DATA REVIEW, SITE SELECTION, AND CONCEPTUAL DESIGN OF A STEAM INJECTION PILOT PLANT

DRAFT REPORT

Prepared for

MCCLELLAN AIR FORCE BASE

Prepared by

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PREFACE

This project was completed for McClellan Air Force Base, California, by CH2M HILL under the Environmental Engineering and Scientific Support Services Contract No. F04699-90-D-0035, Delivery Order No. 5003. CH2M HILL was assisted in this work by Udell Technologies. This report presents the data review, site selection, and conceptual design of a steam injection pilot plant.

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CH2M HILL would like to acknowledge cooperation of the McClellan Air Force Base Office of Environmental Management. In particular, CH2M HILL acknowledges the assistance of Jerry Robbins, Captain Fran Slavich, Bud Hoda, and Alex Johnson.

CONTENTS

APPENDICES

TABLES

FIGURES

1.0 INTRODUCTION

McClellan Air Force Base (McAFB), located in Sacramento County, California, provides logistical support and maintenance of aircraft and ground support systems through the Sacramento Air Logistics Center (ALC) (Figure 1).

The +50-year-old ALC is a key part of the Air Force Logistics Command lifeline of the aerospace team. The command is headquartered at Wright-Patterson AFB, Ohio, and the Sacramento center is one of five such facilities located at strategic points around the country. Each of these centers supports the Air Force's other major commands in key areas of management, procurement, supply distribution and transportation, and maintenance and repair. Each also supports certain aircraft, weapon systems, and various items and commodities.

At Sacramento ALC, aircraft such as the F/EF/FB-111, A-10, F-4, and C-12A/D are kept combat-ready. Surveillance and warning systems, radar sites, space systems such as the Space Shuttle, missile tracking stations, and airborne and ground power generators are also maintained and repaired (Ref. 1).

Environmental efforts at McAFB during the previous decade have identified numerous known or suspected hazardous waste disposal sites. They are located in Operable Units A, B, C, and D (Figure 2). Most of the sites have had some previous soil sampling, monitoring well installation, soil and water sampling, and data analysis. The results of site specific environmental efforts to date at McClellan reside in the Administrative Record (AR) at the Base library.

The purpose of the current effort was to conduct a data review, develop a site selection process, select a site for a pilot-scale in-situ remedial system, and complete a conceptual design of the system. McAFB has selected a promising alternative and innovative technology called steam injection, developed by Kent Udell at the University of California at Berkeley. This technology combines in-situ steam injection into soil and groundwater with vacuum extraction of volatile and semi-volatile contaminants. The goal of the steam injection system is to remove volatile and semi-volatile organic contaminants from both the soil and groundwater within a selected site. CH2M HILL, in conjunction with Udell Technologies, Inc., reviewed the existing environmental data in the AR and developed a site selection process. The optimal siting criteria were developed to define the most appropriate siting conditions and subsequently select the optimal site. Three candidate sites, Sites 2, 22, and 42, have been chosen for further consideration in the site selection process. The final site will be chosen in cooperation with McAFB and the regulatory agencies. Conceptual designs have been drafted for all three locations to aid in the selection process.

The objective of this report is to provide McAFB and the appropriate regulatory agencies with a summary of and an opportunity to comment on the data review, site selection, and conceptual design efforts. This report will provide the necessary input into site selection issues, design modifications, and regulatory considerations of a pilot-scale steam injection system.

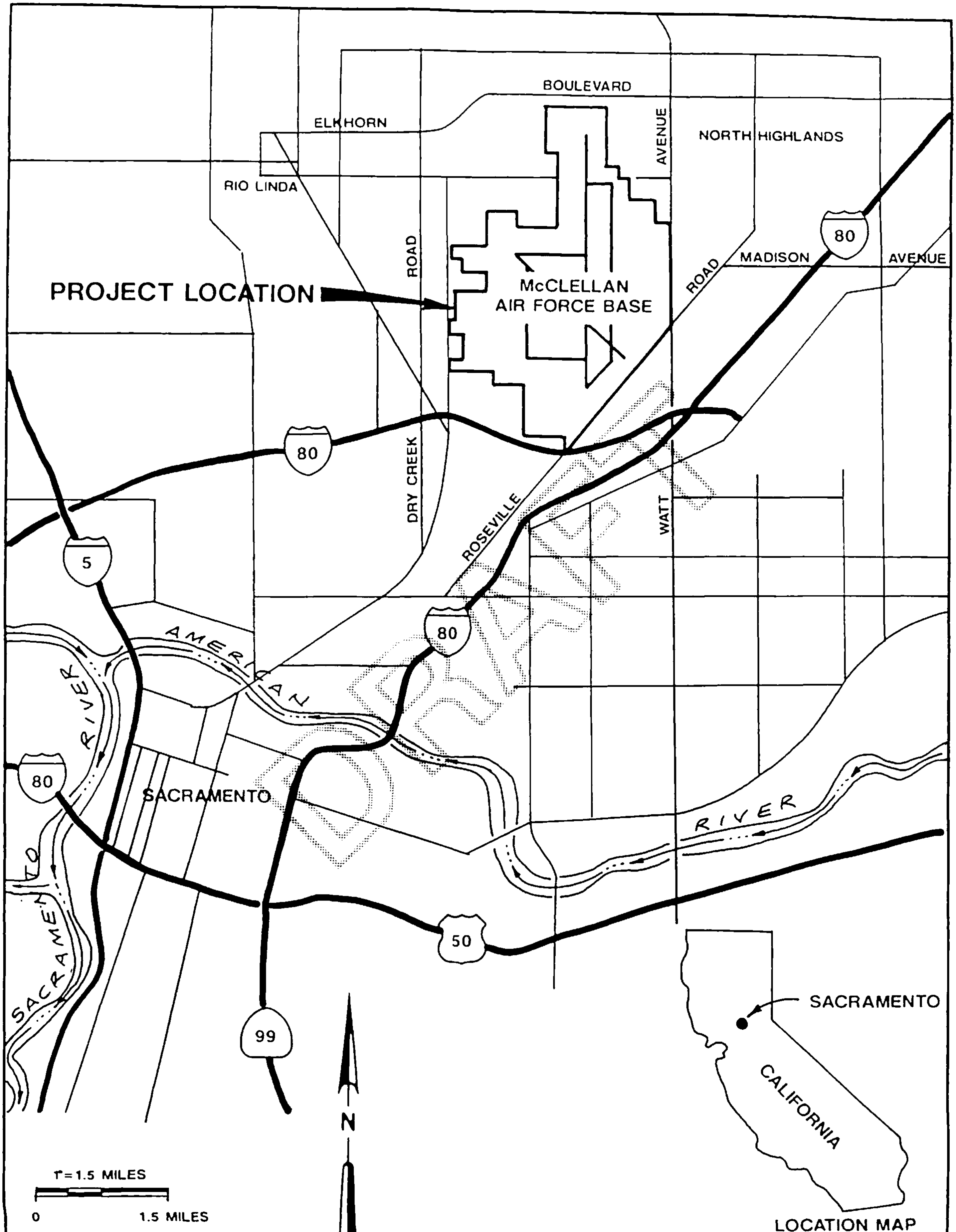

FIGURE 1
LOCATION OF McCLELLAN AIR FORCE BASE

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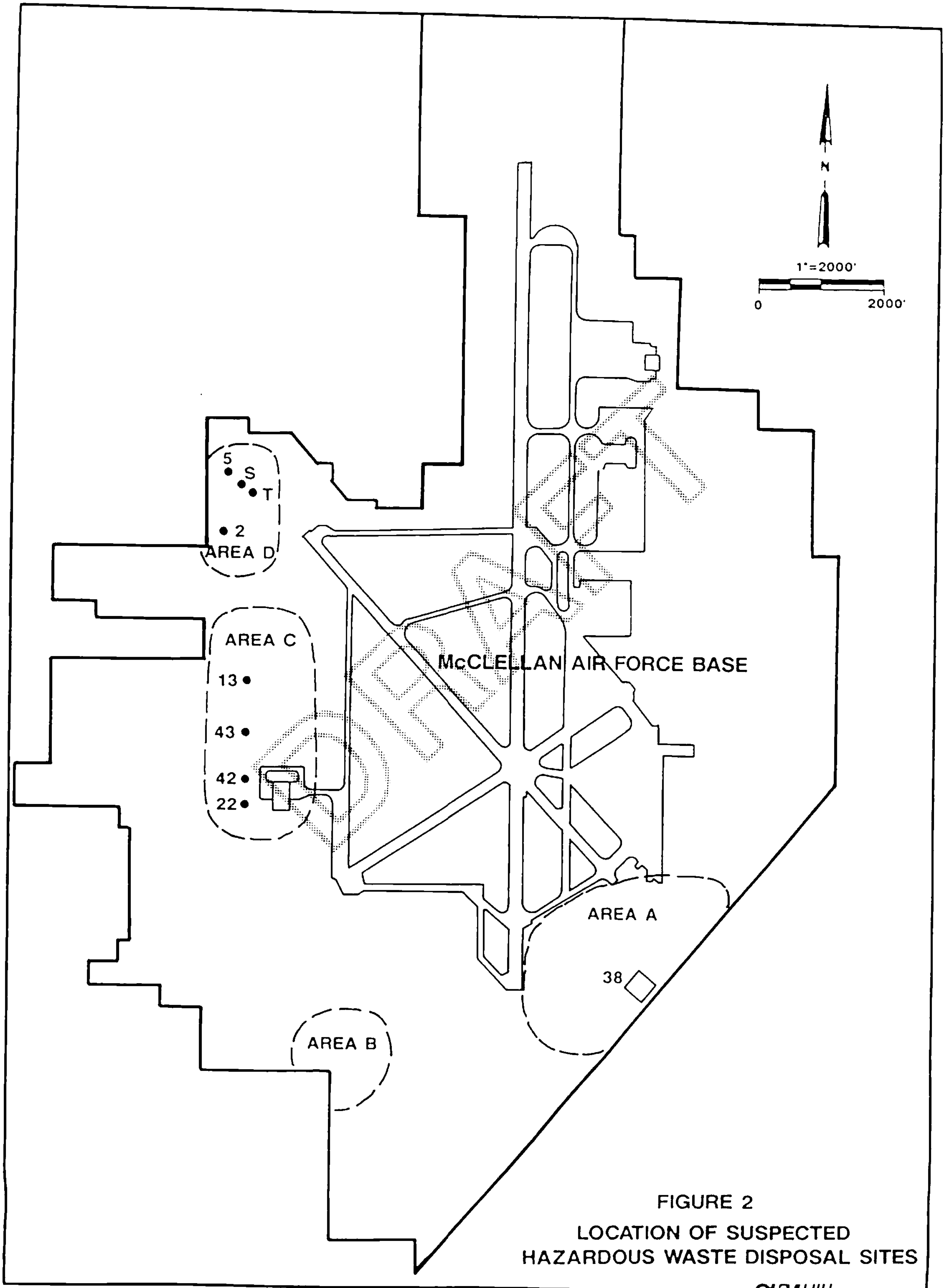

FIGURE 2
LOCATION OF SUSPECTED
HAZARDOUS WASTE DISPOSAL SITES

2.0 REVIEW OF DOCUMENTS

2.1 DOCUMENT REVIEW

The McAFB library houses a collection of 211 documents, largely prepared by contractors, containing information on environmental conditions at the Base. This collection, called the Administrative Record (AR), was assessed to identify those documents pertinent to the task of locating a suitable site for the steam injection pilot facility. A data review of those found to be relevant is provided in Appendix A.

Only documents addressing areas A, B, C, and D were reviewed. Because of a lack of sufficient information, other areas were not considered during the document review. Of particular importance were documents containing specific information on conditions listed in the site selection process. These data were soil boring logs, geophysical logs, monitoring well data, and soil analyses. To ensure that the information in the documents was reliable and accurate, a document Quality Assurance/Quality Control evaluation was compiled.

2.2 QA/QC OF DOCUMENTS

The Index to Data References, prepared for McAFB by Radian Corporation, lists and provides a preliminary assessment of that data (Ref. 2). It was the sole source of information in the QA/QC search of relevant documents in the AR. The index categorizes the data inventory items: chemical/physical measurements, geology, maps, and specific site features. In addition, it allows retrieval of documents by site and by inventory items.

The index uses a coding scale to establish the quality of reviewed data. The preliminary quality ratings of A, B, C are defined as follows:

A   Data that are considered complete, representative, and verifiable. These data can be used for decisionmaking with a high confidence level.

B   Data considered partially lacking in completeness and/or representativeness, and/or not completely verifiable. These data should be used with caution in decisionmaking and only with the support of other data of Code A quality.

C   Data of poor quality or data with indeterminate or undocumented quality control. These data should be used for decisionmaking only when strongly supported by data of Code A quality.

The majority of the documents received either an A or B rating. The limitation of the index is that it provides only a preliminary evaluation of documents (Ref. 3). Due to this limitation, additional criteria used in determining the quality of data were the completeness of information and the existence of supporting documents. Using the index, CH2M HILL determined that existing data were of sufficient quality for the site selection process. However, the data should not be assumed to be completely accurate; sampling is needed. Additional samples will be collected before the demonstration study begins (see Section 6.1). The site selection process involved using information from existing documents to target areas with high contamination and a confining bed or high permeability layer.

3.0 SITE SELECTION PROCESS

A selection process (see Figure 3) was devised to select an optimal site at McAFB for the steam injection system. Evaluation criteria for site selection were developed by CH2M HILL and Udell Technologies in conjunction with McAFB and the regulatory agencies. These criteria were segregated by order of importance into primary and secondary criteria. The primary criteria are necessary conditions for the technical feasibility of the steam injection process; the secondary criteria are relevant design considerations that may affect the performance of the system.

Following are the two primary criteria, which are necessary conditions.

- **Contaminant concentration range (total VOCs and semi-volatiles) of approximately 10 to 1,000 parts per million (ppm)**

  A minimum concentration of about 10 ppm would allow for an observable change in contaminant concentrations during the pilot test. (A 1 percent residual of a 10 ppm contaminant would equal only 100 parts per billion; a lower concentration could give rise to large analytical uncertainties.) A minimum concentration of 10 ppm for an individual VOC compound would be preferable.

  The upper limitation on concentration is most critical for contaminants that are denser than water, and applies only where elevated concentrations are present within a significant volume of soil (i.e., it depends on the total mass of contaminants). If a sufficient mass of dense contaminant is present in the pilot test area, the advancing condensation front could give rise to a bank of dense non-aqueous phase liquids (DNAPLs). The DNAPLs could then migrate downward into deeper, uncontaminated soils or below the water table. (Note: The process flow chart in Figure 3 indicates that the potential for DNAPL migration may exist at contaminant concentrations over 1,000 ppm.)

- **Confining bed or high-permeability bed beneath contaminated zone**

  The vertical movement of contaminants in solution in the steam condensate must be controlled in order to guard against further contamination of the groundwater. Such control can be achieved by operating the pilot above a continuous low permeability confining bed or by the maintenance of a relatively high vapor phase pressure gradient in a steam-bearing zone below the region soil contamination. In the second case, a continuous high permeability zone at least 1 foot thick is required for preferential steam zone movement. Also, this zone should be bounded on the bottom by a region of low vertical permeability. Under these conditions, the trajectory of steam condensate draining into this high permeability zone will be essentially horizontal, allowing effective recovery by liquid pumping from the low pressure recovery wells.

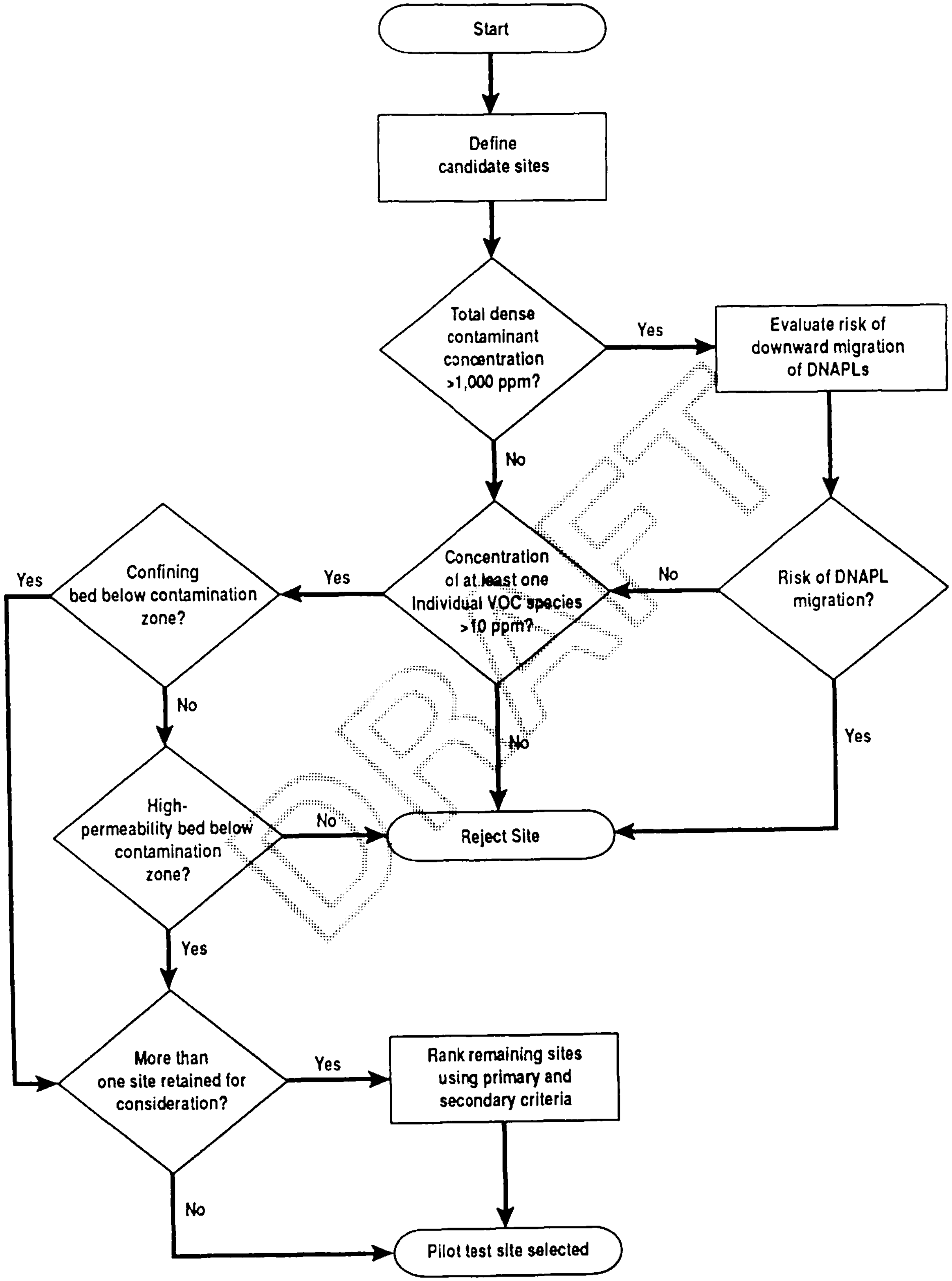

FIGURE 3
STEAM INJECTION SITE
SELECTION PROCESS

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The hydraulically connected high permeability zone should have a permeability on the order of 10 darcy (~100 gal/day/ft^2), a thickness of over 1 foot, and a contrast in horizontal permeability of about two orders of magnitude in relation to adjacent zones in order to promote preferential steam zone growth into barrier zone.

The following criteria are secondary and generally could be compensated for in the engineering design of the pilot plant if they are not met. These criteria were used to select among sites that meet both the two criteria above, by using a weighted-sum scheme.

- **Defined perimeter of contamination**

  The movement of contaminants ahead of the steam condensation front could lead to additional spreading away from the target area if perimeter steam injection wells are placed inside the zone of contamination.

- **Relative site size**

  A pilot-scale demonstration that remediates a "small" site, 1 acre or less, would be preferable.

- **Site accessibility**

  A pilot-scale system would preferably be sited away from buildings, structures, and human intrusion.

- **Distribution of contaminants in both high- and low-permeability zones**

  It is given that significant sampling will be required to establish baseline conditions.

- **Proximity to groundwater treatment plant (GWTP) or GWTP pipeline**

  A pilot-scale system site near the groundwater treatment plant is preferable so that any contaminated condensate can be adequately remediated before discharge.

- **Adequate depth of contamination**

  This is relevant to vadose zone only. A minimum depth of 20 feet should be sufficient.

The following conditions are important and necessary considerations for siting components of the steam stripping process; however, these conditions are not criteria used in the site selection process:

- **Access to utilities (i.e. steam, electrical power)**
- **Adequate work space on the surface**
- **No underground utilities or structures that could be damaged by drilling activities and by elevated temperatures**

3.1 SITES MEETING SELECTION CRITERIA FOR CONTAMINATION

The first criterion in the selection process is that the contaminant concentration range should be approximately 10 to 1,000 ppm. Relevant documents in the AR were consulted to determine contaminant concentration ranges in various sites. Table 1 (pages 9 through 19) is a compilation of sites in Areas A, B, C, and D by contamination. Any site that had no individual contaminant present at or above 10 ppm was rejected as a potential site for the pilot facility. Any sites that met the 10 ppm individual contaminant concentration criteria were designated "initially approved." Therefore, the sites were divided into two categories--initially approved or disapproved--depending on the contamination present. Table 2 (page 20) lists the initially approved sites; Appendix B contains cross sections of the initially approved sites. The initially approved sites were explored further for hydrogeologic selection criteria and secondary selection criteria.

3.2 SITES MEETING SELECTION CRITERIA FOR HYDROGEOLOGY

3.2.1 Explanation of Approach

The nine sites that meet the various conditions for contaminant concentration were evaluated on the basis of the local hydrologic conditions. Existing boring logs and geophysical logs were reviewed to determine if a continuous low-permeability layer or a continuous high-permeability layer appears to be present in the saturated zone beneath the bulk of the contamination. Such a layer is necessary to provide a barrier, either active or passive, to downward migration of contaminants during the pilot test. The intent of this initial screening of hydrogeologic conditions is not to provide a definitive judgement about the feasibility of steam injection, but to determine if the existing data suggest that a continuous low-permeability or high-permeability layer extends across the site.

High-permeability soils, for the purpose of the screening process, are defined as sand or gravel (SW, SP, GW, or GP, by the United Soil Classification System). Clay (CL and CH), silty clay, sandy clay, or "hardpan" are considered to be low-permeability soils. If geophysical logs were available, the resistivity curves were used to identify the high- and low-permeability zones. Sites were retained if existing borings consistently showed the presence of one or more barrier layers at a particular depth. Example geological and geophysical well logs are provided in Appendix C to illustrate how high-permeability and low-permeability layers were identified.

Table 1: Compilation of Sites in Areas A, B, C, and D by Contamination

AREA	SITE NO.	SITE ACTIVITY	BORING NO.	SAMPLE DEPTH (FT)	CONTAMINANTS	CONCENTRATION (PPM)	REFERENCE (See App. A)
A	37	refuse disposal pit	N/A	N/A	VOCs , Semi-VOCs	< 10	60,77,81
	38	engine repair facility(bldg 475)	38SSB01	9.0-9.5	chlorobenzene	15	
					ethylbenzene	72	
					toluene	17	
					2-butanone	12	
					2-hexanone	190	
					4-methyl-2-pentanone	43	
					total xylenes	430	
					TOTAL VOCs	795	
					TOTAL Semi-VOCs	< 10	
B	30	radiological chemical laboratory	N/A	N/A	VOCs	< 10	63,77,81
	36	plating chemical storage area	N/A	N/A	VOCs, Semi-VOCs	< 10	
	47	plating shop-bldg 666(dismantled)	N/A	N/A	VOCs, Semi-VOCs	< 10	
	48	abandoned industrial waste treatment plant	N/A	N/A	VOCs, Semi-VOCs	< 10	
C	7	refuse pit	07WSB04	8.5-30	TOTAL VOCs	< 10	75,77,81
					bis(2-ethylhexyl)phthalate	19	
					TOTAL Semi-VOCs	20	
	8	disposal landfill	N/A	N/A	VOCs, Semi-VOCs	< 10	
	10	burn debris burial pit	10WSB01	6.0-12.5	TOTAL VOCs	< 10	
					bis(2-ethylhexyl)phthalate	12	

Table 1 (Cont.)

AREA	SITE NO.	SITE ACTIVITY	BORING NO.	SAMPLE DEPTH (FT)	CONTAMINANTS	CONCENTRATION (PPM)	REFERENCE (See App. A)
					TOTAL SEMI-VOCs	19	
	11	burn debris burial pit	11CWS01	15.5-24.0	TOTAL VOCs	< 10	
					benzoic acid	45	
					bis(2-ethylhexyl)phthalate	50	
					TOTAL SEMI-VOCs	109	
	12	burn debris burial pit	12WSB01	9.5-25.0	TOTAL VOCs	< 10	
					phenanthrene	34	
					fluoroanthene	28	
					bis(2-ethylhexyl)phthalate	10	
					benzo(A)anthracene	13	
					chrysene	12	
					TOTAL SEMI-VOCs	135	
	13	burn debris burial pit	13WSB02	8.5-10.0	acetone	46	
					2-butanone	43	
					TOTAL VOCs	93	
					TOTAL SEMI-VOCs	< 10	
				10.5-11.0	acetone	76	
					2-butanone	27	
					TOTAL VOCs	108	
					TOTAL SEMI-VOCs	None Detected	

Table 1 (Cont.)

AREA	SITE NO.	SITE ACTIVITY	BORING NO.	SAMPLE DEPTH (FT)	CONTAMINANTS	CONCENTRATION (PPM)	REFERENCE (See App. A)
				8.0-14.0	TOTAL VOCs	None Detected	
					n-nitrosodiphenylamine	22	
					TOTAL SEMI-VOCs	22	
	14	burn debris burial pit	14WSB01	16.5-30.5	TOTAL VOCs	< 10	
					bis(2-ethylhexyl)phthalate	10	
					TOTAL SEMI-VOCs	16	
			14WSB02	9.5-20.5	TOTAL VOCs	< 10	
					bis(2-ethylhexyl)phthalate	11	
					TOTAL SEMI-VOCs	15	
	22	burn debris burial pit	22CWS01	5.0-26.0	total xylenes	13	
					TOTAL VOCs	37	
					2,4-dimethylphenol	22	
					benzoic acid	69	
					1,2-dichlorobenzene	43	
					TOTAL SEMI-VOCs	134	
				29.0-29.5	trichloroethylene	28	
					TOTAL VOCs	34	
					TOTAL SEMI-VOCs	None Detected	
			22SSB03	59.5-60.0	2-hexanone	13	
					total xylenes	12	

Table 1 (Cont.)

AREA	SITE NO.	SITE ACTIVITY	BORING NO.	SAMPLE DEPTH (FT)	CONTAMINANTS	CONCENTRATION (PPM)	REFERENCE (See App. A)
					TOTAL VOCs	37	
					2-methylnaphthalene	13	
					TOTAL SEMI-VOCs	19	
	41	construction debris	N/A	N/A	VOCs, Semi-VOCs	< 10	
	42	oil storage ponds and burn pit-under IWTP	42CWS01	2.0-8.5	total xylenes	20	
					TOTAL VOCs	25	
					TOTAL SEMI-VOCs	11	
			42SSB03	39.5-40.0	total xylenes	38	
					TOTAL VOCs	69	
					TOTAL SEMI-VOCs	17	
	43	waste disposal pit	43CWS02	7.0-21.0	TOTAL VOCs	11	
					benzoic acid	48	
					1,4-dichlorobenzene	11	
					1,2-dichlorobenzene	20	
					bis(2-ethylhexyl)phthalate	51	
					TOTAL SEMI-VOCs	179	
	52	buried disposal area	52WSB01	9.0-11.0	TOTAL VOCs	None Detected	
					pyrene	10	
					benzo(K)fluoranthene	14	
					benzo(A)pyrene	13	

Table 1 (Cont.)

AREA	SITE NO.	SITE ACTIVITY	BORING NO.	SAMPLE DEPTH (FT)	CONTAMINANTS	CONCENTRATION (PPM)	REFERENCE (See App. A)
					3,4-benzofluoranthene	14	
					indeno(1,2,3-CD)pyrene	11	
					TOTAL SEMI-VOCs	103	
	67	burial disposal pit	67WSB01	1.5-7.5	TOTAL VOCs	None Detected	
					1,2-dichlorobenzene	21	
					TOTAL SEMI-VOCs	58	
	69	burn debirs burial pit	N/A	N/A	VOCs, Semi-VOCs	< 10	
D	1	refuse/solid waste burn and burial pit	BP-13	5.0-15.0	TOTAL VOCs	None Detected	7,77,81
					bis(2-ethylhexyl)phthalate	28	
					TOTAL SEMI-VOCs	28	
	2	wastewater sludge disposal and burn pit	BP-8	5.0-10.0	toluene	63	
					total xylenes	58	
					TOTAL VOCs	138	
					naphthalene	35	
					bis(2-ethylhexyl)phthalate	105	
					1,2-dichlorobenzene	66	
					TOTAL SEMI-VOCs	220	
			BP-5	10.0-15.0	1,1-dichloroethane	32	
					1,2-trans-dichloroethylene	23	
					ethylbenzene	19	

Table 1 (Cont.)

AREA	SITE NO.	SITE ACTIVITY	BORING NO.	SAMPLE DEPTH (FT)	CONTAMINANTS	CONCENTRATION (PPM)	REFERENCE (See App. A)
					toluene	250	
					4-methyl-2-pentanone	18	
					total xylenes	92	
					TOTAL VOCs	445	
					naphthalene	46	
					bis(2-ethylhexyl)phthalate	94	
					TOTAL SEMI-VOCs	140	
			BP-4	9.0-12.0	1,1,1-trichloroethane	300	
					1,1-dichloroethane	110	
					1,2-trans-dichloroethylene	73	
					ethylbenzene	27	
					tetrachloroethylene	19	
					toluene	330	
					trichloroethylene	59	
					vinyl chloride	15	
					TOTAL VOCs	940	
					naphthalene	64	
					bis(2-ethylhexyl)phthalate	180	
					phenol	13	
					4-methylphenol	74	

Table 1 (Cont.)

AREA	SITE NO.	SITE ACTIVITY	BORING NO.	SAMPLE DEPTH (FT)	CONTAMINANTS	CONCENTRATION (PPM)	REFERENCE (See App. A)
					TOTAL SEMI-VOCs	331	
				28.0-30.0	1,1,1-trichloroethane	200	
					toluene	24	
					trichloroethylene	79	
					4-methyl-2-pentanone	12	
					total xylenes	16	
					TOTAL VOCs	336.3	
					1,2-dichlorobenzene	380	
					1,3-dichlorobenzene	12	
					1,4-dichlorobenzene	46	
					TOTAL SEMI-VOCs	449	
				55.0-57.0	1,1,1-trichloroethane	19	
					trichloroethylene	22	
					TOTAL VOCs	48	
					1,2-dichlorobenzene	168	
					1,4-dichlorobenzene	13	
					TOTAL SEMI-VOCs	189	
	3	wastewater sludge disposal and burial pit	BP-14	7.0-19.0	TOTAL VOCs	None Detected	
					bis(2-ethylhexyl)phthalate	24	
					TOTAL SEMI-VOCs	24	

Table 1 (Cont.)

AREA	SITE NO.	SITE ACTIVITY	BORING NO.	SAMPLE DEPTH (FT)	CONTAMINANTS	CONCENTRATION (PPM)	REFERENCE (See App. A)
			BP-3	9.0-12.0	TOTAL VOCs	13	
					di-n-butyl phthalate	19	
					TOTAL SEMI-VOCs	22	
	5	wastewater sludge disposal and burial pit	BP-7	11.0-12.0	1,1,1-trichloroethane	58	
					tetrachloroethylene	11	
					toluene	32	
					trichloroethylene	31	
					total xylenes	11	
					TOTAL VOCs	168	
					naphthalene	22	
					bis(2-ethylhexyl)phthalate	140	
					TOTAL SEMI-VOCs	162	
			BP-6	15.0-22.0	chlorobenzene	17	
					1,1,1-trichloroethane	12	
					1,1-dichloroethane	26	
					1,2-trans-dichloroethylene	21	
					ethylbenzene	45	
					toluene	150	
					trichloroethylene	13	
					4-methyl-2-pentanone	10	

Table 1 (Cont.)

AREA	SITE NO.	SITE ACTIVITY	BORING NO.	SAMPLE DEPTH (FT)	CONTAMINANTS	CONCENTRATION (PPM)	REFERENCE (See App. A)
					total xylenes	140	
					TOTAL VOCs	441	
					naphthalene	16	
					bis(2-ethylhexyl)phthalate	100	
					TOTAL SEMI-VOCs	116	
			BP-9	9.0-19.0	ethylbenzene	12	
					toluene	83	
					total xylenes	29	
					TOTAL VOCs	140	
					naphthalene	10	
					bis(2-ethylhexyl)phthalate	150	
					TOTAL SEMI-VOCs	170	
				19.0-22.0	toluene	90	
					total xylenes	33	
					TOTAL VOCs	143	
					1,2-dichlorobenzene	10	
					TOTAL SEMI-VOCs	10	
				54.0-56.0	TOTAL VOCs	< 10	
					di-n-butylphthalate	14	
					TOTAL SEMI-VOCs	27	

Table 1 (Cont.)

AREA	SITE NO.	SITE ACTIVITY	BORING NO.	SAMPLE DEPTH (FT)	CONTAMINANTS	CONCENTRATION (PPM)	REFERENCE (See App. A)
	6	skimmed oil burn area	N/A	N/A	VOCs	< 10	
	26	wastewater sludge disposal and burn pit	N/A	N/A	VOCs, Semi-VOCs	< 10	
	S	fuel and solvent disposal pit	BP-20	7.0-10.0	toluene	14	
					total xylenes	18	
					TOTAL VOCs	38	
					1,2-dichlorobenzene	33	
					bis(2-ethylhexyl)phthalate	26	
					TOTAL SEMI-VOCs	78	
				18.0-20.0	acetone	65	
					TOTAL VOCs	68	
					TOTAL SEMI-VOCs	< 10	
				48.0-50.0	acetone	46	
					TOTAL VOCs	50	
					TOTAL SEMI-VOCs	< 10	
	T	fuel, solvent, and sludge disposal pit	BP-16	9.0-11.0	1,1,1-trichloroethane	190	
					1,2-trans-dichloroethylene	75	
					tetrachloroethylene	36	
					TOTAL VOCs	286	
					1,2-dichlorobenzene	290	
					1,3-dichlorobenzene	42	

Table 1 (Cont.)

AREA	SITE NO.	SITE ACTIVITY	BORING NO.	SAMPLE DEPTH (FT)	CONTAMINANTS	CONCENTRATION (PPM)	REFERENCE (See App. A)
					1,4-dichlorobenzene	520	
					naphthalene	10	
					bis(2-ethylhexyl)phthalate	250	
					TOTAL SEMI-VOCs	1,117	
			BP-18	7.0-9.0	1,1,1-trichloroethane	23	
					toluene	30	
					total xylenes	16	
					TOTAL VOCs	93	
					1,2-dichlorobenzene	100	
					1,3-dichlorobenzene	12	
					1,4-dichlorobenzene	17	
					bis(2-ethylhexyl)phthalate	16	
					TOTAL SEMI-VOCs	155	
			BP-18	11.0-13.0	1,1,1-trichloroethane	35	
					tetrachloroethylene	20	
					toluene	19	
					trichloroethylene	23	
					acetone	19	
					TOTAL VOCs	134	
					TOTAL SEMI-VOcs	< 10	
	East Area	Unknown	N/A	N/A	VOCs, Semi-VOCs	< 10	

For each site, two or more potential barrier layers were described in terms of soil type, depth, and thickness. A qualitative evaluation of the probability that each layer is continuous was made, based on the soil type, layer thickness, the number of available borings of sufficient depth, and the spatial distribution of the borings. Because of the general nature of alluvial systems, clay layers of a given thickness were assumed to be more laterally continuous than sand and gravel lenses of the same thickness. Finally, each site was given an overall qualitative ranking based upon the number of potential barrier layers, the aggregate of the continuity ratings, and the quantity and quality of available data.

Table 2
List of Initially Approved Sites

Area	Approved (Site No.)
A	38
C	13
C	22
C	42
C	43
D	5
D	2
D	S
D	T

Because the candidate sites appear to have affected the local groundwater, the barrier layers should be at some depth below the water table in order to be beneath the most contaminated soils. In general, the stratigraphy at each site was analyzed in detail below an elevation of approximately zero feet mean sea level (msl). The water table elevation at the nine sites is at approximately -30 to -36 feet msl. Boring logs with total depths of less than 60 to 80 feet did not provide useful information.

Within Area D, only those zones below about -80 feet msl were considered because shallower zones are penetrated by numerous extraction wells that are screened across multiple permeable layers. The shallower permeable zones within Area D appear to be contaminated. (The permeable zone immediately below -80 feet msl is Zone C of the CH2M HILL investigations, and is equivalent to the lower part of the middle zone described in the Radian reports.)

3.2.2 Data Limitations

A majority of the existing soil boring logs are restricted to the unsaturated zone. Existing data on soil conditions within the saturated zone are limited to geologic logs and geophysical logs of monitoring wells, deep exploratory borings, and existing base wells. Geophysical logs are usually not available for wells constructed before the mid-1980s. The quality of the earlier geologic logs is quite variable, and several different methods of soil classification were used by the field geologists.

3.2.3 Summary of Sites

Based on existing data, all of the nine sites potentially have a high - or low - permeability layer that could act as a barrier to vertical migration of contaminants. Therefore, none of the nine sites was rejected on the basis of local hydrogeologic conditions, and all were given qualitative ranking as described below. The results of the evaluation of hydrogeologic conditions at each of the nine sites are presented in Table 3. The following summaries of the nine sites supplement the information provided in Table 3.

Area A: Site 38. Five borings within Site 38 indicate the presence of a sand layer between elevations -55 to -70 msl. This layer varies from 2 to 15 feet in thickness. Two of the five boring logs classify this layer as sandy clay, but these logs are of poor quality.

A second 5- to 20-foot-thick sand and/or gravel layer was intercepted by three deep borings. The same three borings also show a 10-foot clay layer midway between the two permeable layers. The available deeper boring log data for Site 38 are distributed over a relatively large area, hence the site is given a low-to-moderate overall ranking.

Area C: Site 13. Deep borings near Site 13 are limited to one cluster of four and one additional boring. The site has a low potential for two barrier layers and is given a low ranking because of the limited amount of data.

Area C: Site 22. Two high-permeability layers appear to extend below this site. The shallower of the two is 9 to 35 feet thick, and the distinctive sand correlates well between borings. There also is good boring log coverage across the site. For these reasons, the site is given a high ranking.

Area C: Site 42. This site is adjacent to Site 22, and the same geologic data were reviewed in its evaluation. Site 42 is given a lower ranking than Site 22, however, because most of the borings are located within or near Site 22.

Area C: Site 43. Two sandy clay layers appear to be present beneath Site 43. The overall ranking of this site is moderate because the limited number of boring logs are of variable quality.

Area D: Site 2. Of all nine sites, Site 2 has the largest number of deeper boring logs within its boundaries or nearby. Zone C, or the lower part of the middle permeable zone, is present at each of the nine borings. The four deepest borings also intercepted another sand layer at about -100 feet msl. For these reasons, the site was given a high qualitative ranking.

Area D: Sites S and T. The same two permeable zones as at Site 2 are found beneath these sites; however, the deeper zone is intercepted by only two borings. The site is given a moderate to high ranking because of the reduced confidence in the continuity of the deeper zone.

Table 3
Results of Hydrogeologic Evaluation

Area	Site	Type of "Barrier" Layer	Soil Classification (USCS)[a]	Depth Interval (feet, msl)[b]	Thickness Range (feet)[c]	Number of Borings to Depth of Barrier (Number with Geophysical Logs)[d]	Confidence in Barrier Continuity	Comments	Relative Qualitative Ranging
A	38	High Permeability	SW, SC at two borings	-55 to -70	2 to 15	5 (4)	Low	Borings that show SC of very poor quality.	Low to moderate
		Low Permeability	CL	-105 to -115	10	3 (3)	Low to moderate		
		High Permeability	SW, SP, GP	-135 to -155	5 to 20	3 (3)	Low		
C	13	Low Permeability	CL, SC, and CL	-39 to -87	5+ to 45	5 + 1 Partial (1)	Low	Four borings are part of one cluster. Partial boring of very poor quality.	Low
		High Permeability	SW	-105 to -125	5 to 15	4 (1)	Low	Three borings are part of one cluster.	
C	22	High Permeability	SP to SW	-95 to -132	9 to 35	7 (2)	High	Four borings are part of two clusters of two each.	High
		High Permeability	SP	-153 to -167	4 to 10	3 (1)	Moderate		
C	42	High Permeability	SP to SW	-95 to -132	9 to 35	7 (2)	Moderate	Available boring logs located south of Site 42, within Site 22.	Moderate to high
		High Permeability	SP	-153 to -167	4 to 10	3 (1)	Moderate		
C	43	Low Permeability	SC, minor CL	-20 to -31	3+ to 9	4 (2)	Moderate	Log showing only 3-foot thickness is of extremely poor quality.	Moderate
		Low Permeability	SC and CL	-41 to -62	4+ to 11+	3 (2)	Low		
D	2	High Permeability	SP, GP, sometimes mixed with SM	-80 to -94	6 to 18	9+ (9)	High	Zone C of CH2M HILL investigations. Lower part of "Middle" Zone of Radian studies.	High
		High Permeability	SP, some SW	-99 to -113	4 to 9	4 (4)	Moderate to High	Stronger indications on E-log than on geologist's logs.	
D	S&T	High Permeability	SW, some SM and SP	-78 to -90	5+ to 12	5+ 1 Partial (6)	High	Zone C of CH2M HILL investigations. Lower part of "Middle" Zone of Radian studies.	Moderate to high
		High Permeability	SP to SW	-96 to -112+	4 to 16+	2 (2)	Low		
D	5	High Permeability	SW, some SM and SP	-78 to -91+	4 to 14	5+ 1 Partial (6)	High	Zone C of CH2M HILL investigations. Lower part of "Middle" Zone of Radian studies.	Moderate to high
		High Permeability	SW with SP	-90 to -115	15 to 16	1 (2)	Low		

[a]United Soil Classification System. SW = Well-sorted sand, SC = Clayey sand, CL = Clay of low plasticity, SP = Poorly-sorted sand, GP = Poorly-sorted gravel, SM = Silty sand.
[b]Lists the highest observed elevation of the layer top and the lowest elevation of the layer bottom.
[c]Numbers followed by a "+" indicate that a boring only partially penetrated the layer.
[d]"Partial" indicates that a boring only partially penetrated the layer.

Area D: Site 5. The boring log information for Site 5 is very similar to the data for Sites S and T; consequently, a ranking of moderate to high is also assigned to this site.

3.3 EVALUATION OF SECONDARY SELECTION CRITERIA

The evaluation of the secondary criteria included six criteria for each of nine sites that met the primary selection criterion for contamination. These evaluations were based on how well the site met the individual secondary criteria and the adequacy of the existing data. Each criterion was assigned a weighting factor based on the importance of that secondary criterion to the siting of the pilot-scale system. First, a scoring plan was developed (Table 4) to provide a basis of ranking the sites by secondary criteria. Next, each site was assigned a score for each criterion. The value of that score was based on how well the site met the particular secondary criterion. Finally, the weighted (the sum of the products of the weighting factors times the score for each secondary criterion) score was calculated for each site and listed in Table 5.

The scoring plan (Table 4) assigns numerical values (scores) based on how well a site meets a specific secondary criteria. The scores range from 0 to 5, where the value 5 was assigned to a site that excels in meeting secondary selection criteria. The score 4 means the site meets secondary selection criteria with some superior features. For the score 3, the site adequately meets secondary selection criteria; however, there may be perceived weaknesses or areas that could use improvement. The score 3 was considered average or acceptable. If the site does not meet secondary selection criteria, but contains deficiencies that can only be corrected by significant engineering changes to the relevant portions of the pilot system, the site was assigned a score of 2. If major engineering changes are needed, a value of 1 was assigned. No value (score 0) was assigned if the site does not meet secondary selection criteria, or was totally deficient and without merit, or insufficient data exist for evaluation.

The weighting factors were assigned values of 5, 10, and 15, corresponding to low, moderate, and high importance, respectively, of the secondary criteria to siting the pilot system.

Each of the six selection criteria are listed below with an explanation on the assignment of a value to the secondary selection criteria's weighting factor and an explanation on the assignment of a score to site for each secondary selection criteria.

3.3.1 Defined Perimeter of Contamination

A defined perimeter of contamination was assigned a high (15) weighting factor. The high weighting factor was assigned to this secondary criterion because of its relative importance. A defined perimeter is described as an outside edge of a waste site beyond which little or no contamination exists and within which contamination is present. If a perimeter of moderate contamination exists at a site, then steam injection wells can be placed just outside the contaminated zone in the "Clean Zone." If a perimeter of contamination does not exist, then the movement of contaminants ahead of the condensation front could lead to additional migration of contaminants away from the site.

Table 4
Secondary Selection Criteria Scoring Plan

Value	
0	Site does not meet secondary selection criteria, or is totally deficient and without merit, or insufficient data exist for evaluation.
1	Site does meet secondary selection criteria but contains deficiencies that can only be corrected by major engineering changes to relevant portions of the pilot system.
2	Site does meet secondary selection criteria but contains deficiencies that may be corrected by significant engineering changes to the relevant portions of the pilot system.
3	Site adequately meets secondary selection criteria; however, there may be perceived weaknesses or areas that could use improvement.
4	Site meets secondary selection criteria with some superior features.
5	Site excels in meeting secondary selection criteria.

Table 5
Scoring for Evaluation of Secondary Selection Criteria

Secondary Selection Criteria	Weighting Factor	Site Number								
		38	13	22	42	43	2	5	S	T
Defined perimeter of contamination	15	1	0	2	2	0	0	0	0	0
Relative site size	10	0	0	1	2	3	3	4	5	5
Site accessibility	15	0	5	5	1	5	2	2	2	2
Distribution of contaminants in high and low permeability zones	5	4	3	4	5	2	3	3	2	2
Proximity to groundwater treatment plant (GWTP) or GWTP pipeline	15	0	3	5	4	3	5	5	5	5
Adequate depth of contamination	5	5	3	3	3	3	5	5	5	5
Site score	--	60	120	225	165	170	170	145	190	190

Each site was evaluated on how well a distinct contamination perimeter existed at the site. Little information to determine a defined perimeter of contamination exists; therefore, all sites scored low on this secondary criterion. Of the nine sites, six have no data outside their perimeters. Site 38 had data outside the perimeter of the site; however, the data show significant contamination beyond the site's boundary and the site was ranked low. Sites 22 and 42 were ranked slightly higher because the existing data beyond the site boundaries indicate relative contamination.

3.3.2 Relative Site Size

Each site was scored for relative site size. The sizes of the sites were based on data contained in the same references used for Table 1. This criterion was given a moderate (10) weighting factor. Ideally, a pilot-size site would best suit a pilot-scale treatment system, but site size is not critical to the demonstration. However, a pilot-scale demonstration that remediates a "small" site would be preferable. Therefore, the smaller sites were scored higher. Scores were assigned to the sites in the following manner: 50,000+ square feet was assigned a zero; 40,000 to 49,000 square feet was assigned a 1; 30,000 to 39,000 square feet was assigned a 2; 20,000 to 29,000 square feet was assigned a 3; 10,000 to 19,000 square feet was assigned a 4; and less than 10,000 square feet was assigned a 5.

3.3.3 Site Accessibility

The accessibility to a candidate site for a pilot-scale demonstration project was considered of high importance (weighting factor = 15). Obstruction of a site by buildings and structures would impede construction of the pilot-scale system. Regular human activity at a site could cause undue risk both to the intruder-receptor and the pilot-scale system operators. Photos of the sites are in Appendix D. Site 38 was scored 0 in site accessibility because Building 475 covers a majority of the site and because of the magnitude of human activity at the site. The area surrounding Building 475 consists of parking lots and operations areas that are not suitable for system siting. Site 42 is covered with large site-restrictive cement holding ponds, so it was assigned a score of 1. These ponds were part of the old industrial wastewater treatment plant. Sites 2, 5, S and T were each scored 2 because the composite cap, which covers most of Area D, would be an impediment to subsurface accessibility. Sites 13, 22, and 43 were highly accessible and scored 5.

3.3.4 Distribution of Contaminants in the High- and Low-Permeability Zones

Contaminant concentrations in unsaturated soils will vary with depth, soil type, and location relative to the source of contaminants. Because of the difficulty in distinguishing between influences on contaminant concentrations with a limited number of soil samples, confidence in the analysis of contaminant distribution over different soil types is low. The distribution of contaminants is consequently given the relatively low weighting factor of 5.

Only data obtained from analyses of native soils were reviewed. Fill materials are poorly characterized and were ignored. For the purpose of this evaluation, gravel, sand, and silty sand are assumed to have a high permeability. Clay, silty clay, sandy clay, and clayey sand are assumed to have a low permeability, and silts are assumed to have a moderate permeability.

Each of the nine sites was qualitatively ranked on the basis of the observed distribution of contaminants in natural soil samples obtained from shallow borings, which range from about 8 to 80 feet deep. The qualitative ranking is based on the total number of soil samples analyzed for organic compounds, the range of soil types represented in the soil samples, and the observed distribution of contaminants. For example, locations where observed concentrations in sands are comparable to those in nearby silts or clays would be considered to have a very good distribution of contaminants in both high- and low-permeability soils. (At low concentrations and at equilibrium, saturated conditions, the total concentration of an individual contaminant in soil is approximately proportional to the fractional organic content of the soil. Under these conditions, clays, which typically contain greater amounts of organic matter, would have higher concentrations of organic contaminants than sands).

Soil samples were usually analyzed for priority pollutants (semi-volatile organic compounds or volatile organic compounds). In the following section, "total organic compounds" refers to the total of the measured concentrations of individual semi-volatile organic compounds (semi-VOCs) and/or volatile organic compounds (VOCs), not to a single analytical technique.

Site 38. Seven borings are located within Site 38, and soil samples from these borings indicate the presence of contamination in silty sands, silt, and clay. For example, in soil boring 38 SS BO6, 36 μg/kg benzene was detected at 40 feet, while 38 μg/kg benzene was measured in sandy silt at 65 feet. No samples of clean sands were analyzed for organic compounds. Rank = 4.

Site 13. All but one sample from the five borings within Site 13 are silt. One sand sample contained a similar amount of toluene (12 μg/kg) to a nearby silt sample collected at approximately the same depth (20 μg/kg). Rank = 3.

Site 22. Samples ranging from clay to sand were collected from five borings at Site 22. Where comparable analyses were made, total organic compound concentrations tended to fall within the range that could be expected given the different soil types. Contours of equal concentration of selected contaminants are presented in Appendix E. Rank = 4.

Site 42. Five soil borings are located within Site 42, and samples ranging from sand to clay were collected from these borings. At two separate locations, total concentrations of organic compounds were higher in sands than in silt or clay. For example at soil boring 42 WSBO2, a total of 21 ppm VOCs was measured in sand at 17 feet deep, while only 3.1 VOCs was detected in silt at 30 feet. The sands are nearer to the source of the pollutants, suggesting that soil type plays a secondary role at these two locations. Rank = 5.

Site 43. All soil samples collected at this location were sand and/or the samples were analyzed using different techniques. A maximum total organic concentration of approximately 1 ppm was observed in one sample of native soil. Rank = 1.

Site 2. Samples retrieved from the three borings at Site 2 ranged from sand to sandy silt. Observed total VOC and semi-VOC concentrations ranged from approximately 100 to 800 ppm. Rank = 3.

Site 5. Soil samples from the three borings at this site that were analyzed using comparable methods are all sand or silty sand. The concentration differences between the two soil types (maximum 5 times difference, 150 ppm VOCs versus 30 ppm VLCs) could be explained on the basis of depth alone. Rank = 3.

Site S. Comparable samples from the two borings at Site S are all sand, with total concentrations of approximately 50 to 70 ppm. Rank = 2.

Site T. Two soil samples were collected at site T. The one silty sand sample had total concentrations approximately 10 times higher than that measured in sand from another boring (sum of VOCs and semi-VOCs, 1,403 ppm and 134 ppm, respectively). Rank = 2.

3.3.5 Proximity to Groundwater Treatment Plan or Groundwater Treatment Plant Pipeline

A substantial amount of groundwater and/or steam condensate will be produced during the demonstration test. Presumably, the condensate will contain contaminants; therefore, treatment of all produced liquids is necessary. The groundwater treatment plant (GWTP) may provide sufficient treatment of the aqueous phase. Selected sites near the GWTP or GWTP pipeline are highly preferable; otherwise the liquid would have to be pumped or transported to the GWTP or an appropriate water treatment system. Therefore, a high (15) weighting factor was assigned to this secondary selection criteria.

Site 38, located in Area A, was scored 0, because the liquid would have to be transported across the Base to the GWTP. Sites 13 and 43 were assigned higher scores (3) because they are within reasonable distance to the GWTP pipeline. Site 42 is closer to the pipeline and therefore scores 4. Closest to the pipeline are Sites 22, 2, 5, S, and T; these sites scored 5.

3.3.6 Adequate Depth of Contamination

An adequate depth of contamination is necessary to prevent short-circuiting of the steam from the injection wells to the surface or air from the surface to the extraction wells. Although an important consideration, especially where contaminants are near the surface, it was assigned a low weighting factor (5) because any problems could be solved by modifying the injection system design. Sites 13, 22, 42, and 43 were each scored 3 because much of the contamination present remains near the surface in the former disposal pits. Site 38 was scored 5 because short-circuiting would probably not occur with Building 475 and adjacent asphalt parking lots covering the site. Even though many of the contaminants were in the original surface pits, Sites 2, 5, S, and T were scored 5 because the non-permeable cap above these sites should prevent short-circuiting.

3.4 FINAL SITE SELECTION

Final site selection was first based on the results of the hydrogeological evaluation. Then these sites were compared to the results of the secondary selection criteria evaluation. Because the hydrogeological evaluation was considered a primary selection criteria, a site rating high in hydrogeology would be considered the more favorable location. If a particular site received high scores in both the above evaluations, the site was a candidate for siting the pilot-scale system.

Therefore, the following selections were based primarily on hydrogeology. However, there were several sites that were not selected but could be given future siting consideration because of an acceptable hydrogeological evaluation and good secondary criteria scores.

The best site for the pilot-scale steam injection system is Site 22 in Area C. This site had the highest hydrogeologic rating among the Area C sites. It also has high-permeability barrier layers at -95 to -132 feet and -153 to -167 feet msl, each consisting of a thickness of sand ranging from 9 to 35 feet and 4 to 10 feet, respectively. In addition, Site 22 scored well above all other sites in the secondary selection criteria evaluation. The site has excellent accessibility with no cap penetration problems, very good distribution of contaminants in high and low permeability zones, and the best location in relation to the GWTP and the pipeline.

Alternate sites were selected in case unforeseen problems would preclude the siting at Site 22. Furthermore, if the future demonstration test proved successful and additional pilot or full-scale use of the technology was desired, the pre-evaluated alternate sites could be considered for future remediation.

Two additional sites selected as alternates to Site 22 are Site 42 in Area C and Site 2 in Area D. Site 42, adjacent to Site 22, received a moderate to high rating in the hydrogeologic evaluation, the second highest rating in Area C. For the secondary selection criteria, Site 42 scored acceptably with distribution of contaminants in the high and low permeability zones and proximity to the GWTP pipeline. Site 2 received a high rating in the hydrogeologic evaluation, the highest rating in Area D. This site also received an acceptable score in the secondary selection criteria evaluation, located close to GWTP pipeline and with depth of contamination. Like most sites in Area D, a major concern during siting and design of a steam injection system will be penetration of the composite cap overlaying Site 2.

Sites 13, 43, 5, S, and T may prove to be acceptable for future siting of the steam injection system, but only after additional hydrogeological data is acquired for further evaluation. Site 38 is not acceptable for siting the pilot-scale system. Site 38 ranked only fair on the hydrogeological investigation and received the lowest score resulting from the secondary selection criteria evaluation. Because Site 38 is located in Area A, no current method exists for transporting and treating the liquid condensate that the steam injection system will generate. Finally, Site 38 is overlaid with a large industrial building (Building 475) and accompanying parking lots that contain many people during working hours. The unknown risk to industrial workers from a new alternative and innovative remedial technology is perceived too great to install the pilot-scale system at the site at this time.

4.0 CONCEPTUAL DESIGN

4.1 DESIGN APPROACH

The candidate sites are not sufficiently characterized to develop detailed designs. Further characterization of the selected site will be necessary. Therefore, flexibility must be designed into the remedial system to take advantage of data that become available. However, sufficient data are available to allow a preliminary conceptual design that can serve as a basis for project planning and a guide for further characterization.

The conceptual designs presented in this report were developed using information contained in the Final Basewide Report on Contamination for the three leading candidate sites (Ref. 4). The conceptual designs are for implementation of the process on representative portions of the three candidate sites. The design may be altered for the selected site using data obtained from further site characterization, laboratory steam treatability tests of the soil, and modeling of the process. Following the design effort, the implementation of the process will ensue. Design of the system will allow for scale-up to a total remediation effort for the selected site in the final phase.

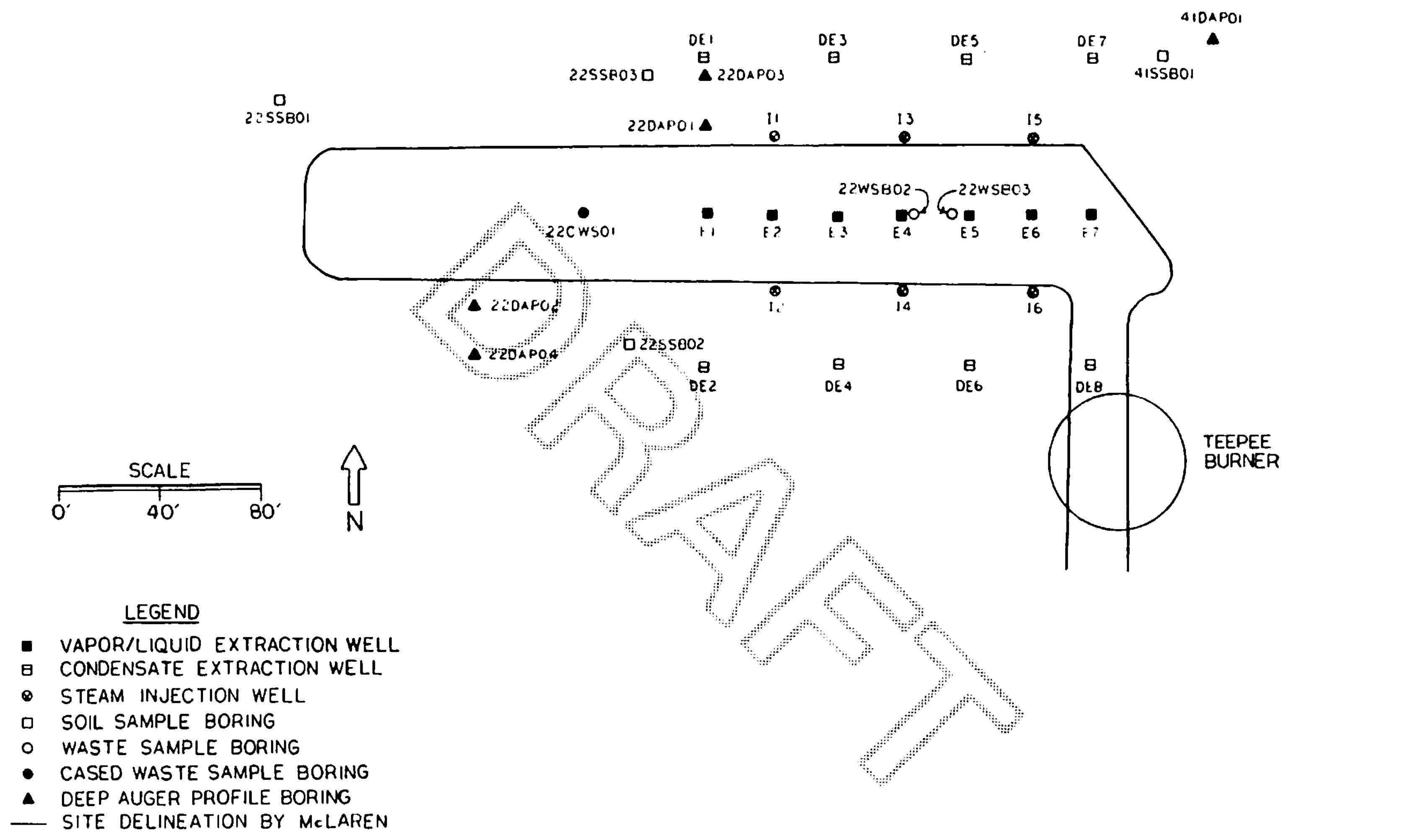
Proving the effectiveness of the combined steam injection and vacuum extraction process for removing volatile and semi-volatile organic contaminants from the soil and groundwater at McAFB is the primary goal of this project. Yet, safety and the possibility of adversely impacting the site are given careful consideration in the designs. The most serious concern is collection of contaminated steam condensate. A number of extra recovery wells are included in these initial designs to ensure adequate condensate capture.

The three candidate sites are Sites 22 and 42 from Area C and Site 2 from Area D. The design for Site 22 of Area C is provided in greatest detail and is the subject of discussion to describe the system characteristics. Summary designs are presented for the other sites. An approximate layout of the steam injection wells, extraction wells, and condensate extraction wells is presented. This is followed by a description of the layout of the piping and major equipment and the operating procedure. Finally, the uncertainties are discussed.

4.2 LAYOUT OF WELLS

For Site 22 of Area C the approximate layout of wells is shown in Figure 4. The cross-section of this site is contained in Appendix B. The conceptual design consists of six injection wells, seven extraction wells and eight condensate extraction wells. The steam injection wells are placed in two five-spot patterns. This pattern can easily be repeated to encompass the remainder of the site for a total cleanup effort. The injection wells (I1-I6 in Figure 4) are about 110 feet deep and the injection interval is the lower 60 feet. The location of the water table in this region is assumed for the conceptual design to be at a depth of approximately 90 feet. The steam injection will occur both below and above the groundwater surface. The seven extraction wells (E1-E7) are completed from nearly the surface to their total depth of approximately 110 feet. A strong vacuum is applied to the extraction wells to assist the flow of water and gases through the contaminated zone. As a precautionary measure, eight condensate extraction wells (DE1-DE8) can be placed outside the zone of contamination. These eight wells would be drilled to an approximate depth of 110 feet and completed over the bottom 30 feet. By applying a moderate vacuum to the condensate extraction wells while slowly pumping the groundwater, a zone of capture can be created for steam condensate that migrates down outside the ring of steam injection. Not shown in Figure 4 is the array of approximately 20 temperature monitoring wells used to track the steam zone growth.

SAC28722.03.01 Fig 4 11-21-90alo



Source: Udell Technologies, Inc.

FIGURE 4
WELL LOCATIONS,
AREA C, SITE 22

CH2M HILL

Further characterization is required to determine the exact placement of the wells. If a significant amount of contamination is encountered in placing an injection well, it must be relocated to ensure surrounding the zone of contamination with injection wells. Further definition of the lateral and vertical extent of contamination in the soil and the geologic and hydrogeologic conditions could alter the total depth and completion interval of the individual wells. Specifically, the depth of steam injection and fluid extraction was chosen using available data. This depth could change after additional site characterization.

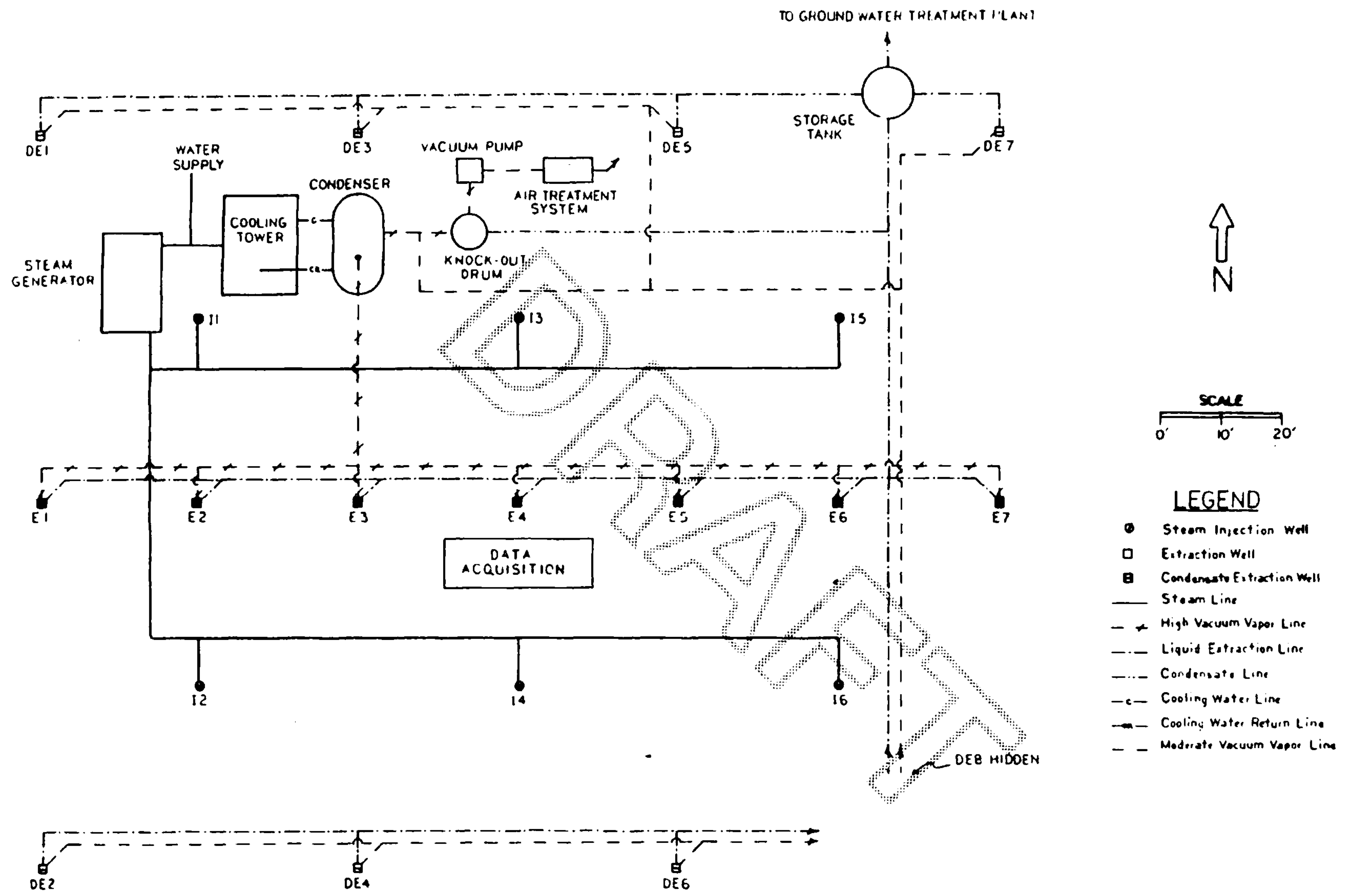
4.3 PIPING AND EQUIPMENT LAYOUT

The piping and layout of equipment for Site 22 of Area C is illustrated in Figure 5. The location and labelling of the wells shown in Figure 5 correspond directly to those shown in Figure 4 for reference to piping and equipment layout on Area C, Site 22. The steam generator supplies steam at a specified flow rate and pressure to each of the injection wells. The steam generator requires a supply of fuel, conditioned water, and air for operation. A schematic of the trailer-mounted steam generation unit is presented in Figure 6. The steam is delivered to each of the injection wells through steel pipe, wrapped with insulation. Liquid traps are placed at appropriate locations to ensure that the injected steam is of a high quality. A pressure regulator is placed upstream of each injection well and maintains the specified steam injection pressure. A flow meter and valve are placed at the head of each injection well to enable adjustment of the flow rate to specified values. The flow rate is highly dependent upon the permeability, or hydraulic conductivity, of the soil layers. Preliminary estimates for the total steam injection rate at this site range from 2,500 to 10,000 pounds per hour. Laboratory analyses of soil samples recovered from the site and groundwater pumping tests are required to obtain a better estimate of the soil permeabilities.

The liquid and vapor surface handling equipment is shown in Figure 7 and corresponds to the equipment layout in Figure 5. A large negative pressure is maintained on the extraction wells by a high volume vacuum pump. The pump draws out the soil gases and provides a differential pressure to direct the steam flow. The liquids are pumped from the bottom of the extraction wells directly to the storage tank. Hot liquids are cooled by fins on the lines to the storage tank. The flow rates of the gases and liquids from each of the extraction wells are monitored with flow meters. The vapors are passed through a condenser and knock-out drum. Recovered air passes through the vacuum pump and the air treatment system before emission to the atmosphere. The condensed liquids are pumped to the storage tank. A cooling tower maintains the condenser water supply at the ambient wet-bulb temperature.

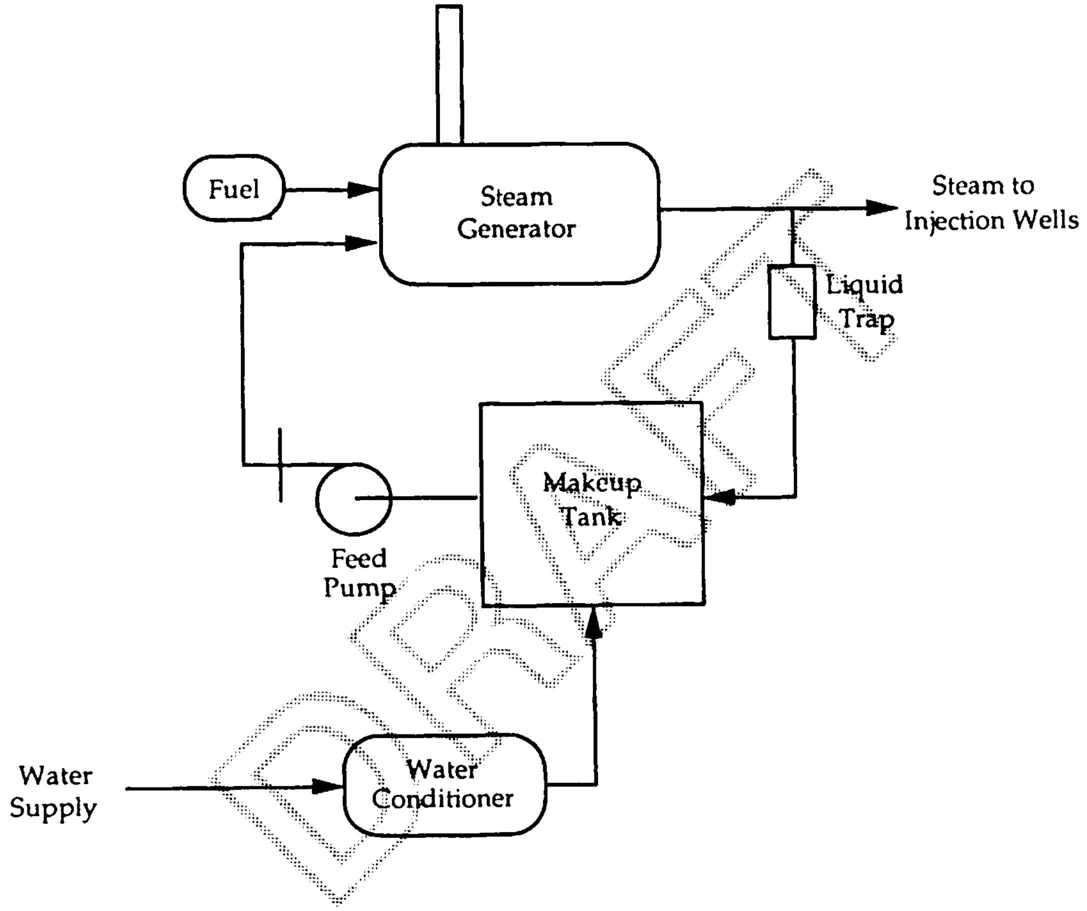
A makeup supply of water is required for the condensing system to replace water lost to the atmosphere by evaporation in the cooling tower. The liquids are pumped intermittently from the storage tank to the groundwater treatment plant. Based on the estimated steam injection rates, the maximum expected rate of condensate recovery is 100 gallons per minute.

SAC28722.03.01 Fig 5 11-21-90alo



PIPING AND EQUIPMENT LAYOUT

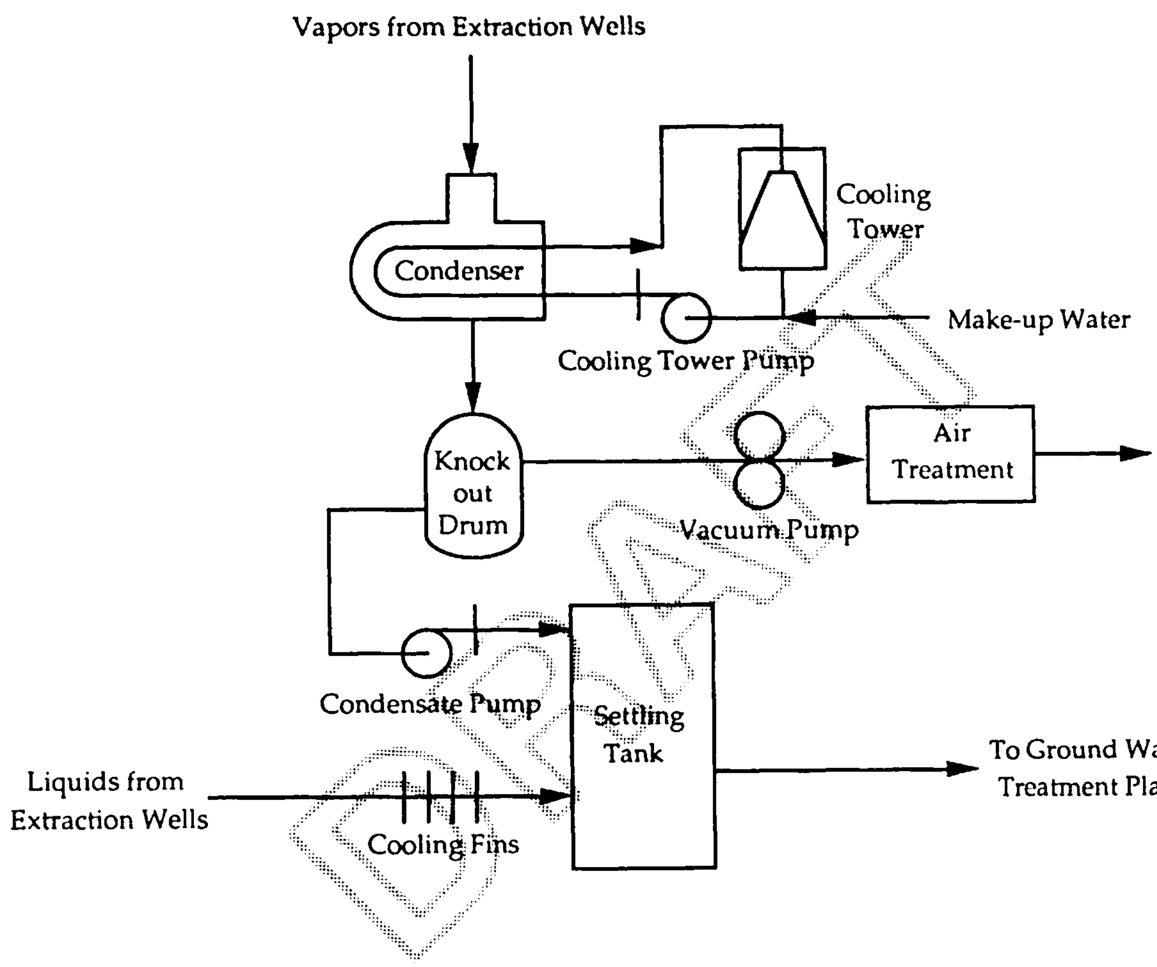
SAC28722.03.01 Fig 6 11-21-90ado



Source: Udell Technologies, Inc.

FIGURE 6
MOBILE STEAM GENERATION UNIT

CH2M HILL



Source: Udell Technologies, Inc.

FIGURE 7
LIQUID/VAPOR
HANDLING EQUIPMENT

The surface must be capped with concrete or asphalt. The cap prevents the short circuiting of the air flow during vacuum extraction. This could be a significant problem if the fill material is highly permeable. The cap also provides protection from the unlikely escape of steam to the surface.

4.4 OPERATIONAL PROCEDURE

During the site characterization, as many soil borings as possible will be converted to injection or extraction wells. After installation of all wells, plumbing and data acquisition equipment, the knock-out drum, vacuum pump, air treatment system, and liquid storage tank are brought on site. Vacuum extraction alone is then applied to the site. The concentrations of contaminants in the soil gas are measured from recovered gas samples. This process continues until its effectiveness can be documented. The vacuum extraction yields baseline permeabilities and gas flow rates that aid in predicting the performance of the steam injection process. The steam generation equipment and condensate/groundwater fluids handling equipment are then put in place.

All steam lines are brought to steam pressure and temperature by venting the steam to the condenser with the vacuum pump operating. Steam injection begins with the closing of the condenser bypass valve and opening of the injection line valves. Individual flow rates into each injection well are monitored and adjusted by control of the throttling valve to maintain specified injection rates into each well. The initial estimate for the steam injection rate per injection well is roughly 1,000 pounds per hour of high quality steam.

For the estimated steam injection rate, the time required to raise the contaminated zone to steam temperature is 25 days. These estimates are highly dependent on soil properties that are currently unknown. Prior to steam breakthrough in the extraction wells, condensate appears and yields the maximum liquid flow rate. After steam breakthrough, if the entire contaminated region has been steamed, the continuous steam injection is terminated. However, the vacuum extraction and liquid pumping continues in all wells. Contaminants held in solution by capillary forces are then removed from low permeability zones by evaporating the water. High boiling point compounds, such as oil and grease, are further evaporated. The vacuum extraction continues until no contaminants are being recovered. To maintain an elevated temperature in the soil contaminated by high boiling point compounds, periodic steam injection may be necessary. The soil temperature is monitored throughout the process by temperature monitoring wells. A duration of 1 to 2 months is estimated for the thermally enhanced vacuum extraction.

The process monitoring consists of measuring the flow rates and pressures of steam into each injection well, the flow rates of recovered gases and liquids, the vacuum pressure in the extraction wells, the concentration of contaminants in recovered gases and liquids, the integrity of the air treatment system, and the soil temperature. The flow rates, pressures, and concentrations are to be measured at least twice daily during steam injection and daily after steam breakthrough. The vertical temperature distributions at various locations are recorded periodically to chart the location of the steam condensation front. This measurement should be made several times daily at locations near the steam front. Elsewhere, the soil temperature should be measured once daily during the steam injection phase and twice weekly in the vacuum extraction phase. The flow rate and pressure of individual wells can be altered if the movement of the steam zone is not as desired.

4.5 ALTERNATE SITES

Conceptual designs for three other candidate sites have been developed. Well layouts for Site 42 of Area C and Site 2 of Area D are presented in Figures 8 and 9, respectively. Based on the available data, the completed interval of the steam injection wells is the same as for Site 22 of Area C. Therefore, the spacing among wells will be nearly identical. The width of the three candidate sites is also similar and allows for placement of the steam injection wells on the perimeter of each site. The five-spot pattern used for the steam injection wells can be repeated for each site. Because of the similarities among the three candidate sites, the piping layout and operational procedures are conceptually identical to those described for Site 22 of Area C.

4.6 UNCERTAINTIES

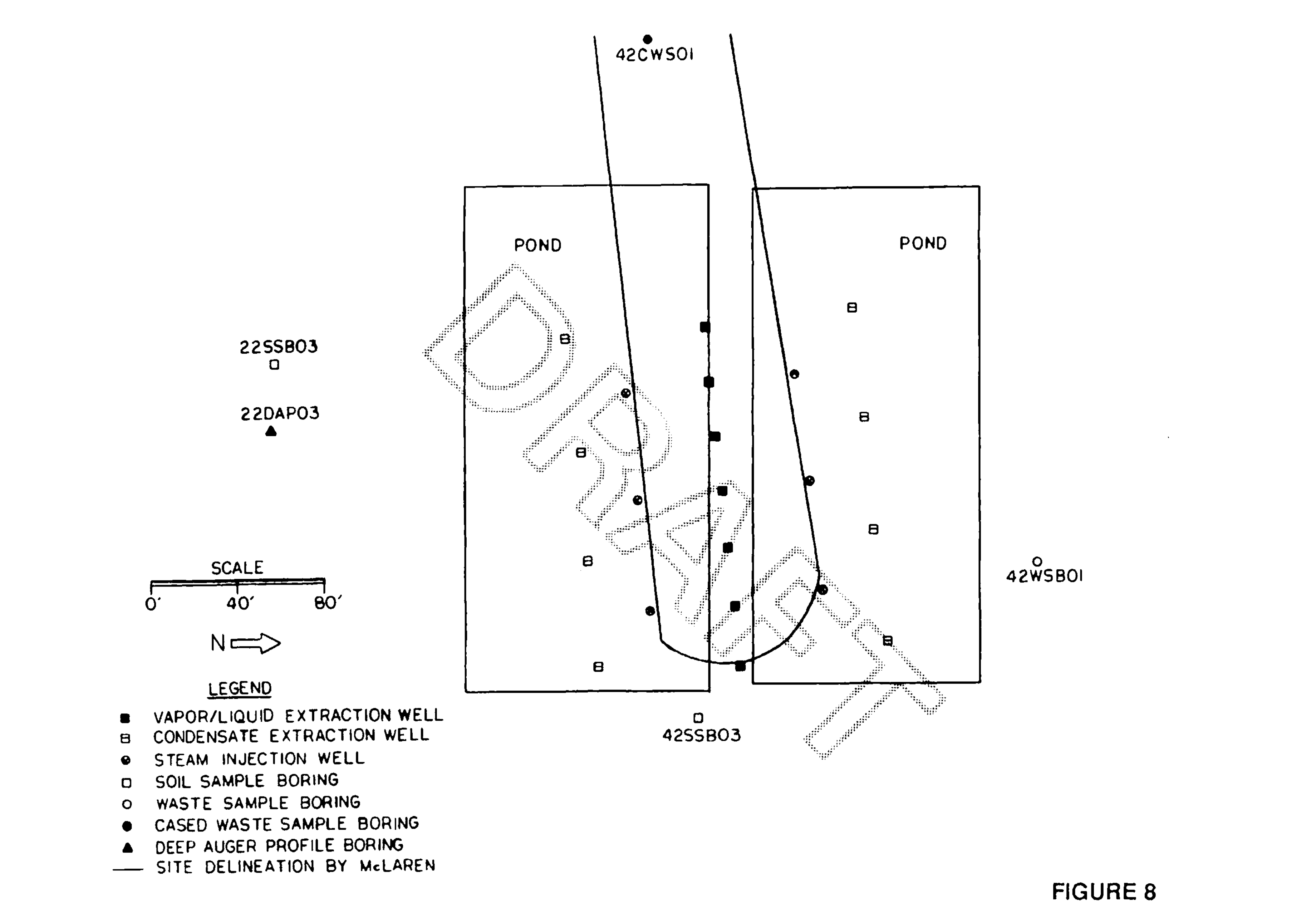
The risk of primary importance is the possibility of adversely impacting groundwater beneath the site. Theoretically, collection of the steam condensate is straightforward using extraction wells, but actual geologic conditions at the site may be complicated and are uncertain. The geology of the site must be better understood prior to the implementation of the final design. If insurmountable problems present themselves during the pilot test, the steam injection will be terminated.

A secondary concern is the possible loss of control over the steam zone growth. This could result in a loss of contact between the contaminated soil and the flowing steam or the migration of contaminants away from an extraction well. Research at the University of California at Berkeley has focused on this topic, and criteria for control of the steam movement have been determined. Also, implementation of this technology will include a level of monitoring to detect the steam zone location. Based on this information, appropriate actions can be taken to provide appropriate control of the process.

Specific to Sites 22 and 42 of Area C is concern over the fill material. The fill material could provide a short circuit to subsurface air and steam flow and diminish the vacuum pressure applied in the extraction wells. To avert this problem, the sites must be capped.

Area D is covered by a composite cap to mitigate the downward movement of contaminants. Site 2 is beneath the cap, and the necessary placement of wells would require piercing the cap. This action may diminish the integrity of the cap.

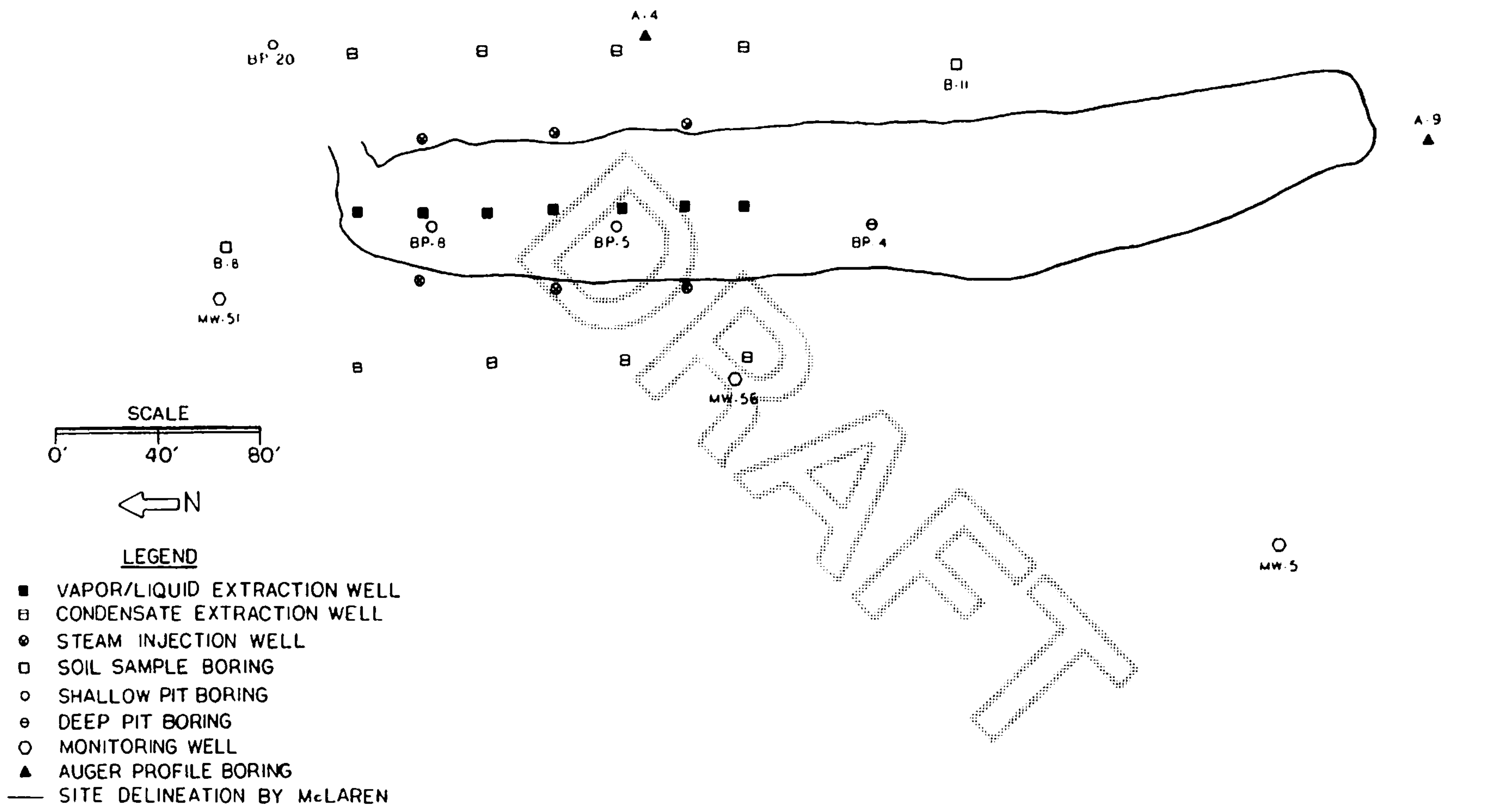
SAC28722.03.01 Fig 8 11-21-90alo



Source: Udell Technologies, Inc.

FIGURE 8
WELL LOCATIONS,
AREA C, SITE 42

CH2M HILL



Source: Udell Technologies, Inc.

FIGURE 9
WELL LOCATIONS,
AREA D, SITE 2

CH2M HILL

5.0 FUTURE EFFORTS REQUIRED

5.1 ADDITIONAL SITE CHARACTERIZATION

The selected site should be further characterized to better define site geology, hydrogeology, and soil and groundwater contamination. To better define the site geology, a minimum of two continuous cores should be drilled to a depth that will sufficiently encompass all contaminants at a site and provide adequate coverage below the water table. The corings should be visually logged by an onsite geologist or hydrogeologist. Additionally, the continuous coring should be accompanied by geophysical well logs to further characterize the site lithology. Also, wells and/or borings should be installed, in addition to the two continuous corings. To characterize the site's hydrogeology, wells should be installed in the borings.

Finally, soil samples should be taken at several depths during the continuous coring as determined by the requirements of geostatistics to produce a statistically valid sample set. The number of samples will be large and assistance from the EPA SITE program is sought. These samples should be analyzed for volatile and semi-volatile organics.

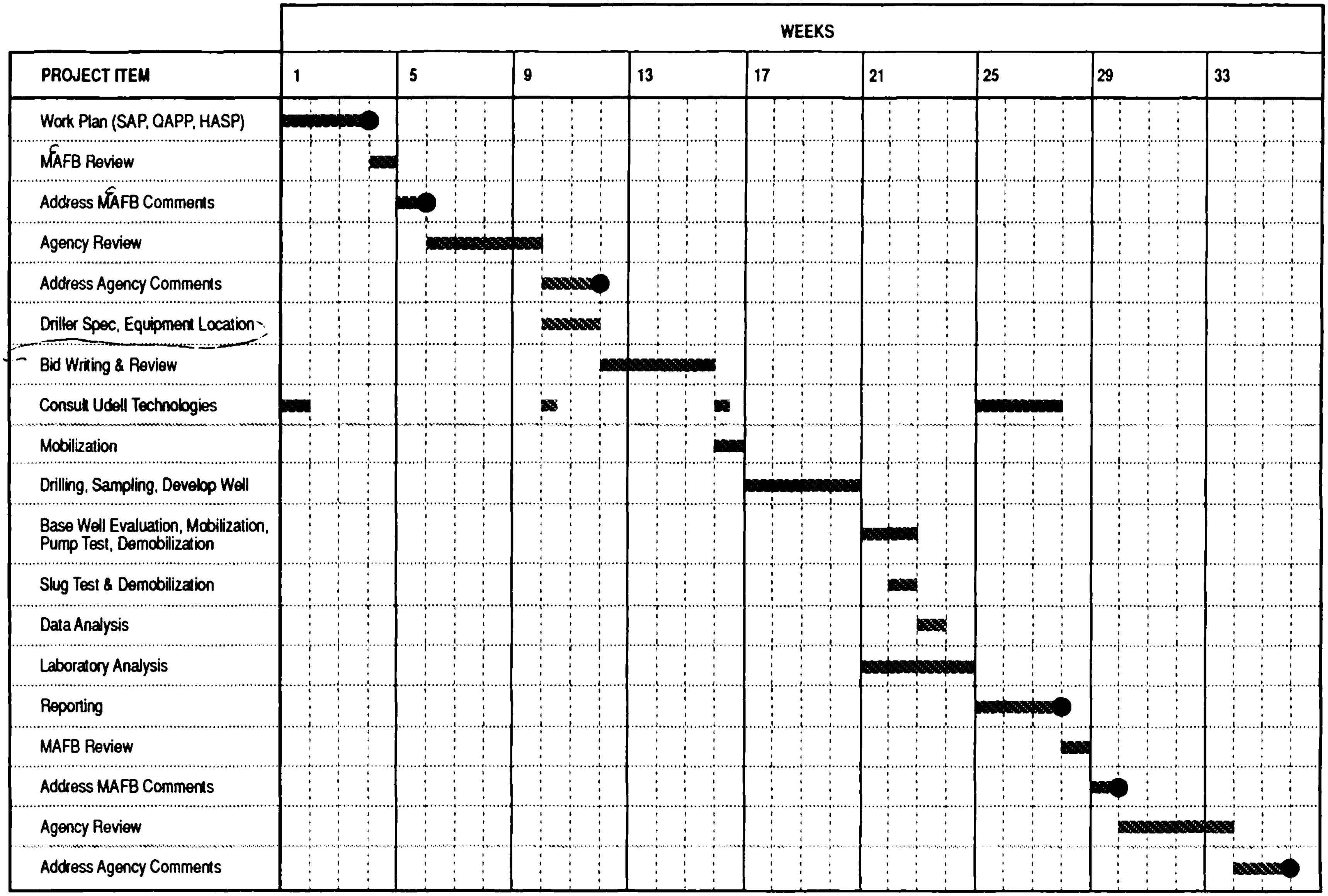
The project items and schedule for the additional site characterization are presented in Figure 10.

5.2 MASS BALANCE CALCULATIONS

A mass balance of contaminants should be calculated at the test site. This mass balance would encompass the quantity (mass) of target contaminants in the soil volume before treatment, the mass of target residual contaminants after treatment, and the deposition and quantity of the removed target contaminants. This mass balance of target contaminants in the soil volume before and after treatment can be performed by three-dimensional geostatistics, such as kriging. The soil volume can be set up as a three-dimensional grid with a contaminant value based on actual samples in the same grid points. A prerequisite to the geostatistics is adequate data. The more data on soil contaminants obtained before geostatistical analysis, the fewer errors in the contaminant mass estimates will result and, therefore, more confidence in the mass balance values is possible. As a notation on deposition and quantification of the removed target contaminants, chemical analyses and a geostatistical evaluation should be performed on the perimeter soil, along side and under the contaminated soil volume, to determine if target contaminants have been driven into this adjacent soil by the stream.

5.3 AIR QUALITY CONSIDERATIONS

The pilot-scale system will contain an air treatment unit for vapors from the extraction well. This air treatment unit will have air emissions resulting from vapor abatement. The steam generator will also have air emissions. All future air quality issues will be addressed with the appropriate agency.



Assume: No wait for power; 30 day agency review

LEGEND:
● Deliverables

Figure 10
SITE CHARACTERIZATION SCHEDULE
McClellan Air Force Base

CH2M HILL

5.4 GROUNDWATER TREATMENT PLANT

The groundwater treatment plant (GWTP) would provide a convenient treatment facility for the contaminated steam condensate generated by the steam injection system. The GWTP provides air stripping and carbon adsorption of a wide spectrum of organic contaminants as well as biological treatment of aldehydes.

The GWTP design capacity is 1,000 gallons per minute (gpm); however, the current utilization is only 240 gpm (Ref. 5). Therefore, 760 gpm of excess capacity exists at the GWTP to treat steam condensate and future groundwater pumping in Area B, but this excess capacity is not available for all the unit operations within the GWTP. For example, the carbon adsorption system has three treatment trains, in parallel, each capable of treating 330 gpm. One treatment train has been removed from the GWTP and would probably not be available for the steam injection pilot test. Consequently, this capacity (330 gpm) would have to be made up by a temporary or permanent carbon unit. Furthermore, the biological treatment unit in the GWTP has also been removed and would not be available for the test. Because the biological treatment unit was capable of treating only 250 gpm, a temporary or permanent replacement, if required, would have to treat the current 240-gpm utilization plus the additional steam condensate.

5.5 LABORATORY EXPERIMENTS AND MODELING

A significant effort in laboratory experiments and modeling is required before the system may be designed. The steam injection rate is a critical factor in sizing equipment and estimating the duration of the project. This rate is primarily dependent upon soil permeability. Soil samples must be extensively tested to obtain accurate measurements of permeability, water content, and heat capacity of the various soil layers. Laboratory experiments scaled to model the effects of gravity on growth of the steam zone at the selected site are desirable. These experiments can also be used to validate numerical models describing the steam flow. Numerical modeling of the implementation of the process at the selected site is necessary for the detail design. The model can also be used interactively during the operation of the system to predict responses to changes in the injection or extraction conditions. Thermodynamic equilibrium models must also be applied to the specific contaminants to determine their recovery rates.

6.0 REFERENCES

1. The Golden State Salutes McClellan Air Force Base. Marcoa Publishing, Inc., San Diego, California. 1987.

2. Index to Data References, Installation Restoration Program, Stage 3, McClellan Air Force Base. Radian Corporation. December 1988.

3. Personal Conversation with Joy Rogalla, Quality Assurance Officer. Radian Corporation, Sacramento, California. November 8, 1990.

4. Final Basewide Report on Contamination, McClellan Air Force Base, Sacramento, California. McLaren Environmental Engineering. December 1986.

5. Personal Conversation with Doug MacKenzie, EMR. McClellan Air Force Base, Sacramento, California. November 9, 1990.

Appendix A
DATA REVIEW OF ADMINISTRATIVE RECORD

DATA REVIEW OF ADMINISTRATIVE RECORD

1. Final Report for Groundwater Contamination as of 30 April 81; Brunner and Zipfel; 4/30/81.
   Missing from Shelf.

2. Installation Restoration Program (IRP) Records Search; CH2M Hill; 7/81.
   Record search and identification of contamination, etc.
   May be some relevant data, but most of it is contained in more recent documents.

3. IRP Phase II Confirmation Vol. 1 & 2 Final Report; Engineering Science; 6/83.
   Report to determine groundwater contamination and recommend measures to mitigate contaminated areas, develop monitoring program.
   A few good cross-sections and some soil sampling results. Some TCE contamination info.

4. IRP Phase III/IV Area D Site Characterization Tech Memo 1 & Tech. Memo 3.; CH2M Hill; 8/84.
   Includes hydrogeologic evaluation and large geologic sections.

5. Interim Presurvey Report Phase II Stage 2, Activities and IRP Work Plan; Radian; 9/28/84.
   Proposal for work. See #8.

6. Source Control Feasibility Study Area D; CH2M Hill; 9/84.
   Compares alternatives for controlling existing hazardous waste disposal sites. Summary of Site Characterization (#4).

7. IRP Phase III/IV Area D Site Characterization Study; CH2M Hill; 10/84.
   Details sites in Area D. Assesses character of wastes and extent of soil contamination. Some cross-sections and boring logs, but should be more recent data.

8&9. IRP Phase II Stage 2-1 Draft Final Report; Radian; 11/1/84.
   Some good cross-sections. #13 is Final.

10. IRP Phase III/IV Area D-Final Report; CH2M Hill; 2/85.
   See also #4, 6 & 7
   Source Control Feasibility Study & Site Characterization study. Shows groundwater contamination and geologic fence diagram. Proposes well locations, cap locations, source control.

11. Site Characterization of A, B, C and Other Sites; McLaren; 3/85.
   Summarizes IRP/FS data previously gathered. Lots of cross-sections, groundwater contours, water and waste sample borings, extent of TCE and other contamination.

12. 10% Submittal Design Analysis for MTN Groundwater Cleanup, Area D, Membrane Cover Installation; CH2M Hill; 3/27/85.
See #14 for Final.

13. IRP Phase II Stage 2-1 Final; Radian; 5/85.
Detailed discussions of results for 13 tasks in this stage. Some good cross-sections.

14. Design Analysis for MTN Groundwater Cleanup Area D, Cap Installation; CH2M Hill; 5/85.
Final design analysis for major elements of cap installation.

15. Area D Monitoring Extraction Tech. Report #1; McLaren; 7/85.
System confirmation by computer modeling. Contains background data and chemical quality of groundwater in Area D. Some discussion of hydraulic conductivity.

16. IRP Phase II Stage 2 Resampling of Monitoring Wells-Tech. Report; Radian; 7/11/85.
Describes resampling and reanalysis effort, as well as the analytical results, for 45 wells. Original sampling and analysis was done in Fall '84.

17. Off-Base Quarterly Sampling and Analysis; Radian; 8/85.
Off-Base.

18. Proposal for Initial Groundwater Treatment System Area D; Metcalf & Eddy; 8/16/85.
Proposes using vapor phase carbon adsorber for treatment system.

19. Groundwater Monitoring Program for Surface Impoundments at IWTP; McLaren; 9/26/85.
Deals primarily with Area C1, come cross-sections through sites with chemical analysis.

20. & 21. Hydrogeologic Assessment Report for Surface Impoundments Area C; INEL; 9/85.
Missing from Shelf
See #134 & 135 for similar, more recent document.

22. thru 53. MAFB Off-Base Well Survey Vol. 1-31 & Tech. Report; Radian; 1985.
Off-Base.

54. Area D Monitoring/Extraction System Tech. Report #2; McLaren; 1/86.
#15 is Tech. Report 1.
Testing of initial extraction well and system confirmation by computer modeling. Results of 30-day aquifer test (recommended in #15), data from monitoring wells, results from computer modeling and water quality data. Lots of borehole lithology.

55. Tech Memo for Shallow Investigation Program in areas A, B, C and other Sites-Area A; McLaren; 2/86.
See also #60, 61, 64.
Presents results of shallow exploration program for 5 sites in area A. Lots of soil boring logs. Details results at each site. Collected to lead to RAP (#64).

56. Tech Memo for Shallow Investigation Program in Areas A, B, C, and Other Sites-Area B; McLaren; 2/86.
See also #57, 62, 63.
Presents results of shallow exploration program at 5 sites in Area B. Lots of soil boring logs. Details results at each site. Collected to lead to RAP (#62).

57. Area B Site Characterization Groundwater Report; McLaren; 2/86.
See also #56, 62, 63.
Presents results of source area groundwater program in Area B. Water level contour maps, distribution of contaminants, borehole lithology. Collected to lead to RAP (#62).

58. MAFB Off-Base Well Sampling and Analysis; Radian; 2/86.
Off-Base

59. Tech. Memo for Shallow Investigation Program for A, B, C and other Sites-Other Sites; McLaren; 4/86.
See also #68.
Six sites not in area A, B, C, or D. Presents results of shallow exploration program at these sites. Details results at each site, cross-sections of sites, soil boring logs and chemical analysis.

60. Report on Contamination in Area A; McLaren; 4/86.
See also #55, 61, 64.
Brings together groundwater info and soil info to lead to RAP (#64). Cross-sections of sites with contamination, chemical results from soil samples, water level contours.

61. Area A Site Characterization Groundwater Report; McLaren; 4/86.
See also #62, 64, 55.
Presents results of source area groundwater program in area A. Water level contour maps, distribution of contaminants, borehole lithology. Collected to lead to RAP (#64).

62. Area B Source Control Feasibility Study and Remedial Action Plan (RAP); McLaren; 4/86.
See also #56, 57, 63
To develop alternative solutions for contaminated sites in Area B. Cross-sections of sites with positive chemical results, vertical & horizontal distributions of TCE.

63. Report on Contamination in Area B; McLaren; 4/86.

See also #56, 57, 62.
Brings together groundwater and soil info to lead to RAP(#62). Cross-sections of sites with contamination, chemical results from soil samples, water level contours.

64. Area A Source Control Feasibility Study and Remedial Action Plan (RAP); McLaren; 5/86.
See also #55, 60, 61
To develop alternative solutions for contaminated sites in Area A. Cross-section of sites, vertical and horizontal distribution of TCE.

65. Area C Site Characterization Groundwater Report; McLaren; 5/86.
See also #75, 76
Presents results of source area groundwater program in area C. Water level contour maps, borehole lithology, distribution of contaminants. Collected to lead to RAP (#76).

66. Off-Base Well Sampling Second Quarter, Analytical Results,
67. Physical Analysis and Appendices; Radian; 5/86.
Off-Base

68. Other Areas Site Control Feasibility Study and Remedial Action Plan (RAP); McLaren; 5/86.
For mitigating soil and groundwater contamination of sites not in Area A, B, C or D. Vertical distributions of soil contamination, some chemical concentrations in groundwater.

69. Tech Memo for Shallow Investigation Program in A, B, C and
70. Others-Area C Site Characterization; McLaren; 5/86.
71. Data collected to assist in RAP for Area C. Goes into a lot of detail about each site in Area C. Analytical results from borings, aerial photographs.

72. IRP Sampling and Analysis Program, Round 3, Informal Tech.
73. Memo; Radian; 6/86.
74. Sample results and analysis, and raw laboratory data for groundwater monitoring wells.

75. Report of Contamination in Area C; McLaren; 6/86.
To help develop RAP (#76). Details the extent of groundwater and soil contamination in Area C, each site. Positive analytical results from boring, cross-sections of sites with positive chemical results.

76. Area C Source Control Feasibility Study and Remedial Action Plan (RAP); McLaren; 6/86.
To mitigate groundwater and soil contamination identified in #75. Some good vertical and horizontal distributions of TCE contamination.

77. Basewide Report on Contamination; McLaren, 7/86.
See #81 for Final.
Geologic cross-sections of all areas & specific sites. Discussion of geology & hydrology of all areas.

78. Off-Base Sampling & Analysis Third Quarter 1986; Radian; 8/86.
79. Off-Base

80. Acetone/Ketone Study; Metcalf & Eddy; 8/86.
Area D. Evaluates various methods of treating groundwater to get rid of acetone/ketones.

81. Final Basewide Report on Contamination; McLaren; 12/86.
Report on contamination in all areas. Pulls together data from previous reports. Leads to RAP (#82). Water contour maps, cross-sections of sites with chemical results, some vertical distributions of soil contamination. Should be good source of info.

82. Final Basewide Source Control Feasibility Study & RAP; McLaren; 12/86.
Some discussion of geologic and hydrologic info. Vertical distributions of TCE in all areas.

83. Response to Regulatory Agencies and Air Force Comments on McLaren Site Characterization and RAP; McLaren; 12/86.
Responses to comments by EPA, DHS, Regional, City of Sac, AF HQ, etc. to #82.

84. thru 86. IRP Phase II Stage 2-2, Final Report for 6/85-12/86; Radian; 12/86.
Installation of 38 monitor wells on- and off-base; sampling and analysis. Plates showing elevation of water levels. Some geologic cross-sections, etc. in #84. Shows occurrence of contaminants in wells.

87. Final Operations and Maintenance Manual for Area D Cap; CH2M Hill; 12/86.
Operations and maintenance manual, but may have some relevant info regarding cap. Shows utilities, cap cross-section.

88. Operations and Maintenance Manual for Groundwater Treatment Facility; Metcalf and Eddy

89. thru 93. 97. Well Sampling and Analysis-Fourth Quarter 1986; Radian; 2/87.
These quarterly sampling reports show levels of contamination in wells. Looking at them over a period of a few years might show how contamination has changed, migration of contaminants, etc. Also contains some good maps of wells sampled and contamination found.

94. Area D Monitoring/Extraction System Tech. Report #4, Operation and Maintenance

Manual; McLaren; 3/87.
Some good cross-sections.

95. IRP-Interim Tech. Report Stage 2-3 Aquifer Testing and Evaluation; Radian; 3/87.
Determines hydrologic characteristics of local groundwater flow system. Should be good source of info.

96. 30-Day Performance Test Report for Groundwater Treatment Facility; Metcalf and Eddy; 4/87.
Groundwater from Area D. Lots of analysis of influent and effluent.

98. IRP-Phase IV-A Work Plan for Site Characterization Assessment- Museum Site; Oak Ridge National Lab.; 5/87.
Proposed museum site, south of Building 814, contaminated soil from aircraft maintenance.

99. IRP-Phase II Stage 2-4 Interim Tech. Report; Radian; 6/87.
100. Further defines extent and magnitude of subsurface contamination. Installation of wells. Good cross-sections.

101. Quarterly Sampling and Analysis Program-First Quarter 1987(#101 through 104), Second Quarter 1987(#106 through 110), Third Quarter 1987 (#113 through 120), Fourth Quarter 1987(#137 through 145); Radian; 6/87, 7/87, 10/87, 2/88.
Quarterly sampling reports for 1987. Might be good to see changes from previous and future quarterly reports.

105. Groundwater Sampling Protocol Manual for MAFB; Radian; 6/87.
Groundwater sampling protocol and instruction to be used with quarterly sampling. Not really any relevant info.

111. IRP-Phase II Stage 2-3 Subregional Groundwater Flow Monitoring; Radian; 8/87.
Develops conceptual model for groundwater system around Base. Some possibly relevant groundwater info.

112. IRP Phase IV-A Task #1-Site Characterization Assessment for Area D; Oak Ridge National Lab; 8/87.
Work Plan.

121. Supporting Documents for Monitoring and Extraction System,Area C; EG&G Idaho; 7/27/87.
Health and Safety Plan for Interim Extraction Project.

122. IRP Phase II Stage 2-5 Off-Base Remedial Investigation and
thru Alternative Assessment Report; Radian; 10/87.
133. Off-Base

134. Hydrogeologic Assessment Report for Surface Impoundments-Area
135. C; EG&G Idaho; 12/87.
Discusses waste characteristics, surface wells, groundwater, vadose zone. Some good cross-sections.

136. Monthly Monitoring Reports-Area D; Metcalf and Eddy; 1/88 through 8/88.
Also #146, 147, 148, 149, 155, 156, 157. #163 is similar.
Useful for comparison.

150. IRP Stage 3-Groundwater Sampling and Analysis-First Quarter 1988(#150 through 154), Second Quarter 1988(#159,160), Third Quarter 1988(#164,165,168), Fourth Quarter 1988(#174,176,177,178); Radian; 6/88, 9/88, 10/88, 3/89.
Groundwater sampling and analysis for 1988. Useful for comparison to earlier and later documents.

158. Dismantling of Building 666 and IWTP #4; Idaho National Engineering Lab; 8/88.
Building 666 was an electroplating shop in Area B. Describes cleanup. Shows depth of sumps, pits & reservoirs after cleanup.

161. Quality Assurance Project Plan (QAPP); Radian; 9/88.
162. QA/QC procedures for RI/FS at Base. Used by field sampling teams.

163. Monthly Monitoring Report-Areas C & D; Metcalf and Eddy; 9/88 through 12/89.
Also #166, 167, 169, 171, 172, 173, 175, 179, 183, 185, 186, 187, 191, 193. #136 is similar.
Useful for comparison.

170. IRP Stage 3 RI/FS Management Plan Draft Copy; Radian; 1/89.
Describes approach to be taken to incorporate results of previous investigations into RI/FS process.

180. Performance Work Statement-Decommission of Building 628; EG&G; 5/89.
Radioactive waste in rear of building 628 in Area B. Mostly about building-description, waste disposal, contamination etc.

181. IRP Stage 5 Area B Groundwater Operable Unit RI Analytical Data and QA/QC Report-Groundwater Samples; Radian; 6/89.
Lots of groundwater sampling results, Area B.

182. IRP Stage 3 Groundwater Sampling and Analysis-First Quarter 1989(#182), Second Quarter 1989(#192), Third Quarter 1989(#188,189,190,194), Fourth Quarter 1989(#196,197,198); Radian; 6/89.
May be useful for comparison to each other. Good plates. Shows TCE contami-nation.

184. MAFB Interagency Agreement; MAFB; 6/89.
No relevant info.

195. IRP Stage 3 Annual Technical Report, Groundwater Sampling-1988; Radian; 11/89.
Examines analytical and hydrologic data collected through 12/88. Looks like a very good, up-to-date source of info. Shows contaminant distribution and migration for all areas. Good plates and maps.

199. IRP Stage 3 Letter of Recommendation for Continuance of Groundwater Sampling and Analysis Program; Radian; 3/90.
Defends continuance of groundwater sampling program.

200. Quarterly Geologic Monitoring Report-Area C and D; Metcalf and Eddy; 3/90.
Used to detect any groundwater level changes and relationship to extraction operation. Good plates. Might be useful to compare to earlier monthly monitoring (See #163).

201. IRP Stage 3 QA/QC Letter-Groundwater Sampling-January to March
202. 1990; Radian; 5/90.
203. Compare to earlier QA/QC Letters.

204. IRP Stage 3 Operable Unit B Preliminary Assessment Summary
205. Report; Radian; 5/90.
206. Some contamination info for various sites.

207. IRP Stage 3 QAPP; Radian; 5/90.
Procedures for QA/QC activities.

208. IRP Stage 6-Preliminary Groundwater Operable Unit Remedial Investigation Sampling and Analysis; Radian; 2/90.
Scope of work, methods and rationale for Hydrogeologic assessment. Good, up-to-date cross-sections and maps, discussions of hydrology.

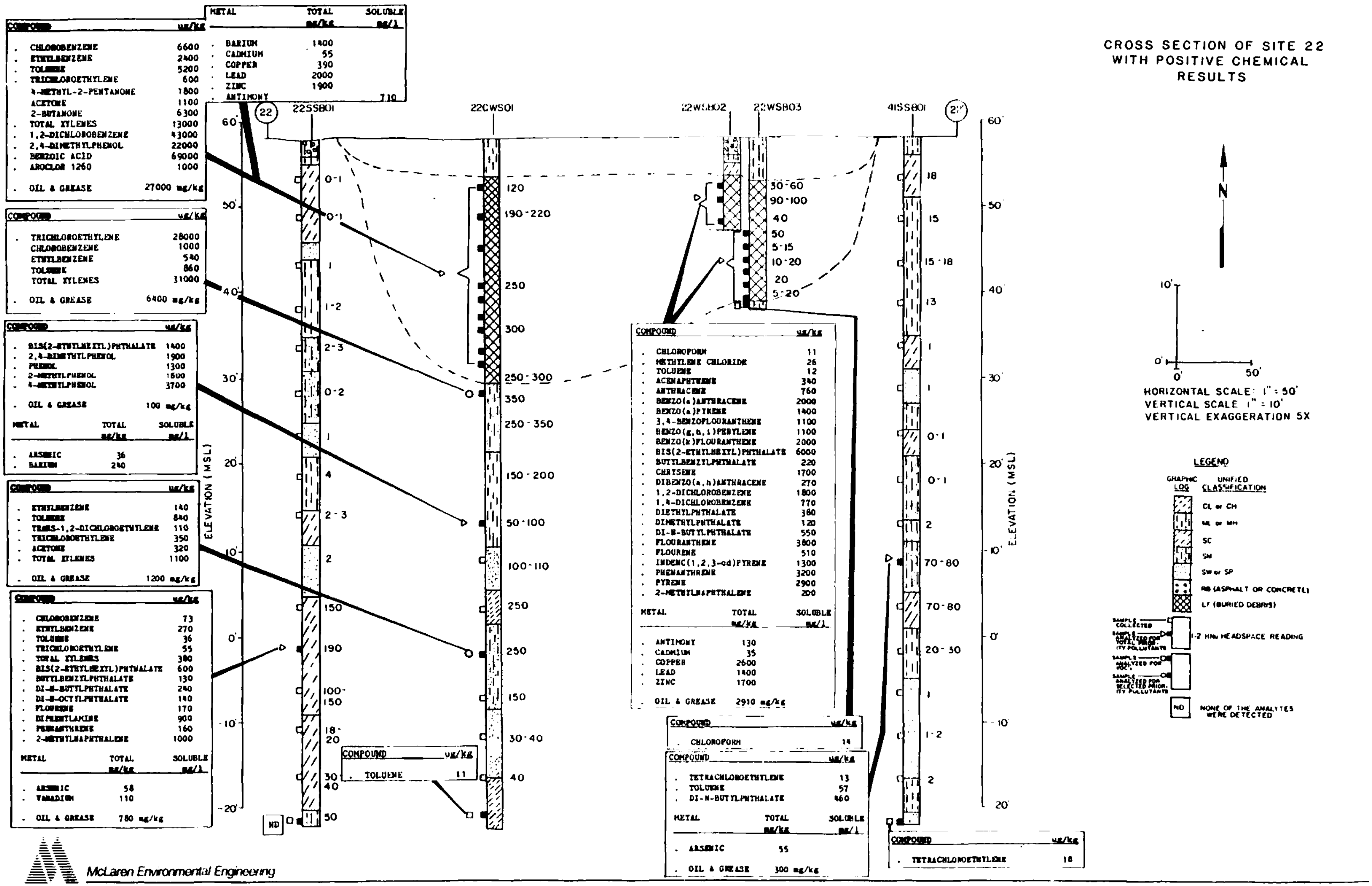
209. IRP Stage 5-Analytical Data Summary: Preliminary Pathways Assessment-Surface Water and Stream Sediment Samples; Radian; 5/90.
Surface water contamination.

210. IRP Stage 3-Groundwater Sampling Data Summary-Fourth Quarter 1989; Radian; 5/90.
Should be good for comparison to earlier reports. Good plates (most up-to-date).

211. Administrative Record Correspondence 10/88 through 3/89.

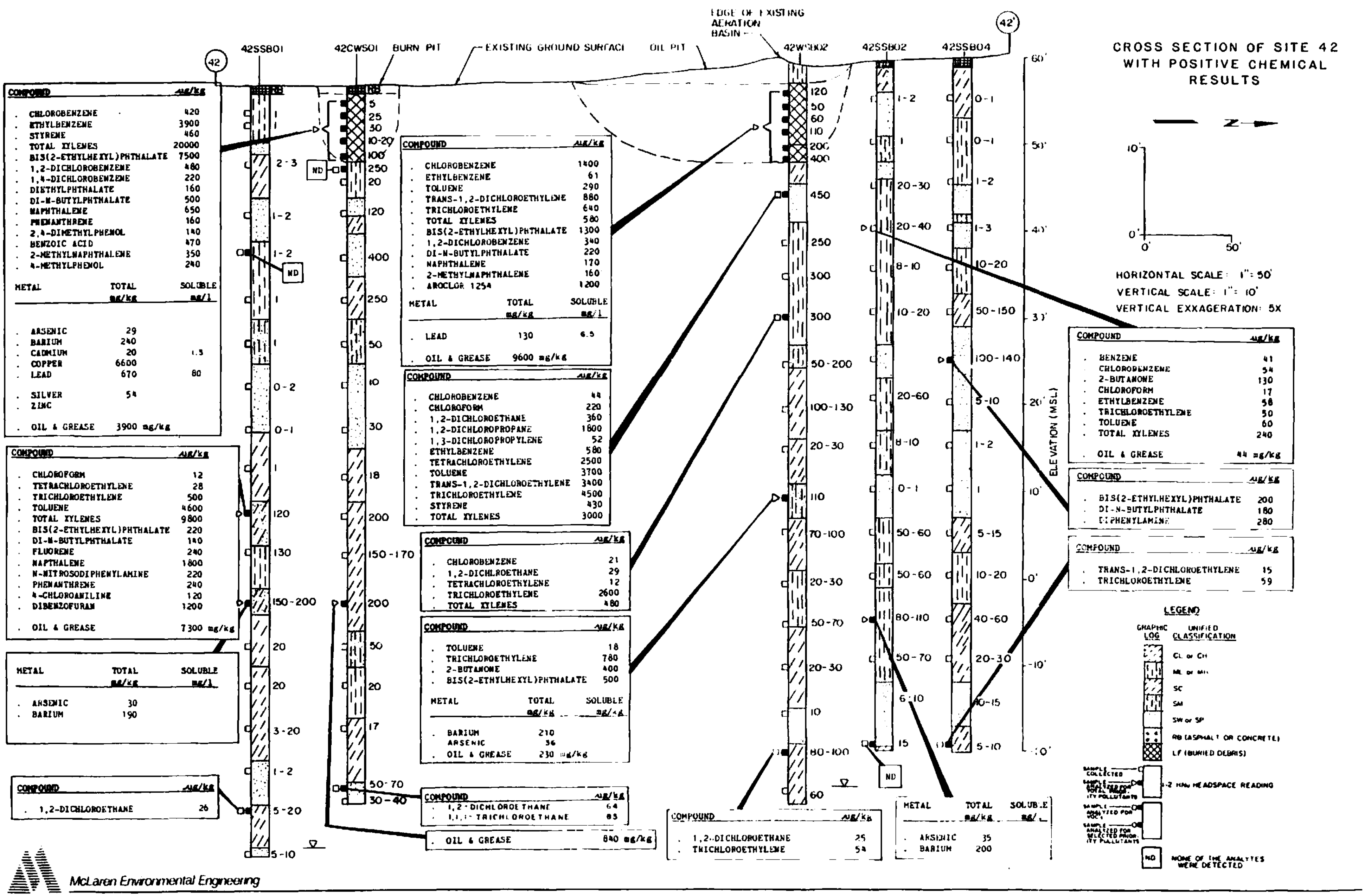
Appendix B
CROSS-SECTIONS OF APPROVED SITES

CROSS SECTION OF SITE 22 WITH POSITIVE CHEMICAL RESULTS



McLaren Environmental Engineering

CROSS SECTION OF SITE 42 WITH POSITIVE CHEMICAL RESULTS



COMPOUND	µg/kg
CHLOROBENZENE	420
ETHYLBENZENE	3900
STYRENE	460
TOTAL XYLENES	20000
BIS(2-ETHYLHEXYL)PHTHALATE	7500
1,2-DICHLOROBENZENE	480
1,4-DICHLOROBENZENE	220
DIETHYLPHTHALATE	160
DI-N-BUTYLPHTHALATE	500
NAPHTHALENE	650
PHENANTHRENE	160
2,4-DIMETHYLPHENOL	140
BENZOIC ACID	470
2-METHYLNAPHTHALENE	350
4-METHYLPHENOL	240

METAL	TOTAL mg/kg	SOLUBLE mg/l
ARSENIC	29	
BARIUM	240	
CADMIUM	20	1.5
COPPER	6600	
LEAD	670	80
SILVER	54	
ZINC		
OIL & GREASE	3900 mg/kg	

COMPOUND	µg/kg
CHLOROFORM	12
TETRACHLOROETHYLENE	28
TRICHLOROETHYLENE	500
TOLUENE	4600
TOTAL XYLENES	9800
BIS(2-ETHYLHEXYL)PHTHALATE	220
DI-N-BUTYLPHTHALATE	140
FLUORENE	240
NAPTHALENE	1800
N-NITROSODIPHENYLAMINE	220
PHENANTHRENE	240
4-CHLOROANILINE	120
DIBENZOFURAN	1200
OIL & GREASE	7300 mg/kg

METAL	TOTAL mg/kg	SOLUBLE mg/l
ARSENIC	30	
BARIUM	190	

COMPOUND	µg/kg
1,2-DICHLOROETHANE	26

COMPOUND	µg/kg
CHLOROBENZENE	1400
ETHYLBENZENE	61
TOLUENE	290
TRANS-1,2-DICHLOROETHYLENE	880
TRICHLOROETHYLENE	640
TOTAL XYLENES	580
BIS(2-ETHYLHEXYL)PHTHALATE	1300
1,2-DICHLOROBENZENE	340
DI-N-BUTYLPHTHALATE	220
NAPHTHALENE	170
2-METHYLNAPHTHALENE	160
AROCLOR 1254	1200

METAL	TOTAL mg/kg	SOLUBLE mg/l
LEAD	130	6.5
OIL & GREASE	9600 mg/kg	

COMPOUND	µg/kg
CHLOROBENZENE	44
CHLOROFORM	220
1,2-DICHLOROETHANE	360
1,2-DICHLOROPROPANE	1600
1,3-DICHLOROPROPYLENE	52
ETHYLBENZENE	580
TETRACHLOROETHYLENE	2500
TOLUENE	3700
TRANS-1,2-DICHLOROETHYLENE	3400
TRICHLOROETHYLENE	4500
STYRENE	430
TOTAL XYLENES	3000

COMPOUND	µg/kg
CHLOROBENZENE	21
1,2-DICHLROETHANE	29
TETRACHLOROETHYLENE	12
TRICHLOROETHYLENE	2600
TOTAL XYLENES	480

COMPOUND	µg/kg
TOLUENE	18
TRICHLOROETHYLENE	780
2-BUTANONE	400
BIS(2-ETHYLHEXYL)PHTHALATE	500

METAL	TOTAL mg/kg	SOLUBLE mg/l
BARIUM	210	
ARSENIC	36	
OIL & GREASE	230 mg/kg	

COMPOUND	µg/kg
1,2-DICHLOROETHANE	64
1,1,1-TRICHLOROETHANE	85

OIL & GREASE	840 mg/kg

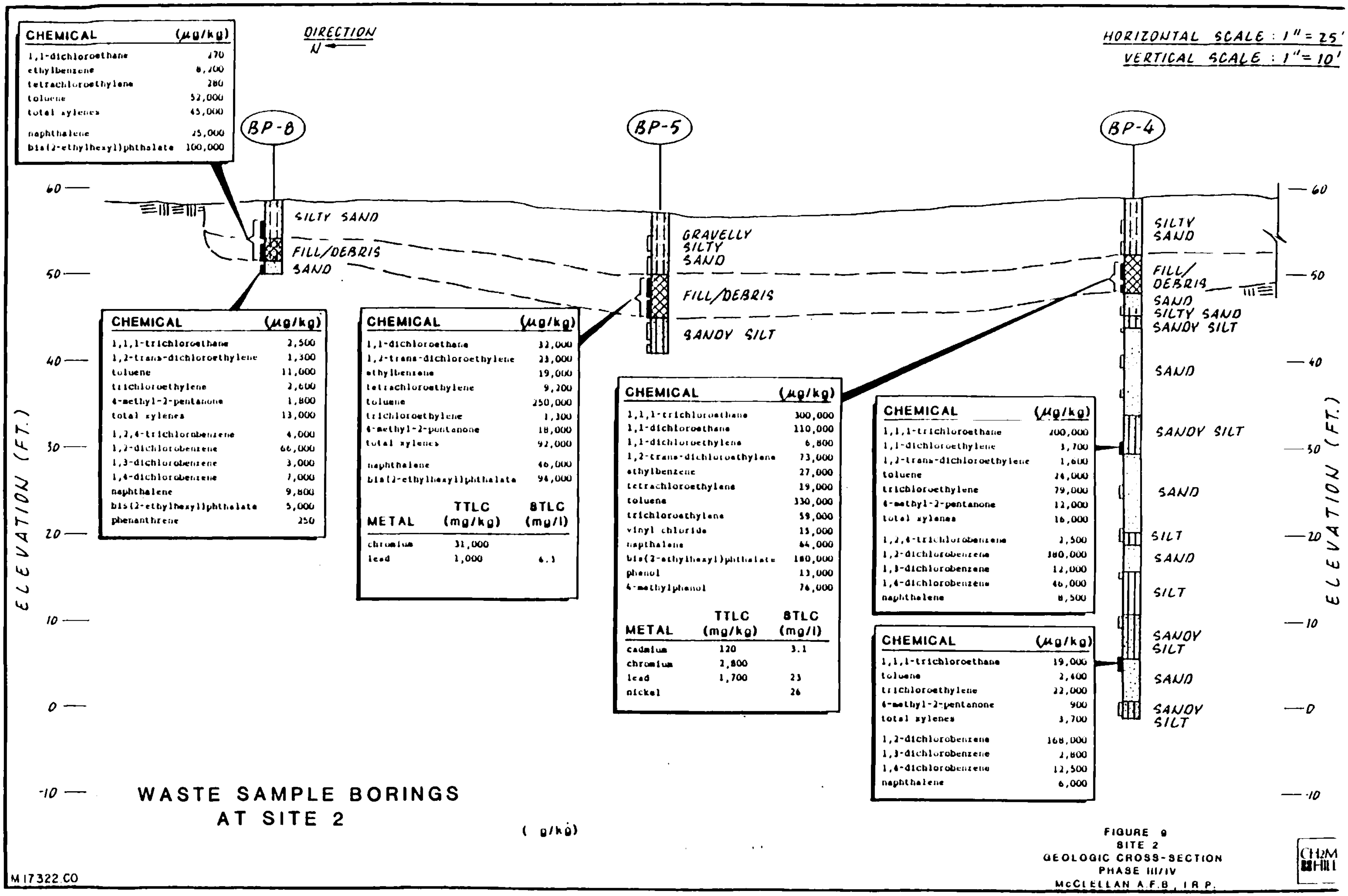
COMPOUND	µg/kg
1,2-DICHLOROETHANE	25
TRICHLOROETHYLENE	54

METAL	TOTAL mg/kg	SOLUBLE mg/l
ARSENIC	35	
BARIUM	200	

COMPOUND	µg/kg
BENZENE	41
CHLOROBENZENE	54
2-BUTANONE	130
CHLOROFORM	17
ETHYLBENZENE	58
TRICHLOROETHYLENE	50
TOLUENE	60
TOTAL XYLENES	240
OIL & GREASE	44 mg/kg

COMPOUND	µg/kg
BIS(2-ETHYLHEXYL)PHTHALATE	200
DI-N-BUTYLPHTHALATE	180
DIPHENYLAMINE	280

COMPOUND	µg/kg
TRANS-1,2-DICHLOROETHYLENE	15
TRICHLOROETHYLENE	59



BP-8 (upper sample)

CHEMICAL	(μg/kg)
1,1-dichloroethane	270
ethylbenzene	8,200
tetrachloroethylene	280
toluene	52,000
total xylenes	45,000
naphthalene	25,000
bis(2-ethylhexyl)phthalate	100,000

BP-8 (lower sample)

CHEMICAL	(μg/kg)
1,1,1-trichloroethane	2,500
1,2-trans-dichloroethylene	1,300
toluene	11,000
trichloroethylene	2,600
4-methyl-2-pentanone	1,800
total xylenes	13,000
1,2,4-trichlorobenzene	4,000
1,2-dichlorobenzene	66,000
1,3-dichlorobenzene	3,000
1,4-dichlorobenzene	7,000
naphthalene	9,800
bis(2-ethylhexyl)phthalate	5,000
phenanthrene	250

BP-5

CHEMICAL	(μg/kg)
1,1-dichloroethane	32,000
1,2-trans-dichloroethylene	23,000
ethylbenzene	19,000
tetrachloroethylene	9,200
toluene	250,000
trichloroethylene	1,300
4-methyl-2-pentanone	18,000
total xylenes	92,000
naphthalene	46,000
bis(2-ethylhexyl)phthalate	94,000

METAL	TTLC (mg/kg)	BTLC (mg/l)
chromium	31,000	
lead	1,000	6.3

BP-4 (fill/debris sample)

CHEMICAL	(μg/kg)
1,1,1-trichloroethane	300,000
1,1-dichloroethane	110,000
1,1-dichloroethylene	6,800
1,2-trans-dichloroethylene	73,000
ethylbenzene	27,000
tetrachloroethylene	19,000
toluene	330,000
trichloroethylene	59,000
vinyl chloride	15,000
napthalene	64,000
bis(2-ethylhexyl)phthalate	180,000
phenol	13,000
4-methylphenol	76,000

METAL	TTLC (mg/kg)	BTLC (mg/l)
cadmium	120	3.1
chromium	2,800	
lead	1,700	23
nickel		26

BP-4 (sample at about 30 ft)

CHEMICAL	(μg/kg)
1,1,1-trichloroethane	200,000
1,1-dichloroethylene	3,700
1,2-trans-dichloroethylene	1,600
toluene	24,000
trichloroethylene	79,000
4-methyl-2-pentanone	12,000
total xylenes	16,000
1,2,4-trichlorobenzene	2,500
1,2-dichlorobenzene	380,000
1,3-dichlorobenzene	12,000
1,4-dichlorobenzene	46,000
naphthalene	8,500

BP-4 (sample at about 5 ft)

CHEMICAL	(μg/kg)
1,1,1-trichloroethane	19,000
toluene	2,400
trichloroethylene	22,000
4-methyl-2-pentanone	900
total xylenes	3,700
1,2-dichlorobenzene	168,000
1,3-dichlorobenzene	2,800
1,4-dichlorobenzene	12,500
naphthalene	6,000

WASTE SAMPLE BORINGS AT SITE 2

(g/kg)

FIGURE 9
SITE 2
GEOLOGIC CROSS-SECTION
PHASE III/IV
McCLELLAN A.F.B., I.R.P.

CH2M HILL

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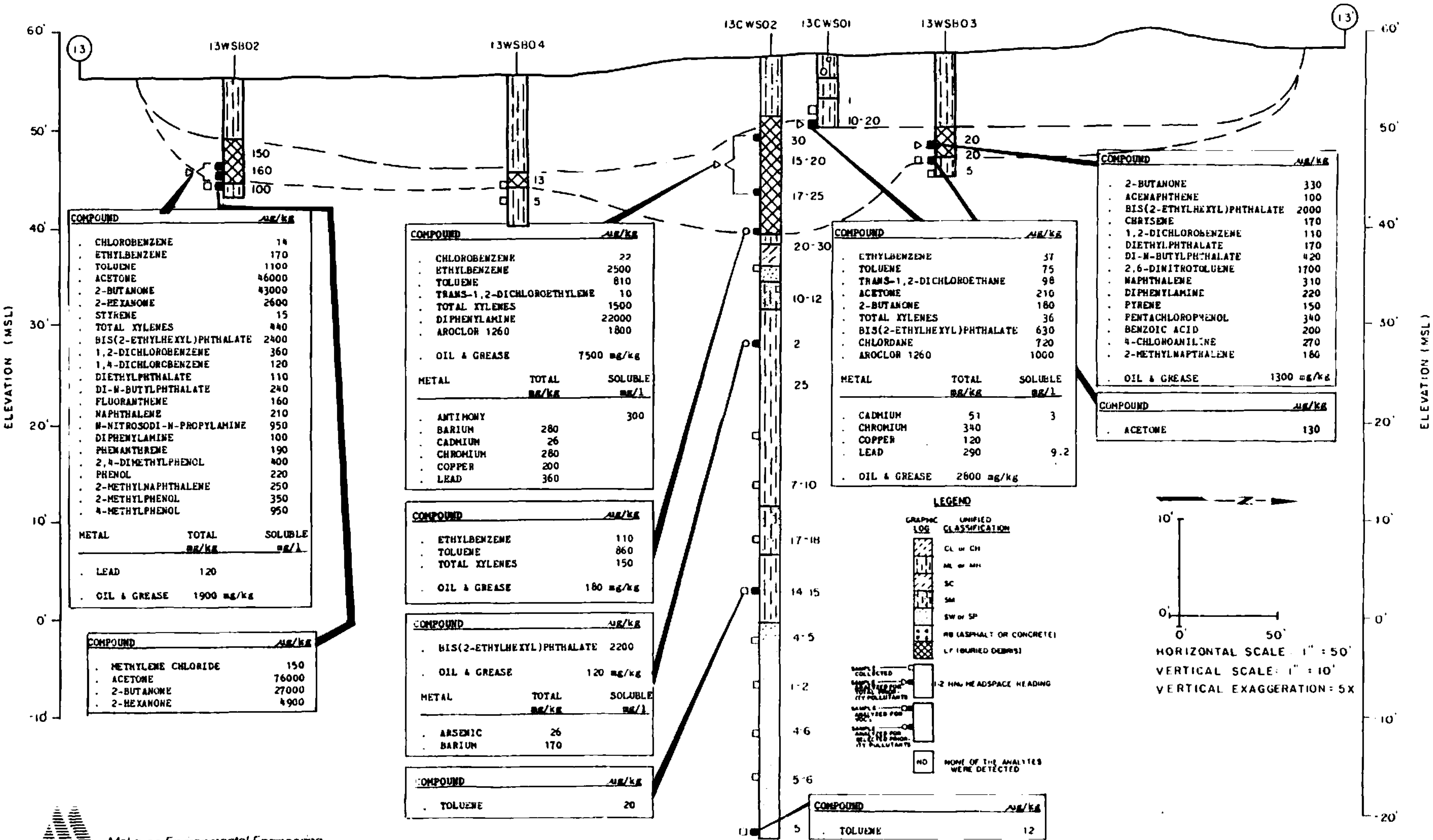
CROSS SECTION OF SITE 13
WITH POSITIVE CHEMICAL
RESULTS



COMPOUND	µg/kg
. CHLOROBENZENE	14
. ETHYLBENZENE	170
. TOLUENE	1100
. ACETONE	46000
. 2-BUTANONE	43000
. 2-HEXANONE	2600
. STYRENE	15
. TOTAL XYLENES	440
. BIS(2-ETHYLHEXYL)PHTHALATE	2400
. 1,2-DICHLOROBENZENE	360
. 1,4-DICHLOROBENZENE	120
. DIETHYLPHTHALATE	110
. DI-N-BUTYLPHTHALATE	240
. FLUORANTHENE	160
. NAPHTHALENE	210
. N-NITROSODI-N-PROPYLAMINE	950
. DIPHENYLAMINE	100
. PHENANTHRENE	190
. 2,4-DIMETHYLPHENOL	400
. PHENOL	220
. 2-METHYLNAPHTHALENE	250
. 2-METHYLPHENOL	350
. 4-METHYLPHENOL	950

METAL	TOTAL mg/kg	SOLUBLE mg/l
. LEAD	120	
. OIL & GREASE	1900 mg/kg	

COMPOUND	µg/kg
. METHYLENE CHLORIDE	150
. ACETONE	76000
. 2-BUTANONE	27000
. 2-HEXANONE	4900

COMPOUND	µg/kg
. CHLOROBENZENE	22
. ETHYLBENZENE	2500
. TOLUENE	810
. TRANS-1,2-DICHLOROETHYLENE	10
. TOTAL XYLENES	1500
. DIPHENYLAMINE	22000
. AROCLOR 1260	1800
. OIL & GREASE	7500 mg/kg

METAL	TOTAL mg/kg	SOLUBLE mg/l
. ANTIMONY		300
. BARIUM	280	
. CADMIUM	26	
. CHROMIUM	280	
. COPPER	200	
. LEAD	360	

COMPOUND	µg/kg
. ETHYLBENZENE	110
. TOLUENE	860
. TOTAL XYLENES	150
. OIL & GREASE	180 mg/kg

COMPOUND	µg/kg
. BIS(2-ETHYLHEXYL)PHTHALATE	2200
. OIL & GREASE	120 mg/kg

METAL	TOTAL mg/kg	SOLUBLE mg/l
. ARSENIC	26	
. BARIUM	170	

COMPOUND	µg/kg
. TOLUENE	20

COMPOUND	µg/kg
. ETHYLBENZENE	37
. TOLUENE	75
. TRANS-1,2-DICHLOROETHANE	98
. ACETONE	210
. 2-BUTANONE	180
. TOTAL XYLENES	36
. BIS(2-ETHYLHEXYL)PHTHALATE	630
. CHLORDANE	720
. AROCLOR 1260	1000

METAL	TOTAL mg/kg	SOLUBLE mg/l
. CADMIUM	51	3
. CHROMIUM	340	
. COPPER	120	
. LEAD	290	9.2
. OIL & GREASE	2600 mg/kg	

COMPOUND	µg/kg
. 2-BUTANONE	330
. ACENAPHTHENE	100
. BIS(2-ETHYLHEXYL)PHTHALATE	2000
. CHRYSENE	170
. 1,2-DICHLOROBENZENE	110
. DIETHYLPHTHALATE	170
. DI-N-BUTYLPHTHALATE	420
. 2,6-DINITROTOLUENE	1700
. NAPHTHALENE	310
. DIPHENYLAMINE	220
. PYRENE	150
. PENTACHLOROPHENOL	340
. BENZOIC ACID	200
. 4-CHLOROANILINE	270
. 2-METHYLNAPTHALENE	180
. OIL & GREASE	1300 mg/kg

COMPOUND	µg/kg
. ACETONE	130

COMPOUND	µg/kg
. TOLUENE	12

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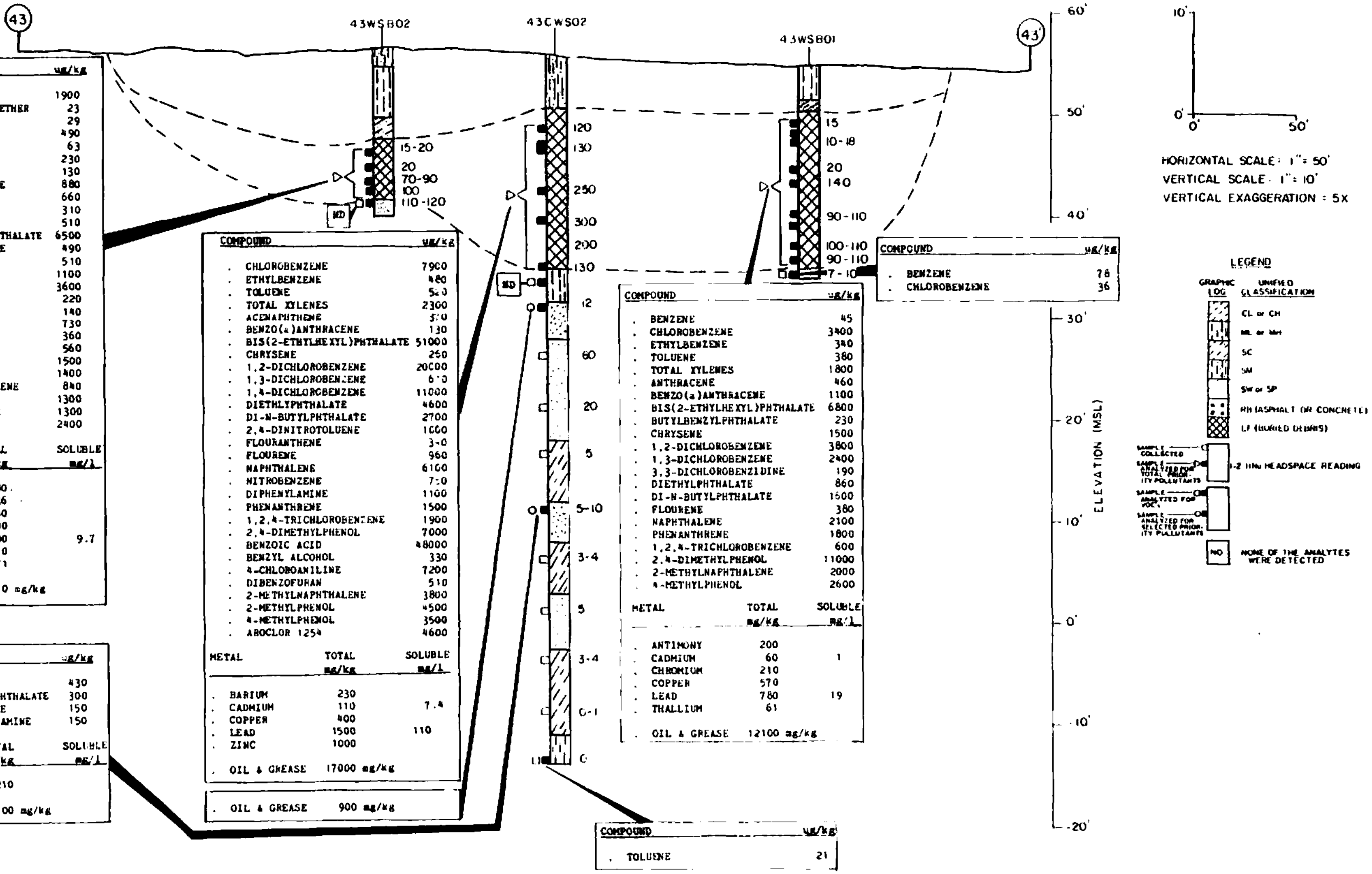
CROSS SECTION OF SITE 43 WITH POSITIVE CHEMICAL RESULTS



COMPOUND	ug/kg
CHLOROBENZENE	1900
2-CHLOROETHYLVINYL ETHER	23
CHLOROFORM	29
ETHYLBENZENE	490
METHYLENE CHLORIDE	63
TOLUENE	230
2-HEXANONE	130
4-METHYL-2-PENTANONE	880
TOTAL XYLENES	660
ANTHRACENE	310
BENZO(a)ANTHRACENE	510
BIS(2-ETHYLHEXYL)PHTHALATE	6500
BUTYLBENZYLPHTHALATE	490
CHRYSENE	510
1,2-DICHLOROBENZENE	1100
1,4-DICHLOROBENZENE	3600
DIETHYLPHTHALATE	220
DIMETHYLPHTHALATE	140
DI-N-BUTYLPHTHALATE	730
2,4-DINITROTOLUENE	360
FLOURENE	560
NAPHTHALENE	1500
PHENANTHRENE	1400
1,2,4-TRICHLOROBENZENE	840
2,4-DIMETHYLPHENOL	1300
2-METHYLNAPHTHALENE	1300
4-METHYLPHENOL	2400

METAL	TOTAL mg/kg	SOLUBLE mg/l
ANTIMONY	180	
CADMIUM	36	
CHROMIUM	340	
COPPER	1100	
LEAD	1000	9.7
NICKEL	210	
THALLIUM	71	
OIL & GREASE	8810 mg/kg	

COMPOUND	ug/kg
BENZENO(a)PYRENE	430
BIS(2-ETHYLHEXYL)PHTHALATE	300
DI-N-BUTYLPHTHALATE	150
N-NITROSODIMETHYLAMINE	150

METAL	TOTAL mg/kg	SOLUBLE mg/l
BARIUM	210	
OIL & GREASE	1100 mg/kg	

COMPOUND	ug/kg
CHLOROBENZENE	7900
ETHYLBENZENE	480
TOLUENE	5[illegible]0
TOTAL XYLENES	2300
ACENAPHTHENE	5[illegible]0
BENZO(a)ANTHRACENE	130
BIS(2-ETHYLHEXYL)PHTHALATE	51000
CHRYSENE	260
1,2-DICHLOROBENZENE	20000
1,3-DICHLOROBENZENE	6[illegible]0
1,4-DICHLOROBENZENE	11000
DIETHLYPHTHALATE	4600
DI-N-BUTYLPHTHALATE	2700
2,4-DINITROTOLUENE	1000
FLOURANTHENE	3[illegible]0
FLOURENE	960
NAPHTHALENE	6100
NITROBENZENE	7[illegible]0
DIPHENYLAMINE	1100
PHENANTHRENE	1500
1,2,4-TRICHLOROBENZENE	1900
2,4-DIMETHYLPHENOL	7000
BENZOIC ACID	48000
BENZYL ALCOHOL	330
4-CHLOROANILINE	7200
DIBENZOFURAN	510
2-METHYLNAPHTHALENE	3800
2-METHYLPHENOL	4500
4-METHYLPHENOL	3500
AROCLOR 1254	4600

METAL	TOTAL mg/kg	SOLUBLE mg/l
BARIUM	230	
CADMIUM	110	7.4
COPPER	400	
LEAD	1500	110
ZINC	1000	
OIL & GREASE	17000 mg/kg	

OIL & GREASE	900 mg/kg

COMPOUND	ug/kg
BENZENE	45
CHLOROBENZENE	3400
ETHYLBENZENE	340
TOLUENE	380
TOTAL XYLENES	1800
ANTHRACENE	460
BENZO(a)ANTHRACENE	1100
BIS(2-ETHYLHEXYL)PHTHALATE	6800
BUTYLBENZYLPHTHALATE	230
CHRYSENE	1500
1,2-DICHLOROBENZENE	3800
1,3-DICHLOROBENZENE	2400
3,3-DICHLOROBENZIDINE	190
DIETHYLPHTHALATE	860
DI-N-BUTYLPHTHALATE	1600
FLOURENE	380
NAPHTHALENE	2100
PHENANTHRENE	1800
1,2,4-TRICHLOROBENZENE	600
2,4-DIMETHYLPHENOL	11000
2-METHYLNAPHTHALENE	2000
4-METHYLPHENOL	2600

METAL	TOTAL mg/kg	SOLUBLE mg/l
ANTIMONY	200	
CADMIUM	60	1
CHROMIUM	210	
COPPER	570	
LEAD	780	19
THALLIUM	61	
OIL & GREASE	12100 mg/kg	

COMPOUND	ug/kg
BENZENE	78
CHLOROBENZENE	36

COMPOUND	ug/kg
TOLUENE	21

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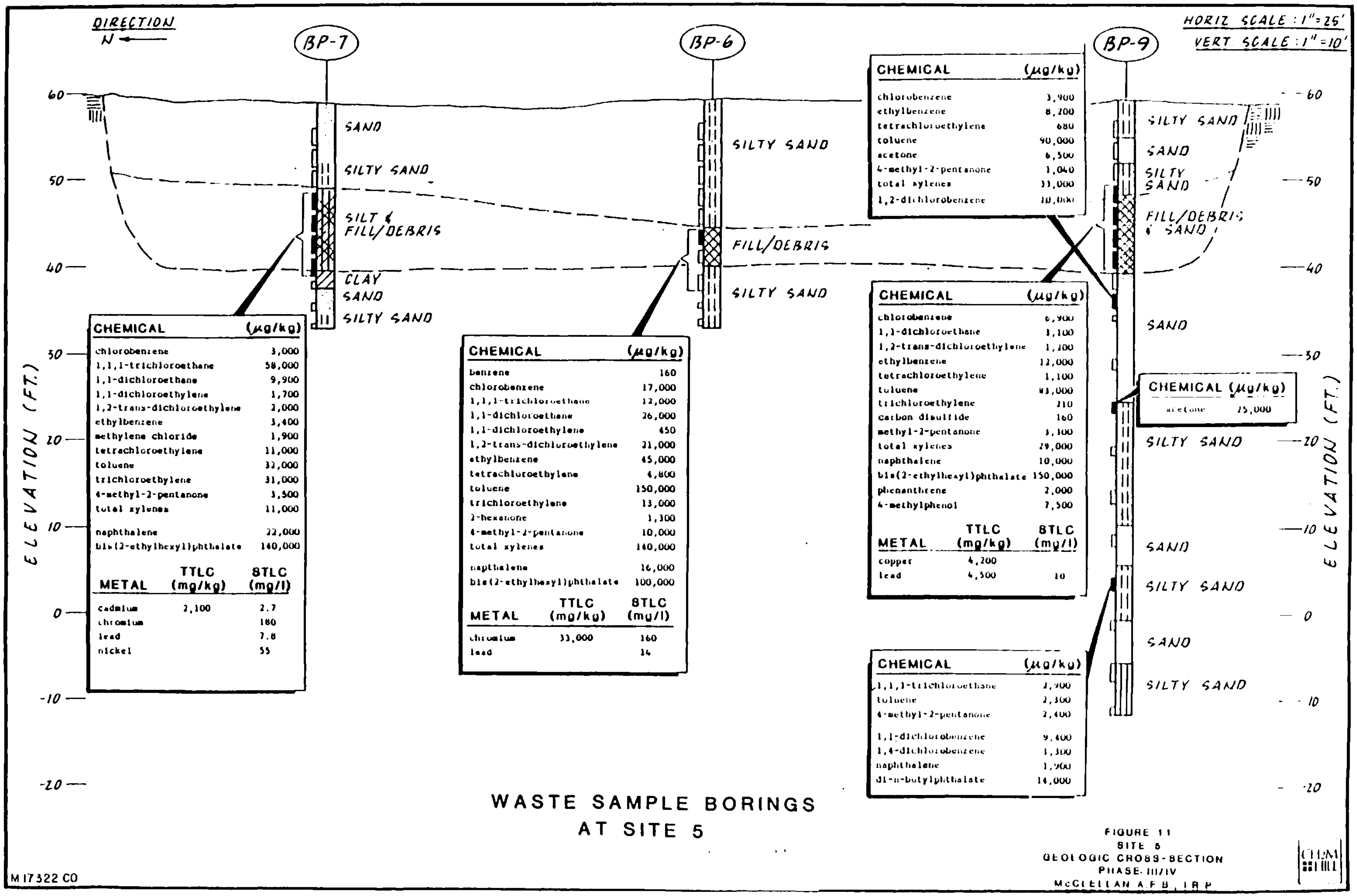


BP-7

CHEMICAL	(µg/kg)
chlorobenzene	3,000
1,1,1-trichloroethane	58,000
1,1-dichloroethane	9,900
1,1-dichloroethylene	1,700
1,2-trans-dichloroethylene	2,000
ethylbenzene	3,400
methylene chloride	1,900
tetrachloroethylene	11,000
toluene	32,000
trichloroethylene	31,000
4-methyl-2-pentanone	3,500
total xylenes	11,000
naphthalene	22,000
bis(2-ethylhexyl)phthalate	140,000

METAL	TTLC (mg/kg)	STLC (mg/l)
cadmium	2,100	2.7
chromium		180
lead		7.8
nickel		55

BP-6

CHEMICAL	(µg/kg)
benzene	160
chlorobenzene	17,000
1,1,1-trichloroethane	12,000
1,1-dichloroethane	26,000
1,1-dichloroethylene	450
1,2-trans-dichloroethylene	21,000
ethylbenzene	45,000
tetrachloroethylene	4,800
toluene	150,000
trichloroethylene	13,000
2-hexanone	1,300
4-methyl-2-pentanone	10,000
total xylenes	140,000
napthalene	16,000
bis(2-ethylhexyl)phthalate	100,000

METAL	TTLC (mg/kg)	STLC (mg/l)
chromium	33,000	160
lead		14

BP-9

CHEMICAL	(µg/kg)
chlorobenzene	3,900
ethylbenzene	8,200
tetrachloroethylene	680
toluene	90,000
acetone	6,500
4-methyl-2-pentanone	1,040
total xylenes	33,000
1,2-dichlorobenzene	10,000

CHEMICAL	(µg/kg)
chlorobenzene	6,900
1,1-dichloroethane	3,100
1,2-trans-dichloroethylene	1,200
ethylbenzene	12,000
tetrachloroethylene	1,100
toluene	43,000
trichloroethylene	210
carbon disulfide	160
methyl-2-pentanone	3,100
total xylenes	29,000
naphthalene	10,000
bis(2-ethylhexyl)phthalate	150,000
phenanthrene	2,000
4-methylphenol	7,500

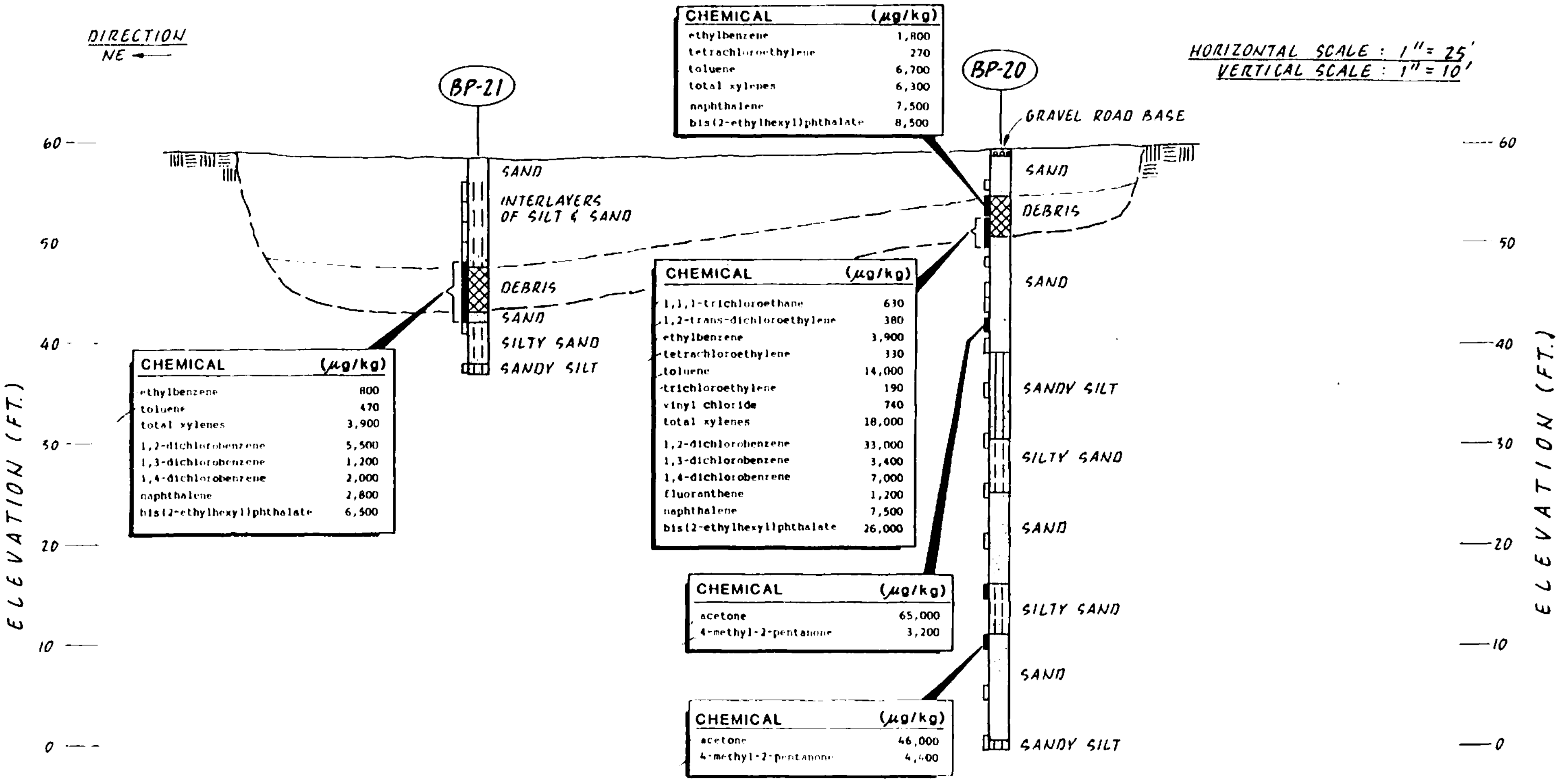
METAL	TTLC (mg/kg)	STLC (mg/l)
copper	4,200	
lead	4,500	10

CHEMICAL	(µg/kg)
acetone	25,000

CHEMICAL	(µg/kg)
1,1,1-trichloroethane	2,900
toluene	2,300
4-methyl-2-pentanone	2,400
1,1-dichlorobenzene	9,400
1,4-dichlorobenzene	1,300
naphthalene	1,900
di-n-butylphthalate	14,000

WASTE SAMPLE BORINGS AT SITE 5

FIGURE 11
SITE 5
GEOLOGIC CROSS-SECTION
PHASE III/IV
McCLELLAN A.F.B., I.R.P.



CHEMICAL	(μg/kg)
ethylbenzene	800
toluene	470
total xylenes	3,900
1,2-dichlorobenzene	5,500
1,3-dichlorobenzene	1,200
1,4-dichlorobenzene	2,000
naphthalene	2,800
bis(2-ethylhexyl)phthalate	6,500

CHEMICAL	(μg/kg)
ethylbenzene	1,800
tetrachloroethylene	270
toluene	6,700
total xylenes	6,300
naphthalene	7,500
bis(2-ethylhexyl)phthalate	8,500

CHEMICAL	(μg/kg)
1,1,1-trichloroethane	630
1,2-trans-dichloroethylene	380
ethylbenzene	3,900
tetrachloroethylene	330
toluene	14,000
trichloroethylene	190
vinyl chloride	740
total xylenes	18,000
1,2-dichlorobenzene	33,000
1,3-dichlorobenzene	3,400
1,4-dichlorobenzene	7,000
fluoranthene	1,200
naphthalene	7,500
bis(2-ethylhexyl)phthalate	26,000

CHEMICAL	(μg/kg)
acetone	65,000
4-methyl-2-pentanone	3,200

CHEMICAL	(μg/kg)
acetone	46,000
4-methyl-2-pentanone	4,400

WASTE SAMPLE BORINGS AT SITE S

FIGURE 13
SITE S
GEOLOGIC CROSS-SECTION
PHASE III/IV
McCLELLAN A.F.B., I.R.P.

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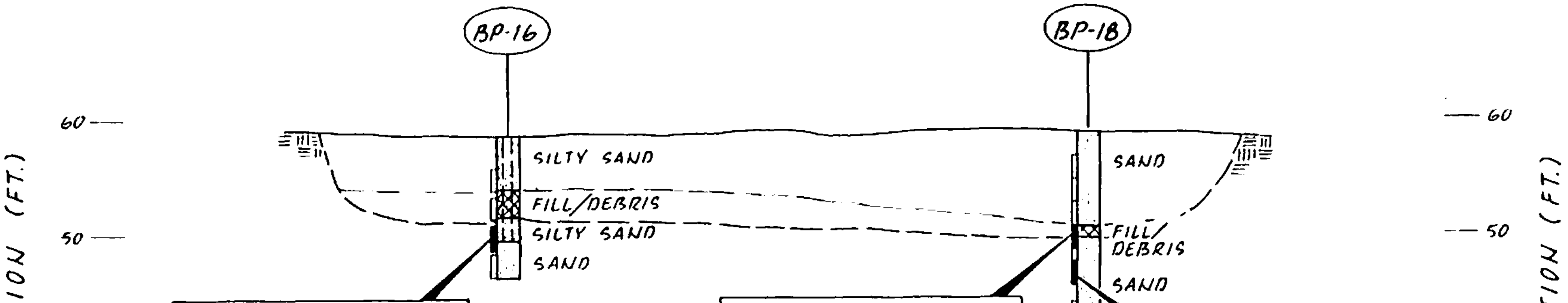
M17322 CO

WASTE SAMPLE BORINGS AT SITE T

DIRECTION
NE ←

HORIZONTAL SCALE: 1" = 25'
VERTICAL SCALE: 1" = 10'



BP-16

CHEMICAL	(μg/kg)
1,1,1-trichloroethane	190,000
1,1-dichloroethane	5,700
1,1-dichloroethylene	4,500
1,2-trans-dichloroethylene	75,000
ethylbenzene	5,000
tetrachloroethylene	36,000
1,2,4-trichlorobenzene	4,900
1,2-dichlorobenzene	290,000
1,3-dichlorobenzene	42,000
1,4-dichlorobenzene	520,000
naphthalene	10,000
bis(2-ethylhexyl)phthalate	250,000

METAL	TTLC (mg/kg)	STLC (mg/l)
cadmium	170	9.8
lead		9.3
nickel		43

BP-18 (FILL/DEBRIS)

CHEMICAL	(μg/kg)
1,1,1-trichloroethane	23,000
1,1-dichloroethane	340
1,1-dichloroethylene	400
1,2-trans-dichloroethylene	3,900
ethylbenzene	4,100
tetrachlorobenzene	4,100
toluene	30,000
trichloroethylene	6,900
4-methyl-2-pentanone	4,700
total xylenes	16,000
1,2-dichlorobenzene	100,000
1,3-dichlorobenzene	12,000
1,4-dichlorobenzene	17,000
naphthalene	9,500
bis(2-ethylhexyl)phthalate	16,000

METAL	STLC (mg/l)
lead	22.

BP-18 (SAND)

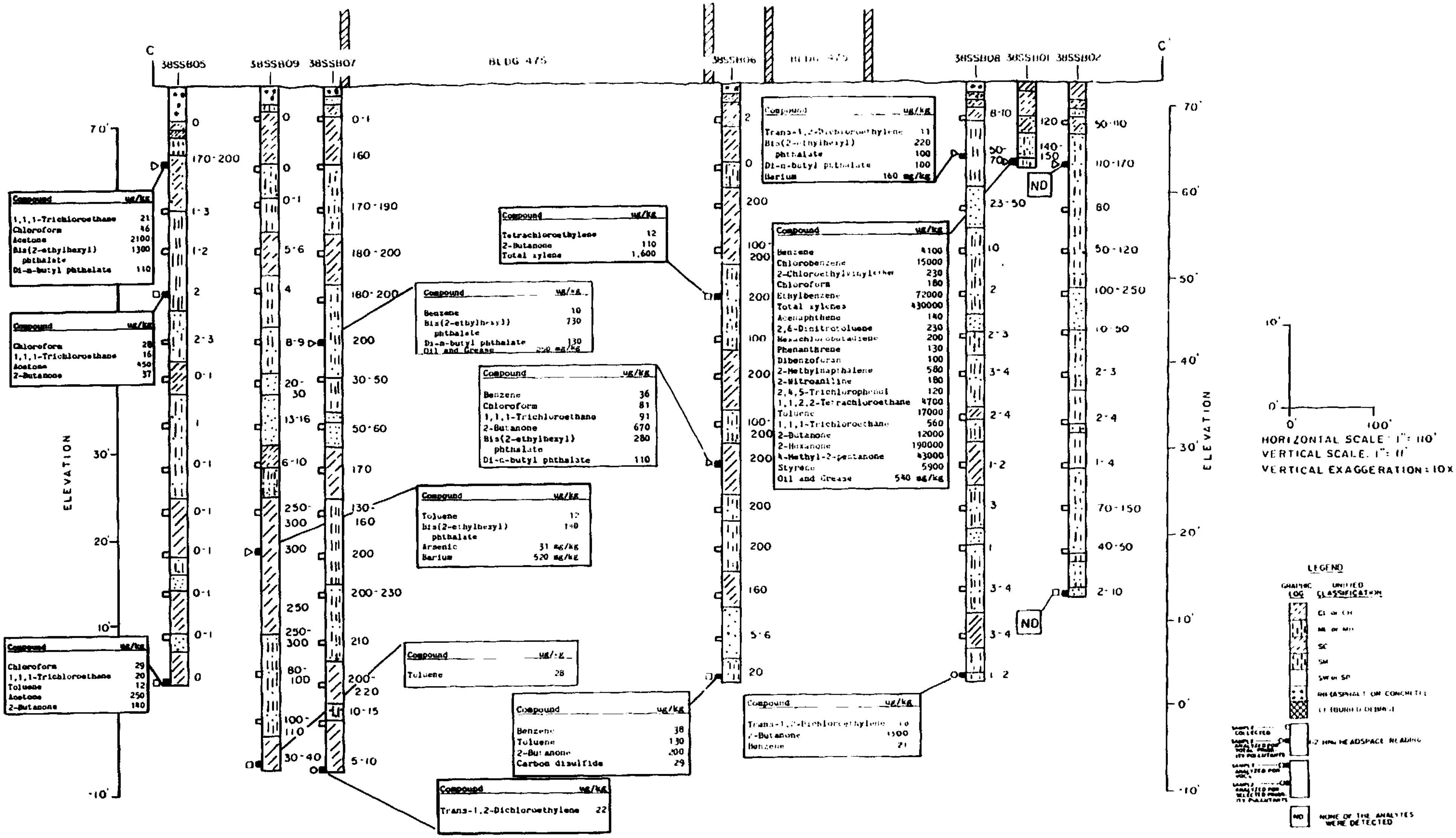
CHEMICAL	
chlorobenzene	300
1,1,1-trichloroethane	35,000
1,1-dichloroethane	140
1,1-dichloroethylene	1,400
1,2-trans-dichloroethylene	100
ethylbenzene	2,200
tetrachloroethylene	20,000
toluene	19,000
trichloroethylene	23,000
acetone	19,000
4-methyl-2-pentanone	5,600
total xylenes	8,200

FIGURE 14
SITE T
GEOLOGIC CROSS-SECTION
PHASE III/IV
McCLELLAN A.F.B., I.R.P.

CH2M HILL

M 17322.CO

CROSS SECTION OF SITE 38
WITH POSITIVE CHEMICAL RESULTS



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Appendix C
GEOLOGICAL AND GEOPHYSICAL WELL LOGS

Appendix C

Examples of geological and geophysical well logs used to identify high- and low-permeability barrier layers.

High-Permeability Barrier

Attached are geophysical and geological well logs from the Deep Exploratory Boring (DEB) and a geological log of PZ-28. Both of these wells are within Site 22.

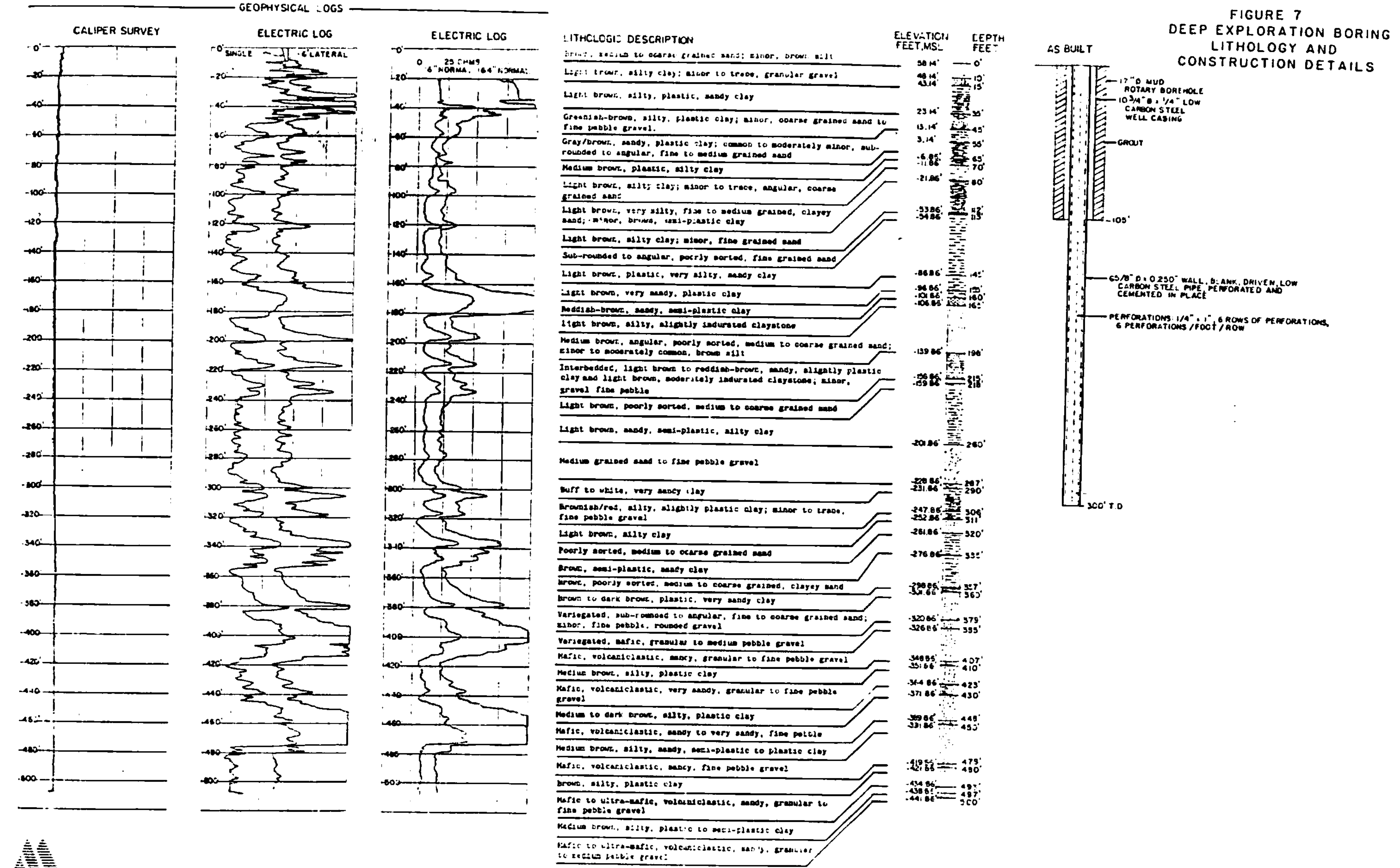
The high-permeability zone that lies between about -95 and -132 feet msl is clearly visible on the geophysical log for the DEB, which indicates a highly resistive layer between -105 and -122 feet msl (depth of 163 and 180 feet bgs). (Resistivity increases to the right along the four curves labelled electric log.) The geological log for PZ-28 shows sand between -107 and -127 feet msl.

Low-Permeability Barrier

Attached are a combination of geophysical and geological well logs for MW-60 and a geological log for MW-445. These wells are within Site 43.

A low-permeability zone at a depth of 82 and 92 feet bgs can be seen as an interval of low resistivity on the geophysical well log for MW-60. (Resistivity increases to the right along the curves for point resistivity and 6-foot lateral.) This zone, which is at an elevation between -20 and -31 feet msl, is indicated on the geological log for MW-445 as SC (clayey sand) and CL (clay) between 74 and 83 feet bgs.

FIGURE 7
DEEP EXPLORATION BORING
LITHOLOGY AND
CONSTRUCTION DETAILS



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RADIAN CORPORATION

LOG OF DRILLING OPERATIONS

Piezometer #: ~~PZ-32~~

PROJECT: PGOURI
LOCATION: McClellan Air Force Base
TOTAL DEPTH: 187.00
START DATE: 4/4/90
FINISH DATE: 4/5/90
GEOLOGIST: Rick Moore
APPROVED BY:
CALIF R.G.#: 1838
DRILLING COMPANY: Water Development Corp.
DRILLER: Tom Moreland
DRILLING METHOD: Air Rotary Casing Drive
EQUIPMENT: Speedstar 15 II
DRILL BIT TYPE AND SIZE: 5.5" Drag Bit
BORING LOCATION (ST. ADDRESS OR DESCRIPTION): Water Treatment Plant off Patrol Road.

Depth Below Surface (ft)	Drill Rate	Lithologic Description (Color, Texture, Moisture, etc.)	Elevation (ft MSL)	Drilling Notes/Construction Details
0			58.17	Top of casing elevation= 57.64' Top of grout PID = 0.0 ppmv at cyclone and in breathing zone.
5		No recovery.	55	
10		SILTY SAND 10YR 4/6, 30% silt, 70% very fine to fine, subangular-subrounded, quartz, mafics, feldspar, (SM).	50	
15	fast	SANDY SILT 2.5Y 5/4, 10% very fine sand, quartz and mica, 90% silt, dry, (SM).	45	
20		SILTY CLAY 2.5Y 6/4, 40% silt, 60% hard, dry clay, (CL).	40	PID = 6.0 ppmv at wellhead. Level C for all drilling crew. All personnel are upwind. Connection at 16:30.
25	fast	SANDY SILT 2.5Y 5/6, 10% very fine to fine, subangular, quartz, mafics, 90% silt, (ML).	35	

NOTES
ppmv parts per million per volume

RADIAN CORPORATION

LOG OF DRILLING OPERATIONS

Piezometer #: PZ-32

PROJECT: PGOURI — LOCATION: McClellan Air Force Base

Depth Below Surface (ft)	Drill Rate	Lithologic Description	Elevation (ft MSL)	Drilling Notes/Construction Details
30		SILTY SAND 5Y 5/6, 20% silt, 40% very fine, subangular, 40% fine subangular-subrounded (50% quartz, 25% feldspar, 25% mafics), (SM).	30	PID = 0.0 ppmv.
			25	
35	fast	SANDY SILT 2.5Y 5/6, 30% very fine subangular quartz, mafics, 70% silt, (ML).		
			20	
40		SILT 2.5Y 5/6, 10% very fine mafics visible, 90% silt with mica, (MH).		Connection at 16:45.
			15	
45		SANDY SILT 2.5Y 4/2, same as 40' except, darker and with more green, 10% very fine to fine sand, (ML).		
			10	
50		SILTY SAND 2.5Y 5/2, 30% silt, 70% very fine to fine subrounded (60% quartz, 25% mafics with mica, 15% pink and white feldspar), (SM).		
			5	
55	fast	At 55', same as above.		
			0	
60	fast	SILTY SAND 2.5Y 4/4, 40% silt, 40% very fine, 20% fine subangular-subrounded (50% quartz, 30% mafics, 20% pink and white feldspar), (SM).		PID = 117 ppmv at cyclone. PID = 96 ppmv in breathing zone.
			-5	

RADIAN CORPORATION

LOG OF DRILLING OPERATIONS

PROJECT: PGOURI LOCATION: McClellan Air Force Base

Depth Below Surface (ft)	Drill Rate	Lithologic Description	Elevation (ft MSL)	Drilling Notes/Construction Details
65	fast	SILTY SAND 2.5Y 4/4, 40% silt, 60% very fine subrounded (50% quartz, 25% mafics with mica and olivine, 25% feldspar), (SM).	-10	
70	fast	SILTY SAND 2.5Y 5/6, 20% silt, 20% very fine subangular-subrounded, 40% fine subangular, 20% medium subrounded (30% quartz, 40% pink and white feldspar (mostly pink), 30% black mafics, few mica), (SM).	-15	PID = 8.3 ppmv at cyclone. PID = 1.5 ppmv in breathing zone.
75		SILTY CLAY 2.5Y 6/2, 20% very fine to medium subrounded quartz, mafics, feldspar, 30% silt, 50% clay, (CL).	-20	Vinyl Chloride detector tube = 0.0 ppmv. TCA detector tube = 150 ppmv in bin.
80		SANDY SILT 2.5Y 5/4, 20% very fine to medium subangular quartz, mafics, 10% clay pieces, 70% silt, (ML).	-25	End of 04/05/90. Beginning of 04/06/90.
85		SILTY CLAY 2.5Y 6/6, 30% silt, 70% clay and clay nodules, (CL).	-30	
90		SANDY SILT 2.5Y 5/2, 20% very fine to fine subangular quartz and mafics, 60% silt, 20% siltstone with Fe staining, (ML).	-35	
95		SAND 2.5Y 5/4, 10% silt, 40% very fine subangular, 40% fine subangular, 10% medium subrounded (50% quartz, 30% mafics, 20% feldspar), (SM).	-40	Hit water.
100				

RADIAN
CORPORATION

LOG OF DRILLING OPERATIONS

Piezometer #: PZ-32 08

PROJECT: PGOURI — LOCATION: McClellan Air Force Base

Depth Below Surface (ft)	Drill Rate	Lithologic Description	Elevation (ft MSL)	Drilling Notes/Construction Details
100		CLAYEY SAND 2.5Y 5/4, 30% clay, 20% silt, 50% subrounded-rounded fine to medium (50% quartz, 30% feldspar, 20% mafics), (SC).	-45	Connection at 08:00.
105	medium	SANDY CLAY 2.5Y 6/4, 30% fine to medium subangular mafics and quartz, 20% silt, 50% clay and very fine silt, small pieces of siltstone, (ML).	-50	
110	medium			
		CLAYEY SILT 2.5Y 6/4, 25% fine to medium subrounded quartz, feldspar, mafics, 35% clay nodules, 40% silt and small siltstone clasts with no Fe staining, (ML).	-55	
115		SILTY CLAY 2.5Y 6/6, 30% siltstone (medium-coarse) red and gray, 70% clay nodules, (CL).		
		SILTY SAND 2.5Y 5/4, 30% silt and small siltstone, 30% very fine subangular, 40% fine subangular-subrounded (50% quartz, 25% feldspar, 25% mafics and mica), (SM).	-60	Organic vapors not detected. Connection at 08:25.
120		SANDY CLAY 2.5Y 6/6, 25% silt, 25% subangular very fine to fine (50% quartz, 25% pink and white feldspar, 25% mafics with mica), 50% 1-3cm clay nodules, (CL).	-65	
125		SANDY CLAY 2.5Y 4/4, 20% silt, 40% clay, 40% very fine-coarse subangular, well graded (50% quartz, 30% mafics and micas, 20% feldspar), (CL).	-70	
130		SANDY SILT 2.5Y 5/4, 20% clay, 40% very fine to medium, subangular-subrounded (50% quartz, 30% feldspar, 20% mafics), 40% silt and siltstone, a few coarse mafics, (ML).	-75	
135				

LOG OF DRILLING OPERATIONS

PROJECT	PGOURI	LOCATION	McClellan Air Force Base

Depth Below Surface (ft)	Drill Rate	Lithologic Description	Graphic Log	Elevation (ft MSL)	Drilling Notes/Construction Details
		GRAVELLY SANDS 10YR 5/8, 30% silt and soft siltstone clasts, 30% very fine to medium, subrounded (60% quartz, 25% mafics, 15% feldspar), 40% coarse gravel (70% quartzite, 20% mafics, 10% feldspar), (SW).		-80	
140					140
		SANDY SILTSTONE 10YR 4/6, 30% very fine to fine, subrounded-subangular (50% quartz, 40% feldspar, 10% mafics), 10% fine to medium subrounded (50% quartz (some fractured), 25% feldspar, 25% mafics), 60% medium to coarse hard siltstone, (ML).		-85	
145		At 145', same as above.			145
				-90	
150		SANDY SILT 5YR 4/4, 30% very fine to fine subrounded (60% quartz, 25% mafics 15% feldspar), less than 10% medium subangular quartz, mafics, feldspar, 60% fine to medium siltstone, (ML).			150
				-95	
155		SILTSTONE 2.5Y 5/4, 10% very fine to medium, subrounded-subangular (quartz, mafics, feldspar), 90% silt and soft siltstone clasts, (ML).			155
		SILTY SAND 2.5Y 4/4, 20% silt, 80% very fine to fine subangular-subrounded (50% quartz, 30% mafics with mica and olivine, 20% pink and white feldspar), (ML).		-100	
160	medium				160
		SANDY SILT 2.5Y 5/2, 30% fine to medium mafic sand (50% black mafics with high percent mica, 30% quartz, 20% feldspar), 70% soft siltstone clasts, (ML).		-105	
165		SAND 2.5Y 4/4, 10% silt, 90% micaceous sands, very fine to fine, subangular (40% quartz, 30% mafics and mica, 30% pink and white feldspars), good sorting, (MH).			165
				-110	
170					170

RADIAN CORPORATION

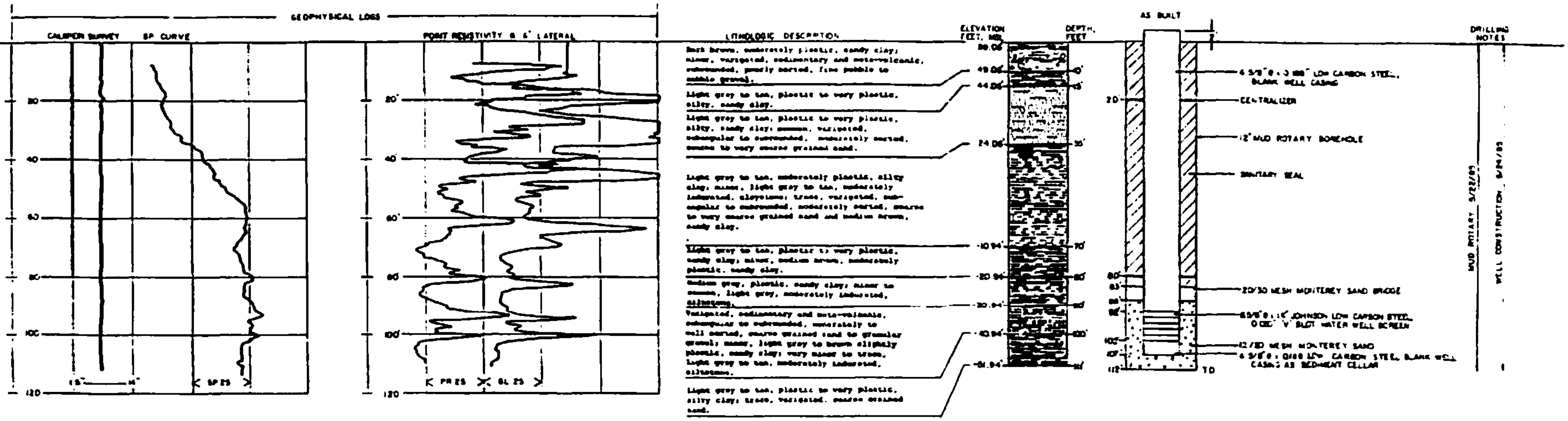
LOG OF DRILLING OPERATIONS

Piezometer #: PZ-32

PROJECT: PGOURI | LOCATION: McClellan Air Force Base

Depth Below Surface (ft)	Drill Rate	Lithologic Description	Elevation (ft MSL)	Drilling Notes/Construction Details
			-115	
	fast	SAND 2.5Y 4/4, 10% silt, 90% very fine to medium, subangular, micaceous (50% quartz, 25% mafics and mica with olivine, 25% feldspar), good sorting, (MH).		Top of bentonite seal 174.0'
175				Cave in during well completion from 181' to 176.5'.
		SAND 2.5Y 5/2, 60% very fine to fine, 40% fine to medium, subangular-subrounded, micaceous sand (50% quartz, 30% white feldspar, 20% mafics, predominantly mica), (SM).	-120	
180				Connection at 09:10.
		At 181', same as above.		Top of sand bridge 181.0'
			-125	Top of sand pack 183.0'
		SILTY SAND 20% silt and siltstone, 80% sand as at 178', (SM).		Top of 0.010" slot stainless steel screen 185.0'
185	medium	SANDY SILT 10YR 5/6, 30% very fine-medium, subrounded-subangular quartz, mafics, feldspar, 70% siltstone and silt, some clay, (ML).		
		SILTY CLAY 10YR 5/4, 10% very fine-medium, subrounded sand, 40% silt and siltstone, 50% clay, (CL).		T.D. at 09:30. Total depth 187.0'.

FIGURE 3
MW-60 BOREHOLE
LITHOLOGY AND
CONSTRUCTION DETAILS



McLaren Environmental Engineering

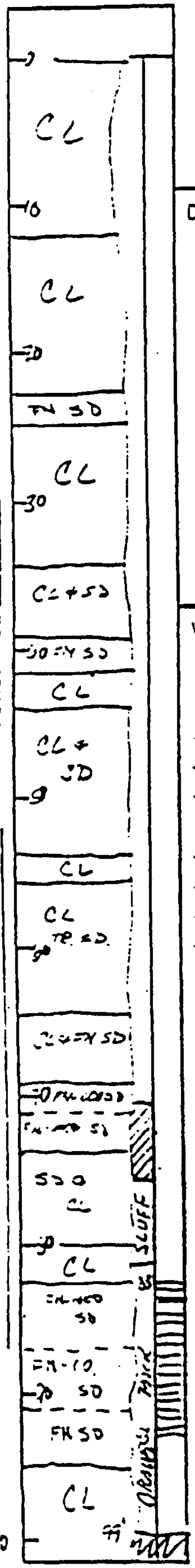
WELL 4-5

WELL CONSTRUCTION SUMMARY

LOCATION or COORDS: ____________________ ELEVATION: GROUND LEVEL 53.7'

TOP OF CASING 1.0' ABOVE G.L.

LOCATION Sacramento, CA
PERSONNEL [illegible]
PROJECT McClellan



DRILLING SUMMARY:

TOTAL DEPTH 99'

BOREHOLE DIAMETER 8½"

DRILLER [illegible]

RIG ______

BIT(S) ______

DRILLING FLUID NAT. MUD

SURFACE CASING N/A

WELL DESIGN:

BASIS: GEOLOGIC LOG X GEOPHYSICAL LOG ___

CASING STRING(S): C=CASING S=SCREEN

–	83	C
83 –	93	S

CASING: C1 4" PVC

C2

C3

C4

SCREEN: S1 4" 10 SLOT JOHNSON

S2 STAINLESS

S3

S4

CENTRALIZERS

FILTER MATERIAL MONTEREY #3

CEMENT 100 lbs BENTONITE ON [illegible]

OTHER

CONSTRUCTION TIME LOG:

TASK	START DATE	START TIME	FINISH DATE	FINISH TIME
DRILLING:	7/28	9:30		11:30
GEOPHYS. LOGGING:				
CASING:	7/28	11:30		1:00
FILTER PLACEMENT:	7/28	1:00		1:05
CEMENTING:				
DEVELOPMENT:				
OTHER:				

WELL DEVELOPMENT

COMMENTS:

5 BAGS MONTEREY IN WELL - LEVEL PROBABLY TO 83 - DURING PLACEMENT CAVING OCCURED TO 76'. SAND LAYER AT [illegible] CAUSED CAVING [illegible] CAUSED CAVING

W.L. 7/30 = 77.75 - 1.0 = 76.75

Field Engr/Tech [illegible] Sheet 1 of 2

Project McCLELLAN Job No. [| | | | - | | | | |] Date 2/83

Ground Elev. ______ Hole No. 44S Dia. 8½ T.D. 99'

Final Hole No ______

Water Table At Drilling:	Water Table After Drilling
Water: Depth 1st Encountered ______ Dry ☐ Won't ☐ Might ☐ Should ☐ Will	Water At Depth ______
Water-After ⌀ ______	Date ______ By ______
Caved-After ⌀ ______	Dry At Depth ______
	☐ Couldn't Find ☐ Covered

Plot	Depth	Class	Field Soil Description	Stiff/Den	Moist	Color	Calc
	0-12	CL	BR CLAY - EASY DRILLING			BR	
	12-23	CL	BR CLAY - w/ FINE SD			BR	
	23-25	SP	F.N SD - NO SAMPLE (1ST MUCH WTR TAKEN WHILE ADD JOINT)			BR	
	25-35	CL	BR - HD DRY CLAY			BR	
	35-39	SC	BR CLAY & SD (INTERBEDDED)			BR	
	39-42	SP	FN - SD (MICACEOUS)			BR	
	42-44	CL	DRY CLAY			BR	
	44-54	SC	RED CLAY w/ SD (INTERBEDDED) INCREASED SD @ 46' (SAME WTR TAKEN, ADD JOINT)			RD	
	54-57	SC	BR. CLAY w/ SD			BR	

Depth	Samples - Spoon: Calif.	Std.	Shelby	Auger	Standard Penetration: Field	Final	Comments: Laboratory Sample Description	

Form 1-102

Field Engr/Tech 1(K Sheet 2 of 3

Project McCLELLAN Job No. [ ][ ][ ][ ]-[ ][ ][ ][ ][ ][ ] Date 8/13

Ground Elev. ______ Hole No. UCS Dia. 24 T.D. 99'

Final Hole No ______

Water Table At Drilling:	Water Table After Drilling
Water: Depth 1st Encountered ______ Dry ☐ Won't	Water At Depth ______
Water-After ______ ☐ Might	Date ______ By ______
Caved-After ______ ☐ Should	Dry At Depth ______
☐ Will	☐ Couldn't Find ☐ Covered

Plot	Depth	Class	Field Soil Description	Semi Pen	Moist	Color	Calc
	57-65	CL	DRY TAN CLAY TRACE SD			TN	
	65-67	SC	INTERBEDDED SD CLAY + FN SD			TN	
	67-71	SP	FN-~~COARSE~~ SD				
	71-72	SW	FN-COARSE SD				
	71-74	SW	FN-MED SD.				
	74-80	SC	SD + DRY CL INTERBEDDED (LITTLE WTR TAKEN)			TN	
	80-83	CL	TN CLAY				
	83-87	SW	FN-MED SD				
	87-91	SW	FN-CO. SD (RND, SUB, ANG)				

-20 -26 -29

Depth	Samples - Spoon: Calif.	Std.	Shelby	Auger	Standard Penetration: Field	Final	Comments: / Laboratory Sample Description	Sample Container

Form 1-102

Field Engr/Tech [illegible] Sheet [illegible] of [illegible]

Project McCLELLAN Job No. [| | | | - | | | | |] Date 8/3

Ground Elev. ______ Hole No. 4US Dia. [illegible] T.D. 99'

Final Hole No. ______

Water Table At Drilling:	Water Table After Drilling
Water: Depth 1st Encountered ____ Dry ☐ Won't	Water At Depth ____
Water-After ____ ☐ Might	Date ____ By ____
Caved-After ____ ☐ Should ☐ Will	Dry At Depth ____ ☐ Couldn't Find ☐ Covered

Plot	Depth	Class	Field Soil Description	Sctn/Pen	Moist	Color	Calc
-4)	91-94	SP	FN. SD.				
41	94-95	SC	FN SD TRACE TN CLAY			TN	
	95-99	CL	GREY "PLASTIC" CLAY HARD DRILLING			GR	

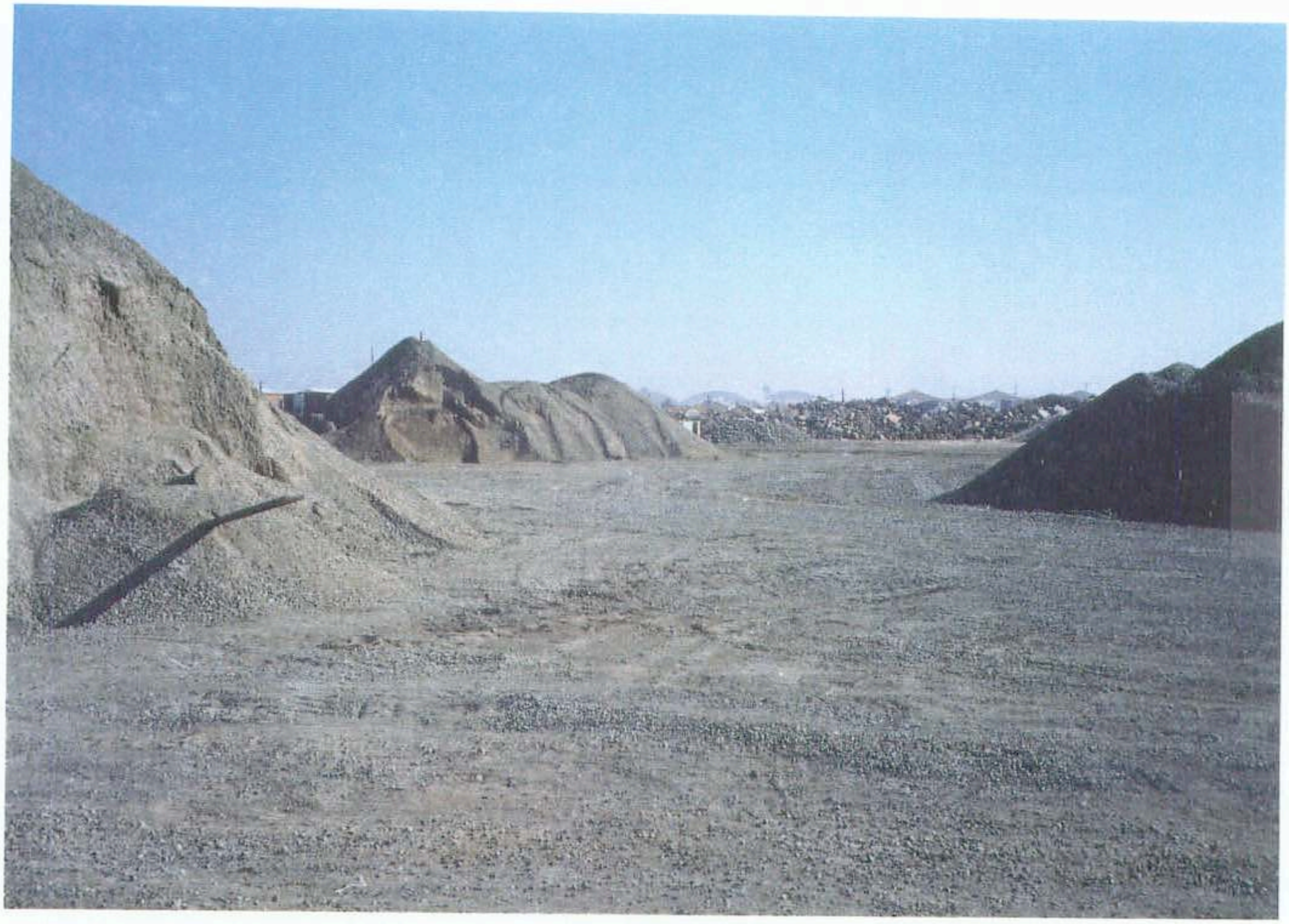
Depth	Samples - Spoon: Calif.	Std.	Shelby	Auger	Standard Penetration: Field	Final	Comments: / Laboratory Sample Description

Form 1-102

Appendix D
PHOTOGRAPHS OF SELECT SITES

SITE 22 - LOOKING NORTH

SITE 22 - LOOKING SOUTH



SITE 22 - LOOKING EAST

SITE 22 - LOOKING WEST

SITE 42 - LOOKING NORTH

SITE 42 - LOOKING EAST

SITE 2 - LOOKING NORTH

SITE 2 - LOOKING SOUTH

SITE 2 - LOOKING EAST

SITE 2 - LOOKING WEST

SITE 13 - LOOKING NORTH

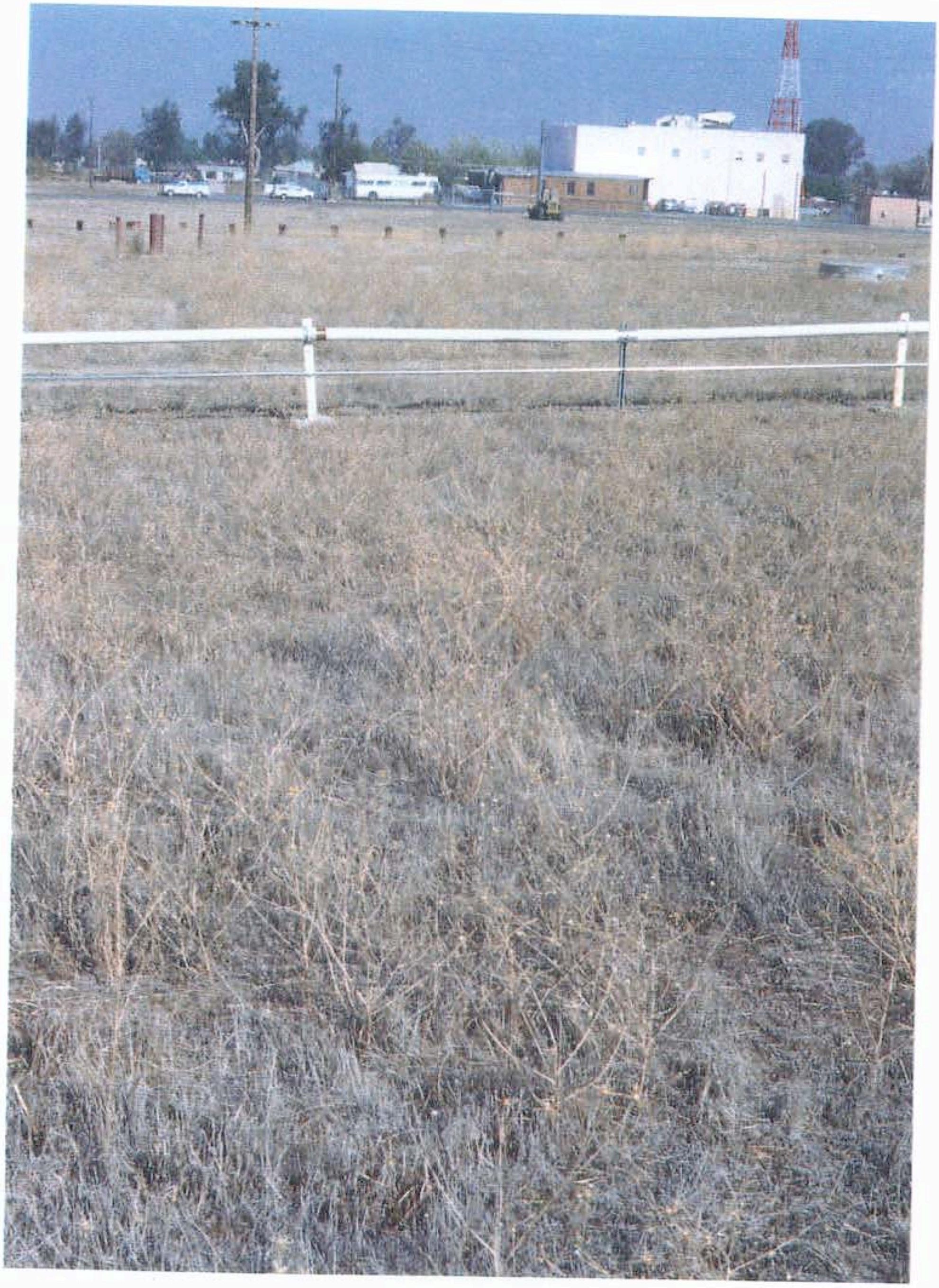
SITE 13 - LOOKING SOUTH

SITE 13 - LOOKING WEST

SITE 43 - LOOKING SOUTH

SITE 43 - LOOKING NORTH

SITE 43 - LOOKING WEST



SITE 5 - LOOKING NORTH

SITE 5 - LOOKING SOUTH

SITE 5 - LOOKING WEST

SITE S AND T - LOOKING NORTH

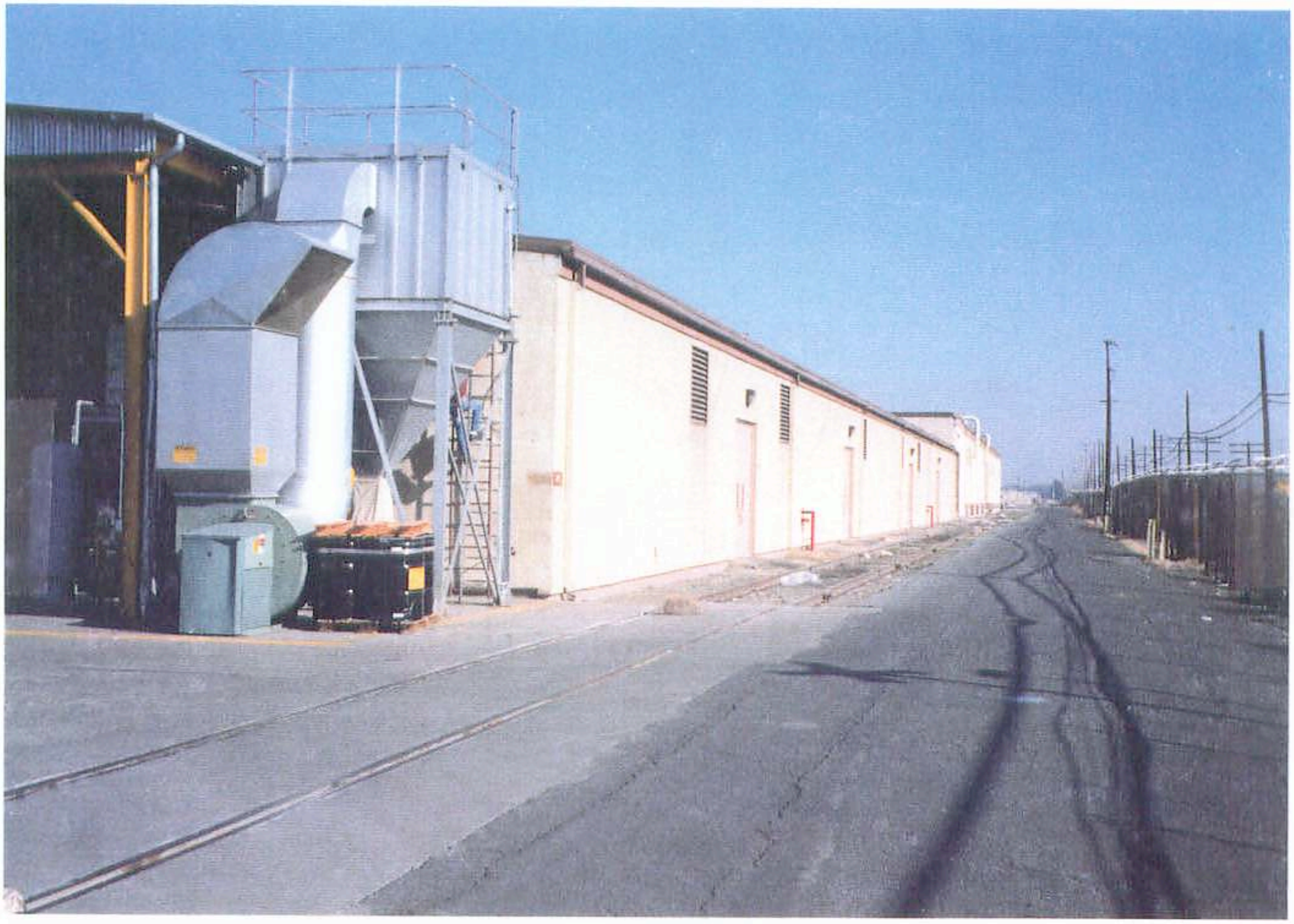
SITE S AND T - LOOKING SOUTH

SITE S AND T - LOOKING EAST

SITE S AND T - LOOKING WEST

SITE 38 - LOOKING NORTH

SITE 38 - LOOKING SOUTH



SITE 38 - LOOKING EAST

SITE 38 - LOOKING WEST

Appendix E
CONTOURS OF EQUAL CONCENTRATION OF SELECTED CONTAMINANTS

ETHYLBENZENE CONCENTRATION ISOPLETHS

CROSS SECTION OF SITE 22, WITH POSITIVE CHEMICAL RESULTS

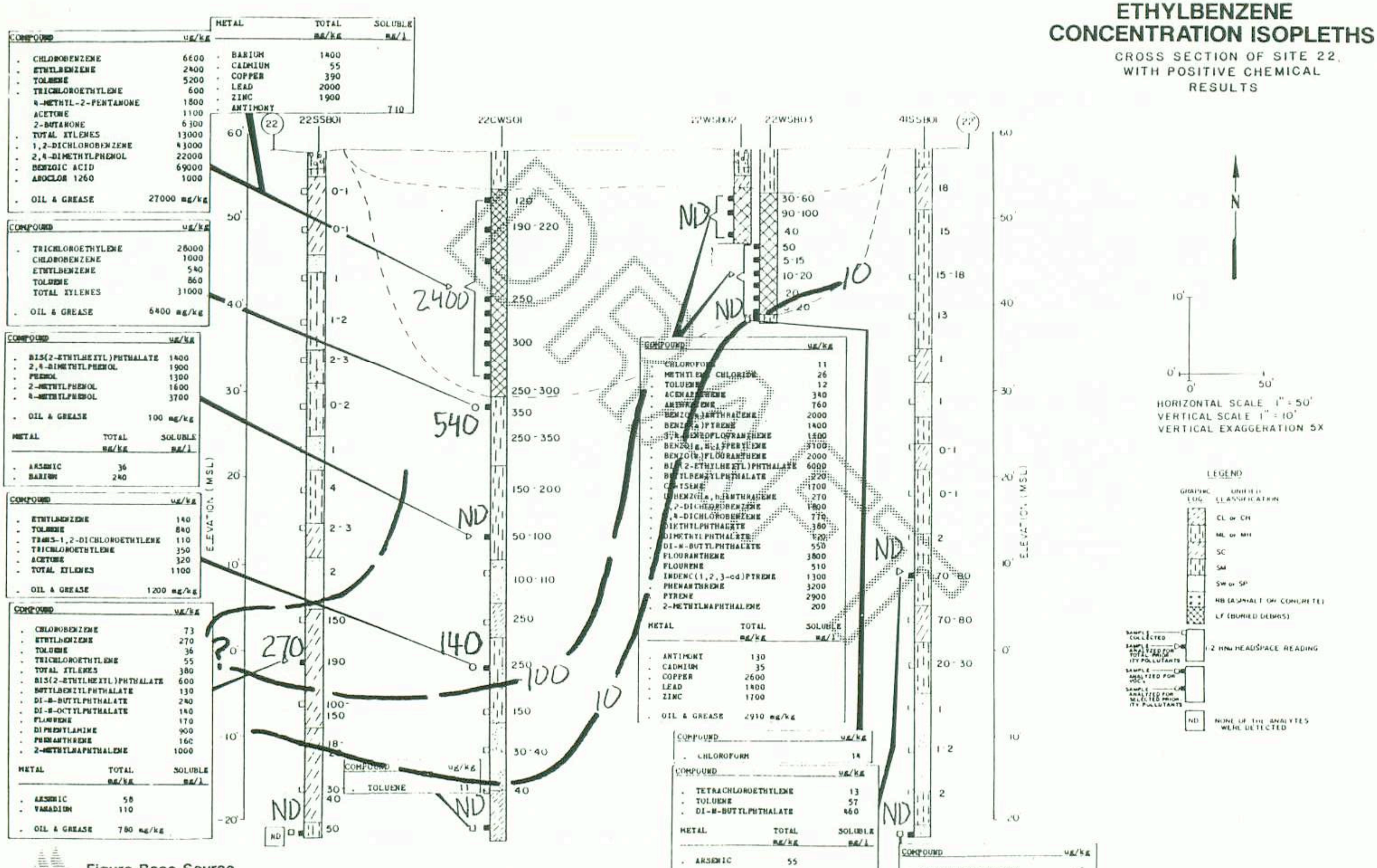


Figure Base Source
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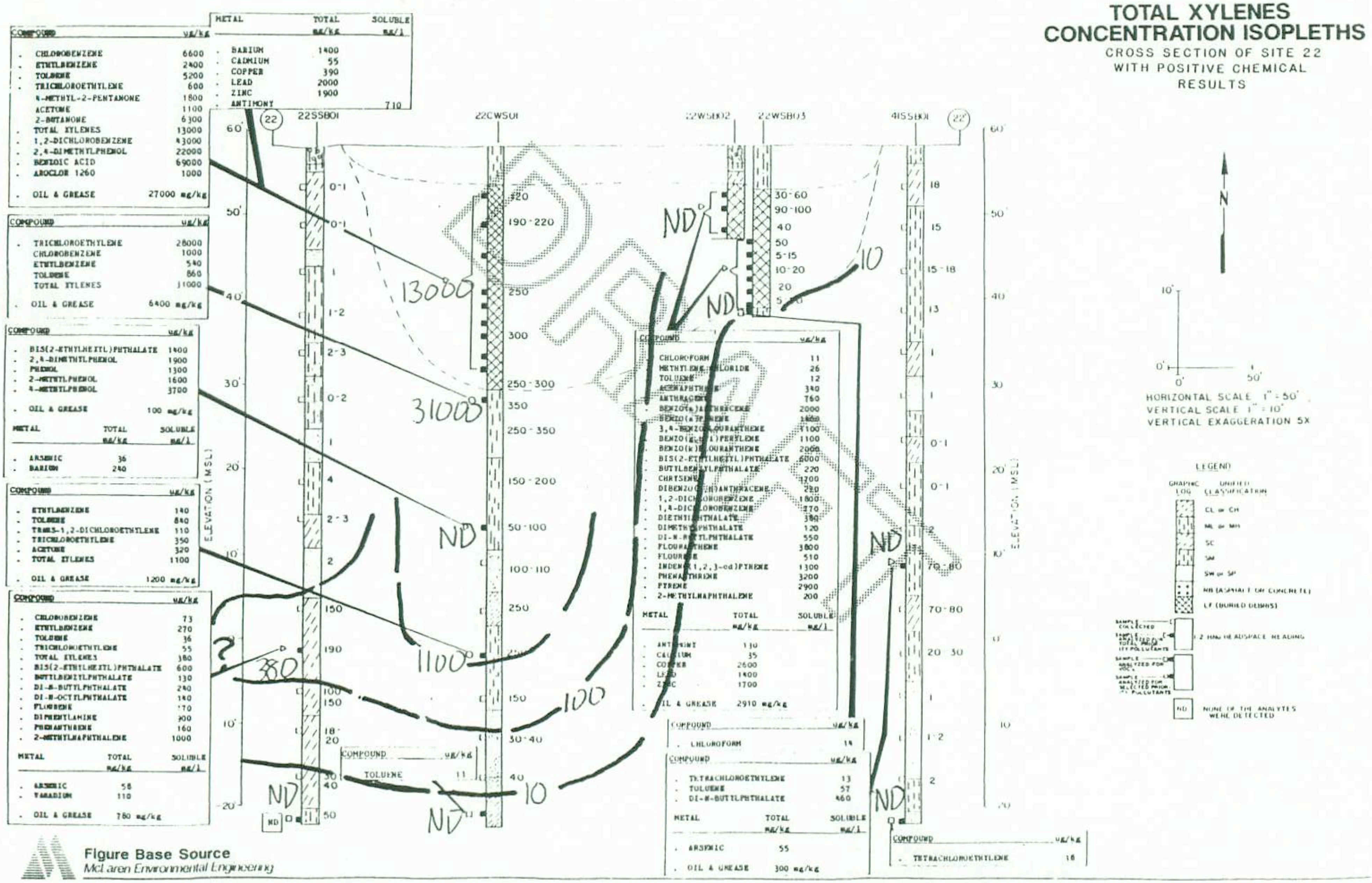
TOTAL XYLENES CONCENTRATION ISOPLETHS

CROSS SECTION OF SITE 22 WITH POSITIVE CHEMICAL RESULTS



COMPOUND	ug/kg
CHLOROBENZENE	6600
ETHYLBENZENE	2400
TOLUENE	5200
TRICHLOROETHYLENE	600
4-METHYL-2-PENTANONE	1800
ACETONE	1100
2-BUTANONE	6300
TOTAL XYLENES	13000
1,2-DICHLOROBENZENE	43000
2,4-DIMETHYLPHENOL	22000
BENZOIC ACID	69000
AROCLOR 1260	1000
OIL & GREASE	27000 mg/kg

METAL	TOTAL mg/kg	SOLUBLE mg/l
BARIUM	1400	
CADMIUM	55	
COPPER	390	
LEAD	2000	
ZINC	1900	
ANTIMONY		710

COMPOUND	ug/kg
TRICHLOROETHYLENE	28000
CHLOROBENZENE	1000
ETHYLBENZENE	540
TOLUENE	860
TOTAL XYLENES	31000
OIL & GREASE	6400 mg/kg

COMPOUND	ug/kg
BIS(2-ETHYLHEXYL)PHTHALATE	1400
2,4-DIMETHYLPHENOL	1900
PHENOL	1300
2-METHYLPHENOL	1600
4-METHYLPHENOL	3700
OIL & GREASE	100 mg/kg

METAL	TOTAL mg/kg	SOLUBLE mg/l
ARSENIC	36	
BARIUM	240	

COMPOUND	ug/kg
ETHYLBENZENE	140
TOLUENE	840
TRANS-1,2-DICHLOROETHYLENE	110
TRICHLOROETHYLENE	350
ACETONE	320
TOTAL XYLENES	1100
OIL & GREASE	1200 mg/kg

COMPOUND	ug/kg
CHLOROBENZENE	73
ETHYLBENZENE	270
TOLUENE	36
TRICHLOROETHYLENE	55
TOTAL XYLENES	380
BIS(2-ETHYLHEXYL)PHTHALATE	600
BUTYLBENZYLPHTHALATE	130
DI-N-BUTYLPHTHALATE	240
DI-N-OCTYLPHTHALATE	140
FLUORENE	170
DIPHENYLAMINE	300
PHENANTHRENE	160
2-METHYLNAPHTHALENE	1000

METAL	TOTAL mg/kg	SOLUBLE mg/l
ARSENIC	58	
VANADIUM	110	
OIL & GREASE	780 mg/kg	

COMPOUND	ug/kg
TOLUENE	11

COMPOUND	ug/kg
CHLOROFORM	11
METHYLENE CHLORIDE	26
TOLUENE	12
ACENAPHTHENE	340
ANTHRACENE	760
BENZO(a)ANTHRACENE	2000
BENZO(a)PYRENE	1800
3,4-BENZOFLUORANTHENE	1100
BENZO(g,h,i)PERYLENE	1100
BENZO(k)FLUORANTHENE	2000
BIS(2-ETHYLHEXYL)PHTHALATE	6000
BUTYLBENZYLPHTHALATE	220
CHRYSENE	1700
DIBENZO(a,h)ANTHRACENE	280
1,2-DICHLOROBENZENE	1800
1,4-DICHLOROBENZENE	170
DIETHYLPHTHALATE	380
DIMETHYLPHTHALATE	120
DI-N-BUTYLPHTHALATE	550
FLUORANTHENE	3800
FLUORENE	510
INDENO(1,2,3-cd)PYRENE	1300
PHENANTHRENE	3200
PYRENE	2900
2-METHYLNAPHTHALENE	200

METAL	TOTAL mg/kg	SOLUBLE mg/l
ANTIMONY	110	
CALCIUM	35	
COPPER	2600	
LEAD	1400	
ZINC	1700	
OIL & GREASE	2910 mg/kg	

COMPOUND	ug/kg
CHLOROFORM	14

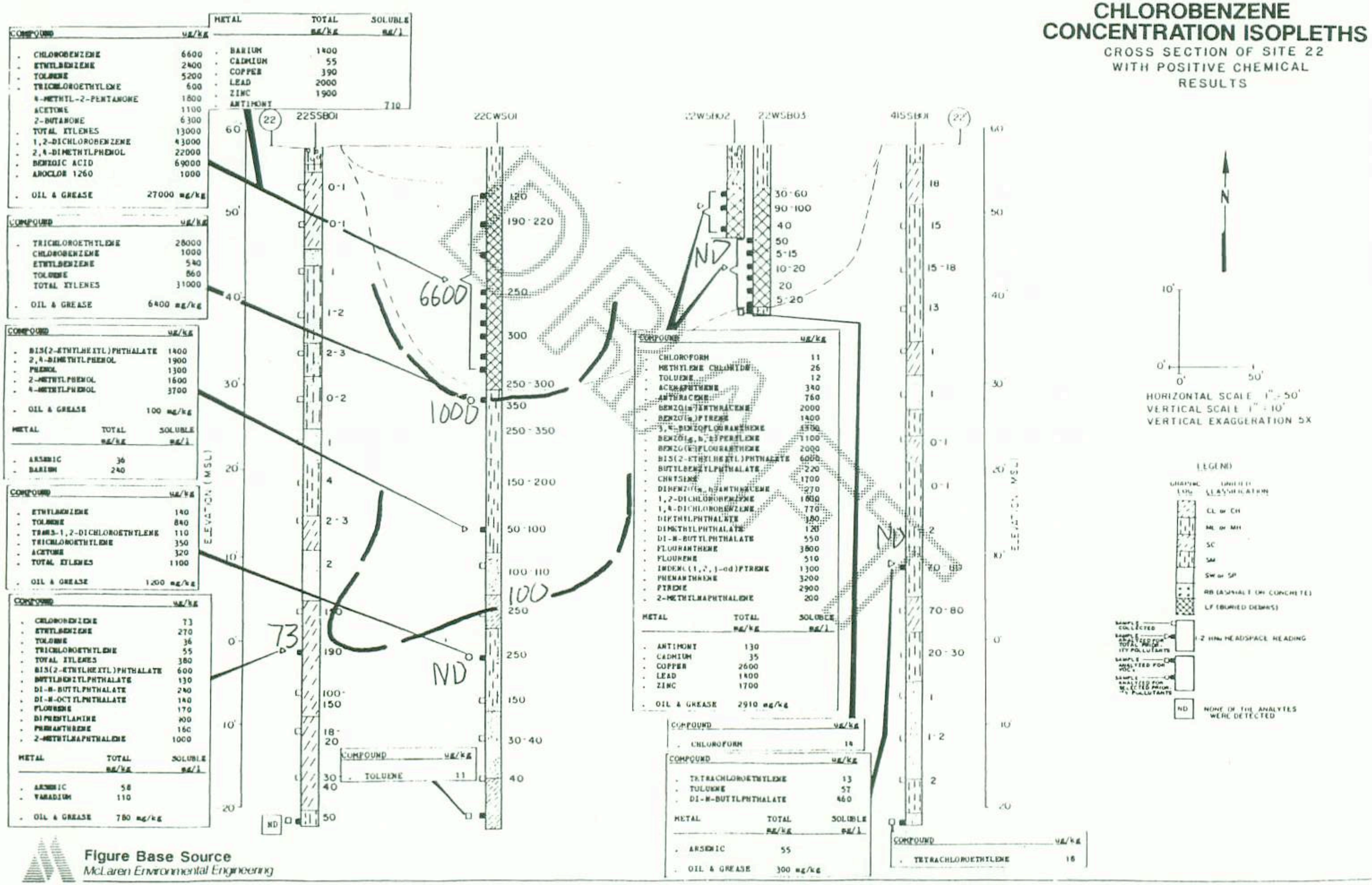
COMPOUND	ug/kg
TETRACHLOROETHYLENE	13
TOLUENE	57
DI-N-BUTYLPHTHALATE	460

METAL	TOTAL mg/kg	SOLUBLE mg/l
ARSENIC	55	
OIL & GREASE	300 mg/kg	

COMPOUND	ug/kg
TETRACHLOROETHYLENE	18

CHLOROBENZENE CONCENTRATION ISOPLETHS

CROSS SECTION OF SITE 22
WITH POSITIVE CHEMICAL
RESULTS



COMPOUND	ug/kg
CHLOROBENZENE	6600
ETHYLBENZENE	2400
TOLUENE	5200
TRICHLOROETHYLENE	600
4-METHYL-2-PENTANONE	1800
ACETONE	1100
2-BUTANONE	6300
TOTAL XYLENES	13000
1,2-DICHLOROBENZENE	43000
2,4-DIMETHYLPHENOL	22000
BENZOIC ACID	69000
AROCLOR 1260	1000
OIL & GREASE	27000 mg/kg

METAL	TOTAL mg/kg	SOLUBLE mg/l
BARIUM	1400	
CADMIUM	55	
COPPER	390	
LEAD	2000	
ZINC	1900	
ANTIMONY		710

COMPOUND	ug/kg
TRICHLOROETHYLENE	28000
CHLOROBENZENE	1000
ETHYLBENZENE	540
TOLUENE	860
TOTAL XYLENES	31000
OIL & GREASE	6400 mg/kg

COMPOUND	ug/kg
BIS(2-ETHYLHEXYL)PHTHALATE	1400
2,4-DIMETHYLPHENOL	1900
PHENOL	1300
2-METHYLPHENOL	1600
4-METHYLPHENOL	3700
OIL & GREASE	100 mg/kg

METAL	TOTAL mg/kg	SOLUBLE mg/l
ARSENIC	36	
BARIUM	240	

COMPOUND	ug/kg
ETHYLBENZENE	140
TOLUENE	840
TRANS-1,2-DICHLOROETHYLENE	110
TRICHLOROETHYLENE	350
ACETONE	320
TOTAL XYLENES	1100
OIL & GREASE	1200 mg/kg

COMPOUND	ug/kg
CHLOROBENZENE	73
ETHYLBENZENE	270
TOLUENE	36
TRICHLOROETHYLENE	55
TOTAL XYLENES	380
BIS(2-ETHYLHEXYL)PHTHALATE	600
BUTYLBENZYLPHTHALATE	130
DI-N-BUTYLPHTHALATE	240
DI-N-OCTYLPHTHALATE	140
FLOURENE	170
DIPHENYLAMINE	300
PHENANTHRENE	160
2-METHYLNAPHTHALENE	1000

METAL	TOTAL mg/kg	SOLUBLE mg/l
ARSENIC	58	
VANADIUM	110	
OIL & GREASE	780 mg/kg	

COMPOUND	ug/kg
TOLUENE	11

COMPOUND	ug/kg
CHLOROFORM	11
METHYLENE CHLORIDE	26
TOLUENE	12
ACENAPHTHENE	340
ANTHRACENE	760
BENZO(a)ANTHRACENE	2000
BENZO(a)PYRENE	1400
3,4-BENZOFLOURANTHENE	3300
BENZO(g,h,i)PERYLENE	1100
BENZO(k)FLOURANTHENE	2000
BIS(2-ETHYLHEXYL)PHTHALATE	6000
BUTYLBENZYLPHTHALATE	220
CHRYSENE	1700
DIBENZO(a,h)ANTHRACENE	270
1,2-DICHLOROBENZENE	1800
1,4-DICHLOROBENZENE	770
DIETHYLPHTHALATE	180
DIMETHYLPHTHALATE	120
DI-N-BUTYLPHTHALATE	550
FLOURANTHENE	3800
FLOURENE	510
INDENO(1,2,3-cd)PYRENE	1300
PHENANTHRENE	3200
PYRENE	2900
2-METHYLNAPHTHALENE	200

METAL	TOTAL mg/kg	SOLUBLE mg/l
ANTIMONY	130	
CADMIUM	35	
COPPER	2600	
LEAD	1400	
ZINC	1700	
OIL & GREASE	2910 mg/kg	

COMPOUND	ug/kg
CHLOROFORM	14

COMPOUND	ug/kg
TETRACHLOROETHYLENE	13
TOLUENE	57
DI-N-BUTYLPHTHALATE	460

METAL	TOTAL mg/kg	SOLUBLE mg/l
ARSENIC	55	
OIL & GREASE	300 mg/kg	

COMPOUND	ug/kg
TETRACHLOROETHYLENE	16

Figure Base Source
McLaren Environmental Engineering

TOLUENE CONCENTRATION ISOPLETHS

CROSS SECTION OF SITE 22 WITH POSITIVE CHEMICAL RESULTS

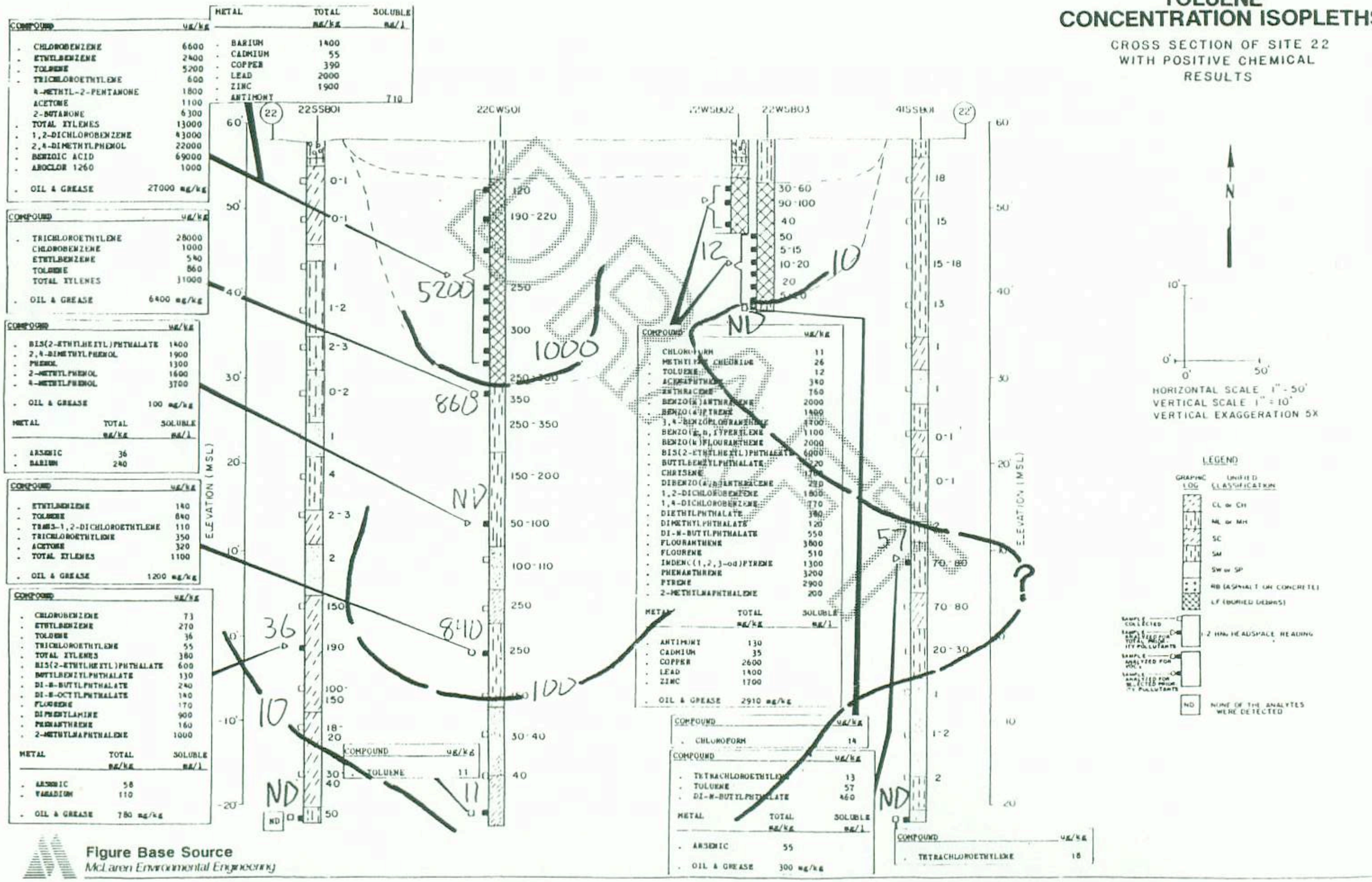
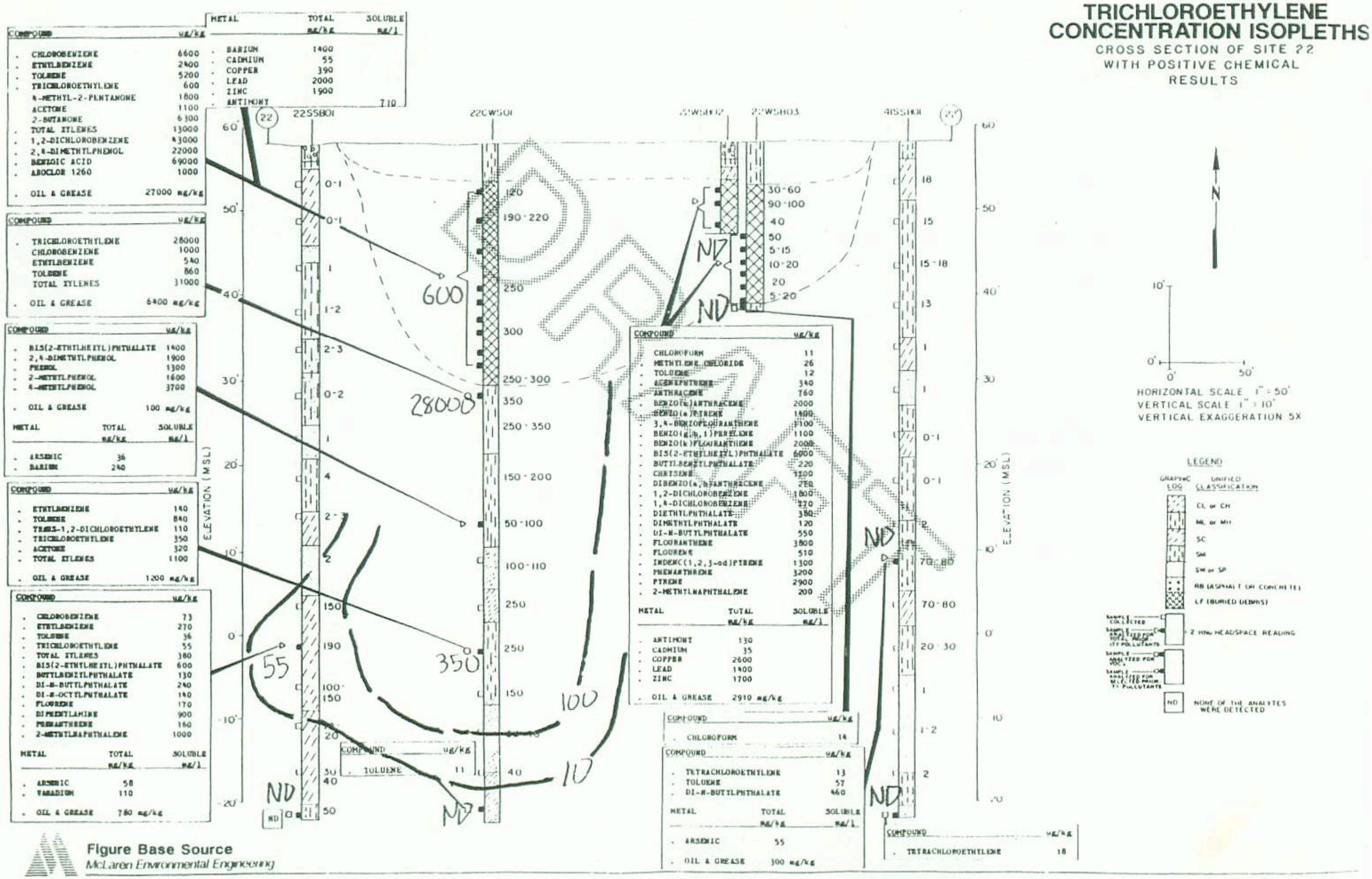


Figure Base Source
McLaren Environmental Engineering

TRICHLOROETHYLENE CONCENTRATION ISOPLETHS

CROSS SECTION OF SITE 22
WITH POSITIVE CHEMICAL
RESULTS



COMPOUND	ug/kg
CHLOROBENZENE	6600
ETHYLBENZENE	2400
TOLUENE	5200
TRICHLOROETHYLENE	600
4-METHYL-2-PENTANONE	1800
ACETONE	1100
2-BUTANONE	6300
TOTAL XYLENES	13000
1,2-DICHLOROBENZENE	43000
2,4-DIMETHYLPHENOL	22000
BENZOIC ACID	69000
AROCLOR 1260	1000
OIL & GREASE	27000 mg/kg

METAL	TOTAL mg/kg	SOLUBLE mg/l
BARIUM	1400	
CADMIUM	55	
COPPER	390	
LEAD	2000	
ZINC	1900	
ANTIMONY		710

COMPOUND	ug/kg
TRICHLOROETHYLENE	28000
CHLOROBENZENE	1000
ETHYLBENZENE	540
TOLUENE	860
TOTAL XYLENES	31000
OIL & GREASE	6400 mg/kg

COMPOUND	ug/kg
BIS(2-ETHYLHEXYL)PHTHALATE	1400
2,4-DIMETHYLPHENOL	1900
PHENOL	1300
2-METHYLPHENOL	1600
4-METHYLPHENOL	3700
OIL & GREASE	100 mg/kg

METAL	TOTAL mg/kg	SOLUBLE mg/l
ARSENIC	36	
BARIUM	240	

COMPOUND	ug/kg
ETHYLBENZENE	140
TOLUENE	840
TRANS-1,2-DICHLOROETHYLENE	110
TRICHLOROETHYLENE	350
ACETONE	320
TOTAL XYLENES	1100
OIL & GREASE	1200 mg/kg

COMPOUND	ug/kg
CHLOROBENZENE	73
ETHYLBENZENE	270
TOLUENE	36
TRICHLOROETHYLENE	55
TOTAL XYLENES	380
BIS(2-ETHYLHEXYL)PHTHALATE	600
BUTYLBENZYLPHTHALATE	130
DI-N-BUTYLPHTHALATE	240
DI-N-OCTYLPHTHALATE	140
FLOURENE	170
DIPHENYLAMINE	900
PHENANTHRENE	160
2-METHYLNAPHTHALENE	1000

METAL	TOTAL mg/kg	SOLUBLE mg/l
ARSENIC	58	
VANADIUM	110	
OIL & GREASE	780 mg/kg	

COMPOUND	ug/kg
TOLUENE	11

COMPOUND	ug/kg
CHLOROFORM	11
METHYLENE CHLORIDE	26
TOLUENE	12
ACENAPHTHENE	340
ANTHRACENE	760
BENZO(a)ANTHRACENE	2000
BENZO(a)PYRENE	1800
3,4-BENZOFLOURANTHENE	3100
BENZO(g,h,i)PERYLENE	1100
BENZO(k)FLOURANTHENE	2000
BIS(2-ETHYLHEXYL)PHTHALATE	6000
BUTYLBENZYLPHTHALATE	220
CHRYSENE	3100
DIBENZO(a,h)ANTHRACENE	280
1,2-DICHLOROBENZENE	1800
1,4-DICHLOROBENZENE	270
DIETHYLPHTHALATE	380
DIMETHYLPHTHALATE	120
DI-N-BUTYLPHTHALATE	550
FLOURANTHENE	3800
FLOURENE	510
INDENO(1,2,3-cd)PYRENE	1300
PHENANTHRENE	3200
PYRENE	2900
2-METHYLNAPHTHALENE	200

METAL	TOTAL mg/kg	SOLUBLE mg/l
ANTIMONY	130	
CADMIUM	35	
COPPER	2600	
LEAD	1400	
ZINC	1700	
OIL & GREASE	2910 mg/kg	

COMPOUND	ug/kg
CHLOROFORM	14

COMPOUND	ug/kg
TETRACHLOROETHYLENE	13
TOLUENE	57
DI-N-BUTYLPHTHALATE	460

METAL	TOTAL mg/kg	SOLUBLE mg/l
ARSENIC	55	
OIL & GREASE	300 mg/kg	

COMPOUND	ug/kg
TETRACHLOROETHYLENE	18

Figure Base Source
McLaren Environmental Engineering