - |
| | 11/19/96 | 6.40 | 426 | 1.1 | 12 | - |
| | 12/19/96 | 6.34 | 331 | 3.5 | - | 66 |
| VE-3 | 6/25/96 | 6.31 | 600 | 1.9 | 21 | - |
| | 7/24/96 | 6.14 | 598 | 2.3 | 25 | - |
| | 8/20/96 | 6.20 | 619 | 2.0 | 22 | - |
| | 9/19/96 | 6.56 | 564 | 1.1 | 13 | - |
| | 10/21/96 | 6.31 | 633 | 1.3 | 13 | - |
| | 11/19/96 | 6.44 | 259 | 2.4 | 25 | - |
| | 12/19/96 | 6.84 | 459 | 2.6 | - | 54 |
| VE-4 | 6/25/96 | 6.59 | 582 | 3.9 | 40 | - |
| | 7/24/96 | 6.09 | 499 | 2.5 | 27 | - |
| | 8/20/96 | 6.37 | 621 | 4.1 | 48 | - |
| | 9/19/96 | 6.50 | 454 | 1.8 | 19 | - |
| | 10/21/96 | 6.30 | 965 | 1.8 | 20 | - |
| | 11/19/96 | 6.65 | 594 | 1.7 | 17 | - |
| | 12/19/96 | 6.40 | 608 | 1.1 | - | 13 |

-- Not Measured

Indicates break between pre-AS/SVE conditions and post AS/SVE Start-up on October 24, 1996

following conditions: 1.) the soils are sandier and more permeable along the eastern limb, allowing for the introduction of more compressed air; 2.) the valving system for the headers was unbalanced, resulting in the introduction of more compressed air at certain sparge points along the eastern limb; and/or 3.) higher concentrations of biodegradable organics are present along the western limb of the system which are consuming a larger proportion of the oxygen being injected.

Dramatic decreases in concentrations of total BTEX, PAHs, and dissolved iron were observed at monitoring wells MW-2R and MW-3 following the AS/SVE start-up. Historical water-quality data for MW-2R and MW-3 are summarized in Tables 14 and 15, respectively. The effect of AS/SVE activities on VOC, PAH, and chlorinated VOC concentrations in ground-water is graphically depicted In Figures 8 and 9. Detailed discussions of ground-water quality and flow monitoring at the site are presented in the quarterly monitoring reports prepared for this project; however, a brief synopsis of observations in water-quality trends along the AS/SVE treatment zone are discussed below.

Comparison of the quarterly sampling results for September and December 1996 demonstrate that both total PAH and BTEX concentrations were reduced from greater than 3 mg/l down to below detectable limits at MW-3. At MW-2, total PAHs were reduced from greater than 3 mg/l down to 0.2 mg/l and total BTEX concentrations were reduced from 0.099 mg/l down to 0.004 mg/l. Dissolved iron concentrations were reduced from 25 mg/l down to 2 mg/l at MW-3 and from 9.1 mg/l down to 1.8 mg/l at MW-2.

## Table 14

Ground-Water Quality Laboratory Analytical Data for Well MW-2/2R, Former Salisbury Town Gas Light Site

| Parameter | MW-2 | | | | | | | | | | | | | | | | MW-2R | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12/87 | 8/88 | 7/89 | 3/92 | 3/93 | 6/93 | 9/93 | 12/93 | 3/94 | 6/94 | 9/94 | 12/94 | 3/95 | 6/95 | 9/95 | 12/95 | 6/96 | 9/96 | 12/96 |
| Volatile Organic Compounds | | | | | | | | | | | | | | | | | | | |
| Acetone | – | – | – | 12 | 13 | 13 | <10 | <10 | 19B | 14 | <10 | <10 | <10 | <10 | <20 | <10 | 22 | <10 | 13 |
| Benzene | 1300 | 1600 | 60 | 14 | 23 | 11 | 11 | 4.7J | 3.2J | 25 | 21 | 6.9 | 5.2 | 4.3J | 6.2J | 6.7 | 15 | 17 | <5 |
| Chlorobenzene | <6 | <1 | <1 | <2 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <10 | <5 | <5 | <5 | <5 |
| Chloroform | <1.6 | <1 | <1 | <2 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <10 | <5 | <5 | <5 | <5 |
| 1,2-Dichloroethane | 82 | 103 | 35 | 2.4 | 3.3J | 3.3J | 2.3J | 2.8J | 2.2J | 2.7J | 2.3J | <5 | <5 | <5 | <10 | 3.4J | <5 | <5 | <5 |
| 1,1-Dichloroethane | <1.6 | <1 | <1 | <2 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 2.2J | <10 | 2.2J | <5 | <5 | <5 |
| 1,1-Dichloroethene | <1.6 | <1 | <1 | <2 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 2.0J | 6.8 | 5.6J | 5.5 | <5 | <5 | <5 |
| 1,2-Dichloroethene (total) | <1.6 | <1 | <1 | <2 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <10 | <5 | <5 | <5 | <5 |
| Ethylbenzene | 65 | 57 | <1 | 56 | 89 | 77 | 68 | 62 | 55 | 87 | 85 | 59 | 30 | 48 | 73 | 35 | 57 | 14 | <5 |
| Methylene Chloride | 12B | <1 | <1 | <2 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <10 | <5 | <5 | <5 | <5 |
| Styrene | – | – | – | <2 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <10 | <5 | <5 | <5 | <5 |
| Tetrachloroethene | <1.6 | <1 | <1 | <2 | <5 | <5 | 2.4J | 2.2J | 2.0J | <5 | <5 | <5 | 2.3J | 2.1J | <10 | 2.6J | <5 | <5 | <5 |
| Toluene | 9 | 14 | <1 | 3.5 | 4.6J | 4.6J | 4.3J | 2.8J | 2.1J | 5 | 4.1J | 3.1J | <5 | 2.5J | <10 | 2.2J | 17 | 8.1 | <5 |
| 1,1,1-Trichloroethane | <3.8 | <1 | <1 | <2 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 2.9J | 8.6 | 7.8J | 7.1 | <5 | <5 | <5 |
| Trichloroethene | 3 | <1 | <1 | <2 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <10 | <5 | <5 | <5 | <5 |
| Xylene (total) | – | 47 | 28 | 42 | 61 | 53 | 54 | 71 | 34 | 37 | 36 | 30 | 21 | 35 | 86 | 26 | 87 | 60 | 3.8 J |
| Total Volatiles | 1471 | 1821 | 113 | 129.9 | 193.9 | 161.9 | 162 | 145.5 | 117.5 | 170.7 | 148.4 | 101 | 63.4 | 109.5 | 180.6 | 90.7 | 198 | 99.1 | 16.8 |
| Base/Neutral Ext. Compounds | | | | | | | | | | | | | | | | | | | |
| Naphthalene | 970 | 2100 | 1100 | <5 | 510 | 423 | 465 | 233 | 304 | 575 | 444 | 485 | 147 | 384 | 312 | 283 | 2510 | 2020 | 69 |
| Acenaphthylene | 150 | 210 | 190 | 17 | 42 | 46 | 36 | 39 | 41 | 42 | 48 | 47 | 25 | 50 | 34 | 62 | <200 | <100 | 5.1 |
| Acenaphthene | 120 | 370 | 300 | 51 | 84 | 85 | 115 | 98 | 97 | 146 | 100 | 129 | 56 | 112 | 107 | 119 | 347 | 394 | 52 |
| Fluorene | 93 | 290 | 160 | 37 | 60 | 50 | 55 | 57 | 54 | 66 | 58 | 82 | 43 | 86 | 71 | 74 | <200 | 107 | 9 |
| Phenanthrene | 130 | 600 | 260 | 37 | 108 | 111 | 109 | 125 | 116 | 115 | 109 | 136 | 65 | 123 | 136 | 201 | 131J | 87J | 14 |
| Anthracene | 35 | 160 | 60 | 14 | 31 | 33 | 31 | 38 | 23 | 22J | 23J | 30 | 14 | 24 | 28 | 55 | <200 | <100 | 4.5 J |
| Di-n-Butyl Phthalate | <2.5 | <10 | <1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Fluoranthene | 16 | 200 | 39 | 16 | 20J | 16J | 19J | 21 | 18 | 24J | 13J | 23J | 10 | 22 | 27 | 90 | <200 | <100 | 10 |
| Pyrene | 59 | 300 | 70 | 23 | 34 | 32 | 31 | 35 | 25 | 39 | 23J | 36 | 15 | 28 | 42 | 138 | <200 | <100 | 14 |
| Butyl Benzyl Phthalate | <2.5 | <10 | <1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Benzo (a) Anthracene | <7.8 | 88 | 13 | 7.2 | 11J | <25 | <25 | 9.3J | 7.1J | 11J | <25 | <25 | <10 | <20 | 11 | 42 | <200 | <100 | 5.1 |
| Dibenz (a,h) Anthracene | <2.5 | <10 | <1 | <5 | <25 | <25 | <25 | <13 | <10 | <25 | <25 | <25 | <10 | <20 | <10 | 5.8J | <200 | <100 | <5 |
| Chrysene | 4 | 41 | 14 | 6.4 | 11J | <25 | <25 | 9.9J | 7.8J | 12J | <25 | 10J | <10 | <20 | 11 | 42 | <200 | <100 | 5.2 |
| Di-n-Octyl Phthalate | 6 | <10 | <1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Benzo (a) Pyrene | <2.5 | 46 | <1 | 6.3 | 12J | 11J | 12J | 7.9J | 9.7J | <25 | <25 | <25 | <10 | <20 | 9.4J | 37 | <200 | <100 | 7.1 |
| Indeno (1,2,3-cd) Pyrene | <3.7 | <20 | <2 | 2.1J | <25 | <25 | <25 | 2.9J | 4.0J | <25 | <25 | <25 | <10 | <20 | 4.9J | 14 | <200 | <100 | <5 |
| Benzo (g,h,i) Perylene | <4.1 | <20 | <2 | <5 | <25 | <25 | <12J | 3.7J | 6.0J | <25 | <25 | <25 | <10 | <20 | 6.2J | 18 | <200 | <100 | 2.0 J |
| Benzo (b+k) Fluoranthene | 5 | 26 | 6 | 6.1J | <25 | <25 | <25 | 7.6J | 9.7J | <25 | <25 | <25 | <10 | <20 | 11 | 34 | <200 | <100 | 5.7 |
| 2-Methyl Naphthalene | – | – | – | <5 | 70 | 44 | 56 | 47 | 40 | 55 | 44 | 61 | 25 | 51 | 44 | 61 | 572 | 546 | 30 |
| Total Base/Neutrals | 1588 | 4451 | 2232 | 223.1 | 993 | 851 | 929 | 734.3 | 762.3 | 1107 | 862 | 1039 | 400 | 680 | 854.5 | 1275.8 | 3560 | 3154 | 233 |
| Dissolved Iron (mg/l) | – | 22 | 27.1 | 19 | 26 | 19.8 | 11 | 10 | 13 | 18 | 17 | 15 | 14 | 11 | 11 | 10 | 17 | 9.1 | 1.8 |
| Cyanide (total, mg/l) | 0.032 | 0.04 | 0.06 | 0.08 | 0.10 | 0.06 | 0.03 | 0.02 | 0.01 | 0.09 | 0.06 | 0.06 | 0.02 | 0.03 | 0.03 | 0.03 | 0.18 | 0.15 | 0.15 |
| Specific Cond. (umhos/cm) | 290 | 306 | 460 | 460 | 443 | 354 | 378 | 420 | 403 | 509 | 518 | 396 | 452 | 449 | 355 | 377 | 523 | 430 | 455 |
| pH (standard units) | 6.96 | 6.03 | 6.06 | 6.20 | 6.50 | 6.25 | 6.33 | 6.28 | 6.36 | 6.41 | 6.42 | 6.55 | 6.43 | 6.44 | 6.49 | 6.58 | 6.20 | 6.06 | 6.62 |
| Dissolved Oxygen (mg/l) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0.3 | 0.6 | 4.3 |
| Eh (mV) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 26.0 |
| Water-Level Elevation (ft, MSL) | 2.88 | 3.15 | 3.75 | 3.33 | 3.96 | 3.98 | 3.47 | 3.10 | 3.85 | 3.84 | 3.74 | 3.36 | 3.45 | 3.39 | 3.50 | 3.11 | 3.82 | 4.27 | 3.25 |

-All concentrations ug/L unless otherwise noted. J-Estimated concentration, below method quantitation limit, B- Compound also detected in blank

-ND - Not detected, – Indicates not measured

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## Table 15

### Ground-Water Quality Laboratory Analytical Data for Well MW-3, Former Salisbury Town Gas Light Site

| Parameter | MW-3 | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12/87 | 8/88 | 7/89 | 3/92 | 3/93 | 6/93 | 9/93 | 12/93 | 3/94 | 6/94 | 9/94 | 12/94 | 3/95 | 6/95 | 9/95 | 12/95 | 3/96 | 6/96 | 9/96 | 12/96 |
| Volatile Organic Compounds | | | | | | | | | | | | | | | | | | | | |
| Acetone | -- | -- | -- | <16 | <50 | <50 | <40 | <40 | <20 | <50 | <50 | <50 | <80 | <50 | <50 | <40 | <25 | <50 | <50 | <10 |
| Benzene | 1100 | 1400 | 1300 | 604 | 790 | 672 | 656 | 736 | 256 | 785 | 580 | 660 | 1040 | 575 | 665 | 456 | 473 | 650 | 825 | <5 |
| Chlorobenzene | <5 | <1 | <1 | <8.0 | <25 | <25 | <20 | <20 | <10 | <25 | <25 | <25 | <40 | <25 | <25 | <20 | <13 | <25 | <25 | <5 |
| Chloroform | <1.6 | <1 | <1 | <8.0 | <25 | <25 | <20 | <20 | <10 | <25 | <25 | <25 | <40 | <25 | <25 | <20 | <13 | <25 | <25 | <5 |
| 1,2-Dichloroethane | 52 | 19.00 | 38 | 12 | <25 | 8.6J | <20 | <20 | 4.7J | <25 | <25 | 19J | 32J | 16J | 26 | 16J | 15 | 19J | 19J | <5 |
| 1,1-Dichloroethane | <1.6 | <1 | <1 | <8.0 | <25 | <20 | <20 | <20 | <10 | <25 | <25 | <25 | <40 | <25 | <25 | <20 | <13 | <25 | <25 | <5 |
| 1,1-Dichloroethene | <1.6 | <1 | <1 | <8.0 | <25 | <20 | <20 | <20 | <10 | <25 | <25 | <25 | <40 | <25 | <25 | <20 | <13 | <25 | <25 | <5 |
| 1,2-Dichloroethene (total) | <1.6 | <1 | <1 | <8.0 | <25 | <25 | <20 | <20 | <10 | <25 | <25 | <25 | <40 | <25 | <25 | <20 | <13 | <25 | <25 | <5 |
| Ethylbenzene | 160 | 170 | 340 | 280 | 375 | 314 | 388 | 408 | 88 | 307 | 215 | 347 | 317 | 360 | 364 | 221 | 209 | 356 | 471 | <5 |
| Methylene Chloride | 12B | <1 | <1 | <8.0 | <25 | <25 | <20 | <20 | <10 | <25 | <25 | <25 | <40 | <25 | <25 | <20 | <13 | <25 | <25 | <5 |
| Styrene | -- | -- | -- | 88 | 134 | 155 | 100 | 87 | 23 | 360 | 112 | 40 | <40 | 78 | 24J | <20 | 41 | 242 | 540 | <5 |
| Tetrachloroethene | <1.6 | <1 | <1 | <8.0 | <25 | <20 | <20 | <20 | <10 | <25 | <25 | <25 | <40 | <25 | <25 | <20 | <13 | <25 | <25 | <5 |
| Toluene | 140 | 300 | 270 | 307 | 299 | 324 | 256 | 381 | 141 | 706 | 172 | 157 | 38J | 220 | 46 | 19J | 151 | 304 | 615 | <5 |
| 1,1,1-Trichloroethane | <3.8 | <1 | <1 | <8.0 | <25 | <25 | <20 | <20 | <10 | <25 | <25 | <25 | <40 | <25 | <25 | <20 | <13 | <25 | <25 | <5 |
| Trichloroethene | 5 | <1 | <1 | <8.0 | <25 | <25 | <20 | <20 | <10 | <25 | <25 | <25 | <40 | <25 | <25 | <20 | <13 | <25 | <25 | <5 |
| Xylene (total) | -- | 364 | 730 | 336 | 439 | 436 | 420 | 374 | 132 | 605 | 297 | 224 | 151 | 413 | 440 | 139 | 202 | 510 | 925 | <10 |
| Total Volatiles | 1469 | 2253 | 2678 | 1507 | 2037 | 1909.6 | 1820 | 1986 | 644.7 | 2762 | 1376 | 1447 | 1578 | 1662 | 1566 | 851 | 1091 | 2081 | 3395 | ND |
| Base/Neutral Ext. Compounds | | | | | | | | | | | | | | | | | | | | |
| Naphthalene | 290 | 1400 | 600 | 689 | 1050 | 760 | 1200 | 924 | 400 | 1270 | 499 | 894 | 164 | 831 | 444 | 368 | 774 | 1880 | 2600 | <5 |
| Acenaphthylene | 110 | 200 | 220 | 116 | 105 | 131 | 212 | 148 | 84 | 151 | 144 | 188 | 66 | 103 | 137 | 130 | 91 | <100 | 133 | <5 |
| Acenaphthene | 38 | 57 | 60 | 37J | 33J | 37J | 54 | 50 | 41 | 58 | 61 | 85 | 42 | 55 | 76 | 74 | 48 | <100 | 40J | <5 |
| Fluorene | 31 | 56 | 53 | 30J | 30J | 29J | 49J | 40J | 28 | 44J | 48 | 73 | 26 | 43J | 50 | 42 | 33 | <100 | <100 | <5 |
| Phenanthrene | 34 | 35 | 63 | 32J | 30J | 35J | 52 | 39J | 31 | 59 | 60 | 62 | 31 | 34J | 54 | 46 | 31 | <100 | <100 | <5 |
| Anthracene | 7 | <20 | 11 | <40 | <50 | <50 | <50 | <50 | <20 | <50 | 15J | 14J | 5.5J | <50 | 8.6J | 8.1J | <30 | 52J | <100 | <5 |
| Di-n-Butyl Phthalate | <2.5 | <20 | 28 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Fluoranthene | <2.5 | <20 | 3 | <40 | <50 | <50 | <50 | <50 | <20 | <50 | <25 | <30 | <10 | <50 | <15 | <20 | <30 | <100 | <100 | <5 |
| Pyrene | 3 | <20 | 4 | <40 | <50 | <50 | <50 | <50 | <20 | <50 | <25 | <30 | <10 | <50 | <15 | <20 | <30 | <100 | <100 | <5 |
| Butyl Benzyl Phthalate | <2.5 | <20 | 28 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Benzo (a) Anthracene | <7.8 | <20 | <1 | <40 | <50 | <50 | <50 | <50 | <20 | <50 | <25 | <30 | <10 | <50 | <15 | <20 | <30 | <100 | <100 | <5 |
| Dibenz (a,h) Anthracene | <2.5 | <20 | <1 | <40 | <50 | <50 | <50 | <50 | <20 | <50 | <25 | <30 | <10 | <50 | <15 | <20 | <30 | <100 | <100 | <5 |
| Chrysene | 9 | <20 | <1 | <40 | <50 | <50 | <50 | <50 | <20 | <50 | <25 | <30 | <10 | <50 | <15 | <20 | <30 | <100 | <100 | <5 |
| Di-n-Octyl Phthalate | <2.5 | <20 | 38 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Benzo (a) Pyrene | <2.5 | <20 | <1 | <40 | <50 | <50 | <50 | <50 | <20 | <50 | <25 | <30 | <10 | <50 | <15 | <20 | <30 | <100 | <100 | <5 |
| Indeno (1,2,3-cd) Pyrene | <3.7 | <40 | <2 | <40 | <50 | <50 | <50 | <50 | <20 | <50 | <25 | <30 | <10 | <50 | <15 | <20 | <30 | <100 | <100 | <5 |
| Benzo (g,h,i) Perylene | <4.1 | <40 | <2 | <40 | <50 | <50 | <50 | <50 | <20 | <50 | <25 | <30 | <10 | <50 | <15 | <20 | <30 | <100 | <100 | <5 |
| Benzo (b+k) Fluoranthene | <4.8 | <40 | <2 | <40 | <50 | <50 | <50 | <50 | <20 | <50 | <25 | <30 | <10 | <50 | <15 | <20 | <30 | <100 | <100 | <5 |
| 2-Methyl Naphthalene | -- | -- | -- | 82 | 120 | 81 | 137 | 92 | 37 | 100 | 52 | 105 | 6.7J | 48J | 34 | 21 | 48 | 79J | 234 | <5 |
| Total Base/Neutrals | 522 | 1748 | 1014 | 986 | 1368 | 1093 | 1704 | 1293 | 621 | 1682 | 879 | 1421 | 341 | 1114 | 804 | 689 | 1025 | 2011 | 3007 | ND |
| Dissolved Iron (mg/l) | -- | 34 | 44.3 | 30 | 39 | 39.3 | 35 | 34 | 17 | 32 | 34 | 34 | 38 | 35 | 37 | 33 | 21 | 29 | 25 | 2 |
| Cyanide (total, mg/l) | 0.049 | 0.03 | 0.05 | 0.06 | 0.16 | 0.09 | 0.10 | 0.08 | 0.06 | 0.05 | 0.04 | 0.043 | 0.03 | 0.14 | 0.07 | 0.04 | 0.16 | 0.16 | 0.2 | 0.023 |
| Specific Cond. (umhos/cm) | 325 | 290 | 375 | 401 | 380 | 328 | -- | 403 | 317 | 415 | 476 | 408 | 531 | 446 | 411 | 442 | 402 | 417 | 372 | 507 |
| pH (standard units) | 7.09 | 6.00 | 6.10 | 6.11 | 6.17 | 6.32 | 6.83 | 6.30 | 6.05 | 6.22 | 6.43 | 6.47 | 6.43 | 6.24 | 6.35 | 6.55 | 6.28 | 6.17 | 5.97 | 3.28 |
| Dissolved Oxygen (mg/l) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.2 | 0.7 | 6.2 |
| Eh (mV) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 453.0 |
| Water-Level Elevation (ft, MSL) | 2.83 | 2.90 | 3.69 | 3.31 | 3.93 | 3.94 | 3.40 | 3.06 | 3.78 | 3.79 | 3.70 | 3.33 | 3.42 | 3.35 | 3.51 | 3.07 | 2.92 | 3.73 | 4.17 | 3.54 |

-All concentrations ug/L unless otherwise noted, J-Estimated concentration, below method quantitation limit, B- Compound also detected in blank

-ND - Not detected, -- Indicates not measured

Figure 8

Ground-Water Quality Temporal Trends for MW-2/2R
at the Former Salisbury Town Gas Light Site

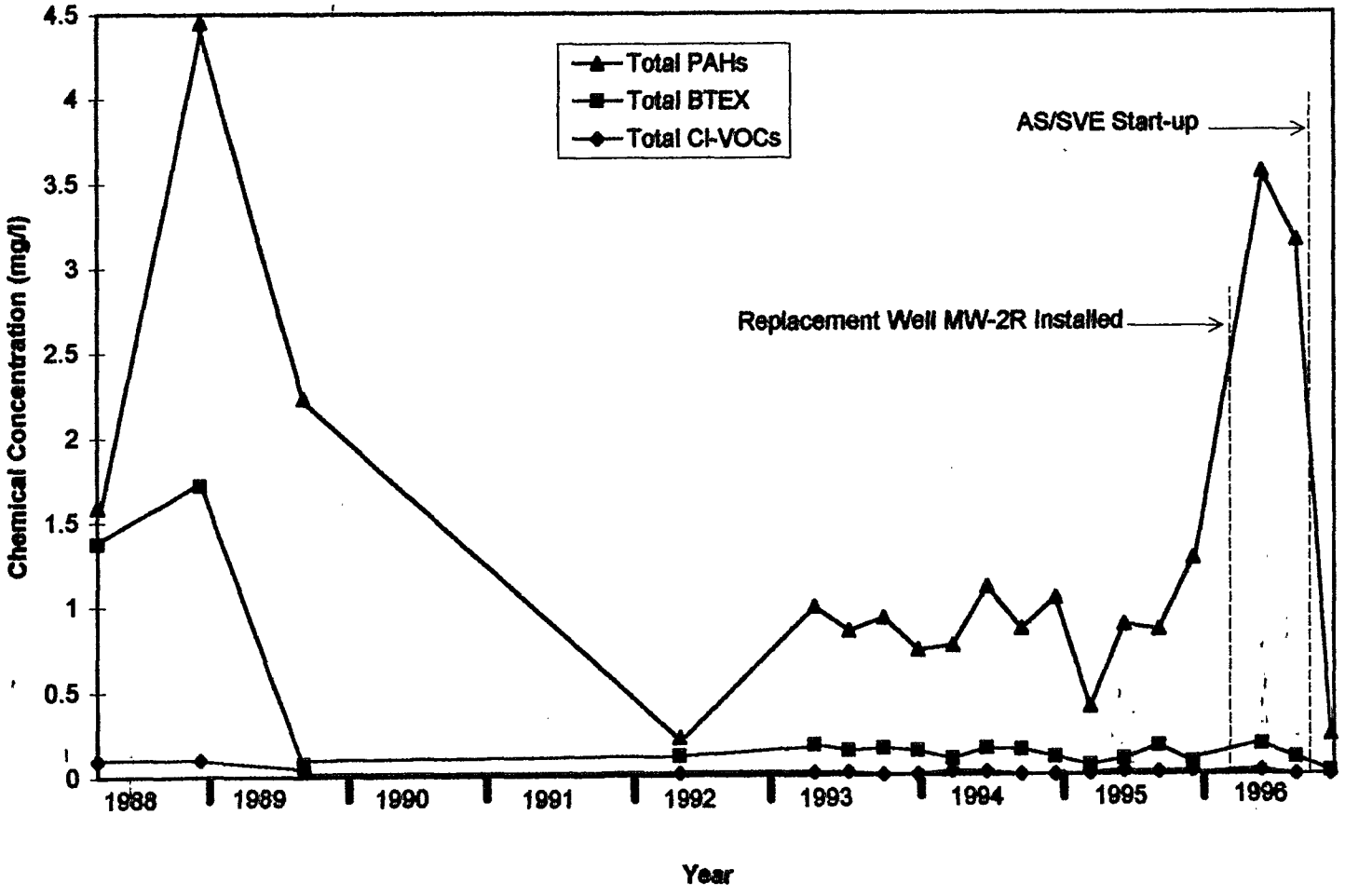
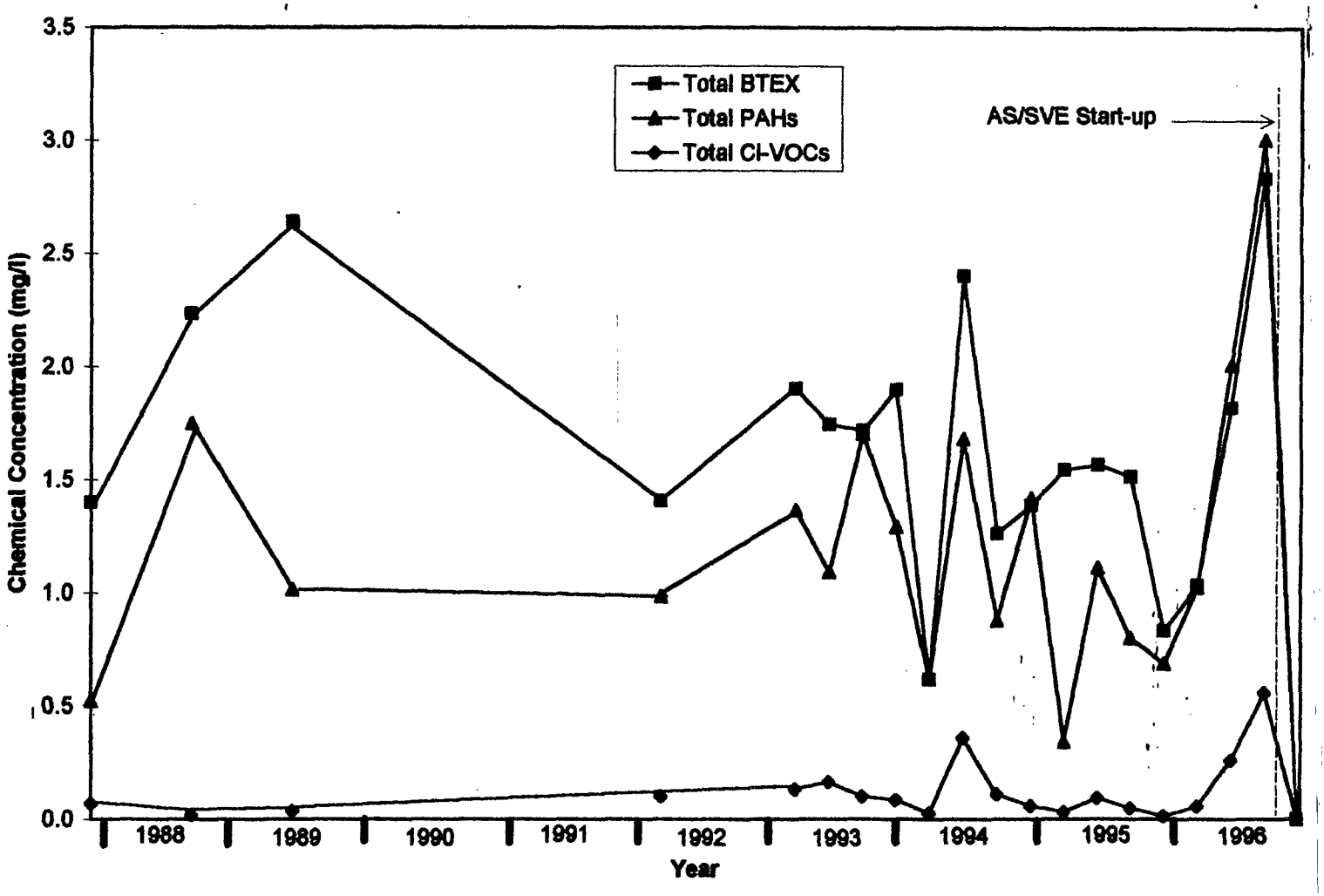


Figure 9

Ground-Water Quality Temporal Trends for MW-3
at the Former Salisbury Town Gas Light Site



# 4.0 REMEDIAL PROGRESS SUMMARY

## 4.1 Product Monitoring & Recovery

The amount of product removed during the second half of 1996 was 3.32 gallons and the cumulative total of product removed for the site through December 31, 1996 now stands at 294.2 gallons. A summary of product thicknesses and product removed during the second half of 1996 and total product removed since monitoring began is presented in Table 16.

Product thicknesses in MW-1 have been maintained predominantly at less than an inch since product recovery operations were initiated in 1993, but have fluctuated up to nearly 0.5 feet on occasion. Product thicknesses at Well D-4 have fluctuated more strongly, although the product thickness at this location has been maintained at a few inches with manual bailing only during the second half of 1996. Historical trends in product thicknesses measured in wells MW-1 and D-4 are illustrated in Figures 10 and 11, respectively.

## 4.2 AS/SVE Operations

Success of the AS/SVE remedial program is measured by observed changes in water quality as well as by the quality of vapors extracted from the subsurface. Trends in water quality are discussed in Sections 3.3 and 4.3. Extracted vapor quality and estimated chemical mass removal rates as a measure of remedial progress are discussed below.

Mass extraction via SVE is one of the mechanisms by which hydrocarbons are removed from the subsurface. Based on the calculations outlined in Section 3.2, a total of approximately 1.12 total VOCs were extracted during the start-up period. With approximately 20 additional operating days during the routine operation period of 1996

and an assumed average VOC mass extraction rate of 0.065 lb/day, the total mass of VOCs extracted during 1996 is estimated at [redacted] pounds.

In-situ biological degradation is the other principal mechanism of hydrocarbon removal, and is often much more significant than physical removal, although difficult to quantify. The by-products of aerobic biodegradation of the non-chlorinated hydrocarbons found at the site are carbon dioxide and water, and carbon dioxide concentrations in the extracted vapors in excess of typical atmospheric concentrations can be used to indirectly estimate the amount of in-situ degradation. Extracted carbon dioxide concentrations were as high as 6.5%, and consistently exceeded typical atmospheric levels of 0.034%, as shown in Table17.

The inferred relationship between carbon dioxide levels and hydrocarbon degradation is based on the balanced equation for the complete oxidation of a C8-hydrocarbon, as described below:

$$2(C_8H_{10}) + 21(O_2) \rightarrow 16(CO_2) + 10\,(H_2O)$$

1 mole C8-hydrocarbon → 8 moles $CO_2$

It is therefore assumed one pound of hydrocarbon oxidized will produce 3.32 pounds of carbon dioxide. Calculated carbon dioxide extraction rates were as high as 273 pounds during the first day of operation, and leveled off at approximately 45 pounds/day at the end of the initial 15 days of operation. The cumulative total of hydrocarbons degraded during the first 15 days of operation is estimated at 381 pounds. At an assumed average degradation rate of 14 pounds per day for an additional 20 operating days, it is estimated that a total of approximately [redacted] pounds of hydrocarbons were degraded in-situ during operation of the AS/SVE system during 1996.



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**Table 17**
**Start-Up Period Carbon Dioxide Levels &**
**Equivalent Hydrocarbon Degradation Potential**
**Former Salisbury Town Gas Light Site**

| Date | Sample ID | Flow Rate (SCFM) | $CO_2$ (%) | $CO_2$ (lbs/day) | $CO_2$ (total lbs.) | Equivalent $C_8H_{10}$ (total lbs.) |
|---|---|---|---|---|---|---|
| 10/22/96 | SVE-1 | 26 | 6.50 | 273 | 273 | 82 |
| 10/23/96 | SVE-2 | 20 | 4.69 | 76 | 349 | 105 |
| 10/23/96 | SVE-3 | 20 | 4.78 | 77 | 426 | 128 |
| 10/24/96 | SVE-4 | 31 | 1.58 | 79 | 505 | 152 |
| 10/28/96 | SVE-5 | 34 | 2.32 | 127 | 633 | 191 |
| 10/29/96 | SVE-6 | 36 | 1.43 | 83 | 716 | 216 |
| 10/30/96 | SVE-7 | 36 | 1.53 | 89 | 805 | 242 |
| 10/31/96 | SVE-8 | 33 | 1.15 | 61 | 866 | 261 |
| 11/1/96 | SVE-9 | 34 | 1.15 | 63 | 930 | 280 |
| 11/2/96 | SVE-10 | 35 | 0.97 | 55 | 984 | 296 |
| 11/3/96 | SVE-11 | 38 | 1.11 | 68 | 1,053 | 317 |
| 11/4/96 | SVE-12 | 36 | 1.04 | 61 | 1,113 | 335 |
| 11/5/96 | SVE-13 | 36 | 1.08 | 63 | 1,176 | 354 |
| 11/6/96 | SVE-14 | 34 | 0.80 | 44 | 1,220 | 367 |
| 11/7/96 | SVE-15 | 36 | 0.77 | 45 | 1,265 | 381 |

NOTES:

1) The equivalent $C_8H_{10}$ level is the amount of hydrocarbon that could have been degraded in order to produce the mass of $CO_2$ removed with the SVE system. As described by:

2) $2(C_8H_{10}) + 21(O_2) \longrightarrow 16(CO_2) + 10(H_2O)$
   1 mole hydrocarbon --> 8 moles $CO_2$
   1 pound hydrocarbon --> 3.32 pounds $CO_2$

### 4.3 Ground-Water Monitoring

Results of the quarterly and monthly ground-water monitoring events demonstrate that operation of the AS/SVE system has dramatically improved ground-water quality and effectively mitigates potential off-site migration of dissolved VOCs and PAHs. High levels of VOCs and PAHs at the monitoring wells located immediately downgradient of the AS/SVE treatment curtain have been substantially reduced to levels close to or below detectable limits. Dissolved oxygen levels necessary for enhancement of natural in-situ biodegradation processes have been restored within the ground-water regime, particularly along the eastern limb of the system.



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EXCERPTS FROM

# REMEDIAL PROGRESS REPORT
# FORMER SALISBURY TOWN GAS LIGHT SITE
# SALISBURY, MARYLAND

Prepared for:

**CHESAPEAKE UTILITIES CORPORATION**

**MARCH, 1996**

Prepared by:

**RUTH ASSOCIATES, INC.**
2017 Chesapeake Road
Annapolis, Maryland 21401

## 3.0 SOIL-VAPOR EXTRACTION MONITORING & RESULTS

SVE operations were initiated in the vicinity of the Former Production Building in August of 1993 and have been continued as part of the remedial program designed to remove petroleum hydrocarbons from this area. A summary of recorded activities and observations for the history of SVE and vacuum-enhanced product recovery performed at the Salisbury site is presented as Appendix B. Salient portions of the SVE summary and product recovery history are depicted in a time-line figure (Figure 3).

SVE start-up testing was conducted to ensure that the targeted remediation area was being influenced by the applied vacuum. Once steady-state conditions were achieved by extracting vapors from a given well at a constant rate, the vacuum induced at the surrounding wells was measured. Linear regression was used to evaluate the relationship between the vacuum induced and distance from the extraction well using well vacuum data. Graphs illustrating SVE vacuum versus distance data collected during start-up tests at wells D-2, D-2R, D-1 and D-4 are included as Appendix C. The inferred zone of influence from SVE at each extraction well is illustrated in isobaric contour drawings, Figures 4, 5, 6 & 7. Review of these figures show that the zone of influence for vapor extraction from each well extends over a large portion of the Former Production Area, with radii of influence from a single extraction point ranging from 76 to 90 feet.

During the initial monitoring phase of SVE operation, vapor grab samples were collected daily and analyzed by Microseeps, Inc. for BTEX compounds, naphthalene and C5- through C10-alkanes. Laboratory certificates of analysis are included as Appendix D. The analytical data and correlating flow rates were used to calculate the chemical mass extraction rates for all analytical parameters. After more than 14 consecutive days of extraction rates well within the permitted limits for benzene and

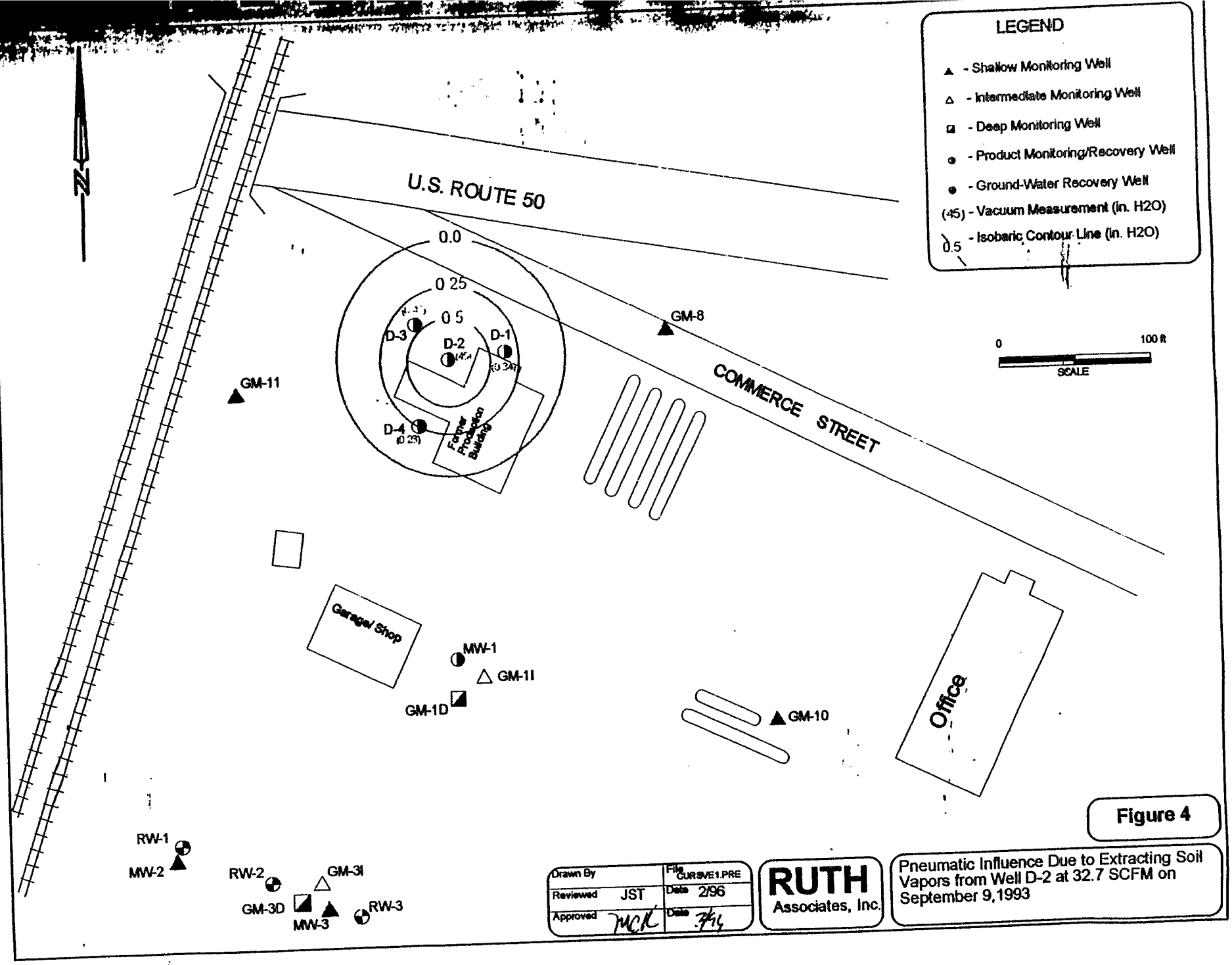



Figure 4

Pneumatic Influence Due to Extracting Soil Vapors from Well D-2 at 32.7 SCFM on September 9,1993

| | | | |
|---|---|---|---|
| Drawn By | | File | CURSVE1.PRE |
| Reviewed | JST | Date | 2/96 |
| Approved | MCK | Date | 3/96 |

RUTH Associates, Inc.

AR309790

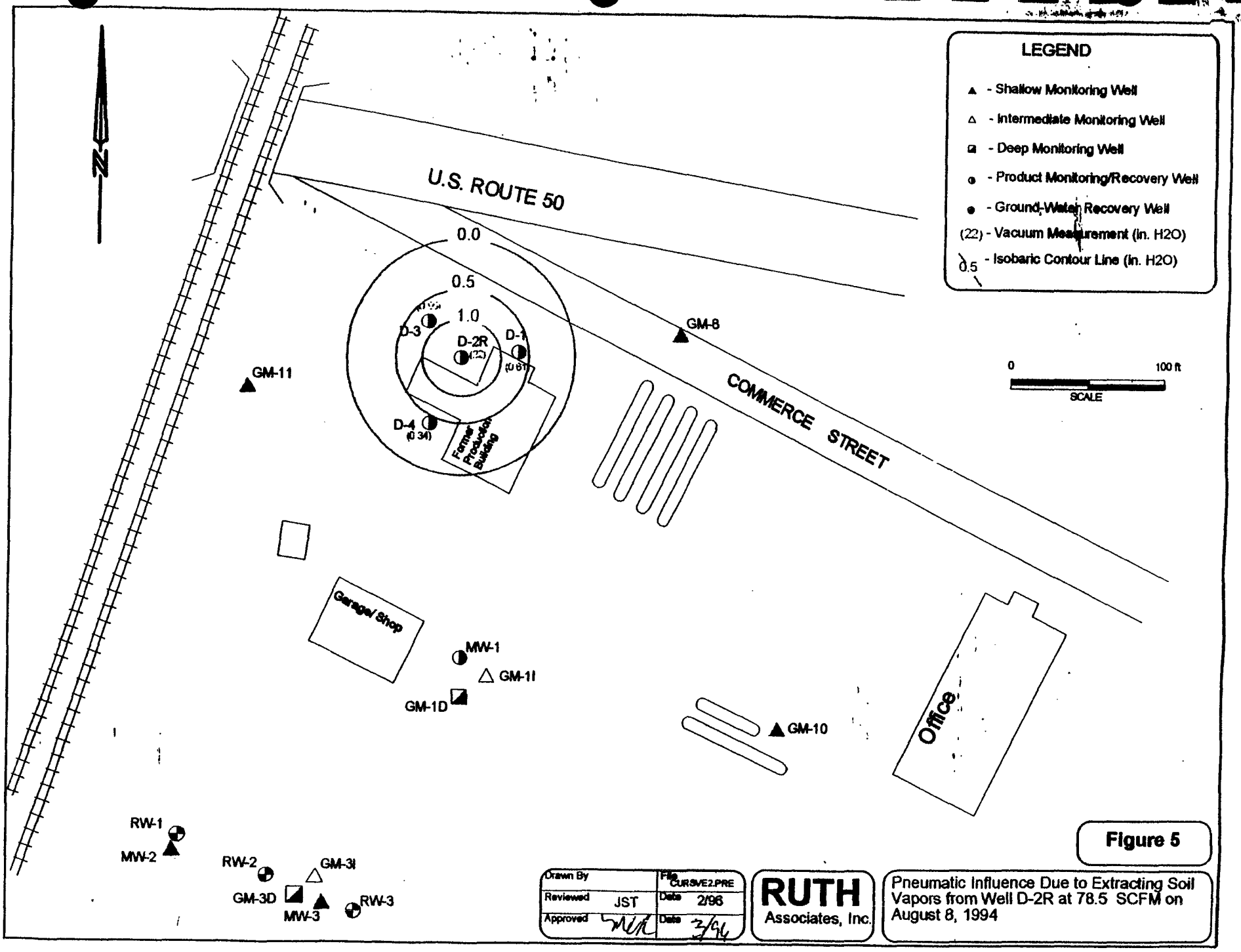



Figure 5

| | | | |
|---|---|---|---|
| Drawn By | | File | CURSVE2.PRE |
| Reviewed | JST | Date | 2/96 |
| Approved | MER | Date | 3/96 |

RUTH Associates, Inc.

Pneumatic Influence Due to Extracting Soil Vapors from Well D-2R at 78.5 SCFM on August 8, 1994

AR309791

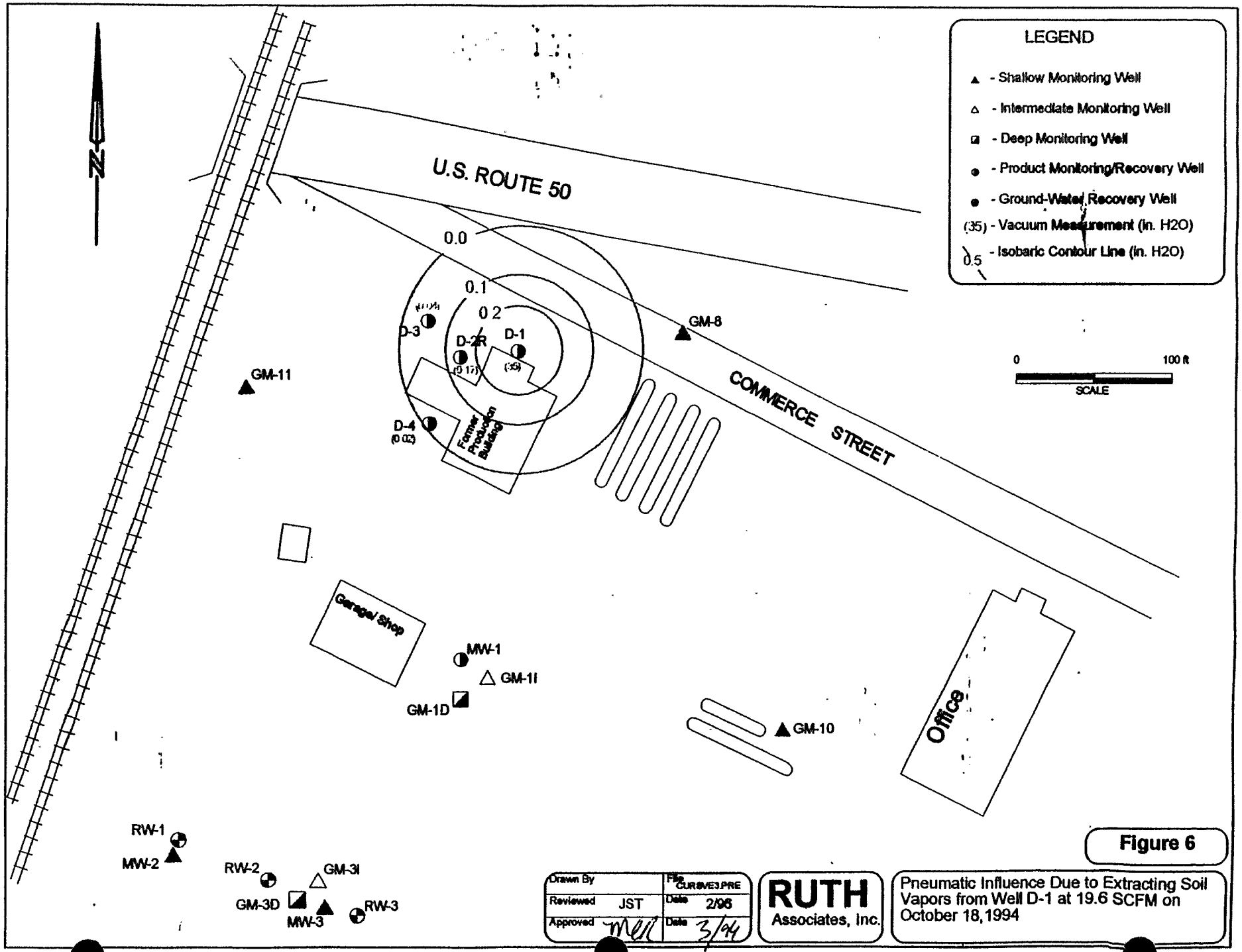



Figure 6

Pneumatic Influence Due to Extracting Soil Vapors from Well D-1 at 19.6 SCFM on October 18,1994

AR309792

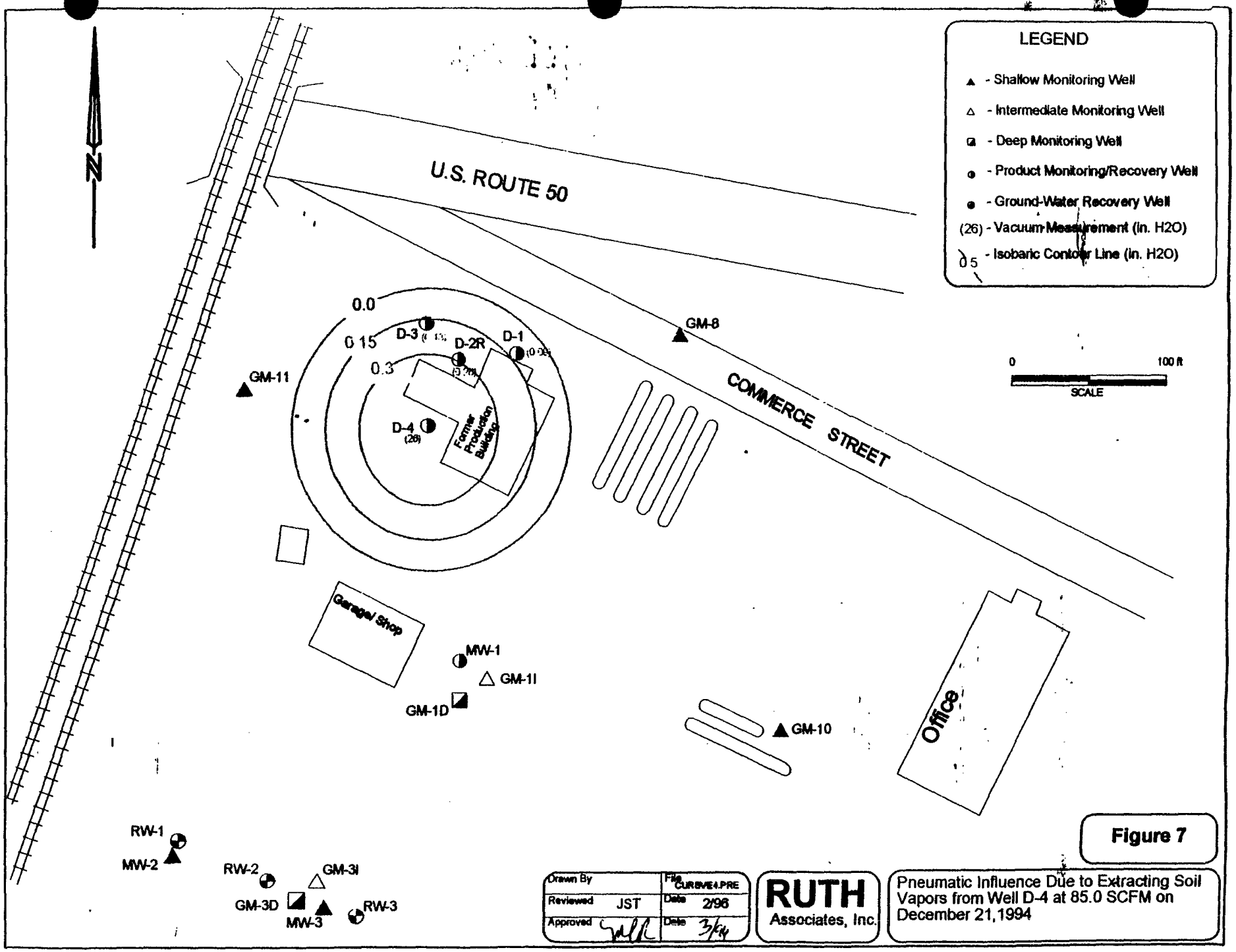



Figure 7

| | | | |
|---|---|---|---|
| Drawn By | | File | CURBVE4.PRE |
| Reviewed | JST | Date | 2/96 |
| Approved | | Date | 3/14 |

RUTH Associates, Inc.

Pneumatic Influence Due to Extracting Soil Vapors from Well D-4 at 85.0 SCFM on December 21,1994

AR309793

total VOCs, a letter prepared by RAI and dated December 6, 1993 was submitted to the MDE Air and Radiation Management Administration. This letter included the calculations and supporting data demonstrating compliance with air emission standards, and permission was requested to remove air emission control devices and discontinue the associated monitoring for the air permit. MDE granted permission in a response letter dated December 9, 1993. SVE was temporarily discontinued at D-2 between late October through mid December 1993 while MDE processed the request and restarted on December 19, 1993 following MDE's waiver of the air emission control portions of the permit. The December 6, 1993 RAI letter and the December 9, 1993 MDE response letter are provided in Appendix E.

RAI continued to collect vapor grab samples on a monthly basis through January of 1995, to monitor the systems performance and to update contaminant vapor removal rates. A summary of the analytical results for all vapor extraction system grab samples is presented in Table 1. Hourly and daily extraction calculations in pounds is given in Tables 2 and 3, respectively. The historical chemical mass extraction rates indicate that at no time has the system exceeded the permitted emission limits for benzene (0.02 pounds/hour) or total VOCs (20 pounds/day).

Extracted vapors prior to carbon treatment have also been monitored in the field using portable instruments. An explosimeter was used to measure oxygen content (%$O_2$) and the percent of the Lower Explosive Limit (%LEL). An HNu photo-ionization detector (PID) was also used to monitor extracted vapor quality. The field monitoring data for Wells D-2/D-2R, D-4 and D-1 are provided in Tables 4, 5 and 6.

At Well D-2, the LEL and PID readings were initially high and oxygen readings were low, but these trends proceeded to reverse as SVE operations progressed. Another effect of SVE was also apparent when product thickness measurements, recorded at the end of the initial monitoring period, revealed that 1.75 feet of product

## TABLE 1 - Summary of Analytical Results for Vapor Extraction System Monitoring

| Extraction Well | Sample Identification | Date | Flow Rate (SCFM) | Benzene (ppmv) | Toluene (ppmv) | Ethylbenzene (ppmv) | Xylenes (ppmv) | Naphthalene (ppmv) | C5-C10 (ppmv) | Total VOCs (ppmv) | Total VOCs + $C_5$ (ppmv) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D-2 | V-1 | 9/9/93 | 35 | 31.76 | 46.63 | 4.86 | 21.04 | 0.69 | 729.91 | 104.98 | 834.89 |
| | V-2 | 9/10/93 | 35 | 27.76 | 46.74 | 5.57 | 22.73 | 0.86 | 656.62 | 103.66 | 760.28 |
| | REP-14 (V-2) | 9/10/93 | 35 | 22.66 | 38.54 | 4.72 | 19.45 | 1.03 | 548.72 | 86.40 | 635.12 |
| | V-3 | 9/13/93 | 37 | 20.68 | 36.07 | 4.19 | 17.53 | 0.56 | 489.24 | 79.03 | 568.27 |
| | V-4 | 9/16/93 | 35 | 15.73 | 35.93 | 4.65 | 21.92 | 1.34 | 383.21 | 79.57 | 462.78 |
| | V-6 | 9/22/93 | 37 | 22.53 | 50.55 | 5.85 | 30.74 | 1.43 | 532.07 | 111.10 | 643.17 |
| | V-20 | 10/4/93 | 33 | 12.43 | 38.18 | 3.56 | 20.96 | 0.81 | 347.74 | 75.94 | 423.68 |
| | V-24 | 10/8/93 | 35 | 11.30 | 38.11 | 3.95 | 22.79 | 0.85 | 339.89 | 77.00 | 416.89 |
| | V-32 | 10/15/93 | 33 | 6.37 | 22.82 | 2.77 | 16.43 | 0.70 | 212.80 | 49.09 | 261.89 |
| | V-33 | 10/16/93 | 33 | 7.25 | 25.74 | 3.04 | 18.70 | 0.62 | 240.30 | 55.35 | 295.65 |
| | V-34 | 10/17/93 | 33 | 7.20 | 25.60 | 2.99 | 18.44 | 0.61 | 253.25 | 54.84 | 308.09 |
| | V-35 | 10/18/93 | 33 | 6.69 | 24.14 | 3.03 | 18.21 | 0.64 | 224.15 | 52.71 | 276.86 |
| | V-36 | 10/19/93 | 33 | 6.94 | 25.38 | 3.22 | 19.30 | 0.72 | 231.97 | 55.56 | 287.53 |
| | V-37 | 10/20/93 | 33 | 6.31 | 22.61 | 2.90 | 17.39 | 0.75 | 214.20 | 49.96 | 264.16 |
| | V-38 | 10/21/93 | 33 | 6.99 | 25.64 | 3.46 | 21.14 | 0.91 | 239.30 | 58.14 | 297.44 |
| | V-39 | 10/22/93 | 33 | 6.69 | 23.94 | 3.10 | 18.55 | 0.56 | 224.02 | 52.84 | 276.86 |
| | V-40 | 10/23/93 | 33 | 6.88 | 24.95 | 3.39 | 20.65 | 0.70 | 233.47 | 56.57 | 290.04 |
| | V-41 | 10/24/93 | 33 | 7.41 | 27.45 | 4.14 | 25.98 | 1.25 | 259.30 | 66.23 | 325.53 |
| | V-42 | 10/25/93 | 33 | 7.24 | 26.71 | 4.02 | 24.98 | 0.96 | 268.93 | 63.91 | 332.84 |
| | V-43 | 10/26/93 | 33 | 8.02 | 29.11 | 4.40 | 27.35 | 1.18 | 277.46 | 70.06 | 347.52 |
| | V-44 | 10/27/93 | 33 | 6.82 | 25.68 | 4.07 | 25.56 | 0.97 | 256.41 | 63.10 | 319.51 |
| | V-45 | 10/28/93 | 28 | 7.51 | 28.24 | 4.48 | 28.40 | 1.26 | 271.14 | 69.89 | 341.03 |
| | REP-50 (V-45) | 10/28/93 | 28 | 8.01 | 30.15 | 4.83 | 30.96 | 1.78 | 285.73 | 75.73 | 361.46 |
| D-2R | A-6/30/94 | 6/30/94 | 84 | 0.35 | 1.35 | 0.37 | 3.64 | <0.30 | 5.57 | 5.71 | 11.28 |
| | B-7/6/94 | 7/6/94 | 84 | 0.29 | 1.14 | 0.38 | 4.15 | 0.69 | 5.43 | 6.65 | 12.08 |
| | C-7/11/94 | 7/11/94 | 89 | 0.45 | 1.74 | 0.70 | 7.37 | 1.09 | 7.39 | 11.35 | 18.74 |
| | V-8/8/94 | 8/8/94 | 83 | 0.86 | 2.20 | 1.00 | 11.57 | 3.04 | 78.35 | 18.67 | 97.02 |
| | V-100 | 9/27/94 | 89 | 0.24 | 1.18 | 0.47 | 3.55 | 0.66 | 32.28 | 6.10 | 38.38 |
| D-1 | V-101 | 10/19/94 | 57 | <0.07 | <0.07 | <0.07 | <0.07 | <0.30 | 0.27 | <0.58 | 0.27 |
| D-2R | V-110 | 11/15/94 | 82 | 0.26 | 1.29 | 0.43 | 3.04 | 0.31 | 35.32 | 5.33 | 40.65 |
| | V-111 | 12/1/94 | 82 | 0.34 | 1.56 | 0.46 | 3.72 | 0.42 | 47.57 | 6.50 | 54.07 |
| D-4 | V-95-1 | 1/31/95 | 58 | 1.08 | 1.04 | 1.20 | 2.46 | <0.30 | 74.20 | 5.78 | 79.98 |

## TABLE 2 - Calculated Hourly Air Emissions for the Vapor Extraction System

| Extraction Well | Sample Identification | Date | Benzene (lb/hour) | Toluene (lb/hour) | Ethylbenzene (lb/hour) | Xylenes (lb/hour) | Naphthalene (lb/hour) | Aromatic Solvent (lb/hour) | Total VOC (lb/hour) | Total VOC (lb/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| D-2 | V-1 | 9/9/93 | 0.015 | 0.025 | 0.003 | 0.013 | 0.001 | 0.349 | 0.057 | 0.406 |
| | V-2 | 9/10/93 | 0.013 | 0.025 | 0.003 | 0.014 | 0.001 | 0.314 | 0.057 | 0.371 |
| | REP-14 (V-2) | 9/10/93 | 0.010 | 0.021 | 0.003 | 0.012 | 0.001 | 0.263 | 0.047 | 0.310 |
| | V-3 | 9/13/93 | 0.010 | 0.021 | 0.003 | 0.012 | 0.000 | 0.248 | 0.046 | 0.293 |
| | V-4 | 9/16/93 | 0.007 | 0.020 | 0.003 | 0.014 | 0.001 | 0.183 | 0.044 | 0.228 |
| | V-6 | 9/22/93 | 0.011 | 0.029 | 0.004 | 0.020 | 0.001 | 0.269 | 0.065 | 0.335 |
| | V-20 | 10/4/93 | 0.005 | 0.020 | 0.002 | 0.012 | 0.001 | 0.157 | 0.040 | 0.197 |
| | V-24 | 10/8/93 | 0.005 | 0.021 | 0.002 | 0.014 | 0.001 | 0.163 | 0.043 | 0.206 |
| | V-32 | 10/15/93 | 0.003 | 0.012 | 0.002 | 0.010 | 0.000 | 0.096 | 0.026 | 0.122 |
| | V-33 | 10/16/93 | 0.003 | 0.013 | 0.002 | 0.011 | 0.000 | 0.108 | 0.030 | 0.138 |
| | V-34 | 10/17/93 | 0.003 | 0.013 | 0.002 | 0.011 | 0.000 | 0.114 | 0.029 | 0.144 |
| | V-35 | 10/18/93 | 0.003 | 0.012 | 0.002 | 0.011 | 0.000 | 0.101 | 0.028 | 0.129 |
| | V-36 | 10/19/93 | 0.003 | 0.013 | 0.002 | 0.011 | 0.001 | 0.105 | 0.030 | 0.135 |
| | V-37 | 10/20/93 | 0.003 | 0.012 | 0.002 | 0.010 | 0.001 | 0.097 | 0.027 | 0.123 |
| | V-38 | 10/21/93 | 0.003 | 0.013 | 0.002 | 0.012 | 0.001 | 0.108 | 0.031 | 0.139 |
| | V-39 | 10/22/93 | 0.003 | 0.012 | 0.002 | 0.011 | 0.000 | 0.101 | 0.028 | 0.129 |
| | V-40 | 10/23/93 | 0.003 | 0.013 | 0.002 | 0.012 | 0.000 | 0.105 | 0.030 | 0.136 |
| | V-41 | 10/24/93 | 0.003 | 0.014 | 0.002 | 0.015 | 0.001 | 0.117 | 0.036 | 0.153 |
| | V-42 | 10/25/93 | 0.003 | 0.014 | 0.002 | 0.015 | 0.001 | 0.121 | 0.035 | 0.156 |
| | V-43 | 10/26/93 | 0.003 | 0.015 | 0.003 | 0.016 | 0.001 | 0.125 | 0.038 | 0.163 |
| | V-44 | 10/27/93 | 0.003 | 0.013 | 0.002 | 0.015 | 0.001 | 0.116 | 0.034 | 0.150 |
| | V-45 | 10/28/93 | 0.003 | 0.012 | 0.002 | 0.014 | 0.001 | 0.104 | 0.032 | 0.136 |
| | REP-50 (V-45) | 10/28/93 | 0.003 | 0.013 | 0.002 | 0.016 | 0.001 | 0.109 | 0.035 | 0.144 |
| D-2R | A-6/30/94 | 6/30/94 | 0.000 | 0.002 | 0.001 | 0.005 | 0.000 | 0.006 | 0.008 | 0.015 |
| | B-7/6/94 | 7/6/94 | 0.000 | 0.001 | 0.001 | 0.006 | 0.001 | 0.006 | 0.010 | 0.016 |
| | C-7/11/94 | 7/11/94 | 0.001 | 0.002 | 0.001 | 0.012 | 0.002 | 0.009 | 0.018 | 0.027 |
| | V-8/8/94 | 8/8/94 | 0.001 | 0.003 | 0.001 | 0.017 | 0.005 | 0.089 | 0.028 | 0.117 |
| | V-100 | 9/27/94 | 0.000 | 0.002 | 0.001 | 0.006 | 0.001 | 0.039 | 0.010 | 0.049 |
| D-1 | V-101 | 10/19/94 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| D-2R | V-110 | 11/15/94 | 0.000 | 0.002 | 0.001 | 0.004 | 0.001 | 0.040 | 0.008 | 0.047 |
| | V-111 | 12/1/94 | 0.000 | 0.002 | 0.001 | 0.005 | 0.001 | 0.053 | 0.009 | 0.063 |
| D-4 | V-95-1 | 1/31/95 | 0.001 | 0.001 | 0.001 | 0.003 | 0.000 | 0.059 | 0.006 | 0.064 |

## TABLE 3 - Calculated Daily Air Emissions for the Vapor Extraction System

| Extraction Well | Sample Identification | Date | Benzene lb/day | Toluene lb/day | Ethylbenzene lb/day | Xylenes lb/day | Naphthalene lb/day | C5-C10 lb/day | Total VOCs lb/day | Total VOCs + C5 lb/day |
|---|---|---|---|---|---|---|---|---|---|---|
| D-2 | V-1 | 9/9/93 | 0.351 | 0.608 | 0.073 | 0.316 | 0.013 | 8.383 | 1.361 | 9.745 |
| | V-2 | 9/10/93 | 0.307 | 0.610 | 0.084 | 0.342 | 0.016 | 7.541 | 1.358 | 8.899 |
| | REP-14 (V-2) | 9/10/93 | 0.251 | 0.503 | 0.071 | 0.292 | 0.019 | 6.302 | 1.135 | 7.438 |
| | V-3 | 9/13/93 | 0.242 | 0.497 | 0.067 | 0.279 | 0.011 | 5.940 | 1.095 | 7.035 |
| | V-4 | 9/16/93 | 0.174 | 0.469 | 0.070 | 0.330 | 0.024 | 4.401 | 1.066 | 5.468 |
| | V-6 | 9/22/93 | 0.263 | 0.697 | 0.093 | 0.488 | 0.027 | 6.460 | 1.569 | 8.030 |
| | V-20 | 10/4/93 | 0.130 | 0.470 | 0.050 | 0.297 | 0.014 | 3.766 | 0.961 | 4.726 |
| | V-24 | 10/8/93 | 0.125 | 0.497 | 0.059 | 0.343 | 0.015 | 3.904 | 1.040 | 4.943 |
| | V-32 | 10/15/93 | 0.066 | 0.281 | 0.039 | 0.233 | 0.012 | 2.304 | 0.631 | 2.936 |
| | V-33 | 10/16/93 | 0.076 | 0.317 | 0.043 | 0.265 | 0.011 | 2.602 | 0.711 | 3.313 |
| | V-34 | 10/17/93 | 0.075 | 0.315 | 0.042 | 0.261 | 0.010 | 2.742 | 0.704 | 3.447 |
| | V-35 | 10/18/93 | 0.070 | 0.297 | 0.043 | 0.258 | 0.011 | 2.427 | 0.679 | 3.106 |
| | V-36 | 10/19/93 | 0.072 | 0.312 | 0.046 | 0.274 | 0.012 | 2.512 | 0.716 | 3.228 |
| | V-37 | 10/20/93 | 0.066 | 0.278 | 0.041 | 0.246 | 0.013 | 2.320 | 0.644 | 2.964 |
| | V-38 | 10/21/93 | 0.073 | 0.315 | 0.049 | 0.300 | 0.016 | 2.591 | 0.752 | 3.344 |
| | V-39 | 10/22/93 | 0.070 | 0.294 | 0.044 | 0.263 | 0.010 | 2.426 | 0.681 | 3.107 |
| | V-40 | 10/23/93 | 0.072 | 0.307 | 0.048 | 0.293 | 0.012 | 2.528 | 0.731 | 3.260 |
| | V-41 | 10/24/93 | 0.077 | 0.338 | 0.059 | 0.368 | 0.021 | 2.808 | 0.863 | 3.671 |
| | V-42 | 10/25/93 | 0.076 | 0.329 | 0.057 | 0.354 | 0.016 | 2.912 | 0.831 | 3.744 |
| | V-43 | 10/26/93 | 0.084 | 0.358 | 0.062 | 0.388 | 0.020 | 3.005 | 0.912 | 3.916 |
| | V-44 | 10/27/93 | 0.071 | 0.316 | 0.058 | 0.362 | 0.017 | 2.777 | 0.824 | 3.600 |
| | V-45 | 10/28/93 | 0.066 | 0.295 | 0.054 | 0.342 | 0.018 | 2.491 | 0.775 | 3.266 |
| | REP-50 (V-45) | 10/28/93 | 0.071 | 0.315 | 0.058 | 0.372 | 0.026 | 2.625 | 0.842 | 3.467 |
| D-2R | A-6/30/94 | 6/30/94 | 0.009 | 0.042 | 0.013 | 0.131 | 0.000 | 0.154 | 0.196 | 0.350 |
| | B-7/6/94 | 7/6/94 | 0.008 | 0.036 | 0.014 | 0.150 | 0.030 | 0.150 | 0.237 | 0.387 |
| | C-7/11/94 | 7/11/94 | 0.013 | 0.058 | 0.027 | 0.282 | 0.050 | 0.216 | 0.429 | 0.645 |
| | V-8/8/94 | 8/8/94 | 0.023 | 0.068 | 0.036 | 0.412 | 0.131 | 2.134 | 0.670 | 2.803 |
| | V-100 | 9/27/94 | 0.007 | 0.039 | 0.018 | 0.136 | 0.030 | 0.943 | 0.230 | 1.173 |
| D-1 | V-101 | 10/19/94 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| D-2R | V-110 | 11/15/94 | 0.007 | 0.039 | 0.015 | 0.107 | 0.013 | 0.950 | 0.182 | 1.132 |
| | V-111 | 12/1/94 | 0.009 | 0.048 | 0.016 | 0.131 | 0.018 | 1.280 | 0.222 | 1.502 |
| D-4 | V-95-1 | 1/31/95 | 0.020 | 0.022 | 0.030 | 0.061 | 0.000 | 1.412 | 0.133 | 1.546 |

**TABLE 4**
**Summary of the Field Monitoring Data for the Vapor Extraction System at D-2/2R**
**Salisbury Town Gas Light Site**
**Chesapeake Utilities Corp. - Salisbury, Maryland**

| Extraction Well | Date | Vacuum (inches H2O) | Flow Rate (SCFM) | O2 (%) | LEL Combustible (%) | PID Readings Total Carbon (ppmv) |
|---|---|---|---|---|---|---|
| D-2 | 8/18/93 | 50.0 | 30 | 2.4 | Max. | 135 |
| | 8/23/93 | 50.0 | 33 | 2.7 | Max. | 200 |
| | 8/24/93 | 49.0 | 33 | 2.1 | Max. | 220 |
| | 9/8/93 | 45.0 | 37 | 6.0 | Max. | 200 |
| | 9/9/93 | 44.0 | 35 | 6.6 | Max. | 150 |
| | 9/10/93 | 43.0 | 35 | 9.5 | Max. | 115 |
| | 9/13/93 | 44.0 | 37 | 9.0 | Max. | 115 |
| | 9/14/93 | 43.0 | 35 | 10.8 | Max. | 112 |
| | 9/16/93 | 44.0 | 35 | 12.2 | Max. | 12 |
| | 9/22/93 | 45.0 | 30 | 8.4 | Max. | 85 |
| | 9/27/93 | 43.0 | 37 | -- | -- | 32 |
| | 9/28/93 | 47.0 | 35 | -- | -- | 8 |
| | 9/29/93 | 45.0 | 35 | -- | -- | 8 |
| | 9/30/93 | 47.0 | 35 | -- | -- | 11 |
| | 10/1/93 | 48.0 | 35 | -- | -- | 12 |
| | 10/2/93 | 47.0 | 35 | -- | -- | 13 |
| | 10/3/93 | 46.0 | 33 | -- | -- | 10 |
| | 10/4/93 | 46.0 | 33 | -- | -- | 16 |
| | 10/5/93 | 49.0 | 33 | -- | -- | 10 |
| | 10/6/93 | 50.0 | 33 | -- | -- | 11 |
| | 10/7/93 | 50.0 | 33 | 15.3 | 2.5 | 10 |
| | 10/8/93 | 47.0 | 35 | 15.6 | 2.5 | 10 |
| | 10/9/93 | 47.0 | 35 | 15.5 | 2.4 | 7 |
| | 10/10/93 | 50.0 | 35 | 15.8 | 2.5 | 9 |
| | 10/11/93 | 49.0 | 33 | -- | -- | 8 |
| | 10/12/93 | 49.0 | 33 | 15.8 | 2.5 | 12 |
| | 10/13/93 | 51.0 | 33 | 15.9 | 2.2 | 22 |
| | 10/14/93 | 50.0 | 33 | 16.1 | 2.2 | 6 |
| | 10/15/93 | 48.0 | 33 | 16.4 | 2.0 | 6 |
| | 10/16/93 | 48.0 | 33 | 16.2 | 2.1 | 0 |
| | 10/17/93 | 47.0 | 33 | 16.1 | 2.2 | 0 |
| | 10/18/93 | 47.0 | 33 | 15.9 | 2.2 | 8 |
| | 10/19/93 | 49.0 | 33 | 16.0 | 2.1 | 12 |
| | 10/20/93 | 49.0 | 33 | 16.1 | 1.9 | 8 |
| | 10/21/93 | 49.0 | 33 | 16.1 | 1.9 | 6 |
| | 10/22/93 | 51.0 | 33 | 16.2 | 1.8 | 13 |
| | 10/23/93 | 52.0 | 33 | 16.3 | 2.0 | 15 |
| | 10/24/93 | 51.0 | 33 | 16.4 | 1.8 | 18 |
| | 10/25/93 | 49.0 | 33 | 16.5 | 1.8 | 15 |
| | 10/26/93 | 49.0 | 33 | 16.7 | 1.9 | 13 |
| | 10/27/93 | 50.0 | 33 | 16.3 | 1.8 | 16 |
| | 10/28/93 | 51.0 | 28 | 16.3 | 1.8 | 17 |
| | 10/29/93 | 51.0 | 28 | 16.5 | 1.8 | 18 |

-- No measurement collected
Max. denotes value >100%

**TABLE 4 (Continued)**
**Summary of the Field Monitoring Data for the Vapor Extraction System at D-2/2R**
**Salisbury Town Gas Light Site**
**Chesapeake Utilities Corp. - Salisbury, Maryland**

| Extraction Well | Date | Well Vacuum (inches H2O) | Flow Rate (SCFM) | O2 (%) | LEL as methane (%) | PID Readings Before carbon (ppmv) |
|---|---|---|---|---|---|---|
| D-2 | 3/14/94 | 50.8 | 15 | 15.1 | 1.9 | -- |
| | 3/15/94 | 50.0 | 33 | 15.2 | 1.7 | 32 |
| | 3/16/94 | 52.0 | -- | 15.2 | 1.8 | 48 |
| | 3/18/94 | 44.3 | -- | 15.9 | 2.1 | -- |
| | 3/21/94 | 48.7 | -- | 16.9 | 1.8 | -- |
| | 3/23/94 | 46.2 | 33 | 17.2 | 1.8 | -- |
| | 3/25/94 | 48.1 | -- | 17.3 | 1.7 | -- |
| | 3/28/94 | 46.0 | 35 | -- | -- | -- |
| | 3/30/94 | -- | -- | 17.7 | 1.3 | -- |
| | 4/6/94 | 41.9 | 11 | 19.1 | 0.5 | -- |
| | 4/8/94 | 47.3 | 2 | 18.6 | 0.8 | -- |
| | 4/11/94 | 45.2 | 2 | 18.5 | 1.0 | -- |
| | 4/13/94 | 44.6 | 5 | 18.3 | 1.1 | -- |
| | 4/15/94 | 46.6 | 2 | 17.9 | 2.5 | -- |
| | 4/18/94 | 46.3 | 2 | 17.7 | 1.2 | -- |
| | 4/19/94 | 45.0 | 17 | -- | -- | -- |
| | 4/21/94 | 50.7 | 31 | 17.2 | 1.2 | -- |
| | 4/22/94 | 52.3 | 2 | 17.2 | 1.4 | -- |
| | 4/25/94 | 42.8 | 2 | 17.2 | 1.5 | -- |
| | 4/28/94 | 39.0 | 22 | 16.3 | 2.9 | -- |
| | 5/2/94 | 41.9 | 2 | 16.7 | 1.4 | -- |
| | 5/4/94 | 42.0 | 2 | 16.7 | 1.6 | -- |
| | 5/6/94 | 42.6 | 2 | 16.6 | 1.4 | -- |
| | 5/9/94 | 43.3 | 2 | 16.7 | 1.4 | -- |
| | 5/11/94 | 43.7 | 2 | 17.0 | 1.2 | -- |
| | 5/13/94 | 43.8 | 2 | 16.9 | 1.4 | -- |
| | 5/16/94 | 42.2 | 9 | 16.8 | 1.5 | -- |
| | 5/19/94 | 40.3 | 11 | 16.4 | 1.4 | -- |
| | 5/20/94 | 42.9 | 2 | -- | -- | -- |
| | 5/31/94 | 44.2 | 2 | 16.4 | 1.5 | -- |
| D-2R | 7/19/94 | 22.1 | 78 | 21.1 | 0.1 | -- |
| | 7/22/94 | 21.1 | 78 | 21.0 | 0.1 | -- |
| | 7/25/94 | 15.6 | 76 | 20.9 | 0.0 | -- |
| | 8/8/94 | 22.0 | 80 | 21.0 | 0.4 | -- |
| | 8/10/94 | 22.0 | 78 | 21.1 | 0.0 | -- |
| | 8/12/94 | 22.0 | 81 | 21.0 | 0.0 | -- |
| | 8/15/94 | 22.0 | 78 | 21.1 | 0.0 | -- |
| | 8/17/94 | 22.0 | 78 | 21.1 | 0.0 | -- |
| | 8/22/94 | 23.0 | 81 | 21.0 | 0.0 | -- |
| | 8/24/94 | 23.0 | 81 | 21.1 | 0.0 | -- |
| | 8/26/94 | 22.0 | 81 | 21.1 | 0.0 | -- |
| | 8/29/94 | 23.0 | 78 | 21.1 | 0.0 | -- |
| | 8/30/94 | 22.0 | 78 | 21.1 | 0.0 | -- |

-- No measurement collected

**TABLE 4 (continued)**
**Summary of the Field Monitoring Data for the Vapor Extraction System at D-2/2R**
**Salisbury Town Gas Light Site**
**Chesapeake Utilities Corp. - Salisbury, Maryland**

| Extraction Well | Date | Vapor Temperature (degrees F) | Vapor Flow (SCFM) | Vacuum (in. Hg) | LEL (%) | PID Reading (corrected ppm) |
|---|---|---|---|---|---|---|
| D-2R | | | | | | |
| | 9/1/94 | 22.0 | 78 | 21.1 | 0.0 | -- |
| | 9/11/94 | 22.0 | 83 | 21.1 | 0.1 | -- |
| | 9/14/94 | 22.0 | 83 | 21.1 | 0.1 | -- |
| | 9/16/94 | 22.0 | 78 | 21.1 | 0.1 | -- |
| | 9/27/94 | 19.4 | 83 | 21.3 | 0.2 | -- |
| | 9/28/94 | 19.5 | 83 | 21.2 | 0.2 | -- |
| | 9/30/94 | 20.0 | 83 | 21.2 | 0.4 | -- |
| | 10/3/94 | 20.5 | 87 | 21.2 | 0.5 | -- |
| | 10/5/94 | 20.5 | 87 | 21.2 | 0.4 | -- |
| | 10/7/94 | 20.9 | 89 | 21.2 | 0.5 | -- |
| | 10/10/94 | 21.0 | 81 | 21.3 | 0.3 | -- |
| | 10/12/94 | 20.5 | 87 | 21.3 | 0.3 | -- |
| | 10/14/94 | 20.4 | 87 | 21.3 | 0.3 | -- |
| | 11/4/94 | 13.9 | 74 | 18.6 | 0.6 | -- |
| | 11/7/94 | 14.8 | 70 | 19.5 | 0.6 | -- |
| | 11/8/94 | 14.9 | 74 | 19.6 | 0.5 | -- |
| | 11/9/94 | 14.3 | 70 | 19.7 | 0.4 | -- |
| | 11/10/94 | 14.5 | 72 | 19.7 | 0.4 | -- |
| | 11/11/94 | 15.2 | 76 | 19.8 | 0.3 | -- |
| | 11/14/94 | 14.3 | 74 | 18.1 | 0.3 | -- |
| | 11/15/94 | 14.4 | 74 | 19.9 | 0.3 | 50 |
| | 11/16/94 | 17.6 | 83 | -- | -- | -- |
| | 11/17/94 | 18.0 | 83 | -- | -- | -- |
| | 11/21/94 | 17.8 | 83 | -- | -- | -- |
| | 11/23/94 | 17.9 | 87 | -- | -- | -- |
| | 11/28/94 | 16.8 | 87 | -- | -- | -- |
| | 12/1/94 | 17.0 | 85 | 21.0 | 0.3 | 60 |

-- No measurement collected

**TABLE 5**
**Summary of the Field Monitoring Data for the Vapor Extraction System at D-4**
**Salisbury Town Gas Light Site**
**Chesapeake Utilities Corp. - Salisbury, Maryland**

| Date | Vacuum (inches H2O) | Flow Rate (SCFM) | O2 (%) | CO (ppm) | PID Reading (ppm-ref hex) |
|---|---|---|---|---|---|
| 12/5/94 | 24.7 | 83 | 21.0 | 0.8 | 57 |
| 12/7/94 | 24.6 | 83 | 21.1 | 0.6 | -- |
| 12/8/94 | 24.7 | 83 | 19.0 | 0.4 | -- |
| 12/21/94 | 26.0 | 85 | -- | -- | 80 |
| 12/29/94 | 13.4 | 39 | -- | -- | -- |
| 1/2/95 | 15.0 | 71 | 16.5 | 1.5 | -- |
| 1/6/95 | 19.0 | 52 | -- | -- | -- |
| 1/10/95 | 19.0 | 53 | 20.0 | 0.4 | -- |
| 1/17/95 | 20.0 | 57 | -- | -- | -- |
| 1/26/95 | 24.0 | 63 | -- | -- | -- |
| 1/31/95 | 22.0 | 58 | 20.6 | 0.4 | 58 |
| 2/14/95 | 22.0 | 58 | 20.4 | 0.4 | -- |
| 2/16/95 | 22.0 | 58 | -- | -- | -- |
| 2/23/95 | 22.5 | 58 | 19.9 | 0.4 | -- |
| 3/7/95 | 21.5 | 56 | 19.5 | 0.2 | 65 |
| 3/13/95 | 23.0 | 58 | 19.8 | 1.0 | 35 |
| 3/22/95 | 23.5 | 57 | -- | -- | 39 |
| 5/9/95 | 23.0 | 61 | 9.1 | 1.1 | 33 |
| 6/21/95 | 22.4 | 59 | 20.6 | 1.2 | -- |
| 7/22/95 | 24.0 | 56 | 21.2 | 0.0 | 55 |
| 8/7/95 | 23.0 | 57 | -- | -- | -- |
| 8/29/95 | 24.0 | 57 | 20.7 | 0.0 | 32 |
| 9/26/95 | 24.0 | 57 | 18.7 | 0.1 | 56 |
| 10/23/95 | 26.0 | 57 | 19.3 | 0.2 | 58 |
| 10/31/95 | 26.0 | 57 | 19.2 | 0.2 | 154 |
| 11/11/95 | 25.5 | 55 | -- | -- | -- |
| 11/18/95 | 24.5 | 63 | -- | -- | -- |
| 11/29/95 | 26.0 | 60 | -- | -- | -- |
| 12/1/95 | 26.5 | 59 | -- | -- | 54 |
| 12/6/95 | 25.0 | 55 | 19.8 | 2.1* | 30 |
| 12/13/95 | 24.5 | 57 | 20.1 | 2.1* | 32 |
| 12/21/95 | 26.0 | 57 | 20.0 | 2* | 28 |

-- No measurement collected
* As hexane (reading collected with Tank Techtor)

**TABLE 6**
**Summary of the Field Monitoring Data for the Vapor Extraction System at D-1**
**Salisbury Town Gas Light Site**
**Chesapeake Utilities Corp. - Salisbury, Maryland**

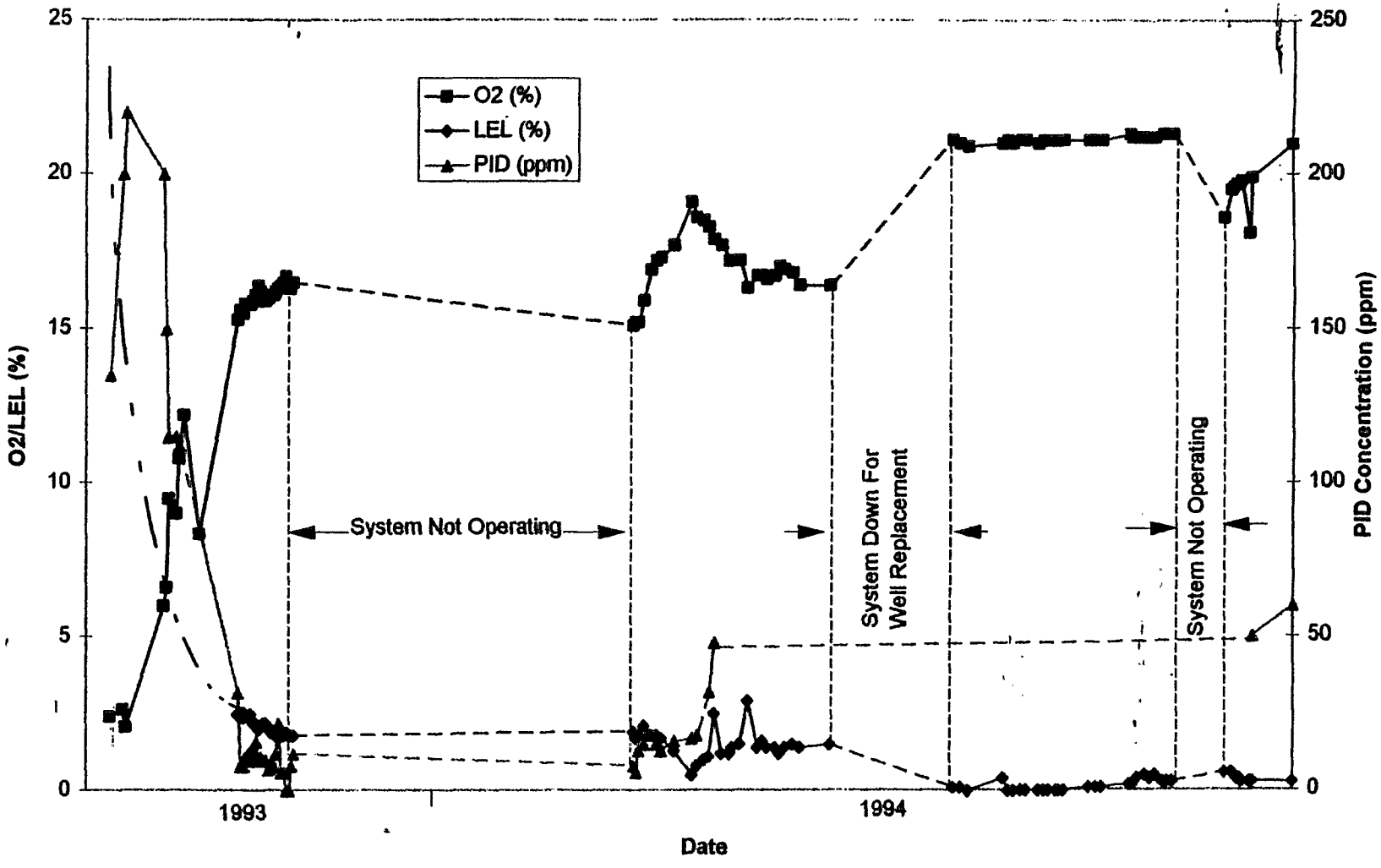
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | PID Reading [illegible] |
|---|---|---|---|---|---|
| 10/18/94 | 32.5 | 52 | 21.2 | 0.1 | 20 |
| 10/19/94 | 34.0 | 57 | 20.5 | 0.1 | -- |
| 10/21/94 | 34.1 | 57 | 20.7 | 0 | -- |
| 10/24/94 | 31.8 | 57 | 20.7 | 0 | -- |
| 10/26/94 | 31.9 | 57 | 20.7 | 0 | -- |
| 10/27/94 | 32.9 | 57 | 20.7 | 0 | -- |
| 10/28/94 | 32.7 | 57 | 20.7 | 0 | -- |
| 10/31/94 | 30.5 | 61 | 20.7 | 0 | -- |
| 11/2/94 | 29.0 | 61 | 20.7 | 0 | -- |
| 11/3/94 | 28.3 | 63 | 20.7 | 0 | -- |
| 11/4/94 | 28.1 | 63 | 20.7 | 0 | -- |

-- No measurement collected

had accumulated in Well D-2 during the second month of SVE operation. No product had been measured in that well prior to SVE activities. The accumulated product was removed by a combination of passive recovery devices and manual bailing. SVE activities resumed following the permit waiver, until system operations were postponed in late December 1993 due to very cold weather and icing, which prevented both normal system operation and access to the system for monitoring. After resuming operation in March, biological fouling of the well screen in D-2 eventually necessitated the construction of a replacement well (D-2R) in June of 1994. In early June, more product (1.83 feet) had accumulated in well D-2 as a result of SVE. Vapor extraction continued at D-2R until the beginning of December, 1994, when monitoring data consistently demonstrated that product accumulation and contaminant levels in extracted vapors were negligible and subsurface oxygen levels had been restored to near ambient conditions.

As can be seen in Table 4 and Figure 8, oxygen values rose to or approached levels of atmospheric oxygen (20.7%) and explosive gases have approached zero percent LEL at D-2/D-2R during SVE operation. LEL and oxygen levels at D-4 and D-1 have hovered at levels comparable to the final values at D-2/D-2R throughout their respective monitoring periods, as indicated in Tables 5 and 6. Extracted soil-vapor quality data indicate that volatile petroleum hydrocarbons in the unsaturated zone have been substantially reduced in the vicinity of the Former Production Building.

Figure 8
O2, LEL and PID Values for D-2/D-2R, August 1993 - December 1994
Chesapeake Utilities Corporation
Salisbury, Maryland

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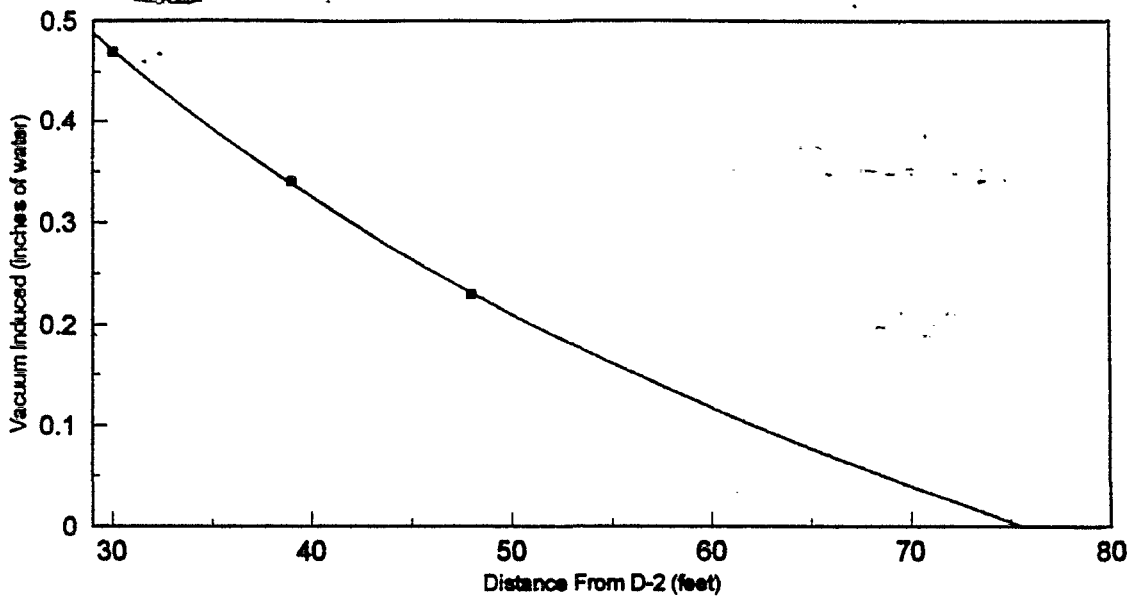
# APPENDIX C

## VAPOR EXTRACTION START-UP TESTING
## LINEAR REGRESSION OF DISTANCE VS. VACUUM DATA

## Vapor Extraction Startup Test, Former Salisbury Town Gas Light Site

Vacuum Induced versus Distance From D-2

32.7 cfm extraction flowrate @ 45 inches of water applied vacuum




Raw Rata - Collected 9/9/93

| Observation Well | Distance from D1 (feet) | Induced Vacuum (inches of water) |
|---|---|---|
| D-1 | 39.0 | 0.34 |
| D-3 | 30.0 | 0.47 |
| D-4 | 48.0 | 0.23 |

Regression Data

$y = a + b (\ln x)$

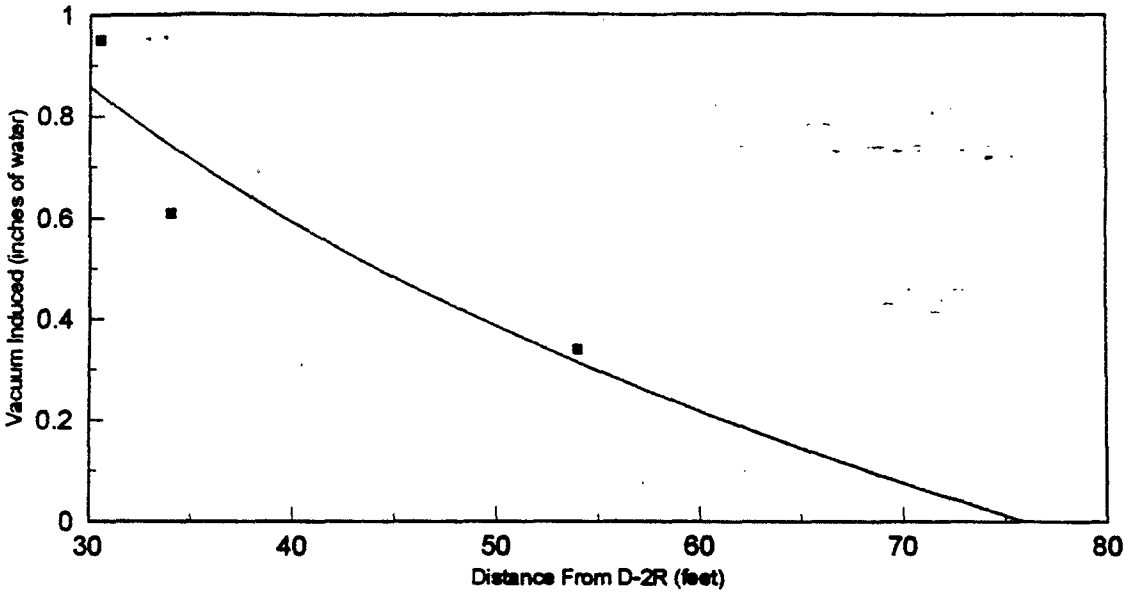
a = 2.20571, b = -0.50998, R-square = 0.99963

**Radius of Influence: @ y = 0, x = 75.6 feet**

## Vapor Extraction Startup Test, Former Salisbury Town Gas Light Site

Vacuum Induced versus Distance From D-2R

78.5 cfm extraction flowrate @ 22 inches of water applied vacuum




Raw Rata - Collected 8/8/94

| Observation Well | Distance from D1 (feet) | Induced Vacuum (inches of water) |
|---|---|---|
| D-1 | 34.0 | 0.61 |
| D-3 | 30.5 | 0.95 |
| D-4 | 54.0 | 0.34 |

Regression Data

$y = a + b (\ln x)$

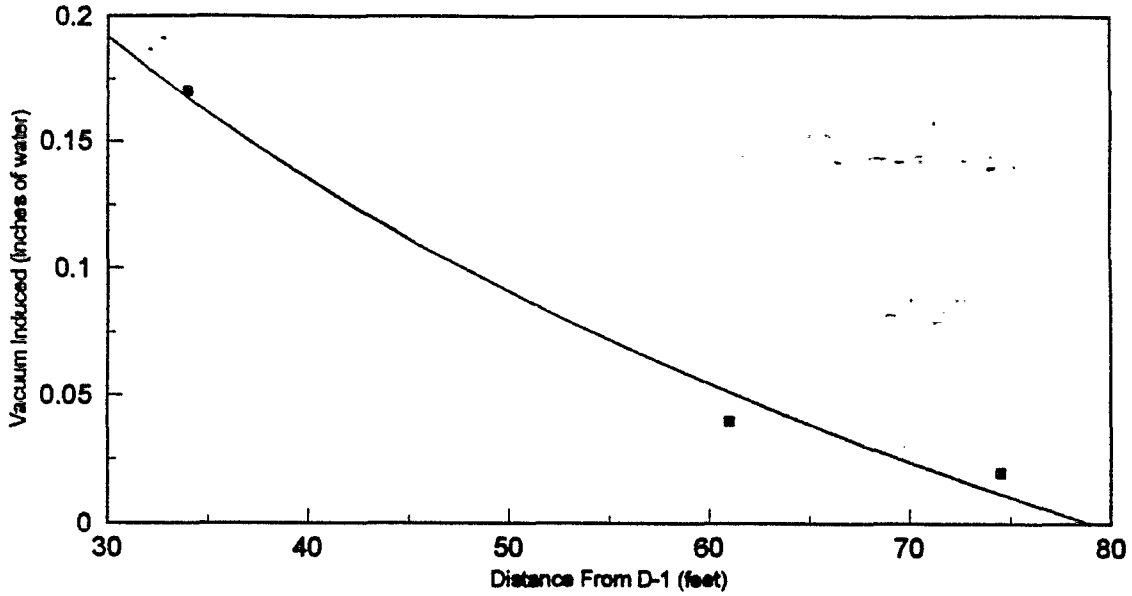
a = 4.00149, b = -0.92421, R-square = 0.84130

**Radius of Influence: @ y = 0, x = 75.9 feet**

## Vapor Extraction Startup Test, Former Salisbury Town Gas Light Site

Vacuum Induced versus Distance From D-1

19.6 cfm extraction flowrate @ 35 inches of water applied vacuum




Raw Rata - Collected 10/18/94

| Observation Well | Distance from D-1 (feet) | Induced Vacuum (inches of water) |
|---|---|---|
| D-2R | 34.0 | 0.17 |
| D-3 | 61.0 | 0.04 |
| D-4 | 74.5 | 0.02 |

Regression Data

$y = a + b (\ln x)$

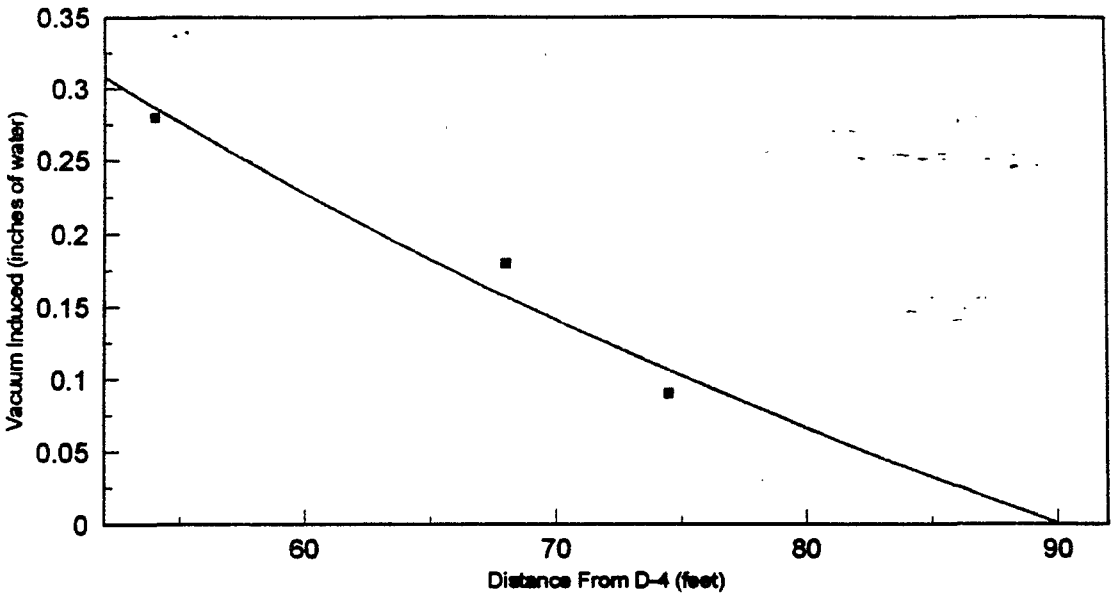
a = 0.86623, b = -0.19825, R-square = 0.98453

**Radius of Influence: @ y = 0, x = 79.0 feet**

## Vapor Extraction Startup Test, Former Salisbury Town Gas Light Site

Vacuum Induced versus Distance From D-4

95.0 cfm extraction flowrate @ 26 inches of water applied vacuum




Raw Rata - Collected 12/21/94

| Observation Well | Distance from D-4 (feet) | Induced Vacuum (inches of water) |
|---|---|---|
| D-1 | 74.5 | 0.09 |
| D-2R | 54.0 | 0.28 |
| D-3 | 68.0 | 0.18 |

Regression Data

$y = a + b (\ln x)$

a = 2.52003, b = -0.55994, R-square = 0.95473

**Radius of Influence: @ y = 0, x = 90.1 feet**