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DATE July 27, 1993
IN REPLY REFER TO ADO/93-614-U
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Mr. Jerry Bellows
Manager, Los Alamos Area Office
Department of Energy
MS A316
Los Alamos, NM 87544

Dear Mr. Bellows:

SUBJECT: PILOT EXTRACTION STUDY PLAN FOR THE ORGANIC VAPOR PLUME AT MATERIAL DISPOSAL AREA (MDA)-L

Enclosed are two copies of the Pilot Extraction Study Plan for the Organic Vapor Plume at MDA-L, to submit to the enviornmental Protection Agency, Region 6. The plan is a revised appendix to the RFI Work Plan for OU 1148.

Should you have any questions, please call Jim Aldrich with the Environmental Restoration Program at 505-665-4230.

Sincerely,

Allen Tiedman
Associate Director for Operations
Environmental Management Division

AT/rr

Enclosure: Two copies of the Pilot Extraction Study Plan for the Organic Vapor Plume at MDA-L

Cy: (w/ one copy of enclosure)
K. Bitner, DOE/AFO, MS A906
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Ms. Guanita Reiter, Acting Chief
RCRA Permits Branch
U.S. Environmental Protection Agency
Region 6
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

Dear Ms. Reiter:

SUBJECT: PILOT EXTRACTION STUDY PLAN FOR THE ORGANIC VAPOR PLUME AT MATERIAL DISPOSAL AREA (MDA)-L

Enclosed are two copies of the Pilot Extraction Study Plan for the Organic Vapor Plume at MDA-L. The plan is a revised appendiz to the Resource Conservation and Recovery Act Facility Investigation Work Plan for Operable Unit 1148.

Should you have any questins, please call Steve Slaten at 505 665-5050.

Sincerely,

Jerry Bellows
Los Alamos Area Office Manager
US Department of Energy

AT/rr

Enclosure: Pilot Extraction Study Plan for the Organic Vapor Plume at MDA-L

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EM-13 File
S. Slaten, LAAO, MS A316
P. Aamodt, EM-13, MS M992
D. Neeper, MEE-13, MS J577

CERTIFICATION

The attached document, "Pilot Extraction Study Plan for the Organic Vapor Plume at MDA L" is true and accurate to the best of our knowledge. The document has been through internal formal review to ensure accuracy in accordance with the Los Alamos National Laboratory (LANL) Environmental Restoration (ER) Program quality assurance procedure. The formal review comments and the resolutions to these comments are part of the public record and are available in the LANL ER Records Processing Facility. The document is being submitted to the Environmental Protection Agency as a revised appendix to the RFI Work Plan for OU 1148.

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Date: 7/26/93

CERTIFICATION

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violation.

Document Title: "Pilot Extraction Study Plan for the Organic Vapor Plume at MDA L"

Name: _____ Date: 7-28-93
Allen J. Tiedman
Associate Director for Operations
Los Alamos National Laboratory

Name: _____ Date: _____
Joseph Vozella
Acting Chief
Los Alamos Environment, Health, & Safety
US Department of Energy

RFI WORK PLAN
OPERABLE UNIT 1148

APPENDIX A

PILOT EXTRACTION STUDY PLAN
FOR THE ORGANIC VAPOR PLUME AT MDA L

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APPENDIX A

PILOT EXTRACTION STUDY PLAN FOR THE ORGANIC VAPOR PLUME AT MDA L

1.0 INTRODUCTION

This Appendix to the RFI Work Plan of Operable Unit 1148 presents the pilot extraction study plan (PESP) to remediate the organic vapor plume emanating from inactive subsurface disposal units at material disposal area (MDA) L (SWMU 54-006).

The purpose of the pilot study is to investigate:

a) retraction of the horizontal boundary of the plume to the vicinity of the security fence at MDA L;
b) retraction of the bottom of the plume to the depth of the basalt layer (if indeed the plume has spread to lower depths); and
c) a means for preventing any future regrowth of the plume away from the subsurface sources.

This plan describes data that are required concerning:

a) natural mechanisms responsible for the generation of the plume, in order to evaluate the engineered application of natural mechanisms to prevent future regrowth of the plume;
b) characteristics of the plume that are necessary to design the corrective action; and
c) characteristics of the subsurface geology that are necessary to design the corrective action.

The field investigations for this study are integrated with field investigations for the RFI to the extent practicable. For example, drill holes will gather data for this study and the RFI. The same drill holes will be used as vapor extraction wells, vapor monitor wells, or air injection wells during pilot extraction of the plume. Some of the drill holes might be used in the future as part of an engineered system that uses passive mechanisms to prevent future regrowth of the plume after it has been retracted by forced venting.

This plan identifies data and outlines pilot tests that are required for design of a full scale vapor extraction system. If the investigations and tests are successful, a full scale vapor extraction system will be designed and implemented. (If the investigations and tests are not successful, a new revised plan will be submitted to EPA.) The objective of this system will be to retract the vapor plume to the vicinity of the disposal shafts that are the evident source of the plume. Even if the extraction process removed all available volatile materials from the disposal shafts, a buried container might in principal rupture at some time in the future, thereby becoming a new source of volatile contaminants. Therefore, after extraction, subsequent regrowth of the plume from any present or future sources in the shafts will be prevented by installation of physical barriers or by continued venting of the region near the

disposal shafts. Data obtained during the investigations described in this plan may enable design of a passive venting system for long-term control of the source region. A plan for the long-term control, with supporting data, will be submitted to EPA before the control is installed.

1.1. Background

MDA L is a 2.58 acre site within TA-54 that was historically used as a disposal site for hazardous chemicals. Land disposal occurred from the late 1950's to 1985. The MDA is currently used for RCRA-permitted chemical waste storage and treatment, and for mixed waste storage under interim status authority. The location of the MDA is shown in Figure A-1. Historical records indicate that solvents were disposed in one pit (Pit A), and 34 disposal shafts. Three impoundments were also used for waste disposal at the MDA. However, there is no information that solvents were disposed in the impoundments. The location of inactive, subsurface disposal units within MDA L are shown in Figure A-2.

Pit A measures 200 ft long, 12 ft wide, and 12 ft deep. Disposal shafts at MDA L range from 3 ft to 8 ft in diameter and 60 ft to 65 ft in depth. The 28 disposal shafts in the eastern part of the MDA (shafts 1-28) were active from February, 1973 to December, 1985. The six disposal shafts in the western part of the MDA (shafts 29-34) were active from December, 1983 to April, 1985. (See Table 5.3-2 in the work plan for dates of use and capacity of the individual disposal units.) Additional information on the history of waste disposal at MDA L is presented in Sec 5.3.1 of the work plan.

1.2 Environmental Setting

The general environmental setting at TA-54 including MDA L is presented in Chapter 3 of the work plan. Specific attributes of the environmental setting that are important to the migration of the OVP are discussed here. MDA L is located on flat land on top of a narrow finger mesa (Mesita del Buey) at an elevation of approximately 6800 ft. The mesa is approximately 400 ft wide at the MDA and is bounded on the north by Canada del Buey and on the south by Pajarito Canyon. The canyon bottoms are approximately 120 feet below the top of the mesa.

The geologic setting of Mesita del Buey is described in Chapter 3 of the work plan and is briefly reviewed here with regard to the setting at MDA L. A geologic section along the axis of the mesa is shown in Figure A-3. Several layers of tuff, formed by volcanic ash flows, extend from the surface to a depth of 200 or 300 ft. The tuff is underlain by basalts with inter-layered conglomerates. As shown in Figure A-3 the volcanic tuff section varies in thickness because of the irregular surface of the basalt. The tuff and a thick section of the basalt are unsaturated. The top of the main aquifer is estimated to be at a depth of 850 feet below the MDA. Surge beds within Unit 2 of the Tshirege member (see Figure A-3) may provide a preferential pathway for lateral migration of contaminants. Refer to Section 3.5.2.3 off the work plan for more information on the surge beds. There is no information on characteristics of the basaltic rock below the MDA. Vertical joints and fractures are common in the basalt at outcrops in the Rio Grande Valley. There is no information to indicate whether the basalt forms a barrier to vertical migration of volatile contaminants.

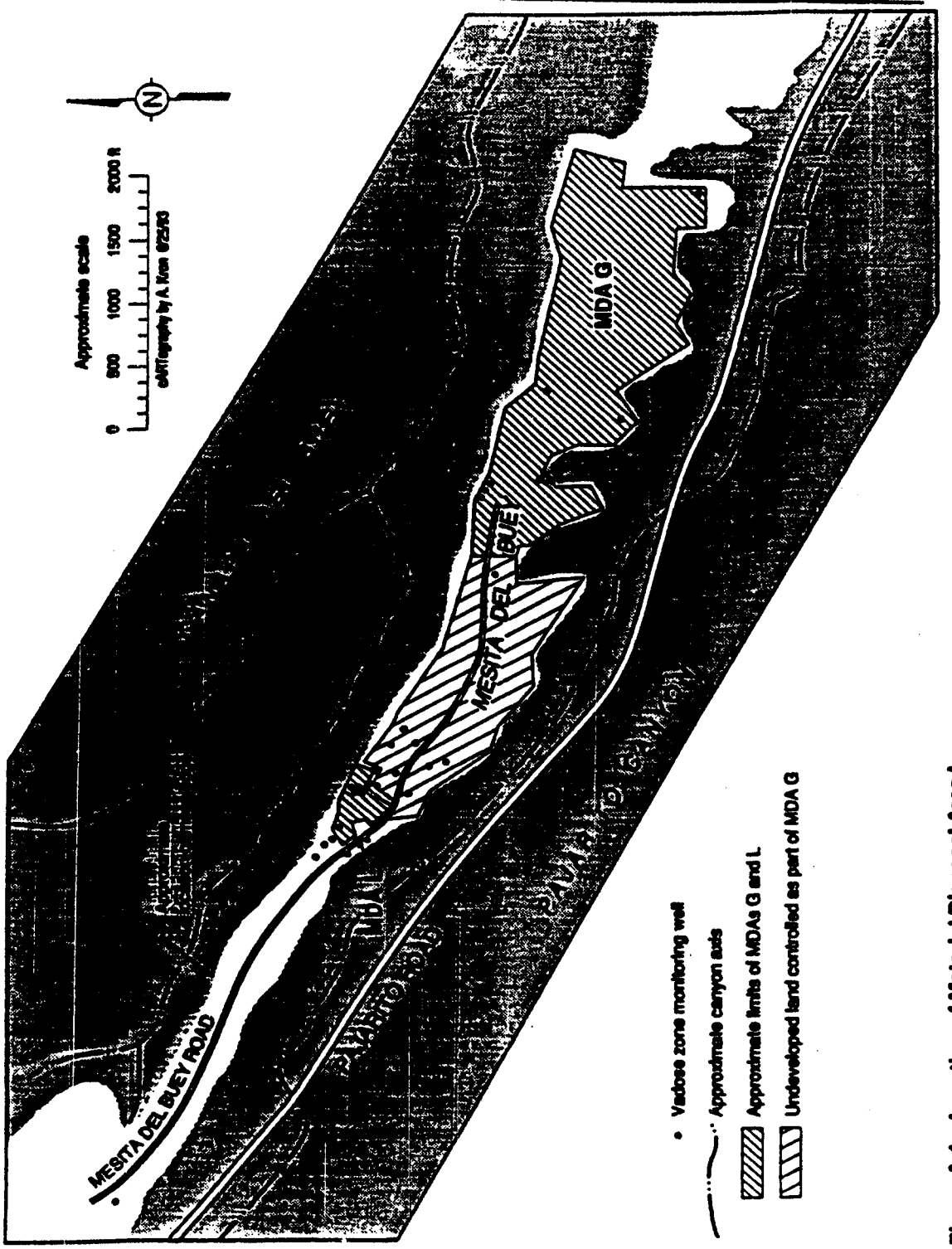


Figure A-1. Location of Material Disposal Area L

Most fractures within the tuff are nearly vertical, generally exhibit spacing intervals between 3 feet and 6 feet, and are believed to be an important pathway for lateral and vertical migration of vapor phase contaminants. A field study of fractures in the walls of a new disposal pit in MDA G was performed in the past year. The pit is 45 feet deep. One objective of this study was to provide information for the optimal angle and direction of drill holes at MDA L to intercept the most fractures at depths greater than 30 feet below the mesa.

Interception of fractures is expected to improve the performance of vapor extraction wells. Fractures in the pit at depths greater than 30 feet display a dominant east-west direction. The preferential dip direction is to the north. For 120 measurements, the median value of the dip angle is 84 degrees from horizontal. The mean value of the dip angle is 75 degrees from horizontal.

In 1985 and 1986, a variety of tests were conducted to evaluate physical characteristics of the unsaturated volcanic tuff beneath MDA L. The tests included instrumentation of boreholes with thermocouple psychrometers, thermistors, and pressure gages (transducers); air injection and vacuum tests in boreholes using packers to isolate test intervals; and laboratory tests on core samples. Complete test results can be found in the IT Corporation report (1987, 0327) and the Kearl et al Report (Citation of Bendix GJ44 1986,0135). A summary of the test results is presented here:

- Porosity of the volcanic tuff is high with average values near 50%.
- Air permeability varies between 10^{-9} and 10^{-7} cm^2 with the highest values measured in fractured zones. The measurements were from packer tests performed in boreholes with air injection.
- Intrinsic permeability (Klinkenberg tests on core samples) varies between 1.5×10^{-9} and 2.5×10^{-9} cm^2.
- Water potential varies from -1 bar near the surface to as low as -15 bars below 30 foot depth. The measured variation is erratic, possibly a result of stability problems with the psychrometers that were used.
- Water content (gravimetric measurement) is usually in the range of 2%-4% (by volume), except at some fractures, or within the more highly welded portion of Unit 1b, or at some contact surfaces, where the content may reach 10% or 20%.
- Temperature is in the range 9-10°C, and is nearly independent of depth, below 30 ft depth. The data indicates a (peak-to-peak) temperature variation of approximately 2°C at all sensors below 30 feet during the month of data acquisition centered on November 1, 1985. However, one cannot tell if this is a diurnal swing, a monotonic seasonal drift or variation correlated with some other phenomenon.

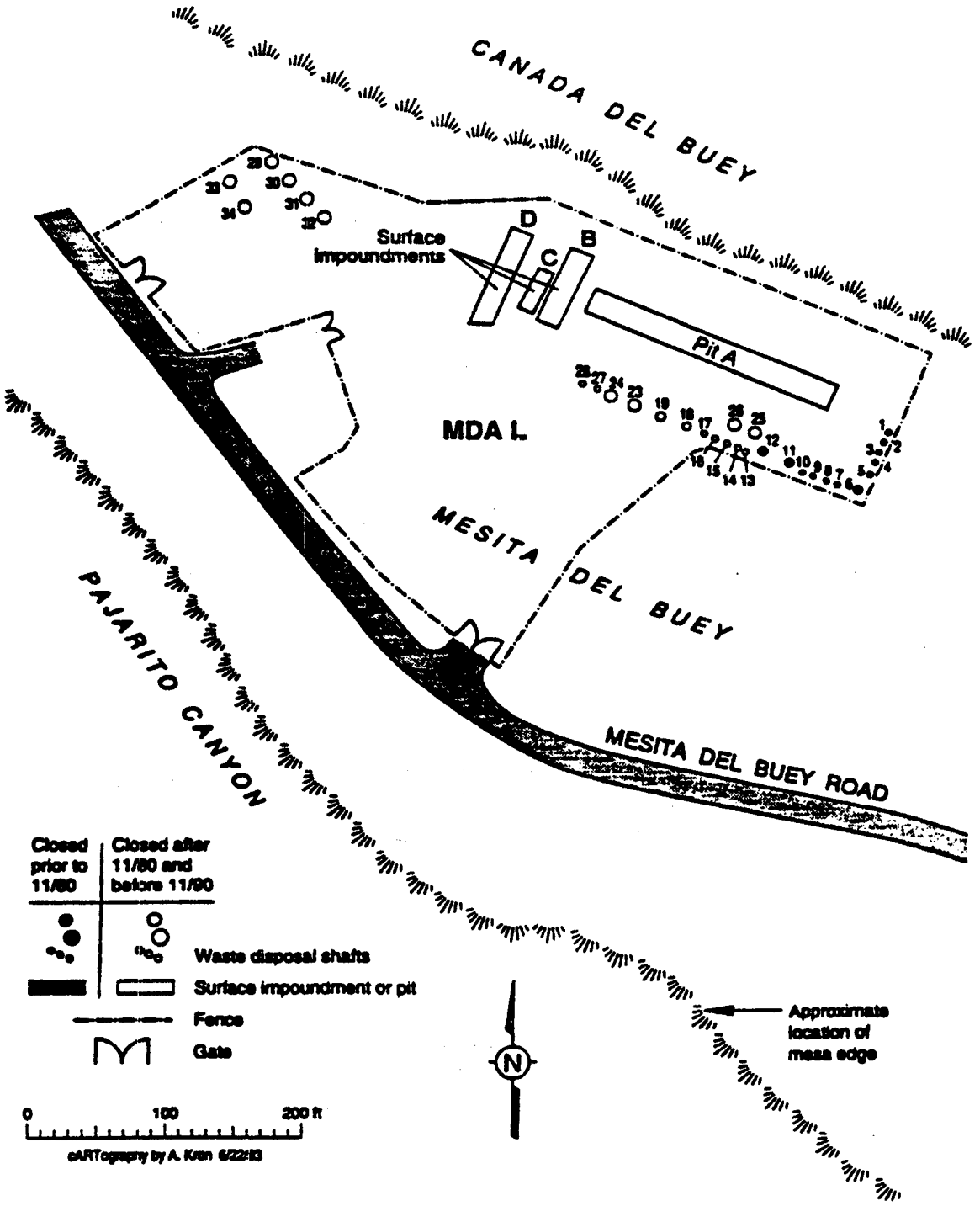


Figure A-2. Location map of inactive pits, shafts, and impoundments (SWMU 54-006) at MDA L.

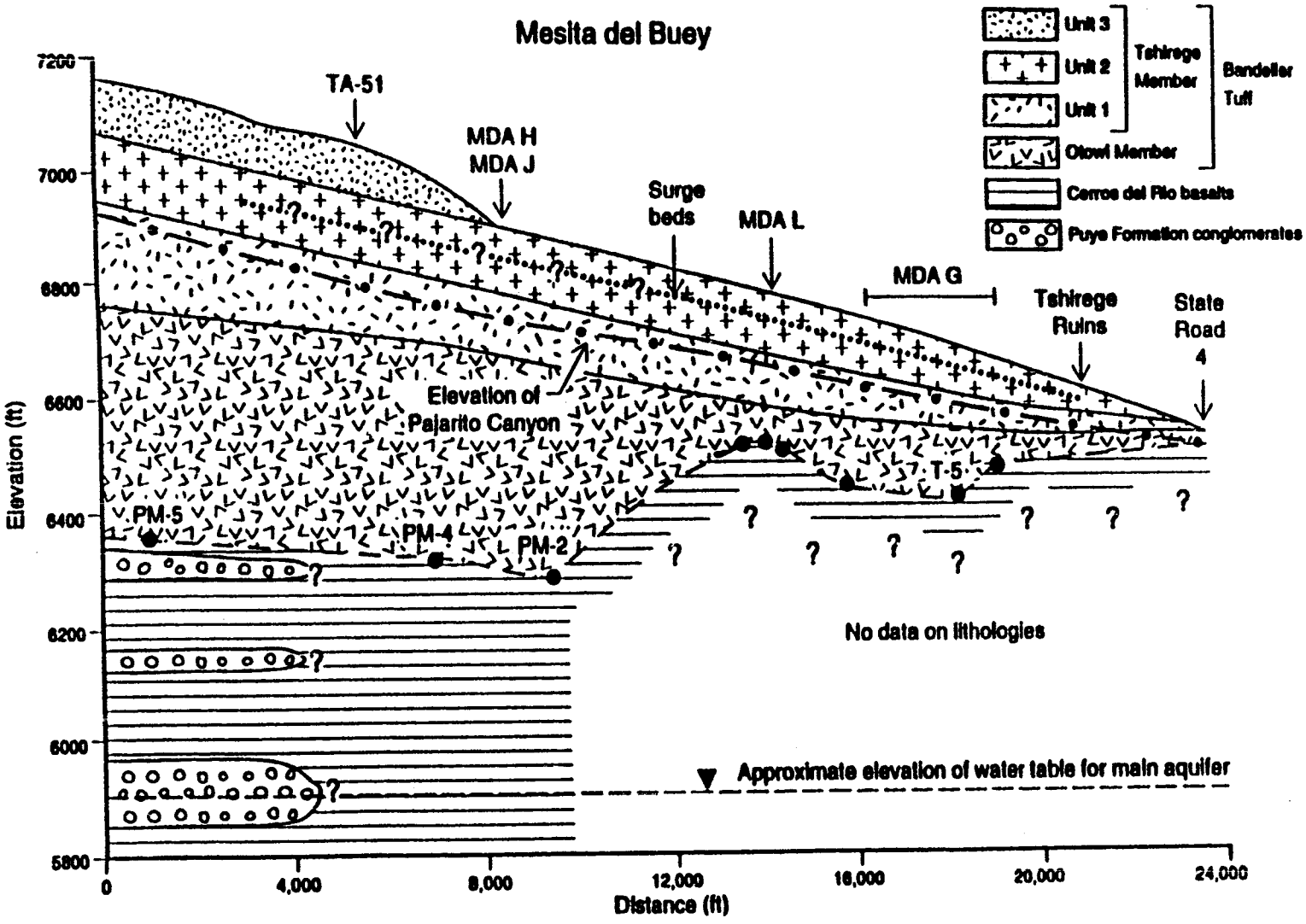


Figure A-3. Profile of Mesita del Buey showing top of mesa, elevation of floor of Pajarito Canyon, and subsurface geologic units and elevation of water table in main aquifer.

- Pressure was measured at the surface and at various depths by transducers. However, review of instrument specifications reveals that the transducers all measured absolute pressure, and were insufficiently sensitive to resolve either typical atmospheric fluctuations or the resulting damped fluctuations at depth.

- Moisture characteristics were measured on core samples over the range of 0 to -15 bars potential. At -15 bars, the volumetric moisture of various samples varied between 0.1% and 10%.

A subsurface plume of vapor is usually considered to spread by diffusion. However, vapor can be dispersed by natural subsurface air flow. Cyclic variations in barometric pressure may cause subsurface air flow in the mesa. The depth in the mesa to which flow is affected by atmospheric pressure change is not known. Rock dilatation due to cyclic gravitational forces may also force air flow in the mesa, probably to great depths. Diurnal and seasonal temperature differences between the rock within the mesa and that of the surrounding atmosphere may affect air flow within the mesa. Wind pressure against the walls of the mesa may also affect air flow within the mesa. Understanding the influence of the natural mechanisms on subsurface air flow is important to evaluating whether an engineered passive system can be used for long term control of the organic vapor plume. Measurements will be made in monitor wells and at land surface to evaluate these mechanisms.

2.0 CURRENT UNDERSTANDING OF THE ORGANIC VAPOR PLUME

2.1 Analysis of Gas Samples

The vapor plume is monitored by a network of 19 multiport monitor wells that are located within and surrounding MDA L. The monitor well locations are shown on Figure A-4. The date of well installation, the construction design, and the depth intervals for sampling ports in each monitor well are listed in Table A-1. Gas samples are collected quarterly. Analytical data are available from June 1988 to the present. Gas samples are analyzed for the compounds listed in Table A-2. The field procedure for collecting gas samples is to first extract a calculated volume of pore gas at each port to purge gas present within the well tubing. Next, 1.2 liters of air was drawn through a cartridge that contained a charcoal sorbent. In the laboratory, carbon disulfide is used to extract VOCs from the cartridge. Analysis is performed with a gas chromatograph/mass spectrometer (GC/MS). The analytical results are reported as micrograms of contaminant per 1.2 L of air. In order to convert this value to ppmv, the temperature and pressure of the extracted air must be known. These data are not available. Therefore, the analytical results are reported in this pilot extraction study plan as μgm/1.2L, which is approximately equal to parts per million (mass). An improved sampling and analytical procedure is being developed.

The principal vapor phase contaminants listed in descending order of concentration are 1,1,1-trichloroethane (TCA), trichloroethene (TCE), carbon tetrachloride, chloroform, tetrachloroethene (PCE), toluene, and benzene. Other contaminants that have been detected at much lower concentrations include chlorobenzene, xylenes, and 1,2,4-trimethylbenzene.

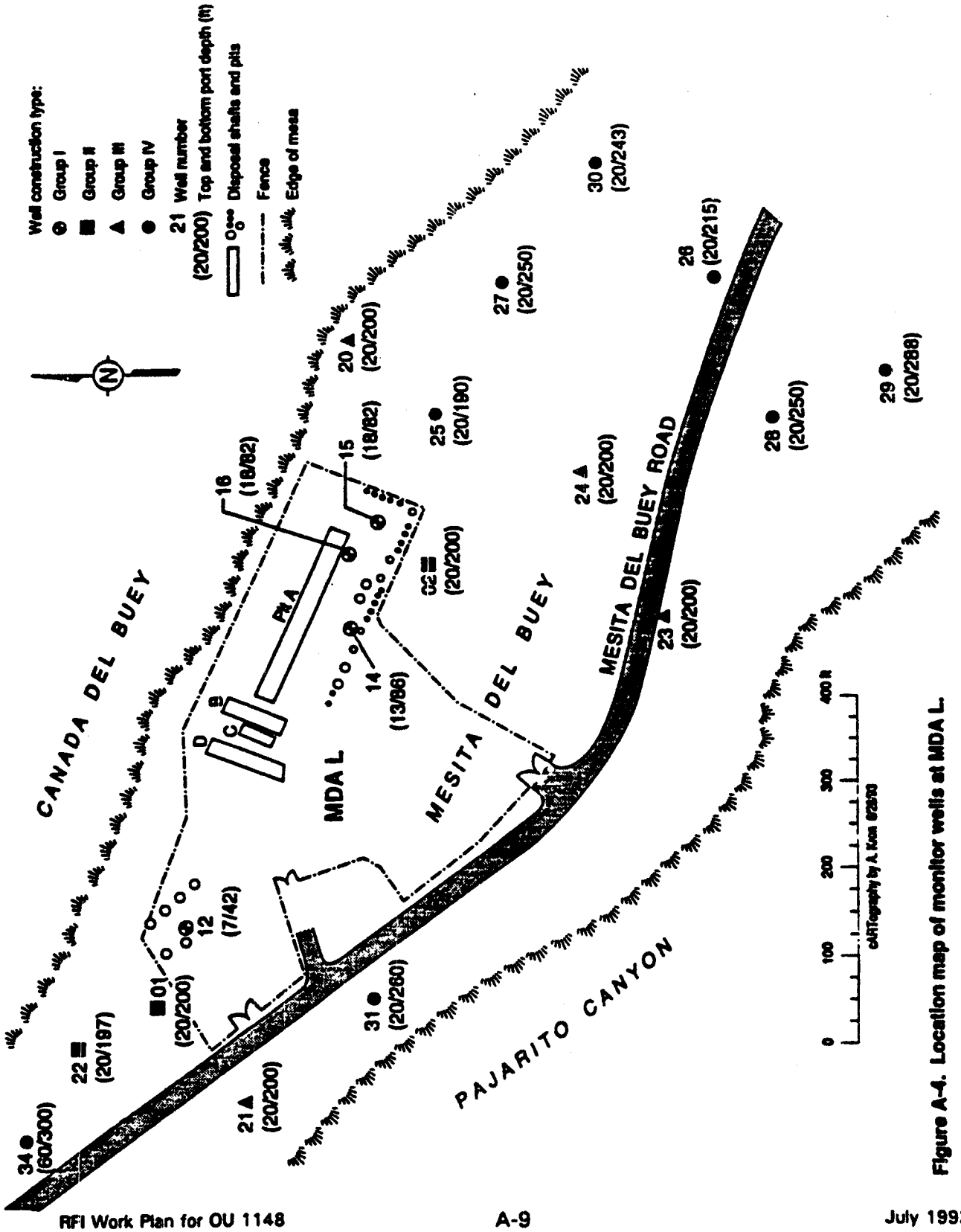


Figure A-4. Location map of monitor wells at MDA L.

TABLE A-1

INSTALLATION INFORMATION ON MONITOR WELLS AT MDA L

WELL[a] NUMBER	INSTALLATION DATE	CONSTRUCTION METHOD[b]	SAMPLE PORT DEPTH (FEET FROM SURFACE)
12	Summer 1985	1	7,27,42
14	Summer 1985	1	13,31,46,86
15	Summer 1985	1	18,31,82
16	Summer 1985	1	7,18,31,82,102
01	Summer 1986	2	20,40,60,80,100,130,140,160,180,200
02	Summer 1986	2	20,40,60,80,100,120,140,160,180,200
20	Summer 1986	3	20,40,60,80,100,130,140,160,180,200
21	Summer 1986	3	20,40,60,80,100,120,140,160,180,200
22	Summer 1986	2	20,40,60,80,100,120,140,160,180,197
23	Summer 1986	3	20,40,60,80,100,120,140,160,180,200
24	Summer 1986	3	20,40,60,80,100,120,140,160,180,200
25	Summer 1988	4	20,60,100,160,190
26	Summer 1988	4	20,60,100,160,200,215
27	Summer 1988	4	20,60,100,160,200,220,250
28	Summer 1988	4	20,60,100,160,200,220,250
29	Summer 1988	4	20,60,100,160,200,220,260,288
30	Summer 1988	4	20,60,100,160,200,220,243
31	Summer 1988	4	20,60,100,160,200,220,260
34	Summer 1988	4	60,100,160,200,220,260,300

(a) Well locations are shown on Figure A-4

(b) Group 1 wells are constructed with welded sample ports on a continuous galvanized steel pipe. Sample tubes run inside the pipe from each sample port to the surface. The annulus space for each sample interval is filled with a 5 ft thick graded sand pack with bentonite seals above and below the sand pack. The annulus space between sample intervals is filled with a bentonite/gravel mixture. Group 1 wells are the only wells constructed with the continuous pipe in the borehole.

Group 2, 3, and 4 wells have individual sampling tubes running from sample zones to the surface.

- In Group 2 wells individual sample zones consist of 5 ft thick graded sand packs with uppe and lower bentonite seals that are 1-3 ft thick. The borehole is filled with crushed tuf between sample intervals.

- In Group 3 wells, individual sample intervals are 20 ft thick and are filled with crushed tuff Thin (1 ft) bentonite seals separate each interval.

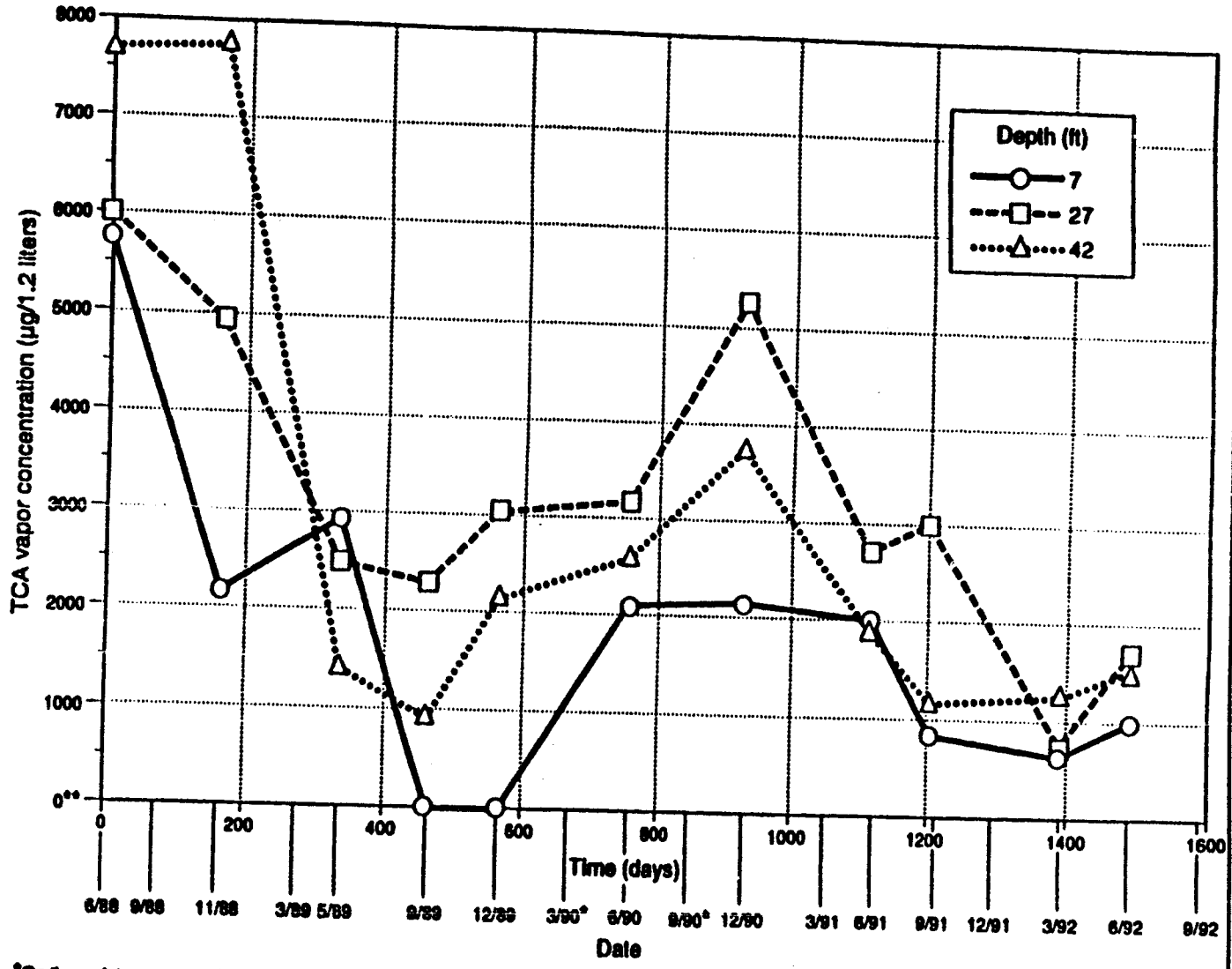
- In Group 4 wells sample ports were separated by a distance of 20 ft and the borehole wa back-filled with clean sand. No bentonite layers were used to isolate individual sample zones

TABLE A-2

ANALYTES FOR QUARTERLY GAS SAMPLES COLLECTED IN CHARCOAL CARTRIDGES FROM MONITOR WELLS AT MDA L

ANALYTE	CAS#
Ethylbenzene	100414
Bromobenzene	108861
Toluene	108883
Chlorobenzene	108907
Tetrachloroethene	127184
Mix-xylenes	1330207
Carbon Tetrachloride	56235
Chloroform	67663
Benzene	71432
1,1,1-Trichloroethane	71556
Trichloroethene	79016
o-Xylene	95476
1,2,4-Trimethylbenzene	95636

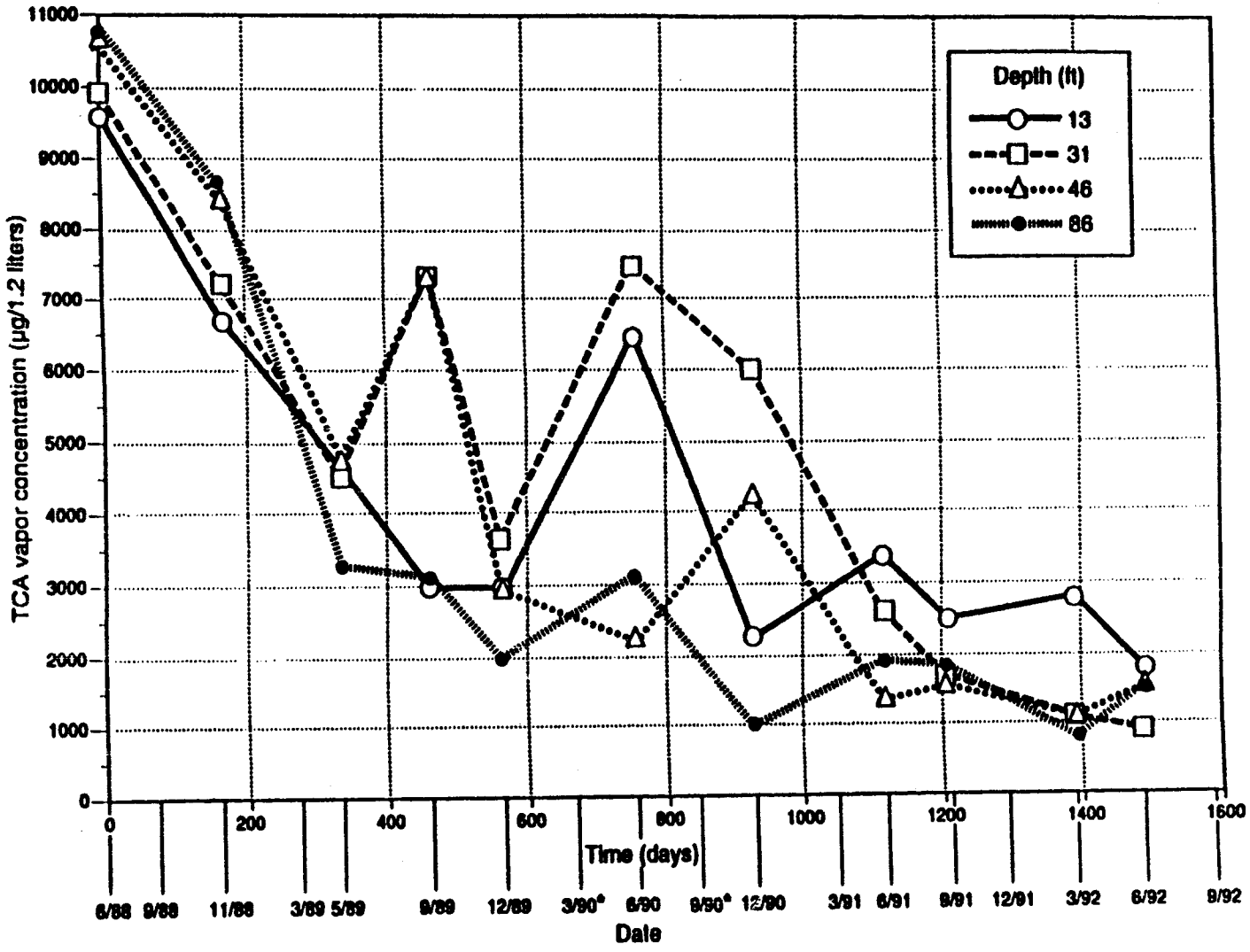
Note: Samples are taken by passing a known volume of gas phase sample through a sample cartridge that contains charcoal as a sorbent. Sample constituents are extracted from the cartridge with carbon disulfide. Analysis is by GC/MS.



*On these dates measured values in all samples were spurious.

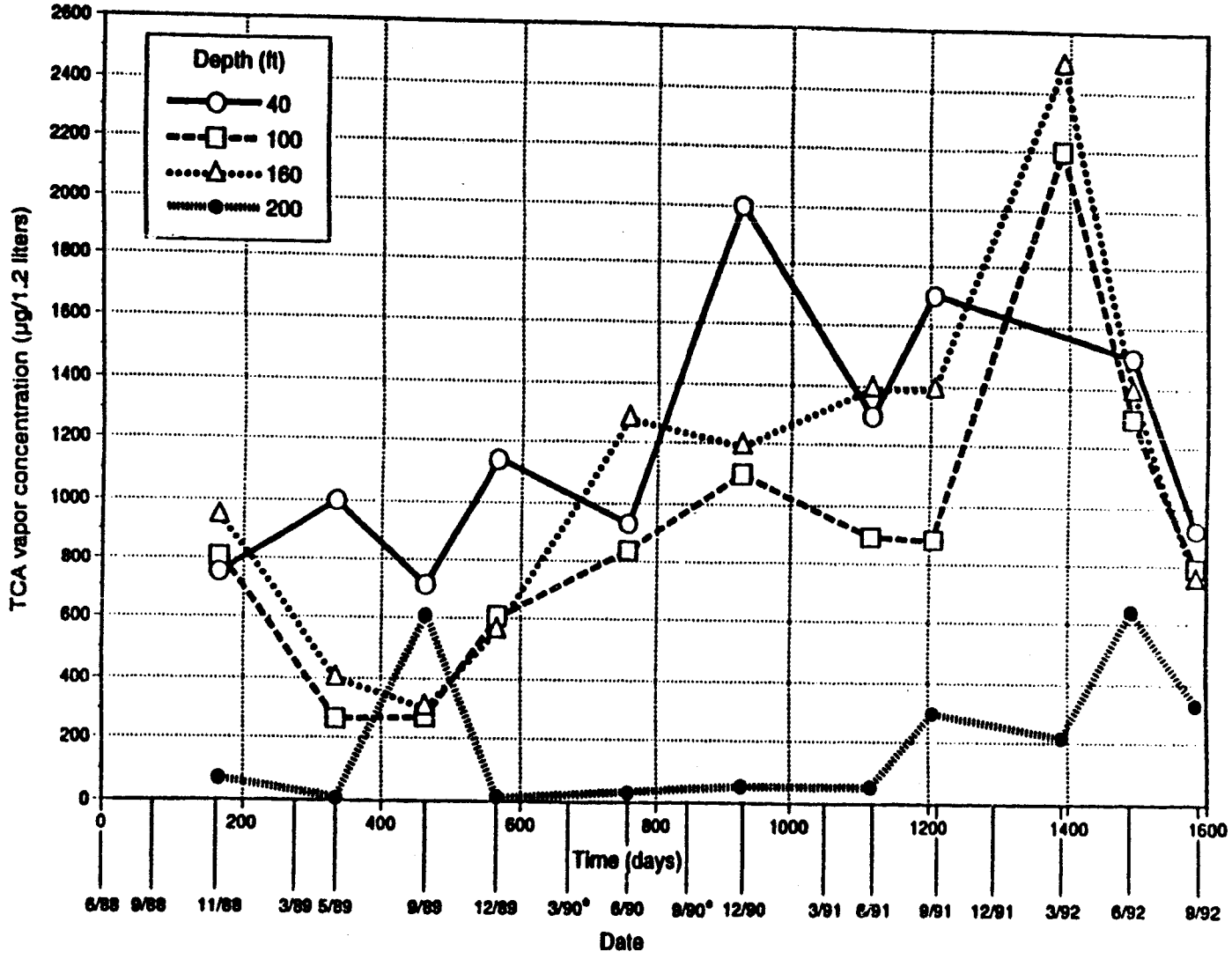
**Zero values indicate contaminant was not detected in the samples.

Figure A-5. Time-series TCA vapor concentration in gas samples from ports in Well #12.



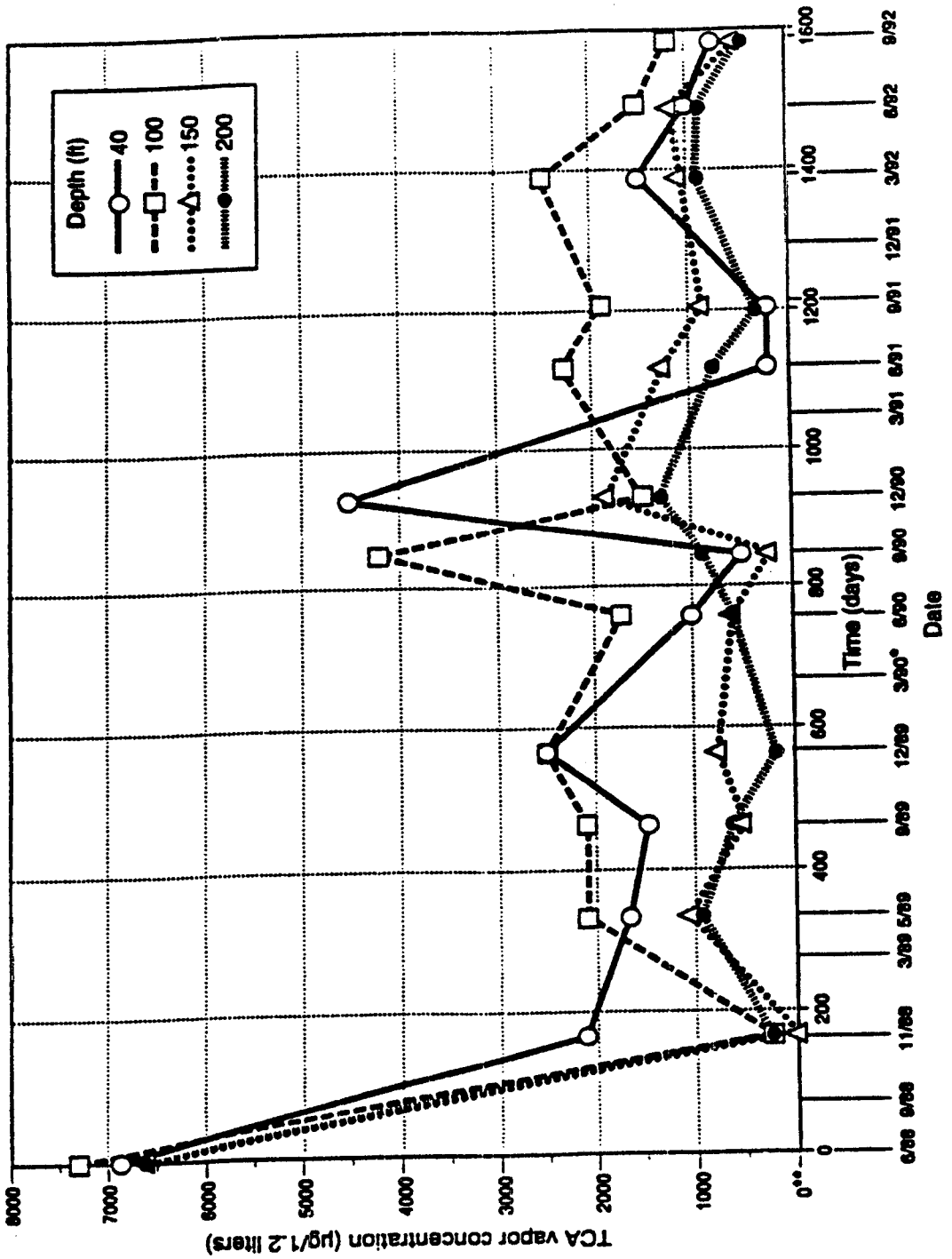
*On these dates measured values in all samples were spurious.

Figure A-6. Time-series TCA vapor concentration in gas samples from ports in Well #14.



*On these dates measured values in all samples were spurious.

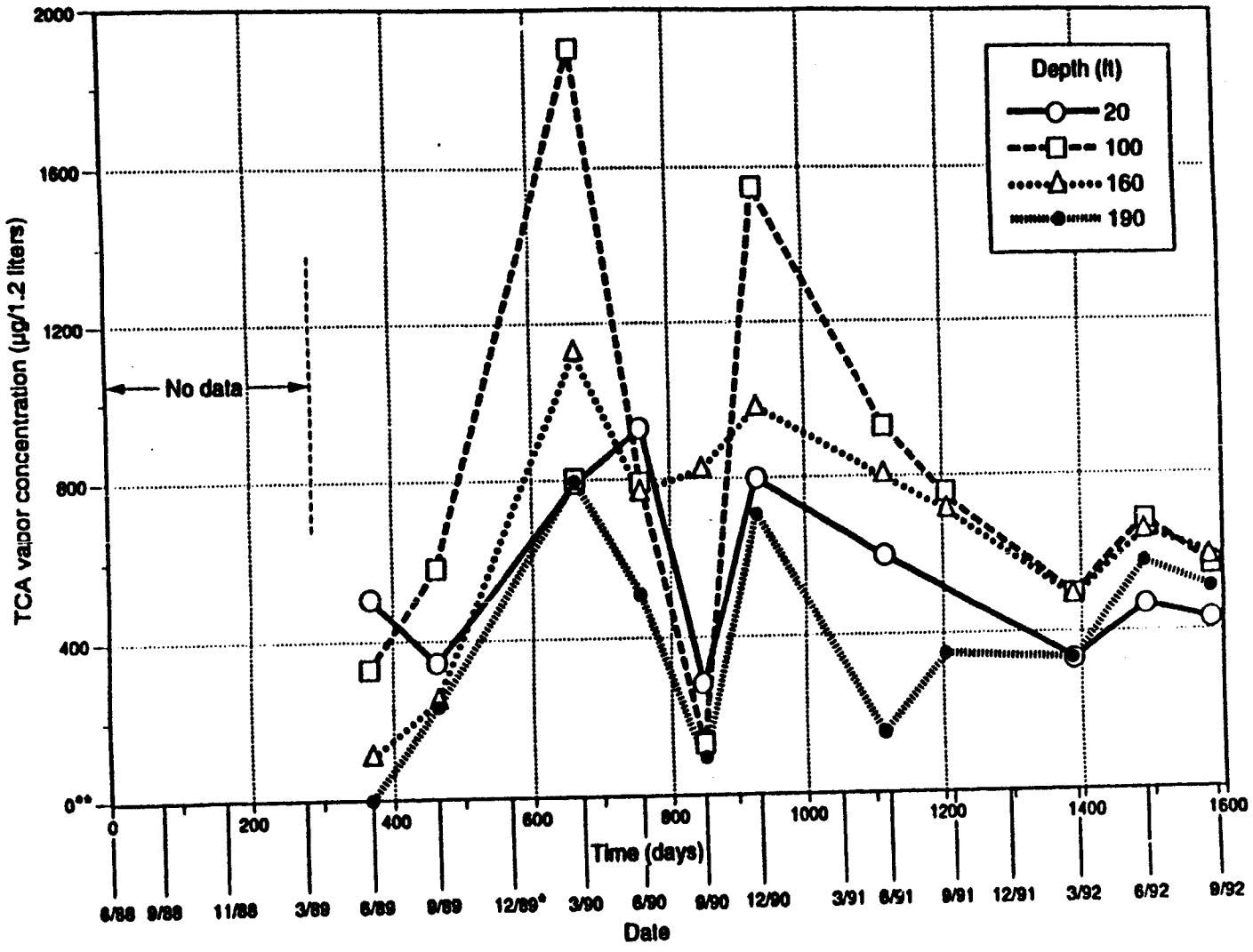
Figure A-7. Time-series TCA vapor concentration in samples from selected ports in Well #1.



*On this date measured values in all samples were spurious.

**Zero values indicate contaminant was not detected in the samples.

Figure A-8. Time-series TCA vapor concentration in gas samples from selected ports in Well #2.



*On this date measured values in all samples were spurious.
**Zero value indicates TCA was not detected in the sample.

Figure A-9. Time-series TCA vapor concentration in gas samples from selected ports in Well #25.

Figures A-10 and A-11 present the maximum TCA and TCE concentrations measured in gas samples collected from the network of monitor wells for the first three quarterly sampling events in 1992. The figures show the maximum measured values at various depths in each monitor well. The highest TCA values (greater than 4,000 ppm (mass)) occur near disposal shafts in the eastern part of MDA L. The maximum value measured near the western cluster of disposal shafts was 3400 ppm (mass) at a depth of 180 ft in well No. 1. TCE values greater than 1000 ppm (mass) were measured in both the western and eastern part of the MDA. Figures A-12 and A-13 are contour maps of the distribution of TCA and TCE that are based on the data reported in Figures A-10 and A-11. The highest TCA and TCE values occur within MDA L near the disposal shafts and Pit A.

TCA and TCE have never been detected in samples from well No. 34, indicating the plume has migrated northwest of the MDA a distance of less than 225 feet. Monitor well Nos. 29,26, and 30 are distributed across the mesa and bound the extent of the plume southeast of the MDA. Low values of TCA (generally less than 10 ppm (mass) are sporadically detected in samples from these wells, where as TCE has never been detected. TCA has migrated approximately 450 feet southeast of disposal shafts in the eastern part of the MDA.

Figures A-14 and A-15 present vertical profiles for VOCs measured in gas samples from well No. 24 in September, 1991 and September 1992. TCA and TCE were detected at all ports, with the highest concentrations in the depth interval between 60 feet to 160 feet. TCA and TCE concentrations exhibit little change from 1991 to 1992. Chloroform, PCE, and carbon tetrachloride were present at low concentrations in the September 1991 samples but were not detected in the September 1992 samples.

In summary, the data indicate that vapor phase concentrations of TCA have declined markedly over time at monitor wells located within or near MDA L, and that TCA (in vapor phase) is continuing to slowly move outward from the MDA. The vertical extent of the plume is not known. The monitor wells located within the MDA do not have sampling ports at depths greater than 86 feet. Figures A-7, A-8, and A-9 show that TCA has consistently been present at a depth of 200 feet. The TCA plume has migrated a distance of approximately 450 ft east of the MDA. Migration of the plume a similar distance vertically below the MDA is possible.

The plots in Figures A-5 to A-9 show that the concentration of TCA at any particular sampling port varies erratically from one quarter to another, sometimes with variation of 50-100%. The data may represent actual variation of the pore gas concentration, caused by natural ventilation of the mesa. However, the variation might also be an artifact of either the sampling method or the analytical process. Therefore, higher quality data are required to evaluate natural air flow in the subsurface and to evaluate the effectiveness of pilot tests to extract the vapor. To meet this need, a revised system for sampling and analyzing pore gas is being developed. The revised system will provide more accuracy, and will detect the larger list of contaminants presented in Table A-3. In addition, data on the subsurface pressures and flows will be gathered so that pore gas concentrations can be correlated with barometric and tidal effects.

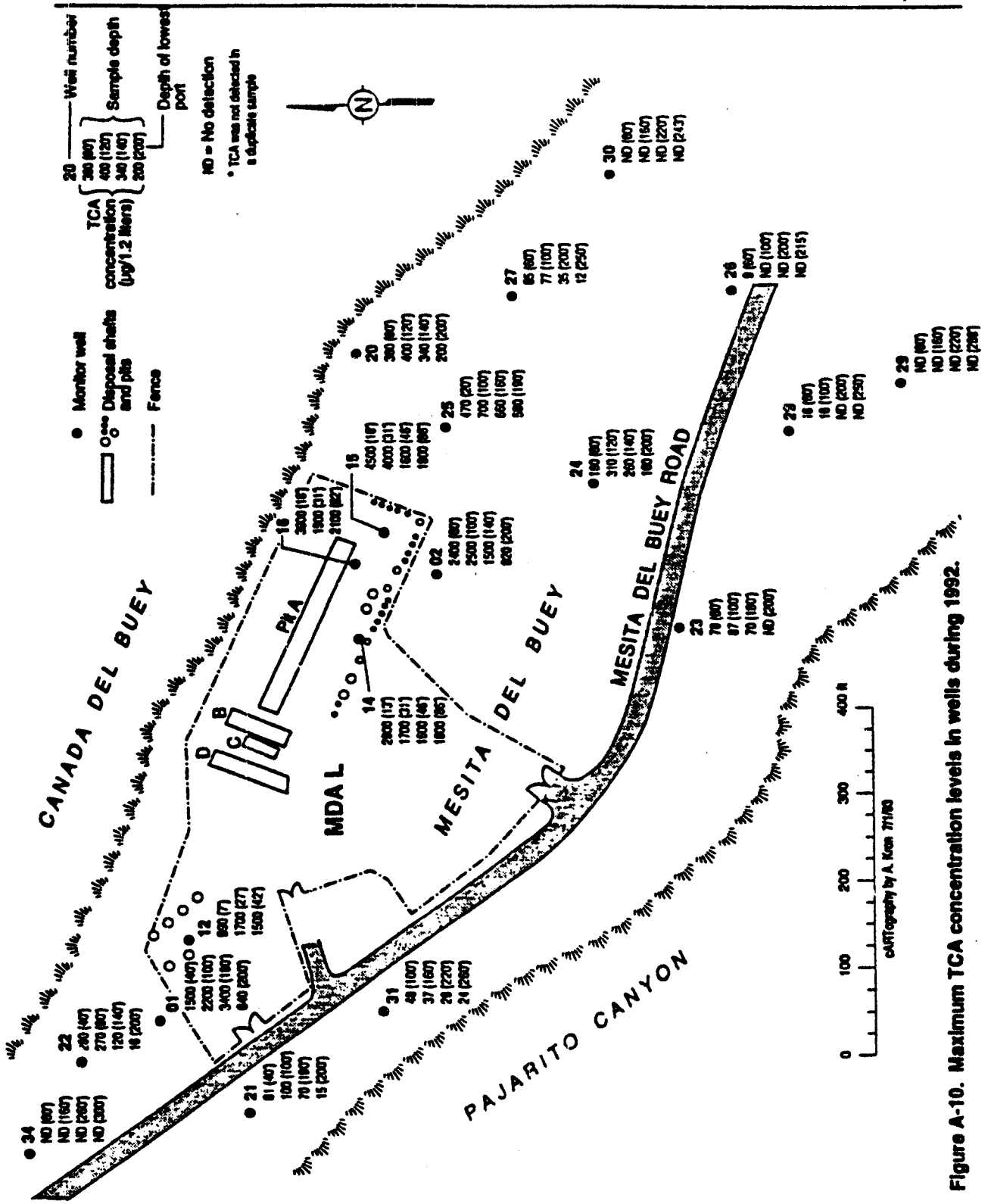


Figure A-10. Maximum TCA concentration levels in wells during 1992.

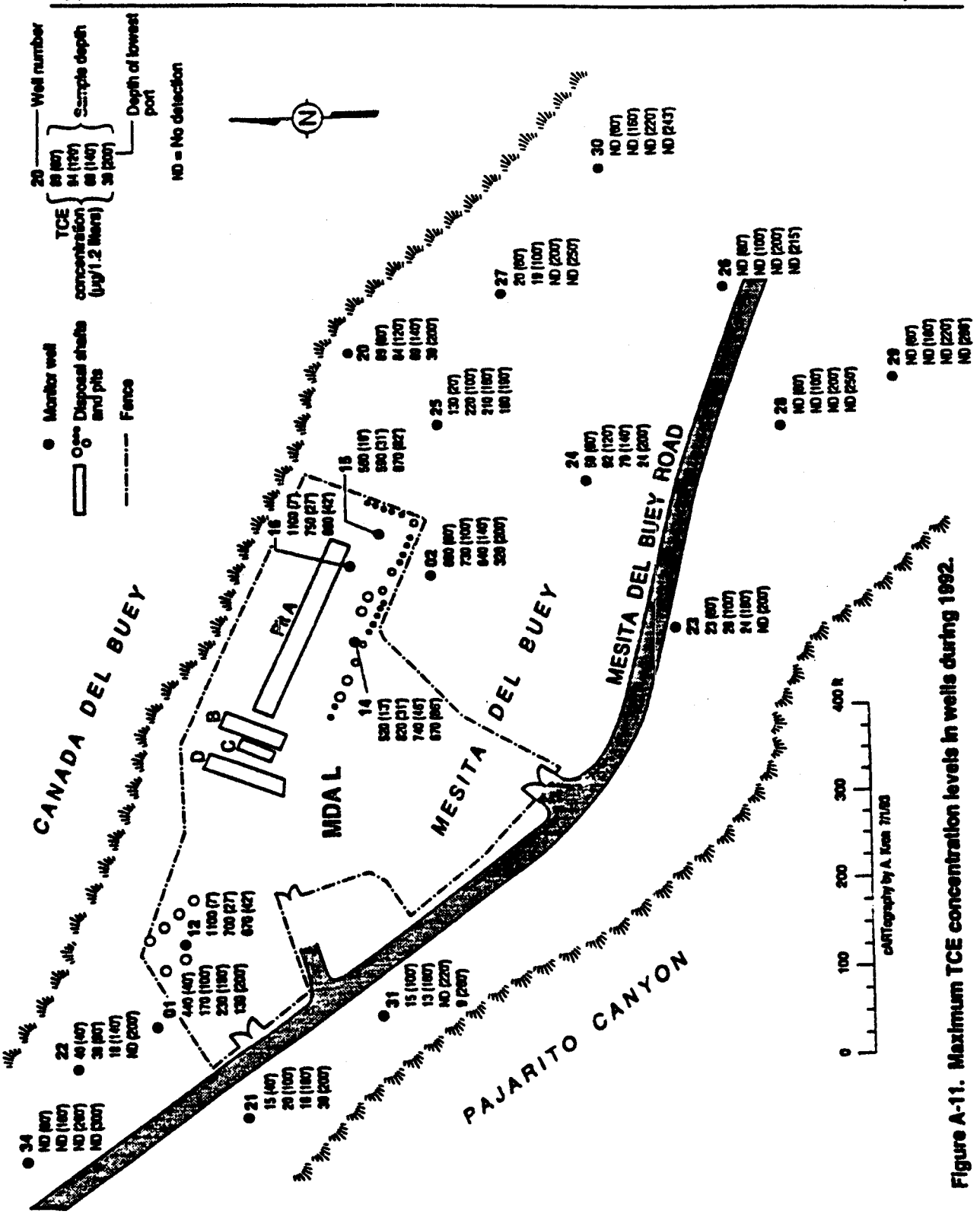


Figure A-11. Maximum TCE concentration levels in wells during 1992.

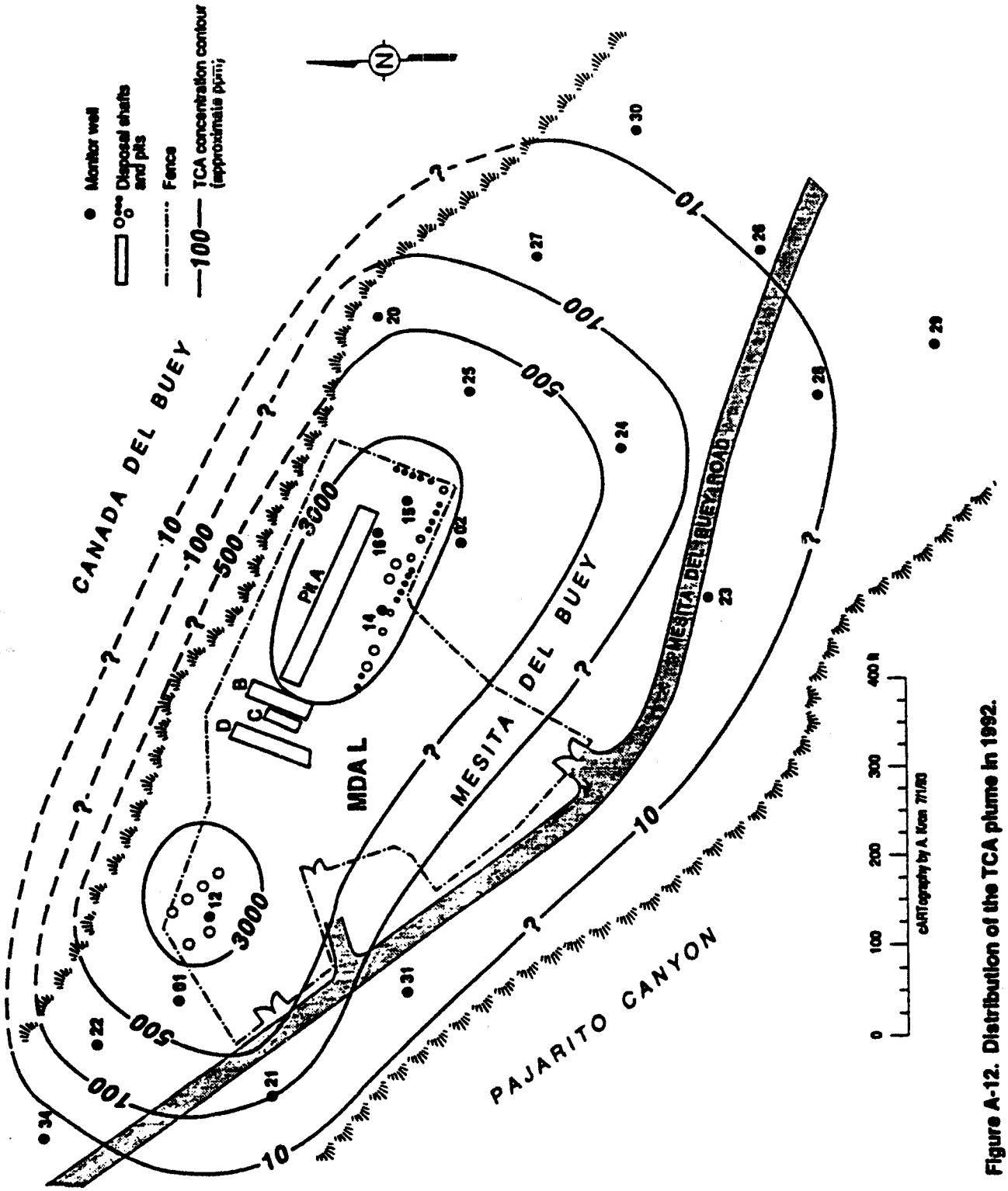


Figure A-12. Distribution of the TCA plume in 1992.

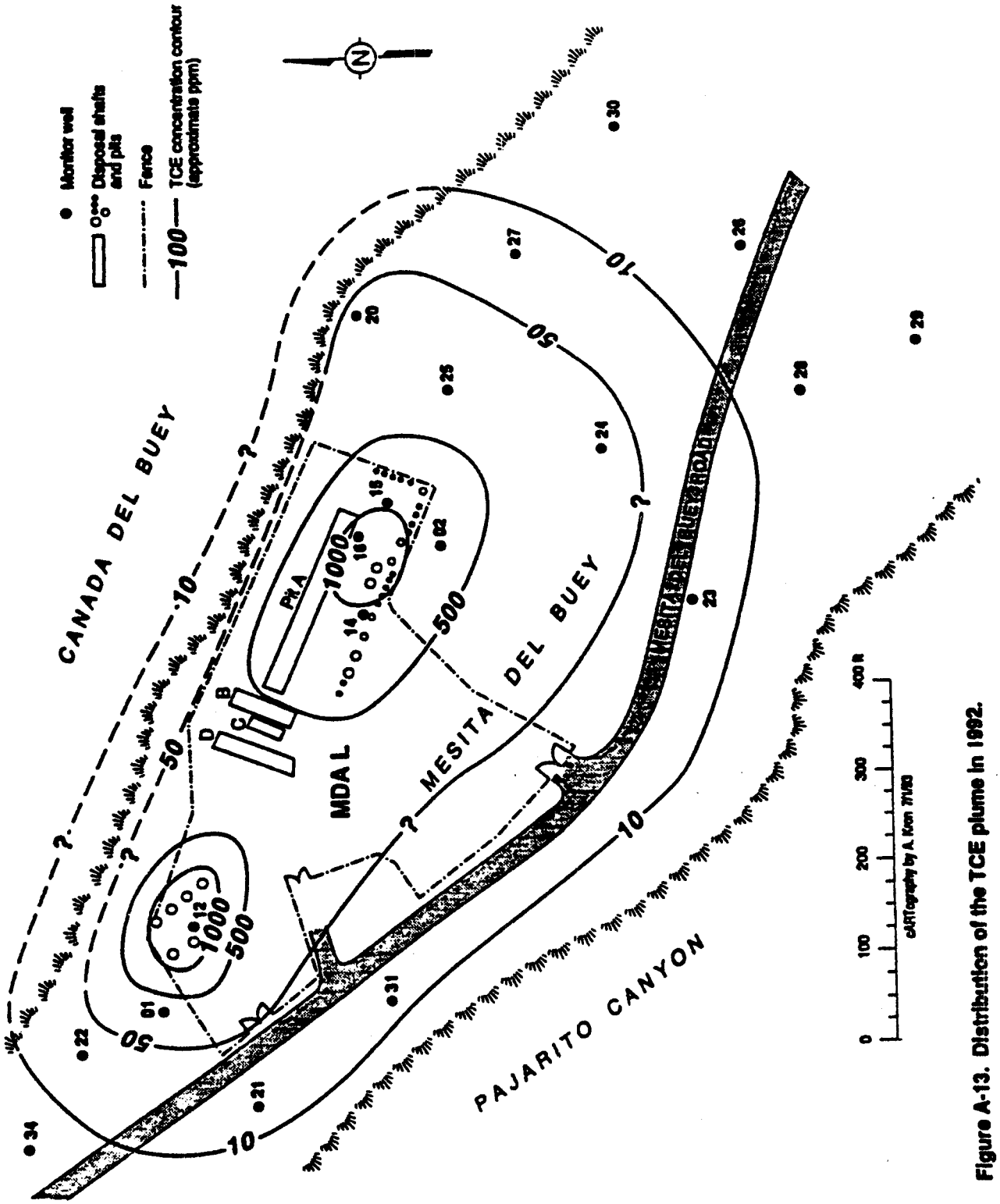
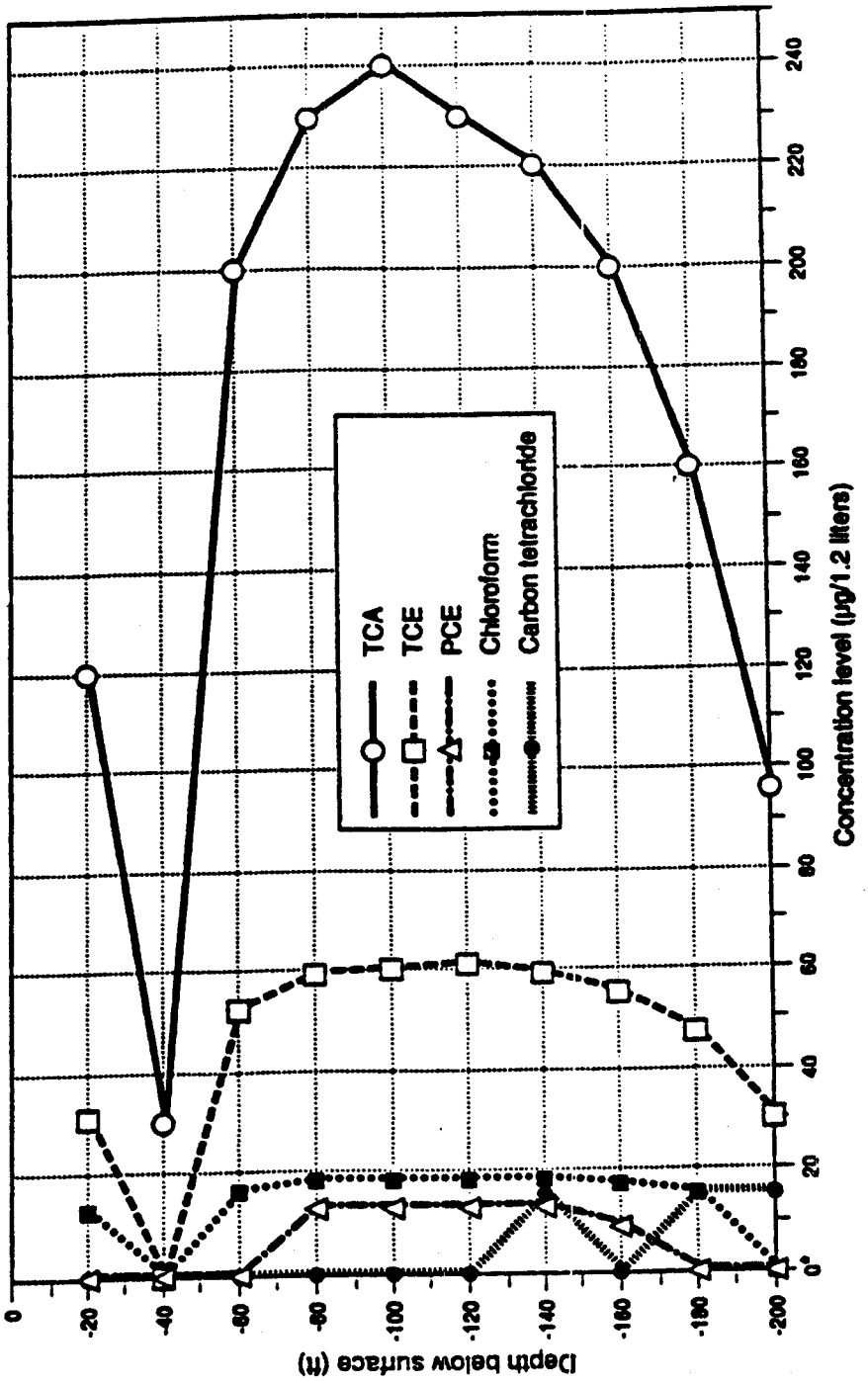
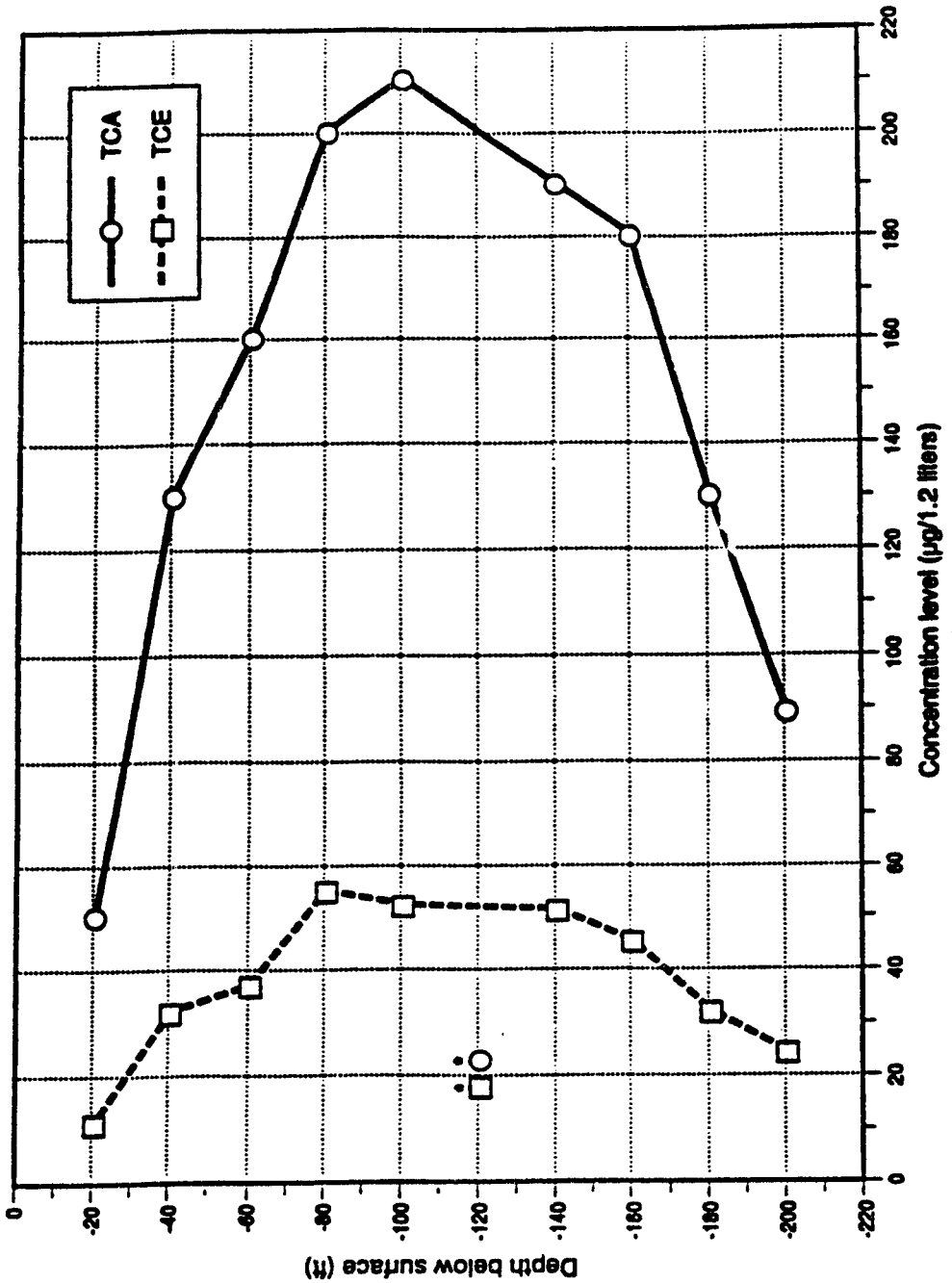


Figure A-13. Distribution of the TCE plume in 1992.



*Zero values indicate the contaminant was not detected in the sample.

Figure A-14. VOC distribution at Well #24 for 9/91 sampling period.



*These values are interpreted as spurious.

Figure A-15. TCA and TCE concentrations at Well #24 for 8/92 sampling period.

TABLE A-3

ANALYTES FOR GAS SAMPLES COLLECTED IN CARTRIDGES CONTAINING CARBON RESIN (revised pore gas monitoring methods)

GROUP[a]	COMPOUND	CAS#
A	Trichlorofluoromethane	75694
A	Chloroethane	75003
A	Chloromethane	74873
A	Dichlorodifluoromethane	75718
A	Vinyl Chloride	75014
A	Bromomethane	74839
B	2,2-Dichloropropane	594207
B	Dibromomethane	74953
B	1,1,1-Trichloroethane	71556
B	1,2-Dichloroethane	107062
B	Chloroform	67663
B	c-1,2-Dichloroethene	156592
B	1,3-Dichloropropene(cis and trans)	10061015
B	1,2-Dichloropropane	78875
B	1,1-Dichloropropene	563586
B	Carbon Disulfide	75150
B	Tetrachloroethene	127184
B	Trichloroethene	79016
B	Trichlorotrifluoroethane	76131
B	1,3-Dichloropropane	142289
B	t-1,2-dichloroethene	156605
B	1,1-Dichloroethene	75343
B	Bromochloromethane	74975
B	1,1-Dichloroethene	75354
B	1,1,2,2-Tetrachloroethane	79345
B	Carbon Tetrachloride	56235
B	1,1,2-Trichloroethane	79005
B	Methylene Chloride	75092
B	1,1,1,2-Tetrachloroethane	630206
B	Bromodichloromethane	75274
B	Chlorodibromomethane	124481
B	t-1,3-Dichloropropene	10061026
C	2-Hexanone	591786
C	Acetone	67641
C	2-Butanone	78933
C	4-Methyl-2-pentanone	108101

TABLE A-3 (Continued)

GROUP[a]	COMPOUND	CAS#
D	Bromobenzene	108861
D	Bromoform	75252
D	Chlorobenzene	108907
D	Ethylbenzene	100414
D	1,3,5-Trimethylbenzene	108678
D	Toluene	108883
D	m-Xylene	1330207
D	Benzene	71432
D	1,3-Dichlorobenzene (M)	541731
D	n-Propylbenzene	103651
D	o-Xylene	1330207
D	1,2,4-Trimethylbenzene	95636
D	Styrene	100425
D	1,4-Dichlorobenzene (P)	106467
D	1,2-Dichlorobenzene (O)	95501
D	p-Xylene	1330207
E	1,4-Difluorobenzene	
E	Chlorobenzene-d5	
F	Toluene-d8	
F	4-Bromofluorobenzene	

(a) Group: Used to sort compounds for the convenience in standards preparation. Group "E" are internal standards and group "F" are surrogates.

Note: Samples tubes (glass, 5mm ID X 9cm length) contain 150mg each of 20/40 carbotrap c, 20/40 carbotrap b, 60/80 carbosieve SIII (custom from Supelco, Inc.)

Samples are taken by passing a known volume of gas phase sample through a sample tube containing the adsorbent material(s) listed above. Organic sample constituents are absorbed onto the adsorbent. While passing an inert gas through the tube, the tube is heated; this desorbs the organic sample constituents off the adsorbent. The inert gas stream is directed to the head of a GC column, where the gas stream is split 1:50. Analysis by GC/MS then proceeds.

2.2 Analysis of Core Samples for Organic Contaminants

Cores from drill holes 14, 15, 16, and 18 were analyzed for the 43 organic compounds listed in Table A-4. This list includes nine of the twelve compounds detected in gas samples obtained from monitoring ports that were subsequently installed in the holes. Of the nine compounds analyzed both in the cores and in the pore gas, only toluene was detected in the cores--and it was detected at a concentration of 12 mg/kg. The analytical results for the core samples are presented in Table A-5. It is somewhat surprising that neither TCA nor TCE were detected in any of the core samples, although these compounds show the largest concentrations of all analytes of the pore gas.

In addition to toluene, priority pollutants detected in the core samples include methylene chloride and 1, 2-dichloroethane. The pore gas samples have not been analyzed for these constituents. The contaminant that occurred at the highest concentration in the core was acetone, which has not been an analyte in the quarterly gas sampling. However, the revised system for pore gas monitoring will include analyses for methylene chloride, 1, 2-dichloroethane, and acetone.

3.0 CORRECTIVE ACTION SELECTION CRITERIA

For the purposes of the pilot study, the site is considered to extend along the crest of Mesita del Buey and includes MDA L and the entire area over which the contiguous contaminant plume can be detected. The selected corrective action must conform to the particular constraints imposed by the setting of the site. These constraints include the following:

- minimal interference with active waste treatment and storage facilities at MDA L and the disposal facilities at MDA G;
- the space restrictions imposed by the site's position along the crest of a narrow ridge;
- the physical setting of the site, including lithology and permeability characteristics;
- natural forces (barometric pressure, earth-tides, wind, and temperature conditions) that may induce air flow within the mesa; and
- the characteristics of the contaminants in the plume.

3.1 Space Restrictions

The site is situated along the crest of a narrow mesa; the width of which ranges from 300 to 500 ft. The depth of the contaminant plume is in excess of 200 feet and may

TABLE A-4

ORGANIC COMPOUNDS ANALYZED IN CORES FROM DRILL HOLES[1]

PRIORITY POLLUTANTS	DETECTION LIMIT (µg/kg)[2]
Acrolein	100
Acrylonitrile	100
Benzene	5
Bromoform	5
Carbon tetrachloride	5
Chlorobenzene	5
Chlorodibromomethane	5
Chloroethane	10
2-Chloroethylvinyl ether	5
Chloroform	5
Dichlorobromomethane	5
1,1-Dichloroethane	5
1,2-Dichloroethane	5
1,1-Dichloroethene	5
1,2-Dichloropropane	5
1,3-Dichloropropylene	5
Ethylbenzene	5
Methylbromide	10
Methylchloride	10
Methylene chloride	10
1,1,2,2-Tetrachloroethane	5
Tetrachloroethene	5
Toluene	5
1,2-trans-Dichloroethene	5
1,1,1-Trichloroethane	5
1,1,2-Trichloroethane	5
Trichloroethene	5
Vinyl chloride	10

NON-PRIORITY POLLUTANTS

Acetone	Dimethoxymethane	Propanol
1,4-Dioxane	Ethanol	1-Butanol
Acetonitrile	2-Propanol	Tetramethylpentanone
Tetrahydrofuran	2-Methyl-2-Propanol	Chlorodifluoromethane
2-Butanone	4-Methyl-2-Pentanone	Bisoxymethane

(1) Data from IT Corporation 1987, 0327.
(2) Analysis by Gas Chromatography/Mass Spectrometry

TABLE A-5
ORGANIC COMPOUND ANALYTICAL RESULTS FOR DRILL HOLE CORES
AUGUST 1985[1]

DRILL HOLE NUMBER	DEPTH INTERVAL (FT)	VOLATILE ORGANIC COMPOUND	CONCENTRATION (µg/kg)
LLC-85-14	38-39	Acetone	190[a]
		Acetonitrile	27[a]
		Tetrahydrofuran	67[b]
	48-49	Acetone	670[a]
		2-Butanone	100[a]
		4-Methyl-2-Pentanone	110[a]
		Acetonitrile	1,100[a]
		Tetrahydrofuran	520[b]
		Dimethoxymethane	25[b]
		Unknown (oxygenated HC)	10[b][c]
		Unknown (oxygenated HC)	7[b]
LLC-85-15	18-19	Methylene Chloride	17
		Toluene	12
		Acetone	4,300[a]
		2-Butanone	470[a]
		4-Methyl-2-Pentanone	140[a]
		Ethanol	5[b]
		2-Propanol	6[b]
		Tetrahydrofuran	210[b]
		2-Methyl-2-Propanol	11[b]
	38-39	Acetone	300[a]
		2-Butanone	170[a]
		4-Methyl-2-Pentanone	420[a]
		Ethanol	170[a]
		Bisoxymethane	270[b]
		Propanol	270[b]
		Propanol (Isomer)	150[b]
		2-Methyl-2-Propanol	77[b]
		1,4-Dioxane	200[b]
		1-Butanol	280[b]

TABLE A-5 (Continued)

VOLATILE ORGANIC ANALYTICAL RESULTS FOR DRILL HOLE CORES
AUGUST 1985[1]

DRILL HOLE NUMBER	DEPTH INTERVAL (FT)	VOLATILE ORGANIC COMPOUND	CONCENTRATION (µg/kg)
LLC-85-16	5.5-7.0	1,2-Dichloroethane	19
		Methylene Chloride	30
		Acetone	110[a]
		4-Methyl-2-Pentanone	27[a]
		2-Propanol	6[b]
		1-Butanol	17[b]
		Fluorinated Aliphatic	6[b]
		Tetramethylpentanone	7[b]
	17-19	Methylene Chloride	18
		Acetone	82[b]
	97-99	Methylene Chloride	15
		Acetone	110[a]
		4-Methyl-2-Pentanone	5[a]
		Chlorodifluoromethane	10[b]
LLC-85-18[d]	18-19	Methylene Chloride	17
		Acetone	130[a]
		Chlorodifluoromethane	12[b]
		Unknown Hydrocarbon	20[b]
		Ethanol	190[b]
		C_8-Hydrocarbon	9[b]
	78-79	Acetone	70[a]
		2-Butanone	55[a]
		Unknown Hydrocarbon	9[b]

(1) Data from IT Corporation 1987, 0327
Analytes not shown were below detection limits.
(a) Concentration determined from analysis of analytical standard.
(b) Concentration estimated using total ionization peak area relative to the internal standard.
(c) Best computer match is [2,2'Methylene bis (oxy)] bis propane.
(d) Drill hole LLC 85-18 was located at the southwestern corner of pit A. This drill hole was not completed as a monitor well for pore gas samples.

be as great as 500 feet. The site occupies approximately 10 acres and includes the source(s) of the plume at inactive waste disposal units located within MDA L, presently operating treatment and storage units at MDA L, support facilities for disposal operations at MDA G, and land that will be occupied by future expansion of MDA G.

The space and usage constraints of the site targeted for corrective action preclude the mass excavation of wastes, soils, and bedrock as a remedial measure. Excavation of the buried organic wastes within the source area is also not considered as an option because of the high cost and increased risk of exposure of personnel. In addition, the vapor plume is located below the maximum depth of cost-effective excavation. *Ex situ* methods are, therefore, precluded, and only *in situ* methods will be considered.

3.2 Physical Setting

The plume is within the Bandelier Tuff, which comprises the mesa upon which the site is located. The air permeability of the tuff matrix is moderate, in the range of 10^{-9} to 10^{-7} cm^2. The rate of vapor migration may be increased by the permeability interconnected fractures and the horizontal surge bed deposits. Several of the stratigraphic units within the Bandelier Tuff exhibit regularly spaced vertical cooling fractures. Fractures are better developed in welded tuff than in nonwelded tuff.

The lateral interconnection of fractures may vary within tuff units, and the vertical interconnection may be interrupted at boundaries between tuff units by differences in fracture systems in the different units. In addition, laterally extensive surge bed deposits may be present. The deposits are especially prominent between units 2a and 2b, at a depth that is penetrated by the disposal shafts. The migration of the vapor may follow lateral movement along the surge beds, combined with both lateral and vertical movement along fractures. In preparing for the remediation, we will investigate the air flow in the fractures and surge beds. If these are dominant pathways for vapor migration, the corrective action method must access them.

The tuff matrix may hinder any attempt to remove or contain the plume. The tuff contains a large amount of poorly connected pore space and may have high sorptive capacity. It is reasonable to assume that organic constituents may have been sorbed onto the matrix. This sorption could have occurred from the vapor phase, and possibly from the liquid phase in the vicinity of the source of the organics. The corrective action might, therefore, be required to remedy both the organic vapors contained within fractures and joints, and the slower desorption from the matrix.

3.3 Contaminant Characteristics

Available data indicates that the plume consists predominantly of TCA, as well as TCE, carbon tetrachloride, chloroform, and tetrachloroethene (PCE). Other detected constituents present at lower concentrations, or detected less consistently include toluene, xylenes, and 1,2,4-trimethylbenzene. TCA, TCE, carbon tetrachloride, chloroform, and PCE have similar major physical and chemical characteristics (See Table A-6). They have relatively high vapor

pressures, low solubilities in water, and relatively high Henry's Law coefficients, indicating strong partitioning into the vapor phase. All have specific gravities in excess of 1 in the pure liquid phase, and relatively low viscosities. In addition, a saturated mixture of air and any of the constituents in vapor phase is considerably more dense than air alone. Dry air saturated with TCA, for example, is approximately 1.5 times more dense than dry air with no TCA (Schwille 1988, 0750). Due to their low viscosity and high specific gravity, the primary constituents migrate readily in the liquid phase through both water-filled and air-filled fracture systems. The density of the vapor evaporated from a liquid encourages downward migration of the vapor plume through interconnected fractures. The fact that the contaminants have migrated extensively in the vapor phase indicates that the corrective action must be capable of removing vapor phase constituents.

The persistence of chlorinated constituents in the subsurface for long periods of time indicates that an active method will be required to retract the vapor plume. In addition, the inactive pit and disposal shafts will continue to be a source of vapor phase chlorinated hydrocarbons in the future, which will require an engineered system to prevent regrowth of the plume.

3.4 Summary of Corrective Action Criteria

The following information was used to select the technology for remediation of the organic vapor plume at MDA L:

- Technologies requiring excavation of the contaminated soil and rock are not feasible due to the depth of contamination, volume of contaminated material, and the operations being performed at MDAs L and G.
- The technology must be able to remove and treat vapor phase contaminants from pore space and fractures at depths exceeding 200 ft.
- The technology must remove and treat contaminant vapors as they are desorbed from the rock matrix over time and as they are released from the source area in the future.
- Bioremediation technologies are not feasible because of the high persistence of the chlorinated solvents and the potential production of vinyl chloride.
- The technology should serve as part of the long term stabilization of the MDA to prevent regrowth of the plume in the future.

4.0 PILOT EXTRACTION STUDY

4.1 Pilot Extraction Study Design

Vapor extraction is selected as the preferred technology for the corrective action. In vapor extraction, a vacuum pump draws vapors from boreholes to an emission treatment system.

REFERENCE SET FOR TECHNICAL AREA 54
VOLUME 4

This reference set is provided to facilitate review of Laboratory Environmental Restoration (ER) Project documents and is organized by ER identification (ER ID) number.

ER Project documents use ER ID numbers to track reference items through its Records-Processing Facility. Because ER ID numbers are issued on an ongoing basis throughout the entire ER Project, gaps may be present in the numbers included in this table of contents.

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23247 IT Corporation 1992. "Operable Unit 1148 Data Report," IT Corporation, Los Alamos, New Mexico. (IT Corporation 1992, 23247)

23251 Graf, W., March 1993. "Geomorphology of Plutonium in the Northern Rio Grande," Los Alamos National Laboratory report LA-UR-93-1963, Los Alamos, New Mexico. (Graf 1993, 23251)

25610 LASL (Los Alamos Scientific Laboratory), October 31, 1969. "Materials Waste Pits, Pit #1 Area 'L' TA-54," Engineering Drawing ENG-R3149, Los Alamos, New Mexico. (LASL 1969, 25610)

TABLE A-6
PHYSICAL PROPERTIES AND ACTION LEVELS FOR VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL GAS SAMPLES AT MDA L AND THEIR BREAKDOWN PRODUCTS

COMPOUND (1)	CAS ID NUMBER (2)	VAPOR PRESSURE (mm @ 20°C) (2)	VAPOR DENSITY (g/L @ 25°c) (2)	HENRY'S LAW CONSTANT (atm m3/mol) (2)	SOLUBILITY IN WATER (mg/L @ 25°C) (2)	PEL (Air) (mg/m3) (2)	SUBPART S ACTION LEVEL (air) (mg/m3) (3)	SUBPART S ACTION LEVEL (soil) (mg/kg) (3)
Benzene	71-43-2	76	3.19	.005	1,780	~30	NL	1
Carbon tetrachloride (a)	56-23-5	90	6.29	.030	800	10 ppm	.03	
Chlorobenzene	108-90-7	9	4.60	.0036	500	~350	20	2,0
Chloroethane	75-00-3	1,011	2.76 kg/m3 @ 20°C	.0111	5,740	~2,600	NL	1
Chloroform (a)	67-66-3	160	4.88	.003	8,200	~240	.04	1
Chloromethane	74-87-3	3,789	2.06	.00882	7,250	~205	NL	1
1,1 Dichloroethane	75-34-3	182.1	4.04	.0043	5,500	~400	NL	
1,2 Dichloroethane (a)	107-06-2	64	4.04	.00091	8,690	50 ppm	.04	
1,1 Dichloroethene (a)	75-35-4	495	3.96	.021	400	~20	.03	
Trans-1,2 Dichloroethene	156-60-5	265	3.96	.00674	600	NL	NL	
Ethylbenzene	100-41-4	7.09	4.34	.0066	152	~435	NL	8,0
Methylene Chloride (a)	75-09-2	348.9	3.47	.0020	20,000	500 ppm	.3	
Tetrachloroethene (a)	127-18-4	14	6.78	.015	150	100 ppm	1	
Toluene	108-88-3	22	3.77	.0067	515	~375	7,000	20,0
1,1,1 Trichloroethane	71-55-6	100	5.45	.018	1,360	~1,900	1,000	7,0
Trichloroethene (a)	79-01-6	57.8	5.37	.009	1,100	~270	NL	
Vinyl chloride	75-01-4	2,580	2.55	2.78	1,100 @ 25°C	1 ppm	NL	
o-Xylene	95-47-6	6.6 @ 25°C	4.34	.005	152	~435	1,000 (b)	200,000

FOOTNOTES:

a. Listed as carcinogen in Appendix A, Proposed Subpart S, 40 CFR, Part 264.
b. Reference for mixed xylenes.
NL Not Listed

REFERENCES:

1. Flotard, R.D., M.T. Homshen, J.S. Wolff and J.M. Moore. 1986. Volatile Organic Anal Methods Performance and Quality Control in Remedial Site Investigation: Hazardous Industrial Solid Waste Testing, Fifth Volume ASTM STP 925.
2. "Groundwater Chemicals Desk Reference", John H. Montgomery and Linda M. Welkom, I Publishers, Chelsea Michigan, 1990.
3. Appendix A, Proposed Subpart S, Part 264, 40 CFR, In "Federal Register 55", 307 July 27, 1990.

Figure A-16 presents a schematic diagram of a typical system. EPA guidance (EPA 1991, 0707) indicates that vapor extraction is a feasible corrective action for a site with intrinsic permeability greater than 10^{-10} cm^2 with contaminants having vapor pressure greater than 0.5 torr. Both of these conditions are met for the plume at MDA L. In addition, vapor extraction meets the criteria discussed in the previous section by requiring only minimal excavation and space so that it will not interfere with ongoing operations at MDAs L and G and by being able to remove vapor phase contaminants from depths greater than 200 ft.

Vapor extraction has the capability to:

- withdraw vapor phase constituents from pore space and fractures;
- enhance the evaporation of constituents from the pure liquid or aqueous phase, if present, and subsequently remove them as a vapor phase; and
- control the further migration of vapors within the subsurface.

4.2 Additional Data Gathering

4.2.1 New Boreholes and Sampling

Additional data on the tuff matrix and the vapor plume are needed for design of a vapor extraction system. Boreholes that will provide samples for the RFI Work Plan will also provide the information needed to design and implement the corrective action. Six angle boreholes to the top of the basalt and three deep vertical boreholes into the basalt will be installed in the plume to further characterize the plume and the site geologic properties.

The six angle boreholes will be 8 inches in diameter to provide good efficiency as extraction wells. Steel casing with 8-inch inside diameter will be installed in the upper 30 feet of the borehole and will be grouted to prevent short circuiting of airflow from the surface near the borehole. The angle boreholes will intercept the near-vertical fractures, and will be drilled to the top of the Chino Mesa Basalt (estimated to be at a depth of 220 feet to 300 feet). The angle borehole locations are shown on Figure A-17. The boreholes are located to provide data on the plume and the subsurface environment. The angle boreholes will reveal the lithology of a cross-section of the mesa, and will be completed so that they can monitor the vapor extraction process or serve as active extraction wells or injection wells in the future. Information to be gathered from the six angle boreholes includes the following:

- Continuous core will be collected for description of lithology, and fractures.
- Geotechnical tests performed on core samples include
  - Saturated hydraulic conductivity;
  - Moisture content, bulk density, and porosity;
  - Moisture characteristic curve with data in the dry range extending to approximately 2% moisture by weight, or drier if possible;
  - Specific gravity (particle density)

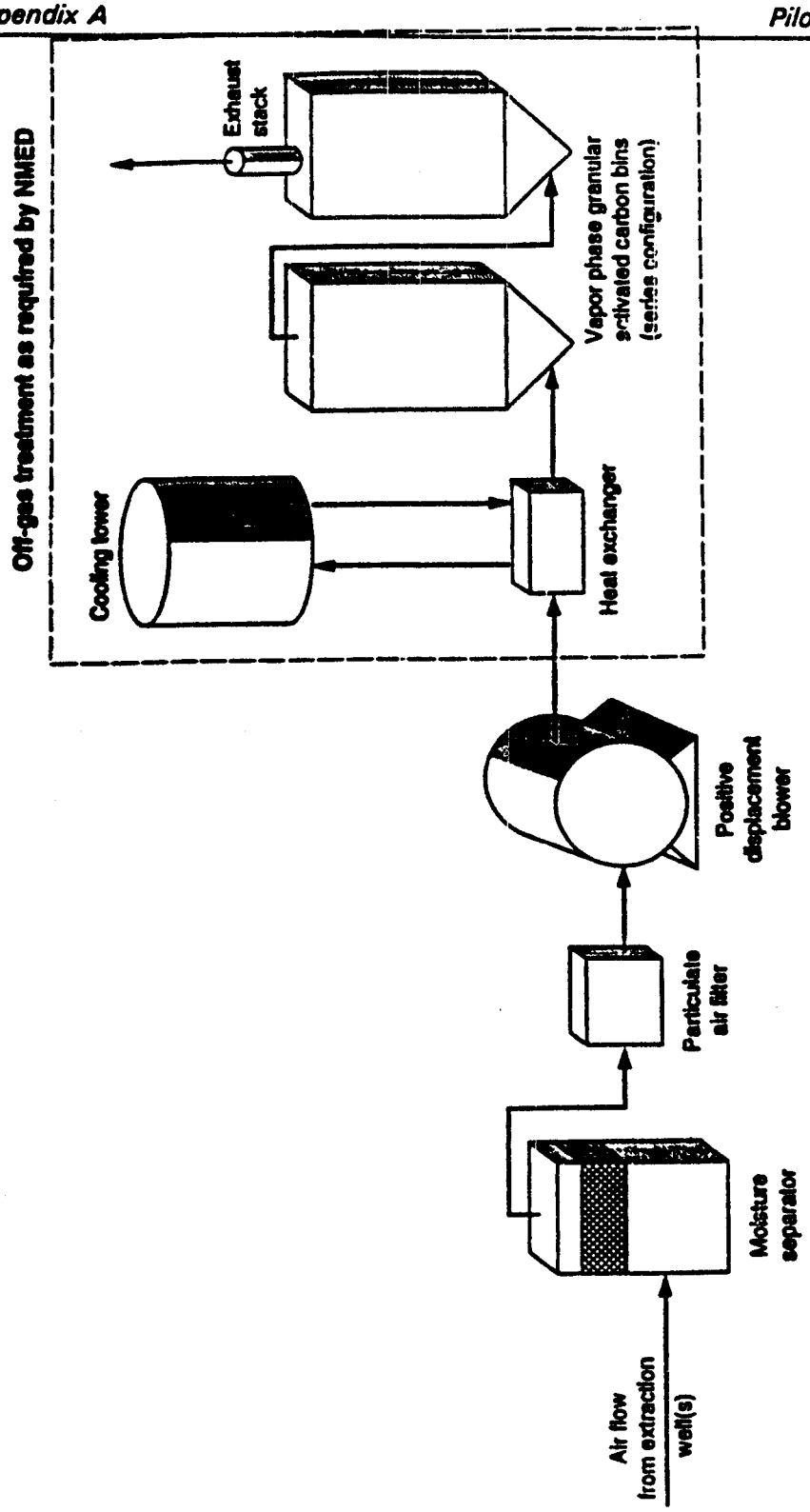

Figure A-16. Conceptual design of vapor extraction unit.

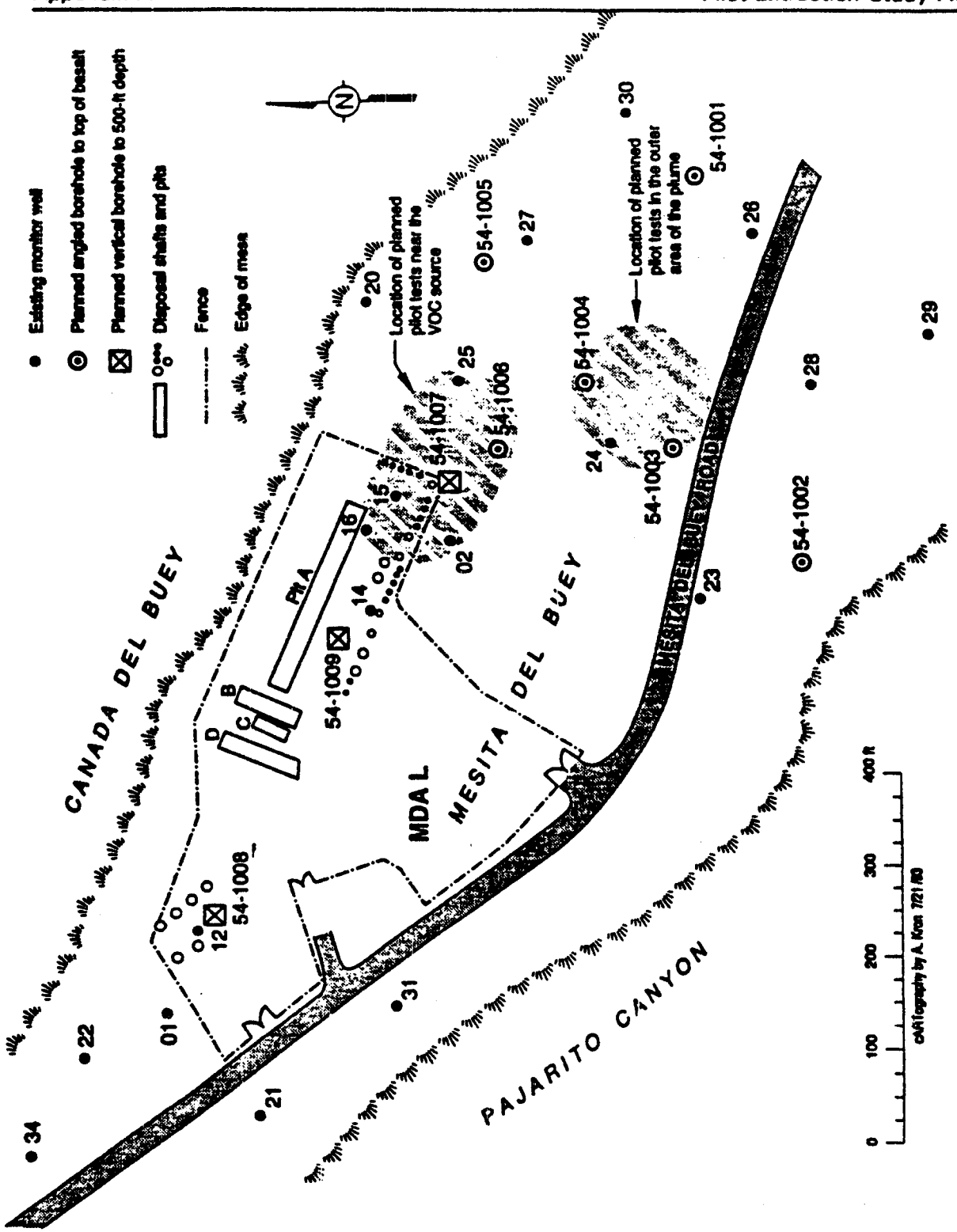

Figure A-17. Location map of planned boreholes and pilot tests in the Voluntary Corrective Action Plan.

- Specific surface (BET method); and
- Air permeability.

- Caliper logs and borehole video logs will be performed in the open boreholes to identify fracture zones and fracture orientations.

- A borehole deviation log will be performed on the open boreholes to determine the trajectory of the angle holes.

- Air flow profiles will be gathered in at least one open borehole to identify zones of relatively higher and lower air permeability.

- Packer tests will be performed in at least one open borehole to determine the air permeability in selected zones.

Cores from the six angle boreholes will be analyzed for moisture and VOCs according to the schedule presented in Attachment 1 to this Appendix. Because of the large distance between these boreholes and the sources, these cores will not be analyzed for non-volatile contaminants.

Five of the angle boreholes (well ID No.s 54-1002 to 54-1006 on Figure A-17 will be instrumented with SEAMIST® flexible liner monitoring systems (or equivalent) to provide the following measurements at selected locations in each borehole at 12 depth intervals:

- temperature,
- matric potential,
- pressure, and
- VOC concentrations in pore gas

One of the angle boreholes (54-1001) will be used for open hole measurements of air flow as a function of changes in atmospheric pressure and/or gravitational tides. This borehole is located at the perimeter of the plume where TCA concentrations are very low. A liner will subsequently be used to seal this borehole. Data from the existing monitor wells and the six angle holes will be used to assess natural air flow within the tuff (to the top of the basalt) that is in response to atmospheric pressure changes, wind, seasonal temperature variation, and gravitational tides.

The sampling and core logging will reveal variations in subsurface geology along the axis of the mesa and transverse to the mesa. The in-situ measurements will reveal the natural breathing of the mesa in response to barometric and tidal variations, and the effect of these variations on vapor concentrations. In turn, this knowledge will enable better design of an active vapor extraction system to retract the plume, and may enable the design of a passive ventilation system for long-term control of the vapor sources. Data on the hydrogeologic properties will be applied in future modeling of transport. (Additional drilling and sampling for the RFI, but not needed for this study, is described in the body of the RFI Work Plan.)

The three deep vertical boreholes near disposal units at MDA L (well ID No.s 54-1007 to 54-1009 on Figure A-17 will assess the vertical extent of contamination below the MDA as part of the RFI for MDA L. The basalt section of the boreholes will be instrumented with SEAMIST® liner systems or equivalent to characterize air flow deep in the mesa and to monitor the vertical extent of the organic vapor plume. The 500 foot depth for these boreholes was determined from the fact that the plume has migrated approximately this distance laterally from the disposal units. The boreholes stop at a distance of 350 to 400 feet above the top of the water table to alleviate concerns that a deep borehole to the aquifer would be a potential pathway for contaminants. The boreholes will be drilled with Odex® technology that installs steel casing during drilling to prevent migration of contaminants along the borehole during or after drilling. After drilling, a polymer casing will be installed within the steel outer casing, and the intervening annular space will be grouted from a tremie while the outer casing is withdrawn. This will leave a secure, gas-tight completion from the surface to the top of the dense basalt, below which flexible or fixed casings may be used. When the deep boreholes are no longer needed, the holes will be drilled to remove the polymer casing and plugged with grout to eliminate a potential pathway for future vertical migration of contaminants.

Information to be gathered from the three 500-foot-deep vertical holes includes the following:

- Continuous core will be collected for description of lithology and fractures.

- Geotechnical tests performed on core samples include

  - Saturated hydraulic conductivity;
  - Moisture content, bulk density, and porosity;
  - Moisture characteristic curve with data in the dry range extending to approximately 2% moisture by weight, or drier if possible;
  - Specific gravity (particle density)
  - Specific surface (BET method); and
  - Air permeability.

- Caliper logs and borehole video logs will be performed in the open boreholes to identify fracture zones and fracture orientations.

- A borehole deviation log will be performed on the open boreholes to determine the path of the vertical holes.

- Air flow profiles will be gathered in an open borehole to identify zones of relatively higher and lower air permeability.

- Packer tests will be performed in an open borehole to determine the air permeability in selected intervals.

- As part of the RFI, core samples will be analyzed for volatiles, semi-volatiles, metals,cyanide, pesticides, herbicides, PCB's, tritium, gamma spectrometry, gross alpha, and gross beta. Analytes and analytical methods are described in the work plan. Attachment 2 to this appendix presents the depth interval for analyses on core.

- As part of the RFI, gas samples will be collected from each 20 foot depth interval during drilling. The samples will be collected on carbon resin and analyzed for the compounds listed in Table A-3. Attachment 2 to this appendix presents the schedule for collection of gas samples at each borehole.

4.2.2 Subsurface Air Flow Studies

Investigation of barometric effects. It is now known that an oscillatory flow of air (as contrasted with a steady flow, or no flow) in a porous medium can dramatically increase the effective rate of diffusion of a contaminant vapor. The barometric pressure at Los Alamos displays cycles with 12-hour, 24-hour, 2-day, and 5-day periods. These cycles may produce oscillatory air flow (so-called "barometric pumping") within the tuff, which may in turn accelerate the spread of the organic vapor plume. In estimating any future dispersion of the plume, it is therefore important to know the magnitude, and the influence, of the natural periodic subsurface flow. Also, vapor extraction to remedy the plume should be conducted so as to work with, rather than against, natural dispersion.

The subsurface pressure will be measured as a function of time at ports in several of the existing monitor wells, and in at least one of the new angle boreholes. By comparison of the Fourier components of the surface pressures with the Fourier components of the subsurface barometric pressure, one can determine the logarithmic decrease of oscillatory pressure amplitude with depth, which is theoretically a function of frequency, permeability, and porosity. Irregular behavior of the penetration depth may reveal whether fractures in the tuff provide barometric ventilation, and therefore whether the fractures will also influence applied vapor extraction. Because many of the fractures are filled with clay, it is not obvious whether the fractures have greater or less permeability than the tuff matrix.

Concurrent with the subsurface pressure measurements, a continuous-reading instrument will be used to monitor changes in the concentration of one or more of the volatile contaminants in the pore gas as a function of time. The existing monitor wells have been sampled quarterly for several years. As shown in Figure A-5 through A-9, measured concentrations of VOCs show a large scatter. It is possible that the scatter is due to barometric pumping. Continuous measurement of pressure and VOC concentration may reveal the extent to which barometric pumping causes short-term variations in VOC concentration. The techniques developed for subsurface pressure and VOC monitoring will be applied during vapor extraction pilot tests to measure the distribution of vacuum and short-term changes in pore gas concentration. These techniques will also be used as diagnostics if forced oscillatory flow is deliberately applied to circumvent diffusion limitation during pilot or full-scale extraction.

Long-term remediation. It is expected that application of conventional soil vapor extraction technology, possibly enhanced by forced oscillatory flow, will retract the VOC plume to the vicinity of the disposal shafts at Area L. However, applied vapor extraction is unlikely to remedy the sources within the shafts because much of the waste was buried in containers that may still be sealed. In principle, a container could rupture at any time in the future, thereby permitting a new release of volatile materials from a shaft. The subsurface air flow studies may enable design of a passive ventilation system operated by barometric oscillations. The system would be intended to intercept and extract any future volatile emissions from the

shafts. Such a system would prevent future re-growth of the plume without electric power, rotating machinery, or extensive maintenance.

4.3 Preliminary Design Criteria

The following sections provide information on the vapor extraction system (VES) that will be designed to retract the plume at MDA L. The current design parameters are based on present knowledge of site and plume conditions and the documented experience with VES at other sites. Pilot tests will be conducted near one or more of the six angle boreholes in the low contaminated area to evaluate the initial design parameters and to develop a final VES design. Tentative locations for the pilot tests are shown on Figure A-17.

4.3.1 Extraction Wells

Wells utilized for vapor extraction may be vertical or angled. As discussed in Section 1.2, the fracture systems within which the vapor plume is presumably migrating appear to have an orientation which is predominantly vertical and near-vertical. Angle and/or horizontal wells may therefore encounter a larger number of fractures than vertical wells, with a correspondingly higher removal efficiency. However, such wells would be both more difficult and more costly to install than vertical wells. The information obtained from the six angle boreholes for site characterization will be used to determine the best design for vapor extraction wells.

4.3.2 Piping

All well heads of a final VES will include the following accessories:

- Flow rate indicator;
- pressure gauge;
- a sample port; and
- a valve to admit atmospheric air.

Grading and sumps will collect condensed moisture. A knockout device and particulate filter will be installed on the suction side of the vacuum pump. This will remove entrained liquid and remove particles that might damage the pump.

4.3.3 Emissions Control System

The New Mexico Environment Department may require an emissions control system to reduce contaminant concentrations in the effluent airstream of a pilot test and/or the full-scale operation. Treatment options include thermal oxidation, catalytic oxidation, condensation, carbon absorption, and incineration. Of these options, thermal oxidation and incineration provide incomplete destruction of chlorinated hydrocarbons. Condensation would require

sophisticated cooling and heat exchange systems to achieve greater than 90 percent contaminant removal, especially because adiabatic compression increases the temperature of the extracted air.

If treatment is required, carbon absorption will be used during the initial pilot tests because it is a proven technology that is cost effective for short-duration tests at low concentrations. Because the purpose of the pilot test is to evaluate the effects of different pumping rates and flow schemes on contaminant movement in the subsurface, adjustment of a catalytic oxidation system is impractical. Carbon absorption units are easily changed when breakthrough occurs. The actual carbon usage rate and contaminant flux determined from the pilot test will be used to evaluate the cost effectiveness of carbon absorption versus catalytic oxidation for emissions control if it is required during full-scale operation.

4.4 Pilot Tests to Evaluate Active Extraction

Pilot tests to provide information for the design of the full-scale VES at MDA L will be conducted at two locations; first in the perimeter region of the plume where total concentrations are low; and second, near the source area where total concentrations are high and more contaminants are present.

4.4.1 Pilot Tests in the Perimeter Area

The pilot tests of the VES in the vicinity of the angle boreholes, near the perimeter of the plume, will be conducted in two steps:

- performance of a stepped extraction test from a single extraction well; and if diffusion limitation occurs
- performance of a test using two or more wells which will oscillate between extraction, passive venting, and injection.

The data gained from the pilot tests will be used to assess flow, radius of influence, and contaminant removal rate from extraction intervals of various depths. If data from the initial pilot tests on contaminant removal rates are inconclusive, additional tests will be conducted closer to the sources of vapor.

Based on the additional data described in Section 4.2, the location of the initial pilot test will be determined. This well will be located in the middle of the mesa in the perimeter area where VOC concentrations are low (Figure A-17). The pilot extraction well will be approximately 25 feet from one of the instrumented angle boreholes.

The initial pilot tests will provide information on the vacuum required to achieve a specific flow rate, radius of influence, whether diffusion limitation occurs, and contaminant concentrations in extracted air. The information will be used to design a second pilot system employing two or more wells and time-varying flows.

6.0 SCHEDULE

TABLE A-7

SCHEDULE FOR IMPLEMENTATION OF PESP *

Appendix A *Pilot Extraction Study Plan*

The second pilot system will use two or more extraction wells. The wells will be alternated between extraction, passive venting, and injection. The oscillatory flow scheme will be designed to prevent dead air zones and to improve contaminant extraction rates under diffusion limited conditions.

4.4.2 Pilot Tests in the Source Area

One or more pilot tests will be conducted in the region of higher contamination, near the source. Test(s) in this region are necessary because the presence of additional VOCs with different properties may affect the extraction efficiency.

5.0 INSTALLATION OF THE ACTIVE EXTRACTION SYSTEM

The extraction wells installed for the pilot tests will be the first wells in the active system to extract the plume. Additional wells will be added in a phased approach based on performance. When practicable, existing monitor wells will be converted to serve as extraction wells. The schedule for characterization, pilot tests, and installation of the full-scale volatile extraction system is presented in Table A-7.

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ATTACHMENT 1

SCHEDULE OF CORE SAMPLES FROM ANGLE BOREHOLES

location id	sample no	sample depth	voa	moisture	semi-voa	metal	pesticide	herbicide	pcb	cn	tritium	gross alpha	gross beta	gamma spec
54-1001	1	5		x										
	2	10		x										
	3	15		x										
	4	20	x	x										
	5	25		x										
	6	30		x										
	7	35		x										
	8	40	x	x										
	9	45		x										
	10	50		x										
	11	55		x										
	12	60	x	x										
	13	65		x										
	14	70		x										
	15	75		x										
	16	80	x	x										
	17	85		x										
	18	90		x										
	19	95		x										
	20	100	x	x										
	21	105		x										
	22	110		x										
	23	115		x										
	24	120	x	x										
	25	125		x										
	26	130		x										
	27	135		x										
	28	140	x	x										
	29	145		x										
	30	150		x										
	31	155		x										
	32	160	x	x										
	33	165		x										
	34	170		x										
	35	175		x										
	36	180	x	x										
	37	185		x										
	38	190		x										
	39	195		x										
	40	200	x	x										
	41	205		x										
	42	210		x										

SCHEDULE OF CORE SAMPLES FROM ANGLE BOREHOLES

	43	215		x										
	44	220	x	x										
	45	225		x										
	46	230		x										
	47	235		x										
	48	240	x	x										
	49	245		x										
	50	250		x										
	51	255		x										
	52	260	x	x										
	53	dup	x	x										
	54	blind	x											
	55	method	x											
	56	field	x											
54-1002	57	5		x										
	58	10		x										
	59	15		x										
	60	20	x	x										
	61	25		x										
	62	30		x										
	63	35		x										
	64	40	x	x										
	65	45		x										
	66	50		x										
	67	55		x										
	68	60	x	x										
	69	65		x										
	70	70		x										
	71	75		x										
	72	80	x	x										
	73	85		x										
	74	90		x										
	75	95		x										
	76	100	x	x										
	77	105		x										
	78	110		x										
	79	115		x										
	80	120	x	x										
	81	125		x										
	82	130		x										
	83	135		x										
	84	140	x	x										
	85	145		x										
	86	150		x										
	87	155		x										
	88	160	x	x										
	89	165		x										
	90	170		x										
	91	175		x										
	92	180	x	x										

SCHEDULE OF CORE SAMPLES FROM ANGLE BOREHOLES

	93	185		x										
	94	190		x										
	95	195		x										
	96	200	x	x										
	97	205		x										
	98	210		x										
	99	215		x										
	100	220	x	x										
	101	225		x										
	102	230		x										
	103	235		x										
	104	240	x	x										
	105	245		x										
	106	250		x										
	107	255		x										
	108	260	x	x										
54-1003	109	5		x										
	110	10		x										
	111	15		x										
	112	20	x	x										
	113	25		x										
	114	30		x										
	115	35		x										
	116	40	x	x										
	117	45		x										
	118	50		x										
	119	55		x										
	120	60	x	x										
	121	65		x										
	122	70		x										
	123	75		x										
	124	80	x	x										
	125	85		x										
	126	90		x										
	127	95		x										
	128	100	x	x										
	129	105		x										
	130	110		x										
	131	115		x										
	132	120	x	x										
	133	dup	x	x										
	134	blind	x											
	135	method	x											
	136	field	x											
	137	125		x										
	138	130		x										
	139	135		x										
	140	140	x	x										
	141	145		x										
	142	150		x										

SCHEDULE OF CORE SAMPLES FROM ANGLE BOREHOLES

	143	155		x										
	144	160	x	x										
	145	165		x										
	146	170		x										
	147	175		x										
	148	180	x	x										
	149	185		x										
	150	190		x										
	151	195		x										
	152	200	x	x										
	153	205		x										
	154	210		x										
	155	215		x										
	156	220	x	x										
	157	225		x										
	158	230		x										
	159	235		x										
	160	240	x	x										
	161	245		x										
	162	250		x										
	163	255		x										
	164	260	x	x										
54-1004	165	5		x										
	166	10		x										
	167	15		x										
	168	20	x	x										
	169	25		x										
	170	30		x										
	171	35		x										
	172	40	x	x										
	173	45		x										
	174	50		x										
	175	55		x										
	176	60	x	x										
	177	65		x										
	178	70		x										
	179	75		x										
	180	80	x	x										
	181	85		x										
	182	90		x										
	183	95		x										
	184	100	x	x										
	185	105		x										
	186	110		x										
	187	115		x										
	188	120	x	x										
	189	125		x										
	190	130		x										
	191	135		x										
	192	140	x	x										

SCHEDULE OF CORE SAMPLES FROM ANGLE BOREHOLES

	193	145		x										
	194	150		x										
	195	155		x										
	196	160	x	x										
	197	165		x										
	198	170		x										
	199	175		x										
	200	180	x	x										
	201	185		x										
	202	190		x										
	203	195		x										
	204	200	x	x										
	205	205		x										
	206	210		x										
	207	215		x										
	208	220	x	x										
	209	225		x										
	210	230		x										
	211	235		x										
	212	240	x	x										
	213	dup	x	x										
	214	blind	x											
	215	method	x											
	216	field	x											
	217	245		x										
	218	250		x										
	219	255		x										
	220	260	x	x										
54-1005	221	5		x										
	222	10		x										
	223	15		x										
	224	20	x	x										
	225	25		x										
	226	30		x										
	227	35		x										
	228	40	x	x										
	229	45		x										
	230	50		x										
	231	55		x										
	232	60	x	x										
	233	65		x										
	234	70		x										
	235	75		x										
	236	80	x	x										
	237	85		x										
	238	90		x										
	239	95		x										
	240	100	x	x										
	241	105		x										
	242	110		x										

SCHEDULE OF CORE SAMPLES FROM ANGLE BOREHOLES

	243	115		x										
	244	120	x	x										
	245	125		x										
	246	130		x										
	247	135		x										
	248	140	x	x										
	249	145		x										
	250	150		x										
	251	155		x										
	252	160	x	x										
	253	165		x										
	254	170		x										
	255	175		x										
	256	180	x	x										
	257	185		x										
	258	190		x										
	259	195		x										
	260	200	x	x										
	261	205		x										
	262	210		x										
	263	215		x										
	264	220	x	x										
	265	225		x										
	266	230		x										
	267	235		x										
	268	240	x	x										
	269	245		x										
	270	250		x										
	271	255		x										
	272	260	x	x										
	273	dup	x	x										
	274	blind	x											
	275	method	x											
	276	field	x											
54-1006	277	5		x										
	278	10		x										
	279	15		x										
	280	20	x	x										
	281	25		x										
	282	30		x										
	283	35		x										
	284	40	x	x										
	285	45		x										
	286	50		x										
	287	55		x										
	288	60	x	x										
	289	65		x										
	290	70		x										
	291	75		x										
	292	80	x	x										

SCHEDULE OF CORE SAMPLES FROM ANGLE BOREHOLES

	293	85		x										
	294	90		x										
	295	95		x										
	296	100	x	x										
	297	105		x										
	298	110		x										
	299	115		x										
	300	120	x	x										
	301	125		x										
	302	130		x										
	303	135		x										
	304	140	x	x										
	305	145		x										
	306	150		x										
	307	155		x										
	308	160	x	x										
	309	165		x										
	310	170		x										
	311	175		x										
	312	180	x	x										
	313	185		x										
	314	190		x										
	315	195		x										
	316	200	x	x										
	317	205		x										
	318	210		x										
	319	215		x										
	320	220	x	x										
	321	225		x										
	322	230		x										
	323	235		x										
	324	240	x	x										
	325	245		x										
	326	250		x										
	327	255		x										
	328	260	x	x										
	329	dup	x	x										
	330	blind	x											
	331	method	x											
	332	field	x											
	333		98	316	0	0	0	0	0	0	0	0	0	0

ATTACHMENT 2

SCHEDULE OF GAS AND CORE SAMPLES
FROM DEEP VERTICAL BOREHOLES

location id	sample no	sample depth	moisture	gas-voa	voa core	metals	cn	semi voas	pesticide	herbicide	PCB's	gamma spec	tritium	gross alpha	gross beta
54-1007	1	5	x												
	2	10	x		x	x	x	x	x	x	x	x	x	x	x
	3	15	x												
	4	20	x	x	x	x	x	x	x	x	x	x	x	x	x
	5	25	x												
	6	30	x		x	x	x	x	x	x	x	x	x	x	x
	7	35	x												
	8	40	x	x	x	x	x	x	x	x	x	x	x	x	x
	9	45	x												
	10	50	x		x	x	x	x	x	x	x	x	x	x	x
	11	55	x												
	12	60	x	x	x	x	x	x	x	x	x	x	x	x	x
	13	65	x												
	14	70	x		x	x	x	x	x	x	x	x	x	x	x
	15	75	x												
	16	80	x	x	x	x	x	x	x	x	x	x	x	x	x
	17	85	x												
	18	90	x												
	19	95	x												
	20	100	x	x	x	x	x	x	x	x	x	x	x	x	x
	21	105	x												
	22	110	x												
	23	115	x												
	24	120	x	x	x	x	x	x	x	x	x	x	x	x	x
	25	125	x												
	26	130	x												
	27	135	x												
	28	140	x	x	x	x	x	x	x	x	x	x	x	x	x
	29	145	x												
	30	150	x												
	31	155	x												
	32	160	x	x	x	x	x	x	x	x	x	x	x	x	x
	33	165	x												
	34	170	x												
	35	175	x												
	36	180	x	x	x	x	x	x	x	x	x	x	x	x	x
	37	185	x												
	38	190	x												
	39	195	x												
	40	200	x	x	x	x	x	x	x	x	x	x	x	x	x

	41	205	x												
	42	210	x												
	43	215	x												
	44	220	x	x											
	45	225	x												
	46	230	x												
	47	235	x												
	48	240	x	x	x										
	49	245	x												
	50	250	x												
	51	255	x												
	52	260	x	x											
	53	265	x												
	54	270	x												
	55	275	x												
	56	280	x	x	x										
	57	285	x												
	58	290	x												
	59	295	x												
	60	300	x	x	x	x	x	x	x	x	x	x	x	x	x
	61	305	x												
	62	310	x												
	63	315	x												
	64	320	x	x											
	65	325	x												
	66	330	x												
	67	335	x												
	68	340	x	x											
	69	345	x												
	70	350	x												
	71	355	x												
	72	360	x	x	x										
	73	365	x												
	74	370	x												
	75	375	x												
	76	380	x	x											
	77	385	x												
	78	390	x												
	79	395	x												
	80	400	x	x	x	x	x	x	x	x	x	x	x	x	x
	81	dup		x											
	82	field		x											
	83	method		x											
	84	blind		x											
	85	405	x												
	86	410	x												
	87	415	x												
	88	420	x	x											
	89	425	x												

	90	430	x												
	91	435	x												
	92	440	x	x	x										
	93	dup			x										
	94	field			x										
	95	method			x										
	96	blind			x										
	97	445	x												
	98	450	x												
	99	455	x												
	100	460	x	x											
	101	465	x												
	102	470	x												
	103	475	x												
	104	480	x	x	x										
	105	485	x												
	106	490	x												
	107	495	x												
	108	500	x	x	x	x	x	x	x	x	x	x	x	x	x
	109	dup				x	x	x	x	x	x	x	x	x	x
	110	field				x	x	x	x	x	x	x	x	x	x
	111	method				x	x	x	x	x	x	x	x	x	x
	112	blind				x	x	x	x	x	x	x	x	x	x
			100	29	26	21	21	21	21	21	21	21	21	21	21
location id	sample no	sample type	moisture	gas-voa	core-voa	metals	cn	semi voas	pesticide	herbicide	PCB's	gamma spec	tritium	gross alpha	gross beta
54-1008	1	5	x												
	2	10	x		x	x	x	x	x	x	x	x	x	x	x
	3	15	x												
	4	20	x	x	x	x	x	x	x	x	x	x	x	x	x
	5	25	x												
	6	30	x		x	x	x	x	x	x	x	x	x	x	x
	7	35	x												
	8	40	x	x	x	x	x	x	x	x	x	x	x	x	x
	9	45	x												
	10	50	x		x	x	x	x	x	x	x	x	x	x	x
	11	55	x												
	12	60	x	x	x	x	x	x	x	x	x	x	x	x	x
	13	65	x												
	14	70	x		x	x	x	x	x	x	x	x	x	x	x
	15	75	x												
	16	80	x	x	x	x	x	x	x	x	x	x	x	x	x
	17	85	x												
	18	90	x												
	19	95	x												

	20	100	x	x	x	x	x	x	x	x	x	x	x	x	x
	21	105	x												
	22	110	x												
	23	115	x												
	24	120	x	x	x	x	x	x	x	x	x	x	x	x	x
	25	125	x												
	26	130	x												
	27	135	x												
	28	140	x	x	x	x	x	x	x	x	x	x	x	x	x
	29	145	x												
	30	150	x												
	31	155	x												
	32	160	x	x	x	x	x	x	x	x	x	x	x	x	x
	33	165	x												
	34	170	x												
	35	175	x												
	36	180	x	x	x	x	x	x	x	x	x	x	x	x	x
	37	185	x												
	38	190	x												
	39	195	x												
	40	200	x	x	x	x	x	x	x	x	x	x	x	x	x
	41	205	x												
	42	210	x												
	43	215	x												
	44	220	x	x											
	45	225	x												
	46	230	x												
	47	235	x												
	48	240	x	x	x										
	49	dup			x										
	50	field			x										
	51	method			x										
	52	blind			x										
	53	245	x												
	54	250	x												
	55	255	x												
	56	260	x	x											
	57	265	x												
	58	270	x												
	59	275	x												
	60	280	x	x	x										
	61	dup		x											
	62	field		x											
	63	method		x											
	64	blind		x											
	65	285	x												
	66	290	x												
	67	295	x												
	68	300	x	x	x	x	x	x	x	x	x	x	x	x	x

	69	305	x												
	70	310	x												
	71	315	x												
	72	320	x	x											
	73	325	x												
	74	330	x												
	75	335	x												
	76	340	x	x											
	77	345	x												
	78	350	x												
	79	355	x												
	80	360	x	x	x										
	81	365	x												
	82	370	x												
	83	375	x												
	84	380	x	x											
	85	385	x												
	86	390	x												
	87	395	x												
	88	400	x	x	x	x	x	x	x	x	x	x	x	x	x
	89	405	x												
	90	410	x												
	91	415	x												
	92	420	x	x											
	93	425	x												
	94	430	x												
	95	435	x												
	96	440	x	x	x										
	97	445	x												
	98	450	x												
	99	455	x												
	100	460	x	x											
	101	465	x												
	102	470	x												
	103	475	x												
	104	480	x	x	x										
	105	485	x												
	106	490	x												
	107	495	x												
	108	500	x	x	x	x	x	x	x	x	x	x	x	x	x
	109	dup				x	x	x	x	x	x	x	x	x	x
	110	field				x	x	x	x	x	x	x	x	x	x
	111	method				x	x	x	x	x	x	x	x	x	x
	112	blind				x	x	x	x	x	x	x	x	x	x
	113		100	29	26	21	21	21	21	21	21	21	21	21	21