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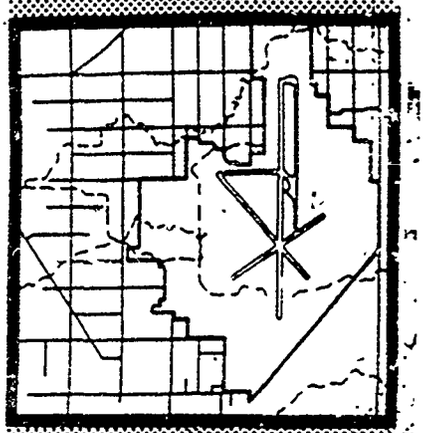

OPERABLE UNIT B ENGINEERING EVALUATION/ COST ANALYSIS - ENVIRONMENTAL ASSESSMENT

PRELIMINARY FINAL

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PREPARED FOR:
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United States Air Force
Human Systems Division (AFSC)
IRP Program Office (HSD/YAQ)
Brooks Air Force Base, Texas 78235-5000

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SUBJECT: Revisions to Operable Unit B Engineering Evaluation/Cost Analysis-Environmental Assessment

To Whom It May Concern:

Enclosed is one copy of revisions to the cost tables contained in the Operable Unit (OU) B Engineering Evaluation/Cost Analysis-Environmental Assessment (EE/CA-EA) Final Report, February 1991. These revisions reflect changes to several cost tables contained in the EE/CA-EA Report. The following tables have been revised:

Table	Page
6-4	6-38
6-13	6-56
C5-1	C5-2, C5-3
C5-2	C5-4, C5-5
C5-7	C5-13

In order for you to conveniently insert these revisions, we have enclosed double-sided pages that completely replace those pages contained in the EE/CA-EA Final Report, distributed on 01 February 1991.

If you have any questions, please contact Bill Knight.

Sincerely,

Jack D. Gouge
Delivery Order Manager

JDG:jlh

cc: Mr. P. Haas/Capt. H. Thompson
McClellan AFB EM
Jerry Robbins (McClellan AFB EMR)
Alex Johnson (McClellan AFB EMR)
Capt. Fran Slavich (McClellan AFB EMR)

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TABLE 6-4. ESTIMATED COSTS FOR ALTERNATIVE 3A -- EXTRACTION WELLS PIPELINE TO GWTP TO MAGPIE CREEK

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$200,000	$17,000
B.	Conveyance			
	Piping (4000' x 4/95 ft)		19,000	6,000
	Elbows (8 x $38.70)		300	
	Holding Tank		47,000	
	Pumps	1 Feed	3,000	1,000
		2 Sump	1,000	
	Jacking Pits		60,000	
	Horizontal borings		76,000	
			$206,000	$ 7,000
C.	Treatment -- GWTP		0	4,500
D.	Discharge -- Magpie Creek		0	0
E.	Other Direct Costs[1] (% of Conveyance/Treatment)			
	Site Work	10%	21,000	
	Piping/Valving	5%	10,000	
	Instrumentation	10%	21,000	
	Controls	5%	10,000	
	Electrical	10%	21,000	
	Contingency	25%	52,000	
	Contractor	15%	31,000	
	Engineering	10%	21,000	
			$187,000	0
	TOTAL COSTS:		$593,000	$29,000
	PRESENT WORTH COSTS[2]:		$665,000	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

GWTP = Groundwater Wastewater Treatment Plant

packed bed catalytic reactor which uses a nickel-based catalyst to decompose reactor off-gas ozone into oxygen. No other emissions are produced.

Products Generated. Products generated by the UV/ozone/peroxide treatment process include treated effluent water and excess ozone off-gas, which is purified by reduction or in a catalytic oxidation reaction.

Performance. Performance data provided by vendors and based on proposed flows and concentrations of the OU B extraction wells, indicate that nondetectable levels (<5 μg/L) can be achieved for all contaminants within the OU B plumes. Complete oxidation of VOCs has also been demonstrated using this treatment alternative. However, results were demonstrated on relatively low levels of VOC contaminants, and long reaction times were required for VOCs such as methylene chloride and 1,1,1-trichloroethane. Treatability studies performed on several pilot-scale UV/ozone/peroxide units as well as on full-scale operational plants indicate that this is a reliable and cost-effective treatment alternative for the remediation of contaminated groundwater. Vendor data also indicate that ozone concentrations within unit off-gas can be reduced to less than 0.1 ppm, meeting OSHA permissible exposure standards for workers. In addition, effluent from this treatment process can then be used for industrial, irrigation, and other purposes.

Once complete, this alternative would provide immediate results; removal of contaminated groundwater will minimize exposure to local groundwater and reduce migration of contaminants off-base.

Implementability. Construction and operation of the UV/ozone/peroxide unit at McClellan AFB is a new yet available and implementable technology; several fully operational units currently exist throughout the United States and Europe. Installation of the unit should not create significant inconveniences to McClellan AFB operations.

A completely functioning UV/ozone/peroxide treatment unit would require approximately three to four months to construct, deliver, and install. The limiting factor associated with the implementation of this alternative is the time required to construct the accompanying extraction wells, flow equalization tanks, discharge pipeline construction, and intra-system piping. Six months to one year would be required to complete and integrate these components.

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TABLE 6-13. ESTIMATED COSTS FOR ALTERNATIVE 2 -- EXTRACTION WELLS PIPELINE TO SANITARY SEWER

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$200,000	$17,000
B.	Conveyance			
	Piping		1,000	6,000
	Elbows		100	
	Holding Tank		47,000	
	Pumps	1 Feed	3,000	1,000
		2 Sump	1,000	
	Jacking Pits		10,000	
	Horizontal borings		0	
			$ 62,000	$ 7,000
C.	Treatment		0	0
D.	Discharge -- Sanitary Sewer		$243,000	$ 87,000
E.	Other Direct Costs[1]			
	Site Work	10%	6,000	
	Piping/Valving	5%	3,000	
	Instrumentation	10%	6,000	
	Controls	5%	3,000	
	Electrical	10%	6,000	
	Contingency	25%	15,000	
	Contractor	15%	9,000	
	Engineering	10%	6,000	
			$54,000	0
	TOTAL COSTS:		$559,000	$111,000
	PRESENT WORTH COSTS[2]:		$835,000	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

Products generated by the IWTP include effluent water and process sludge. The effluent is discharged to the interceptor line as described above. Process sludge is disposed of at appropriate on and off-base disposal facilities.

Performance. This alternative is very reliable in that both conveyance by pipeline and the quality of the water to be discharged meet the pretreatment standards applied to IWL discharges. Therefore, this discharge is not expected to upset the SWTP treatment processes or to result in the SWTP exceeding its effluent discharge requirements.

Once complete, this alternative would provide immediate results; removal of contaminated groundwater will minimize exposure to local groundwater and reduce migration of contaminants off-base.

Implementability. The construction of a pipeline to convey groundwater from the extraction well facilities to a local IWL access cover is a readily implementable task, given the relatively short length of piping necessary to connect pipelines from the flow equalization tanks to the closest IWL access cover.

The IWTP is currently operating at fifty percent of its maximum capacity and can therefore easily accommodate the increase of 155 gpm of flow created by groundwater from the northern TCE/1,2-DCE plume in its treatment influent. However, during peak demand periods, such as during severe storm events, the system capacity has been exceeded. It is a possibility that during severe storm events, the groundwater extraction wells will be shut down to avoid discharging when the system capacity has been exceeded.

Safety. There are no special safety considerations for the construction and operation of this alternative.

Regulatory and Institutional Concerns. The ARARs that may be applicable to extraction and discharge to a sanitary sewer include:

- Sacramento County Building Permit;
- Sacramento County Sanitary District sewer use permit; and
- Sacramento Metropolitan Air Quality Management District permit.

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C5.0 COST ESTIMATES

Cost estimates were developed for both of the following alternatives:

- An extraction well system with a temporary pipeline connection to the sanitary sewer system; and
- An extraction well system with a permanent pipeline connection to the GWTP.

For the sanitary sewer discharge option, two cost estimates were developed based on a range of sanitary sewer connection fees expected to be imposed by the County of Sacramento Department of Public Works. For the GWTP discharge option, cost estimates were developed for three different piping design options. The detailed cost estimates for each of the sanitary sewer and GWTP discharge options are shown in Tables C5-1 through C5-4. The cost to construct the three extraction wells and the three monitoring wells (one for each hydrogeologic zone) are common to all the discharge options and are presented separately in Table C5-5. Table C5-6 presents the O&M costs for each option. The following sections describe each discharge option and discuss the relative costs for each. Table C5-7 summarizes the relative costs for all the discharge options.

C5.1 Sanitary Sewer Discharge

The majority of the capital cost for the sanitary sewer discharge option is expected to be due to the sanitary sewer connection fee. However, the County of Sacramento, Department of Public Works has not yet determined the connection fees to charge facilities that discharge contaminated groundwater into the sanitary sewer. For this reason, two capital cost estimates were developed for the sanitary sewer discharge option based on an estimated range of sanitary sewer connection fees.

The first cost estimate is shown in Table C5-1. In this cost estimate, the $660,000 sanitary sewer connection fee estimate is based on the fees McClellan AFB paid to purchase a permanent connection to the sanitary sewer for their Industrial Wastewater Treatment Plant effluent. The second cost estimate is also shown in Table C5-1. This $240,000 cost estimate was based on the fees recently charged to a company in Sacramento to purchase a temporary connection to the sanitary sewer for discharge of

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TABLE C5-1. SANITARY SEWER DISCHARGE COST ESTIMATES

Construction Item	Units[1]	Quantity	Unit Price	Total Cost
1. New Manhole[2]				
Concrete in place	ea	1	1,025	1,025
Slab top (4' manhole)	ea	1	206	206
Frame and cover	ea	1	197	197
2. Single Wall Above Ground Pipe[3]	ft	210	12.7	2,667
3. Fittings				
4" tee[2]	ea	3	48	144
4" 90 degree ell[2]	ea	9	39	351
Miscellaneous fittings (retrofit to direct flow west)	ls			500
4. Retrofit MH 44A[2] (to handle forced flow)	ls			2,000
5. Potential Sewer Connection Fees				
"Permanent" connection fees				660,000
"Temporary" connection fees				243,000

(Continued)

[1] ea = each
ft = foot
ls = lump sum

[2] Source: Means Site Work Cost Data, 1990; 9th Annual Edition.

[3] Source: Vendor quote.

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TABLE C5-1. (Continued)

"PERMANENT" CONNECTION FEES

Total Direct Costs:	$ 7,090
Sacramento Cost Index (10%):	709
Contingency (5%):	354
SUBTOTAL:	8,153
General Contractor O&P (25%):	2,038
CONSTRUCTION SUBTOTAL:	10,191
Engineering Design Cost (10%):	1,019
Bonding and Insurance (10%):	1,019
Construction Management (7%):	713
GRAND TOTAL:	$672,942

"TEMPORARY" CONNECTION FEES

Total Direct Costs:	$ 7,090
Sacramento Cost Index (10%):	709
Contingency (5%):	354
SUBTOTAL:	8,153
General Contractor O&P (25%):	2,038
CONSTRUCTION SUBTOTAL:	10,191
Engineering Design Cost (10%):	1,019
Bonding and Insurance (10%):	1,019
Construction Management (7%):	713
GRAND TOTAL:	$255,942

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TABLE C5-2. GWTP PIPELINE COST ESTIMATE (UTILITY TRENCH DESIGN OPTION)

Construction Item	Units [1]	Quantity	Unit Price	Total Cost
1. Pipeline Trench Sitework				
A. Earthwork				
1. Conc Trench Excav [2]	CY	847	2.89	2,448
2. Jacking Pits	EA	6	10,000	60,000
3. Horizontal Boring [2] (24-inch casing)	LF	300	254	76,200
B. Backfill	CY	283	0.44	125
1. Conc Trench Excav [2]				
C. Compaction				
1. Conc Trench Excav [2]	CY	283	1.92	543
2. Borrow Material [2]	CY	283	5.4	1,528
3. Borrow Material-Haul [2]	CY	283	4.88	1,381
2. Pipeline Trench Concrete				
A. Formwork				
1. Conc Trench: [2]				
Inside Form	SFCA	11,430	4.61	52,692
Outside Form	SFCA	10,160	1.99	20,218
B. Reinforcing Steel [2]				
1. Trench	TONS	29	805	23,345
C. Concrete in Place [2]	CY	236	186.8	44,085
3. Trench Covers [2]	SF	3,810	23.72	90,373
Add for 5/8" thick plate	SF	3,810	8	30,480
4. Soil Disposal				
A. Transportation and Disposal	TON	1,128	200	225,600
5. Pipe				
A. Double Contained-6" [3]	LF	1,570	36.75	57,698
1. Fittings/Joints [3]	LS			19,700
2. Fabrication [3]	HRS	68	50	3,400
3. Installation Labor [2]	LF	1,570	9.25	14,523
4. Pipe Supports	EA	105	95	9,975
5. Valves	EA	2	500	1,000

(Continued)

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TABLE C5-2. (Continued)

Construction Item	Units [1]	Quantity	Unit Price	Total Cost
5. (Continued)				
B. Single Wall-6" [3]	LF	2,680	12.7	34,036
1. Fittings/Joints [3]	LS			6,000
2. Fabrication [3]	HRS	116	50	5,800
3. Installation Labor [2]	LF	2,680	9.25	24,790
4. Aboveground Pipe Supports	EA	179	125	22,375
5. Valves	EA	2	500	1,000
6. Holding Tank (4-hour storage capacity) [3]	LS	1	7,800	7,800
1. Secondary Cont/Leak Detection [3]	LS	1	3,700	3,700
2. Conical Tank Roof [3]	LS	1	1,124	1,124
3. Tank Pad [2]	SF	263	4.36	1,147
4. Tank Installation [2,3]	LS			5,800
5. GAC Vent Unit	LS	1		800
7. Pumps				
1. Booster Pumps [3]	EA	2	1,800	3,600
TOTAL DIRECT COSTS:				$853,285
Sacramento Cost Index (10%):				85,329
Contingency (5%):				42,664
SUBTOTAL:				981,278
General Contractor O&P (25%):				245,320
SUBTOTAL:				1,226,598
Engineering & Design (10%):				122,660
Bonding & Insurance (10%):				122,660
Construction Management (7%):				85,862
GRAND TOTAL COST ESTIMATE:				$1,557,780

[1] CY = cubic yard; LF = linear foot; LS = lump sum; SF = square foot; SFCA = square foot contact area.

[2] Source: Means Site Work Cost Data, 1990; 95h Annual Edition.

[3] Source: Vendor quotes.

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TABLE C5-3. GWTP PIPELINE COST ESTIMATE (DIRECT BURIAL DESIGN OPTION)

Construction Item	Units[1]	Quantity	Unit Price	Total Cost
1. Sitework				
A. Earthwork				
1. Trenching (incl. Excav, Backfill, Compaction)[2]	LF	1,270	6.52	8,280
2. Jacking Pits	EA	6	10,000	60,000
3. Horizontal Boring[2] (24-Inch Casing)	LF	300	254	76,200
2. Pipe Bedding[2]	LF	1,270	0.57	724
3. Soil Disposal				
A. Transportation and Disposal (Assume 10% Spoil)	TON	47	200	9,400
4. Pipe				
A. Double Contained-6"[3]	LF	1,570	36.75	57,698
1. Fittings/Joints[3]	LS			19,700
2. Fabrication	HRS	68	50	3,400
3. Installation Labor[2]	LF	1,570	9.25	14,523
4. Valves	EA	2	500	1,000
B. Single Wall - 6"[3]	LF	2,680	12.7	34,036
1. Fittings/Joints[3]	LS			6,000
2. Fabrication[3]	HRS	116	50	5,800
3. Installation Labor[2]	LF	2,680	9.25	24,790
4. Abv Grnd Pipe Supports	EA	179	125	22,375
5. Valves	EA	2	500	1,000
5. Holding Tank (4 Hr Storage Capacity)[3]	LS	1	7,800	7,800
1. Secondary Cont/Leak Detection[3]	LS	1	3,700	3,700
2. Conical Tank Roof	LS	1	1,124	1,124
3. Tank Pad[2,3]	SF	263	4.36	1,147
4. Tank Installation[3]	LS			5,800
5. GAC Adsorption Unit	EA	1	800	800

(Continued)

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TABLE C5-7. SUMMARY OF COST ESTIMATES

Item		Estimated Construction Cost*
1.	Extraction Well/ Monitoring Well System	$ 197,600
2.	Sanitary Sewer Discharge	
	"Temporary" Connection Fee	255,942
	"Permanent" Connection Fee	672,942
3.	GWTP Discharge	
	Utility Trench Option	1,557,780
	Direct Pipe Burial Option	567,400
	Above Ground Pipe Option	559,000

* Includes direct and indirect capital costs, construction management costs, bonding and insurance costs, and engineering and design costs.

contaminated groundwater. As can be seen from Table C5-1, the potential sanitary sewer connection fees charged to McClellan AFB will have a direct impact on the cost of the sanitary sewer discharge option. The estimated O&M cost for the sanitary sewer discharge option is shown in Table C5-6. Monthly sanitary sewer use fees charged by the County of Sacramento Department of Public Works constitute approximately 80% of the estimated O&M costs. The remainder of the estimated O&M cost is due to expected pipeline and fitting repairs.

C5.2 Groundwater Treatment Plant Discharge

Cost estimates were developed for the extraction well/GWTP pipeline alternative based on three different piping design options. In the first piping design alternative, the portion of the pipeline route along Kilzer Avenue (see Figure C2-5) consists of double containment pipe placed in a concrete utility trench; the remainder of the pipeline route consists of single-wall pipe constructed aboveground. The concrete utility trench would have removable steel covers and is assumed to be approximately 3 feet wide and 4 feet deep to accommodate both the groundwater pipeline and other utilities. As can be seen in the cost estimate contained in Table C5-2, approximately 75 percent of the direct capital costs associated with this option are due to the construction of the utility trench and disposal of the soil removed from the trench.

In the second piping design alternative, the portion of the pipeline route along Kilzer Avenue is placed underground by direct burial. In this option, the underground pipe consists of double containment pipe, and the aboveground pipe consists of single containment pipe. The direct capital cost estimate for this option (see Tables C5-3 and C5-7) is approximately 40 percent that of the utility trench option. However, this option does not have the added benefit of allowing other base utilities to be installed along the same pipeline route.

In the third piping design alternative, the entire pipeline route except for street and railroad crossings is constructed aboveground with single-wall pipe. The major advantage of this option is that it is the least expensive of the three options evaluated (see Tables C5-4 and C5-7). However, this option may not be feasible because aboveground piping along Kilzer Avenue may hinder access to existing and planned facilities west of the pipeline route.

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INSTALLATION RESTORATION PROGRAM (IRP)
STAGE 3

OPERABLE UNIT B
ENGINEERING EVALUATION/COST ANALYSIS -
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DECEMBER 1990

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HSD/YAQ
Mr. Patrick Haas (Technical Project Manager)/
Capt. Henry Thompson (Contracting Officers' Technical Representative)

HUMAN SYSTEMS DIVISION (AFSC)
IRP PROGRAM OFFICE (HSD/YAQ)
BROOKS AIR FORCE BASE, TEXAS 78235-5000

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NOTICE

This Engineering Evaluation/Cost Analysis-Environmental Assessment (EE/CA-EA) has been prepared for the Air Force for the purpose of aiding in the implementation of a final remedial action plan under the Air Force Installation Restoration Program (IRP). As the EE/CA-EA relates to actual or possible releases of potentially hazardous substances, its release prior to an Air Force final decision on remedial action is in the public interest. The limited objectives of this EE/CA-EA, the ongoing nature of the IRP, and the evolving knowledge of site conditions and chemical effects on the environment and human health, all must be considered when evaluating this EE/CA-EA since subsequent facts may become known which may make this EE/CA-EA premature or inaccurate. Acceptance of this EE/CA-EA in performance of the contract under which it was prepared does not mean that the Air Force adopts the conclusion, recommendation, or other views expressed herein, which are those of the contractor only and do not necessarily reflect the official position of the Air Force.

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This Engineering Evaluation/Cost Analysis-Environmental Assessment Report presents the results of a comparative analysis of removal action options for the McClellan AFB Operable Unit B. This evaluation was performed for the period of November 1989 through August 1990. This report documents the removal action selection process and presents the removal actions selected to mitigate the groundwater beneath Operable Unit B. A risk assessment is also presented.

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PREFACE

Radian Corporation is the contractor for the Installation Restoration Program (IRP), Stage 3 Remedial Investigation/Feasibility Study (RI/FS) at McClellan Air Force Base (AFB), California. The work is being performed for the Human Systems Division (AFSC), Installation Restoration Program Office (HSD/YAQC) under Air Force Contract No. F33615-87-D-4023, Delivery Order 0011.

This Engineering Evaluation/Cost Analysis-Environmental Assessment Report presents the results of a comparative analysis of removal action options for the McClellan AFB Operable Unit (OU) B. This evaluation was performed for the period of November 1989 through August 1990. This report documents the removal action selection process and presents the removal actions selected to mitigate the contaminated groundwater beneath OU B. A risk assessment is also presented.

Key Radian project personnel were:

Nelson Lund, P.E.--Contract Program Manager
Jack D. Gouge'--Delivery Order Manager
William C. Knight--Project Manager
Leo Dielmann--Project Director

Radian acknowledges the cooperation of the McClellan AFB Office of Environmental Management. In particular, Radian acknowledges the assistance of Mr. Mario Ierardi and Mr. Jerry Robbins.

The work presented herein was accomplished between 30 November 1989 and 30 August 1990. Mr. Patrick Haas, Human Systems Division (AFSC), Installation Restoration Program Office (HSD/YAQ), was the Technical Project Manager. Capt. Henry Thompson, Human Systems Division (AFSC), Installation Restoration Program Office (HSD/YAQ), was the Contracting Officers' Technical Representative.

Approved: Nelson H. Lund

Nelson H. Lund, P.E.
Contract Program Manager

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This report has been prepared by the staff of Radian Corporation under our supervision. The presentation of information contained herein has been approved after thorough technical review. The conclusions and recommendations in this report are based upon the data collected in the field and laboratory by Radian Corporation personnel. We believe the data presented are of high quality. The interpretation of these data and the conclusions drawn were governed by our experience and professional judgement.

Thomas F. Cudzilo, Ph.D
Registered Geologist 4473

Leo M.J. Dielmann III, P.E.

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EXECUTIVE SUMMARY

This Engineering Evaluation/Cost Analysis-Environmental Assessment (EE/CA-EA) has been performed to evaluate and recommend removal actions for groundwater contaminated with volatile organic compounds (VOCs) within Operable Unit (OU) B at McClellan Air Force Base (AFB). To determine the appropriateness of a removal action, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) lists eight criteria to be considered. One criterion is the "actual or potential contamination of drinking water supplies or sensitive ecosystem" (NCP, 1990). The contaminated groundwater has been shown to be migrating toward two water supply wells in OU B, Base Well (BW) 18 and City of Sacramento Well (CW) 132. City Well 150 (also in OU B) had previously been taken out of service because contamination exceeding California Action Level concentrations for drinking water had been detected in samples collected from this well. In 1986, residences within and outside of OU B were connected to municipal water supplies to prevent potential exposure to domestic water supply wells contamination. The potential for human health risks to develop due to exposure to dissolved contaminants at BW-18 or CW-132 justified a removal action.

Groundwater contamination has been recognized at McClellan AFB since 1981. More recent studies have found that contaminants in OU B have migrated vertically to depths of 350 feet below the surface and horizontally as far as 2000 feet beyond the McClellan AFB boundary. (These studies include the continuing sampling and analysis of groundwater at McClellan AFB, the OU B Groundwater Remedial Investigation [OUBGRI], formerly called the Area B Groundwater Operable Unit Remedial Investigation or ABGOURI; and the basewide Preliminary Groundwater Operable Unit Remedial Investigation [PGOURI].) On the basis of the data obtained from these recent investigations, four geographic Areas of Concern, which are underlain by contaminant plumes, have been delineated in OU B (Figure S-1): a tricholorethene/tetrachloroethene (TCE/PCE) plume, a PCE plume, and the northern and southern TCE/1,2-dichloroethene (TCE/1,2-DCE) plumes. These Areas of Concern have differing levels of contamination and pose differing potential threats to human health, welfare and the environment. The two Areas of Concern posing the greatest potential threat are the TCE/PCE plume and the northern TCE/1,2-DCE plume. Concentrations of VOCs in groundwater beneath these areas range from 2 to 1000 times greater than federal or state Maximum Contaminant Levels (MCLs). Details of the geology, hydrogeology, and contaminant distribution and migration are presented in Appendix A.

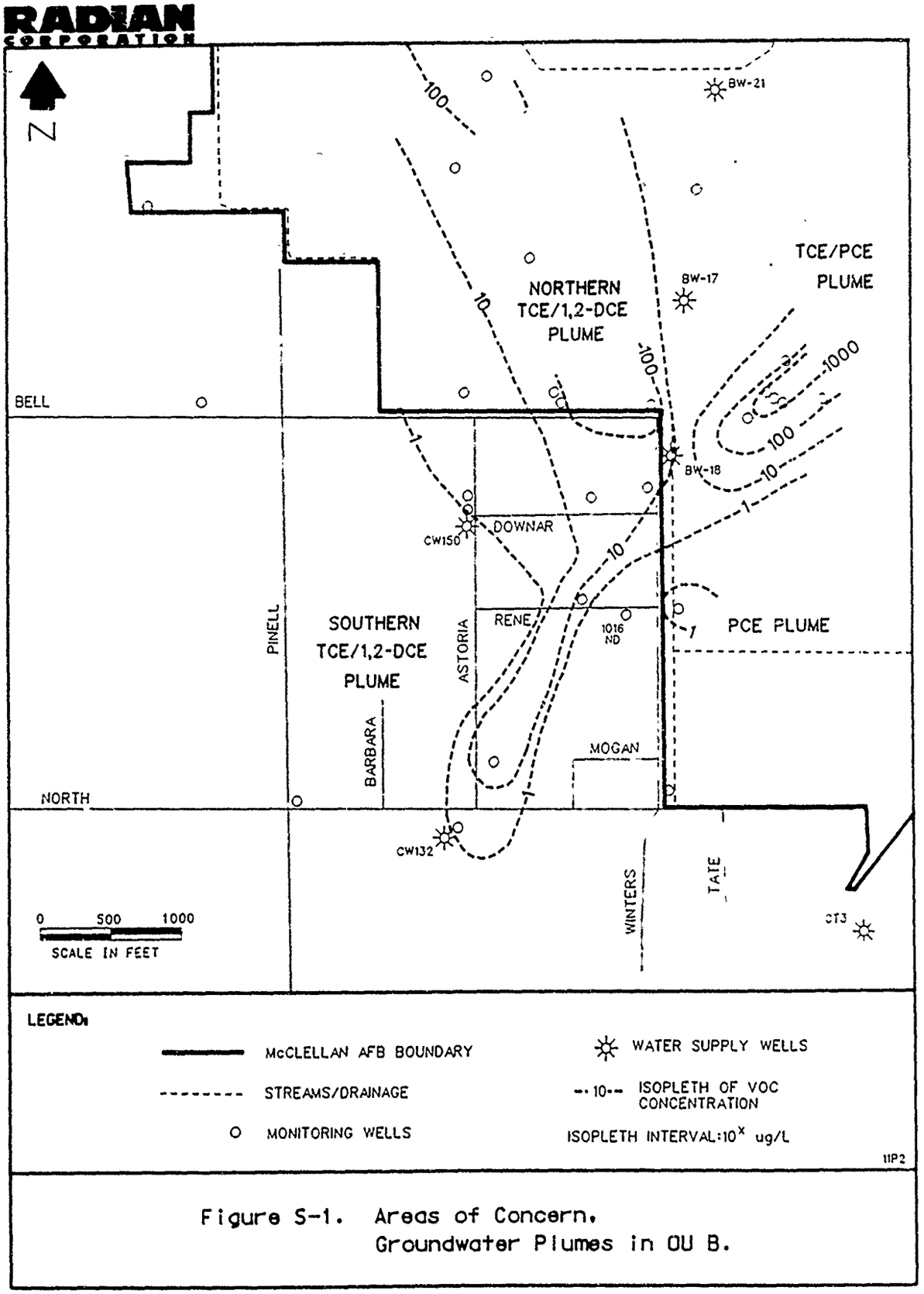

Figure S-1. Areas of Concern, Groundwater Plumes in OU B.

To determine what risks, if any, may exist as a result of the contaminants in the groundwater beneath OU B, a Baseline Risk Assessment was conducted. This Baseline Risk Assessment was also intended to determine the need for removal actions. The Baseline Risk Assessment was limited to exposure pathways originating with contaminants in the groundwater beneath OU B, and associated with the use of BW-18 and CW-132.

The primary human exposure pathway to contaminants detected beneath OU B may occur by using water in homes and workplaces, either on- or off-base, that is drawn from wells in the path of migrating contamination. Exposure may be through ingestion (drinking the water), dermal contact (e.g., showering), or inhalation of VOCs that have evaporated from the water (e.g., while showering or dishwashing). The risk assessment evaluated the potential exposures of individuals in residential, three-year tour-of-duty, and occupational scenarios if no removal actions were taken. Finally, both chronic and subchronic exposures were considered. Chronic exposure scenarios included long-term residential and occupational exposures resulting from use of the water from BW-18, and residential exposure from use of water from CW-132. The subchronic exposure scenario evaluated short-term exposure to water from BW-18 in the event that the wellhead treatment system currently operating at BW-18 failed, and water was distributed without treatment. For all exposure scenarios, the risk assessment used a conservative, "worst-case" approach.

The results of the risk assessment indicate that carcinogenic and noncarcinogenic risks would be posed for users of the groundwater if removal actions are not taken to control contaminant migration. Risks associated with continued use of water from BW-18 are lower than for use of water from CW-132, because the wellhead treatment system at BW-18 effectively removes contaminants to less than detectable concentrations from the water prior to distribution. There is no similar pretreatment for water from CW-132; however, this well is not used except during emergency situations such as a fire. It should be noted that all carcinogenic risks and potential noncarcinogenic effects calculated for the Baseline Risk Assessment are hypothetical. The assessment considered increased VOC concentrations that are predicted to occur at some time in the future if no removal actions are taken. No contamination has yet been detected at CW-132, and the risk assessment for BW-18 considered hypothetical future contaminant concentrations greater than those now entering the well. The Baseline Risk Assessment is summarized in Section 2.0; the entire Baseline Risk Assessment is included as Appendix B.

The objective of the proposed removal actions in OU B is to protect human health, welfare, and the environment. This objective will be met through implementation of response actions that are consistent with and contribute to potential remedial actions and will reduce the potential for human health risks that would result from the migration of higher concentrations of contaminants to water supply wells within OU B, and to mitigate potential impacts to the environment that could result form migration of high concentrations of contaminant to currently unaffected groundwater. According to U.S. Environmental Protection Agency (U.S. EPA) regulatory guidance documents (OSWER Directive 9360.0-0313), the removal actions to be undertaken in OU B are considered "non-time critical"; that is, there is a planning period of more than 6 months available before on-site activities must begin due to the risks associated with the groundwater. Groundwater containing contaminants have migrated to the area of the two water supply wells in OU B. Groundwater with contaminant concentrations that are 10 to 100 times greater is 600 to 900 feet away from each of the wells. At the current groundwater flow rates, the increased concentrations will not reach the wells within the next 12 months. The proposed actions are consistent with a short-term approach to limit the contaminant impact on two wells and the continuing spread of contamiants in groundwater. Longer term objectives and final remedial actions for groundwater and other contaminated media will be developed and addressed in the OU B Remedial Investigation and Feasibility Study (RI/FS).

The removal actions proposed and evaluated in this report address each of the four Areas of Concern. For the two areas with the highest concentrations of contaminants, the proposed removal actions consist of controlling contaminant flow; extracting, treating, and disposing of the groundwater; and continued monitoring of the contaminant migration. For the other two areas, removal actions include the closing of CW-132, the continued use of BW-18 to control contaminant migration, and monitoring the contaminant migration.

For the TCE/PCE plume, an Expedited Response Action (ERA) was proposed in January 1990 and implemented in October 1990 to control and reduce the contaminated groundwater moving toward BW-18, which is the principal water supply well for McClellan AFB. Because of the plume's contaminant concentrations and its migration path toward BW-18, actions to control the plume's migration were given priority over other potential removal actions in OU B.

The ERA for the TCE/PCE plume consists of extracting contaminated groundwater from two extraction wells in the shallow water-bearing zone; treating it with

granular activated carbon at a treatment plant that will be constructed nearby for this purpose (Figure S-2); and discharging the effluent into the McClellan AFB Industrial Wastewater Line (IWL) (Figure S-3). Other alternatives that were evaluated included piping the contaminated groundwater through a proposed pipeline directly to the existing Groundwater Treatment Plant (GWTP) for treatment; piping the contaminated groundwater to the sanitary sewer system; or treating the extracted groundwater with one of several different treatment methods and subsequent discharge to the IWL, the sanitary sewer, surface water drainages, or reinjection into the aquifer. These other methods were eliminated because they were technically impractical, because of difficulty gaining acceptance from regulatory agencies, or because of the length of time needed for implementation.

The proposed removal actions for the northern TCE/1,2-DCE plume consist of: extracting groundwater with three extraction wells, each screened over a different depth interval (Figures S-4, S-5, and S-6); piping the groundwater to the sanitary sewer on an interim basis (Figure S-7); piping the groundwater to the GWTP through a proposed pipeline on a long-term basis (Figure S-8); treating the extracted groundwater with granular activated carbon at the GWTP; continued pumping of BW-18 for the hydrologic control it exerts over the aquifers; destroying four unused wells and a boring that may be acting as vertical conduits for contaminants; and constructing monitoring wells in the plume, to monitor the effectivness of the extraction system. The GWTP should remove contaminants from the water until they can no longer be detected.

Other alternatives that were evaluated for the northern TCE/1,2-DCE plume consisted of combining treatment and discharge options, or discharge options alone. Treatment options included ultraviolet/ozone/peroxide, air stripping, and aqueous phase granular activated carbon; discharge options included piping the treated groundwater to the IWL, to the sanitary sewer, to surface water drainages, or reinjecting it into the aquifer. Each alternative was evaluated on the basis of technical feasibility, cost-effectiveness, on- and off-site impacts during construction and operations, and regulatory considerations, including compliance with Applicable or Relevant and Appropriate Requirements (ARARs).

The proposed removal actions for the southern TCE/1,2-DCE plume consist of: using CW-132 for emergency use only; implementing the removal actions for the TCE/PCE and northern TCE/1,2-DCE plume, which will remove contaminants from the groundwater before they can migrate further; continued pumping of BW-18 for the hydrologic control it exerts on the aquifer; abandoning and destroying CW-150; and

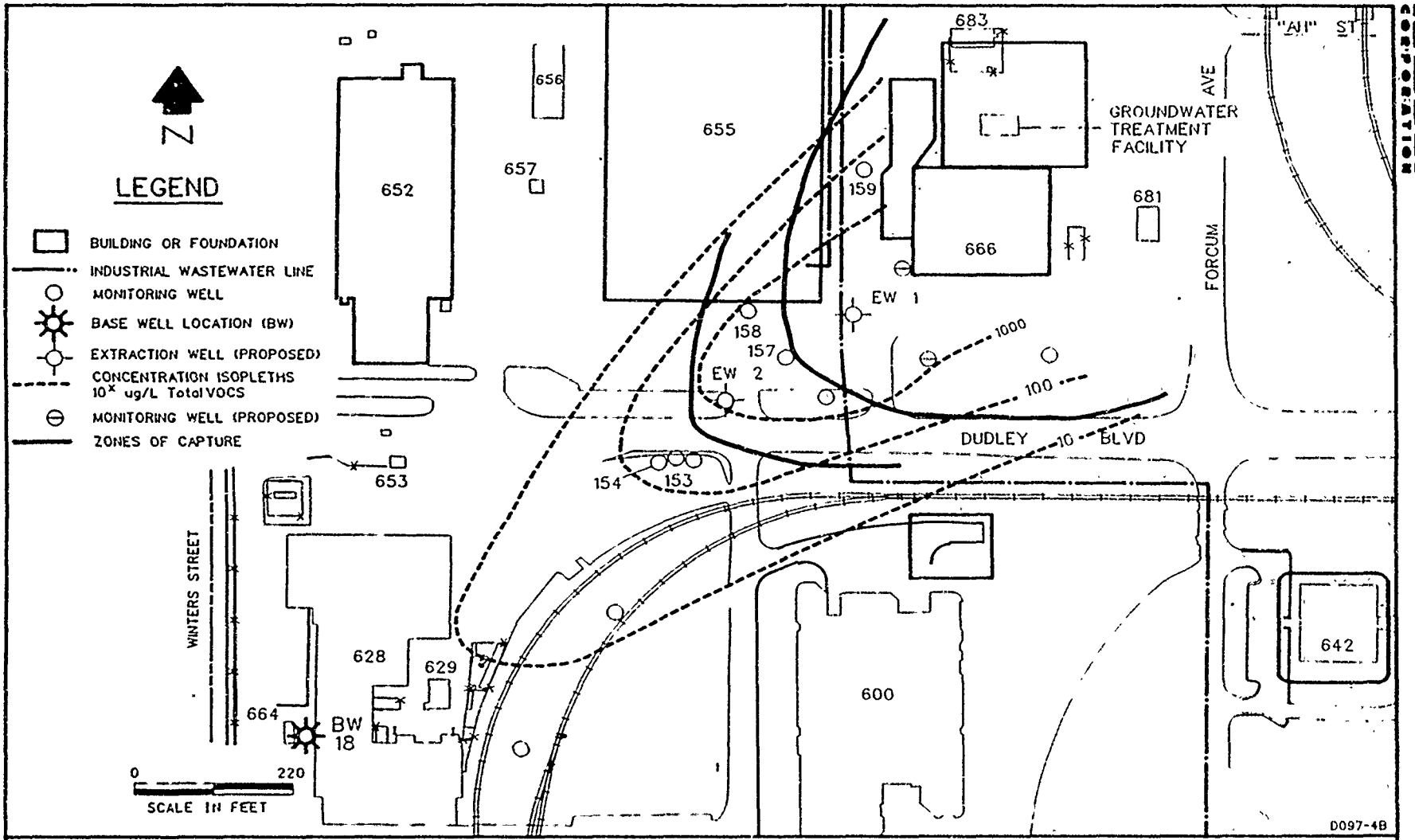

Figure S-2. Location of Extraction Wells for Expedited Removal Action, TCE-PCE Plume, Operable Unit B.

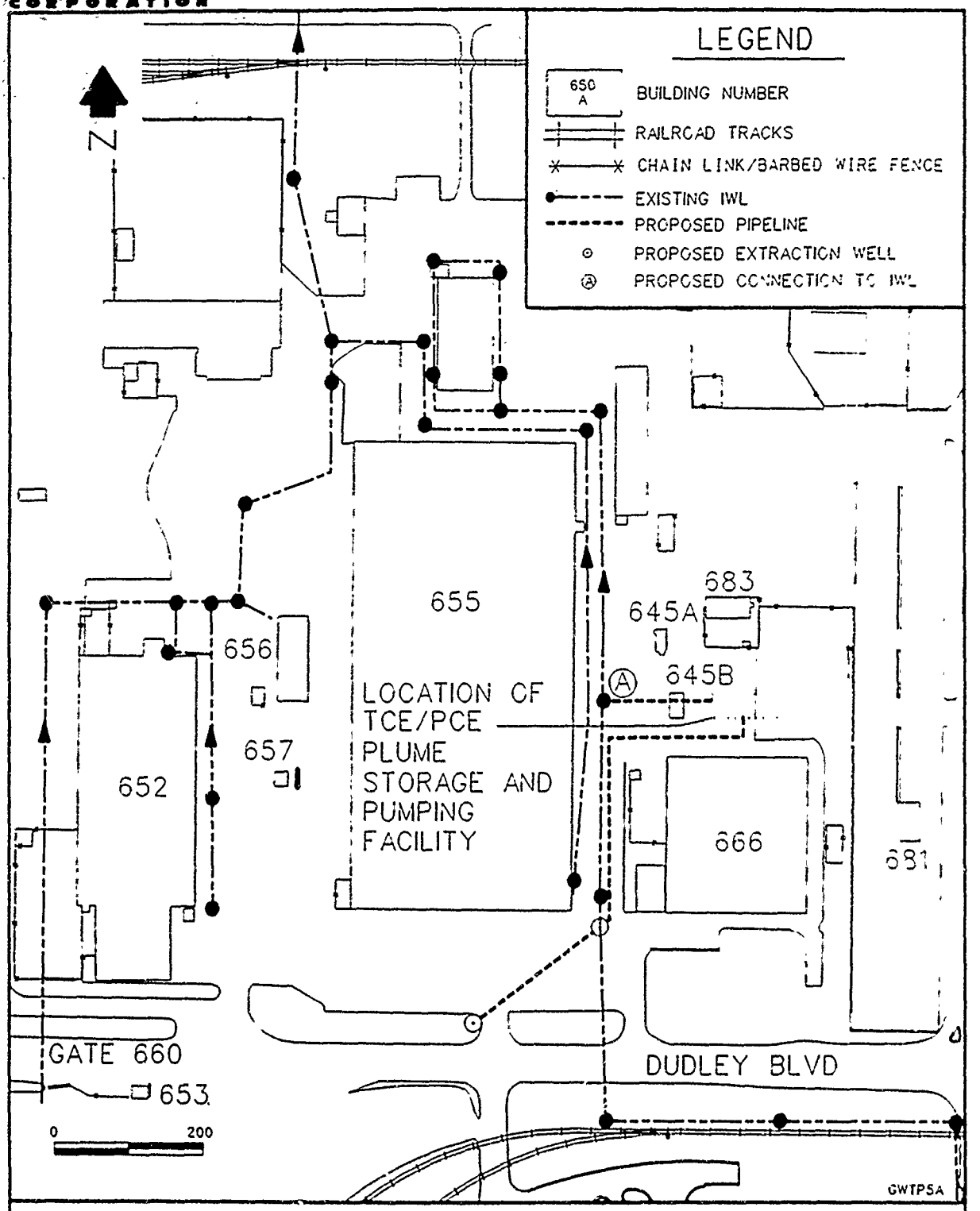

Figure S-3. Proposed Piping Route to the IWL for Expedited Removal Action, TCE-PCE Plume.

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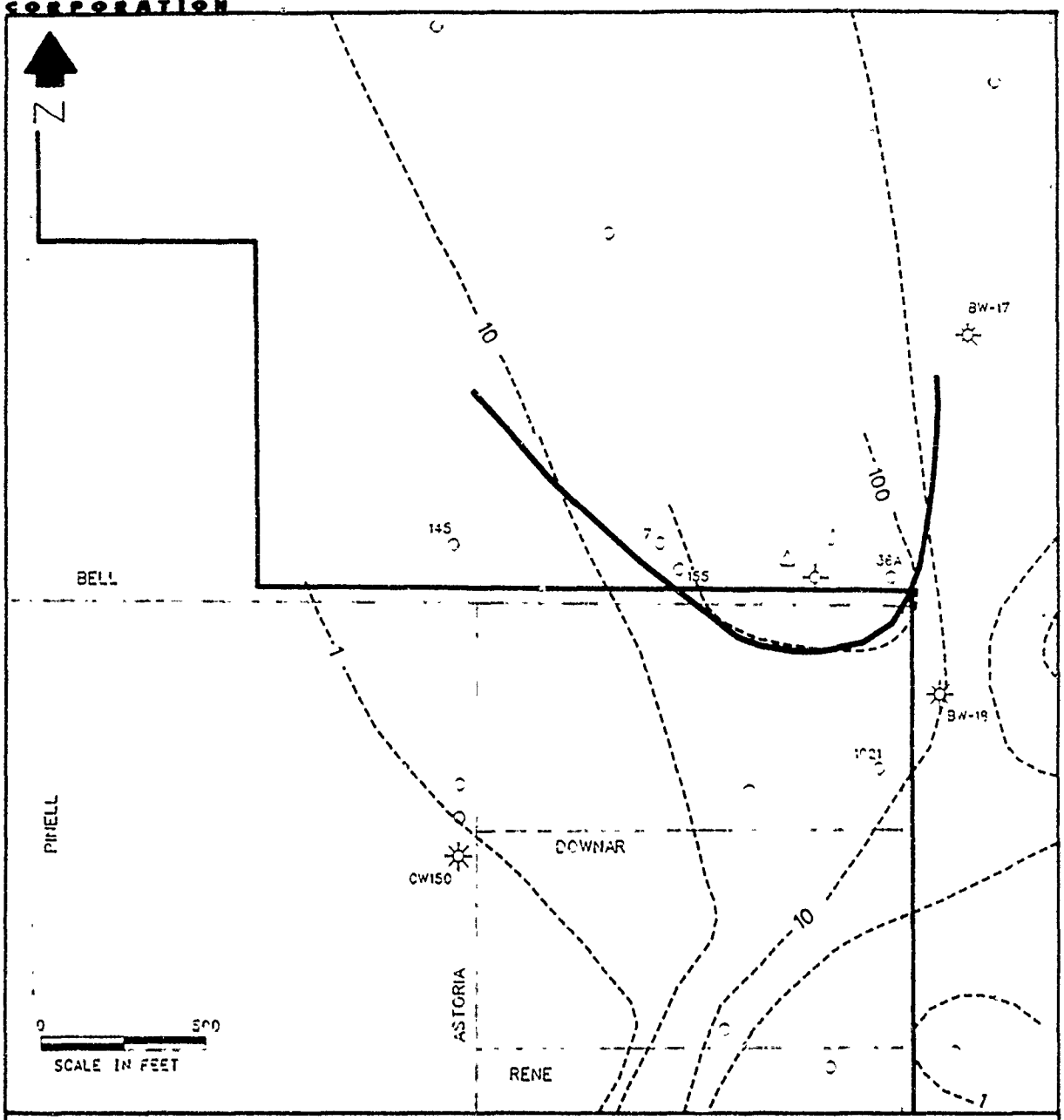

Figure S-4. Location of Proposed Extraction Well for Removal Action. Northern TCE/1,2-DCE Plume:A Zone.

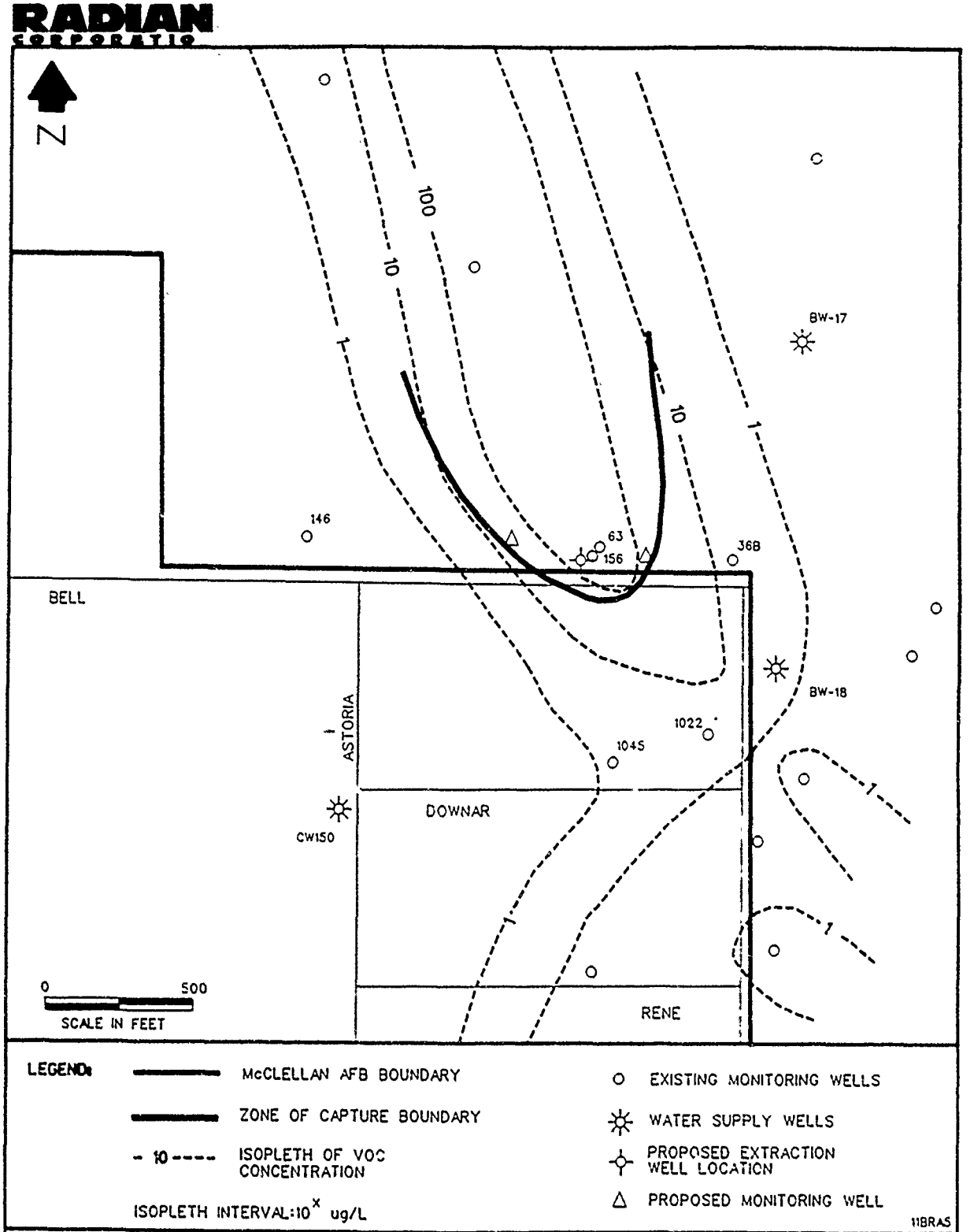

Figure S-5. Location of Proposed Extraction Well for Removal Action, Northern TCE/1,2-DCE Plume:B Zone.

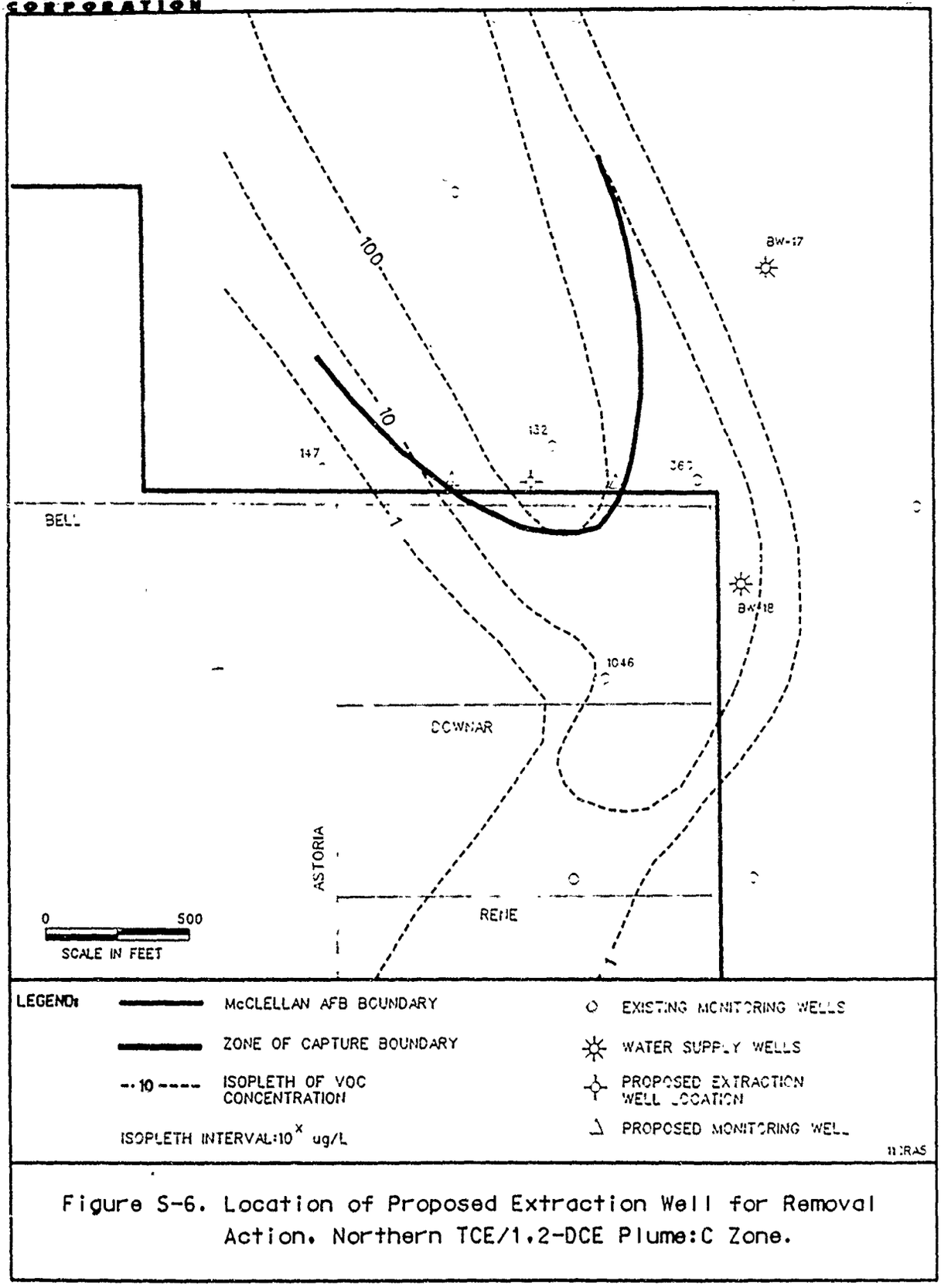

Figure S-6. Location of Proposed Extraction Well for Removal Action. Northern TCE/1,2-DCE Plume:C Zone.

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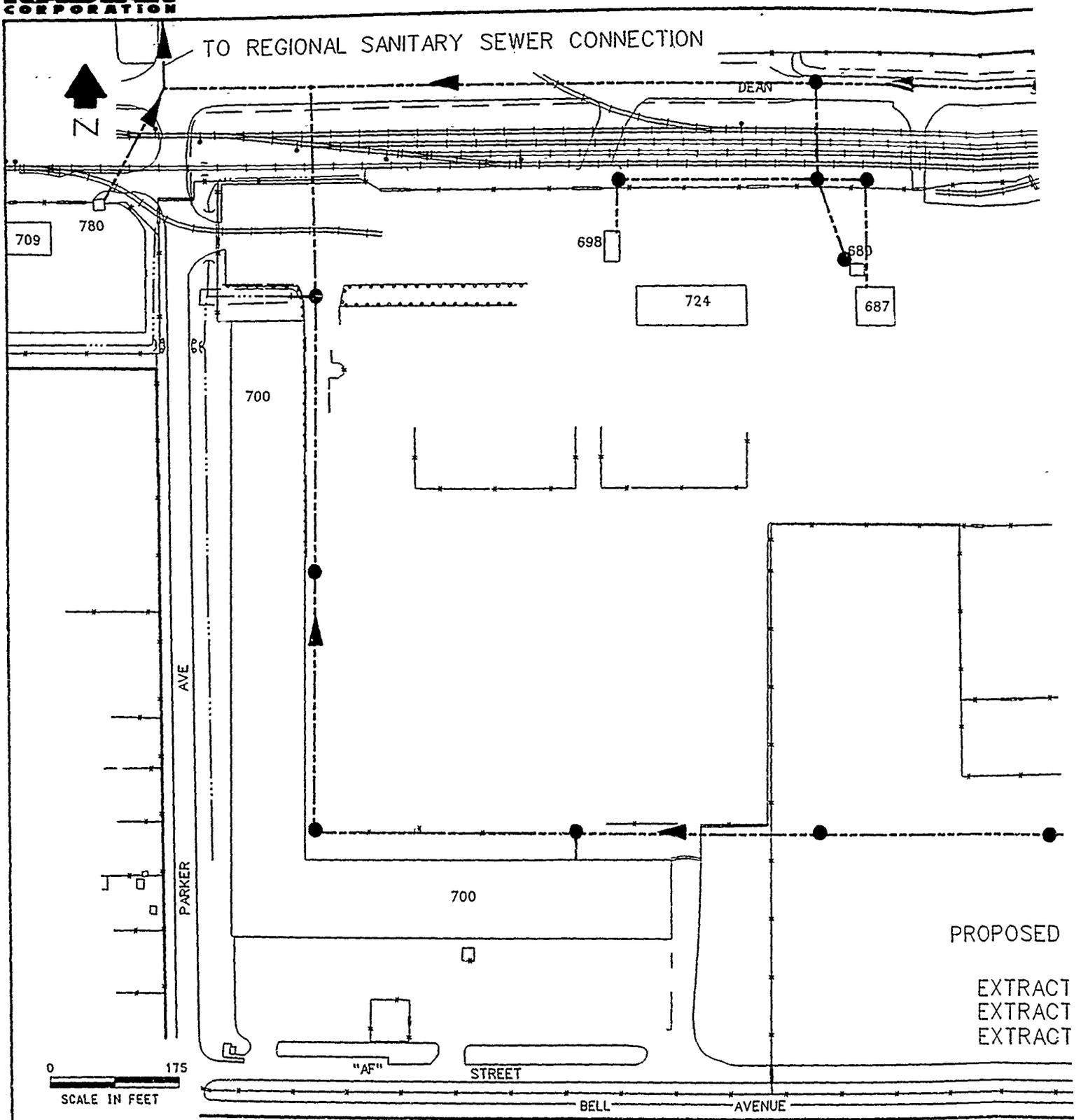

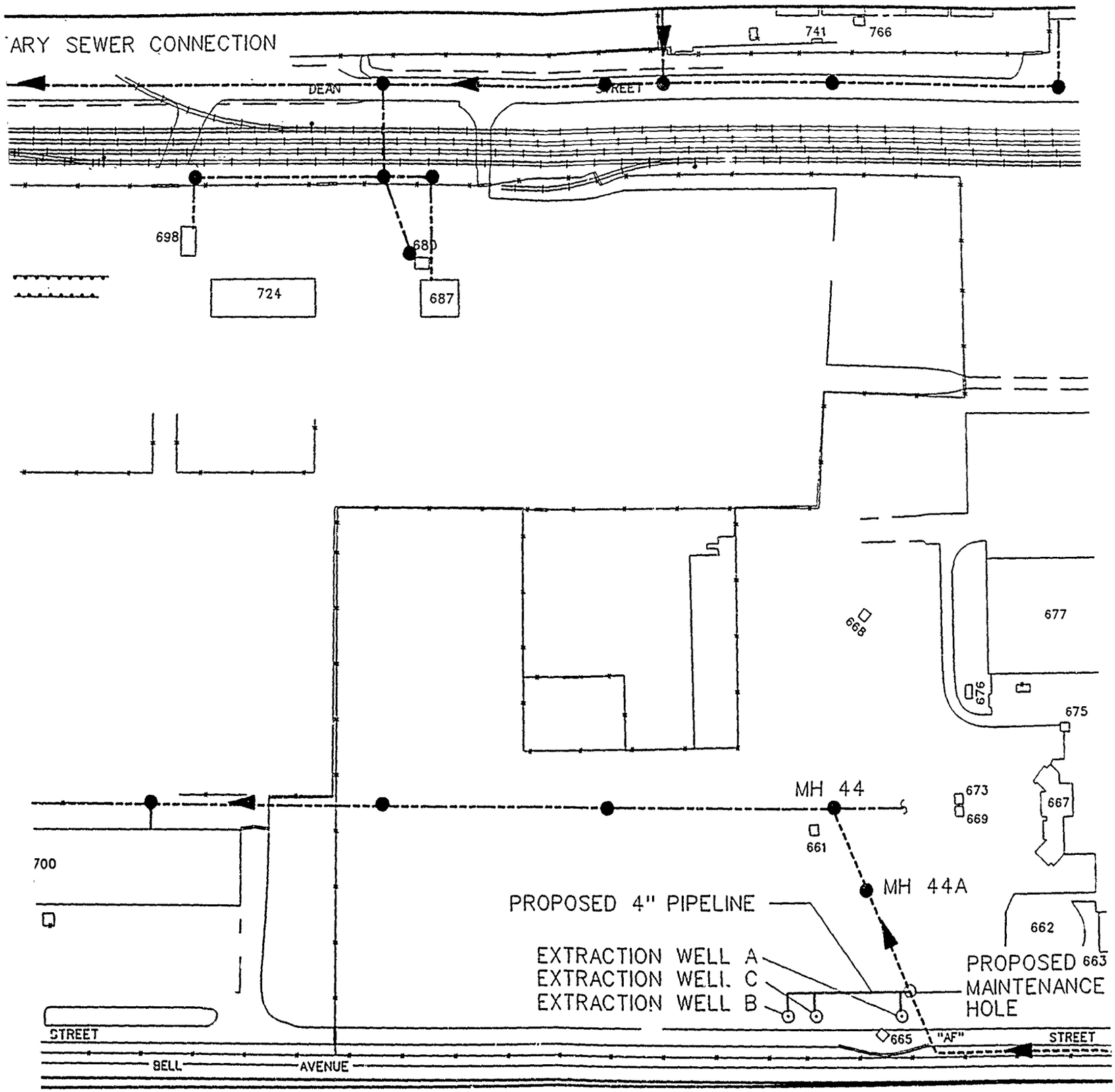
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700
MH 44A
PROPOSED 4" PIPELINE
662
EXTRACTION WELL A
EXTRACTION WELL C
EXTRACTION WELL B
PROPOSED 663
MAINTENANCE
HOLE
665
"AF"
STREET
STREET
BELL
AVENUE

Fig

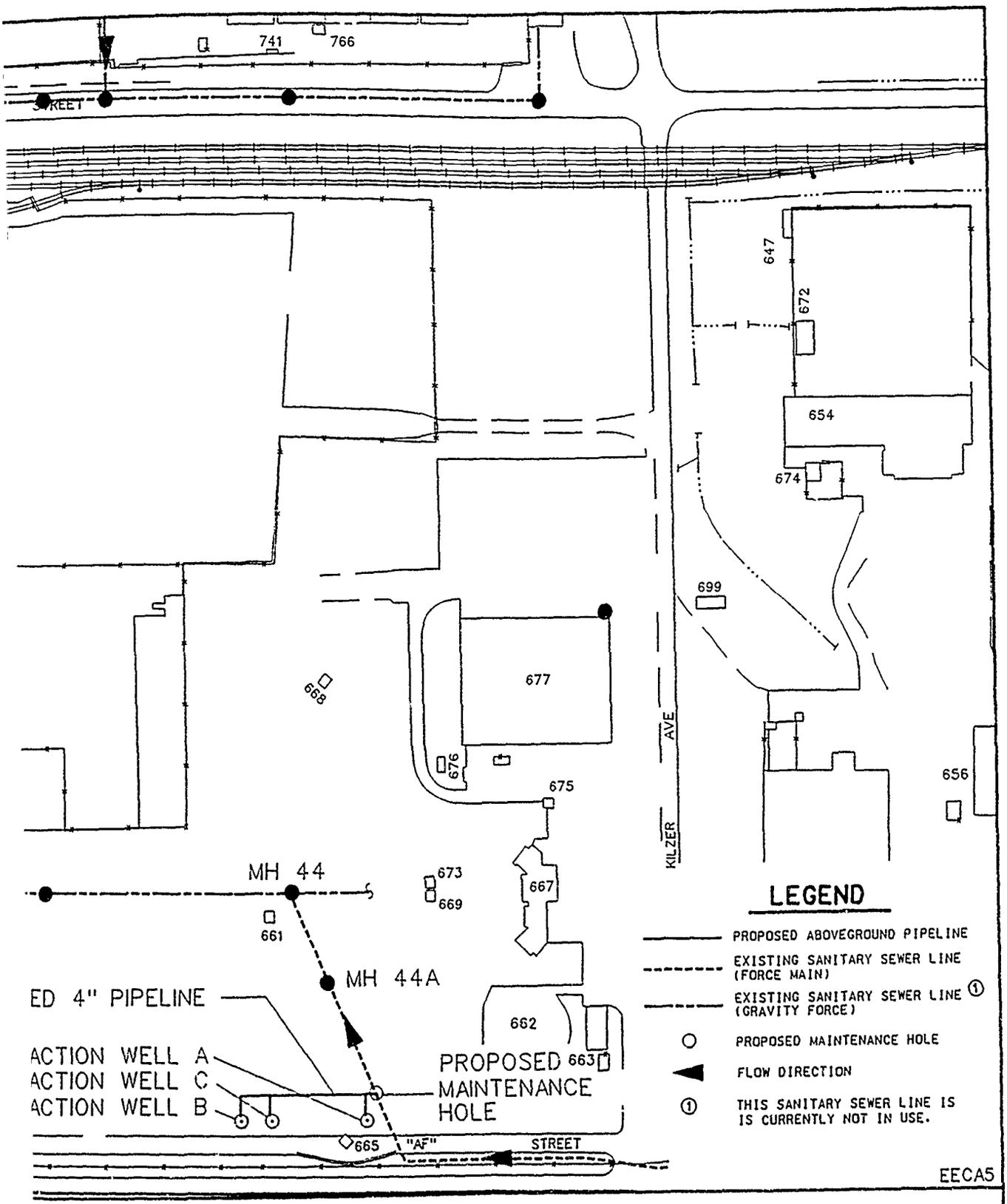

Figure S-7. Proposed Pipeline Route to the Existing Sanitary Sewer Line.

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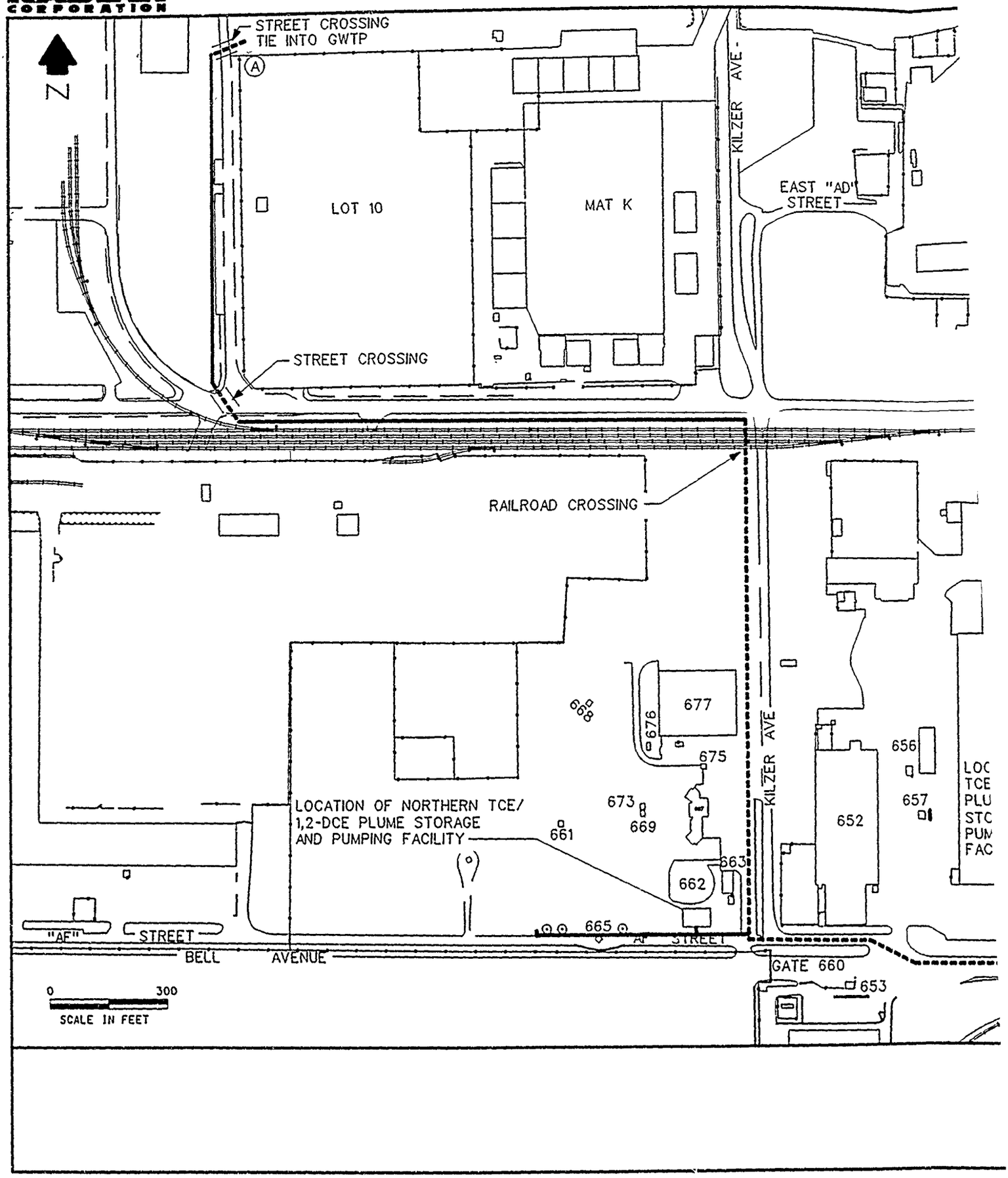

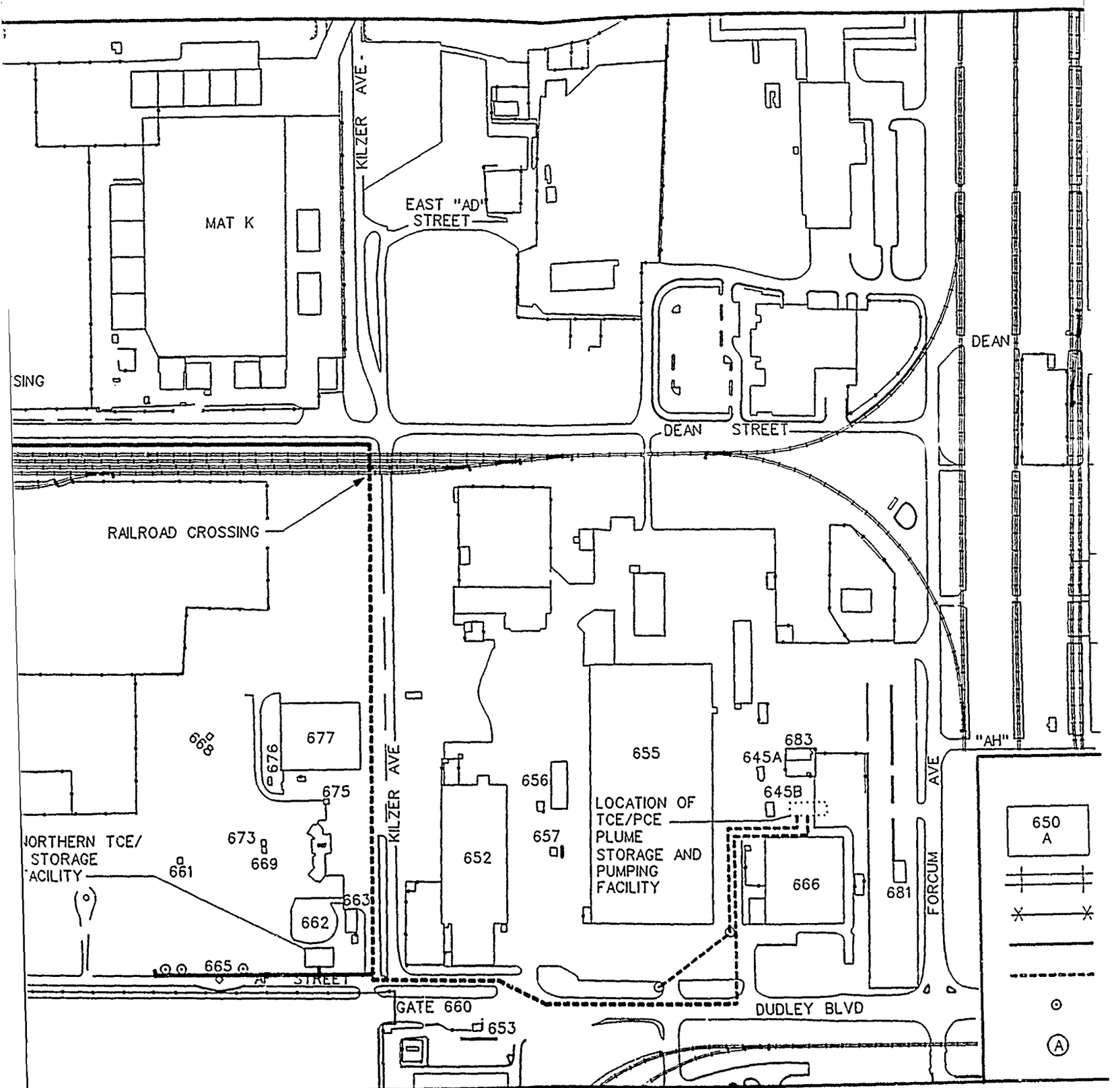
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RAILROAD CROSSING
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673
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661
NORTHERN TCE/ STORAGE FACILITY
662
663
665
"AF" STREET
KILZER AVE
652
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655
LOCATION OF TCE/PCE PLUME STORAGE AND PUMPING FACILITY
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FORCUM AVE
"AH"
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GATE 660
653
DUDLEY BLVD

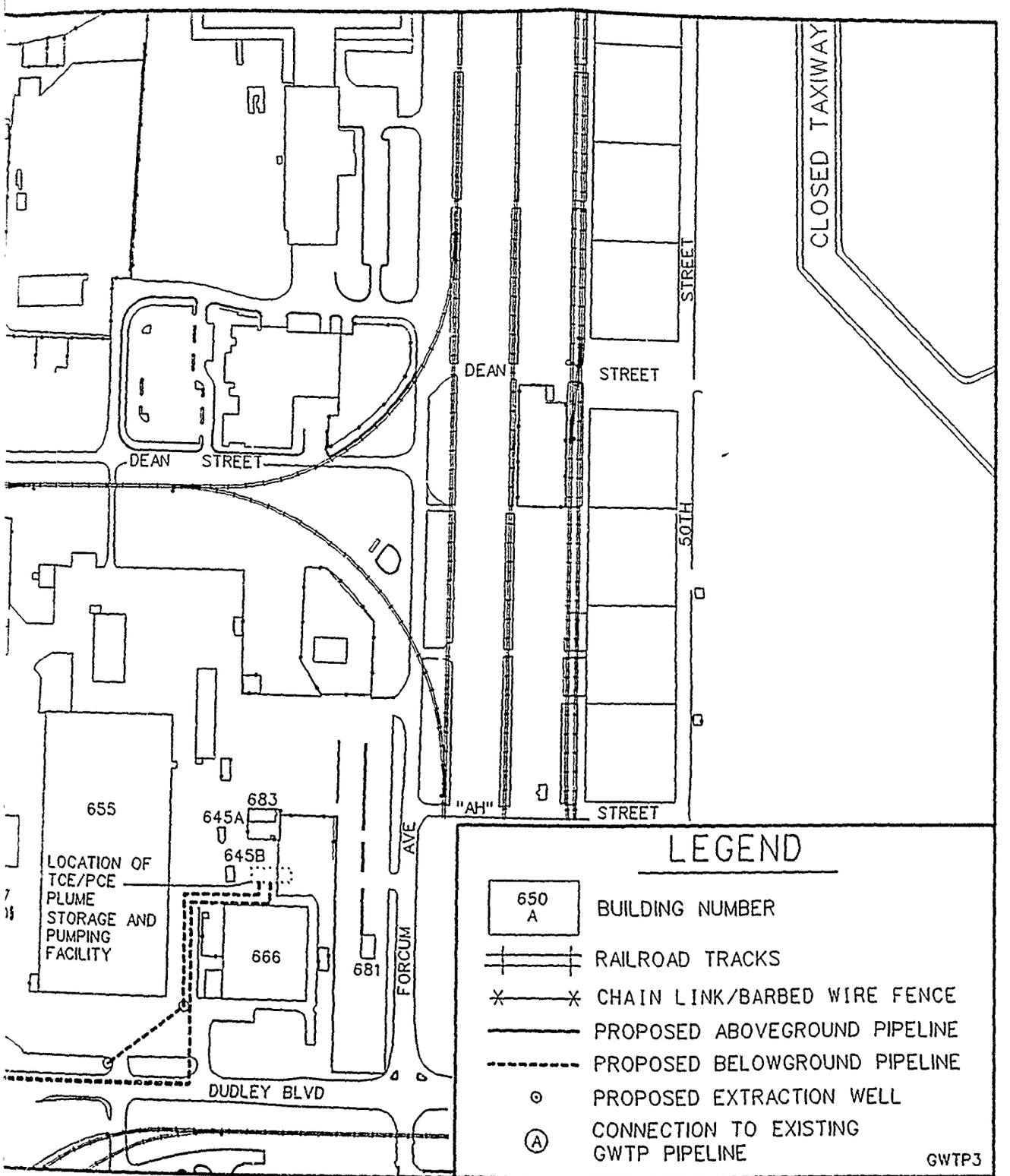

Figure S-8. Proposed GWTP Pipeline Route.

constructing three monitoring wells south of McClellan AFB and monitoring the groundwater quality quarterly; and reevaluating the extent and migration of the plume in a comprehensive or focused OU B Remedial Investigation (RI).

The proposed removal actions for the PCE plume consist of: implementing the removal actions for the TCE/PCE plume and northern TCE/1,2-DCE plume, including the continued pumping of BW-18; and determining the source and extent of the PCE contamination in the OU B RI.

The Operable Unit B EE/CA-EA recommends implementing response actions for four contaminated groundwater plumes that are intended to:

- Reduce the potential for health risks that will result from the continued migration of greater contaminant concentrations to water supply wells within OU B;

- Minimize the environmental impacts that could result from the continued migration of contaminated groundwater; and

- Implement removal actions that are consistent with the potential long-term remedial action.

In order to accomplish these objectives, a phased approach will be used for the removal action implementation and to begin the evaluation of remedial actions.

Groundwater extraction systems have been proposed to remove isolated areas of groundwater containing VOCs at concentrations that are greater than 100 micrograms per liter (μg/L) and one to two orders of magnitude greater than the surrounding groundwater. Due to the continuing contaminant migration of groundwater plumes, further long-term actions for the OU B groundwater may be appropriate.

In the phased approach, the Air Force McClellan AFB would implement the OU B removal actions, monitor the response action effectiveness and, as needed, modify the response action to achieve the removal action objectives. The response actions would be initiated as removal actions but would be completed as remedial actions over a period exceeding 12 months. In general, response actions that are implemented in a period exceeding 12 months would require that a Record of Decision (ROD) document be prepared. Therefore, the OU B removal actions will be implemented and followed

by an interim ROD as dictated by program priorities. This approach would satisfy the need to implement and modify the removal actions as needed while also proceeding with the evaluation for long-term remedial action needs. Currently, the OU B RI/FS has the highest priority among the OUs; however, the ROD for OU B will not be completed until 1994 with remedial work scheduled to start the following year. Because work should begin as soon as practicable to support the removal action, it is proposed to prepare a focused FS that evaluates the need for remedial action for the contaminated groundwater problem. If remedial actions were required, they would be documented in an interim ROD. This interim ROD would precede the OU B RI/FS and would be reviewed and incorporated in the OU B RI/FS report and finalized in the OU B ROD. In summary, this approach would lead to implementation of the removal actions described in the OU B EE/CA-EA report first and be followed by the selection of appropriate cleanup actions addressing the OU B groundwater and contaminant sources.

During the OU B focused FS and interim ROD, McClellan AFB would:

- Analyze groundwater monitoring data in the southern TCE/1,2-DCE and PCE plumes;
- Review extraction, treatment, and disposal alternatives of the southern TCE/1,2-DCE and PCE plumes;
- Evaluate an innovative technology such as ultraviolet (UV)/ozone/peroxidation on extracted OU B groundwater;
- Incorporate that portion of OU C that may be a major source of the groundwater contamination into OU B; and
- Assess performance of the extraction systems proposed in this report.

This document addresses only short-term measures to reduce potential health risks from on- and off-base water supply wells, which extract groundwater from aquifers that contain migrating contaminants. This action meets the long-term remedial goals. A final action or actions will be proposed in the future OU B RI/FS, which also further analyze environmental impacts.

Details of the alternatives, the proposed actions, and the evaluation process used for the removal action alternatives are presented in Sections 5.0 and 6.0. A conceptual design for the proposed treatment facility and attendant discharge pipeline for the northern TCE/1,2-DCE plume is included as Appendix C.

1.0 INTRODUCTION

In February 1989, a remedial investigation was begun in Operable Unit (OU) B of McClellan Air Force Base (AFB) to determine the extent and migration direction of contaminated groundwater. Interpretations of data collected in the Operable Unit B Groundwater Remedial Investigation (OUBGRI), formerly known as the Area B Groundwater Operable Unit Remedial Investigation (ABGOURI), lead to the conclusion that concentrations of volatile organic compounds (VOCs) exceeding federal and state drinking water standards were migrating in groundwater toward City of Sacramento Water Supply Well (CW) 132. The OUBGRI results also indicated that groundwater containing trichloroethene (TCE) at greater concentrations (1000 to 5400 micrograms per liter [μg/L]) was migrating toward McClellan AFB Base Supply Water Well (BW) 18.

After reviewing the initial results of the OUBGRI, the Air Force initiated this Engineering Evaluation and Cost Analysis-Environmental Assessment (EE/CA-EA) of removal action alternatives to address the extent and migration of contaminated groundwater. An EE/CA-EA is a process of comparative analyses used to develop, evaluate, and select removal action options for sites such as McClellan AFB, involved in programs under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA). The EE/CA-EA process is intended to supplement removal action requirements under those programs.

This report documents the evaluation and selection of technologies appropriate for removal actions to mitigate contaminants in groundwater beneath OU B. The basis for decisions made in the selection of alternatives are reported. Sections of the report represent the basic components of the EE/CA-EA process. Section 1.0 describes the site characterization that is the basis for considering the removal actions. Section 2.0 describes site conditions and risk characterization. Section 3.0 identifies removal action objectives. Section 4.0 discusses the proposed removal actions and the recommended removal action alternative. Sections 5.0 and 6.0 identify and compare removal action alternatives, respectively. The report sections are supported by the detailed presentation and interpretation of data in Appendix A, Groundwater Remedial Investigation and Appendix B, Baseline Risk Assessment. The conceptual design for the recommended removal action alternative is presented in Appendix C, Conceptual Design. Appendix D contains analytical data used in preparing this report.

The OU B EE/CA-EA report addresses only short-term actions to reduce the potential exposure to contaminated groundwater from on- and off-base water supply wells. The proposed EE/CA-EA actions will facilitate the long- term action that will be implemented in OU B given the data currently available. The long-term action will be proposed in the future OU B Remedial Investigation/Feasibility Study (RI/FS) report currently scheduled to be finalized in November 1993. Further analysis of environmental impacts resulting from possible OU B actions and the no action alternative will be documented in the OU B RI/FS report.

1.1 Site Description

McClellan AFB, an Air Force Logistics Command Center, is located approximately 7 miles northeast of downtown Sacramento, California (Figure 1-1). It comprises 2,952 acres within irregularly configured boundaries. The base property is bounded approximately by Elkhorn Boulevard on the north, Roseville Road on the south, Watt Avenue on the east, and Raley Boulevard on the west. McClellan AFB lies near the eastern edge of the Sacramento Valley, an area characterized by low topographic relief. Its land surface slopes very gently to the west. The major drainages in the region are the Sacramento and American Rivers, which lie to the west and south, respectively.

McClellan AFB currently employs approximately 17,000 personnel, including 3,500 military personnel and approximately 13,500 civilian employees. Base operations include the management, and maintenance and repair of jet aircraft, electronics, and communications equipment.

The land on which McClellan AFB was developed was low density residential and agricultural prior to 1936. Land in the area surrounding McClellan AFB is now used for a combination of industrial, commercial, residential, and agricultural purposes. To the east of the base are low density residential subdivisions. In the area south of McClellan AFB and bordering residential areas are parcels zoned for commercial and office use. The Rio Linda community northwest of the base consists of large-lot rural residences. Some of the Rio Linda area immediately adjacent to the base has been zoned industrial-intensive. To the southwest of McClellan AFB in OU B, land use is principally low density residential, with some industrial and a few commercial parcels.

The approximate boundaries of the Operable Units (OUs) are shown in Figure 1-2. The eastern side of McClellan AFB, including OUs A and H, is densely

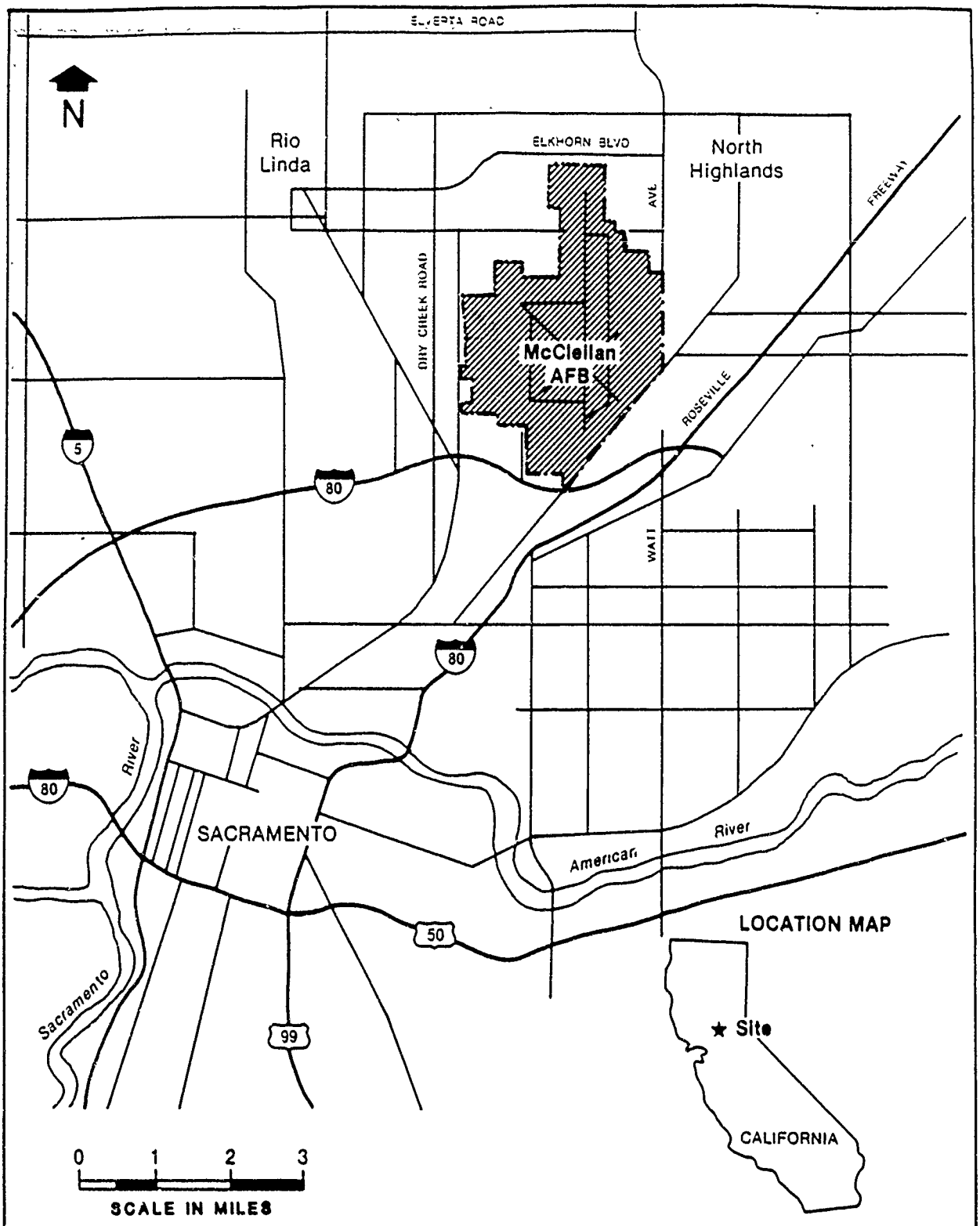

Figure 1-1. Location of McClellan Air Force Base, California.

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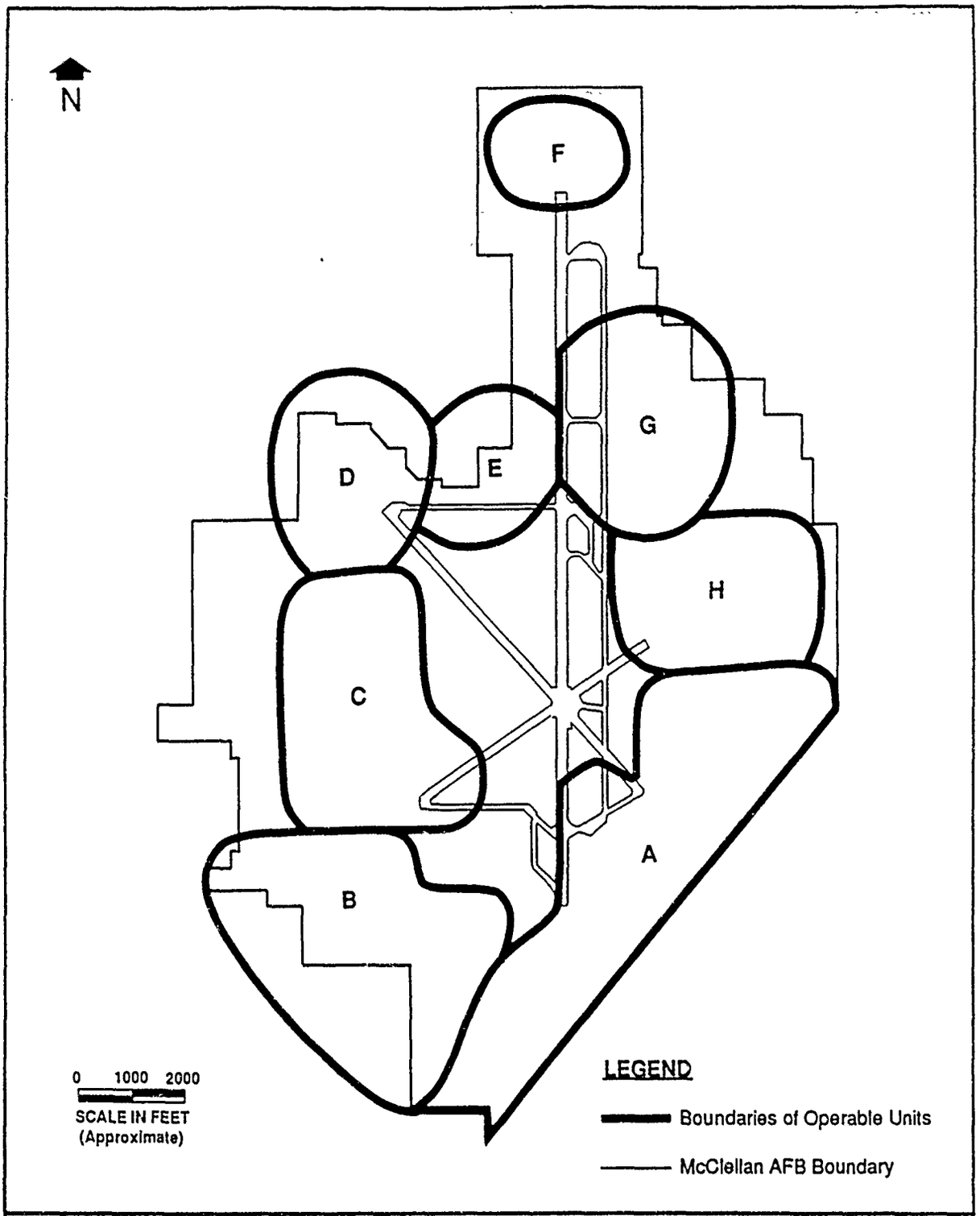

Figure 1-2. Approximate Boundaries of Operable Units at McClellan AFB.

0890-074-3

developed, and contains the administration offices, housing for active duty personnel, and most of the repair and maintenance facilities and aircraft hangers. The western side of McClellan AFB, including OUs C and D, has fewer buildings and is dominated by large grassy fields. The northern part of the base, OUs E, F, and G are open fields interrupted only by the northern part of the aircraft runway and service roads.

Operable Unit B covers the southwestern portion of McClellan AFB and a portion of the residential off-base area to the south (Figure 1-3). The on-base facilities in OU B consist of open storage lots; warehouses; former waste storage, disposal, and treatment areas; maintenance facilities; underground tanks and pipelines; a dismantled plating shop; and the site of a former laboratory. Approximately half the surface area of the on-base part of OU B is occupied by open storage lots and warehouses. The off-base portion of OU B is characterized by low density residential housing, open fields, and limited commercial or industrial facilities.

1.1.1 Type of Facilities and Operational Status

The distribution of on-base facilities in OU B are shown in Figure 1-4. Warehouses and open storage areas, particularly those where hazardous materials handling was confirmed, are identified on Figure 1-5. In addition, four inactive waste disposal sites and three inactive waste treatment facilities are located in OU B (Figure 1-6) and are discussed in Section 1.2. There are currently no operating waste disposal or treatment facilities in OU B. However, the Defense Reutilization and Marketing Office (DRMO) maintains a hazardous materials storage lot near the western edge of OU B (Lot 3--Potential Release Location S-13, Figure 1-5).

Aircraft and vehicle maintenance facilities in OU B, centered around the Building 655 area (Figure 1-4), include a paint stripping washrack, vehicle maintenance shops, a steam boiler plant, and vehicle fueling/defueling areas. Until they were dismantled in 1988, a metal plating shop (Building 666) and its wastewater pretreatment plant (Industrial Wastewater Treatment Plant No.4) stood to the east of Building 655. Additional maintenance facilities are the aircraft maintenance hangers located on the perimeter of Mat K, and the washracks located near Building 688.

Underground facilities include the Industrial Wastewater Line (IWL) (shown as PRL L-5 on Figure 1-5), which runs through the central portion of OU B, and the underground storage tanks located throughout OU B. Laboratories are located in Buildings 618, 620, 628, and 677. The laboratory that formerly occupied part of Building

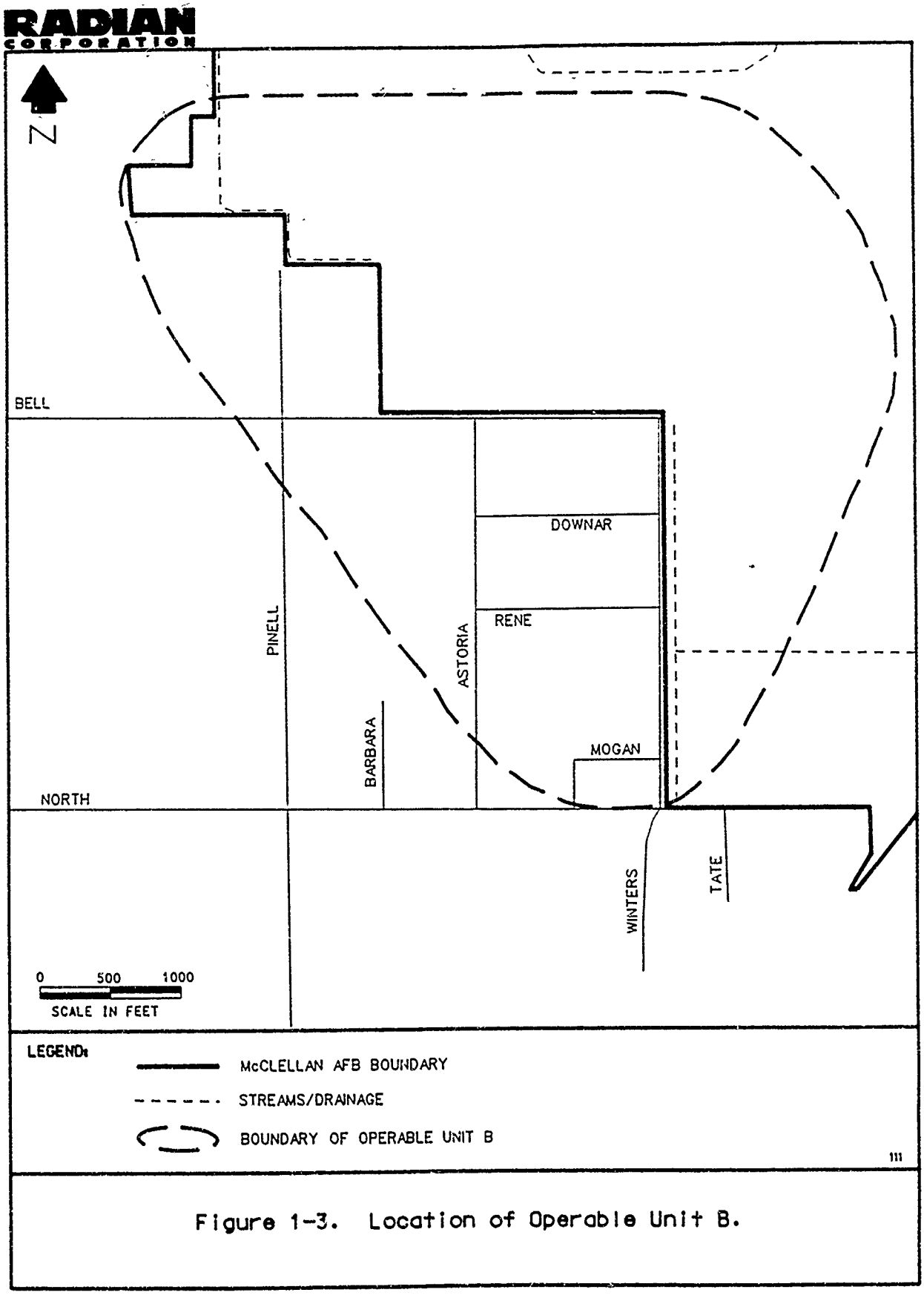

Figure 1-3. Location of Operable Unit B.

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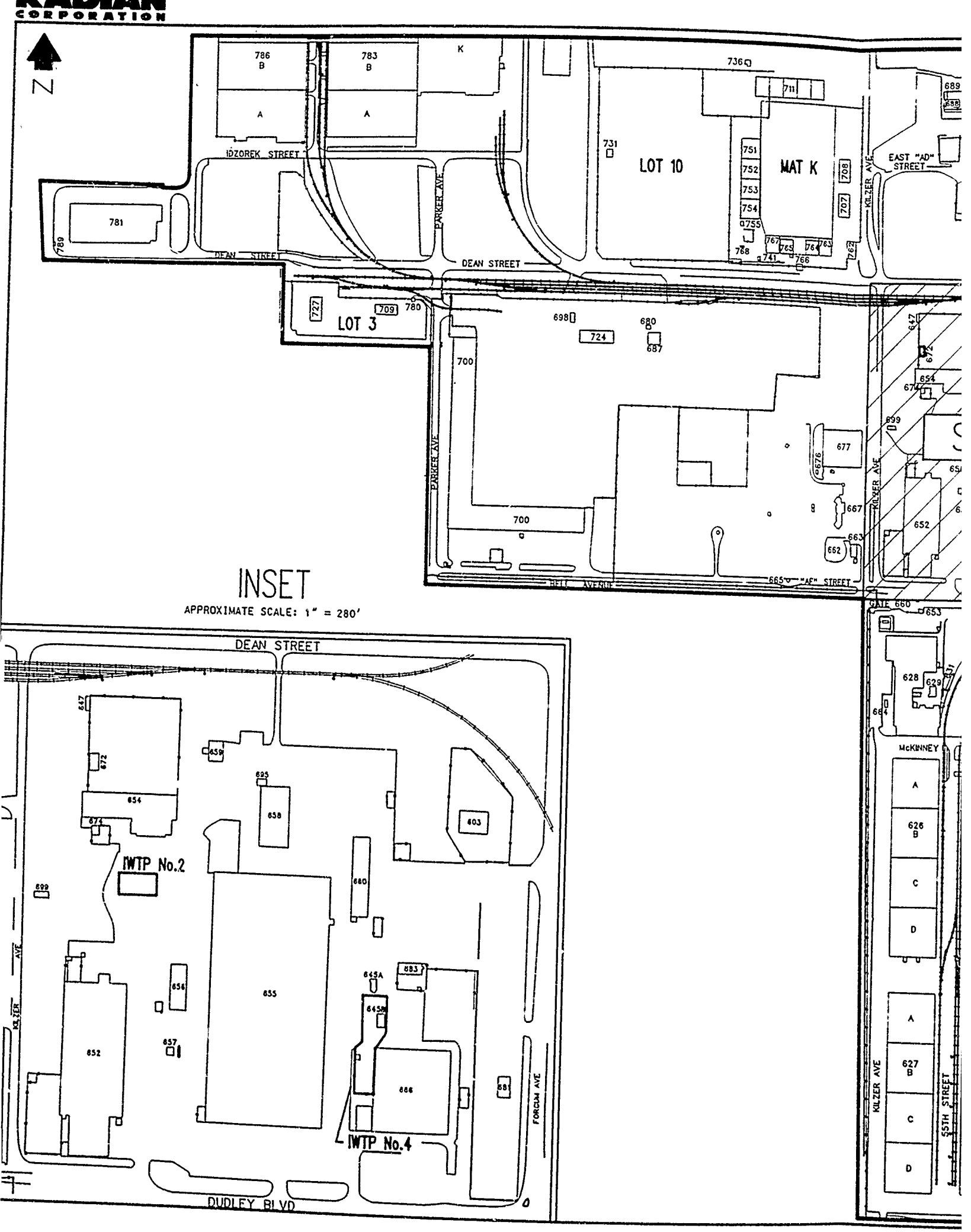

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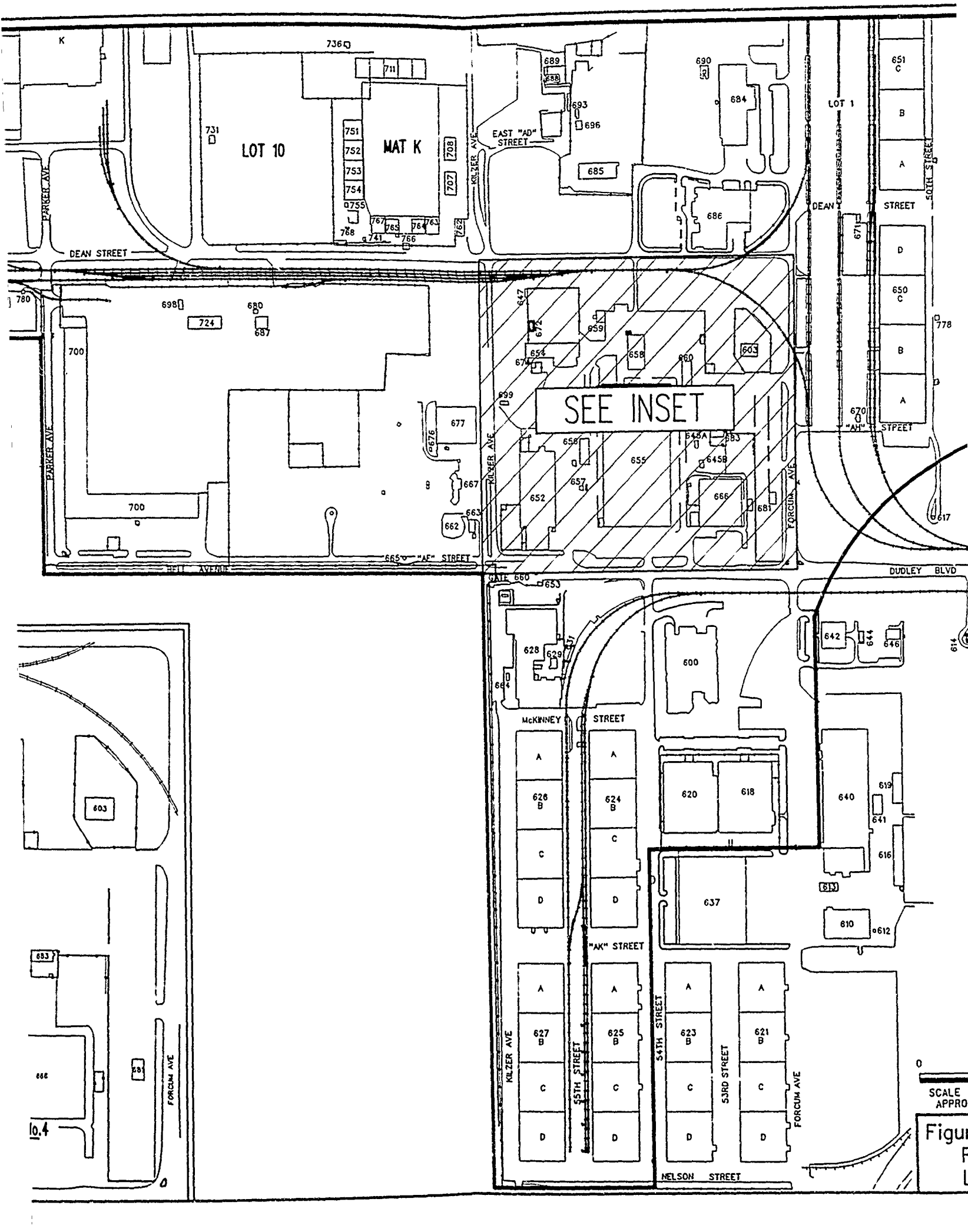
LOT 10
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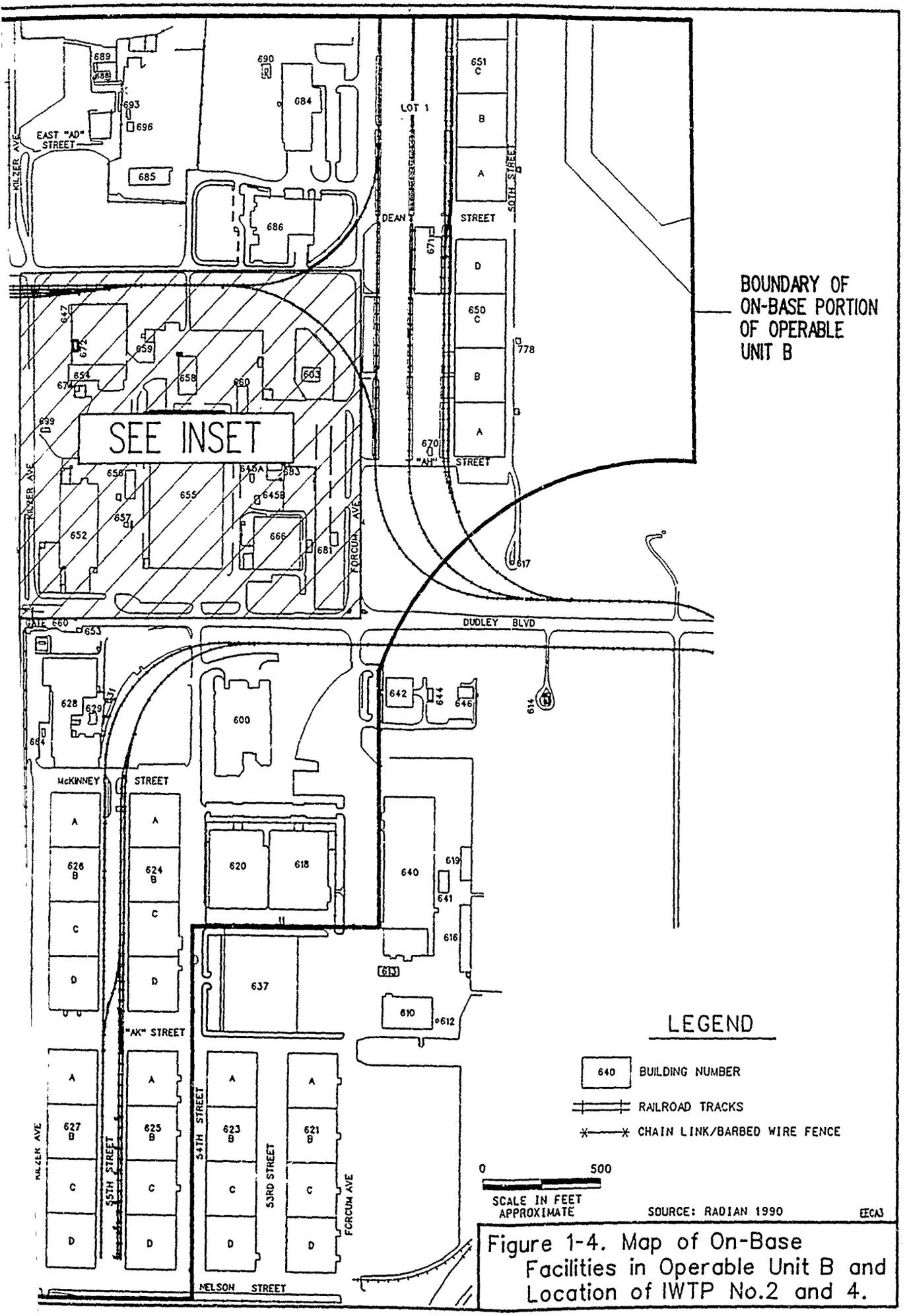

Figure 1-4. Map of On-Base Facilities in Operable Unit B and Location of IWTP No.2 and 4.

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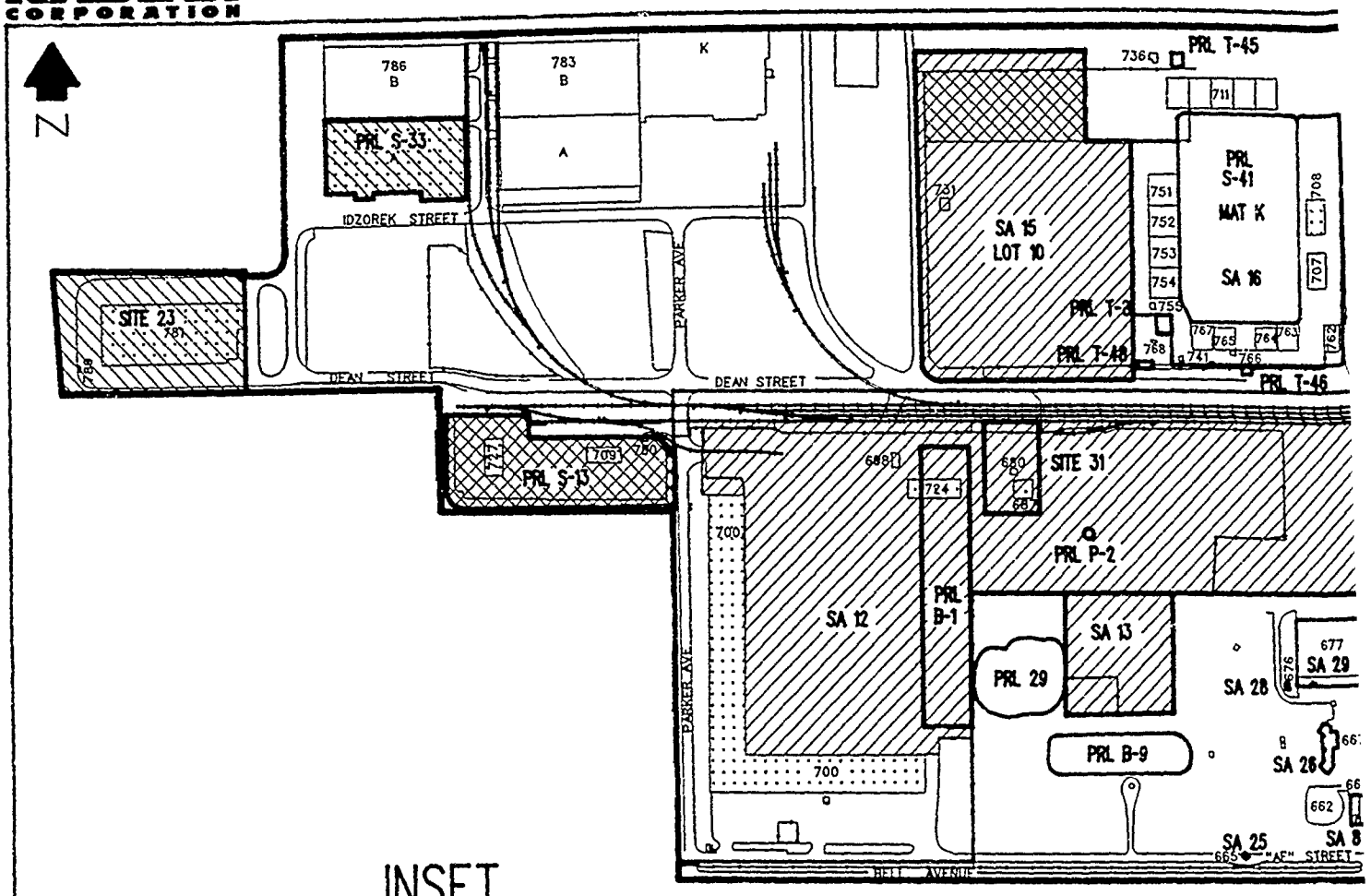

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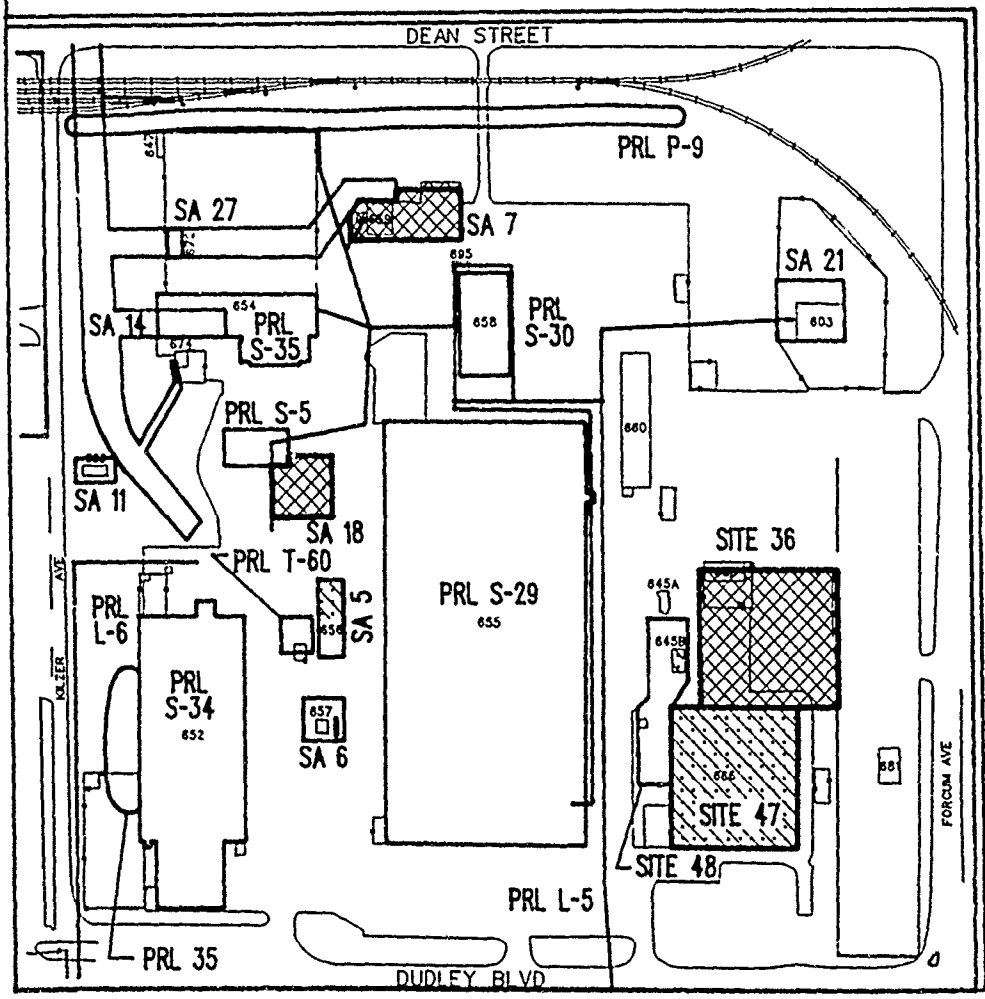

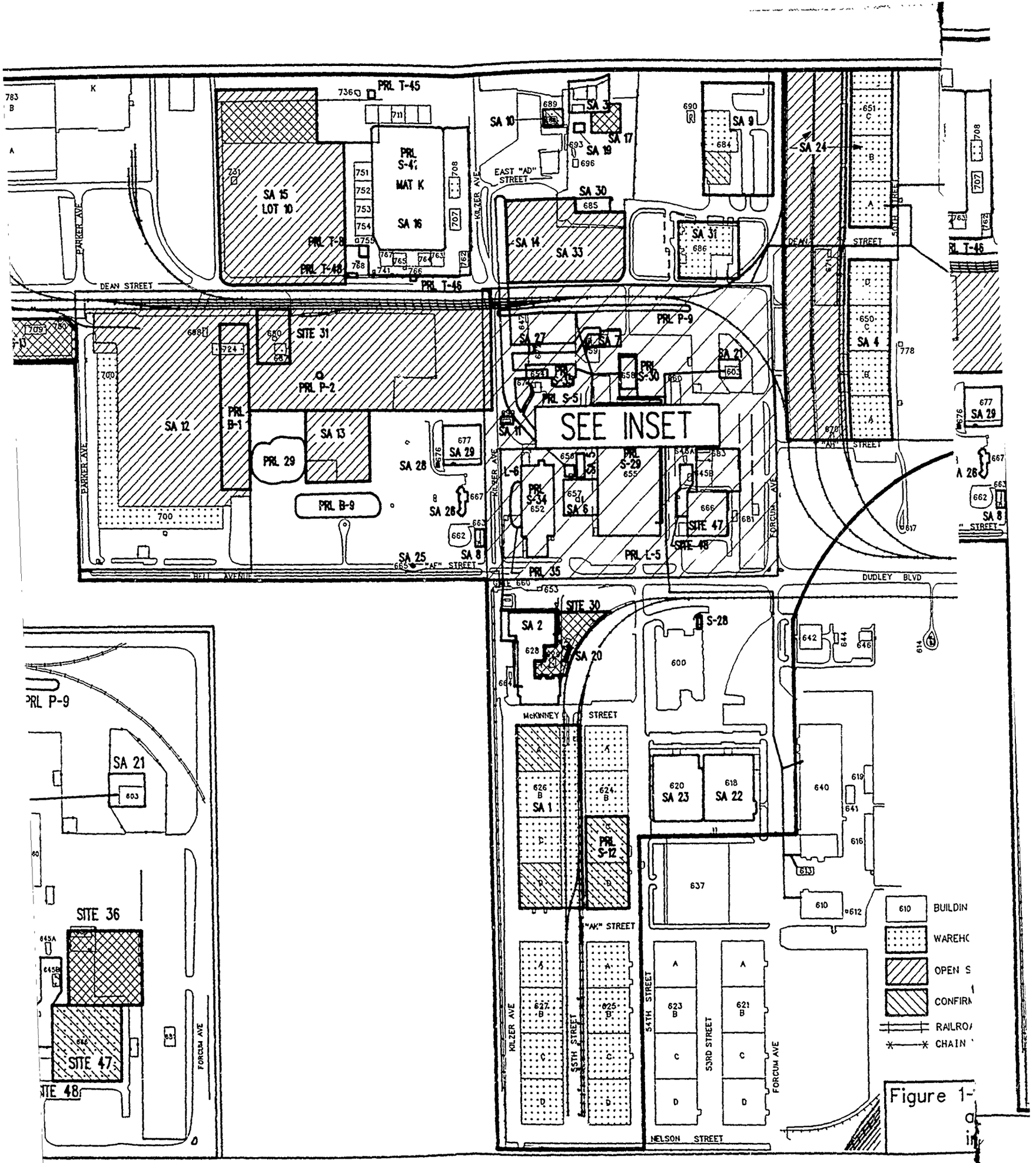
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PRL T-46
PRL T-48
PRL T-8
PRL P-9
PRL P-2
PRL B-1
PRL B-9
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PRL S-4
PRL S-5
PRL S-12
PRL S-28
PRL S-29
PRL S-30
PRL S-34
PRL L-5
PRL L-6
MAT K
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SITE 36
SITE 47
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KILZER AVE
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DUDLEY BLVD
McKINNEY STREET
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RAILRO
CHAIN

Figure 1-

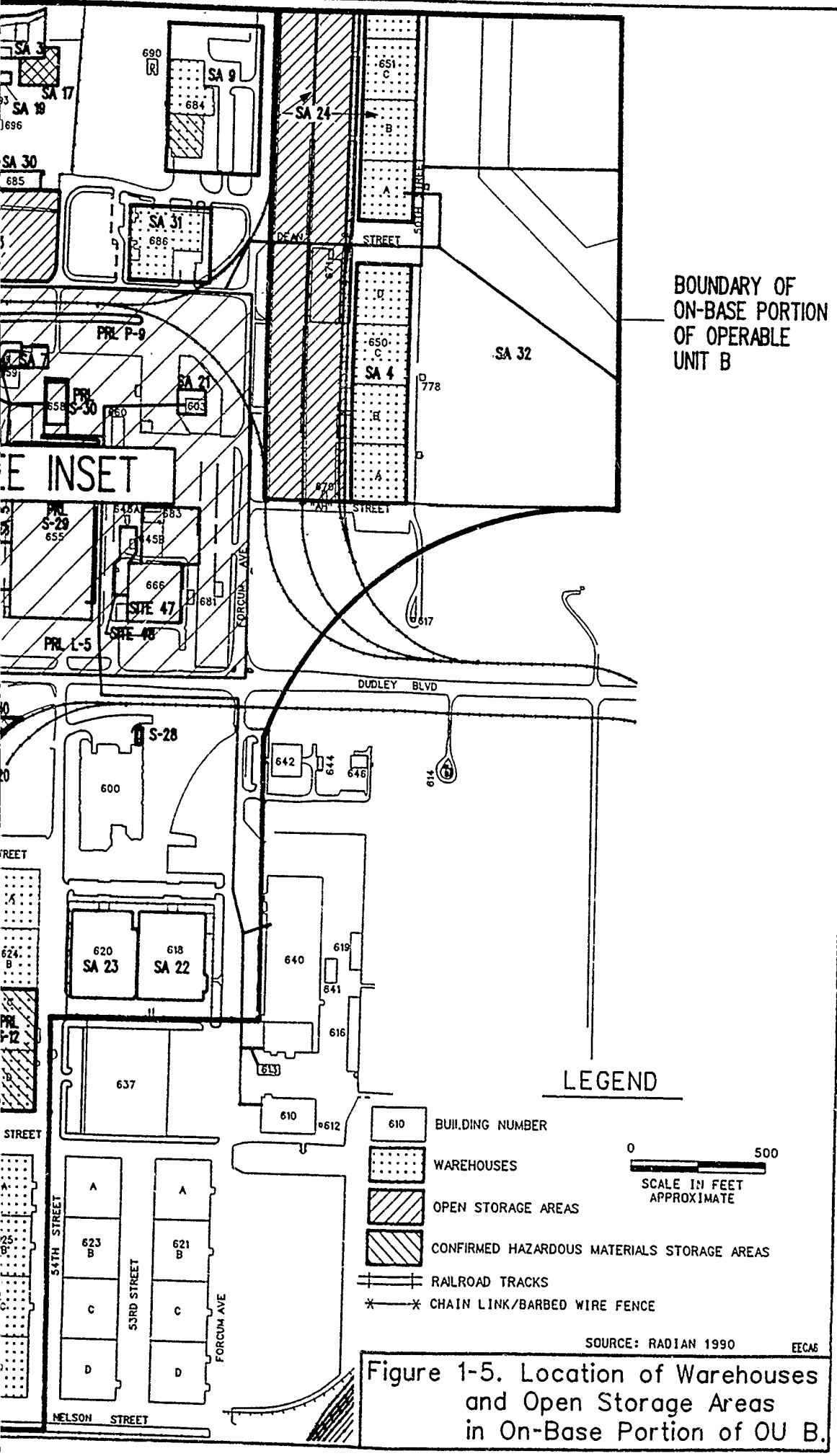
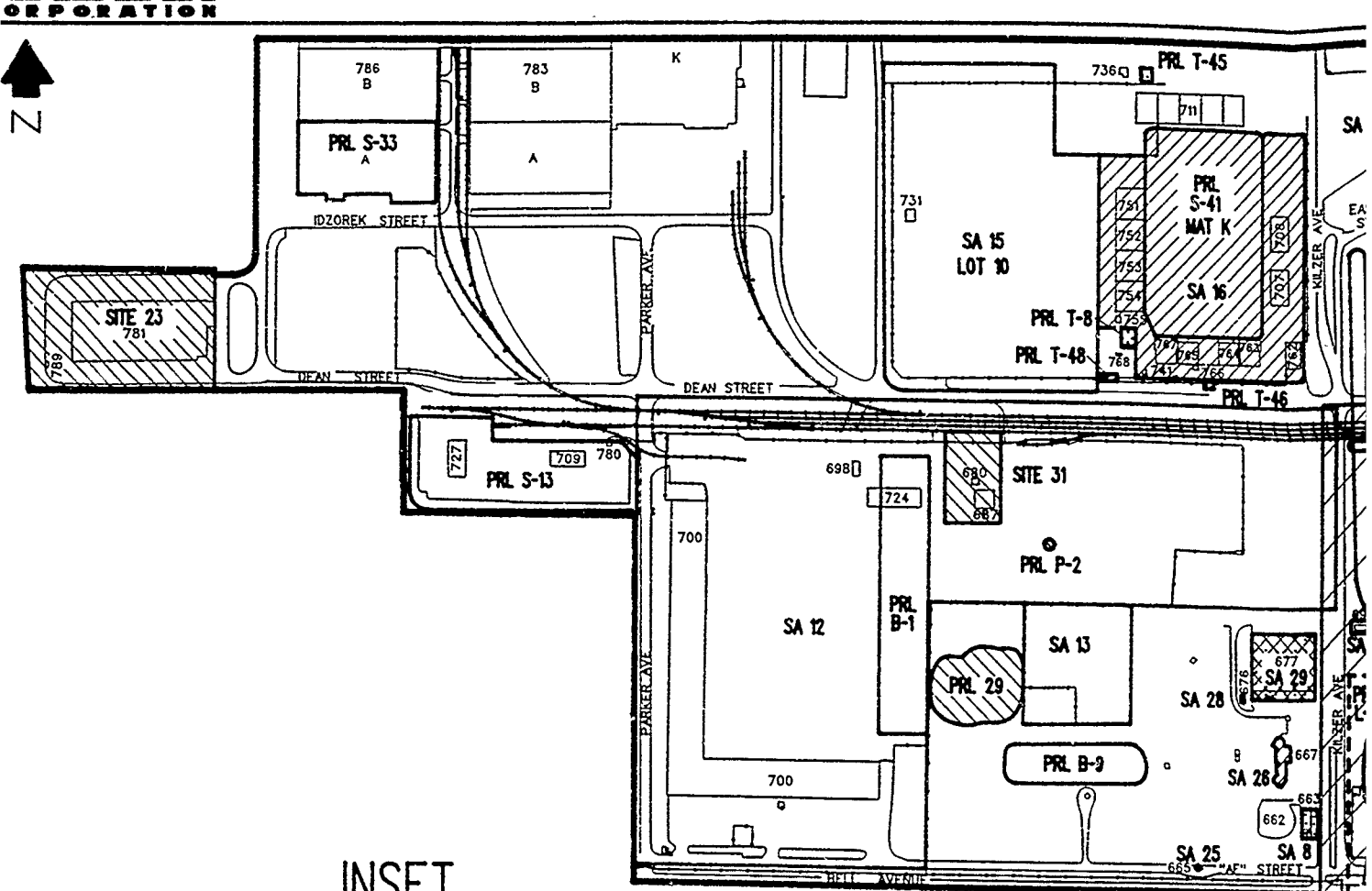


Figure 1-5. Location of Warehouses and Open Storage Areas in On-Base Portion of OU B.



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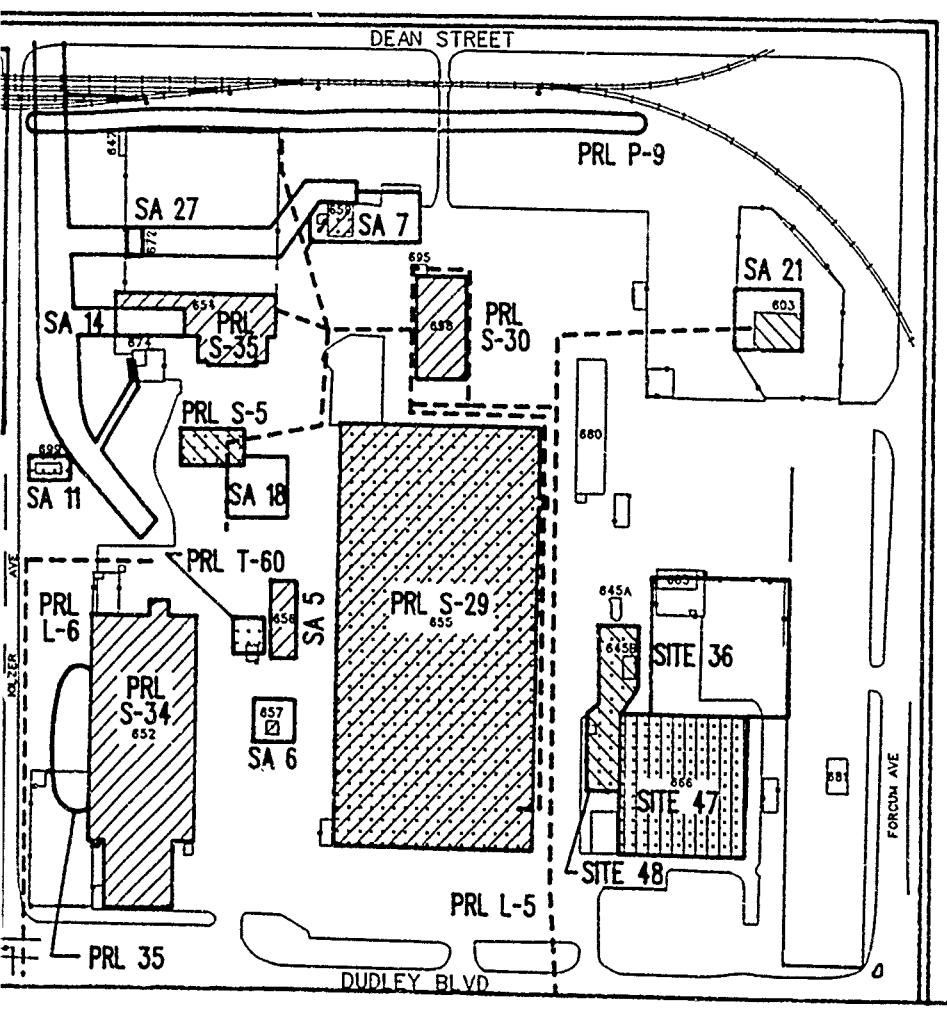

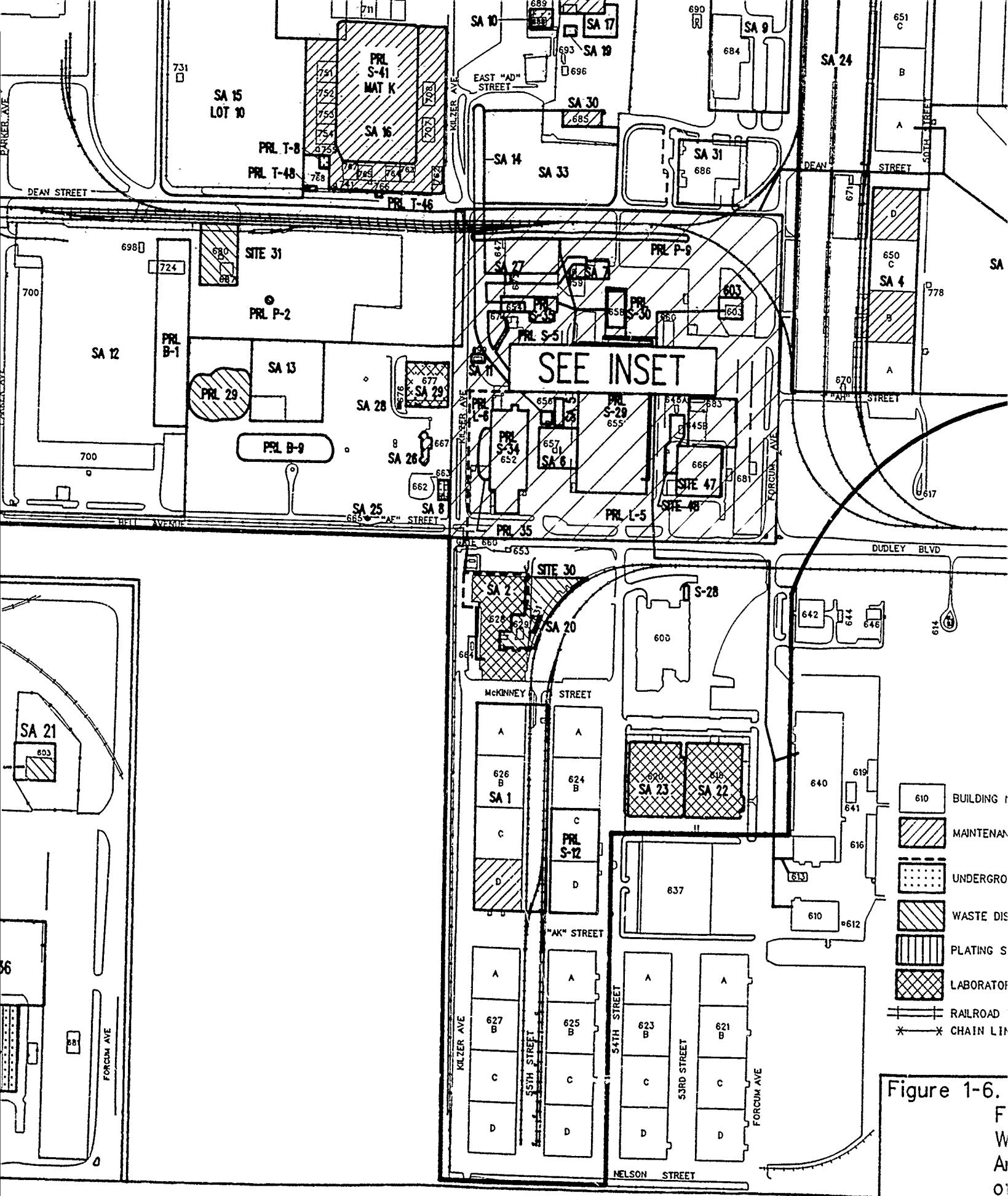
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Figure 1-6.

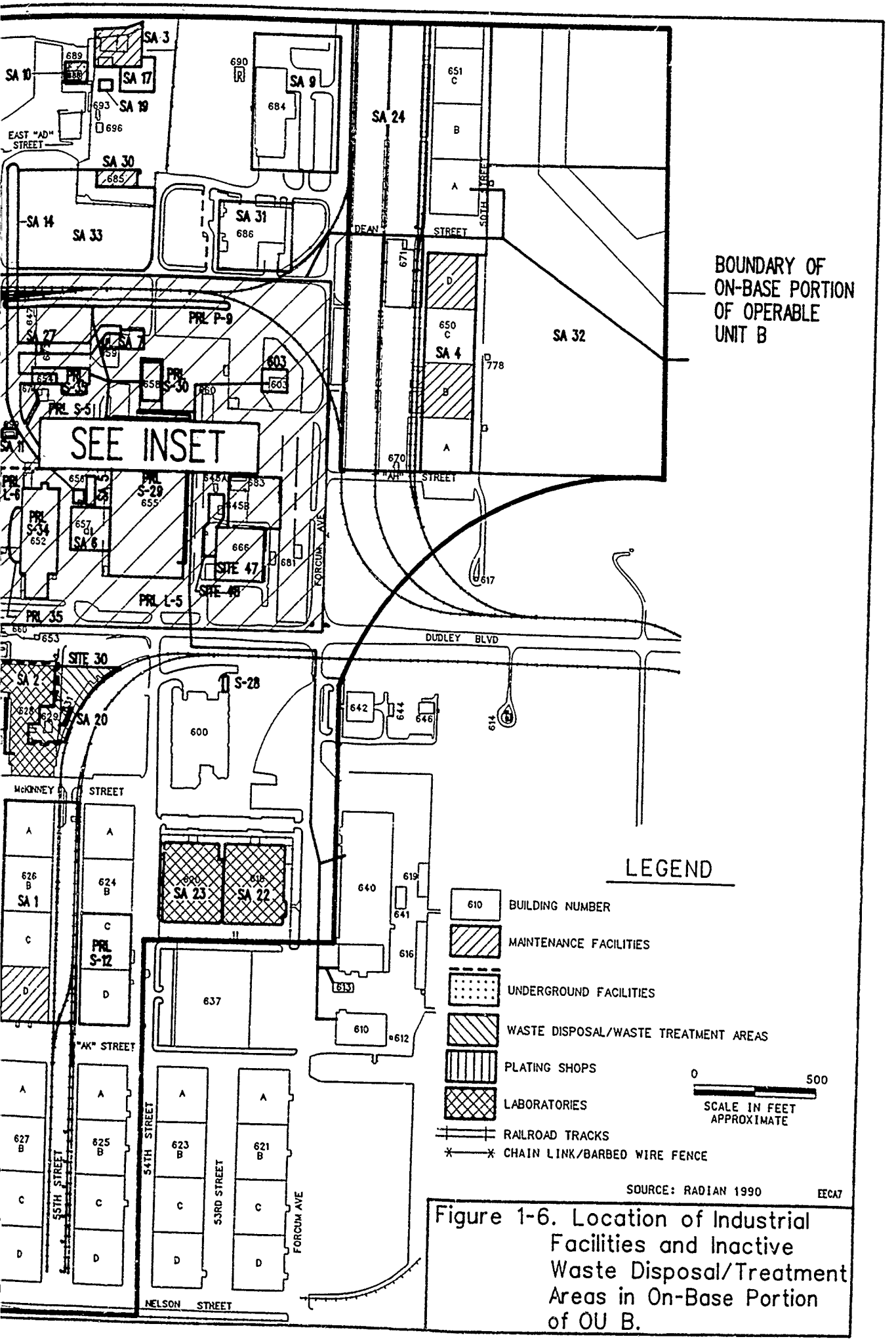

Figure 1-6. Location of Industrial Facilities and Inactive Waste Disposal/Treatment Areas in On-Base Portion of OU B.

628 was used for research and chemical analysis, and generated hazardous materials, including radionuclides. It is no longer in operation. Building 677 is an equipment calibration laboratory, and Buildings 618 and 620 are software and electronics laboratories; these three buildings generate little or no hazardous waste.

The warehouses and open storage areas of OU B are served by an extensive network of roads and railroad tracks. Major on-base access to OU B is via Dudley Boulevard, which connects the southwestern, southern, and eastern sides of McClellan AFB. Off-base access to OU B is via Gate 660 at Bell Avenue.

1.1.2 Site Topography and Surface Features

The land surface of McClellan AFB is a relatively level plain, which slopes gently to the west. Elevations range from 80 feet above mean sea level (msl) on the east side to approximately 50 feet above msl on the west side, a drop of 30 feet in elevation over approximately 2 miles. The major drainages in the vicinity are the Sacramento River, located approximately 6 miles west of McClellan AFB, and the American River, located approximately 4 miles to the south (Figure 1-7).

The major surface features at McClellan AFB include the north-south runway, taxiways, paved aircraft parking areas, aircraft maintenance hangers, and warehouses. Approximately forty percent of the surface of McClellan AFB is covered by building foundations, parking areas, runways, roads, and other paving; the remainder of the surfaces consists of grassy fields or soils with little or no vegetation. A system of open drainage ditches and covered storm drains direct runoff from the paved and unpaved areas to natural and man-made drainage channels.

Land elevation in OU B ranges from about 65 feet at the eastern boundary to about 50 feet at the western boundary. Approximately 60 percent of OU B is covered by building foundations and paving. Surface water runoff in the northwestern part of OU B flows into the Magpie Creek channel, which drains off-base to the west. Runoff from the southeastern part of OU B flows to Arcade Creek through artificial drainage ditches. Principal drainage areas are discussed in Section 1.1.6.

1.1.3 Soils

Soil types in the vicinity of McClellan AFB are extremely variable. The surface soils (less than five feet deep) have formed from mixed alluvium derived from

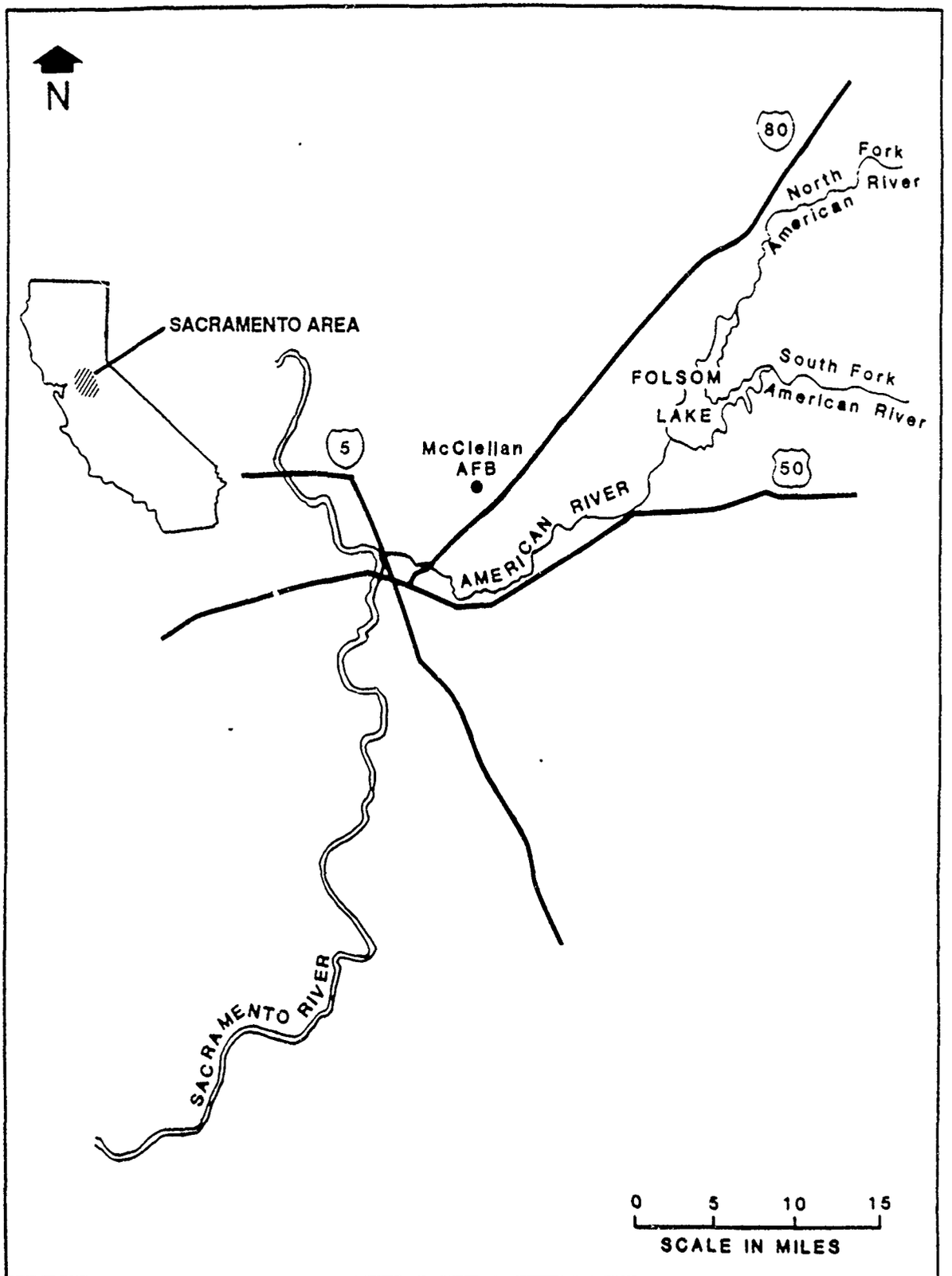

Figure 1-7. Major Drainages in the Sacramento Area.

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stream erosion of rocks in the Sierra Nevada granitic rock. A silica-cemented hardpan has developed over large areas at 20 to 40 inches below the surface. Surface textures are predominantly loams and sandy loams which are underlain by finer-textured loam and sandy clay loam horizons above the hardpan. Soils on McClellan AFB may not have the natural textures or layering of the original soils because of excavation and disturbance from development or covering by concrete and asphalt. Where soils are relatively undisturbed, permeabilities range from 0.6 to 2.6 inches per hour, depending on local amounts of clay and hardpan. The local soils are classified as San Joaquin fine sandy loam, Fiddyment fine sand loam, or San Joaquin-Xeralfic Arents complex. These soils have a low shrink-swell potential, a slight erosion potential, and a very low available water capacity of approximately 0.10 to 0.14 inches of water per inch of soil. These soils are primarily used for pasture; their agricultural capabilities are reported to range from fair to poor (McClellan AFB, 1987).

The primary surface soil types in OU B are urban land and xeralific arents, as shown on the McClellan AFB agricultural soils classification map (Figure 1-8). Urban land soils, which are indicated as mapping unit "A" on Figure 1-9, are those which have been covered by paving, buildings, or are otherwise obscured. Xeralfic arents are soils that have been mixed by plowing, spading, or other human activities and, therefore, do not contain their natural soil horizons.

1.1.4 Surface Water

Surface water from McClellan AFB drains toward and is discharged primarily into four small creeks: Robla, Don Julio, Magpie, and Arcade. These creeks are fed by the McClellan AFB storm drainage system, which is a network of underground pipes, culverts, and open drainage ditches that collect runoff water from streets and other paved areas. Two of these creeks, Robla and Magpie, originate off-base to the east, and convey surface water onto the base from the east. The drainage patterns and the courses of Robla, Don Julio, and Magpie Creeks have been modified on McClellan AFB for building, runway, and road construction. The most southerly creek, Arcade, does not cross McClellan AFB.

Because of surficial topography, McClellan AFB is divided into four drainage areas, each of which runs from east to west (Figure 1-9). Surface water originating in each area is channeled into the nearest creek draining that area and is discharged from the base to the west (Robla and Magpie) or to the south (Arcade). All

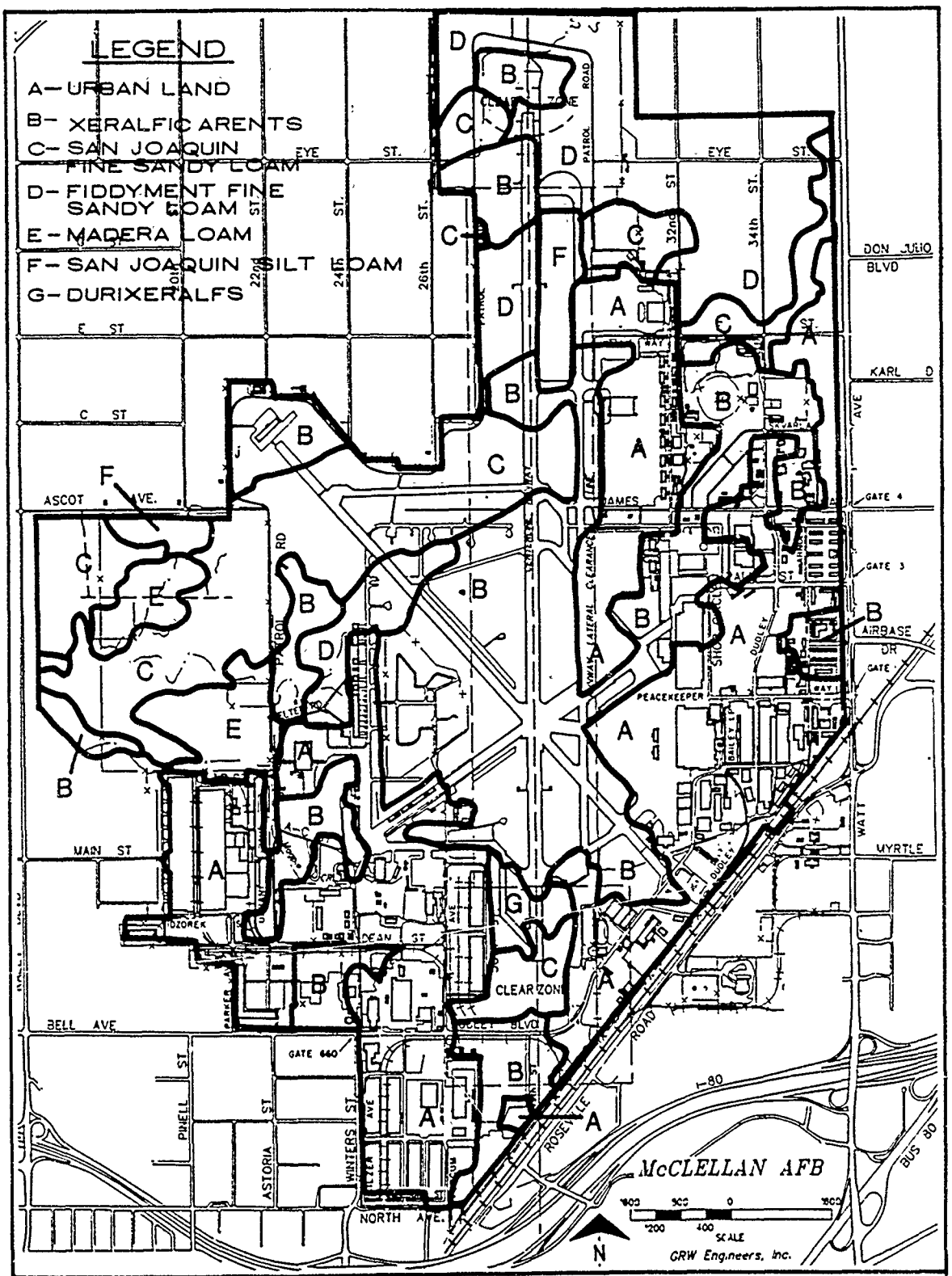

Figure 1-8. Soils Classifications at McClellan AFB.

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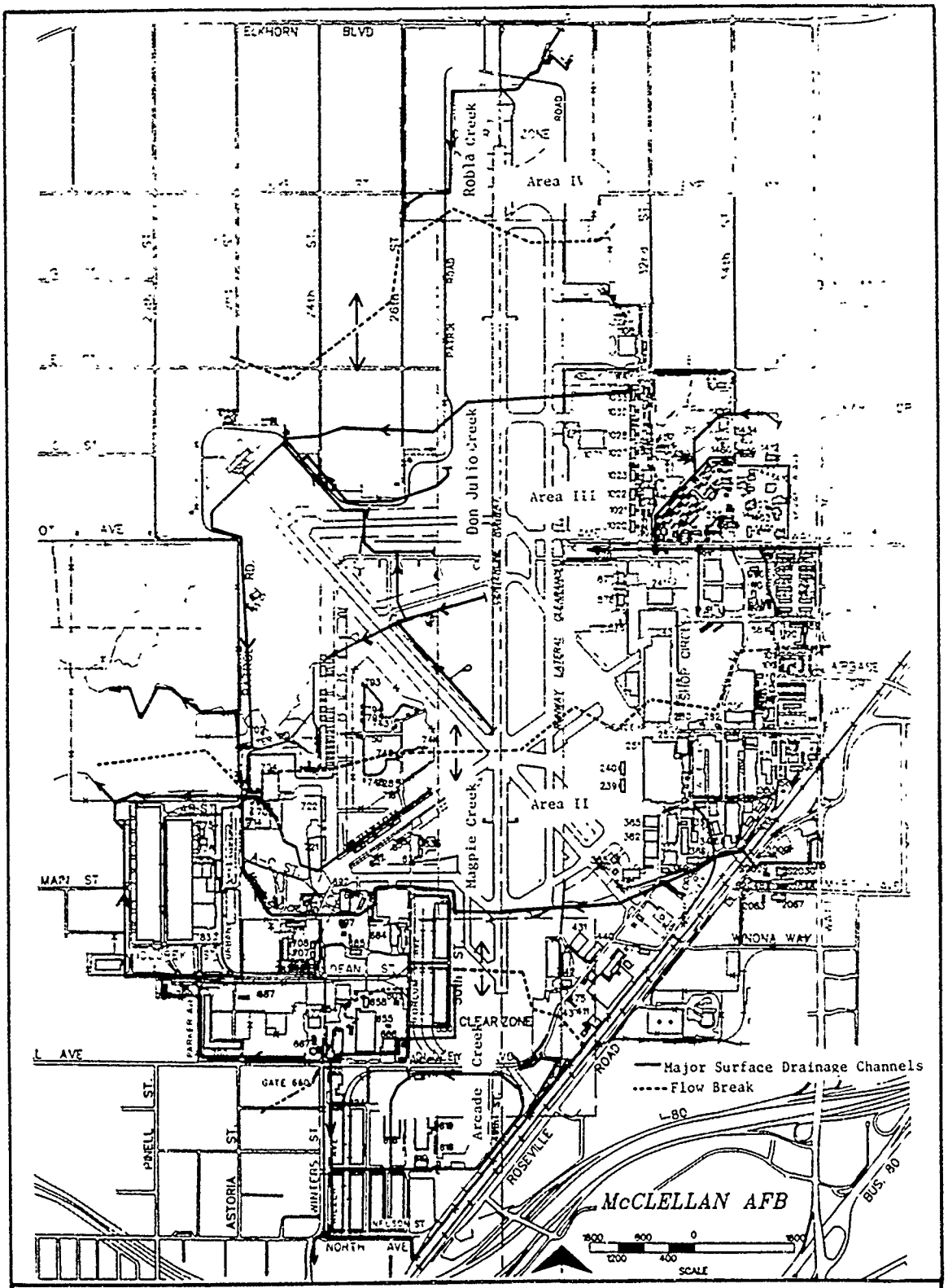

Figure 1-9. Surface Drainages at McClellan AFB.

0890-074-5

four creeks flow into the Natomas East Drainage Canal southwest of McClellan AFB. The canal flows south and west until it discharges into the American River.

Magpie Creek enters the southeast side of the base near Myrtle Avenue and flows generally to the west across the base. Most of Magpie Creek has been channelized and a portion of it has been routed underground beneath the southern end of the runway. Magpie Creek is unpaved west of Patrol Road and the creek exits the base approximately 650 feet east of Raley Boulevard. Magpie Creek handles 38 percent of the drainage on the base and has major ponding problems (McClellan AFB, 1987). The 100-year flood plain map (Figure 1-10) indicates that Magpie Creek, as well as Robla and a portion of Don Julio creeks, will flood during the 100-year storm event.

Because of extensive paving and storm drain installation, recharge of groundwater by surficial water at McClellan AFB is extremely limited. Recharge is also restricted by the impermeable hardpan layers that are common in McClellan AFB soils. The most significant recharge source on the base is probably infiltration through unpaved stream channels and drainage ditches. Discharge of groundwater onto the surface at the base is precluded by the depth to groundwater, which is typically about 90 to 100 feet below the ground surface.

Operable Unit B is split into two drainage areas by a slight topographic high that trends from southwest to northeast through the middle of the operable unit. Surface water north of this dividing line flows into Magpie Creek, and surface water south of this line is discharged into Arcade Creek. The 100-year flood plain map indicates that the part of northern section of OU B along the course of Magpie Creek will be flooded during the 100-year storm event (Figure 1-10).

1.1.5 Groundwater

Beneath McClellan AFB and adjacent areas, groundwater migrates through the pores of unconsolidated sediments deposited by runoff from the Sierra Nevada. Groundwater flows beneath McClellan AFB from the east and is drawn toward depressions in the groundwater surface created by well pumping. The entry and spread of contaminant compounds has locally affected the quality of groundwater and has brought about groundwater investigations and remedial actions.

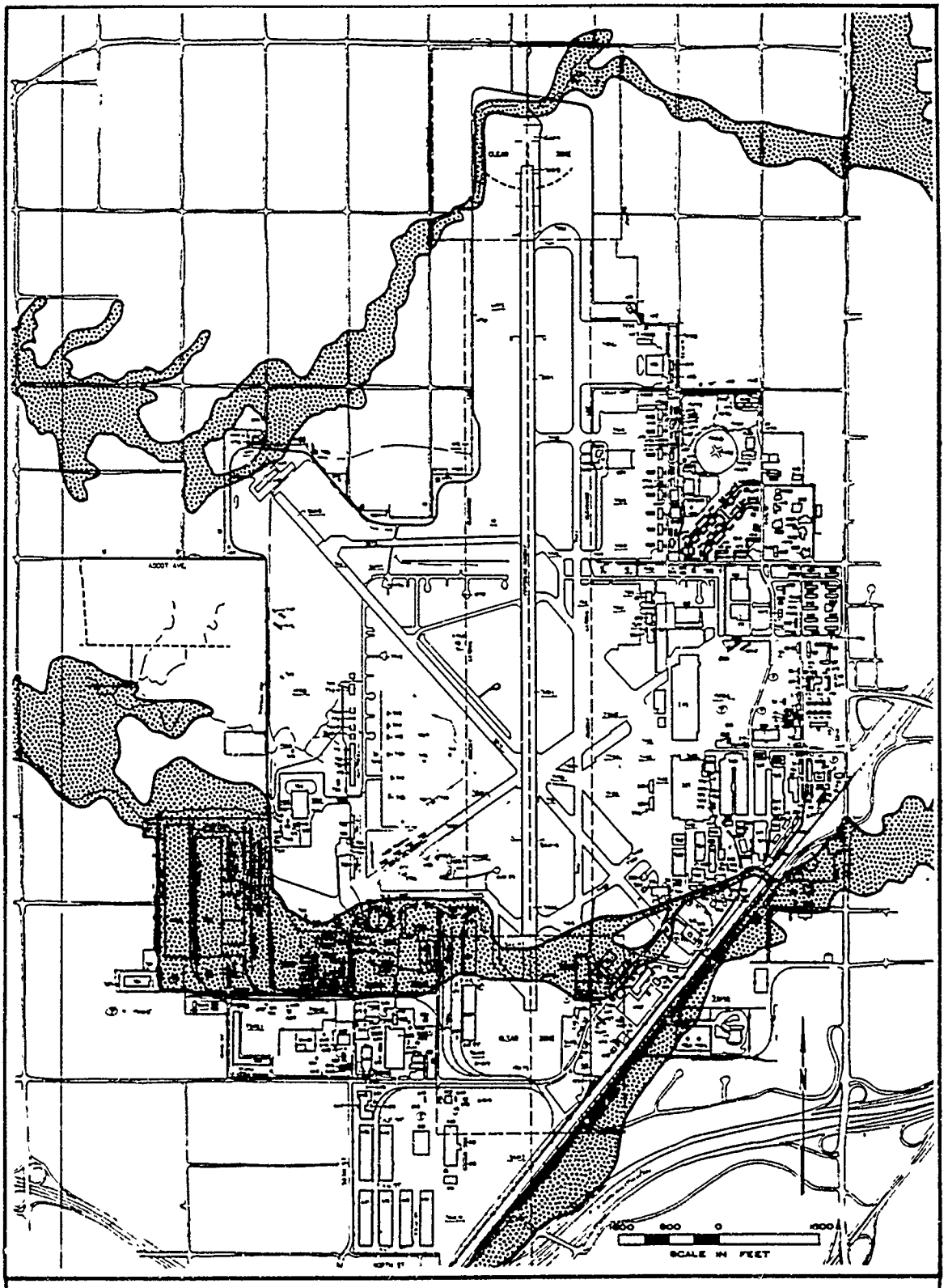

Figure 1-10. 100-Year Flood Plain at McClellan AFB.

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Groundwater Hydrology

In the vicinity of McClellan AFB, fresh groundwater may occur in deposits from depths of approximately 90 to 1400 feet, but water is withdrawn primarily from production wells screened from approximately 145 to 400 feet below ground surface (BGS). Groundwater recharge in the eastern portion of the Sacramento Valley occurs as a result of leakage from streams and rivers, percolation of precipitation and irrigation water through soils, and migration of runoff along fracture zones and formation contacts in the foothills of the Sierra Nevada. The upper waterbearing zone in the Sacramento Valley is recharged predominantly through percolation of water from the ground surface. This process is generally inhibited by the presence of a hardpan layer. Therefore, groundwater recharge to the upper zone occurs predominantly through past and present stream channels where they penetrate the hardpan. These channels consist of permeable sands and gravels that allow percolation of surface waters into the saturated zone. The permeable buried stream channels interlayed with less permeable sediments has resulted in a network of tabular, shallow aquifers throughout Sacramento County (CDWR, 1974).

A large portion of groundwater discharge in the Sacramento Valley is attributable to water supply well withdrawals. Since the turn of the century, the extraction of groundwater for irrigation, industrial, municipal, and domestic uses has substantially lowered groundwater levels. In the vicinity of Sacramento, groundwater flows toward two groundwater depressions (Figure 1-11). One of the depressions is centered just south of McClellan AFB, and the second is centered south of Sacramento approximately 15 miles south of McClellan AFB. These depressions are caused by the pumping of municipal and private wells. When McClellan AFB base wells are inactive, the regional groundwater flow beneath the base, and specifically beneath OU B, is to the south/southwest. Municipal wells located south of McClellan AFB that lie within the northern groundwater depression and cause southerly flow are shown in Figure 1-12. However, when base wells are pumping, groundwater flow under the base is strongly affected by the withdrawal of groundwater. Groundwater withdrawals at a principal McClellan AFB supply well in OU B cause groundwater at depths of 100 to 350 feet beneath OU B to flow toward the well from on-base areas to the northwest, northeast, and southeast and from off-base areas to the southwest of the well (Appendix A, Section 3.2).

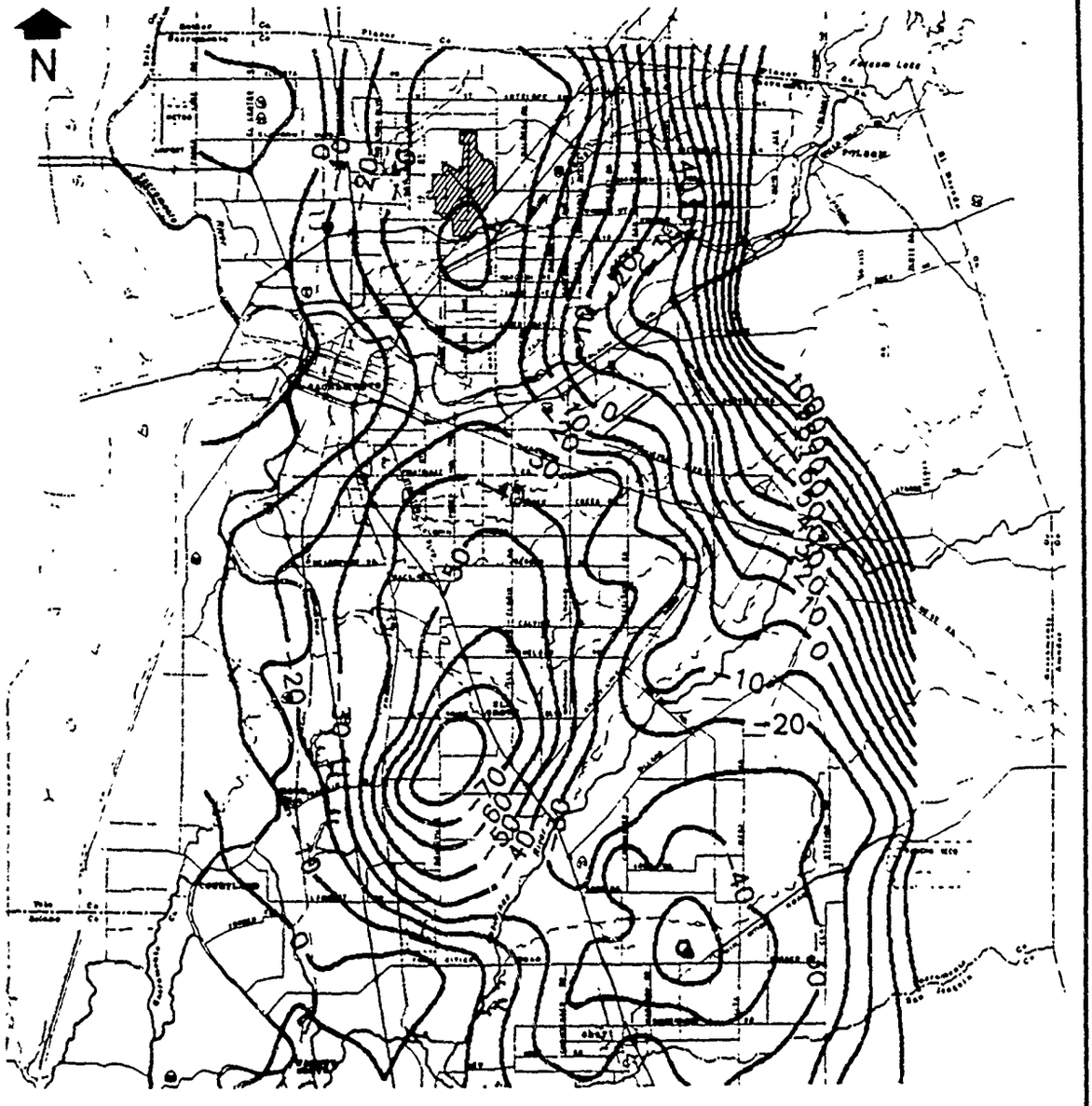


Figure 1-11. Groundwater Depressions Beneath Sacramento County Created by Supply Well Pumping, Fall 1989.

SOURCE: County of Sacramento Department of Public Works
Water Resources Division, 1989

0990-074-11

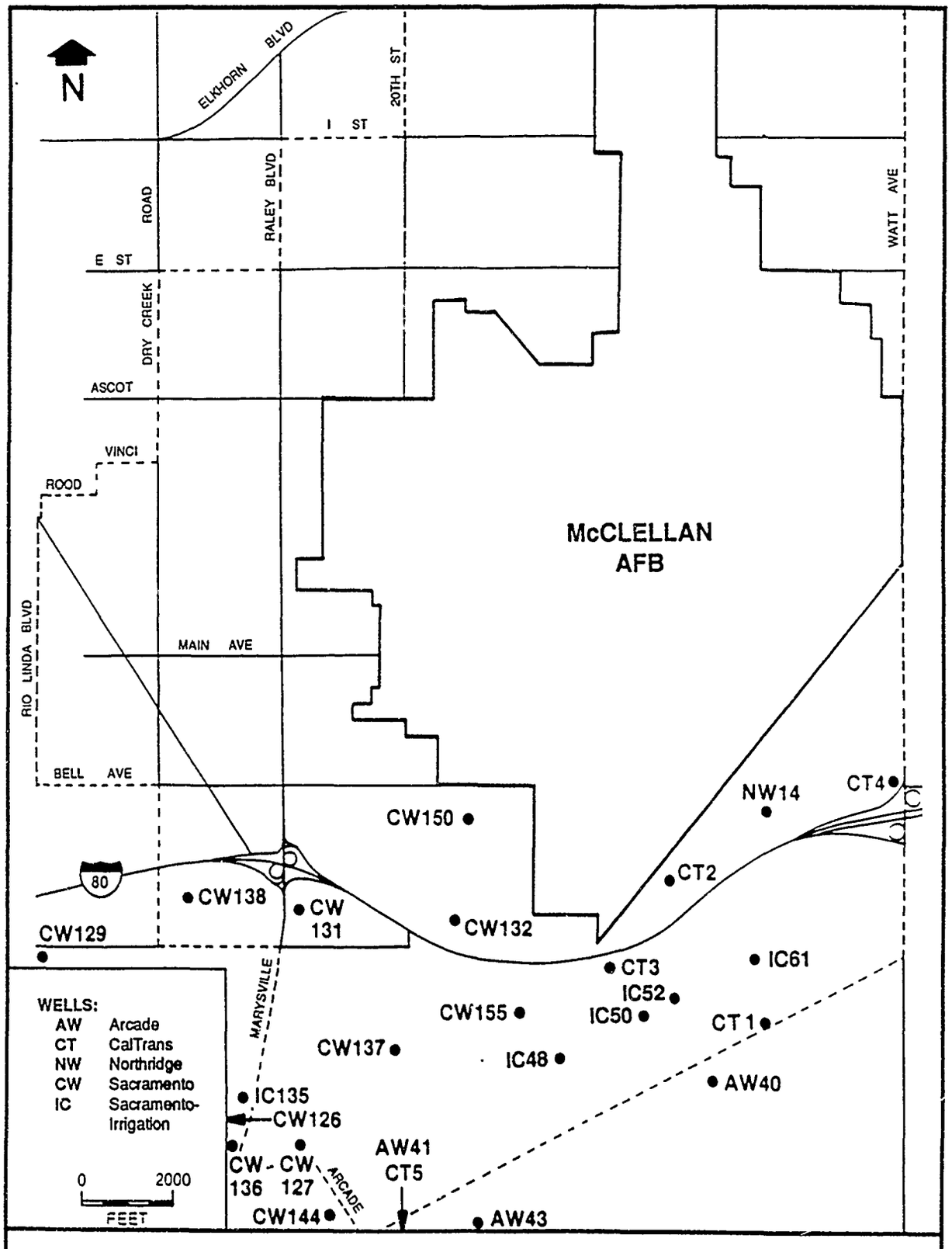


Figure 1-12. Location of Municipal Wells in or Near OU B.

0990-074-10

Geology

Groundwater and contaminant migration beneath McClellan AFB is controlled and influenced by geologic and hydrologic variability. The subsurface deposits beneath OU B and much of McClellan AFB to a depth of 430 feet are sands, gravels, silts, and clays that were deposited by streams and floods flowing down from the Sierra Nevada over the last two million years. Evidence from the subsurface deposits of OU B and other areas of McClellan AFB suggests that streams active in the Pleistocene and Holocene epochs flowed from east to west, or northeast to southwest, through McClellan AFB and OU B. Stream deposits have great length along their downgradient course but are narrow in width and shallow depth. Deposits consisting of one lithologic type, therefore, are limited in horizontal and vertical extent. Changes in the courses of streams over time cause the relative location and thickness of the coarsest stream bed sands and gravels and overbank silts and muds to vary. As a result of stream deposition and migration, characteristics of the deposits that affect groundwater flow (e.g., the horizontal and vertical permeability and thickness of deposits) vary widely with location and depth beneath McClellan AFB. Sand and gravel deposits occurring in or near former stream channels have the greatest permeability. However, stream channel deposits at depths of 100 to 430 feet are relatively narrow, widely spaced, and frequently separated from sands and gravels above and below by less permeable silt and clay deposits. The hydraulic properties of the deposits beneath McClellan AFB cannot be generalized because they vary from location to location.

The geology of deposits beneath OU B is similar to the remainder of McClellan AFB. Coarse sands and gravels deposited by streams lie 190 to 430 feet BGS in the central part of OU B. Data from deeper deposits is limited, and so knowledge of the deeper geology is also limited. To the north and south and at depths less than 190 feet BGS, deposits consist of fine sands, silts, and clays. The finer deposits have lower permeabilities and slow the movement of groundwater and any contaminants that are present.

Hydrogeology

The water table beneath McClellan AFB is typically 90 to 110 feet BGS and varies locally because of topography and the locations of cones of depression created by supply wells. Beneath the water table are deeper waterbearing zones that are hydrologically separated over large areas but are locally interconnected where continuous fine-grained deposits are absent. Where they are present, fine-grained

deposits, such as silts and clays, have the ability to restrict vertical movement of groundwater. Much of the groundwater flows horizontally through the coarser deposits in several groundwater zones. Because of local changes in the thickness or grain size of deposits, groundwater may move vertically between shallow and deeper groundwater zones.

To evaluate the movement of groundwater and contaminants beneath McClellan AFB, the subsurface from the water table to a depth of 430 feet BGS has been divided into six geohydrologic zones using geologic and hydrologic criteria. Each geohydrologic zone consists of a high to moderate permeability zone of sands or gravels and an overlying low permeability zone of silts or clays which appear to form a reasonably distinct hydraulic unit within OU B. The geohydrologic zone designations are from shallowest to deepest, A, B, C, D, E, and F. Only one well has been completed in the F zone, and hydraulic conditions in this zone have not been evaluated. Beneath OU B, groundwater in each of the zones may move at a greater velocity or in a slightly different direction than in the zone above or below because of differences in permeability and hydraulic effects between zones.

Groundwater Flow

When McClellan AFB supply wells are inactive, groundwater in the A, B, C, D, and E geohydrologic zones beneath OU B flows to the south or southwest, toward the large groundwater depression created by municipal well pumping for the City of Sacramento. However, when BW-18 (Figure 1-13) is pumping, groundwater flow under OU B is strongly affected by the withdrawal of groundwater. During much of 1989 and early 1990, BW-18, the principal supply well for McClellan AFB, was pumped at a rate of approximately 1140 gallons per minute (gpm) (dry season) and 930 gpm (wet season), 20 to 24 hours a day, seven days a week. Hydrologic data collected during 1989 and 1990 indicate that BW-18 significantly alters groundwater flow within all zones and affects both vertical and horizontal gradients within each zone beneath OU B (See Appendix A, Section 3.2). Under the current daily rate of discharge, a large portion of flow through the A, B, C, D, and E geohydrologic zones is captured by BW-18. The effects of pumping by BW-18 differ within each zone and the hydraulic response by each zone is dependent upon hydraulic separation between zones, permeability, depth, recharge from surface waters, and the depth of screen intervals in BW-18.

In general, the cone of depression created by pumping BW-18 within OU B is elliptical and trends northeast to southwest. The effects on water levels of pumping

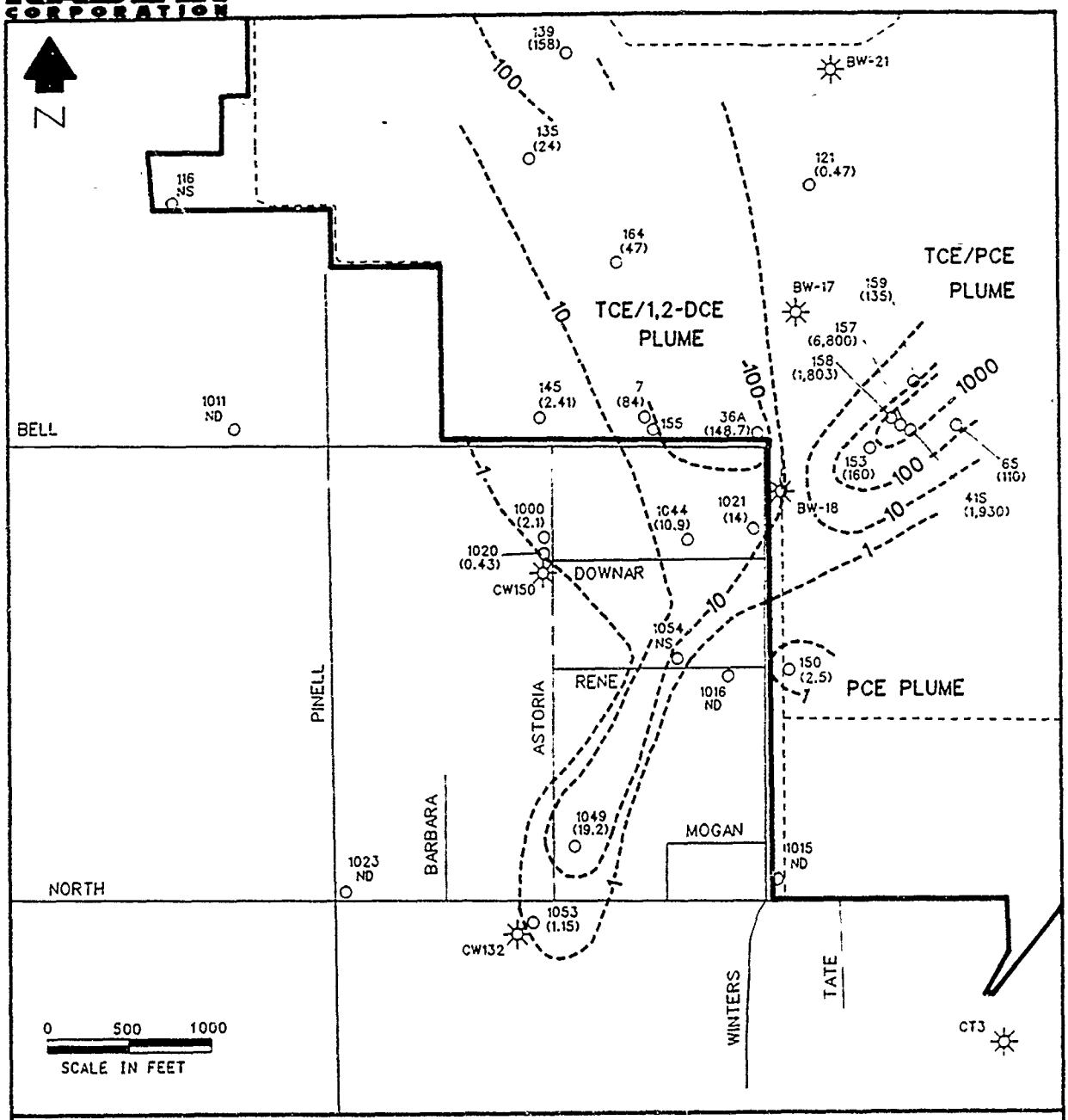


Figure 1-13. Total Volatile Organic Compound Concentrations (ug/L) in A Zone Monitoring Wells, Operable Unit B, January and February, 1990.

BW-18 decreases with distance from the well; that distance varies between zones. Base Well 18 has four screened intervals occurring from 169 to 185 feet (B zone), 210 to 260 feet (C zone), 304 to 349 (D zone), and 378 to 387 feet (E zone) BGS. In general, the water-level data show that the C geohydrologic zone is the most strongly affected by BW-18 because the zone experiences the largest and most widespread difference in water levels between pumping and non-pumping conditions. The C zone is the most affected because the largest screened interval (50 feet) of BW-18 and the most permeable deposits occur in this zone. The B zone, however, is also strongly influenced near BW-18 although the supply well is only screened over 16 feet in this zone. Lower permeability deposits in the B zone and partial hydraulic connection with the C zone may contribute to BW-18's strong effect on the zone. The hydraulic impacts of BW-18 are less in the D zone and are least, but still important to groundwater flow, in the E and A zones. Pumping of BW-18 alters both vertical and horizontal hydraulic gradients in all zones. Vertical gradients between zones which are upward when BW-18 is not pumping, are downward from A to B and B to C zones when the base well is pumping. Base Well 18, however, did not have the same impact in the past that it currently has because it was pumped much less frequently from 1978 to 1989. It was shut down entirely from 1981 to 1985 when contaminants were detected in its discharge and it could not be used for McClellan AFB water supply.

In addition to BW-18, CW-132 (Figure 1-12) was actively pumping during April and May 1989. City Well 132 pumped approximately 700 gpm, averaging 700 hours per month until June 1989 when pumping was stopped. Analysis of the hydrologic data indicates that CW-132 alone had a lesser effect on groundwater flow under OU B than BW-18. When BW-18 is off, groundwater flow beneath OU B is not strongly influenced by CW-132, the nearest municipal well, but is drawn southwesterly toward the cone of depression for CW-132 by the large, pumping-induced groundwater depression created by the City of Sacramento well field. This well had a lesser effect on groundwater flow because it pumped at a lower rate and less frequently than BW-18.

Groundwater Quality Beneath OU B

Historical and recent analytical data for samples collected from on-base monitoring wells show that a suite of VOCs are present within each of five geohydrologic zones in OU B. Contaminant plumes are represented on maps of OU B by dashed isopleth lines. The lines were approximated from contaminant concentrations detected in monitoring well samples and from historical and recent groundwater flow directions. Beneath the areas enclosed by the isopleths, contaminant concentrations in

groundwater are estimated to range between values indicated on the adjacent isopleths (Figures 1-13, 1-14, 1-15, 1-16, and 1-17). In off-base areas, three zones, A, B, and C, are known to contain VOCs. In the A zone, for which more data are available, three plumes can be identified: a widespread trichloroethene/1,2-dichloroethene (TCE/1,2-DCE) plume, a trichloroethene/ tetrachloroethene (TCE/PCE) plume, and a PCE plume (Figure 1-13). The TCE/1,2-DCE plume has been detected in the A, B, C, D, and E geohydrologic zones, the TCE/PCE plume in the A and B zones, and the PCE plume in the A and B zones. Analytical data collected over several years led to the conclusion that contaminants have migrated both vertically and horizontally in groundwater beneath OU B.

Volatile organic compounds have migrated to the south beyond the base boundary from locations on McClellan AFB and are detectable at lower concentrations in monitoring wells in the off-base areas. The increase in TCE and 1,2-DCE concentrations in the upgradient flow direction within OU B indicate a source for the TCE/1,2-DCE plume northwest of BW-18, probably in OU C, and a source for the TCE/PCE plume northeast of BW-18, in the vicinity of Monitoring Well (MW) 157 (Figure 1-13).

Dissolved contaminants in groundwater occurring in the southern part of the TCE/1,2-DCE plume between BW-18 and CW-132 could have migrated south of BW-18 when the well was inactive, presumably from 1981 to 1985, or when it was pumped less frequently than it was in 1989 and the first six months of 1990. When the base well is operating (withdrawing 900,000 to 1,600,000 gallons per day 300 or more days per year), its effects on groundwater flow directions in the A, B, C, and D zones prohibits the migration of contaminants to the south from northeast or northwest of the base well. Groundwater gradients and analytical data for groundwater samples collected in January and February 1990 (shown as isopleths of total VOC concentration in Figures 1-13 through 1-17) suggest that groundwater containing contaminants in the A, B, and C zones are being drawn back northeastward toward the pumping well from the southwest. Contaminant plumes that have migrated to the southwest in the B and C zones are being drawn back to BW-18 from distances of at least 2500 feet. The contaminant plume in the A zone is being drawn back to the northeast from a distance of at least 1500 feet. The portion of the plume in the A zone that is greater than 1500 feet from BW-18 is not being drawn back to the northeast.

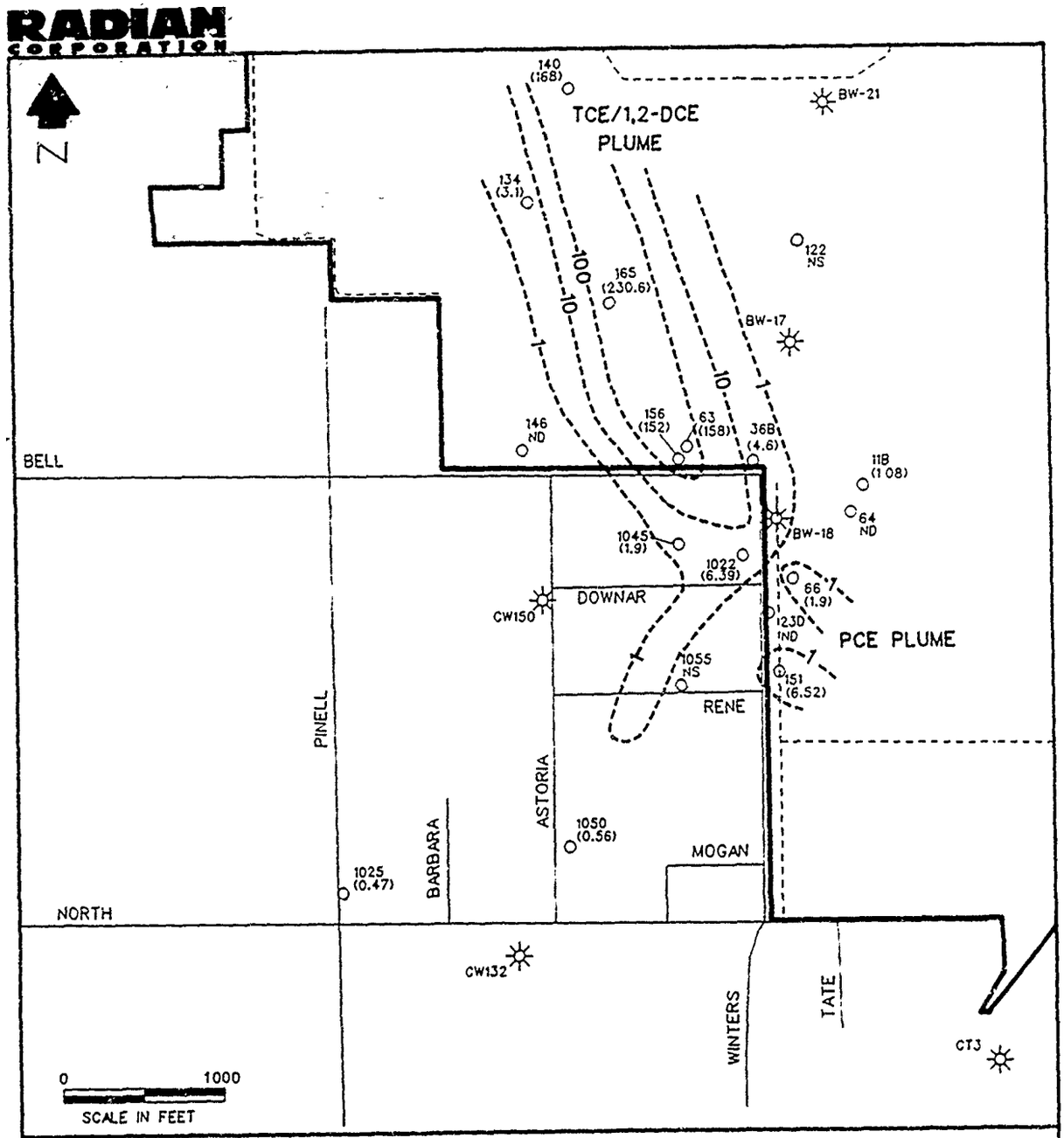


Figure 1-14. Total Volatile Organic Compound Concentrations (ug/L) in B Zone Monitoring Wells, Operable Unit B, January and February, 1990.

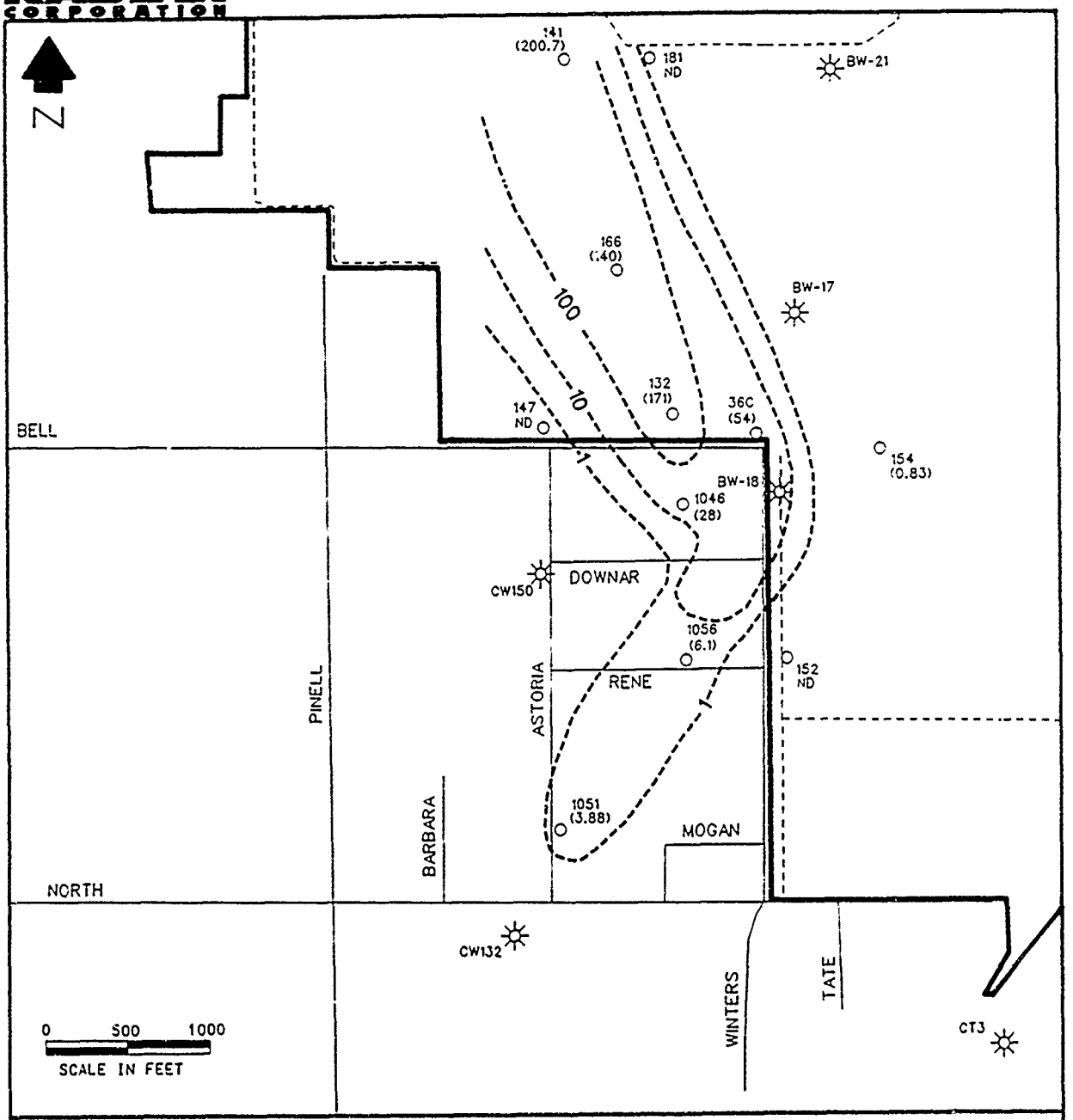


Figure 1-15. Total Volatile Organic Compound Concentrations (ug/L) in C Zone Monitoring Wells, Operable Unit B, January and February, 1990.

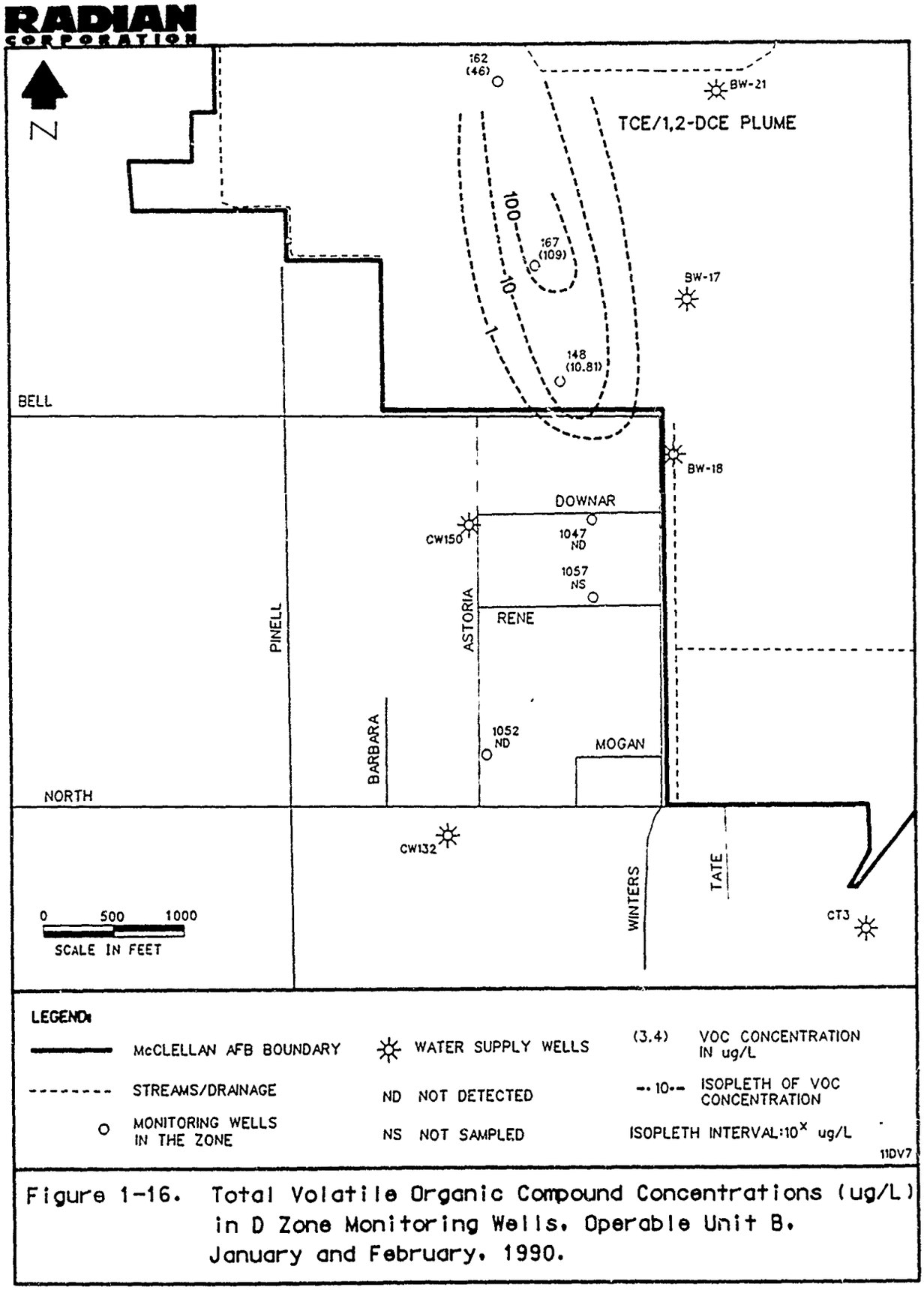


Figure 1-16. Total Volatile Organic Compound Concentrations (ug/L) in D Zone Monitoring Wells, Operable Unit B, January and February, 1990.

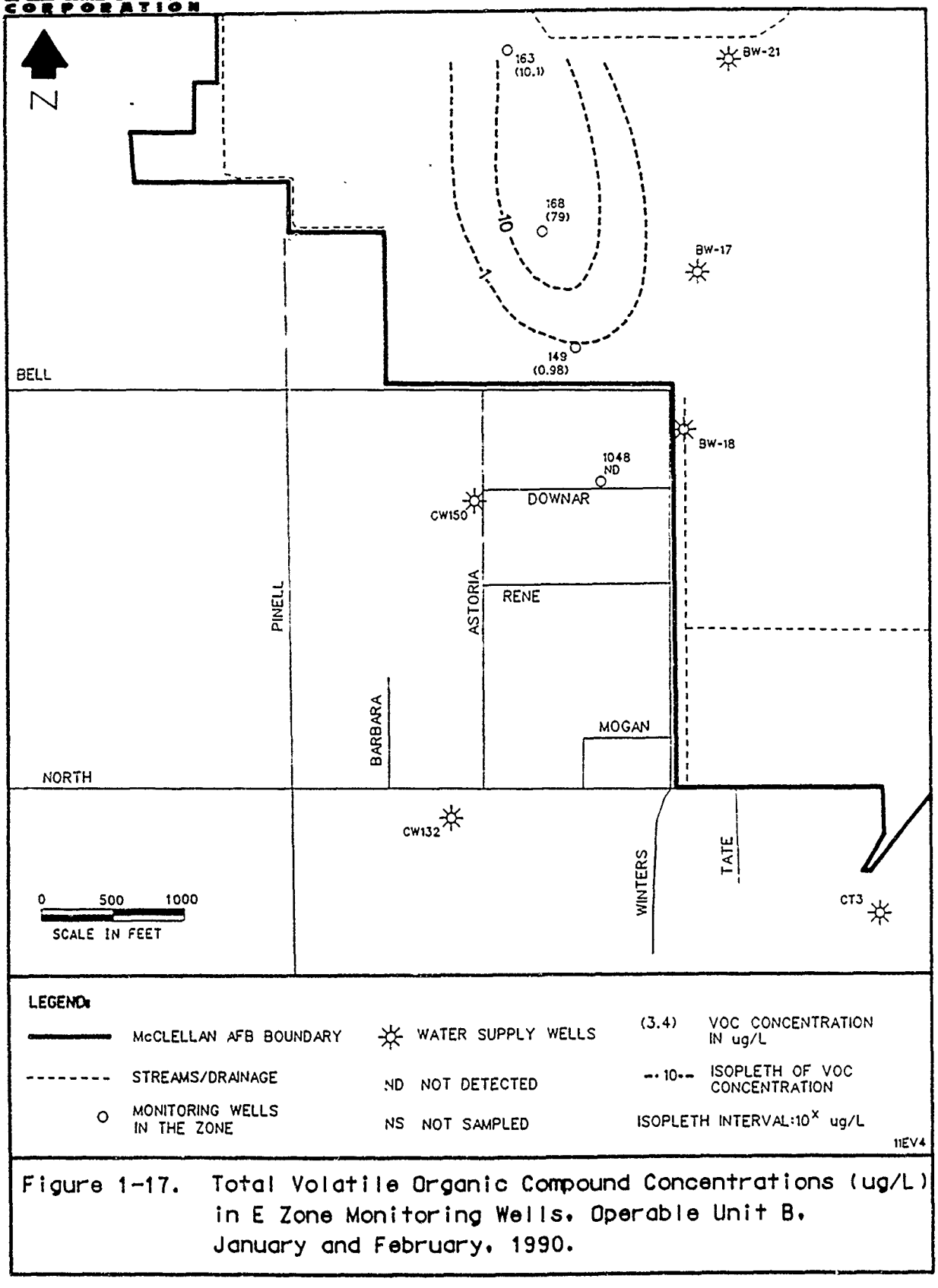


Figure 1-17. Total Volatile Organic Compound Concentrations (ug/L) in E Zone Monitoring Wells, Operable Unit B, January and February, 1990.

Groundwater Use

The communities in the vicinity of McClellan AFB receive water from private and municipal wells. Most of the water supply for North Highlands is supplied by the Arcade Water District. The Rio Linda Water District and the Northridge Water District also supply water to the North Highlands community. North Sacramento receives water from the City of Sacramento Water Department. Private wells are still in use in the area north of El Camino Boulevard in North Sacramento. In the area adjacent to McClellan AFB, on the west and southwest, private supply wells are used only for irrigation. Rio Linda and Elverta receive water from the Rio Linda Water District and from private wells.

McClellan AFB obtains water from on-base groundwater wells. Four are currently in use; the principal supply well is BW-18 located within OU B. The Northridge Water District also supplies water to McClellan AFB from an off-base well when the four base wells cannot meet demand.

Volatile organic compounds were detected in groundwater migrating beneath McClellan AFB and adjacent areas to the west and southwest during sampling from 1981 to 1985. The pumping of domestic, municipal, or McClellan AFB wells for water supplies creates the potential for contaminants to migrate toward the wells. In 1986, the Air Force provided connections to the municipal water supplies for 550 Rio Linda, Elverta, and North Sacramento residences in an area west and southwest of McClellan AFB. The residents in this area previously used private wells for their domestic water needs. As a result of contaminants having been detected in samples collected from each, eight base supply wells, two City of Sacramento wells, and one private well have been taken out of operation.

1.1.6 Cultural Resources

A cultural resource records search was conducted for the Magpie Creek Diversion Channel Improvement and Realignment Project and documented in an Environmental Impact Report (Jones and Stokes, 1989). The ERA extraction wells and treatment facility and the proposed EE/CA-EA extraction wells are approximately 4,500 feet southeast of the on-base channel improvement work. The proposed pipeline from the EE/CA-EA extraction wells will join an existing pipeline to the OU D Groundwater Treatment Plant (GWTP) that already crosses an improved section of Magpie Creek.

The Jones and Stokes record search of the California Archeological Inventory, North Central Information Center at California State University, Sacramento "revealed no recorded cultural sites on or near the project area." A search of the sacred lands file at the Native American Heritage Commission "did not reveal any special Native American cultural resources that would be of concern to local Native Americans, tribal groups, or elders." Jones and Stokes also reported that the only historically significant site is approximately one mile west of the base on Arcade Creek.

1.1.7 Vegetation and Wildlife

The project area has been developed for industrial and commercial-type enterprises and has interspersed grassland/old-field habitats. Jones and Stokes (1989) report that the annual grasslands in the Magpie Creek Project contain a variety of "annual non-native grass species intermixed with various amounts of native and non-native forbs (broad-leafed herbs)." This vegetation is not mowed and attains a height of two to three feet. Jones and Stokes conducted a records search of the California Natural Diversity Data Base and found that no special status plant species are known to exist in the Magpie Creek Project Area.

The grasslands in the EE/CA-EA project area are of less benefit to wildlife species due to the absence of open water in the immediate area. Several common species of reptiles, mammals, and birds typically use annual grasslands for foraging and nesting. Jones and Stokes research determined that five special-status species could potentially use the grassland portions of the Magpie Creek project area or were known to use grassland habitats existing in the project area. These species are the Swainson's hawk, the short-eared owl, the burrowing owl, the northern harrier, and the American Badger. The Swainson's hawk and the American badger have a low potential for occurrence while the two owl species and the northern harrier have a high potential for occurrence in the Magpie Creek Project Area (Jones and Stokes, 1989). The species with a high potential for occurrence are known to use grasslands for foraging and possibly nesting.

Jones and Stokes report three aquatic environments within the Magpie Creek Project Area. These are the freshwater marsh, woody riparian, and northern hardpan vernal pool. The first two environments would not be found within the EE/CA-EA project area due to the lack of flowing, channelized water in the project area. Northern hardpan vernal pools may exist in the area where the three extraction

dumping and utility (sewer line) installation in previous years. As a result, water may readily percolate into the ground without forming a pool.

Additional vegetation and wildlife information from an earlier report that focused on McClellan AFB is reviewed in Appendix B3.1.1, starting on page B3-8.

1.1.8 Socioeconomic Setting

The EE/CA-EA project area is totally located on McClellan AFB, which is generally surrounded by the north Sacramento area. Details concerning the surrounding communities may be found in Appendix B3.1.2, starting on page B3-9. This area has grown more slowly than the rest of the Sacramento area. Factors contributing to this trend include retention of older houses, demolition of dwellings for the construction of Interstate 80 and Business 80, and the abundant supply of easily developed land in other areas of the city and county (Jones and Stokes, 1989).

1.1.9 Land Use

Utilities associated with McClellan AFB and the surrounding communities include those typically found in major metropolitan areas. Electricity is supplied by the Sacramento Metropolitan Utility District (SMUD). SMUD owns and operates its own generating facilities and purchases power from other agencies to meet demand.

Water is supplied to McClellan AFB from water supply wells located on base and from an off-base municipal water district. Off-base water supplies in the vicinity of the base rely largely on groundwater but are gradually converting to surface water sources.

Wastewater from the base is piped to the Sacramento Regional Wastewater Treatment Plant. The residences in the area rely on septic tanks or City of Sacramento sewer service (Jones and Stokes, 1989).

Pacific Gas and Electric Company (PG&E) provides natural gas service to the base and some of the local residences. Pacific Bell provides telephone services both on and off base using primarily aerial cabling.

1.2 Site Background

Removal actions have been evaluated and proposed for OU B and other parts of McClellan AFB because contaminant concentrations are present in groundwater beneath those areas and are migrating toward water supply wells. Contaminants have been discharged to the soils beneath parts of McClellan AFB--and have apparently penetrated to the groundwater surface--as a result of activities occurring on the ground surface from approximately 1936 to the mid 1970s. The activities that resulted in the discharges were, at the time, considered prudent, economic, and necessary to the aircraft repair and maintenance operations at McClellan AFB. In hindsight, the errors of the historical practices are apparent. In this section of the EE/CA-EA report, the historical activities that lead to the contamination of soils and groundwater and the actions taken to investigate and correct historical errors are described.

1.2.1 Site History

Prior to the development of McClellan AFB, the land within and adjacent to its boundaries was occupied by rural residences, farms, and pasture land. The Sacramento Air Depot was established by Congressional authority in 1936. The air base was renamed McClellan AFB in 1939. Through World War II and the Korean War, McClellan AFB was a maintenance depot for bomber aircraft. In the 1950s, maintenance responsibilities were shifted to fighter aircraft and worldwide logistical support. Since the 1960s, McClellan AFB has continued in the role of jet fighter repair and maintenance facility. McClellan AFB is one of five Air Force Logistics Command Centers in the United States. In addition to aircraft maintenance, such activities as equipment repair, automotive maintenance, construction of aircraft ground support facilities, laboratory testing, and parts storage are conducted at McClellan AFB. Within OU B, the principal activities have been maintenance, storage, electronic equipment repair and testing, and preparation of ground support equipment. Three facilities that were a small part of the activities in OU B, but may have had a larger impact on the discharge of contaminants were the former plating shop at Building 666, and the former Industrial Wastewater Treatment Plant (IWTP) No. 4, adjacent to Building 666, the former research laboratory in Building 628, and the segment of the IWL conveying wastewater from the laboratory.

As a result of the activities conducted in OU B from 1940 to the present, toxic and hazardous materials have been used, stored, and locally disposed of. The types of materials include: industrial solvents (VOCs), caustic cleaners, electroplating

wastes (metals, arsenic, and cyanide compounds), oils contaminated with polychlorinated biphenyls (PCBs), contaminated jet fuels, automotive fuels, oils and lubricants, and radionuclides. A number of these materials have been detected in soils, and VOCs and metals have been detected in groundwater beneath OU B.

The specific areas of usage, storage or disposal of wastes are described in the next section.

1.2.2 Use, Storage, and Disposal of Chemicals

The current and historical use, storage, and disposal of chemicals in OU B is specified by location in Table 1-1. These locations, shown in Figure 1-18, include Sites, Potential Release Locations (PRLs), and Study Areas (SAs). The materials handled, stored, or disposed at each location and facility are categorized by type of chemical (e.g., acids and bases, fuels and oils, PCBs). The use or storage of these materials at these locations does not necessarily indicate that these chemicals have been released into the environment.

Fuels, oils, and solvents are the principal types of chemicals handled historically or currently within the various facilities. While acids and bases were in widespread use historically, they are currently used in only a few facilities (see Table 1-1). Toxic metals were historically used at 12 facilities and are currently used or stored in three: Buildings 677, 781, and Lot 3 (PRL S-13). Polychlorinated biphenyls historically were used or handled at five locations and facilities; currently, PCBs are handled at PRL S-12, PRL S-13, and SA 12 in Building 724. Historically, burn residues were generated or stored in four areas located near Building 700 (SA 12). No burn residues are currently generated in OU B. Cyanide compounds were historically used in the Building 666 plating shop (Site 47) and adjacent areas (the old storage area, Site 36, and the old IWTP, Site 48). With the exception of the hazardous materials storage lot (PRL S-13) in the western portion of OU B, the handling of cyanide compounds in OU B appears to have ceased.

The locations of confirmed storage of hazardous materials is shown in Figure 1-5. Prominent locations include Site 23, the site of a former burial pit that is currently the location of Building 781. Building 781 has been the primary chemical storage and distribution facility for McClellan AFB since 1971.

TABLE 1-1. CHEMICALS HANDLED AT SITES, LOCATIONS, AND STUDY AREAS IN OU B

Site/PRL/SA No.	Fuels and Oils	Solvents/ Paints	Acids/ Bases	Heavy Metals	PCBs	Radionu-clides	Burn Residues	Cyanide Compounds
Site 23	C	C	C	C			H	
Site 30		C	C			H		
Site 31							H	
Site 36		H	H	H				H
Site 47	H	H	H	H				H
Site 48		H	H	H				H
PRL 29							H	
PRL 35[1]								
PRL B-9[2]								
PRL L-5								
PRL L-6	C	C	C	H				
PRL P-2[2]		H		H		H		
PRL P-9								
PRL S-5		H	H	H				H
PRL S-12	H	H		H				
PRL S-13					C			
PRL S-28	C	C	C	C	C			C
PRL S-29	H	H						
PRL S-30	H	C			H			
PRL S-33	H	C	H					
PRL S-34	H	H	H					
PRL S-35	H	H						
PRL S-41	C	C						
PRL T-8	C							
PRL T-45	C							
PRL T-46	H							
PRL T-48	H	H						
PRL T-60	C							
SA 1	H							
SA 2	C	C	C					
SA 3[2]	H	H	H	H		H		
SA 4[3]								
SA 5	H	C						
SA 6	C	C						

(Continued)

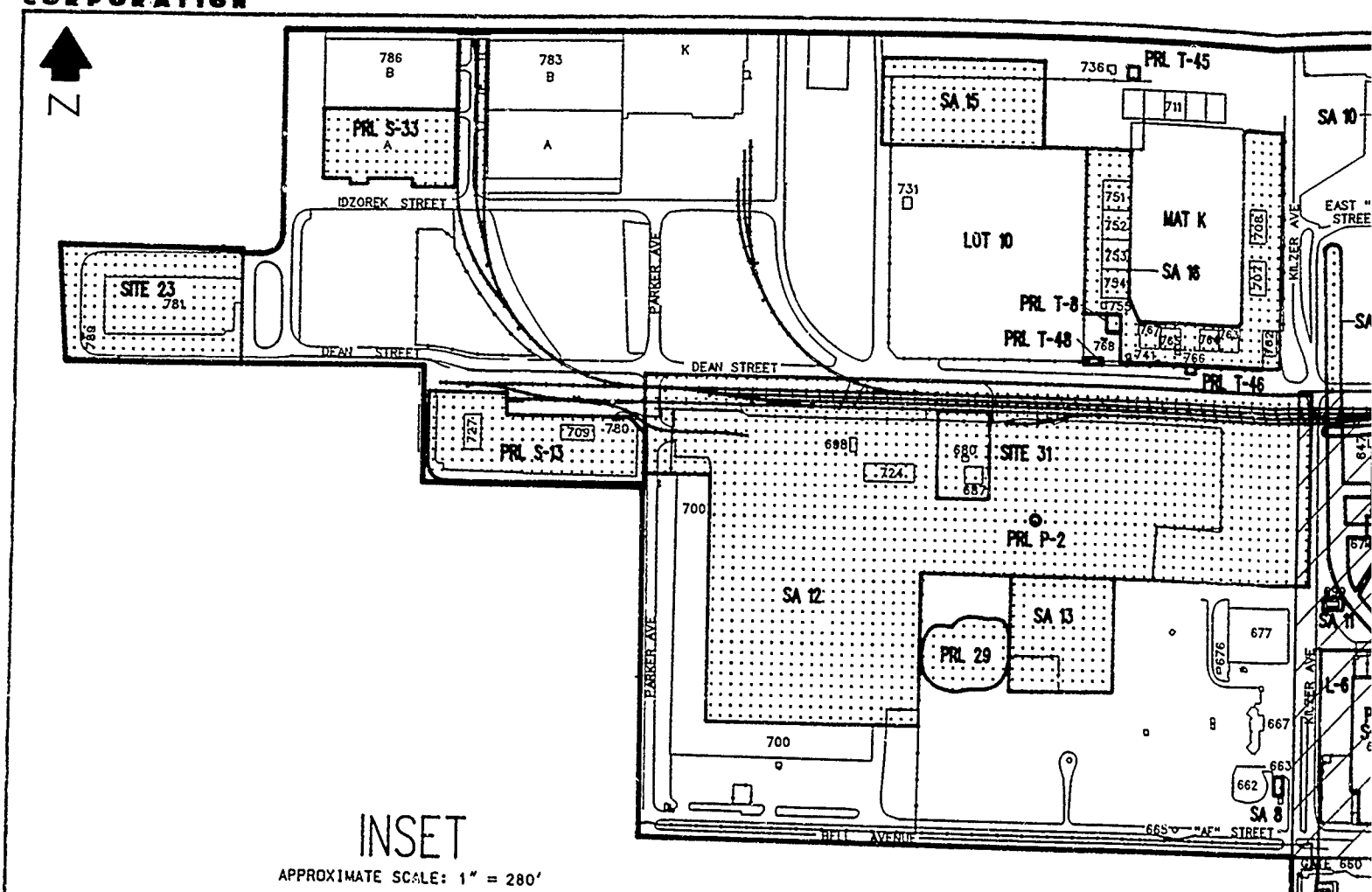
TABLE 1-1. (Continued)

Site/PRL/SA No.	Fuels and Oils	Solvents/ Paints	Acids/ Bases	Heavy Metals	PCBs	Radionu-clides	Burn Residues	Cyanide Compounds
SA 7	H	C						
SA 8	C							
SA 9	C	C	C					
SA 10[4]								
SA 11	H							
SA 12	H	H			C		H	
SA 13					H			
SA 14	H	H		H				
SA 15		H						
SA 16	C							
SA 17	H							
SA 18	H							
SA 19[2]								
SA 20		C						
SA 21	C	C						
SA 22[2]								
SA 23		C	C					
SA 24[2]								
SA 25[1]								
SA 26[1]								
SA 27[1]								
SA 28[2]								
SA 29	C	C		C		C		
SA 30	H	H						
SA 31		C						
SA 32[2]								
SA 33[2]								

[1] No hazardous materials handled.
[2] Materials handled unknown.
[3] Pesticides and herbicides historically stored.
[4] Pesticides and herbicides currently stored.

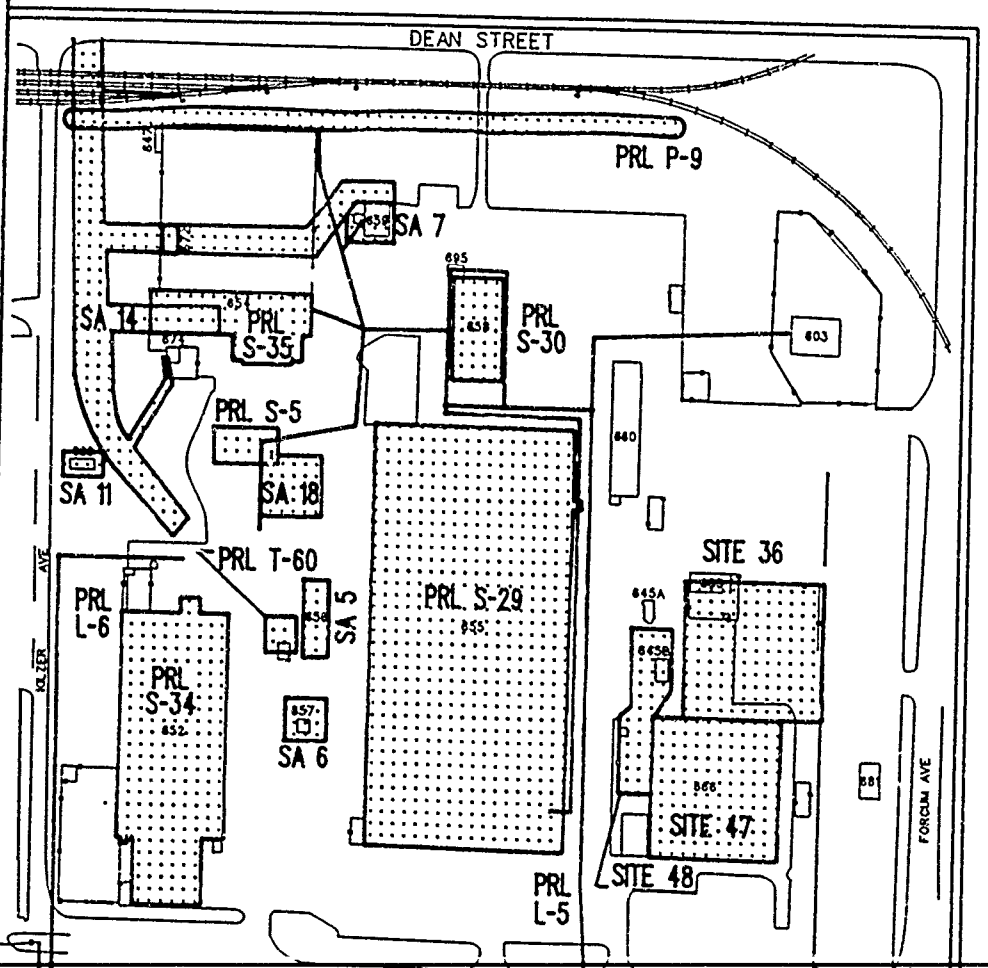
NOTES: H = Materials that were only handled historically.
C = Materials which continue to be handled.
PRL = Potential Release Location
SA = Study Area
Source: Radian, 1990b

RADIAN
CORPORATION



INSET

APPROXIMATE SCALE: 1" = 280'



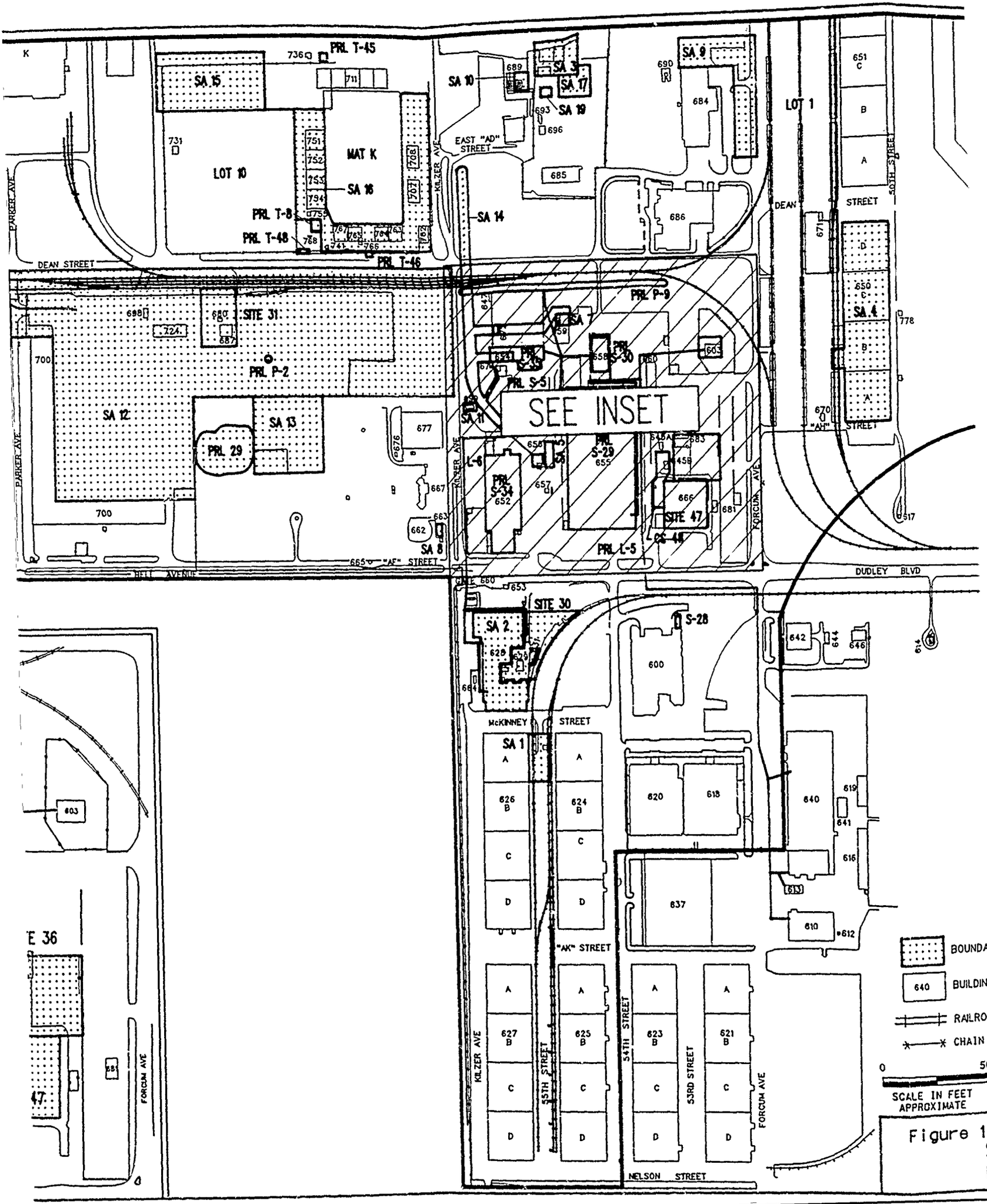

SEE INSET
PRL T-45
SA 15
LOT 10
MAT K
SA 16
PRL T-8
PRL T-48
PRL T-46
SA 14
SA 10
SA 3
SA 17
SA 19
SA 9
LOT 1
EAST "AD" STREET
DEAN STREET
PARKER AVE
KILZER AVE
FORCUM AVE
SITE 31
PRL P-2
SA 12
SA 13
PRL 29
SA 11
PRL P-9
SA 7
PRL S-30
PRL S-5
PRL S-29
PRL S-34
PRL L-5
SITE 47
SA 8
"AF" STREET
BELT AVENUE
DUDLEY BLVD
SITE 30
SA 2
S-28
McKINNEY STREET
SA 1
"AK" STREET
54TH STREET
55TH STREET
53RD STREET
NELSON STREET
SA 4
STREET
BOUNDA
BUILDIN
RAILROA
CHAIN
0
50
SCALE IN FEET
APPROXIMATE

Figure 1-
S
U

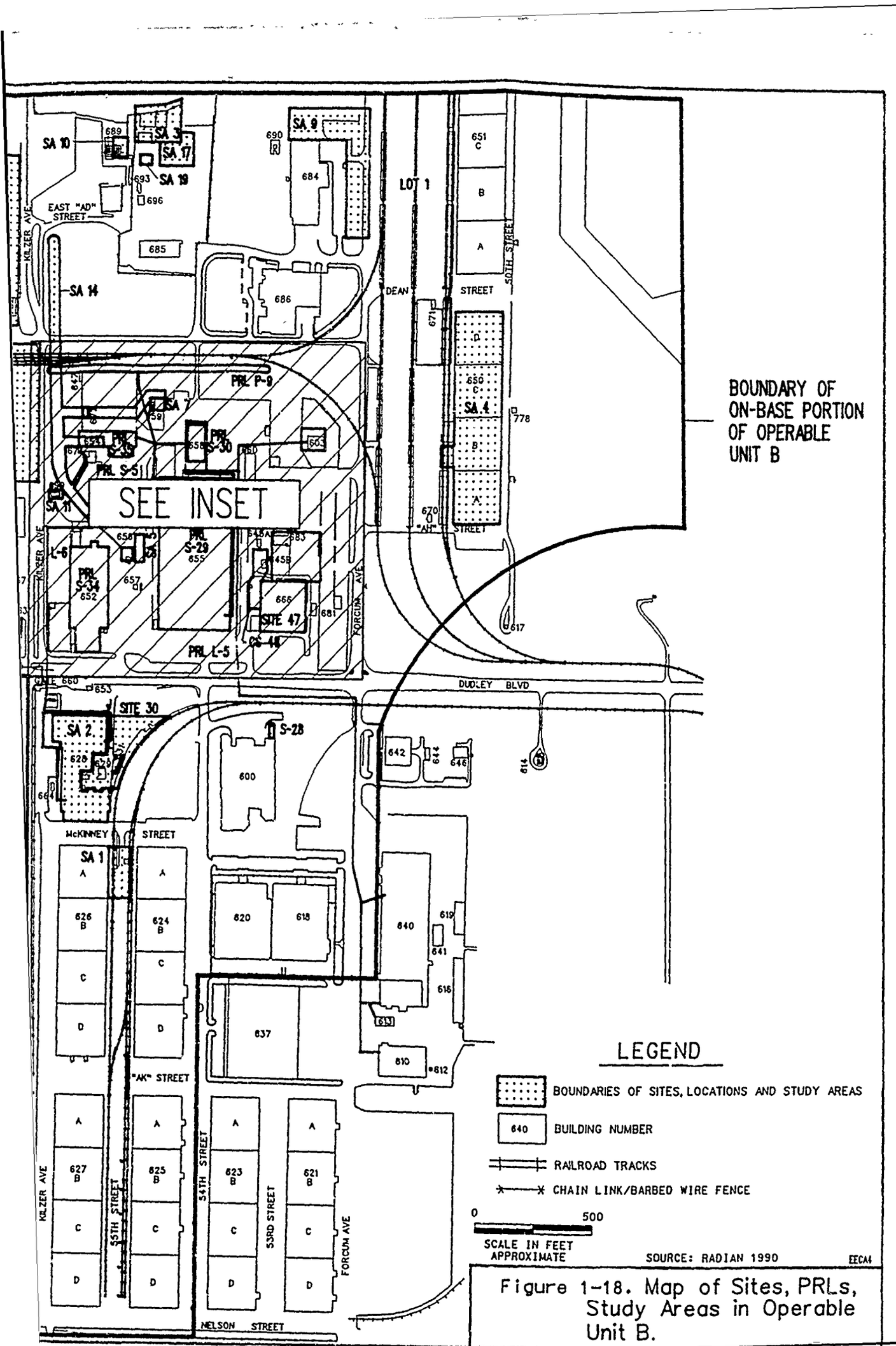


Figure 1-18. Map of Sites, PRLs, Study Areas in Operable Unit B.

Four historical waste disposal areas and three historical waste treatment areas were located in OU B, and are shown on Figure 1-6. The burial pit (Site 23) located along the western edge of McClellan AFB operated between 1957 and 1971. Potential Release Location 30 (east of the Building 628 laboratory) was used as a disposal area for laboratory chemicals between approximately 1960 and 1971. Potential Release Location 29 was reportedly used to bury aircraft generators, and PRL P-2 was reportedly used to dispose of oil; however, these reports have not been confirmed.

A refuse incinerator (Site 31) adjacent to Building 687 operated between 1963 and 1968. Industrial Wastewater Treatment Plant No. 2 (PRL S-5) and IWTP No. 4 (Site 48) operated in OU B until they were dismantled in 1976 and 1980, respectively. Industrial Wastewater Treatment Plant No. 2 treated wastewater generated in the vicinity of Building 655 (i.e., Buildings 652, 655, and 658). Industrial Wastewater Treatment Plant No. 4 treated wastewater generated in the Building 666 plating shop.

Historical disposal practices included the proper collection, treatment, and disposal of waste chemicals, but also included practices such as the dumping of solvents onto the ground (west of Building 628) and onto asphalt pavement where the solvents were allowed to evaporate (SA 1, PRL-30). Industrial wastewater generated by the washdown of floors in Building 666 was directed in part into trenches that drained into IWTP No. 4, and in part onto the dirt outside the building (Radian, 1990b).

Current disposal methods include containerization and transport of chemical wastes off-base to an appropriate disposal area. There are no currently operating waste disposal or treatment facilities in OU B. Industrial wastewater, such as that created by washrack use, or by the washdown of floors onto which chemicals have been spilled, is directed into drains that are connected to the IWL. The IWL runs through the central portion of OU B, and carries the wastewater from OU B to an on-base treatment facility where it is treated and discharged for subsequent treatment at the Sacramento County Publically Owned Treatment Works. Industrial wastewater sludge is transported off-base for disposal at a Class I landfill.

1.2.3 Potential and Known Discharges

Sites, PRLs, and SAs in OU B that have documented releases of contaminants are Sites 23, 30, 31, 36, 47, and 48, PRLs B-1, L-5, and S-13, and SAs 9, 12, and 15 (Radian, 1990b). Soil contamination has been confirmed at Sites 23, 30, 31, 36, 47, and 48, and SAs 3, 9, and 12. There is the potential that soil contamination will

be found at some of the 43 chemical handling locations within OU B, as a result of undocumented disposal, spills, or leaks. These 43 locations, which have been recommended for further investigation, are listed in Table 1-2.

Contaminants discharged into the soil in OU B include VOCs, semivolatile organic compounds, toxic metals, PCBs, cyanide compounds, and oil and grease (Radian, 1990b). Volatile organic compounds in the soils include TCE, PCE, acetone, toluene, and 1,1,1-trichloroethane.

Semivolatile organic compounds detected in OU B soils include 2-methylnaphthalene, N-nitrosodiphenylamine, and pentachlorophenol. Toxic metals detected in OU B soils include chromium, lead, and mercury. Documented discharges of chemicals to the soil in OU B have resulted in the past from the burial of waste material, leakage from underground storage tanks, leakage from the IWL, and spills in storage lots resulting from operational practices. In addition, undocumented releases have occurred as a result of spills of liquid or powdered chemicals onto dirt or pavement. For example, spills that occurred inside Building 666 were periodically washed from the interior floor with high pressure hoses and directed out through the door on the north side of the building onto the soil at Site 36 (Radian, 1990b).

Available information (Radian, 1990b) indicates that the largest documented contaminant releases in OU B are:

- A number of confirmed leaks in the underground IWL (PRLs L-5 and L-6). (This pipeline has transported industrial wastewater for approximately 30 years.)

- Reported spills in PRL S-13, a hazardous materials storage lot that has been in operation since 1955. (Stored materials include fuels, oils, acids, bases, solvents, and PCBs.)

Releases of contaminants into surface water are believed to have occurred at PRL T-45 and SA 14, and possibly at other locations where drainage ditches collected runoff from contaminated soil or pavement. Potential Release Location T-45 is an abandoned concrete oil-water separator tank located adjacent to Magpie Creek. Supernatant liquids from the oil-water separator are reported to have been discharged into Magpie Creek. Study Area 14 is a drainage ditch that received wastewater and

TABLE 1-2. SITES, PRLs, AND STUDY AREAS RECOMMENDED FOR FURTHER INVESTIGATION

Site/PRL/SA	Rationale for Recommendations
Site 23	Contamination detected in soil. Additional data needed to characterize.
Site 30	Contamination detected in soil. Additional data needed to characterize.
Site 31	Burn residues from former refuse incinerator are a potential contaminant source.
Site 36	Contamination detected in soil. Additional data needed to characterize.
Site 47	Contamination detected in soil. Additional data needed to characterize.
Site 48	Contamination detected in soil. Additional data needed to characterize.
PRL 29	Reported burn pit or transformer storage area may be a contaminant source.
PRL L-5	Confirmed leaks in IWL are suspected contaminant sources.
PRL L-6	Confirmed leaks in IWL are suspected contaminant sources.
PRL P-2	Possible former waste pit may be a contaminant source.
PRL P-9	Ditch that collected waste from IWTP is a suspected contaminant source.
PRL S-5	Former IWTP is a suspected contaminant source.
PRL S-13	Documented releases of hazardous materials. Suspected contaminant source.
PRL S-28	Former paint and oil storage facility is a potential contaminant source.
PRL S-29	Underground piping may have leaked. Potential contaminant source.
PRL S-30	Trench, catch basin, and pipes which transport wastes may have leaked. Potential contaminant source.
PRL S-33	Former chemical storage facility is a potential contaminant source.

(Continued)

TABLE 1-2. (Continued)

Location No. Study Area	Rationale for Recommendations
PRL S-34	Pits, sumps, trenches, and pipelines may have leaked. Potential contaminant source.
PRL S-35	Trench, underground drain, and piping which transport wastes may have leaked. Potential contaminant source.
PRL T-8	Underground fuel storage tanks leaked in the past. Suspected contaminant source.
PRL T-45	Abandoned tank and piping may have leaked. Potential contaminant source.
PRL T-46	Abandoned tank and piping may have leaked. Potential contaminant source.
PRL T-48	Abandoned tank and piping may have leaked. Potential contaminant source.
PRL T-60	Underground storage tank may have leaked. Potential contaminant source.
SA 1	Freon® waste reportedly dumped outside building. Potential contaminant source.
SA 2	Laboratory and former outdoor radioactive storage areas are potential contaminant sources
SA 3	Washrack is a suspected contaminant source.
SA 4	Large quantitites of paints and solvents handled. Potential contaminant source.
SA 5	Fuels, oils, and paints are potential contaminants. Further investigation necessary.
SA 6	Underground fuel storage tanks may have leaked. Potential contaminant source.
SA 7	Previously analyzed soil data unavailable. Further investigation of Underground Storage Tanks is necessary.
SA 8	Underground storage tanks may have leaked. Potential contaminant source.
SA 9	Contamination detected in soil. Additional data needed to characterize.
SA 10	Concrete wastewater sump may have leaked. Potential contaminant source.

Continued)

TABLE 1-2. (Continued)

Study Area	Rationale for Recommendations
SA 11	Underground storage tank and associated piping may have leaked. Potential contaminant source.
SA 12	Contamination detected in soil. Additional data needed to characterize.
SA 13	Open storage of hazardous materials. Suspected contaminant source.
SA 14	Ditch transported wastewater. Suspected contaminant source.
SA 15	Contaminants potentially released during fire in a chemical storage area.
SA 16	Underground tanks and piping may have leaked. Potential contaminant source.
SA 17	Open storage of hazardous materials. Suspected contaminant source.
SA 18	Open storage of hazardous materials. Suspected contaminant source.
SA 19	Former spray booth is a suspected contaminant source.

PRL = Potential Release Location
SA = Study Area
IWL = Industrial Wastewater Line
IWTP = Industrial Wastewater Treatment Plant

SOURCE: Radian, 1990b.

spilled fuel from several sources. This drainage ditch discharged its effluent into Magpie Creek.

Releases of contaminants into groundwater have not been confirmed in OU B. However, several locations with confirmed or suspected soil contamination (e.g., Sites 36, 47, and 48) are strongly suspected of being sources of groundwater contamination (See Appendix A, Section 4.3).

Data from four groundwater monitoring wells (MW-41S, MW-153, MW-157, and MW-158) located downgradient from Sites 36, 47, and 48 indicate that many of the contaminants in the soil are also found in the groundwater. These compounds include TCE, 1,2-DCE, chloroform, PCE, and 1,1,1-trichloroethane. Although additional site characterization and evaluation of the vadose zone will be required to specifically identify the source(s) of groundwater contaminants, one or more of these sites is a likely source of local groundwater contamination.

The 43 locations listed in Table 1-2 will be investigation for the potential of being sources of contamination in the OU B Remedial Investigation (RI).

1.2.4 Previous Remedial Investigations

The major soil contamination investigation of OU B was conducted in 1985 and 1986. Additional soil borings, soil sample analyses, and other soil-related investigations in OU B including testing and evaluation of underground storage tanks and the Industrial Wastewater Collection System have been compiled and presented in site-specific Technical Memorandums and Preliminary Assessments (Radian, 1990b).

The major groundwater remedial investigation of OU B, formerly called the Area B Groundwater Operable Unit Remedial Investigation, or ABGOURI (Radian, 1990f), consisted of drilling and groundwater sampling program that was conducted to determine the on-base and off-base extent of groundwater contamination, the presence of which was known from the quarterly sampling and analysis of OU B groundwater wells prior to 1989. This investigation is now referred to as the Operable Unit B Groundwater Remedial Investigation (OUBGRI).

Soil Contamination Investigations

Beginning in 1984, site characterization investigations were conducted at 56 sites within Areas A, B, C, and other Areas on base. These investigations included

waste, soil, and groundwater testing. More than 700 soil borings were drilled, and soil samples collected from the borings analyzed. In addition, a total of 86 additional potential sites were identified. The investigations were conducted throughout 1985 and 1986, and results were documented in a series of reports and technical memorandums, including the Final Basewide Report on Contamination (McLaren, 1986).

Within OU B, soil borings were drilled at Sites 23, 30, 31, 36, 47, and 48, PRLs 29, 35, T-60, and SAs 3, 9, 12, 20, and 32.

Samples from selected soil borings were analyzed for VOCs, semivolatile organic compounds, pesticides, PCBs, metals and inorganic compounds, and oil and grease. Quality assurance/quality control (QA/QC) information available for these analyses is generally limited to sample detection limits and some duplicate results. The results of these analyses are summarized in Section 1.2.5.

Soil borings also have been drilled at PRL T-60 and SAs 2, 9, 12, and 32. The exact location of each boring is uncertain due to a lack of adequate documentation (Radian, 1990f). However, analytical results are available for many of the samples from these borings, and are summarized in Section 1.2.5.

Groundwater Contamination Investigation

Prior to the OUBGRI, 29 monitoring wells had been installed in OU B and the southwest area off base. Reported results from quarterly sampling and analysis of these monitoring wells indicated the presence of dissolved VOCs and metals contamination in source of these wells. The purpose of the OUBGRI was to define the nature and extent of the contamination plumes, and to provide additional information on the subsurface geology and hydrology.

The OUBGRI field investigation was conducted from March through December 1989. During that period, three pilot holes and 14 monitoring wells were placed off base; three pilot holes and 15 monitoring wells were installed on base. From January to May 1990, an additional pilot hole and 11 monitoring wells were installed on McClellan AFB in OU B under the Preliminary Groundwater Operable Unit Remedial Investigation (PGOURI) program. Pilot holes 10, 11, 12, 13 17, and 21 and monitoring well locations 11A, 11B, 36A, 36B, 36C, 145 through 159, 162 through 168, and 1044 through 1057, completed under the OUBGRI and the PGOURI programs, are shown in Figure 1-19. Of the 40 groundwater monitoring wells, 14 were screened in the A geohydrologic zone, 9 in the B, 8 in the C, 5 in the D, 3 in the E, and 1 in the F. These

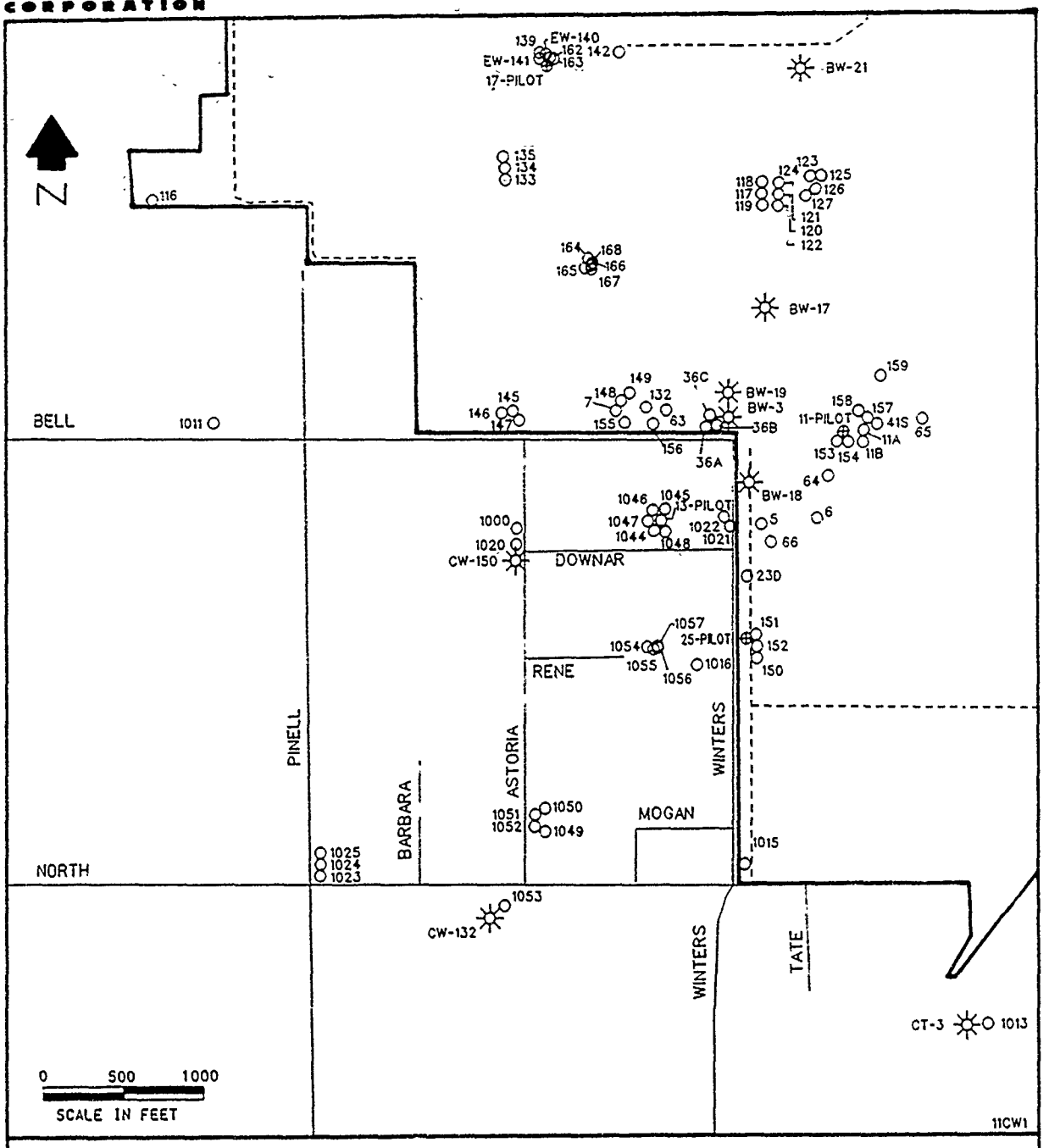


Figure 1-19. Location of New Well Clusters and Existing Wells.

groundwater zones are defined in Section 1.1.7. The specific results of the investigation are summarized below.

1.2.5 Contamination Distribution

Contaminants have been detected in the soils and the groundwater in OU B. Disbribution of the contaminants is discussed below.

Soil Contamination

As noted in Section 1.2.3, soil contamination has been confirmed at Sites 23, 30, 31, 36, 47, and 48, and SAs 3, 9, and 12 (Table 1-3). In addition, reported chemical disposal, spills, or leaks have created the potential that 35 additional sites are contaminated. A complete list of contaminated and potentially contaminated locations in OU B is presented in Table 1-2 (Section 1.2.3) and the locations are shown on the OU B site map (Figure 1-18, Section 1.2.2).

A complete list of contaminants detected in the soil at each site is presented in the OU B Preliminary Assessment Summary Report (Radian, 1990b), along with maps showing specific soil boring locations at each site (if known). The areas of highest levels of confirmed soil contamination are:

- Building 666 (the old plating shop [Site 47]) and adjacent areas (the old IWTP No. 4 [Site 48] and a storage area [Site 36]) where 10 different VOCs were detected in soil samples from depths ranging from 9.5 to 80 feet BGS;

- The former landfill along the western base boundary (Site 23) where 10 VOCs and 4 semivolatile organic compounds were detected in soil samples from depths ranging from 24 to 60 feet BGS;

- The Building 628 research laboratory and the open lot east of the laboratory (Site 30), where six VOCs were detected in soil samples from depths ranging from 24 to 60 feet BGS; and

TABLE 1-3. SITES AND STUDY AREAS WITH CONFIRMED SOIL CONTAMINATION

Site/PRL/SA	Volatiles	Semivolatiles	PCBs	Cyanide	Oil and Grease
Site 23	√	√			√
Site 30	√	√			√
Site 31					√
Site 36	√	√		√	√
Site 47	√	√			√
Site 48	√	√		√	
SA 3	√	√			
SA 9	√				
SA 12	√	√	√		

SA = Study Area

SOURCE: Radian, 1990b.

- The Building 700 storage area (SA 12) where PCB contamination was detected in soils from depths ranging from 0 to 10 inches BGS.

Of the fourteen locations in which soil borings were drilled, soil contamination was detected at all locations except PRLs 29, 35, and T-60, SA-20, and possibly SA 32. Study Area 32 is not listed on Table 1-3 as a site with confirmed soil contamination because the location of the borings at SA 32 are not known, and it is possible that the soil borings are not within the study area boundaries.

Volatile organic compounds detected in the soil at OU B include TCE, PCE, acetone, toluene, methylene chloride, xylenes, 1,1,1-trichloroethane, chloroform, 2-butanone, 2-hexanone, benzene, ethylbenzene, 4-methyl-2-pentanone, dichloromethane, trichlorofluoromethane, and trans-1,2-dichloroethene. Semivolatile organic compounds detected in the soil at OU B include 2-methylnaphthalene, N-nitrosodiphenylamine, pentachlorophenol, phenanthrene, 1,2,4-trichlorobenzene, benzo[a]pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)perylene, ideno(1,2,3-c,d)pyrene, benzo(k)fluoranthene, and chrysene.

Toxic metals identified in the soil at OU B include arsenic, barium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, and vanadium. These metals are not necessarily present in hazardous quantities; they are trace substances that are also natural constituents of soil and rock.

Groundwater Contamination

Volatile organic compounds have been detected in groundwater samples from five geohydrologic zones in the depth interval 100 to 350 feet BGS beneath McClellan AFB. Beneath off-base areas, three geohydrologic zones, A, B, and C (100 to 260 feet BGS) are known to contain VOCs. The distribution of contaminants in on-base and off-base areas are shown in Figures 1-13, 1-14, 1-15, 1-16, and 1-17, Section 1.1.7. The contaminant distribution in groundwater indicates that three contaminant plumes are migrating beneath OU B in the A or shallowest groundwater zone. The three plumes, the TCE/PCE plumes, the TCE/1,2-DCE plume, and the PCE plume are shown in Figure 1-11 with isopleths of total VOC concentration. The TCE/1,2-DCE plume has been detected in groundwater samples from the A through E zones beneath McClellan AFB. The PCE plume has been detected in groundwater samples from the A and B zones, and the TCE/PCE plume has been detected in the A and B zones beneath McClellan AFB.

The distribution of VOCs in the plume and historical, regional groundwater flow directions lead to the conclusion that the contaminants have migrated from source areas on McClellan AFB. Potential sources of the contaminants in groundwater are sites in OU B (for example, Building 666, a former plating shop) and OU C (Appendix A, Section 4.0).

In addition to organic compounds, metal ions have been detected in groundwater samples from both on- and off-base monitoring wells of OU B. A number of metal ions detected in the wells result from natural dissolution of minerals as groundwater migrates through rocks and sediments. The metal ions calcium, sodium, magnesium, silicon, and iron are the dissolved metals occurring most commonly and in the greatest concentration in groundwater. Other metals may also occur in groundwater in smaller or "trace" concentrations as a result of mineral dissolution or near-surface contamination. The trace metals arsenic, boron, chromium, cadmium, copper, lead, mercury, nickel, vanadium, and zinc are metals that have been detected historically in monitoring wells on McClellan AFB in OU B. Not all of the metals have been detected in any one well, and concentrations of the metals in samples from any of the monitoring wells have fluctuated between sampling events performed since 1982.

Trace metals ions detected in on-base monitoring wells have also been detected in analyses of samples from six off-base monitoring wells located within or near OU B. Concentrations of metal ions detected in the off-base groundwater samples are equal to or less than the lowest concentrations detected in samples from on-base monitoring wells. In analyses of samples from several off-base and on-base monitoring wells, the concentrations of one metal exceeded U.S. Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCLs) for drinking water. However, in subsequent samplings of the wells, the concentration of the metal was less than its MCL value. Concentrations of boron, vanadium, and zinc detected in on- and off-base monitoring wells were evaluated for potential health risks that could result from ingestion of groundwater in the Baseline Risk Assessment (Appendix B).

The suite of trace metals occurring in groundwater in the off-base monitoring wells of the OU B are the same as those occurring in samples from wells on McClellan AFB and near the McClellan AFB boundary. This suggests that the metals are migrating with groundwater beneath the McClellan AFB boundaries. However, it cannot be determined with available data if the metals originate from natural dissolution of minerals in deposits beneath or upgradient from McClellan AFB or if the metals have

entered the groundwater from a near-surface discharge source on McClellan AFB. Unlike VOCs, dissolved metals, including the trace metals discussed in this section, may dissolve in groundwater as a result of natural processes. At the relatively low concentrations of trace metals which occur in OU B groundwater, the origin of the dissolved metals cannot be clearly determined with available data.

Surface Water

A limited investigation of contaminants in surface waters on McClellan AFB was conducted in 1989 (Radian, 1990g). Samples of surface waters standing on or flowing across the McClellan AFB were taken at 24 locations. The purpose of the investigation was to determine if contaminants were present in surface waters entering flowing across or exiting McClellan AFB. Only one of the sampling points occurred within OU B because the major on-base drainages occur north of OU B. The sampling point in OU B was a storm drainage ditch in western OU B along a short segment of the east-west boundary of McClellan AFB.

Acetone was the only VOC detected, at 16 μg/L in the sample from the sampling point. No semivolatile organic compounds were detected. Analyses for 27 metals were conducted on the sample. Twenty-five metals, including commonly occurring (sodium, calcium, magnesium) and trace metals (chromium, copper, zinc), were detected. However, none of the concentrations of metals detected in the sample from OU B exceeded established MCLs for drinking water.

1.2.6 Potential Health or Environmental Impacts

Exposure to a number of the compounds detected in OU B, at the conentrations detected in the soil, soil gas, groundwater, and surface water (Section 1.2.5), has the potential to pose risks to human health or to otherwise impact the environment on or near McClellan AFB. The potential for health risks or environmental impacts would be greater if exposure pathways to human populations or if mechanisms of migration to the environment existed.

Exposure pathways to human populations that may exist within OU B for contaminants in soil are: direct contact, ingestion, and inhalation of contaminant vapors or particles. For contaminants in soil gas, the exposure pathway is inhalation of contaminant vapors that may migrate to the surface and enter the air. Exposure pathways for contaminants in surface water or groundwater are: ingestion of dissolved

VOCs, metals, or inorganic compounds, dermal contact, or inhalation of VOCs that enter the air when the water is heated or aerated.

Mechanisms that may cause migration of contaminants to the environment from OU B are: volatilization of contaminant vapors into the air and transport by wind, dissolution or suspension of contaminants in runoff from contaminated soils and transport in surface water, and percolation of contaminants through the soils and transport in groundwater.

Within OU B, the populations that may be exposed to contaminants in the soil or soil gas are limited to on-base civilian workers and military personnel who work near contaminated sites. The potential for exposure is reduced for many of these people because most of the Sites and PRLs where contaminant concentrations were found are covered with building foundations or asphalt. The presence of a surface covering over contaminated soils diminishes the potential for increased risk through direct contact, inhalation of vapors or particles, and ingestion. Migration to the environment is also limited because there is diminished potential for migration to surface water or air below the pavement. A full characterization of exposure pathways, health risks, and environmental impacts resulting from contaminants in soils and soil gas will be performed in the comprehensive OU B RI.

Contaminants detected in surface waters, for example in storm drainage or creeks, have not been detected in or near OU B in the drainages at the point where they flow beyond the McClellan AFB boundary. Therefore, health risks or environmental impacts resulting from contaminant concentrations in the surface waters are unlikely. This potential migration pathway will also be more fully characterized in the OU B RI.

The principal mechanism of contaminant migration identified in OU B is groundwater migrating in the subsurface deposits. Volatile organic compound migration toward McClellan AFB, City of Sacramento, and domestic supply wells was recognized in 1981. Because of that migration and the potential health risks posed by the use of the contaminated groundwater from the wells: one City of Sacramento well, CW-150, was reduced in its use for water supply; the McClellan AFB supply well (BW-18) was shut down until it was retrofitted with a treatment system; and domestic well owners in OU B were supplied with connections to a municipal water supply.

The OUBGRI focused on the migration of contaminants and the potential exposure pathways resulting from that migration. The results of the OUBGRI indicate that VOCs dissolved in groundwater have migrated to depths of 350 feet BGS and 2,000 feet southwest of the McClellan AFB boundary. Some of the groundwater volume beneath OU B is migrating toward water supply wells: on-base, BW-18, and off-base, CW-132. The concentrations of contaminants in some of the groundwater volume (principally, in the A geohydrologic zone within the base boundaries) exceed federal and state MCLs for drinking water. Because of these levels of contamination in the groundwater, a Baseline Risk Assessment was conducted to evaluate the exposure pathways and health risks that could result from exposure to the water from those two wells. The Baseline Risk Assessment considered the following exposure pathways:

- Ingestion of contaminated groundwater from public wells;
- Inhalation of VOCs released from the groundwater surface and transported in soil gas to the air phase at the soil surface;
- Inhalation of VOCs released from contaminated groundwater due to aeration during showering, clothes washing and dishwashing; and
- Direct contact with contaminated groundwater.

The results of the Baseline Risk Assessment for groundwater are summarized in Section 2 and are described in detail in Appendix B.

Environmental Assessment

The contaminants detected within OU B are most widely distributed in the groundwater. The shallowest groundwater surface beneath the operable unit occurs at depths of 95 to 100 feet BGS. Therefore, contaminants in the groundwater are remote from most fauna and flora unless groundwater is pumped to the surface.

A 1987 report by the U.S. Department of Interior, Office of Environmental Management stated that "no important fish or wildlife trust resources are known to occur at the McClellan AFB site; however, extremely significant water fowl and anadromous fish populations occur within McClellan's area of potential influence" (Dept. of Interior, 1987). Because water fowl and fish are unlikely to be exposed to any contaminated groundwater or significant amounts of VOCs in soil gas, wildlife on or

adjacent to McClellan AFB are probably minimally impacted by groundwater contaminants.

1.2.7 Previous Removal Actions

Results of groundwater sampling and analysis and soil boring sampling and analysis conducted prior to the OUBGRI indicated the presence of contaminants in soil and groundwater beneath OU B (Section 1.2.5). On the basis of the results of the earlier investigations, the Air Force implemented removal actions to decrease the potential for contaminant migration. A removal action addressed groundwater contamination in the off-base portion of OU B, and another addressed soil contamination on base in OU B.

The removal action addressing groundwater contamination in off-base areas was begun in the spring of 1986 when McClellan AFB announced a plan to provide municipal drinking water to approximately 550 residences in the area west of the base that used private wells for drinking water supplies. The area in which water connections were made is shown in Figure 1-20. The area included the off-base areas beneath which groundwater contamination has been detected that may be attributed to sources within McClellan AFB. The southern part of the area includes all of the off-base portion of OU B. Water connections were completed in August 1987. This removal action was taken to decrease the potential for migration of contaminants in groundwater into the deposits near private water wells. In providing the water connections to the residences in OU B and off-base areas to the north, the need to use groundwater for potable water supply was eliminated. Private wells were maintained and operated for other uses, but water supplies for drinking, bathing, dishwashing, and other domestic uses were provided by the connections. Residential wells withinthe northern portion of the removal action area are in use for irrigation and livestock watering. Within OU B, residential wells are no longer in use, and the County of Sacramento has prohibited the installation of any additional potable water supply wells in the off-base area, shown in Figure 1-20.

The second removal action undertaken in OU B was completed in March 1988. A former electroplating facility at Building 666 (Site 47) was dismantled. The building was used from 1957 to 1980 as an electroplating shop and from 1980 to 1982 for hazardous waste storage space. Demolition also included the affiliated industrial

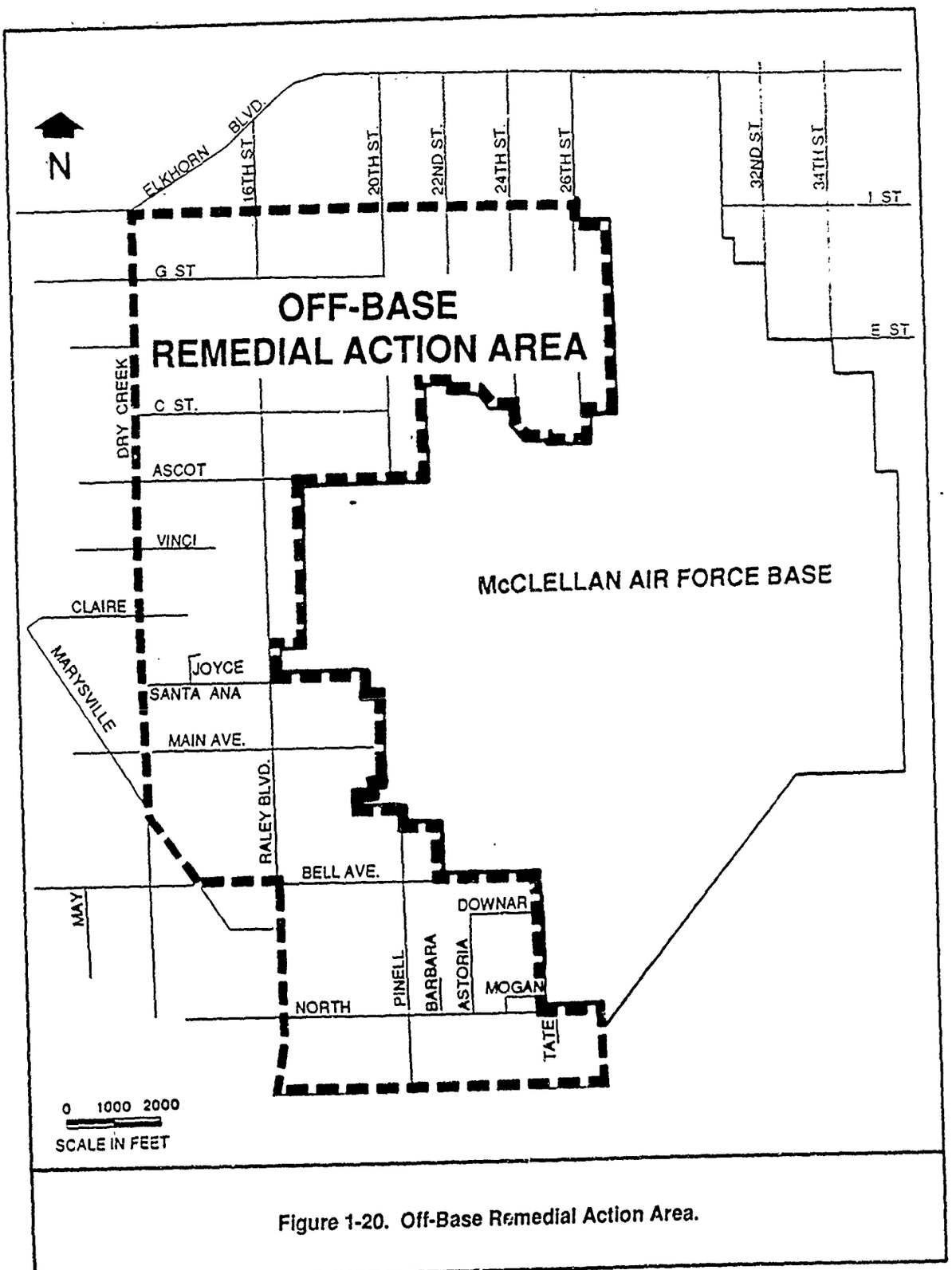


Figure 1-20. Off-Base Remedial Action Area.

0890-074-8

wastewater treatment facility (IWTP No. 4, Site 48). Contractors covered all doors and windows, removed all material and debris inside and surrounding the building, and vacuumed the floors, trenches, and pits. Piping, valves, pumps, tanks, and other interior aboveground components were dismantled and disposed, while maintaining the facilities' structural integrity and washing air pump discharge to make sure airborne particulate could not escape. The walls and roof of the facility were removed intact. Trenches and floor drains were filled with concrete. Sumps were covered with metal caps to prevent entry of surface water (Figure 1-21). The concrete pads for the buildings were left in place.

The removal action at Building 666 was taken to prevent migration of contaminants in the soil to groundwater. Soil borings sampled around the foundation of Building 666 and IWTP No. 4 (McLaren, 1986) indicated that concentrations of contaminants had migrated to 80 feet BGS. The activities conducted in Building 666 during its operating life are suspected of being the source for the TCE/PCE plume migrating southwest of the building's foundation. The soils beneath the foundation of Building 666 and adjacent areas (IWTP No. 4) will be investigated to determine sources of soil contamination and to evaluate remedial action alternatives in the comprehensive OU B RI.

1.3 Analytical Data

The OUBGRI focused on the extent and migration of contaminants in groundwater. Analytical data collected during the investigation were principally derived from samples collected from monitoring wells. Only five soil samples were collected for total organic carbon analysis (Appendix A, Section A2.0). Groundwater samples were collected from each well and analyzed several times during the OUBGRI. The initial sampling of new monitoring wells is described in Appendix A, Section A2.0, and the data are tabulated in Appendix D. However, for the evaluation of contaminant extent and the Baseline Risk Assessment, the most recent analytical data were selected to provide a synoptic view of contaminant distribution. The most recent, fully validated suite of analytical data for the wells in OU B available during the preparation of this report were the Fourth Quarter 1989 and First Quarter 1990 data from the McClellan AFB Groundwater Sampling and Analysis Program (GSAP). Those data have been evaluated for use in the interpretation.

In addition to the validated GSAP data, analytical data from initial samples collected from monitoring wells constructed under the PGOURI were available

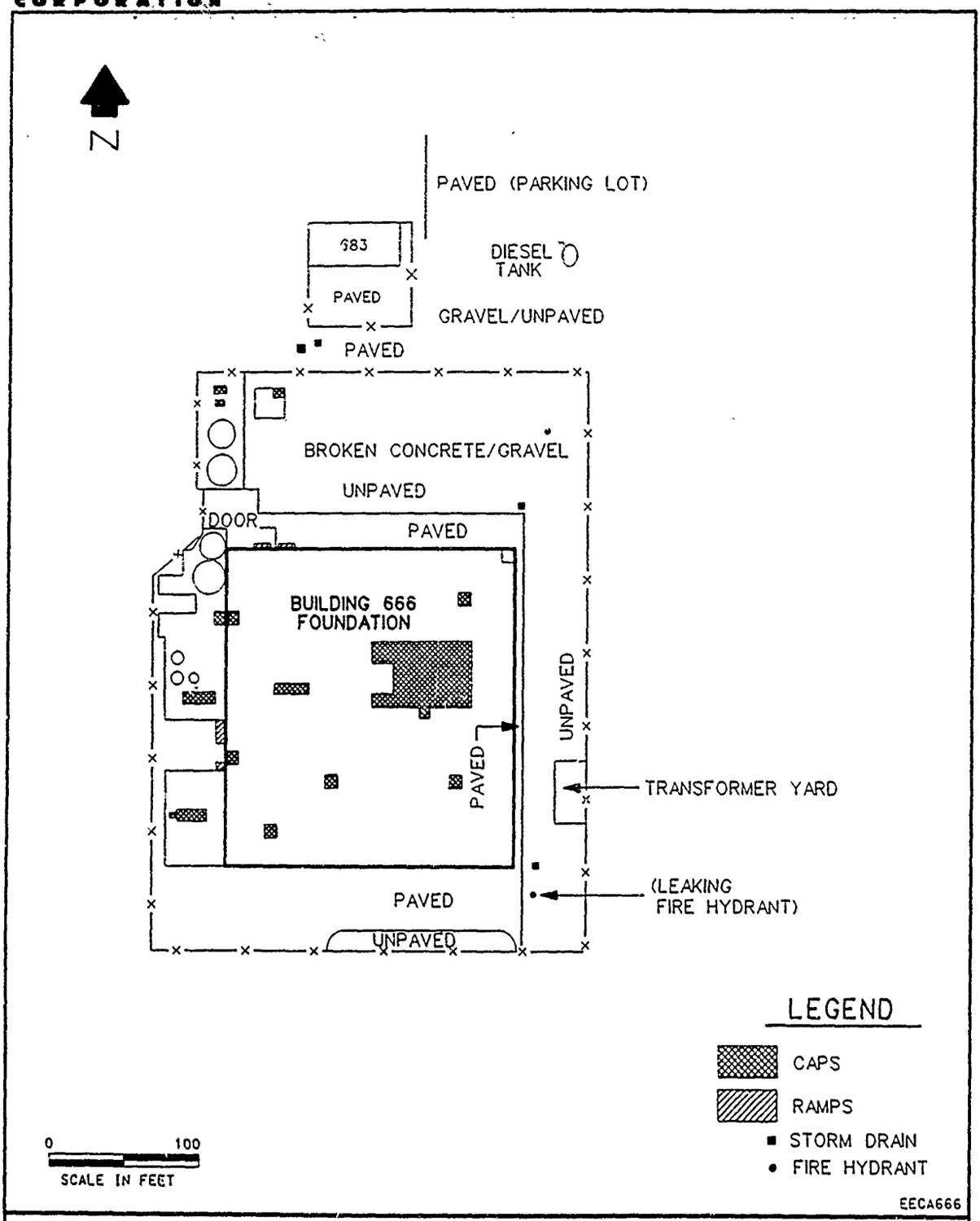


Figure 1-21. Foundation of Building 666.

in January through May 1990. These data have not been fully validated and should not be considered validated data where they may be used in text or figures in this report or in Appendix A. The data are identified as nonvalidated in tables where they are reported. The analytical data from well locations 11A, 11B, 21F, 36A, 36B, and 36C are unvalidated. The results of VOC analyses of samples from these wells are used only qualitatively to indicate the presence or absence of certain analytes.

1.3.1 Data Evaluation

Standard U.S. EPA Methods 8010 and 6010 from Test Methods for Evaluating Solid Waste (U.S. EPA SW-846) were used to analyze the samples for VOCs and metals. Results from the analyses were used for the Baseline Risk Assessment and to determine the extent of groundwater contamination. The analyses were performed according to Standard Operating Procedures (SOPs) developed by the Radian Corporation laboratory in Sacramento. The SOPs establish procedures and specifications for sample preparation, analysis, and data reduction. These include instrument settings; calibration procedures and specifications; QA/QC procedures including analysis of blank, duplicate, and spiked samples to monitor system performance; requirements for control charts to document that the analytical system is in statistical control; and data reduction and reporting protocols. The specific methods and protocols included in the SOPs developed by the Radian laboratory are included in Attachment B to Appendix B.

1.3.2 Summary of QA/QC Procedures and Results

This section describes Radian's data validation process and presents the QA/QC data from the McClellan AFB GSAP for the period from January through March 1990, for groundwater samples collected from OU B. Validation of all analyses, tables for all QC samples, and data for the other areas sampled during this period are presented in both the QA/QC Letter (Radian 1990c) and the Data Summary, January through March 1990 (Radian, 1990a). A summary of the results of the QA/QC activities is presented below, and qualified data are presented in Table 1-4.

The McClellan AFB Remedial Response Program has implemented a comprehensive QA/QC program that includes the preparation of the McClellan AFB Quality Assurance Project Plans (QAPPs) and Sampling and Analysis Plans (SAPs) that are available in the McClellan AFB Administrative Record. The OU B sampling activity was performed in accordance with this QA/QC document.

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TABLE 1-4. SUMMARY OF QUALIFIED DATA[1] IN OU B OF McCLELLAN AFB, JANUARY - MARCH 1990

Sample ID	U.S. EPA Method	Analyte(s)	Type of Qualification	Reason
MW-7	8010	Methylene chloride	E	Estimated value
MW-61	8010	Methylene chloride	E	Estimated value
		Tetrachloroethene	E	Estimated value
MW-135	8010	1,2-Dichloroethene	PF	High RPD in duplicate sample
	6010	Iron	PF	High RPD in duplicate sample
MW-149	8010	1,1,1-Trichloroethane	O	Detected in equipment blank
MW-150	8240	Methylene chloride	R	Detected in reagent blank
MW-153	8010	Trichloroethene	PL	High RPD in MS/MSD
MW-155	8010	Total-1,2-Dichloroethene	G	Estimated value
MW-157	8010	Tetrachloroethene	M	High surrogate recovery
MW-1000	8010	Methylene chloride	O	Detected in ambient blank
MW-1021	8010	Trichloroethene	PL	High RPD in MS/MSD
MW-1022	8010	Tetrachloroethene	E	Estimated value
MW-1023	8010	1,1,1-Trichloroethane	E	Estimated value
MW-1045	8010	Trichloroethene	E	Estimated value
MW-1046	8010	1,2-Dichloroethane	E	Estimated value
MW-1047	6010	Boron	O	Detected in equipment blank
		Zinc	O	Detected in equipment blank
		Iron	O	Detected in equipment blank
MW-1050	8010	Methylene chloride	E	Estimated value
		Trichloroethene	E	Estimated value

PL = Qualified as estimated due to high laboratory variability as measured by laboratory matrix spikes/matrix spike duplicates.
PF = Qualified as estimated due to high total variability as measured by field duplicates.
RPD = Relative percent difference.
R = Detected in reagent blank.
O = Detected in blank other than reagent blank.
M = Qualified as inaccurate due to matrix spike or surrogate recoveries outside the control limits.
E = Estimated value.
[1] = The value of data listed as qualified should be interpreted as an estimate or as approximate.

Quality assurance refers to the activities of planning, implementation, and oversight that are conducted to ensure that the data produced are valid and complete and that they can be used for their intended purpose.

Quality control is defined as the system or series of activities established to control the quality of a product or service so it meets the needs of the user. One measure of quality is the extent of errors. Some potential sources of errors in the McClellan AFB groundwater monitoring effort are contamination from reagents or equipment, interferences, and matrix effects, and deviation from established sampling and analytical methodology. The established QA/QC procedures serve to minimize the potential for errors to occur and to quickly identify and correct any problems that may arise.

The three primary objectives in Radian's QA/QC system are to:

- Ensure that correct sampling, analytical, and data reduction protocols are followed and to reduce or eliminate sources of errors affecting the quality of the data;
- Provide a quantitative assessment of the precision and accuracy of the measurement data; and
- Assess data completeness.

Radian's QA/QC system meets these objectives through a series of checks and statistical tests designed to detect any systematic error while minimizing the effects of random error. This system uses a combination of five categories of checks that establish the validity and quality of the data with respect to:

- Calibration and control standards;
- Blanks;
- Duplicates;
- Spike recoveries; and
- Transcription and reporting checks.

These tests investigate both systematic and random errors arising from the three major project activities: field sampling, laboratory analysis, and reporting.

The QA/QC data have been evaluated according to the quality assurance objectives specified in Section 4.0 of the McClellan AFB Quality Assurance Project Plan (QAPP) (Radian, 1990e). These accuracy and precision objectives are used to assess performance for each method. In addition, objectives are specified for completeness, representativeness, and comparability.

The quality assurance objectives for precision are a relative percent difference (RPD) of less than or equal to 50 percent for field duplicate sample results and an RPD of less than or equal to 30 percent for laboratory duplicate analysis results. The objectives for accuracy are analyte-specific and are listed in the SOP for each method. The objective for completeness is to have greater than 90 percent of all data reported as valid. The objectives for comparability and representativeness are a function of the sampling program and are evaluated in terms of program objectives. However, comparability is achieved in part by using standard methods for sampling and analysis, reporting data in standard units, and using standard and comprehensive reporting formats.

1.3.3 Summary of QA/QC Results

The following is a summary of the QA/QC data, qualified data, and corrective actions taken from January through March 1990 for monitoring wells in OU B.

There were no systematic problems that affected the overall data quality reported for the period of January, February, and March 1990. Although data from several wells were qualified because of random errors, the majority of the data satisfied the quality assurance objectives. Qualified data for samples collected from monitoring wells in OU B are presented in Table 1-4.

The term "qualified data" refers to data that fell outside the specified tolerance limits and, therefore, did not meet the program's quality assurance objectives. Such qualified data and their results should be interpreted as estimated or uncertain values. The term "corrected data" refers only to data for analytical spikes. If analytical spike recoveries are outside of method-specified control limits, a method of standard addition is performed. The results from the analysis are corrected for the original conditions that caused the analytical spike to be outside its limits. Such corrected data are considered valid. Valid data meet the quality assurance objectives of the program.

For U.S. EPA Method 8010, there were samples in which the quantitation of some analytes was affected by interferences on the first chromatographic column. Because the detected concentrations from the two columns were not within a factor of two, the analytes for both the first and second column were reported as unconfirmed. As indicated by historical results, these compounds were previously confirmed; therefore, the data for seven monitoring wells are reported as estimated using the values obtained from the column which the analyst determined would provide the most representative results. The analytical data estimated by this procedure are indicated with an "E" qualification in Table 1-4.

More than 98 percent of the data are valid, fulfilling the project objectives for accuracy and precision for the sampling program from January through March 1990. The completeness objective of 90 percent valid data was attained.

2.0 RISK CHARACTERIZATION AND NEED FOR ACTIONS

Non-time critical removal actions and Expedited Response Actions (ERAs) proposed for sites on the National Priorities List such as McClellan Air Force Base (AFB) are provided for in the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), Superfund Ammendments and Reauthorization Act of 1986 (SARA), and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Three categories of removal actions are established in the guidance documents concerning removal action policies: classic emergencies, time-critical removal actions, and non-time critical removal actions. Classic emergencies are those actions which must be taken within hours or days because of recognized threats to public health, welfare, or the environment. Time-critical removal actions are those which must be initiated within six months because of threats to public health, welfare, or the environment. Non-time critical actions are those for which implementation may be delayed six months or more, but less than two years, because threats to human health, welfare, or the environment exist but are not time critical.

Contaminant plumes migrating in groundwater toward water supply wells in Operable Unit (OU) B create the need for the identified action. If no action is taken for the migrating contamination, exposure to the contaminants could occur over time. The contaminant concentrations exceed U.S. Environmental Protection Agency (U.S. EPA) and California Department of Health Services (DHS) Maximum Contaminant Levels (MCLs) for drinking water. Therefore, a potential threat of human exposure to dissolved contaminants at Base Well (BW) 18 or City of Sacramento Well (CW) 132 was considered a condition which justified a removal action in OU B. Contaminants with concentrations exceeding federal and state drinking water standards are not entering City of Sacramento or McClellan AFB water supplies. Therefore, the condition was considered non-time critical.

To justify a removal action, the NCP (1990) lists eight criteria to be considered [40 CFR Sec. 300. 415(b)(2)]. The second criterion on the NCP list is "Actual or potential contamination of drinking water supplies or sensitive ecosystem." Groundwater contamination beneath OU B had led to the removal of CW-150 from service in 1982, and of BW-18 in 1981. Base Well 18 was brought back into service in 1985 after it was retrofitted with a water treatment system. However, no assessment of risks had been performed to determine what, if any, additional risks may exist because of the contaminants in groundwater beneath OU B. Therefore, to determine the appropriateness of and to select removal actions, a Baseline Risk Assessment was

conducted for groundwater beneath OU B. Results of the Baseline Risk Assessment, which are summarized in the following sections, are the principal justification for proposed removal actions. Details of the Baseline Risk Assessment are provided in Appendix B.

2.1 Baseline Risk Assessment

The purpose of the OU B Groundwater Baseline Risk Assessment was to identify and to characterize the current or "baseline" risks to the human populace living and working in and around OU B at McClellan AFB. The Baseline Risk Assessment was performed to determine the need for a removal action. It provides information required to identify, evaluate, and select removal actions. Therefore, it is an important part of any Engineering Evaluation and Cost Analysis-Environmental Assessment (EE/CA-EA) process.

The site-specific objectives for the OU B Groundwater Baseline Risk Assessment were to identify the potential receptors, contaminants of concern, exposure pathways, and health risks that may result from groundwater use. Two major water supply wells are located within the boundaries of OU B. Base Well 18 serves on-base military personnel and their dependents, as well as civilian personnel working on base. City Well 132 is located in the southern portion of the operable unit and is part of a City of Sacramento well field serving primarily off-base residential, commercial, and industrial users through the city water system. The Baseline Risk Assessment identifies and characterizes the potential risks associated with use of contaminated groundwater to residential, military, and civilian personnel in and around the operable unit.

Use of contaminated groundwater in the Baseline Risk Assessment was based on two hydrologic scenarios: (1) BW-18 pumping and CW-132 off, and (2) BW-18 off and CW-132 pumping. Exposure assumptions and algorithms were developed for the following: the average and upperbound (9- and 30-year) exposure periods for resident adults and children; the 3-year exposure period associated with one tour of military duty; and the 30-year occupational exposure period for civilians working at McClellan AFB. The baseline risk was calculated using the two hydrologic scenarios, exposure assumptions, and modeled concentrations of contaminants in groundwater at the wells.

The Baseline Risk Assessment consists of five principal parts, summarized in the following sections. These include: Compounds of Potential Concern, Exposure

Assessment, Toxicity Assessment, Risk Characterization, and Conclusions and Recommendations.

2.1.1 Compounds of Potential Concern

The compounds of potential concern in OU B were selected on the basis of the quality of the available data and whether the compounds were potentially site-related. A "snap-shot" approach was implemented to select a specific data set to be used in the quantitative risk assessment. The most recent data available for this assessment, from January 1990, was selected as the primary data set. All other data were used in a qualitative analysis to determine if there were any historically significant changes in concentrations. Some contaminants detected in the January 1990 sampling and analysis effort were eliminated from the quantitative risk assessment based on data evaluation--background comparisons, frequency of detection, and evaluation of quantitation limits. These included two U.S. EPA-designated Group A carcinogens, benzene and vinyl chloride, which were eliminated from the initial contaminant list because of their low concentrations and/or infrequent occurrence.

The compounds selected for the Baseline Risk Assessment are listed in Table 2-1.

2.1.2 Exposure Assessment

This assessment was limited to exposure pathways originating with contaminants in the groundwater beneath OU B and associated with the use of BW-18 and CW-132. Environmental fate and transport modeling was used to predict the magnitude of contamination that could migrate to the two supply wells. Since the original source(s) of the contaminants in the groundwater have not been identified and evaluated, potential pathways of exposure unrelated to the groundwater medium have not been examined. Potentially applicable transport and fate mechanisms could include, for example, volatilization of chemicals to the air and fugitive dust generation from shallow contaminants, surface soils, and surface runoff. These mechanisms will be assessed and reported in the upcoming OU B Remedial Investigation (RI).

Complete exposure pathways that exist at the site include: 1) groundwater migration to potable well: ingestion of drinking water; 2) groundwater migration to potable well: dermal contact with drinking water; 3) groundwater migration to potable well: volatilization of volatiles during home use and inhalation of vapors (e.g., while

TABLE 2-1. SUMMARY OF COMPOUNDS OF POTENTIAL CONCERN IN OU B AT McCLELLAN AFB

Compounds	U.S. EPA Weight-of-Evidence Classification	CAS Number
Carbon tetrachloride	B2	56-23-5
Chloroform	B2	67-66-3
Dichloroethane, 1,2-	B2	107-06-2
Dichloroethene, 1,1-	C	75-35-4
Dichloroethene, 1,2-	--	156-60-5
Methylene chloride	B2	75-09-2
Tetrachloroethane, 1,1,2,2-	C	79-34-5
Tetrachloroethene	B2	127-18-4
Trichloroethane, 1,1,1-	D	71-55-6
Trichloroethane, 1,1,2-	C	79-00-5
Trichloroethene	B2	79-01-6
Boron	--	7440-42-8
Vanadium	--	7440-62-2
Zinc	--	7440-66-6

CAS = Chemical Abstract Service
B2 = Probable Human Carcinogen
C = Possible Human Carcinogen
D = Not Classifiable as to Human Carcinogencity
-- = No Classification Ranking
Source: IRIS, 1990

showering, washing clothes, or washing dishes); and 4) groundwater migration to potable well: use of water to irrigate backyard garden, root uptake by plants, and ingestion of fruits and vegetables.

Of these pathways, the first three are considered potentially significant. The fourth pathway was not quantified for this risk assessment because the majority of compounds of concern are volatile and will tend to evaporate from the soil surface before significant plant uptake can occur. The exposure resulting from this irrigation pathway was considered to have a much lower potential for human exposure than drinking water from the same source, a pathway which was quantified.

The primary point at which human exposure to contaminants detected beneath OU B may occur is at the tap in homes and workplaces, on base and off base, that are serviced by water drawn from wells in the path of migrating contaminant plumes. The exposure scenarios that were evaluated in the risk assessment were residential, three-year tour-of-duty, and occupational. Residential water use can lead to exposure via ingestion of the water, dermal contact with the water, and inhalation of vapors released from the water as it leaves the tap. Water use by workers can lead to exposure by the same routes; however, dermal contact and inhalation of vapors are less significant for workers. Activity patterns of on-base civilian workers and off-base office and industrial workers do not typically include showering, washing dishes, and washing clothes. These primarily domestic activities involve the greatest potential for dermal contact with the water and the release of vapors which can be inhaled.

Probable future land uses in the vicinity of McClellan AFB--increased industrial/commercial development and increased density of residential housing--will not alter these exposure points and exposure routes unless the source of potable water distributed to on-base and off-base residences and workplaces changes. If CW-132 were to continue in operation as a source of off-base water supplies, the size of the potentially exposed population off-base will increase.

Table 2-2 summarizes the exposure scenarios which were evaluated in the risk assessment.

2.1.3 Toxicity Assessment

Chronic and subchronic exposures were considered in the risk assessment for potential noncarcinogenic effects. The chronic exposure scenarios include residential

TABLE 2-2. EXPOSURE SCENARIOS

Scenario	Brief Rationale
Chronic Exposure	
On-Base Residential/Lifetime (9-30 years) • Child • Adult	McClellan AFB houses a residential community for military personnel and families. The base water system draws from the the wells on base.
On-Base Residential/3-Year Tour of Duty • Child • Adult	Three years is the typical tour of duty for military personnel. It is unlikely that any one person will reside on-base for a lifetime.
On-Base Worker (30-year) • Adult	Civilian personnel work on base, but reside off base.
Off-Base Residential • Child • Adult	The city water system draws from the groundwater downgradient from the base.
Subchronic Exposure	
On-Base Residential (Applicable to Both Lifetime and 3-Year Tour of Duty Scenarios) • Child • Adult	The monitoring and treatment system on base could fail, allowing untreated groundwater to be distributed to residences and work stations for a period of time before the failure is detected and corrected.
On-Base Worker (30 days) • Adult	The monitoring and treatment system on base could fail, allowing untreated groundwater to be distributed to residences and work stations for a period of time before the failure is detected and corrected.

and occupational exposure resulting from use of water from BW-18, and off-base residential exposure from use of water from CW-132. The chronic Reference Dose (RfD) values presented in Appendix B, Table 6-3, were used for calculating Hazard Indices for these scenarios. The subchronic exposure scenario includes exposure for a maximum of 30 days to water from BW-18 that is contaminated due to a failure of the treatment system. The RfD values, also presented in Appendix B, Table 6-3, were used to calculate the Hazard Indices for the subchronic exposure scenario. Use of the RfD is considered appropriate for exposure periods of two weeks to seven years (U.S. EPA, 1989b). For carcinogenic effects, exposure was averaged over a lifetime (U.S. EPA, 1989b).

The RfD values for the compounds of concern presented in Appendix B, Table 6-3, were obtained from an Integrated Risk Information System (IRIS) search dated 21 May 1990 or from U.S. EPA Health Effects Assessment Summary Tables (HEAST) (U.S. EPA, 1989a). No RfD values are currently available for 1,2-dichloroethane, 1,1,2-tetrachloroethane, or trichloroethene (TCE). Inhalation RfD values are only available for methylene chloride and 1,1,1-trichloroethane. The oral RfD for 1,1,1-trichloroethane was calculated from the inhalation RfD based on route-to-route extrapolation. It should be noted that the RfD for vanadium is based on a dosage at which no effects were observed; an uncertainty factor of 100 was also applied to this dosage.

The carcinogenic potential classifications for the compounds of concern made by the U.S. EPA are shown in Table 2-1. The values presented were obtained from the IRIS search dated 21 May 1990. Several compounds on the list of compounds of concern have not been classified as carcinogens. These include 1,2-dichloroethene (1,2-DCE), boron, vanadium, and zinc. Three of the compounds have been classified in Group C - Possible Human Carcinogen; the remainder were classified by the U.S. EPA as Group B2 - Probable Human Carcinogen (sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans). The U.S. EPA has classified 1,1,1-trichloroethane in Group D - Not Classifiable as to Human Carcinogenicity. It has been tested in two species with no evidence of a carcinogenic effect.

2.1.4 Risk Characterization

The carcinogenic risks estimated for each exposure scenario are summarized in Table 2-3. The greatest risk is associated with the use of contaminated water from

TABLE 2-3. SUMMARY OF ESTIMATED CARCINOGENIC RISKS BY EXPOSURE SCENARIO

Pathway/Scenario	Estimated Carcinogenic Risk	
	Average	Upperbound
BW-18		
Residential	9E-07	8E-06
3-Year Tour-of-Duty	3E-07	9E-07
Occupational	1E-06	2E-06
CW-132		
Residential	3E-06	1E-05

CW-132. However, it should be emphasized that, as yet, contamination has not been demonstrated in this well. More importantly, this well is not presently in service and would not be brought into service except during an emergency, such as a fire. The estimated risks associated with use of water from this well indicate that CW-132 should not be used for water supply once contaminants are detected in the well. Although higher levels of contamination are predicted to occur at BW-18 than at CW-132, the risks associated with residential use of water from BW-18 are lower because a treatment system at BW-18 is used to remove contaminants from the water prior to distribution. The risks estimated for the residential, three-year tour-of-duty, and occupational scenarios are very conservative, because concentrations of contaminants at the detection limit were assumed to be present in the water that was distributed. The actual concentrations in the water are expected to be much lower and, therefore, the risks associated with use of the water will also be lower. Because it is not possible to estimate how much lower those concentrations might be, the appropriate, conservative method for risk assessment purposes is to use the detection limit. This method may not, however, be useful for risk communication because using the detection limit overestimates the actual amount of contamination present. The estimated risks for occupational exposure are larger than those estimated risks for residential exposure because the average residential scenario assumes 9 years of exposure at a residence, as directed by the current Superfund guidance, while the average occupational scenario assumes 30 years of exposure at work.

Noncarcinogenic risks calculated in the Baseline Risk Assessment are summarized in Table 2-4. The Hazard Index is a measure of the noncarcinogenic risk that is the ratio of anticipated exposures to the limit allowed under Federal law. A ratio under 1 represents a reasonable risk. All exposure scenarios result in predicted contaminant intakes that are unlikely to result in adverse health effects for adults and children. Hazard Indices are typically higher for children than for adults. This is due primarily to the greater volume of fluid intake per unit body weight in children than in adults and is a reflection of children's relatively higher metabolic rates. The higher Hazard Indices for children, however, are well below one, the benchmark value for acceptable exposure.

It should be emphasized that the carcinogenic risks and potential noncarcinogenic effects calculated for the Baseline Risk Assessment are hypothetical; the assessment considered modeled concentrations of contaminants predicted to occur at some time in the future, if no removal actions are undertaken. No contamination has

TABLE 2-4. SUMMARY OF NONCARCINOGENIC RISKS BY EXPOSURE SCENARIO

Scenario	Hazard Index			
	Children		Adults	
	Average	Upperbound	Average	Upperbound
Chronic				
BW-18				
Residential	0.2	0.5	0.09	0.2
3-Year Tour-of-Duty	0.2	0.3	0.07	0.1
Occupational	-	-	0.05	0.09
CW-132				
Residential	0.2	0.4	0.05	0.08
Subchronic				
BW-18				
Residential	0.2	0.4	0.08	0.1
3-Year Tour-of-Duty	0.2	0.4	0.08	0.1
Occupational	-	-	0.05	0.1

yet been found at CW-132, and the risk assessment for BW-18 considered hypothetical future concentrations of contaminants.

The major factor driving the risk is the ingestion pathway. Carcinogenic and noncarcinogenic compounds present in groundwater may be ingested by users of the water from BW-18 and CW-132. The major compounds driving the carcinogenic risk for BW-18 is 1,1-dichloroethene, followed by 1,1,2,2-tetrachloroethane. For CW-132, the major compounds are TCE and tetrachloroethene (PCE). The major compounds driving the noncarcinogenic effects are vanadium and boron for BW-18, followed by carbon tetrachloride and PCE. For CW-132, the most important compound is PCE followed by 1,2-DCE. The most important pathway for noncarcinogenic effects is ingestion for the average case and inhalation for the upperbound (or estimated maximum) case.

There were several major factors which contributed to the uncertainties in this risk assessment. For BW-18, the major compounds driving the risk (1,1-dichloroethene and 1,1,2,2-tetrachloroethene) are those which have the lowest usable weight-of-evidence classification for a risk assessment. This reduces the overall confidence in the risk assessment because of the greater degree of uncertainty associated with predicting carcinogenic effects for compounds with a weaker classification. For CW-132, the major compounds driving the risk are under review. Tetrachloroethene is currently under review by the Carcinogen Risk Assessment Verification Endeavor (CRAVE) Workgroup, which may result in a change in the slope factor. (Slope is a numerical description of the relationship of the dose to the response.) The slope factor for TCE has been removed from IRIS pending further review (the value used was obtained from HEAST). This indicates that there may also be a change in the slope factor for this compound and may reduce the confidence in the outcome of the risk assessment.

For the determination of noncarcinogenic effects, a major uncertainty is the lack of an RfD for TCE, a contaminant predicted to be present in concentrations greater than those of the other chemicals. Additional uncertainty is provided by the relatively large contribution of boron and vanadium to the Hazard Index. The extent to which these metals are entering BW-18 is unknown. Moreover, the exposure assessment assumed the "worst-case" of 100% adsorbtion of these compounds from the gastrointestinal tract; this is unlikely to occur. The potential chronic effects of exposure to vanadium are unknown, since the RfD is based on a study in which no effects were observed. Finally, chronic effects attributable to exposure to boron and vanadium are likely to be different from those associated with exposure to volatile organic chemicals

(VOCs), so adding the Hazard Indices for the metals to those of the VOCs will tend to overestimate the likelihood of adverse health effects.

2.1.5 Conclusions and Recommendations

The Baseline Risk Assessment for the McClellan AFB OU B was limited in scope to exposure pathways originating with contaminants in the groundwater beneath OU B and associated with the use of BW-18 and CW-132. Environmental fate and transport modeling was used to predict the magnitude of contamination which could migrate to the two wells. Fourteen compounds of potential concern were identified as the result of environmental sampling and modeling. The potential noncarcinogenic and carcinogenic risks associated with exposure to each compound of concern were evaluated.

The greatest carcinogenic risk for all exposure scenarios was associated with the use of contaminated water from CW-132 in the residential exposure scenario. It should be emphasized that contamination has never been detected in samples taken for analysis from CW-132, and as a preliminary removal action, the well was taken out of operation for normal water supply needs. The well will only be used for short-term emergency needs. The estimated risks associated with exposure to water from this well, however, indicate that if contaminant concentrations migrate to the well, the groundwater should not be used for regular supplies. The carcinogenic risks associated with use of BW-18 (residential, three-year tour-of-duty, and occupational exposure scenarios) are lower than those for CW-132. This is primarily due to the BW-18 treatment system which removes contaminants prior to distribution. The risks calculated for BW-18 exposures are very conservative because concentrations of contaminants at the detection limit were assumed to be present in the water that was distributed. The actual concentrations are expected to be much lower, which would also lower the carcinogenic risks associated with exposure.

On the basis of the conclusions from the Baseline Risk Assessment, the following recommendations are made:

- Initiate a removal action to decrease the potential for migration of groundwater containing concentrations of contaminants toward CW-132 and, thereby prevent any health risks posed to users of water from this well; and

- Initiate a removal action to decrease the migration of increased concentrations of contaminants toward BW-18 and, thereby prevent any health risks posed to users of water from this well.

The removal of both wells from service as sources of supply to on-base or off-base users is the most direct way of decreasing the potential migration of contaminants. However, there may be a valid reason for maintaining either or both wells in operation. The rationale for that alternative was beyond the scope of the Baseline Risk Assessment. If one or both wells are kept in operation as water supply wells, it is recommended that removal actions be initiated to limit the migration of more concentrated contaminants before they enter the wells and are distributed in the supply network.

3.0 REMOVAL ACTION OBJECTIVES

The proposed removal actions in Operable Unit (OU) B were determined necessary by McClellan AFB, with the concurrence of the U.S. Environmental Protection Agency (U.S. EPA) and California Department of Health Services, based on the results of groundwater samples and the potential imminent and substantial danger to the public health or welfare that the contaminated groundwater represents. The removal actions discussed in Section 4.0 are "non-time critical" actions that have been taken or will be initiated within 12 months of the preparation of this document. The actions proposed are not time critical because the threats to public health and welfare and the environment will not become critical within the next 12 months. On the basis of the data available from the site characterization (Section 1.0) and baseline risk assessment (Section 2.0), risks to health and welfare would develop over a period of time greater than 12 months if no actions were taken. Each Engineering Evaluation/Cost Analysis-Environmental Assessment (EE/CA-EA) must document the objectives to be attained by the proposed removal action and the rationale for the objectives.

The objectives of the removal actions proposed are:

- Reduce the potential for health risks that will result from the continued migration of greater contaminant concentrations to water supply wells within OU B;
- Prevent environmental impacts that could result from the continued migration of contaminant groundwater; and
- Develop removal actions that are consistent with the potential long-term remedial action.

3.1 Removal Scope

The OU B removal actions are short-term actions proposed to protect public health and welfare and to comply with the Applicable or Relevant and Appropriate Requirements (ARARs), which are discussed in more detail in Section 3.4. The removal actions selected must be consistent with and contribute to the performance of potential remedial actions that may be implemented in the future (USC Sec. 9604(a)(2) and Sec. 11.5 of the McClellan Interagency Agreement). Longer term, Phase Two actions will be evaluated during the OU B Remedial Investigation and Feasibility Study (RI/FS).

Removal actions are intended to prevent health risks or impacts on the environment that could be caused by migration of the contaminant plumes in groundwater. Immediately after implementation, the actions will result in: extraction and management of groundwater containing contaminants at concentrations greater than 100 micrograms per liter (μg/L) total volatile organic compounds (VOCs) that is migrating toward a water supply well and the McClellan Air Force Base (AFB) boundary; and control of groundwater flow beneath all of OU B. The extraction of groundwaters that contain contaminant concentrations greater than 100 μg/L total VOCs has been the focus of the removal action design because this portion of the contaminated groundwater represents the most significant threat to the McClellan AFB water supply well (BW) 18 and to the environment. After all removal actions have been implemented and have been in operation for a period of time, the concentration of contaminants extracted will decrease as groundwater at greater distances from the wells in the zone of capture migrate to the extraction wells. Although the removal action design has been largely focused on the extraction of the groundwater containing greater than 100 μg/L total VOCs, the removal action also will intercept and extract groundwaters located beyond the 100 μg/L zone of capture, and therefore, result in the mitigation of a greater portion of the contaminated groundwater.

3.2 Removal Action Schedule

The urgency of implementing the removal actions in OU B is dictated by the location, concentration, and rate of movement of the plumes toward BW-18, City of Sacramento Well (CW) 132, and groundwater areas not yet impacted by the migration of contaminants. It is anticipated that the design, construction, and operation of removal actions will be completed within 6 to 12 months .

3.3 Statutory Limits On Removal Actions

The requirements for actions funded under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) include:

- Present-worth expenditures are limited to $2 million; and
- Time period for removal action implementation is limited to 12 months.

McClellan AFB is not obligated to comply with these specific administrative requirements which specifically apply to CERCLA or U.S. EPA "fund financed" actions. However, the McClellan AFB CERCLA Response Program will consider funding issues and will seek to implement the removal actions in a timely manner.

3.4 Identification of ARARs

This section provides an overview of the ARARs identified during the evaluation of removal action alternatives for the groundwater contamination within OU B. These ARARs are standards promulgated by a state or federal agency pertinent to the chemical contamination of specific hazardous waste sites or are those standards consistently applied to hazardous waste sites. These requirements can include contaminant concentration limits in environmental media as well as applicable design standards for treatment or disposal systems. For this EE/CA-EA, all relevant local, state, and federal requirements were considered for selection as pertinent ARARs.

Section 5.0 provides detailed discussions of the removal action alternatives evaluated, including alternative-specific ARARs and how each alternative ensures compliance with the applicable ARARs.

3.4.1 Regulatory History of ARARs

Sections 104 and 106 of the CERCLA, also known as "Superfund," authorize financing of remedial actions at prioritized hazardous waste sites. However, this act does not specify the procedures by which these remedial actions should be evaluated and selected. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) of 1990 provides guidelines for determining the appropriate remedial actions at Superfund sites (NCP, 1990). The NCP established a general requirement that remedial actions "attain or exceed applicable or relevant and appropriate federal requirements."

The Superfund Amendments and Reauthorization Act of 1986 (SARA) specified that remedial actions shall attain a degree of cleanup that assures protection of human health and the environment. In Section 121(d)(2)(A) of SARA, Congress specified that any standard, requirement, criterion, or limitation under any federal environmental law and any promulgated standard, requirement, or criterion under more

stringent state environmental or facility siting laws are legally applicable to any contaminant remaining at a site.

3.4.2 General Discussion

The ARARs applicable to this removal action are based on the project objectives outlined in Section 3.0. The ARARs pertinent to groundwater contamination treatment or disposal actions involve establishing groundwater cleanup levels, operating treatment processes, and managing any treatment residues. However, ARARs evaluated for this EE/CA-EA have been limited to ARARs pertinent to treatment or disposal of groundwater contamination and the management of any treatment residues. McClellan AFB, as the lead agency, may take any appropriate removal action to minimize, and stabilize the current groundwater contaminant releases, because of the actual or potential exposure to residences (40 CFR Sec. 300.415(b)(1) and (i)). However, restoration of the groundwater contamination is considered outside the scope of the removal action; therefore, the establishment of groundwater cleanup levels will not be conducted because they are neither applicable, or relevant and appropriate. The ARARs for establishing groundwater cleanup levels will be evaluated during a subsequent OU B RI/FS effort.

3.4.3 "Applicable" vs. "Relevant and Appropriate"

"Applicable" requirements are cleanup standards, control standards, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law which specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other conditions at a CERCLA site.

"Relevant and appropriate" requirements, like applicable requirements, are cleanup standards, control standards, or other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law. However, while not technically "applicable" to a hazardous substance, pollutant or contaminant, remedial action, location, or other conditions at CERCLA sites, "relevant and appropriate" requirements are well suited to address problems or situations sufficiently similar to those encountered at a CERCLA site.

The difference between "applicable" and "relevant and appropriate" is that the responsible party is legally obliged to fulfill an applicable requirement. For example, the minimum technology requirement for landfills under the Resource,

Conservation, and Recovery Act (RCRA) would apply if a new hazardous waste landfill unit (or an expansion of an existing unit) were to be built on a CERCLA site.

The relevance and appropriateness of a requirement can be judged by comparing a number of factors, including the characteristics of the remedial action, the hazardous substances in question, or the physical circumstances of the site, with those addressed in the requirement. The objectives and origin of the requirement are also important factors. For example, while RCRA regulations are not applicable to closing undisturbed hazardous waste in place, the RCRA regulations for closure by capping may be deemed relevant and appropriate.

A requirement that is judged to be relevant and appropriate must be complied with to the same degree as it would if it were applicable. However, there is more discretion in this determination; it is possible for only part of a requirement to be considered relevant and appropriate, the remainder being dismissed if judged not to be relevant and appropriate in a given case.

3.4.4 Application of ARARs to Removal Actions at OU B

The CERCLA of 1980 as amended by the SARA of 1986 requires that selected remedial actions at Superfund hazardous waste sites are protective of human health and environment, cost-effective, and technologically and administratively feasible. Section 121 of CERCLA specifies that response actions must be undertaken in compliance with ARARs established in Federal and State environmental laws. Several different types of requirements are identified with which Superfund remedial actions must comply: (1) ambient or chemical-specific requirements; (2) action-specific requirements; and (3) location-specific requirements. Because situations at CERCLA sites are widely variant, the U.S. EPA cannot categorically specify requirements that will be ARARs for every National Priority List (NPL) site. The ARARs can only be identified on a site-specific basis (i.e., established in connection with the characteristics of the particular site, the chemicals present at the site, and the remedial alternatives suggested by the circumstances of the site).

Section 121(d)(2)(A) of CERCLA as amended by SARA states that:

> With respect to any hazardous substance, pollutant or contaminant that will remain on site, if [any state or federal environmental standard] is legally applicable to the hazardous substances or pollutant or

> contaminant concerned or is relevant and appropriate under the release or threatened release of such hazardous substance or pollutant or contaminant, the *remedial* action selected...shall require, at the completion of the remedial action, a level or standard of control for such hazardous substance or pollutant or contaminant which at least attains such legally applicable or relevant and appropriate standard...

The statutory language of CERCLA limits the application of ARARs to remedial actions and not specifically to removal actions such as the ones proposed for OU B. However, U.S. EPA policy states that ARARs should be applied where practicable. In the NCP, the U.S. EPA lists two factors to be considered in determining practicability: (1) the exigencies of the circumstance; and (2) the scope of the removal action.

No federal, state, or local permit is required for the portion of any removal action conducted entirely on-site, in accordance with Section 121(e) of CERCLA and 40 CFR 300.400(e).

The McClellan AFB removal actions are being conducted pursuant to CERCLA Section 104 authority delegated by the President to and funded by the Defense Environmental Restoration Program (DERP, 10 USC Sec. 2701 et seq., in particular Sec. 2703) and are not U.S. EPA "fund-financed" actions. Therefore, neither CERCLA nor the NCP require that ARARs apply to the McClellan AFB removal actions. However, the McClellan AFB Interagency Agreement states that removal actions must contribute to the efficient performance of any long-term remedial action to the extent the Air Force deems practicable (42 USC Sec. 9604(a)(2) and Sec. 11.5 of the IAG).

The ARAR identification and selection process will involve a request from Air Force representation to the state and federal agencies to suggest ARARs for consideration followed by selection of ARARs by the Air Force. Based on a review of the ARARs that are submitted, ARARs will be selected by the Air Force that are deemed practicable based on the purpose of the removal action and the need to contribute to long-term remedial actions.

Based on the current removal action objectives and scope, the ARARs considered appropriate to groundwater remedies being evaluated for the McClellan AFB OU B removal actions are the ones associated with potential groundwater treatment and

disposal actions, and managing treatment residuals. These treatment and disposal ARARs are presented in Table 3-1. In general, the water quality ARARs identified are associated with groundwater discharge options and air quality ARARs are related to regulation of potential air emissions from treatment systems. The Clean Water Act (53 FR 34079, 2 September 88 and 55 FR 29230 18 July 90) identifies the requirements for the design of any wastewater treatment tanks, pipelines, and other ancillary equipment used to convey wastewater to a treatment system. The current removal action objectives and scope do not require that groundwater cleanup ARARs be established for the OU B plumes at this time. It is recommended that establishing groundwater cleanup level ARARs should await implementation of the OU B RI/FS effort.

3.4.5 ARARs for OU B Interim Record of Decision

An interim Record of Decision (ROD) could be prepared for the OU B removal actions selected in this EE/CA-EA before the start of the OU B RI/FS. If an interim ROD were prepared, it is anticipated that long-term response action objectives and ARARs for the OU B plumes would be developed and added to the stated objectives and ARARs to fully address public health, and environmental concerns. Preliminary groundwater ambient or chemical-specific ARARs could be developed for the interim ROD and finalized during the OU B RI/FS. Remedial actions would be evaluated and selected to meet these goals.

TABLE 3-1. ARARs IDENTIFIED FOR RECOMMENDED REMOVAL ACTION ALTERNATIVES SELECTED FOR THE TCE/PCE AND NORTHERN TCE/1,2-DCE PLUMES

ARARs For Recommended Extraction, Treatment, and Discharge Removal Action -- TCE/PCE Plume

Extraction wells and conveyance of groundwater to local aqueous phase granular activated carbon (GAC) adsorption, followed by discharge to the Industrial Wastewater Line (IWL), treatment by the Industrial Wastewater Treatment Plant (IWTP), and discharge into the Sacramento County Regional Sanitation District (SCRSD) interceptor system and Regional Treatment Plant.

- Clean Water Act pretreatment standards for discharges to the SCRSD Publicly Owned Treatment Works (POTW);
- Clean Air Act (CAA) Primary and Secondary Ambient Air Quality Standards;
- National Ambient Air Quality Standards (NAAQS);
- National Emission Standards for Hazardous Air Pollutants;
- California Ambient Air Quality Standards;
- SCRSD Sanitary Sewer Fees and Discharge Requirements; and
- Sacramento Metropolitan Air Quality Management District Requirements.

ARARs For Recommended Extraction, Treatment, and Discharge Removal Action -- Northern TCE/1,2-DCE Plume

Extraction wells, conveyance of groundwater by piping to Groundwater Treatment Plant (GWTP), and surface water discharge to Magpie Creek.

- Clean Air Act (CAA) Primary and Secondary Ambient Air Quality Standards;
- National Pollutant Discharge Elimination System (NPDES) of the Clean Water Act;
- National Ambient Air Quality Standards (NAAQS);
- National Emission Standards for Hazardous Air Pollutants;

Continued

TABLE 3-1. (Continued)

- California Ambient Air Quality Standards; and
- Sacramento Metropolitan Air Quality Management District Requirements.

ARARs for Recommended Interim Remedy -- Extraction and Discharge -- Northern TCE/1,2-DCE Plume

Extraction wells and conveyance of groundwater by piping to the nearest sanitary sewer connection.

- Clean Water Act pretreatment standards for discharges to the SCRSD Publicly Owned Treatment Works (POTW); and
- SCRSD Sanitary Sewer Fees and Discharge Requirements.

4.0 PROPOSED ACTIONS

On the basis of data obtained from the Operable Unit B Groundwater Remedial Investigation (OUBGRI) and other previous and ongoing investigations, the extent and concentrations of contaminant plumes in groundwater have been estimated. Contaminant plumes are represented on maps of Operable Unit (OU B) by dashed isopleth lines. The lines were approximated from contaminant concentrations detected in monitoring well samples and from historical and recent groundwater flow directions. Beneath the areas enclosed by the isopleths, contaminant concentrations in groundwater are estimated to range between values indicated on the adjacent isopleths. Four geographic areas in OU B have been designated Areas of Concern (Figure 4-1) because groundwater beneath them contains volatile organic compounds (VOCs) that exceed U.S. Environmental Protection Agency (U.S. EPA) Maximum Contaminant Levels (MCLs) or California Department of Health Services (DHS) MCLs for drinking water. Because of the contaminant concentrations present, groundwater in one or more zones beneath the Areas of Concern cannot be used for drinking water without pretreatment.

Within the Areas of Concern, VOC concentrations are greatest beneath McClellan Air Force Base (AFB) in the trichloroethene/tetrachloroethene (TCE/PCE) plume and the northern trichloroethene/1-2,dichloroethene (TCE/1,2-DCE) plume. The greatest concentrations of VOCs in these two Areas of Concern are 120 to 5,400 micrograms per liter (μg/L) TCE, 210 to 1,400 μg/L PCE, and 45 to 74 μg/L 1,2-DCE exceeding MCL values of 5 μg/L TCE, 4 μg/L PCE, and 16 μg/L 1,2-DCE, respectively. In the southern TCE/1,2-DCE plume and the PCE plume, the greatest VOC concentrations are 13 μg/L TCE, 6.1 μg/L PCE, and 6.2 μg/L 1,2-DCE. The presence of the VOCs in groundwater beneath the Areas of Concern has led to the connection of residences to municipal water supplies for drinking water in 1986, removal from service of City of Sacramento municipal well (CW-150) in 1982, and the temporary removal (1981 to 1985) of McClellan AFB water supply well (BW) 18. Residences in and south of OU B that relied upon domestic water supply wells for drinking water were provided with connections to City of Sacramento water supplies in 1986, to replace groundwater supplies that were potentially contaminated. McClellan AFB BW-18 was retrofitted with a carbon adsorption treatment system and returned to service in 1985.

After the Areas of Concern were delineated in concentration and vertical and horizontal extent, the Air Force proceeded with an Engineering Evaluation and Cost Analysis-Environmental Assessment (EE/CA-EA) of removal actions to address groundwater contaminants beneath the Areas of Concern. A major component of the

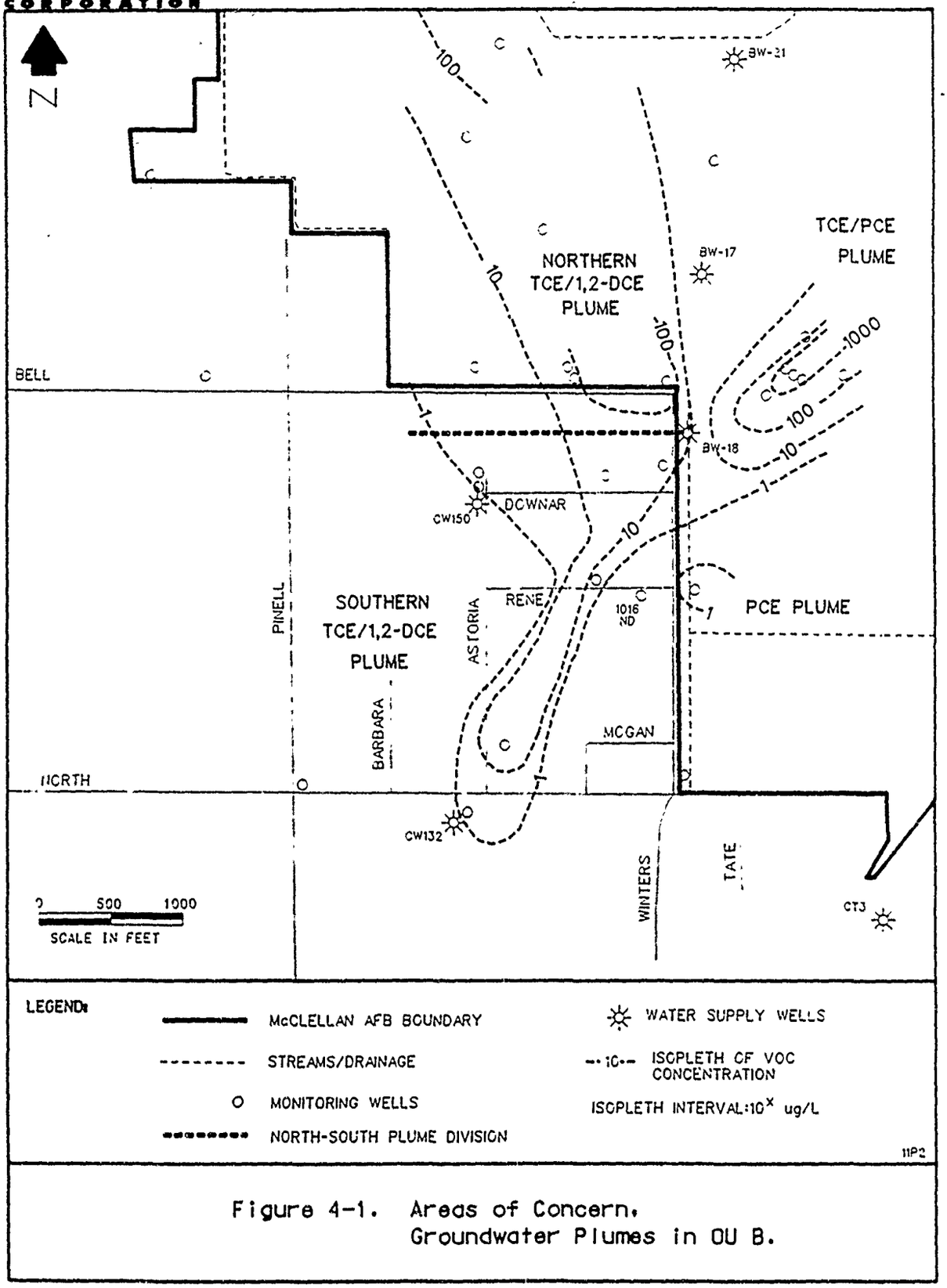


Figure 4-1. Areas of Concern, Groundwater Plumes in OU B.

EE/CA-EA was the preparation of a Baseline Risk Assessment for groundwater. The objective of the Baseline Risk Assessment was to evaluate health risks that may result from the continued migration of groundwater containing contaminant concentrations from its location in January and February 1990 toward two supply wells, CW-132 and BW-18. The Baseline Risk Assessment considered the future exposure and health risks that could impact CW-132 or BW-18 after a period of contaminant migration. The results of the risk assessment indicate that carcinogenic and noncarcinogenic risks would develop for the users of the groundwater, if removal actions are not taken to control the migration; groundwater containing greater concentrations of contaminants will continue to move toward either well after one is shut down and the other continues to operate (Section 2.1.5). Therefore, removal actions are warranted in OU B on the basis of potential health risks that would result from the migration of contaminants toward and into supply wells.

In addition to health risks, Applicable or Relevant and Appropriate Requirements (ARARs) promulgated by federal or California State government, removal effectiveness, technical feasibility, administrative feasibility, and costs were evaluated in selecting the proposed actions. The details of the Baseline Risk Assessment are provided in Appendix B. The technical basis for proposed actions for groundwater are described in detail in Appendix A. The evaluation of ARARs, technical and administrative feasibility, effectiveness, and costs are evaluated in Sections 5.0 and 6.0.

4.1 TCE/PCE Plume - Proposed Action

An Expedited Response Action (ERA) was proposed for the TCE/PCE plume in January 1990 to representatives of the regulatory agencies and will be implemented in October 1990 because of the potential threat that the plume poses for a principal McClellan AFB supply well (BW-18) and groundwater resources beneath off-base areas beyond the base supply well. Because of this plume's contaminant concentration (>1000 micrograms per liter [μg/L]) and migration path toward the supply well, actions to control the migration of the plume were given priority and were expedited over other potential actions needed in OU B.

The TCE/PCE plume consists of groundwater contaminated with dissolved VOCs, apparently from soils beneath the foundation of Building 666 (Site 47) is migrating in a southwesterly direction toward BW-18 (Figure 4-2). It is probable that

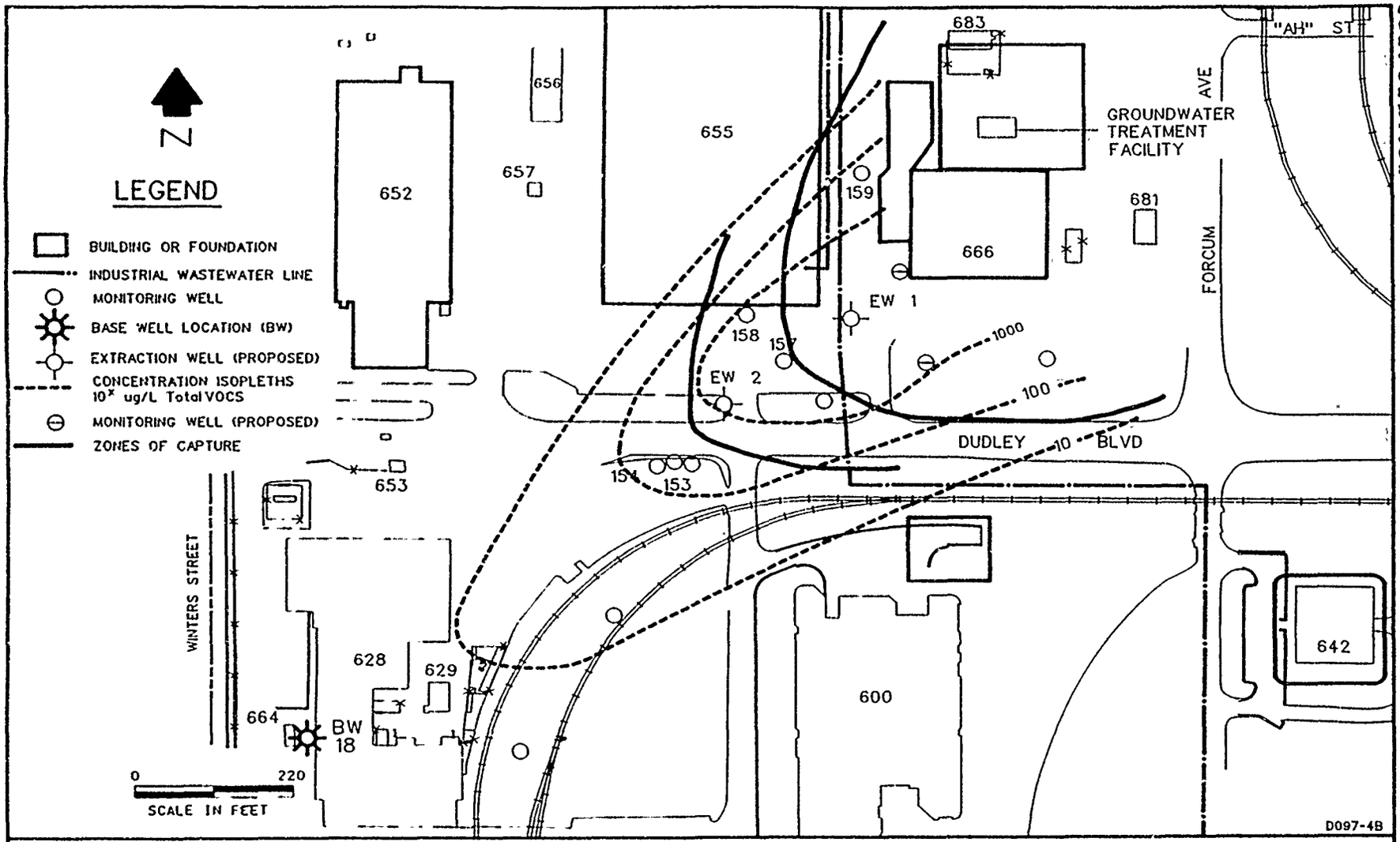


Figure 4-2. Location of Extraction Wells for Expedited Removal Action, TCE-PCE Plume, Operable Unit B.

the VOC contamination has entered the groundwater from one or more sources which existed during the operational history of Building 666, the former plating shop in OU B. Contaminant concentrations in the A geohydrologic zone range from 10 to greater than 8,000 μg/L total VOCs. The A zone extends from the water table (approximately 100 feet below ground surface [BGS]) to 135 feet BGS. In samples from wells constructed in the B zone (135 to 180 feet BGS), and the C zone (180 feet to 260 feet BGS), concentrations of VOCs are less than 5 μg/L (Appendix A, Section A4.2). Groundwater containing greater concentrations of VOCs apparently has not penetrated vertically to deeper zones because of very fine-grained deposits in the bottom of the A zone that impede vertical migration. The removal action undertaken to control the TCE/PCE plume was focused on the VOC concentrations (1,000 μg/L or greater) in the A geohydrologic zone. A volume of groundwater containing VOCs in concentrations of less than 1,000 μg/L will continue to migrate toward BW-18 in groundwater of the A zone. As the contaminant concentrations in the A zone migrate toward BW-18, mixing with groundwater of lower or nondetectable concentrations will occur. The well draws groundwater from four depth intervals beneath the A zone, each of which now has groundwater with VOC concentrations of less than 100 μg/L. The groundwater from all depths is mixed in the well before it reaches the surface. Therefore, contaminant concentrations from the A zone will be further diluted. The diluted concentrations resulting from the mixing of groundwater in the well will be removed by the well's treatment system before use. The impact of the migration of contaminants in concentrations less than 1,000 μg/L toward BW-18 will be evaluated in the OU B Remedial Investigation (RI). If there is potential for health risk development for users of BW-18 water as a result of the migration, remedial actions to control the migration will be considered after the OU B RI.

The portion of the contaminant plume in which VOC concentrations exceed 1,000 μg/L is approximately 700 feet from BW-18. If the contaminant plume were allowed to move toward the well, its velocity of movement would increase because the groundwater gradient increases when the well is pumping. A minimum 3 to 5 fold increase in the velocity of plume migration will occur because the potentiometric surface between the plume position and the well increases in slope toward the well.

An ERA is proposed for the TCE/PCE plume in the A zone because the contaminant concentrations greater than 1,000 μg/L:

- Are migrating horizontally and vertically as a result of the movement of groundwater and will degrade the quality of a larger volume of groundwater with time if migration is allowed to continue;

- Are migrating in the zone of capture for BW-18, a major source of groundwater supply for McClellan AFB, and if greater concentrations enter the well, health risks to water users will develop;

- Could cause the shutdown of BW-18 if concentrations in groundwater brought to the surface by the base well rise above levels that can be treated for use in the McClellan AFB water supply; and

- Will migrate beyond the southern boundary of McClellan AFB, thereby causing additional groundwater resource degradation and potential health risks to downgradient groundwater users if BW-18 is taken out of service.

The ERA proposed for the TCE/PCE plume consists of extracting contaminated groundwater with two wells, treating the extracted water, and discharging the treated water to the McClellan AFB Industrial Wastewater Line (IWL) which leads to the Industrial Wastewater Treatment Plant (IWTP).

For the conditions existing in the TCE/PCE plume, the installation of an extraction well field is the most feasible removal action for control of groundwater flow and reduction of contaminant concentrations. An extraction field of two extraction wells has been proposed to draw groundwater from depths ranging from 100 to 125 feet BGS. The wells, shown in Figure 4-2, are located within the most highly concentrated areas of the groundwater plume enclosed by the 1,000 μg/L isopleth. Zones of capture, representing the areas from which contaminated groundwater will flow to the wells, are shown in Figure 4-2. Extraction Well (EW) 2 operating alone has a zone of capture that would eventually draw in the entire 1,000 μg/L plume. However, the use of only EW-2 would cause groundwater with concentrations exceeding 10,000 μg/L to be drawn downgradient away from the probable source area before it is captured by a well. Removal of contaminated groundwater near the source is a more effective method of removal to prevent greater spreading of contaminants.

Extraction Well 1 is located closest to the foundation of Building 666, which contained several potential sources of contamination when it was operating. The well will initially extract groundwater that has a concentration of VOCs exceeding 10,000 μg/L. It will pump at a rate of 5 gallons per minute (gpm). Extraction Well 2 is located 200 feet to the southwest from EW-1. The well will pump at a rate of 15 gpm and will initially extract groundwater with a VOC concentration exceeding 1,000 μg/L. The details of extraction well siting, construction, and pumping rate determination are presented in Section A6.1 , Appendix A.

Contaminants that are expected to be brought to the surface in extracted groundwater are: TCE, PCE, 1,2-DCE, chloroform, methylene chloride (MC), and 1,1,1-trichloroethane (1,1,1-TCA). Other contaminants used in Building 666 or found in the soils may migrate to the extraction wells over a period of time. Although none have been detected in samples of groundwater in the plume, the other potential groundwater contaminants are acetone, methyl ethyl ketone, trichlorotrifluoroethane, 2-hexanone, benzene, toluene, and xylenes. The contaminants in the groundwater that is pumped to the surface will be removed in the treatment facility built near the site (Figure 4-2) to decrease concentrations below detection limits. Details of the groundwater treatment and post-treatment discharge alternatives selected are presented in Section 6.2.

The ERA for the TCE/PCE plume uses proven extraction technologies for containing a concentrated plume of contaminants migrating in groundwater. Extraction of groundwater from the two wells will immediately control the migration of contaminants exceeding 1,000 μg/L. As the wells continue to operate, groundwater containing contaminants at concentrations of 10 to 100 μg/L will flow into the zones of capture from the northeast. A volume of groundwater with concentrations of 1 to as much as 900 μg/L total VOCs which is beyond the zone of capture for the extraction wells, will continue to migrate to the well, but will be diluted before treatment at BW-18. Controlling migration of the greater contaminant concentrations will allow the continued operation of BW-18, prevent health risks that could result from groundwater use on McClellan AFB, and decrease the potential for spreading of the contaminants to larger volumes of groundwater beneath McClellan AFB and off-base areas to the south. This action is consistent with any ultimate long-term OU B remedial action.

Additional technical details regarding the extraction well siting, flow rate, and design are provided in Section A6.2 of Appendix A. The details of selection of the ERA are discussed on Sections 5.0 and 6.0.

4.2 Northern TCE/1,2-DCE Plume Actions

Removal actions are proposed that will be effective in controlling the southerly migration of contaminants in the northern TCE/1,2-DCE plume. The actions will prevent the migration of greater contaminant concentrations to water supply wells and will mitigate the groundwater contamination beneath McClellan AFB and off-base areas. The removal actions will consist of: the extraction of groundwater from three geohydrologic zones; the treatment of the extracted water at a facility that will remove contaminant concentrations to non-detectable levels before discharge; the continuation of pumping by BW-18 for hydrologic control; the destruction of four unused wells and a boring that may be acting as vertical conduits for contaminants; and construction of monitoring wells in the plume to monitor the effectiveness of the extraction well field.

The northern TCE/1,2-DCE plume is an Area of Concern, identified from the results of the OUBGRI, that includes groundwater containing contaminants in five geohydrologic zones (100 to 350 feet BGS). The northern TCE/1,2-DCE plume is that portion of the TCE/1,2-DCE plume that is north of an east-west line passing through BW-18 (Figure 4-1). The northern portion of the plume is distinguished from the southern portion by:

- Total VOC concentrations exceeding 100 μg/L in the A, B, C, and D zones;
- A migration path from OU C to the southeast toward BW-18;
- The largest volume of the plume presently lying north of the McClellan AFB boundary and the potential to be captured before migrating beyond the boundary; and
- Concentrations of VOCs exceeding U.S. EPA and DHS MCLs within 600 feet of BW-18 in the A, B, and C zones.

Concentrations of VOCs in the A, B, and C zones of the northern TCE/1,2-DCE plume are greater than 100 μg/L. Trichloroethene and 1,2-DCE are the principal contaminants, with concentrations of each exceeding U.S. EPA or DHS MCLs for drinking water.

A removal action is proposed for implementation to control the southerly migration of the northern TCE/1,2-DCE plume because if no action is taken:

- The contaminant plume will continue to migrate toward BW-18, if it is operating, and will cause future health risks to on-base water users when greater concentrations of contaminants are drawn into the well;

- The contaminants in the plume may cause the shutdown of BW-18 because of health risks;

- The contaminant plumes will continue to migrate to the south under the influence of regional gradients if BW-18 is taken out of operation, and that migration will cause the contaminants to spread horizontally and vertically, degrading larger volumes of groundwater; and

- A plume containing total VOCs exceeding concentrations of 100 μg/L in its present horizontal and vertical extent will migrate toward the depression caused by the City of Sacramento well field if BW-18 is out of operation.

The depth, concentration (greater than 100 μg/L total VOCs), and location (within 600 feet of an active water supply well) of the northern TCE/1,2-DCE plume support the selection of an extraction well field as the most feasible removal action. Three extraction wells are proposed near the east-west McClellan AFB boundary in the removal action for the northern TCE/1,2-DCE plume. Each well will be constructed with its screen interval fully penetrating one of three geohydrologic zones, A, B, and C. No extraction well is proposed for the D zone because VOCs in groundwater of that zone occur in concentrations of 10 μg/L or less near the McClellan AFB boundary and would be diluted to concentrations less than 5 μg/L as they continue to migrate to BW-18. The contaminant concentrations from the D zone that could reach BW-18 after a period of time would be removed by the well's treatment system without posing health risks to water users. The impacts of contaminants in the D and E zones will be evaluated in the OU B RI beginning in 1991.

Extraction wells shown individually by zone in Figures 4-3, 4-4, and 4-5, are located within the most concentrated volume of contaminated groundwater in each

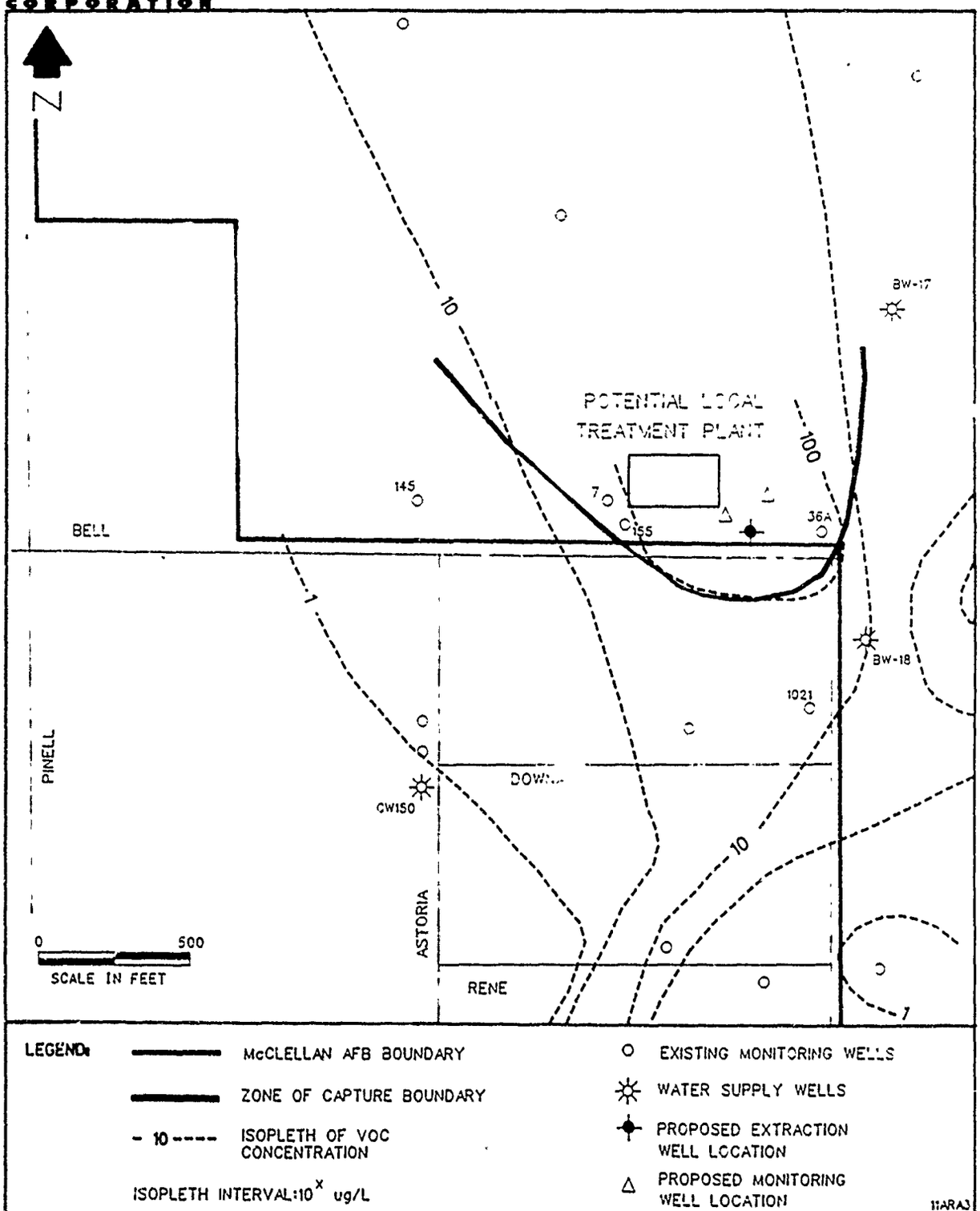


Figure 4-3. Location of Proposed Extraction Well for Removal Action, Northern TCE/1,2-DCE Plume-A Zone.

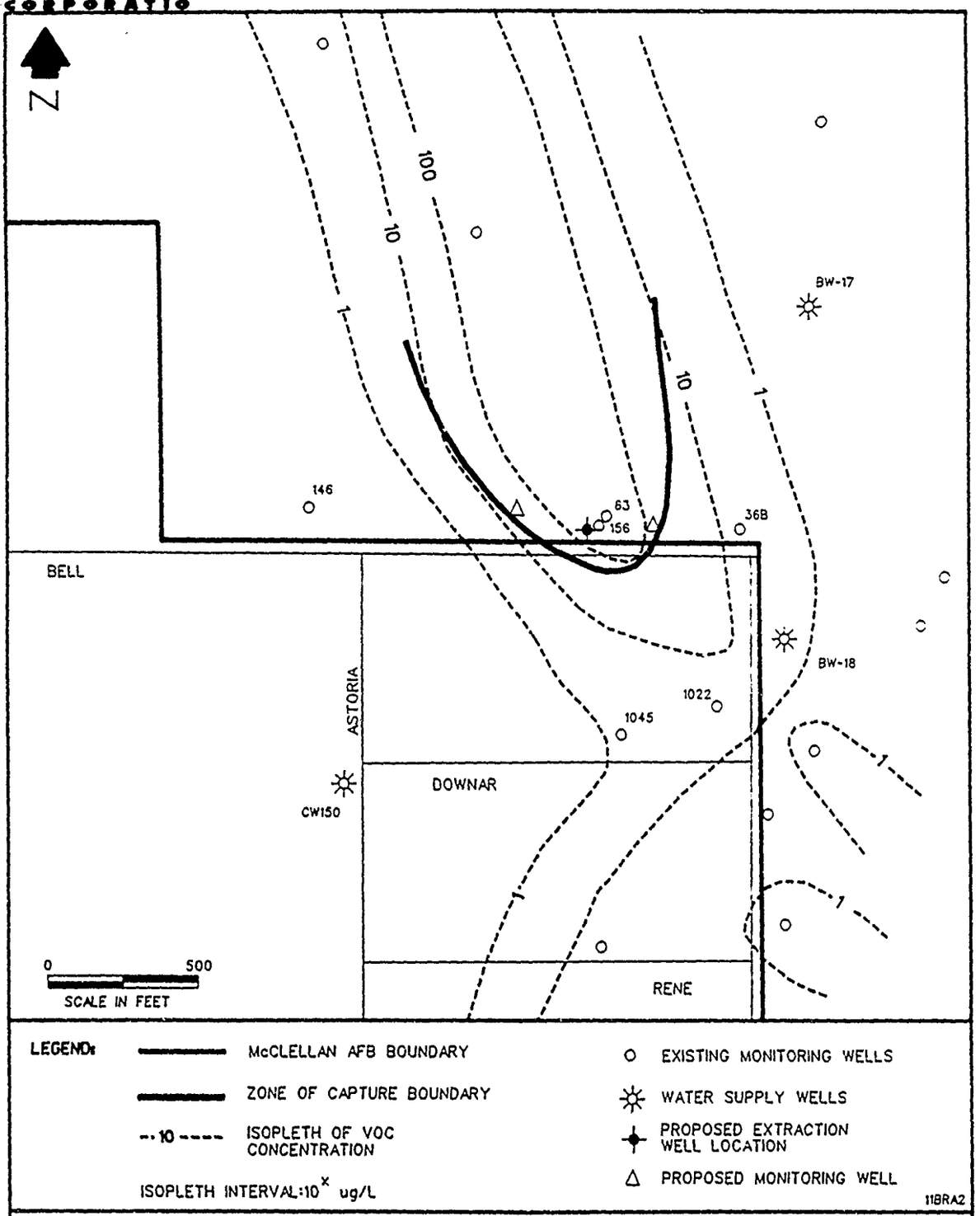


Figure 4-4. Location of Proposed Extraction Well for Removal Action, Northern TCE/1,2-DCE Plume-B Zone.

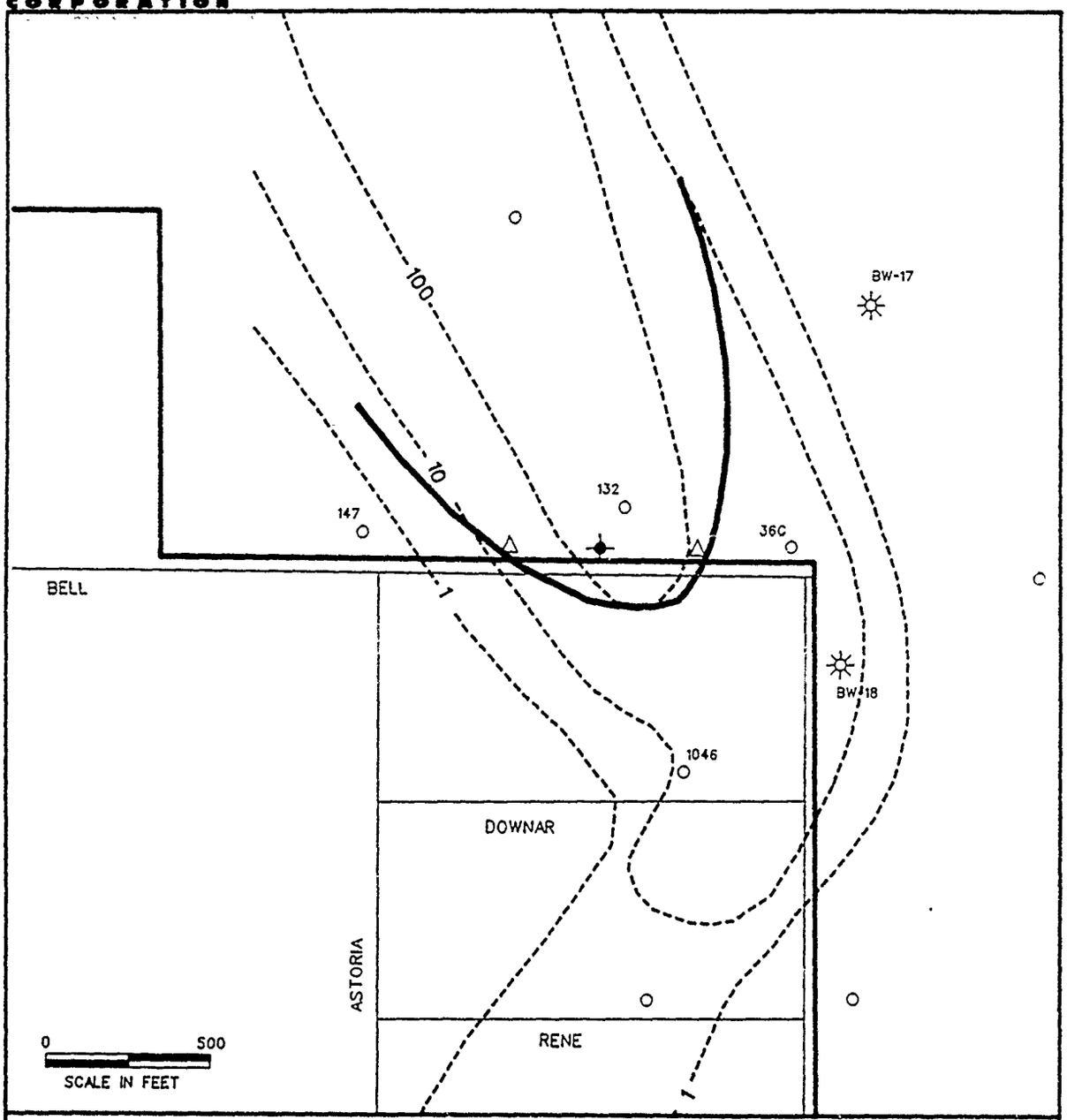


Figure 4-5. Location of Proposed Extraction Well for Removal Action, Northern TCE/1,2-DCE Plume-C Zone.

zone near the McClellan AFB boundary. Isopleths in the figures indicate the estimated extent of groundwater exceeding concentrations of 1, 10, and 100 μg/L. The wells are located to immediately begin capturing the portion of the plume exceeding 100 μg/L in each zone as soon as they begin operating. When pumping begins, the extraction well in each geohydrologic zone will control the flow of groundwater and allow the removal of contaminants exceeding 100 μg/L in total VOC concentration from the groundwater closest to the well. As extraction continues over a period of months and years, groundwater with lower concentrations of contaminants will reach the well from greater distances away in the zone of capture. The zone of capture for each well is determined by the pumping rate of the well, the hydraulic conductivity of the deposits, and the hydraulic gradient in the zone at the well location. Pumping rates for each well were selected to produce the zone of capture necessary to extract groundwater with contaminant concentrations greater than 100 μg/L VOCs migrating to the east and west sides of the proposed well location. Half of the zone of capture extends east and half extends to the west of the well location (Figure 4-3, 4-4, 4-5).

The width of zones of capture near each well, Z_{cw}, and pumping rates required to produce them, Q, are the following:

A zone: Z_{cw} = 700 feet, Q_A = 30 gpm
B zone: Z_{cw} = 400 feet, Q_B = 25 gpm
C zone: Z_{cw} = 600 feet, Q_C = 100 gpm

The installation of one extraction well per zone is the most effective removal action approach for the northern TCE-1,2-DCE plume. The principal objective of the action is control of the groundwater with 100 μg/L or greater VOC concentrations. The control of that groundwater and, after a period of time, control of groundwater with lower concentrations will prevent much of the VOC contamination from migrating across the east-west McClellan AFB boundary toward BW-18. Additional extraction wells could be added to each zone to provide a larger combined zone of capture. However, increasing the number of extraction wells in each zone will cause the contaminant plume in the northern part of OU B to migrate away from the source areas at a greater velocity and over a wider area along the east-west McClellan AFB boundary. The net effect would be the spreading of the plume that is now migrating toward BW-18. Additional extraction well locations (in northern OU B or OU C) as well as other alternatives that would prevent spreading of the plume, will be evaluated after more data are collected in the OU B RI. The selection of single

extraction wells in each zone is the preferred action to effectively prevent migration of the plume to BW-18 and spreading of the plume in a larger groundwater volume.

The pumping rates selected for each well will be sufficient to draw water from the entire thickness of each zone. Each well will be screened through the entire geohydrologic zone. Upgradient to the north-northwest, the width of each zone of capture will be twice as wide as the zone of capture at the well; therefore, groundwater with VOC concentrations less than 10 μg/L will also flow to the well from the upgradient direction. Each well will also draw groundwater containing contaminants that has migrated downgradient beyond the well, back to the well from a limited distance. The downgradient extent of the zone of capture for each well will principally affect the portion of the plume exceeding 100 μg/L that has migrated beyond the east-west McClellan AFB boundary toward BW-18. The wells will not have sufficient discharge to draw groundwater with lower concentrations into the well if that groundwater has passed to the south of the extraction well location or the east-west base boundary. However, the groundwater containing those concentrations will flow to BW-18. Details of zone of capture and pumping rate determinations for each zone are presented in Appendix A, Section A6.2.

Groundwater containing contaminants that is not captured by the wells will continue to migrate toward the zone of capture for BW-18 as long as the well is operating. The lower concentrations of contaminants from the northern TCE/1,2-DCE plume that are not captured by the extraction wells in the A, B, and C zones will approach BW-18 from the north and west sides before entering the well and being diluted by groundwater with lower concentrations of contaminants that has moved to the well from the south and east. Groundwater captured by BW-18 will continue to be used for McClellan AFB needs even if low concentrations of contaminants enter the well, because the well has a carbon adsorption treatment system that removes VOC contaminants before the water is used. If BW-18 is not operating each day at a rate of at least 900,000 gallons per day (gpd), the lower concentrations of contaminants may migrate to the south away from McClellan AFB in one or more zones. Therefore, an important part of the proposed removal action for the northern TCE/1,2-DCE plume is the continued operation of BW-18 at a pumping rate of 900,000 to 1.6 million gpd (625 - 1140 gpm) with continuing treatment of its water before use.

The extraction well proposed for construction in the A zone (screened from approximately 110 to 140 feet BGS) will extract groundwater at a rate of 30 gpm. The concentration of VOCs entering the well upon startup will be approximately 110

μg/L. The extraction well in the B zone screened from approximately 140 to 180 feet BGS will extract groundwater at a rate of 25 gpm with an initial VOC concentration of approximately 160 μg/L. The C zone extraction well screened approximately 190 to 260 feet BGS will extract groundwater at 100 gpm with a concentration of approximately 130 μg/L. As the wells continue to operate, the concentrations of VOCs in groundwater are anticipated to fluctuate and then decrease steadily as groundwater with concentrations of 1 to 10 μg/L are drawn into the wells from the wider zone of capture to the north.

Each extraction well location is sited such that the central part of the contaminant plume migrating in a zone will flow into the well's zone of capture. Therefore, the wells will not be constructed adjacent to each other. All wells will be located within McClellan AFB boundaries in the groundwater flow path toward BW-18. The siting of wells on McClellan AFB will cause no disruption of private properties south of the McClellan AFB boundary. The details and rationale for siting are presented in Appendix A, Section A6.2.5.

After the groundwater is pumped to the surface, it will be conveyed by pipelines to a treatment facility, and after treatment to discharge. Details of the treatment system and discharge recommended for the extracted water are presented in Section 6.3.

The operational effectiveness of the extraction wells will be monitored by weekly water level readings and quarterly analyses of samples from monitoring wells constructed in each of the zones near the east-west McClellan AFB boundary. Two new monitoring wells will be constructed in each of the A, B, and C zones (Figures 4-3, 4-4, and 4-5) to provide water level measurements that will indicate the effectiveness of the extraction system in maintaining the planned zone of capture for each well. Analyses of samples from the wells for VOCs will indicate changes in plume concentration. Concentrations of VOCs in monitoring well samples will decrease gradually over a period of years of extraction as the contaminant plume moving from the north is fully captured by the well. If concentrations increase in the monitoring wells of one zone, the rate of groundwater extraction in that zone may require adjustment to increase its zone of capture.

In addition to the control of groundwater contaminant migration in the northern TCE/1,2-DCE plume through operation of the extraction wells and BW-18, removal actions will be implemented to reduce the vertical migration of contaminants between geohydrologic zones. Four unused water supply wells (BW-3, BW-6, BW-19,

and unnumbered well) that are located in OU B and OU C (Figure 4-6) may be providing a conduit for vertical migration of contaminants from the A zone to deeper zones. Some vertical migration of contaminants may occur as a result of gradients between zones. However, if the unused supply wells have screen intervals that cross zone boundaries, the open well casing and gravel pack may provide a vertical conduit for migration of contaminated groundwater. To prevent continued vertical migration between zones, a removal action (McClellan AFB Well Abandonment Program) is in progress to locate, investigate, and properly destroy the unused wells. Three of the wells must be found before they can be investigated or destroyed. Base supply wells 3, 6, and 19 have been covered by surface construction. They must be found, excavated, opened, and investigated to determine what methods are needed to destroy them.

The removal actions proposed for the northern TCE/1,2-DCE plume will use proven well construction and extraction technologies to capture contaminated groundwater in the depth interval from 100 to 260 feet BGS. Extraction of groundwater by the three wells will initially capture the groundwater plume with a concentration exceeding 100 μg/L in the three zones. After a period of pumping, plume concentrations of 10 μg/L or less will be drawn to the wells. Control of the contaminant migration in the zones of capture will allow the continued operation of BW-18, which has a strong influence on groundwater and contaminant migration throughout OU B. The capture of the contaminants exceeding 10 to 100 μg/L after a period of extraction well operation will prevent increased health risks to users of groundwater on McClellan AFB. By controlling the southerly migration of the northern TCE/1,2-DCE plume, the extraction wells will reduce the potential for degradation of groundwater supplies beneath OU B. The hydrologic control caused by the operation of BW-18 will mitigate contaminants that have migrated in groundwater beneath off-base areas.

Additional technical details regarding the extraction well siting, flow rate determination, and design are provided in Appendix A, Section A6.2 The details of the selection of groundwater treatment and discharge options are provided in Sections 5.0 and 6.0.

4.3 Southern TCE/1,2-DCE Plume Actions

Removal actions are proposed to reduce the potential health risks and groundwater degradation posed by the migration of the southern TCE/1,2-DCE plume.

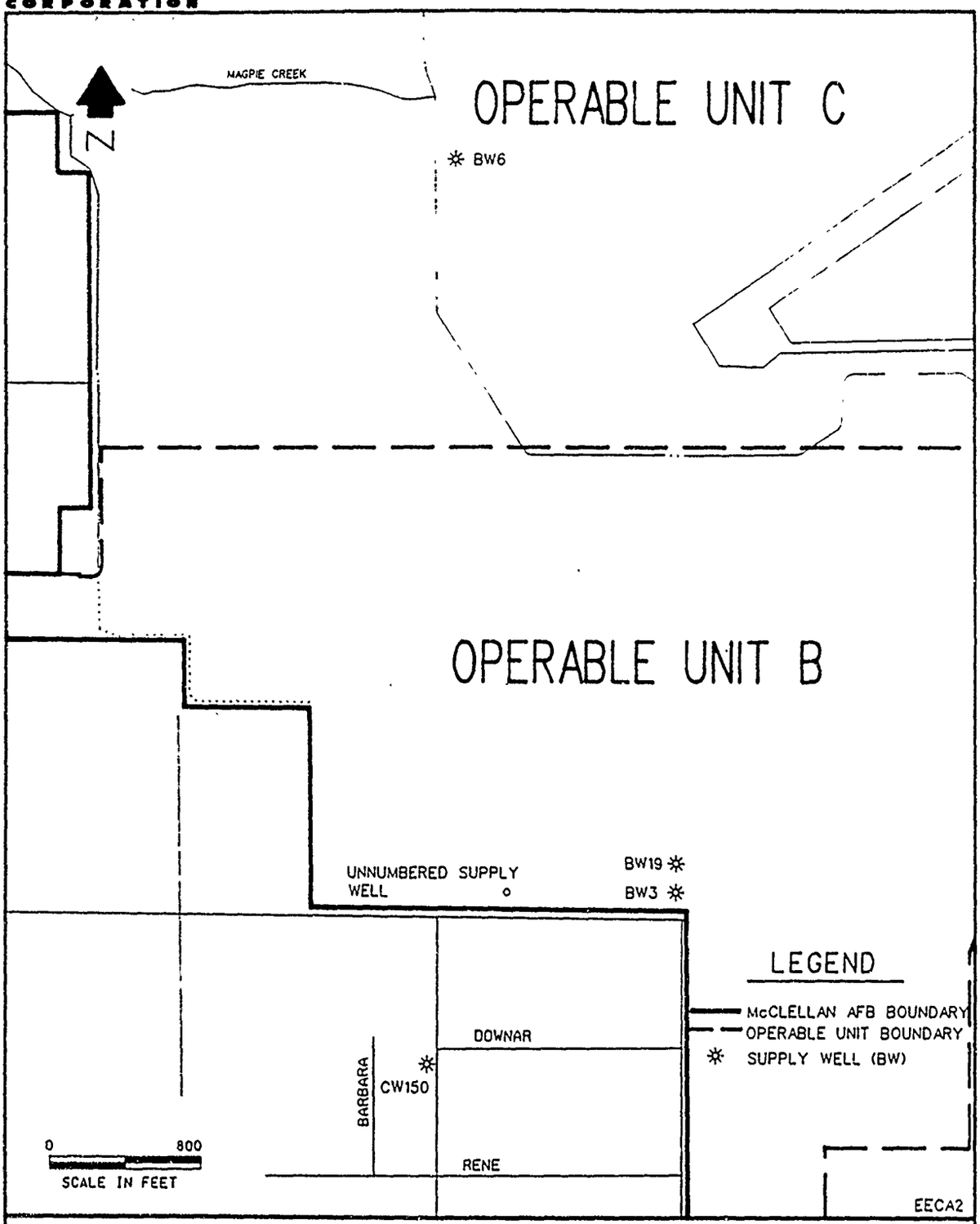


Figure 4-6. Location of Supply Wells to be Investigated for Abandonment.

The actions will prevent health risks from developing by reducing the potential for exposure of municipal water users to contaminant concentrations in the plume. The actions will reduce groundwater degradation by slowing or reversing the migration of contaminants away from McClellan AFB. The removal actions will consist of: the shutdown of CW-132 except for emergency use; implementation of the removal actions in the TCE/PCE plume and northern TCE/1,2-DCE plume (Sections 4.1 and 4.2); continued pumping of BW-18 for hydrologic control of plume migration; abandonment and destruction of CW-150; construction of three monitoring wells and the quarterly monitoring of 10 monitoring wells south of McClellan AFB; and reevaluation of the extent and migration of the plume in the OU B RI.

The southern TCE/1,2-DCE plume is an Area of Concern, identified from the results of the OUBGRI, which includes groundwater containing contaminants in three geohydrologic zones (100 to 260 feet below surface). The southern TCE/1,2-DCE plume is that portion of the TCE/1,2-DCE plume that is south of the east-west line passing through BW-18 (Figure 4-1). The southern portion of the plume is distinguished from the northern portion by:

- Total VOC concentrations less than 100 μg/L and much of the plume having concentrations of 1 to 10 μg/L; and

- Northeasterly migration paths toward BW-18 in the A, B, and C geohydrologic zones when the well is in operation.

Concentrations of total VOC contaminants in the A, B, and C zones are less than 100 μg/L in the southern TCE/1,2-DCE plume. Trichloroethene exceeds the DHS MCL (5 μg/L) for drinking water in the A zone near MW-1021 in the northeastern part of the plume and near MW-1049 in the southwestern part of the plume (Figure 4-7). In the B zone, TCE exceeds the MCL only at MW-1022 in the northeastern part of the plume (Figure 4-8). In the C zone, TCE exceeds the MCL at MW-1046 in the northeastern part of the southern TCE/1,2-DCE plume (Figure 4-9). No other compounds detected in samples from any zone within the plume exceed federal or state MCLs. Therefore, much of the groundwater in the southern TCE/1,2-DCE plume would be in compliance with U.S. EPA or California standards if used for drinking water. However, if the concentration of total VOCs exceeding 100 μg/L in the northern TCE/1,2-DCE plume or in the TCE/PCE plume were to migrate to the present position of the southern TCE/1,2-DCE plume, the contaminant concentration in groundwater would be such that the groundwater would be out of compliance with

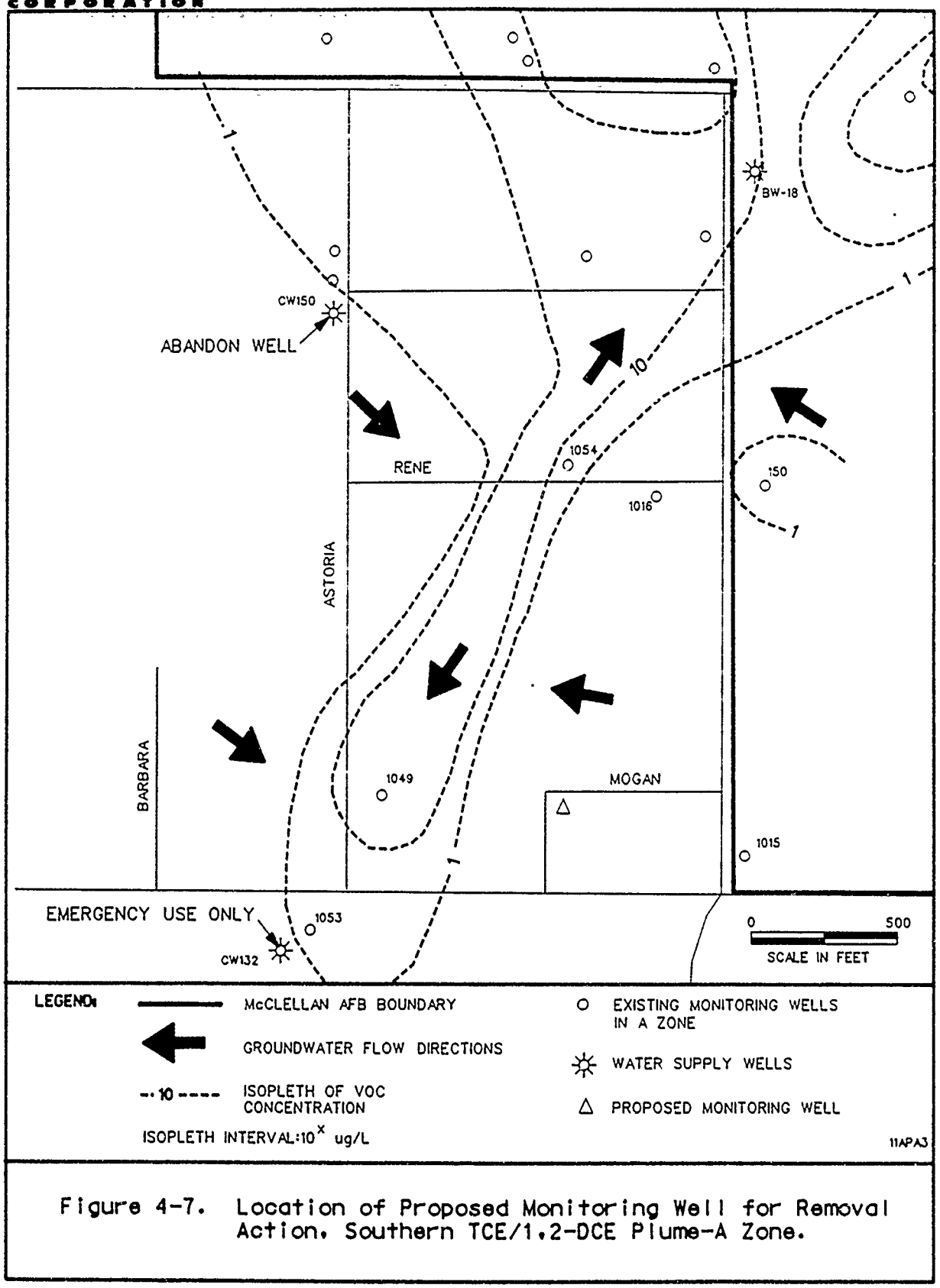


Figure 4-7. Location of Proposed Monitoring Well for Removal Action. Southern TCE/1,2-DCE Plume-A Zone.

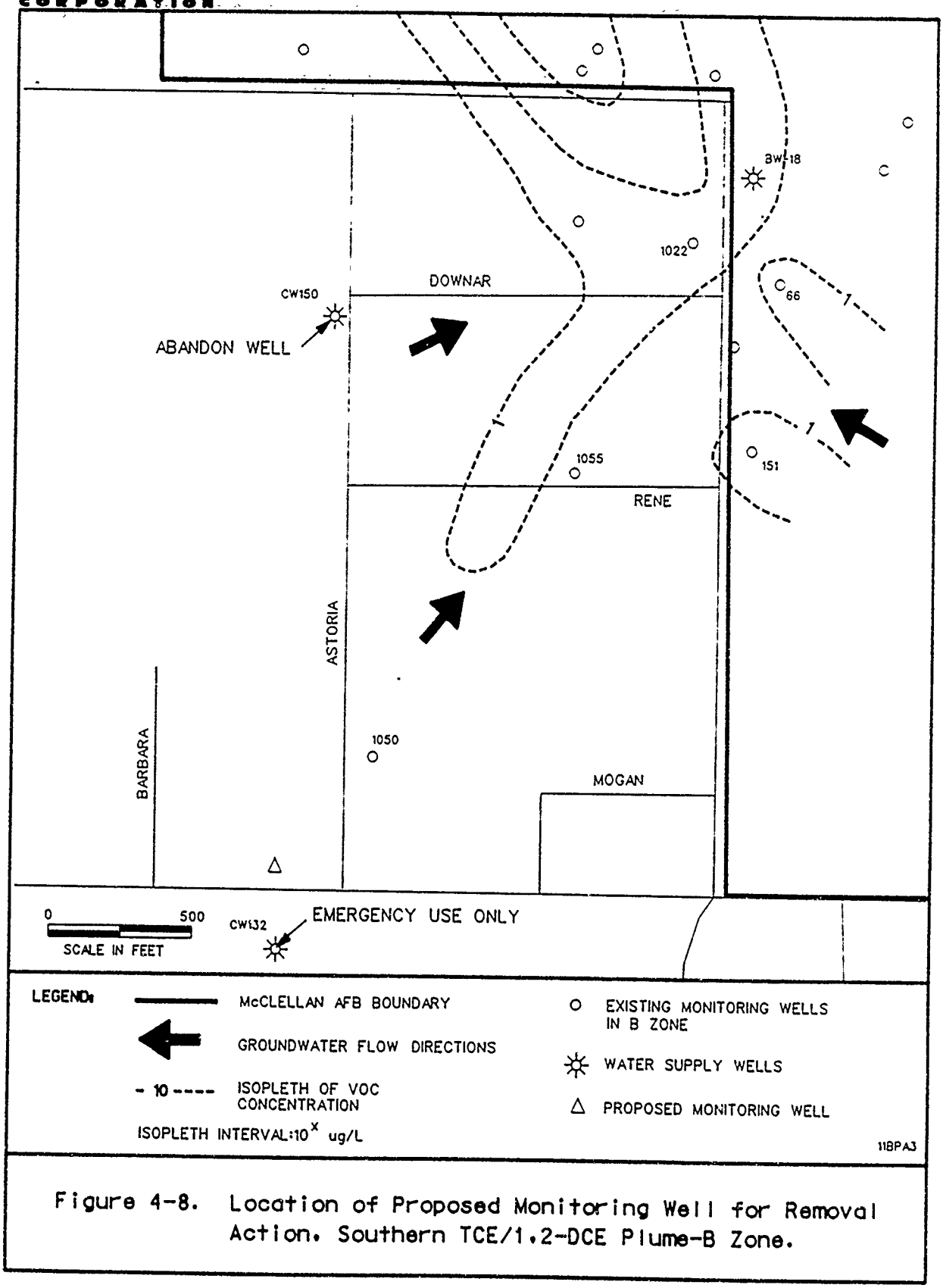


Figure 4-8. Location of Proposed Monitoring Well for Removal Action. Southern TCE/1,2-DCE Plume-B Zone.

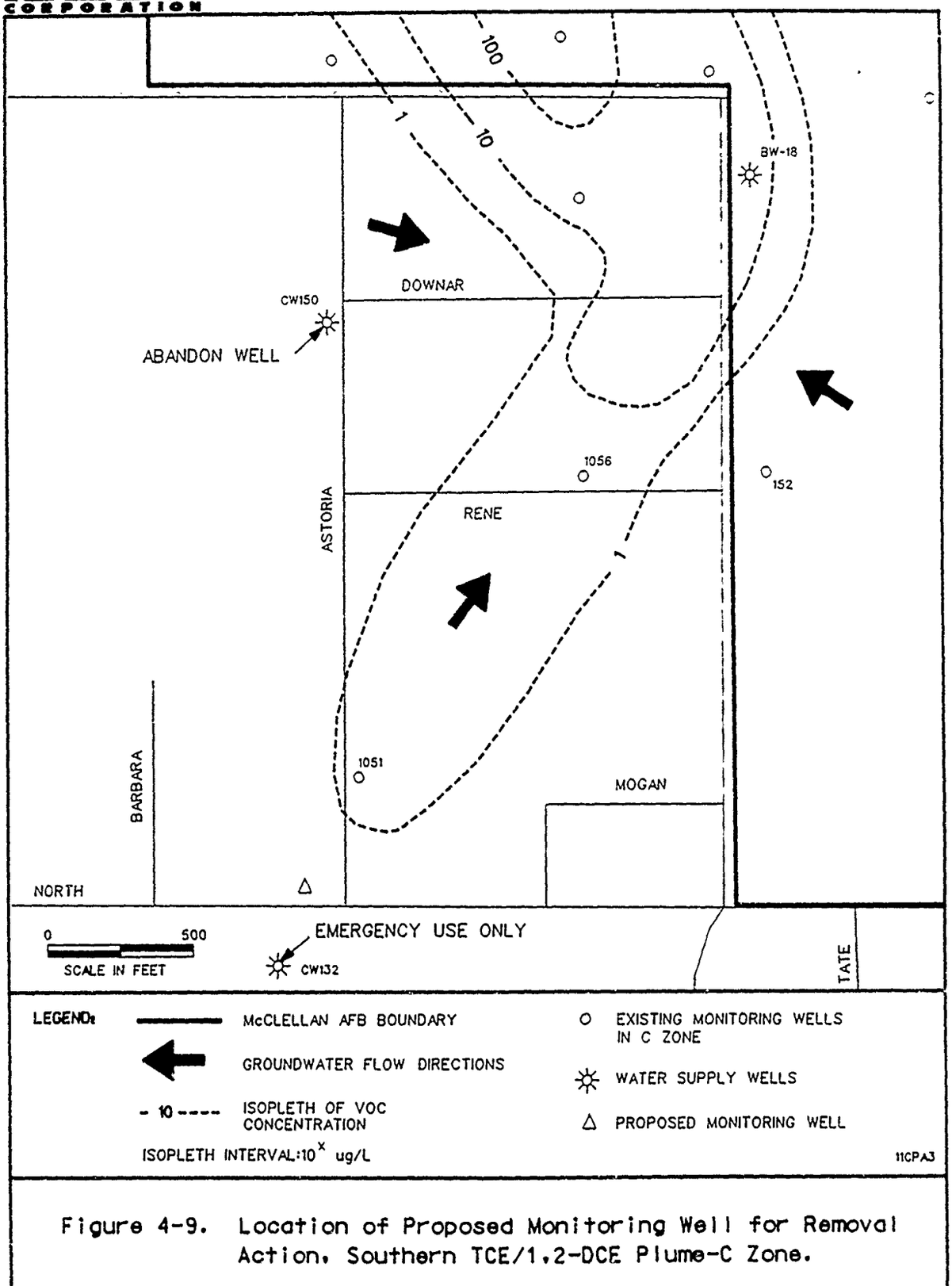


Figure 4-9. Location of Proposed Monitoring Well for Removal Action, Southern TCE/1,2-DCE Plume-C Zone.

federal and state drinking water standards. Therefore, removal actions are proposed for implementation in the southern TCE/1,2-DCE plume because if no actions are taken:

- The contaminant plume will continue to migrate to the southwest in three or more geohydrologic zones and may pose future health risks to users of groundwater as a result of contaminants being drawn into City of Sacramento or private supply wells; and

- The contaminant plume will spread horizontally and vertically, degrading large volumes of groundwater south of McClellan AFB.

One action has already been implemented in the southern TCE/1,2-DCE plume. City of Sacramento Well 132 has been reduced to emergency use only at the request of the Air Force in January 1990. The well will not supply water to the Sacramento supply system unless an extreme water shortage occurs, for example, during a serious fire. Any future potential health risks that could result from contaminant migration to the well have been greatly reduced because exposure to the groundwater from CW-132 could only occur during short-term emergencies. Concentrations of contaminants that are present in the B and C zones near CW-132 are below federal and state MCLs. With the removal actions implemented, contaminant concentrations exceeding MCLs would not enter the well or the supply system during short-term emergency use.

The actions proposed for the southern TCE/1,2-DCE plume include the implementation of the removal actions for the TCE/PCE and northern TCE/1,2-DCE plumes, and the continued operation of BW-18. The proposed actions are linked because migration of contaminants to the south from the northern plume would increase concentrations in the southern plume, and the migration of groundwater in both plumes is controlled by the daily withdrawal of 900,000 to 1,600,000 gpd (625-1140 gpm) at BW-18.

The present distribution of contaminants indicated by isopleths in Figures 4-7, 4-8, and 4-9 indicate that the southern TCE/1,2-DCE plume migrated beyond the McClellan AFB boundary from the north and from the east. The 1 μg/L isopleths, representing the approximate outer limits of the plume, cross the east-west and north-south boundaries in OU B. Southerly to southwesterly groundwater flow directions from McClellan AFB result when BW-18 is not operating or is operating less than 300 to 360 days per year and less than approximately 900,000 gpd (Section A3.1 and A4.2, Appendix A). In the 10-year period prior to January 1989, BW-18 did not operate for

four years (1981 - 1985) and, when operating, pumped less than half of each year. During that period and possibly before, contaminants migrating in groundwater flowed beneath the east-west and north-south boundaries in the A, B, and C geohydrologic zones. During that period, total VOC concentrations in the groundwater probably ranged from less than 1 μg/L to greater than 20 μg/L (but less than 100 μg/L). This is the range of VOC concentrations that has been estimated from samples taken from wells in the southern TCE/1,2-DCE plume during 1989 and 1990.

Since January 1989, BW-18 has operated each day producing 900,000 to 1,600,000 gpd, except for days it was out of operation for repairs (April 1989) and replacement of the carbon in the treatment system (December 1989 - January 1990). Water level measurements and analytical data from monitoring well samples taken in 1989 and early 1990 indicate that when BW-18 is operating daily, groundwater from the TCE/PCE, northern TCE/1,2-DCE, PCE, and much of the southern TCE/1,2-DCE plumes flows toward the well (Section A4.2, Appendix A). Since January 1989, the well has provided hydrologic control that limits the migration of contaminant plumes to the southwest. Groundwater gradients determined from monitoring wells in the southern TCE/1,2-DCE plume in April 1990 indicate that the plume in the B and C zones is being drawn back to the northeast from a distance of 2,200 feet by BW-18 (Figures 4-7, 4-8, and 4-9). Groundwater gradients determined from water levels measured in the southern TCE/1,2-DCE plume in April 1990 when BW-18 was operating were 0.0003 feet/foot to the northeast in the B zone (between MW-1050 and MW-1055) and 0.002 feet/foot to the northeast in the C zone (between MW-1051 and MW-1056). The hydrologic influence of the well is apparently less in the A zone because groundwater in the A zone is being drawn back to the northeast from the lesser distance of approximately 1,200 feet (Figure 4-7). Groundwater gradients in April 1990 were 0.0003 feet/foot to the northeast (between MW-1054 and MW-1021), 0.0001 feet/foot to the southwest (between MW-1054 and MW-1049), and 0.0005 feet/foot to the southwest (between MW-1049 and MW-1053). Therefore, the operation of BW-18 daily at 1.5 to 1.6 million gpd is reducing the extent of the southern TCE/1,2-DCE plume in the B and C zones and decreasing the potential for migration for contaminants in groundwater toward supply wells to the southwest.

With BW-18 kept in operation to control groundwater migration beneath OU B, groundwater in the southern TCE/1,2-DCE plume will migrate at velocities determined by the hydraulic conductivity, hydraulic gradient, and effective porosity of each zone. (Velocity = hydraulic conductivity x gradient/porosity). If the A zone has a mean hydraulic conductivity of 18 to 39 feet/day (Appendix A, Section A5.1) and an

estimated effective porosity of 0.25 throughout the southern TCE/1,2-DCE plume, hydraulic gradients determined from April 1990 data indicate groundwater will flow: to the northeast toward BW-18 at a velocity of 0.02 to 0.05 feet/day (7 to 18 feet/year); to the southwest between MW-1054 and MW-1049 at 0.007 to 0.02 feet/day (3 to 7 feet/year); and to the southwest between MW-1049 and MW-1053 at 0.04 to 0.08 feet/day (15 to 30 feet/year). In the B zone, an estimated hydraulic conductivity range of 17.5 to 20 feet/day and mean effective porosity of 0.25 throughout the plume result in a groundwater velocity of approximately 7 to 8 feet/year toward BW-18. In the C zone, an estimated hydraulic conductivity range of 40 to 64 feet/day and mean effective porosity of 0.25 indicate a groundwater velocity of 110 to 183 feet/year toward BW-18.

If BW-18 were not operating, groundwater containing the southern TCE/1,2-DCE plume would flow southerly away from BW-18 in all zones (Appendix A, Section A3.2). Velocities of groundwater migration without BW-18 in operation, using January 1990 gradients to represent the condition, are estimated to be: A zone, 29 to 63 feet/year; B zone, 21 to 24 feet/year; and C zone, 220 to 360 feet/year. Therefore, without BW-18 in operation, the southern TCE/1,2-DCE plume would migrate southerly toward other municipal supply wells at velocities 2 to 3 times greater than the velocities to the northeast caused by BW-18.

Removal actions proposed for the TCE/PCE plume (Section 4.1) and northern TCE/1,2-DCE plume (Section 4.2) are proposed as actions for the southern TCE/1,2-DCE plume as well. The construction and operation of the extraction well fields in the TCE/PCE plume and the northern plume will have an impact on the southern plume under the conditions of BW-18 operating or not operating. If BW-18 is maintained in operation, contaminants from the TCE/PCE and northern TCE/1,2-DCE plume will continue to migrate to the well. To keep the well in operation for its favorable hydrologic influence without causing future health risks to users of its water, concentrations of contaminants entering the well must be kept at current concentrations or reduced. Extraction well fields in the TCE/PCE plume and the northern TCE/1,2-DCE plume will reduce the potential for greater contaminant concentrations reaching BW-18 and posing health risks to users of the water.

If BW-18 were not operating for several months or more and, therefore, not having its hydrologic influence on the southern TCE/1,2-DCE plume, the extraction wells operating in the TCE/PCE and northern TCE/1,2-DCE plumes would continue to prevent groundwater with greater contaminant concentrations from migrating past the McClellan AFB boundary and into the southern TCE/1,2-DCE plume. Therefore, the

two removal actions will reduce the potential for health risks by capturing greater concentrations of contaminants before they migrate to the south in the southern TCE/1,2-DCE plume.

An additional action proposed for the southern TCE/1,2-DCE plume is the abandonment and destruction of CW-150. The well has been in limited use for very high water demand conditions since 1982 when TCE was detected in groundwater samples collected from the well. The well was taken out of service in June, 1989. The well has a screen extending from 144 to 372 feet BGS. This screen interval crosses the B, C, D, and E geohydrologic zones and may provide a conduit for migration of contaminants between zones. Contaminant concentrations in samples from monitoring wells near CW-150 have been 1 μg/L or less in recent sampling and analyses (Radian 1990a, 1990d). However, if the well were operating at its capacity of 892 gpm, contaminants in the western side of the southern TCE/1,2-DCE plume would migrate toward the well. Contaminants from the A zone would be drawn downward into deeper zones, not because the well is screened in the A zone, but because it would create a vertical potential beneath the A zone that would result in downward contaminant migration. Therefore, the well could not be pumped except for emergency use until the contaminants in the western part of the southern plume are drawn much closer to BW-18, and in its current condition, it could provide a conduit for contaminant migration. Abandonment will consist of removing the pump, well head, and holding tank, followed by the filling of the well casing and the gravel outside of the screen interval with cement grout.

After implementation of the principal removal actions for the southern TCE/1,2-DCE plume, three new monitoring wells will be constructed south of the known extent of the plume to monitor groundwater flow directions and quality. The three wells, whose locations are shown in Figures 4-7, 4-8, and 4-9, will consist of one well constructed in each of the A, B, and C zones. The wells are to be placed to provide monitoring data for locations and zones where none exist. The A zone well location was selected to provide data to determine groundwater flow direction and the presence of any contaminants to the southeast of the southern plume. Although the data available from MW-1015, southeast of the new well location, indicate the plume has not spread to that location, the potential exists that the southern plume may follow a more southerly migration path. The new A zone monitoring well will indicate if southerly migration is occurring.

Proposed new A zone wells will be constructed upgradient and in the zone of capture for the extraction well to monitor hydraulic effectiveness and concentrations moving toward the well. The proposed new B and C zone monitoring wells will be constructed in a cluster between CW-132 and the southern extent of the southern TCE/1,2-DCE plume. Monitoring of water levels in the new wells will indicate the groundwater gradient and flow directions in the B and C zones between that location and B and C zone wells located to the northeast. Analyses of samples from the wells will indicate if contaminants have migrated to the location and if the concentrations increase or decrease with time.

Water levels will be measured and samples will be analyzed each quarter from the three new wells and seven existing wells in or south of the southern TCE/1,2-DCE plume. The data provided by the monitoring will be used to determine the effectiveness of the actions taken. The data will be evaluated in the comprehensive OU B RI, which will begin in the first quarter of 1991. Data compiled from the quarterly monitoring will be used to determine if the removal actions taken are effective in reducing the potential for increased health risks from the use of groundwater from the southern TCE/1,2-DCE plume.

Within the remedial investigation, additional monitoring data from the southern TCE/1,2-DCE plume will be evaluated to determine the need for additional wells or additional actions in the southern TCE/1,2-DCE plume. Those decisions will be based upon:

- The presence of VOCs in samples from new monitoring wells and hydraulic gradients indicating continued southerly flow of the plume;

- A continuing increase in VOC concentration and an increase in gradient in the southernmost A zone wells indicating the southerly migration of contaminant concentrations at increased velocities; and

- A reversal in the northeasterly flow direction and increasing TCE or 1,2-DCE concentrations in B and C zone monitoring wells in the southern part of the southern plume.

The removal actions proposed for the southern TCE/1,2-DCE plume will be effective in preventing health risks that may develop for users of groundwater from CW-132 if no action is taken. With CW-132 capable of operating only during high water

demand emergencies, contaminant concentrations that could pose health risks will not be drawn into the water supply through the well. When operating for short periods, the well will draw groundwater from the B and C zones (140 to 260 feet BGS) because the well's screen interval (192 to 23 feet BGS) is in the C zone. Within 750 feet of CW-132, the known contaminant concentrations in groundwater of the B and C zones are less than federal or state MCLs. Contaminant concentrations known to be present in the A zone within 750 feet of CW-132 may exceed MCLs. However, groundwater from the A zone is unlikely to be drawn into CW-132 during short-term, emergency pumping of the well because the well did not have a strong hydraulic effect on the A zone when it was pumping 700 or more hours per month (Section A3.2.2, Appendix A). Therefore, with CW-132 operating only under short-term, emergency conditions, users of groundwater from the well will not be exposed to detectable concentrations of contaminants unless concentrations in the groundwater of the B and C zones increase and are drawn into the well during pumping. Extraction well installation on McClellan AFB and continued operation of BW-18 are the actions proposed to prevent increases in concentration in the B and C zones near CW-132.

With CW-132 reduced to emergency use operation, the destruction of CW-150, and all domestic wells in off-base areas of OU B no longer in use, occupants of residences in off-base areas of OU B will not be exposed to contaminants in groundwater of the southern TCE/1,2-DCE plume. No new water supply wells will be permitted by Sacramento County in the area. Therefore, the groundwater in the plume will not be drawn to local off-base wells, but will be hydrologically influenced by the consistent withdrawal of groundwater at BW-18 to the northeast.

The daily pumping of BW-18 at rates of 900,000 to 1.6 million gpd has the effect of drawing groundwater containing contaminants back toward McClellan AFB from off-base areas. Pumping of the well at those rates on a daily schedule draws groundwater in the southern TCE/1,2-DCE plume to the northeast and reduces southerly migration of the plume. Therefore, BW-18 provides a means of controlling and mitigating groundwater contamination in the southern TCE/1,2-DCE plume.

The part of the southern TCE/1,2-DCE plume that is not controlled by BW-18 pumping, in the A zone between MW-1054 and MW-1053 (Figure 4-7), is slowed in its velocity of migration by the hydrologic impact of BW-18. Although the contaminant concentrations in groundwater of the A zone between the two wells are not mitigated by BW-18, they pose no health risks to occupants of residences in OU B because the groundwater is not being drawn to supply wells. The contaminants present

in the A zone of the southern part of the southern TCE/1,2-DCE plume are a minimum of 2,000 feet from the nearest consistently operating municipal supply well, CW-155, downgradient from the plume. On the basis of the available velocity and gradient data, the contaminants would not reach CW-155 for 60 years or more if current pumping conditions south of McClellan AFB were unchanged in that period and, if contaminants were to reach the well, would be present in much lower concentrations as a result of dilution by uncontaminated groundwater. The groundwater flow directions and contaminant concentrations in the southern TCE/-1,2-DCE plume will be monitored on a quarterly basis prior to and during the OU B RI. Results of that monitoring and evaluation during the OU B RI will determine if any additional actions are necessary to mitigate the southern TCE/1,2-DCE plume beneath OU B.

Details of the hydrogeologic basis for the proposed actions are provided in Sections A3.1 and A4.1 of Appendix A. The evaluation and the analysis of alternatives is provided in Sections 5.0 and 6.0.

4.4 PCE Plume Action

Removal actions are proposed to reduce the potential health risks and groundwater degradation resulting from the migration of the PCE plume in OU B. Proposed actions consist of: continued operation of BW-18 to hydrologically control the migration direction of the plume; implementation of the removal actions proposed for the TCE/PCE and northern TCE/1,2-DCE plumes; and determination of the source and extent of the PCE plume in the OU B RI.

The PCE plume is an Area of Concern, identified from the results of the OUBGRI, that includes groundwater containing VOC contaminants in the A and B geohydrologic zones (100 to 185 feet BGS). The PCE plume has been detected at only two wells located on McClellan AFB, 950 feet south of BW-18 (Figures 4-7 and 4-8 in Section 4.3). The only contaminant detected in the samples from the A zone well taken in the February 1990 was PCE at a concentration of 2.5 μg/L. Methylene chloride and PCE were detected in samples of the B zone well at concentrations of 0.42 and 6.1 μg/L, respectively. The concentration of PCE in the B zone sample exceeds the DHS MCL of 5 μg/L for drinking water. The occurrence of PCE in a groundwater sample without detectable TCE is unique on McClellan AFB. In no other monitoring wells sampled since 1985 has PCE been detected without TCE also being detected. No source for the PCE has been determined, and it has not been detected in wells to the southwest or north. Therefore, the horizontal extent or migration path cannot be

indicated in figures. On the basis of April 1990 groundwater gradients determined for the A and B zones, the plume was migrating to the northwest toward the groundwater depression created by BW-18.

The principal actions proposed for the PCE plume are those which have been proposed or implemented for other plumes. The continued operation of BW-18 will provide sufficient hydrologic control of groundwater in the A and B zones to prevent the PCE plume from migrating to the south or southwest. Control of the plume's migration prevents the contaminants from migrating and spreading into larger volumes of uncontaminated groundwater.

The implementation of removal actions for the TCE/PCE and northern TCE/1,2-DCE plumes are proposed as appropriate actions for the PCE plume because those independent actions will prevent a shutdown of BW-18 because of increased health risks. If higher concentrations of contaminants from the TCE/PCE plume and the northern TCE/1,2-DCE plume were to increase concentrations in BW-18, the well might be required to cease operation, thereby ending the hydrological controls needed to control migration of the PCE plume. Therefore, one previously proposed and one implemented removal action are proposed for the PCE plume as well.

The remaining actions to be taken in the PCE plume are the determination of the source and extent of the plume. These actions will be taken in the OU B RI. After the source and the horizontal and vertical extent of the plume have been determined the need for additional actions will be evaluated. If the PCE concentrations that have been detected are the leading edge of a plume of much greater extent, the actions proposed in this report may not be the most effective actions for remediation of the plume. Extraction wells or other actions located near the source or within the body of the plume may be more effective actions. The effectiveness and feasibility of alternative actions will be evaluated in the feasibility study for OU B.

Details of the hydrogeologic basis for the proposed actions are provided in Appendix A, Sections A3.0 and A4.0.

5.0 REMOVAL ACTION ALTERNATIVES

The development of removal action alternatives for both the trichloroethene/tetrachloroethene (TCE/PCE) plume and the northern trichloroethene/1,2-dichloroethene (TCE/1,2-DCE) plume began with the identification of response actions and control measures for managing the contaminated groundwater plumes. Response actions included:

- No response;
- Institutional;
- Containment;
- Extraction; and
- Treatment.

Technologies were identified and then screened based on the site conditions and knowledge of removal action practices for each of these response categories. Table 5-1 presents a summary of the response actions and technologies available to implement a given response action. The result of the screening was the identification of a select number of technologies. These technologies were then combined to develop removal action alternatives. Removal action alternatives consisting of only institutional controls were not evaluated separately. Removal technologies were identified and screened using technical feasibility, institutional considerations, environmental aspects, and cost criteria. Technologies considered unproven or inappropriate for managing the contaminated groundwater plumes were eliminated from further consideration. Technologies that remained after the initial screening were then assembled into removal action alternatives and further evaluated. In general, removal action alternatives were developed that consisted of both institutional and remediation controls. Several alternatives were identified. However, each alternative generally consisted of three components:

- Groundwater extraction;
- Treatment or no treatment; and
- Discharge of treated or untreated groundwater.

The following sections will discuss removal action alternatives which fall under these three common components: Section 5.1 discusses the groundwater extraction alternative, Section 5.2 lists the treatment or no treatment alternatives, and Section 5.3 describes the discharge of treated or untreated groundwater alternatives. Other components which are common to one or more alternatives are presented in

TABLE 5-1. GENERAL RESPONSE ACTIONS AND ASSOCIATED TECHNOLOGIES

General Response Action	Technology	Process Description
No Response	None	Not applicable.
Institutional		Deed to property restricts use of wells in potentially affected area.
	Monitoring	Monitoring of groundwater wells to evaluate the extent of contamination, groundwater movement, and/or effectiveness of removal action.
Containment	Capping	Capping areas of contamination with materials including clay and soil; asphalt; concrete; and clay and synthetic membranes.
	Subsurface Barriers	Installation of vertical and/or horizontal barriers using techniques such as slurry wall, grout curtain, vibrating beam, sheet piles, hydraulic barriers, liners, and grout injection.
	Fixation	Precipitation of metal contaminants in groundwater to insoluble compounds.
Extraction	Collection Systems	Interception of groundwater using techniques such as subsurface drains and groundwater extraction well fields.
Treatment	In Situ	Treatment by techniques including neutralization, aerobic biological, anerobic biological, adsorption bed, and chemical treatment.
	Physical	Treatment by techniques including grout, separation, air stripping, steam stripping, carbon adsorption, granular media filtration, centrifigation, evaporation and dissolved air flotation.
	Biological	Treatment by techniques including activated sludge, fixed film, fluidized bed reactor, rotating biological contactor, and anerobic lagoon.
	Chemical	Ion exchange/resin adsorption, oxidation/reduction, neutralization, reverse osmosis, precipitation/flocculation/ sedimentation.
	Thermal Destruction	Thermal technologies including electric reactors, rotary kiln, fluidized bed, circulating bed combustor, and supercritical water.
	Discharge	Discharge of treated or untreated groundwater to local streams, aquifer recharge using reinjection wells, or recharge basins, sanitary sewer, industrial wastewater system, and Publically-Owned Treatment Works (POTWs).

Section 5.4. An alternative of using a combined pipeline for the TCE/PCE and northern TCE/1,2-DCE plumes is presented in Section 5.5. Section 5-6 addresses what actions would and would not be taken under the no-action alternative.

Figure 5-1 presents the general removal action alternative created from technologies within each of the labeled response actions. An additional response action, conveyance or transport of groundwater, is needed before and after possible treatment.

5.1 Groundwater Extraction

The use of subsurface drains and groundwater extraction well fields are two groundwater interception systems that can contain the movement of groundwater contamination in an aquifer. Subsurface drains can be installed to the base of an aquifer where groundwater is collected in conduits by gravity drainage. However, the construction techniques for subsurface drains have not been developed for collection of groundwater to depths of 270 feet below ground surface (BGS) needed in Operable Unit (OU) B.

Groundwater extraction wells will be installed in the area of the OU B northern and southern TCE/1,2-DCE contaminant plumes. Extraction wells are effective for intercepting contaminant groundwater both within and outside base boundaries. This remedial technology is well suited for the depth of contamination and the hydrologic and geologic characteristics occurring in areas adjacent to the base. These systems have been demonstrated in similar settings and have been shown to be very versatile in controlling migration of contaminated groundwater. The use of either extraction wells or a combination of extraction and injection wells are currently the most appropriate remedial technologies for mitigating the groundwater contamination.

5.2 Treatment and No Treatment

Four treatment systems and a no treatment option were selected for further evaluation of the OU B northern and southern TCE/1,2-DCE contaminated groundwater plumes. The treatment technologies included:

- Air stripping with vapor phase granular activated carbon (GAC);
- Aqueous phase granular activated carbon;
- Ultraviolet (UV)/ozone/peroxide; and
- Groundwater Treatment Plant (GWTP).

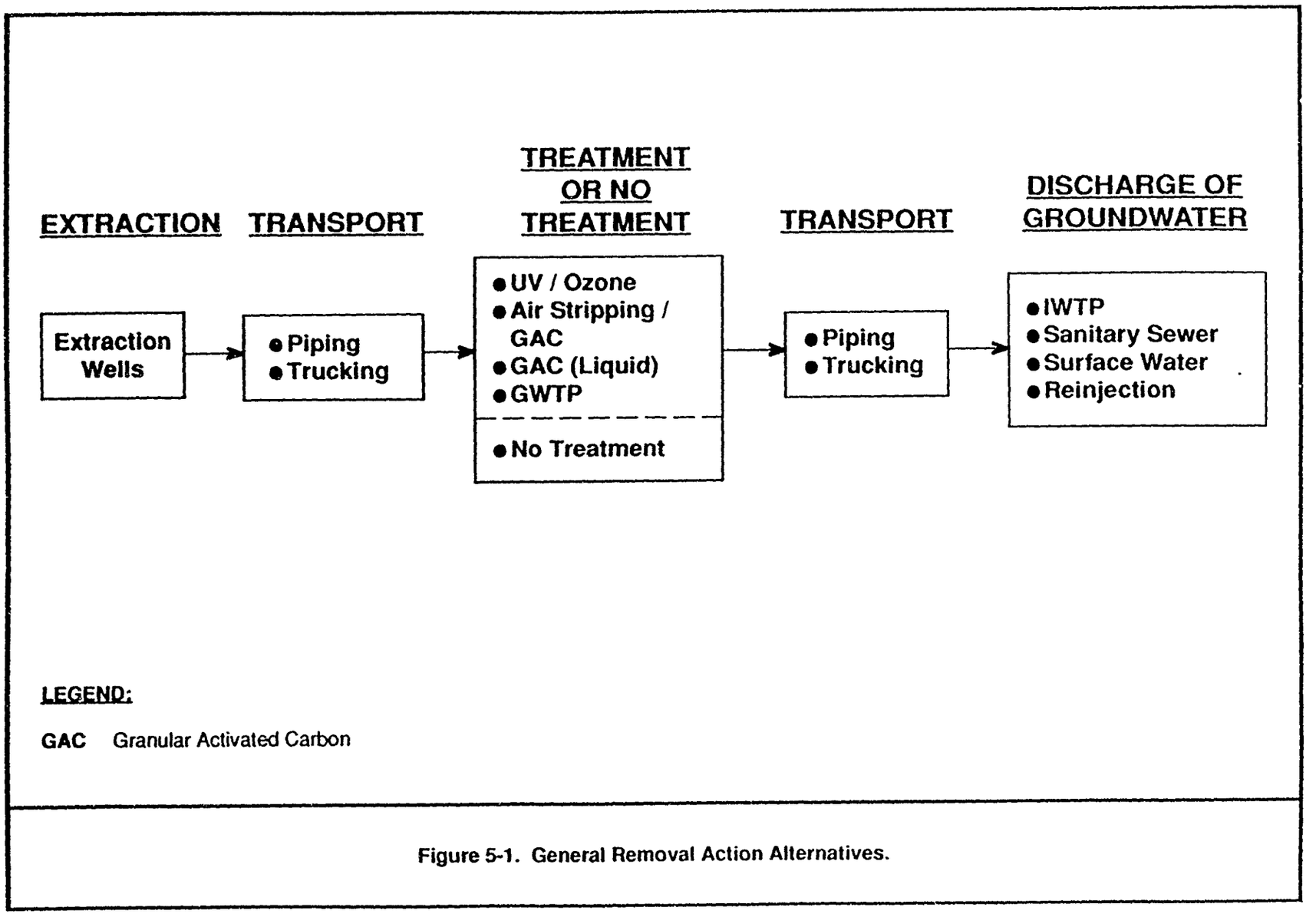


Figure 5-1. General Removal Action Alternatives.

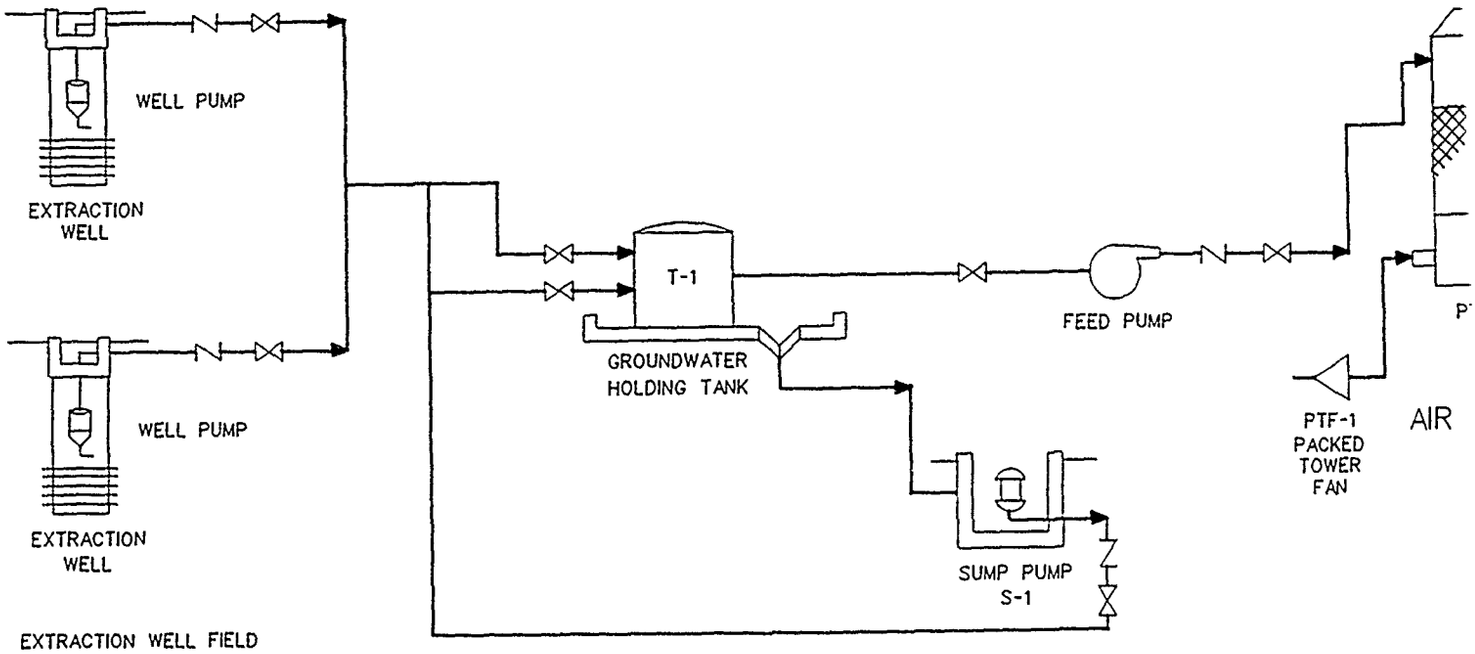
The first three treatment options were evaluated as treatment systems situated near the extraction well network. The GWTP option is the treatment system removed some distance from the extraction well network. The "no treatment" option was considered when treatment prior to discharge was not required. The need to apply a treatment technology or "no treatment" and to allow discharge of untreated groundwater was based on a review of groundwater quality and the Applicable or Relevant and Appropriate Requirements (ARARs) associated with the discharge options.

In-situ treatment technologies were found to be unproven for use as a removal action. These technologies are still being developed and not appropriate where system/technology failure can have significant negative consequences.

5.2.1 Air Stripping With Vapor Phase GAC Adsorption

The combined use of air strippers with vapor phase GAC adsorption is an effective and commonly used groundwater treatment process for removing contaminants with relative volatilities (vapor pressure of contaminant to vapor pressure of water) greater than 100 from wastewater. The U.S. Environmental Protection Agency (U.S. EPA) has established air stripping as a Best Available Technology (BAT) for volatile organic compound (VOC) removal as defined in Section 301 of the Clean Water Act and 40 CFR Section 125.3 (Criteria and Standards for the National Pollutant Discharge Elimination System). The air stripping/carbon adsorption system can achieve a 99 percent or greater contaminant reduction, depending on the contaminants involved and the system design. Figure 5-2 shows a simplified process flow schematic of an air stripping with vapor phase carbon adsorption treatment systems.

The air stripper treatment is a process in which a low pressure air stream is introduced at the bottom of the column in a stripping tower, and contaminated water is introduced at the top. The tower is generally a vertical shell filled with packing material and fitted with fans to draw air though the tower in either a countercurrent or crossflow pattern. In a countercurrent air stripper, the air stream moves upward, countercurrent to the water stream. Organic compounds are stripped from the water and exit the top of the column in the air stream. After exiting the top of the air stripping column, the volatile organic-laden air enters a vapor phase GAC adsorption system where organic compounds are removed from the air stream, eliminating contaminant air emissions. The treatment system does have some limitations. The contaminants removed from the groundwater during the vapor phase GAC adsorption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EXTRACTION WELL
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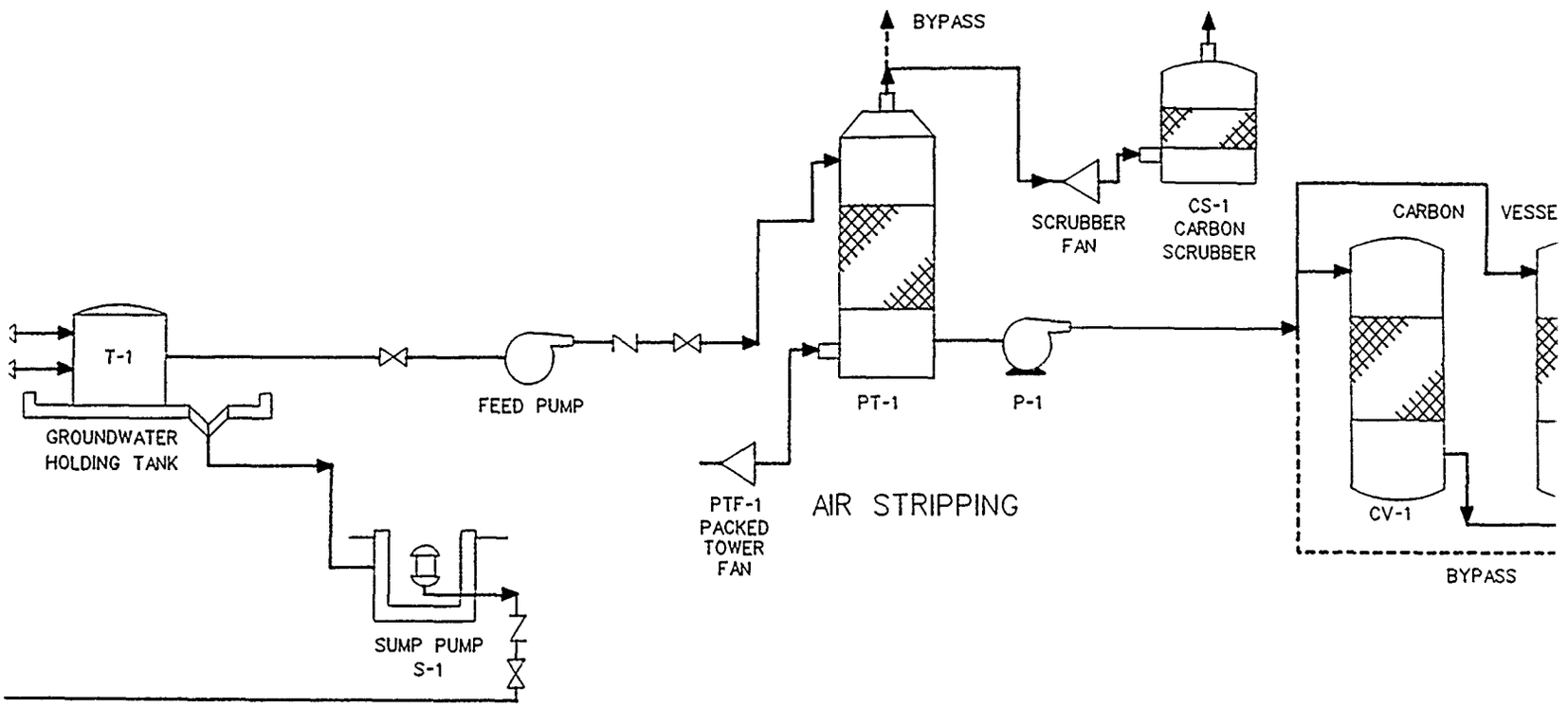
T-1
GROUNDWATER HOLDING TANK
FEED PUMP
SUMP PUMP S-1
PTF-1 PACKED TOWER FAN
AIR


BYPASS
SCRUBBER FAN
CS-1 CARBON SCRUBBER
CARBON
VESSE
T-1
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PT-1
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PTF-1 PACKED TOWER FAN
AIR STRIPPING
CV-1
BYPASS
SUMP PUMP S-1

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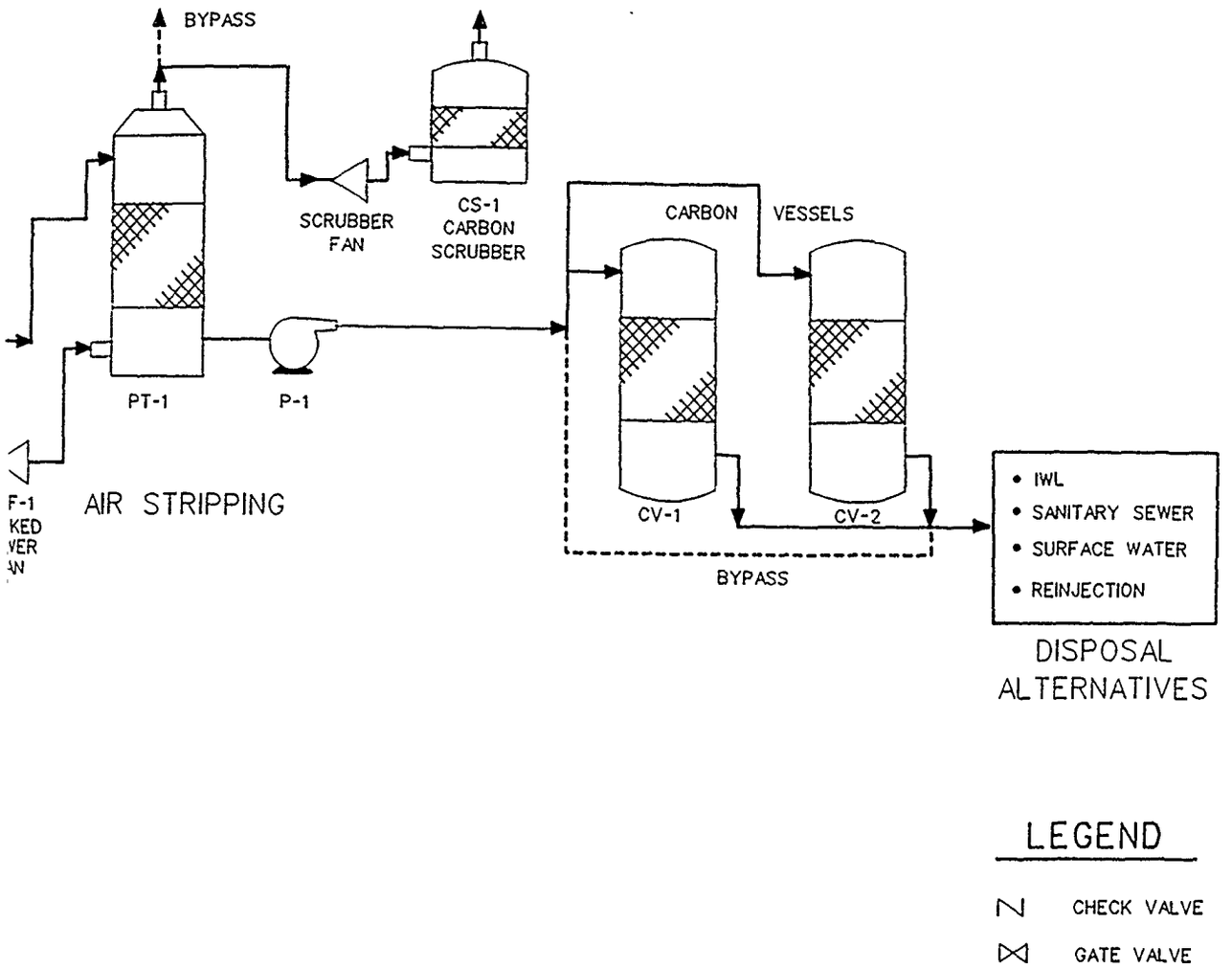

Figure 5-2. Process Schematic of Air Stripping with Vapor Phase Carbon Adsorption Treatment Alternative.

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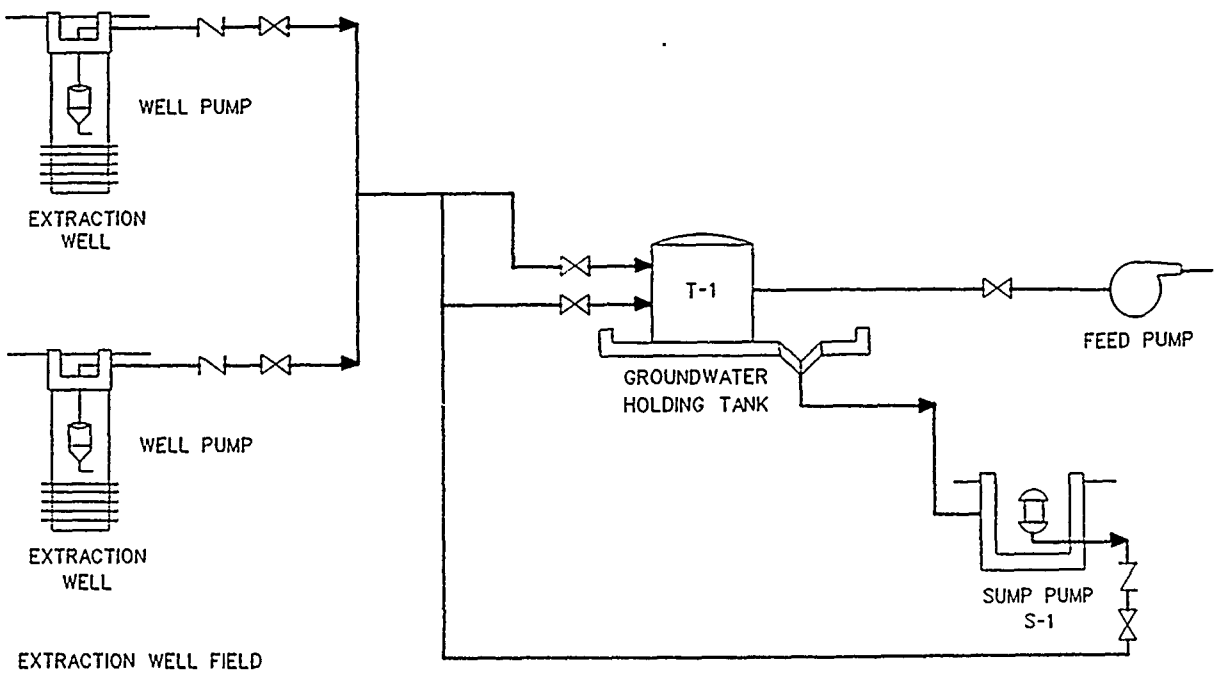
are concentrated on the carbon filters which must be destroyed, regenerated, or landfilled. Also, the air stripper is prone to inorganic and biological fouling; disinfection of the stripper may be required, as well as pretreatment of the influent stream to remove iron. Because of relatively high costs, carbon adsorption is most often used as a finishing or polishing step following other less expensive treatment processes; in this case, it follows air stripping. The application of air stripping to remove multi-component leachate, like that found at McClellan Air Force Base (AFB), has some performance limitations but is generally acceptable for controlling VOCs, vinyl chloride, and most halogenated organic compounds. Also, this technology is one with which operators of the McClellan AFB GWTP are familiar, since a similar system is currently being used.

5.2.2 Aqueous Phase GAC Treatment

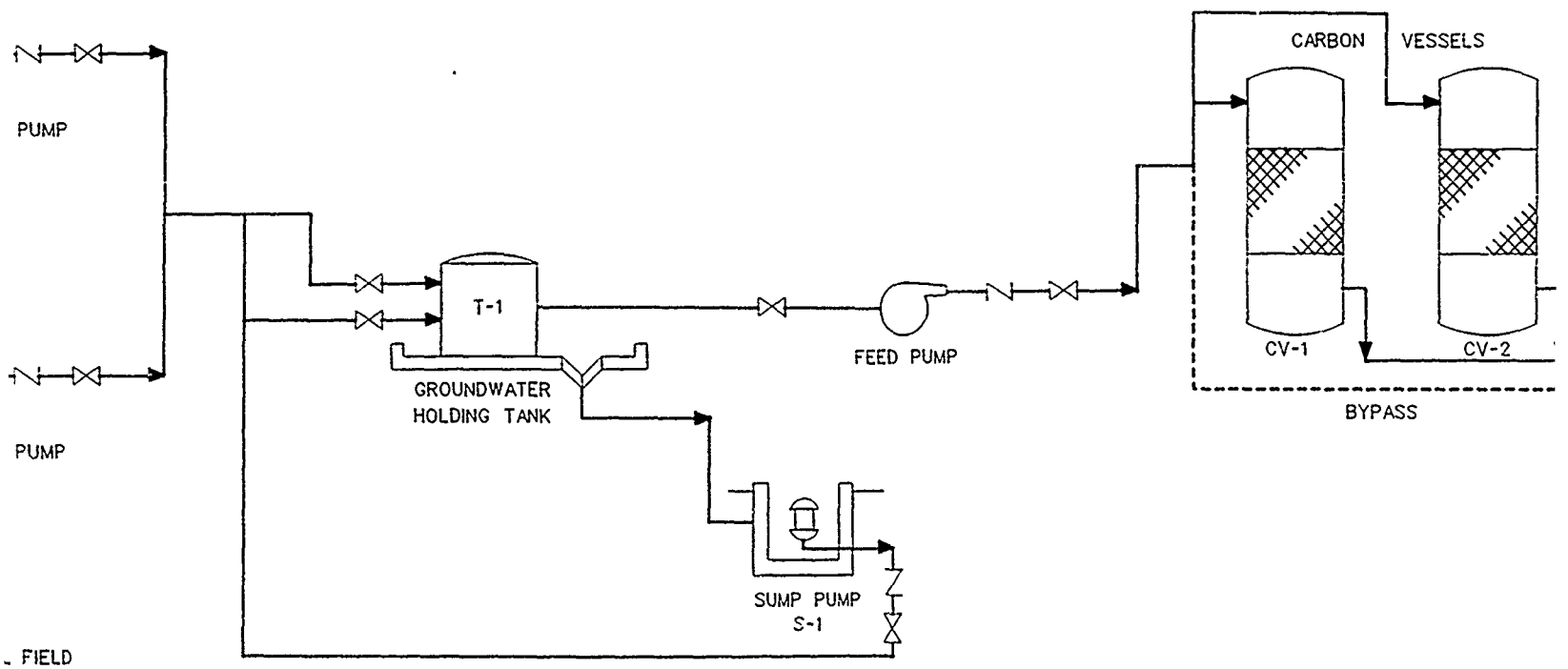
Granular activated carbon treatment is also an established and demonstrated technology capable of removing VOCs from contaminated groundwater. The U.S. EPA has established carbon adsorption as a BAT for removal of VOCs as defined in Section 301 of the Clean Water Act and 40 CFR Section 125.3. The GAC removes organic compounds from contaminated groundwater by physically adsorbing contaminants onto the carbon. Figure 5-3 is a simplified process schematic of an aqueous phase GAC treatment system. The rate and magnitude of contaminant adsorption is influenced by molecular structure, solubility, temperature, competition for adsorption between contaminants in a mixed contaminant stream, and the properties of the GAC. The major design parameters of a GAC system is the contact time between the groundwater and the carbon bed, the carbon bed design, and the method for handling spent carbon. Carbon adsorption is theoretically capable of reducing organic concentrations to non-detectable levels. The application of carbon adsorption on a multi-component contaminated groundwater has some limitations but is generally accepted for controlling VOCs, some metals, and most halogenated organic compounds.

5.2.3 UV/Ozone/Peroxide Treatment

Chemical oxidation using UV light, ozone and hydrogen peroxide is a relatively new treatment process for removing VOCs. Figure 5-4 is a simplified process flow schematic of a UV/ozone/peroxide treatment system. During this process, the oxidants are introduced into the contaminated groundwater, causing free radical decomposition reactions to occur. These reactions oxidize the organic compounds to carbon dioxide and water in the presence of sufficient oxidants. Because ozone reactions are relatively slow, hydrogen peroxide is added to catalyze the reaction. The



EXTRACTION WELL FIELD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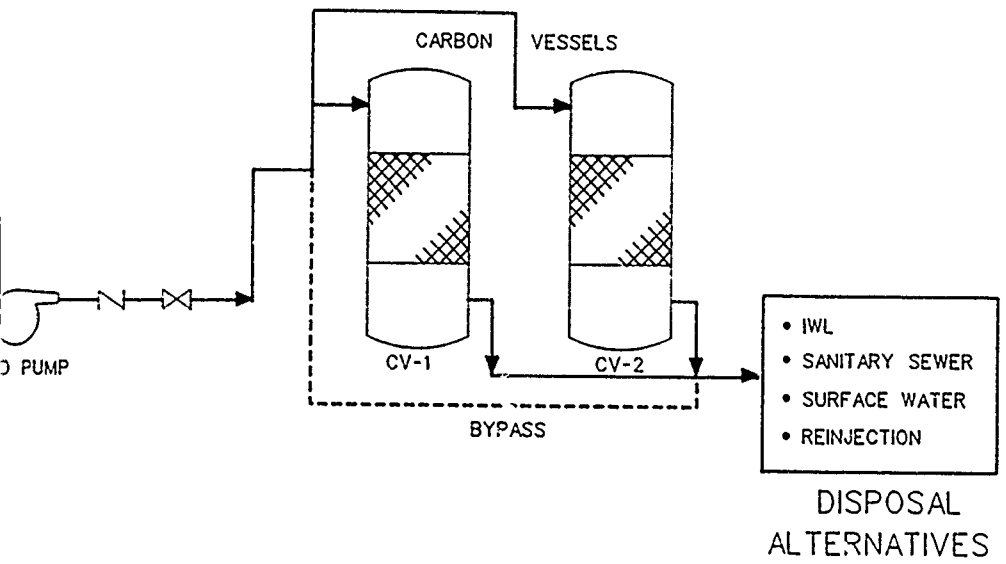
S-1
FEED PUMP
CARBON
VESSELS
CV-1
CV-2
BYPASS



LEGEND

CHECK VALVE

GATE VALVE

Figure 5-3. Process Schematic Aqueous Phase Carbon Adsorption Treatment Alternative.

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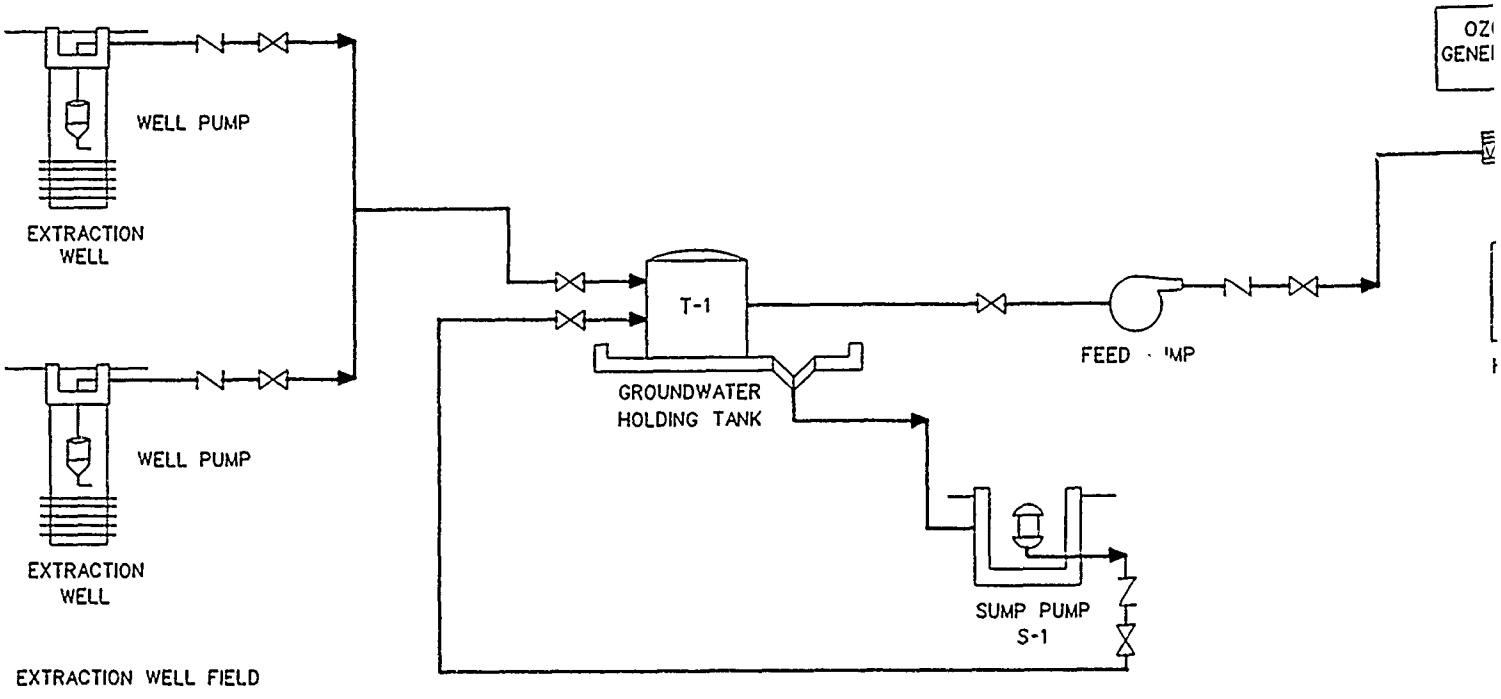
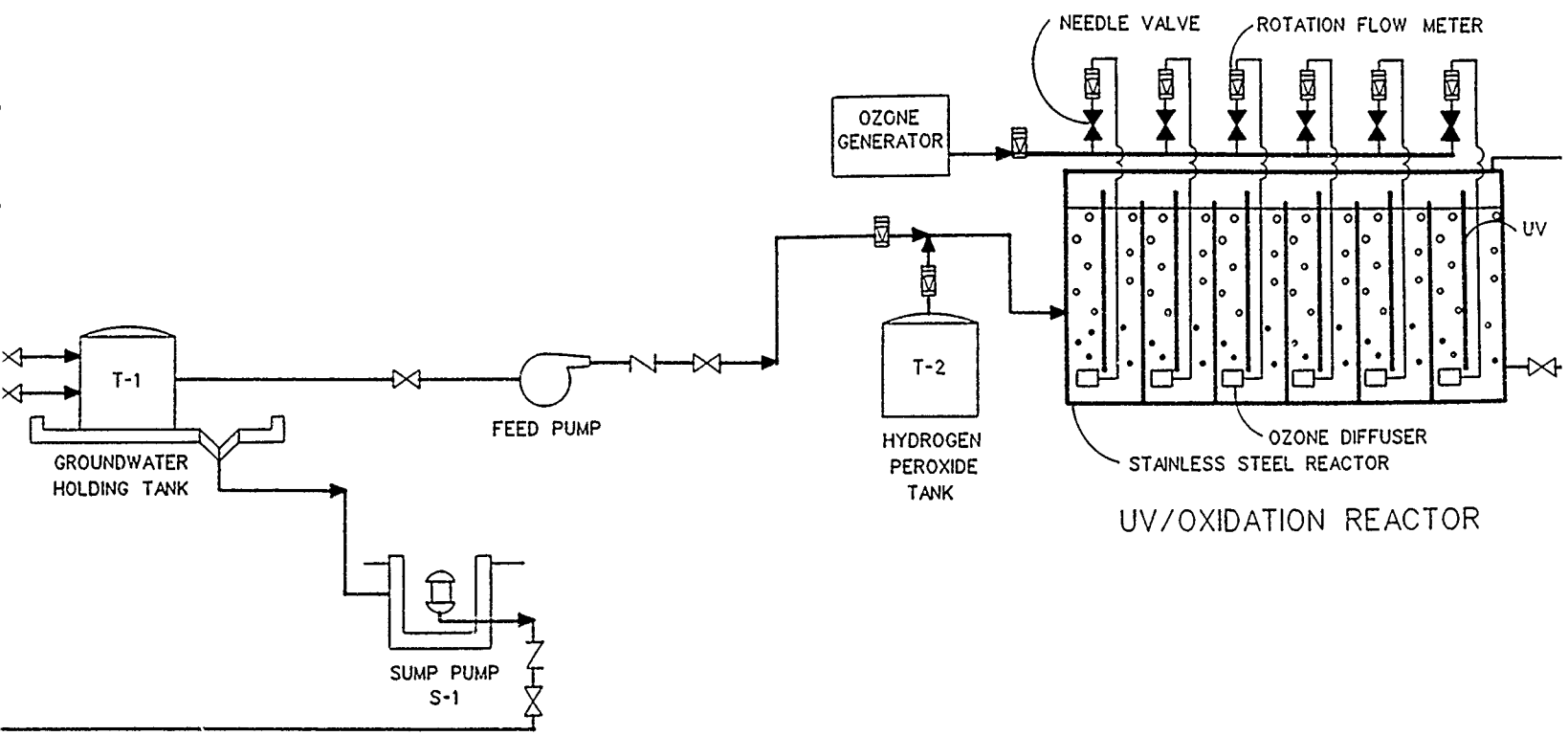


EXTRACTION WELL FIELD



UV/OXIDATION REACTOR

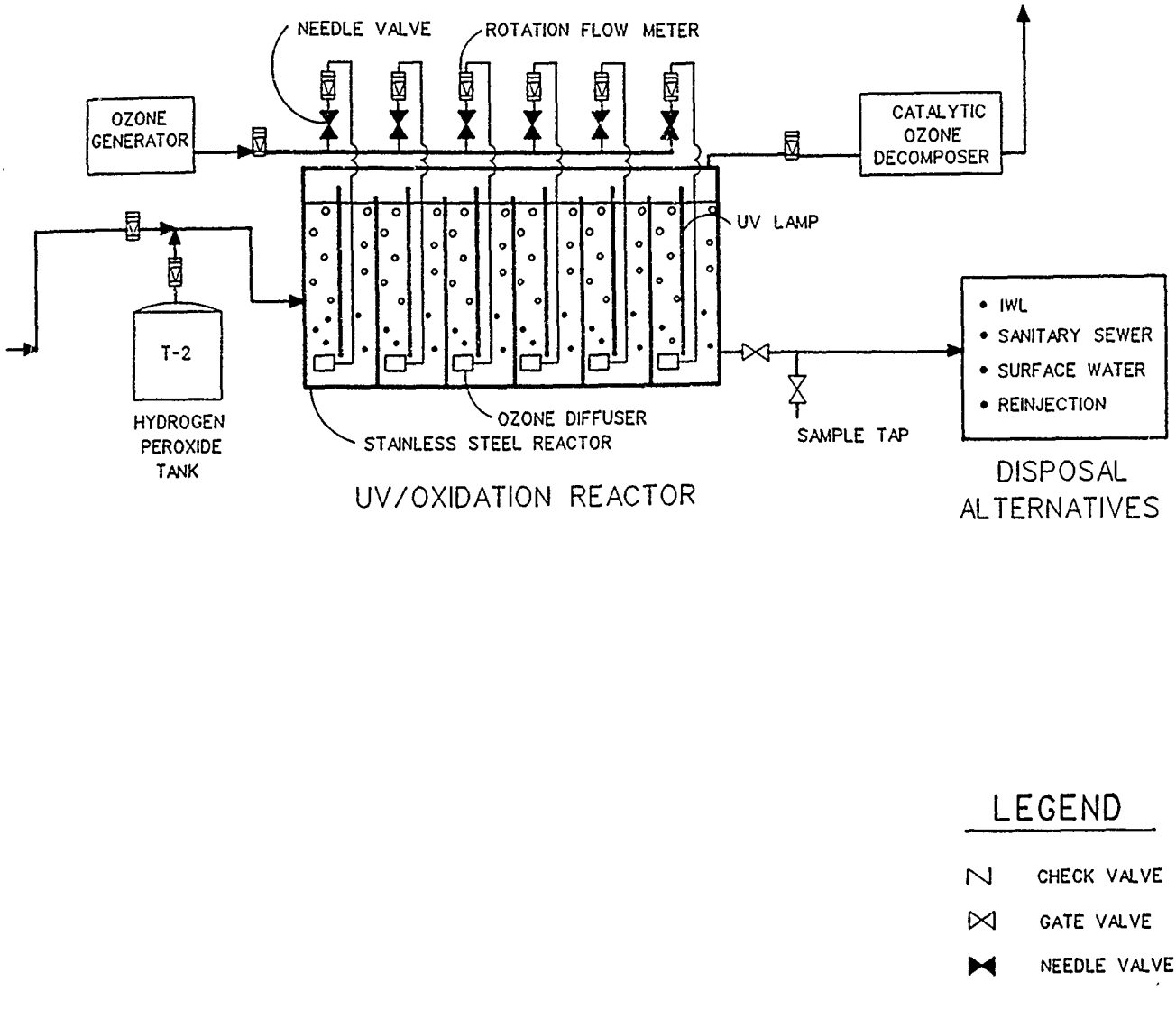


Figure 5-4. Process Schematic of UV/Ozone/Peroxide Treatment Alternative.

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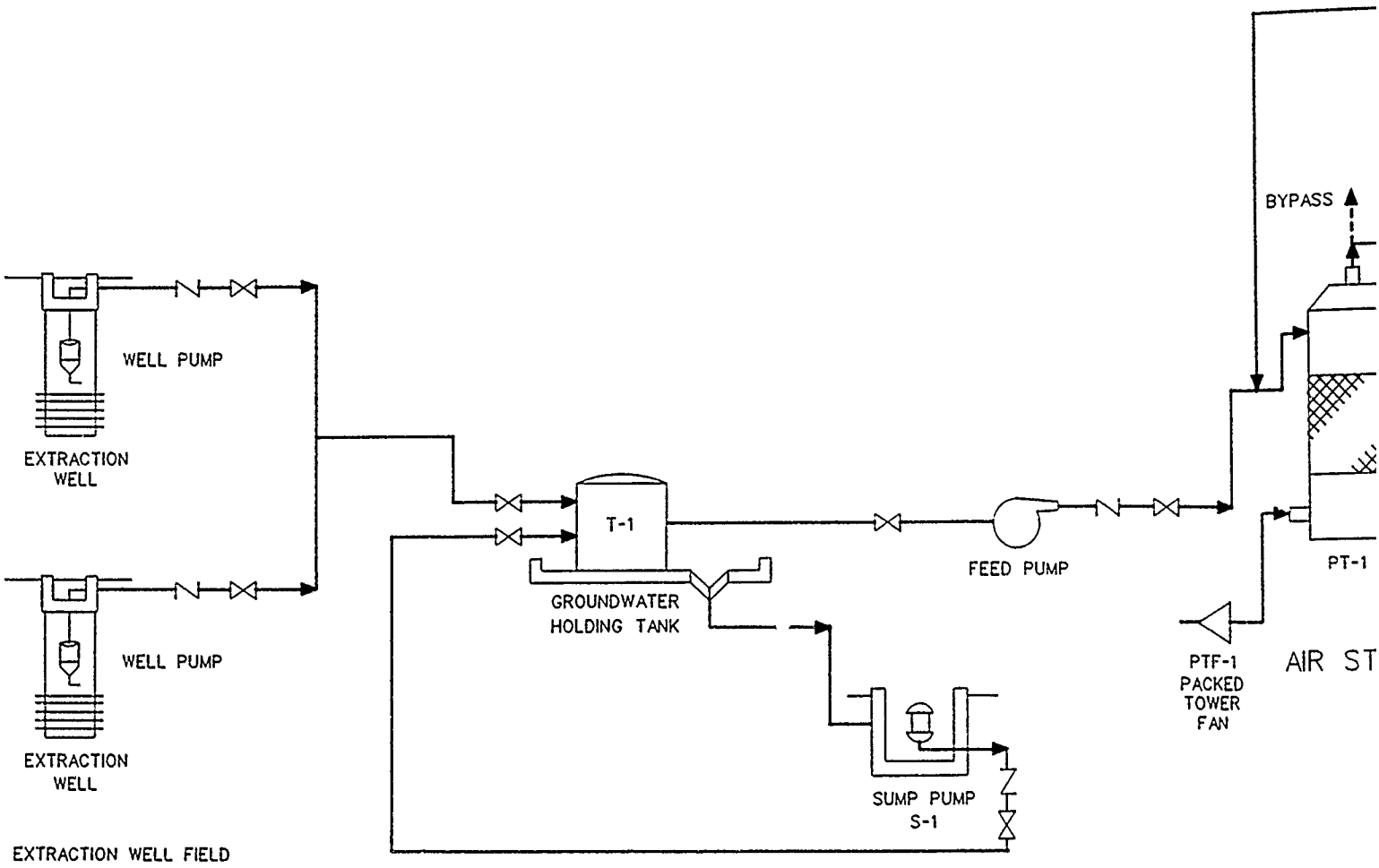
primary advantage with this process is that organic contaminants can be completely destroyed. Chemical oxidation has been tested with excellent results, and appears to be cost competitive with other more established VOC removal technologies. Chemical oxidation can be used to treat groundwaters with high VOC concentrations by applying increasingly higher UV, ozone, and hydrogen peroxide doses, because oxidant requirements are proportional to the concentration of the waste stream to be treated. However, kinetic effects can limit the process by requiring extremely long residence times to complete the reactions. High concentrations of inorganics, such as bicarbonate, can also adversely affect chemical oxidation, by consuming the ozone before it can be used for VOC oxidation. It is not anticipated that inorganic concentrations in OU B groundwater would adversely impact the chemical oxidation treatment technology. Based on results of pilot and bench testing of similar contaminated groundwater, the data for this process indicate that nondetectable levels for VOCs can be achieved for the anticipated flow rates and concentrations from the OU B groundwater plumes.

5.2.4 Groundwater Treatment Plant

The McClellan AFB GWTP is a treatment facility that uses several processes to treat contaminated groundwaters. The treatment plant processes include:

- Flow equalization/storage;
- Air stripping;
- Aqueous phase GAC treatment; and
- Off-gas incinerator and caustic scrubber.

Figure 5-5 presents a simplified process flow schematic of the GWTP. The GWTP is designed to treat 1,000 gallons per minute (gpm) (1.44 million gallons per day [MGD]). Currently, the GWTP treats approximately 250 gpm (0.36 MGD) from extraction wells located in OUs C and D. The proposal to add approximately 155 gpm (0.22 MGD) from the proposed OU B groundwater extraction systems will not exceed the design capacity of this plant. Groundwaters from OU D and OU C are transported to the GWTP for treatment via pipelines. The influent waters are first stored in the flow equalization/storage tanks. The waters flow from the tanks to a series of heat exchangers and then to the air stripper. The air stripper volatilizes the VOCs into the air stream. The water exits the air stripper and flows through a series of heat exchangers and onto the GAC contactors. The GAC treatment removes the organic contaminants that were not removed in the air stripper. The off-gas from the air stripper, which contains VOCs, is treated in the incinerator. The contaminants are burned to produce an air stream containing carbon dioxide, water, and hydrochl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GROUNDWATER HOLDING TANK
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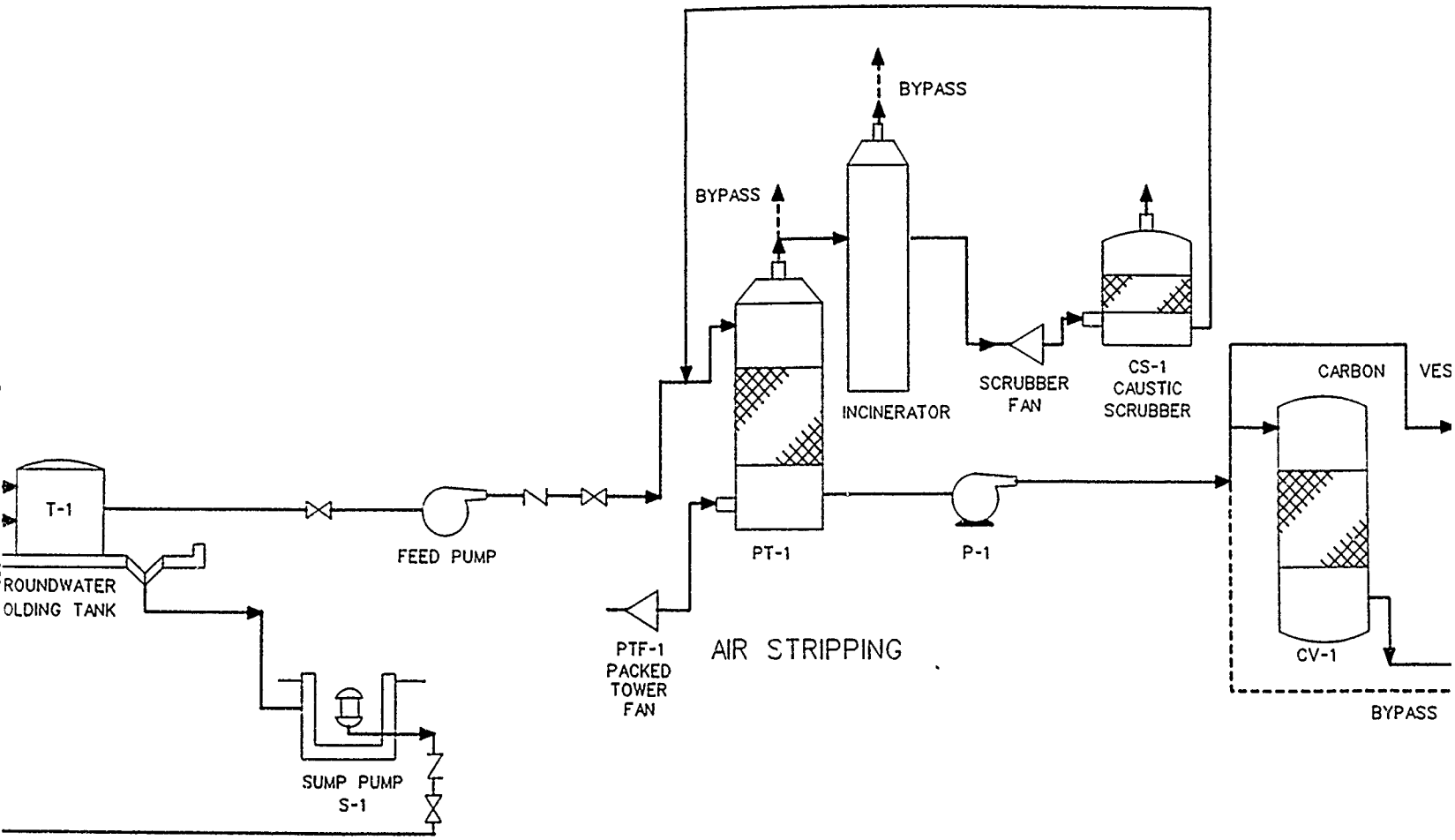
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CARBON
VES
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FEED PUMP
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AIR STRIPPING
CV-1
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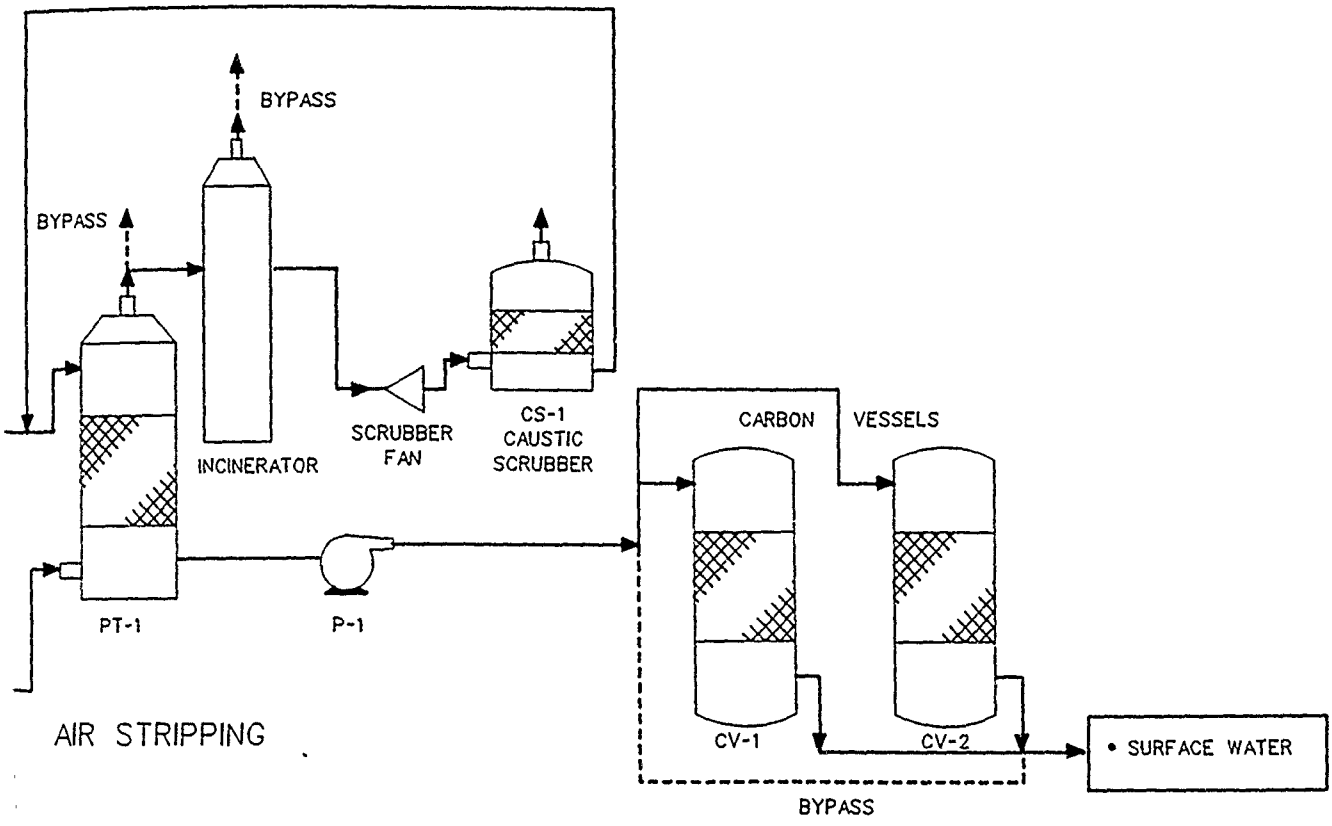

DISPOSAL ALTERNATIVE

LEGEND

CHECK VALVE

GATE VALVE

Figure 5-5. Process Schematic of Groundwater Treatment Plant Treatment Alternative.

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oric acid vapor. A caustic scrubber is used to treat the hydrochloric acid vapor. The acid vapors dissolve into the water stream used in the scrubber and produce a solution of ordinary table salt. The scrubber water is recycled into the influent stream of the air stripper and the scrubbed off-gases are discharged to the atmosphere. The GWTP discharges treated groundwater to Magpie Creek.

The GWTP currently has a National Pollution Discharge Elimination System (NPDES) permit to discharge 0.36 MGD with a total allowable discharge of 1.45 MGD (30-day average flowrate) from additional groundwater extraction systems. The proposal to treat an additional 0.22 MGD flow of groundwater from the northern TCE/1,2-DCE plume would not exceed the permitted capacity. The NPDES permit also establishes strict effluent water quality requirements. The GWTP has successfully demonstrated the use of air stripping combined with aqueous phase GAC processes to treat VOC contaminated groundwater.

5.3 Discharge of Treated or Untreated Groundwater

The discharge of treated or untreated groundwater is a fundamental requirement for each of the removal action alternatives. Four discharge options were considered most appropriate alone or in conjunction with prior treatment of the groundwater. The discharge options included:

- Industrial Wastewater Line (IWL);
- Sanitary Sewer System;
- Surface Water Discharge; and
- Reinjection.

The discharge of untreated groundwater was considered appropriate for the IWL and the sanitary sewer system options. Treatment is required to discharge to surface water or reinject into the aquifer.

5.3.1 Industrial Wastewater Treatment Plant (IWTP) Via the IWL

It is proposed that treated or untreated groundwater extracted from OU B be transported to the IWTP for treatment prior to discharge into the Sacramento Regional County Sanitation District's (SRCSD) interceptor system. Figure 5-6 shows a simplifed schematic of a proposed pipeline route from the TCE/PCE and northern TCE/1,2-DCE plume areas to the most convenient IWL connection point.

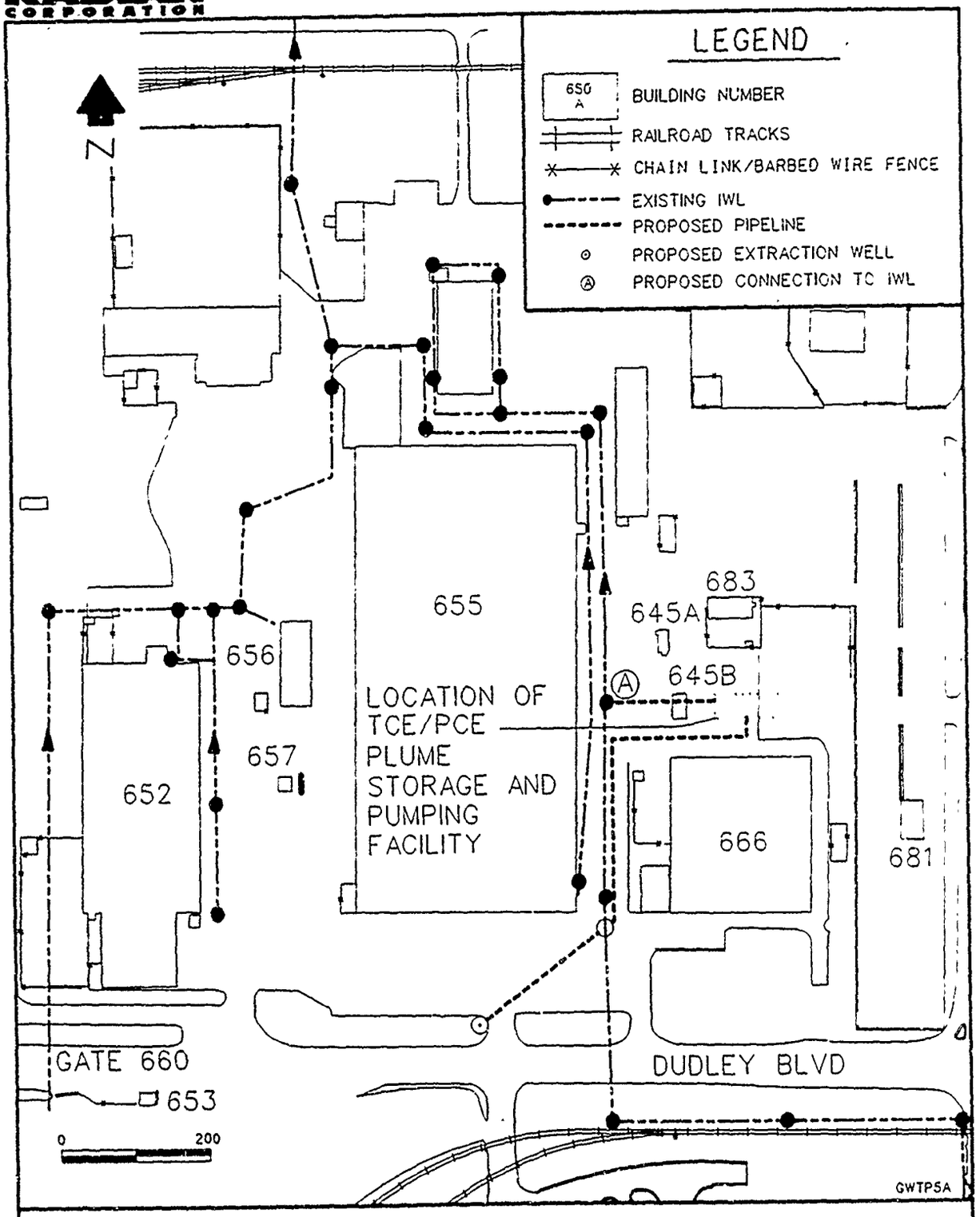

Figure 5-6. Proposed Piping Route from TCE/PCE Plume Storage and Pumping Facility to Industrial Wastewater Line.

The IWTP was constructed in the early 1970s to treat industrial wastewater generated at McClellan AFB. Wastewater is collected from operations performed basewide and transported to the IWTP via the IWL. Sources of the wastewater influent included the following:

- Effluent from aircraft washracks and equipment paint stripping facilities;
- Effluent from the IWTP No. 2 which pretreats wastewater generated by the Building 243 plating operations; and
- Effluent from other base industrial operations.

The IWTP consists of a number of processes to treat the industrial wastewater streams generated at the base; these are shown in a simplified schematic of the IWTP, Figure 5-7. The maximum wastewater flow capacity of the IWTP is 1.2 MGD. The average daily flow rate through the IWTP is approximately 0.6 MGD; however, the daily flow rate can dramatically increase during storm events due to rainwater infiltration to the system. Treatment processes include:

- Gravity oil separation;
- Flow equalization/storage;
- Chromium reduction;
- pH adjustment;
- Heavy metal precipitation;
- Aeration;
- Trickling filtration;
- Clarification;
- Phenol removal;
- Disinfection; and
- Filtration.

Industrial wastewater collected basewide is transported via the IWL to the influent pump station located at the south end of the IWTP. The wastewater is then pumped into an oil-water separator and the water stored in one of two holding tanks located east of the GWTP. After the flow equalization/storage, the water is chemically treated in three stages.

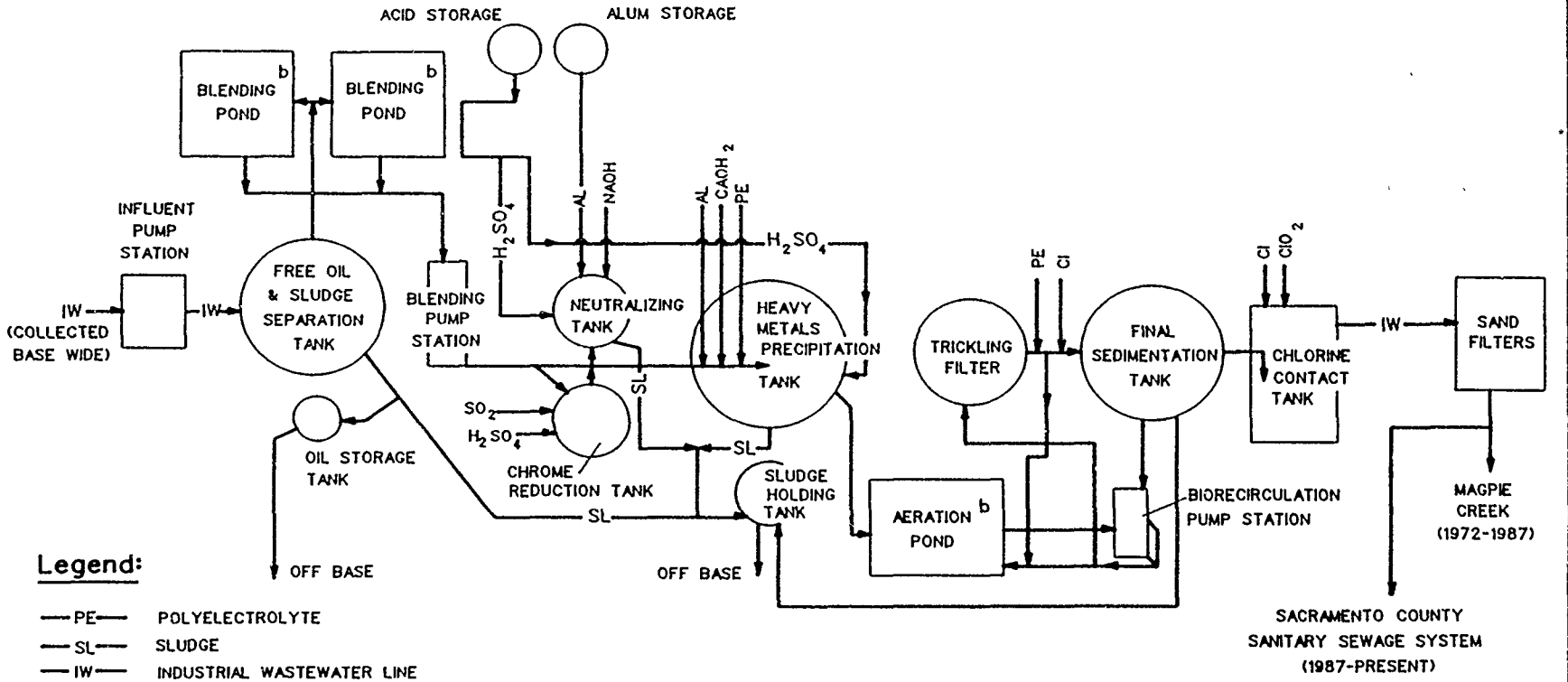

Figure 5-7. Simplified Schematic[a] of the Industrial Wastewater Treatment Plant Process.

The first chemical treatment stage is for chromium reduction and consists of adding sulfuric acid and sulfur dioxide to reduce hexavalent chromium to trivalent chromium. The next stage is pH adjustment to prepare the water for heavy metal precipitation. Additional caustic chemicals and coagulant aids are added in the third stage to precipitate heavy metals.

After chemical treatment, the water is aerated in a basin tank located east of the GWTP for biological treatment of the water. A trickling filter provides additional oxidation of organic compounds. From the trickling filter tank, wastewater flows to the final sedimentation tank to remove any remaining solids, such as the biological sludge produced in the aeration tank and sloughed biofilm from the trickling filter. A portion of the sludge is recirculated to the aeration tank, and the remainder of the sludge is pumped to the sludge conditioning tank for storage and dewatering. The wastewater effluent from the final sedimentation tank is chlorinated in the chlorine contact chamber to remove any pathogenic organisms. Finally, the water is pumped through two pressure sand filters to remove any remaining solids. Between 1972 and 1987, the effluent was then discharged to Magpie Creek. Since 1987, the water has been discharged into the Sacramento Regional sanitary sewer system.

Currently, untreated domestic wastewater and treated industrial wastewater discharge from the base to the Dry Creek Interception at Rio Linda Boulevard. After leaving McClellan AFB property, the trunk line becomes part of the SRCSD. Traveling west on Santa Ana Avenue, the trunk line connects to the SRCSD sewer line and Arden Pump Station. From there, the wastewater is transported to the Sacramento Regional Wastewater Treatment Plant, which eventually discharges into the Sacramento River.

5.3.2 Sanitary Sewer System

Another possible discharge option is disposal to the McClellan AFB sanitary sewer system. A simplified schematic of a pipeline to the sanitary sewer is shown in Figure 5-8.

The McClellan AFB sanitary sewer system is connected to the SRCSD Dry Creek interceptor line at Rio Linda Boulevard. A combined flow of untreated sanitary sewer wastewater and treated industrial wastewater are discharged to the SRCSD interceptor system. Sanitary sewage flow at McClellan AFB averages approximately 1.5 MGD. In the past, the sewage was treated at the Sanitary Wastewater Treatment Plant (SWTP), Facility 333, and then transported to the SRCSD interceptor system. The

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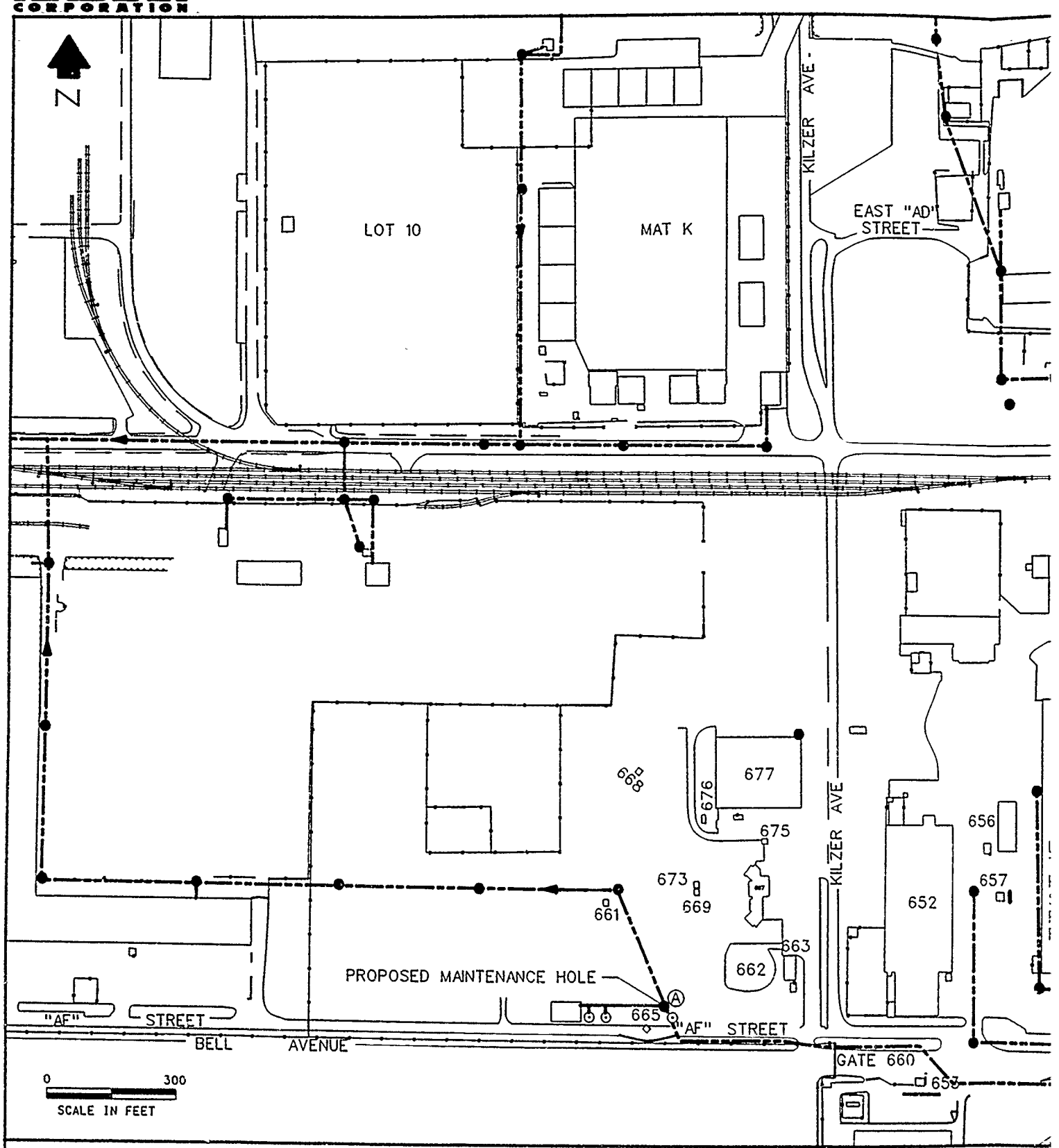

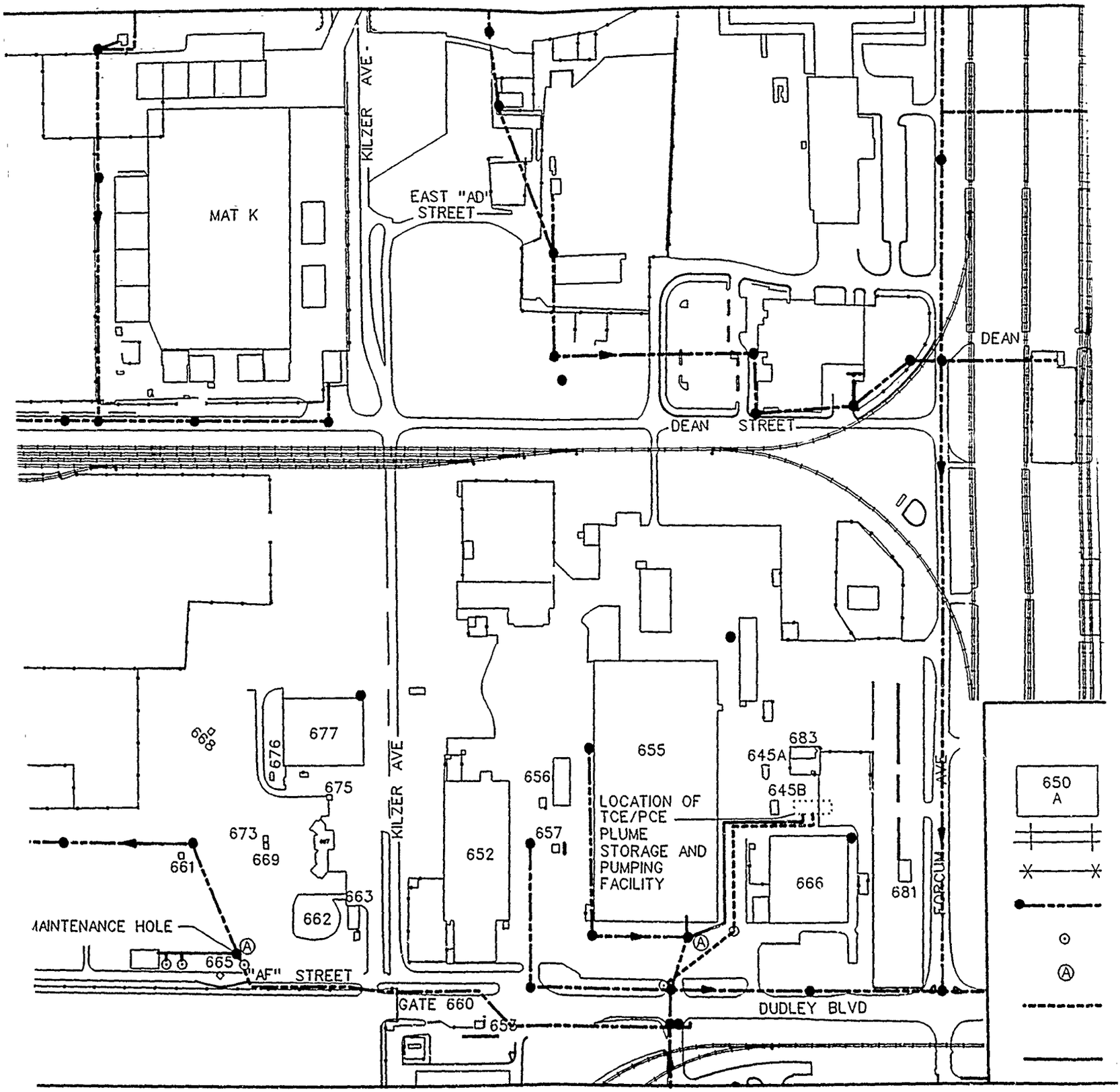
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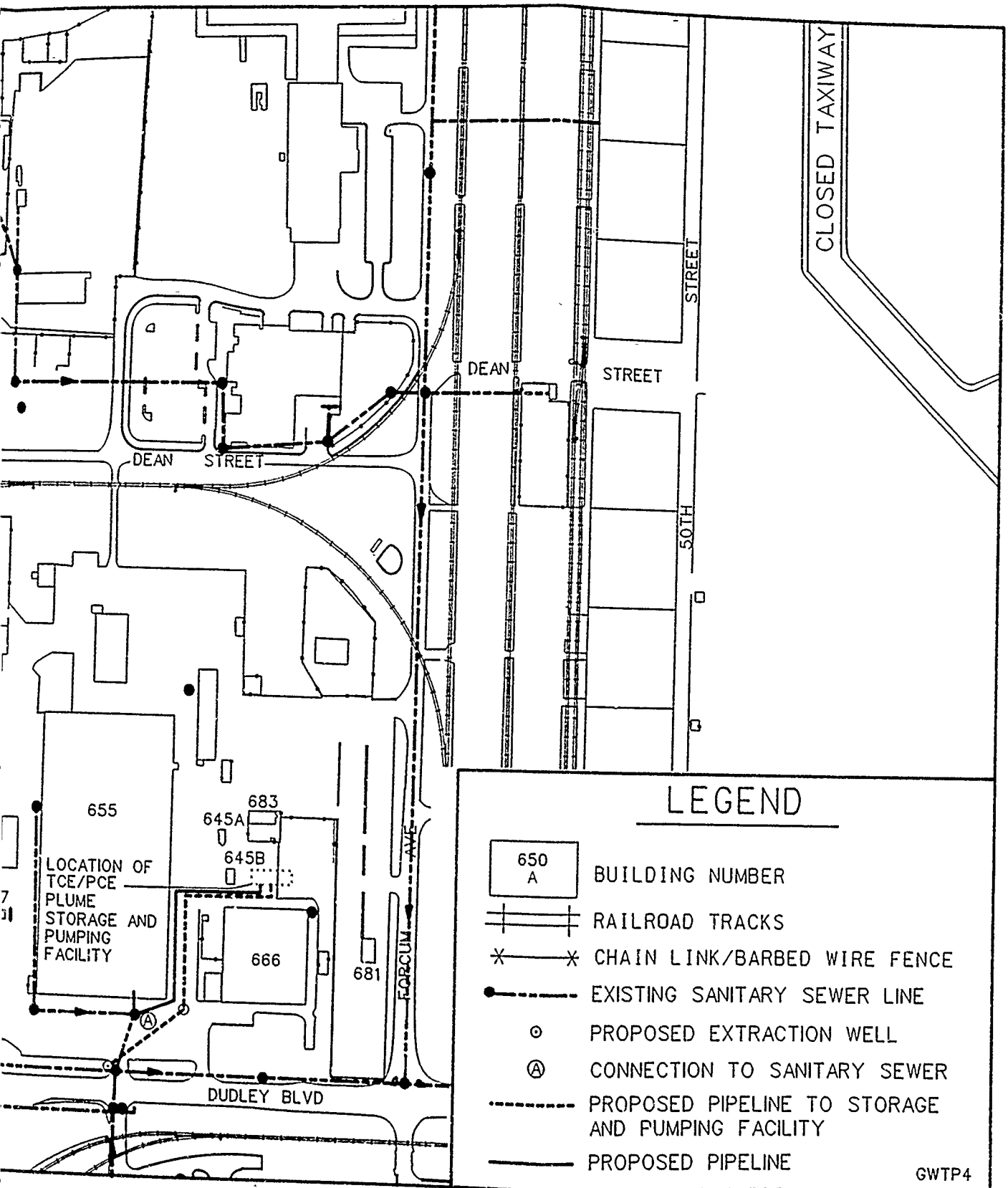

Figure 5-8. Proposed Pipeline Route to Sanitary Sewer.

SWTP is no longer in service, and the untreated sewage is now transported to the SRCSD interceptor system. The SRCSD regulates the use of its interceptor system through district ordinance number SRSD-0029, SRCSD Sewer Rate Ordinance, and sewer use permits. The McClellan AFB sewer use permit allows for the conveyance and treatment service for a combined pretreated industrial waste and untreated sanitary waste discharge. A summary of the allowable permitted flow rates is presented in Table 5-2.

Preliminary investigation indicates that the base sanitary sewer system currently may have excess capacity to accept contaminated groundwaters from either the TCE/PCE plume, the northern TCE/1,2-DCE plume, or both. The anticipated quantities of extracted groundwater to be discharged into the sewer from the TCE/PCE plume is 20 gpm, equivalent to 0.03 MGD, and approximately 175 gpm, equivalent to 0.25 MGD, from the northern TCE/1,2-DCE plume. A total combined flow from both groundwater extraction systems will be 175 gpm, equivalent to 0.28 MGD. The current (1989) dry weather flows were approximately 40.3 million gallons per month. Compared to the permitted 45 million gallons per month flow rate, the system has an apparent 4.66 million gallon per month, or 0.16 MGD, excess capacity. The discharge of a 0.03 MGD flow from the TCE/PCE plume would not exceed permitted levels; however, either the discharge of 0.25 MGD flow of contaminated groundwater from the northern TCE/1,2-DCE plume, or the discharge of 0.28 MGD flow from the combined plumes, would exceed the permitted level, but not the design capacity. McClellan AFB would be required to purchase additional capacity to accommodate discharges exceeding currently permitted flows.

5.3.3 Surface Water Discharge

Surface water discharge following treatment is a discharge option evaluated for each of the treatment technologies. Surface water discharge is considered an acceptable and reliable method for disposing of treated water. Two discharge points were evaluated for acceptance of treated groundwaters: nearby surface drainages that flow into Magpie Creek or to Arcade Creek. Figure 5-9 shows possible pipeline routes from the TCE/PCE and the northern TCE/1,2-DCE plumes to the Magpie Creek water discharge point. Magpie Creek is currently monitored under an existing GWTP NPDES permit. Arcade Creek is closer to the proposed extraction well network and local treatment site, but no discharges to Arcade Creek drainages are currently permitted. Minimal additional apparatus would be needed to transport treated water to either discharge point in the surface drainages. A single pipeline may be used, which could be

TABLE 5-2. SRCSD SEWAGE SERVICE SPECIFICATION FOR McCLELLAN AFB

Service: Conveyance and treatment for combined pretreated industrial waste and untreated sanitary waste discharges.

	Average Daily	Average Hourly	Equivalent Monthly
Permitted Dry Weather Flow (May 1 to October 21):			
Industrial Waste Stream	0.5 MGD	--	--
Sanitary Waste Stream	1.0 MGD	--	--
TOTAL	1.5 MGD	1,042 gpm	45 MG
Current (1989) Dry Weather Flow	1.34 MGD	934 gpm	40.342 MG
Permitted Wet Weather Flows (November 1 to April 30):			
TOTAL	2.0 MGD	1,389 gpm	60 MG
Permitted Maximum Flow	3.0 MGD	2,084 gpm	90 MG

MGD = million gallons per day
gpm = gallons per minute
MG = million gallons
-- Not available.

SOURCE: Sacramento Regional County Sanitation District Utility Service Contract No. F04699-85-C0030P00001. McClellan AFB. 1 October 1988.

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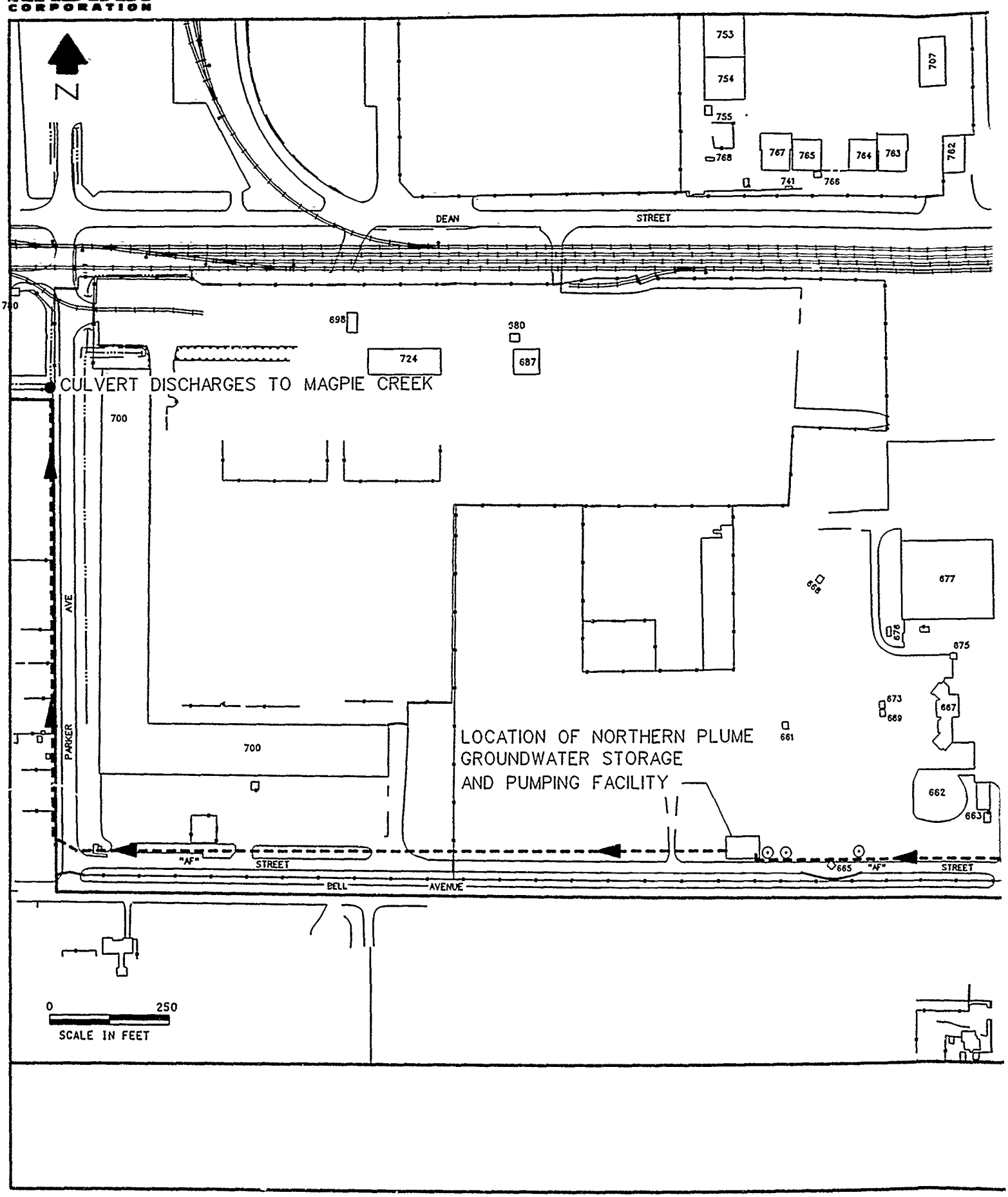

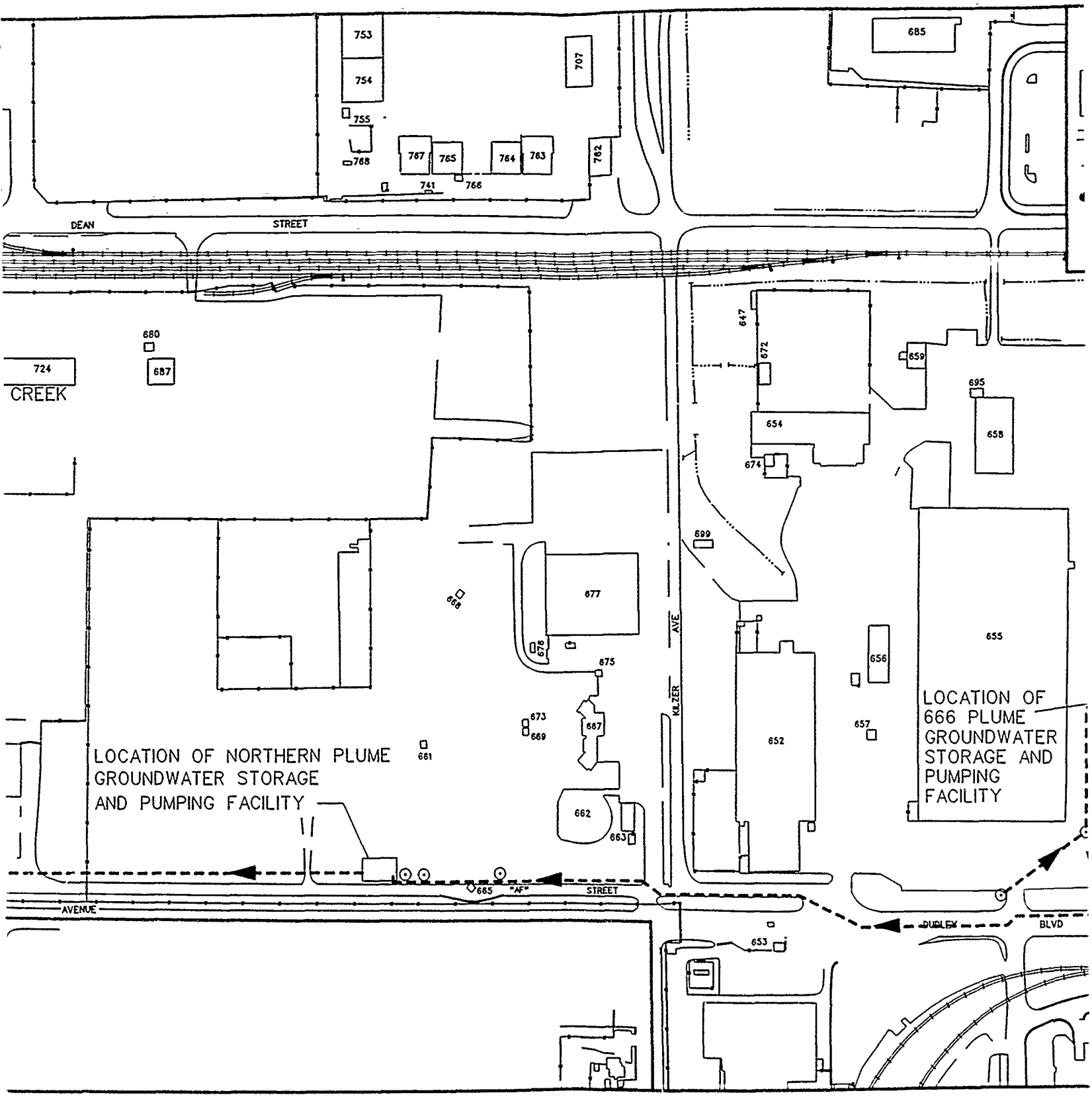
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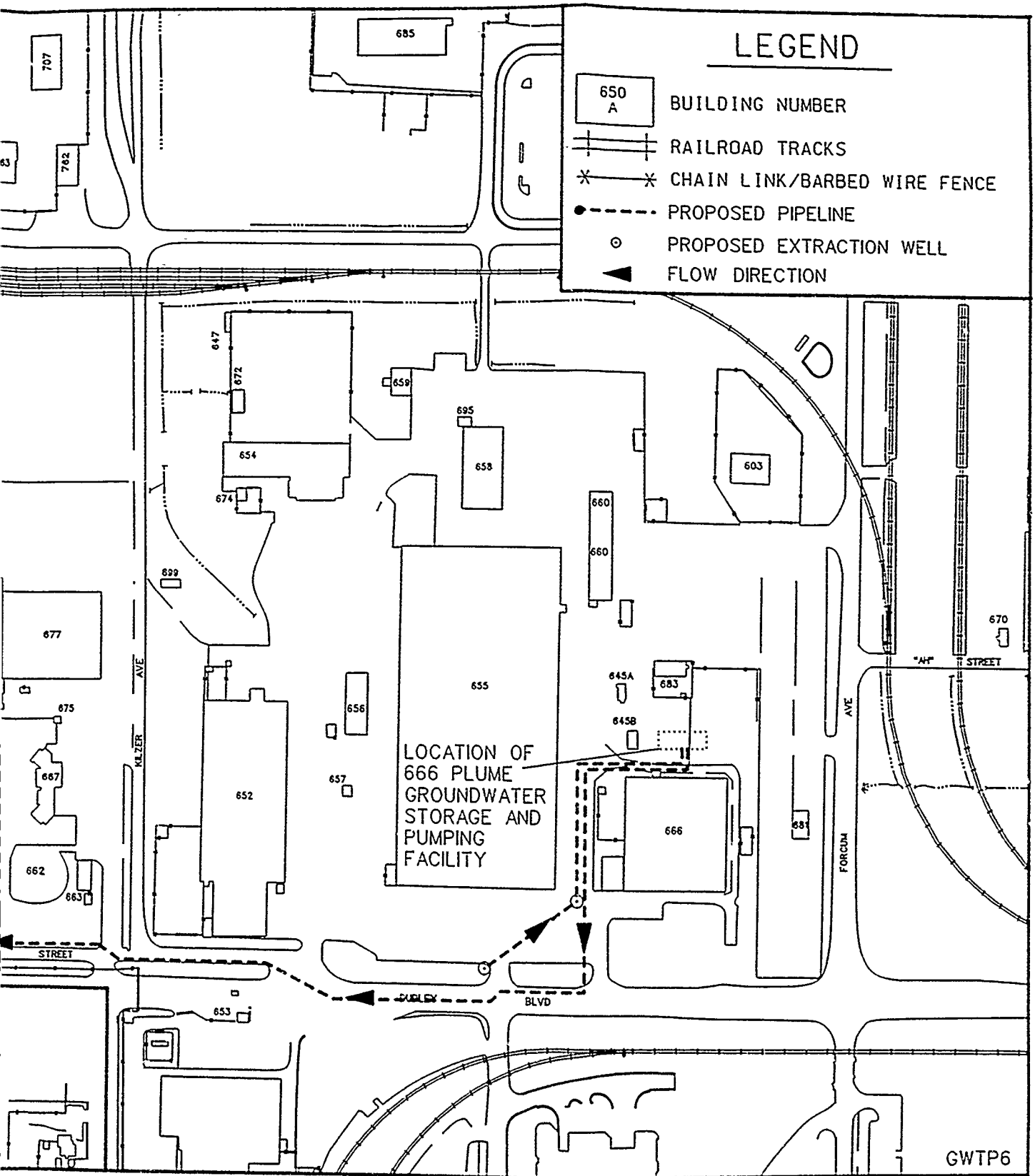

Figure 5-9. Proposed Pipeline Routes to Surface Water Discharge (to Magpie Creek).

implemented quickly. Surface discharges must meet Federal and State water quality criteria. It is anticipated that public sentiment will be strongly against this option.

5.3.4 Reinjection of Treated Groundwaters into Aquifer

The use of injection wells to reinject treated groundwaters into an aquifer is a proven technology. Reinjection or recharge is a process in which effluent of acceptable quality is injected into an aquifer through wells. The rate of injection depends on the ability of the aquifer to accept the water. Once the water is injected, it is assimilated by the aquifer. The injection well technology is well understood. Groundwater injection (recharge) wells are similar in design to extraction wells, and drilling equipment and well components are readily available. Well designs are flexible to meet site-specific conditions. The use of reinjection wells can provide a means to dispose of treated waters, and assist in the management of extraction well networks. The use of reinjection wells can enhance the efficiency of the extraction systems, and assist in the natural purging process by stimulating movement of contaminants. This technology is promising for McClellan AFB, pending more detailed analysis of regional and site-specific hydrological and geological data. Although technically very implementable, the reinjection option may be one of the least supported options by the public. The use of this technology is contingent upon the production of treated groundwater of sufficient quality to meet the appropriate regulatory acceptance criteria. Figure 5-10 shows a possible pipeline route to a possible reinjection well field area in OU B. The selection of this reinjection well field area was based on a desire to create a hydraulic barrier to retard migration of contaminated groundwater located to the north and to promote movement of contaminated groundwaters north of the reinjection area toward the extraction system. It is recognized that other reinjection well field areas are possible. This particular approach has been presented for discussion purposes of the concept and presents a cost estimate for its construction.

Conveyance of Groundwater to GWTP

The GWTP has been in operation since 1987 treating contaminated groundwater extracted from OU C and OU D and discharging the treated water to Magpie Creek. An aboveground piping system located in OU C and OU D conveys the extracted groundwater to the GWTP.

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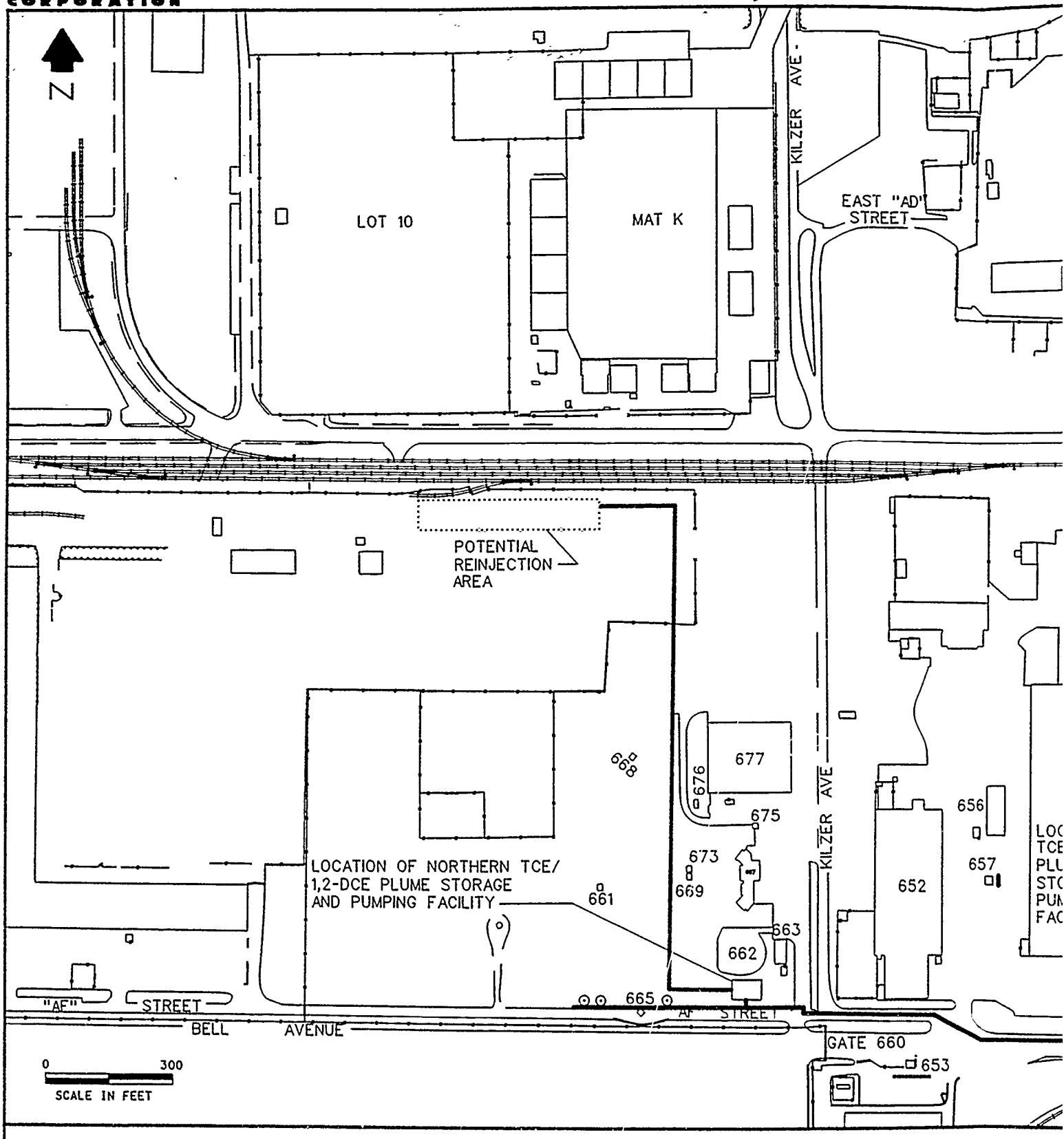

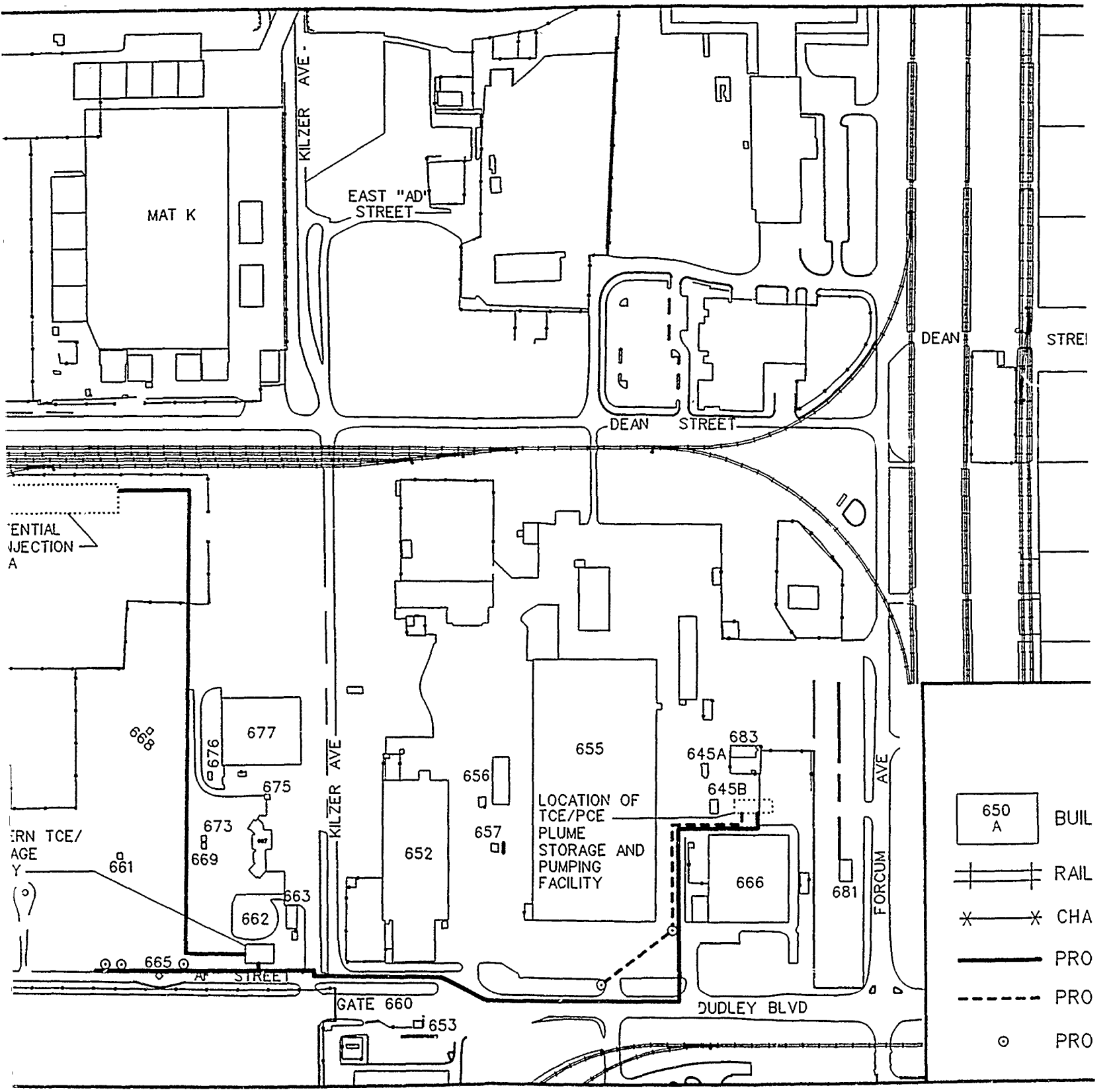
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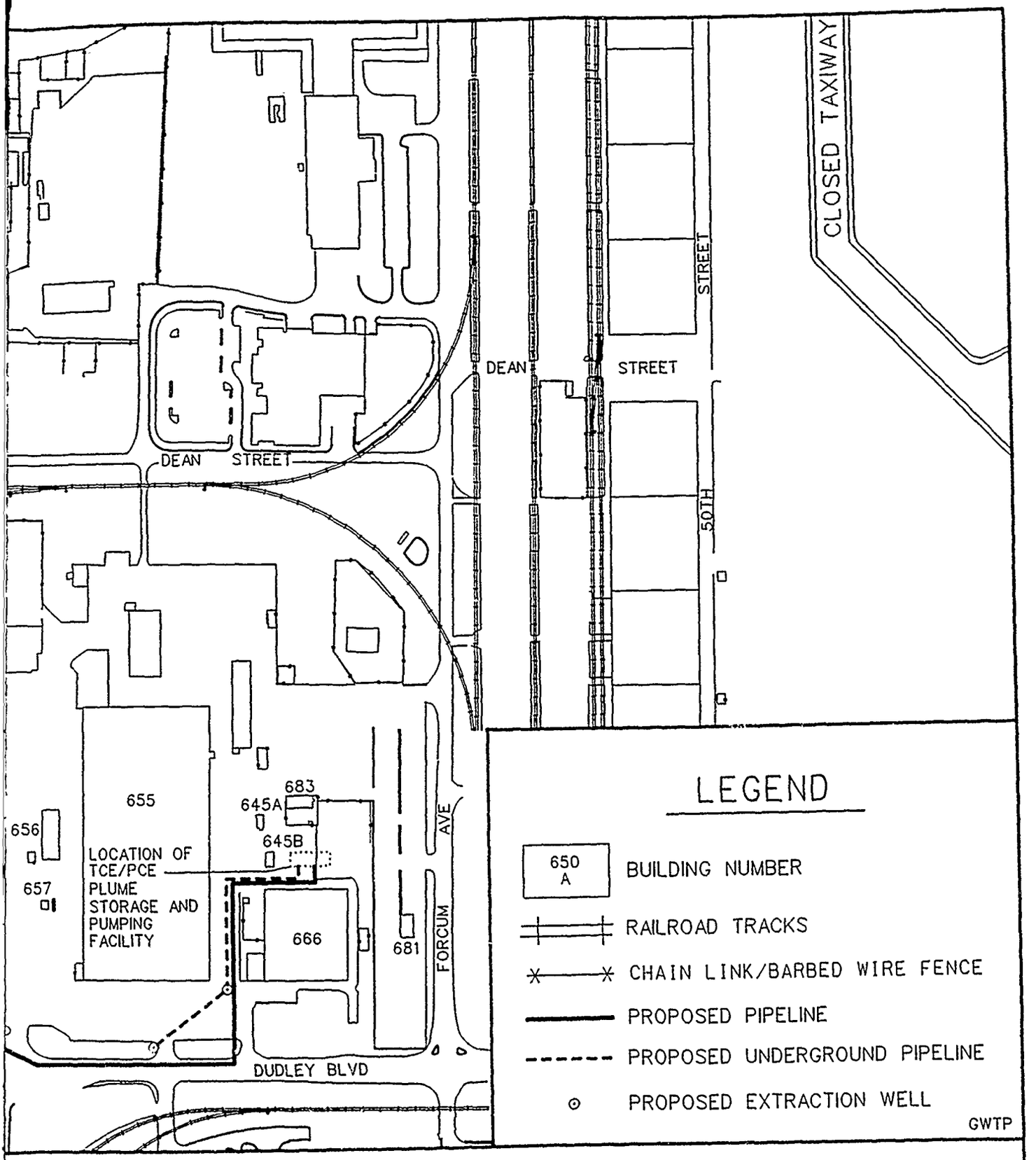


Figure 5-10. Proposed Pipeline to Reinjection Well Area.

To convey extracted groundwater from OU B to the GWTP (approximately 3,000 feet north), a new pipeline must be constructed from the OU B extraction wells to the existing OU C pipeline that flows to the GWTP. The proposed route for the new pipeline is presented in Figure 5-11. Approximately 40 percent of the pipeline will be underground to pass beneath on-base railroad tracks and roads and to allow access to facilities along Kilzer Avenue.

To reduce the horsepower requirements of the submersible well pumps, two booster pumps will be used to pump extracted groundwater from a flow equalization/storage to the GWTP.

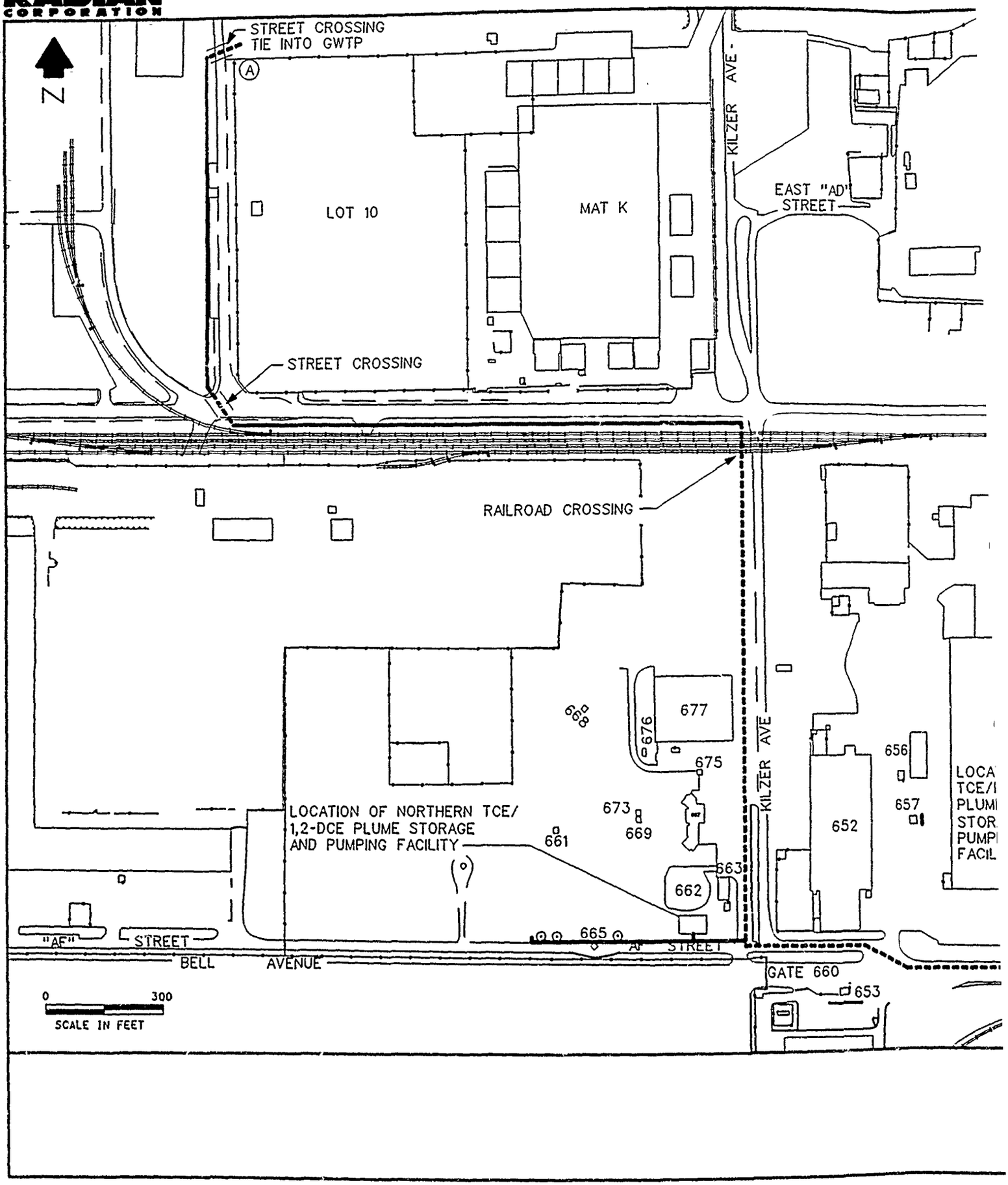
Due to the logistical problems associated with the pipeline construction, approval, funding, and construction of the pipeline could require three years to complete. Because this time limitation is not considered appropriate for the urgency of the situation, another alternative for conveyance was considered. Storage of extracted groundwater in flow equalization tanks near the extraction wells with periodic truck transport to the GWTP was suggested. While labor intensive, the alternative would allow pumping to begin as soon as the extraction, storage, and transport elements were designed and constructed. Once the pipeline is completed most elements of the alternative could be integrated into the system. Truck transport is considered an appropriate backup method for conveying contaminated groundwater to the GWTP over a short time period.

5.4 Other Components Common to Alternatives

The following removal action components common to one or more alternatives include:

- Flow Equalization/Storage;
- Conveyance of Groundwater by Pipeline; and
- Groundwater Monitoring.

Each of these common alternative components are described in the following sections.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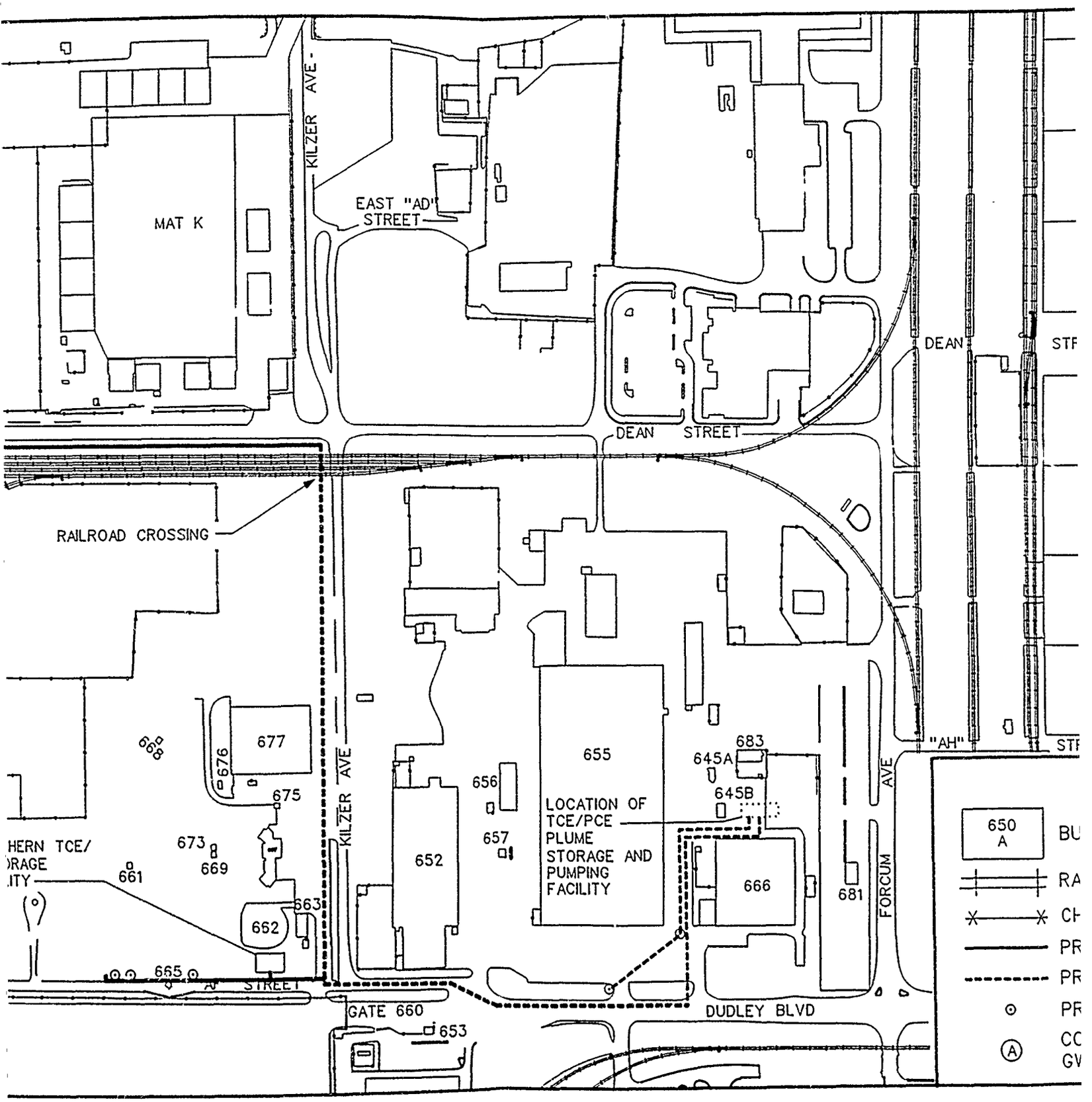
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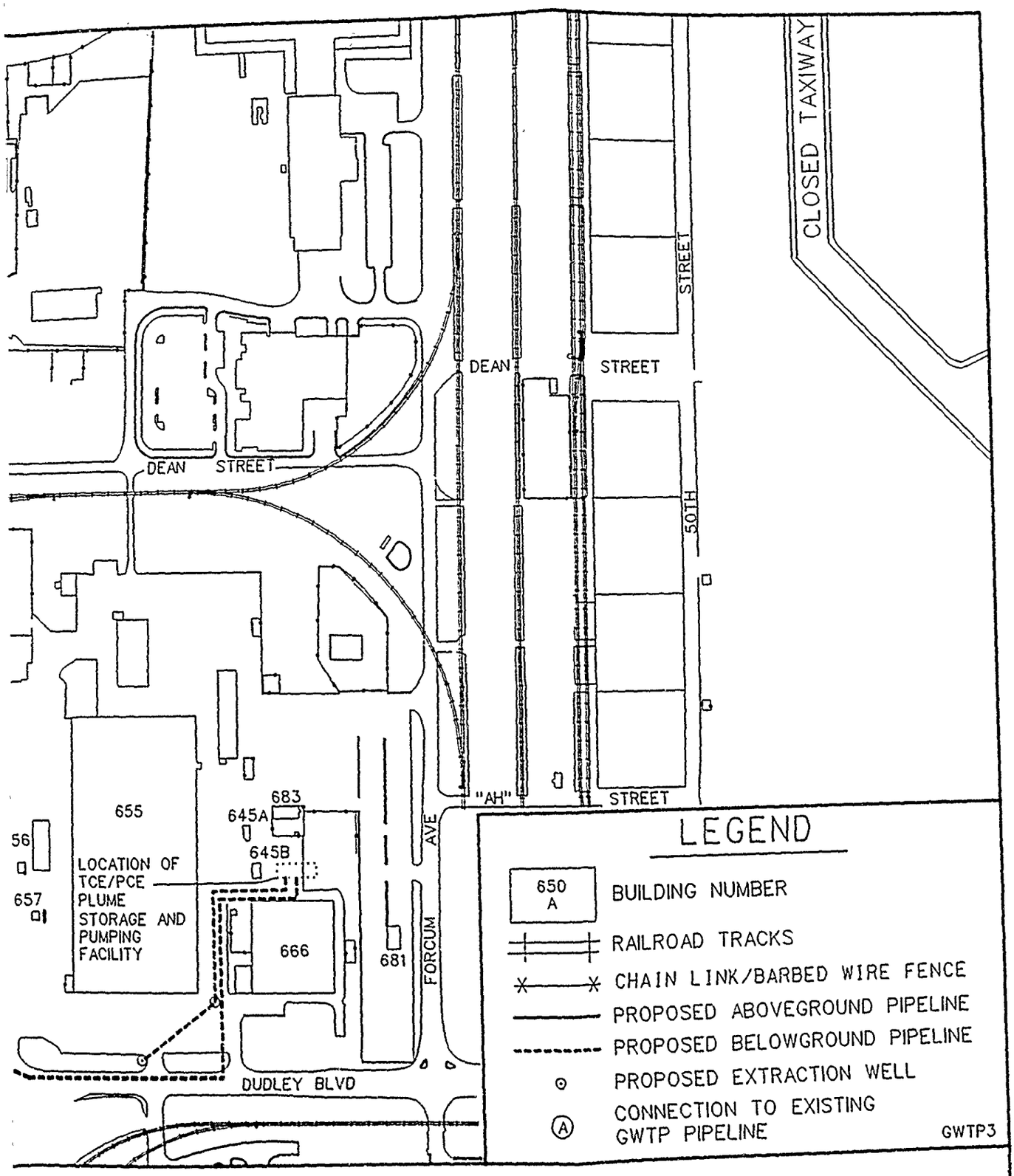

Figure 5-11. Proposed GWTP Pipeline Route.

5.4.1 Flow Equalization/Storage

Contaminated groundwater extracted from the extraction wells will be pumped to an equalization tank. Flow equalization is not a treatment in the typical sense, but refers to liquid storage facilities and associated equipment for influent and effluent streams that are part of all wastewater treatment processes. Major components of a flow equalization system can include tanks, pumps, mixers, and aeration equipment. Equalization involves "smoothing out" hydraulic and/or concentration load surges. Treatment facilities are generally designed for specific flow rates (quantity per unit time) and the amount of contaminant contained in this quantity of water. In equalization, storage in tanks or ponds is used to maintain an average flow rate with minimum fluctuations. Reducing hydraulic and concentration variability in the waste stream avoids potential upsets of treatment processes and results in a more economical design. Flow equalization tanks and equipment can always be integral parts of a groundwater interception and transport system as well as of any wastewater treatment process. Flow equalization tanks will not be required for alternatives that extract and discharge of the untreated groundwaters to the sanitary sewer or IWL. These discharge options do not require "smoothing" of hydraulic surges.

5.4.2 Groundwater Monitoring

A groundwater monitoring program will be recommended with any of the removal action alternatives selected. The purpose of the groundwater monitoring program is to monitor the present and future extent of groundwater contamination in four Areas of Concern: the TCE/PCE plume, northern and southern TCE/1,2-DCE plumes, and PCE plume in OU B. The results of the monitoring will help determine the effectiveness of the removal actions implemented and will provide needed information to help evaluate and select information on long-term remedial actions. Volatile organic compounds and metals have been frequently detected in several monitoring wells in OU B both on and off McClellan AFB. Approximately 25 existing monitoring wells and 12 proposed monitoring wells, and five proposed extraction wells have been selected to monitor water levels and water quality in four geohydrologic zones. Table 5-3 presents a summary of the monitoring and extraction wells selected for the removal action monitoring program for each of the four Areas of Concern.

Figure 5-12 shows the location of existing and proposed monitoring wells, and the location of the proposed extraction wells for the northern TCE/1,2-DCE plume.

TABLE 5-3. SUMMARY LIST OF MONITORING AND EXTRACTION WELLS SELECTED FOR OU B MONITORING PROGRAM

Well Number	Geohydrologic Zone	Proposed/Existing
Northern TCE/1,2-DCE Plume		
EW-1	A	P
EW-1	A	P
EW-1	C	P
MW[1]	A	P
MW[1]	A	E
MW-7	A	E
MW-155	A	E
MW-36A	A	E
MW[1]	B	P
MW[1]	B	P
MW-63	B	E
MW-156	B	E
MW-36B	B	E
MW[1]	C	P
MW[1]	C	P
MW-132	C	E
MW-147	C	E
MW-36C	C	E
MW-148	D	E
MW-145	A	E
MW-146	B	E
Southern TCE/1,2-DCE Plume		
MW[1]	A	P
MW-1049	A	E
MW-1053	A	E
MW-1054	A	E
MW[1]	B	P
MW-1050	B	E
MW-1055	B	E
MW[1]	C	P
MW-1051	C	E
MW-1056	C	E
MW-1022	B	E
MW-1015	A	E
MW-1025	A	E
PCE Plume		
MW-150	A	E
MW-151	B	E
MW-152	C	E

(Continued)

TABLE 5-3. (Continued)

Well Number	Geohydrologic Zone	Proposed/Existing
TCE/PCE Plume		
EW[1]	A	P
EW[1]	A	P
MW[1]	A	P
MW[1]	A	P
MW[1]	A	P

[1] Monitoring or extraction wells to be named.

EW = Extraction well
MW = Monitoring well
P = Proposed
E = Existing

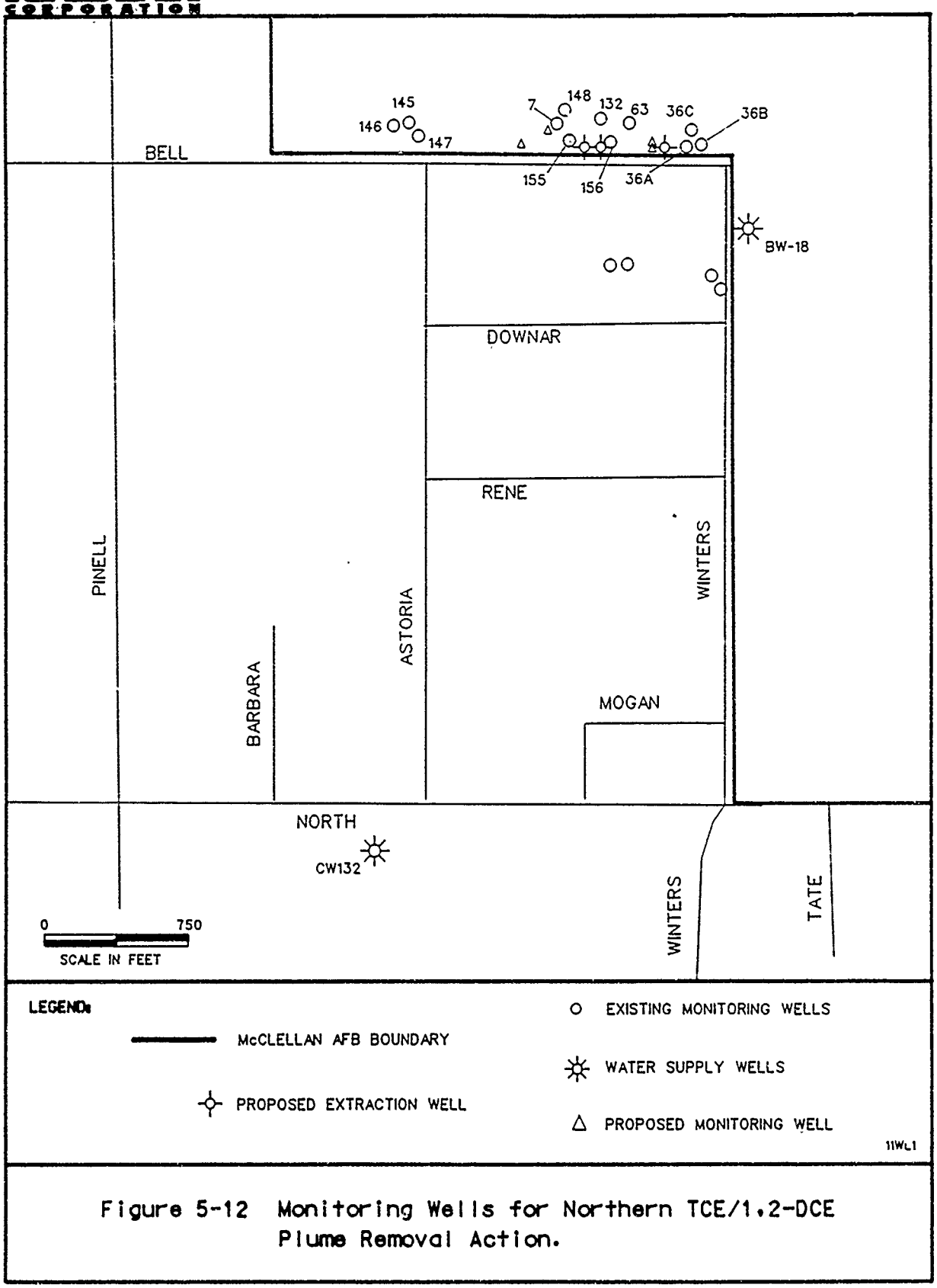

Figure 5-12 Monitoring Wells for Northern TCE/1,2-DCE Plume Removal Action.

Figure 5-13 shows similar information for the southern TCE/1,2-DCE plume, PCE plume, and TCE/PCE plume.

Sampling and Analysis

The wells identified in this groundwater monitoring program will be sampled weekly to obtain water-level data and quarterly to obtain water quality data. Groundwater samples will be collected and analyzed for VOCs and metals by U.S. EPA Methods 8010, 8020, and 6010. In addition, analyses for arsenic (U.S. EPA Method 7060), selenium (U.S. EPA Method 7740), lead (U.S. EPA Method 7421), mercury (U.S. EPA Method 7470), and pesticides (U.S. EPA Method 8080) will be performed. Analyses for VOCs and metals are proposed for the first four quarters of the program. It is recommended that after the fourth quarter, analyses be performed for only volatile and semivolatile organic compounds.

5.5 Combined Pipeline for the TCE/PCE and Northern TCE/1,2-DCE Plumes

Two removal action alternatives were considered involving the design and construction of a shared pipeline to convey extracted groundwater from the TCE/PCE plume and northern TCE/1,2-DCE plume to final discharge locations. Five groundwater discharge options have been identified and included:

- GWTP;
- IWL;
- Sanitary sewer;
- Surface water; and
- Reinjection wells.

The GWTP and reinjection wells discharge options were considered most appropriate to benefit from a combined pipeline design for discharge of groundwater from the two plumes. The other discharge options were not considered appropriate because the individual pipeline systems for these plumes did not share common discharge destinations.

The pipeline route to the GWTP, shown in Figure 5-11, is a combined pipeline system. The pipelines from the respective flow equalization tanks located near the TCE/PCE and northern TCE/1,2-DCE extraction well fields would merge along the route to the GWTP. A single 6-inch diameter pipeline would be installed from the

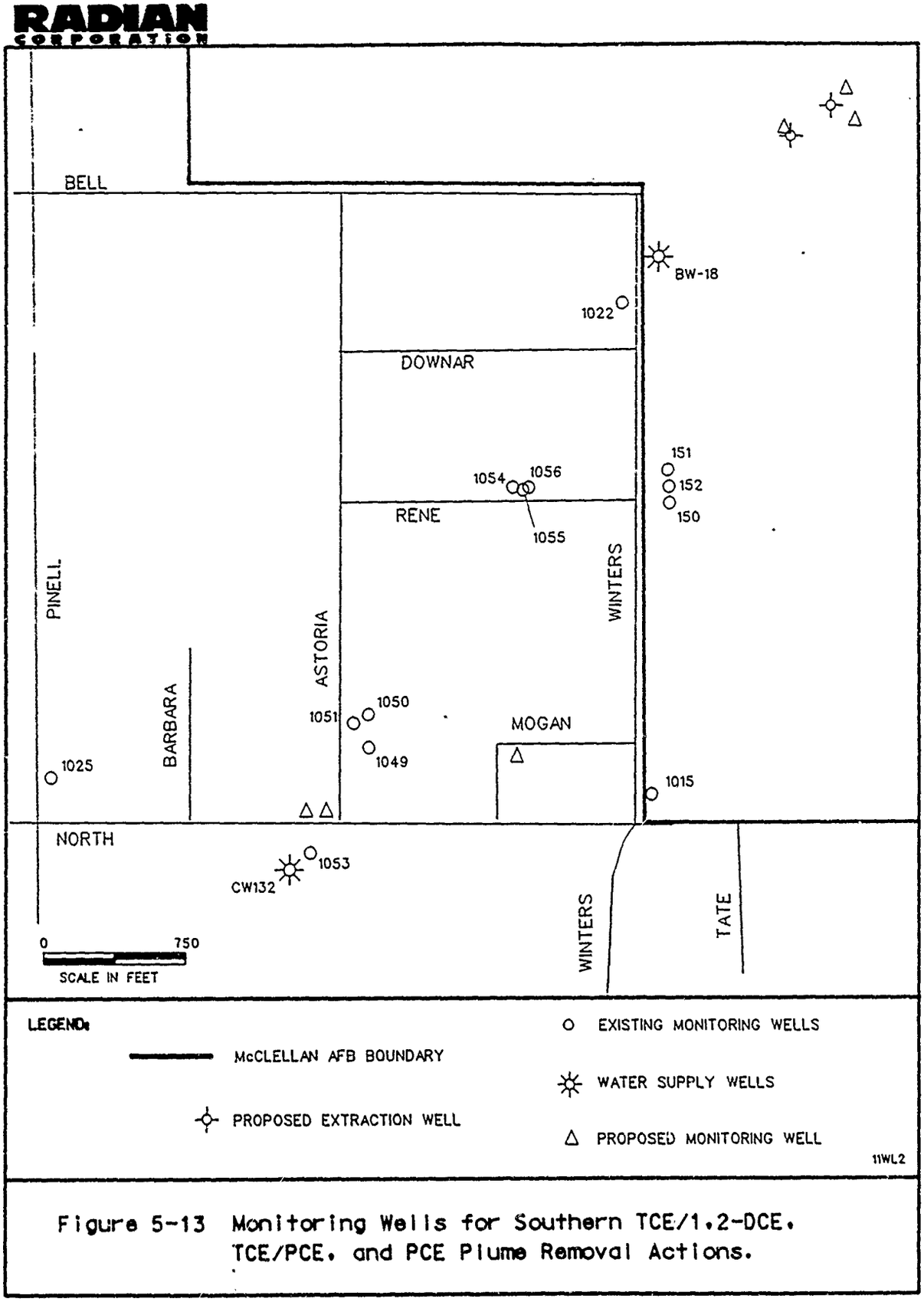

Figure 5-13 Monitoring Wells for Southern TCE/1,2-DCE, TCE/PCE, and PCE Plume Removal Actions.

junction of the separate pipelines to the GWTP. This design offers the flexibility of constructing a larger capacity pipeline to carry the combined flows.

The pipeline route to the proposed reinjection well field in the northern TCE/1,2-DCE plume, shown in Figure 5-10, is also a combined pipeline system. A separate pipeline from the TCE/PCE plume extraction well would be constructed to transport groundwater to the TCE/1,2-DCE plume flow equalization tanks. From the flow equalization tank located in the northern TCE/1,2-DCE plume, a single pipeline would be used to convey the combined flows groundwater to the reinjection well field.

The use of a combined pipeline in these two cases will allow for the operation of individual well extraction systems in the TCE/PCE and northern TCE/1,2-DCE plumes. Treatment of the contaminated groundwater using UV/ozone/peroxide or air stripping/GAC technology, if selected, would also be performed separately for each plume at treatment units located near their extraction well fields.

5.6 No-Action Alternative

The no-action alternative provides a baseline for comparison against the other alternatives. Timeliness, implementability, and cost do not apply to this alternative. In terms of protectiveness, contaminant toxicity, mobility, and volume would not be reduced; potential human exposure to contaminated groundwater would continue; migration of groundwater carrying increasing contaminant concentrations would continue towards BW-18 and off base; CW-150 would continue to be used only in emergency situations, but not be abandoned; and BW-18 would continue to supply drinking water to the base until the wellhead treatment system could no longer remove the VOC contaminant concentrations. Also, groundwater monitoring would continue to reflect the ongoing migration of contaminants. No extracted groundwater would be initially carried off base in a sanitary sewer line, and ultimately, the capacity of the GWTP would not be used for treatment of the extracted OU B groundwater.

Under the no-action alternative, there would be no changes made to the TCE/PCE plume action proposed in Section 4.1. Construction of this action is currently under way and will be completed in early 1991. The four water supply wells recommended for abandonment in Section 4.2 (Base Wells 3, 6, and 19 and the unnumbered well) would remain in their current state and provide a conduit for vertical migration of contaminants to lower aquifers. The abandonment of CW-150 would also not take place resulting in the same contaminant migration consequences as the four

unused Base Wells. Construction of the three additional monitoring wells identified in Section 4.3 would not occur. Therefore, the extent and quality of the migrating southern TCE/1,2-DCE plume would not be determined. However, regular sampling of the existing OU B monitoring wells would continue under the no-action alternative. Finally, the decision to determine the extent of the PCE plume (Section 4.4) would still be made in the OU B Remedial Investigation/Feasibility Study (RI/FS).

6.0 ANALYSIS OF REMAINING REMOVAL ACTION ALTERNATIVES

The following sections describe the proposed removal action alternatives and selection process for the trichloroethene/tetrachloroethene (TCE/PCE) and the northern trichloroethene/1,2-dichloroethene (TCE/1,2-DCE) plumes.

As was shown in Sections 4.3 and 4.4, the actions mitigating the TCE/PCE plume and the northern TCE/1,2-DCE plume will have a positive effect on the southern TCE/1,2-DCE plume and the PCE plume. Consequently, the following Comparative Analysis also addresses those benefits common to the southern TCE/1,2-DCE and PCE plumes. The additional actions to be taken, abandon four base and one city water supply wells, construction of three monitoring wells, continuance of groundwater monitoring, and determining the extent of the PCE plume, are yes/no propositions, and thus, not subject to comparison with other actions.

6.1 Comparative Analysis of Removal Action Alternatives

A matrix evaluation was conducted on the primary removal action alternatives for the TCE/PCE plume and the northern TCE/1,2-DCE plume. The matrix approach shows information about each removal action alternative in relation to a set of evaluation criteria. Evaluations were performed using information presented in this report and engineering experience about each of the removal actions evaluated. Results of the removal action evaluation for the TCE/PCE plume and the northern TCE/1,2-DCE plume are included in Sections 6.2 and 6.3.

6.1.1 Matrix Approach

Eleven criteria, including cost, were evaluated in the matrix used for the McClellan Air Force Base (AFB) Operable Unit (OU) B Engineering Evaluation and Cost Analysis-Environmental Assessment (EE/CA-EA). These evaluation criteria included:

- Technology status;
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs);
- Implementability;

- Off-Site environmental impacts;
- Need for further study;
- Environmental impacts to base operations;
- Products generated;
- Reliability;
- Regulatory and public acceptance;
- Permitting requirements; and
- Cost.

Table 6-1 shows a summary list of the evaluation criteria and the scoring basis for each criterion.

Figure 6-1 shows a generic evaluation matrix table showing a list of alternatives, evaluation parameters, weighting factors, cost measures, the effectiveness total column, and the effectiveness to cost quotient column.

Six primary removal action alternatives are shown, but additional alternatives involving discharge and pipeline options were also evaluated. These alternatives are identified by the addition of a lower case letter to the primary alternative number. For example, the use of an ultraviolet (UV)/ozone/peroxide treatment, Alternative 4, with a discharge option to reinjection wells is designated as Alternative 4c. Using the matrix approach, evaluation scores for the 11 parameters are developed for each alternative. These evaluation scores are determined by the weighting factors listed in the weighting factor row. The sum of the 11 weighted evaluation parameter scores is totaled in the effectiveness total column for each alternative. The present worth cost total for each alternative is then combined with the effectiveness total. The alternative having the greatest quotient of the sum of effectiveness "total score" divided by the present worth cost total is considered to be the most cost-effective alternative. The quotient value is presented in the right-hand column of the matrix.

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TABLE 6-1. OPERABLE UNIT B EE/CA-EA EVALUATION PARAMETERS

Parameter	Scoring Basis
1. Technology Status	4 = Proven or widely used 3 = Commercially available 2 = Demonstrated 1 = Experimental
2. Compliance with ARARs	3 = Will meet or exceed ARARs 2 = Will meet ARARs 1 = Will not meet ARARs
3. Implementability	3 = No impediments 2 = Some impediments 1 = Severe impediments
4. Off-Site Environmental Impacts	3 = No major off-site construction or disruptions to normal way of life 2 = Short-term off-site construction, with minor disruptions to normal way of life 1 = Major long-term construction, with major disruptions to normal way of life
5. Need for Further Study	3 = Minimal data and/or studies required 2 = Some data and/or studies required 1 = Extensive data and/or studies required
6. Environmental Impacts to Base Operations	3 = Minimal direct interference or destruction 2 = Some operational interference or partial destruction 1 = Major impacts resulting from removal action construction and/or building/structures demolition
7. Products Generated	3 = No residuals are produced requiring treatment and/or off-site disposal 2 = 1 to 2 residuals are produced requiring minimal treatment and/or off-site disposal 1 = More than 2 residuals are produced requiring treatment and/or off-site disposal

(Continued)

TABLE 6-1. (Continued)

Parameter	Scoring Basis
8. Reliability	3 = Minimal "working" components in alternative 2 = Some "working" components 1 = Complex components in alternative (e.g., pumps, filter presses, chemical use)
9. Regulatory and Public Acceptance	3 = Alternative readily accepted 2 = Some question of acceptance 1 = Major difficulty in gaining acceptance
10. Permitting Requirements	3 = Only local construction permits needed 2 = NPDES permit required for low volume discharge and/or short term; air quality permit 1 = NPDES permit required for perpetual high volume discharges; discharge permits to sanitary sewer systems and renegotiation of fee ordinances required

NPDES = National Pollution Discharge Elimination System.

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PRIMARY ALTERNATIVES	COST (In $10,000)			EVALUATION PARAMETERS											
	Capital	Annual O & M	Present Worth Cost Total	Technology Status	Compliance with ARARs	Implementability	Off-Site Environmental Impacts	Need for Further Study	Environmental Impacts to Base Operation	Products Generated	Reliability	Regulatory and Public Acceptance	Permitting Requirements	Effectiveness Total	Effectiveness Total / Cost Total
WEIGHTING FACTORS	1	1		4	4	4	3	2	3	3	3	5	5		
1 Extraction Wells Pipe to IWL															
2 Extraction Wells Pipe to Sanitary Sewer															
3a Extraction Wells Pipe to GWTP to Surface Water															
3b Extraction Wells Truck to GWTP and Discharge to Surface Water															
4a Extraction Wells Pipe to UV/Ozone to IWL															
4b Extraction Wells Pipe to UV/Ozone to Sanitary Sewer															
4c Extraction Wells Pipe to UV/Ozone to Reinjection Wells															
4d Extraction Wells Pipe to UV/Ozone to Surface Water															
5a Extraction Wells Pipe to Air Stripping/GAC to IWL															
5b Extraction Wells Pipe to Air Stripping/GAC to Sanitary Sewer															
5c Extraction Wells Pipe to Air Stripping/GAC to Reinjection Wells															
5d Extraction Wells Pipe to Air Stripping/GAC to Surface Water															
6 Extraction Wells Pipe to Liquid Phase GAC to IWL															

Figure 6-1. Evaluation Matrix.

An explanation of each evaluation parameter follows.

Technology Status

Technology status was evaluated in four categories. Technologies were considered either proven and/or widely used, commercially available, demonstrated, or experimental when applied to similar site conditions. The proven and/or widely used evaluation parameter is self-explanatory. A technology was considered commercially available if it has been demonstrated on similar sites and full-scale treatment units are available. Technologies in this category may have been applied in one or more instances, but have not been used extensively. A technology was considered demonstrated if a pilot-scale unit had been successfully used at sites with similar conditions. A technology was considered experimental if it had only been demonstrated as a bench-scale unit, with treatability studies, or for applications other than waste site remediations.

Compliance with ARARs

This criterion evaluates the ability of each alternative to perform to standards or goals established by ARARs. An example of an ARAR is the effluent water quality standards established for surface water discharges. This ARAR would be applied to treatment technologies that must produce an acceptable effluent water quality to allow a surface water discharge. Alternatives will be evaluated for their ability to protect public/human health, welfare, and the environment.

Implementability

The implementability criterion evaluates the ease with which an alternative can be constructed and operated. Physical access to construction areas, availability of materials, availability of appropriate human resources, extensive use of non-owned land or need for acquisition of land are conditions which are evaluated.

Off-Site Environmental Impacts

Impacts to the surrounding neighborhoods are considered under this criterion. An impact can be broadly defined as any change in the normal way of life which can be directly or indirectly attributed to the remedial action. These include increased noise, increased dust, increased traffic, need for detours, potential for spills, environmental impacts, etc.

Need for Further Study

The extent to which more data are needed to fully design or assess a removal action alternative is considered by this criterion. Technologies are considered to need further study when bench-scale treatability studies, pilot-scale testing, and collection of design data are needed before the action can be implemented.

Environmental Impacts to Base Operation

Disruption or inconvenience of daily operations or destruction of on-site structures and facilities during construction are the types of impacts evaluated by this criterion.

Products Generated

The quantity of residual products generated during operation of the removal action alternative which require further treatment is addressed using this evaluation criterion. The possibility of additional permitting and/or disposal requirements also is considered.

Reliability

The ability for an alternative to operate reliably is considered using this criterion.

Regulatory and Public Acceptance

The ease with which it is anticipated the regulatory agencies and the public will accept all aspects of the removal action alternative is assessed using this evaluation criterion.

Permitting Requirements

Response actions conducted in accordance with the McClellan AFB Interagency Agreement (Section 19.1) and implemented on site are exempted from procedural requirements to obtain federal, state, or local permits. Subsequently, this criterion evaluates both the anticipated difficulty in acquiring permits, when permits are required, and the anticipated difficulty in satisfying the applicable or relevant and appropriate federal and state standards, requirements, criteria, or limitations of those permits whose procedural requirements have been exempted.

Costs

Capital, annual operation and maintenance, and present worth costs were determined for each alternative. The methods and assumptions used to develop the costs are detailed in the following sections. All alternatives evaluated for the TCE/PCE plume were based on the extraction and potential treatment of a 20 gallons per minute (gpm) groundwater flow rate having a constant and estimated contaminant concentration. All alternatives evaluated for the TCE/1,2-DCE plume were based on the extraction and potential treatment of a 155 gpm groundwater flow rate having a constant and estimated contaminant concentration. Cost estimates were developed to within 50 percent of the actual costs, but do not necessarily represent a budgetary estimate for construction.

6.2 Evaluation of Removal Action Alternatives and Description of the Proposed Action for the TCE/PCE Plume

The removal action for the TCE/PCE plume was elevated to an expedited status in December 1989. As a result, the removal action was initiated prior to performing this EE/CA-EA report. The following section presents the development and evaluation of removal action alternatives as well as rationale for selecting the proposed action.

A modified matrix approach was used to identify and evaluate removal action alternatives for the TCE/PCE plume in OU B. The proposed action was chosen from an abbreviated list of alternatives that had been evaluated using the methods described in Section 6.1. The abbreviated list of removal action alternatives (Figure 6-2) were chosen from a larger list of alternatives (Table 6-3, page 6-24) developed from the diagram shown on Figure 5-1.

6.2.1 Description of the Proposed Action for the TCE/PCE Plume

The removal action alternative chosen for the TCE/PCE plume was Alternative 8a, extraction with aqueous phase granular activated carbon (GAC) adsorption and discharge to the Industrial Wastewater Line (IWL). The selection rationale, as well as a description and evaluation of the alternative, is given in the following paragraphs.

PRIMARY ALTERNATIVES	COST (In $10,000)			EVALUATION PARAMETERS											
	Capital	Annual O & M	Present Worth Cost Total	Technology Status	Compliance with ARARs	Implementability	Off-Site Environmental Impacts	Need for Further Study	Environmental Impacts to Base Operation	Products Generated	Reliability	Regulatory and Public Acceptance	Permitting Requirements	Effectiveness Total	Effectiveness Total / Cost Total
WEIGHTING FACTORS	1	1		4	4	4	3	2	3	3	3	5	5		
5a Extraction Wells Pipe to Local UV/Ozone to IWTP	105.3	11.1	133.1	1	3	2	3	2	2	3	2	3	2	83	0 62
5b Extraction Wells Pipe to Local UV/Ozone to Reinjection Wells	142.5	1.2	145.5	1	3	2	3	2	3	3	2	1	1	71	0.49
5c Extraction Wells Pipe to Local UV/Ozone to Surface Water	105.1	1.2	108.0	1	3	2	3	2	3	3	2	1	1	71	0 66
5d Extraction Wells Pipe to Local UV/Ozone to Sanitary Sewer	116.3	1.6	120.2	1	3	3	3	2	3	3	2	2	2	85	0 71
8a Extraction Wells Pipe to Local Liquid Phase GAC to IWTP	94.1	18.6	140.5	3	3	3	3	3	2	2	3	3	2	93	0 66
8b Extraction Wells Pipe to Local Liquid Phase GAC to Reinjection Wells	131.3	8.7	152.3	3	3	2	3	3	3	2	2	1	1	78	0 51
8c Extraction Wells Pipe to Local Liquid Phase GAC to Surface Water	93.9	8.7	115.4	3	3	3	3	3	3	2	2	1	1	82	0 71
8d Extraction Wells Pipe to Local Liquid Phase GAC to Sanitary Sewer	105.1	9.1	127.7	3	3	3	3	3	3	2	2	2	2	92	0 72

Figure 6-2. Evaluation Matrix for TCE/PCE Plume Removal Action Alternatives.

Process Description

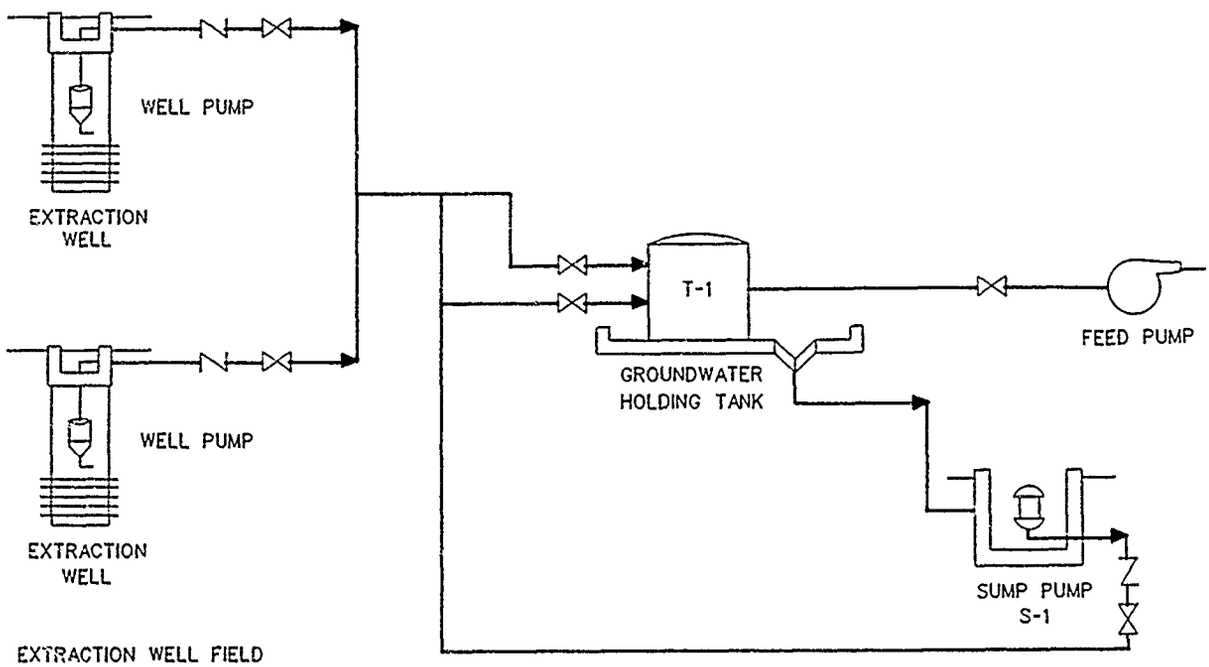
Two groundwater extraction wells will be located south of Building 655 in the parking area. The groundwater will be pumped from the extraction wells by two submersible, centrifugal well pumps. The extraction well discharge pipeline will be equipped with 2-inch discharge piping with isolation valves. The two discharge pipes will be connected via a 3-inch double containment pipeline equipped with a leak detection system.

Two holding tanks will be used as reservoirs for the carbon tank feed pumps, for storm water and contingency holding purposes, and to equalize flows and concentrations. The holding tanks will be equipped with vapor-tight tops and GAC adsorption units for treatment of displaced vapor phase organics forced from the tanks by rising liquid levels.

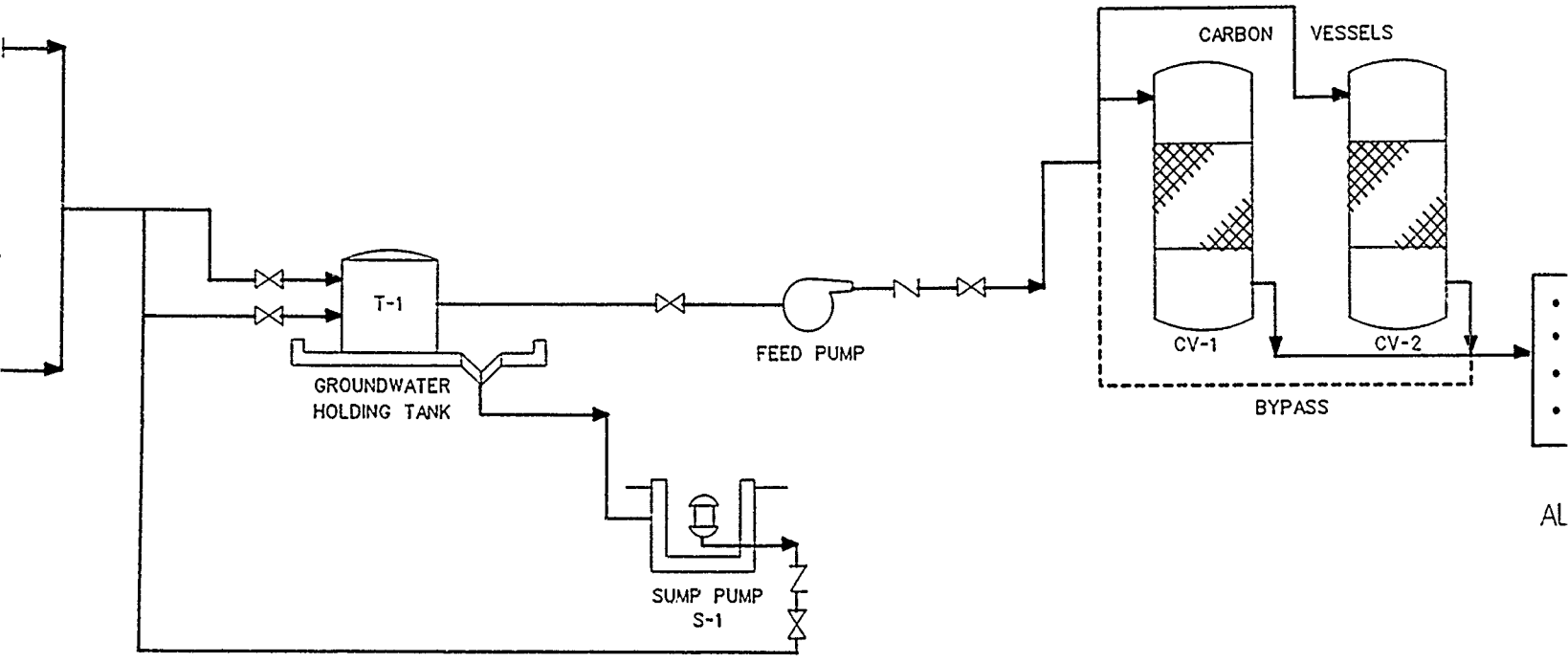
The stored groundwater will be pumped from the holding tanks to the GAC adsorption tanks for treatment by two horizontal, centrifugal carbon tank feed pumps. The pumped water will be filtered by one of two bag-type filters before entering one of two GAC adsorption units. The filters will remove particulate matter from the water stream which would otherwise be filtered by the activated carbon. Filtration of the inlet water stream will allow for longer adsorption runs prior to backwashing operations, and will allow for increased carbon utilization by the GAC adsorption units. A schematic of the aqueous phase GAC treatment process is presented in Figure 6-3.

The organic contaminants in the water stream will be removed via adsorption mechanisms by the GAC adsorption units. The GAC units will normally be operated in series for maximum utilization of the carbon. These units will be piped and valved to allow each of the units to be operated as either the lead or secondary unit. The GAC units will be equipped for backwashing via a direct connection to the base water supply system. The connection piping to the water supply will be equipped with a backflow prevention device to prevent contamination of the water supply piping. The backwash flow rate and duration will be controlled by a hand valve and flow indicating water meter.

Effluent from the treatment unit will be discharged to the IWL along with backwash water, as necessary.



EXTRACTION WELL FIELD


CARBON
VESSELS
T-1
GROUNDWATER
HOLDING TANK
FEED PUMP
CV-1
CV-2
BYPASS
SUMP PUMP
S-1
AL

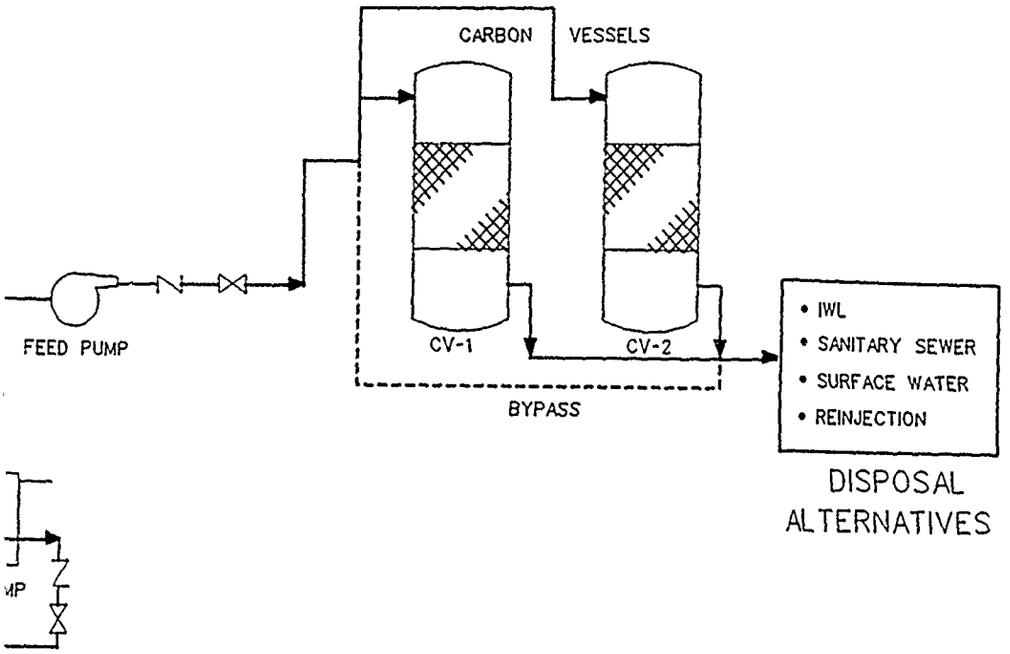


Figure 6-3. Process Schematic Aqueous Phase Carbon Adsorption Treatment Alternative.

MAFB DO11 FLOW5

Selection Rationale

The proposed removal action for the TCE/PCE plume was selected on the basis of preliminary engineering and rough cost estimates. The selection was made with a tendency to select a proven and familiar process that would require little to no permitting and could be implemented quickly. Therefore, the rationale used to select the proposed action may not necessarily be valid for selection of alternatives for other removal actions in OU B.

Alternatives that discharged to the sanitary sewer or Magpie Creek were avoided. Groundwater discharged to the sanitary sewer will be treated by the Sacramento County Regional Wastewater Treatment Plant and groundwater discharged to the McClellan AFB Groundwater Treatment Plant (GWTP) will eventually be discharged to Magpie Creek. While both these treatment systems should be able to treat the contaminated groundwater to acceptable levels, in the event of a plant upset or unnoticed breakthrough in the treatment systems, untreated groundwater could be discharged. Contaminant levels in the TCE/PCE plume are high enough that neither McClellan Environmental Management (EM) nor the agencies believed discharge of untreated groundwater to either the sanitary sewer or Magpie Creek was an acceptable alternative. At the time the selection was made, both McClellan EM and the agencies preferred discharging the treated groundwater to the IWL. By discharging the treated groundwater to the IWL, an extra factor of safety has been added. In the event of a plant upset or an undetected breakthrough of the carbon beds, some of the contaminated water could be discharged, but would be treated at the Industrial Wastewater Treatment Plant (IWTP) and ultimately at the Sacramento Regional County Wastewater Treatment Plant.

Alternatives that used the UV/ozone/peroxide were avoided for several reasons. While it is a potentially applicable process, some treatability testing would be necessary to determine if the process could successfully treat groundwaters in the TCE/PCE plume and, if it could, to develop design parameters. The time constraints for the removal action prevented a treatability study from being performed. The aqueous phase GAC adsorption process has been used at the McClellan AFB, and elsewhere, to treat groundwater with similar contamination. The existing OU C GWTP has used the same carbon adsorbers to successfully treat contaminated groundwater of similar consistency from OUs C and D. McClellan AFB operational personnel are familiar with the process. Therefore, very few operational problems would be expected during startup and continued operation of the treatment system. The UV/ozone-

/peroxide process also generates ozone during treatment. The explosion hazards inherent to the generation of ozone were also of some concern to McClellan AFB because of the close proximity of the treatment system to a large number of base personnel.

The results of the evaluation described in Section 6.2.2. below, indicate that the proposed action, 8a, ranked first among the eight alternatives in effectiveness scores. While it had the lowest initial capital cost, it also had the highest operation and maintenance cost, and third highest present worth cost. Overall, it ranked fourth in cost effectiveness amongst the eight alternatives. Alternatives that ranked ahead of the selected alternative in cost effectiveness (Alternatives 8d, 8b, and 5d) discharged to the sanitary sewer or Magpie Creek (Alternatives 8d, 8b, and 5d) or used the UV/ozone/peroxide treatment process (Alternative 5d) and were therefore eliminated from further consideration.

Products Generated

The primary product generated in the proposed treatment action is spent GAC containing volatile organic compound (VOC) contaminants. Carbon will have to be removed from the units periodically and replaced with fresh carbon. Disposal options for the spent carbon include landfilling and regeneration.

Backwash water generated during the carbon changeout will be discharged to the IWL. It cannot be discharged to surface water or reinjected because it will contain measurable amounts of fine carbon particles.

The treated groundwater produced by this alternative is of high quality and could be used for industrial, irrigation, or other needs. Contaminant concentrations should be reduced below State Action Levels, and achieving undetectable levels may be possible. The treated groundwater will initially be discharged to the IWL, but could be discharged to a body of surface water in the future.

Performance

The application of aqueous phase GAC adsorption to remove hazardous organic contaminants is a proven and widely used technology; however, the treatment process has several limitations. The application of carbon adsorption to concentrated multi-component leachate is generally acceptable for controlling VOCs, some metals,

vinyl chloride, and most halogenated organic compounds. The effectiveness of the system can be limited by the level of total suspended solids and by the pH of the influent solution. The contaminants removed from the groundwater during GAC adsorption are concentrated on the carbon filters and must eventually be destroyed, regenerated, or landfilled. Also, the adsorption unit may be subject to inorganic and biological fouling and may require pretreatment of the influent stream.

Once complete, this alternative would provide immediate results; removal of contaminated groundwater will minimize exposure to local groundwater and reduce migration of contaminants off base.

Implementability

Construction of a liquid phase carbon adsorption unit at McClellan AFB is readily implementable. The existing GWTP has two skid-mounted carbon adsorption units that are not needed and can be used to implement the removal action alternative. In addition to the carbon adsorption units, the plant also has two biological reactors that could be modified to serve as flow/equalization tanks. The use of existing equipment will reduce the capital cost of the removal action alternative, as well as the time needed to implement the alternative. Using existing equipment with slight modifications will eliminate the long lead time necessary to design, fabricate, and deliver the absorbers and the tanks to McClellan AFB. The system could be constructed and fully operational in approximately three to four months. The limiting factor associated with the implementation of the alternative is the time required to construct the accompanying extraction wells, intra-system piping, and discharge piping and structures.

Installation of the carbon adsorption unit should not create significant inconveniences for McClellan AFB operations. Movement of the units from the existing GWTP may cause some temporary road closings and detours; however, the move should not take more than four to eight hours and could be performed during off-peak traffic hours. Installation of the extraction wells and the influent piping to the treatment unit may temporarily disrupt parking in the lot south of Building 655. A phased approach should be considered for construction of the wells and the influent piping so that disruptions are minimized. Extraction well and influent piping construction should not disrupt parking for more than one to two months.

Once complete, the alternative should provide immediate results; removal of contaminated groundwater will minimize local exposures and reduce migration.

When fully operational, the alternative should require very little attention from the operators. Daily monitoring of the influent and effluent streams will be necessary to determine loading and to identify possible breakthrough and tentative carbon changeout times.

Safety

There are no special safety considerations for the construction or operation of the aqueous phase GAC adsorption system. Because of the possibility of contaminated soils in the area affected by the TCE/PCE plume, excavation of soils for the treatment system foundation and for the conveyance pipeline may have to be performed in accordance with 29 Code of Federal Regulations (CFR) 1910.120 (OSHA regulations related to work in and around hazardous materials).

Regulatory and Institutional Concerns

The following ARARs are applicable for discharge to the IWL:

- National Pretreatment Standard Discharges to Publicly Owned Treatment Works for discharges to the Sacramento County Regional sanitary sewer system connection; and

- Sacramento County Sanitary Sewer Fees and Discharge requirements.

It is anticipated that this alternative can comply with the identified ARARs.

Costs

The total cost for Alternative 8a is presented along with the costs for the remaining seven alternatives, in Table 6-2. In developing costs for the removal action alternatives, several assumptions were made about the site work cost, piping and valuing costs, instrumentation costs, controls costs, electrical costs, contingency costs, and engineering costs. The preceding costs were estimated as a percentage of the capital costs associated with conveyance and treatment. Because the removal action for the TCE/PCE plume has progressed to the design and bid stage, the estimated costs derived as percentages for site work, piping and valving, instrumentation, controls, and electrical

TABLE 6-2. SUMMARY OF ESTIMATED COSTS FOR TCE/PCE PLUME REMOVAL ACTION ALTERNATIVES

Item	Alternative No. 8A		Alternative No. 8B		Alternative No. 8C		Alternative No. 8D	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
A. Extraction/Monitoring Wells	147,000	3,200	147,000	3,200	147,000	3,200	147,000	3,200
B. Conveyance								
Piping (utility trench from ext. wells to treatment)	51,200		51,200		51,200		51,200	
Fittings	2,100		2,100		2,100		2,100	
Pumps -- Transfer Pumps	5,000	3,200	5,000	3,200	5,000	3,200	5,000	3,200
-- Sump Pumps	3,000		3,000		3,000		3,000	
Holding Tank	15,000		15,000		15,000		15,000	
C. Treatment -- Aqueous Phase GAC Adsorption	76,000	80,000	76,000	80,000	76,000	80,000	76,000	80,000
-- UV/Ozone/Hydrogen Peroxide								
D. Discharge -- IWTP		99,864						
-- Magpie Creek								
-- Reinjection Wells								
-- Sanitary Sewer			147,000					
Piping (from holding tank to discharge point)	2,800		10,500	500	1,800	200	33,078	4,000
Fittings	2,100		2,100		2,100		15,200	500
							2,100	
E. Contaminated Soils Disposal	98,000		98,000		98,000		98,000	
	$402,200	$186,264	$556,900	$86,900	$401,200	$86,600	$447,678	$90,900
F. Other Direct Costs								
Site Work (@ 25%)	100,550		139,225		100,300		111,920	
Piping/Valving (@ 5%)	20,110		27,845		20,060		22,384	
Instrumentation (5%)	20,110		27,845		20,060		22,384	
Controls (@ 5%)	20,110		27,845		20,060		22,384	
Electrical (@ 15%)	60,330		83,535		60,180		67,152	
	$623,410		$863,195		$621,860		$693,901	
G. Adjustments								
Minus holding tank cost savings	0		0		0		0	
Minus GAC units cost savings	-16,000		-16,000		-16,000		-16,000	
H. Construction/Operation Subtotals	$607,410		$847,195		$605,860		$677,901	
I. Fees and Contingencies								
Contingency (@ 5%)	30,371		42,360		30,293		33,895	
Contractor Fees (@ 15%)	91,112		127,079		90,879		101,685	
Engineering Services During Construction								
-- Construction Management (@ 15%)	91,112		127,079		90,879		101,685	
-- Startup, Treatability, and Performance (@ 10%)	60,741		84,720		60,586		67,790	
-- Verification & Quality Assurance Sampling (@ 10%)	60,741		84,720		60,586		67,790	
J. Total Costs	$941,486	$186,264	$1,313,152	$86,900	$939,083	$86,600	$1,050,746	$90,900
K. Present Worth Costs	$1,404,696		$1,529,260		$1,154,444		$1,276,801	

(Continued)

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TABLE 6-2. (Continued)

Item	Alternative No. 5A		Alternative No. 5B		Alternative No. 5C		Alternative No. 5D	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
A. Extraction/Monitoring Wells	147,000	3,200	147,000	3,200	147,000	3,200	147,000	3,200
B. Conveyance								
Piping (utility trench from ext. wells to treatment)	51,200		51,200		51,200		51,200	
Fittings	2,100		2,100		2,100		2,100	
Pumps – Transfer Pumps	5,000	3,200	5,000	3,200	5,000	3,200	5,000	3,200
– Sump Pumps	3,000		3,000		3,000		3,000	
Holding Tank	15,000		15,000		15,000		15,000	
C. Treatment – Aqueous Phase GAC Adsorption	112,300	5,200	112,300	5,200	112,300	5,200	112,300	5,200
– UV/Ozone/Hydrogen Peroxide								
D. Discharge – IWTP		99,864						
– Magpie Creek								
– Reinjection Wells			147,000					
– Sanitary Sewer								
Piping (from holding tank to discharge point)	2,800		10,500	500	1,800	200	33,100	4,000
Fittings	2,100		2,100		2,100		15,200	
							2,100	
E. Contaminated Soils Disposal	98,000		98,000		98,000		98,000	
	$438,500	$111,464	$593,200	$12,100	$437,500	$11,800	$484,000	$15,600
F. Other Direct Costs								
Site Work (@ 25%)	109,625		148,225		190,300		121,920	
Piping/Valving (@ 5%)	21,925		29,660		21,875		24,200	
Instrumentation (5%)	21,925		29,660		21,875		24,200	
Controls (@ 5%)	21,925		29,660		21,875		24,200	
Electrical (@ 15%)	65,775		88,980		65,625		72,600	
	$679,675		$919,460		$678,125		$750,200	
G. Adjustments								
Minus holding tank cost savings								
Minus GAC units cost savings								
H. Construction/Operation Subtotals	$679,675		$919,460		$678,125		$750,200	
I. Fees and Contingencies								
Contingency (@ 5%)	33,984		45,973		33,906		37,510	
Contractor Fees (@ 15%)	101,951		137,919		101,719		112,530	
Engineering Services During Construction								
– Construction Management (@ 15%)	101,951		137,919		101,719		112,530	
– Startup, Treatability, and Performance (@ 10%)	67,968		91,946		67,813		75,020	
– Verification & Quality Assurance Sampling (@ 10%)	67,968		91,946		67,813		75,020	
J. Total Costs	$1,053,496	$111,464	$1,425,163	$12,100	$1,051,094	$11,800	$1,162,810	$15,600
K. Present Worth Costs	$1,330,691		$1,455,254		$1,080,439		$1,201,605	

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can be compared to the actual bid prices received from contractors during the contract procurement of construction services to implement Alternative 8a. The engineering costs associated with the selected alternative have also been estimated so the percentage for engineering costs could also be adjusted. In order to maintain a common basis for comparison of the eight alternatives, cost estimates based on percentages developed in the preceding manner for Alternative 8a were also used for the other seven alternatives.

A 10 percent discount rate was used in the present worth analysis to establish the cost in 1990 dollars for operation and maintenance of the removal action over a three-year operating period.

6.2.2 Evaluation of Removal Action Alternatives for the TCE/PCE Plume

The ratings for each alternative relative to each evaluation parameter are presented in Figure 6-2. "Ratings" were selected using the scoring basis for each alternative described in Section 6.1. Each rating was multiplied by the weighting factor for each evaluation parameter and the sum of these products is shown in the "Effectiveness Total" column. Alternative 8a had the highest effectiveness total, while Alternatives 5b and 5c had the lowest effectiveness totals.

The information in the "Cost Measures" columns include capital, annual operations and maintenance (O&M), and present worth costs, each presented in tens of thousands of dollars. The capital and O&M costs have been assigned equal weighting factors. These factors were multiplied by each cost figure, the products summed, and the present worth value calculated and presented in the "Present Worth Cost Total" column of Figure 6-2. Alternative 5b had the highest capital cost and Alternative 8b had the lowest. For O&M costs, Alternative 8a had the highest and Alternative 5c had the lowest. When the capital costs were combined with the present worth value in 1990 dollars of the O&M costs, Alternative 8b had the highest and Alternative 5c had the lowest.

The final assessment of this matrix approach is to evaluate which alternative is most cost-effective. The "Effectiveness Total" value is divided by the "Present Worth Cost Total" value and the quotient, the "Cost Effectiveness Ratio," is presented in the far right-hand column in Figure 6-2 for each alternative. Using this methodology, the most cost-effective alternative will have the greatest value. Alternative 8d has the highest cost effectiveness ratio while Alternative 5b had the lowest.

Aqueous Phase GAC Adsorption Treatment Alternatives

Aqueous phase GAC treatment was described and evaluated in Section 6.2.1. The advantages and disadvantages of the different discharge options were also discussed in Section 6.2.1 as part of the selection rationale for the proposed action.

Costs. Estimated costs for the discharge options not described in Section 6.2.1 (i.e., to Magpie Creek, to reinjection, and to the sanitary sewer) are presented in Table 6-2.

UV/Ozone/Peroxide Treatment Alternatives (Alternatives 5a, 5b, 5c, and 5d)

Process Description. This treatment technology uses a combination of UV radiation, ozone, and hydrogen peroxide to oxidize organic compounds in the water. The influent water is first exposed to hydrogen peroxide as it flows through the inlet line from the flow equalization tank to the process reactor. In the reactor, the water is simultaneously exposed to UV radiation and ozone. The reactor is divided by five vertical baffles into six chambers which contain UV lamps evenly distributed throughout the reactor. Spargers uniformly diffuse ozone gas from the base of the reactor into the water. As a result of this process, hydroxyl radicals are formed from the ozone; these hydroxyl radicals are known to react with organics more rapidly than ozone or hydrogen peroxide alone. A schematic diagram of the UV/ozone/peroxide treatment process is shown in Figure 5-3.

The treated water is discharged from the reactor to one of four discharge points: the IWL, a reinjection well, Magpie Creek (surface water discharge), or sanitary sewer. Any unreacted ozone is destroyed in a catalytic packed bed oxidation reactor which uses a nickel-based catalyst to decompose reactor off-gas ozone into oxygen. No other emissions are produced.

Products Generated. Products generated by the UV/ozone/peroxide treatment process include only treated effluent water and excess ozone off-gas, which is purified by reduction or in a catalytic oxidation reaction.

Performance. Performance data, supplied by vendors based upon proposed flows and concentrations of the OU B extraction wells, indicate that the process should be capable of removing the contaminants within the TCE/PCE plumes to

less than detection limits (standard detection limits for chlorinated hydrocarbons using U.S. Environmental Protection Agency (U.S. EPA) Method 8010 are 5 micrograms per liter [μg/L]). Complete oxidation of VOCs has also been demonstrated using this treatment alternative. However, results were demonstrated on relatively low levels of VOC contaminants, and long reaction times were required for VOCs such as methylene chloride and 1,1,1-trichloroethane. Treatability studies performed on several pilot-scale UV/ozone/peroxide units, as well as on full-scale operational plants, indicate that this is a reliable and cost-effective treatment alternative for the remediation of contaminated groundwater. Vendor data also indicate that ozone concentrations within unit off-gas can be reduced to less than 0.1 parts per million (ppm), meeting OSHA worker safety permissible exposure standards. In addition, effluent from this treatment process can then be used for industrial, irrigation, and other purposes.

Once complete, this alternative would provide immediate results; removal of contaminated groundwater will minimize exposure to local groundwater and reduce migration of contaminants off-base.

Implementability. Construction and operation of the UV/ozone/peroxide unit at McClellan AFB is a new yet implementable technology; several fully operational units currently exist throughout the United States and Europe. Installation of the unit should not create significant inconveniences for McClellan AFB personnel. Installation of the extraction wells and the influent piping to the treatment unit may temporarily disrupt parking in the lot south of Building 655. A phased approach should be considered for construction of the wells and the influent piping so that disruptions are minimized. Extraction well and influent piping construction should not disrupt parking for more than one to two months.

A completely functioning UV/ozone/peroxide treatment unit would require approximately three to four months to construct, deliver, and install. The limiting factor associated with the implementation time of this alternative is the time required to construct the accompanying extraction wells, flow equalization tanks, discharge construction, and intra-system piping. Six months to one year would be required to complete and integrate these components.

Once complete, this alternative would provide immediate results; removal of contaminated groundwater will minimize exposure to local groundwater and reduce migration of contaminants off-base.

Safety. There are no special safety considerations for the construction or operation of the UV/ozone/peroxide unit. A contingency plan may need to be developed. Ozone is a highly reactive and corrosive material and ozone generation and use increases safety risks to personnel in the vicinity during generation.

Regulatory and Institutional: Several action-specific ARARs related to atmospheric emissions and water quality discharges apply to the operation of this treatment process. In addition, there are specific ARARs identified for each of the four treated groundwater discharge processes: IWL, sanitary sewer, surface water, or reinjection. The ARARs applicable to the UV/ozone/peroxide treatment alternative include:

- National Ambient Air Quality Standards and California Ambient Air Quality Standards for UV/ozone treatment system and possible ozone emissions. The UV/ozone treatment system has a catalytic oxidation reactor by Ultrox®.

For discharge of treated groundwater to the sanitary sewer and the IWL:

- National Pretreatment Standard Discharges to Publicly Owned Treatment Works for discharges to the Sacramento Regional County Sanitary Sewer System connection; and

- Sacramento County Sanitary Sewer Fees and Discharge requirements.

For discharge of treated groundwater to surface water:

- National Pollutant Discharge Elimination System requirements as a new discharge source for the existing NPDES permit for GWTP discharges to Magpie Creek.

Specific McClellan AFB rules regarding land access and usage also may be relevant. It is anticipated that this alternative can comply with the identified ARARs.

Costs. Estimated costs for a UV/ozone/peroxide treatment for the proposed 20 gpm flow from the TCE/PCE plume and combined with each potential discharge option are presented in Table 6-2.

6.2.3 Screening of Initial Removal Action Alternatives for the TCE/PCE Plume

The preliminary list of 22 alternatives was screened to reduce the number of alternatives that required detailed evaluation. Guidance for conducting EE/CA-EAs allows for the use of engineering judgement in the development and preliminary screening of alternatives, so preliminary screening criteria were based mostly upon engineering experience and judgement. Public and regulatory acceptability, risk perception, operation and maintenance concerns, implementability, and cost were also used to a lesser extent to screen removal action alternatives. The following text explains the rationale for screening alternatives.

Alternatives involving direct discharge of contaminated water to either the sanitary sewer, the IWL, or to surface water were eliminated due to regulatory opposition, anticipated public perception, and the potential for migration of contaminants to uncontaminated media. Contaminant levels in the TCE/PCE plume are high enough that neither McClellan AFB EM nor the regulatory agencies believed discharge of untreated groundwater to either the sanitary sewer or Magpie Creek was an acceptable alternative. The agencies initial impression was that leaks in either of the two sewers could potentially result in the spread of contaminants from the TCE/PCE plume over a much wider area, and therefore it was not an acceptable alternative. Direct discharge of contaminated water to Magpie Creek could potentially be in violation of the Clean Water Act (see Section 3.0), and increased migration of contaminants. In addition, discharge of contaminated water form the TCE/PCE plume could pose health risks to base personnel or local residents coming into contact with it. The rationale used to screen the direct discharge alternatives may not necessarily be valid for alternatives evaluation and screening for other removal actions in OU B.

The use of trucking to transport contaminated groundwater from the extraction wells to the treatment system was eliminated due to the increase in perceived risks, the potential for disruptions in normal base operations, and the operation costs. The potential for spills or accidents to occur during the numerous loading, unloading, and transport operations could increase the risk of exposure to contaminants from the extracted groundwater for on-base personnel. Spills and accidents could also result in migration of contaminants over a much wider area, as well as to other media. Trucking operations would increase traffic in the areas surrounding the extraction wells and the proposed treatment units. Of particular concern was the parking lot south of Building 655, because of the number of employees working nearby and the large amount of vehicular traffic in the area. The perceived costs to operate a vacuum truck 6 to 8

hours a day, 365 days a year, combined with the preceding concerns appeared to eliminate trucking as a viable method of transporting contaminated groundwater from the extraction wells to the treatment. Therefore, all of the alternatives involving trucking were eliminated from further consideration.

The pipeline alternative to the existing treatment plant was eliminated because of the time constraints of the removal action. The removal action for the TCE/PCE plume was elevated to expedited status due to the threat to Base Well 18 (BW-18). The alternative was initially thought to be very attractive. The GWTP is currently operating at about 25 percent of its design capacity and the anticipated additional flow and contaminant loading may have enhanced the performance and operational characteristics of the plant. However, the time necessary to secure the route and rights-of-way on base, together with the time to design and construct the pipeline, was estimated to be two to three years. In that time the contaminants would migrate, and possibly jeopardize the continued operation of BW-18 and nearby city wells, and would thus impact the water supply system for McClellan AFB and surrounding residences. The pipeline alternative was therefore eliminated from further consideration.

Both steam stripping and air stripping alternatives were eliminated due to potential air emissions problems in the vicinity of Buildings 666 and 655. An existing boiler west of Building 655 has in the past had problems achieving its air permit requirements. While both the air stripping and steam stripping processes should operate as closed loop systems with minimal organic emissions, during a process upset condition, both processes could discharge VOCs. The increased organic load in the vicinity could result in permit violations and interrupt boiler operation. Since the boiler provides steam for the southeast portion of McClellan AFB, base officials were reluctant to implement a removal action that could endanger the operation of the boiler. The removal action alternatives involving the use of air or steam stripping which use the boiler west of Building 655 were therefore eliminated from further consideration.

6.2.4 Preliminary List of Removal Action Alternatives for the TCE/PCE Plume

Eight primary alternatives were identified for migrating the contaminated groundwater in the TCE/PCE plume and the northern TCE/1,2-DCE plume. In addition, other alternatives were developed from these primary alternatives by considering the several available options to discharge the treated groundwater. The

primary alternatives determined to be the most feasible for the TCE/PCE plume are presented below:

- ALTERNATIVE 1: (Alternative 1 as shown on Table 6-3.) Extraction wells, conveyance of groundwater by piping to the IWL, treatment at the IWTP, and subsequent discharge into the Sacramento Regional County Sanitation District (SRCSD) interceptor system and Regional Treatment Plant.

- ALTERNATIVE 2: (Alternative 2 in Table 6-3.) Extraction wells and direct conveyance of groundwater by piping to a sanitary sewer and discharge into the SRCSD interceptor system and Regional Treatment Plant.

- ALTERNATIVE 3: (Alternatives 3a and 3b in Table 6-3.) Extraction wells and direct conveyance of groundwater by piping to McClellan AFB storm sewer or by truck transport with subsequent discharge into either Magpie or Arcade Creek.

- ALTERNATIVE 4: (Alternatives 4a and 4b on Table 6-3.) Extraction wells, conveyance of groundwater by piping or truck transport to GWTP, and a surface water discharge to Magpie Creek.

- ALTERNATIVE 5: (Alternatives 5a, b, c, and d on Table 6-3.) Extraction wells, conveyance of groundwater by piping to a local UV/ozone/peroxide treatment system, conveyance of treated groundwater by pipeline and discharge to one of four discharge points: IWL, a reinjection well, Magpie Creek (surface water discharge), or sanitary sewer.

- ALTERNATIVE 6: (Alternatives 6a, b, c, and d on Table 6-3.) Extraction wells, conveyance of groundwater by piping to a nearby air stripping and vapor phase GAC treatment system, conveyance and discharge to one of four discharge points: IWL, a reinjection well, Magpie Creek (surface water discharge), or sanitary sewer.

TABLE 6-3. PRELIMINARY ALTERNATIVE LIST FOR THE TCE/PCE PLUME OPERABLE UNIT B, McCLELLAN AFB, CALIFORNIA

Alt. No.	Description
1	Groundwater extraction wells conveyance by pipeline and discharge to the IWL.
2	Groundwater extraction wells conveyance by pipeline and discharge into the SRCSD interceptor system and Regional Treatment Plant.
3a	Groundwater extraction wells conveyance by pipeline and discharge to Magpie or Arcade Creek.
3b	Groundwater extraction wells conveyance by truck transport and discharge to Magpie or Arcade Creek.
4a	Groundwater extraction wells conveyance by pipeline to GWTP and discharge to Magpie Creek.
4b	Groundwater extraction wells conveyance by truck transport to the GWTP and discharge to Magpie Creek.
5a	Groundwater extraction wells conveyance by pipeline to local UV/ozone/peroxide treatment system and discharge to the IWL.
5b	Groundwater extraction wells conveyance by pipeline to local UV/ozone/peroxide treatment system and reinjection of treated groundwater.
5c	Groundwater extraction wells conveyance by pipeline to local UV/ozone/peroxide treatment system and discharge to Magpie Creek.
5d	Groundwater extraction wells conveyance by pipeline to local UV/ozone/peroxide treatment system and discharge to the sanitary sewer.
6a	Groundwater extraction wells conveyance by pipeline to local Air Stripping/GAC adsorption treatment system and discharge to the IWL.
6b	Groundwater extraction wells conveyance by pipeline to local Air Stripping/GAC adsorption treatment system and reinjection of treated groundwater.
6c	Groundwater extraction wells conveyance by pipeline to local Air Stripping/GAC adsorption treatment system and discharge to Magpie Creek.
6d	Groundwater extraction wells conveyance by pipeline to local Air Stripping/GAC adsorption treatment system and discharge to the sanitary sewer.
7a	Groundwater extraction wells conveyance by pipeline to local steam stripping treatment system and discharge to the IWL.
7b	Groundwater extraction wells conveyance by pipeline to local steam stripping treatment system and reinjection of treated groundwater.

(Continued)

TABLE 6-3. (Continued)

Alt. No.	Description
7c	Groundwater extraction wells conveyance by pipeline to local steam stripping treatment system and discharge to Magpie Creek.
7d	Groundwater extraction wells conveyance by pipeline to local steam stripping treatment system and discharge to the sanitary sewer.
8a	Groundwater extraction wells conveyance by pipeline to local aqueous phase GAC adsorption treatment system and discharge to the IWL.
8b	Groundwater extraction wells conveyance by pipeline to local aqueous phase GAC adsorption treatment system and reinjection of treated groundwater.
8c	Groundwater extraction wells conveyance by pipeline to local aqueous phase GAC adsorption treatment system and discharge to Magpie Creek.
8d	Groundwater extraction wells conveyance by pipeline to local aqueous phase GAC adsorption treatment system and discharge to the sanitary sewer.

- ALTERNATIVE 7: (Alternatives 7a, b, c, and d on Table 6-3.) Extraction wells, conveyance of groundwater by piping to a nearby aqueous phase GAC treatment system, conveyance and discharge of treated waters to one of four discharge points: IWL, a reinjection well, Magpie Creek (surface water discharge), or sanitary sewer.

- ALTERNATIVE 8: (Alternatives 8a, b, c, and d on Table 6-3.) Extraction wells, conveyance of groundwater by piping to a nearby steam stripping treatment system, conveyance and discharge to one of four discharge points: IWL, a reinjection well, Magpie Creek (surface water discharge), or sanitary sewer.

6.2.5 Environmental Impacts from the TCE/PCE Plume Proposed Action

Two extraction wells, a treatment facility, and a discharge to the IWL will be constructed for this action. Construction will temporarily impact air quality and increase noise pollution. This facility is within a current and former industrial area; there will be no impact to vegetation or wildlife. Operation of the facility is not expected to affect the environment or public health.

During construction, air quality will be impacted by construction vehicle and equipment emissions. Dust generation will be controlled during construction. As this action is being taken between an area frequented by trucks and a major on-base thoroughfare, noise will not significantly affect those personnel away from the construction site. Construction workers will wear suitable hearing protection.

Construction activities will result in open excavations and trip and fall hazards. General access to such areas will be restricted by barricades and access restrictions.

6.3 Evaluation of Removal Action Alternatives and Description of the Proposed Action for the Northern TCE/1,2-DCE Plume

A modified matrix approach was used to identify and evaluate removal action alternatives for the northern TCE/1,2-DCE plume in OU B. The proposed action was chosen from the an abbreviated list of alternatives that had been evaluated using the methods described in Section 6.1. The abbreviated list of removal action

alternatives shown on Figure 6-4 were chosen from a larger list of alternatives (Table 6-15, page 6-57) developed from the diagram shown on Figure 5-1.

6.3.1 Description of the Proposed Action for the Northern TCE/1,2-DCE Plume

Two removal action alternatives were chosen as the proposed action for the northern TCE/1,2-DCE plume: 2 and 3a. Alternative 2 was selected as an interim action and consists of extraction of groundwater, the construction of a pipeline, and discharge of the groundwater to the sanitary sewer line. This interim action is to replaced by Alternative 3a when fully implemented, and consists of the continued extraction of groundwater, construction of a pipeline, and discharge of the groundwater to the GWTP. The selection rationale, as well as a description and evaluation of these alternatives, is given in the following paragraphs.

Alternative 2 was selected for its simple design, ease of construction, and low O&M costs. Alternative 3 was selected because it uses proven treatment technologies, has demonstrated successful treatment of similar contaminated groundwater, and has the potential to become part of a longer term remedy.

Interim Sanitary Sewer Discharge

In this interim action, the groundwater will be pumped directly from the three extraction wells to the on-base sanitary sewer line. No groundwater holding tank or booster pumps will be necessary in this design.

A 210-foot aboveground pipeline to the sanitary sewer line is proposed and will consist of 4-inch, single-wall, aboveground pipe. A 4-inch line was selected because it has sufficient hydraulic capacity to handle flow from the extraction wells up to 235 gpm (at 6 feet per second [ft/s]). Aboveground piping was selected because the pipeline to the sanitary sewer is only a temporary connection and it is more cost-effective to run the pipeline aboveground for the short term.

The groundwater pipeline will connect to a segment of the existing on-base sanitary sewer line currently not in use and has sufficient capacity to accept the groundwater from the extraction wells. A new access cover will be constructed at the tie-in point where the groundwater pipeline will connect to the sanitary line.

PRIMARY ALTERNATIVES	COST (In $10,000)			EVALUATION PARAMETERS											
	Capital	Annual O & M	Present Worth Cost Total	Technology Status	Compliance with ARARs	Implementability	Off-Site Environmental Impacts	Need for Further Study	Environmental Impacts to Base Operation	Products Generated	Reliability	Regulatory and Public Acceptance	Permitting Requirements	Effectiveness Total	Effectiveness Total / Cost Total
WEIGHTING FACTORS	1	1		4	4	4	3	2	3	3	3	5	5		
1 Extraction Wells Pipe to IWL	39.0	159.6	435.9	3	3	1	3	3	2	3	3	3	3	97	0.22
2 Extraction Wells Pipe to Sanitary Sewer	55.9	11.1	83.5	3	3	3	3	3	3	3	3	2	2	98	1 17
3a Extraction Wells Pipe to GWTP to Surface Water	59.3	2.9	66.5	3	1	1	3	3	3	2	2	3	3	86	1.29
3b Extraction Wells Truck to GWTP and Discharge to Surface Water	41.3	17.0	83.6	3	2	2	3	3	3	2	1	3	3	91	1 09
4a Extraction Wells Pipe to UV/Ozone to IWL	92.1	81.4	294.5	1	3	2	3	2	2	3	2	3	2	83	0.28
4b Extraction Wells Pipe to UV/Ozone to Sanitary Sewer	150.8	11.5	179.4	1	3	3	3	2	3	3	2	2	2	85	0 47
4c Extraction Wells Pipe to UV/Ozone to Reinjection Wells	104.0	4.5	115.2	1	3	2	3	2	3	3	2	1	1	71	0.62
4d Extraction Wells Pipe to UV/Ozone to Surface Water	91.0	2.8	98.0	1	3	2	3	2	3	3	2	1	1	71	0.72
5a Extraction Wells Pipe to Air Stripping/GAC to IWL	167.5	92.3	397.0	3	3	2	3	3	2	2	2	3	2	90	0 23
5b Extraction Wells Pipe to Air Stripping/GAC to Sanitary Sewer	182.5	22.4	238.2	3	3	3	3	3	3	2	2	2	2	92	0 39
5c Extraction Wells Pipe to Air Stripping/GAC to Reinjection Wells	178.8	15.4	217.1	3	3	2	3	3	3	2	2	1	1	78	0 36
5d Extraction Wells Pipe to Air Stripping/GAC to Surface Water	170.4	13.7	204.5	3	3	2	3	3	3	2	2	1	1	78	0 38
6 Extraction Wells Pipe to Liquid Phase GAC to IWL	53.7	114.9	339.5	3	3	2	3	3	2	2	2	3	2	90	0 27

Figure 6-4. Evaluation Matrix for TCE/1,2-DCE Plume Removal Action Alternatives.

The majority of the cost for the sanitary sewer discharge option is expected to be due to the sanitary sewer connection fee. However, the County of Sacramento, Department of Public Works has not yet determined the connection fees to charge facilities that discharge contaminated groundwater into the sanitary sewer.

The existing sanitary sewer line will convey the groundwater to the Sacramento Regional County Wastewater Treatment Plant.

Groundwater Extraction/Conveyance to the GWTP

Groundwater from the northern TCE/1,2-DCE plume will be extracted via three extraction wells located along the east-west base boundary in OU B. Groundwater from the extraction wells will be pumped to a local groundwater holding/flow equalization tank and from this tank to the GWTP. The proposed pipeline route is shown in Figure 6-5, and a preliminary process flow diagram is shown in Figure 6-6. The major components of the groundwater extraction/GWTP conveyance system include:

- Extraction wells;
- Groundwater holding tank; and
- Pipeline to OU C Extraction System.

The extraction wells were designed with hydraulic capacities above the current requirements to handle potentially greater flow rates in the future. The piping, fittings and valves of the A and B zone extraction wells are sized to handle flows of up to 45 gpm (at 4.6 ft/s). Similarly, the piping, fittings, and valves of the C zone extraction well are sized to handle flows of up to 140 gpm (at 4 ft/s). To accommodate these flow requirements, 2-inch lines for wells A and B zone wells and a 4-inch line for C zone wells were selected to transport the groundwater from the pump inlet up to the wellhead. A 4-inch header line was selected to transport the groundwater from each wellhead to the groundwater holding tank. This 4-inch line can transport up to 235 gpm (at 6 ft/s).

Groundwater Holding Tank

The groundwater holding tank will be used as a reservoir for the GWTP pipeline booster pump and for contingency holding purposes. The holding tank will be equipped with a vapor-tight top and with a GAC adsorption unit for treatment of

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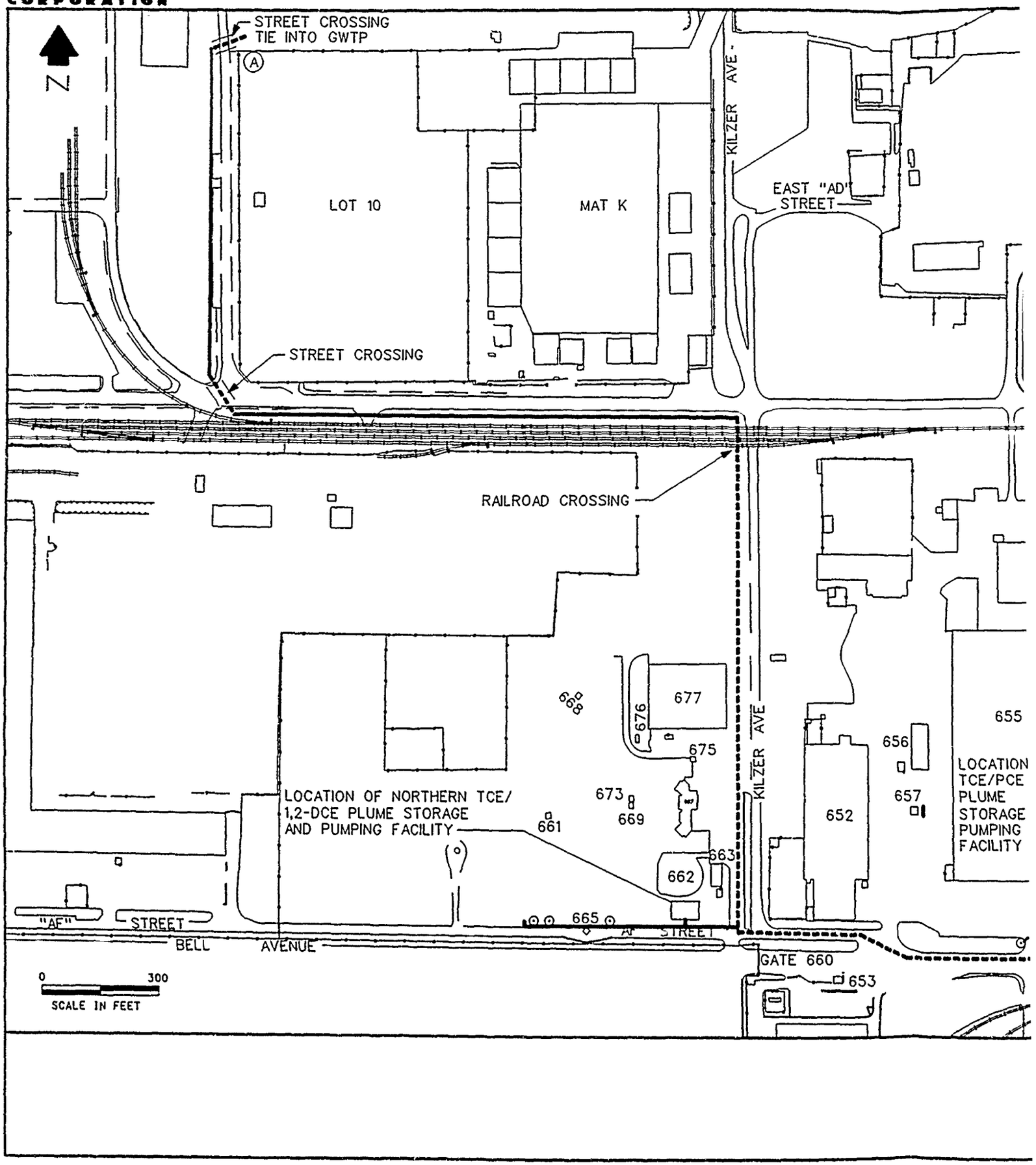

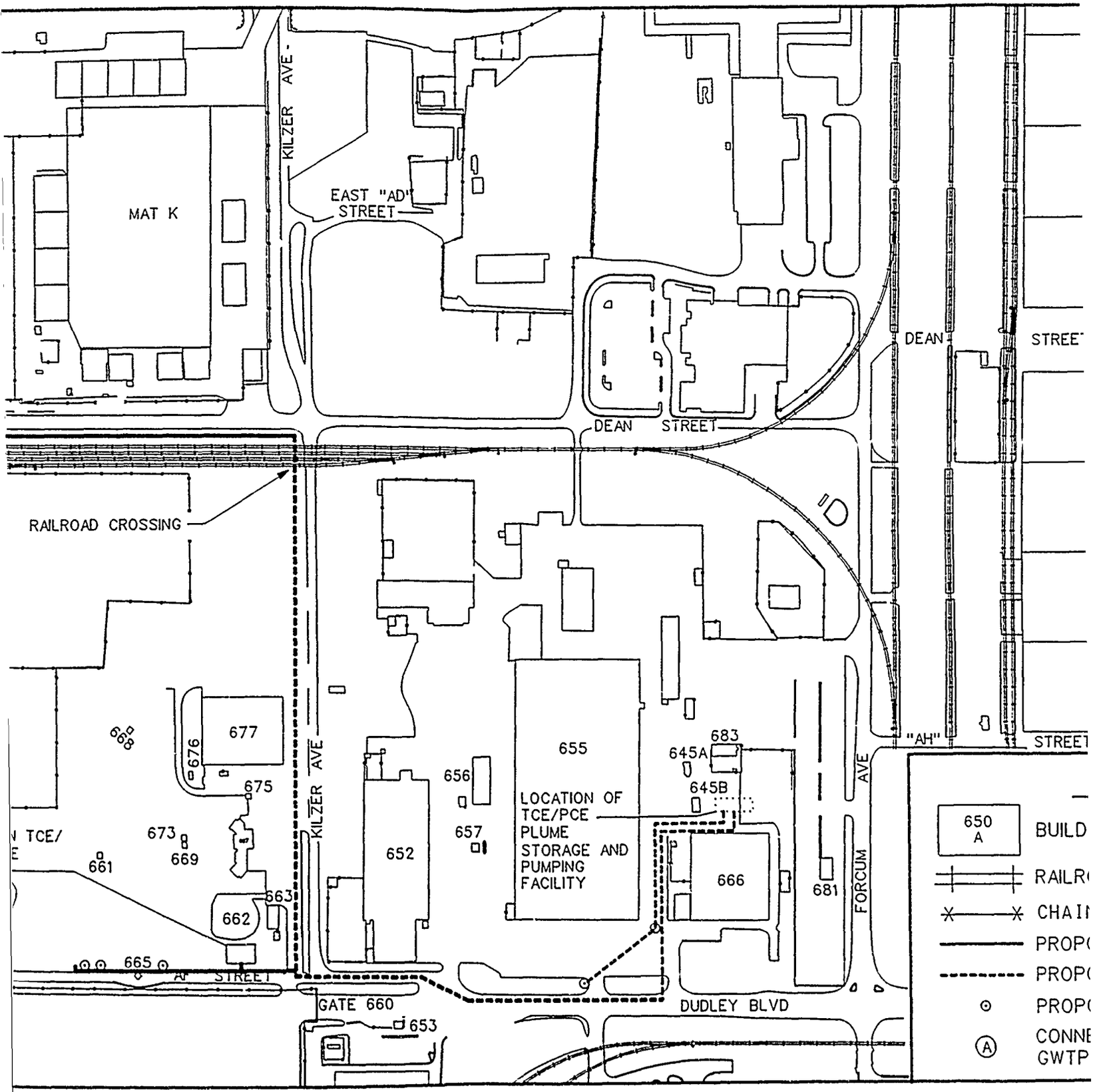
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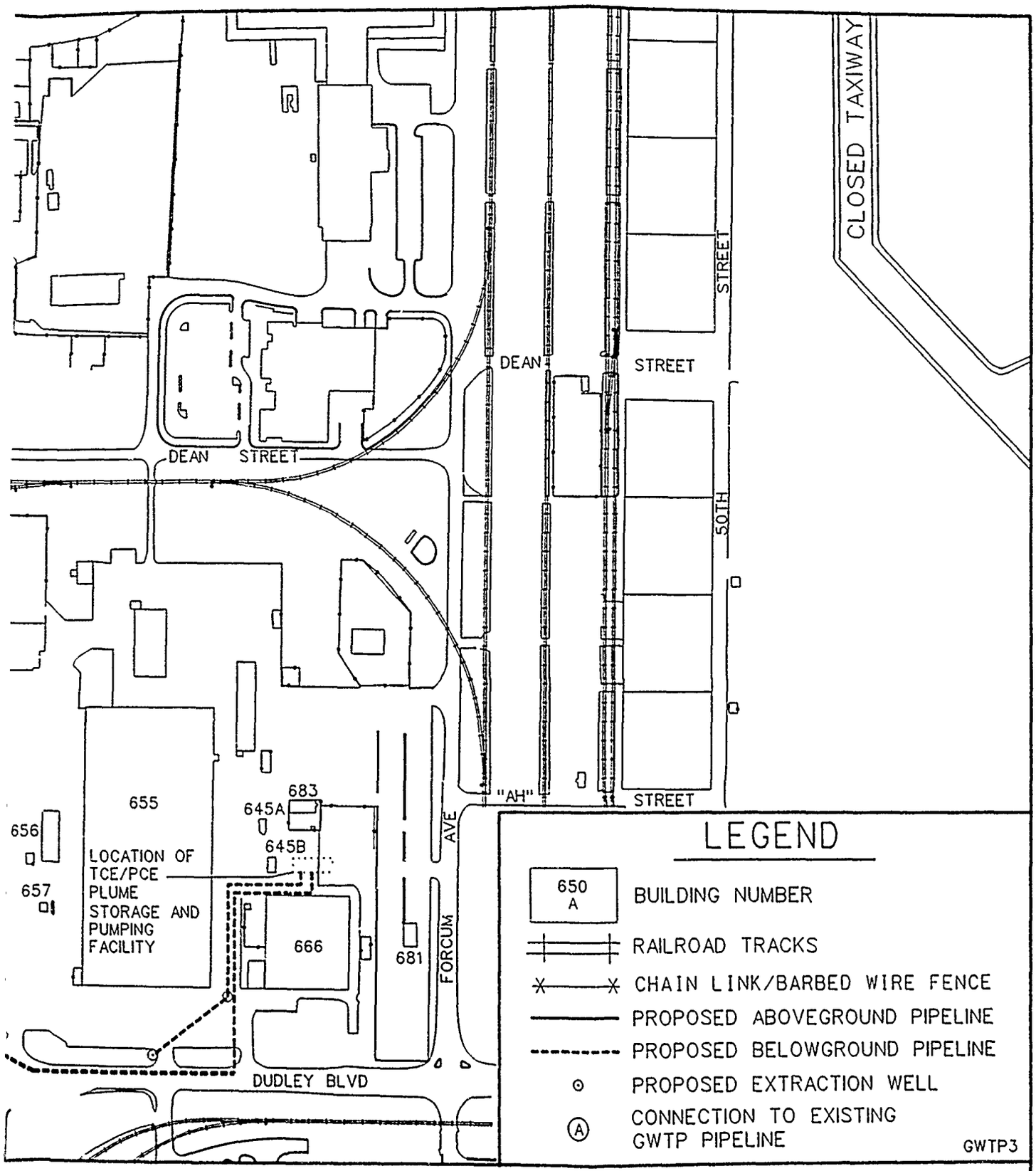

Figure 6-5. Proposed GWTP Pipeline Route.

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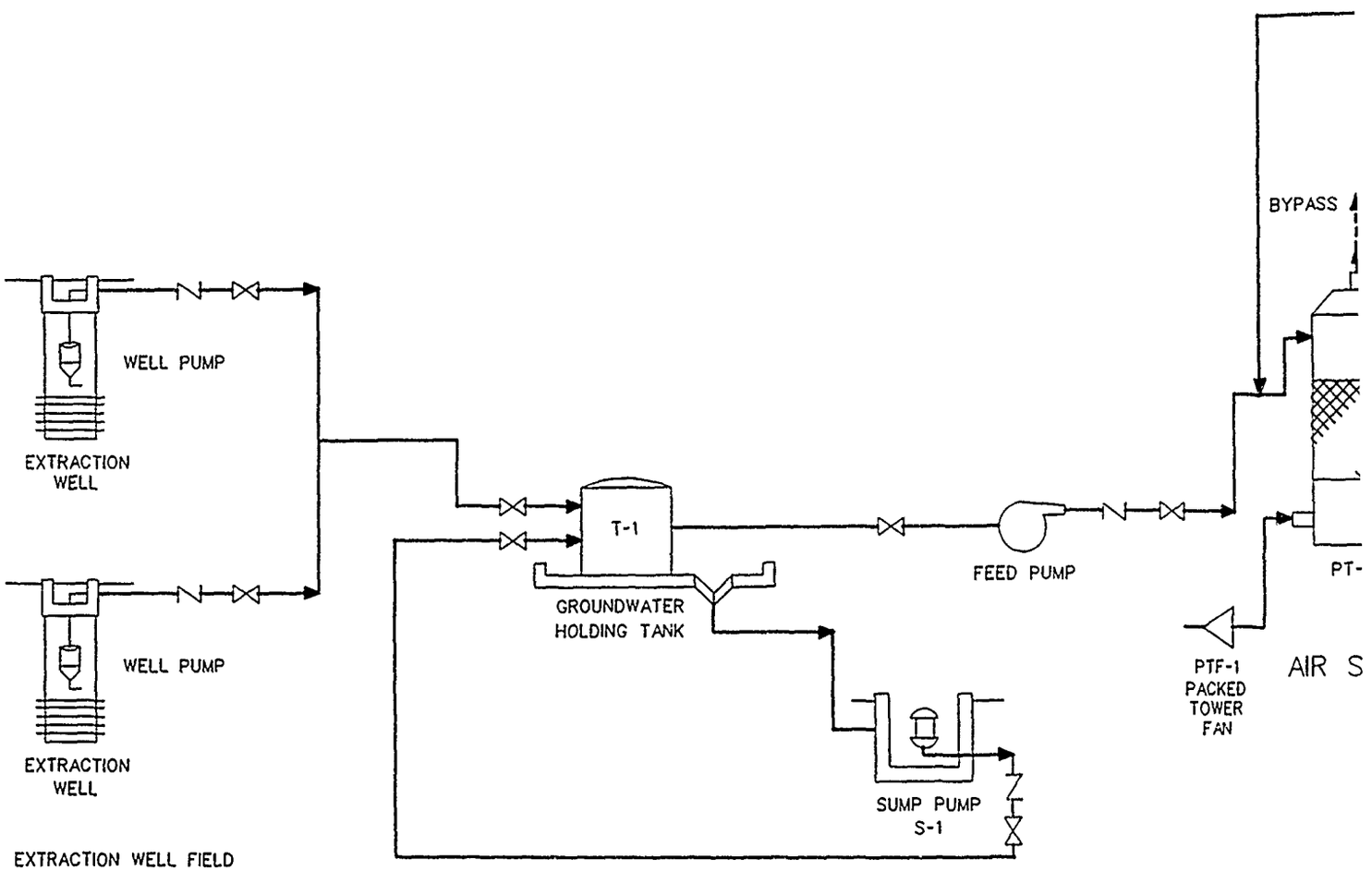

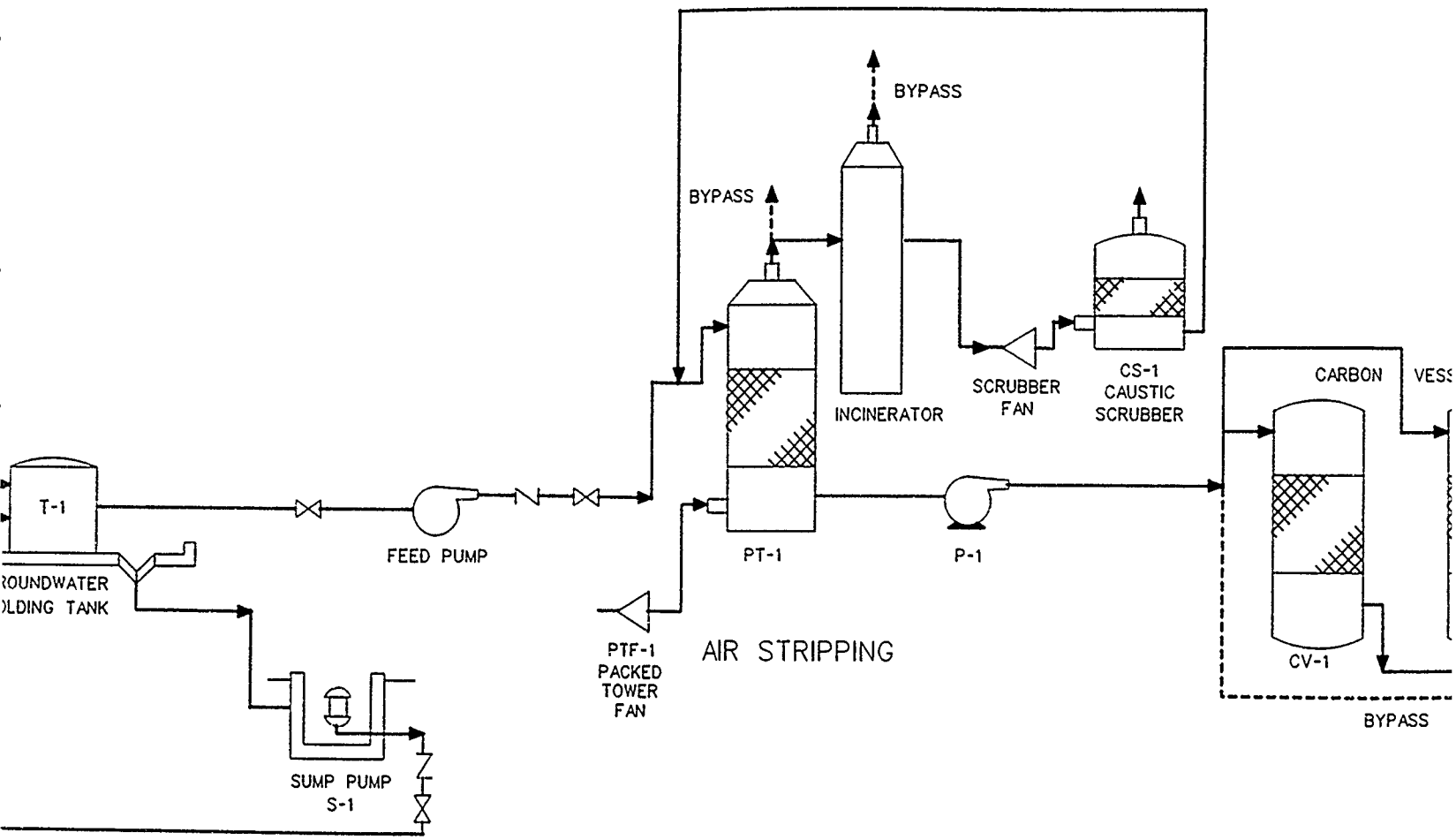
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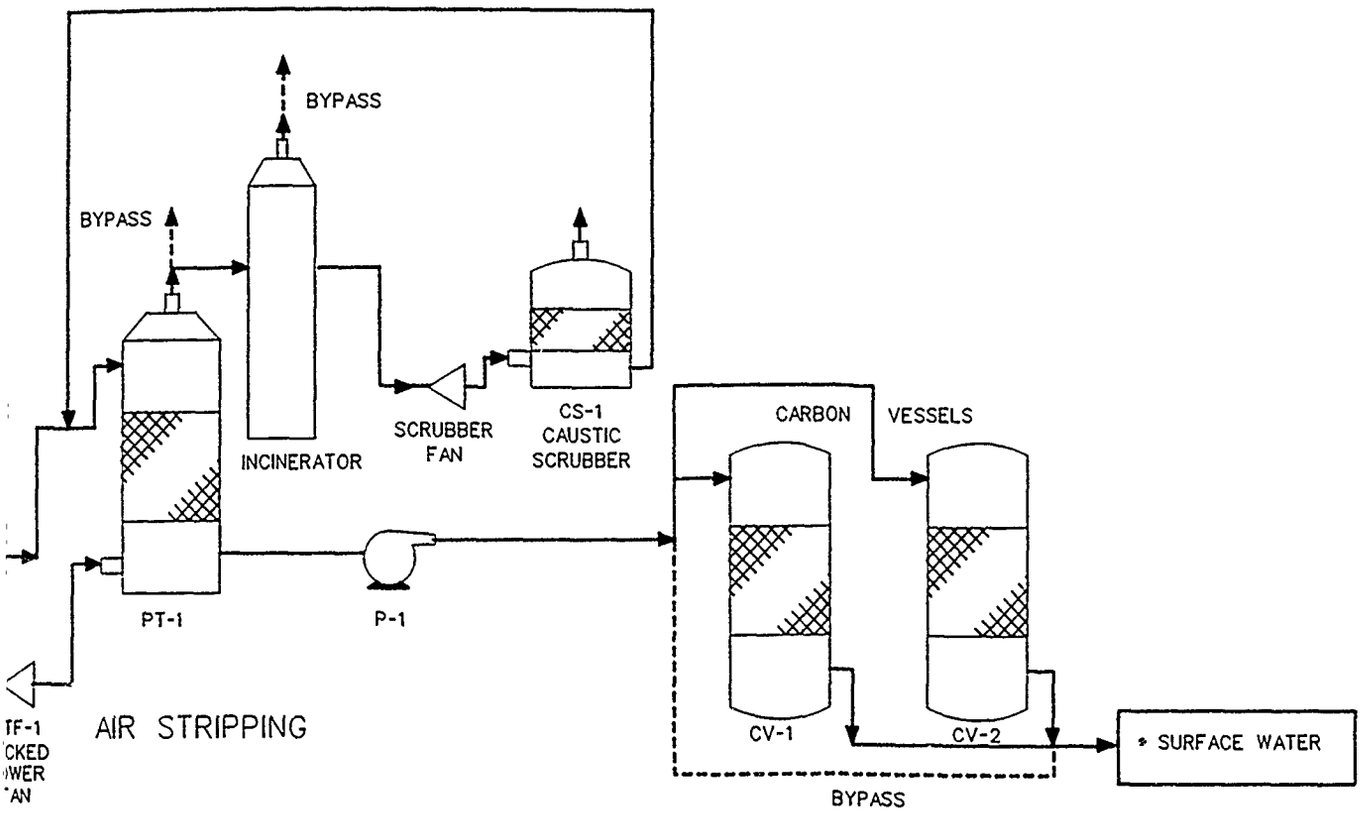

Figure 6-6. Process Schematic of Groundwater Treatment Plant Treatment Alternative.

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displaced vapor phase organics forced from the tank by a rising liquid level. For purposes of this evaluation, the tank design includes a secondary containment liner and a leak detection system. The proposed design was a result of a conservative engineering approach and not based on any legal requirement. The final selected design may be different.

Pipeline to the OU C Extraction System

Figure 6-5 presents the proposed route for the new pipeline that will transport groundwater from the holding tank to the GWTP via the existing pipeline system in OU C. The new pipeline will consist of a 6-inch diameter fibercast pipe that connects the groundwater holding tank to the 6-inch OU C extraction pipeline. A 6-inch line through OU B was selected to provide sufficient hydraulic capacity to transport the groundwater to the GWTP from the northern plume extraction wells and to provide extra capacity to handle flows from any future extraction wells that are constructed in OU B. The 6-inch line in OU B can carry up to 375 gpm (at 6 ft/s) additional flow. However, the existing flow in the OU C/OU D pipeline may limit this excess capacity to 100 gpm.

The results of the matrix approach evaluation for the northern TCE/1,2-DCE plume removal alternative are presented below. The ratings for each alternative relative to each evaluation parameter are presented in Figure 6-4. "Ratings" were selected using the scoring basis for each alternative. Each rating was multiplied by the weighting factor for each evaluation parameter and the sum of these products is presented in the "Effectiveness Total" column. Based on the results of this evaluation for the northern TCE/1,2-DCE plume, the proposed action for the non-cost evaluation is Alternative 2, with Alternatives 5 and 6 being roughly comparable as the second choices. Alternative 1 is least preferred.

The information in the "Cost Measures" columns include capital, annual O&M, and present worth costs, each presented in tens of thousands of dollars. The local air stripper, discharge to the IWL or sanitary sewer, or reinjection alternatives have the highest capital costs and high operating costs.

The capital and O&M costs have been assigned equal weighting factors. These factors were multiplied by each cost figure, the products summed and the present worth value calculated and presented in the "Present Worth Cost Total" column of

Figure 6-4. Review of the "Present Worth Cost Total" column indicates that Alternative 1 has the lowest overall cost.

The final assessment of this matrix approach is to evaluate which alternative is most cost-effective. The "Effectiveness Total" value is divided by the "Present Worth Cost Total" value and the quotient is presented in the far right-hand column in Figure 6-4 for each alternative. The most cost-effective alternative will have the greatest value. The results indicate that Alternatives 2 and 3 are the most cost-effective with Alternatives 4 and 6 preferred as the second choices. Alternative 1 is the least cost-effective.

6.3.2 Evaluation of Removal Action Alternatives for the TCE/1,2-DCE Plume

Removal action components identified in Section 5.0 have been assembled into option packages, each of which represents a complete alternative for the northern TCE/1,2-DCE plume.

Extraction Wells and Piping to the Groundwater Treatment Plant

Extracted groundwater will be transported directly from flow equalization tanks, located near the northern TCE/1,2-DCE extraction wells, to the GWTP via pipeline. No treatment prior to transport to the GWTP will be involved. Figure 6-5 shows the proposed pipeline routes extending from the TCE/PCE plume and northern TCE/1,2-DCE plume extraction facilities to the GWTP. The pipeline routes shown would be used for either separate or combined pipeline systems. Groundwater from either or both the TCE/PCE plume or the northern TCE/1,2-DCE plume would be transported to the GWTP in a common pipeline.

Five processes are used in the GWTP to treat the influent groundwater from the extraction wells: flow equalization/storage, air stripping, GAC treatment, off-gas incineration, and treatment in a caustic scrubber. The GWTP treatment processes are discussed in more detail in Section 5.2.4.

Products Generated. No products or residuals are generated from the use of the pipeline technology. The potential for leakage of the pipeline exists but can be reduced by the use of a leakage detection system.

The GWTP generates spent carbon which must be regenerated or landfilled. Treated groundwater is discharged to Magpie Creek and meets the effluent quality requirements by its NPDES permit.

Implementability. The construction and operation of a pipeline to convey groundwater to the GWTP is a reliable and readily available technology. However, the new pipeline must be constructed underground over 50 percent of its length to pass beneath railroad tracks, on-base roads, and other facilities that lie between the extraction wells and the GWTP. Construction will require approximately three years.

The GWTP currently has the capacity to treat 1,000 gpm, but only treats 250 gpm. The proposed 155 gpm (0.22 million gallons per day [MGD]) generated from the northern TCE/1,2-PCE plume would not exceed the plant flow capacity or organic loading capacity. The GWTP is a proven treatment system for the remediation of VOC contaminated groundwater.

Safety. There are no special considerations for the construction and operation of the pipeline system or operation of the GWTP. Standard safety procedures should be followed for protection of personnel during construction of the pipeline and operation of the GWTP.

Regulatory and Institutional Concerns. Construction and operation of the pipeline will require adherence to the Clean Water Act design standards (54 FR 34079, 2 Sept 88 and 55 FR 29230, 18 July 90). No ARARs apply specifically to the pipeline as it does not emit or release substances to the environment.

However, ARARs regulating water quality and atmospheric emissions that may be applicable to the GWTP operation and discharge of treated groundwater. These include:

- California Ambient Air Quality Standards and Sacramento Metropolitan Air Quality Management District Rules and Regulations because of possible air emissions from the GWTP; and

- Clean Water Act discharge requirements.

It is anticipated that this alternative can comply with the identified ARARs. This technology would likely have favorable public acceptance because it uses a proven treatment technology.

Costs. The cost estimate for implementing this alternative for the northern TCE/1,2-DCE plume includes the capital costs for construction of extraction wells, flow equalization tanks, pumps, intra-system piping, and discharge costs. A cost estimate for O&M costs for the pipeline and GWTP to transport and treat the groundwater was also developed. These estimates are presented in Table 6-4.

UV/Ozone/Peroxide Treatment Alternative

This treatment technology uses a combination of UV radiation, ozone, and hydrogen peroxide to oxidize organic compounds in the water. The influent water is first exposed to hydrogen peroxide as it flows through the inlet line from the flow equilization tank to the process reactor. In the reactor, the water is simultaneously exposed to UV radiation and ozone. The reactor is divided by five vertical baffles into six chambers which contain UV lamps evenly distributed throughout the reactor. Spargers uniformly diffuse ozone gas from the base of the reactor into the water. As a result of this process, hydroxyl radicals are formed from the ozone; these hydroxyl radicals are known to react with organics more rapidly than ozone or hydrogen peroxide alone. Figure 5-3 presents a schematic diagram of the UV/ozone/peroxide treatment process. The UV/ozone/peroxide system evaluated was designed to treat a flow of 150 to 250 gpm. The UV/oxidation reactor has dimension of 14 feet x 7 feet x 6 feet (length x width x height) and had a wet volume of 4,650 gallons. A dosing rate of 0.12 lbs/1,000 gallons for the hydrogen peroxide and for the ozone was anticipated and treatment was to occur during a 30-minute residence time. The UV radiation is expected to be provided continuously during the treatment.

The treated water is discharged from the reactor to either of four discharge locations discussed in Section 5.3. Any unreacted ozone is destroyed in a packed bed catalytic reactor which uses a nickel-based catalyst to decompose reactor off-gas ozone into oxygen. No other emissions are produced.

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TABLE 6-4. ESTIMATED COSTS FOR ALTERNATIVE 3A -- EXTRACTION WELLS PIPELINE TO GWTP TO MAGPIE CREEK

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$200,000	$17,000
B.	Conveyance			
	Piping (4000' x 4/95 ft)		19,000	6,000
	Elbows (8 x $38.70)		300	
	Holding Tank		47,000	6,000
	Pumps	1 Feed	3,000	1,000
		2 Sump	1,000	
	Jacking Pits		60,000	
	Horizontal borings		76,000	
			$206,000	$ 7,000
C.	Treatment -- GWTP		0	4,500
D.	Discharge -- Magpie Creek		0	0
E.	Other Direct Costs[1] (% of Conveyance/Treatment)			
	Site Work	10%	21,000	
	Piping/Valving	5%	10,000	
	Instrumentation	10%	21,000	
	Controls	5%	10,000	
	Electrical	10%	21,000	
	Contingency	25%	52,000	
	Contractor	15%	31,000	
	Engineering	10%	21,000	
			$187,000	0
	TOTAL COSTS:		$593,000	$29,000
	PRESENT WORTH COSTS[2]:		$665,000	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

GWTP = Groundwater Wastewater Treatment Plant

Products Generated. Products generated by the UV/ozone/peroxide treatment process include treated effluent water and excess ozone off-gas, which is purified by reduction or in a catalytic oxidation reaction.

Performance. Performance data provided by vendors and based on proposed flows and concentrations of the OU B extraction wells, indicate that nondetectable levels (<5 μg/L) can be achieved for all contaminants within the OU B plumes. Complete oxidation of VOCs has also been demonstrated using this treatment alternative. However, results were demonstrated on relatively low levels of VOC contaminants, and long reaction times were required for VOCs such as methylene chloride and 1,1,1-trichloroethane. Treatability studies performed on several pilot-scale UV/ozone/peroxide units as well as on full-scale operational plants indicate that this is a reliable and cost-effective treatment alternative for the remediation of contaminated groundwater. Vendor data also indicate that ozone concentrations within unit off-gas can be reduced to less than 0.1 ppm, meeting OSHA permissible exposure standards for workers. In addition, effluent from this treatment process can then be used for industrial, irrigation, and other purposes.

Once complete, this alternative would provide immediate results; removal of contaminated groundwater will minimize exposure to local groundwater and reduce migration of contaminants off-base.

Implementability. Construction and operation of the UV/ozone/peroxide unit at McClellan AFB is a new yet available and implementable technology; several fully operational units currently exist throughout the United States and Europe. Installation of the unit should not create significant inconveniences to McClellan AFB operations.

A completely functioning UV/ozone/peroxide treatment unit would require approximately three to four months to construct, deliver, and install. The limiting factor associated with the implementation of this alternative is the time required to construct the accompanying extraction wells, flow equalization tanks, discharge pipeline construction, and intra-system piping. Six months to one year would be required to complete and integrate these components.

Safety. There are no special safety considerations for the construction of the UV/ozone/peroxide unit. However, a contingency plan may need to be developed for potential ozone release. Ozone is a highly reactive and corrosive material and ozone

generation and use would increase safety risks during generation and would require the use of knowledgeable operators.

Regulatory and Institutional. Several action-specific ARARs related to atmospheric emissions and water quality discharges apply to the operation of this treatment process. In addition, there are specific ARARs identified for each of the four treated groundwater discharge processes: IWL, sanitary sewer, surface water, or reinjection. The ARARs applicable to the UV/ozone/peroxide treatment alternative include:

- National Ambient Air Quality Standards and California Ambient Air Quality Standards for UV/ozone treatment system and possible ozone emissions. The UV/ozone treatment system has a catalytic oxidation reactor by Ultrox®.

For discharge of treated groundwater to the sanitary sewer and the IWL:

- National Pretreatment Standard Discharges to Publicly Owned Treatment Works for discharges to the Sacramento Regional County Sanitary Sewer System connection; and

- Sacramento County Sanitary Sewer Fees and Discharge requirements.

For discharge of treated groundwater to surface water:

- National Pollutant Discharge Elimination System requirements as a new discharge source for the existing NPDES permit for GWTP discharges to Magpie Creek.

Specific McClellan AFB rules regarding land access and usage also may be relevant. It is anticipated that this alternative can comply with the identified ARARs.

Costs. Estimated costs for a UV/ozone/peroxide treatment for the proposed 155 gpm flow from the northern TCE/1,2-DCE plume and combined with each potential discharge option are presented in Tables 6-5 through 6-8.

TABLE 6-5. ESTIMATED COSTS FOR ALTERNATIVE 4A -- EXTRACTION WELLS PIPELINE TO UV/OZONE/PEROXIDATION WITH DISCHARGE TO IWL

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$200,000	$17,000
B.	Conveyance			
	Piping (550')		3,000	6,000
	Elbows (1)		40	
	Holding Tank		47,000	
	Pumps	1 Feed	3,000	1,000
		2 Sump	1,000	
	Jacking Pits		20,000	
	Horizontal borings		25,000	
			$ 99,000	$ 7,000
C.	Treatment -- UV/Ozone/H_2O_2		280,000	4,000
D.	Discharge -- IWL		0	786,000
E.	Other Direct Costs[1] (% of Conveyance/Treatment)			
	Site Work	10%	38,000	
	Piping/Valving	5%	19,000	
	Instrumentation	10%	38,000	
	Controls	5%	19,000	
	Electrical	10%	38,000	
	Contingency	25%	95,000	
	Contractor	15%	57,000	
	Engineering	10%	38,000	
			$342,000	
	TOTAL COSTS:		$921,000	$814,000
	PRESENT WORTH COSTS[2]:		$2,945,400	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

UV = Ultraviolet radiation.
IWL = Industrial Wastewater Line.
H_2O_2 = Hydrogen peroxide.

TABLE 6-6. ESTIMATED COSTS FOR ALTERNATIVE 4B -- EXTRACTION WELLS PIPELINE TO UV/OZONE/PEROXIDATION WITH DISCHARGE TO SANITARY SEWER

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$200,000	$17,000
B.	Conveyance			
	Piping (200')		1,000	6,000
	Elbows (1)		40	
	Holding Tank		47,000	
	Pumps	1 Feed	3,000	1,000
		2 Sump	1,000	
	Jacking Pits		10,000	
	Horizontal borings		0	
			$ 62,000	$ 7,000
C.	Treatment -- UV/Ozone/H_2O_2		280,000	4,000
D.	Discharge -- Sanitary Sewer		660,000	87,000
E.	Other Direct Costs[1]			
	Site Work	10%	34,000	
	Piping/Valving	5%	17,000	
	Instrumentation	10%	34,000	
	Controls	5%	17,000	
	Electrical	10%	34,000	
	Contingency	25%	85,000	
	Contractor	15%	51,000	
	Engineering	10%	34,000	
			$ 306,000	
	TOTAL COSTS:		$1,508,000	$115,000
	PRESENT WORTH COSTS[2]:		$1,794,000	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

UV = Ultraviolet radiation.
H_2O_2 = Hydrogen peroxide.

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TABLE 6-7. ESTIMATED COSTS FOR ALTERNATIVE 4C -- EXTRACTION WELLS PIPELINE TO UV/OZONE/PEROXIDATION WITH DISCHARGE TO REINJECTION WELLS

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$200,000	$17,000
B.	Conveyance			
	Piping (1100')		5,000	6,000
	Elbows (2)		100	
	Holding Tank		47,000	
	Pumps	1 Feed	3,000	1,000
		2 Sump	1,000	
	Jacking Pits		0	
	Horizontal borings		0	
			$ 56,000	$ 7,000
C.	Treatment -- UV/Ozone/H_2O_2		280,000	4,000
D.	Discharge -- Reinjection Wells		200,000	17,000
E.	Other Direct Costs[1]			
	Site Work	10%	34,000	
	Piping/Valving	5%	17,000	
	Instrumentation	10%	34,000	
	Controls	5%	17,000	
	Electrical	10%	34,000	
	Contingency	25%	84,000	
	Contractor	15%	50,000	
	Engineering	10%	34,000	0
			$ 304,000	0
	TOTAL COSTS:		$1,040,000	$45,000
	PRESENT WORTH COSTS[2]		$1,151,900	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

UV = Ultraviolet radiation.
H_2O_2 = Hydrogen peroxide.

TABLE 6-8. ESTIMATED COSTS FOR ALTERNATIVE 4D -- EXTRACTION WELLS PIPELINE TO UV/OZONE/PEROXIDATION WITH DISCHARGE TO MAGPIE CREEK

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$200,000	$17,000
B.	Conveyance			
	Piping (4120')		20,000	6,000
	Elbows (7)		300	
	Holding Tank		47,000	
	Pumps	1 Feed	3,000	1,000
		2 Sump	1,000	
	Jacking Pits		20,000	
	Horizontal borings		2,500	
			$ 94,000	$ 7,000
C.	Treatment -- UV/Ozone/H_2O_2		280,000	4,000
D.	Discharge -- Magpie Creek		0	0
E.	Other Direct Costs[1]			
	Site Work	10%	37,000	
	Piping/Valving	5%	19,000	
	Instrumentation	10%	37,000	
	Controls	5%	19,000	
	Electrical	10%	37,000	
	Contingency	25%	94,000	
	Contractor	15%	56,000	
	Engineering	10%	37,000	
			$336,000	0
	TOTAL COSTS:		$910,000	$28,000
	PRESENT WORTH COSTS[2]:		$979,600	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

UV = Ultraviolet radiation.
H_2O_2 = Hydrogen peroxide.

Air Stripping/GAC Treatment Alternatives

The combined use of air strippers with vapor phase GAC adsorption is an effective and commonly used groundwater treatment process for removing contaminants with relative volatilities greater than 100 from wastewater. The U.S. EPA has established air stripping as a Best Available Technology (BAT) as defined in Section 301 of the Clean Water Act and 40 CFR section 125.3 for removal of VOCs and can achieve a 99 percent or greater contaminant reduction, depending on the contaminants and the system design.

Contaminated groundwater is first introduced to an air stripping tower. The tower is generally a vertical shell filled with packing material and fitted with fans to draw air through the tower in a countercurrent direction to the influent stream. A low pressure air stream is forced upwards in the tower column while contaminated water is discharged downwards from the top of the column. Volatile organic compounds are stripped from the water and exit the top of the column in the air stream.

After exiting the top of the air stripping column, the VOC laden off-gas will pass through a series of activated carbon packed beds where contaminants are adsorbed onto the carbon. The spent carbon must eventually be regenerated or disposed of. Figure 5-2 presents a schematic of a flow process for an air stripping/GAC treatment system. Support facilities for an air stripper treatment system can include a flow equalization tank, water fuel pump, one or two parked tower fans, a scrubber fan for the stripped gases effluent pump, and GAC treatment trains for the vapor and aqueous effluent, treatment and process control instrumentation.

Products Generated. Products generated in this treatment alternative include stripper off-gas, treated groundwater, and spent carbon containing VOC contaminants. Off-gas emissions are effectively reduced to acceptable levels by the GAC treatment. The treated groundwater produced by this alternative is of high quality and could be used for industrial, irrigation, or other needs. Concentrations can be reduced below State Action Levels, but achieving nondetectable levels may not be possible. The treated groundwater can be discharged by one of several discharge options, including the IWL, sanitary sewer, surface water, and reinjection into the aquifer.

Performance. The application of air stripping to remove hazardous organic contaminants is a proven and widely used technology; however, this treatment system has several limitations. The effectiveness of the system is limited by the level of

total suspended solids and also by the pH of the influent solution. The contaminants removed from the groundwater during the vapor phase GAC adsorption are concentrated on the carbon filters and must eventually be destroyed, regenerated, or landfilled. Also, the air stripper is prone to inorganic and biological fouling and may require disinfection of the stripper and pretreatment of the influent stream to remove iron. Because of relatively high costs, carbon adsorption is more often used as a finishing or polishing step following other less expensive treatment processes; in this case, it follows air stripping.

The application of carbon adsorption to concentrated multi-component leachate has some performance limitations, but is generally acceptable for controlling VOCs, vinyl chloride, and most halogenated organic compounds.

Once complete, this alternative would provide immediate results; removal of contaminated groundwater will minimize exposure to local groundwater and reduce migration of contaminants off-base.

Implementability. Construction and operation of the air stripper/GAC unit at McClellan AFB is an available and readily implementable technology. This technology is one with which operators of the McClellan AFB GWTP are familiar since a similar system is currently being used. Installation of the unit should not create significant inconveniences for McClellan AFB personnel or operations; the unit can be installed or removed without major construction or traffic disruption.

A completely functioning air stripping/GAC treatment unit would require approximately three to four months to construct, deliver, and install. The limiting factor associated with the implementation of this alternative is the time required to construct the accompanying extraction wells, flow equalization tanks, discharge pipeline construction, and intra-system piping. Six months to a year is required to complete and integrate all these components. The treatment unit could also be adapted to a larger remediation system in the future.

Once complete, this alternative would provide immediate results; removal of contaminated groundwater will minimize exposure to local groundwater and reduce migration of contaminants off-base.

Safety. There are no special safety considerations for the construction or operation of the air stripping/GAC.

Regulatory and Institutional Concerns. Several ARARs related to atmospheric emissions and water quality apply to the air stripping/GAC treatment process. Additional ARARs also are associated with the four possible discharge options: IWL, sanitary sewer, surface water, or reinjection wells.

The ARARs applicable to the air stripping/GAC treatment alternative include:

- California Ambient Air Quality Standards and Sacramento County Air Pollution Control District Rules and Regulations because of possible air emissions from the air stripping/GAC treatment system; and

- Land Disposal Restrictions for the spent carbon which will contain unknown concentrations of organic contaminants.

For discharge of treated groundwater to the IWL and sanitary sewer line, the following ARARs are applicable:

- National Pretreatment Standard Discharges to Publicly Owned Treatment Works for discharges to the Sacramento Regional County Sanitary Sewer System connection; and

- Sacramento County Sanitary Sewer Fees and Discharge requirements.

For discharge of treated groundwater to surface water, the applicable ARAR is:

- NPDES requirements as a new discharge source to Magpie Creek.

For discharge of treated groundawter to reinjection wells, the following ARARs are applicable:

- Underground injection controls for reinjection into a public drinking water supply and Land Disposal Restrictions under Resource Conservation and Recovery Act (RCRA) for injection wells; and

- California Domestic Water Quality and Monitoring requirements for public and drinking water supplies.

It is anticipated that this alternative can comply with the identified ARARs.

Costs. The total costs for the air stripping/GAC treatment along with each potential discharge alternative are presented in Tables 6-9 through 6-12.

Extraction Wells to Sanitary Sewer Discharge

This alternative consists of the use of an extraction well system in the northern TCE/1,2-DCE plume to intercept contaminated groundwater. The extracted groundwater will then be transported directly to the closest accessible base sanitary sewer system access cover. The groundwater will not be treated prior to discharge into the sanitary sewer. Figure 6-7 presents a schematic of proposed pipeline routes for both routes from the individual TCE/PCE plume extraction facility and the northern TCE/1,2-DCE plume extraction facility to a local sanitary sewer access cover connection point.

The sanitary sewer access covers are part of the basewide sanitary sewer system which eventually discharges to the Sacramento Regional County Sanitation District Dry Creek interceptor line at Rio Linda Boulevard. The line terminates at the Sacramento County Sanitary Waste Treatment Plant (SWTP).

The SWTP is a secondary wastewater treatment system. Influent to the SWTP is treated using aerated grid tanks, oxygenated activated sludge, and chlorination. Sludges from the aerated grid tanks and activated sludge processes are disposed of in facultative ponds for five years and then treated in on-site land farms. The SWTP currently operates at a 150 MGD level with a 300-MGD peak flow capacity.

Products Generated. No products are generated from the use of the pipeline technology. A leak in the pipeline from the tanks to the sewer access cover would result in the spilling of contaminants onto the ground; however, the pipeline, if constructed, may have incorporated a leak detection program to minimize the possibility of leakage.

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TABLE 6-9. ESTIMATED COSTS FOR ALTERNATIVE 5A -- EXTRACTION WELLS PIPELINE TO AIR STRIPPING/GAC WITH DISCHARGE TO IWL

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$ 200,000	$ 17,000
B.	Conveyance			
	Piping (550')		3,000	6,000
	Elbows (1)		100	
	Holding Tank		47,000	
	Pumps	1 Feed	3,000	1,000
		2 Sump	1,000	
	Jacking Pits		20,000	
	Horizontal borings		25,400	
			$ 100,000	$ 7,000
C.	Treatment - Air Stripping/GAC		675,000	113,000
D.	Discharge - IWL		0	786,000
E.	Other Direct Costs[1]			
	Site Work	10%	78,000	
	Piping/Valving	5%	39,000	
	Instrumentation	10%	78,000	
	Controls	5%	39,000	
	Electrical	10%	78,000	
	Contingency	25%	193,000	
	Contractor	15%	116,250	
	Engineering	10%	78,000	
			$ 700,000	0
	TOTAL COSTS:		$1,675,000	$923,000
	PRESENT WORTH COSTS[2]		$3,970,500	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

Air Stripping/GAC = Air stripping with vapor phase granular activated carbon.
IWL = Industrial Wastewater Line.

TABLE 6-10. ESTIMATED COSTS FOR ALTERNATIVE 5B -- EXTRACTION WELLS PIPELINE TO AIR STRIPPING/GAC WITH DISCHARGE TO SANITARY SEWER

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$ 200,000	$ 17,000
B.	Conveyance			
	Piping (200')		1,000	6,000
	Elbows (1)		100	
	Holding Tank		47,000	
	Pumps	1 Feed	3,000	1,000
		2 Sump	1,000	
	Jacking Pits			
	Horizontal borings			
			$ 52,100	$ 7,000
C.	Treatment -- Air Stripping/GAC		675,000	113,000
D.	Discharge -- Sanitary Sewer		243,000	87,000
E.	Other Direct Costs[1]			
	Site Work	10%	73,000	
	Piping/Valving	5%	36,000	
	Instrumentation	10%	73,000	
	Controls	5%	36,000	
	Electrical	10%	73,000	
	Contingency	25%	182,000	
	Contractor	15%	109,000	
	Engineering	10%	73,000	0
			$ 655,000	0
	TOTAL COSTS:		$1,825,000	$224,000
	PRESENT WORTH COSTS[2]:		$2,382,100	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

Air Stripping/GAC = Air stripping with vapor phase granular activated carbon.

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TABLE 6-11. ESTIMATED COSTS FOR ALTERNATIVE 5C -- EXTRACTION WELLS PIPELINE TO AIR STRIPPING/GAC WITH DISCHARGE TO REINJECTION WELLS

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$200,000	$17,000
B.	Conveyance			
	Piping (1100')		5,300	6,000
	Elbows		100	
	Holding Tank		47,000	
	Pumps	1 Feed	3,000	1,000
		2 Sump	1,000	
	Jacking Pits		0	
	Horizontal borings		0	
			$ 56,000	$ 7,000
C.	Treatment -- Air Stripping/GAC		675,000	113,000
D.	Discharge -- Reinjection Wells		200,000	17,000
E.	Other Direct Costs[1]			
	Site Work	10%	73,000	
	Piping/Valving	5%	36,000	
	Instrumentation	10%	73,000	
	Controls	5%	36,000	
	Electrical	10%	73,000	
	Contingency	25%	183,000	
	Contractor	15%	110,000	
	Engineering	10%	73,000	
			$ 657,000	0
	TOTAL COSTS:		$1,788,000	$154,000
	PRESENT WORTH COSTS[2]:		$2,171,000	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

Air Stripping/GAC = Air stripping with vapor phase granular activated carbon.

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TABLE 6-12. ESTIMATED COSTS FOR ALTERNATIVE 5D -- EXTRACTION WELLS PIPELINE TO AIR STRIPPING/GAC WITH DISCHARGE TO MAGPIE CREEK

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$200,000	$17,000
B.	Conveyance			
	Piping (4120')		20,000	6,000
	Elbows (7)		300	
	Holding Tank		47,000	
	Pumps	1 Feed	3,000	
		2 Sump	1,000	
	Jacking Pits		20,000	
	Horizontal borings		25,400	
			$ 117,000	$ 7,000
C.	Treatment -- Air Stripping/GAC		675,000	113,000
D.	Discharge -- Magpie Creek		0	0
E.	Other Direct Costs[1]			
	Site Work	10%	79,000	
	Piping/Valving	5%	40,000	
	Instrumentation	10%	79,000	
	Controls	5%	40,000	
	Electrical	10%	79,000	
	Contingency	25%	198,000	
	Contractor	15%	118,000	
	Engineering	10%	79,000	
			$ 712,000	0
	TOTAL COSTS:		$1,704,000	$137,000
	PRESENT WORTH COSTS[2]:		$2,044,700	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

Air Stripping/GAC = Air stripping with vapor phase granular activated carbon.

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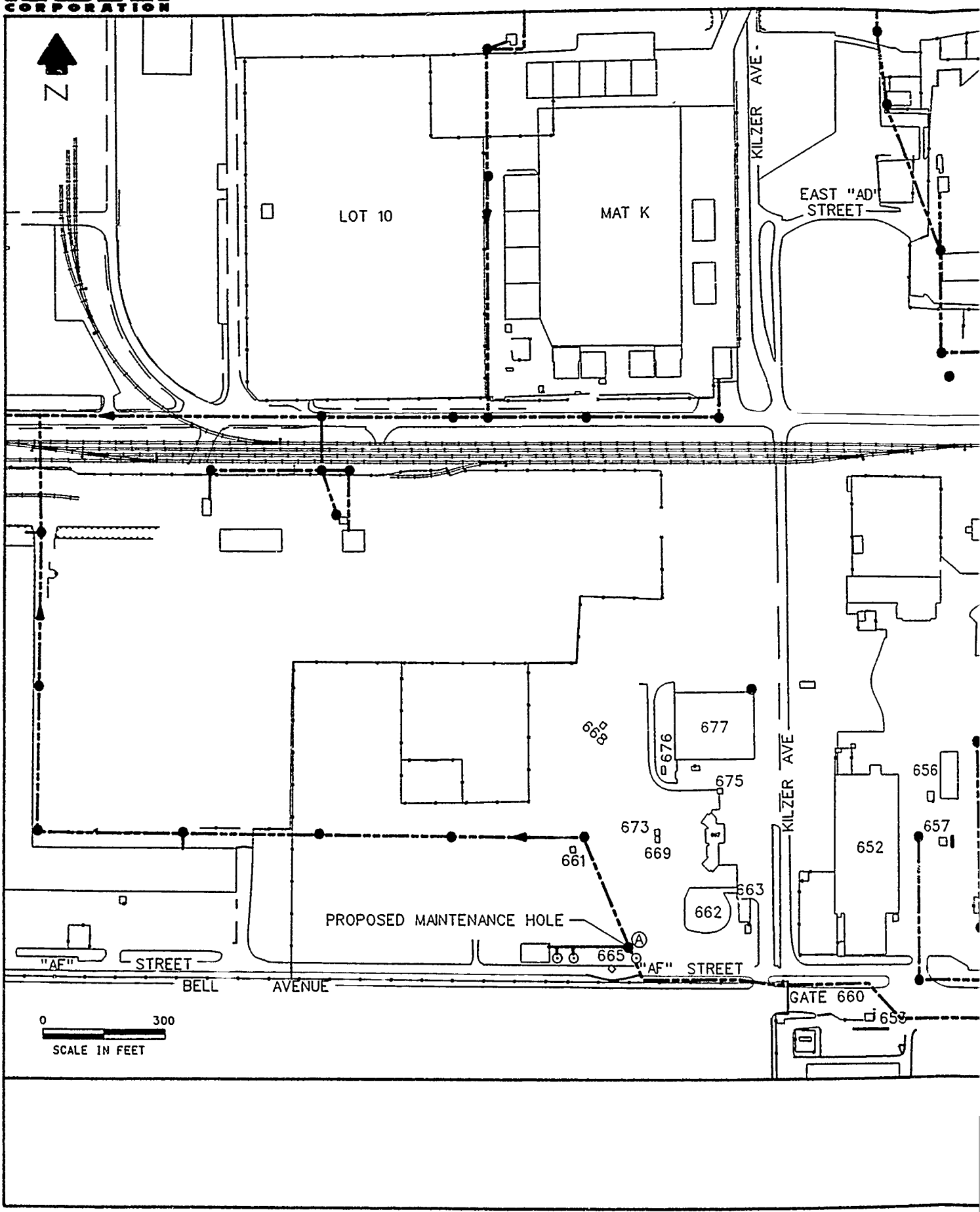

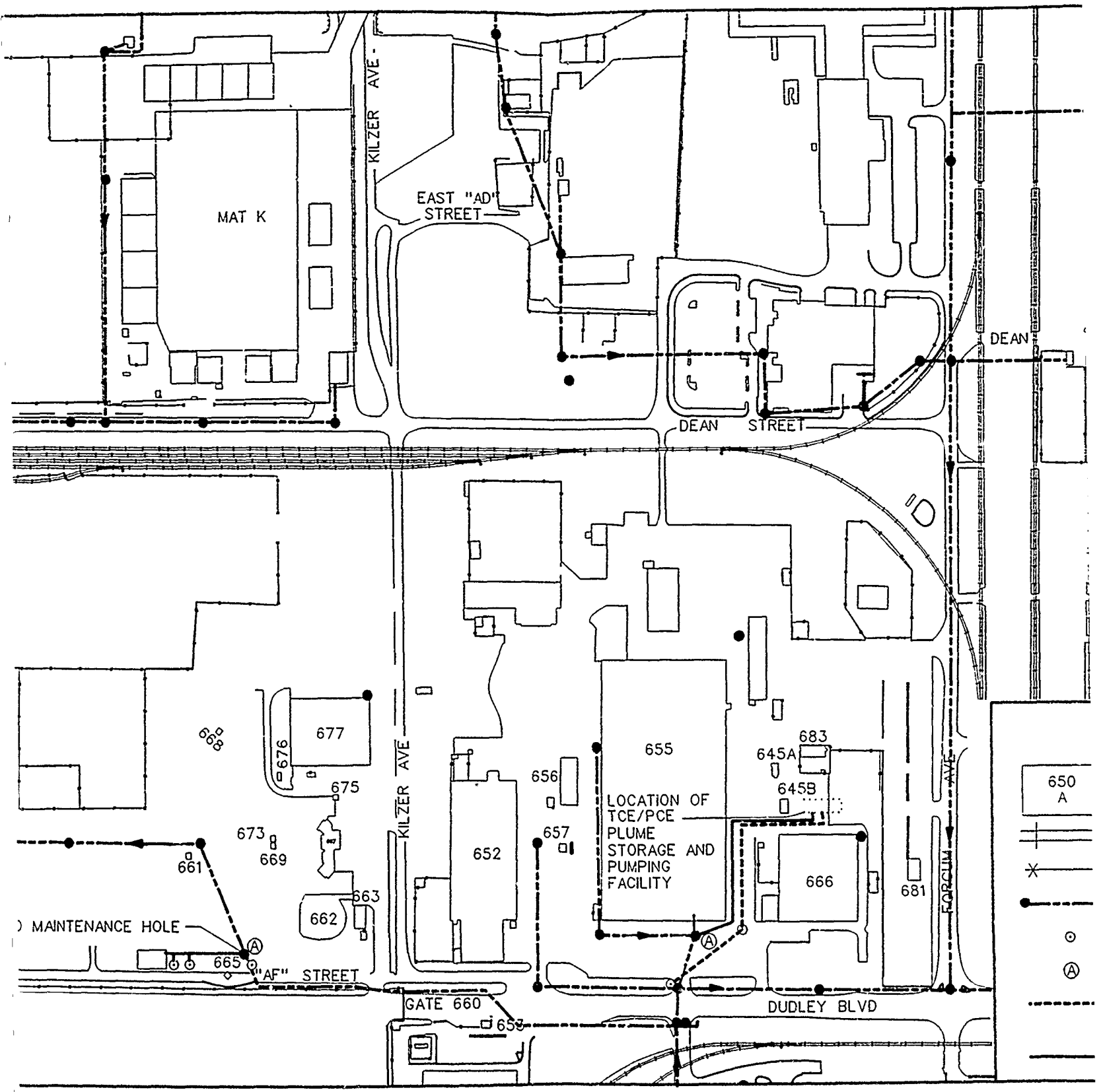
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EAST "AD" STREET
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677
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663
MAINTENANCE HOLE
665
"AF" STREET
KILZER AVE
652
656
655
657
LOCATION OF TCE/PCE PLUME STORAGE AND PUMPING FACILITY
683
645A
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681
FORCUM AVE
650 A
GATE 660
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DUDLEY BLVD

Figu

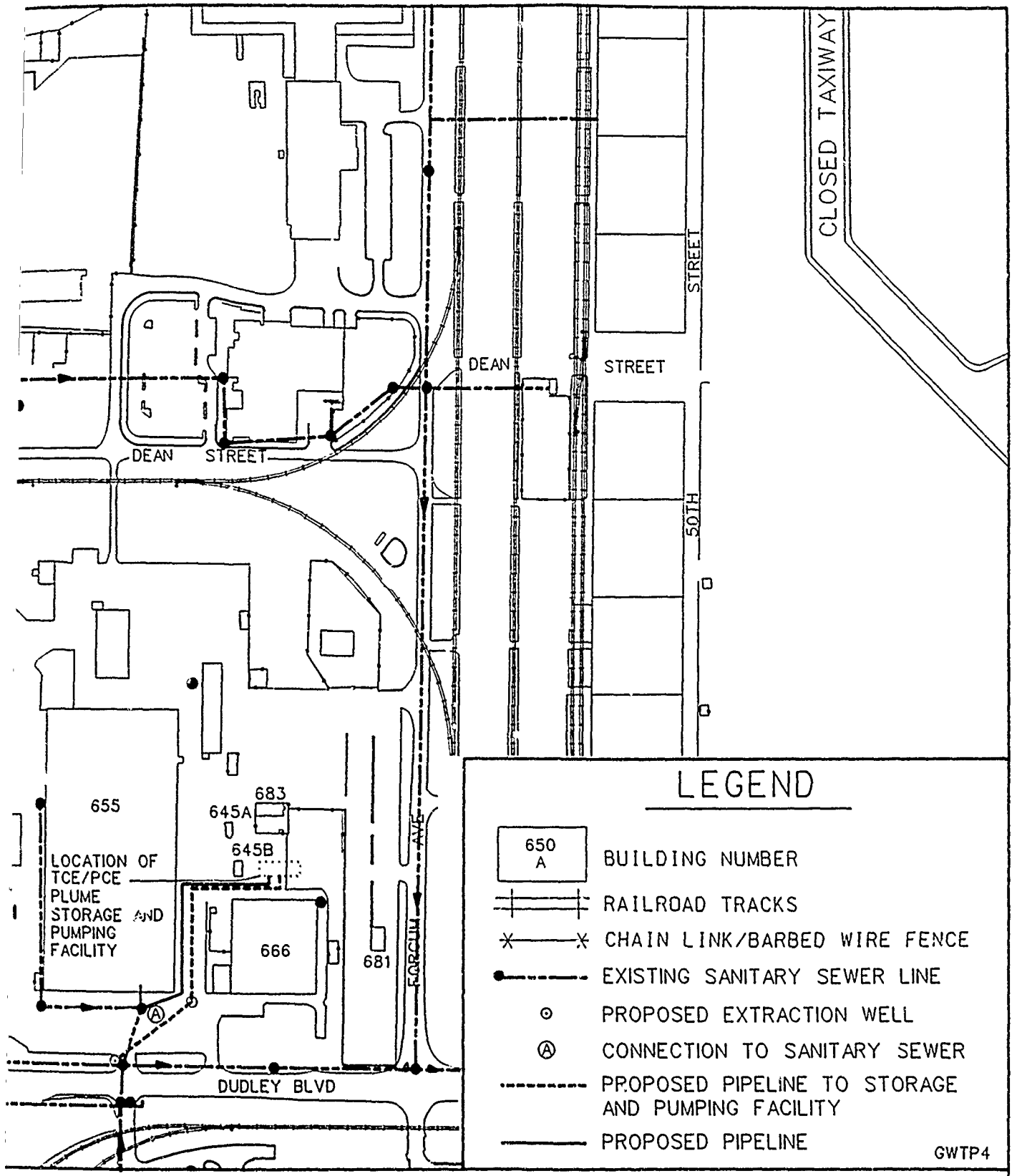

Figure 6-7. Proposed Pipeline Route to Sanitary Sewer.

Products generated by the SWTP include effluent water and process sludge. The effluent is discharged to the Sacramento River. Process sludge is first sent to on-site facultative treatment ponds and stored there for five years. After this period, the sludge is moved to an on-site land farm.

Performance. This alternative is very reliable in that both conveyance by pipeline and the quality of the water to be discharged to the sanitary sewer meets the pretreatment standards applied to IWL discharges. Therefore, this discharge is not expected to upset the SWTP treatment processes or to result in the SWTP exceeding its effluent discharge requirements.

Once complete, this alternative would provide immediate results; removal of contaminated groundwater will minimize exposure to local groundwater and reduce migration of contaminants off-base.

Implementability. The construction and operation of a pipeline to convey groundwater to a local sanitary sewer access cover is a readily implemented task, given the relatively short length of piping necessary to connect pipelines from the TCE/1,2-DCE plume with the closest sanitary sewer.

The installation of a pipeline between the plume extraction well facilities to the sanitary sewer would require approximately six months to complete, given the relatively short length of piping required. The time required to install extraction wells, equalization tank, booster pumps, and to integrate all of the components of this alternative could require an additional two months.

Safety. There are no special safety considerations for the construction and operation of this alternative.

Regulatory and Institutional Concerns. The ARARs that may be applicable to extraction and discharge to a sanitary sewer include:

- Sacramento County building permit;
- Sacramento County Sanitary District sewer use permit; and
- Sacramento County Air Quality Management District permit.

Specific McClellan AFB rules regarding land access and usage may also be relevant. It is anticipated that this alternative can comply with the identified ARARs.

Costs. Cost estimates for capital and O&M costs are presented in Table 6-13.

Extraction Wells to IWTP Discharge

This alternative consists of the use of an extraction well system in the northern TCE/1,2-DCE plume to intercept contaminated groundwater. The extracted groundwater will then be transported directly from flow equalization tanks located near the extraction well field to the closest accesible base IWL access cover. The groundwater will not be treated prior to discharge into the IWL. Figure 5-6 presents a schematic of the proposed pipeline routes from both the northern TCE/1,2-DCE plume and TCE/PCE plume to the nearest IWL inlet.

The IWL access covers are part of a basewide system which transports collected wastewater to the base IWTP. At the IWTP, influent wastewater is treated using a variety of treatment processes as described in Section 5.3.1.

Once treated, the effluent wastewater is discharged to the Dry Creek interceptor at Rio Linda Boulevard. From there, the wastewaters travel to the SWTP, which eventually discharges into the Sacramento River.

Products Generated. No products are generated from the use of the pipeline technology. A leak in the pipeline from the tanks to the sewer access cover would result in the spilling of contaminants onto the ground; however, the pipeline, if constructed, may have incorporated a leak detection program to minimize the possibility of leakage. This design is based on conservative engineering practices and not on any legal requirements.

Products generated by the IWTP include effluent water and process sludge. The effluent is discharged to the interceptor line as described above. Process sludge is disposed of at appropriate on and off-base disposal facilities.

Performance. This alternative is very reliable in that both conveyance by pipeline and the quality of the water to be discharged meet the pretreatment standards applied to IWL discharges. Therefore, this discharge is not expected to upset the SWTP treatment processes or to result in the SWTP exceeding its effluent discharge requirements.

TABLE 6-13. ESTIMATED COSTS FOR ALTERNATIVE 2 -- EXTRACTION WELLS PIPELINE TO SANITARY SEWER

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$200,000	$17,000
B.	Conveyance			
	Piping		1,000	6,000
	Elbows		100	
	Holding Tank		47,000	
	Pumps	1 Feed	3,000	1,000
		2 Sump	1,000	
	Jacking Pits		10,000	
	Horizontal borings		0	
			$ 62,000	$ 7,000
C.	Treatment	76,000 339,000	0	0
D.	Discharge -- Sanitary Sewer		$243,000	$ 87,000
E.	Other Direct Costs[1]			
	Site Work	10%	6,000	
	Piping/Valving	5%	3,000	
	Instrumentation	10%	6,000	
	Controls	5%	3,000	
	Electrical	10%	6,000	
	Contingency	25%	15,000	
	Contractor	15%	9,000	
	Engineering	10%	6,000	
			$54,000	0
	TOTAL COSTS:		$559,000	$111,000
	PRESENT WORTH COSTS[2]:		$8,350,000	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

Once complete, this alternative would provide immediate results; removal of contaminated groundwater will minimize exposure to local groundwater and reduce migration of contaminants off-base.

Implementability. The construction of a pipeline to convey groundwater from the extraction well facilities to a local IWL access cover is a readily implementable task, given the relatively short length of piping necessary to connect pipelines from the flow equalization tanks to the closest IWL access cover.

The IWTP is currently operating at fifty percent of its maximum capacity and can therefore easily accommodate the increase of 155 gpm of flow created by groundwater from the northern TCE/1,2-DCE plume in its treatment influent. However, during peak demand periods, such as during severe storm events, the system capacity has been exceeded. It is a possibility that during severe storm events, the groundwater extraction wells will be shut down to avoid discharging when the system capacity has been exceeded.

Safety. There are no special safety considerations for the construction and operation of this alternative.

Regulatory and Institutional Concerns. The ARARs that may be applicable to extraction and discharge to a sanitary sewer include:

- Sacramento County Building Permit;
- Sacramento County Sanitary District sewer use permit; and
- Sacramento Metropolitan Air Quality Management District permit.

The current Sacramento County Sanitary District sewer use permit for McClellan AFB may require modification or reissuance. Obtaining the other listed permits is not required according to Section 19.1 of the McClellan AFB Interagency Agreement. However, the standards, requirements, criteria, or limitations of these permits must be satisfied.

Costs. Cost estimates for capital and O&M costs are presented in Table 6-14.

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TABLE 6-14. ESTIMATED COSTS FOR ALTERNATIVE -- EXTRACTION WELLS PIPELINE AND DISCHARGE TO IWL

			CAPITAL	O&M
A.	Extraction/Monitoring Wells		$200,000	$17,000
B.	Conveyance			
	Piping (550')		3,000	6,000
	Elbows (7)		100	
	Holding Tank		47,000	
	Pumps	1 Feed	3,000	1,000
		2 Sump	1,000	
	Jacking Pits		20,000	
	Horizontal borings		25,400	
			$ 99,000	$ 7,000
C.	Treatment -- None		0	0
D.	Discharge -- IWL		0	786,000
E.	Other Direct Costs[1]			
	Site Work	10%	10,000	
	Piping/Valving	5%	5,000	
	Instrumentation	10%	10,000	
	Controls	5%	5,000	
	Electrical	10%	10,000	
	Contingency	25%	25,000	
	Contractor	15%	15,000	
	Engineering	10%	10,000	
			$ 90,000	0
	TOTAL COSTS:		$389,000	$810,000
	PRESENT WORTH COSTS[2]:		$2,403,470	

[1] Other direct costs were estimated based on percentages of the combined costs for Items B and C.
[2] Present worth costs were calculated based on a 10% discount rate and a three-year operation.

IWL = Industrial Wastewater Line.

6.3.3 Preliminary List of Removal Action Alternatives for the Northern TCE/1,2-DCE Plume

Six primary alternatives were identified for mitigating the contaminated groundwater in the northern TCE/1,2-DCE plume. In addition, other alternatives were developed from these primary alternatives by considering the several available options to discharge the groundwater. The six primary alternatives determined to be the most feasible for the northern TCE/1,2-DCE plume are presented below.

- ALTERNATIVE 1: (Alternative 1 as shown on Table 6-15.) Extraction wells, conveyance of groundwater by piping to the IWL, treatment at the IWTP and subsequent discharge into the SRCSD interceptor system and Regional Treatment Plant.

- ALTERNATIVE 2: (Alternative 2 in Table 6-15.) Extraction wells and direct conveyance of groundwater by piping to a sanitary sewer and discharge into the SRCSD interceptor system and Regional Treatment Plant.

- ALTERNATIVE 3: (Alternatives 3a and 3b on Table 6-15.) Extraction wells, conveyance of groundwater by piping to GWTP, and a surface water discharge to Magpie Creek.

- ALTERNATIVE 4: (Alternatives 4a, 4b, 4c, and 4d on Table 6-15.) Extraction wells, conveyance of groundwater by piping to a local UV/ozone/peroxide treatment system, conveyance of treated groundwater by pipeline and discharge to one of three discharge points: Magpie Creek (surface water discharge), a reinjection well, or sanitary sewer.

- ALTERNATIVE 5: (Alternatives 5a, 5b, 5c, and 5d on Table 6-15.) Extraction wells, conveyance of groundwater by piping to a nearby air stripping and vapor phase GAC treatment system,conveyance and discharge to one of three discharge points: Magpie Creek (surface water discharge), a reinjection well, or sanitary sewer.

Table 6-15. PRELIMINARY ALTERNATIVE LIST FOR THE NORTHERN TCE/1,2-DCE PLUME OPERABLE UNIT B, McCLELLAN AFB, CALIFORNIA

Alt. No.	Description
1	Groundwater extraction wells conveyance by pipeline and discharge to the IWL.
2	Groundwater extraction wells conveyance by pipeline and discharge into the sanitary sewer, SRCSD interceptor system, and Regional Treatment Plant.
3a	Groundwater extraction wells conveyance by pipeline to GWTP and discharge to Magpie Creek.
3b	Groundwater extraction wells conveyance by truck transport to the GWTP and discharge to Magpie Creek.
4a	Groundwater extraction wells conveyance by pipeline to local UV/ozone/peroxide treatment system and discharge to the IWL.
4b	Groundwater extraction wells conveyance by pipeline to local UV/ozone/peroxide treatment system and discharge to the sanitary sewer, SRCSD interceptor system, and Regional Treatment Plant.
4c	Groundwater extraction wells conveyance by pipeline to local UV/ozone/peroxide treatment system and reinjection of treated groundwater.
4d	Groundwater extraction wells conveyance by pipeline to local UV/ozone/peroxide treatment system and discharge to Magpie or Arcade Creek.
5a	Groundwater extraction wells conveyance by pipeline to local Air Stripping/GAC adsorption treatment system and discharge to the IWL.
5b	Groundwater extraction wells conveyance by pipeline to local Air Stripping/GAC adsorption treatment system and discharge to the sanitary sewer, SRCSD interceptor system, and Regional Treatment Plant.
5c	Groundwater extraction wells conveyance by pipeline to local Air Stripping/GAC adsorption treatment system and reinjection of treated groundwater.
5d	Groundwater extraction wells conveyance by pipeline to local Air Stripping/GAC adsorption treatment system and discharge to Magpie or Arcade Creek.
6	Groundwater extraction wells conveyance by pipeline to local aqueous phase GAC adsorption treatment system and discharge to the IWL.

- ALTERNATIVE 6: (Alternative 6 on Table 6-15.) Extraction wells, conveyance of groundwater by piping to a nearby aqueous phase GAC treatment system, conveyance and discharge of treated waters to the IWL, a reinjection well, or sanitary sewer.

6.3.4 Environmental Impacts from the Northern TCE/1,2-DCE Plume Proposed Action

Three extraction wells, a pipeline to the sanitary sewer, and a pipeline to the existing on-base GWTP will be constructed. The construction and operation of these facilities may impact one or more of the following environmental areas of concern:

- Vegetation and wildlife;
- Air quality and noise; and
- Public health and safety.

The following sections evaluate the potential impacts of the construction and operation of the EE/CA-EA facilities to each of the areas listed above.

Vegetation and Wildlife

The project area has been developed for industrial and commercial enterprise and has interspersed annual grasslands/old-field habitats. The EE/CA-EA construction activities will result in the loss of an insignificant amount of annual grassland. This small loss is not considered significant because this type of vegetation is widespread and not threatened in California. Wildlife nesting and forging in the area may be disrupted during the installation of the extraction wells and pipeline.

Air Quality Noise

During construction of the extraction wells and pipelines for the EE/CA-EA project, exhaust emissions from the construction vehicles and equipment will temporarily impact the air quality in the immediate vicinity of the construction activities. However, the volume of these emissions will be low and the exhaust will be emitted for a relatively short duration. Dust control measures will be implemented during construction as necessary to minimize the impact of particulates on the air quality. During the operation of the groundwater extraction system and the pipeline conveyance

system to the sanitary sewer or the GWTP, no significant air quality impacts are expected.

Noise will be generated during the construction of the extraction wells and pipelines. However, the EE/CA-EA facilities will be constructed on-base in an industrial area; the only potentially sensitive receptors are the residents that live near the western boundary of the base near the proposed extraction well locations. This noise impact can be minimized by limiting construction to daylight hours. To minimize the noise impact on the personnel operating the construction equipment, ear protection devices will be supplied as necessary. During the operation of the EE/CA-EA facilities, no significant noise production is expected.

Public Health and Safety

Construction of the extraction wells and pipelines will occur on base so potential health and safety impacts are limited to on-base personnel. Potential health and safety impacts include the air quality and noise impacts discussed above as well as the potential hazards posed by open excavations and contaminated soil. The hazards posed by open excavations (or boreholes) will be minimized by clearings, markings, and barricades. Human exposure to contaminated soil will be minimized by containment in enclosed bins and storage in designated areas prior to proper disposal.

Abandonment of production wells will create an open excavation hazard for small children. The construction area is away from base housing and fenced off from the public, thereby reducing potential access to the area by small children. Barricades or obstacles will be placed around or over open wells if left in that condition overnight.

6.4 Evaluation of No Response Alternative

If the No Response option is selected, no groundwater extraction wells will be installed, no local or remote treatment of the contaminated groundwater will be performed, and no disposal of contaminated or treated groundwater will be necessary. However, groundwater contaminant plumes from OU B that are currently migrating toward water supply wells, Base Well 18 (on-base) and City Well 132 (off-base), will continue to migrate unchecked toward these water supply wells. The distribution of contaminants in the on-base and off-base areas is shown in Figures 1-13, 1-14, 1-15, 1-16, and 1-17 (see Section 1.1.7). Analytical data gathered from on-base monitoring wells in

OU B indicate that a suite of VOCs are present within each of the five geohydrologic zones in OU B. In the off-base areas, three zones, A, B, and C, are known to contain VOCs. The three plumes, the TCE/PCE plumes, the TCE/1,2-DCE plume, and the PCE plume are shown in Figure 1-11 with isopleths of total VOC concentration.

The contaminants in the on-base and off-base plumes occur in concentrations that exceed U.S. EPA and California Department of Health Services (DHS) Maximum Contaminant Levels (MCLs) for drinking water. Although contaminants with concentrations exceeding federal and state drinking water standards have not yet entered City of Sacramento or McClellan AFB water distribution lines, the potential for contaminants to enter water supply wells will increase as contaminants continue to migrate from sources in OU B toward the water supply wells. This in turn will increase the potential threat of human exposure to dissolved contaminants in the groundwater from the water supply wells. For this reason, the No Response alternative has been eliminated from further consideration.

Certain benefits would be realized by not responding in accordance with the proposed actions. Such benefits include no air quality impacts from construction equipment operation, no disruption of traffic patterns during construction, and no use of electric power to operate pumps and treatment facilities.

7.0 PERSONS AND AGENCIES CONSULTED DURING THE PREPARATION OF THE OPERABLE UNIT B ENGINEERING EVALUATION/COST ANALYSIS-ENVIRONMENTAL ASSESSMENT (EE/CA-EA)

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Glen DelSarto
County of Sacramento
Department of Public Works

Mike Crooks
California Department of Health Services
Public Water Supply Branch

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APPENDIX A

GROUNDWATER REMEDIAL INVESTIGATION

A1.0 INTRODUCTION

The Operable Unit B Groundwater Remedial Investigation (OUBGRI, formerly called the ABGOURI) began in March 1989 with the drilling and construction of new monitoring wells. The field investigation continued through May 1990 when the forty-first new well was constructed, sampled, and analyzed. The OUBGRI was conducted as part of the Air Force Installation Restoration Program (IRP) and the Remedial Investigation Feasibility Study (RI/FS) in compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the Superfund Amendment and Reauthorization Act (SARA).

The OUBGRI was initiated as an expedited portion of the basewide Preliminary Groundwater Operable Unit Remedial Investigation (PGOURI) that was described in the PGOURI Sampling and Analysis Plan (1990). The principal objectives of the PGOURI are characterization of hydrogeologic conditions and definition of the extent of groundwater contamination between McClellan Air Force Base (AFB) and adjacent off-base areas. The investigation of groundwater in Operable Unit (OU) B was expedited because it was known that contaminants existed in groundwater beneath off-base areas and southerly groundwater flow directions indicated potential migration to municipal supply wells.

The OUBGRI was implemented to define the extent of off-base groundwater contamination and to determine if the contaminant migration was to off-base water supply wells. After nineteen monitoring wells at six locations with screen intervals in five geohydrologic zones had been constructed, sampled, and analyzed, it was concluded that dissolved volatile organic contaminants were migrating in groundwater toward a McClellan AFB supply well and municipal supply wells beneath OU B. On the basis of that conclusion, the Air Force initiated an Engineering Evaluation/Cost Analysis-Environmental Assessment (EE/CA-EA) for groundwater removal actions in OU B.

In conjunction with the EE/CA-EA, eleven additional OUBGRI monitoring wells were constructed, sampled, and analyzed to determine the distribution of contaminants in the geohydrologic zones and to evaluate zonal characteristics that would affect the selection of removal actions. Fifteen additional monitoring wells were constructed in or near OU B under the PGOURI field program which began in September 1989. Additional data used to evaluate contaminant distribution and groundwater migration for the remedial investigation and EE/CA-EA were compiled

from the Ground Water Sampling and Analysis Program (GSAP) for McClellan AFB. The GSAP program includes quarterly measurements of water levels and volatile organic compound analyses of groundwater samples from monitoring wells in OU B.

To evaluate the horizontal and vertical extent of contaminants in groundwater, the geologic, hydrologic, and chemical data of subsurface deposits were compiled from the OUBGRI, PGOURI, GSAP, and previous investigations. Proposed removal actions, expedited response actions, and other investigative actions presented in Section 3 of the EE/CA-EA report and in Appendix A are based upon the conclusions reached from analysis of the compiled data. The following sections explain the interpretation of the data that led to those conclusions.

A2.0 FIELD INVESTIGATIONS

Field activities for the Operable Unit B Groundwater Remedial Investigation (OUBGRI) were completed from March to May 1989 and from September to December 1989. Five pilot holes were drilled and geophysically logged, and nineteen monitoring wells were installed and sampled for groundwater analysis during the first phase of the investigation. From September to December 1989, one additional pilot hole was drilled, four piezometers were constructed, and ten new monitoring wells were installed and sampled. Data were also obtained from the drilling of thirteen wells in Operable Unit (OU) B and OU C under a separate investigation, the Preliminary Groundwater Operable Unit Remedial Investigation (PGOURI). Ten aquifer tests were performed on various saturated zones at locations within OU B. All pilot holes and monitoring wells from which data were obtained for hydrogeologic or contaminant distribution analyses are presented in Figure A2-1.

During the course of the OUBGRI, six geohydrologic zones were identified in subsurface levels beneath OU B. The zones, designated A, B, C, D, E, and F, are monitored for groundwater levels and contaminant concentrations. Most of the monitoring wells screened in the A through F zones have 10-foot screen intervals; some of the A zone wells have 20-foot screen intervals. The characteristics and basis for selection of zones is described in Section A3.0., Hydrogeological Results.

The OUBGRI was implemented to determine the potential for contaminant migration to off-base municipal water supplies. A staged approach to monitoring well placement was implemented during the first phase of the OU B investigation. The intent of the staged approach was to determine the vertical extent of groundwater contamination at any particular location by completing wells at both shallow and successively greater depths. To accomplish this, the C well in the well clusters was the first to be drilled, installed, and sampled for volatile organic analysis. If a C zone well had detectable contamination, a D zone well was drilled at that location; if the D zone well had contamination, an optional E zone well was placed. No F geohydrologic zone wells were constructed during the OUBGRI. However, one was constructed in OU B for the PGOURI program in 1990 because a sample from the E zone well, Monitoring Well (MW) 168, had detectable concentrations of volatile organic compound (VOC) contaminants. Regardless of the sample results of the wells in the C, D, and E zones, A and B wells were placed at most of the clusters.

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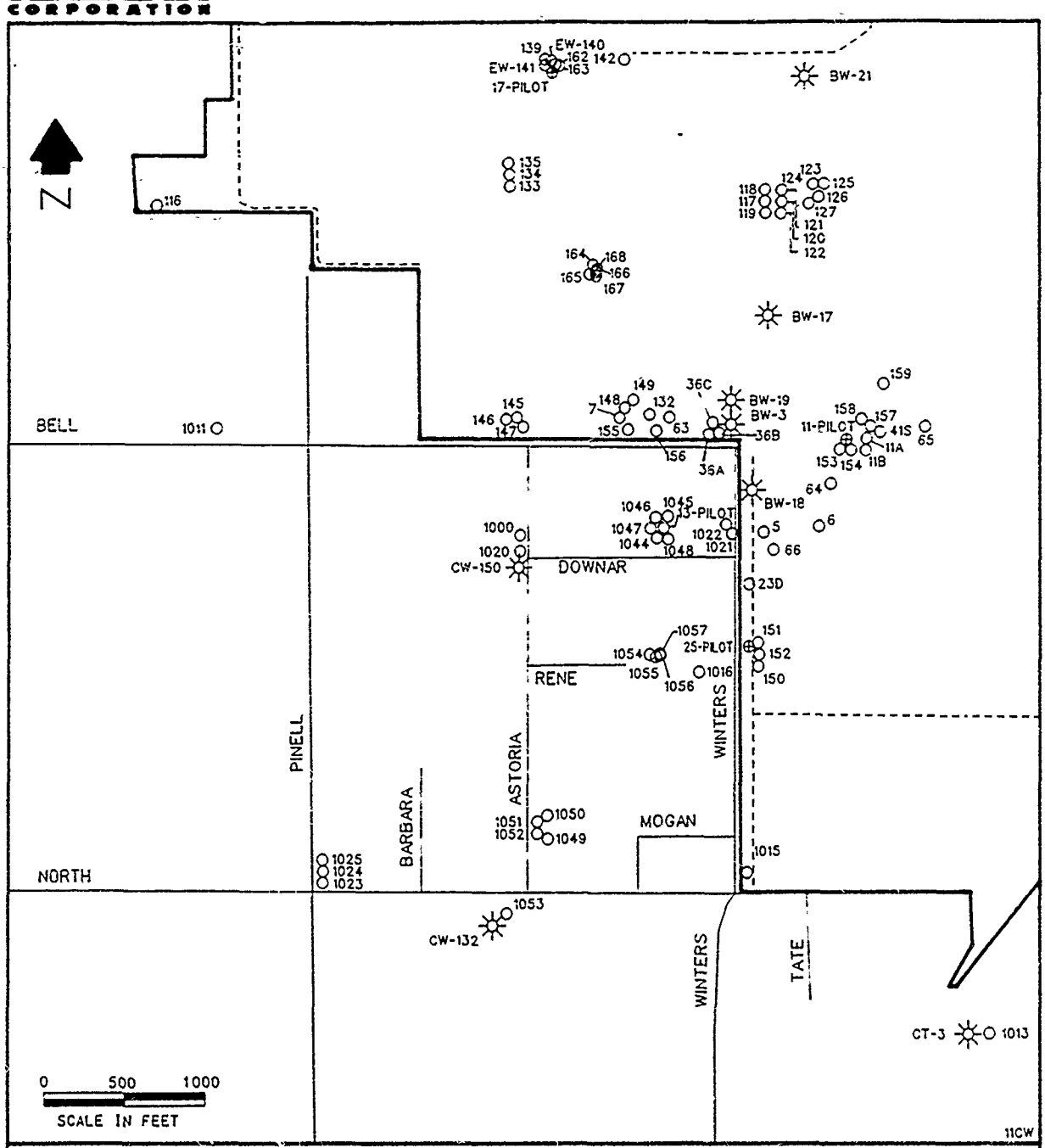

LEGEND:

——— McCLELLAN AFB BOUNDARY	⊕ PILOT HOLES	EW	EXTRACTION WELL
☼ WATER SUPPLY WELLS	CW	CITY OF SACRAMENTO WATER SUPPLY WELL
- - - - - - - - STREAMS/CREEKS	○ MONITORING WELLS		
	BW BASE WATER SUPPLY WELL	CT	CAL-TRANS WELL

Figure A2-1. Location of New Well Clusters and Existing Wells.

On the basis of data obtained from the initial OUBGRI, ten additional monitoring wells and four piezometers were installed to further characterize off-base groundwater contamination, contaminant migration at base boundaries, and contaminant migration at MW-41S. Aquifer tests were conducted to determine hydraulic parameters for the A, B, C, and D geohydrologic zones at the base boundaries, for the A and B geohydrologic zones at off-base locations and for the A zone. The cluster emplacement procedures described above were not used for the second phase of the investigation. The data obtained during the initial investigation allowed monitoring wells to be installed to target depths at specific locations where further characterization of contaminants and groundwater flow were necessary. Only one monitoring well cluster (MW-1054, MW-1055, MW-1056, and MW-1057) was emplaced in an off-base location during the second phase of the OU B investigation. The pilot hole drilled for this cluster was converted to a D zone monitoring well, MW-1057. Subsequently, A, B, and C zone wells were installed at this location. The remainder of the monitoring wells in the second phase of the investigation were installed in the A geohydrologic zone, except for one B zone well installed near the east-west portion of the southern base boundary.

The OUBGRI and subsequent investigations resulted in the construction of:

- Thirteen A zone wells: MWs 11A, 36A, 145, 150, 153, 155, 157, 158, 159, 164, 1044, 1049, and 1053;
- Nine B zone wells: MWs 11B, 36B, 146, 151, 156, 165, 1045, 1050, and 1055;
- Eight C zone wells: MWs 36C, 147, 152, 154, 166, 1046, 1051, and 1056;
- Six D zone wells: MWs 148, 162, 167, 1047, 1052, and 1057;
- Four E zone wells: MWs 149, 168, 163, and 1048; and
- One F zone well: MW-21F, all of which are in or adjacent to OU B.

The location of OUBGRI, PGOURI, and previously constructed monitoring wells in OU B are shown in Figure A2-2, A geohydrologic zone; Figure A2-3, B

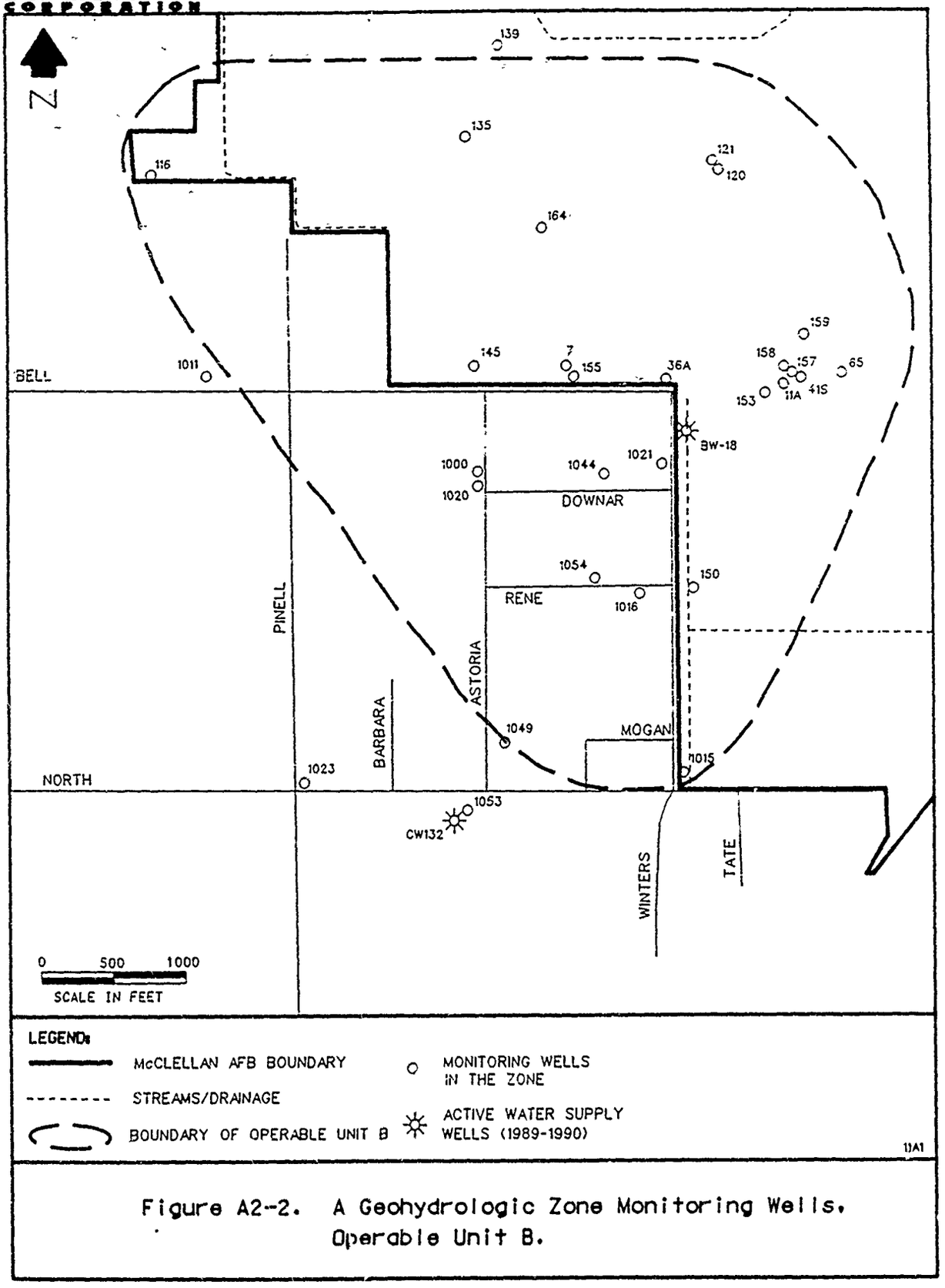

Figure A2--2. A Geohydrologic Zone Monitoring Wells, Operable Unit B.

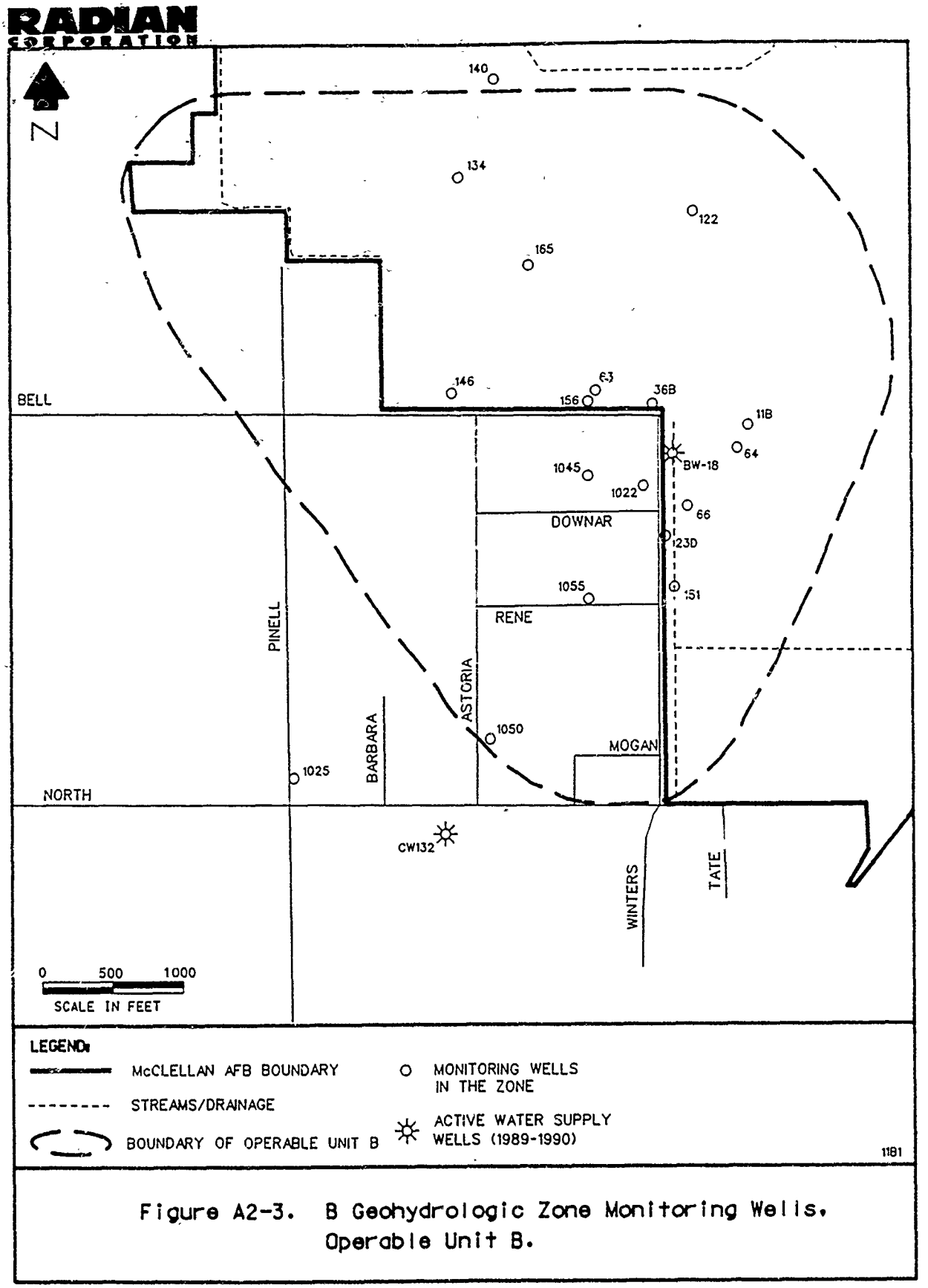

Figure A2-3. B Geohydrologic Zone Monitoring Wells, Operable Unit B.

geohydrologic zone; Figure A2-4, C geohydrologic zone; Figure A2-5, D geoghydrologic zone; and Figure A2-6, E geohydrologic zone. The F zone well is not shown in a figure but was constructed adjacent to MWs 163 and 168. Depths and screen intervals for all monitoring wells are presented in Table A2-1 (page A2-40).

A2.1 Monitoring Well Drilling and Construction

The following sections describe drilling methodologies, monitoring well installation, and post-drilling activities. Radian Corporation received notice to proceed with this activity on 2 February 1989; field work commenced on 3 March 1989. The second phase of the investigation was performed on an expedited schedule; field activities began on 6 September 1989 and were completed on 20 December 1989.

A2.1.1 Rights-of-Entry, Permits, and Clearances

Monitoring wells are located on private and off-base land parcels and on McClellan AFB property. The U.S. Army Corps of Engineers obtained a Right-of-Entry for construction of each off-base site; all of the off-base sites were checked by Underground Services Alert to ensure that underground utilities would not be damaged during well installation or present a hazard to the field personnel. Wells installed on base required an Air Force excavation permit, which was obtained by McClellan AFB Environmental Management (EM).

All groundwater monitoring wells drilled and installed outside the McClellan AFB boundary required a water well permit from the Sacramento County Health Department. During well installation, the Sacramento County Health Department was kept informed of the drilling schedule, so that well completion activities could be inspected.

A2.1.2 Drilling Methods

All drilling and well installation activities were supervised by a Radian geologist and overseen by a California Registered Geologist. The rig geologist classified and logged the subsurface materials encountered in the borehole, supervised the installation of the monitoring well, and performed drill site health and safety monitoring. A portable organic vapor analyzer was used to monitor for the presence of volatile organic contaminants during drilling procedures. The wellhead, drill cuttings, breathing zone in the immediate work area, and ambient conditions were monitored.

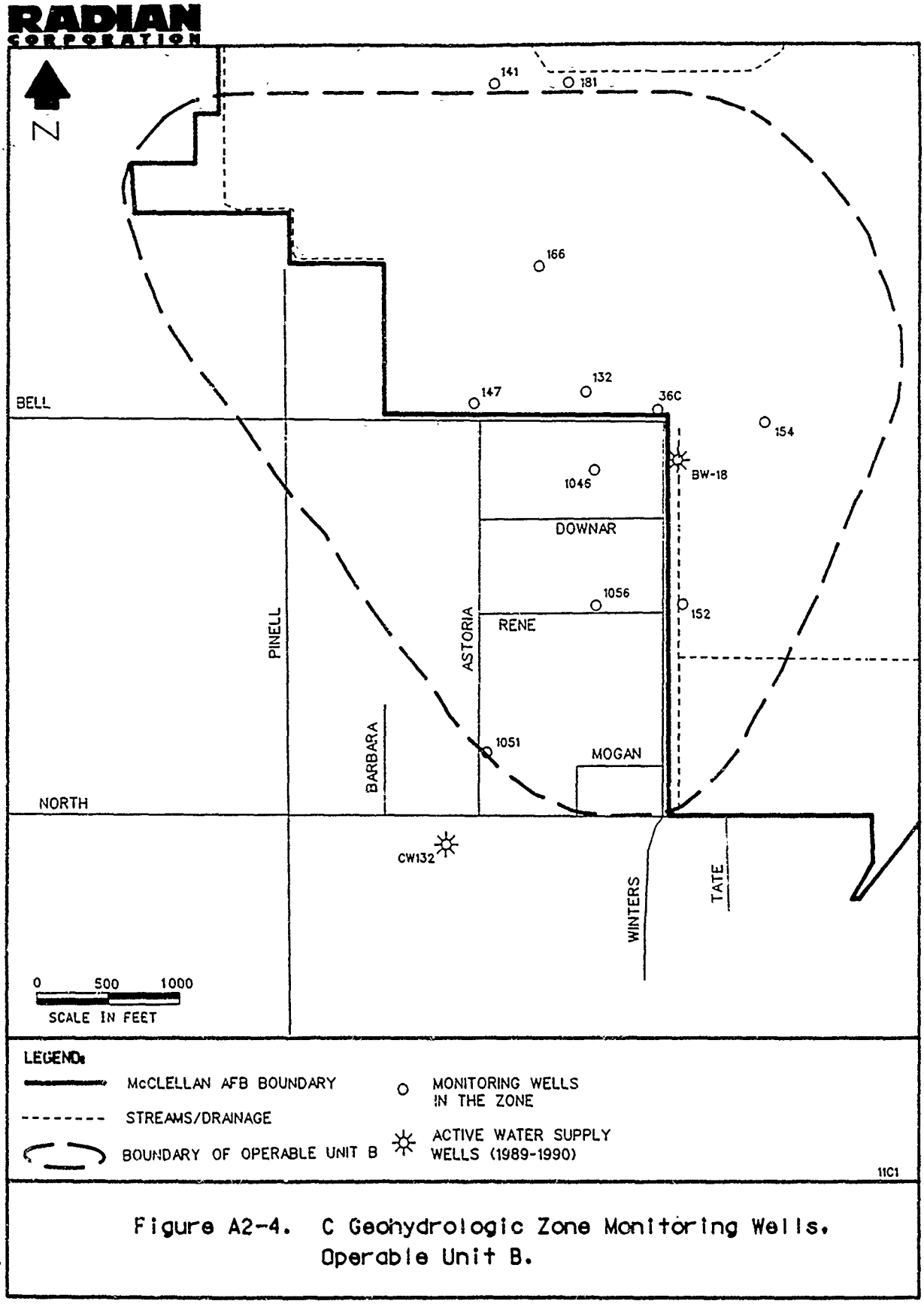

Figure A2-4. C Geohydrologic Zone Monitoring Wells. Operable Unit B.

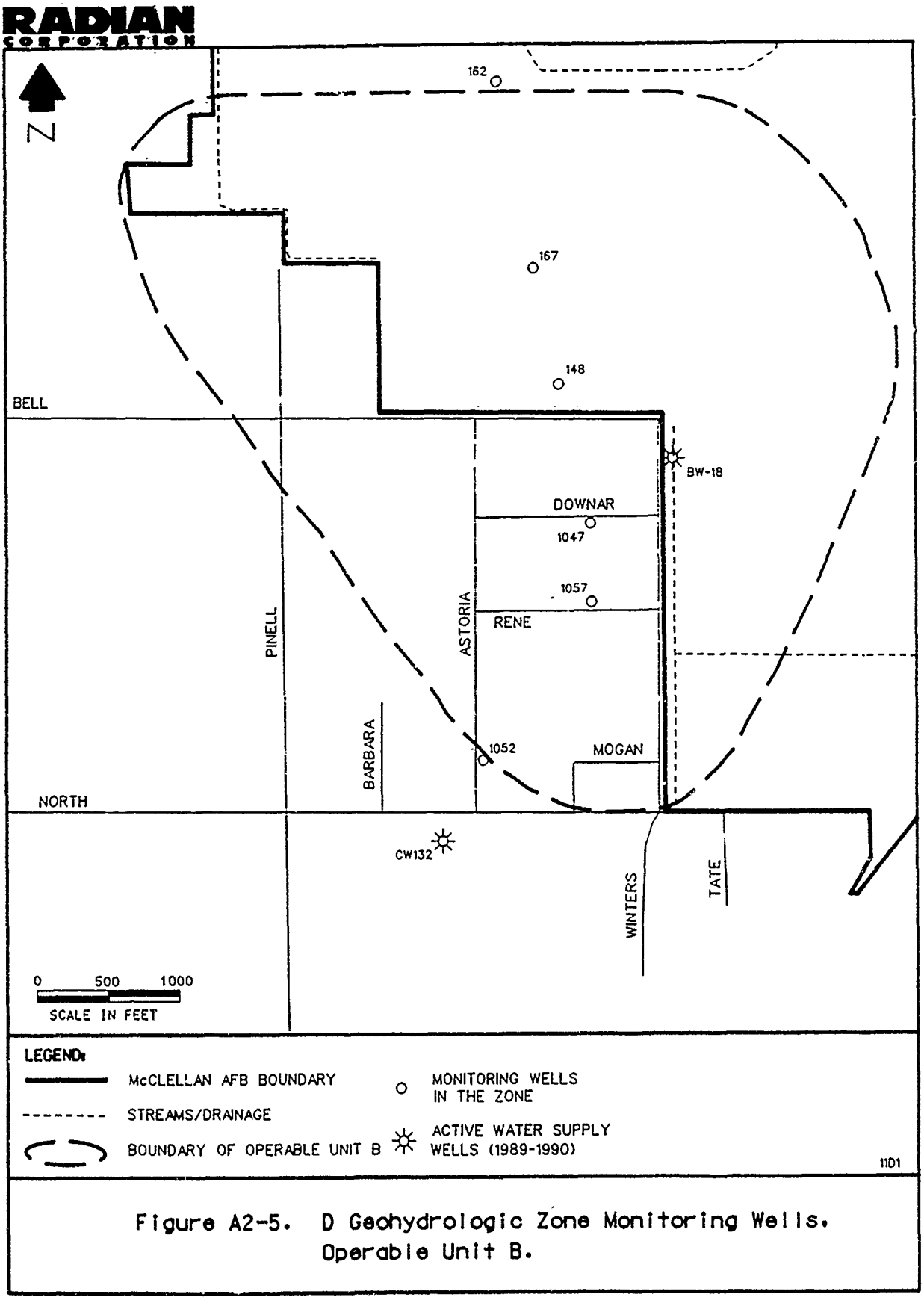

Figure A2-5. D Geohydrologic Zone Monitoring Wells. Operable Unit B.

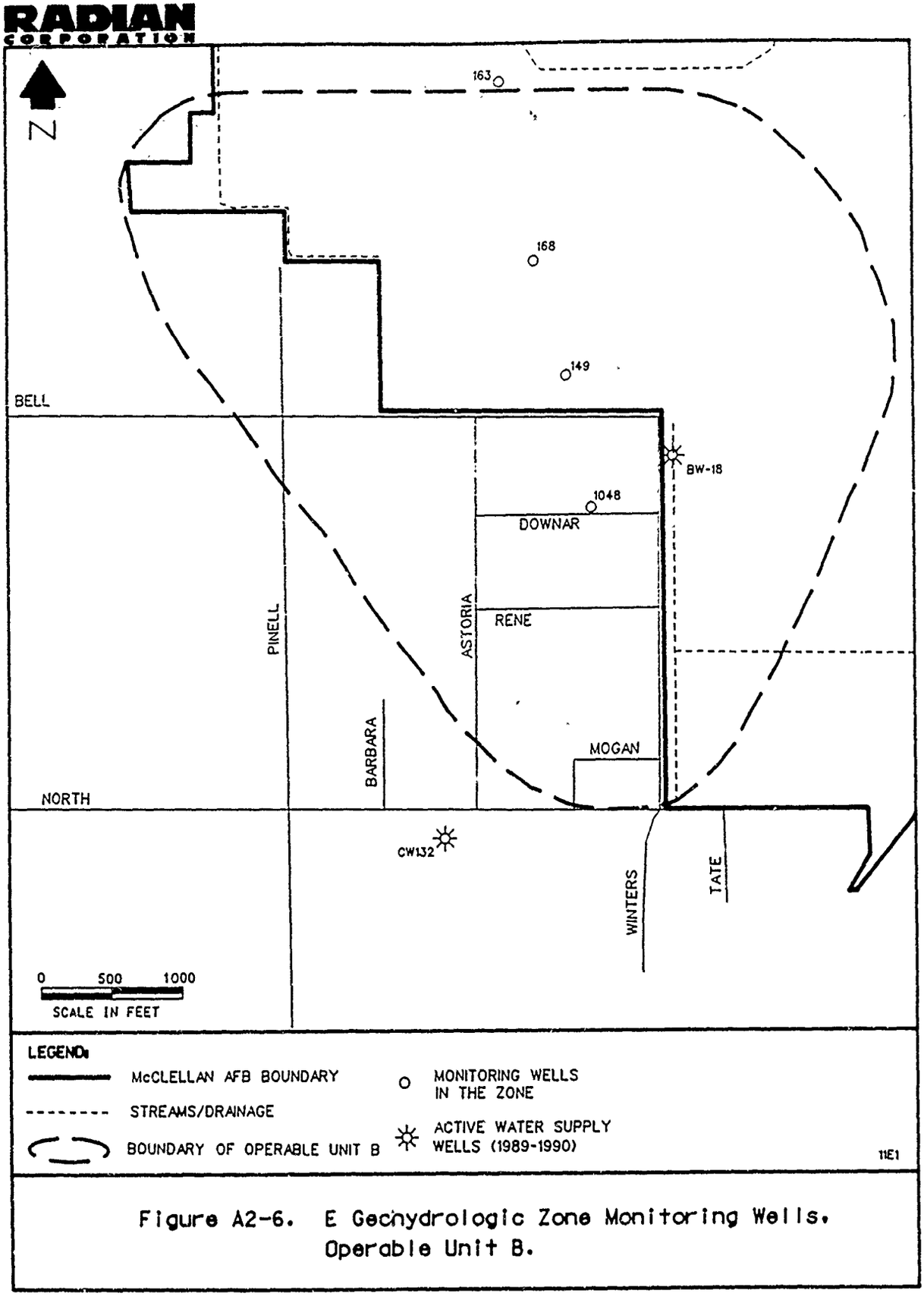

Figure A2-6. E Geohydrologic Zone Monitoring Wells, Operable Unit B.

Pilot holes (exploratory borings) were drilled by the direct mud rotary method. The mud-supported and uncased pilot holes allowed the geologists to run geophysical logs including resistivity, spontaneous potential, natural gamma ray, caliper, and declination logs. Evaluation of the electric logs from new pilot borings and from previous borings allowed for increased understanding of the local hydrostratigraphy and provided a basis for determining optimum screen interval elevations in the proposed wells.

The drilling mud and the cuttings were discharged to a separation table where sand and gravel were separated from the mud. The mud was then recirculated down the borehole. Drill cuttings were directed from the separation table into a 1-yard front-end loader bucket, which was dumped into a 20-yard-capacity metal holding and transportation bin. Drilling mud was collected and transported from drill sites by vacuum trucks, and contained in 4,000-gallon tanks. The rig geologist monitored continually drilling fluid weight, viscosity, and percent sand content, and observed the return of cuttings; samples were grabbed at two to five foot intervals for lithologic description as drilling progressed.

All boreholes for monitoring wells were drilled with air rotary-casing drive drilling equipment. During air rotary drilling, cuttings were discharged into a cyclonic separator which facilitated sampling, lithologic monitoring, and drill cuttings containment. Borehole cuttings generated during drilling were discharged into 20-yard roll-off bins located at the drill sites. Groundwater produced during drilling was collected by a vacuum truck. The sampling, transfer, and disposal of these materials is discussed in Section A2.1.5 of this appendix.

After completion of each well, all drilling tools, including drill bits, drill pipe, drive casing, etc., were decontaminated by steam cleaning at a designated site on McClellan AFB.

A2.1.3 Well Installation and Completion

The termination depth and screened interval for each monitoring well was determined by the supervising rig geologist in consultation with Air Force Occupational and Environmental Health Laboratory/Technical Services (AFOEHL/TS) and McClellan AFB EM engineers. The geophysical logs from the pilot boring in any cluster, in combination with the lithologic log for the well being drilled, were used to determine the depth of the screen interval. A pilot boring was not drilled and

geophysically logged at the following monitoring well locations: MWs 11A, 11B, 148, 149, 155, 156, 157, 158, 159, and 1053. For these locations, geophysical logs from nearby borings were used to select appropriate screen intervals.

A summary of well completion depths and materials used in construction of each well is presented in Table A2-1 (page A2-40). The materials used include stainless steel screen, flush joint threaded polyvinyl chloride (PVC) and stainless steel casing, low carbon or mild steel casing, stainless steel casing centralizers, sand pack, sand bridge, non-beneficiated bentonite, and cement-bentonite seals. The stainless steel casing was used for that portion of the monitoring well that lies below the water table. Low carbon steel and PVC casing were used where well casing passes through the vadose zone. Each well drilled and constructed at a depth below approximately 200 feet was completed with 4-inch inside diameter, low carbon, steel water well casing from the top of the stainless steel casing (approximately 10 feet above the highest anticipated groundwater level) to the ground surface. Each well drilled and constructed at a depth less than or equal to approximately 200 feet was completed with 4-inch inside diameter, PVC water well casing from the top of the stainless steel casing to the ground surface. All screens and casings were cleaned at a designated on-base site by steam cleaning prior to installation.

A2.1.4 Monitoring Well Development

All groundwater monitoring wells were developed to remove any fine-grained sediment from the screen and improve the permeability of the sand pack and adjacent formation. Monitoring well development began approximately 30 to 48 hours following placement of the grout sanitary seal. Development consisted of bailing, surging, and pumping. The four piezometers installed during the second phase of the investigation were developed by bailing and surging.

Prior to development of each well, total depth and depth to the static water level were measured. Development was then initiated by bailing to remove sediment that accumulated inside the screen because of formation disturbance during drilling. Bailing was accomplished with a 10-foot-long, 2-inch diameter, 2.5 gallon-capacity steel bailer. Bailing continued until the sediment recovered from the well was a very small amount of fine material in the bottom of the bailer. After bailing, each well was surged with a close-fitting, vented, surge block. As a surge block was moved up and down inside a well casing, it forced water through the screen openings to eliminate any bridging of fine-grained material in the sand pack and adjacent formation. After surging

for several minutes, any material brought into the well was removed by additional bailings. The bailing and surging procedure was repeated until the amount of sediment entering the well was decreased to a level deemed acceptable to the supervising geologist.

Following bailing and surging, each well was pumped with a one-half horsepower electric submersible pump. Wells were pumped at discharge rates ranging from approximately 2.5 to 26.0 gallons per minute for time intervals of up to 2 hours. Monitoring Well 1057 was installed in a pilot hole drilled by the mud rotary method; therefore, an extended period of pumping was required to remove excess bentonite mud that may have entered the surrounding formation during drilling. Pumping intervals and discharge rates were dictated by the yield of each well, the amount of development required and, in the case of high yield, deeper wells, the maximum capability of the submersible pump. All wells were pumped until they produced clear, sediment-free water.

In addition to the minimum of three casing volumes removed during well development, approximate volumes equivalent to any clean water introduced from the surface during drilling or well construction were removed during well development. Following initial well development, the wells were sampled as described in Section A2.2.2.

A2.1.5 Characterization and Disposal of Borehole Cuttings, Drilling Mud, and Groundwater

American Environmental Management Corporation, a licensed hazardous waste disposal company under subcontract to Radian, transported and disposed of all drill cuttings and mud removed from the boreholes during the first phase of the investigation. Universal Engineering, Incorporated, a licensed hazardous waste management company, transported and disposed of these materials during the second phase of the OU B investigation and the PGOURI. The procedures for characterizing and disposing of borehole cuttings, drilling mud, and groundwater are discussed below.

Borehole cuttings generated during drilling were discharged into 20-yard capacity roll-off bins located at the drill sites. During drilling activities, the site geologist monitored the wellhead and the cuttings being discharged from the cyclonic separator into the roll-off bins for potentially hazardous vapors. For the purposes of disposal, all cuttings were considered hazardous and were transported to the Chemical Waste

Management Facility at Kettleman Hills with a California Department of Health Services (DHS) Hazardous Waste Manifest. A predisposal analysis using U.S. Environmental Protection Agency (U.S. EPA) Methods 6010, 8010, and 8020 was conducted on one bin of cuttings. The analysis indicated the cuttings contained barium and total chromium at concentrations of 99 milligrams per kilogram (mg/kg) and 25 milligrams per liter (mg/L), respectively. These concentrations do not exceed total Threshold Limit Concentrations for 10,000 mg/kg for barium and 500 mg/kg for total chromium that would indicate the cuttings were hazardous wastes. However, analyses for soluble concentrations of the metals were not performed, and as a precaution, they were disposed as hazardous wastes.

Bentonite drilling mud generated during drilling of the pilot holes was contained in tanks on base. To characterize the mud, analyses using U.S. EPA Methods 6010, 8010, and 8020 were conducted on each of the three tanks of accumulated drilling mud. Analyses indicated the first tank of mud had concentrations of barium (32.6 mg/L) and total chromium (8.6 mg/L); this material was sent with a California DHS Uniform Hazardous Waste Manifest and transported to Gibson Oil Recycling in Bakersfield, California. Analyses of the second tank of mud indicated that this material was transported to a quarry operated by Valley Rock, Incorporated, a state-approved mud disposal facility located in Orland, California. Analyses of the third tank of mud indicated it contained total chromium at a concentration of 5.5 mg/L; this material was sent with a DHS Hazardous Waste Manifest to the Kettleman Hills Class I landfill operated by Chemical Waste Management, Incorporated.

The metal concentrations obtained from analyses of drill cuttings and drilling muds did not indicate that the cuttings or muds were solid hazardous wastes under the Total Threshold Limit Concentrations criteria set by the DHS. The analytical values for barium and total chromium in three samples did approach or exceed Soluble Threshold Limit Concentrations of 100 mg/L and 5 mg/L, respectively for the metals. No soluble metal concentration analyses were performed, and it is unlikely that the metals in the cuttings and muds are entirely soluble. However, as a precaution, the Air Force decided to dispose of the cuttings and muds at a Class I disposal facility. The metals detected in the materials are unlikely to be the result of contaminant discharge to soils on McClellan AFB. The borings from which the cuttings and muds were taken are located in areas off-base or near McClellan AFB boundaries where no operations requiring the use of barium or chromium have occurred. The metal concentrations in the cuttings may be the result of dissolution of metals from mineral grains in the sample caused by acid extraction during analysis.

Groundwater generated during air rotary casing drive drilling was discharged into water-tight, 20-yard capacity, roll-off bins located at the drill sites. The water was then transferred by vacuum trucks to settling tanks located on McClellan AFB. The sediment-free water was then transported and disposed of at the McClellan AFB Industrial Wastewater Treatment Plant.

A2.1.6 Static Water-Level Measurements

Eight rounds of water level soundings were conducted in monitoring wells in the OU B during the field activities. Water levels were measured both during periods of time when Base Well (BW) 18 was operating and when it was not operating. The wells added additional data points to those normally measured on a quarterly basis to produce potentiometric surface maps. The monitoring well measurements used to derive potentiometric surface maps for hydrologic zones A, B, C, and D are presented on Tables A3-4 to A3-5. The potentiometric surface maps are presented and discussed in Section A3.2. Water level measurements taken at one well (MW-66) during the April 1989 sounding and two wells (MW-145 and MW-147) during the May 1989 sounding are suspected of being erroneous. No cause for error in the suspect readings have been determined, but the data are suspect when compared to water levels measured in nearby wells and to previous water level measurements in the same wells. The suspect data are presented here but were not used in hydrologic interpretations.

A2.1.7 Wellhead Survey

Hunter Land Surveying, a licensed surveyor, surveyed pilot holes and groundwater monitoring well locations and wellhead elevations to an accuracy of ± 1.0 feet and ± 0.01 feet, respectively. The survey crew notched the top of the north side of each well casing as a reference point for water level measurements. Wellhead elevations (referenced to National Geodetic Survey sea level datum of 1929) and horizontal coordinates (referenced to National Geodetic Survey, California Grid, Zone 2) are listed in Table A2-2. Wellhead elevations are also indicated on the well logs presented in Appendix D.

A2.2 Monitoring Well Sampling and Analysis

Groundwater from all new wells installed during the field investigations was sampled and analyzed during the course of the field activities. New monitoring wells constructed for the OU B investigation were incorporated into the quarterly

TABLE A2-2. SURVEY DATA FOR PILOT HOLES, WELLS AND PIEZOMETERS COMPLETED IN OU B DURING THE OPERABLE UNIT B REMEDIAL INVESTIGATION

Monitoring and Pilot Hole Well Number	North (ft)	East (ft)	Elevation at Top of Well Casing (ft msl)	Elevation at Ground Surface (ft msl)
MW-145	357777.8	2167234.7	59.50	60.32
MW-146	357776.3	2167208.8	59.27	60.32
MW-147	357777.0	2167260.2	59.49	60.34
P10	357775.5	2167288.6		60.19
MW-148	357816.1	2167908.0	64.01	62.03
MW-149	357830.9	2167901.9	64.24	62.53
MW-150	356363.9	2168701.7	57.22	57.99
MW-151	356442.8	2168701.4	57.01	57.91
MW-152	356404.7	2168701.5	56.82	57.95
P25	356431.9	2168698.2		57.88
MW-153	357603.2	2169237.9	61.93	62.52
MW-154	357602.9	2169282.9	61.52	62.44
P11	357604.8	2169270.7		62.56
MW-155	357766.61	2167911.81	63.56	61.5
MW-156	357769.82	2168137.38	63.34	62.4
MW-157	357758.81	2169419.17	62.63	63.5
MW-158	357804.07	2169355.80	62.96	63.9
MW-159	358053.00	2169513.70	63.35	64.3
MW-162	359877.67	2167467.73	56.97	
MW-163	359877.90	2167488.40	56.27	57.05
P17	359888.40	2167540.20	-----	57.43
MW-164	358716.36	2167683.51	61.68	62.46
MW-165	358695.67	2167682.82	61.90	62.64
MW-166	358733.36	2167684.59	61.78	62.48
MW-167	358674.33	2167682.35	61.83	62.64
MW-168	358652.88	2167681.92	62.05	62.82
P21	—	—	—	—
MW-181	359864.46	2167909.00	56.47	57.30
MW-200 (11A)	357714.39	2169342.57	63.03	63.81
MW-201 (11B)	357603.00	2169301.43	61.64	62.56
MW-36A	357715.80	2168534.40	61.92	62.75
MW-36B	357717.70	2168481.80	61.85	62.62
MW-36B	357717.60	2168463.00	61.77	62.58

Continued

TABLE A2-2. (Continued)

Monitoring and Pilot Hole Well Number	North (ft)	East (ft)	Elevation at Top of Well Casing (ft msl)	Elevation at Ground Surface (ft msl)
MW-1044	357047.8	2168115.3	62.14	62.70
MW-1045	357069.9	2168115.7	61.82	62.59
MW-1046	357107.7	2168115.6	61.56	62.22
MW-1047	357090.6	2168115.3	61.70	62.31
MW-1048	357032.6	2168115.7	61.90	62.74
P13	357063.0	2168130.8	----	62.57
MW-1049	355366.8	2167413.8	56.07	57.10
MW-1050	355384.4	2167423.1	56.08	57.10
MW-1051	355385.1	2167392.4	56.78	57.60
MW-1052	355385.2	2167377.2	57.03	58.10
MW-1053	354820.21	2166824.54	54.10	55.0
MW-1054	356393.97	2167985.18	54.95	55.5
MW-1055	356446.41	2167987.85	55.58	56.3
MW-1056	356430.46	2167987.84	55.30	55.8
MW-1057	356412.36	2167986.23	55.22	55.6
P12	355383.7	2167407.1	----	58.10
PZ-1	357779.57	2167927.06	60.71	61.2
PZ-2	357785.97	2168124.86	62.21	62.5
PZ-1000	355372.77	2167399.34	57.24	57.6
PZ-1001	355376.45	2167409.88	56.79	57.2

NOTE: Horizontal control was based on National Geodetic Survey, California Grid, Zone 2. Starting points are USCE #130, B-9, B-11, Water Tank West, Water Tank East, and Water Tank North. Coordinate values were furnished by McClellan AFB. Vertical control originated from National Geodetic Survey, Sea Level Datum of 1929. Level Line #112 and 1947 adjustment. Bench marks: 86 (USED), V1199 USC & GS, BM 7-20--US Bureau of Public Roads, and BM 12-31--County of Sacramento.

Groundwater Sampling and Analysis Program (GSAP). The sampling and analysis plan, and sampling methods implemented for the OUBGRI and PGOURI are briefly described below. Sampling, analysis, and quality assurance/quality control (QA/QC) procedures which were used during the sampling events are described in the Quality Assurance Project Plan (QAPP) for McClellan AFB (Radian, 1990c).

A2.2.1 Sampling and Analysis Plan and Rationale

Well clusters were installed in a staged approach for the first phase of the OU B investigation. As previously described, the intent of the staged approach was to determine the vertical extent of groundwater contamination at any particular location by completing wells at both shallow and successively greater depths. Each well was sampled once immediately after well development and analyzed by U.S. EPA Method 8010 for purgeable halocarbons. The samples were collected within approximately 48 hours after completion of each monitoring well. Samples were analyzed with a 24-hour turnaround time to allow timely decisions to be made about the drilling of any subsequent wells at each location. Several wells were resampled to verify initial sampling results.

Groundwater samples collected from monitoring wells installed during the second phase of the investigation were also analyzed for purgeable halocarbons by U.S. EPA Method 8010. The results of U.S. EPA Method 8010 analyses for all new monitoring wells installed during the OUBGRI are presented in Table A4-1, in Section A4-1.

Additional analyses were performed on groundwater samples collected from selected monitoring wells installed during the second phase of the investigation. These analyses include: purgeable aromatics, semivolatile organic compounds, phenols, metals and other major cations, common anions, alkalinity, total dissolved solids, total suspended solids, and total hardness. Additional organic analyses and metals analyses were performed to provide information on contaminant distribution. Several background water quality tests were performed to determine what impacts, if any, natural groundwater quality would have on remedial action alternatives. All laboratory analytical results for the OU B investigation are presented in the Appendix D. Monitoring wells constructed in OU B were resampled under the GSAP in the Fourth Quarter 1989 and/or the First Quarter 1990. Groundwater sample results for VOC analyses under GSAP are discussed in Section A4.0.

Samples of deposits from the A and B geohydrologic zones were recovered by coring at five borings drilled for piezometers or monitoring wells, PZ1000 (A zone near MW-1049), PZ1001 (B zone near MW-1050), PZ1 (A zone near MW-155), PZ2 (B zone near MW-156), and MW-158. These samples were analyzed for total organic carbon content and grain size distribution. Core samples were analyzed for total organic carbon to evaluate what impact natural organic content may have on contaminant migration velocities. Grain size distribution analyses were performed on core samples and from cuttings collected during the drilling of MW-11A locations to estimate effective porosity and determine filter pack design and screen slot sizes for potential extraction wells within the zones at these locations. Results of total organic carbon analyses are listed in Table A2-3. Grain size distribution are summarized in Table A2-4 and presented in Appendix D.

A2.2.2 Sampling Methods

The monitoring wells were initially sampled immediately following well development. Samples were collected using an open-top, 36-inch Teflon bailer in early 1989 and a closed-top, 36-inch Teflon bailer during subsequent sampling. The sampling, storage, documentation, and transport followed all procedures specified in the McClellan AFB QAPP (Radian, 1990c). These procedures, the standard operating procedure followed by the McClellan GSAP, were also employed on subsequent resampling of wells.

A2.3 Aquifer Testing

Aquifer testing was conducted within OU B to determine the hydraulic properties of and the hydraulic connection between geohydrologic zones. Tests were conducted by pumping new and existing wells for a period of 6 to 24 hours, while simultaneously monitoring water levels in the pumping well and in adjacent wells. The information obtained was used to calculate hydraulic properties needed to determine velocities of groundwater migration and, where removal actions are proposed, the optimum screen intervals, pumping rates and location, and zone of capture for possible extraction wells.

Previous aquifer testing within OU B was performed by McLaren Environmental Engineering, Inc., in 1985. Pumping tests were performed on two monitoring wells constructed in OU B. Between 22 August 1985 and 6 November 1985,

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TABLE A2-3. TOTAL ORGANIC COMPOUND CONCENTRATIONS IN A AND B ZONE DEPOSITS FROM OU B

Boring	Location	Zone[a]	Total Organic Carbon[b]	
			mg/Kg	Weight Fraction
PZ-1	near MW-155	A	225	0.225
PZ-1000	near MW-1049	A	39	0.039
MW-158	near MW-157	A	82	0.082
PZ-2	near MW-156	B	102	0.102
PZ-1001	near MW-1050	B	164	0.164

[a] Sampled from core driven in screen interval

[b] Total organic compound concentration after volatilization of volatile organic compounds

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TABLE A2-4. SUMMARY OF PARTICLE SIZE DISTRIBUTION ANALYSES FROM SELECTED A AND B ZONE BORINGS, OPERABLE UNIT B

Boring	Zone	Depth (ft. BGS)	Particle Diameter (mm) at Percentage of Sample Weight Passing		
			60%	30%	10%
MW-11A	A	100 to 110	0.590	0.245	0.096
MW-11A	A	111 to 120	0.829	0.097	0.022
MW-11A	A	121 to 125	3.962	1.492	0.071
PZ-1	A	116 to 123	0.334	0.138	0.019
PZ-1000	A	129 to 134	0.481	0.295	0.118
MW-158	A	106 to 112.5	--a	--	--
PZ-2	B	179.5 to 184.5	--b	--	--
PZ-100	B	166 to 171	0.173	--c	--

a 64.9% of sample weight less than 0.075 mm
b 87.3% of sample weight less than 0.075 mm
c 48.4% of sample weight less than 0.075 mm

two 4-hour tests were performed at MW-63, and one 4-hour test and one 24-hour test were performed at MW-66.

In 1985, nine observation wells and two production wells were constructed in the northern part of OU B (Figure A2-7). The wells were used to perform two aquifer tests to determine the hydraulic characteristics of underlying waterbearing zones. The location of the aquifer test wells is in the northern part of OU B; however, the test results are pertinent to the OUBGRI. Aquifer test activities were initiated on 30 December 1985 and completed on 17 January 1986. The two production wells were screened in separate monitoring zones. During each pump test, only one production well was pumped at a time and the response of the water levels were monitored in all nine of the observation wells throughout the duration of the test. The results of pumping tests conducted prior to the OUBGRI, are briefly summarized in Section A5.1.

During the OUBGRI, ten aquifer tests were performed in nine wells in OU B (Figure A2-8). The rationale for the location, geohydrologic zones, and duration of pumping tests conducted for the OUBGRI are discussed in the following section. The methodology used for performing the pumping tests, and for analyzing the data, are also presented below.

A2.3.1 Aquifer Testing Rationale

Ten pumping tests were conducted at on- and off-base locations within OU B. To evaluate hydraulic parameters of several geohydrologic zones at the east-west McClellan AFB boundary, aquifer tests were conducted in MWs 132, 148, 155, 156, and 1022. Monitoring Wells 132 and 148 are screened in the C and the D geohydrologic zones, respectively. Monitoring Well 155 is an A zone monitoring well and MWs 156 and 1022 are B zone wells. Prior to these tests, only one aquifer test (MW-63, McLaren, 1986a) had been conducted at the McClellan AFB boundary.

Interpretations of OUBGRI data, obtained during the first phase of the investigation, led to the conclusions that contaminants detected in off-base MW-1049 and MW-1050 represent the southern part of the TCE/1,2-DCE plume. Therefore, to determine A and B geohydrologic zone parameters and contaminant migration velocities in the southern TCE/1,2-DCE plume, aquifer pump tests were conducted in the A and B zones at MW-1049 and MW-1050, respectively.

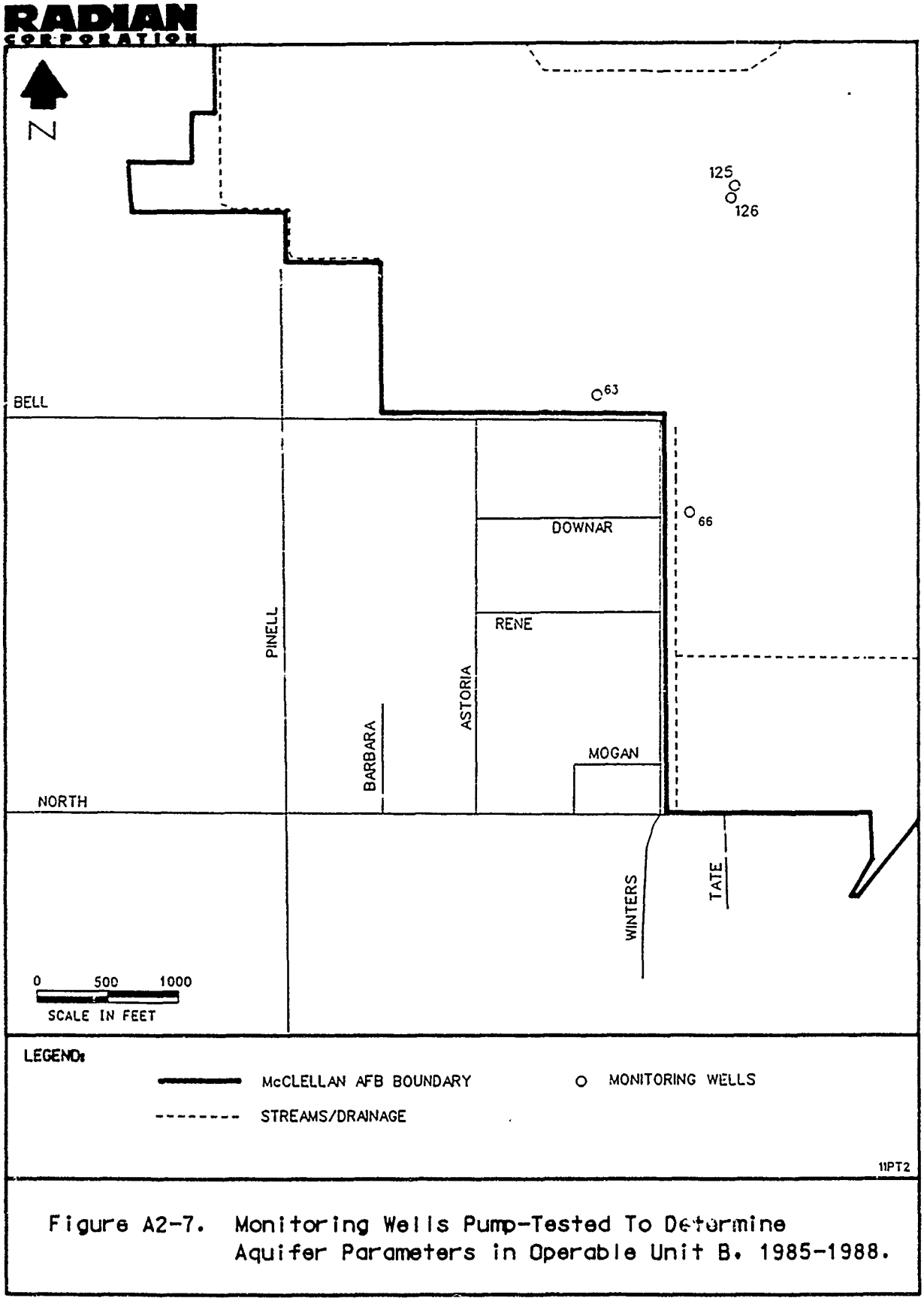

Figure A2-7. Monitoring Wells Pump-Tested To Determine Aquifer Parameters in Operable Unit B. 1985-1988.

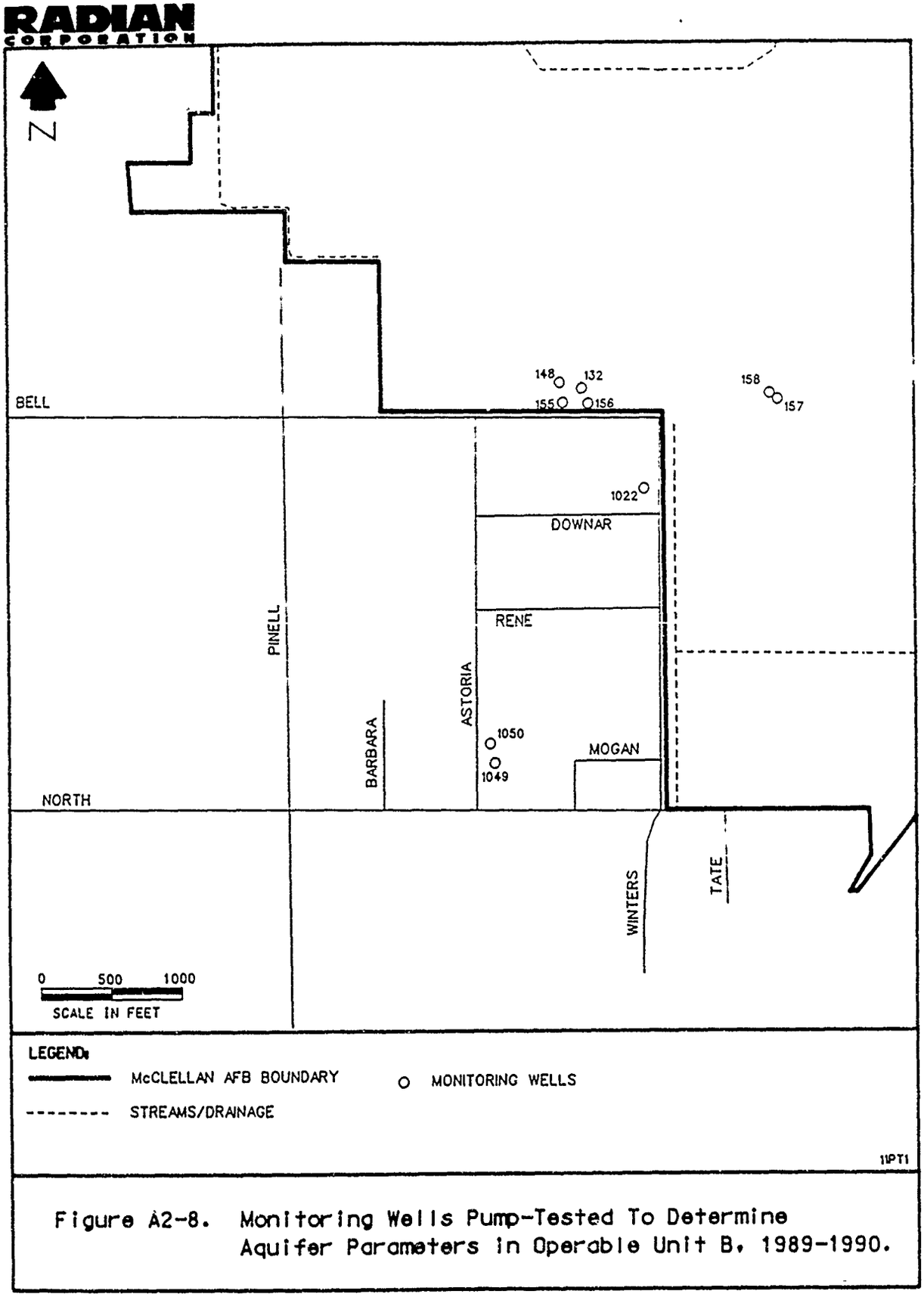

Figure A2-8. Monitoring Wells Pump-Tested To Determine Aquifer Parameters in Operable Unit B, 1989-1990.

Efforts in the OUBGRI to determine the horizontal extent of contamination that had been detected in the vicinity of MW-41S led to the installation and sampling of two additional A zone monitoring wells (MW-157 and MW-158). Concentrations of 6,800, 1,800, and 1,900 micrograms per liter (μg/L) of total VOC concentration detected in samples from MW-157, MW-158, and MW-41S, respectively, suggest that a concentrated plume of contaminants, now designated the TCE/PCE plume, is moving past the wells to the southwest toward BW-18. To determine the hydraulic properties of the A geohydrologic zone that are affecting migration of the TCE/PCE plume, pump tests were conducted on MW-157 and MW-158. Aquifer test well locations and zone designations for pump tests conducted during the OUBGRI are presented in Figure A2-8.

A2.3.2 Aquifer Test Methodology

A California certified (C-61) well installation company was subcontracted by Radian to install and remove submersible pumps and drop pipe, supply a generator to power the pumps, and connect and maintain any plumbing necessary to transfer water from the wellhead to on-site holding tanks. A 1.5, 3.0, or 5.0 horsepower Red Jacket® submersible pump was installed in the well to be pumped after the optimum pumping rate was determined during the step test. In A zone wells, the pump was installed at the bottom of the screened interval to allow for maximum drawdown in the pumping well. In B zone or deeper wells, the pump was installed approximately 50 feet below the static water level in the pumping well.

Water levels were continuously monitored and recorded in the pumping well observation wells, or piezometers using the In-Situ, Inc., Model SE2000 environmental data logger and silicon strain gauge bridge transducers. The data logger records changes in hydrostatic pressure that are detected by pressure transducers suspended below the static water level of each well that is monitored. The data logger was programmed to record water level readings at specified time intervals. Once pumping began, data were recorded and stored in memory. Quality control water-level measurements were taken on a regular basis with a manually operated meter to verify the electronically collected data.

Pump installation and transducer emplacement were supervised by a Radian geologist. Between each test, the submersible pump, drop pipe, and transducer cables were thoroughly decontaminated in conformance with the procedures for submersible sampling pumps described in the McClellan AFB QAPP (Radian, 1990c).

Each pump test was preceded by a period of at least 24 hours during which static water level changes were measured and a step test to determine the optimum pumping rates. Before step testing, wells MW-132 and MW-1022, which were more than six months old, were redeveloped. Wells less than six months old were not redeveloped. A low flowrate was initiated at each well. Drawdown (in the pumping well) versus time was monitored while the pumping rate was systematically stepped up. The pump rate was stepped up each time drawdown stabilized for a given flow rate. An optimum pumping rate was selected such that the aquifer would be sufficiently stressed to yield adequate drawdown data during the actual pump test that followed. Pump tests were conducted after the water level in the pumped well had fully recovered from the step test.

Two types of aquifer tests were performed, single well tests and multiple well tests. During the single well tests, drawdown data were collected in the pumping well only for calculation of aquifer parameters. During multiple well tests, drawdown was measured in the pumping well and in one or more adjacent observation wells screened at the same interval. During all aquifer tests, water levels in adjacent wells screened in different zones were also monitored to evaluate the hydraulic connection between waterbearing zones. The duration of pumping tests ranged from approximately 8 to 24 hours. After each pump test, a recovery test was conducted. After the pumping portion of the test was completed and the pump shut off, the data logger was set to monitor water levels until both the pumping well and observation wells had very nearly recovered to their prepumping water levels. Details of each pumping test are provided in Section A2.3.3.

The influence of McClellan AFB BW-18 on water levels was a consideration for all pumping tests because of its strong hydrologic influence in OU B. Throughout the test periods in October and November 1989, BW-18 was pumping at a steady rate of 1.5 million gallons per day. The well was not in operation during December 1989 when tests were performed on A zone wells MW-155 (Test 2), MW-157 and MW-158, and MW-1049 (Test 2). Therefore, all data were evaluated under the assumption that the potentiometric surface in each zone had a constant slope during the tests.

Groundwater produced during aquifer testing was discharged to portable 4,000 gallon tanks located at each test site. Universal Engineering, a licensed hazardous waste management company, transported the groundwater from the test locations to the

Groundwater Treatment Plant and/or Industrial Wastewater Treatment Plant. Groundwater was collected and transported by vacuum truck. If the flow rate from the well would cause the capacity of the holding tanks to be exceeded within an eight hour period, a vacuum truck was stationed on-site to transport water throughout the duration of the pump test.

A2.3.3 Aquifer Test Data Analysis

The results of both pumping and recovery tests were analyzed to determine numerical values for the aquifer characteristics of transmissivity, storativity, and hydraulic conductivity. These hydraulic properties were used to calculate natural and pumping-induced velocities for groundwater and to evaluate contaminant plume migration.

Graphical solution methods were used to determine aquifer characteristics. The following solution methods were used for unconfined aquifer conditions: Jacob's (1944) correction of drawdown for an aquifer with small saturated thickness, Boulton (1963) with delayed yield, and Neuman (1975) semilog for both drawdown and recovery. For semiconfined or confined conditions, the following solution methods used: Theis (1935) solution for drawdown and recovery, Jacob (1950) straight line method, Walton (1962) method, and the Papadopulos and Cooper (1967) method for a single well test. All tests are described below in outline form by zone. Comments on the data are provided in the remarks section for each test. Pumping test curves are provided in Appendix D. The results of the aquifer test data analysis are summarized in Table A2-5.

A Geohydrologic Zone Tests

Aquifer tests in the A zone beneath OU B were conducted: two at MW-155 along the east-west McClellan AFB boundary; one at MW-157 and one at MW-158 south of Building 655 and downgradient from the Building 666 foundations; and one at MW-1049 in the residential area south of McClellan AFB. The A geohydrologic zone had an average saturated thickness of approximately 30 feet. None of the monitoring wells used for pumping fully penetrated the zone. Only saturated sand or gravel thicknesses lying adjacent to the screened interval in each well are considered the saturated interval stressed by the test. Data analysis was performed on observation well data only, unless pumped well analysis is specified.

TABLE A2-5. PARAMETERS CALCULATED FROM OUBGRI AQUIFER TEST, A, B, C, AND D GEOHYDROLOGIC ZONES, OUB

Location	Pumped Well	Aquifer Type	Transmissivity Range (ft^2/d)	Storage Coefficient $x10^{-3}$	Analysis Method
A GEOHYDROLOGIC ZONE					
East-West Boundary	MW-155	Unconfined	316-575	0.9 - 1.1	Boulton Delay Curve
			320-550	-----	Neuman Recovery
Northeast of BW-18	MW-157	Unconfined	131	10	Neuman Curve
			214	---	Neuman Semilog[a]
			67	____	Neuman Curve[a]
Northeast of BW-18	MW-158	Unconfined	91	7.7	Neuman Curve
			155	---	Neuman Semilog[a]
			94	---	Neuman Curve[a]
Off-base, Southwest	MW-1049	Semi-confined	540	0.9	Walton Curve
B GEOHYDROLOGIC ZONE					
East-west Boundary	MW-156	Semi-confined	440	0.4	Walton Curve
Off-base, Southwest	MW-1022	Semi-confined	85.3	0.1	Papadopolus-Cooper[a]
Off-base, Southwest	MW-1050	Semi-confined	390	0.3	Walton Curve
C GEOHYDROLOGIC ZONE					
East-West Boundary	MW-132	Semi-confined	940-1150	0.1-0.01	Papadopolus-Cooper[a]
			1070-1260	---	Theis Recovery[a]
			4150	7	Jacob's Straight Line[b]
			5160	8	Jacob's Straight Line[b]
D GEOHYDROLOGIC ZONE					
East-West Boundary	MW-148	Semi-confined(?)	280	0.1	Papadopolus-Cooper[a]

[a] = Analysis performed on pump well drawdown data
[b] = Analysis performed on drawdown data from observation well screened in zone separate from pumped well

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MW-155

Observation wells PZ1, MW-7

Screen Intervals (ft msl)	**MW-155**	**PZ1**	**MW-7**
	-54 - -64	-55.8 - -60.8	-37.85 - 63.85
Radius from MW-155:	-----	20 ft	46 ft

Sand-gravel thickness: 6 ft.

Discharge rate during test: 8.2 gpm (1.10 ft^3/min)

Elapsed time pumping: 572 minutes

Step Test: Date: 10-20-89

- Pumping rates: 2.5, 7, and 13 gallons per minute (gpm)
- Elapsed time: 31 minutes
- Static water level: 105.3 ft BGS
- Depth of pump: 123.5 ft BGS
- Maximum drawdown level: 119.87 ft. BGS

Remarks: Pump rate selected - 8 to 9 gpm

Aquifer Test 1 Date: 10-25-89

Discharge rate during test: 8.2 gpm (1.1 ft^3/min)

Water levels (ft BGS)	**MW-155**	**PZ1**	**MW-7**
Static:	105.41	104.90	104.60
End of pumping:	115.26	106.32	105.28
Maximum drawdown:	9.85	1.42	0.68

Analysis Method:

- Boulton Delay Index: Unconfined aquifer
  - Transmissivity: 316 - 575 ft^2/day
  - Storage coefficient: 0.0009 - 0.0011
- Neuman Semilog
  - Transmissivity: 361 - 441 ft^2/day
  - Storage coefficient: 0.0099 - 0.0012

Remarks: Drawdown curve not a good fit on Boulton type curve.

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Aquifer Test 2 Date: 12-13-89

Discharge rate: 8.45 gpm
Pumping, elapsed time: 1444 minutes

Water levels (ft BGS)	MW-155	PZ1	MW-7
Static:	NM	102.80	102.52
End of pumping:	NM	105.15	103.53
Maximum drawdown:	10.26	2.35	1.01

Analysis Method:
Neuman Recovery: PZ1, MW-7
Transmissivity: 320 - 550 ft^2/day

Remarks: Log - log plot of drawdowns are not a good fit with any type curves.

MW-157
Observation well: MW-158

Screen Intervals (ft msl)	MW-157	MW-158
	-33.5 - -53.5	-38.6 - -48.6
Radius from MW-157:	-----	77.9 ft

Sand-gravel thickness: 8 feet

Step Test: Date: 12-6-89

Pumping rates: 4.5 and 7.8 gpm
Elapsed time: 214 minutes
Static water level: 104.2 ft BGS
Depth of pump: 117 ft BGS
Maximum drawdown level: 112.7 ft BGS

Remarks: Pump rate selected 5.5 to 6 gpm.

Aquifer Test Date: 12-7-89

Discharge rate: 5.4 to 6.2 (.72 - .83 ft^3/min.)
Elapsed time pumping: 1452 minutes

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Water levels (ft BGS)	MW-157	MW-158
Static:	104.1	104.0
End of pumping:	107.06	104.08
Maximum drawdown:	2.96	0.08

Analysis Method:

Neuman Curve Matching: MW-158
- Transmissivity: 131.2 ft^2/day
- Storage coefficient: 0.01

Neuman Semilog
- Transmissivity: 214 ft^2/day

Neuman Curve Match - Pumped Well
- Transmissivity 67 ft^2/day

Remarks: All late-time curve data corrected by Jacob (1944) method because drawdown was greater than 10 percent of estimated saturated thickness.

MW-158

Observation Well: MW-157

Screen Intervals (ft msl):	MW-158	MW-157
	-38.6 - -48.6	-33.5 - -53.5
Radius from MW-158:	-----	77.9 ft

Sand-gravel thickness: 4 ft.

Step Test — Date: 10-02-89

Pumping rates:	2.6, 5.5, 8.1 gpm
Elapsed time:	65 minutes
Static water level:	104.4 ft BGS
Depth of pump:	111 ft BGS
Maximum drawdown level:	109.5

Remarks: Pump rate selected: 5 to 6 gpm

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Aquifer Test: Date: 12-4-89

Discharge rate:	5.5 gpm (0.74 ft^3/min.)	
Elapsed time pumping:	1437 minutes	
Water levels (ft BGS):	**MW-158**	**MW-157**
Static:	104.4	104.0
End of pumping:	108.9	104.16
Maximum drawdown:	4.5	0.16

Analysis Method:

Neuman Curve Matching: MW-157
- Transmissivity: 91 ft^2/day
- Storage coefficient: 0.0077

Neuman Semilog on Pumped Well "late" Data
- Transmissivity: 155 ft^2/day

Neuman Curve Matching on Pumped Well "late" Data
- Transmissivity: 94 ft^2/day

Remarks: All late-time curve corrected by Jacob (1944) method because drawdown was greater than 10 percent of estimated saturated thickness.

MW-1049

Observation wells: PZ1000, MW-1050 (B Zone)

Screen Intervals (ft msl):	**MW-1049**	**PZ1000**	**MW-1050**
	-67.7 - -77.7	-71.4 - -76.4	-107.31 - 117.31
Radius to MW-1049:	-----	15.7 ft	19.9 ft

Sand-gravel thickness: 9.5 ft.

Step Test: Date: 11-13-89

Pumping rates:	16, 19.5, 24, 29, 33.5, 39.5, 41, 42, 43.5
Elapsed time:	127 minutes
Static water level:	101.81 ft BGS
Depth of pump:	115.5 ft BGS
Maximum drawdown level:	112.69

Remarks: Pump rate selected 42 gpm.

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Aquifer Test 1 — Date: 11-14-89

Discharage rate:	43 gpm (5.75 ft^3/min.)		
Elapsed time pumping:	535 minutes.		
Water levels (ft BGS):	**MW-1049**	**PZ1000**	**MW-1050**
Static:	NM	101.96	101.42
End of pumping:	NM	106.39	101.81
Maximum drawdown level:	11.30	4.43	0.39

Remarks: Electronic data from test lost; test was rerun.

Aquifer Test 2 — Date: 12-19-89

Discharge rate:	42.5 gpm (5.68 ft^3/min)		
Elapsed time pumping:	566 minutes		
Water levels (ft BGS):	**MW-1049**	**PZ1000**	**PZ1001**
Static:	NM	100.35	99.80
End of Pumping:	NM	104.70	100.07
Maximum drawdown level:	11.73	4.35	0.27

PZ1001:	B zone piezometer
Screen Interval:	-108.8 - -113.8 ft. msl
Radius from MW-1049:	10.42 ft

Analysis Method:

Neuman Curve Matching (unconfined): PZ1001
Transmissivity: None calculated, poor match

Boulton Curve Matching (unconfined): PZ1001
Transmissivity: None calculated, poor match

Walton or Cooper Curve Matching (Leaky confined, no storage in confining layer): PZ1001
Transmissivity: 540 ft^2/day
Storage Coefficient: 0.0009
Vertical conductivity confining layer: 0.09 ft/day.

Remarks: The A zone at this location is semiconfined. There is hydraulic communication between A and B zones but hydraulic response between screened intervals is not strong.

B Geohydrologic Zone Tests

Aquifer tests in the B zone were conducted: at MW-156, near the east-west McClellan AFB boundary; MW-1022, in the residential area 200 west of the north-south McClellan AFB boundary; and MW-1050 in the residential area south and west of McClellan AFB. The B Geohydrologic zone has an average saturated thickness in the area of the tests of approximately 45 feet. None of the monitoring wells used for pumping fully penetrated the zone. Data analysis was performed on observation wells only, except in the case of MW-1022 where no B zone observation well was available.

MW-156

Observation Wells: PZ2, MW-63

Screened Intervals (ft msl):	**MW-156**	**PZ2**	**MW-63**
	-113.1 - -123.1	-117 - -122	-101.02 - -111.02
Radius from MW-156	------	20.4 ft	43.26 ft

Sand-gravel thickness: 6.5 feet

Step Test — Date: 10-27-89

Pumping rates:	6.5, 11.8, 14.9, 18.5, 18.7 gpm
Elapsed time:	241 minutes
Static water level:	106.6 ft BGS
Depth of pump:	126.5 ft BGS
Maximum drawdown load:	118.55 ft BGS

Remarks: Pumping rate selected 20 to 22 gpm

Aquifer Test — Date: 10-30-89

Discharage rate during test:	21.5 gpm (2.87 ft^3/min)
Elapsed time pumping:	717 minutes

Water levels (ft BGS)	**MW-156**	**PZ2**	**MW-63**
Static:	107.4	106.05	107.32
End of pumping:	123.1	108.63	106.68
Maximum drawdown:	15.74	2.58	1.36

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Analysis Method

Walton Curve Matching (Leaky confined, no storage in confining layer): MW-63

Transmissivity:	440 ft^2/day
Storage coefficient:	0.0004

Remarks: Data from observation well PZ2 do not fit curves or allow straight-line analysis.

MW-1022

Observation wells: MW-1021 (A zone)

Screen Intervals (ft msl):	**MW-1022**	**MW-1021**
	-85.98 - -95.98	-37.99 - -47.99
Radius from MW-1022:	------	18.1 ft.

Sand-gravel thickness: 10 ft.

Step Test — Date: 11-29-89

Pumping rates:	4.1, 6.0, 8, 8.3, 9.1, 10 gpm
Elapsed time:	189 minutes
Static water level:	112.45 ft BGS
Depth of pump:	148.4 ft
Maximum drawdown level:	147.33

Remarks: Pumping rate selected 7.5 to 8 gpm

Aquifer Test — Date: 11-30-89

Discharge rate during test:	7.8 gpm	
Elapsed time pumping:	480 minutes	
Water levels (ft BGS)	**MW-1022**	**MW-1021**
Static	112.45	108.15
End of pumping	140.88	108.27
Maximum drawdown	28.43	0.12

Analysis Method

Papadopoulous and Cooper (Single Well) Curve Match: MW-1022

Transmissivity:	85.3 ft^2/d
Storage coefficient:	0.0001

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Remarks: Data for observation well were not plotted for analysis; drawdown in the A zone well (MW-1021) indicates hydraulic communication between the zones.

MW-1050

Observation Wells: PZ1001, MW-1049 (A Zone)

Screen Intervals (ft msl):	**MW-1050**	**PZ1001**	**MW-1049**
	-107.31 - -117.31	-108.7 - -113.8	-67.71 - -77.71
Radius from MW-1050	———	15.43 ft	19.9 ft

Sand-gravel thickness: 10 ft

Step Test — Date: 11-17-89

Pumping rates:	16.5, 26, 30, 30.5, 35, 38, 48, 52 gpm
Elapsed time:	166 minutes
Static water level:	101.4 ft BGS
Depth of pump:	145.8 ft BGS
Maximum drawdown level:	134 ft BGS

Remarks: Pump rate selected 55-65 gpm; water levels were recovering slightly at 51 to 52 gpm in step test but pump would not increase discharge.

Aquifer Test — Date: 11-20-89

Discharge rate:	56 gpm (7.49 ft^3/min)
Elapsed time pumping:	494 minutes

Water levels (ft BGS)	**MW-1050**	**PZ1001**	**MW-1049**
Static:	101.35	101.34	101.42
End of pumping:	136.75	114.12	102.2
Maximum drawdown level:	35.40	12.78	0.78

Remarks: Drawdown of 0.78 feet was measured in the A zone during pumping. This indicated hydraulic communication and vertical flow to the pumping well. The A zone data for MW-1049 were not analyzed for aquifer parameters.

Analysis Method

Walton Curve Matching (Leaky artesian, no storage in confining layer): PZ1001

Transmissivity: 390 ft^2/d

Storage coefficient: 0.0011

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C Geohydrologic Zone

One aquifer test was conducted in the C zone at MW-132, on base near the east-west McClellan AFB boundary in OU B. The C zone is approximately 70 feet thick in the area of MW-132. The well is screened in a fine grained sand in the the upper half of the C zone. A seven-foot thick sandy silt deposit separates the sand from B zone sands above. There were no other C zone wells in the area to use as observation wells.

MW-132

Observation wells: MW-156 (B zone), MW-148 (D zone)

Screen intervals (ft msl):	**MW-132**	**MW-156**	**MW-148**
	-145.8 - -155.8	-113.1 - -123.1	-225.97 - -235.97
Radius from MW-132:	-----	84.3 ft	150.3 ft

Sand-gravel thickness: 10 feet

Step Test — Date: 11-04-89

Pumping rates:	18, 24.9, 33, 40, 46, 51, 55, 60 gpm
Elapsed time:	141 minutes
Static water level:	106.78 ft BGS
Depth of pump:	128.5 ft
Maximum drawdown level:	17.02 ft

Remarks: Pump rate selected 60 gpm

Aquifer Test — Date: 11-06-89

Discharge rate:	60 gpm		
Elapsed time pumping:	482 minutes		
Water levels (ft BGS):	**MW-132**	**MW-156**	**MW-148**
Static:	NM	105.3	102.72
End of pumping:	NM		
Maximum drawdown:	17.26	0.90	0.56

Analysis Method

Papadopolous - Cooper Single Well Curve Match: MW-132

Transmissivity: 940 to 1150 ft^2/d

Storage coefficient: 0.0001 to 0.00001

Theis Recovery - Straight Line Analysis: MW-132
Transmissivity: 1070 to 1260 ft^2/d

Jacobs Straight Line Analysis: MW-156
Transmissivity: 4150 ft^2/d
Storage coefficient: 0.007

Jacobs Straight Line Analysis: MW-148
Transmissivity: 5160 ft^2/d
Storage coefficient: 0.008

Remarks:

1. The drawdown data for MW-156 show a hydraulic response in the B zone less than one minute after pumping began in the C zone. This suggests very good hydraulic communication between the B and C zones in this area.

2. Drawdown data for MW-148 show a hydraulic response in the D zone at MW-148, which is 150 feet from the pumping well, after ten minutes of pumping. This response suggests a hydraulic communication between the C and D zones.

3. When the pump was turned off, after 482 minutes of pumping, there was 0.9 feet and 0.56 feet of drawdown in the B and D zones, respectively. This indicates both upward and downward vertical flow into the C zone in response to the decrease in potential caused by pumping in the zone.

4. The drawdown curve for the pumping well flattens after approximately one minute of pumping. The pump used in the test was operating at its maximum capacity. It is probable that the discharge rate for the pump would have been adequate to stress the sands in the screened interval of MW-132. However, the flow of groundwater from the B and D zones during pumping decreased stress on the C zone sands.

5. The hydraulic response in the B, C, and D zones during pumping suggests that the C zone is a semiconfined aquifer that receives flow from above and below when pumping proceduces a vertical potential difference across zone boundaries.

6. In an attempt to characterize the parameters of the deposits from the screen in MW-132 to the screen in MW-156 (-118.1 to -150.8 = 32.7 ft.) the drawdown curve from MW-156 was analyzed. The log-log plot of the data did not fit available families of curves. Therefore, a Jacob straight line analysis was performed to estimate parameters.

7. In an attempt to characterize the parameters of the deposits from the screen in MW-132 to the screen in MW-148 (-150.8 to -230.97 = 80.2 ft), the data from MW-148 were analyzed by Jacob straight line analysis to estimate parameters.

D Geohydrologic Zone

One aquifer test was conducted in the D zone at MW-148, near the east-west McClellan AFB boundary in OU B. The D zone is approximately 50 feet thick in the area of MW-148. The well is screened partially in a sandy silt (2 feet), a fine to coarse grained sand (5 feet), and a coarse grained sand with fine to medium pebble gravel (2 feet). The well was constructed in the upper half of the D zone thickness. There were no other D zone wells in the area to use as observation wells.

MW-148

Observation Wells: MW-132 (C zone), MW-149 (E zone)

Screen Intervals (ft msl)	MW-148	MW-132	MW-149
	-225.97 - -235.97	-145.8 - -155.8	-285.76 - -295.76
Radius of MW-148	-----	150.3 ft	16 ft
Sand-gravel thickness:	8 feet		

Step Test — Date: 11-22-89

Discharge rate:	42, 43.5 gpm
Elapsed time pumping:	121 minutes
Static water level:	105.08 ft BGS
Depth of pump:	155 ft BGS
Maximum drawdown level:	38.98 ft BGS

Remarks: Pump rate selected 41 gpm

Aquifer Test — Date: 11-27-89

Discharge rate:	41 gpm (5.48 ft^3/min)
Elapsed time pumping:	467 minutes

Water levels (ft BGS):	MW-148	MW-149	MW-132
Static:	105.5	105.85	110.40
End of pumping:	145.5	106.11	110.50[a]
Maximum drawdown:	40.0	0.36	0.22[a]

[a] Transducer data for this well erratic. Drawdown fluctuated with no apparent pattern. Data not used for analysis.

Analysis Method

Papadopolous - Cooper Curve Match: MW-148

Transmissivity: 280 ft^2/d

Storage coefficient: 0.0001

Theis Recovery: MW-149

Transmissivity: 2370 ft^2/d

Remarks: Hydraulic communication between D and E zones was demonstrated by the 0.36 feet of drawdown in MW-149 as a result of pumping in MW-148. The drawdown response was evident in the E zone at approximately 0.1 minutes.

TABLE A2-1. SUMMARY OF MONITORING WELL CONSTRUCTION DATA FOR OUBGRI

Well[a] Number	Well Depth (ft BGS)	Screen[b] Elevation (ft msl)	Monitoring Zone	Screen Slot Size (in)	Casing[c] Material	Filter Pack Interval (ft BGS)	Filter Pack Type	Bridge[g] Seal Interval (ft BGS)	Sand Bentonite Seal Interval (ft BGS)	Grout Seal[j] Interval (ft BGS)
MW-11A	139.0	-64.69 to -74.69	A	0.010	Sch. 40 PVC S.S.[d]	139.0 to 127.2	Lonestar[f] 1C	127.2 to 125.5	125.5 to 121.5	121.5 to 000.00
MW-11B	170.0	-95.44 to -105.44	B	0.010	Sch. 40 PVC S.S.	170.0 to 156.0	Lonestar 1C	156.0 to 154.0	154.5 to 150.5	150.5 to 000.00
MW-36A	137.0	-64.25 to -74.25	A	0.010	Sch. 40 PVC S.S.	137.0 to 125.0	Lonestar 1C	125.0 to 122.0	122.0 to 118.0	118.0 to 000.00
MW-36B	186.0	-123.38 to -113.38	B	0.020	Sch. 40 PVC S.S.	186.0 to 174.0	Lonestar #3 (8x16)	174.0 to 171.5	171.5 to 168.5	168.5 to 000.00
MW-36C	240.0	-166.92 to -176.92	C	0.020	L.C.S.[e] S.S.	240.0 to 226.5	Lonestar #3 (8x16)	226.5 to 223.5	223.5 to 219.0	219.0 to 000.00
MW-145	121.50	-51.50 to -61.50	A	0.010	Sch. 40 PVC S.S.	121.50 to 108.0	Lonestar 1C[5]	108.00 to 104.5	104.50 to 100.00	100.00 to 000.00
MW-146	201.50	-131 to -141	B	0.020	Sch. 40 PVC S.S.	201.50 to 186.00	Lonestar #3 (8 x16)	186.00 to 183.00	183.00 to 179.50	179.50 TO 000.00
MW-147	242.30	-171.96 to -181.96	C	0.020	L.C.S. S.S.	242.30 to 229.00	Lonestar #3 (8x16)	229.00 to 226.00	226.00 to 222.00	222.00 to 000.00
MW-148	298.50	-225.97 to -235.97	D	0.020	L.C.S. S.S.	298.50 to 284.00	Lonestar #3 (8x16)	284.00 to 280.50	280.50 to 276.00	276.00 to 000.00
MW-149	360.00	-285.76 to -295.76	E	0.020	L.C.S. S.S.	360.00 to 350.00	Lonestar #3 (8x16)	350.00 to 349.00	349.00 to 343.00	343.00 to 000.00
MW-150	122.50	-54.41 to -64.51	A	0.010	Sch. 40 PVC S.S.	122.00 to 112.00	Lonestar 1C	112.00 to 106.00	106.00 to 102.00	102.00 to 000.00

Continued

TABLE A2-1. Continued

Well[a] Number	Well Depth (ft BGS)	Screen[b] Elevation (ft msl)	Monitoring Zone	Screen Slot Size (in)	Casing[c] Material	Filter Pack Interval (ft BGS)	Filter Pack Type	Bridge[g] Seal Interval (ft BGS)	Sand Bentonite Seal Interval (ft BGS)	Grout Seal[i] Interval (ft BGS)
MW-151	185.50	-117.59 to -127.59	B	0.010	Sch. 40 PVC S.S.	185.70 to 166.60	Lonestar 1C	166.60 to 164.60	164.60 to 163.61	163.61 to 000.00
MW-152	265.24	-197.30 to -207.30	C	0.020	L.C.S. S.S.	265.25 to 249.30	Lonestar #3 (8x16)	249.30 to 247.30	247.30 to 246.50	246.50 to 000.00
MW-153	126.50	-53.98 to -63.98	A	0.020	Sch. 40 PVC S.S.	126.50 to 116.00	Lonestar #3 (8x16)	116.00 TO 109.00	109.00 TO 105.00	105.00 TO 000.00
MW-154	267.50	-195.06 to -205.06	C	0.020	L.C.S. S.S.	267.50 to 251.00	Lonestar #3 (8x16)	251.00 to 249.00	249.00 to 215.50	215.50 to 000.00
MW-155	125.50	-54.00 to -64.00	A	0.010	Sch. 40 PVC S.S.	125.50 to 112.00	Lonestar 1C	112.00 to 110.00	110.00 to 107.00	107.00 to 000.00
MW-156	186.00	-113.10 to -123.10	B	0.010	Sch. 40 PVC S.S.	186.00 to 172.50	Lonestar 1C	172.50 to 171.00	171.00 to 168.00	168.00 to 000.00
MW-157	117.50	-33.50 to -53.50	A	0.010	Sch. 40 PVC S.S.	117.50 to 94.00	Lonestar 1C	94.00 to 92.00	92.00 to 88.50	88.50 to 000.00
MW-158	112.50	-38.60 to -48.60	A	0.010	Sch. 40 PVC S.S.	112.50 to 199.50	Lonestar 1C	99.50 to 97.50	97.50 to 94.50	94.50 to 000.00
MW-159	117.00	-42.70 to -52.70	A	0.010	Sch. 40 PVC S.S.	117.00 to 104.50	Lonestar 1C	104.50 to 101.50	101.50 to 98.50	98.50 to 000.00
MW-162	326.00	-256.03 to -266.03	D	0.010	L.C.S. S.S.	326.00 to 311.50	Lonestar 1C	311.50 to 304.00	304.00 to 300.50	300.50 to 000.00
MW-163	364.00	-296.95 to -306.95	E	0.010	L.C.S. S.S.	364.00 to 347.00	Lonestar 1C	347.00 to 346.00	346.00 to 342.00	342.00 to 000.00

Continued

TABLE A2-1. Continued

Well[a] Number	Well Depth (ft BGS)	Screen[b] Elevation (ft msl)	Monitoring Zone	Screen Slot Size (in)	Casing[c] Material	Filter Pack Interval (ft BGS)	Filter Pack Type	Bridge[g] Seal Interval (ft BGS)	Sand Bentonite Seal Interval (ft BGS)	Grout Seal[f] Interval (ft BGS)
MW-164	114.50	-32.04 to -52.04	A	0.010	Sch. 40 PVC S.S.	114.50 to 93.00	Lonestar 1C	93.00 to 88.50	88.50 to 84.50	84.50 to 000.00
MW-165	180.50	-107.86 to -117.86	B	0.010	Sch. 40 PVC S.S.	180.50 to 164.50	Lonestar 1C	164.50 to 160.50	160.50 to 155.50	155.50 to 000.00
MW-166	248.00	-174.52 to -184.52	C	0.010	L.C.S. S.S.	248.00 to 233.50	Lonestar 1C	233.50 to 230.50	230.50 to 226.50	226.50 to 000.00
MW-167	331.50	-258.36 to -268.36	D	0.010	L.C.S. S.S.	331.50 to 316.00	Lonestar 1C	316.00 to 312.00	312.00 to 309.00	309.00 to 000.00
MW-168	348.00	-275.18 to -285.18	E	0.010	L.C.S. S.S.	348.00 to 336.50	Lonestar 1C	336.50 to 333.50	333.50 to 328.00	328.00 to 000.00
MW-1044	122.00	-48.46 to -58.46	A	0.010	Sch. 40 PVC S.S.	122.00 to 108.00	Lonestar 1C	108.00 to 106.00	106.00 to 102.00	102.00 to 000.00
MW-1045	179.10	-105.77 to -115.77	B	0.010	Sch. 40 PVC S.S.	179.10 to 165.50	Lonestar 1C	165.50 to 163.50	163.50 to 160.00	160.00 to 000.00
MW-1046	258.00	-185.15 to -195.15	C	0.020	L.C.S. S.S.	258.00 to 225.00	Lonestar #3 (8x16)	225.00 to 223.00	223.00 to 219.50	219.50 to 000.00
MW-1047	324.50	-251.58 to -261.58	D	0.020	L.C.S. S.S.	324.50 to 311.40	Lonestar #3 (8x16)	311.40 to 309.40	309.40 to 306.80	306.80 to 000.00
MW-1048	363.40	-290.66 to -300.66	E	0.010	L.C.S. S.S.	363.40 to 349.30	Lonestar 1C	349.30 to 348.70	348.70 to 343.00	343.00 to 000.00
MW-1049	136.50	-67.71 to -77.71	A	0.010	Sch. 40 PVC S.S.	136.50 to 122.00	Lonestar 1C	122.00 to 119.00	119.00 to 116.00	116.00 to 000.00

Continued

TABLE A2-1. Continued

Well[a] Number	Well Depth (ft BGS)	Screen[b] Elevation (ft msl)	Monitoring Zone	Screen Slot Size (in)	Casing[c] Material	Filter Pack Interval (ft BGS)	Filter Pack Type	Bridge[g] Seal Interval (ft BGS)	Sand Bentonite Seal Interval (ft BGS)	Grout Seal[i] Interval (ft BGS)
MW-1050	176.00	-107.31 to -117.31	B	0.010	Sch. 40 PVC S.S.	176.00 to 162.00	Lonestar 1C	162.00 to 159.00	159.00 to 155.00	155.00 to 000.00
MW-1051	242.00	-169.91 to -179.91	C	0.020	L.C.S. S.S.	242.00 to 222.00	Lonestar #3 (8x16)	222.00 to 219.00	219.00 to 216.00	216.00 to 000.00
MW-1052	340.00	-270.45 to -280.45	D	0.010	L.C.S. S.S.	340.00 to 315.00	Lonestar 1C	315.00 to 313.00	313.00 to 310.00	310.00 to 000.00
MW-1053	136.40	-61.00 to -81.00	A	0.010	Sch. 40 PVC S.S.	136.40 to 112.50	Lonestar 1C	112.50 to 110.00	110.00 to 107.00	107.00 to 000.00
MW-1054	123.50	-58.00 to -68.00	A	0.010	Sch. 40 PVC S.S.	123.50 to 105.00	Lonestar 1C	105.00 to 104.00	104.00 to 101.00	101.00 to 000.00
MW-1055	183.5	-117.00 to -127.00	B	0.010	Sch. 40 PVC S.S.	183.50 to 170.00	Lonestar 1C	170.00 to 168.00	168.00 to 164.00	164.00 to 000.00
MW-1056	273.00	-207.20 to -217.20	C	0.020	L.C.S. S.S.	273.00 to 223.50	Lonestar 3# (8x16)	223.00 to 221.00	221.00 to 203.00	203.00 to 000.00
MW-1057	360.00	-257.40 to -267.40	D	0.010	L.C.S. S.S.	325.50 to 306.00	Lonestar 1C	306.00 to 302.00	302.00 to 289.00	289.00 to 000.00

a = All wells 4-inches in diameter.
b = All screens are stainless steel.
c = Casing centralizers set at top and bottom of screens, and at 40' intervals on well casing.
d = S.S. - Stainless Steel.
e = L.C.S. - Low Carbon Steel.
f = Lonestar 1C filter pack = 2.36 to 1.40 mm or 0.09 to 0.05 inches.
Lonestar #3 filter pack = 1.68 to 0.417 mm
g = Sand bridge (30 mesh sand)
h = Grout mixture: 1 to 2% bentonite (by wt.), 6.5 to 8.3 gal. water per sk of Type 1 Portland cement.
BGS= below ground surface
msl= mean sea level

A3.0 HYDROGEOLOGIC RESULTS

Groundwater containing contaminants is migrating through geologic deposits beneath much of Operable Unit (OU) B. Characterization of the hydrogeology beneath OU B is critical, therefore, in order to determine groundwater flow velocities and horizontal and vertical gradients that control or influence contaminant distribution and migration. Results of monitoring well drilling, lithologic logging, and water level measurement are reported and interpreted in this section. Subsurface geology is described in Section A3.1.1; groundwater flow and hydrologic data are presented and interpreted in Section A3.1.2.

A3.1 Subsurface Hydrogeology

The subsurface hydrogeologic interpretations in the Operable Unit B Groundwater Remedial Investigation (OUBGRI) are based both on previously existing data and recently acquired data. Previously existing data are lithologic and geophysical logs, potentiometric surface maps, groundwater sampling and analytical results, and historical base production well data. The sources of these data are cited in Section A7.0, References. Data acquired recently, during 1989-1990 field activities, are lithologic and geophysical logs of eight pilot holes, groundwater sampling and analyses of 41 monitoring wells, and eight rounds of static water-level soundings for all available OU B monitoring wells. These previously existing and recently acquired data have been evaluated to characterize the subsurface deposits and their influence on groundwater flow and the horizontal and vertical extent of contaminant migration.

A3.1.1 Subsurface Geology

Two geologic cross sections have been developed from stratigraphic information available during the OUBGRI (Plates 1, 2). Lithologic and geophysical logs from McClellan Air Force Base (AFB) Base Well (BW) 18 and Deep Exploration Boring (DEB) B1 were reviewed and incorporated with more recent data. These data were obtained from eight pilot holes drilled and logged to depths of approximately 430 feet, and from monitoring wells completed at depths ranging from 120 to 360 feet below ground surface (BGS).

As recognized in previous investigations (McLaren, 1986b; Radian, 1988, 1989a), the subsurface deposits underlying OU B and much of McClellan AFB to a depth of at least 430 feet are sands, gravels, silts, and clays deposited in a frequently

changing fluvial (stream) environment. Stream deposits have great length along their downgradient course, but are narrow and thin in their other dimensions. Therefore, in the fluvial environment, deposits consisting of one lithologic type are limited in horizontal and vertical extent.

Evidence from the subsurface deposits of OU B and other areas of McClellan AFB suggests that streams active in the Pleistocene and Holocene eras flowed from east to west or northeast to southwest through OU B. Therefore, stream deposits are narrowest and become thinner in the north-south direction. The course of streams in an alluvial plain environment tend to migrate with time in directions approximately perpendicular to stream flow, thereby affecting not only the relative location and thickness of the coarsest sands and gravels, but the fine overbank silts and muds as well. Evidence of north to south fluvial migration is evident in the lithology of deposits found in the OUBGRI drilling. Layers of gravel, sand, silt, and clay do not consist of one grain size and may thicken or thin in any direction. Coarse deposits may grade laterally into fine deposits and fine into coarse in the distances between logged holes. This is most evident in following deposits north or south from buried stream courses. Correlating units of similar lithology between boring locations is difficult due to a lack of lateral continuity. Therefore, a method of characterizing the subsurface without relying on correlation between thin, individual deposits is applied in this section.

For purposes of determining subsurface groundwater conditions, the laterally variable deposits in the OU B are classed as high, moderate, and low permeability rather than attempting to correlate specific lithologic types from place to place. The classes of high, moderate, and low permeability units are estimates based on the geologists' observations in the field and from evaluation of the complete set of data once the field activities were concluded. The descriptions of soil types were based upon the Unified Soil Classification System (USCS) and the Wentworth Scale. Descriptions on lithologic logs are based on both classifications; for permeability classification, and illustrations, the USCS classification is used. In addition, the distinction between clay and silt fines was based upon the United States Department of Agriculture (USDA) soil textural classification limit.

The high permeability class of deposits includes sands, gravels, and sand-gravel mixtures with little or no fine sediment fraction. Deposits described by the following USCS designations are included in the high permeability class:

- GW--poorly sorted (well-graded) gravels, and gravel mixtures with little or no fines;

- SW--poorly sorted (well-graded) sands, and gravelly sands with little or no fines; and

- SP--well sorted (poorly graded) sands and gravelly sands with little or no fines.

The high permeability strata would have the greatest hydraulic conductivity of the three classes.

The moderate permeability class of strata includes silty gravels and sands, fine sands, fine sandy silts, and clayey sands. Deposits described by the following USCS designations are included in the moderate permeability class:

- GM--silty gravels and gravel-sand-silt mixtures with various grades of sorting;

- SM--silty sands and sand-silt mixtures with various grades of sorting;

- SC--clayey sands and sand-clay mixtures which inherently would be very poorly sorted (very well-graded); and

- ML--inorganic silts, and silty fine sands which would be moderately to poorly sorted (moderately to well-graded).

The moderate permeability strata would have estimated hydraulic conductivity that would be relatively less than the high permeability class of strata but significantly greater than the low permeability class of strata.

The low permeability class of strata includes silt, clay, and very fine sandy clays. Deposits described by the following USCS designations are included in the low permeability class:

- ML--clayey silts;

- CL--inorganic clays of low to medium plasticity, silty sandy, or gravelly clays; and

- MH--inorganic silts, elastic silts and micaceous very fine sandy silts.

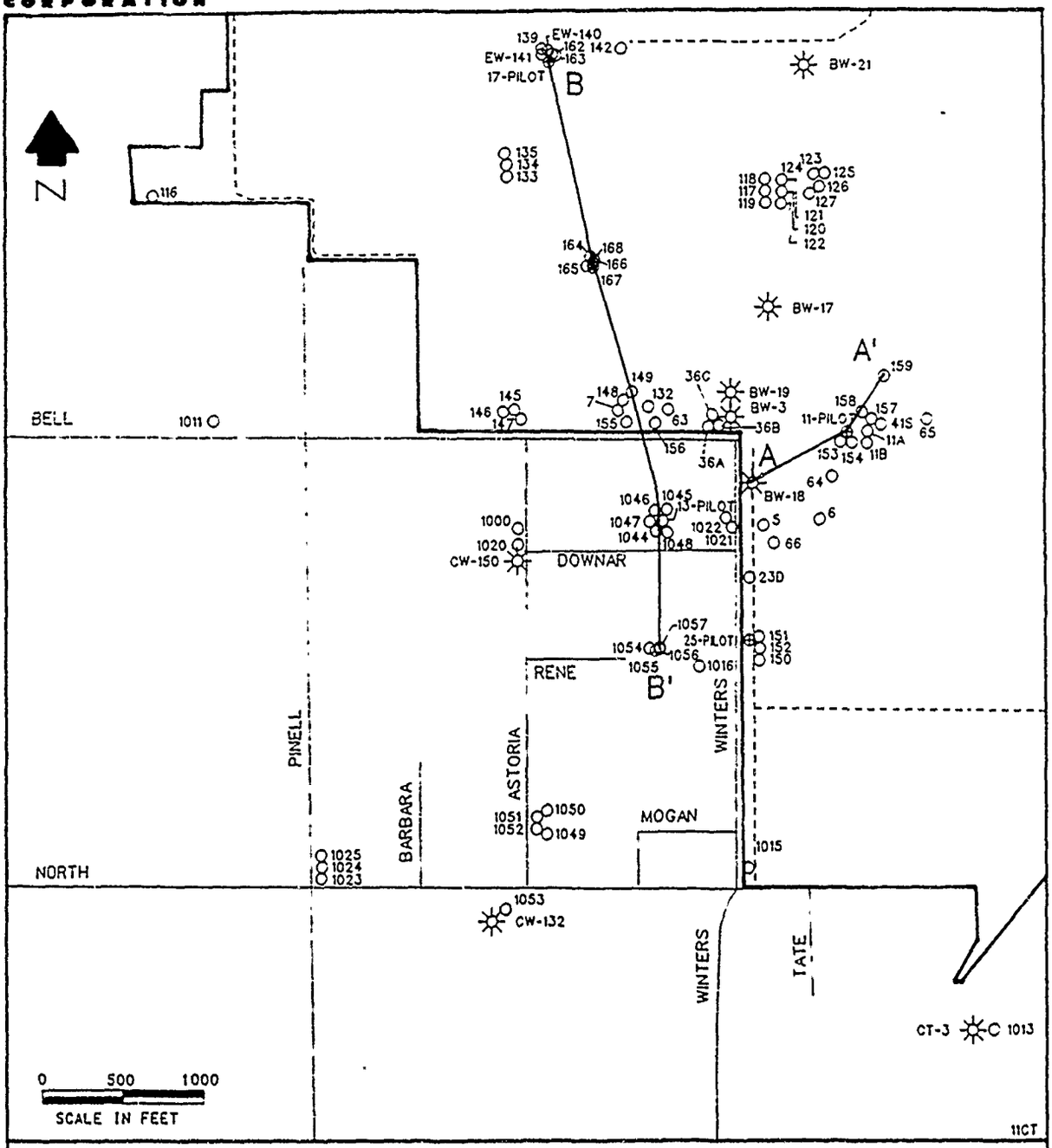
The low permeability class of strata would have the lowest hydraulic conductivity of the three permeability classes and would be considered the aquitards of the groundwater regime in the subsurface at McClellan AFB.

Geologic Cross Sections

For several reasons, caution must be exercised by the reader when examining the geologic cross sections (Plates 1, 2). First, the vertical scale is larger than the horizontal scale. Therefore, thickness of the stratigraphic section is exaggerated with respect to horizontal distance. The vertical exaggeration is different for each of the two cross sections. Second, the high, moderate, and low permeability units were extrapolated laterally to some extent to each side of the borehole with the interpretation that thicker units are more continuous laterally than thinner units. Third, the geologic cross sections may give the false impression that many of the boreholes drilled penetrated the thickest point of certain high and low permeability units of considerable lateral extent. These units were not necessarily encountered at their thickest point, and thicker and thinner sections may be present throughout the subsurface. In addition to those shown on the geologic cross sections, other less extensive units of high and low permeability may exist between borings. Judgements made from these cross sections must take into account these limitations. The surface traces of geologic cross sections A-A′ and B-B′ are presented in Figure A3-1.

Geologic Cross Section A-A′

Geologic cross section A-A′, shown in Plate 1, trends southwest-northeast and was constructed with the lithologic and geophysical logs from BW-18 through P11 and Monitoring Well (MW) 158 to MW-159. The upper 125 feet of this section is generally dominated by low and moderate permeability deposits. To the southwest, moderate permeability strata interfinger with thinner, lower permeability strata. Lower permeability deposits dominate this upper section to the northeast, although a thin, high permeability sand is present at 100 feet BGS in MW-159. In general, the upper 125 feet of the cross section does not contain significant high permeability zones. The shallowest groundwater (100 to 125 feet BGS) occurs within fine-grained low permeability deposits



LEGEND:

- McCLELLAN AFB BOUNDARY
- A A' TRACE OF CROSS SECTION
- STREAMS/CREEKS
- ⊕ PILOT HOLES
- WATER SUPPLY WELLS
- O MONITORING WELLS
- BW BASE WATER SUPPLY WELL
- EW EXTRACTION WELL
- CW CITY OF SACRAMENTO WATER SUPPLY WELL
- CT CAL-TRANS WELL

Figure A3-1. Location of New Well Clusters, Existing Wells, and Trace of Cross Sections.

along much of the section. The lower portion of the cross section, however, contains some high permeability sand-gravel accumulations which represent buried stream courses. These high permeability deposits are evidence of the fluvial deposition that persisted west of the Sierra Nevada in Pliocene and Pleistocene eras. High permeability strata are best developed and thickest in BW-18. Thick sections of high permeability sand-gravel deposits do not occur elsewhere along the profile. The coarse sands and gravels penetrated by BW-18 occur at 170 to 200 feet, 225 to 290 feet, and 305 to 365 feet BGS. The upper and lower high permeability deposits at BW-18 grade laterally to the northeast into and are overlain by moderate to low permeability deposits at P11 that probably represent overbank deposits. The middle sand-gravel deposit occurring in BW-18 continues laterally to the northeast, thinning slightly, and is present in P11 from 235 to 285 feet BGS. Although this high permeability deposit is present, P11 is generally dominated by moderate permeability deposits that interfinger with finer, lower permeability deposits. These strata probably represent point bar and overbank deposits associated with the coarser stream deposits that lie outside of the section's plane. The geometry of the high permeability deposits in this cross section suggests that stream activity which deposited the sands and gravels occurring from 170 to 365 feet BGS persisted for a lengthy geologic time interval. The courses of the streams that deposited most of the high permeability deposits continue out of the plane of the cross section, except for of the deposits at 235 to 285 feet BGS.

Geologic Cross Section B-B′

Geologic cross section B-B′ (Plate 2) trends north to south and was constructed with the lithologic and geophysical logs from P17, P21, P13, and MW-1056. Only a lithologic log was available for the subsurface deposits at MW-149. The upper 200 feet BGS of this cross section is composed of low and medium permeability deposits that are intercalated with thinner high permeability layers. One thicker, high permeability, sand interval occurs from 60 to 85 feet BGS in P21, but is not important to groundwater flow because it is now located within the vadose zone. The lower portion of the profile, below 200 feet BGS, is dominated in the south by high permeability deposits that occur in P13 and MW-1056. These high permeability coarse sands and gravels represent buried Pleistocene or Holocene stream deposits that were apparently deposited by the same stream activity as those penetrated by BW-18. Sands and gravels occur in P13 from 214 to 360 feet BGS and grade laterally to the north into finer deposits of medium and low permeability. In MW-149, 750 feet north of P13, the equivalent depth interval consists of medium permeability silty sands interbedded with low permeability silts. High permeability sands and gravels occur only from 330 to 360

feet BGS in MW-149. However, the coarse sands and gravels do not extend to the north and are not present in P21, 750 feet north of MW-149. In general, the lower portion of the cross section, through MW-149, P21 and P17, consists of medium permeability deposits interlayered with low permeability deposits. Deposits in this depth interval are thinner and contain more clay and silt to the north, suggesting increased distance from stream courses and probably represent flood plain deposits.

The Vadose Zone

The vadose (unsaturated) zone beneath OU B consists of interbedded, alluvial sands, silts, and clays. The deposits were laid down in fluvial environments that existed in the late Pleistocene and the Holocene eras. Fluvial deposition that occurred in these time intervals is normally characterized by gravel and sand deposited by streams. Evidence of deposits representing stream activity are rare in the vadose zone beneath OU B. Available lithologic data also suggest that the stream deposits migrated laterally and vertically with time. Adjacent to the course of buried streams, silty to clayey overbank deposits interfinger with flood-deposited sands and increase in clay content with distance from the channels. Fluvial and interfluvial deposits of the kind recognized beneath McClellan AFB are heterogeneous in their grain size distribution and in their permeabilities.

Permeability, which is a measure of the ability of porous deposits to allow fluid flow, is an important parameter in determining the path of migration for chemical compounds or water from the surface toward the saturated zone. The permeability of deposits in the vadose zone of OU B is categorized as moderate to low. Vadose zone deposits consist of sandy to silty clays and sandy to clayey silts at most of the OUBGRI borings. Sand-dominated strata are relatively thin and non-continuous laterally. Therefore, the flow of groundwater and dissolved contaminants through the vadose zone and beneath much of OU B has been limited by low to moderate permeability deposits.

A3.1.2 Subsurface Hydrology

To evaluate the groundwater and potential contaminant migration within the volume of OU B, geologic and hydrologic variability must be characterized. The character of geologic deposits affects permeability and water storage in the saturated zone and, thereby, influences the movement of groundwater. Groundwater behavior is additionally influenced by natural or artificially induced hydraulic potentials and gradients.

The deposits which comprise the subsurface volume of groundwater OU B are described in Section A3.1. To simplify discussion of the geologically complex subsurface environment, the deposits were combined into estimated permeability classes based on descriptions of their grain size distribution, sorting or grading, and cementation characteristics. Plates 1 and 2 depict the interpretation made of the lateral and vertical extent of deposits by their estimated permeability classes. The lateral and vertical heterogeneity in the subsurface is evident even after the deposits are grouped in three permeability classes. The variations in permeabilities within the operable unit cause a lack of homogeneity in the behavior of groundwater and contaminants from point to point in the subsurface.

The additional influences on groundwater behavior that are not illustrated in subsurface cross sections are the hydraulic potentials acting on the mass of water. Hydraulic potentials are differences in physical forces, measured as water elevations (head) in wells, which cause groundwater to move. In OU B hydraulic gradients are caused by differences in hydraulic potential both that are natural and are artificially induced by well pumping activity.

To evaluate the movement of groundwater and contaminants within OU B, the subsurface from the water table to a depth of 430 feet BGS has been divided into six zones. Both geologic and hydrologic criteria are the bases for designation of geohydrologic zones.

Geohydrologic Zones

Six geohydrologic zones have been identified in the subsurface of OU B. The designation of geohydrologic zones is intended to replace previous depth-dependent designations used for the groundwater environment beneath OU B. The adaptation of geohydrologic zones is based on the usage of Maxey (1964).

Each geohydrologic zone consists of a high to moderate permeability zone and the overlying low permeability zone which appears to form a reasonably distinct hydraulic unit within OU B. The geohydrologic zones designations are, from shallowest to deepest, A, B, C, D, E, and F. The zones differ from monitoring zone designations used in previous investigations at McClellan AFB.

The vertical distribution of geohydrologic zones in OU B is depicted with subsurface geology in Plates 1 and 2. The geohydrologic zones were selected on the

basis of permeability and hydraulic characteristics of subsurface deposits. Therefore, depths and thicknesses of the zones vary from place to place in the operable unit.

In planning the OUBGRI field investigation, geophysical and lithologic logs were used to target potential depth or elevation zones for monitoring well completions. However, during the drilling and well construction phase of the OUBGRI, it became apparent that depth or elevation designations were inadequate to describe and interpret geologic and hydrologic conditions. The designation of geohydrologic zones A through F appears to be more appropriate for subsurface conditions in OU B. Table A3-1 lists the elevations that approximate the boundaries of geohydrologic zones in OU B.

Each monitoring well completed during the OUBGRI field activities was screened within one of the first five geohydrologic zones. Wells were not completed in the sixth or F zone until mid-1990 during the Preliminary Groundwater Operable Unit Remedial Investigation (PGOURI) program. Screen intervals for each well in each cluster are shown adjacent to the lithologic or geophysical log for the deepest boring in the cluster in Plates 1 and 2. Screens were placed within both high or moderate permeability deposits. Placement of screens in the zones was determined by the apparent continuity of deposits between locations and not solely on the depth of high permeability deposits.

Monitoring wells in OU B constructed prior to the OUBGRI well construction activities have been reassigned to geohydrologic zones. No pre-existing monitoring well could be assigned to the D or E zones because none had screen intervals at the approximate depth of those zones, 271 to 371 BGS. Fourteen pre-existing monitoring wells within the operable unit area are designated as A geohydrologic zone wells; eight are designated B zone wells; and one is designated a C zone well. Hydrologic data from those pre-existing wells are included in the evaluation of hydrology and water quality of each zone in the following subsections.

A3.2 Groundwater Flow

When McClellan AFB supply wells are inactive, the regional groundwater flow in the A, B, C, and geohydrologic zones beneath OU B is to the south/southwest, toward a large groundwater depression created by municipal well pumping for the city of Sacramento. However, when BW-18 is pumping, groundwater flow under OU B is strongly affected by the withdrawal of groundwater. During much of 1989 and early

TABLE A3-1. GEOHYDROLOGIC ZONE DESIGNATIONS

Operable Unit B Groundwater Remedial Investigation

A Geohydrologic Zone	Water table to -80 feet msl
B Geohydrologic Zone	-80 feet to -130 feet msl
C Geohydrologic Zone	-131 feet to -210 feet msl
D Geohydrologic Zone	-211 feet to -280 feet msl
E Geohydrologic Zone	-281 feet to -311 feet msl
F Geohydrologic Zone	-312 feet to -370 feet msl

msl = mean sea level

1990, BW-18 was pumped at a rate of approximately 1140 gallons per minute (gpm) (dry season) and 930 gpm (wet season), 24 hours a day, seven days a week. Hydrologic data collected during 1989 and 1990 indicate that BW-18 significantly alters groundwater flow within all zones and affects both vertical and horizontal gradients within each zone beneath OU B. Under the current daily rate of discharge, a large portion of flow through the A, B, C, D, and E geohydrologic zones is captured by BW-18.

In addition to BW-18, City Well 132 (CW-132) was actively pumping during April and May 1989. City Well 132 pumped approximately 700 gpm, averaging 700 hours per month until June 1989, when pumping ceased. Analysis of the hydrologic data indicates that CW-132 alone had a minimal effect on groundwater flow under OU B. When BW-18 is off, groundwater flow beneath OU B is not strongly influenced by CW-132, the nearest municipal well, but is drawn southwesterly toward the large, pumping-induced, groundwater depression.

A3.2.1 Hydrologic Data

Hydrologic data collected during 1989-1990 OUBGRI and Engineering Evaluation/Cost Analysis-Environmental Assessment (EE/CA-EA) field activities consist of eight rounds of synoptic water-level measurements. The measurements reflect seasonal variations in groundwater flow conditions and reflect the influence of different supply well pumping conditions. Because of variations in the pumping of major supply wells in OU B, it may not be possible to characterize stabilized or steady-state conditions. However, the variations allow for analysis of hydraulic conditions that may have affected flow within OU B over the last 10 years. Table A3-2 summarizes the various conditions under which water-level measurements were obtained during 1989 and 1990. Water levels measured at eight different times in 1989 and 1990 are listed in Table A3-3. The May 1989 data should be evaluated with caution as BW-18 had only been returned to service for two weeks and the hydraulic effects from BW-18 may not have completely stabilized. Water levels from 8 December 1989 should also be evaluated with caution as they were measured only one week after BW-18 had been shut off and those measurements do not represent hydraulic conditions equivalent to steady-state conditions without pumping of BW-18. The April 1989 and January 1990 data are more representative of steady-state groundwater flow under nonpumping conditions. The January data set includes additional monitoring wells and well clusters which were drilled and completed after September 1989 during PGOURI and EE/CA-EA field activities. Figure A3-1 shows the current locations of all wells within and adjacent to OU B.

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TABLE A3-2. WATER-LEVEL MEASUREMENTS VERSUS PUMPING ACTIVITY IN OU B, 1989-1990

Month Measured	BW-18	CW-132	Comment
April 1989	Off	On	BW-18 off for 17 days
May 1989	On	On	BW-18 on for 14 days
August 1989	On	Off	
October 1989	On	Off	
December 1, 1989	On	Off	
December 8, 1989	Off	Off	BW-18 off only for 7 days
January 1990	Off	Off	BW-18 off for over a month
April 1990	On	Off	

TABLE A3-3. WATER-LEVEL MEASUREMENTS IN THE VICINITY OF OU B, 1989-1990

Well Number	Water-Level Elevations (msl) feet							
	Apr. 1989	May 1989	Aug. 1989	Oct. 1989	Dec. 1, 1989	Dec. 8, 1989	Jan. 1990	Apr. 1990
A ZONE								
MW-7	-39.47	-40.77	-44.30	-44.13	-42.88	-41.38	-40.21	-40.75
MW-41S	-38.62	-38.72	-40.93	-41.33	-41.39	-	-40.31	-39.59
MW-65	-	-38.28	-40.53	-40.92	-38.87	-	-39.89	-39.14
MW-116	-36.10	-36.19	-37.74	-38.24	-38.43	-38.32	-37.92	-37.51
MW-120	-36.84	-37.12	-40.45	-	-	-	-	-
MW-121	-37.18	-38.55	-41.28	-41.33	-40.73	-	-38.64	-39.19
MW-135	-37.75	-38.32	-41.50	-41.30	-40.45	-40.00	-39.23	-38.95
MW-145	-39.12	-44.41[a]	-44.18	-43.48	-42.25	-41.10	-39.80	-40.42
MW-150	-40.31	-41.70	-44.93	-44.84	-43.83	-40.79	-41.32	-41.73
MW-153	-	-	-49.75	-42.28	-42.16	-41.92	-40.62	-40.30
MW-155	-	-	-	-	-42.82	-41.99	-40.29	-40.84
MW-157	-	-	-	-	-	-41.47	-40.32	-39.67
MW-158	-	-	-	-	-41.54	-41.04	-40.36	-39.77
MW-159	-	-	-	-	-	-	-39.21	-38.60
MW-164	-	-	-	-	-	-	-	-39.10
MW-1000	-40.09	-41.77	-44.91	-	-43.08	-41.58	-40.28	-41.17
MW-1011	-35.55	-38.82	-40.33	-	-40.88	-40.81	-36.75	-39.60
MW-1015	-40.94	-41.72	-44.51	-44.71	-43.52	-45.17	-42.73	-41.28
MW-1016	-40.63	-42.23	-45.08	-45.39	-44.06	-43.52	-41.22	-41.85
MW-1020	-40.18	-41.83	-44.97	-44.96	-41.08	-41.63	-40.32	-
MW-1021	-39.64	-42.79	-45.35	-46.42	-49.81	-36.46	-40.72	-42.23
MW-1023	-43.16	-43.54	-44.70	-44.98	-44.19	-49.12	-41.47	-41.23
MW-1044	-40.13	-41.99	-44.99	-45.51	-44.16	-36.80	-40.95	-41.99
MW-1049	-	-44.26	-44.26	-45.71	-44.93	-43.18	-29.71[a]	-42.32
MW-1053	-	-	-	-	-44.77	-44.65	-42.53	-42.75
MW-1054	-	-	-	-	-44.30	-44.67	-41.16	-42.19

continued

TABLE A3-3. (Continued)

Well Number	Water-Level Elevations (msl) feet							
	Apr. 1989	May 1989	Aug. 1989	Oct. 1989	Dec. 1, 1989	Dec. 8, 1989	Jan. 1990	Apr. 1990
B ZONE								
MW-23D	-39.15	-45.53	-50.09	-48.20	-46.53	-40.72	-40.61	-44.38
MW-63	-38.92	-43.07	-47.60	-45.78	-44.25	-39.10	-39.14	-42.32
MW-64	-	-44.98	-50.04	-47.60	-	-39.38	-39.68	-43.78
MW-66	-47.99[a]	-46.36	-51.79	-49.98	-47.21	-38.66	-40.33	-46.12
MW-122	-36.37	-39.53	-43.05	-42.33	-40.52	-	-37.40	-
MW-134	-37.61	-38.61	-42.53	-41.40	-40.16	-39.30	-38.68	-38.76
MW-146	-38.84	-44.98	-45.04	-43.73	-42.34	-40.74	-39.37	-40.61
MW-151	-39.66	-43.93	-48.32	-46.54	-45.01	-40.09	-40.64	-42.95
MW-156	-	-	-	-	-44.24	-40.22	-39.25	-
MW-165	-	-	-	-	-	-	-	-39.39
MW-1022	-39.10	-47.77	-51.93	-51.18	-45.65	-35.87	-40.21	-46.67
MW-1025	-44.74	-45.84	-47.03	-46.83	-45.09	-47.74	-45.90	-43.24
MW-1045	-39.67	-44.69	-48.48	-47.41	-45.78	-37.80	-40.00	-43.68
MW-1050	-	-44.60	-46.97	-45.82	-45.27	-42.52	-41.69	-42.40
MW-1055	-	-	-	-	-45.63	-44.32	-40.56	-42.73
C ZONE								
MW-132	-38.84	-44.45	-49.64	-46.95	-45.28	-40.22	-39.43	-43.30
MW-147	-38.59	-41.46[a]	-46.19	-44.05	-42.41	-41.21	-39.22	-40.71
MW-152	-39.26	-46.29	-51.25	-48.58	-46.73	-40.70	-40.78	-44.65
MW-154	-	-	-50.20	-47.28	-45.33	-38.83	-38.76	-43.32
MW-166	-	-	-	-	-	-	-	-39.09
MW-181	-	-	-	-	-	-	-	-37.63
MW-1046	-39.24	-46.64	-48.91	-48.99	-47.16	-38.68	-39.63	-44.99
MW-1051	-	-45.18	-47.90	-46.17	-44.72	-42.47	-41.54	-42.81
MW-1056	-	-	-	-	-47.20	-44.80	-39.97	-43.91

continued

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TABLE A3-3. (Continued)

Well Number	Water-Level Elevations (msl) feet							
	Apr. 1989	May 1989	Aug. 1989	Oct. 1989	Dec. 1, 1989	Dec. 8, 1989	Jan. 1990	Apr. 1990
D ZONE								
MW-148	-	-40.38	-47.18	-43.14	-41.01	-38.29	-37.48	-39.30
MW-162	-	-	-	-	-	-	-	-35.99
MW-167	-	-	-	-	-	-	-	-37.45
MW-1047	-36.84	-40.33	-47.33	-43.20	-40.90	-37.97	-37.44	-39.17
MW-1052	-	-39.70	-46.79	-42.37	-40.27	-38.82	-37.97	-38.70
MW-1057	-	-	-	-	-40.43	-38.43	-37.38	-38.78
E ZONE								
MW-149	-	-39.40	-47.16	-42.36	-40.02	-37.84	-37.05	-38.33
MW-168	-	-	-	-	-	-	-	-37.39
MW-1048	-38.24	-40.23	-47.30	-43.12	-46.05	-37.40	-44.08	-39.15

[a] These measurements are suspect and have not been used in hydrologic evaluations.

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A3.2.2 Vertical Hydraulic Potentials and Gradients

A comparison of water-level measurements for pumping and non-pumping conditions shows a decline in water-level elevations as a result of the pumping of BW-18 (Table A3-3). The impact of BW-18 is emphasized in Tables A3-4 and A3-5 which compare measurements obtained in January 1990, when BW-18 was off, to those obtained 1 December 1989 and April 1990 when BW-18 was on. A similar comparison of May and April 1989 data is presented in Table A3-3. Differences in water-level data in these three tables indicate that when the base well is on, water levels in each zone decrease as groundwater around the well's screens is drawn into the well by the pump. Base Well 18 has four screened intervals occurring from 169 to 185 feet (B zone), 210 to 260 feet (C zone), 304 to 349 (D zone), and 378 to 387 feet (E zone) BGS. In general, the water-level data show that the C geohydrologic zone is the most affected by BW-18, as this zone experiences the largest and most widespread difference in water levels between pumping and non-pumping conditions. The C zone is the most affected because the largest screened interval (50 feet of BW-18) and the most permeable deposits are located in this zone. The B zone, however, is also strongly influenced near BW-18, although the supply well is only screened over 16 feet in this zone. Lower permeability deposits in the B zone and partial hydraulic connection with the C zone may contribute to BW-18's strong effect on the B zone. Water-level differences are less significant in the D zone, and are least in the E and A zones. The relative effects of BW-18 on the different geohydrologic zones are clearly illustrated in a comparison of water level differences between January 1990 and April 1990 for MW-1044, MW-1045, MW-1046, MW-1047, and MW-1048, a cluster of wells 800 feet to the southwest from BW-18.

In general, the effects of BW-18 on water levels decrease with increasing distance from the base well (Table A3-3). Declines in water level between April and May 1989 suggest the effects of BW-18 on wells in the A and B zones as far as 3,500 feet away. Similar influence by the base well is exhibited radially in the A, B, and C zones in a comparison of January 1990 with December and April 1989 data (Tables A3-4 and A3-5). MW-1053, MW-1011 and MW-1023, which are 2900 feet, 3350 feet, and 3500 feet away respectively, all exhibit significant recovery in January, when the base well was turned off, compared to December 1989 water levels when the base well was operating. These wells are at large radial distances downgradient from the base well, and other unknown impacts on their water levels may exist. The wide spacing between the monitoring wells and BW-18 places limits on the interpretation of these

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TABLE A3-4. WATER LEVELS FOR WELLS IN THE VICINITY OF OU B COMPARING EFFECTS WITH AND WITHOUT PUMPING (DECEMBER 1989 VERSUS JANUARY 1990 DATA)

Well Number	With Pumping December 1 Elevation (msl) feet	Without Pumping January Elevation (msl) feet	Head Difference (Dec-Jan)	Distance From BW-18 (feet)
A ZONE				
MW-1021	-49.81	-40.72	-9.09	280
MW-153	-42.16	-40.62	-1.51	600
MW-1044	-44.16	-40.95	-3.21	680
MW-158	-41.54	-40.36	-1.18	800
MW-155	-42.82	-40.29	-2.53	850
MW-41S	-41.39	-40.31	-1.08	880
MW-7	-42.88	-40.21	-2.67	900
MW-150	-43.83	-41.32	-2.51	980
MW-65	-38.87	-39.89	+1.02	1,130
MW-1016	-44.06	-41.22	-2.84	1,140
MW-1054	-44.30	-41.16	-3.14	1,185
MW-1000	-43.08	-40.28	-2.8	1,480
MW-1020	-41.08	-40.32	-0.76	1,490
MW-145	-42.25	-39.80	-2.45	1,520
MW-101S	-43.52	-42.73	-0.79	2,260
MW-135	-40.45	-39.23	-1.22	2,500
MW-1053	-44.77	-42.53	-2.24	2,900
MW-1011	-48.88	-36.75	-4.13	3,350
MW-1023	-44.19	-41.47	-2.72	3,500
MW-116	-38.43	-37.92	-0.51	4,080
B ZONE				
MW-1022	-45.65	-40.21	-5.44	300
MW-66	-47.21	-40.33	-6.88	380
MW-23D	-46.53	-40.61	-5.92	590
MW-1045	-45.78	-40.00	-5.78	680
MW-156	-44.24	-39.25	-4.99	680
MW-63	-44.25	-39.14	-5.11	700
MW-151	-45.01	-40.64	-4.37	940
MW-1055	-45.63	-40.56	-5.07	1,120
MW-146	-42.34	-39.37	-2.77	1,520
MW-122	-40.52	-37.40	-3.12	1,700
MW-1050	-45.27	-41.69	-3.58	2,300
MW-134	-40.16	-38.68	-1.48	2,440
MW-1025	-45.09	-45.90	+0.81	3,480

continued--

TABLE A3-4. (Continued)

Well Number	With Pumping December 1 Elevation (msl) feet	Without Pumping January Elevation (msl) feet	Head Difference (Dec-Jan)	Distance From BW-18 (feet)
C ZONE				
MW-154	-45.33	-38.76	-6.57	650
MW-1046	-47.16	-39.63	-7.53	680
MW-132	-45.28	-39.43	-5.85	800
MW-152	-46.73	-40.78	-5.95	960
MW-1056	-47.20	-39.97	-7.23	1,130
MW-147	-42.41	-39.22	-3.19	1,520
MW-1051	-44.72	-41.54	-3.18	2,375
D ZONE				
MW-1047	-40.90	-37.44	-3.46	680
MW-148	-41.01	-37.48	-3.53	940
MW-1057	-40.43	-37.38	-3.05	1,130
MW-1052	-40.27	-37.97	-2.30	2,375
E ZONE				
MW-1048	-46.05	-44.08	-1.97	680
MW-149	-40.02	-37.05	-2.97	940

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TABLE A3-5. WATER LEVELS FOR WELLS IN THE VICINITY OF OU B COMPARING EFFECTS WITH AND WITHOUT PUMPING (JANUARY VERSUS APRIL 1990 DATA)

Well Number	Without Pumping January Elevation (msl) feet	With Pumping April Elevation (msl) feet	Head Difference (Apr-Jan)	Distance From BW-18 (feet)
A ZONE				
MW-1021	-40.72	-42.23	-1.51	280
MW-153	-40.62	-40.30	+0.32	600
MW-1044	-40.95	-41.99	-1.04	680
MW-158	-40.36	-39.77	+0.59	800
MW-157	-39.19	-40.32	-1.13	820
MW-155	-40.29	-40.84	-0.55	850
MW-41S	-40.31	-39.59	+0.54	880
MW-7	-40.21	-40.75	-0.54	900
MW-150	-41.32	-41.73	-0.41	980
MW-159	-39.21	-38.60	+0.61	1,000
MW-65	-39.89	-39.14	+0.75	1,130
MW-1016	-41.22	-41.85	-0.63	1,140
MW-1054	-41.16	-42.19	-1.03	1,185
MW-1000	-40.28	-41.17	-0.89	1,480
MW-145	-39.80	-40.42	-0.62	1,520
MW-121	-38.64	-39.19	-0.55	1,700
MW-1015	-42.73	-41.28	+1.45	2,260
MW-135	-39.23	-38.95	+0.28	2,500
MW-1053	-42.53	-42.75	-0.22	2,900
MW-1011	-36.75	-39.60	-2.85	3,350
MW-1023	-41.47	-41.23	+0.24	3,500
MW-116	-37.92	-37.51	+0.41	4,080
B ZONE				
MW-1022	-40.21	-46.67	-6.46	300
MW-66	-40.33	-46.12	-5.78	380
MW-64	-39.68	-43.78	-4.10	470
MW-23D	-40.61	-44.38	-3.77	590
MW-1045	-40.00	-43.68	-3.68	680
MW-63	-39.14	-42.32	-3.18	700
MW-151	-40.64	-42.95	-2.31	940
MW-1055	-40.56	-42.73	-2.17	1,120
MW-146	-39.37	-40.61	-1.24	1,520
MW-1050	-41.69	-42.73	-1.04	2,300
MW-134	-38.68	-38.76	-0.08	2,440
MW-1025	-45.90	-43.24	+2.66	3,480

continued--

TABLE A3-5. (Continued)

Well Number	Without Pumping January Elevation (msl) feet	With Pumping April Elevation (msl) feet	Head Difference (Apr-Jan)	Distance From BW-18 (feet)
C ZONE				
MW-154	-38.76	-43.32	-4.56	650
MW-1046	-39.63	-44.99	-5.36	680
MW-132	-39.43	-43.30	-3.87	800
MW-152	-40.78	-44.65	-3.87	960
MW-1056	-39.97	-43.91	-3.94	1,130
MW-147	-39.22	-40.71	-1.49	1,520
MW-1051	-41.54	-42.81	-1.27	2,375
D ZONE				
MW-1047	-37.44	-39.17	-1.73	680
MW-148	-37.48	-39.30	-1.82	940
MW-1057	-37.38	-38.78	-1.40	1,130
MW-1052	-37.97	-38.70	-0.73	2,375
E ZONE				
MW-1048	-44.08	-39.15	+4.93	680
MW-149	-37.05	-38.33	-1.28	940

data. A 3,000 to 3,500 foot zone of influence resulting from pumping at BW-18 is unexpected, particularly in the A zone in which the well is not screened. A comparison of water-level differences between April and May 1989 and between December 1989 and January 1990 for upgradient wells in OU C that are at similar distances from BW-18 shows the influence of BW-18 on all zones monitored (Metcalf and Eddy, 1989). Fluctuations in water levels in OU C wells occurred immediately after the base well was turned on (April 1989) or shut off (December 1989) and are, therefore, attributable to the base well. In contrast, wells in OU D, located at greater radial distances upgradient from BW-18, showed smaller variations in water levels during the first week and gradual changes over time (Figure A3-2).

Water levels in wells in OU C upgradient from BW-18 should, theoretically, be more strongly influenced by pumping than wells at an equal distance downgradient in OU B because the groundwater surface in downgradient wells is lower and slopes away from BW-18. However, recoveries of 2.24, 4.13, and 2.72 feet were exhibited by A zone wells MW-1053, MW-1011, and MW-1023, respectively, when BW-18 was shut off. It appears that the permeability of deposits in the A zone and the continuity of deposits with lower zones are sufficiently great that the base well significantly affects the groundwater in the zone at large radial distances upgradient and downgradient.

Base Well 18 does not have equal screen intervals in each of the five geohydrologic zones. Therefore, the well would not be expected to have an equivalent influence on all zones. The notable differences in water levels that persist between geohydrologic zones with and without pumping supports the hypothesis that the zones are not completely interconnected and that hydraulic potentials occur between zones as a result of confining or semi-confining, fine-grained deposits in each zone. In Tables A3-6 to A3-8, water-level (head) differences and vertical gradients between adjoining zones are compared both with and without pumping. The well pairs compared are those which lie within the same cluster, but are screened in separate geohydrologic zones. The wells in each pair are located within a radius of 50 feet. Therefore, the head differences between zones represent vertical and not horizontal potential differences. Vertical gradient magnitudes and directions measured in April 1990 between wells screened in adjacent zones are included on Plates 3 and 4 for well pairs along cross sections A-A′ and B-B′.

Potentials and gradients between the A and B zones and between the B and C zones for the majority of well pairs reverse with the onset of pumping. These two

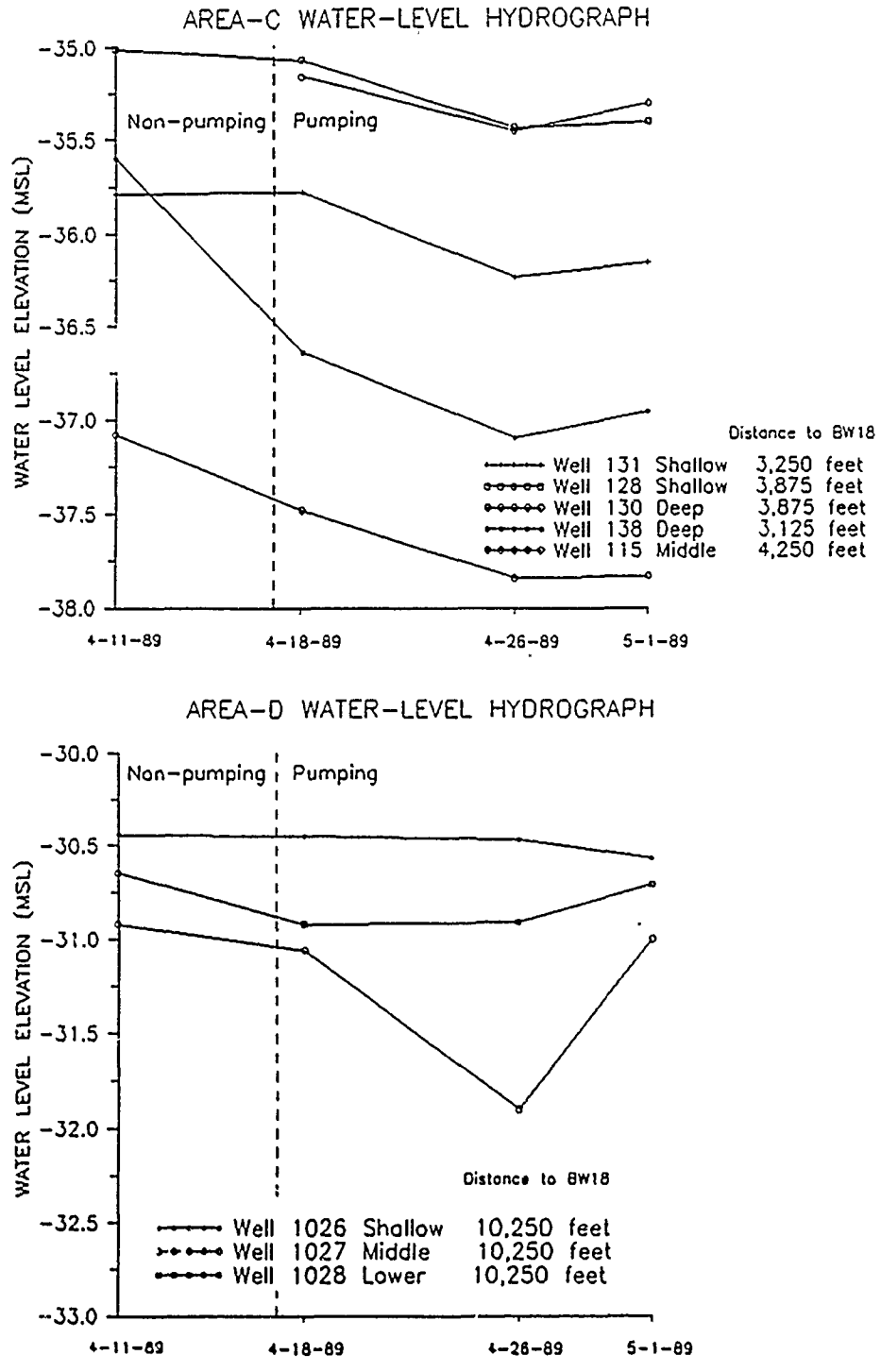

Figure A3-2. Hydrographs for Select Monitoring Wells in Areas C and D During April 1989.

SOURCE: Water-Level Data from Metcalf and Eddy, June 1989 Monthly Monitoring Report

0890-074-7

TABLE A3-6. VERTICAL HYDRAULIC GRADIENTS BETWEEN ADJACENT GEOHYDROLOGIC ZONES IN OU B FOR AUGUST AND OCTOBER 1989

Well Pair	Geohydrologic Zones	Head Difference (feet) August (BW-18 on)	Head Difference (feet) October (BW-18 on)	Gradient[a] (feet/foot) August (BW-18 on)	Gradient[a] (feet/foot) October (BW-18 on)
MW-120/122	A/B	-2.60	-	-0.03	-
MW-145/146	A/B	-0.86	-0.25	-0.01	-0.003
MW-150/151	A/B	-3.39	-1.70	-0.05	-0.03
MW-1021/1022	A/B	-6.58	-4.76	-0.14	-0.10
MW-1044/1045	A/B	-3.49	-1.90	-0.06	-0.03
MW-1049/1050	A/B	-2.71	-0.11	-0.07	-0.003
MW-134/135	A/B	-1.03	-0.10	-0.02	-0.002
MW-146/147	B/C	-1.15	-0.32	-0.03	-0.008
MW-151/152	B/C	-2.93	-2.04	-0.04	-0.03
MW-1045/1046	B/C	-0.43	-1.58	-0.005	-0.02
MW-1050/1051	B/C	-0.93	-0.35	-0.01	-0.006
MW-1046/1047	C/D	+1.58	+5.79	+0.02	+0.09
MW-1051/1052	C/D	+1.11	+3.80	+0.01	+0.04
MW-148/149	D/E	+0.02	+0.78	+0.0003	+0.01
MW-1047/1048	D/E	+0.03	+0.08	+0.001	+0.002

[a] Positive numbers indicate upward gradients between zones; negative numbers indicate downward gradients.

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TABLE A3-7. VERTICAL HYDRAULIC GRADIENTS BETWEEN ADJACENT GEOHYDROLOGIC ZONES IN OU B FOR DECEMBER, 1989

Well Pair	Geohydrologic Zones	Head Difference (feet) Dec. 1 (BW-18 on)	Head Difference (feet) Dec. 8 (BW-18 off)	Gradient[a] (feet/foot) Dec. 1 (BW-18 on)	Gradient[a] (feet/foot) Dec. 8 (BW-18 off)
MW-120/122	A/B	-	-	-	-
MW-145/146	A/B	-0.09	+0.36	-0.001	+0.0045
MW-150/151	A/B	-1.18	+0.70	-0.02	+0.01
MW-1021-1022	A/B	+4.16	+0.59	+0.09	+0.01
MW-1044/1045	A/B	-1.62	-1.00	-0.03	-0.02
MW-1049/1050	A/B	-0.34	+0.66	-0.01	+0.02
MW-134/135	A/B	+0.29	+0.70	+0.005	+0.01
MW-155/156	A/B	-1.42	+1.77	-0.02	+0.03
MW-1054/1055	A/B	-1.06	+0.35	-0.02	+0.006
MW-146/147	B/C	-0.07	-0.47	-0.002	-0.01
MW-151/152	B/C	-1.72	-0.61	-0.02	-0.01
MW-1045/1046	B/C	-1.38	-0.88	-0.02	-0.01
MW-1050/1051	B/C	+0.55	+0.05	+0.01	+0.001
MW-1055/1056	B/C	+5.2	+5.89	+0.06	+0.07
MW-1046/1047	C/D	+6.26	+0.71	+0.09	+0.01
MW-1051/1052	C/D	+4.45	+3.65	+0.04	+0.04
MW-1056/1057	C/D	+6.77	+6.37	+0.13	+0.12
MW-148/149	D/E	+0.99	+0.45	+0.02	+0.01
MW-1047/1048	D/E	-5.15	+1.03	-0.13	+0.03

[a] Positive numbers indicate upward gradients between zones; negative numbers indicate downward gradients.

TABLE A3-8. VERTICAL HYDRAULIC GRADIENTS BETWEEN ADJACENT GEOHYDROLOGIC ZONES IN OU B FOR JANUARY AND APRIL 1990

Well Pair	Geohydrologic Zone	Head Difference (feet) January 1990 (BW-18 off)	Gradient[a] (feet/foot) January 1990 (BW-18 off)	Head Difference (feet) April 1990 (BW-18 on)	Gradient[a] (feet/foot) April 1990 (BW-18 on)
MW-120/122	A/B	--	--	--	--
MW-145/146	A/B	+0.23	+0 003	-0.19	-0.0002
MW-150/151	A/B	+0.68	+0.01	-1.22	-0.019
MW-1021/1022	A/B	+0.51	+0.01	-4.24	-0.088
MW-1044/1045	A/B	+0.95	+0.02	-1.69	-0.029
MW-1049/1050	A/B	+11.98[b]	+0.3	-0.08	-0.002
MW-135/134	A/B	+0.55	+0.01	+0.19	+0.003
MW-155/156	A/B	+5.04	+0.02	--	--
MW-1054/1055	A/B	+0.60	+0.01	-0.54	-0.009
MW-164/165	A/B	--	--	-0.29	-0.004
MW-146/147	B/C	+0.35	+0.01	-0.10	-0.002
MW-151/152	B/C	-0.14	-0.002	-1.7	-0.02
MW-1045/1046	B/C	+0.37	+0.005	-1.31	-0.016
MW-1050/1051	B/C	+0.15	+0.002	-0.41	-0.006
MW-1055/1056	B/C	+0.59	+0.007	-1.18	-0.013
MW-165/166	B/C	--	--	+0.30	+0.004
MW-1046/1047	C/D	+2.19	+0.03	+5.82	+0.088
MW-1051/1052	C/D	+3.57	+0.04	+4.11	+0.41
MW-1056/1057	C/D	+2.59	+0.05	+10.13	+0.20
MW-166/167	C/D	--	--	+1.64	+0.02
MW-148/149	D/E	+0.43	+0.01	+0.97	+0.016
MW-1047/1048	D/E	-6.64	-0.17	+0.02	+0.0005
MW-167/168	D/E	--	--	+0.06	+0.004

[a] Positive numbers indicate upward gradients between zones; negative numbers indicate downward gradients.

[b] Water levels measured in one of these wells appeared to be erroneous when compared to other data and are not considered in the hydrologic evaluation.

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zone boundaries exhibit upward flow (positive potential) under nonpumping conditions at BW-18 (April 1989 and January 1990) and downward flow (negative potential) when BW-18 is pumping. In general, gradients at these two boundaries are greater when under the influence of pumping than under nonpumping conditions. The reversal of gradients exhibited by zone boundaries between the A and B and the B and C zones, and the downward flow to the C zone during pumping supports the conclusion that the C zone is the zone most strongly influenced by BW-18.

While the majority of well pairs exhibited a gradient reversal at the A/B and B/C boundaries with the onset of pumping, a few well pairs did not. Well pair MW-134 and MW-135, located 2450 feet northwest of BW-18, was reduced from a positive gradient in April 1989 to an unmeasurable gradient in May 1989 after BW-18 had been turned on. In August and October 1989, the gradient was negative while the well was pumping. A gradient reversal at the well pair may have been delayed because BW-18 had only been pumping for two weeks in May 1989 and the full hydraulic effects of the pumping well may not have stabilized at this distance. However, on December 1 (BW-18 on), the gradient at this well pair was slightly positive. When BW-18 was shut off in January, the gradient increased and remained positive. In April 1990, when the base well had been in operation for over a month, the gradient was not reversed but was small and positive. Therefore, the location of this well cluster represents at least one point in OU B where an upward gradient may exist between the A and B geohydrologic zones even under the influence of an actively pumping BW-18. A positive gradient was also recorded across the A/B zone boundary at MW-1021 and MW-1022 on December 1 when BW-18 was on. However, this well pair, which is located within 280 feet of BW-18, had a negative gradient during all other measurement events when BW-18 was on. A positive gradient is unexpected during pumping, as the well pair is only 280 feet from the base well, and is due to an unusually low water level in MW-1021. It is possible that an error was made in recording the measurement. However, MW-1022, the B zone well, had been pump tested just prior to December 1, and draw down had been observed in MW-1021.

At the B/C geohydrologic zone boundary, the majority of well pairs exhibit a gradient reversal with the onset of pumping. Exceptions occurred on 1 December 1989 at pairs MWs 1050 and 1051, and MWs 1055 and 1056, and in April 1990 at MWs 165 and 166. Positive gradients were recorded at those times when BW-18 was on. These well pairs, therefore, represent locations at which, under certain conditions, upward gradients can exist even when BW-18 is pumping. In January 1990, a B/C zone well pair, MW-151 and MW-142, showed a negative gradient when BW-18 was not pumping.

This is an exception to the general behavior of the majority of B/C well pairs and highlights the geologic and hydrologic differences that occur within and between zones. These exceptions illustrate that well pair response is not always identical and predictable under the conditions that prevail during each measuring event.

The vertical gradient data for the C/D zone boundary does not show a reversal in response to pumping by BW-18. The gradient at this boundary is always positive and increases in magnitude when BW-18 is on. The largest increase is exhibited by the well pairs closest to BW-18, MWs 1046 and 1047, and MWs 1056 and 1057, and the smallest increase by the C/D well pair farthest from BW-18, MWs 1051 and 1052. The increase in upward gradient during pumping again emphasizes the influence of BW-18 on the C zone over other zones and that hydraulic continuity exists between zones. It should be noted that larger gradients occur across the C/D zone boundary than across any other boundary in any measurement event. For example, all well-pair gradients across the C/D boundary in January and April 1990 are larger than those at any other boundary during the same sounding.

Vertical gradient data for the D/E zone boundary is very limited and is more ambiguous than that for the other boundaries. Only one well pair was available for measurement in April 1989, MWs 1047 and 1048, and only two pairs, MWs 1047 and 1048, and MWs 148 and 149, were available for August, October, December 1989 and January 1990 measurements; in April 1990 a third pair, MWs 167 and 169, was measured. In general, the data show that when BW-18 is on, the D/E boundary experiences an upward gradient; this was observed in May, August, and October of 1989 and April 1990. However, on 1 December 1989, MWs 1047 and 1048 exhibited a downward gradient while MWs 148 and 149 showed an upward gradient.

The data are more ambiguous for the D/E boundary when the base well is off. The well pair, MW-148 and MW-149, always exhibits an upward gradient whether the base well is on or not, and the pair has an increased gradient under the influence of pumping (compare January 1990 and December 1989 data). The well pair, MW-167 and MW-168, has only been measured once, and the gradient was positive when BW-18 was on. The gradients for MW-1047 and MW-1048 are generally positive when BW-18 is on (except on December 1), but are not consistent when the base well is off. The gradient at this well pair is negative in April 1989 and January 1990, but is positive on December 8, 1989 (after being negative on December 1). The variable behavior of this well pair suggests that other factors besides BW-18, have influences on gradients.

In addition to BW-18, CW-132 was actively pumping during April and May 1989 (Table A3-2). The effects of pumping activity by CW-132 on groundwater under OU B can be best determined by comparing May (BW-18 on, CW-132 on) with August or October 1989 data (BW-18 off, CW-132 on). Water levels in the two southernmost clusters of wells closest to CW-132 (MW-1023, MW-1025, MW-1049, MW-1050, MW-1051, and MW-1052) were lower in August and October when CW-132 was off than in May when CW-132 was on. This indicates that seasonal variations in precipitation and recharge had more of an influence on water level differences between May and August or October than did pumping by CW-132. The pumping activity of the municipal well appeared to have little effect on groundwater even in the closest monitor wells. A difference in head of only -1.58 feet was recorded for well pair MW-1023 and MW-1025 in April 1989 (BW-18 off, CW-132 on), as compared to -4.43 feet recorded in January 1990 (BW-18 off, CW-132 off). If CW-132 had a large effect on groundwater flow beneath OU B, the larger head difference for the two measurement periods would be expected in April 1989. The larger difference was recorded in January 1990, which suggests that variations in recharge between the two measurements had a greater influence on water levels than did pumping by CW-132. City Well 132 appeared to have negligible effects on the groundwater beneath OU B when it was operating.

In summary, hydrologic data collected in the measurement events during 1989 and 1990 indicate that the geohydrologic zones beneath OU B exhibit changes in vertical potential when conditions of pumping at BW-18 are compared to nonpumping conditions. The data show that there is some degree of hydraulic separation between zones, but that hydraulic communication exists. Vertical hydraulic potentials in each of the five identified geohydrologic zones are affected over radial distances of at least 3000 feet by the pumping of BW-18 at its current rate of 1.5 to 1.6 million gallons per day.

A3.2.3 Horizontal Hydraulic Potentials and Gradients

Water-level elevations, listed in Table A3-3, were used to construct potentiometric maps and to determine horizontal gradients. A sufficient number of wells were available for measurement in the A, B, and C geohydrologic zones during each measuring event to contour the potentiometric surfaces for each of these zones. A potentiometric surface for the D geohydrologic zone was constructed with April 1990 water levels. With the exception of April 1990, potentiometric maps were not constructed for the D or E geohydrologic zones because of the limited number of measuring points in those zones. Potentiometric surface maps for May and April 1989,

and maps based on subsequent data listed in Table A3-3, are shown here in Figures A3-3 to A3-21.

Regional groundwater gradients and flow directions to a depth of 360 feet BGS in OU B are best approximated by April 1989 and January 1990 potentiometric surface maps from data collected when BW-18 was inactive (Figures A3-3 to A3-5, A3-15 to A3-17). In generai, the potentiometric surfaces indicate a decrease in potential from the north and northeast to the south and southwest in the A and B geohydrologic zones. At the time of these two measurements, groundwater within these two zones in OU B was flowing away from McClellan AFB to the southwest. The hydraulic potential gradient causing the flow to the southwest is attributable to a large groundwater depression caused by municipal well pumping. The center of the depression is located to the south or southwest of McClellan AFB. Water levels were slightly lower in the A and B zones in January 1990 than in April 1989. Differences in hydraulic head between the two measurements may be attributed to one or more of the following: differences in recharge between the two measurements, the continuing regional decline due to municipal pumping, or the incomplete stabilization of hydraulic conditions because BW-18 had been inactive for only 17 days in April 1989.

Groundwater flow directions in the C geohydrologic zone when BW-18 is not pumping cannot be readily determined. Four C zone wells were measured in April 1989, and seven in January 1990. On the basis of measurements from that limited array of wells, the groundwater flow direction in the C zone appears to be southeasterly (Figures A3-4 and A3-16). Because BW-18 was inactive, flow direction cannot be in response to pumping by the supply well. Regardless, an interpretation of groundwater flow direction should not be made based on such a limited data set.

As discussed in Section A3.2.2, when BW-18 is actively pumping, groundwater flow in OU B is affected. Pumping of the well creates a hydraulic potential which influences local flow direction in all zones. The magnitude and radial extent of this influence varies with pumping schedules and seasonal recharge differences. In general, once the hydraulic effects due to pumping of BW-18 have stabilized, much of the groundwater in the A, B, C, and D zones in OU B flows toward BW-18. Boundaries on the zone of capture are undefined in the C and D zones due to limited data. However, the data are sufficient to show that groundwater flows toward BW-18 in the C zone and does not flow preferentially parallel to the high permeability stream deposits which trend west and southwest from BW-18 toward MW-1046. The limited data set for the D zone for April 1990 indicates that, for this zone too, flow in the vicinity of BW-18 (minimum

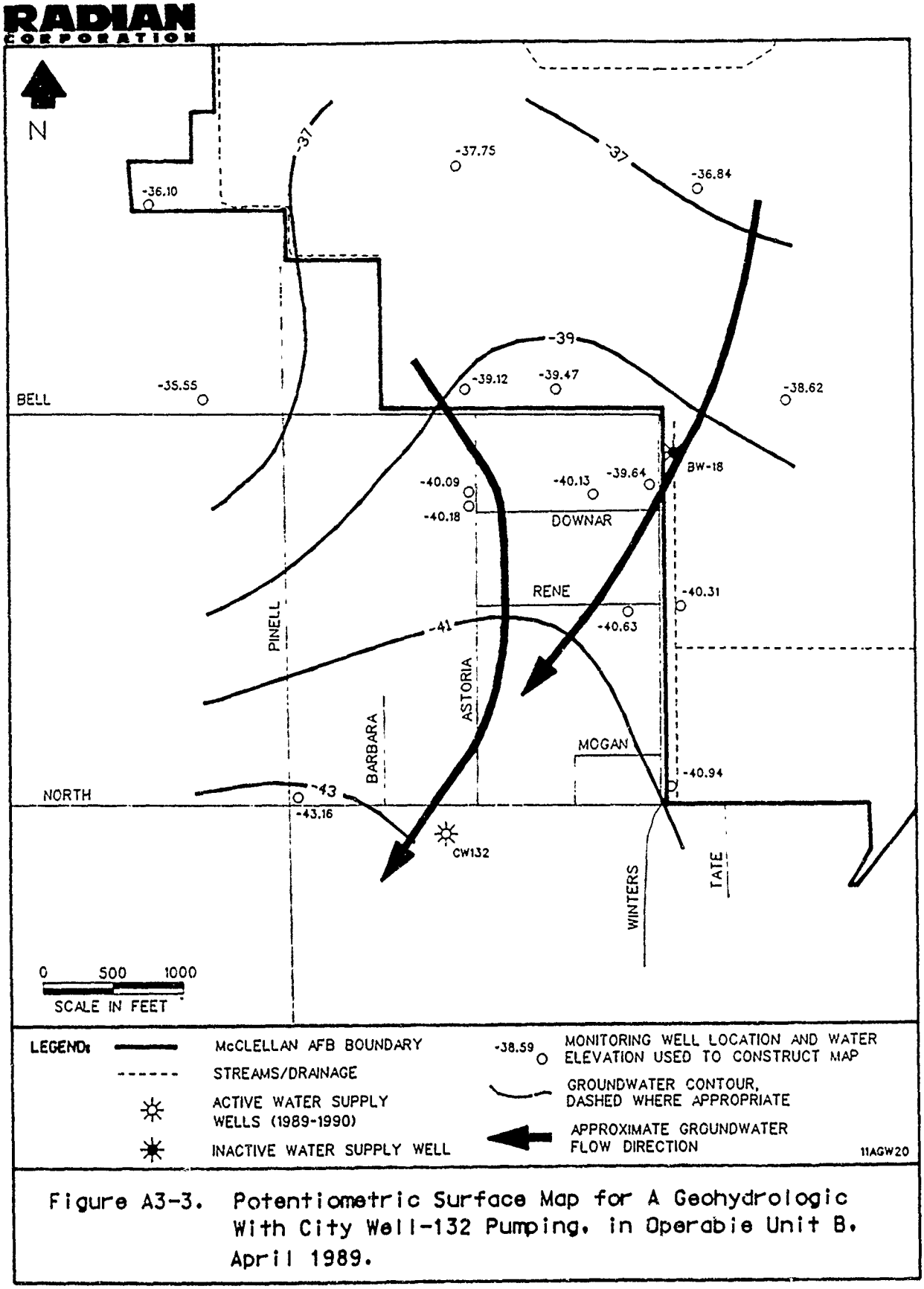

Figure A3-3. Potentiometric Surface Map for A Geohydrologic With City Well-132 Pumping, in Operable Unit B, April 1989.

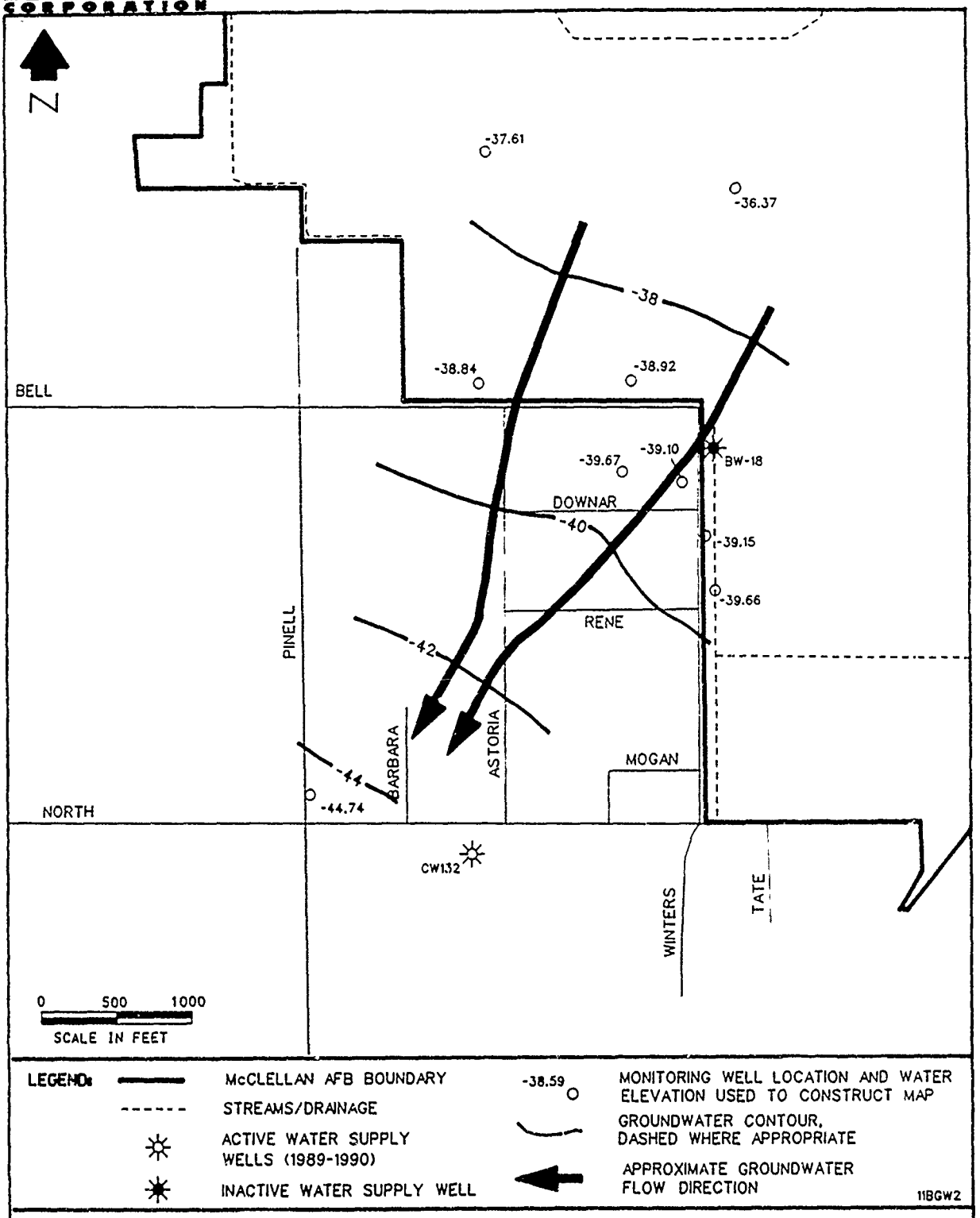

Figure A3-4. Potentiometric Surface Map for the B Geohydrologic Zone, With City Well-132 Pumping, April 1989, Operable Unit B.

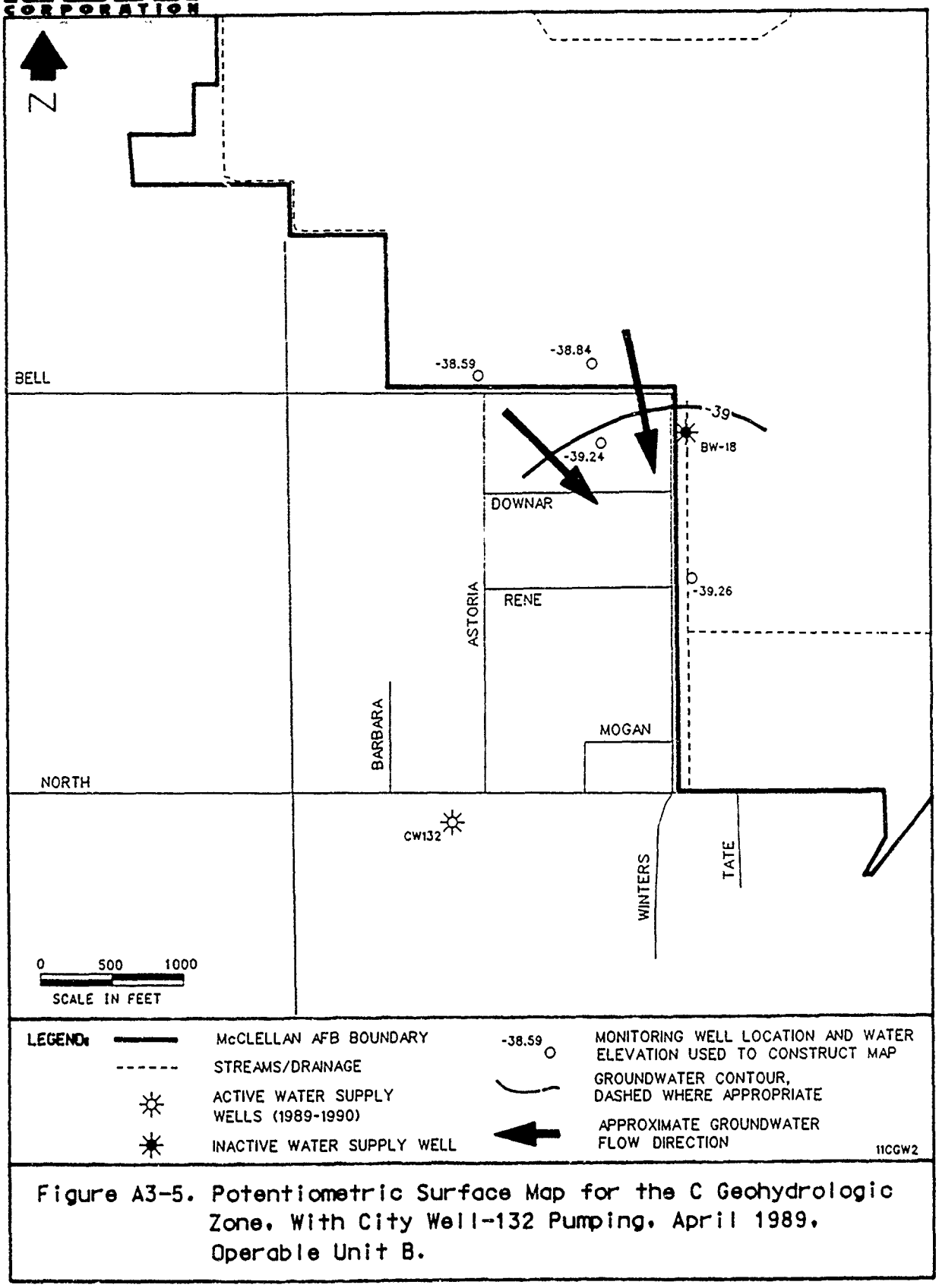

Figure A3-5. Potentiometric Surface Map for the C Geohydrologic Zone, With City Well-132 Pumping, April 1989, Operable Unit B.

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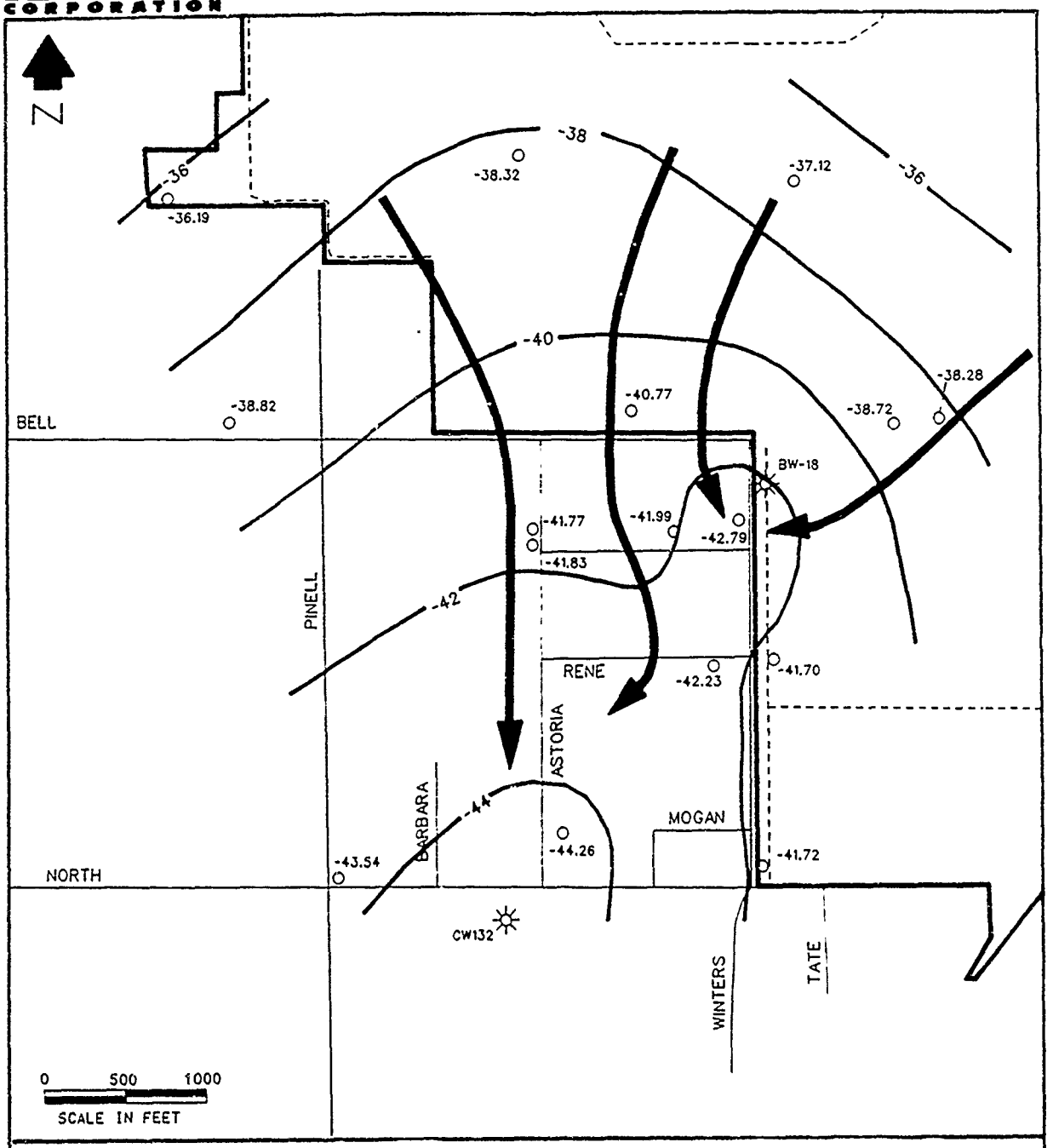

Figure A3-6. Potentiometric Surface Map for the A Geohydrologic Zone, With Base Well-18 and City Well-132 Pumping, May 1989, Operable Unit B.

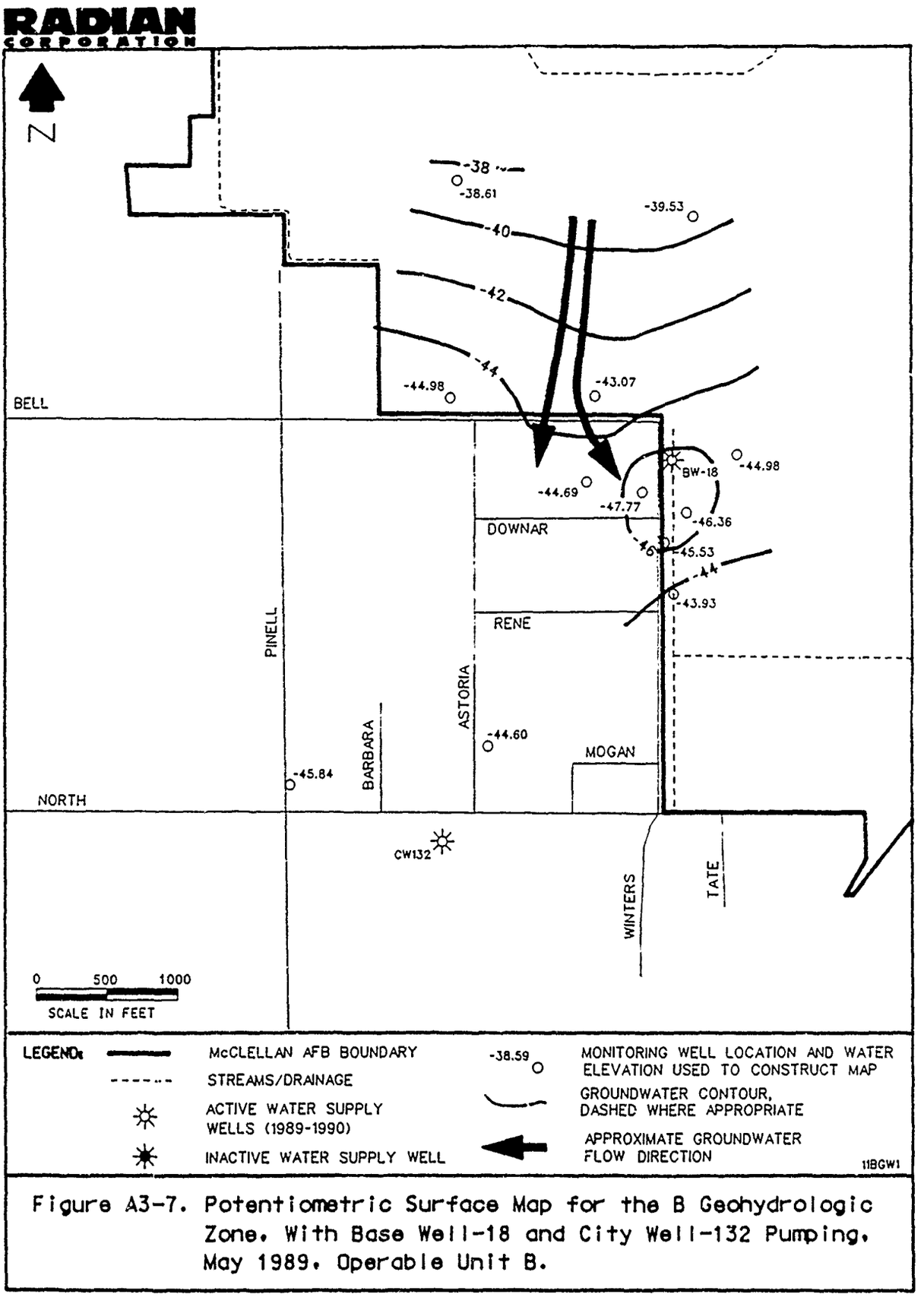

Figure A3-7. Potentiometric Surface Map for the B Geohydrologic Zone, With Base Well-18 and City Well-132 Pumping, May 1989, Operable Unit B.

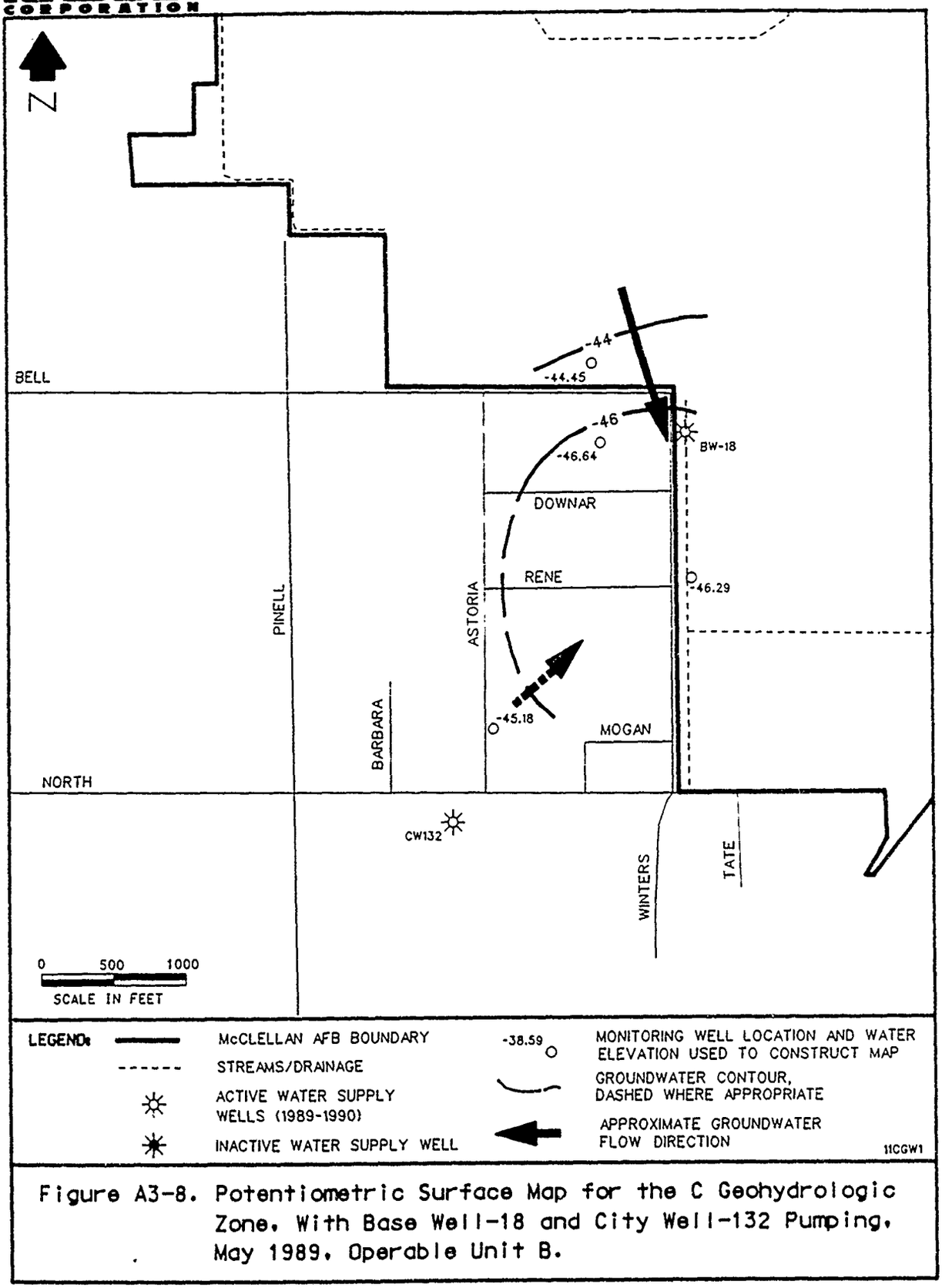

Figure A3-8. Potentiometric Surface Map for the C Geohydrologic Zone, With Base Well-18 and City Well-132 Pumping, May 1989, Operable Unit B.

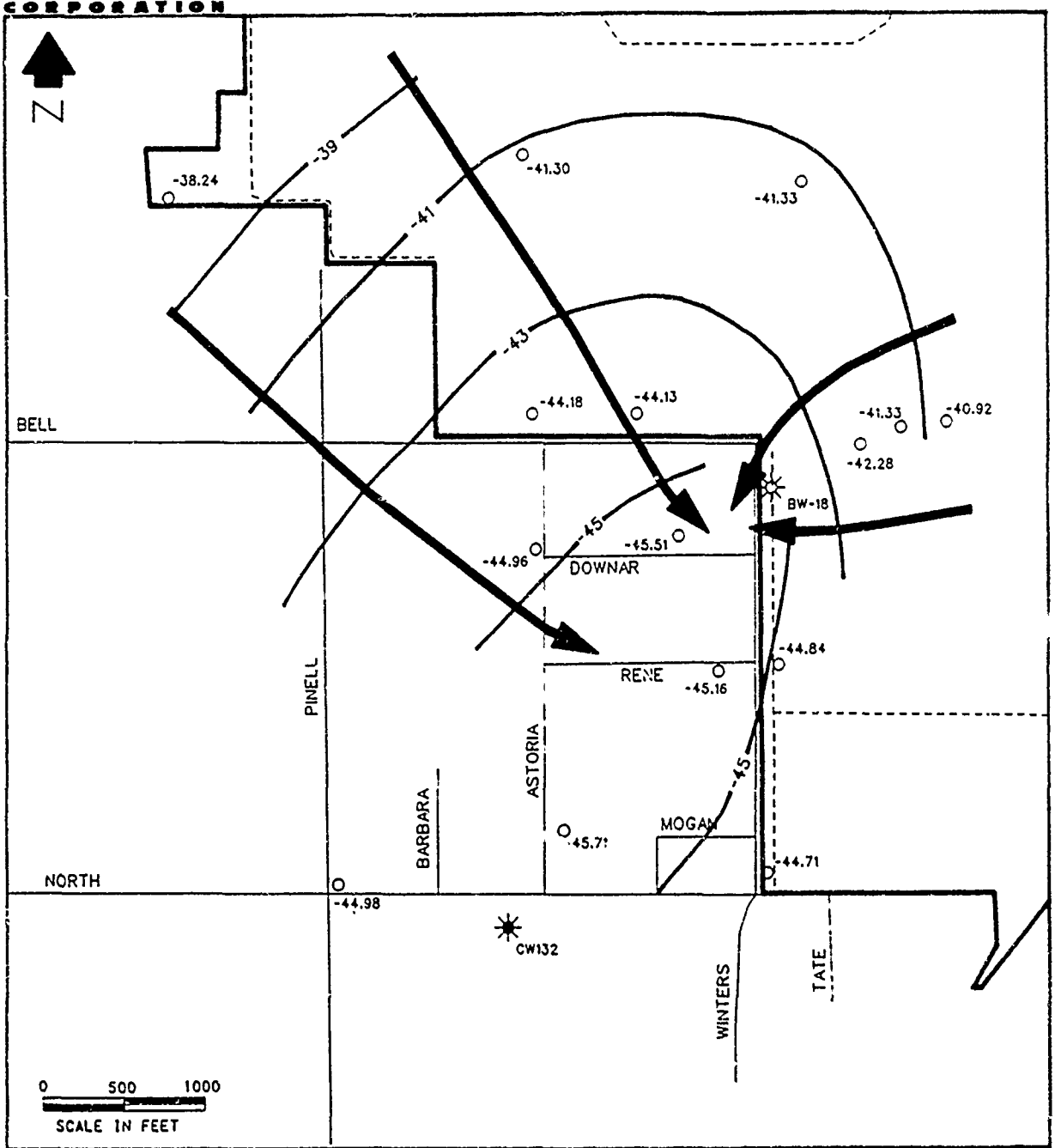

Figure A3-9. Potentiometric Surface Map for the A Geohydrologic Zone, With Base Well-18 Pumping, October 1989, Operable Unit B.

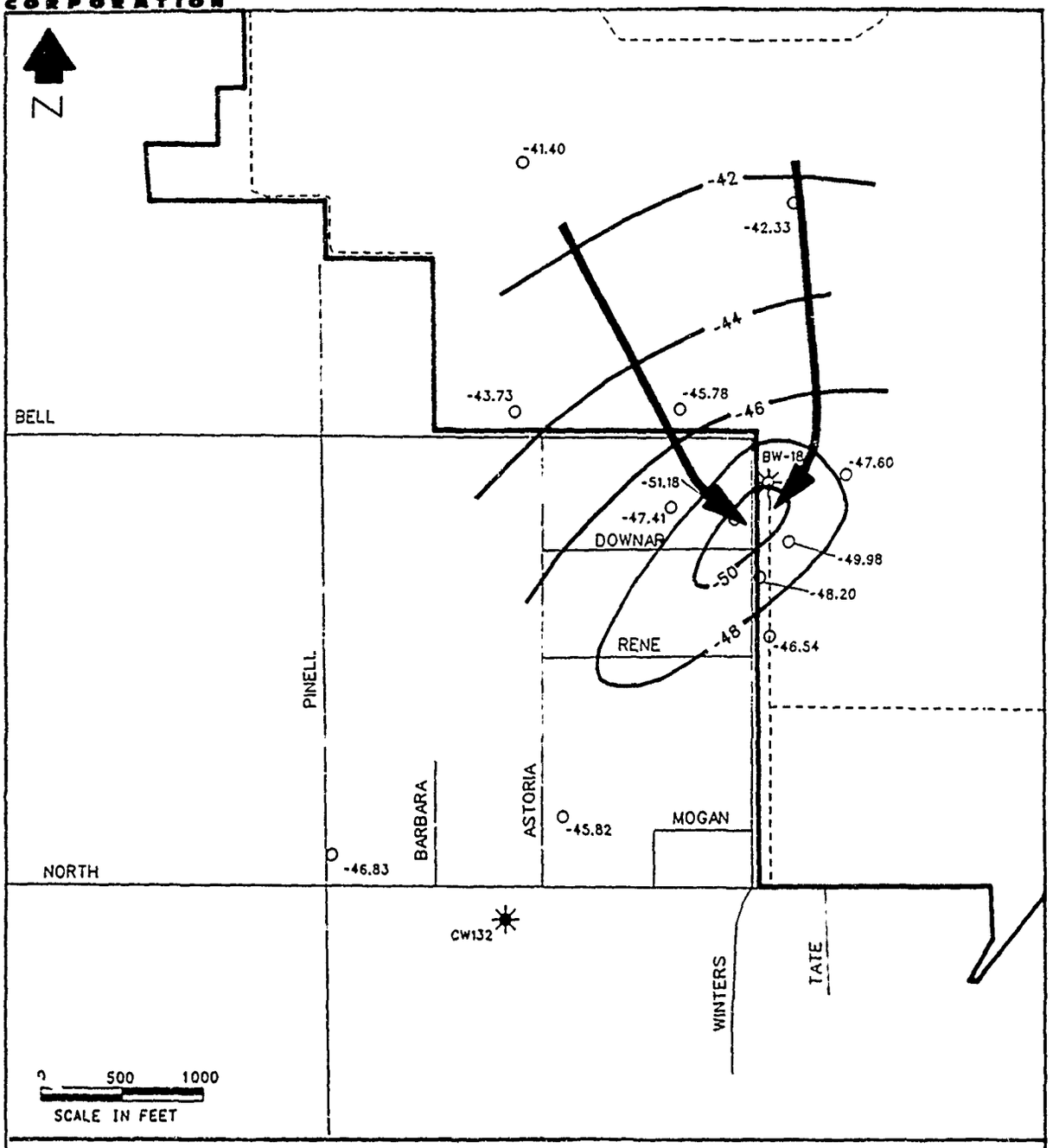

Figure A3-10. Potentiometric Surface Map for the B Geohydrologic Zone, With Base Well-18 Pumping, October 1989, Operable Unit B.

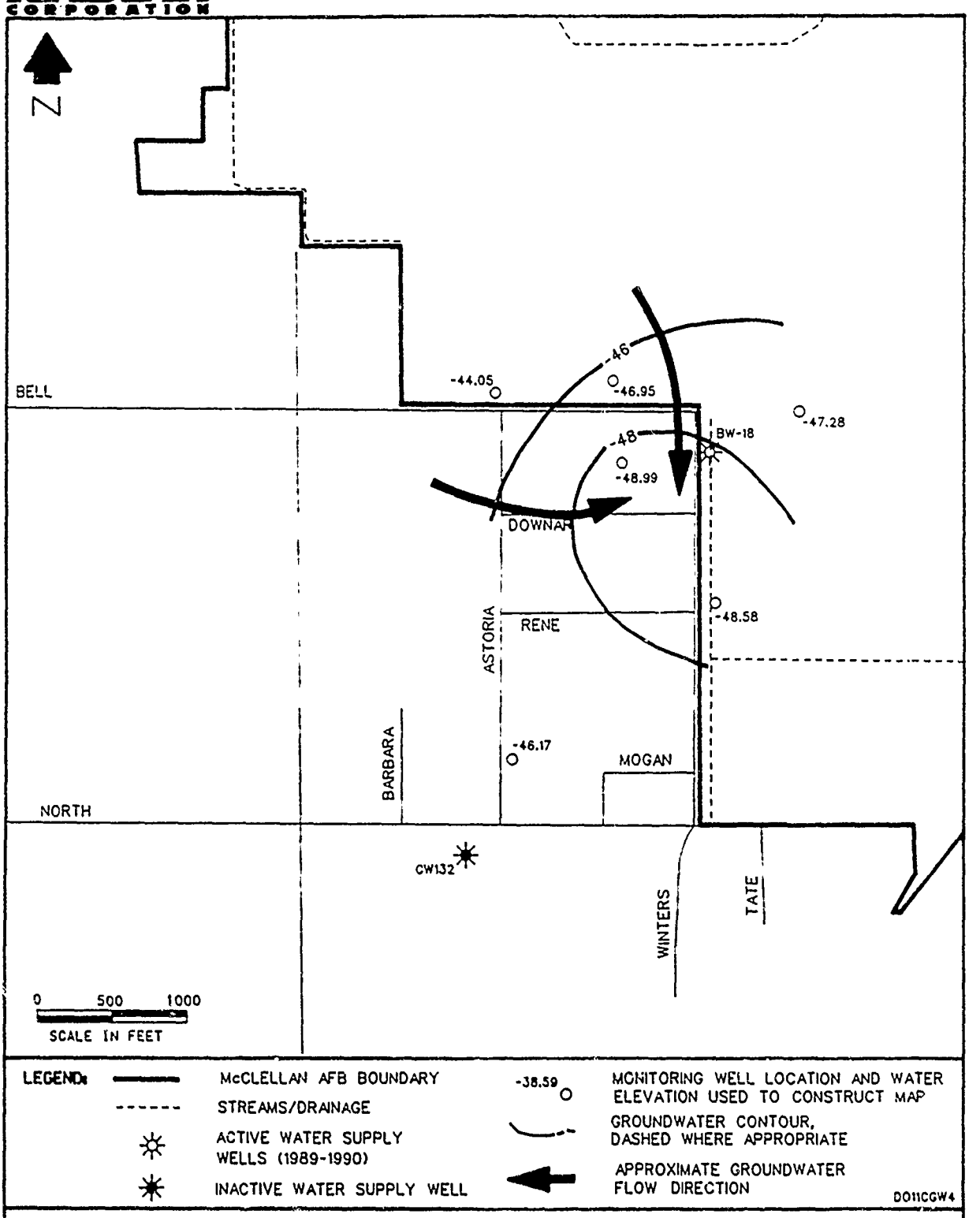

Figure A3-11. Potentiometric Surface Map for the C Geohydrologic Zone, With Base Well-18 Pumping, October 1989, Operable Unit B.

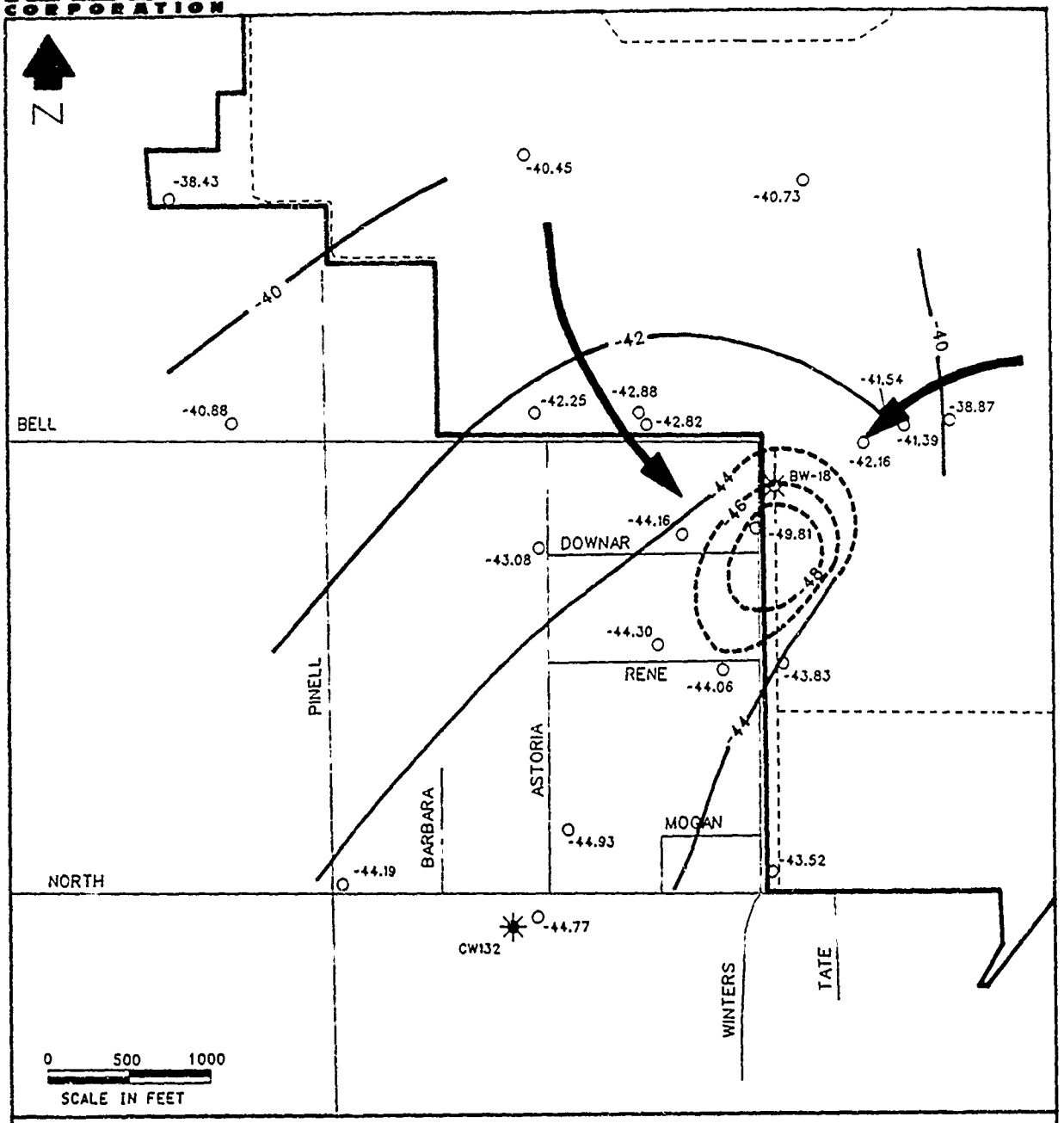

Figure A3-12. Potentiometric Surface Map for the A Geohydrologic Zone, With Base Well-18 Pumping, December 1, 1989, Operable Unit B.

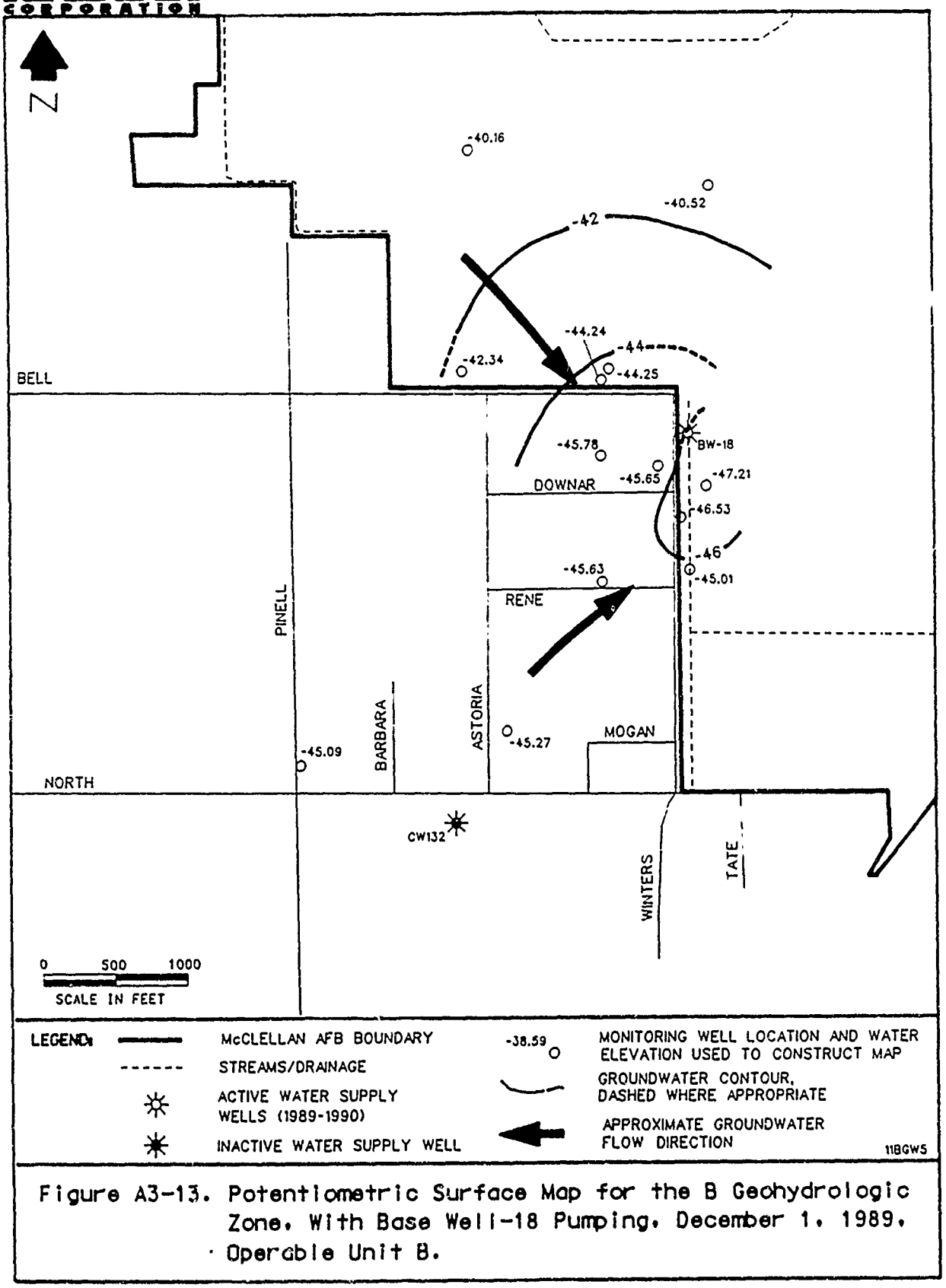

Figure A3-13. Potentiometric Surface Map for the B Geohydrologic Zone, With Base Well-18 Pumping, December 1, 1989, Operable Unit B.

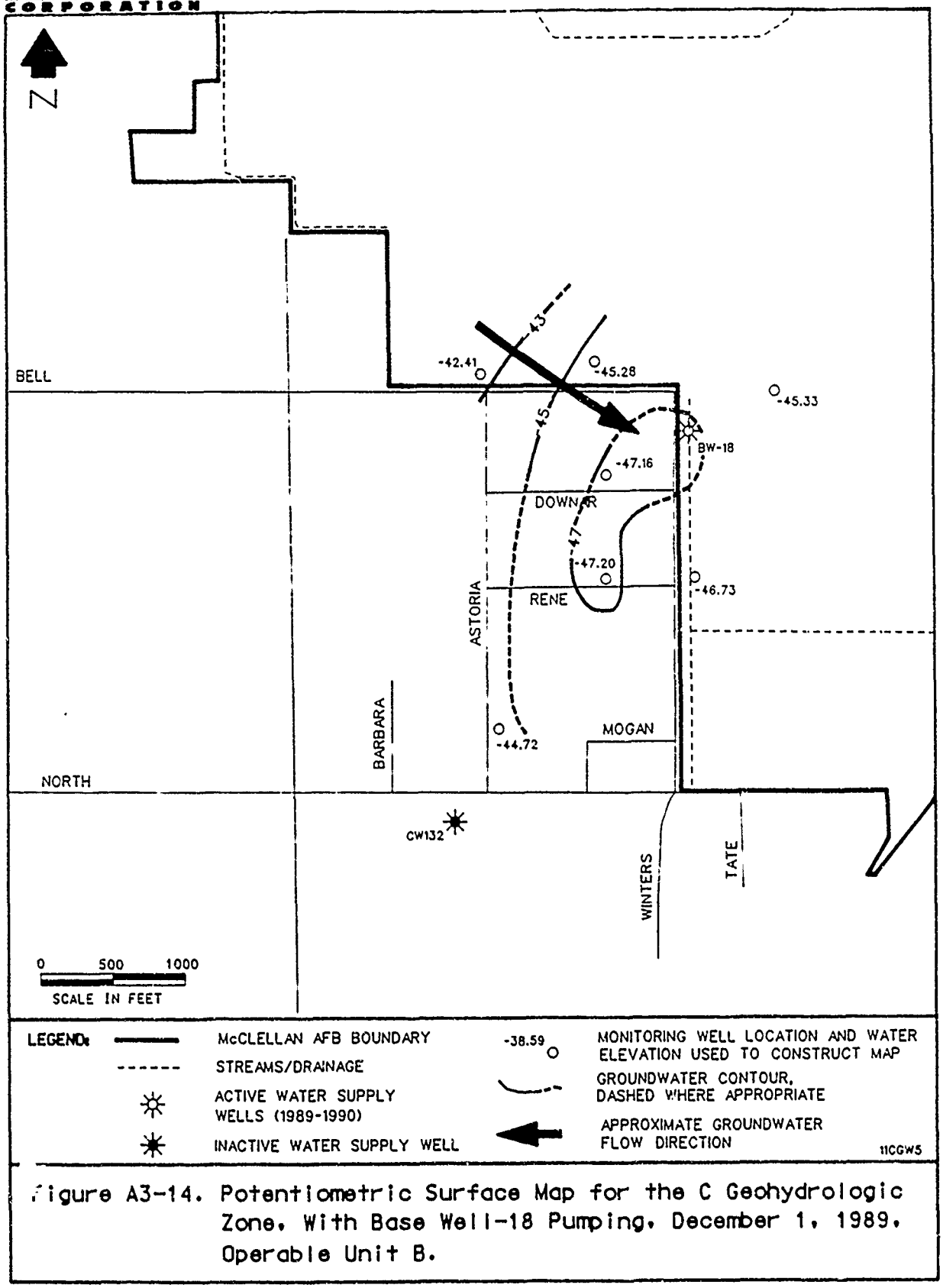

Figure A3-14. Potentiometric Surface Map for the C Geohydrologic Zone, With Base Well-18 Pumping, December 1, 1989, Operable Unit B.

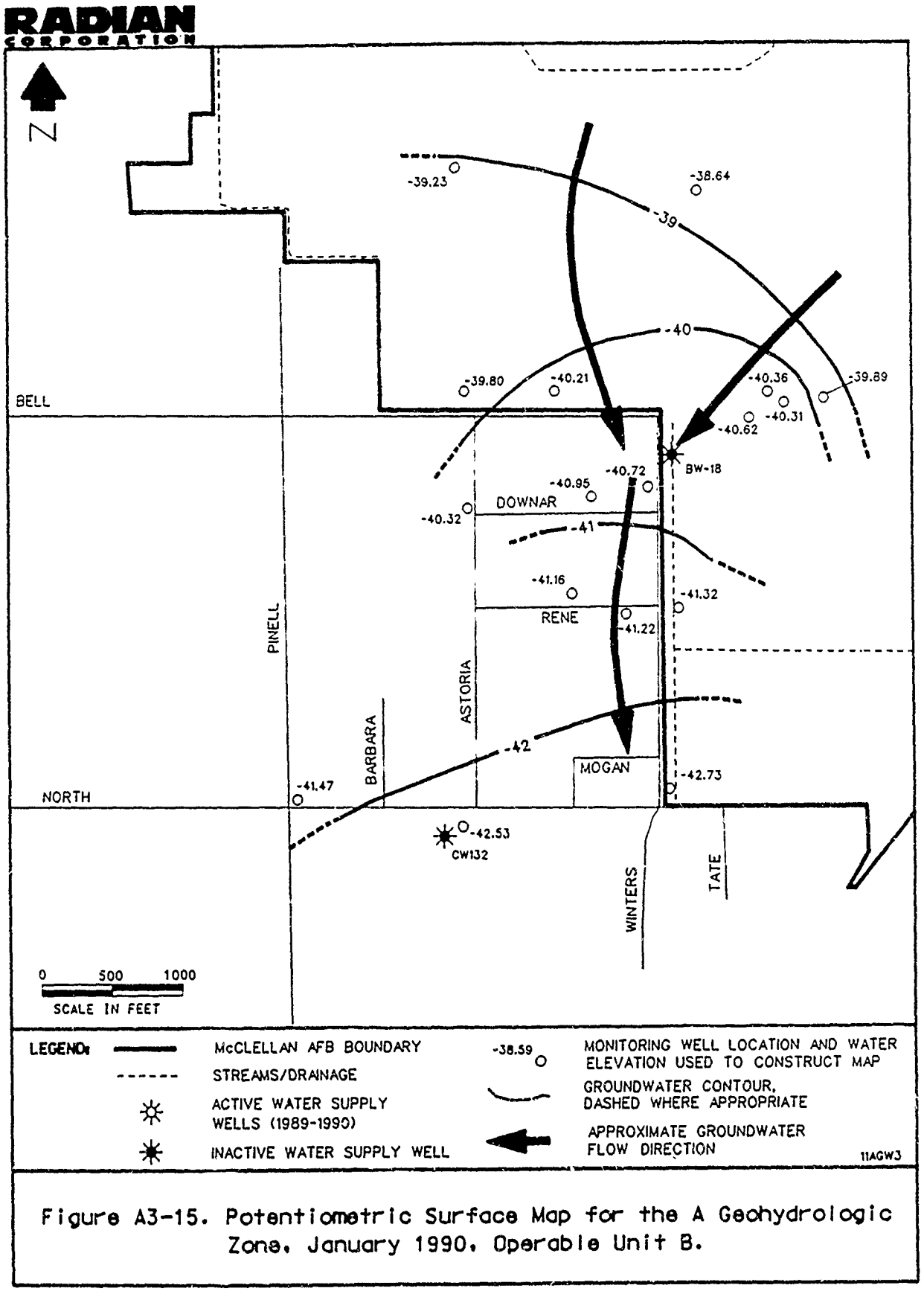

Figure A3-15. Potentiometric Surface Map for the A Geohydrologic Zone, January 1990, Operable Unit B.

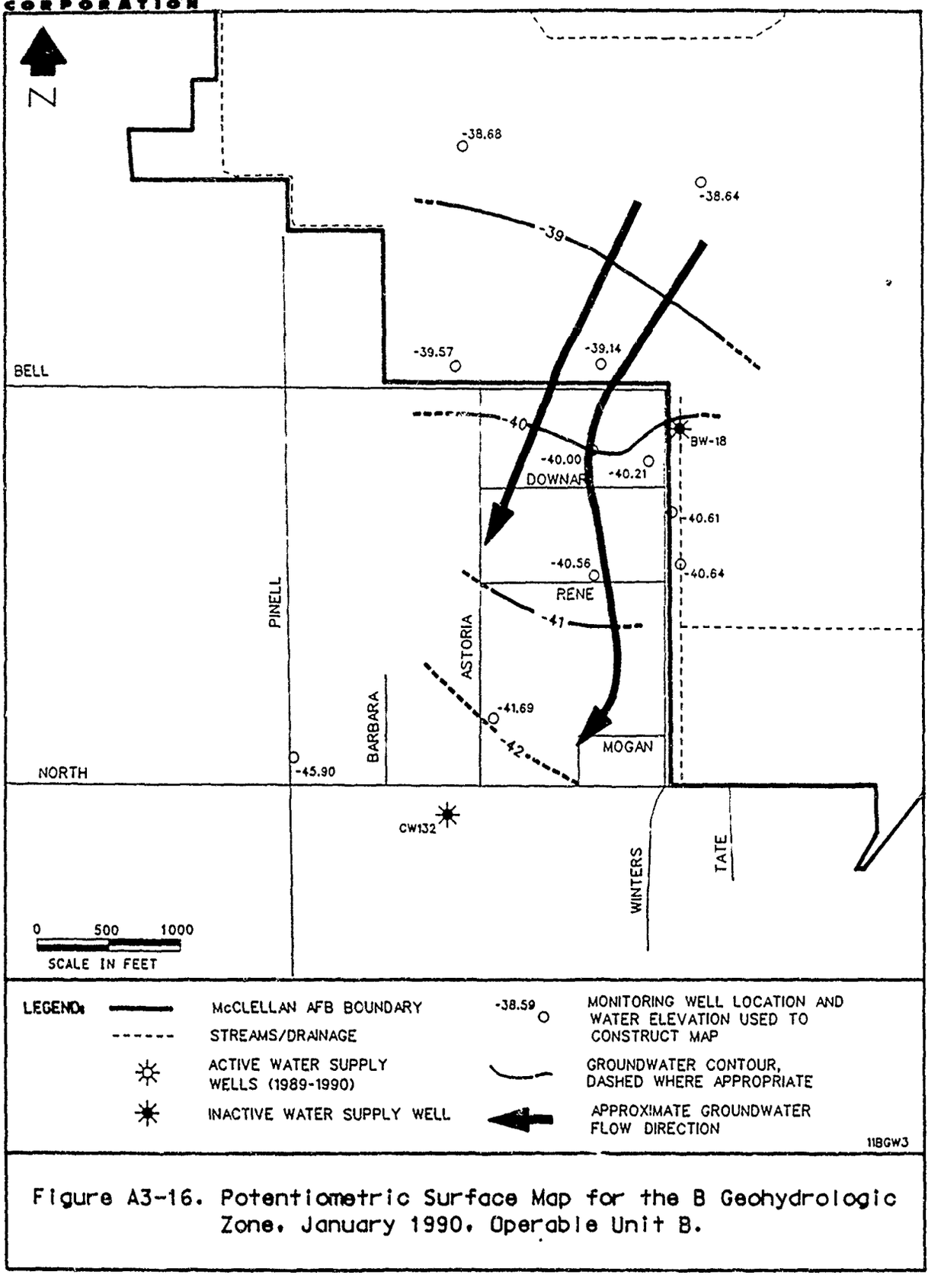

Figure A3-16. Potentiometric Surface Map for the B Geohydrologic Zone, January 1990, Operable Unit B.

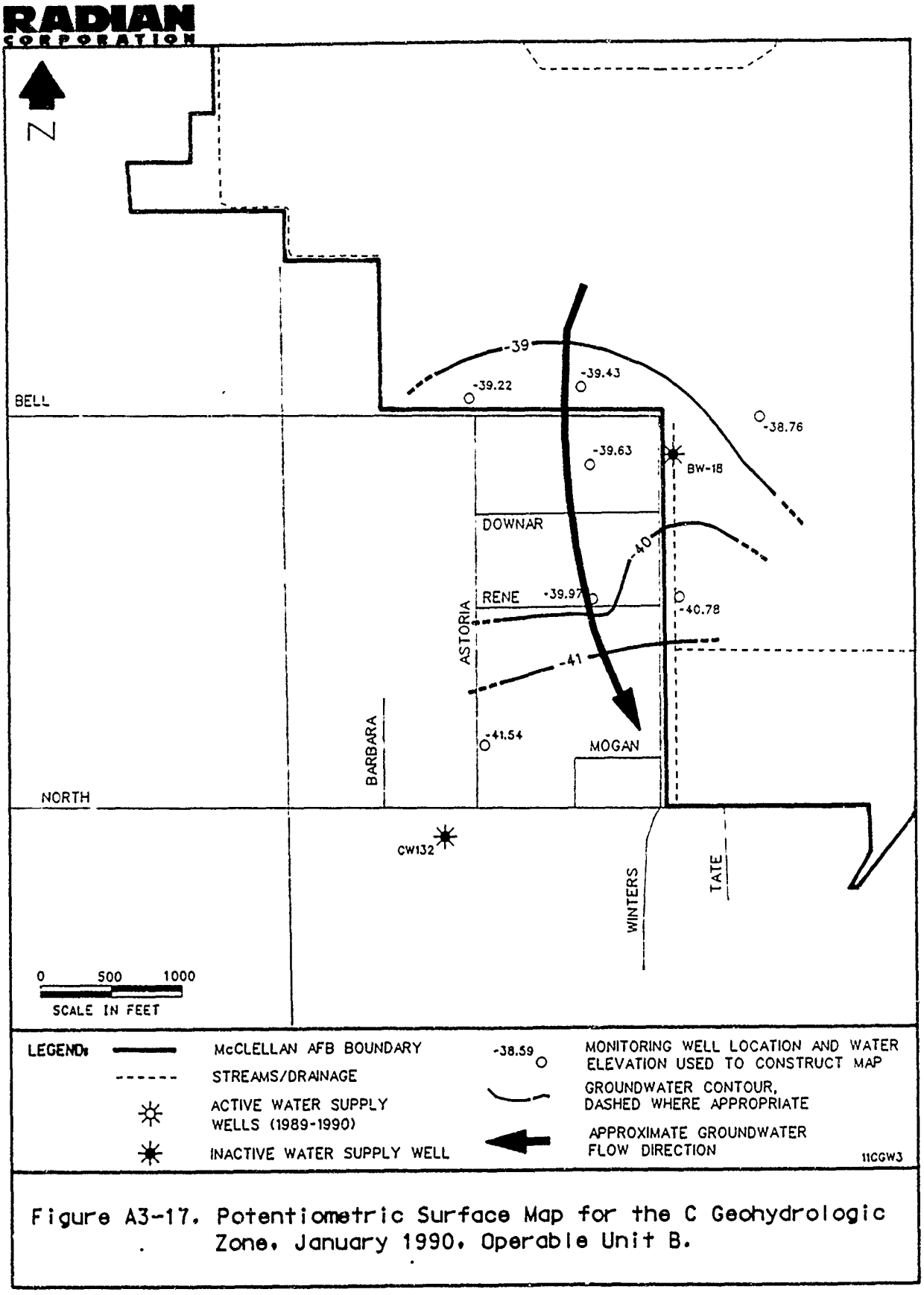

Figure A3-17. Potentiometric Surface Map for the C Geohydrologic Zone, January 1990, Operable Unit B.

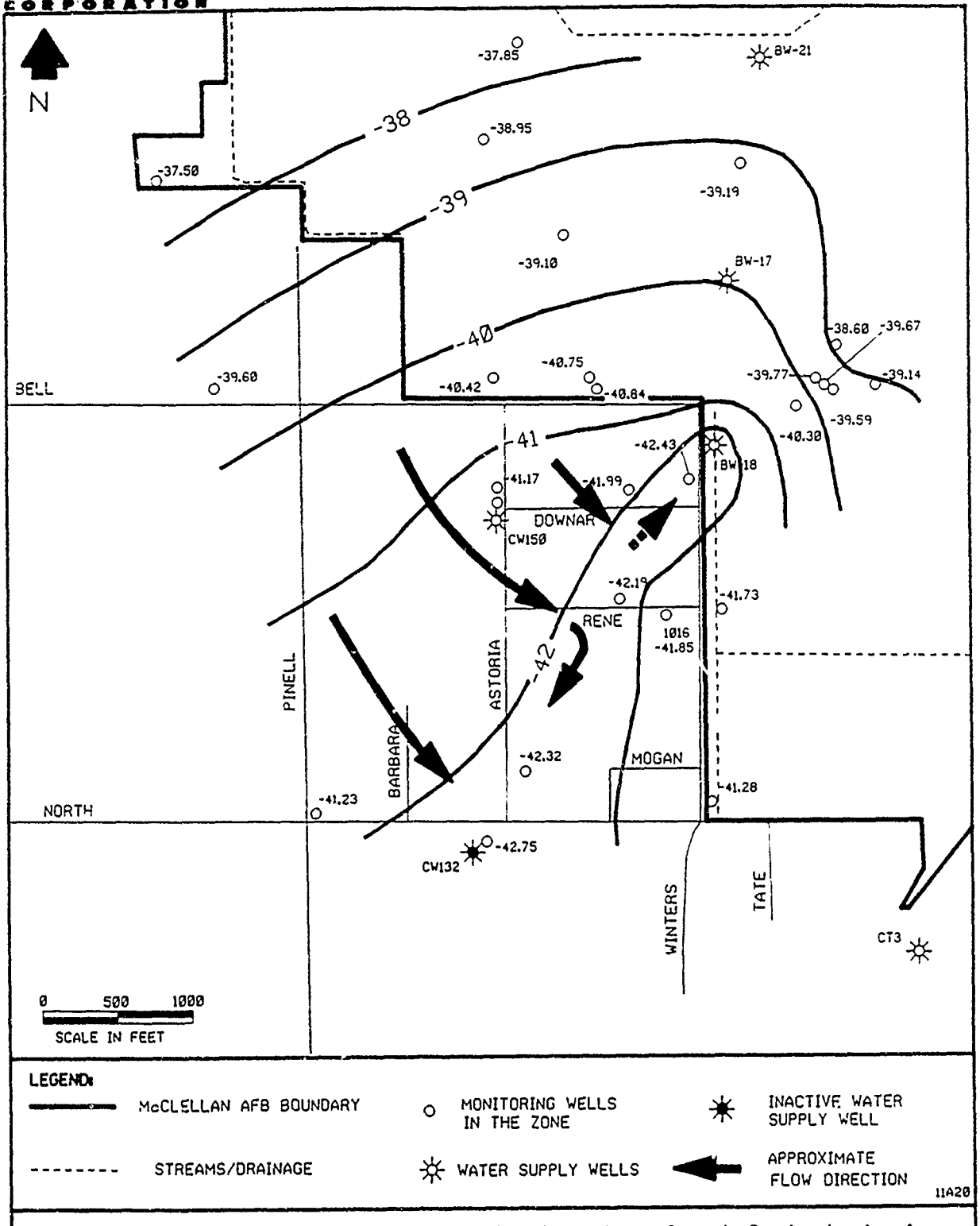

Figure A3-18. Potentiometric Surface Map for A Geohydrologic Zone With BW-18 Pumping, Operable Unit B April 1990.

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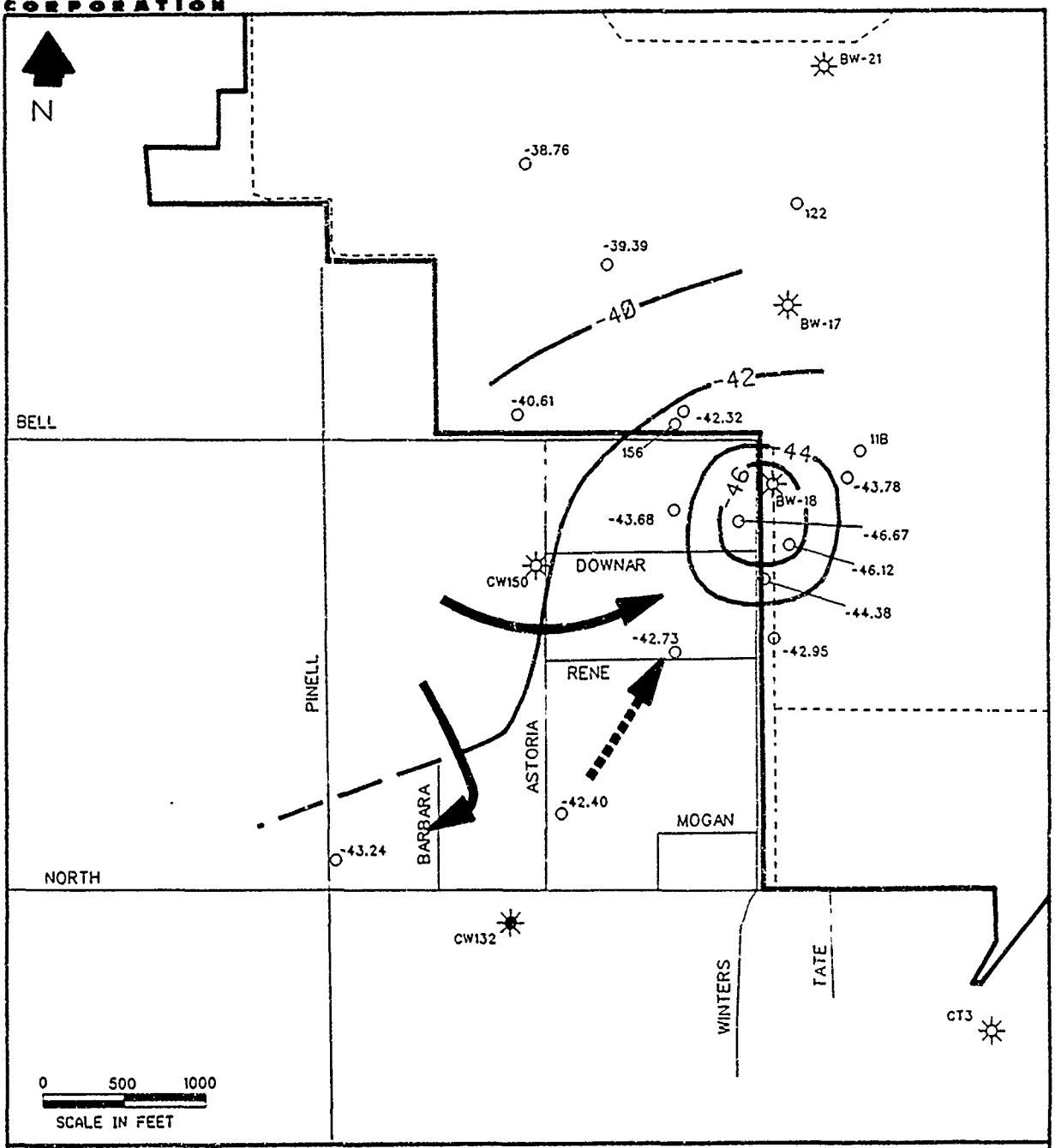

Figure A3-19. Potentiometric Surface Map for B Geohydrologic Zone, With BW-18 Pumping in Operable Unit B, April 1990.

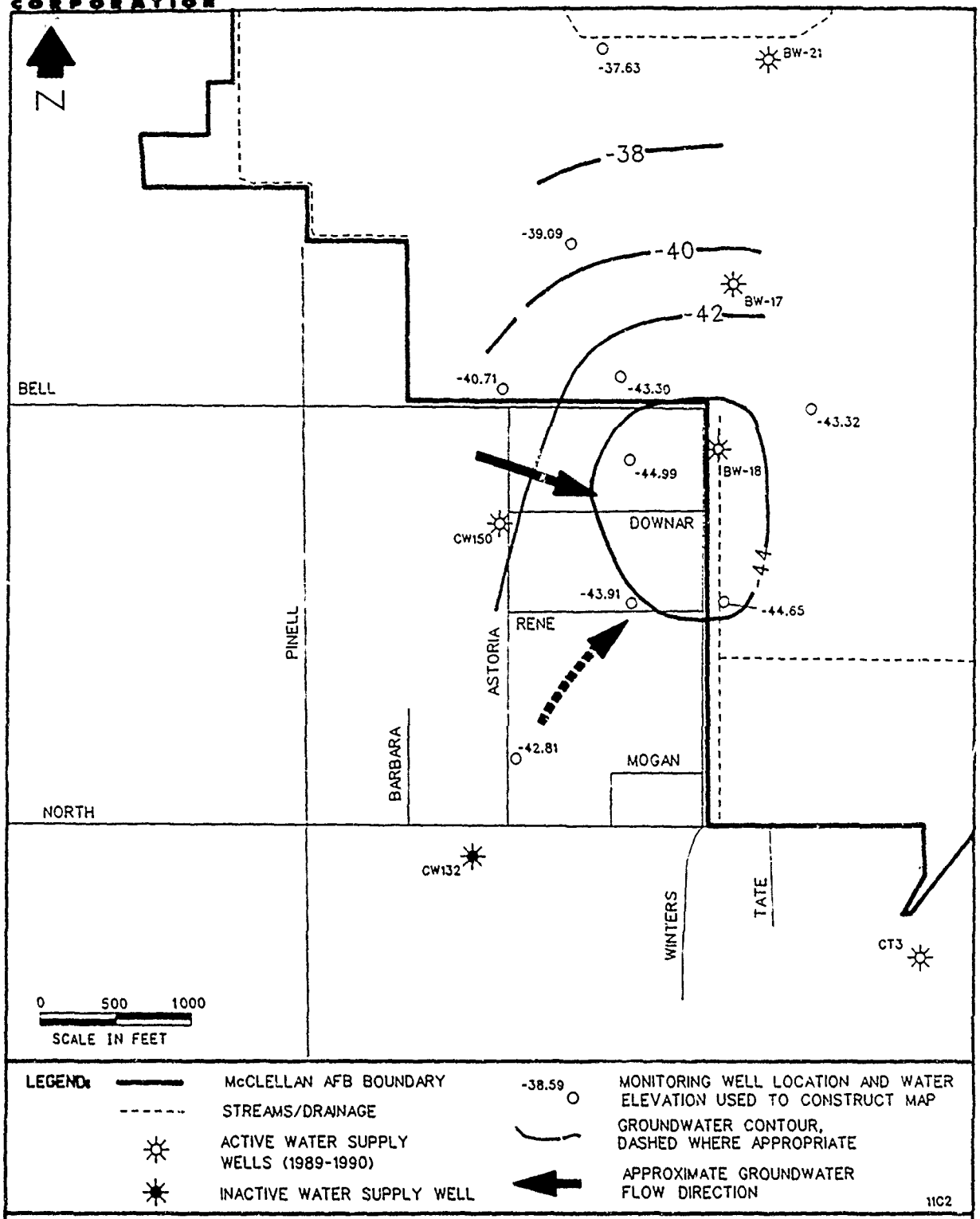

Figure A3-20. Potentiometric Surface Map for C Geohydrologic Zone, With Base Well-18 Pumping, Operable Unit B, April 1990.

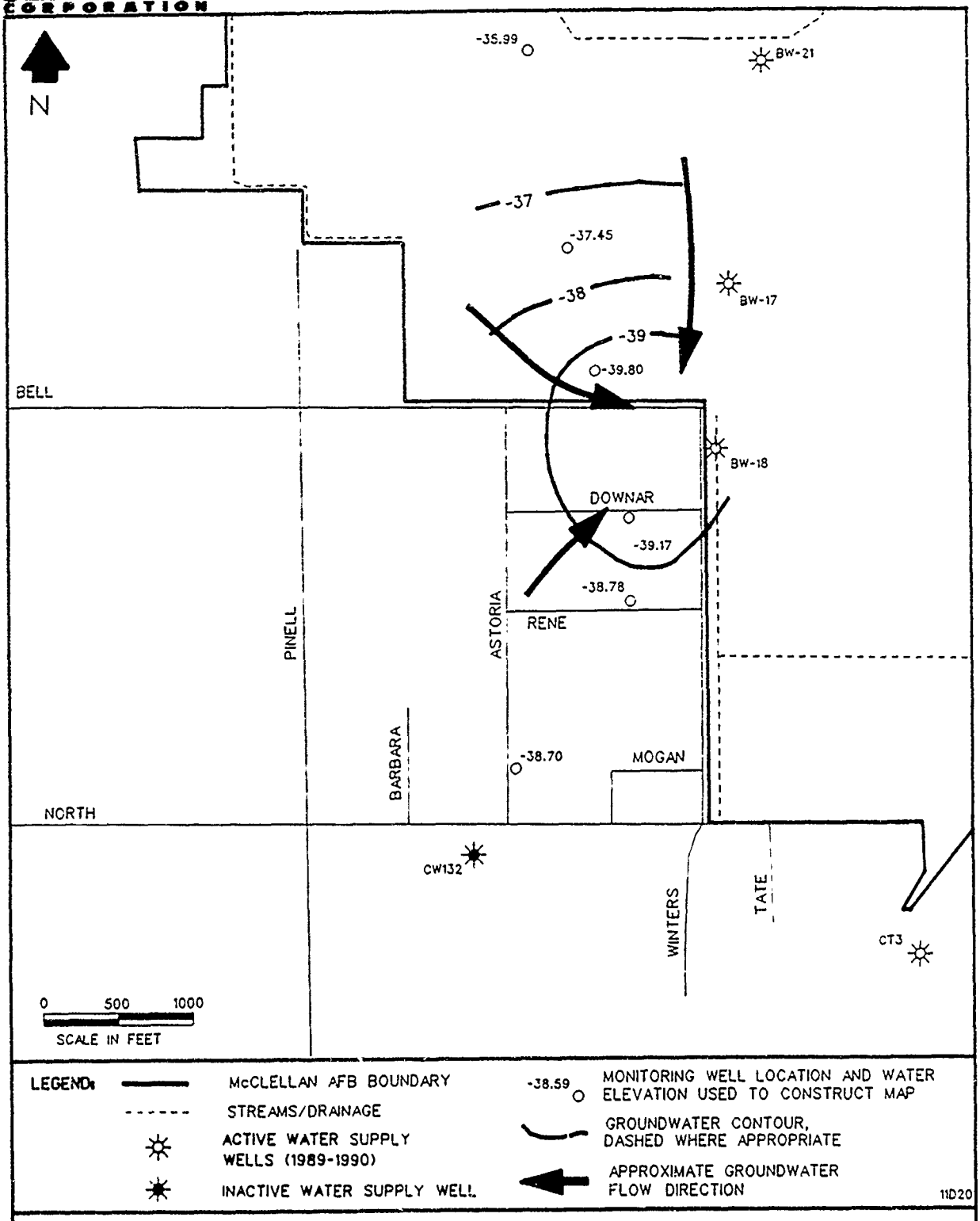

Figure A3-21. Potentiometric Surface Map for D Geohydrologic Zone, With BW-18 Pumping in Operable Unit B, April 1990.

of 1000 feet away) is toward the supply well. Water levels, gradients, and limits of the zone of capture differ between zones and between measurement rounds, presumably in response to seasonal recharge and differences in hydraulic parameters. Observations based on potentiometric surfaces that have been drawn for each measurement period when BW-18 was active are discussed below.

In May 1989, BW-18 had only been in operation for two weeks, after a three-week shutdown for repairs, and the hydraulic effects due to pumping may not have yet fully stabilized. The base well did not have as strong an influence on groundwater flow and potentiometric surfaces in May 1989 as it did in October 1989, December 1989, or April 1990 when the base well had been in continuous operation for at least two months. In the A and B zones beneath the western half of OU B in May 1989, groundwater flowed in a south to southwesterly direction as it did in April 1989 (Figures A3-3 to A3-8); however, flow in the zones beneath the eastern half is influenced by BW-18. In the A zone, groundwater was captured in a radius of 600 to 700 feet to the west and east, and 500 feet to the south from BW-18. In the B zone, groundwater flowing from the north or northeast was captured whereas groundwater 800 feet to the west or south may have flowed away from BW-18 (Figure A3-7). The limited four-point data set for the C zone suggests that groundwater flow up to 1000 feet away from BW-18 was also toward the well (Figure A3-8).

In October 1989, potentiometric surfaces (water-level elevations) for the A, B, and C zones, were lower than during other measurement events, presumably because of limited recharge and greater water withdrawals during the dry season (Figures A3-9 to A3-11). In contrast to May 1989 data, the zone of groundwater capture for BW-18 was apparently greater in October 1989. In the A zone, an elliptical depression trended northeast/southwest (Figure A3-9). The southwestern extent of the depression was undefined due to limited data. In the B zone, the potentiometric surface for October 1989 exhibited steeper gradients than in the A zone, because the base well has 16 feet of screen in the B zone. As in the A zone, the limits of the depression in the B zone are not clearly defined, but in general an elliptical depression trends northeast/southwest indicating that a large portion of the groundwater in this zone was being captured by BW-18. Additional data to the southwest were not available to define more clearly the flow directions. Compared with May 1989 data, the October 1989 depression in the B zone is larger or better developed because there had been little recharge between May and October and/or because the hydraulic effects on the zone due to pumping at BW-18 had not fully stabilized at the time of the May 1989 sounding.

The C geohydrologic zone data set for October 1989 contains only seven data point, which limits the potential for interpretation of flow directions for this zone. However, water-level differences between data points show that groundwater in the vicinity of these wells was being drawn toward BW-18. The boundaries of the zone of capture are undefined, but it extends at least 1400 feet to the west and north and as much as 2400 feet to the southwest (Figure A3-10). Similarities between May and October data sets are the strongest for the C zone.

Potentiometric surfaces based on 1 December 1989 data (Figures A3-12 to A3-14) generally exhibit higher hydraulic heads in all zones than in October 1989, presumably because of greater recharge and decreased regional withdrawals. Similar to October 1989 measurements, much of the groundwater in the A and B zones appears to have been flowing toward BW-18. Data in the C zone are too limited to interpret. The A zone appears to have had a steep potentiometric gradient near BW-18 because of an exceptionally low water-level elevation in MW-1021. Horizontal gradients across OU B, away from MW-1021, were less steep than in October 1989 possibly because of a less consistent pumping schedule in the later part of November and on 1 December 1989 (BW-18 had pumped for only 4 out of 12 hours on the morning of December 1 before it was shut down). Groundwater in the B zone flowed toward BW-18 in December 1989, but potentiometric surface gradients were less steep in the vicinity of BW-18 than in the A zone. The B zone gradients in December were also less steep than they were in October 1989. Gradients in December in the C zone were slightly steeper than those in the B zone. The pumping depression in each of the three zones is asymmetric and is oriented northeast/southwest as it was in October.

Hydraulic heads in April 1990 were higher in all zones than in October and December 1989, suggesting increased recharge between December and April measurements. Heads averaged 0.5 to 0.75 feet lower in April 1990 than those measured in April 1989. These head differences may reflect the continuing regional decline caused by annual groundwater withdrawal volumes greater than annual recharge volumes. In the A zone, much of the groundwater to the north, northwest, northeast, west, and east of BW-18 was being captured by the well (Figure A3-18). Groundwater in the A zone between MW-1054, 1200 feet southwest of BW-18, and MW-1049 had a southwesterly gradient away from the supply well. However, in the B zone, the April potential difference between MW-1055 and MW-1050 suggests flow in the opposite direction, toward BW-18 (Figure A3-19). Gradients in the A zone, at a distance from MW-1021, were similar to those in December and were less steep than those in October. The B zone had a steeper gradient near BW-18 than in the A zone, similar to October,

because the base well is screened in the zone. In the C zone, groundwater potential differences between well pairs among the nine data points indicate flow only toward BW-18 (Figure A3-20). Six water levels were measured in the D zone in April 1990 (Figure A3-21). Groundwater gradients between D zone well pairs indicate flow toward BW-18. The areal extent of BW-18's influence in the D zone, however, cannot be determined from the limited data set.

Horizontal hydraulic head differences and hydraulic gradients calculated for August 1989 through April 1990 sounding measurements are listed in Table A3-9, and October 1989 through April 1990 data are the basis for groundwater flow directions shown in Figures A3-8 to A3-21. For each geohydrologic zone, groundwater elevations for monitoring wells from various locations within OU B were compared to determine the magnitude and direction of gradients for each sounding. Well pairs include those pairs available for April and May 1989 gradient calculations and additional newly completed wells. The magnitude of gradient between two wells in a zone indicates the tendency for groundwater to move from one well to the other. Gradients are compared between locations and between geohydrologic zones to identify potential groundwater flow lines between wells in each zone. Maximum hydraulic head differences and gradients are measured when the two wells compared lie on the same flow line. The wells for which heads and gradients are compared are not necessarily along the same flow lines, and the gradients calculated may not be the maximum for the geohydrologic zone. However, the comparison of hydraulic heads and gradients in Table A3-9 offers an estimation of gradient and flow direction by zone with a limited number of data points.

The data for April 1989 and January 1990, when BW-18 was inactive, show that flow in all zones is predominantly to the south. Without the hydraulic influence of BW-18, the A geohydrologic zone exhibited a uniform horizontal hydraulic gradient of 0.001 vertical feet per horizontal foot from north to south.

Horizontal hydraulic gradients calculated for the B zone in January 1990 are generally similar to those in the A zone. The B zone gradients in April 1989, however, are approximately twice as large as April 1989 A zone gradients. The larger gradients calculated for the B zone in April 1989 compared to January 1990 may be the result of greater pumping in the municipal well field in April 1989.

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TABLE A3-9. HORIZONTAL HYDRAULIC GRADIENTS BETWEEN SELECTED WELLS IN GEOHYDROLOGIC ZONES IN OU B FOR AUGUST 1989, OCTOBER 1989, DECEMBER 1 1989, JANUARY 1990, AND APRIL 1990

Well Pairs	Horizontal Distance (feet)	Gradient[a] (feet/foot) August (BW-18 on)	October (BW-18 on)	December 1 (BW-18 on)	January (BW-18 off)	April (BW-18 on)
"A" Geohydrologic Zone						
MW 41S/65	300	0.001 SW	0.001 SW	0.008 SW	0.001 SW	0.001 SW
MW 7/1044	750	0.001 S	0.002 S	0.002 S	0.001 S	0.002 S
MW 1021/1016	850	0.0003 N	0.001 N	0.007 N	0.001 S	0.001 N
MW 116/145	2675	0.002 SE	0.002 SE	0.001 SE	0.001 SE	0.001 SE
MW 1044/1049	1825	0.0004 N	0.0001 S	0.0004 S	0.006 N[b]	0.0002 S
MW 1054/1015	1460	--	--	0.0005 N	0.001 S	0.001 N
MW 135/155	1640	--	--	0.001 S	0.001 S	0.001 S
MW 135/164	800	--	--	--	--	0.0002 S
MW 164/155	1050	--	--	--	--	0.002 S
"B" Geohydrologic Zone						
MW 23D/151	350	0.005 N	0.005 N	0.004 N	0.0001 S	0.004 N
MW 122/63	1550	0.003 S	0.002 S	0.002 S	0.001 S	--
MW 1045/1025	2850	0.0005 NE	0.0002 NE	0.0002 NE	0.002 SW	0.0004 NE
MW 1045/1050	1825	0.001 N	0.001 N	0.0003 N	0.001 S	0.001 N
MW 1050/1025	1300	0.0001 SW	0.001 SW	0.0001 NE	0.003 SW	0.001 SW
MW 156/1045	500	--	--	0.003 S	0.001 S	--
MW 1055/1050	1180	--	--	0.0003 NE	0.001 SW	0.0003 NE
MW 134/165	750	--	--	--	--	0.001 SE
MW 165/156	1000	--	--	--	--	--
"C" Geohydrologic Zone						
MW 132/1046	750	0.001 N	0.003 S	0.002 S	0.0003 S	0.002 S
MW 147/1046	1125	0.002 SE	0.004 SE	0.004 SE	0.0004 SE	0.004 SE
MW 152/1051	1750	0.002 NE	0.001 NE	0.001 NE	0.0004 SW	0.001 NE
MW 1046/1051	1625	0.001 N	0.002 N	0.001 N	0.001 S	0.001 N
MW 1051/1056	1230	--	--	0.002 NE	0.001 SW	0.001 NE
MW 1056/1046	660	--	--	0.0001 S	0.0005 S	0.002 N
MW 166/132	900	--	--	--	--	0.005 S
"D" Geohydrologic Zone						
MW 148/1047	950	0.0002 S	0.0001 S	0.0001 N	0.00004 N	0.0001 N
MW 1047/1052	1825	0.0003 N	0.0005 N	0.0003 N	0.0003 S	0.0003 N
MW 162/167	1250	--	--	--	--	0.001 S
MW 167/148	800	--	--	--	--	0.002 S
MW 1057/1052	1200	--	--	0.0001 NE	0.0005 SW	0.0001 NE
"E" Geohydrologic Zone						
MW 149/1048	850	0.0002 S	0.001 S	0.007 S	0.008 S	0.001 S
MW 168/1048	800	--	--	--	--	0.002 S

[a]Gradients are assigned an approximate direction indicating the direction of head decrease.
[b]Water levels measured in one of these wells appeared to be erroneous when compared to other data and are not considered in the hydrologic evaluation.
--One of the wells in the pair was not measured during this sounding event.
SW Southwest
SE Southeast
NE Northeast
S South
N North

The C zone gradients for April 1989 and January 1990 appear similar in magnitude and are less than gradients in the A and B zones during the same measurement periods. The lower magnitudes of the C zone gradients may indicate that the hydraulic potential (for example, pumping in the municipal well field) that was affecting the A and B zones had less hydraulic influence on the C zone.

Only one well was completed in the D and E zones in April 1989, and therefore, no horizontal gradients were calculated for that measurement. Hydraulic gradients were calculated using January 1990 data for three well pairs in the D zone and one in the E zone. Gradients for the D zone are approximately equivalent to those for the C zone. No assumptions can be made for the E zone based on one well pair. However, it should be noted that the highest gradient calculated for January (0.008 feet/foot) is for the well pair within the E zone.

In general, gradient magnitudes and flow directions are more uniform within each zone under static conditions than under the influence of pumping. Pumping by BW-18 distorts the groundwater flow pattern in each zone and changes horizontal gradients (Table A3-9). Well pairs north of BW-18 that are within its zone of influence show increased southerly gradients due to pumping. This increase is expected because the groundwater flow direction at these wells is to the south without BW-18 pumping, and pumping at the well causes a greater potential difference and larger gradients. South of BW-18, a minimum of one well pair per zone during each measurement event shows a flow direction reversal from south to north in response to pumping by BW-18. Other southern well pairs, which are further from BW-18, do not show a reversal in flow direction, but do indicate a decrease in the southerly groundwater gradient as a result of pumping. In general, gradient magnitudes in the A and B zones do not increase significantly under pumping conditions; however, within the C zone, gradients increase 2 to 10 fold with pumping.

Horizontal gradients vary less in the A zone than other zones (except for December 1) between static and pumping conditions because BW-18 is not screened in the A zone, and the zone in unconfined beneath much of OU B. Unconfined geohydrologic zones will show a lesser decrease in water levels (and lower gradients) over a larger area than confined zones in response to pumping. However, the base well affects groundwater flow within this zone as evidenced by gradient reversals from south to north between well pairs MWs 1021 and 1016, and MWs 1054 and 1015 when compared under pumping and nonpumping conditions. All other well pairs in the A zone maintained southerly flow gradients both with and without base well pumping. The

A zone gradients were larger and more variable on 1 December 1989 than during any other measurement event. Potentiometric heads were higher and gradients near BW-18 were steeper (MWs 41S and 65; and MWs 1021 and 1016) in December than in August or October. The higher potentiometric surface may be the result of increased recharge during the wetter winter months. However, the steeper gradient is not readily explained unless a greater volume of water was being drawn from the A zone in December.

Horizontal gradients for well pairs in the B zone when BW-18 was pumping were consistent between measurement events (Table A3-9). Well pairs with at least one of the two wells located to the north of BW-18, for example, MWs 122 and 63, and MWs 156 and 1045, showed increased southerly gradients under the influence of pumping. Four well pairs to the south of BW-18 had gradient reversals (MWs 23D and 151, MWs 1045 and 1025, MWs 1045 and 1050, and MWs 1055 and 1050) demonstrating the influence of pumping on the B zone. Monitoring wells MW-23D, MW-1045, and MW-1055 appear to be within BW-18's zone of capture. The magnitude of the gradient under the influence of pumping at well pair MW-23D and MW-151 is more than twice as large as that which occurs when the base well is off. The strong influence of pumping at MW-23D is due to its proximity to BW-18. The influence of the base well decreases with increasing radial distance. When BW-18 is on, the gradient between MW-1055 and MW-1050 reverses from a southerly to a northerly gradient with a magnitude of 0.0003 NE. The gradient between MW-1050 and MW-1025 when BW-18 is on is to the southwest, indicating groundwater between MW-1050 and MW-1025 is not within the zone of capture for BW-18. While the gradient between MW-1050 and MW-1025 remained southerly (except in December), the average southerly gradient decreased by about 60% when BW-18 was compared to when it was off in January. The gradient decrease indicates that groundwater 2400 feet downgradient, in the B zone, is influenced by the pumping of BW-18. On 1 December 1989, water levels in well pair MWs 1050 and 1025 showed a slight gradient to the northeast (0.0001 NE), demonstrating a larger zone of influence to the southwest for BW-18 on that date. This is similar to the steeper gradients in the A zone reflected in December 1 measurements. The reversal in gradient more than 2400 feet downgradient suggests anomalous pumping conditions on that date.

Horizontal hydraulic gradients in the C zone were, in general, two to three times larger when BW-18 was active than when it was off. The larger gradient magnitudes for this zone compared to other zones during pumping may occur because BW-18 has its largest screened interval in the C zone and because permeabilities of deposits are higher in this zone. Well pairs MWs 132 and 1046, and MWs 147 and 1046

generally show increased southerly gradients due to pumping. Wells MW-132 and MW-147 are located north of BW-18 such that groundwater flow even without BW-18 on would be south from these wells. The increased southerly gradients indicate that these wells are within the zone of capture for BW-18. The well pair MWs 132 and 1046, however, exhibited a small (0.001) northerly gradient in August when the base well was on, differing in direction from gradients recorded during other measurement events. This is best explained by the fact that these wells are almost equivalent in distance from the base well, but they lie in different directions from BW-18 (MW-132 is northwest; MW-1046 is southwest) and are not on the same flow line to the well. An undetermined hydrologic condition in August apparently caused a greater decrease in the water level at MW-132 than at MW-1046 creating an apparent northern gradient. The northern gradient is only apparent because there are no other August gradients for the C zone that suggest flow away from the supply well.

True gradient reversals are observed in the three well pairs in the B zone (MWs 152 and 1051, MWs 1046 and 1051, MWs 1051 and 1056). The northern gradients exhibited by these well pairs during pumping are roughly three times the magnitude of gradients when the base well is off. These are the largest pumping-induced gradient increases of any zone. The reversals suggest that MW-152, MW-1046, and MW-1056 are within the zone of capture for the base well. Fluctuations in B zone gradient magnitudes between measurement periods when the base well can be observed in the data (Table A3-9). These probably reflect seasonal variations in recharge to the C zone.

A limited amount of data is available in the D zone, but in general there is little difference in horizontal gradient magnitudes between pumping and nonpumping conditions. Gradients in general are one-tenth of the gradient magnitudes of the A, B, and C zones. Two well pairs, MWs 1047 and 1052, and MWs 1057 and 1052, exhibit gradient reversals when BW-18 is on indicating that MW-1047 and MW-1057 are within its zone of capture. Well pairs MWs 162 and 167, and MWs 167 and 148 in the northern portion of OU B were not available prior to April 1990 measurements and, therefore, can be evaluated only for that measurement. Potential differences between the pairs reflect the expected southerly gradient. Well pair MW-148 and MW-1047 shows increased gradient magnitudes when BW-18 is on, but flow direction varies. Flow was to the south in August 1989 and October 1989, but was to the north in December 1989, January 1990, and April 1990. Fluctuations in gradient directions between the wells can be attributed to their differing radial directions from BW-18. As with the MW-132 and MW-1046 well pair in the C zone, the D zone wells are not on the same

flow line. Therefore, the northerly gradient direction does not indicate flow away from the pumping well. Northerly gradient directions only indicate which well is being more influenced by BW-18 during that measurement event. Hydrologic conditions in August and October of 1989, were such that BW-18 caused greater decreases in water levels at MW-1047, whereas MW-148 water levels were lower in the winter.

Insufficient data have been collected from the E zone to interpret gradients for this zone. However, it should be noted that the largest measured gradients under OU B, 0.007 and 0.008 feet per foot, with the exception of well pairs in the A zone, were calculated for well pair MW-149 and MW-1048 in the E zone in December 1989 and January 1990 (Table A3-9).

In summary, data collected during 1989-90 indicate that when BW-18 is actively pumping, water levels and groundwater flow under OU B are significantly affected. Pumping of the well creates a hydraulic potential decrease near the well which influences horizontal and vertical hydraulic gradients and local flow direction in the A through E zones. A large portion of the groundwater in the five zones is captured by the supply well when it is pumping. The magnitude and radial extent of this influence differ with each zone, and the hydraulic response by each zone is dependent upon seasonal recharge and hydraulic parameters (confinement, vertical flow, permeability).

In general, the cone of depression created by pumping BW-18 is asymmetrical and trends northeast/southwest. The effects of BW-18 on water levels decreases with increasing distance from the well. Groundwater flow in the C zone appears to be the most affected by the well's activity. Pumping alters both vertical and horizontal hydraulic gradients in all zones. Vertical gradients, which are normally upwards across zone boundaries, are downward from A to B and B to C zone when the base well is on. Base Well 18, however, has not had the same impact consistently over the last ten years as it was shut down from 1981 to 1985 when contaminants were detected in its discharge.

A4.0 CONTAMINANT DISTRIBUTION

Results of groundwater analyses performed on samples collected in Operable Unit (OU) B during December 1989 and during the first quarter of 1990 are reported and interpreted in this section. Analytes detected in groundwater monitoring wells are discussed in Section A4.1. The present extent of contamination and interpretation of contaminant migration based on recent 1989-90 data and historical analytical data are presented in Section A4.2. Potential contaminant sources are discussed in Section A4.3.

A4.1 Analytes Detected in Groundwater Monitoring Wells

Volatile organics compounds (VOCs) and metals have been detected in monitoring wells in OU B both on and off McClellan Air Force Base (AFB). Details of historical monitoring well analyses are reported in the Groundwater Sampling and Analysis Program (GSAP) Technical Report (Radian, 1990b). Because the principal purpose of the OU B Groundwater Remedial Investigation was to determine the present extent of groundwater contamination and future migration potential, the discussion of contaminants will focus on recent analytical results. During December 1989 and the first quarter of 1990, monitoring wells in OU B, including those on McClellan AFB and those in the off-base area to the southwest, were sampled and analyzed as part of the McClellan AFB GSAP. Results of December 1989 and first quarter 1990 analyses for VOCs are listed in Table A4-1. Reported in this section are analytical results from this time period for 60 monitoring wells. All wells from which data is used are shown in Figure A2-1. Groundwater samples from these wells were analyzed for VOCs by U.S. Environmental Protection Agency (U.S. EPA) Method 8010.

The VOCs trichloroethene (TCE), total 1,2-dichloroethene (1,2-DCE), 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethane (1,2-DCA), tetrachloroethene (PCE), chloroform, and methylene chloride have been detected consistently in several on-base monitoring wells in OU B for several years. No single well sample has had detectable concentrations of all the compounds, but TCE is detected most frequently. Volatile organic compounds have been identified in five geohydrologic zones beneath OU B. One monitoring well has recently been constructed with a screened interval in the F zone in the northern part of OU B, in the cluster of wells that includes MWs 164, 165, 166, 167, and 168. Preliminary analytical data, which have not been validated, indicate no detectable VOCs in the sample from that zone.

TABLE A4-1. ANALYTES DETECTED BY U.S. EPA METHOD 8010 IN OU B MONITORING WELL SAMPLES FIRST QUARTER 1990 SUPPLEMENTED BY FOURTH QUARTER 1989 AND MAY 1990

		Concentration (µg/L) "A" GEOHYDROLOGIC ZONE MONITORING WELLS														
Well		MW-7	MW-11A[a]	MW-41S	MW-65	MW-121	MW-135	MW-139	MW-145	MW-150	MW-153	MW-155	MW-157	MW-158	MW-159	MW-164
Date Sampled		02/90	01/90	01/90	02/90	01/90	01/90	01/90	01/90	02/90	02/90	02/90	02/90	02/90	12/89	01/90
Compound	DHS Action Level or MCL															
1,1-Dichloroethene	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	0.5	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachlorethene	5	ND	ND	130	ND	ND	ND	ND	ND	2.5	6.5	ND	1400	210	1.3	ND
1,2-Dichloroethene	16	34	4	ND	ND	ND	3.5	28	0.51	ND	3.5	ND	ND	42	45	17
Trichloroethene	5	47	2.4	1800	110	ND	19	110	1.9	ND	150	ND	5400	1500	85	25
Chloroform	100	ND	ND	ND	ND	ND	0.91	ND	ND	ND	ND	ND	ND	ND	3.9	1.5
1,1,1-Trichloroethane	200	2.8	ND	ND	ND	0.47	ND	ND	ND	ND	ND	ND	ND	29	ND	ND
Carbon Tetrachloride	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	NE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.54	ND	22	ND	ND
Total VOC	--	83.8	6.4	1930	110	0.47	24.41	158	2.41	2.5	160	0.54	6800	1803	135.2	47
Ratio of Concentrations of TCE/1,2-DCE	--	1.38	0.6	-	-	-	5.43	3.93	3.73	-	42.86	-	-	35.71	1.89	1.47

		Concentration (µg/L) "A" GEOHYDROLOGIC ZONE MONITORING WELLS											
Well		MW-1000	MW-1011	MW-1015	MW-1016	MW-1020	MW-1021	MW-1023	MW-1044	MW-1049	MW-1053	MW-1054	MW-36A[a]
Date Sampled		02/90	02/90	01/90	01/90	02/90	02/90	01/90	01/90	02/90	02/90	10/89	05/90
Compounds	DHS Action Level or (MCL)												
1,1-Dichloroethene	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	0.14	ND	ND	ND
Tetrachlorethene	5	ND	ND	ND	ND	ND	0.84	ND	ND	ND	ND	0.17	ND
1,2-Dichloroethene	16	ND	ND	ND	ND	ND	ND	ND	ND	5.7	0.49	0.20	74
Trichloroethene	5	ND	ND	ND	ND	0.43	13	ND	3.3	13	0.66	1.1	65
Chloroform	100	ND	ND	ND	ND	ND	0.42	ND	7.6	ND	ND	0.19	9.7
1,1,1-Trichloroethane	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	NE	2.1	ND	ND	ND	ND	ND	ND	ND	0.41	ND	ND	ND
Total VOC	--	2.1	ND	ND	ND	0.43	14.26	ND	10.9	19.25	1.15	1.66	ND
Ratio of Concentrations of TCE/1,2-DCE	--	-	-	-	-	-	-	-	-	2.28	1.35	5.5	0.88

ND = Nothing Detected
NE = Action level not established
a = Data for this sample have not undergone quality assurance - quality control validation.

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TABLE A4-1. (Continued)

Compounds	DHS Action Level or (MCL)	Concentration (µg/L) "B" Geohydrologic Zone Monitoring Wells																
Well		MW-11B[a]	MW-23D	MW-36B[a]	MW-63	MW-64	MW-66	MW-134	MW-140	MW-146	MW-151	MW-156	MW-165	MW-1022	MW-1025	MW-1045	MW-1050	MW-1055
Date Sampled		03/90	01/90	05/90	01/90	02/90	02/90	1/90	2/90	02/90	02/90	02/90	11/89	02/90	01/90	02/90	02/90	10/89
1,1-Dichloroethene	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.1	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene	16	ND	ND	2.4	43	ND	ND	0.21	48	ND	ND	52	57	0.49	ND	1.9	0.21	ND
Trichloroethene	5	ND	ND	1.9	110	ND	ND	2.9	120	ND	ND	100	170	5.9	ND	ND	ND	ND
Chloroform	100	ND	ND	0.25	ND	ND	ND	ND	ND	ND	ND	ND	3.6	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	200	ND	ND	ND	5.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.47	ND	0.35	ND
Carbon Tetrachloride	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	NE	0.72	ND	ND	ND	ND	1.9	ND	ND	ND	0.42	ND	ND	ND	ND	ND	ND	ND
Total VOC	--	1.08	ND	0.79	158.2	ND	1.9	3.1	168	ND	6.52	152	230.6	6.39	0.47	1.9	0.56	ND
Ratio of Concentrations of TCE/1,2-DCE	--	-	-	-	2.56	-	-	-	2.5	-	-	1.92	2.98	12.04	-	-	-	-

Compounds	DHS Action Level or (MCL)	Concentration (µg/L) "C" GEOHYDROLOGIC ZONE MONITORING WELLS										
Well		MW-36C[a]	MW-132	MW-141	MW-147	MW-152	MW-154	MW-166	MW-1046	MW-1051	MW-1056	MW-181
Date Sampled		05/90	01/90	01/90	02/90	02/90	02/90	11/89	02/90	02/90	12/89	12/89
1,1-Dichloroethene	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	0.5	0.32	2	8.7	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	5	ND	ND	ND	ND	ND	ND	ND	ND	0.41	ND	ND
1,2-Dichloroethene	16	12	47	19	ND	ND	ND	40	6.2	1	ND	ND
Trichloroethene	5	54	120	160	ND	ND	0.83	100	20	2	4.6	ND
Chloroform	100	ND	2.5	ND	ND	ND	ND	ND	0.19	ND	ND	ND
1,1,1-Trichloroethane	200	ND	ND	13	ND	ND	ND	ND	0.35	0.47	ND	ND
Carbon Tetrachloride	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	NE	ND	ND	ND	ND	ND	ND	ND	1.5	ND	1.5	ND
Total VOC	--	4.5	171.5	200.7	ND	ND	0.83	140	28.24	3.88	6.1	ND
Ratio of Concentrations of TCE/1,2-DCE	--	--	2.55	8.42	-	-	-	2.5	3.22	2.00	-	ND

NE = Action level not established
ND = Nothing Detected
a = Data for this sample have not undergone quality assurance - quality control validation.

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EECA/081090/jlh

TABLE A4-1. (Continued)

		Concentration (µg/L)									
		"D" GEOHYDROLOGIC ZONE MONITORING WELLS						"E" GEOHYDROLOGIC ZONE MONITORING WELLS			
	Well	MW-148	MW-162	MW-167	MW-1047	MW-1052	MW-1057	MW-149	MW-163	MW-168[b]	MW-1048
	Date Sampled	02/90	12/89	12/89	2/90	02/90	12/89	02/90	01/90	01/90	02/90
Compounds	DHS Action Level or (MCL)										
1,1-Dichloroethene	6	2.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	0.08	ND
Tetrachlorethene	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene	16	ND	6.9	30	ND	ND	ND	ND	0.7	22	ND
Trichloroethene	5	7.2	39	79	ND	ND	ND	0.98	7.3	57	ND
Chloroform	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	200	0.39	0.37	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	NE	0.72	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total VOC	--	10.81	46.27	109	ND	ND	ND	0.98	10.1	79	ND
Ratio of Concentrations of TCE/1,2-DCE	--	-	5.6	2.63	-	-	-	-	10.43	2.59	-

NE = Action level not established
ND = Nothing Detected
b = Well initially designated as "E" zone probably was constructed in the lower part of "D" zone.

Analyses of samples taken from October 1989 through March 1990 from on-base monitoring wells indicate that VOCs are present in the pre-existing wells and in a number of newly constructed wells (Table A4-1). Trichloroethene was detected in on-base monitoring wells in concentrations ranging from 0.43 to 5,400 micrograms per liter (μg/L). Concentrations of 1.9 to 120.0 μg/L of TCE were identified in MWs 7, 63, 132, 145, 148, 149, and 156, all of which are located within 200 feet of McClellan AFB boundaries. Tetrachloroethene was detected in samples with TCE from on-base monitoring wells in concentrations ranging from 0.41 to 1400 μg/L. The only wells in which PCE was detected without TCE present were MW-150 and MW-151, in which 2.5 and 6.1 μg/L of PCE were detected, respectively. In January and February 1990, 1,1,1-trichloroethane (1,1,1-TCA) was detected, at levels below California Department of Health Services (DHS) Maximum Contaminant Levels (MCLs), for the first time in four on-base monitoring wells, MWs 7, 68, 148, and 158, which are centrally located within OU B. The source of and reason for the sudden appearance of 1,1,1-TCA is unknown.

Groundwater samples from MW-157, located on base approximately 900 feet east of the McClellan AFB boundary in the Building 666 area, had the highest concentration of any VOCs detected within the operable unit area. February 1990 samples from MW-157 contained both the highest concentrations of TCE (5,400 μg/L) and of PCE (1,400 μg/L). Monitoring Well 158 and MW-41S, which are approximately 75 feet to the northwest and southeast of MW-157, respectively, also had concentrations of greater than 1,000 μg/L TCE and greater than 100 μg/L PCE in groundwater samples.

Volatile organic compounds similar to those detected in on-base monitoring wells near the McClellan AFB boundary have been detected in off-base monitoring wells at lower concentrations. Trichloroethene is the most frequently detected organic compound. Of the regularly sampled off-base wells, MW-1021 and MW-1022, which are within 150 feet of the north-south base boundary, have yielded samples with TCE concentrations of 4.8 to 57 μg/L from 1981 to 1988. Monitoring Wells 1000 and 1020 and City of Sacramento Well (CW) 150, which are located approximately 700 feet south from the east-west McClellan AFB boundary have sporadically had concentrations of 0.86 to 5 μg/L. The southernmost off-base monitoring well within OU B, MW-1015, has not had detectable concentrations of TCE in any samples since 1985, but had methylene chloride at a concentration of 17 μg/L in one sampling in 1986. The wells MW-1023 and MW-1025, which are approximately 1200 feet to the southwest at the western boundary of OU B, have been sampled regularly since 1986. Samples from these wells have never had detectable concentrations of TCE. Other VOCs were only detected in a few sampling events. In 1989, one sample from MW-1023 contained 1.1 μg/L methylene

chloride, and MW-1025 has had low concentrations of 1,1,1-TCA since October 1989 (0.42 μg/L in October and 0.47 μg/L in January 1990). The compound, 1,1,1-TCA, has been only sporadically detected in off or on-base wells in OU B. The source of and reason for the occurrence of 1,1,1-TCA at these wells cannot be accurately determined.

During 1989, fourteen monitoring wells were completed off base in three clusters (MWs 1044 to 1048, MWs 1049 to 1052, MWs 1054 to 1057) and a single well (MW-1053) adjacent to CW-132. Ten of these wells, MWs 1044, 1045, 1046, 1047, 1048, 1049, 1050, 1051, 1054, and 1056, had detectable concentrations of TCE in at least one sample analysis. In two monitoring wells, MW-1052 and MW-1057, no VOCs were detected. In MWs 1044, 1045, 1046, 1049, 1050, 1051, 1053, 1054, and 1056, TCE and one or more other volatile compounds, most commonly 1,2-DCE, were also detected. Analytical data for VOCs in the new off-base wells are listed in Table A4-1. It should be noted that in the first quarter of 1990, 1,1,1-TCA was also detected in newly constructed wells MWs 1046, 1050, and 1051. The latter two wells are within 1200 feet of the two older wells, MW-1024 and MW-1025, samples of which have recently yielded detectable 1,1,1-TCA concentrations.

The historical and recent analytical data from monitoring wells in OU B indicate that VOCs have migrated vertically into five geohydrologic zones extending to depths of approximately 380 feet below the surface, and that VOCs have migrated horizontally beyond the base boundary to monitoring wells in the off-base areas. Several facts, based on the data presented above, indicate migration of some VOCs across McClellan AFB boundaries. First, a suite of VOCs, including TCE, 1,2-DCE, and chloroform, occurs in on-base monitoring wells within 200 feet of the southwest boundary of McClellan AFB. Second, TCE and other VOCs, have been detected in off-base A, B, and C zone monitoring wells in locations 150 to 1,300 feet south and west from McClellan AFB boundaries. Third, regional groundwater flow directions are south to southwest, from on base to off base, in at least the A and B zones. On the basis of these facts, it can be concluded that VOCs have migrated across McClellan AFB boundaries. However, not all VOC contaminants detected in off-base wells can be attributed to migration from McClellan AFB. The occurrence of 1,1,1-TCA at MWs 1024, 1025, 1050, and 1051 does not appear to be a result of migration across McClellan AFB boundaries in OU B. The occurrence of 1,1,1-TCA will be discussed more extensively in Section A4.2.1.

In addition to organic compounds, metal ions have been detected in groundwater samples from both on- and off-base monitoring wells in OU B. Groundwater

samples were analyzed by U.S. EPA Method 6010. Details of historical monitoring well analyses are reported in the GSAP Technical Report (Radian, 1990b). A number of metal ions detected in monitoring wells result from natural dissolution of minerals as groundwater migrates through rocks and sediments. Aluminum and silicon are two of the most abundant metals in the earth's crust. Calcium, sodium, magnesium, potassium, and iron are other common dissolved metals which occur naturally and in the greatest concentration in groundwater. It is appropriate, therefore, to assume that the low concentrations of these metals detected in OU B are a result of naturally occurring background concentrations and not contamination from McClellan AFB. Additional metals may occur in groundwater in smaller or "trace" concentrations as a result of mineral dissolution or near-surface contamination. The trace metals, arsenic, boron, barium, chromium, cadmium, copper, lead, mercury, nickel, vanadium, and zinc, are metals that have been detected historically in monitoring wells in OU B. All of the metals have not been detected in any one well, and concentrations of the metals in samples from any of the monitoring wells have fluctuated since 1982.

Metals detected in fourth quarter 1989 and first quarter 1990 groundwater samples from monitoring wells in OU B are listed in Table A4-2. Trace metal ions were detected in both on- and off-base monitoring wells. Concentrations of metals detected in off-base groundwater samples are generally equal to or less than the lowest concentrations detected in on-base well analyses with the exception of chromium and boron. Chromium was detected on base in concentrations ranging from 0.007 milligram per liter (mg/L) in MW-146 to 0.013 mg/L in MW-11B. Off base in OU B, chromium was reported in groundwater samples in concentrations ranging from 0.008 mg/L in MW-1047 to a maximum of 0.025 mg/L in MW-1050. The California Department of Health Services (DHS) Maximum Contaminant Level (MCL) for chromium is 0.05 mg/L.

Boron was detected in fourteen of the groundwater samples from monitoring wells analyzed during the fourth quarter 1989 and first quarter 1990 (Table A4-2). No MCL has been established for boron. Low concentrations ranging from 0.022 mg/L (MW-146) to 0.042 mg/L (MW-11B) were detected in on-base monitoring wells. Off base, boron was reported in concentrations ranging from 0.21 mg/L (MW-1045) to 0.37 mg/L (MW-1050).

TABLE A4-2. TRACE METAL ANALYTES[1] DETECTED BY U.S. EPA METHOD 6010 IN OU B MONITORING WELL SAMPLES, FOURTH QUARTER 1989 THROUGH FIRST QUARTER 1990

Metal	Well No.: Date Sampled:	A GEOHYDROLOGIC ZONE MONITORING WELLS					
		MW-135 10/89	MW-155 09/89	MW-158 10/89	MW-1011 11/89	MW-1023 01/90	MW-1054 10/89
	MCL	Concentration (mg/L)					
Barium	1	0.06	0.02	0.031	ND	0.057	0.03
Boron	NE	0.23	0.28	0.30	ND	0.31	0.30
Chromium	0.05	0.013	ND	ND	ND	ND	0.010
Copper	NE	0.023	0.17	ND	ND	0.023	ND
Vanadium	NE	0.031	0.02	0.022	ND	0.009	0.022
Zinc	NE	0.010	0.068	0.014	ND	0.012	0.012

(Continued)

TABLE A4-2. (Continued)

Metal	Well No.: / Date Sampled:	B GEOHYDROLOGIC ZONE MONITORING WELLS						
		MW-11B[2] 03/90	MW-66 02/90	MW-134 10/89	MW-146 11/89	MW-151 11/89	MW-156 09/89	MW-1045 10/89
	MCL	Concentration (mg/L)						
Barium	1	0.043	0.026	0.053	0.022	0.034	0.043	0.048
Boron	ND	NA	0.40	0.29	0.41	0.20	0.28	0.21
Chromium	0.05	0.014	ND	0.012	0.007	0.010	0.011	0.018
Copper	NE	0.016	ND	0.008	0.016	0.070	0.11	ND
Vanadium	NE	0.027	0.017	0.026	0.021	0.027	0.025	0.025
Zinc	NE	0.017	0.039	0.012	0.66	0.033	0.035	0.067

Metal	Well No.: / Date Sampled:	MW-1050 11/89	MW-1055 10/89
	MCL	Concentration (mg/L)	
Barium	1	0.024	0.019
Boron	NE	0.37	0.29
Chromium	0.05	0.025	ND
Copper	NE	0.033	ND
Vanadium	NE	0.026	0.024
Zinc	NE	1.10	0.036

(Continued)

TABLE A4-2. (Continued)

Metal	Well No.: Date Sampled:	C GEOHYDROLOGIC ZONE MONITORING WELLS MW-147 02/90	MW-152 11/89	MW-1051 02/90
	MCL	Concentration (mg/L)		
Barium	1	0.066	0.032	0.012
Boron	NE	0.39	0.44	0.32
Chromium	0.05	ND	0.008	0.017
Copper	NE	0.020	.034	0.021
Vanadium	NE	0.024	0.020	0.011
Zinc	NE	0.062	0.035	0.16

Metal	Well No.: Date Sampled:	D GEOHYDROLOGIC ZONE MONITORING WELLS MW-1047 02/90
	MCL	Concentration (mg/L)
Barium	1	0.044
Boron	NE	0.33
Chromium	0.05	ND
Copper	NE	0.008
Vanadium	NE	ND
Zinc	NE	0.010

[1] Major metal analytes (e.g., aluminum, calcium, etc.) were detected in the analysis, but are not presented here. All concentrations of major metals were below established EPA MCLs. Other trace metals not detected.

[2] Data have not been validated.

MCL = Maximum contaminant level.
NA = Not analyzed.
NE = Not established.
ND = Not detected.

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Metals for which the California DHS has established MCLs (for example, chromium, lead, and mercury) were not detected in concentrations above MCLs in monitoring wells in OU B (Table A4-2). Other metals (for example, boron, vanadium, and zinc) were detected for which no DHS MCLs have been established. Of these, calcium, magnesium, potassium, manganese, and sodium are essential human nutrients and were detected in low concentrations that pose no threat to human health. In addition, low concentrations of copper, nickel, vanadium, and zinc were detected in groundwater samples from OU B.

Copper, for which no MCL has been established, was detected in eleven of the sixteen monitoring well analyses reported in Table A4-2. Concentrations in on-base groundwater analyses ranged from 0.016 mg/L in MW-146 to 0.07 mg/L in MW-151. Off-base concentrations ranged from 0.008 mg/L in MW-1047 to 0.033 mg/L in MW-1050.

Nickel was detected in concentrations of 0.043 and 0.094 mg/L in on-base MW-147 and MW-146, respectively. Nickel concentrations in samples from monitoring wells ranged from 0.042 mg/L (MW-1050) to 0.016 mg/L (MW-1023, MW-1046). No MCL for nickel has been established.

Vanadium was detected in groundwater samples from six on-base monitoring wells that were analyzed and are listed in Table A4-2. Concentrations ranged from 0.017 in MW-66 to 0.028 in MW-11B. Off base, vanadium was detected in concentrations ranging from 0.009 mg/L (MW-1023) to 0.026 mg/L (MW-1046, MW-1050) in eight of the monitoring well samples analyzed. No MCL for vanadium has been established.

Zinc was also detected in low concentrations in on-base monitoring wells. Concentrations ranged from 0.013 mg/L in MW-11B to 0.55 mg/L in MW-146. Zinc was detected off-base in groundwater samples in concentrations ranging from 0.0050 mg/L (MW-1024) to 1.1 mg/L in MW-1050.

The suite of trace metals occurring in groundwater in the off-base monitoring wells of OU B are the same as those occurring in samples from wells on base and near the McClellan AFB boundary. This suggests that the metals are migrating with groundwater beneath the McClellan AFB boundaries. However, it cannot be determined with available data if the metals originate from natural dissolution of minerals in deposits beneath or upgradient from McClellan AFB, or if the metals have entered the ground-

water from a near-surface discharge source on McClellan AFB. Unlike VOCs, dissolved metals, including the trace metals discussed in this section, may dissolve in groundwater as a result of natural processes. At the relatively low concentrations of trace metals which occur in OU B, the origin of the dissolved metals cannot be clearly determined with available data.

A4.2 Extent of Contamination

In Section 4.1, the historical and recent analytical data for monitoring wells within OU B were presented. On the basis of the similarity of detected organic analytes, the distribution of monitoring wells on and off of McClellan AFB, and the groundwater flow directions, the conclusion is drawn that contaminants dissolved in groundwater have migrated to the south and southwest from the area beneath McClellan AFB to off-base areas. Potentiometric surface maps and groundwater flow directions, determined from water-level soundings during 1989-1990, suggest that contaminant migration to the south away from Base Well (BW) 18 occurred when the well had less hydrologic impact on the groundwater. During 1989 and 1990, when BW-18 was pumping at a daily rate of 1.5 to 1.6 million gallons, groundwater containing contaminant concentrations in areas upgradient from BW-18 were captured by the base well. Therefore, groundwater containing contaminants is likely to have migrated beyond the base boundary when the well was inactive, as it was from 1981 through 1985, or was pumping at a lower daily rate. The following sections describe the vertical and horizontal distributions of contaminants in groundwater that lend additional support to this conclusion.

A4.2.1 Horizontal Extent of Contamination

The fourth quarter 1989 and first quarter 1990 analyses of groundwater samples from monitoring wells in and near OU B were evaluated to determine the horizontal extent of contaminant migration within the operable unit area. Analytical data from samples collected after the first quarter of 1990 are used for a few wells that were not available for sampling in that period. Data were evaluated from analyses for VOCs using U.S. EPA Method 8010 (Table A4-1). For each zone, an isopleth map has been constructed using the total VOC concentration detected at each well. If TCE, PCE, 1,2-DCE, or 1,1,1-TCA were detected within a zone, an isopleth map was also prepared to illustrate the distribution of these contaminant concentrations.

Recent studies indicate that 1,2-DCE is a product of microbial or chemical degradation of PCE or TCE (McCarty, 1986). The step-wise removal of chlorine from a compound such as PCE could alter it first to TCE, to 1,2-DCE, and then to vinyl chloride. Other VOC degradation series that may be occurring in OU B are 1,1,1-TCA to 1,1-DCE to vinyl chloride or 1,1,1-TCA to 1,2-DCA to chloroethane. Neither of the final products of dehalogenation, vinyl chloride or chloroethane, has been confirmed in samples from OU B. One step in the dehalogenation process may take a number of years to occur in groundwater, and not all of the quantity of one compound may be dehalogenated simultaneously. Therefore, a quantity of PCE, TCE, or 1,1,1-TCA discharged in groundwater may result, over 10 years, in detectable concentrations of the original compound and several of its dehalogenated "daughter" products. In OU B, TCE was used extensively and, therefore, it is probable that TCE and not PCE was more frequently the "parent" compound in the dehalogenation process. Available data indicate 1,2-DCE, 1,2-DCA, and 1,1-DCE were not used as degreasing agents, but TCE, 1,1,1-TCA, and PCE were, in activities conducted within OU B. Dehalogenation beneath McClellan AFB is indicated by the presence of 1,2-DCE, 1,2-DCA, and 1,1-DCE in groundwater beneath OU B. Analysis of the distribution of TCE relative to its breakdown products may provide insight into migration pathways and source locations.

The horizontal and vertical distribution of VOCs in each zone is determined by a number of factors that may be collectively referred to as the transport history. Transport history includes the time interval, location, and mechanism of contaminant entry into each zone. Once in the zone, the contaminant's transport history is affected by groundwater flow direction, contaminant behavior (i.e., degradation to "daughter" products, adsorption on mineral grains in each zone, volatilization to soil gas, and changes in solubility), and the character of the deposits in the zone (resulting in decreases in groundwater or contaminant transport velocity and dispersion or spreading of contaminants). The transport history of VOCs in groundwater cannot be fully addressed until source areas are identified in the OU B Remedial Investigation. Reference is made to the effects of transport history on contaminant distribution in the following discussions of horizontal and vertical extent.

Figures A4-1 through A4-20 at the end of this section (pages A4-35 to A4-54) depict the areal distribution of contaminant concentrations within each zone in OU B. Distribution maps were constructed using data listed in Table A4-1. Isopleths have been drawn to represent the estimated extent of the contaminant concentration in groundwater. The isopleth lines, each of which represents a 10-fold change in concentration in comparison to the adjacent isopleth, represent the approximate areal

extent of the contaminant plume dissolved in groundwater. Groundwater flow directions were taken into account in the placement of isopleths. Isopleths are not connected or "closed" in the upgradient direction because the sources of the contaminants have not been determined in OU B. Isopleths are closed in the downgradient direction wherever analytical data from wells provide adequate information. The isopleth lines were drawn from the interpretation of monitoring well analytical data and 1989 and 1990 potentiometric surface-flow direction maps (see Figures A3-18 to A3-21). The isopleths were drawn to reflect the distribution of VOC concentrations resulting from current groundwater flow directions affected by the present pumping rate of BW-18. Therefore, the isopleth maps shown in Figures A4-1 to A4-20, may differ in the illustration of contaminant distributions used in other parts of this report (i.e., the Baseline Risk Assessment included as Appendix B) in which a more conservative horizontal contaminant distribution was used for calculations.

Figures A4-1 through A4-20 show that contaminants are present in the A, B, C, D, and E zones and that concentrations generally decrease from shallower to deeper geohydrologic zones. This contaminant distribution indicates vertical migration of groundwater and dissolved compounds. Examination of both recent and historical contaminant data indicates the presence of three different plumes in the A geohydrologic zone in OU B. The three plumes occurring in the A zone are outlined and labeled in Figure A4-1. They consist of: a TCE/1,2-DCE plume that trends north to south through the length of OU B; a TCE/PCE plume in the Building 666 area that trends northeast to southwest toward BW-18; and a PCE plume that is present to the south of BW-18. There are other VOC contaminants present in each of the plumes; however, in the following discussion, the plumes will be referred to by the one or two VOCs that are present in the largest concentrations.

The TCE/1,2-DCE plume detected in the first quarter 1990 occurs in all zones (Figures A4-6 to A4-13). In the A, B, and C zones, the plume extends from OU C to the southwest boundary of OU B. In the A zone, TCE is detected as far south as MW-1053 (Figure A4-6). Isopleths drawn for each zone suggest a source in the upgradient direction to the north because concentrations increase and are highest in that direction. The data suggest that TCE entered the groundwater of the A zone in OU C, north of the OU B boundary. Fewer wells are completed in the deeper D and E geohydrologic zones, and therefore, the distribution of the TCE plume is more difficult to estimate (Figures A4-9 and A4-10). At the depth of the D zone, TCE and other VOCs appear to be confined to the area north of and including MW-148. Volatile organic compounds in the E zone appear to be confined to the area north of MW-149.

Trichloroethene concentrations are generally highest in the B and C zones; concentrations of TCE are approximately equivalent in these two zones (Figures A4-7 and A4-8). Concentrations are next highest in the A zone and are the least in the D and E zones.

The distribution of contaminants in each geohydrologic zone is caused by groundwater flow. Groundwater flow, discussed in Section A3.2.2, is affected principally by the pumping of BW-18. The well, when pumping, has the greatest effect on the B and C zones, but also affects the A, D, and E zones. The presence of VOCs south of BW-18 can be attributed to migration when the base well had less hydrologic impact on groundwater flow prior to 1989 (Figures A4-1 to A4-3) because it is unlikely that contaminants dissolved in groundwater could migrate southwest of BW-18 when the well was pumping at 1 to 1.5 million gallons per day. Lower contaminant concentrations in the D and E zones may also reflect the longer time required for contaminants to migrate vertically into these deeper zones. In each zone however, the TCE/1,2-DCE plume increases in TCE concentrations in the north toward OU C, with the highest concentrations found in wells north of BW-18. Lower concentrations are detected south of BW-18. For the following discussion, the TCE/1,2-DCE plume is divided into a northern and southern portion with an imaginary east-west dividing line passing through BW-18.

In the northern TCE/1,2-DCE plume, northwest of BW-18, TCE (or VOC) concentrations increased from the second quarter 1989 to the first quarter 1990 in the A, B, and C zone monitoring wells (Figures A4-6, A4-7 and A4-8). The limited amount of data for the D and E zones precludes an interpretation of concentration changes for these zones (Figures A4-9 and A4-10). In the A zone, the TCE concentration increased between the second quarter 1989 and the first quarter 1990 in MW-7 by 20 percent, but this increased is within the range of variability for sample analyses (Tables A4-1 and A4-3). In the B zone, TCE in MW-63 increased by 49 percent, from 74 μg/L to 110 μg/L. In the C zone, MW-132 showed a TCE increase of 60 percent, from 75 μg/L to 120 μg/L. These increased concentrations in each of the three shallowest zones suggest that the greater contaminant concentrations migrating from the northwest (upgradient) are approaching the east-west base boundary and BW-18. However, the statistical significance of the increase in the A zone cannot be demonstrated because the increase is in the range of analytical variability.

In contrast, TCE concentrations are not increasing in groundwater sampled from monitoring wells south of BW-18, in the southern part of the TCE/1,2-DCE plume

TABLE A4-3. ANALYTES DETECTED BY U.S. EPA METHOD 8010 IN OU B MONITORING WELL SAMPLES FROM MARCH, APRIL, AND MAY, 1989

Compounds		DHS Action Level	Concentrations (µg/L) "A" Geohydrologic Zone Monitoring Wells							
		Well Date Sampled	MW-7 04/28/89	MW-41S 04/11/89	MW-65 04/26/89	MW-120 04/14/89	MW-121 04/20/89	MW-1000 04/12/89	MW-1015 04/06/89	MW-1016 04/10/89
1,1-Dichloroethene	(0.10)	6	ND	ND	ND	ND	ND	ND	ND	ND
Total-1,2-Dichloroethene	(0.10)	16	23C	ND	ND	4.4C	ND	ND	ND	ND
Chloroform	(0.10)	100	2.1C	ND	ND	0.38C	ND	ND	ND	ND
1,2-Dichloroethane	(0.10)	1	ND	ND	ND	0.15C	ND	ND	ND	ND
Bromodichloromethane	(0.10)	100	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	(0.20)	5	26C	2700C	58C	4.5C	ND	ND	ND	ND
Tetrachloroethene	(0.10)	4	ND	150C	0.78C	ND	ND	ND	ND	ND
Carbon tetrachloride	(0.20)	5	ND	ND	ND	ND	ND	ND	ND	ND

Compounds		DHS Action Level	Concentrations (µg/L) "A" Geohydrologic Zone Monitoring Wells							
		Well Date Sampled	MW-1020 04/10/89	MW-1021 04/10/89	MW-1021 04/10/89	MW-1023 04/07/89	MW-145 (10A) 03/24/89	MW-150 (25A) 03/24/89	MW-153 (11A) 05/05/89	MW-1044 (13A) 04/08/89
1,1-Dichloroethene	(0.10)	6	ND	ND	ND	ND	ND	ND	ND	ND
Total-1,2-Dichloroethene	(0.10)	16	ND	0.97C	0.93C	ND	ND	ND	3.8C	1.4C
Chloroform	(0.10)	100	ND	0.20C	0.25C	ND	ND	ND	0.80C	6.0C
1,2-Dichloroethane	(0.10)	1	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloromethane	(0.10)	100	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	(0.20)	5	0.23P	9.3C	8.5C	ND	1.3C	ND	12C	3.8C
Tetrachloroethene	(0.10)	4	ND	1.1C	1.0C	ND	ND	ND	ND	ND
Carbon tetrachloride	(0.20)	5	ND	ND	ND	ND	ND	ND	ND	ND

ND = Nothing detected/not detected at the detection limit specified in parenthesis.
C = Analysis confirmed in second column analysis.
P = Identity previously confirmed.
NE = Not established.

(Continued)

TABLE A4-3. (Continued)

			Concentrations (µg/L)
			"A" Geohydrologic Zone Monitoring Wells
	Well		MW-1049 (12A)
	Date Sampled		04/24/89
Compounds		DHS Action Level	
1,1-Dichloroethene	(0.10)	7	ND
Total-1,2-Dichloroethene	(0.10)		3.8C
Chloroform	(0.10)	100	0.22C
1,2-Dichloroethane	(0.10)	5	0.20C
Bromodichloromethane	(0.10)	100	ND
Trichloroethene	(0.20)	5	7.0C
Tetrachloroethene	(0.10)		ND
Carbon tetrachloride	(0.20)	5	ND

			Concentrations (µg/L)							
			"B" Geohydrologic Zone Monitoring Wells							
	Well		MW-23D	MW-63	MW-64	MW-66	MW-122	MW-1022	MW-1024	MW-1025
	Date Sampled		04/19/89	04/13/89	04/24/89	04/27/89	04/14/89	04/20/89	04/10/89	04/07/89
Compounds		DHS Action Level								
1,1-Dichloroethene	(0.10)	6	ND	ND	ND	ND	ND	ND	ND	ND
Total-1,2-Dichloroethene	(0.10)		ND	40P	ND	ND	ND	1.2P	ND	ND
Chloroform	(0.10)	100	ND	ND	ND	ND	ND	0.3P	ND	ND
1,2-Dichloroethane	(0.10)	1	ND	1.0P	ND	ND	ND	ND	ND	ND
Bromodichloromethane	(0.10)	100	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	(0.20)	5	ND	76P	ND	ND	ND	5.2P	ND	ND
Tetrachloroethene	(0.10)	4	ND	ND	ND	ND	ND	0.5P	ND	ND
Carbon tetrachloride	(0.20)	5	ND	ND	ND	ND	ND	ND	ND	ND

ND = Nothing detected/not detected at the detection limit specified in parenthesis.
C = Analysis confirmed in second column analysis.
P = Identity previously confirmed.
NE = Not established.

(Continued)

TABLE A4-3. (Continued)

Compounds		DHS Action Level	Concentrations (µg/L) "B" Geohydrologic Zone Monitoring Wells			
Well			MW-146 (10B)	MW-151 (25B)	MW-1045 (13B)	MW-1050 (12B)
Date Sampled			03/24/89	03/20/89	04/06/89	04/24/89
1,1-Dichloroethene	(0.10)	6	ND	ND	ND	ND
Total-1,2-Dichloroethene	(0.10)	16	ND	ND	1.2C	0.43C
Chloroform	(0.10)	100	ND	ND	ND	ND
1,2-Dichloroethane	(0.10)	1	ND	ND	ND	ND
Bromodichloromethane	(0.10)	100	ND	ND	ND	ND
Trichloroethene	(0.20)	5	ND	ND	3.4C	1.0C
Tetrachloroethene	(0.10)	4	ND	ND	ND	ND
Carbon tetrachloride	(0.20)	5	ND	ND	ND	ND

Compounds		DHS Action Level	Concentrations (µg/L) "C" Geohydrologic Zone Monitoring Wells						
Well			MW-132	MW-147 (10C)	MW-152 (25C)	MW-154 (11C)	MW-1046 (13C)	MW-1046 (13C)	MW-1051 (12C)
Date Sampled			04/17/89	03/20/89	03/17/89	05/01/89	04/06/89	03/30/89	04/08/89
1,1-Dichloroethene	(0.10)	6	ND	ND	ND	ND	ND	0.26C	ND
Total-1,2-Dichloroethene	(0.10)	16	37P	ND	ND	ND	12.0C	1.0C	ND
Chloroform	(0.10)	100	1.7P	ND	ND	ND	ND	0.55C	ND
1,2-Dichloroethane	(0.10)	1	3.0P	ND	ND	ND	0.33C	0.25C	ND
Bromodichloromethane	(0.10)	100	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	(0.20)	5	75P	ND	ND	ND	30.0C	21.0C	ND
Tetrachloroethene	(0.10)	4	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	(0.20)	5	ND	ND	ND	ND	ND	ND	ND

ND = Nothing detected/not detected at the detection limit specified in parenthesis.
C = Analysis confirmed in second column analysis.
P = Identity previously confirmed.
NE = Not established.

(Continued)

TABLE A4-3. (Continued)

Compounds		DHS Action Level	Concentrations (µg/L) "D" Geohydrologic Zone Monitoring Wells				
Well			MW-148 (16D)	MW-148 (16D)	MW-1047 (13D)	MW-1047 (13D)	MW-1052 (12D)
Date Sampled			04/06/89	03/30/89	04/21/89	04/06/89	04/17/89
1,1-Dichloroethene	(0.10)	7	ND	ND	ND	ND	ND
Total-1,2-Dichloroethene	(0.10)		2.8C	5.2C	ND	ND	ND
Chloroform	(0.10)	100	ND	0.37C	ND	ND	ND
1,2-Dichloroethane	(0.10)	5	ND	ND	ND	ND	ND
Bromodichloromethane	(0.10)	100	ND	ND	ND	ND	ND
Trichloroethene	(0.20)	5	10.0	7.2C	0.31C	ND	ND
Tetrachloroethene	(0.10)		ND	ND	ND	ND	ND
Carbon tetrachloride	(0.20)	5	ND	ND	ND	ND	ND

Compounds		DHS Action Level	Concentrations (µg/L "E" Geohydrologic Zone Monitoring Wells		
Well			MW-149 (16E)	MW-1048 (13E)	MW-1048 (13E)
Date Sampled			04/25/89	04/19/89	04/21/89
1,1-Dichloroethene	(0.10)	7	ND	ND	ND
Total-1,2-Dichloroethene	(0.10)	ND	ND	ND	ND
Chloroform	(0.10)	100	ND	ND	ND
1,2-Dichloroethane	(0.10)	5	ND	ND	ND
Bromodich_oromethane	(0.10)	100	ND	ND	ND
Trichlorcethene	(0.20)	5	0.23C	0.36C	ND
Tetrachloroethene	(0.10)	4	ND	ND	ND
Carbon tetrachloride	(0.20)	5	ND	ND	ND

ND = Nothing detected/not detected at the detection limit specified in parenthesis.
C = Analysis confirmed in second column analysis.
P = Identity previously confirmed.
NE = Not established.

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(Tables A4-1 and A4-3). In addition, the leading edge of the TCE/1,2-DCE plume does not appear to have migrated appreciably to the south/southwest during 1989-90. These two observations can be attributed to the impact of BW-18 on groundwater flow in the A through E geohydrologic zones that is described in Section A3.2.3. When BW-18 is actively pumping, as it has been almost continually since 1985, the well reverses the southerly flow of groundwater as far to the southwest as MWs 1054, 1050, 1051, and 1052 in the A, B, C, and D zones, respectively. Contaminants detected in those wells may have migrated past BW-18 when the well was inactive from 1981 to 1985. When BW-18 is pumping, the reversal of groundwater flow from south-southwest to north-northeast prevents the migration of contaminants away from BW-18, and groundwater containing contaminants is being drawn back toward BW-18. This condition of migration back to the northeast may be observed at MW-1050 in the B zone where the TCE/1,2-DCE plume has withdrawn to the northeast and was not detectable in January 1990 as it had been in May 1989. In comparison, MW-1049, the A zone well southwest of BW-18, showed an increase from 7.0 μg/L in May 1989 to 13 μg/L in February 1990 (Tables A4-1 and A4-3). Potentiometric surface maps for October and December 1989, and April 1990 show MW-1049 to be downgradient from MW-1054 because the water level elevation is lower at MW-1049. Therefore, groundwater in the A zone south of MW-1054 can flow toward MW-1049 even when BW-18 is pumping. As a result, contaminants in the A zone, south of BW-18 and south of MW-1054, may continue to migrate toward MW-1049 and MW-1053 under current hydraulic conditions.

The TCE/PCE plume is smaller in areal extent than the TCE/1,2-DCE plume, but contains higher concentrations of contaminants (Figure A4-1). The highest concentrations of any VOCs in OU B have been detected in the A zone monitoring wells within the TCE/PCE plume. The presence of relatively high concentrations of PCE and TCE in this plume (Figures A4-14 to A4-16) indicates a difference in source and transport history in comparing this plume with the TCE/1,2-DCE plume. The compound 1,2-DCE is known to be present in the TCE/PCE plume (Figure A4-11) along with 1,2-DCA, chloroform, and methylene chloride. However, these compounds are often not detectable in the samples from this plume because of the much higher concentrations of TCE and PCE. Samples with high concentrations of TCE-PCE are diluted in the laboratory to more accurately quantify higher concentrations. However, the dilution step causes VOCs present at lower concentrations to become nondetectable. The presence or extent of the TCE/PCE plume in zones other than A cannot currently be determined due to a smaller amount of data for the deeper zones. In January 1990, the only deeper well was MW-154, a C zone well which had been constructed downgradient from the TCE/PCE plume (Figure A4-16). In the A zone, the highest contami-

nant concentrations were detected in MW-157 in February, 1400 μg/L of TCE and 5400 μg/L of PCE (Figures A4-6 and A4-14). The plume trends northeast to southwest toward BW-18 with concentrations decreasing over short distances to the northwest, the southwest, and the southeast from MW-157; this suggests that MW-157 is near the center of the plume where which concentrations are greatest. Comparison of recent analytical data (Table A4-1) with the March-May 1989 data (Table A4-3) shows that contaminant concentrations in that plume have also increased. Trichloroethene in MW-153 increased from 17 μg/L to 150 μg/L, and PCE, which had been below detection limits in March 1989, was present at 6.5 μg/L in February 1990. Trichloroethene concentrations increased in MW-65 from 58 μg/L to 110 μg/L.

The data available for groundwater contaminants in the TCE/PCE plume suggest that the plume has not migrated a great distance from its source area. Evidence to support the proximity of the plume to its probable source are the relatively high (1000 to 8000 μg/L) concentrations of total VOCs detected only in the A zone and the relative narrowness, 250 to 350 feet, of the plume between the 100 μg/L isopleth lines. The relatively high concentrations confined to a narrow width in the A zone suggest a nearby upgradient source because a longer horizontal migration path would be expected to cause a wider plume width in the A zone and greater vertical migration into the more permeable B or C zones. If the source were a much greater distance to the northeast, VOC concentrations in the C zone at MW-154 might be expected to exceed 100 μg/L because contaminant cncentrations reaching the one would migrate a greater distance at higher velocities than those in the A zone. The portion of the TCE/PCE plume exceeding 99 μg/L might be expected to be 500 to 600 feet wide in the A zone as a result of lateral dispersion, or spreading, if the source area were a greater distance upgradient.

The PCE plume thus far has been detected only in the A and B zones in cluster wells MW-150 and MW-151, respectively (Figures A4-14 and A4-16). This plume was not detected in any other wells in these zones and has not been detected in a third cluster well, MW-152, in the C zone (Figure A4-17). There are no monitoring wells present in a radial distance of 2000 feet to the northeast, east or southeast which may be upgradient from MW-150 and MW-151. The areal extent of this plume, therefore, has not been determined. Concentrations of PCE are much lower in this plume than in the TCE/PCE plume, the only other area where PCE has been detected. However, this PCE plume is unique in the remedial investigation of McClellan AFB because it is the only plume that has been detected with PCE and no TCE concentrations. Tetrachoroethene was detected at 2.5 μg/L in MW-150 and at 6.1 μg/L in MW-151 in February

1990 (Table A4-1). Methylene chloride was also detected in MW-151 at that time. No VOCs were found in these wells in March-May 1989. However, 18 μg/L of PCE were detected in MW-150 and 9.9 μg/L in MW-151 in the third quarter of 1989 as part of the McClellan AFB GSAP. Concentrations were lower, therefore, in February 1990. Additional monitoring wells and analyses are needed to define the horizontal extent of this plume and to evaluate fluctuations in contaminant concentrations. The PCE plume does not extend west to MW-1016 (Figure A4-14); no VOCs have been detected in this well. Under the present hydraulic conditions, horizontal gradients in the A and B zone monitoring wells indicate the PCE plume is migrating toward BW-18. Therefore, the PCE plume may never migrate to MW-1016 if the hydrologic conditions causing the northerly gradients are maintained.

In addition to contaminants associated with the three major plumes, 1,1,1-TCA was detected in groundwater samples from nine wells in the first quarter of 1990, in MWs 7, 63, 121, 148, 158, 1025, 1046, 1050, 1051 (Figures A4-17 to A4-20). Historically, 1,1,1-TCA has been detected only sporadically in OU B. In the first quarter of 1990, 1,1,1-TCA was found in the A, B, C, and D geohydrologic zones in two separate areas. One area is centrally located within OU B near BW-18 and is defined by five wells. The source and reason for the appearance of 1,1,1-TCA at this time and in this vicinity is unknown.

The other area where 1,1,1-TCA was recently detected was within the extreme southwest part, and just outside of, OU B in MWs 1025, 1050, and 1051 screened in the B and C zones (Figures A4-18 and A4-19). The large zone of capture produced by BW-18 in the B and C zones results in groundwater as far away as MW-1050 and MW-1051 being drawn toward the well (Section A3.2.3). Under 1989 and 1990 hydraulic conditions, groundwater flows to those wells from the west or northwest (Figures A3-18 and A3-20). Therefore, groundwater containing 1,1,1-TCA from an area to the northwest of these wells (not within OU B or McClellan AFB) is apparently being drawn to MW-1025, MW-1050, and MW-1051. The absence of TCE in MW-1025 and MW-1050 suggests another source area. The contaminant plume migrating south from McClellan AFB consistantly contains TCE concentrations. Additional data is needed to confirm this hypothesis.

The compound 1,1,1-TCA can degrade to 1,1-DCE to vinyl chloride or can degrade to 1,2-DCA to chloroethane (Vogel et al., 1987). Within OU B during the first quarter of 1990, 1,1-DCE was detected along with 1,1,1-TCA in D zone samples from MW-148 suggesting that this VOC degradation series may be active in OU B (Table

A4-1). In addition, 1,2-DCA was detected in A zone samples from MW-135 and MW-1049, and in C zone samples from MW-132 and Extraction Well 141. The compound 1,1,1-TCA was detected with 1,2-DCA only in the sample from Extraction Well 141. Extraction Well 141, north of MW-135, is where 1,2-DCA was detected. Monitoring Well 1049 is in the same cluster of wells as MW-1050, a B zone well where 1,1,1-TCA was detected. Monitoring Well 132 is also located near other wells where 1,1,1-TCA was detected (MWs 7, 1046, and 148). Therefore, while 1,2-DCA was not detected in every groundwater sample in which 1,1,1-TCA was detected, 1,2-DCA was detected in the same geographic areas as 1,1,1-TCA and is likely to be present locally due to the degradation of 1,1,1-TCA. The sporadic occurrence of these compounds in groundwater samples may be the result of differences in the transport histories of these contaminants, and therefore, does not allow for a determination of migration pathways and source locations for 1,1,1-TCA or its degradation products.

As previously described, the distribution of TCE relative to its breakdown product, 1,2-DCE, may provide insight into contaminant migration pathways and source locations. The distribution of 1,2-DCE under OU B parallels that of TCE although concentrations of 1,2-DCE are lower in most monitoring well samples (Figures A4-6 to A4-13). Like TCE, 1,2-DCE is present in groundwater in all zones and generally increases in concentration both to the northwest and to the northeast away from BW-18, thus indicating that greater concentrations of both compounds are present in groundwater near potential source areas. Distribution patterns suggest that TCE and 1,2-DCE have migrated via the same mechanism and that 1,2-DCE is present as a degradation product of TCE. Examination of historical and recent data suggests TCE degradation is continuing with migration distance from probable source areas. The increasing concentration of 1,2-DCE relative to TCE concentrations in some portions of the plumes in each zone suggests a parent-daughter relationship. However, the relationship should be fully evaluated with historical data in another investigation.

In addition to TCE, PCE, 1,1,1-TCA, and their breakdown products, chloroform and methylene chloride were detected within OU B during fourth quarter 1989 and first quarter 1990 (Table A4-1.) The source for the later two compounds is currently unknown, but they have been repeatedly detected in monitoring wells within OU B for several years. During the first quarter of 1990, chloroform was detected in A zone samples from MWs 135, 159, 164, 1021, 1044, and 1054, in B zone samples from MW-165, and in C zone samples from MW-132 and MW-1046. Concentrations ranged from 0.19 μg/L (MW-1046) to 7.6 μg/L (MW-1044) and were the highest in A zone monitoring wells. Methylene chloride was detected in A zone samples from MWs 155,

158, 1000, and 1049, in B zone samples from MWs 11B, 66, and 151, in C zone samples from MWs 1046 and 1056 and in D zone samples from MW-148. Concentrations ranged from 0.41 μg/L (MW-1049) to 22 μg/L (MW-158). Additional data is required to understand the sources and migration pathways for chloroform and methylene chloride.

In summary, historical and recent data show that a suite of VOCs are present within each of five geohydrologic zones in both on- and off-base monitoring wells in OU B. In the A zone, for which more data are available, three plumes can be identified: a widespread TCE/1,2-DCE plume, a TCE/PCE plume, and a PCE plume. The TCE/1,2-DCE plume has been detected in each of six geohydrologic zones, the TCE/PCE plume in the A zone only, and the PCE plume in the A and B zones. The analytical data lead to the conclusion that contaminants have migrated both vertically and horizontally under OU B. Volatile organic compounds have migrated beyond the base boundary from locations on McClellan AFB and are detectable at lower concentrations in monitoring wells in the off-base areas. The decreases in TCE/1,2-DCE ratios and contaminant concentrations from upgradient to downgradient flow directions indicate that a source for the TCE/1,2-DCE plume appears to be northwest of BW-18 probably in OU C, and a source for the TCE/PCE plume is northeast of the base well in the vicinity of MW-157. Based on groundwater flow directions under nonpumping versus pumping conditions at BW-18, groundwater and dissolved contaminants migrated south of BW-18 when the well was pumped at a rate and frequency less than that in 1989 and 1990. When the base well is frequently pumped at 1.6 million gpd, the zone of capture in the A, B, C, and D zones is large enough to prohibit the migration of contaminants from northeast or northwest of the base well to the south. Analytical data for groundwater samples collected in January/February, 1990 (Figure A4-7) suggest that in the A, B, and C zones, plumes are being drawn back northeastward toward the pumping well. Contaminant plumes that have migrated to the southwest in the B and C zones are being drawn back to BW-18 from distances of at least 2500 feet. The contaminant plume in the A zone is being drawn back to the northeast from a distance of at least 1500 feet. The detection for the first time of 1,1,1-TCA in early 1990 in the B zone samples from MW-1025 and MW-1050 and in the C zone samples from MW-1051 suggests that groundwater originating west of OU B which contains 1,1,1-TCA concentrations is being drawn from the northwest toward those wells in OU B by the groundwater depression created by the pumping of BW-18 and the City of Sacramento well field.

A4.2.2 Vertical Extent of Contamination

Evaluation of the geologic and hydrologic data has led to the identification of six geohydrologic zones beneath OU B. The geohydrologic zones, A, B, C, D, and E, are described in Section A3.2.1. Data for the F zone beneath OU B are insufficient to provide a description of the zone in this report. Each of the zones has geologic and hydrologic characteristics which separate it from overlying or underlying zones. Differences in characteristics between zones result in differences in groundwater flow velocities and horizontal and vertical gradients. Two cross sections are described to illustrate the geohydrologic zones, their lithologic differences, monitoring well screen intervals, and contaminants detected in samples from each well (Plates 3 and 4).

Plate 3 is southwest to northeast cross section A-A′ constructed from BW-18 through P11 to MW-159. The cross section transects the TCE/PCE plume. Contaminant concentrations from fourth quarter 1989 and first quarter 1990 analyses are listed adjacent to monitoring well-screen intervals from which they were sampled except for BW-18. The supply well's four screen intervals are not sampled individually. However, the contaminants, TCE and 1,2-DCE, have been detected in groundwater from the well since 1985. Plate 3 shows that the greatest concentration of VOCs is in the A zone. The compounds, TCE, 1,2-DCE, and PCE, are present in each of the A zone monitoring wells. Chloroform was detected in MW-159, and methylene chloride and 1,1,1-TCA were detected in MW-158, indicating that the plume is not homogenous in contaminant distribution.

Groundwater flow is from A′ to A, from northeast to southwest approximately parallel to the line of section. The VOC concentrations are highest in MW-157 (not shown in the cross section) and MW-158 and are lower both upgradient in MW-159 and downgradient in MW-153 suggesting a source for this plume near MW-157 and MW-158. Monitoring Well 11B was constructed in the B geohydrologic zone adjacent to P11 in April 1990. A sample from 11B had no TCE or PCE detected in one sample analysis. In the C zone MW-154, a low concentration (0.83 μg/l) of TCE was detected. No monitoring wells deeper than the C zone are located along this section line. The presence of VOCs at concentrations 1000 to 10,000 times greater in the A zone than in the B or C zones suggests that vertical migration of contaminants from the A zone has been impeded. Fine-grained, low permeability deposits that may impede the vertical migration of groundwater and contaminants dominate the vadose zone and A zone between MW-158 and MW-159.

Cross section B-B′ on Plate 4 trends north-south and shows lithologic data for P17, P21, P13, MW-149, and MW-1056 and the screen intervals for monitoring wells along the section line. Cross section B-B′ transects the TCE/1,2-DCE plume. The cross section may not be constructed through the central axis of the TCE/1,2-DCE plume, and some monitoring wells that lie outside of the section line have been projected into the section to provide contaminant distribution data. Contaminant concentration data displayed on Plate 4 indicate that within McClellan AFB boundaries, VOCs have migrated from the A zone down to the E zone. Groundwater flow along the line of section is from north to south toward BW-18, or from P17 to MW-149 and from MW-1056 to P13 in the line of cross section. As described in Section A4.2.1, the distribution of contaminants in each zone is controlled by groundwater flow direction and velocity, by individual contaminant behavior, and by characteristics of deposits in each zone. Cross section B-B′ reflects differences in contaminant transport history in each zone. In an effort to interpret contaminant migration along the section, the vertical gradients between zones and the potential mixing of contaminant plumes in the area of MW-1044, MW-1045, and MW-1046 must be considered. The vertical gradients (shown in Plate 4 for well pairs) induced at least partially by pumping provide a potential for upward or downward migration of groundwater and dissolved contaminants. The area of plume mixing near MW-1044 and described in Section A4.2.1 has a strong impact on the interpretation of contaminant migration along this section. The section should be considered in two parts, the north part from P17 to MW-149 and the south part near P13 and MW-1056.

In the A zone, TCE (25 μg/L), 1,2-DCE (17 μg/L), 1,1-DCA (3.9 μg/L), and chloroform (1.5 μg/L) were detected in samples from MW-164 to the north; TCE (47 μg/L), 1,2-DCE (34 μg/L), and 1,1,1-TCA (2.8 μg/L) were detected at MW-7; TCE (3.3 μg/L) and chloroform (7.6 μg/L) were detected at MW-1046; and TCE (1.1 μg/L), 1,2-DCE (0.2 μg/L), chloroform (0.19 μg/L), and PCE (0.17 μg/L) were detected at MW-1054. Variations in the number and concentrations of contaminants in A zone monitoring wells from north to south along the cross section illustrates the nature of the plume in the A zone is not homogenous. Although cross section B-B′ does not lie along the central axis of the plume, the general trends in contaminant concentrations from north to south and from A zone to E zone can be illustrated. Trichloroethene, the only compound detected in all A zone well samples, generally decreases from north to south. The decrease is expected if the source of TCE contamination lies in northern OU B or OU C and downgradient dilution (from advection and longitudinal dispersion) and mixing at MW-1044 are occurring as the plume migrates to the south. Decreasing concentrations from the shallowest zone to the deepest zone are also expected in most

situations with successively deeper groundwater zones, for example, contamination along cross section A-A′ (Plate 3) in OU B. However, along cross section B-B′, concentrations for TCE increase and the number of VOCs decreases from the A zone to the B zone along the north part of the section at MWs 164 and 165 and MWs 7 and 156.

Samples from the B zone at MW-165 have concentrations of TCE (170 μg/L), 1,2-DCE (57 μg/L), and chloroform (3.6 μg/L). Therefore, compared to the nearest A zone well, MW-164, there is an increase of 680 percent in TCE, 335 percent in 1,2-DCE, and 240 percent in chloroform. Between MW-7 in the A zone and MW-156 (250 feet east) in the B zone, concentrations in samples increase 255 percent in TCE and 200 percent in 1,2-DCE. At location P21, the B, C, and D zone TCE and 1,2-DCE concentrations exceed the A zone concentrations. However, the 1,1-DCA and 1,1,1-TCA concentrations detected in the A zone were not detected in the B zone. On the southern end of cross section B-B′, there is a decrease in TCE concentration of A zone samples MW-1044 (3.3 μg/L) to B zone MW-1045 (nondetectable), and a decrease of all VOCs, TCE (1.1 μg/L), 1,2-DCE (0.2 μg/L), chloroform (0.19 μg/L), and PCE (0.17 μg/L) to nondetectable in samples from A zone MW-1054 to B zone MW-1055. The increasing downward concentrations of TCE and 1,2-DCE on the north side of the section do not continue from the B zone to the C zone. Concentrations of TCE and 1,2-DCE decrease with depth from the B zone to the E zone in monitoring wells on the north side of cross section B-B′. On the south side, at monitoring wells near P13 and MW-1056, concentrations and the number of VOCs detected increase from the B to the C zones and then decrease from the C zone downward.

To interpret the vertical distribution of contaminants in cross section B-B′, it is necessary to introduce additional information not shown in the cross section. Since September 1988, two extraction wells (EW-140 and EW-141) have been operating to the north of Location 17, both of which are screened in the C zone to draw groundwater containing VOC contaminants to the surface for treatment. At the time when the extraction well field started extracting groundwater, concentrations of TCE exceeding those detected in 1990 at P21 were detected in the A, B, and C zones north of P17 (EG&G Idaho, 1988). No D or E zone wells had been constructed prior to 1989. Therefore, the presence of VOCs in those zones was not known at the time of extraction well construction. However, MW-162 and MW-163 which were constructed in 1989 have yielded samples containing VOC concentrations including TCE and 1,2-DCE. Therefore, there is evidence that to the north of OU B a contaminant source caused the distribution of VOCs, principally TCE and 1,2-DCE, through the groundwater column

from 100 to approximately 350 feet below surface. The same suite of VOCs are now known to be present and migrating southward in OU B.

Both the decreasing concentration of TCE and 1,2-DCE concentrations relative to TCE in each zone from P17 at the northern boundary of OU B to MW-149, led to the conclusion that TCE entering the groundwater in OU C is migrating southward and degrading to 1,2-DCE with time and distance of migration. However, source and cause of TCE distribution in OU C and OU B does not account for the increase in VOC concentrations in the B and C zones in comparison to the A zone along cross section B-B' in OU B. Furthermore, the vertical migration of TCE through four geohydrologic zones is not readily explained by hydrogeologic conditions in northern OU B.

The difference in contaminant transport history between zones is the reason for greater VOC concentrations in the B and C zones than in the A zone in the northern part of OU B. The potential differences in transport history that may have caused the observed distribution are represented by three hypotheses:

- Downward migration of A zone groundwater containing VOCs along with dilution of the upper zone by less concentrated groundwater;
- Slower migration of the plume in the A zone in OU B as a result of lower permeability, lower gradient, or a greater fraction of natural organic material to retard VOC migration; or
- More rapid migration of the plume in the A zone such that the greater VOC concentrations have previously passed the wells in OU B.

The last of the hypotheses is readily dismissed because very high concentrations of VOCs (greater than 10,000 μg/L TCE) are present in A zone wells in OU C (EG&G Idaho, 1988; Radian, 1990a, 1990b), and concentrations to the south are only slightly greater at MW-7 than MW-164.

The most likely of the two remaining hypotheses to explain differences is the slower migration of the plume in the A zone. The A zone deposits at P17 and P21 consist of low permeability deposits that could account for a lower velocity of migration in the A zone. There is potential for downward migration from the A to the B zone as a result of a downward gradient measured between MW-164 and MW-165. However,

the gradient and vertical hydraulic conductivity do not appear to be great enough to drive large volumes of A zone water into the B zone. In further support of the slower plume migration hypothesis is the concentration ratio of TCE/1,2-DCE at MW-164 in comparison to the ratio in the B, C, D, and E zones. The ratio at MW-164 is 1.47; in the four deeper zones, the ratio is approximately 2.5. The ratio indicates that more 1,2-DCE has formed by degradation of TCE in the A zone than in the deeper zones at approximately the same geographic location. The lower ratio suggests that TCE has had a longer time in groundwater to degrade. If the TCE entered the A zone before or at the same time it entered the deeper zones and the A zone plume is moving more slowly than the B, C, D, or E zone plumes, TCE in the A zone would be more highly degraded at a location than would TCE in plumes that are moving at a greater velocity, for example in the B, C, D, and E zones.

There are several conditions which may be the cause of migration of TCE contamination through four geohydrologic zones even though fine-grained, low permeability layers occur within each zone. The potential causes are:

- The reversal and increase in magnitude of vertical gradients induced by base supply wells causing contaminants from the A and B zones to migrate vertically into the C geohydrologic zone as they move laterally toward BW-18;

- Horizontal and vertical migration from a more distant source under the influence of greater groundwater velocities in the more permeable C, D, and E zone deposits; and

- Artificial vertical conduits between geohydrologic zones provided by unused and improperly abandoned water supply wells with multiple or continuous screens, continuous gravel packs, and no seal above or between screen intervals.

Changes in the direction and magnitude of vertical gradients as a result of base well pumping is indicated by the reversal in gradients from the A zone to the B zone and the B zone to the C zone in the comparison of head differences between well pairs measured when BW-18 was off versus when BW-18 was pumping (see Section A3.2.2). Interpretation of the gradient data indicates vertical migration from the A to B zones and from the B to C zones for well pairs within approximately 1500 feet of BW-18 and under its influence. Downward gradients to the C zone do not explain migration to

the D and E zones. Vertical gradients calculated for the D and E zones in the few available well pairs were generally upward even with the base well pumping. The presence of contaminants in the D and E zones in the northern part of OU B cannot be explained by the observed influence of BW-18 on vertical gradients. The contaminants in the D and E zones must be migrating from a source north of OU B if the gradient conditions (upward from the D and E zones) measured in 1989 and 1990 are representative of conditions that prevailed over the last 5 to 15 years. Furthermore, the hydrologic conditions that exist in the source area for the D and E zone contaminants must provide a downward potential great enough to overcome any upward gradients in all zones. Therefore, at a location in OU C, north of P17 (Plate 1), a contaminant source and a cause of the strong downward hydraulic gradient exist in close proximity.

Horizontal and vertical migration of contaminants at relatively high velocities at locations north and northwest of OU B may account tor the occurrences of TCE and other VOCs in the C, D, and E geohydrologic zones. In the C zone of MW-1046, more contaminants are present than in other zones in nearby wells. The presence of additional compounds and generally higher concentrations of TCE in the C zone may be attributable to vertical or horizontal migration at a greater velocity in the C zone than is possible in the A or B zones. If TCE and other contaminants have migrated at a higher velocity in the C zone than in the less permeable A or B zones, then TCE may also be migrating in the D and E zones at higher velocities than in the A and B zones. The lithologic character of the C, D, and E zones in OU B indicate they have more permeable deposits than the A or B zones. Greater permeability provides the potential for higher velocity of horizontal and vertical groundwater flow than in less permeable zones under the same conditions. Before the compounds reached the more permeable C, D, and E zones, they first must have traveled vertically through upper geohydrologic zones at greater vertical velocities than seem to be possible in the A and B zones in this area. In addition to artificial vertical conduits discussed below, the thinning or absence of fine-grained, low permeability deposits overlying the C, D, and E zones near a discharge point for the contaminants could account for vertical migration at higher velocity through the A and B zones. This condition could occur where a stream cut through lower permeability deposits in the A and B zones and deposited higher permeability deposits. There is, however, no direct evidence of this stream activity in the A and B zones. Even if high permeability deposits exist in the A and B zones at a location beneath a discharge point for contaminants, the presence of those deposits alone is not sufficient to account for the vertical migration of contaminants to the D and E zone. A strong downward hydraulic potential, near or downgradient from the contaminant source, is necessary to cause migration of contaminants from the surface

source area through the A, B, and C zones. The northernmost well pairs monitored in OU B during 1989 and 1990 do not indicate a downward gradient. The cause of the downward potential may exist within OU C.

Vertical migration of contaminants may be artificially assisted in OU B by the casing and gravel packs in unused water supply wells. Four unused McClellan AFB wells, BWs 3, 17, and 19, and an unnumbered well, lie within OU B where contaminants are suspected to be migrating in shallow geohydrologic zones. The well locations are shown in Figure A4-21. Construction data are available for only one of the wells (Luhdorff and Scalmanini, 1984). Base Well 19 was 360 feet deep BGS, had screen intervals from 174 to 193 feet, 214 to 239 feet, and 305 to 360 feet BGS, and had gravel pack from surface to total depth. Base Wells 3 and 19 were reported as abandoned or destroyed. No data have been found for the unnumbered well. If BW-3, BW-19, or the unnumbered well have not been properly destroyed by perforation and grouting of the gravel pack through the perforations, the gravel pack and casing may act as a vertical conduit for contaminant migration. Therefore, each of the wells is a potential conduit and should be properly destroyed. These wells may account for limited vertical contaminant migration to the north-central part of OU B. However, none of the unused water wells in OU B can account for the vertical migration of contaminants to the D and E zones. The wells shown in Figure A4-1 are located too far to the south and downgradient from the contaminant concentrations detected at MWs 162, 167, and 168 to have caused the vertical migration of contaminants that are detected in those wells. The contaminants must have entered the deeper geohydrologic zones further north, perhaps in OU C.

A potential artificial conduit for contaminant migration exists within OU C. The potential conduit is McClellan Base Well (BW) 6, an "old farm well" (Luhdorff and Scalmanini, 1984) for which no records exist. The location of BW-6 is shown in Figure A4-21. The unused well, if it has not been properly abandoned, is a potential artificial conduit for the migration of contaminants in an area of OU C where contaminant sources have previously been identified (McLaren, 1986c; EG&G, 1987). However, sufficient hydrologic data are not available in the area of this well to indicate that a downward hydraulic potential is present to force groundwater containing contaminants downward to the D and E geohydrologic zones.

Of the alternatives proposed to account for the presence of TCE in the C, D, and E geohydrologic zones, none is clearly the definitive answer. The presence of higher permeability deposits in the A and B zones north of OU B near a contaminant

source and the potential presence of artificial conduits may explain the pathways of vertical migration. However, neither explains the downward hydraulic potential that must exist to cause migration to the D and E geohydrologic zones.

A4.3 Potential Contaminant Sources

Although three sites and 24 potential release locations (PRLs) have been identified in OU B, no single location has been specifically indicated as a source of groundwater contamination. Additional site characterization and evaluation of the vadose zone will be required at most of the Sites and PRLs in the operable unit. However, data from previous site investigations (McLaren, 1986a) and 1988 to 1989 groundwater analyses from MW-41S (Radian, 1990b) indicate that a group of four Sites and PRLs occurring in a relatively small area may be the source of TCE and PCE contamination in the A geohydrologic zone in the TCE/PCE plume.

Contaminants (principally TCE) at concentrations of 2,700 to 3,000 μg/L are migrating in the A geohydrologic zone from one or more Sites or PRLs near MW-157 and MW-41S. The Site and PRLs are shown in Figure 1-18. Groundwater flow in the A zone near MW-157 and MW-41S trends from northeast to southwest toward BW-18. The cluster of monitoring wells around MW-157 lie downgradient from at least part of the Site and PRL. Groundwater analyses from MW-159, 300 feet to the northeast of MW-157, and from MW-65, 350 feet to the east, show lower contaminant concentrations at these wells. The distribution of contaminant concentrations in the TCE/PCE plume suggests the presence of a contaminant source upgradient (northeast) of MW-157.

Trichloroethene and several other VOCs have been detected in soil samples analyzed from Sites 47 and 48 and PRL 36, and from the flow through the section of the Industrial Wastewater Line (IWL), which is designated PRL L-5. Leaks detected in the wastewater line have been repaired, but no soil samples have been taken for analysis. No other potential release areas where contaminants have been detected occur for distances of 3,000 to 4,000 feet upgradient from MW-157. Thus, one or more of confirmed site 47 and 48 PRLs 36 and L-5 are likely sources for the high concentrations of TCE detected in the cluster of wells around MW-157.

Groundwater analyses for monitoring wells within the northern TCE/1,2-DCE plume indicate a source to the north of OU B, probably within OU C. Located in OU C is an Industrial Wastewater Treatment Plant (IWTP) with formerly active surface impoundments at which most of the compounds detected in groundwater samples have

been detected. Previous reports have shown that VOCs and heavy metal contaminants have migrated from the vicinity of the impoundments at the IWTP and are migrating in groundwater beneath OU C (EG&G, 1987). Potentiometric surfaces and total VOC concentration isopleths for the A geohydrologic zone (Figure A4-22) indicate that contaminant concentrations of 20,000 to 21,000 μg/L are migrating from OU C to the northern portion of OU B. Therefore, the IWTP and its impoundments are a possible source for the TCE/1,2-DCE plume in OU B. Closure activities were conducted on two IWTP surface impoundments, which were the most likely sources of releases. These impoundments were capped to minimize continued migration of contaminants from percolation of surface water runoff through contaminated soils. Additional data are needed, however, to confirm a source for this plume.

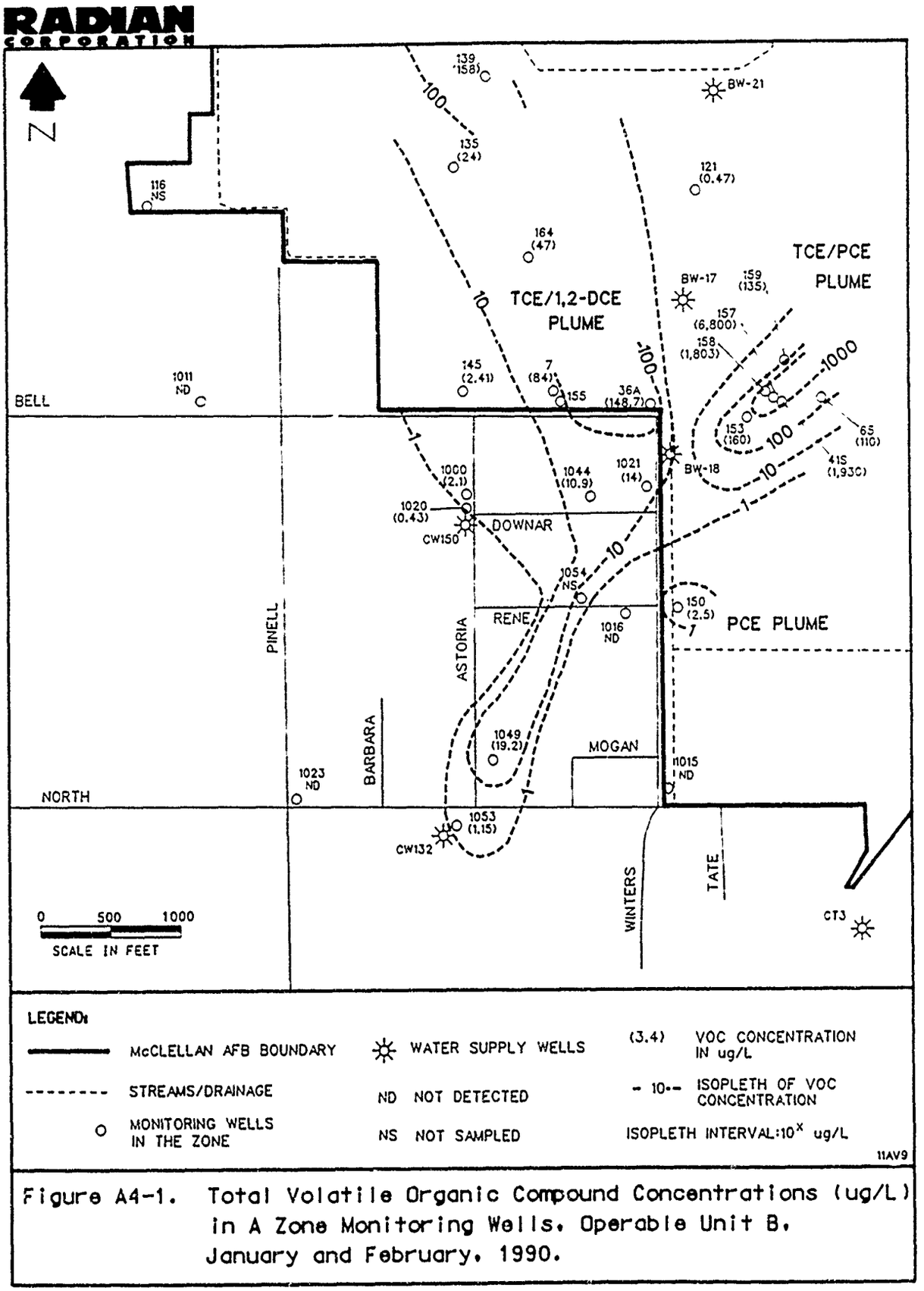


Figure A4-1. Total Volatile Organic Compound Concentrations (ug/L) in A Zone Monitoring Wells, Operable Unit B, January and February, 1990.

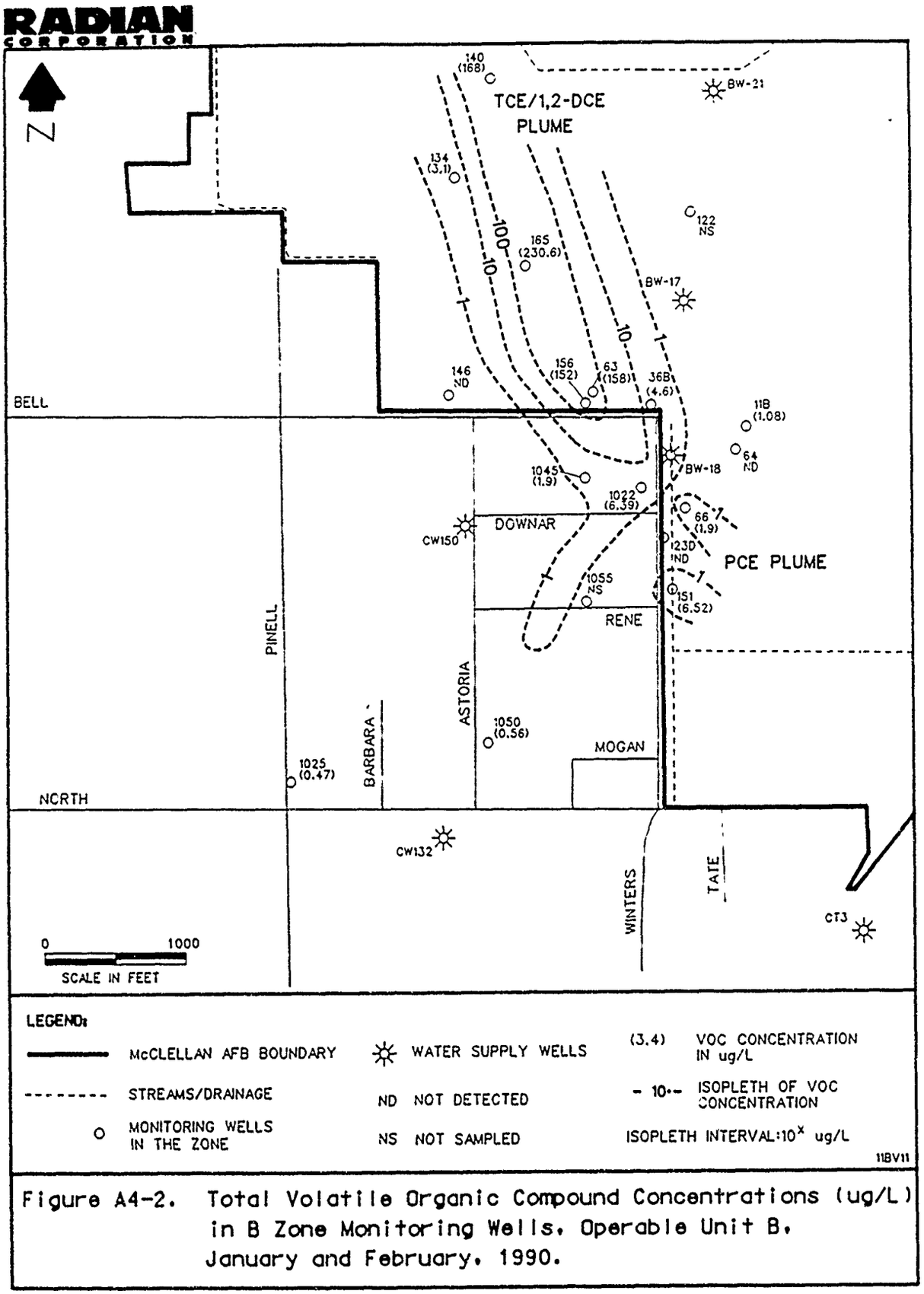


Figure A4-2. Total Volatile Organic Compound Concentrations (ug/L) in B Zone Monitoring Wells, Operable Unit B, January and February, 1990.

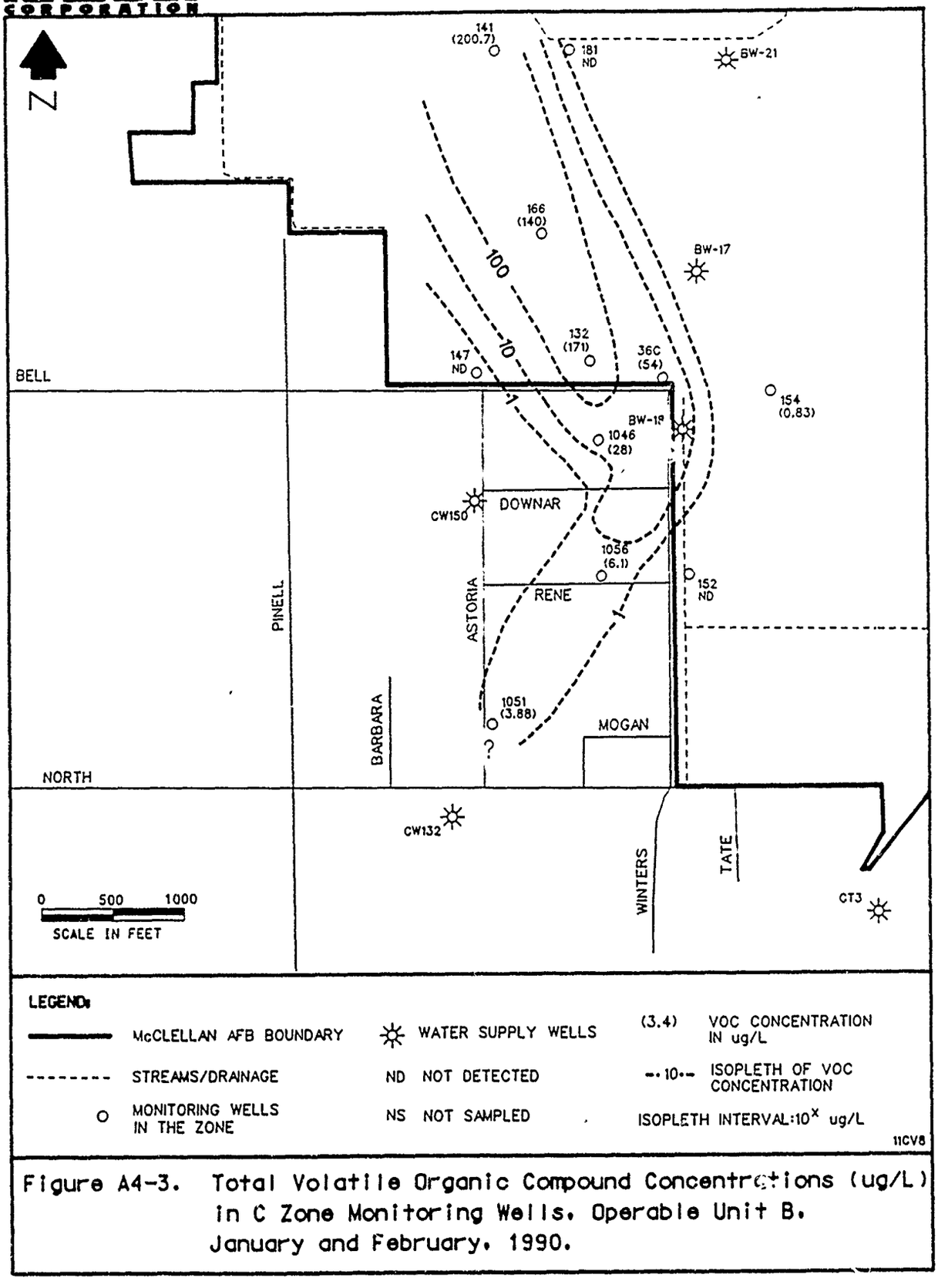
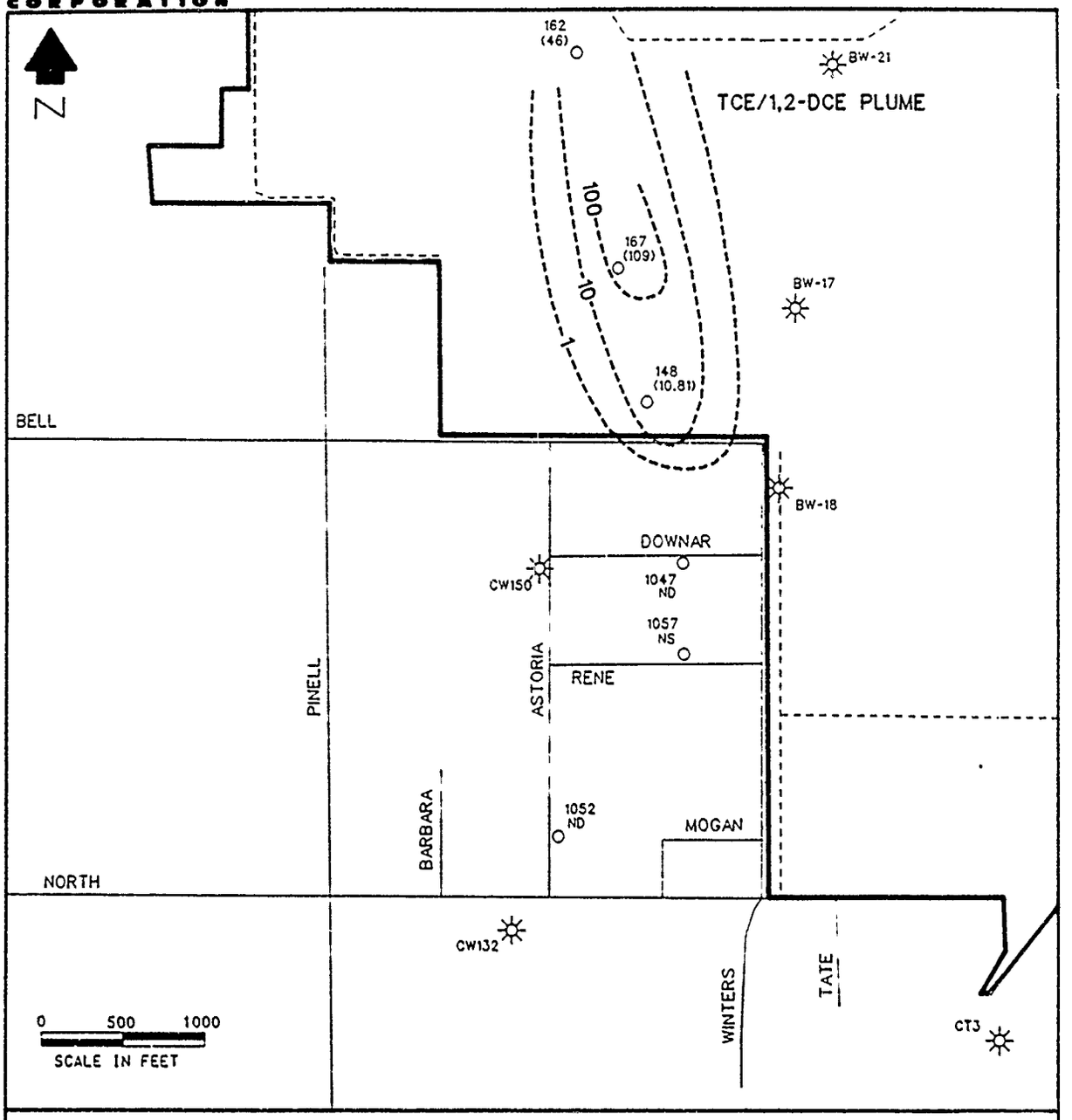


Figure A4-3. Total Volatile Organic Compound Concentrations (ug/L) in C Zone Monitoring Wells, Operable Unit B, January and February, 1990.

RADIAN CORPORATION



LEGEND:

McCLELLAN AFB BOUNDARY	WATER SUPPLY WELLS	(3.4)	VOC CONCENTRATION IN ug/L
STREAMS/DRAINAGE	ND NOT DETECTED	--10--	ISOPLETH OF VOC CONCENTRATION
MONITORING WELLS IN THE ZONE	NS NOT SAMPLED	ISOPLETH INTERVAL: 10^{X} ug/L	

11DV1

Figure A4-4. Total Volatile Organic Compound Concentrations (ug/L) in D Zone Monitoring Wells, Operable Unit B, January and February, 1990.

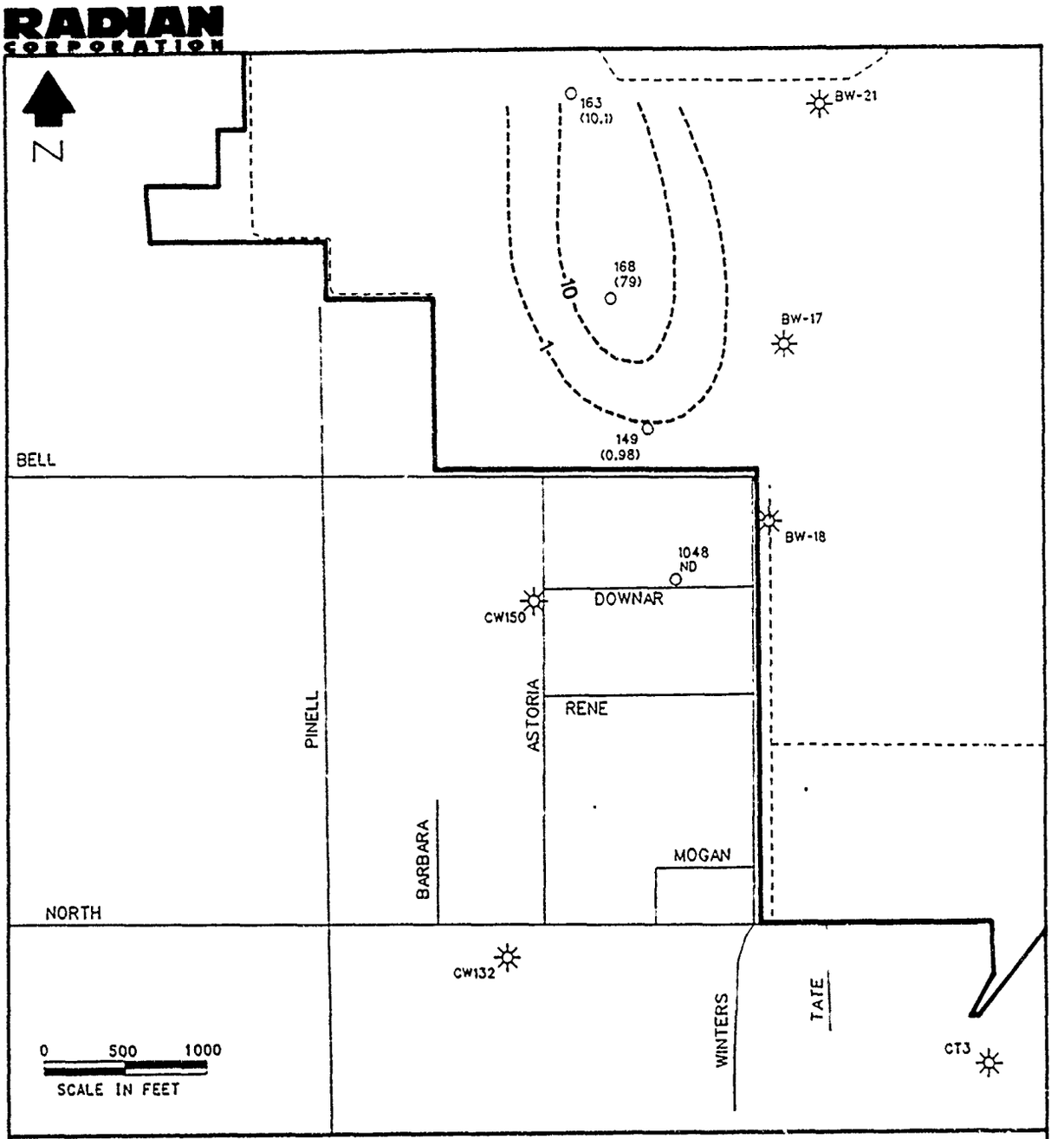


Figure A4-5. Total Volatile Organic Compound Concentrations (ug/L) in E Zone Monitoring Wells, Operable Unit B, January and February, 1990.

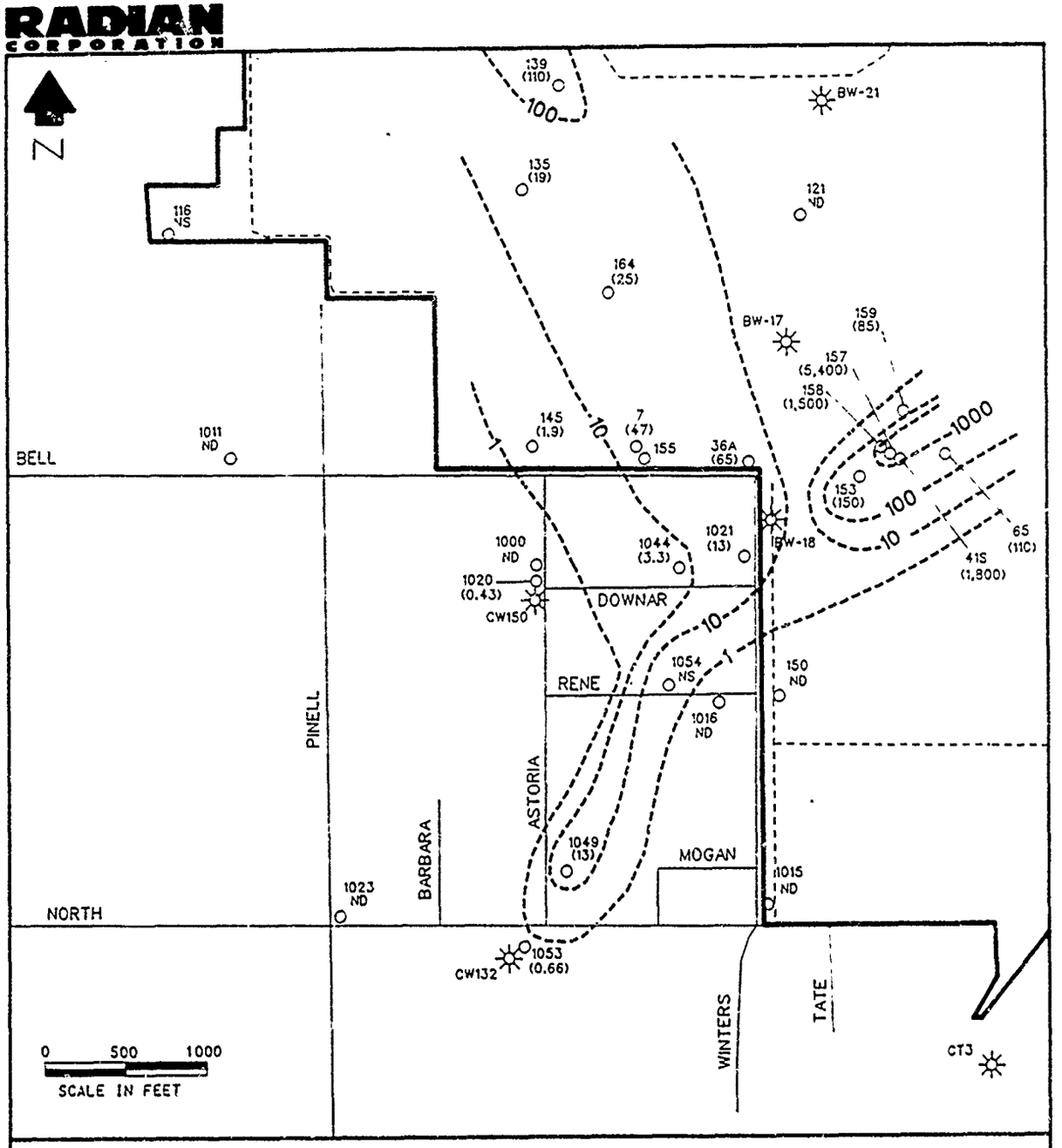
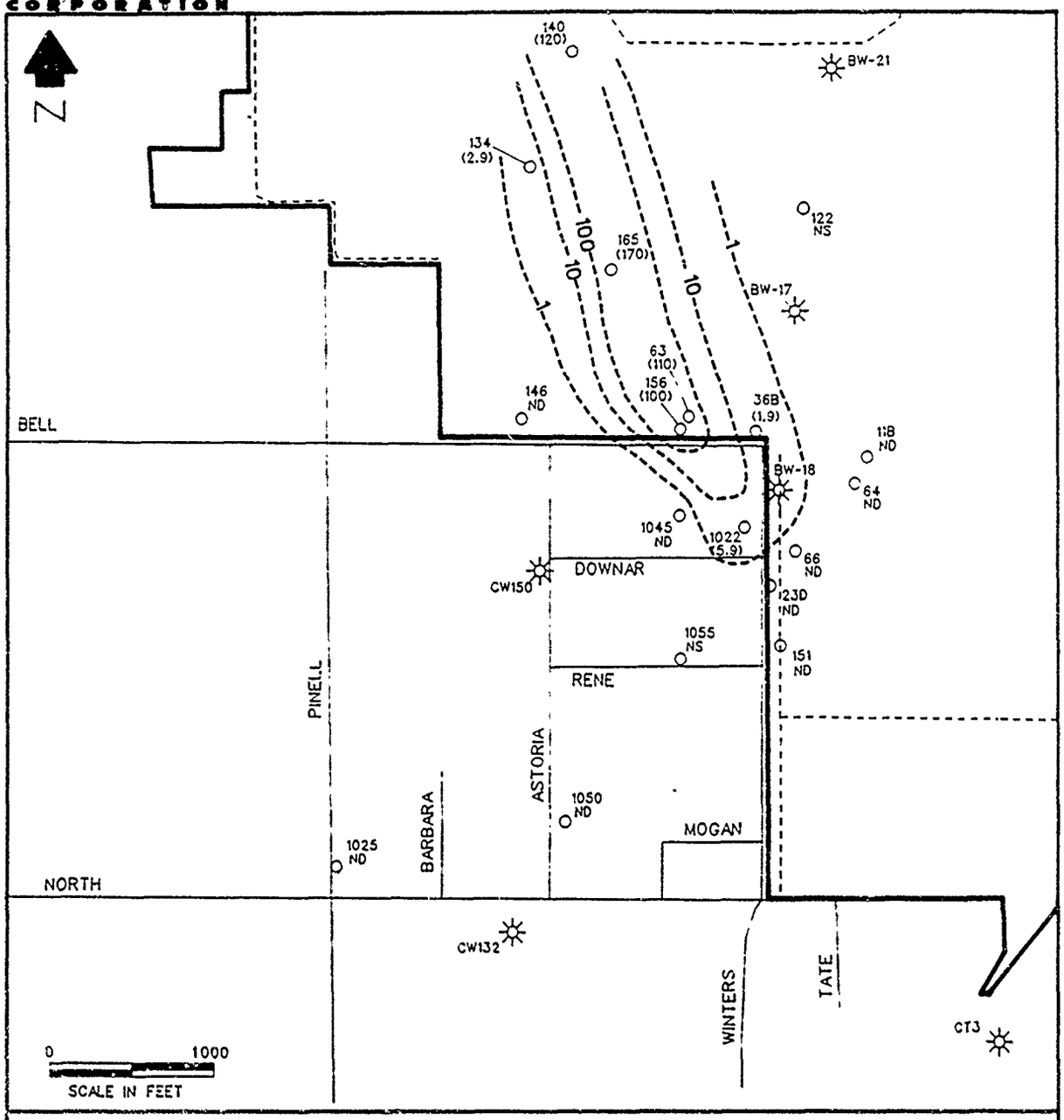


Figure A4-6. Trichloroethene Concentrations (ug/L) in A Zone Monitoring Wells, Operable Unit B, January and February, 1990.

RADIAN CORPORATION



LEGEND:

- McCLELLAN AFB BOUNDARY
- STREAMS/DRAINAGE
- MONITORING WELLS IN THE ZONE
- WATER SUPPLY WELLS
- (3.4) TCE CONCENTRATION IN ug/L
- --10-- ISOPLETH OF TCE CONCENTRATION
- ISOPLETH INTERVAL: 10^{X} ug/L

11BV7 7/19/90

Figure A4-7. Trichloroethene Concentrations (ug/L) in B Zone Monitoring Wells, Operable Unit B, January and February, 1990.

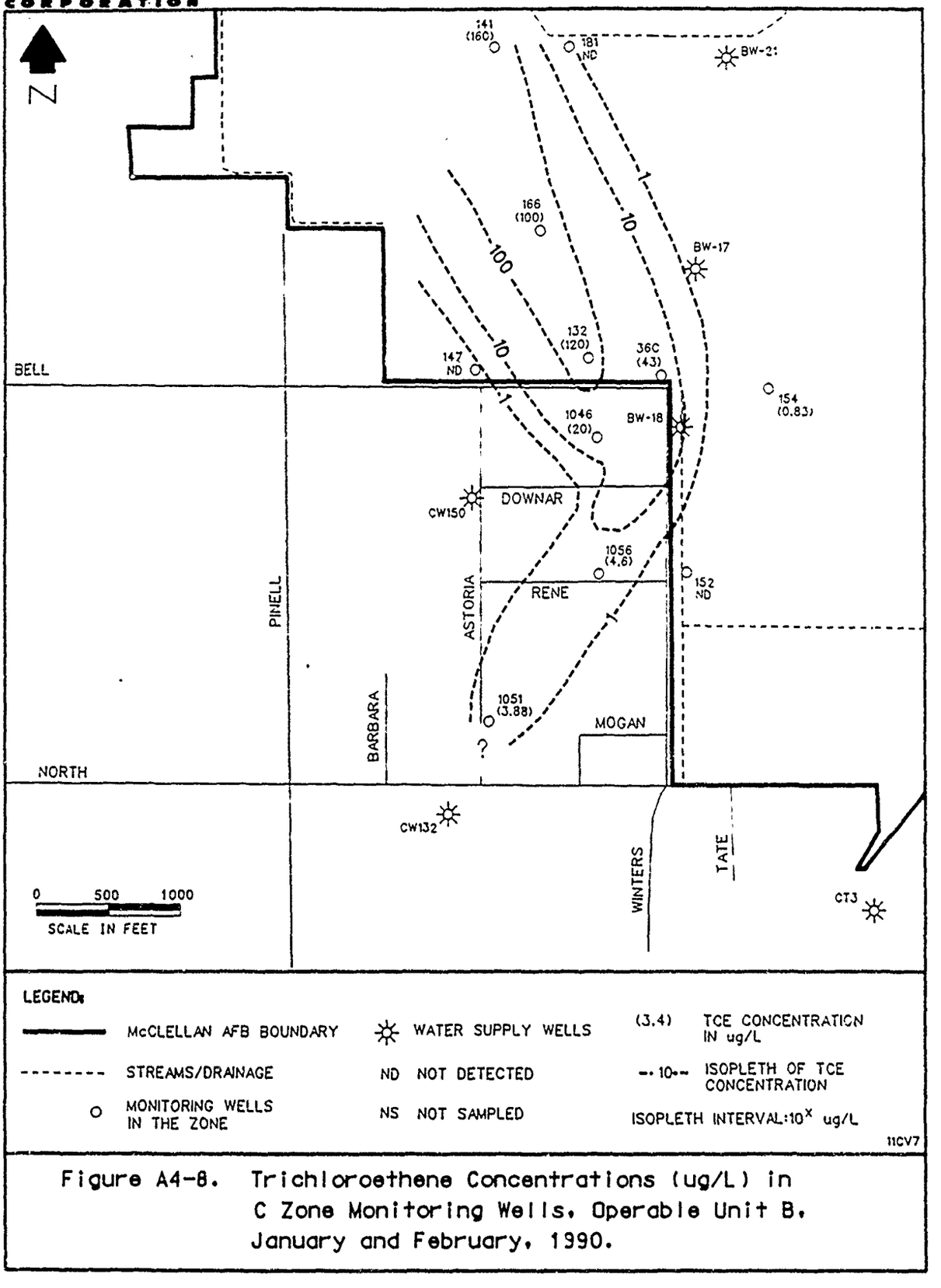


Figure A4-8. Trichloroethene Concentrations (ug/L) in C Zone Monitoring Wells, Operable Unit B, January and February, 1990.

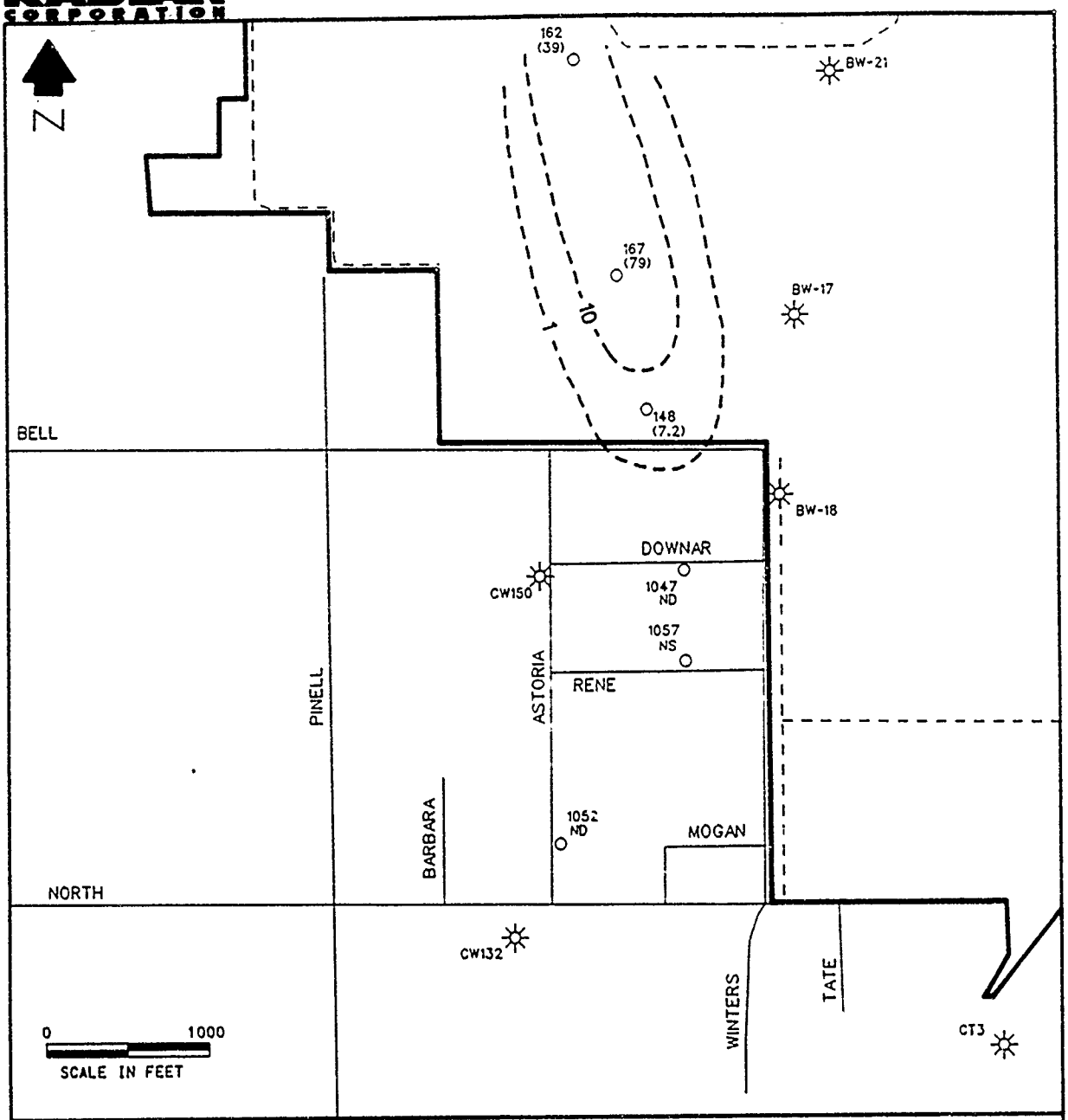


Figure A4-9. Trichloroethene Concentrations (ug/L) in D Zone Monitoring Wells, Operable Unit B, January and February, 1990.

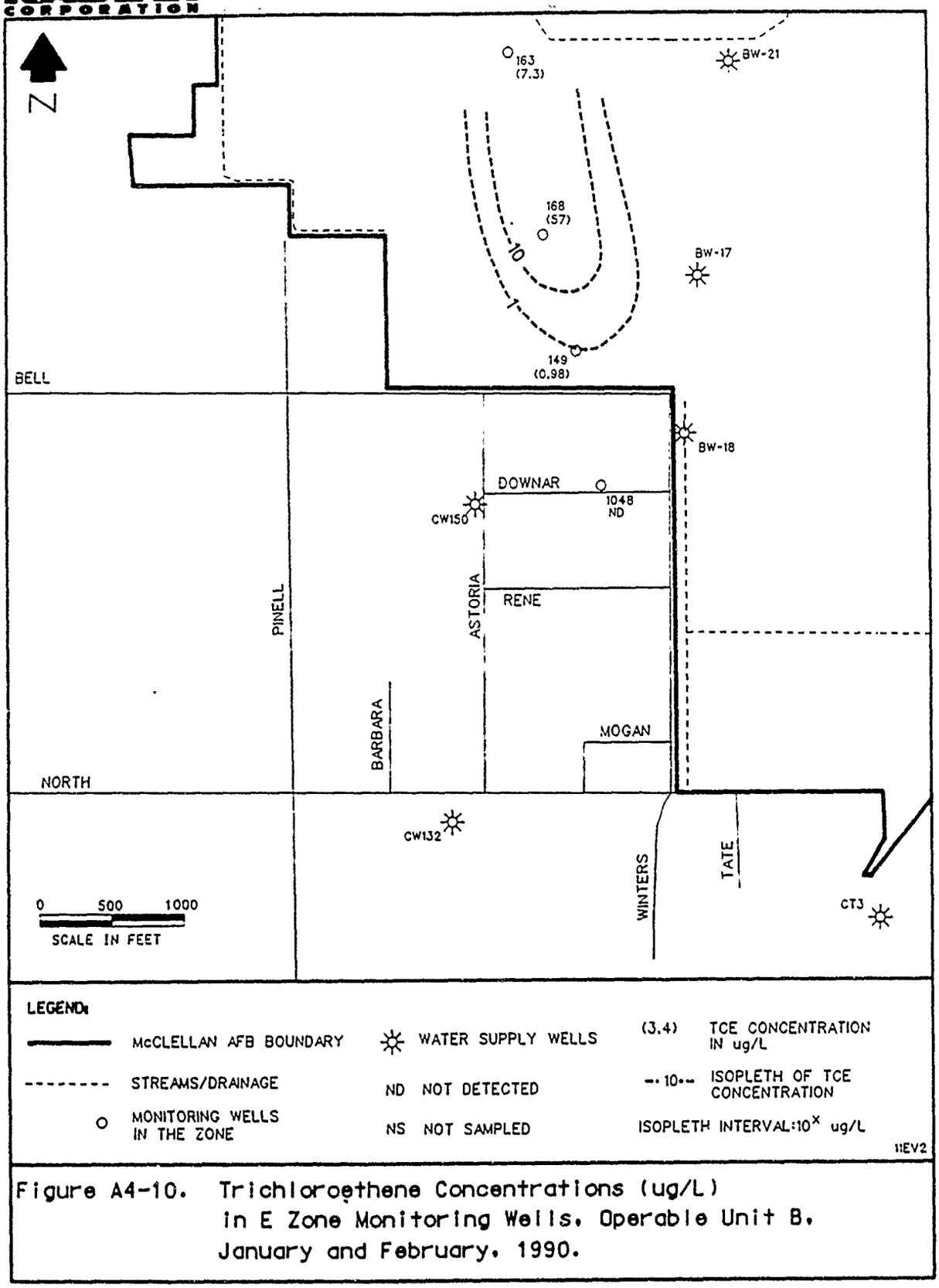


Figure A4-10. Trichloroethene Concentrations (ug/L) in E Zone Monitoring Wells, Operable Unit B, January and February, 1990.

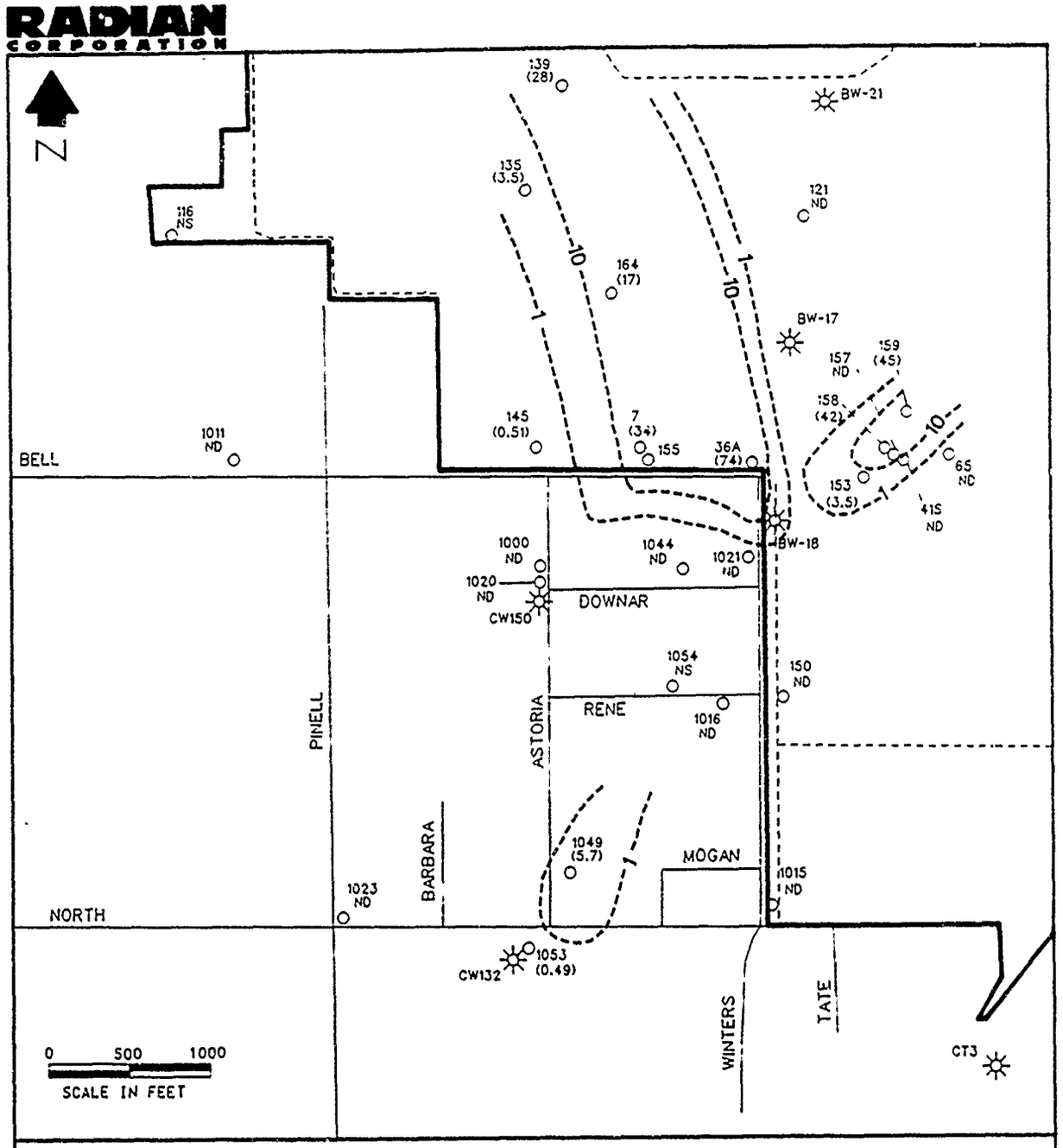


Figure A4-11. 1,2-Dichloroethene Concentrations (ug/L) in A Zone Monitoring Wells, Operable Unit B, January and February, 1990.

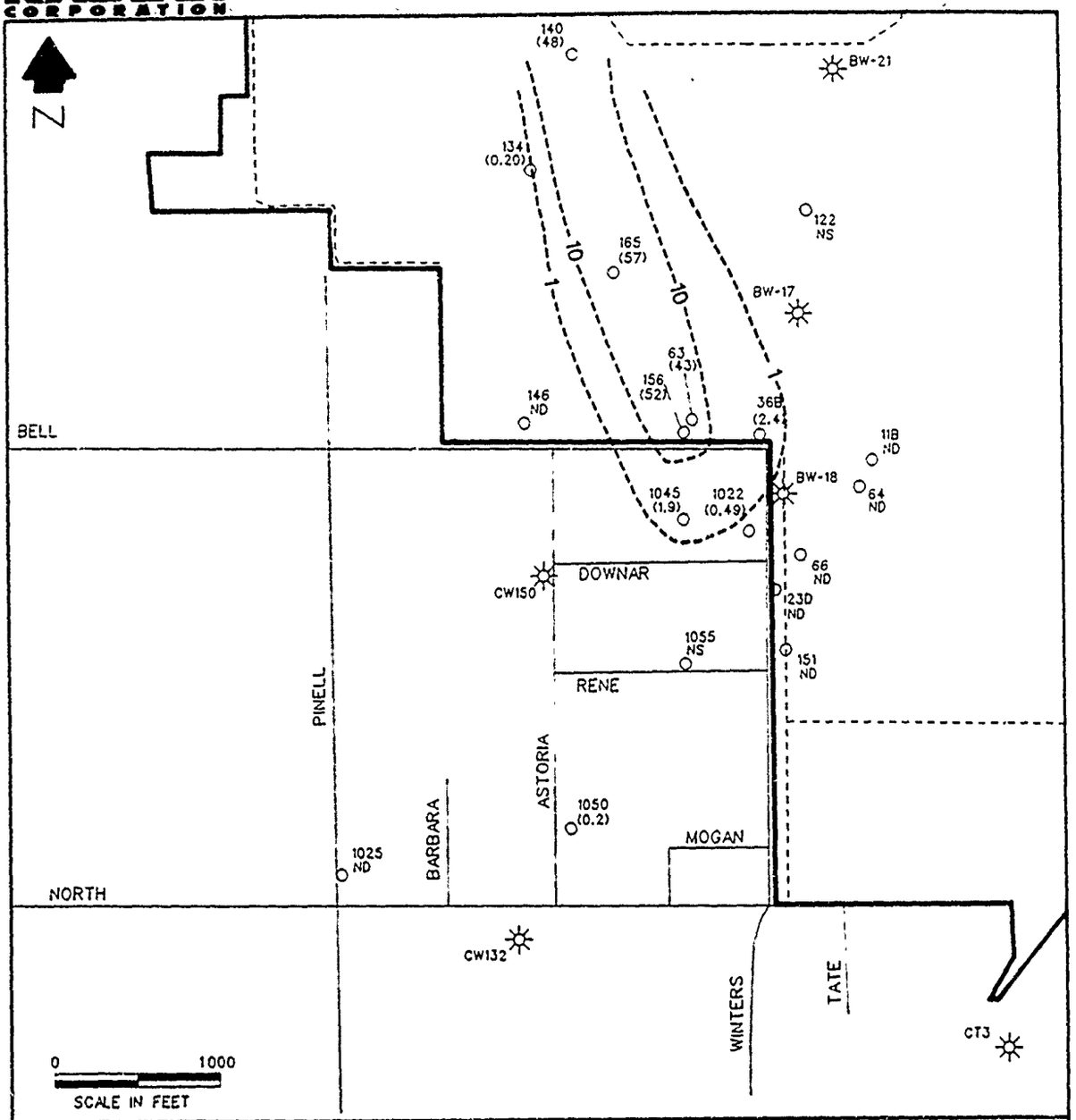


Figure A4-12. 1,2-Dichloroethene Concentrations (ug/L) in B Zone Monitoring Wells, Operable Unit B, January and February, 1990.

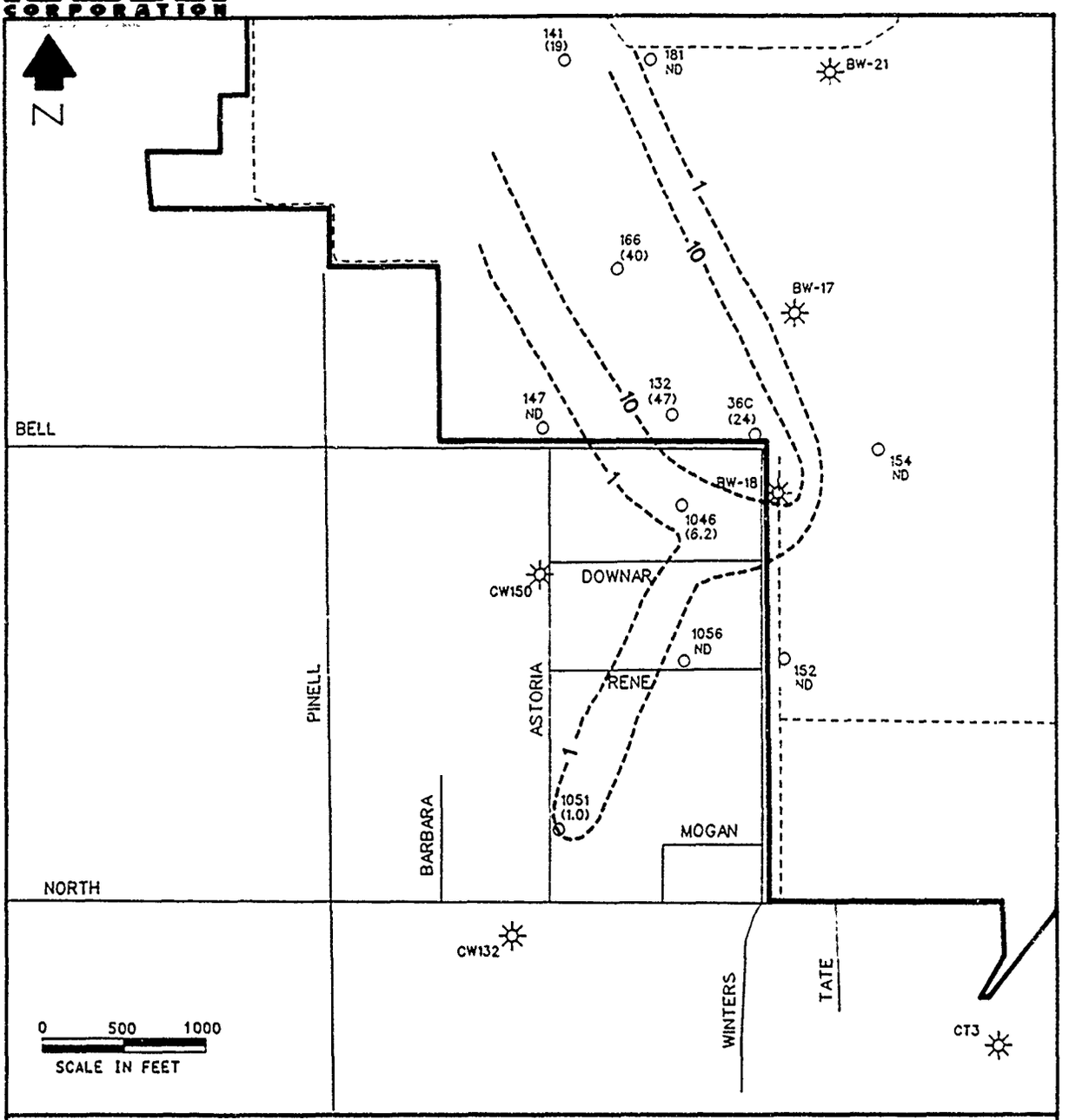


Figure A4-13. 1,2-Dichloroethene Concentrations (ug/L) in C Zone Monitoring Wells, Operable Unit B, January and February, 1990.

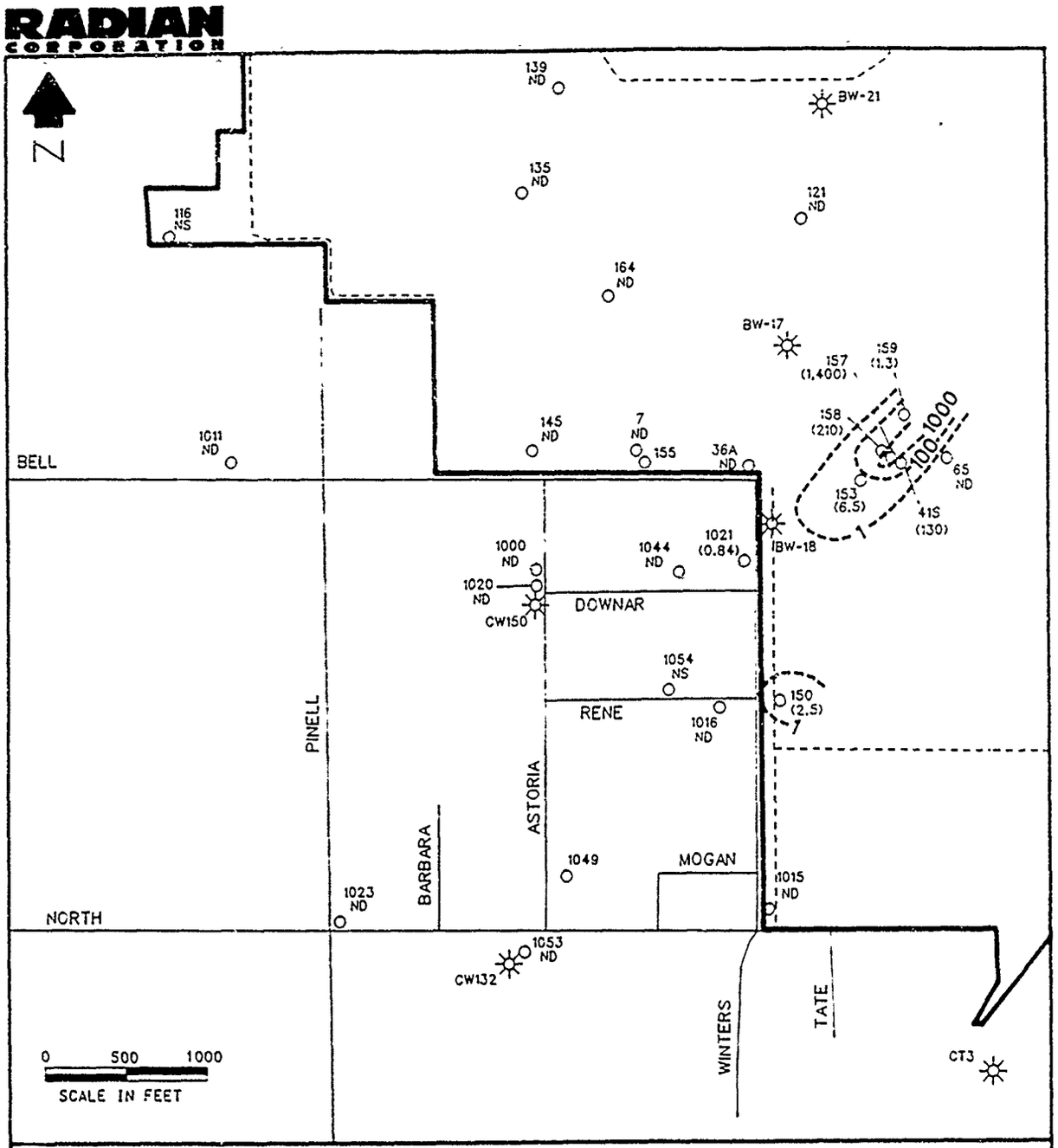
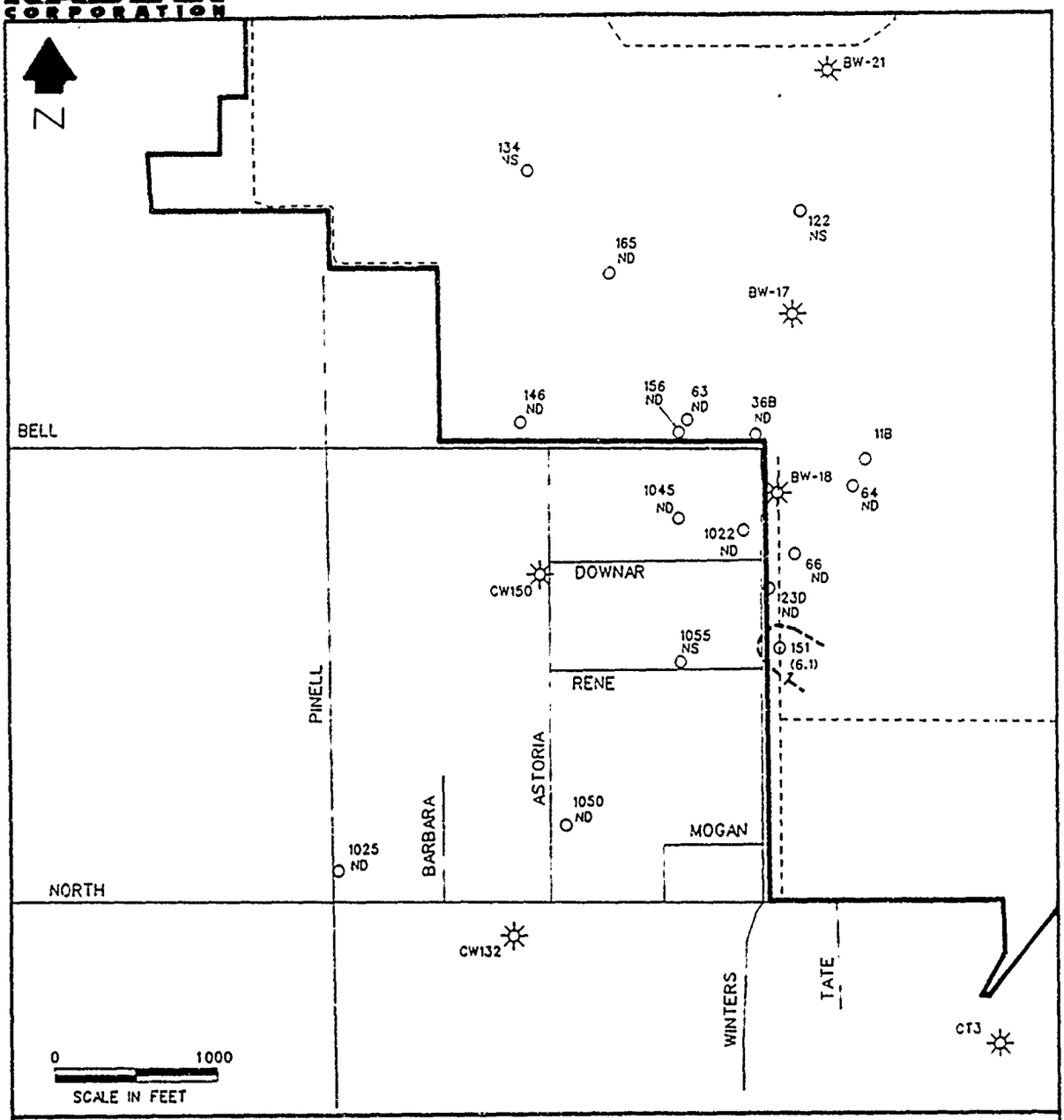


Figure A4-14. Tetrachloroethene Concentrations (ug/L) in A Zone Monitoring Wells, Operable Unit B, January and February, 1990.



LEGEND:

- McCLELLAN AFB BOUNDARY
- STREAMS/DRAINAGE
- MONITORING WELLS IN THE ZONE
- WATER SUPPLY WELLS
- ND NOT DETECTED
- NS NOT SAMPLED
- (3.4) PCE CONCENTRATION IN ug/L
- --1-- ISOPLETH OF PCE CONCENTRATION
- ISOPLETH INTERVAL:10^{X} ug/L

11BV6

Figure A4-15. Tetrachloroethene Concentrations (ug/L) in B Zone Monitoring Wells, Operable Unit B, January and February, 1990.

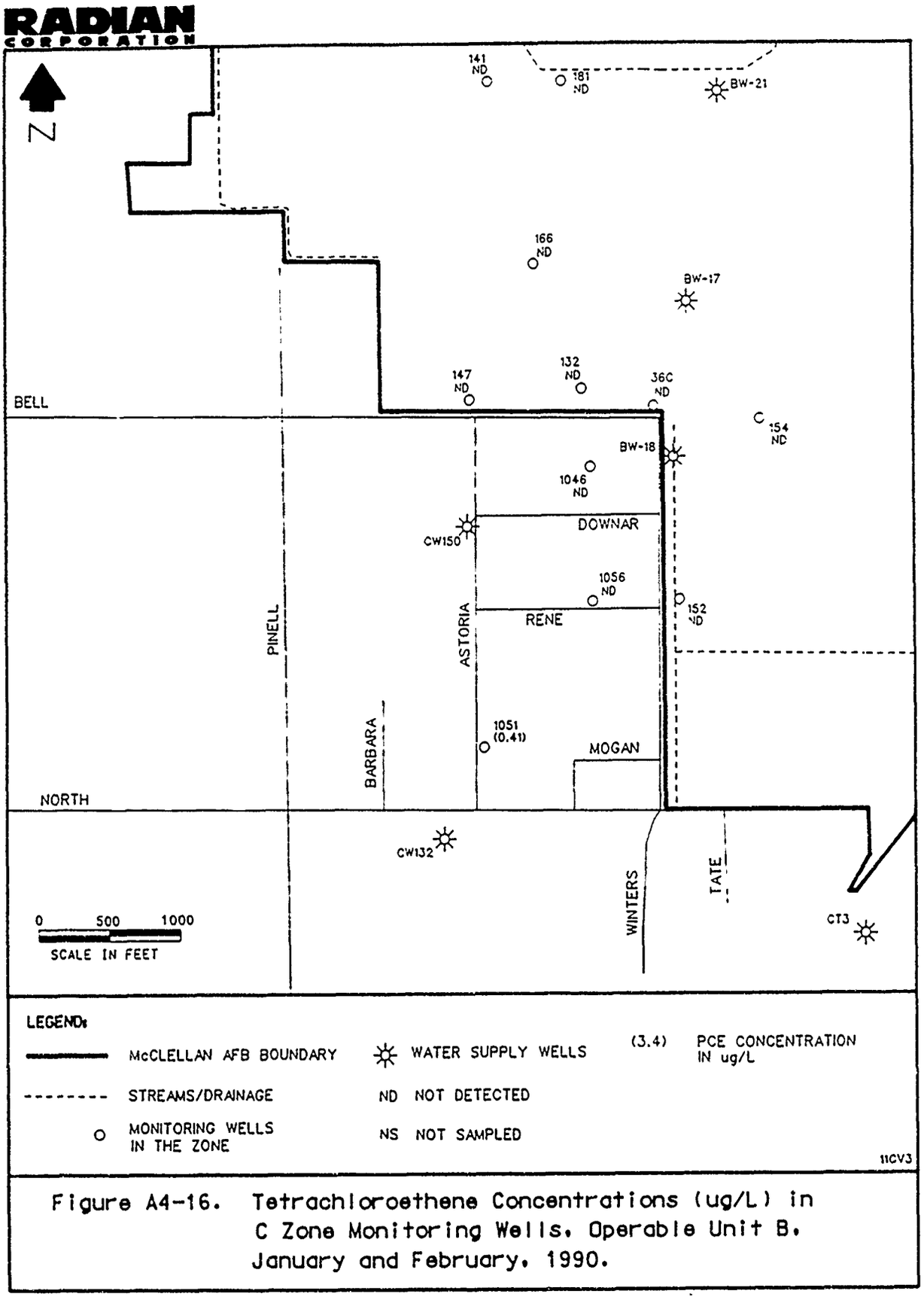


Figure A4-16. Tetrachloroethene Concentrations (ug/L) in C Zone Monitoring Wells, Operable Unit B, January and February, 1990.

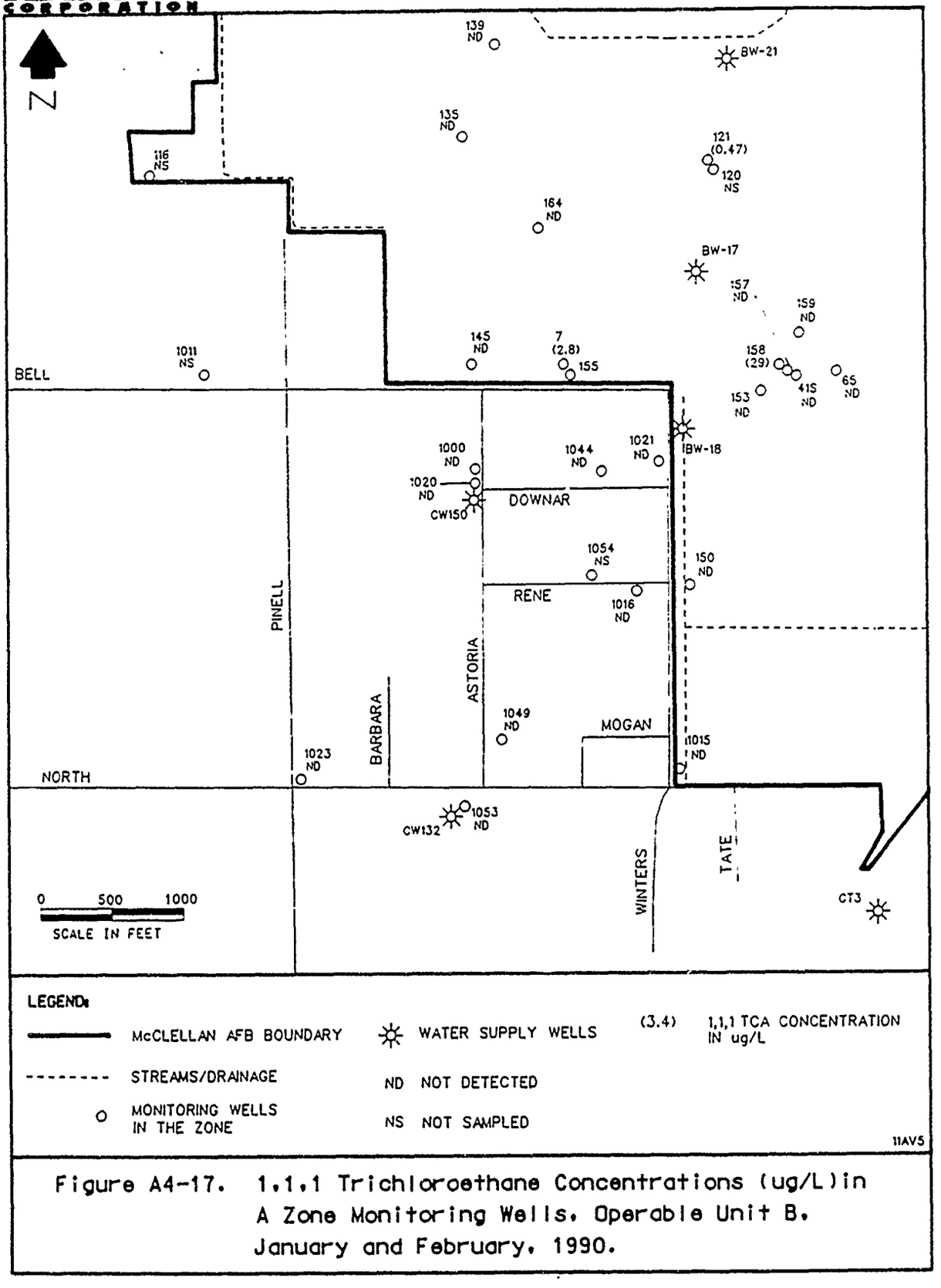


Figure A4-17. 1,1,1 Trichloroethane Concentrations (ug/L) in A Zone Monitoring Wells, Operable Unit B, January and February, 1990.

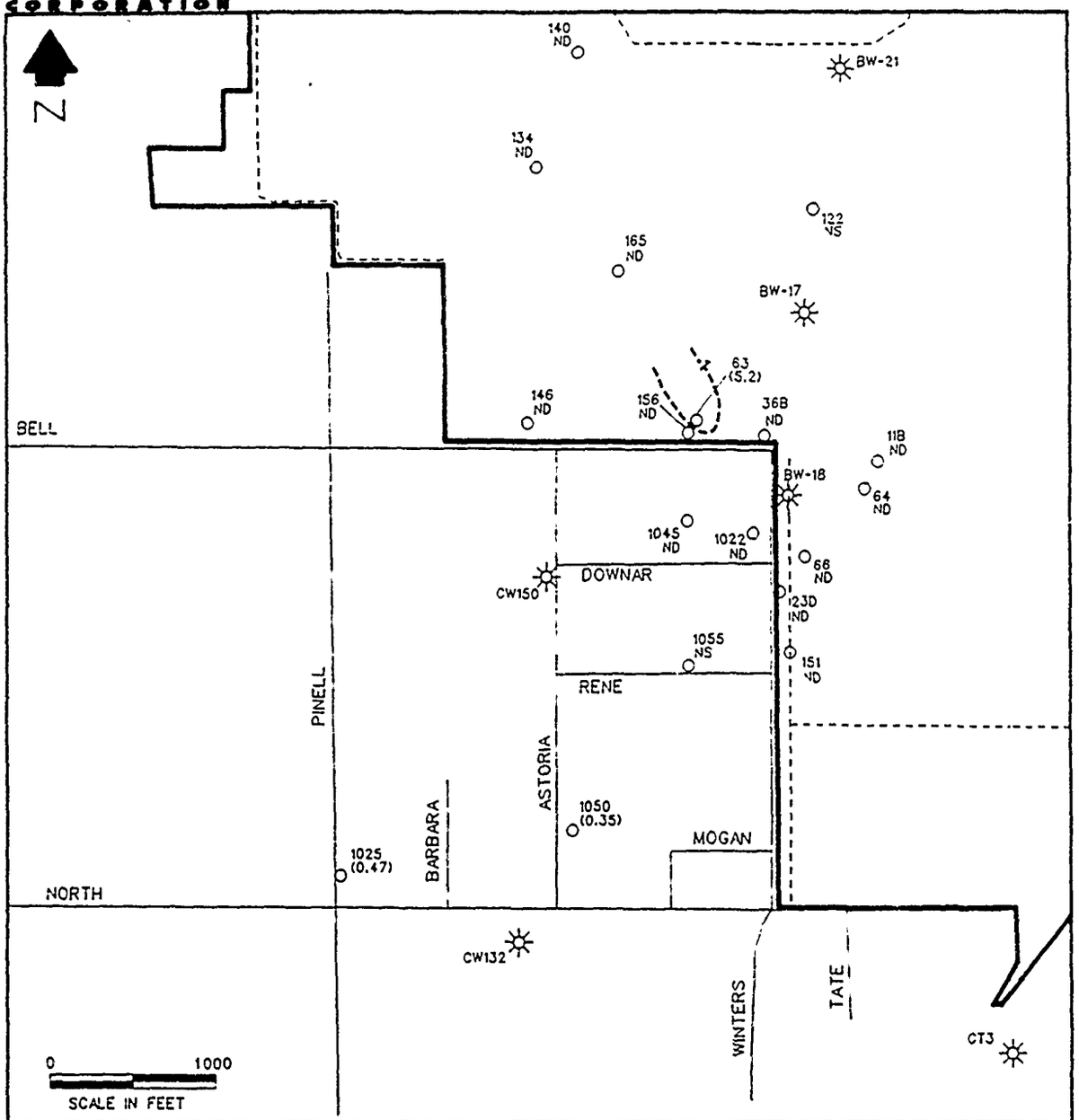


Figure A4-18. 1,1,1-Trichloroethane Concentrations (ug/L) in B Zone Monitoring Wells, Operable Unit B, January and February, 1990.

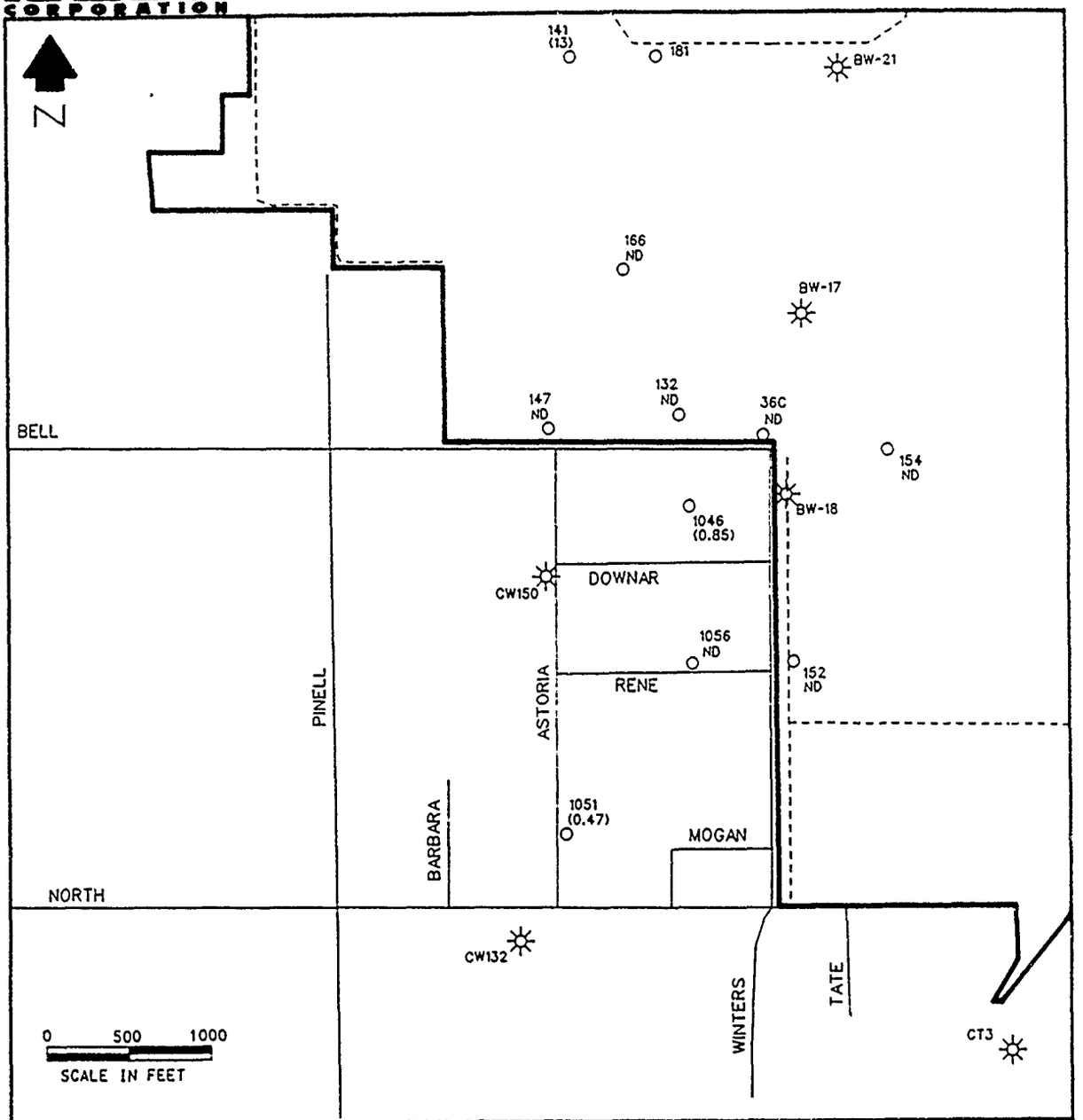


Figure A4-19. 1,1,1-Trichloroethane Concentrations (ug/L) in C Zone Monitoring Wells, Operable Unit B, January and February, 1990.

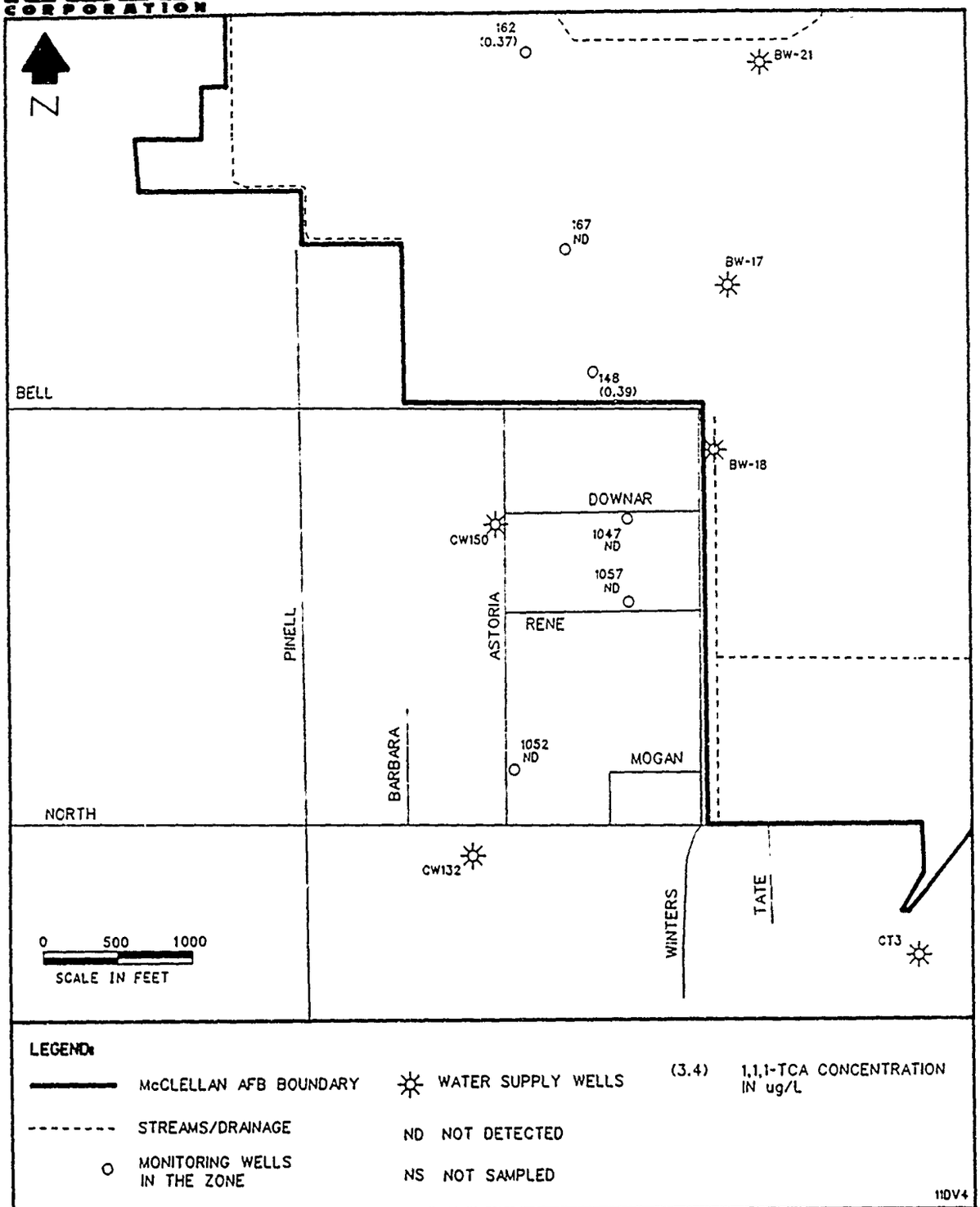


Figure A4-20. 1,1,1,-Trichloroethane Concentrations (ug/L) in D Zone Monitoring Wells, Operable Unit B, January and February, 1990.

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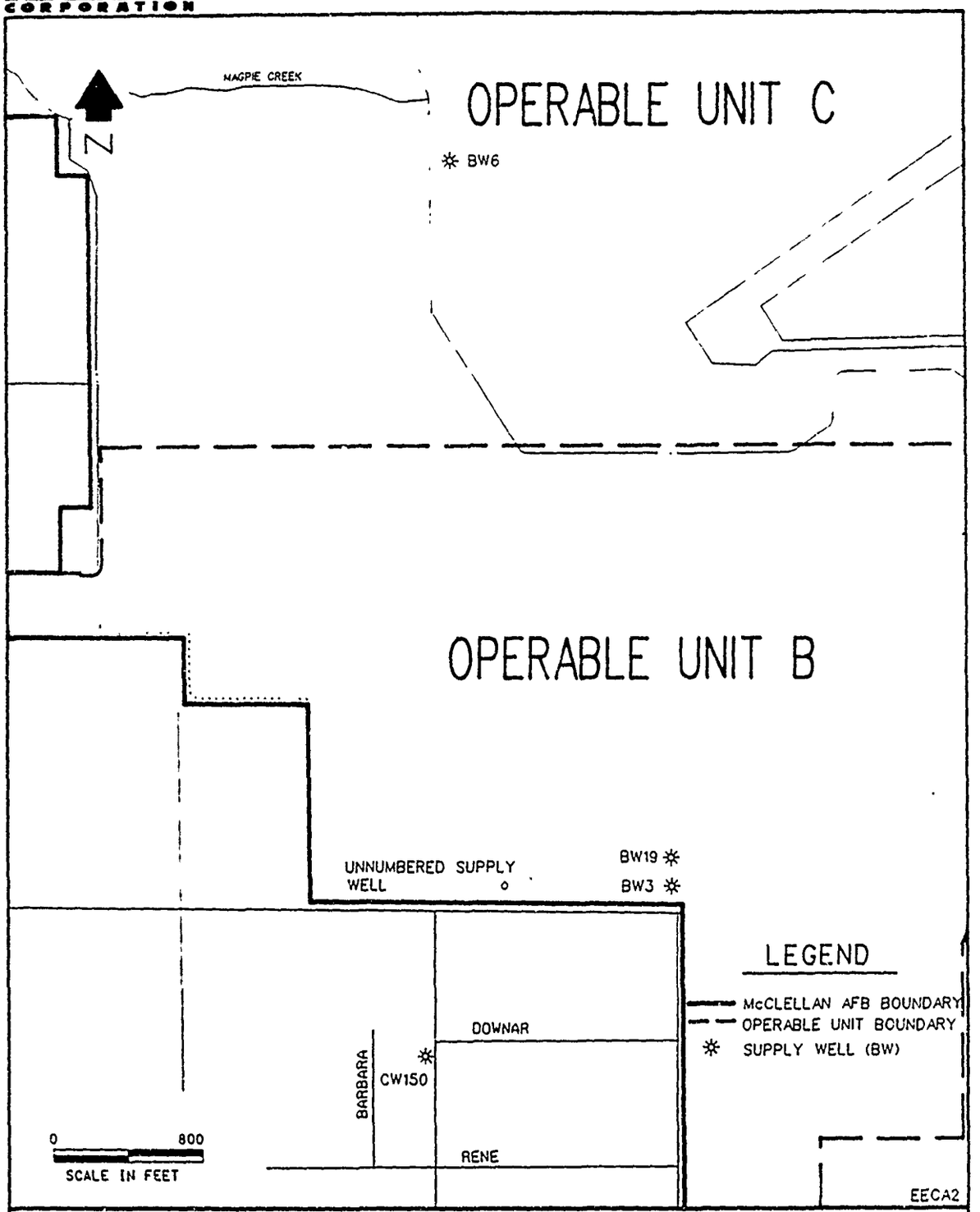

Figure A4-21. Location of Supply Wells to be Investigated for Abandonment.

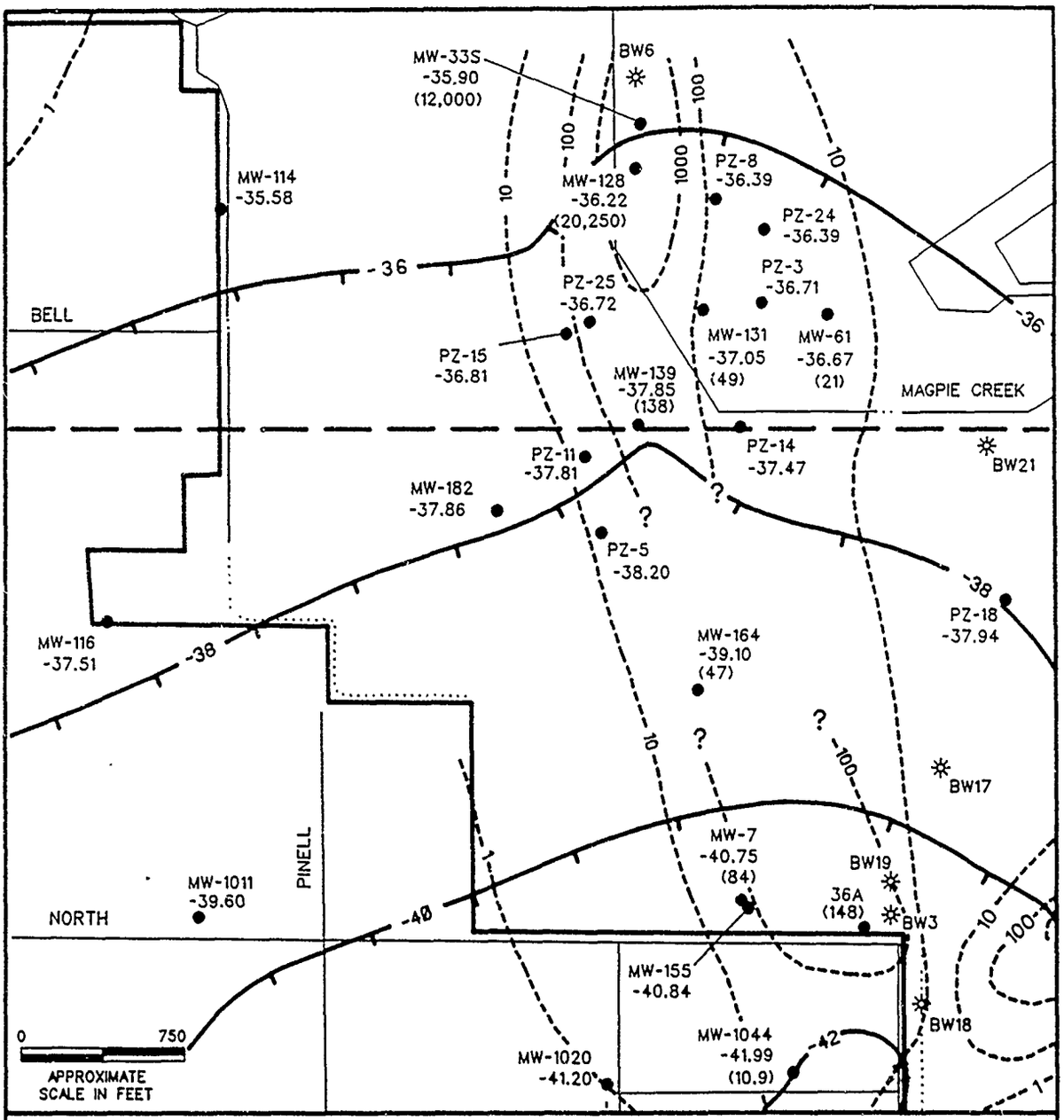

Figure A4-22. Potentiometric Surface and Total VOC Concentrations, A Geohydrolgic Zone, Operable Units B and C, April 1990.

A5.0 GROUNDWATER FLOW CHARACTERIZATION

To evaluate contaminant migration velocities, design effective extraction wells, or predict groundwater flow behavior under varying hydraulic conditions beneath Operable Unit (OU) B, equations representing the movement of groundwater through pores in subsurface deposits must be solved. The equations are mathematical expressions that include variables representing the hydraulic parameters of the deposits. With measured and reasonably estimated hydraulic parameters for the deposits through which groundwater is moving, the equations can be solved with a level of confidence in their results. The mathematical expressions of groundwater flow are differential equations that characterize changes in groundwater behavior with changes in gradient, time or distance traveled, and hydraulic parameters from point to point. The equations are solved to determine the direction, quantity, and velocity of flow when changes are introduced into the variables. The equations are commonly simplified to provide a solution by holding one or more variables, including hydraulic parameters, constant.

Solutions to the equations to characterize one location in one geohydrologic zone are the simplest and most commonly used with one set of measured or estimated variables. These simplified equations are valid for use in determining flow behavior in specific locations in OU B. However, the groundwater regime in five geohydrologic zones beneath OU B is large in volume and complex. To characterize flow through the groundwater regime, two mathematical models were used to predict groundwater flow behavior in the larger volume in which hydraulic parameters change with horizontal and vertical location and hydraulic behavior changes with time.

Aquifer tests, water-level measurements, and other hydrogeologic data compiled for OU B were evaluated to estimate hydraulic parameters. The estimation of the hydraulic parameters is described in Section A5.1 An analytical flow model used in Baseline Risk Assessment is described in Attachment A to Appendix B. A numerical flow model used to characterize flow under a variety of hydraulic conditions is described in Section A5.2.

A5.1 Hydraulic Parameter Estimation

The deposits beneath OU B vary in hydraulic parameters both horizontally and vertically because they vary in the size and distribution of pore spaces. Deposits within the geohydrologic zones are nonhomogeneous and parameters (permeability,

storage coefficient, hydraulic potential) that determine the hydraulic behavior of water vary horizontally and vertically. To solve the flow equations and characterize groundwater flow in the groundwater volume of interest (approximately 8.4 billion gallons of water in 1.1 billion cubic feet of pore space) in the A through D zones of OU B, estimates of hydraulic parameters are needed at a number of locations and depths. Parameters in the E and F zones were not characterized because contaminants in the E zone occur in relatively low concentrations in a limited area and no contaminants have been detected in the F zone. Because time and logistical constraints did not allow for extensive subsurface testing to be conducted in the large nonhomogeneous groundwater volume, certain key zones and locations were selected as indicators. The locations and zones selected for testing are widely-spaced within three of the identified contaminant plumes. The subsurface tests consisted of aquifer testing in monitoring wells constructed in the trichloroethene-tetrachloroethene (TCE/PCE) plume, northern TCE-1,2-dichloroethene (1,2-DCE) plume, and southern TCE/1,2-DCE plume (Figure A2-7 and A2-8). The locations and zones tested were selected for one or more of the following reasons:

- The parameter of permeability or hydraulic conductivity in a zone or zones at the location had not previously been measured;
- Groundwater in the location or zone contains contaminant concentrations;
- The location or zone is upgradient from a supply well; and
- Results may indicate that the location or zone requires a removal action.

In addition to the aquifer tests performed during the Operable Unit B Groundwater Remedial Investigation (OUBGRI), tests were performed in OU B during previous investigations (McLaren, 1986a; Radian, 1987; EG&G Idaho, 1988). Parameters obtained from the previous testing were also used in determining flow characteristics.

Aquifer testing is performed by pumping groundwater from a well to exert a hydraulic potential change at the well. The hydraulic response measured as drawdown over a period of time in the pumped well and nearby wells is used to determine variables in well performance equations. The well performance equations are solved for

the hydraulic parameters, transmissivity, and storage coefficient. The shape of the curve of drawdown measurements plotted at successively greater pumping times indicates whether the zone being pumped is confined, unconfined, or semiconfined (confined with leakage through the confining layer).

In an evaluation of hydraulic response data from the aquifer tests performed, the following additional factors were considered:

- Published well response equations used in data analysis were developed from aquifer tests performed on large capacity wells with screened intervals that extend 100 feet or more through thick and areally extensive sand deposits, whereas monitoring wells available for testing in OU B are screened over 10-foot intervals in sands that are limited in areal extent;

- Geohydrologic zones defined beneath OU B (Section A3.1) are 40 to 70 feet thick, and the hydraulic parameters determined in aquifer test wells may not represent the full thickness of the zone; and

- Groundwater containing contaminants migrates through fine-grained, low permeability deposits as well as coarser sands in each geohydrologic zone.

Including these factors in the evaluation of hydraulic parameters from the aquifer tests required an interpretation of the effects that all of the deposits in a zone had on the hydraulic parameters obtained in the aquifer testing. In developing hydraulic parameters for zones in specific areas, for example, near aquifer test sites, local hydrogeologic relationships determined from drill hole logs were used. To develop hydraulic parameters in the modeling of groundwater flow beneath all of OU B, hydraulic parameters estimated for geohydrologic zones at the specific aquifer test sites were extended to adjoining areas through the interpretation of hydrogeologic relationships between the sites. Therefore, the hydraulic parameters applied to zones on the small scale of one site or the larger scale of all of OU B are based not only on aquifer test values, but on local and areal hydrogeologic data.

A5.1.1 Area-Specific Parameters

The results of hydraulic parameter estimation methods applied to specific aquifer test areas are described in the following summary. For each area tested, a single value or range of values of hydraulic conductivity were determined from the transmissivity of the test interval. The test interval is the thickness of deposits in or beyond the screen interval of the monitoring well that is likely to have affected the test results. The hydraulic conductivity value and the character of the test interval were evaluated relative to the full saturated thickness of the geohydrologic zone. The sum of all estimated hydraulic conductivities multiplied by the thickness of the deposit to which it applies is the transmissivity value for the zone. These transmissivity estimates include low permeability deposits that occur within the test interval and the zone. Test intervals, average hydraulic conductivity values for the test interval, saturated thickness of the geohydrologic zone, estimated transmissivities for the zone, and storage coefficients for specific areas in OU B are listed in Table A5-1 on page A5-62. In zones where no tests were performed, transmissivities were estimated for zones for use in flow model calculations.

TCE/PCE Plume. Two 24-hour aquifer tests were performed in the A geohydrologic zone in this plume. One test was performed in monitoring well (MW) 157; MW-158, the nearest A zone well, was the observation well. The second test was performed in MW-158, with MW-157 as the observation well. Transmissivity values obtained for MW-157 ranged from 67 to 214 ft^2/day. The well has a 20-foot screened interval, but the saturated zone from which groundwater could flow was only 13.4 feet thick at the beginning of the test. There are 8 feet of sand and 5.4 feet of silty clay in the deposits adjacent to the screen in the well. Much of the water withdrawn from the well during the test was derived from the more permeable sand. It is unlikely that any sands below the clay affected the pumping test results. However, the transmissivity range determined from the test data is attributed to a test interval of 13.4 feet. The test interval is estimated to be 13.4 feet because the clay deposit occurs at the bottom of the screen interval. It is unlikely that any sands below the clay affected the pumping test results. The range of hydraulic conductivities for the sand is the transmissivity range (67 to 214 ft^2/day) divided by 13.4 feet of saturated interval results in a hydraulic conductivity range of 5 to 16 ft/day.

The same approach may be applied to the results of the aquifer test at MW-158. The transmissivity value range for the test was 91 to 155 ft^2/day. The saturated zone was 8.5 feet in the screen interval of the well. Two feet of sand occur at

the bottom of the well screen. The full thickness of sand that may have influenced the aquifer test was not determined. However, in this area and at this depth, sands in the A zone are approximately 5 feet thick. The test interval is estimated to be 11.5 feet. Therefore, the hydraulic conductivity range of the test interval in MW-158 is 8 to 11 ft/day. A hydraulic conductivity range of 10 to 20 ft/day is appropriate for the test interval in the A zone in the area of the TCE/PCE plume in which contaminant concentrations are greatest.

In the downgradient direction, approximately 100 feet from the aquifer test wells, coarser sands with greater estimated permeabilities were found in the A zone. No aquifer testing was conducted in the downgradient area; however, grain size distribution indicated hydraulic conductivities of 235 to 1440 ft^2/day in thin deposits. In a 20-foot thickness in the A zone, a mean hydraulic conductivity of 100 ft/day was estimated.

Hydraulic conductivities are quite variable in the A zone beneath this area; therefore, a transmissivity range of 100 to 300 ft^2/day is estimated for the entire zone. Aquifer tests were not performed in the B, C, or D zones in the TCE/PCE plume. On the basis of grain size in the two zones, transmissivities were estimated at 200 to 400 ft^2/day in the B zone, 600 to 1000 ft^2/day in the C zone, and 2000 to 4000 ft^2/day in the D zone. Storage coefficient values for the B, C, and D zones were estimated from values measured in other testing in OU B. Estimated values of hydraulic conductivity and transmissivity for each zone are listed in Table A5-1.

Northern TCE/1,2-DCE Plume. The area of principal interest in this plume is near the east-west McClellan Air Force Base (AFB) boundary in the central part of OU B (Figure A5-1 on page A5-25). Aquifer testing was conducted in wells constructed in the A, B, C, and D zones in the east-west boundary area.

Testing in the A geohydrologic zone was conducted in MW-155 which has 10 feet of screen in the zone. There are 6 feet of sand and 4 feet of clay adjacent to the screened interval. The sand is overlain and underlain by clays. Therefore, the test interval during testing was estimated to be 10 feet. The range of transmissivity values obtained from aquifer test analyses is 316 to 575 ft^2/day is considered more representative of the saturated interval. The estimated range of hydraulic conductivity is 30 to 55 ft/day over the 10-foot screen interval. A storage coefficient of 0.01 is assigned to the zone based on aquifer test analyses.

The B geohydrologic zone was tested twice in this area. The first testing (McLaren, 1986b) was conducted over a 4-hour period in MW-63, which is screened over 15 feet in the B zone. Single-well test analysis resulted in a transmissivity range of 174 to 214 ft^2/day and a hydraulic conductivity range of 12 to 14 ft/day. During the OUBGRI, aquifer tests were conducted in MW-156, a new monitoring well 43 feet from MW-63 and screened over 10 feet. Deposits adjacent to the screen interval in MW-156 contain 6.5 feet of sand in the upper part and 3.5 feet of clayey silt at the bottom of the screen. The test interval is estimated at 10 feet. The older well, MW-63, and a piezometer, PZ-2, were used as observation wells for these tests. Analysis of the results from MW-63 indicate a transmissivity of 440 ft^2/day and an average conductivity of 44 ft/day for the deposits in the screen interval.

One C zone monitoring well, MW-132, was available for aquifer testing in the northern TCE/1,2-DCE plume during the OUBGRI. Very fine to coarse-grained sand deposits lie adjacent to the entire screened interval in the well. Lithologic logs from the area indicate that a 20-foot thick sand is present at this approximate depth in the C zone. The test interval is estimated at 20 feet. Single-well analysis of the drawdown data from the test indicated a transmissivity range of 940 to 1260 ft^2/day. The transmissivity range from the test analysis divided by the estimated 20-foot test interval yields a range in hydraulic conductivity of 47 to 63 feet/day for the sands in the C zone test interval. This range represents minimum hydraulic conductivities for the sand in the test interval because leakage from other deposits, above and below the test interval, occurred in a short time interval after pumping began. An indication of leakage from other deposits was identified from drawdowns recorded at less that 1 minute in the B zone and less than 10 minutes in the D zone that continued to increase during pumping in the C zone well. Because the C zone well only partially penetrates the C zone, there were no observation wells available in the C zone, and the full test interval was not determined, drawdown data from the B and D zone wells were analyzed in an attempt to verify transmissivity. The resultant transmissivity values were 4150 ft^2/day and 5160 ft^2/day, from the B zone and D zone wells, respectively. The transmissivities from the B and D zone well analyses are considered more representative of the entire C zone than the transmissivity from the single well test.

The aquifer test in the D zone was conducted in MW-148. There were no other D zone wells to be used as observation wells. The C zone well, MW-132, and the E zone well, MW-149, were monitored during the test. However, the C zone data were not useable possibly due to a defective transducer. There are 7.5 feet of sand and 2.5

feet of clayey silt adjacent to the screen interval in MW-148. The test interval was larger than the 10 feet of screen interval because there was a hydraulic response detected in the E zone well with a screen interval 60 feet deeper than the D zone well. Any response in the C zone was not recorded.

The transmissivity determined from a single-well aquifer test analysis was 280 ft^2/day. This is considered a minimum value for the zone because there was a silt deposit in the screen interval and there are approximately 30 feet of silty, fine to gravelly sand in the zone, either above or below the screen interval. Analysis of the drawdown recovery data from MW-149 was performed. Because the well is screened in a deeper zone, it represents hydraulic response resulting from the pumping in the D zone over a larger part of the zone. The transmissivity value determined from the recovery of the E zone well is 2370 ft^2/day. The value is considered more representative of deposits in the lower D and upper E zones than the single well analysis value. A transmissivity range of 2300 to 3200 ft^2/day is estimated for the D zone on the basis of the result from the aquifer test analysis and the greater thickness of fine to coarse sand deposits (40 feet) than silt or clay (24 feet). A storage coefficient of 0.0001 is estimated for this zone.

Southern TCE/1,2-DCE Plume. Aquifer testing to determine parameters in the southern TCE/1,2-DCE plume was focused on the A and B geohydrologic zones in the southernmost part of the plume. The parameters in this area are of interest because of the potential for migration of contaminant concentrations to the southwest or to the northeast in the A and B zones.

Monitoring Wells 1049 (A zone) and 1050 (B zone) (Figure A5-1) were the wells pumped during the testing. For the testing, a piezometer in the A zone, PZ-1000, and a piezometer in the B zone, PZ-1001, were constructed and monitored for drawdown.

The A zone aquifer test well, MW-1049, has a 10-foot screen interval with 10 feet of very fine to coarse-grained sand adjacent to the entire screen interval. A sandy silt deposit is present just below the screen interval. Prior to the test, the water level was approximately 25 feet above the bottom of the screen. The test interval was estimated to be 30 feet and includes very fine to coarse-grained sands and sandy to clayey silts. Analysis of the drawdown curve indicated that the A geohydrologic zone is a semi-confined aquifer in this area. Drawdown curves matched most closely to type

curves (Walton, 1962) for a leaky confined aquifer, having no water storage in the confining layer. The transmissivity calculated from curve matching is 540 ft^2/day. Analysis of recovery data from the A zone observation well yielded transmissivities of 690 to 1170 ft^2/day. There was a hydraulic response in the B zone piezometer after 4 minutes of pumping; however, the data did not match a type curve and were not analyzed. The average conductivity over the test interval is estimated to be 18 to 39 feet/day based on a transmissivity range of 540 to 1170 ft^2/day for the A zone.

The aquifer test in the B zone was conducted in MW-1050 which has 10 feet of fine to coarse-grained silty sand in the screen interval. The test interval was estimated to be 25 feet. Analysis of drawdown data from the B zone piezometer resulted in a transmissivity of 390 ft^2/day and a storage coefficient of 0.0011. A hydraulic response was evident in the A zone after 4 minutes of pumping. However, the A zone data did not fit a curve and were not analyzed. The average hydraulic conductivity over the test interval is 16 feet/day. This relatively low value probably results from the silt deposits that separate sands in the test interval and much of the B zone in the area. The estimated transmissivity range for the B zone is 700 to 800 ft^2/day.

Aquifer tests were not conducted in the C or D zones in the area of the A and B zone testing because the southern TCE/1,2-DCE plume is not detectable in the C and D zones beneath the area. Transmissivity ranges of 3,000 to 5,000 ft^2/day and 4,000 to 6,000 ft^2/day were estimated for the C and D zones, respectively, on the bases of deposit types and thickness in the zones.

Another aquifer test was conducted in the southern TCE/1,2-DCE plume approximately 2,000 feet northeast of the MW-1049 and MW-1050. The B zone monitoring well located 275 feet southwest of Base Well (BW) 18 was tested to determine aquifer parameters in another location within the southern TCE/1,2,-DCE plume. An A zone well, MW-1021, was also planned for testing, but there were only four feet of groundwater in the well screen, too little to be tested. The test in MW-1022 was conducted while BW-18 was operating. Therefore, drawdown detected in the well was a composite drawdown caused by the operation of BW-18 and the test well. A fine to medium-grained sand deposit with some silt occurs adjacent to the entire screen interval in MW-1022 and extends 2.6 feet below the screen. An 11-foot thick clay lies five feet above the sand. Therefore, the test interval was estimated to be 17 to 20 feet thick for the test at MW-1022. There were no B zone observation wells. However, MW-1021 in the A zone was monitored for drawdown.

A transmissivity value of 85 ft^2/day was determined from single-well curve matching with drawdown data from the pumped well. This value is considered very low and not representative of sands that occur in the 17-20 foot test interval. However, BW-18 was operating at a relatively short radial distance (275 feet) from MW-1022. It is probable that the drawdown achieved during the aquifer test and the resulting transmissivity are residual parameters that are an addition to the hydraulic response to BW-18 withdrawal in the B zone. The full drawdown and transmissivity of the B zone were not determined during the test because of its proximity to the well that was causing a greater hydraulic response. A transmissivity of 200 to 500 ft^2/day is estimated from the thickness and nature of deposits in the B zone at MW-1022.

Single-well aquifer tests were conducted prior to the OUBGRI (McLaren, 1986b) in B zone well MW-66. The well is located 250 feet south of BW-18 and has a 20-foot screen interval. The tests were conducted for 4 and 24 hours when BW-18 was not in operation. Transmissivities determined from the tests were 160 to 267 ft^2/day. The values are presented for comparison with other values for the B zone.

Northern OU B. Aquifer tests were conducted in the northern portion of OU B at MWs 126 and 127 (Figure A5-1) located outside of or within the east boundary of the northern TCE/1,2-DCE plume (Radian, 1987). The data obtained from the tests were used to estimate hydraulic parameters for zones at a distance of 1,600 feet from the OUBGRI tests. The tests were lengthy (55 to 71 hours), well monitored with observation wells, and carefully analyzed (Radian, 1987). From the test analysis, the mean transmissivity for the B zone was calculated at 1070 ft^2/day over a saturated thickness of 30 feet. The mean transmissivity determined for the C zone was 1600 ft^2/day over a thickness of 31 feet. The resulting hydraulic conductivities were 36 and 52 feet/day for the B and C zones, respectively.

In comparison to estimates from OUBGRI aquifer tests and other estimates, the transmissivities determined in the northern part of OU B are greater for the B zone and lower for the C zone. The data from the northern OU B tests were used in groundwater flow modeling in the zones beneath that portion of OU B.

A5.2 Numerical Groundwater Flow Modeling

The purpose of groundwater modeling in OU B at McClellan AFB was to predict the hydraulic response of the geohydrologic zones to extraction well and supply

well pumping. The complex nature of the geologic deposits, the existing and proposed pumping wells, and the layered hydrogeologic units separated by confining layers required the use of a three-dimensional numerical model. The McDonald-Harbaugh modular, three-dimensional, finite difference, groundwater flow model, also known as MODFLOW, was chosen for use at the site because of its applicability to OU B, widespread acceptance, and ease of use.

The purpose of using a numerical groundwater flow model in OU B was to mathematically characterize the behavior of the groundwater flow regime under a variety of hydrologic conditions. When the groundwater flow regime beneath an area has been characterized mathematically, the model can be used to simulate the behavior of the flow regime under hydraulic conditions that are of interest but which cannot be measured because they do not exist. A model that accurately simulates the behavior of one or more geohydrologic zones beneath an area, such as OU B, can be used to predict the behavior of the zones under conditions that are desired, for example, extraction well or supply well pumping, or that would take a long time period to demonstrate with water-level measurements. Therefore, a model allows hypothetical hydraulic conditions to be tried without installing wells and changing existing conditions.

A5.2.1 Objectives of the Modeling Effort

There were several objectives for the application of a three-dimensional groundwater flow model to the study of OU B. The primary objective of modeling was to characterize groundwater flow for optimum placement of extraction wells to control contaminant migration. Although analytical models were used to predict capture zone boundaries, those models are dependent upon hydrologic variations outside of the capture zone. Three-dimensional numerical modeling was used to examine the response of the aquifer to the hydraulic impacts from large capacity well pumping. The model was first calibrated to the hydrogeologic environment beneath OU B without the influence of pumping wells; then, the model was refined to simulate the response of the geohydrologic zones during pumping. Before hypothetical conditions were attempted, the model was calibrated to both non-pumping and pumping hydraulic conditions caused by BW-18 for which actual field measurements were available. After calibration (described below), the hydraulic effects of extraction wells were simulated to evaluate the response of the zones to the pumping of these wells.

Simulation with numerical models becomes increasingly accurate with the density of hydraulic measurement data for the model area. For example, the relatively dense group of monitoring wells located in OU B near BW-18 and along the McClellan AFB boundaries provided a number of measurements for hydraulic conditions in this area. However, the model of OU B required that necessary boundaries be established well beyond the area of influence of major pumping wells such as BW-18. Because areas outside of OU B were not specifically investigated, hydraulic parameters and measurements were extrapolated to the larger area. The complex hydrogeology of OU B that resulted from the erosion and depositional process of streams resulted in nonhomogeneous deposits that are difficult to delineate even with many more borings and wells. The modeling effort indicated some areas and depths in OU B where additional hydraulic information is needed to improve the model. These areas and depths may warrant further investigation. The model will be applied in the OU B Remedial Investigation. The model should be updated with additional data collection and input to improve the accuracy of predictions in that investigation.

A5.2.2 Description of the Model

The model is a modular, three-dimensional, groundwater flow model (MODFLOW) developed by Michael G. McDonald and Arlen W. Harbaugh from the basic concepts described in the models by Trescott (1975), Trescott and Larson (1976), and Trescott, Pinder, and Larson (1976). The MODFLOW uses a modular structure to allow flexibility in the program, and is set up as a basic program which calls user specified "packages." The major options available include the simulation of the effects of wells, recharge, rivers, drains, evapotranspiration, and "general-head boundaries." The user is also able to choose between two iteration techniques.

The model uses the following partial-differential equation for the three-dimensional movement of groundwater of constant density through porous deposits:

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right) - W = S_s\frac{\partial h}{\partial t}$$

where:

K_{xx}, K_{yy}, and K_{zz} are values of hydraulic conductivity along the x, y, and z coordinate axes, which are assumed to be parallel to the major axes of the model (units are feet/day);

h is the potentiometric head (feet);

W is a volumetric flux per unit volume and represents sources and/or sinks of water (per day);

S_s is the specific storage of the porous material (per foot); and

t is time.

This equation describes groundwater flow under non-equilibrium conditions in a heterogeneous and anisotropic medium, as exists in the subsurface of OU B, provided the principal axes of hydraulic conductivity are aligned with the coordinate directions. The equation is solved for each unit of volume or "cell" in layers in the model.

The model requires specification of either flow and/or head conditions at the boundaries of the aquifer system and initial head conditions. With those conditions specified, the mathematical representation of the groundwater flow system is complete. The solution of the equation for each cell in the model by analytical means would only be possible with a very simple system. Therefore, the MODFLOW program employs numerical methods to obtain approximate solutions. The MODFLOW uses a finite-difference method, in which the groundwater flow system is replaced by a set of discrete points in space and time, and the partial derivatives in the equation are replaced by terms calculated from the differences in head at these discrete points. This leads to a system of linear equations whose solutions provide head values at specified points in space and time.

The MODFLOW requires that a modeled aquifer system be subdivided into discrete user-specified rows, columns, and layers. The aquifer system is then represented by an array defined by a row, column, and layer positions of cells. All input specified to the model is based on block-centered formulation.

The basic structure used by MODFLOW to define the groundwater flow system allows the user to select the specific modules, or "packages", that apply to the system. This modular approach allows similar program functions to be grouped

together, as well as specific hydrologic options. This allows the user to add different options (i.e., wells, recharge, evapotranspiration, etc.) without changing existing subroutines.

Model Assumptions

The following assumptions were made in applying the MODFLOW model in OU B:

- The subsurface deposits from 95 to 400 feet BGS beneath OU B are an inhomogeneous and anisotropic porous medium for groundwater flow;
- Inhomogenity exists in the horizontal and vertical directions;
- Layering in the deposits results in greater anisotropy in the vertical direction than in the horizontal direction, and conditions approaching isotropy exist for parameters in the horizontal x and y directions;
- Groundwater enters the modeled area from the x and y directions in layers, and there is no significant source of recharge within the modeled area;
- Groundwater is discharged from the model area only through x and y directions through layers or through major pumping centers (wells);
- Groundwater moves between layers as a result of vertical leakage through fine-grained deposits (aquitards) that separate the principal water-bearing layers;
- The uppermost layer is an unconfined aquifer and deeper layers are semi-confined throughout the modeled area;
- Steady-state conditions exist in the modeled area and are represented by water levels measured when the supply wells in the center of the grid were not pumping; and

- Groundwater may flow in any direction from one point to another in the modeled area; however heads are held constant along the boundaries of the model area.

Model Setup

The model consists of an array of blocks, defined by the user, by which the groundwater flow can be more readily characterized. The x and y horizontal dimensions of the blocks are defined by a grid of rows and columns. The number and width of rows and columns is specified by the user. Grid boundaries were defined by setting columns and rows beyond the furthest reaches of all known pumping wells in the area. Data points at monitoring wells occur in greater density near the center of the study area; therefore, the width of the columns and rows that define the blocks are smaller in that area. The grid, therefore, has more blocks in areas with better control. Errors in simulation are minimized by the use of large blocks in outlying areas where data points are further apart.

Figure A5-1 shows the modflow grid overlain on a map of the southern part of McClellan AFB and the off-base area to the south. The grid consists of 400 blocks. The center of the grid is a region of 250 feet square blocks, the smallest blocks. The outer corners of the grid consist of the largest blocks which are 1500 feet square The grid was prepared with the columns trending northeast-southwest roughly parallel to the regional groundwater flow direction.

Preparation of the groundwater model for OU B is an attempt to portray groundwater behavior in a complex hydrogeologic setting. The grid blocks are used to subdivide the natural setting into units of subsurface volume to which variables can be assigned. The subdivision allows assigned variable values (for example, hydraulic conductivity, initial hydraulic head, storage coefficient) to vary from block to block to represent lateral and vertical changes in deposits caused by alluvial deposition. For blocks in which measured data from water level measurements and aquifer tests were available, those data were assigned. There were not enough measurement points to assign measured data to all blocks in the model. Therefore, reasonable estimates of variables were used to extrapolate to blocks for which no data were available. Lithologic and geophysical data from borings in OU B were used to interpret geology and hydraulic parameters in blocks for which no measurements were available. The use of extrapolation and parameter estimation is common practice in modeling because field measurements for variables are seldom available for each block.

Hydrogeologic interpretations of OU B (Section A3.1) indicated that several geohydrologic zones were needed in the model. Data available from the OUBGRI indicated that removal actions would be focused on the three uppermost geohydrologic zones, and therefore, they were included in the model. One additional zone below the three upper zones was also included. These model zones represent the more permeable thicknesses in A, B, C, and D zones, and are identified by four separate layers in the model.

The model layers are separated by semi-confining layers. Although these confining layers are represented in the model, they are not treated as discrete layers. The model treats a confining layer as a two-dimensional array between layers containing values which represent leakance, or the ability of the semi-confining layer to permit leakage from one model layer to another.

For the hydraulic conductivity value in the three lower zones, the model utilizes transmissivity values (hydraulic conductivity X thickness of the layer) assigned to blocks in which three-dimensional data are reduced to a two-dimensional data array. For an unconfined condition in the upper most layer, the model uses a hydraulic conductivity value in layer 1 (A zone) to calculate transmissivity by using variable head values to determine saturated thicknesses. Tops or bottoms of layers were taken from elevation deposits measured in borings and estimated between borings. Each layer was assigned values for initial heads taken from field measurements and estimated storage coefficients. Hydraulic conductivity and storage coefficient values were estimated by methods described in Section A5.1.

Model Input

The MODFLOW program requires three modules to solve a groundwater flow system: the Basic package, the Block-Centered Flow (BCF) package, and one of two of the solution packages--Strongly Implicit Procedure (SIP) or Slice Successive Overrelaxation (SSOR). For this report, SIP was used. The other packages used were the Output Control Package and the Well Package. All aquifer parameters were stored in separate arrays and called into the specific packages as needed.

The Basic package contained information specifying the number of rows and column, the time unit, the number of time steps and stress periods, and head data. The head data consisted of an array called IBOUND which specified constant flow, constant head, or variable head for each cell in the grid. Constant heads were specified

for each cell on the outer boundary of the model variable. The HEAD array contained the initial heads for each cell.

The BCF package requires input of the information indicating steady or transient flow, the number and types of layers, the spacing of the rows and columns, and specific parameters assigned to cells. The parameter arrays were created on spreadsheets and stored separately from the BCF package to allow for easy manipulation. The BCF package retrieved the data from these arrays when called for in the program.

The BCF package requires input of parameters for each cell in the model. The principal input parameters are transmissivity (or hydraulic conductivity for unconfined layers), a vertical leakance term (VCONT), primary and secondary storage coefficients, and thickness of model layers.

The model uses transmissivity values for layers 2, 3, and 4 in calcualtions. In the case of layer 1, a water table unit, transmissivities are recalculated during the model run to accournt for changes in transmissivity resulting from the changing saturated thickness of the aquifer. The transmissivity takes into account both the conductivity and the thickness of the unit to indicate how much water the unit can provide. Transmissivites measured in the field therefore can only indicate water the formation can provide, and cannot indicate changes in thickness or conductivities in areas away from the borehole. Hydraulic conductivity and transmissivity values measured in the field or extrapolated from measured values were initially entered into a 16 column by 16 row grid. Those values are shown for each layer in Tables A5-2 to A5-5 on pages A5-63 to A5-66.

VCONT is a term indicating the leakance of a confining layer. VCONT takes into account both the conductivity and the thickness of a confining unit, reducing these concepts to the two-dimensional environment the model uses. The model uses this series of two dimensional calculations between conducting and confining layers to produce three dimensional results. VCONT values were derived from estimated thickness and conductivity of various deposits in cells which compose the confining layer. This is a common modeling technique for systems with such variable geology. Initial VCONT values estimated for the aquitard between model layers are shown in Tables A5-6 to A5-8 on pages A5-67 to A5-69.

The thickness of modeled layers and aquitards vary across the modeled area to represent actual hydrogeologic conditions. Elevations of tops and bottoms of layers 1 through 4 were determined for cells from lithologic or geophysical logs where they were available and extrapolated to other areas on the basis of geologic interpretation. The elevation of the bottom of each layer that was input to the model for the entire 20 row by 20 column grid are shown in Tables A5-9 through A5-12 on pages A5-70 to A5-73.

The Output Control Package controls the saving and printing of the heads and drawdown at specific points in the simulation. For this report, the heads and drawdowns were saved and printed for the first and last time step of each stress period.

The SIP package input contained the maximum number of iteration per time step, the number of iterations parameters used, and the closure criteria for a time step.

The Well package contained the well locations and pumping rates. For wells that were screened in more than one layer, the model required that a separate well be placed in each layer with a flow rate specific to each layer. To use this approach, the pumping rate for the well must be apportioned among the individual layers. The method used for this model was to divide the well discharge in proportion to the individual layer transmissivities using the following:

$$\frac{Q_1}{Q_w} = \frac{T_1}{\Sigma T}$$

where:

Q_1 is the discharge from layer 1 to a well;

Q_w is the total well discharge;

T_1 is the transmissivity of layer 1; and

ΣT is the sum of the transmissivities of all layers penetrated by the well.

All initial input to the model was based on actual measurements or estimates based on field data. Hydraulic heads were measured in monitoring wells eight

times in OU B and six times outside of OU B from April 1989 through April 1990. Initial head values input to the model were based on January 1990 measurements taken when BW-18 was not pumping. Initial heads input for each layer are shown in Tables A5-13 through A5-16 on pages A5-74 to A5-77.

A5.2.3 Model Calibration

Model calibration involved model convergence, steady state calibration to non-pumping conditions, transient calibration, and calibration to pumping conditions. Details of the calibration are provided below. Figures illustrating groundwater contours resulting from calibration and test runs are included together on pages A5-26 to A5-61. The east-west base boundary is shown on each figure, along with asterisks that represent the block centers. Hachures are shown on the downgradient side of any closed groundwater contours which does not have an elevation value in one of the figures.

Convergence. The first step in calibrating MODFLOW is to force the model to converge. The MODFLOW program uses an acceleration/relaxation parameter and a seed value to achieve this convergence. When the seed value is user-specified, the user goes through a trial and error method of determining the optimum seed value for convergence. This method consists of determining whether the model is "overshooting" or "undershooting" the calculated heads and adjusting the seed accordingly. For this calibration, the model converged on the first try, so no trial and error was needed.

Manipulation of Array Data. Calibration of the model involved the manipulation of the various input arrays: initial heads, hydraulic conductivities and transmissivities, VCONT (vertical conductivity divided by the thickness of the material between layers), primary and secondary storage factors, and pumping rates. General calibration was accomplished by factoring entire data arrays. Calibration of specific areas of the model was accomplished by changing values in specific blocks or groups of blocks. Parameters measured in the field or estimated from lithologic data and extrapolated to adjacent cells were changed by a trial and error method to achieve calibration. All values changed during calibration were limited to ranges that could be expected to occur in the types of deposits in each cell. The sensitivity of the model to changes in hydraulic conductivity or transmissivity and VCONT values was determined through a sensitivity analysis (see Steady State Calibration). The sensitivity of the model to changes was used to set limits on the parameter changes made in calibration.

Model runs were documented by assigning a sequential run number, with the input files noted for each run. All changes to input files were saved as a separate spreadsheet for easy retrieval when necessary. The input files were named with an eight character system--for example HEAD0521. The first four characters indicate the array name, the fifth and sixth characters indicate the sequential numbering of the particular array changes, and the last two characters indicate the unit number on which the file is saved for incorporation into the program.

Control Points. The control points used for calibration were established as the cells which contained monitoring wells with available water level data. Calibration of the model was determined by comparing calculated output heads with actual well data. A certain tolerance was accepted because wells were rarely located at the cell center, where the head was calculated. This discrepancy is more significant in the outer cells because of their size. Control points in each layer are indicated as shaded cells in Tables A5-9 to A5-23 on pages A5-70 to A5-84.

Steady-State Calibration. Calibration of the model started with steady-state, non-pumping conditions. The initial head data were taken from January 1990 water level data, (Section A3.2). The well data were contoured to determine the head values in cells without monitoring wells. Contour maps for actual non-pumping conditions for zones A, B, C, and D are presented in Figures A5-2, A5-3, A5-4, and A5-5, respectively.

The sensitivity of input parameters was tested by varying the values within reasonable limits for each parameter. The original input values for conductivity/ transmissivity and VCONT were factored by large amounts (0.01, 0.1, 10, 100, 1000) and small amounts (0.6, 0.8, 1.2, 2, 5). This was performed first on all layers, then on separate layers, and finally on individual areas of the layers throughout the calibration procedures. The boundary heads were raised or lowered by less than 1 1/2 feet. It was found that conductivity/transmissivity had the greatest effect, while VCONT and boundary heads had lesser effects, but were still significant.

The general trends found by factoring an entire array or layer were used to indicate the direction of change for conductivity/transmissivity and VCONT for individual problem areas. The boundary heads were raised or lowered when the predicted heads for the entire model (control points) differed by a consistent amount. Because each parameter used for calibration had an effect on the model, the exact

amount of change could not be determined from the factoring of the entire array or layer. This resulted in a "trial and error" approach for each parameter.

A utility program (MODSENS) was written to perform a sensitivity analysis of the groundwater flow system to the values assigned to transmissivity at individual cells. This program increased the transmissivity at each cell in the model in increments of 10 percent and calcualted the residual for user-specified areas of thte model. Through this program, cells of interest were specified and the effect of increasing the transmissivity in any cell of the model was determined. For this demonstration, MODSENS was performed on the control points and certain areas that were difficult to calibrate. Calibration was achieved by identifying the areas of the model which had the greatest amount of residual (difference between actual and predicted heads), and reducing the residual in these areas to equal the level of the remainder of the model by adjusting the parameters incrementally for each trial. This was continued until the tolerance for the residual was acceptable (see Model Evaluation).

The final hydraulic conductivity (Layer 1), transmissivity (Layers 2, 3, and 4), and VCONT (for aquitards between layers) values that resulted from the calibration step are presented for each layer in Tables A5-17 through A5-23 on pages A5-78 to A5-84. These values were used for all model runs to simulate pumping conditions.

Transient Calibration. From steady-state calibration, the model was taken to transient calibration. The main difference in these runs was the inclusion of primary and secondary storage factors. In general, no changes were noted when the model was run in the transient state. To confirm this, storage factors were changed to reflect the smallest storage that could reasonably be expected at the site, leading to the slowest equilibration of the aquifers. After no changes were noted, the aquifer was confirmed to be at equilibrium. The model was then run generally in a steady state mode to save computer run time.

Calibration to Pumping Conditions. For calibration to pumping conditions, the model was set up to run for two stress periods, 30 days each. The first stress period represented a non-pumping scenario while the second period represented the pumping scenario. Water levels for monitoring wells measured during the pumping of Base Well 18 (BW-18) in December 1989 (Section A3.2) were used. Contour maps for actual pumping conditions for zones A, B, C, and D are presented in Figures A5-6, A5-7, A5-8, and A5-9, respectively.

When the model was simulating a pumping rate of 1,150 gallons per minute (gpm) from BW-18, it was found that the drawdowns were significantly less than actual data indicated. This was corrected by factoring the conductivity/transmissivity arrays down to values in the range of drawdowns shown from field data. This created problems in non-pumping conditions which were solved by raising or lowering the boundary heads for each layer. Although extraction rates are reported in gpm in the text of the report, all units in the model are in feet and days, so extraction well rates reported in model output are listed in cubic feet per day.

A second problem was that City of Sacramento Well (CW) 131 was pumping at a rate of approximately 569 gpm during this period. Although the effects of CW-131 could not be verified from water level measurements because the distribution of monitoring wells in the vicinity of CW-131 is limited. However, the addition of the removal of 569 gpm from CW-131 improved the match of the control points in that area, so CW-131 was included in the calibration of pumping conditions.

Lastly, it was discovered that the drawdowns in zone A, which should have resulted solely from the pumping of zones B, C, and D, could only be reproduced if some leakage from zone A was occurring around the base well. The calibrated model includes the result of that leakage. Only a relatively small amount of the total water available from zone A leaks into the well.

Model output was checked against control points and contour plots were periodically made of model input and output heads to ensure that the general flow patterns were maintained. Contour maps for model-calculated water levels during non-pumping conditions for zones A, B, C, and D are presented in Figures A5-10, A5-11, A5-12, and A5-13, respectively. These maps can be compared with plots of the actual water levels in Figures A5-2, A5-3, A5-4, and A5-5, respectively. Contour maps for model calculated water levels during pumping conditions for zones A, B, C, and D are presented in Figures A5-14, A5-15, A5-16, and A5-17, respectively. These maps can be compared with plots of the actual water levels in Figures A5-6, A5-7, A5-8, and A5-9, respectively.

City of Sacramento Well (CW) 155 which is located 2,000 feet south of the southern boundary of OU B began pumping in January 1990 at a rate of 480 gpm. Decreased water levels during pumping may have resulted from this well pumping simultaneously with CW-131. The effects of CW-155 could not be noted during actual measurements because of the small number of wells in the southernmost part of OU B. For completeness, one model simulation was made which reflects BW-18 pumping at

1,150 gpm, CW-131 pumping at 569 gpm, and CW-155 pumping at 480 gpm. Contour maps for model-calculated water levels for this simulation during pumping conditions for zones A, B, C, and D are presented in Figures A5-18, A5-19, A5-20, and A5-21, respectively.

Model Evaluation. Although there is no standard method for the evaluation of the MODFLOW groundwater model, certain basic statistics can be useful in analyzing the error inherent in the model. Residuals, or the difference between the predicted heads and the actual heads, were calculated to aid in the calibration of the model. An examination of these residuals shows that error in the model ranged from 0.0 feet to 4.0 feet, with a median of 0.5 feet. This suggests that the model can predict heads to within 0.5 feet at the majority of the control point locations. In addition, water budget can also be examined. Water budget is calculated by the model during each model run to examine the amount of water flowing into and out of the model. In all model runs used in this report, the budget discrepancy was 0.00 percent.

Some of the error appears to be caused by either erroneous field measurements or by spurious effects from unrecorded sources For instance, at some locations, measurements show water levels to be rising when the water table should have been depressed during pumping. Minor errors may also result from the control wells not being located in the center of the blocks for which flow is calculated.

Overall, the model appears to perform satisfactorily. During simulations, there is a possibility that the model may predict some slightly greater drawdowns in lower layers in the model than would actually be measured under actual pumping conditions.

A5.2.4 Model Simulations

The model was used to simulate certain hydraulic conditions that could impact groundwater removal actions in OU B. These simulations are discussed below.

BW-18 and CW-155 Pumping. Since CW-131 was shut off in January 1990, all simulations for remediation begin with a condition of BW-18 and CW-155 pumping at 1,150 gpm and 480 gpm, respectively. Contour maps for model-calculated water levels for this simulation during pumping conditions for zones A, B, C, and D are presented in Figures A5-22, A5-23, A5-24, and A5-25, respectively.

BW-18, CW-155, Extraction Wells 1 and 2 Pumping. Extraction wells, EW-1 and EW-2, are planned for construction 700 to 800 feet northeast of BW-18. This simulation reflects conditions similar to BW-18 and CW-155 pumping above, with the notable addition of the two planned extraction wells in zone A, EW-1 and EW-2, pumping at 15 gpm and 5 gpm, respectively. Contour maps for model calculated water levels for this simulation during pumping conditions for zones A, B, C, and D are presented in Figures A5-26, A5-27, A5-28, and A5-29, respectively. Note that the relatively low rate of extraction from these wells compared to BW-18 does not provide an indication of the effects of EW-1 and EW-2 on the plot with one-foot contour intervals.

BW-18, CW-155, and Extraction Wells 1, 2, 3, 4, and 5 Pumping. Three extraction wells have been proposed as removal actions to control the migration of contaminants in the northern TCE/1,2-DCE plume. These extraction wells, which are designated EW-3, EW-4, and EW-5, are proposed for construction in locations along the east-west McClellan AFB boundary in zones A, B, and C, respectively. This simulation reflects conditions similar to BW-18, CW-155, and EW-1 and EW-2 pumping above, with the notable addition of these new extraction wells. It is anticipated that both EW-1 and EW-2 will be constructed and pumping when the three new wells are installed. Groundwater extraction rates for EW-3, EW-4, and EW-5 were estimated using an analytical capture zone model (Section A6.2). In this simulation the modeled wells are pumping at 30 gpm, 25 gpm, and 100 gpm, respectively. Contour maps for water levels calculated by the model for this simulation for zones A, B, C, and D are presented in Figures A5-30, A5-31, A5-32, and A5-33, respectively. The effects of pumping of the three new extraction wells are not evident on the plot of head data from this simulation because of the relatively low rate of extraction compared to BW-18 and the definition allowed by one-foot contour intervals.

Reduction of Pumping Rate in BW-18. The last simulation included in this report examined the effects of reducing the pumping rate at BW-18 to 650 gpm. The model conditions included all extraction wells operating with the BW-18 pumping rate reduced from 1,150 gpm to 650 gpm. Contour maps for model-calculated water levels for this simulation during pumping conditions for zones A, B, C, and D are presented in Figures A5-34, A5-35, A5-36, and A5-37, respectively. Note that the decrease in pumping rate increases the hydraulic impact of CW-155. Although contaminants flowing from the north into EW-3, EW-4, and EW-5 would continue to be captured, contaminants already to the south of the base boundary which are currently being drawn back by BW-18 may begin to flow toward CW-155.

A5.2.5 Conclusion

The modeling effort to predict groundwater flow behavior under various hydraulic conditions was successful in simulating the impact of BW-18 and City of Sacramento supply wells within and near OU B. The potentiometric (head) contours produced for each zone and shown in the figures are in excellent agreement with measurements obtained from monitoring wells under similar hydraulic conditions. Therefore, the model can be used to predict changes in groundwater flow directions that may be caused by changes in pumping rates or schedule for the large production wells, BW-18 or CW-155, in OU B. The model can be used in the OU B Remedial Investigation and other future planning efforts to evaluate potential changes in operating conditions.

The model could not predict the impacts that will result from the pumping of proposed removal action extraction wells, EW-1 through EW-5. The large supply wells have such a major impact on hydraulic conditions and the extraction wells have a relatively limited hydraulic impact within the model area, that potentiometric head changes are not apparent when illustrated with a one-foot contour interval in the figures. The fact that the model does not clearly illustrate the impacts of the extraction wells does not imply that the wells will be ineffective. The model grid is large to allow the hydraulic impacts of major pumping wells to be simulated and illustrated. The grid and contour interval are too coarse to simulate the changes in hydraulic head that would result from pumping of the extraction wells. With the larger model grid calibrated and capable of predicting large scale hydraulic impacts, a model with a finer grid scaled for the area of the extraction wells may be considered in a future investigation.

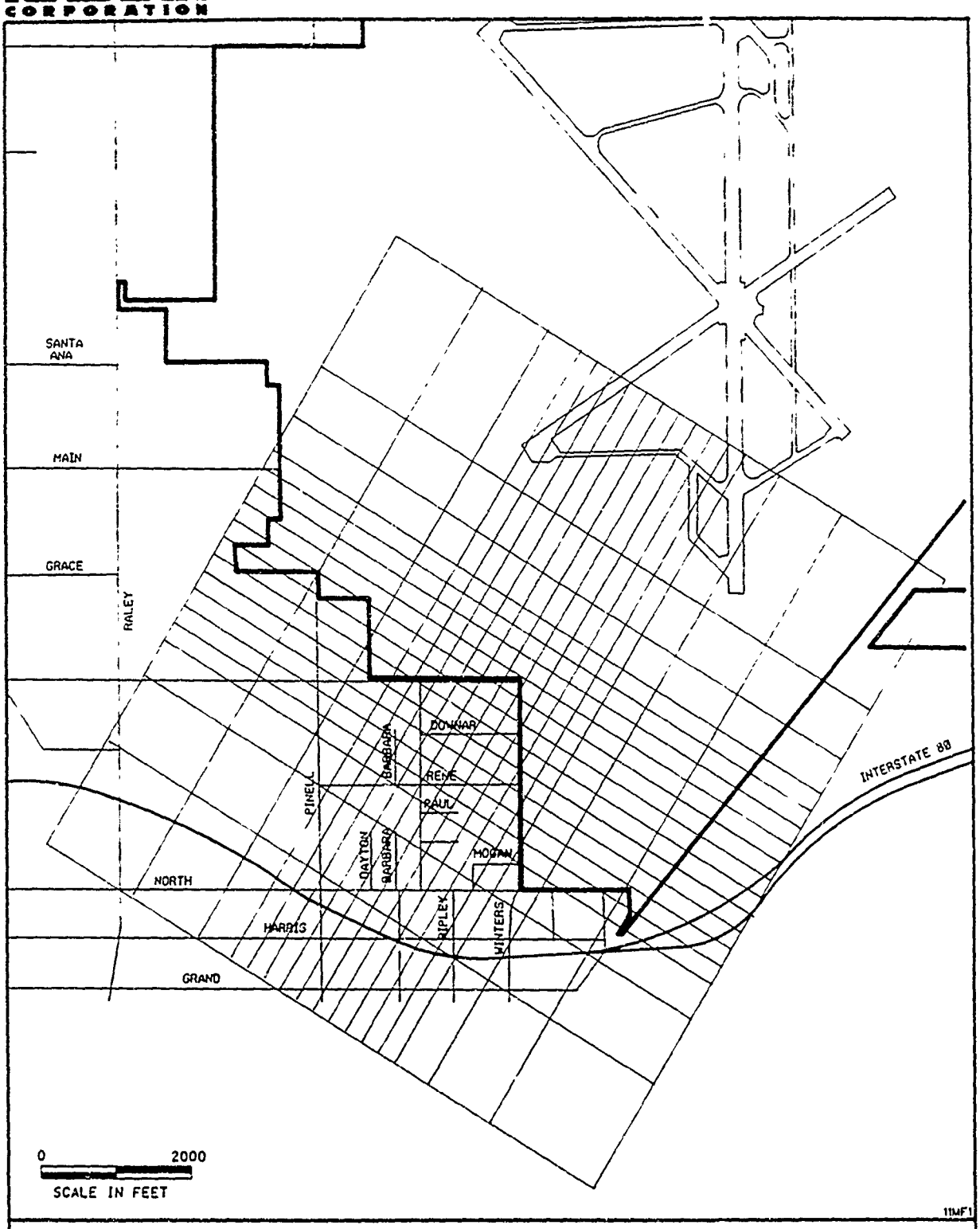

Figure A5-1. MODFLOW Grid Area.

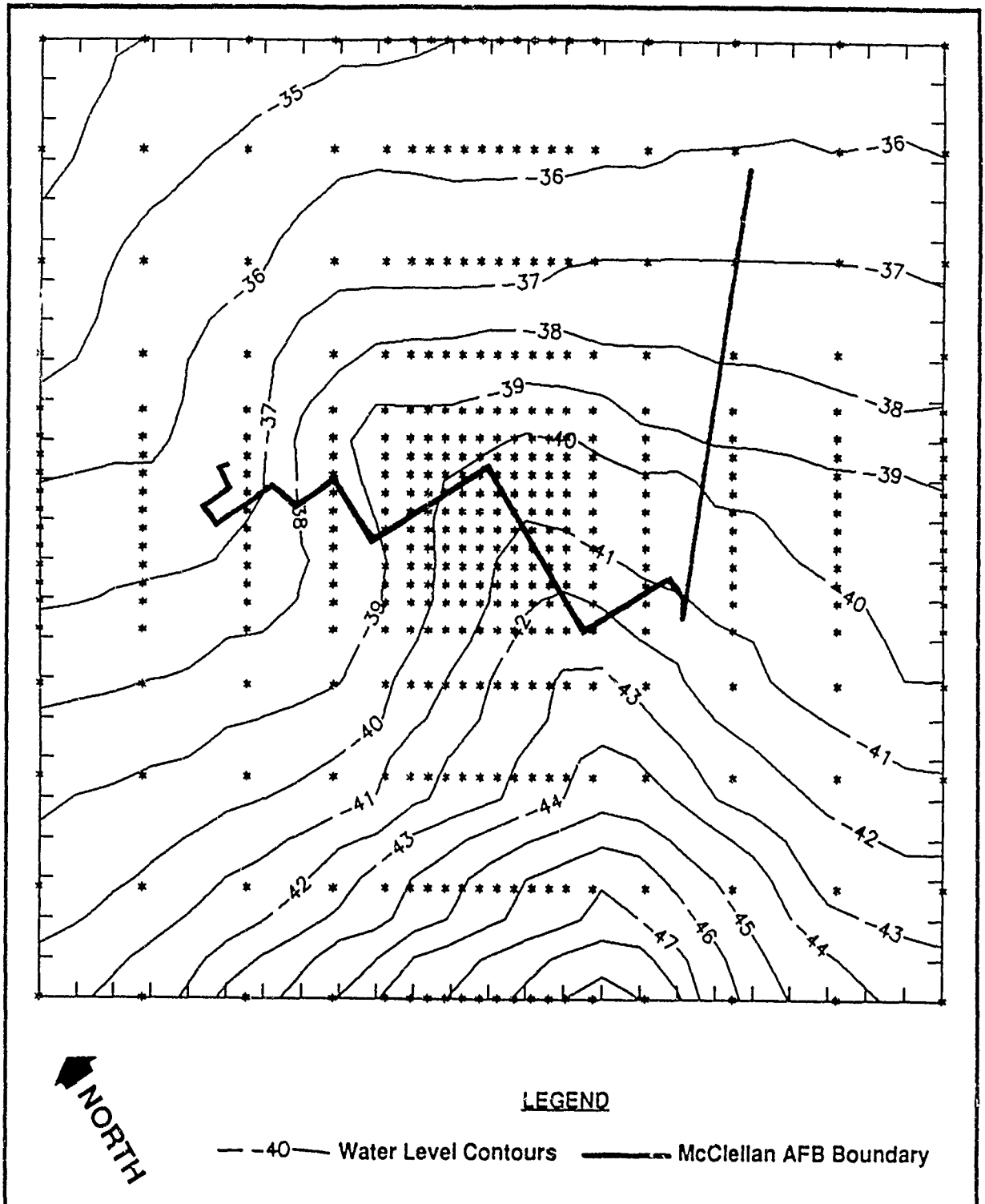

Figure A5-2. Actual Non-Pumping Heads - Zone A.

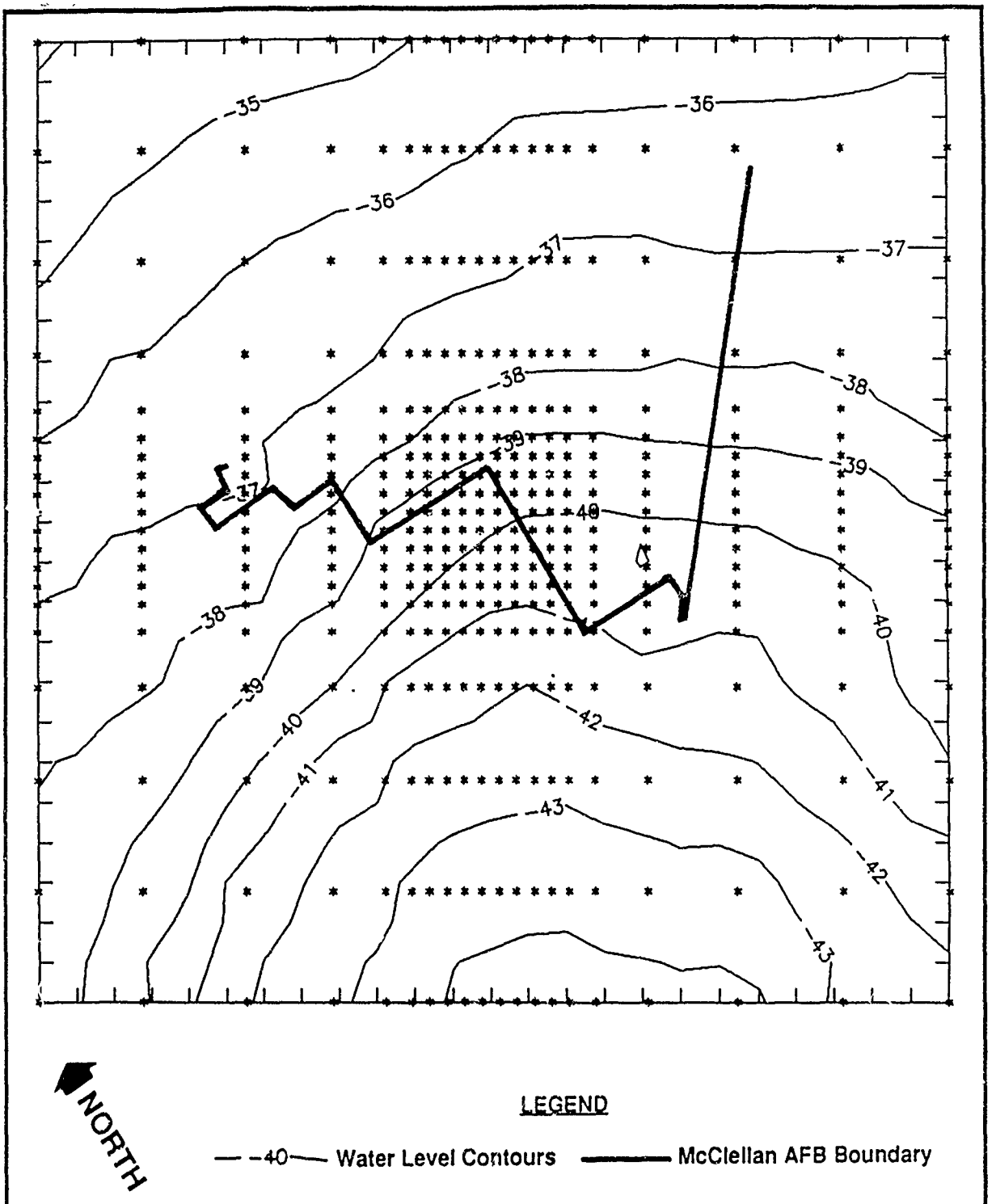

Figure A5-3. Actual Non-Pumping Heads - Zone B.

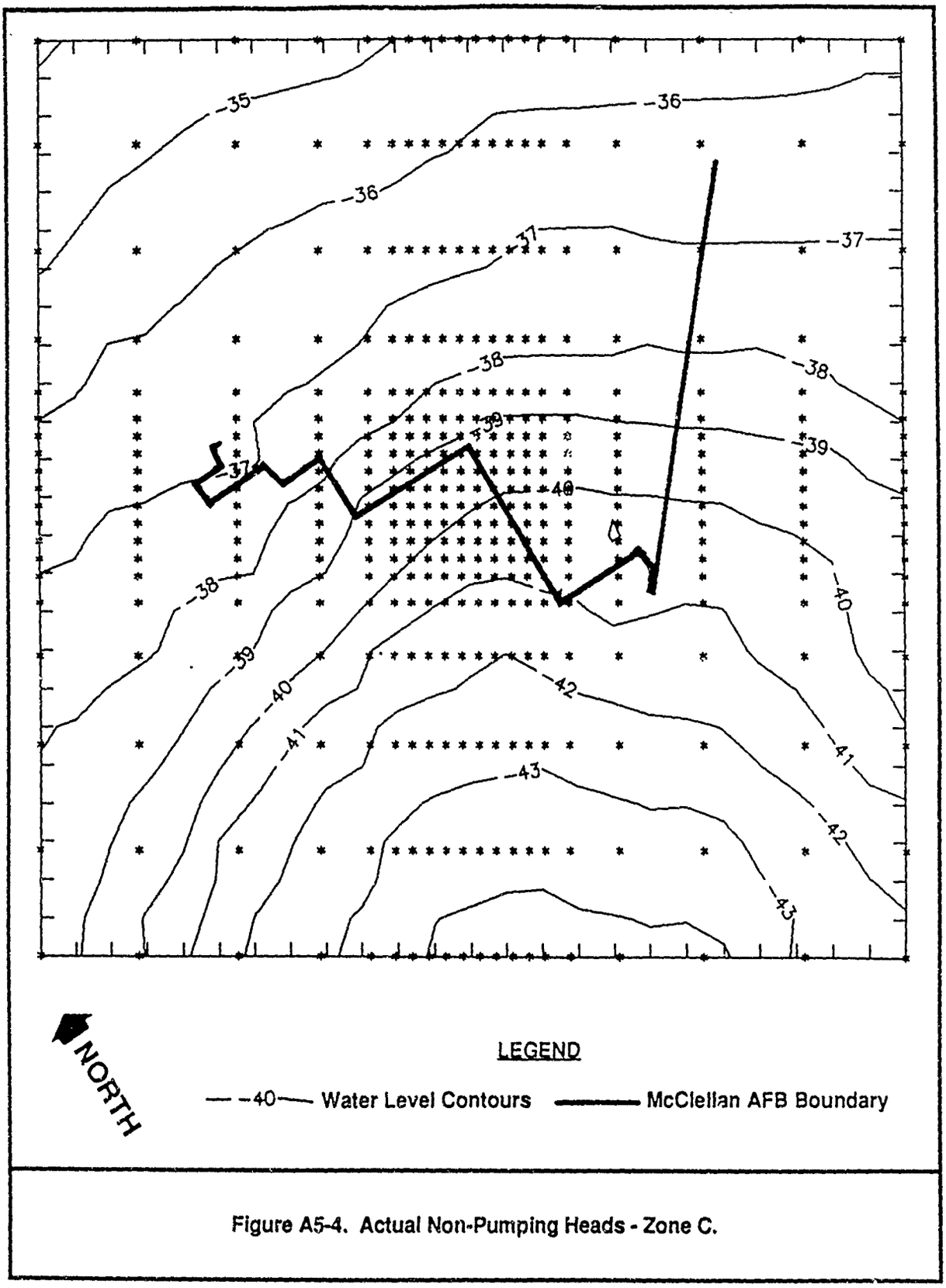

Figure A5-4. Actual Non-Pumping Heads - Zone C.

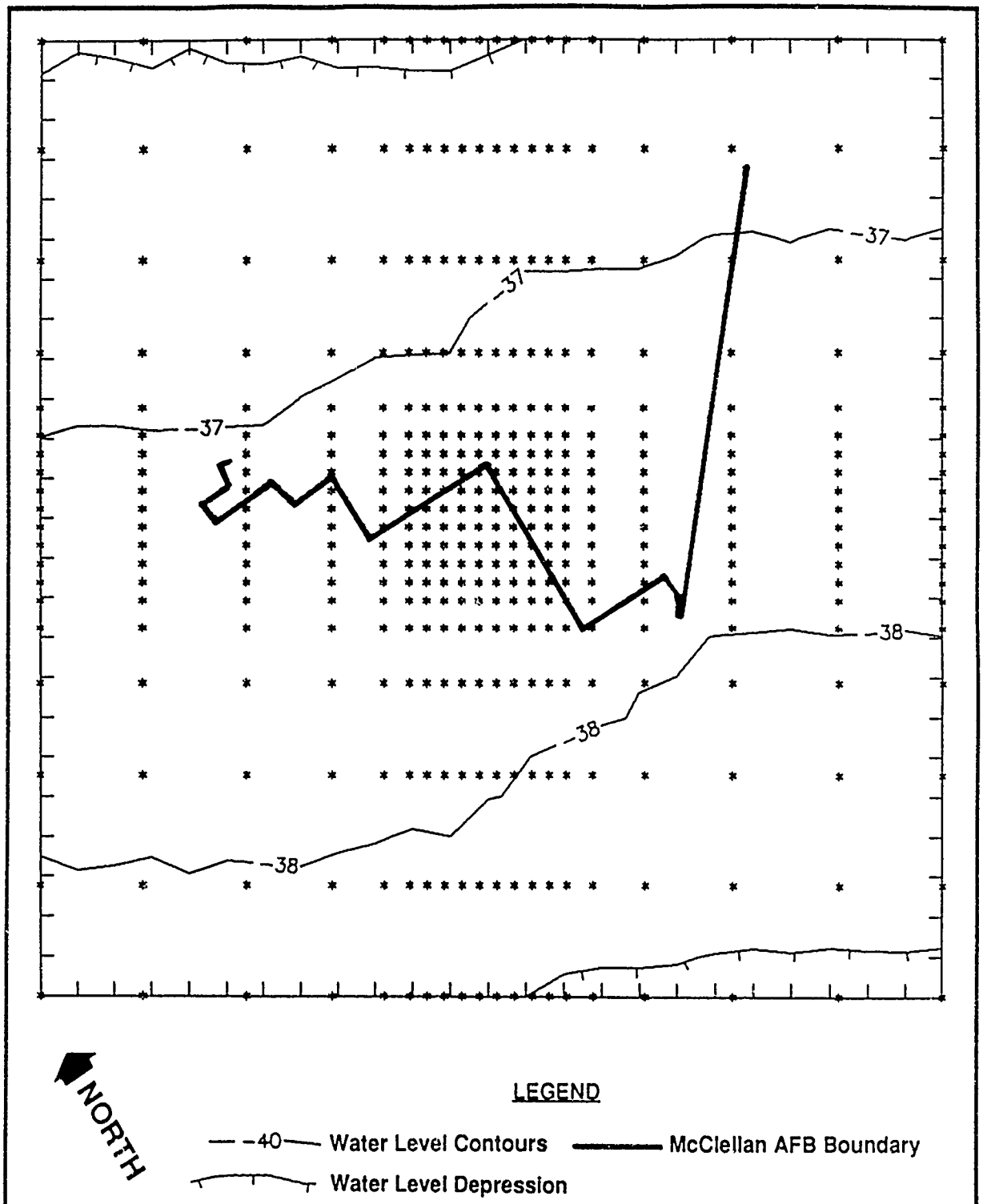

Figure A5-5. Actual Non-Pumping Heads - Zone D.

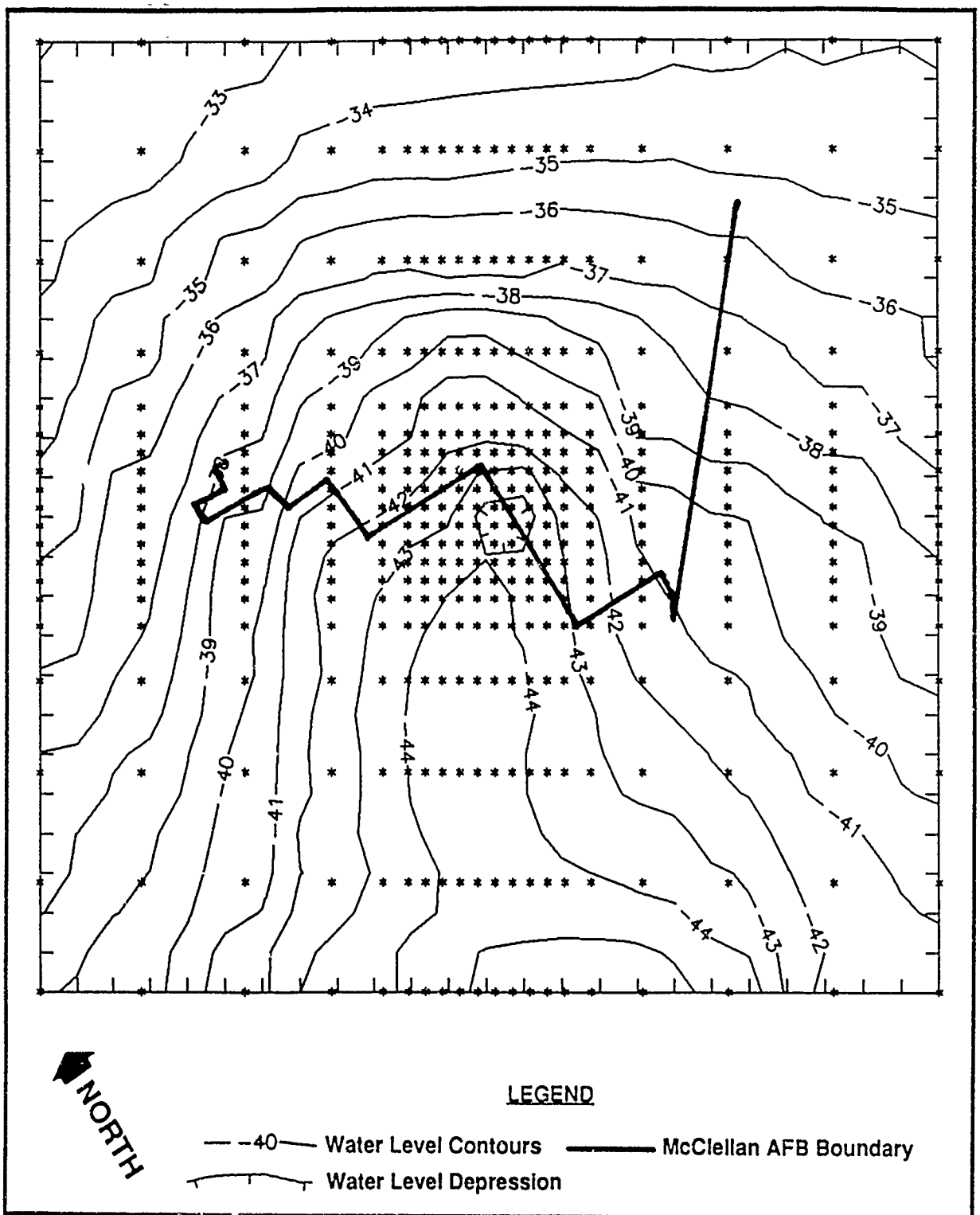

Figure A5-6. Actual Pumping Heads - Zone A.

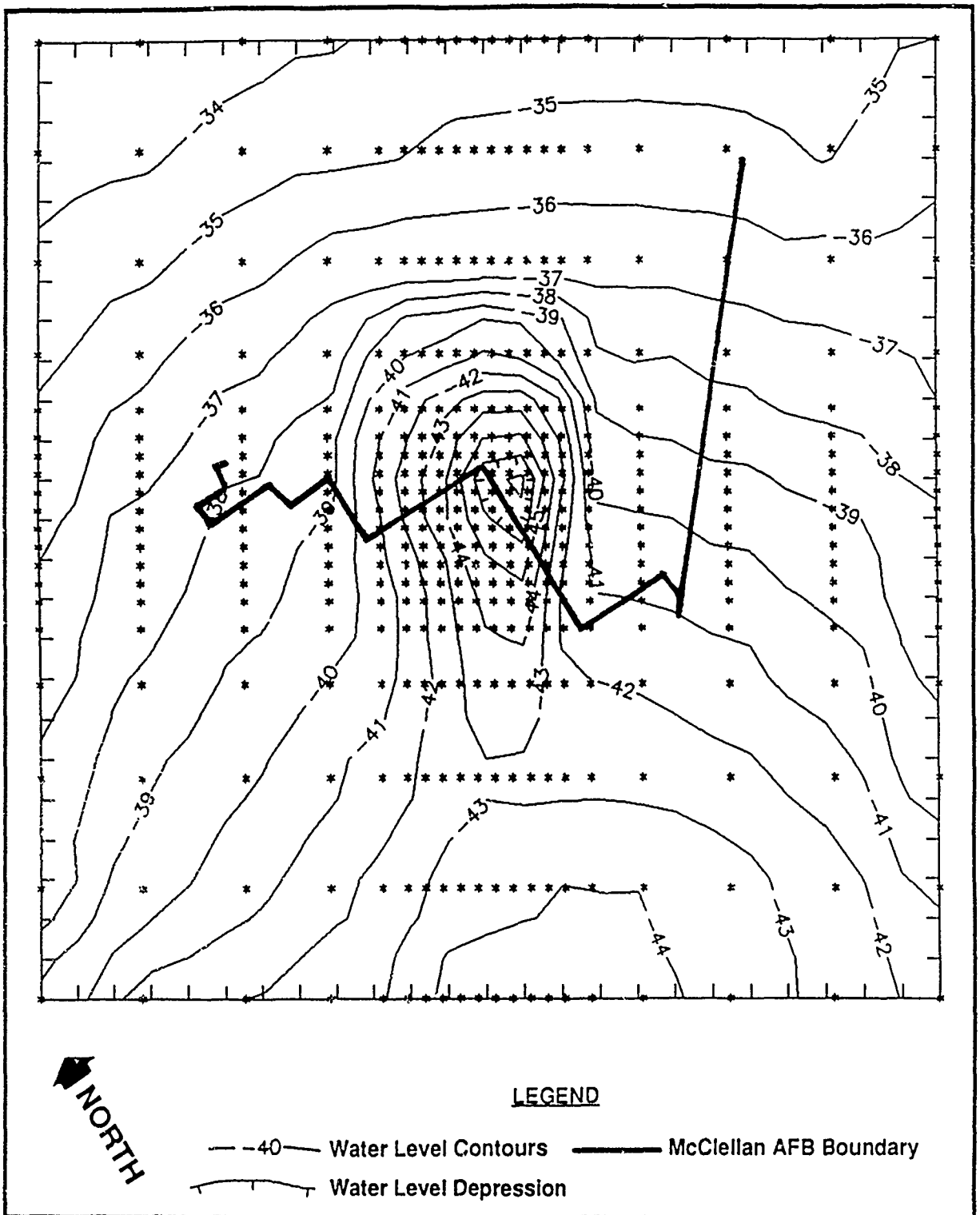

Figure A5-7. Actual Pumping Heads - Zone B.

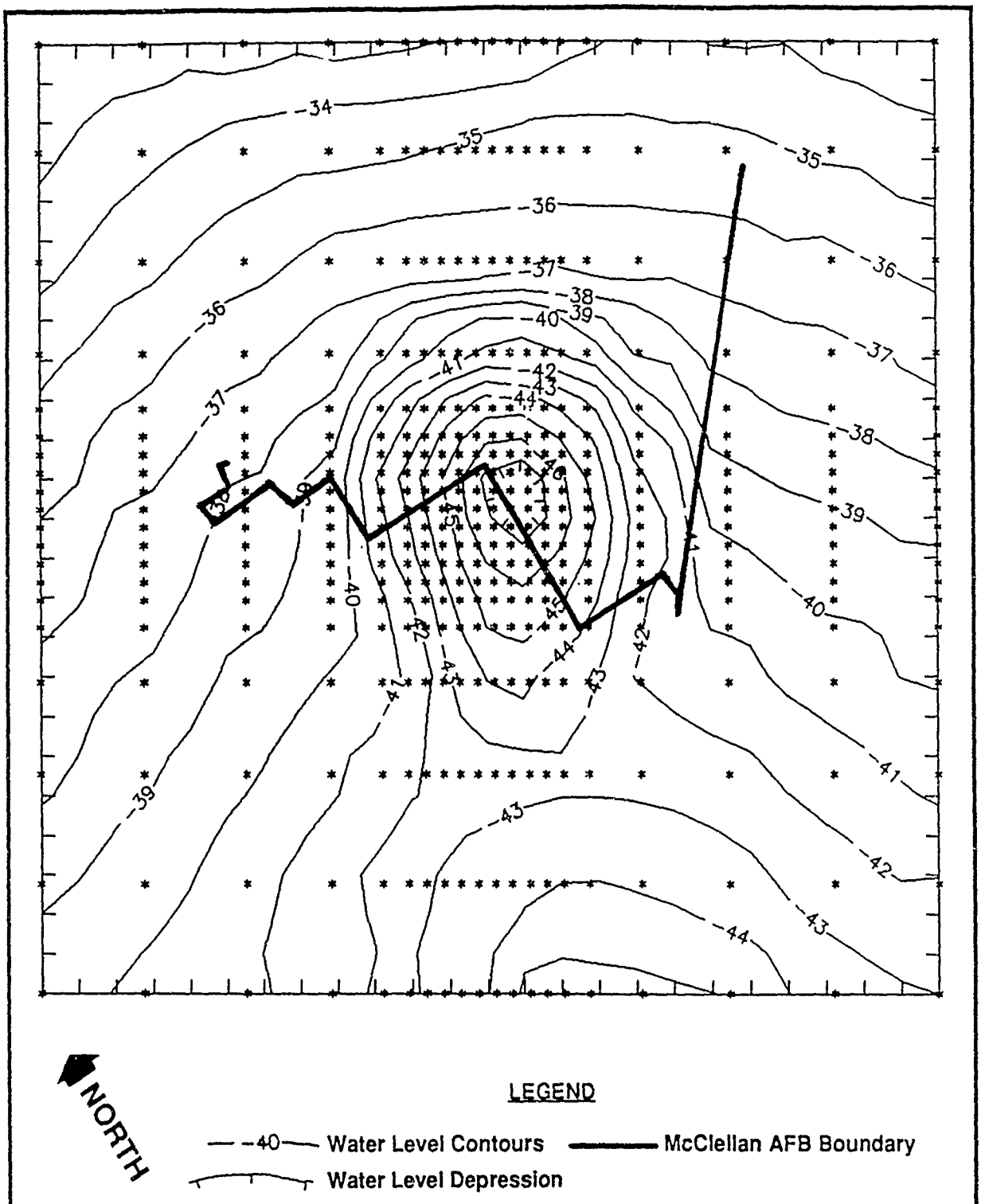

Figure A5-8. Actual Pumping Heads - Zone C.

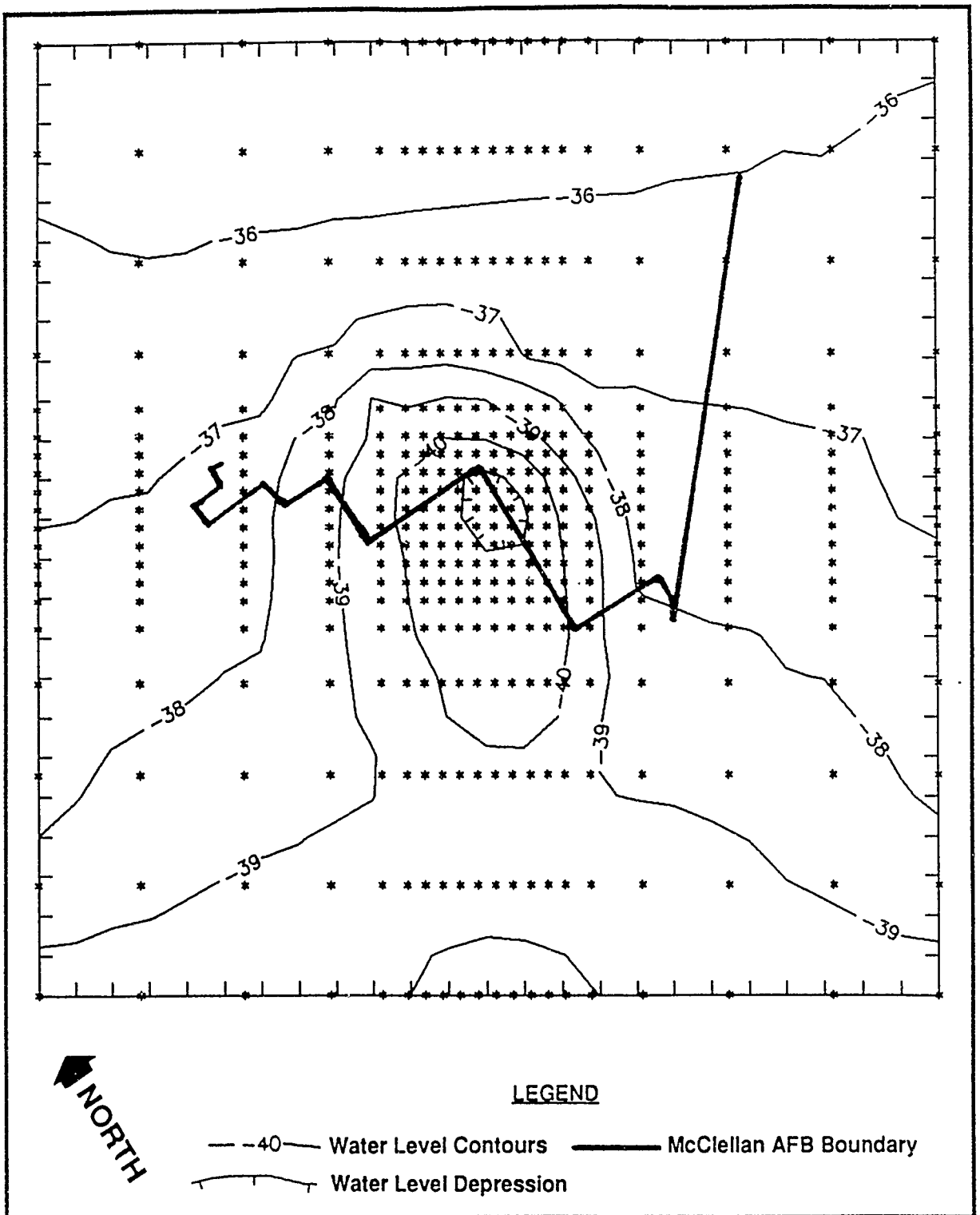

Figure A5-9. Actual Pumping Heads - Zone D.

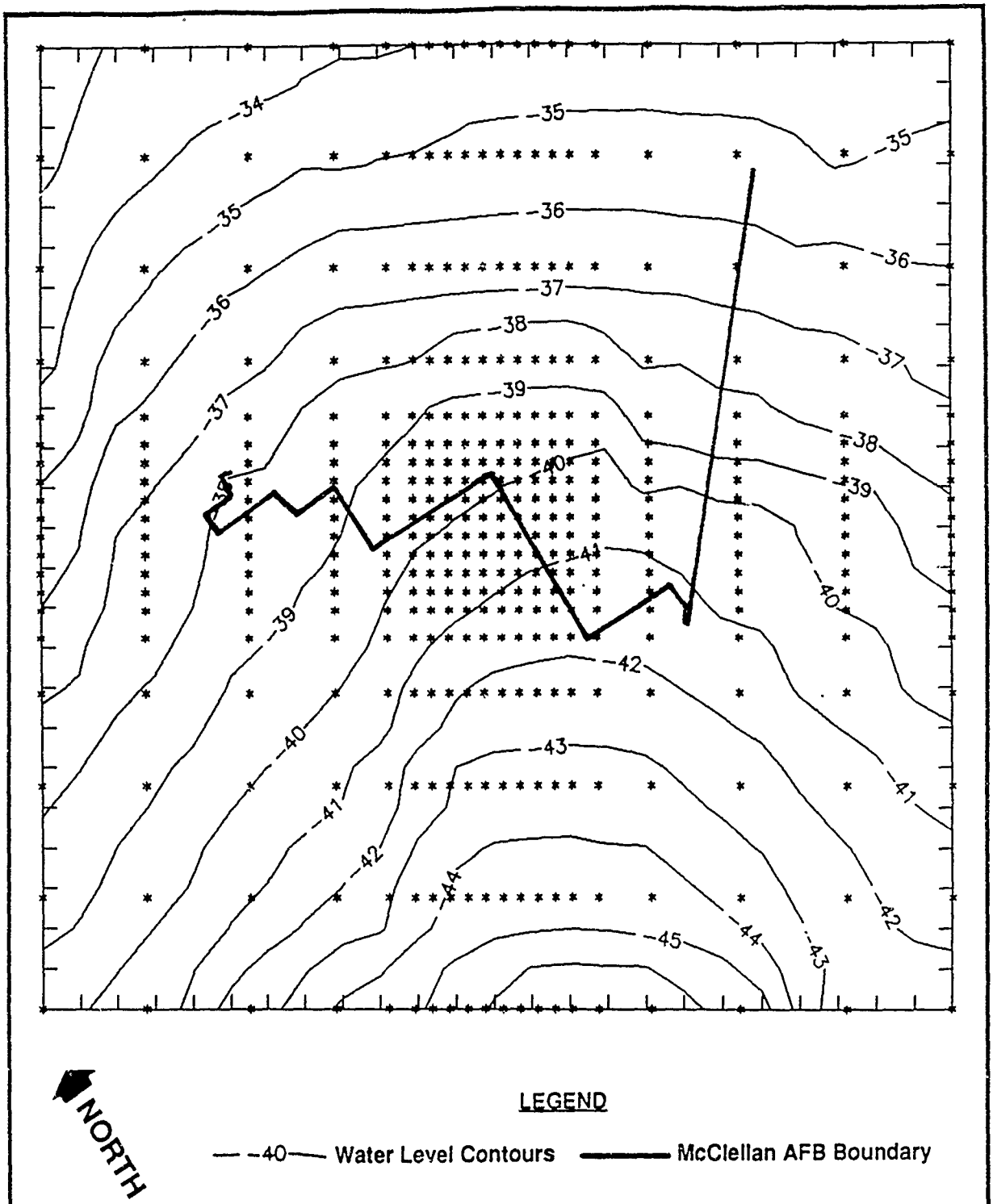

Figure A5-10. Calculated Non-Pumping Heads - Zone A.

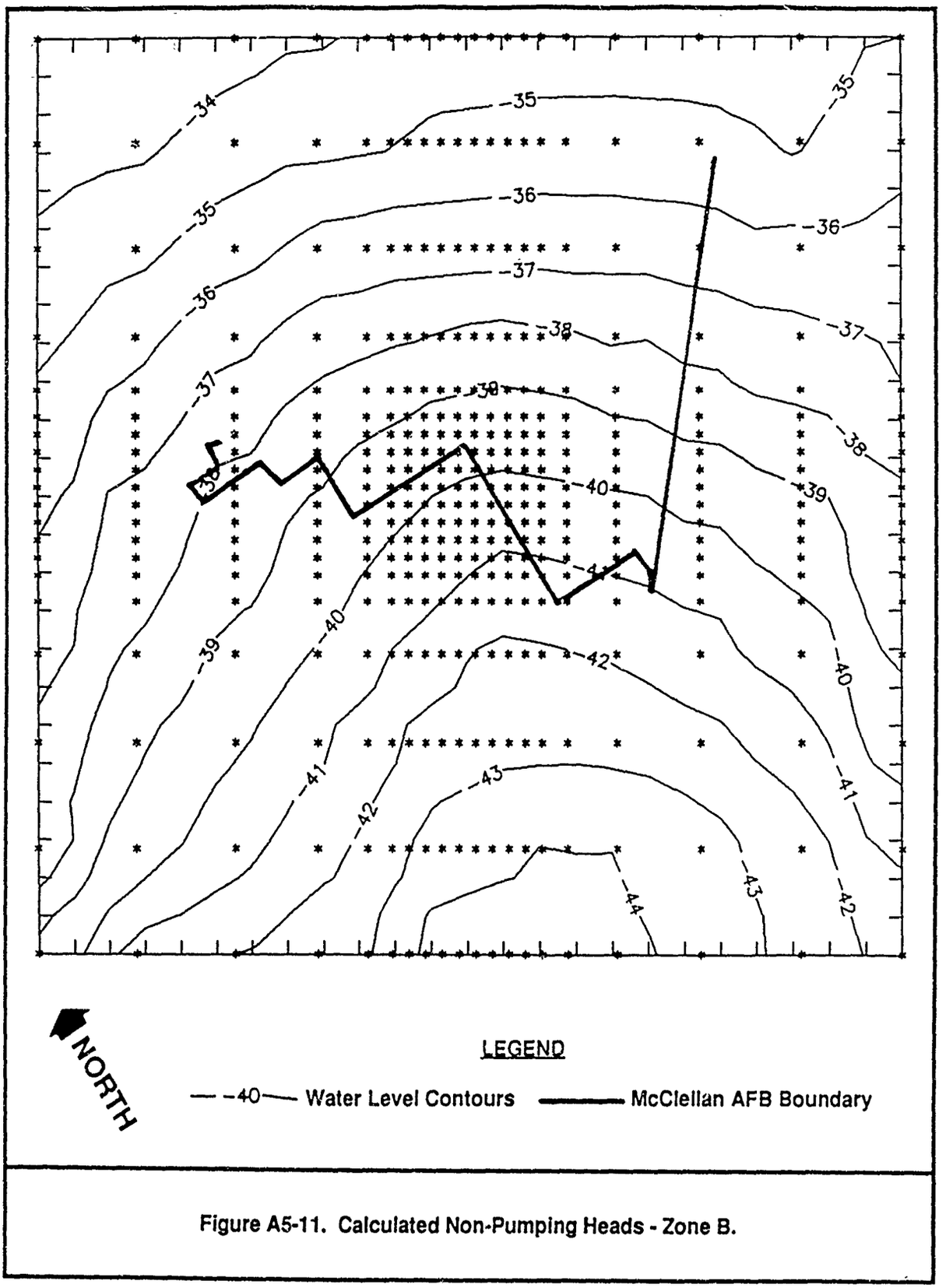

Figure A5-11. Calculated Non-Pumping Heads - Zone B.

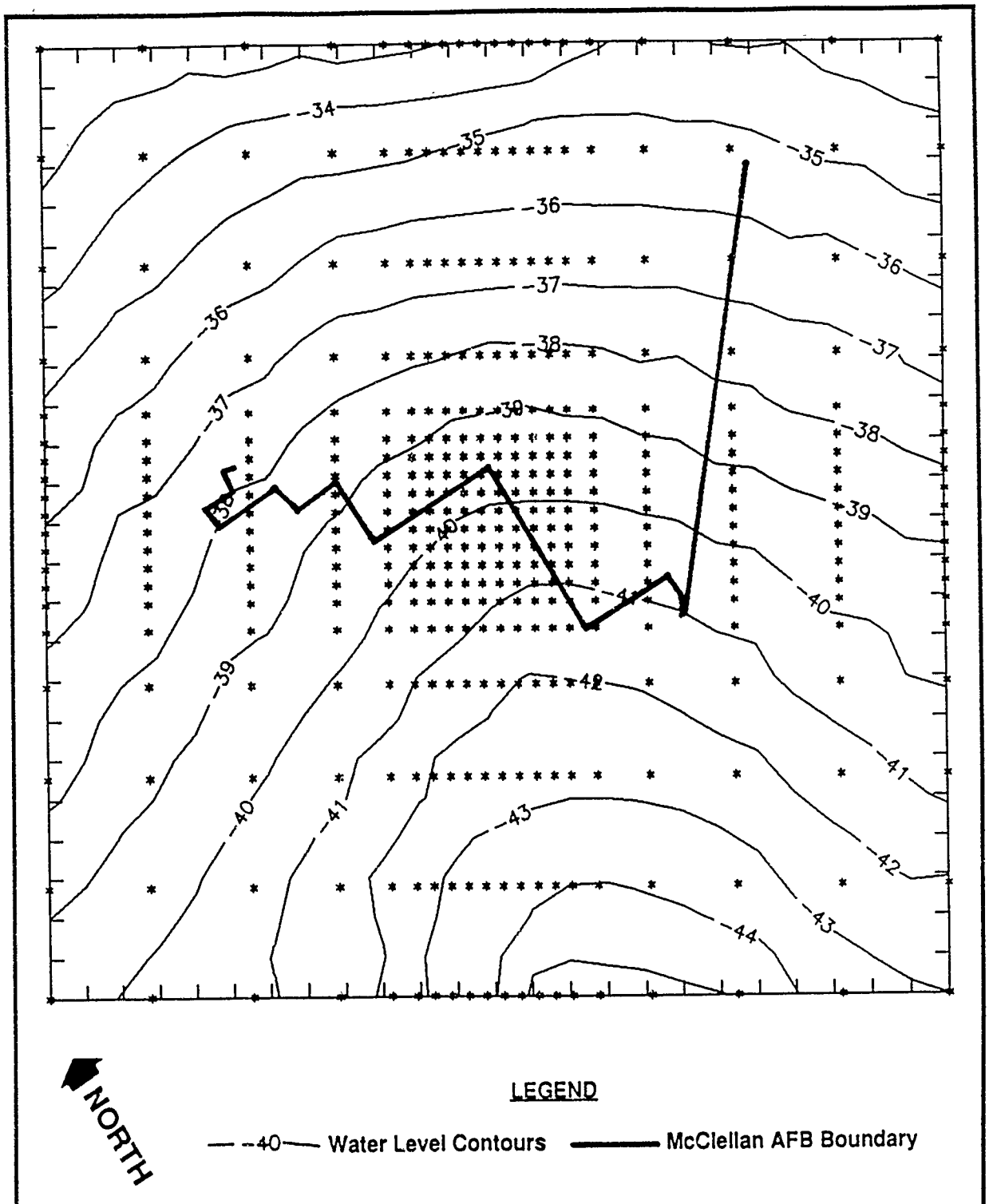

Figure A5-12. Calculated Non-Pumping Heads - Zone C.

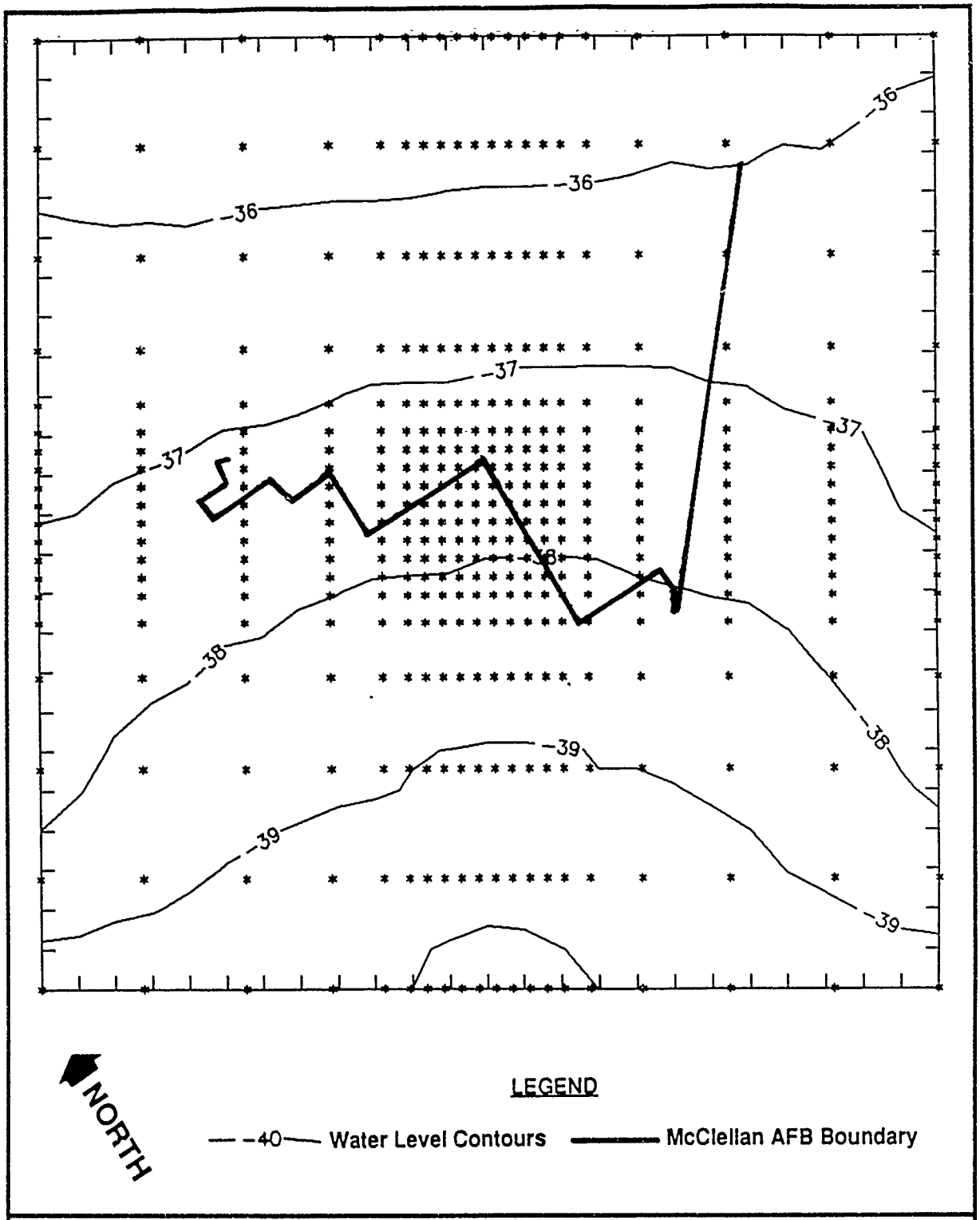

Figure A5-13. Calculated Non-Pumping Heads - Zone D.

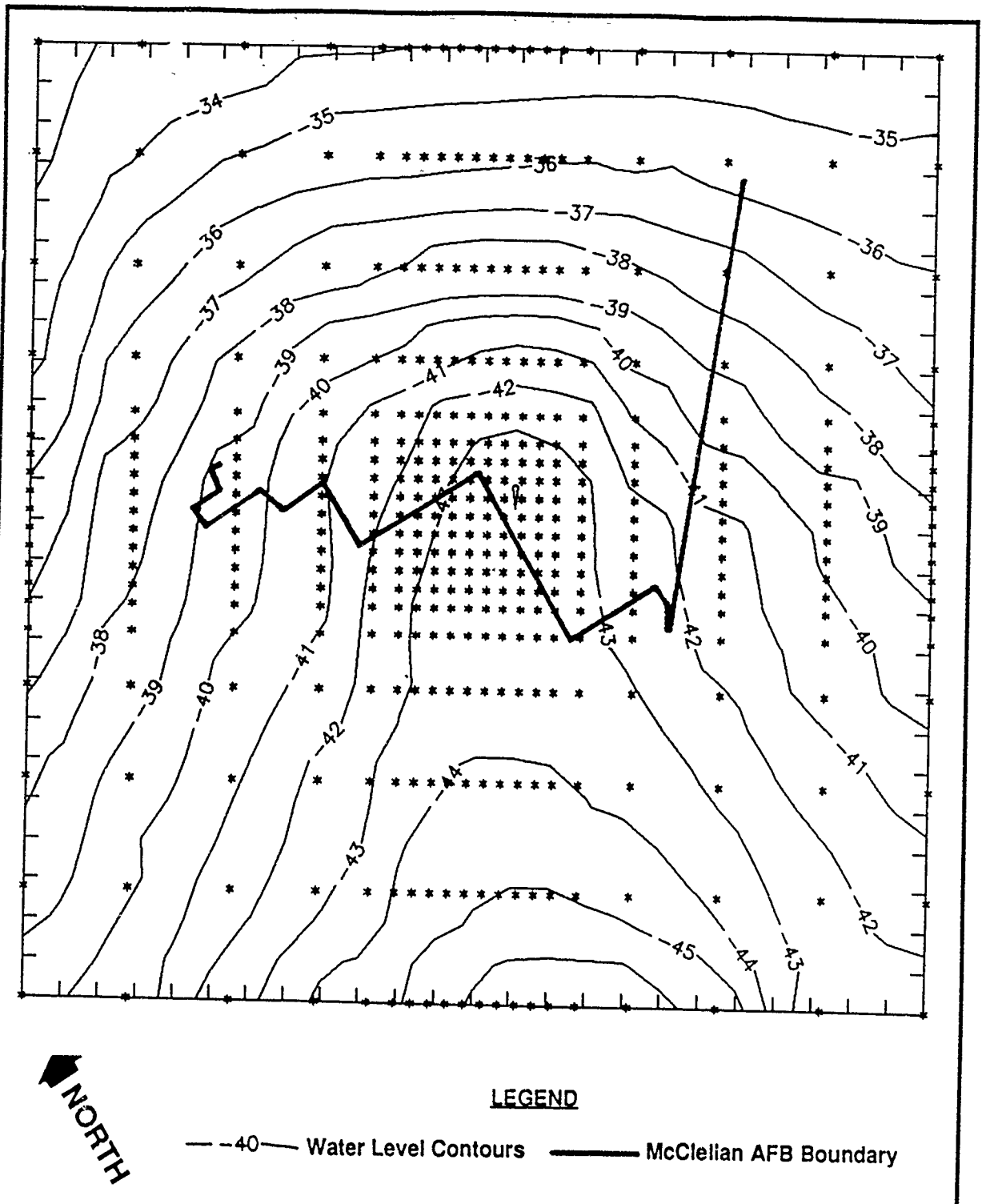

Figure A5-14. Calculated Pumping Heads - Zone A.

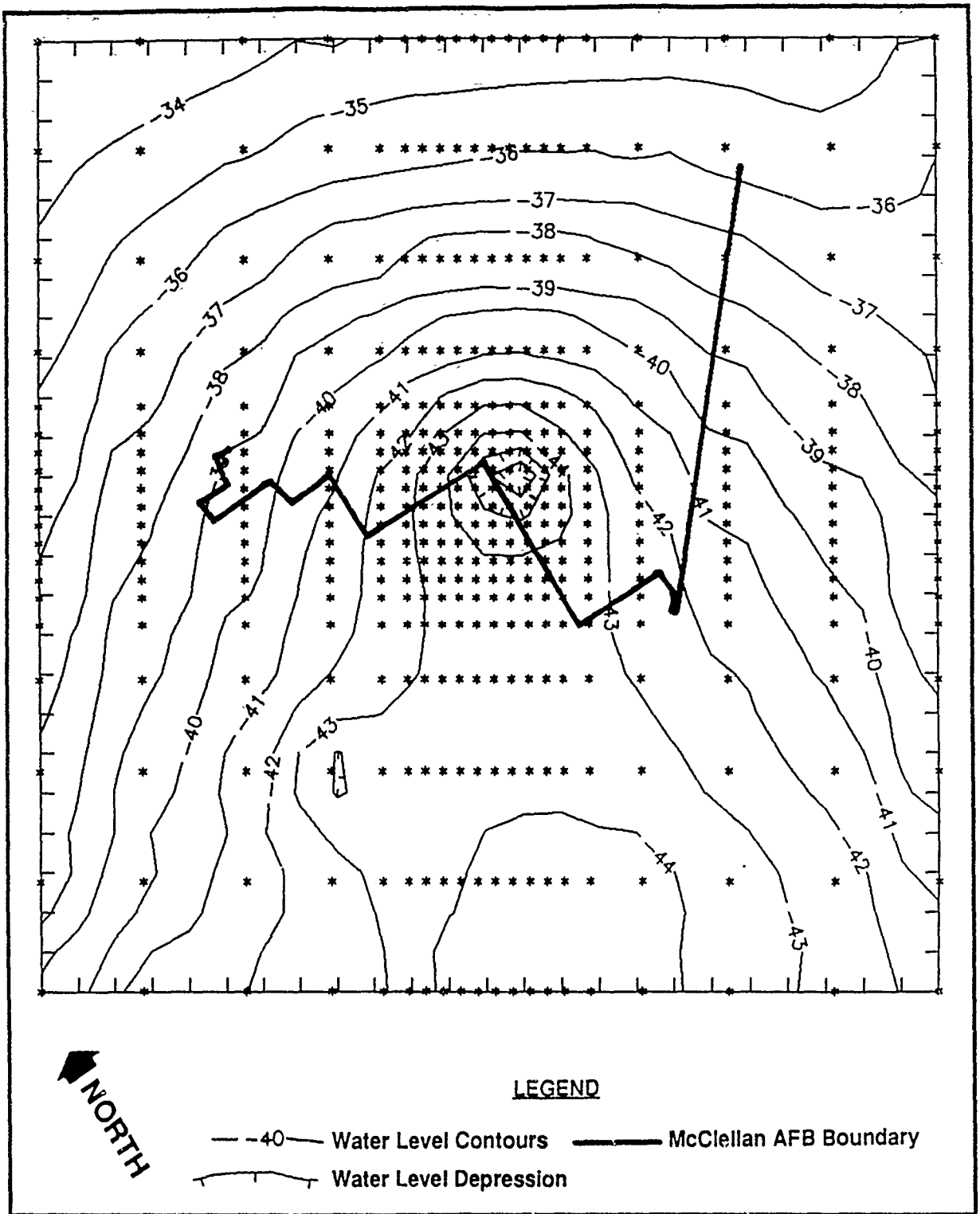

Figure A5-15. Calculated Pumping Heads - Zone B.

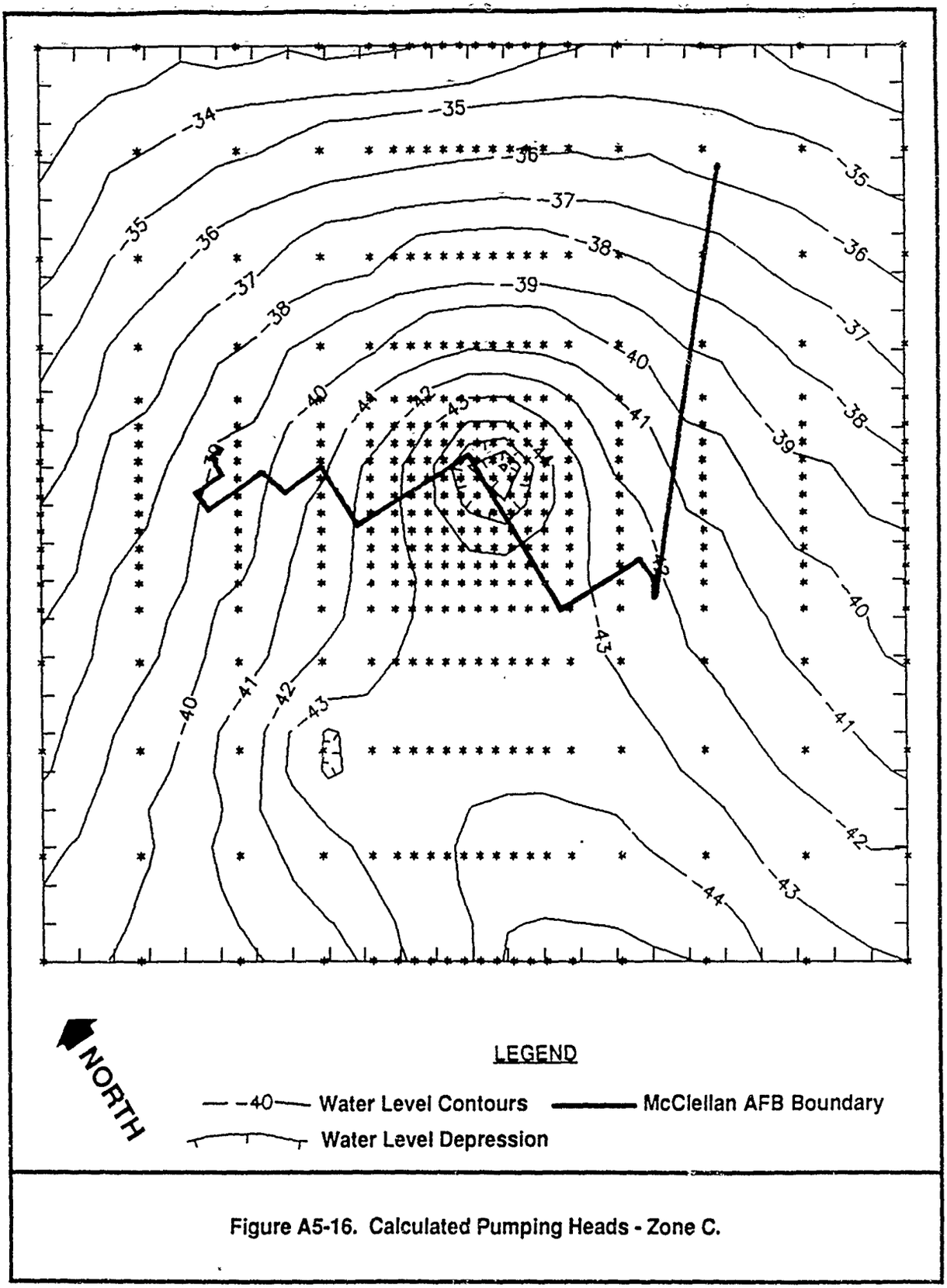

Figure A5-16. Calculated Pumping Heads - Zone C.

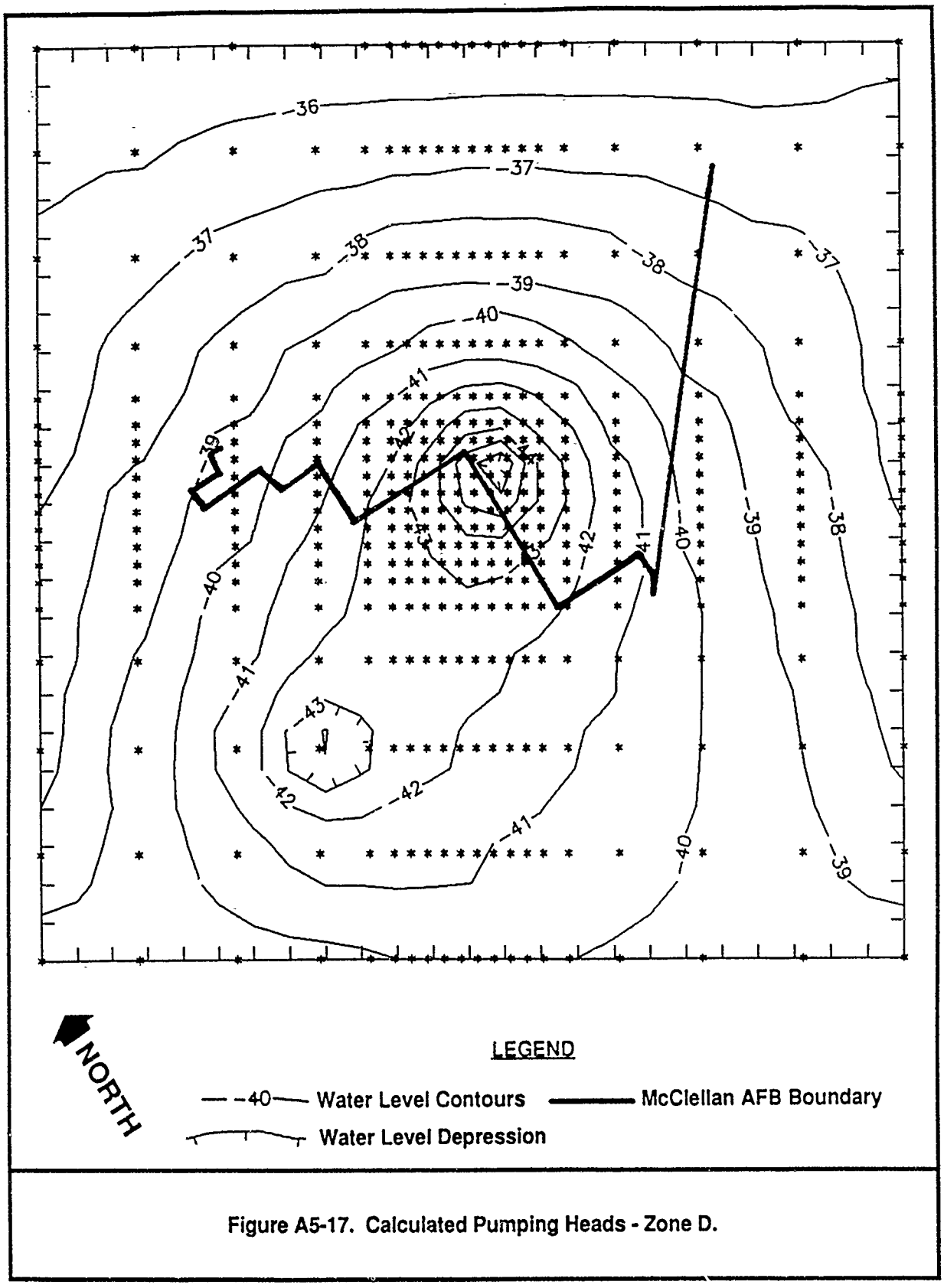

Figure A5-17. Calculated Pumping Heads - Zone D.

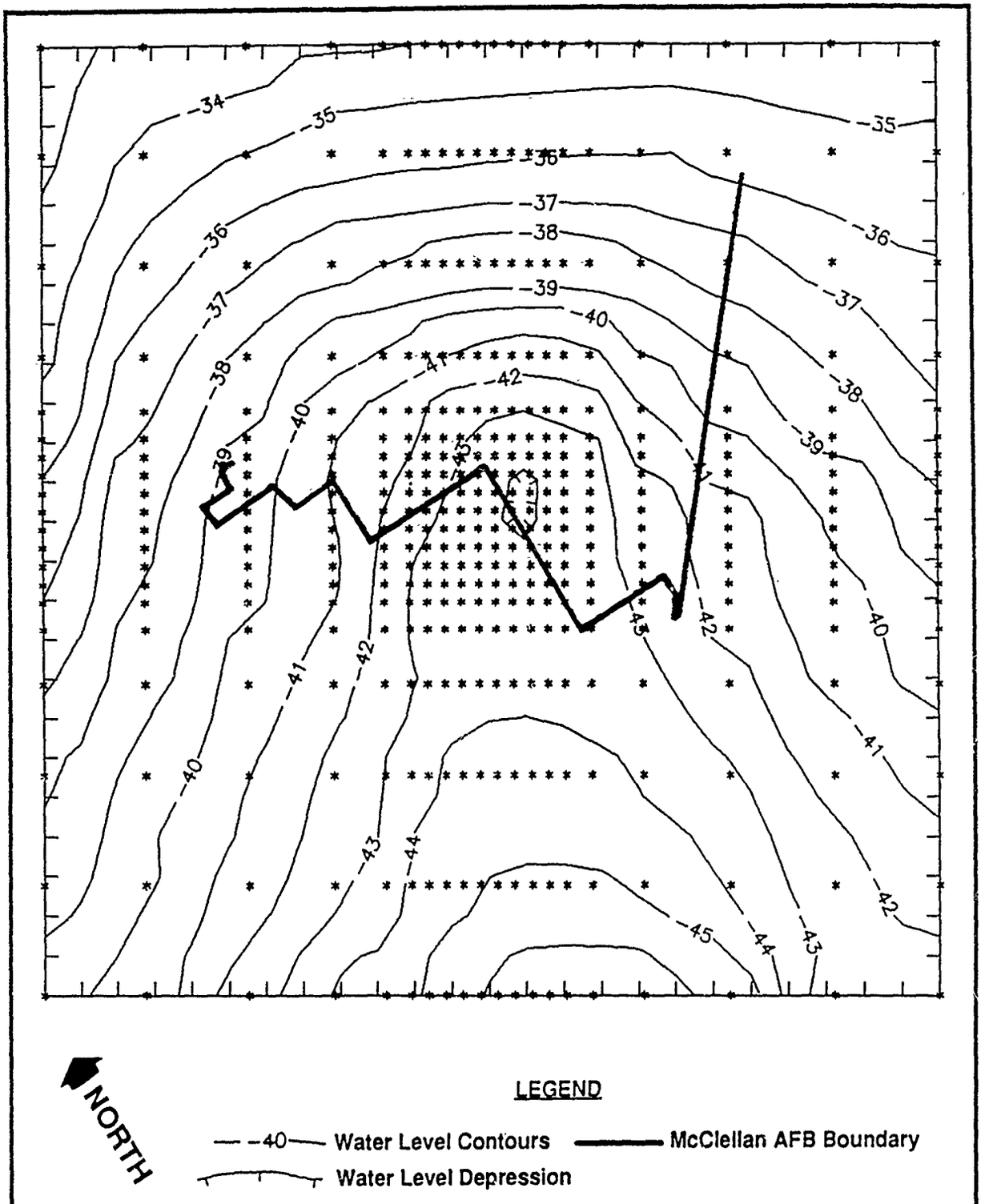

Figure A5-18. Simulation of Pumping BW-18, CW-131, and CW-155 - Zone A.

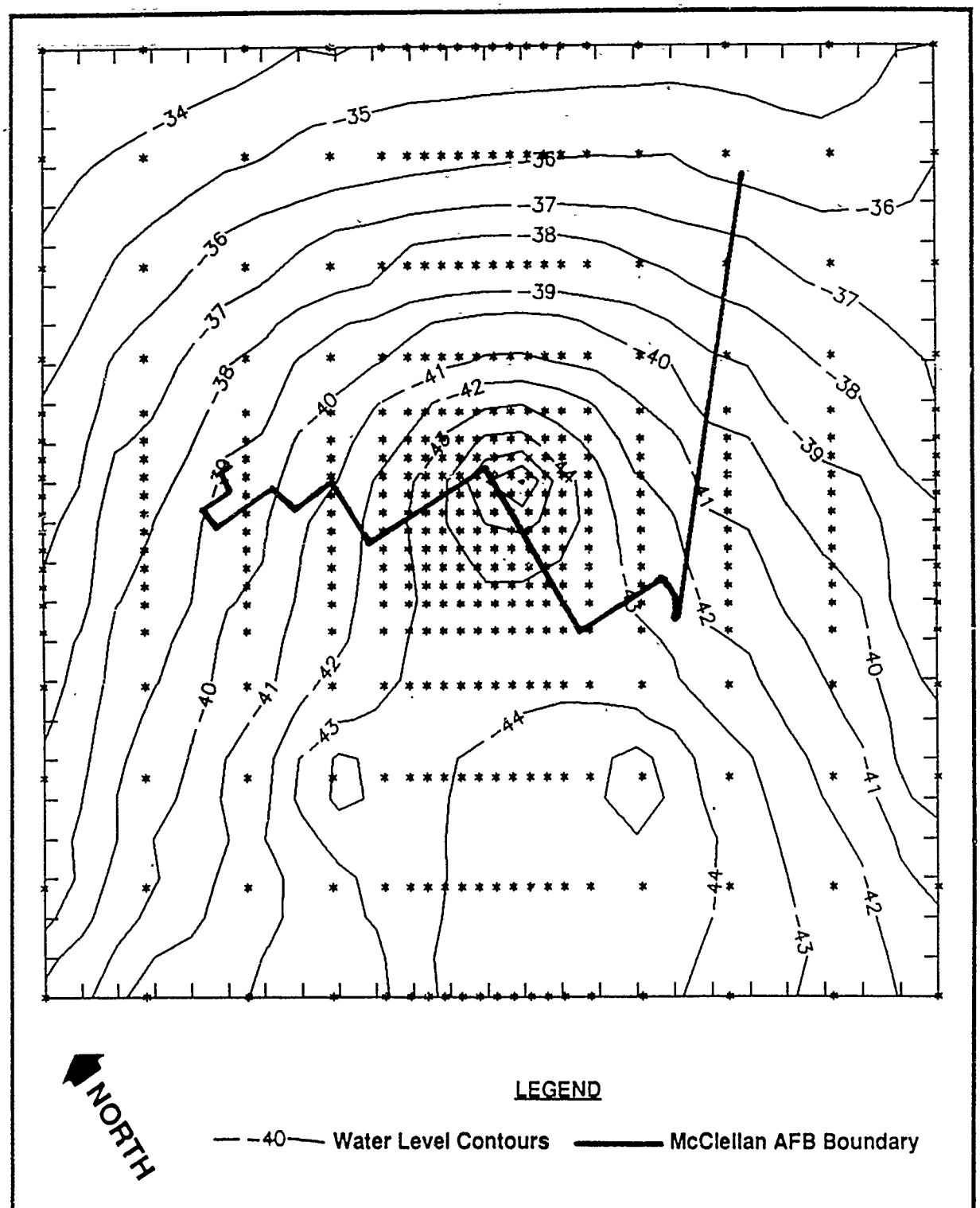

Figure A5-19. Simulation of Pumping BW-18, CW-131, and CW-155 - Zone B.

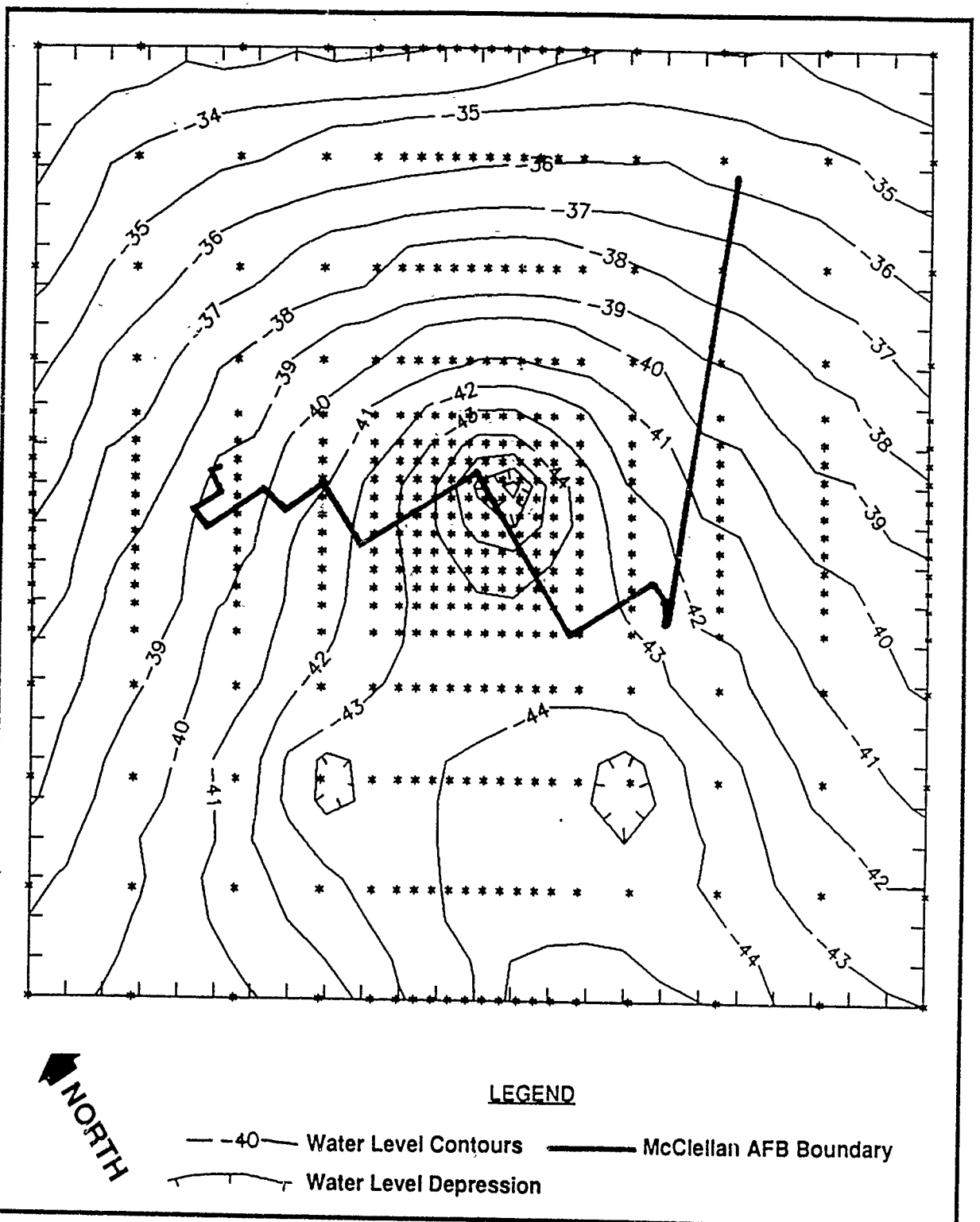

Figure A5-20. Simulation of Pumping BW-18, CW-131, and CW-155 - Zone C.

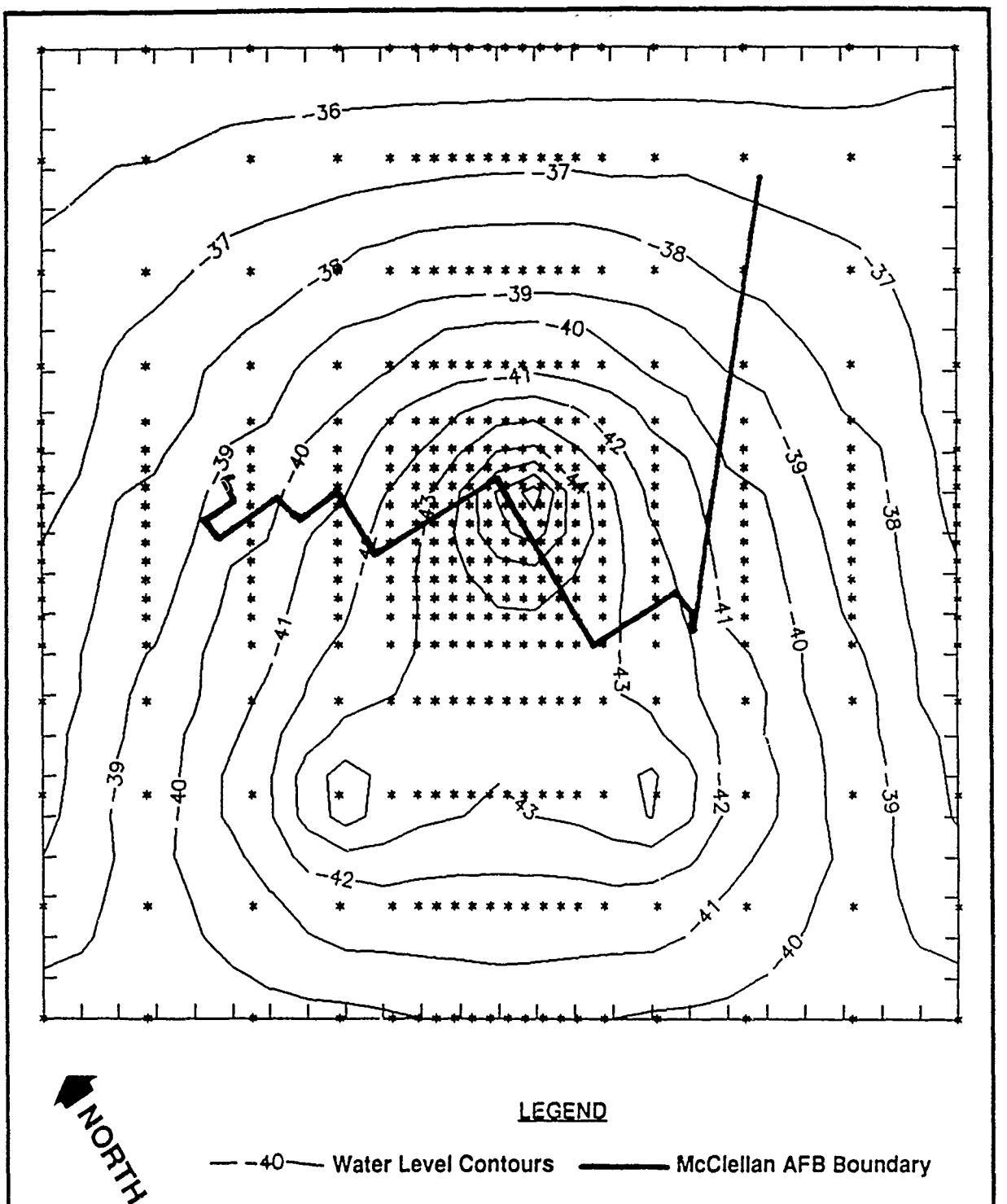

Figure A5-21. Simulation of Pumping BW-18, CW-131, and CW-155 - Zone D.

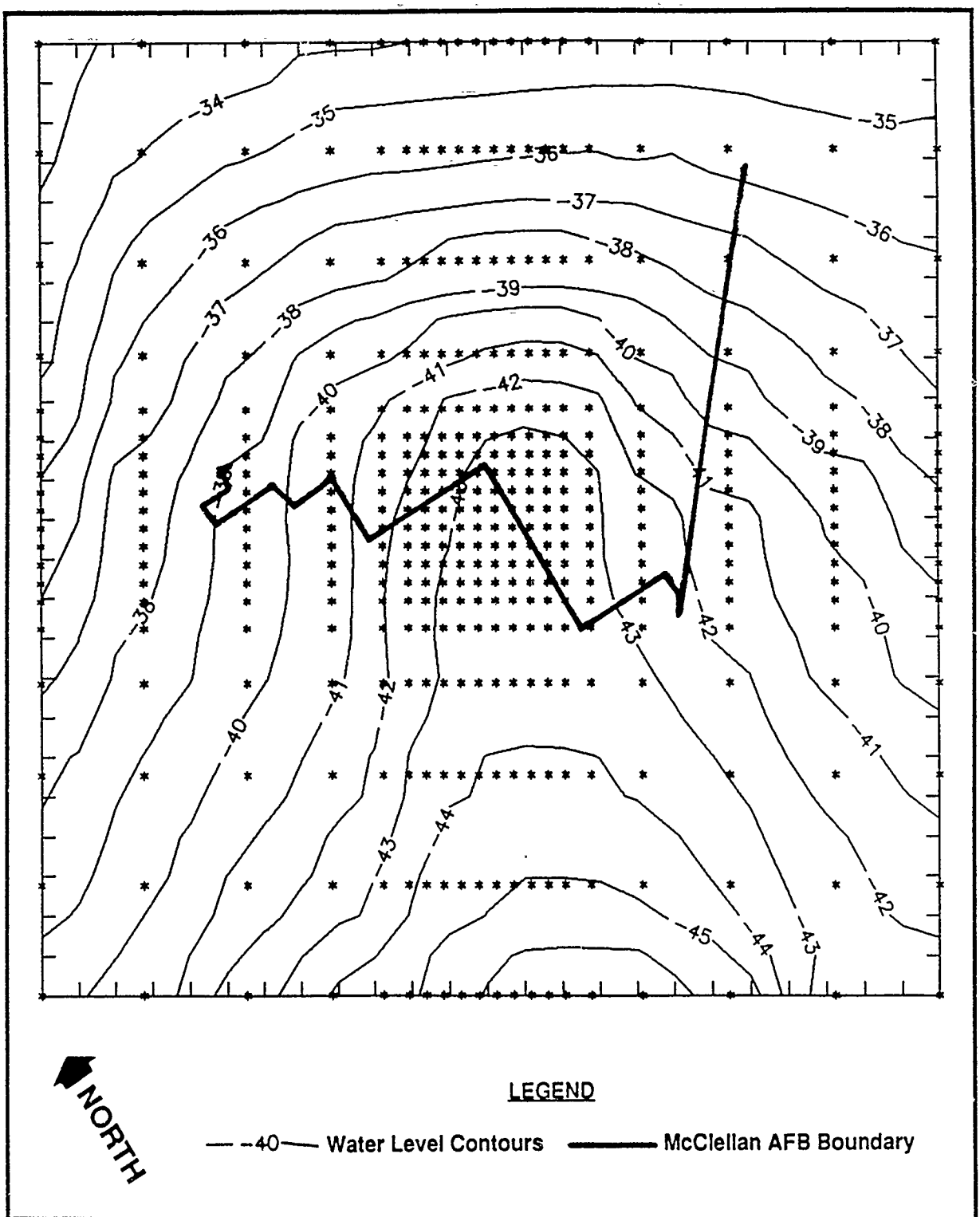

Figure A5-22. Simulation of Pumping BW-18 and CW-155 - Zone A.

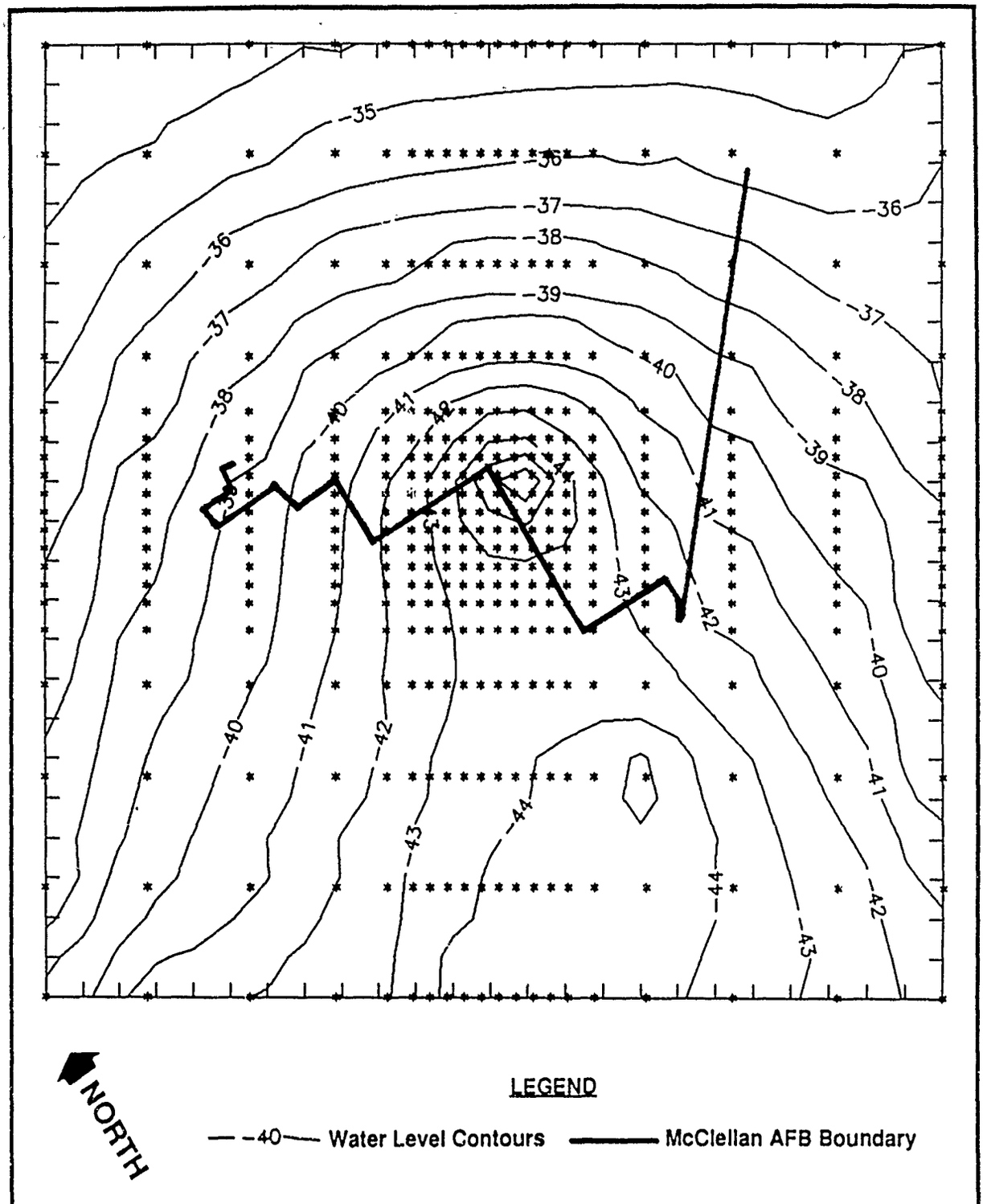

Figure A5-23. Simulation of Pumping BW-18 and CW-155 - Zone B.

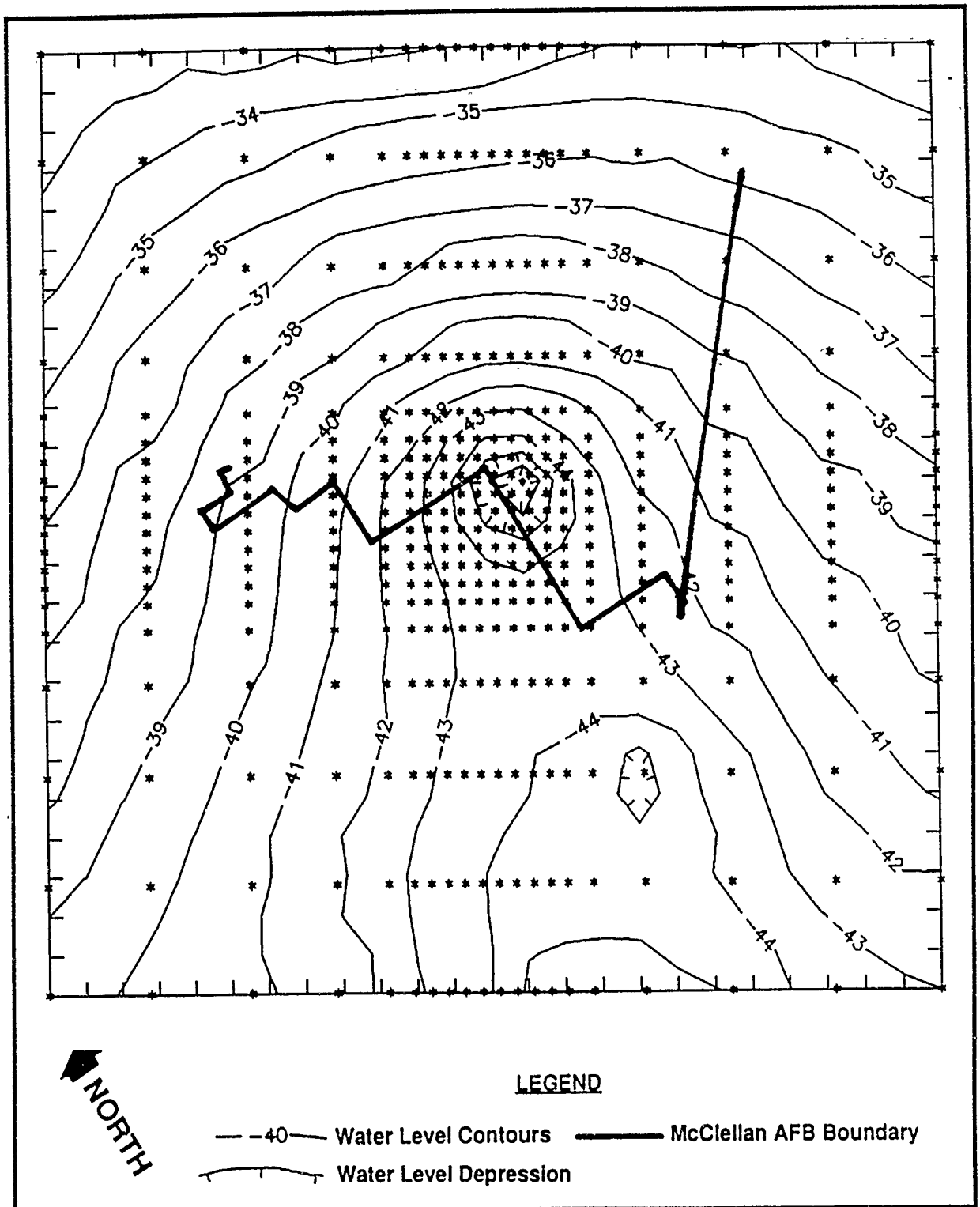

Figure A5-24. Simulation of Pumping BW-18 and CW-155 - Zone C.

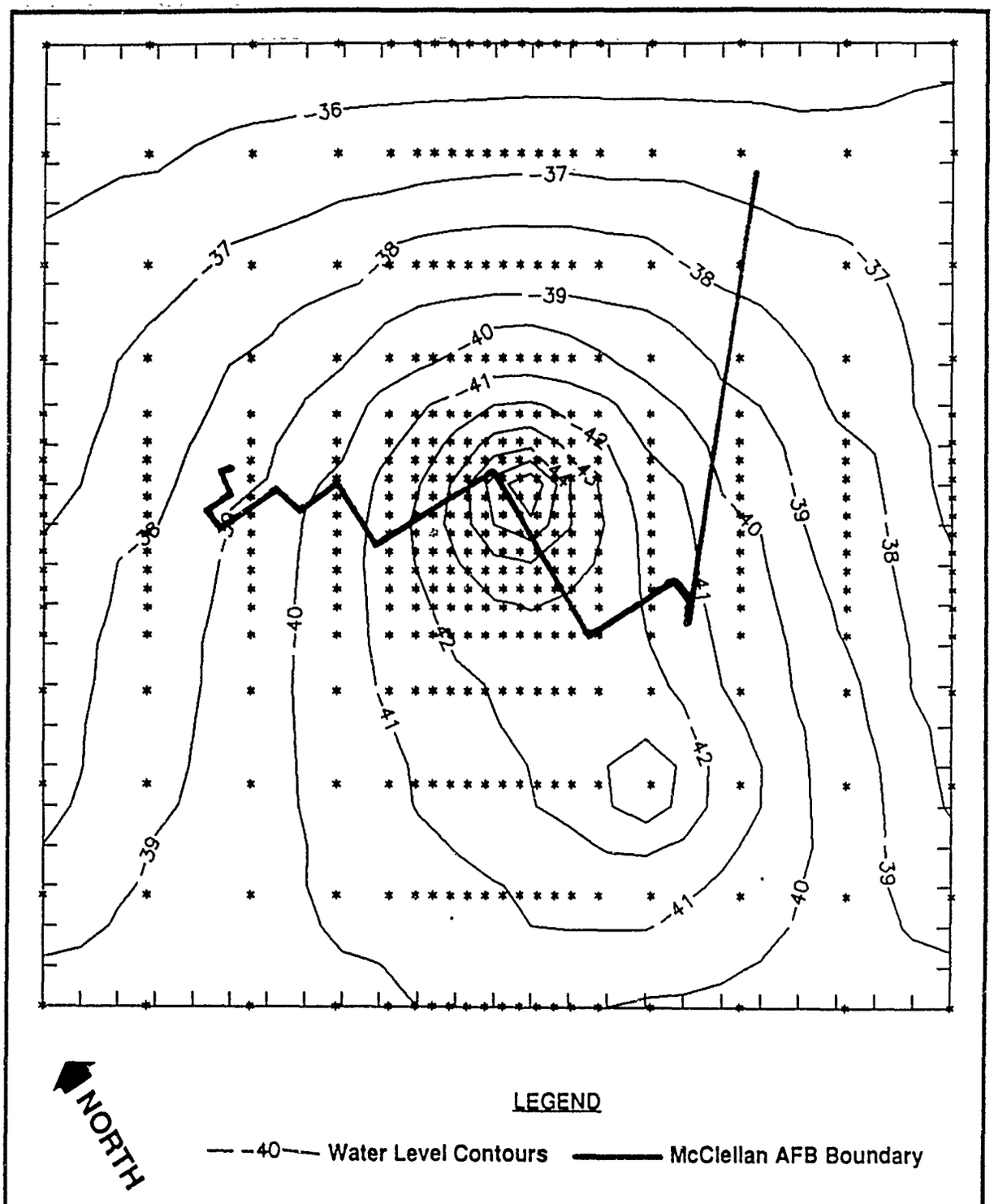

Figure A5-25. Simulation of Pumping BW-18 and CW-155 - Zone D.

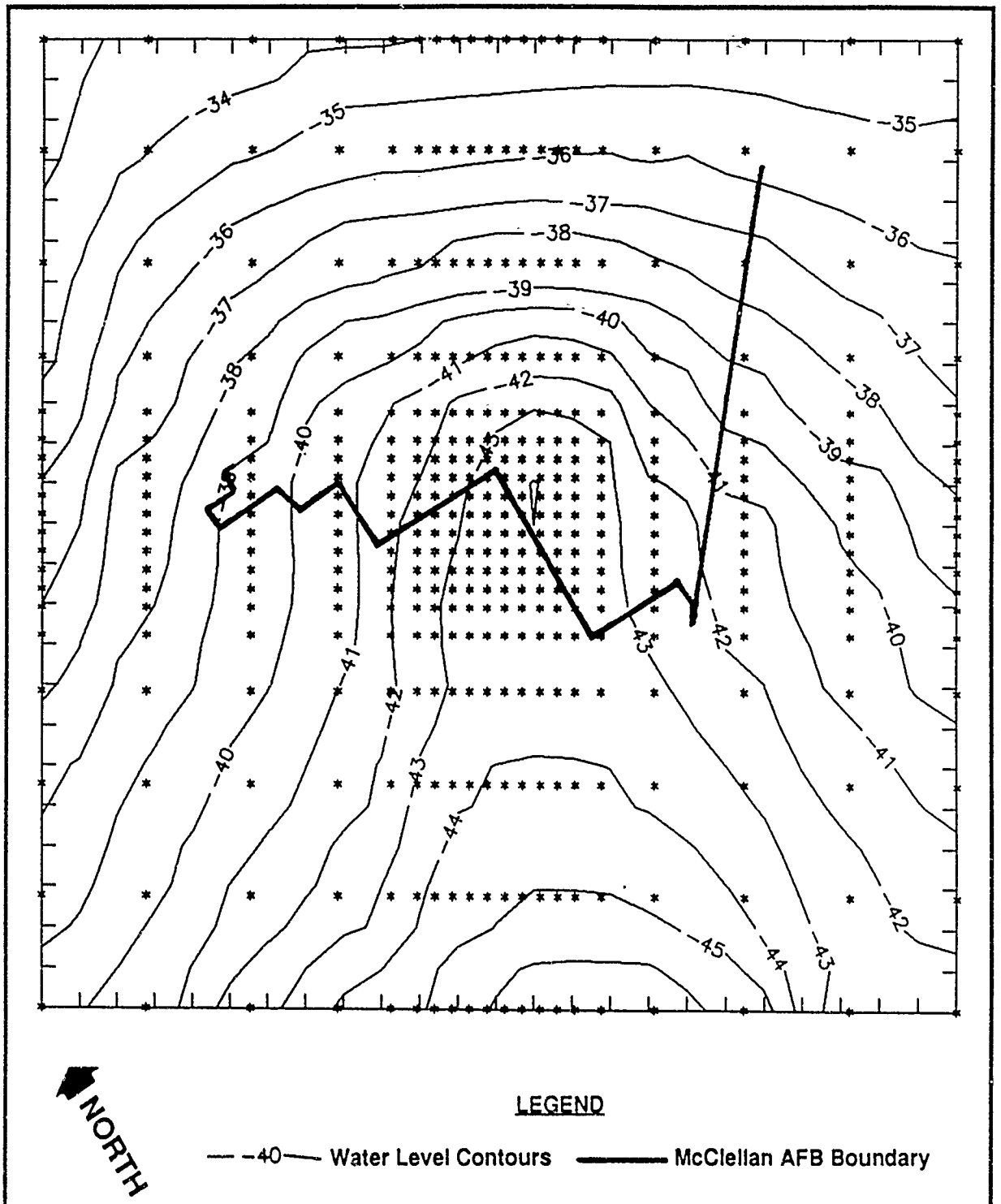

Figure A5-26. Simulation of Pumping BW-18, CW-155, and ERA 1/2 - Zone A.

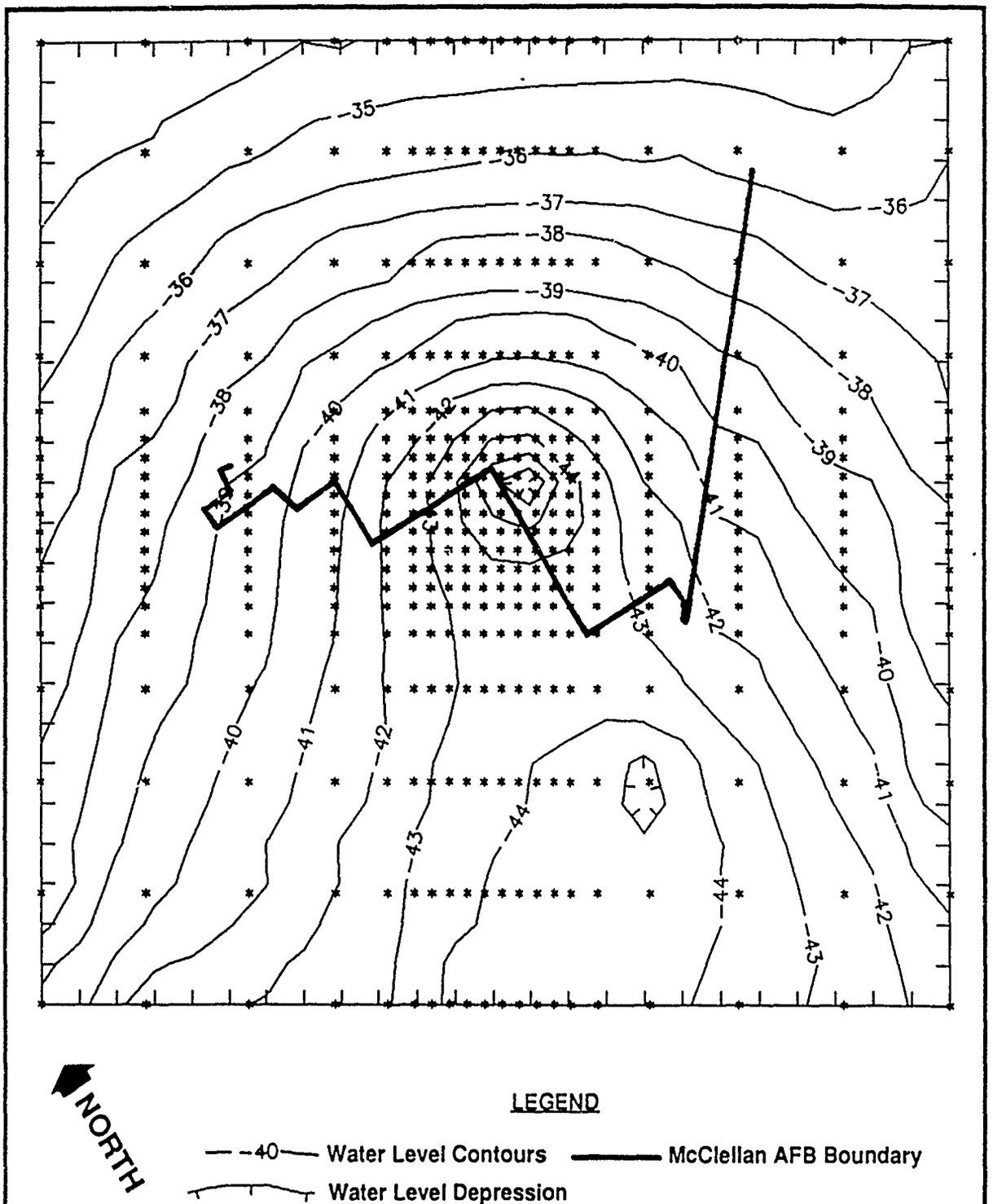

Figure A5-27. Simulation of Pumping BW-18, CW-155, and ERA 1/2 - Zone B.

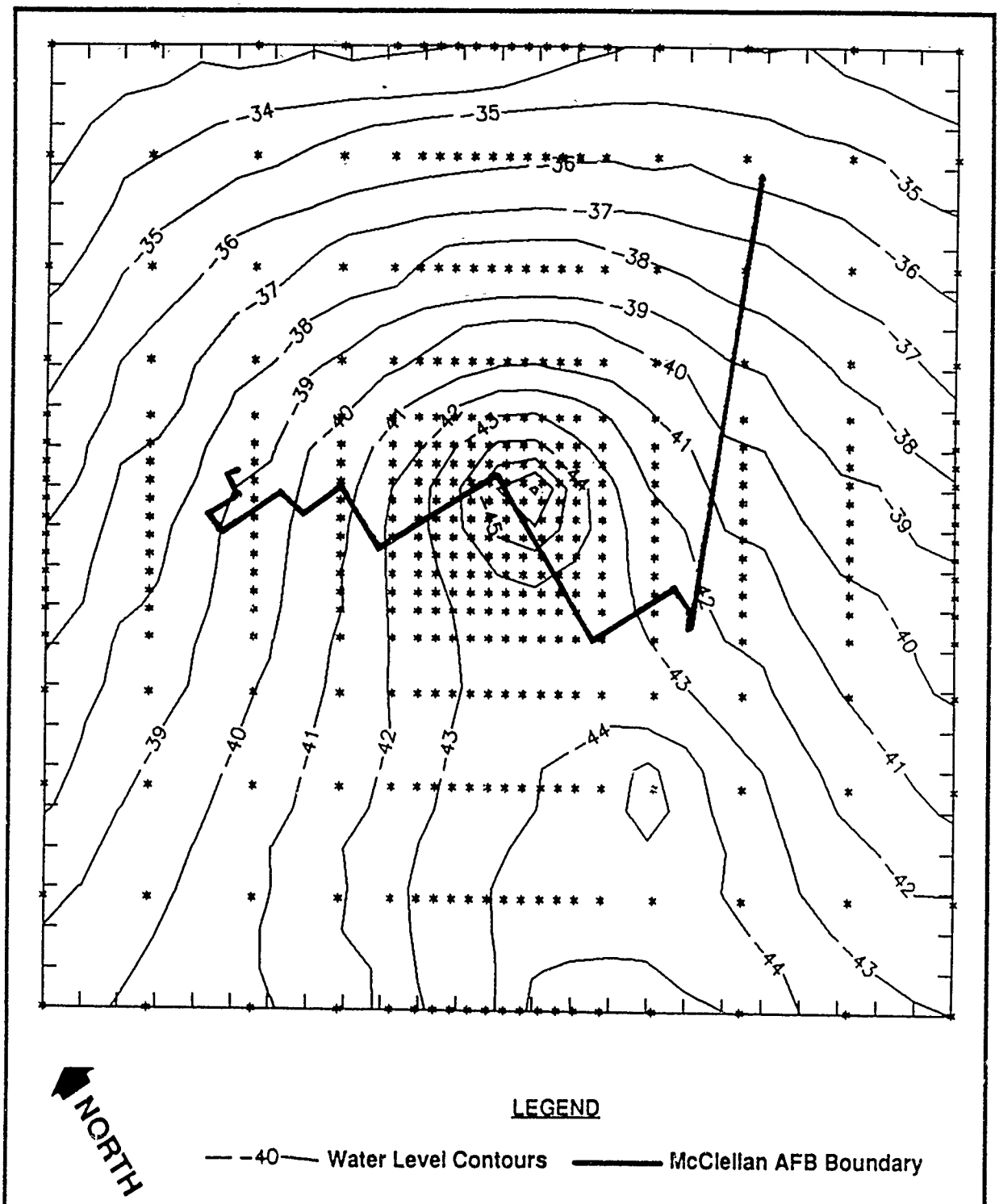

Figure A5-28. Simulation of Pumping BW-18, CW-155, and ERA 1/2 - Zone C.

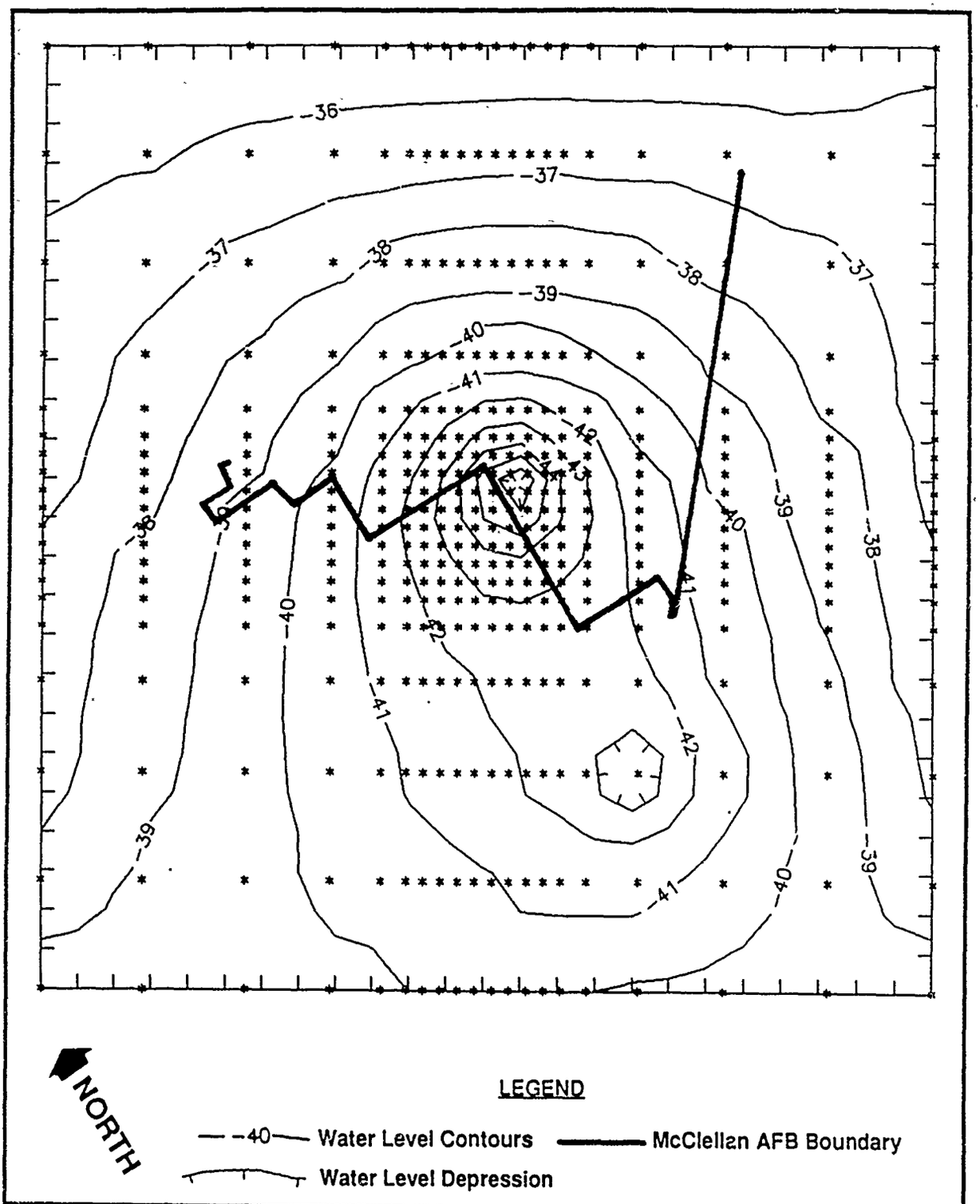

Figure A5-29. Simulation of Pumping BW-18, CW-155, and ERA 1/2 - Zone D.

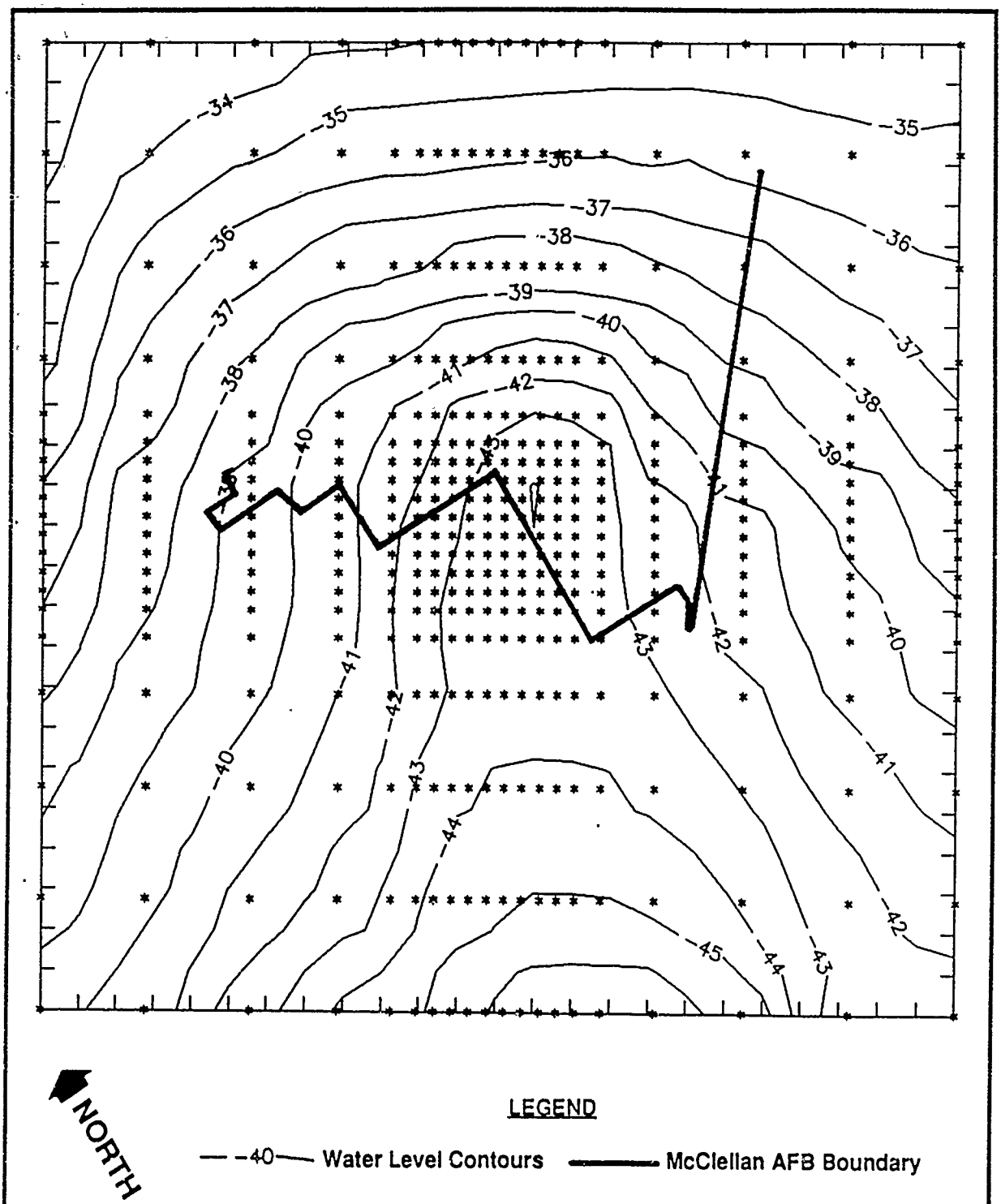

Figure A5-30. Simulation of Pumping BW-18, CW-155, ERA 1/2, and EW 3/4/5 - Zone A.

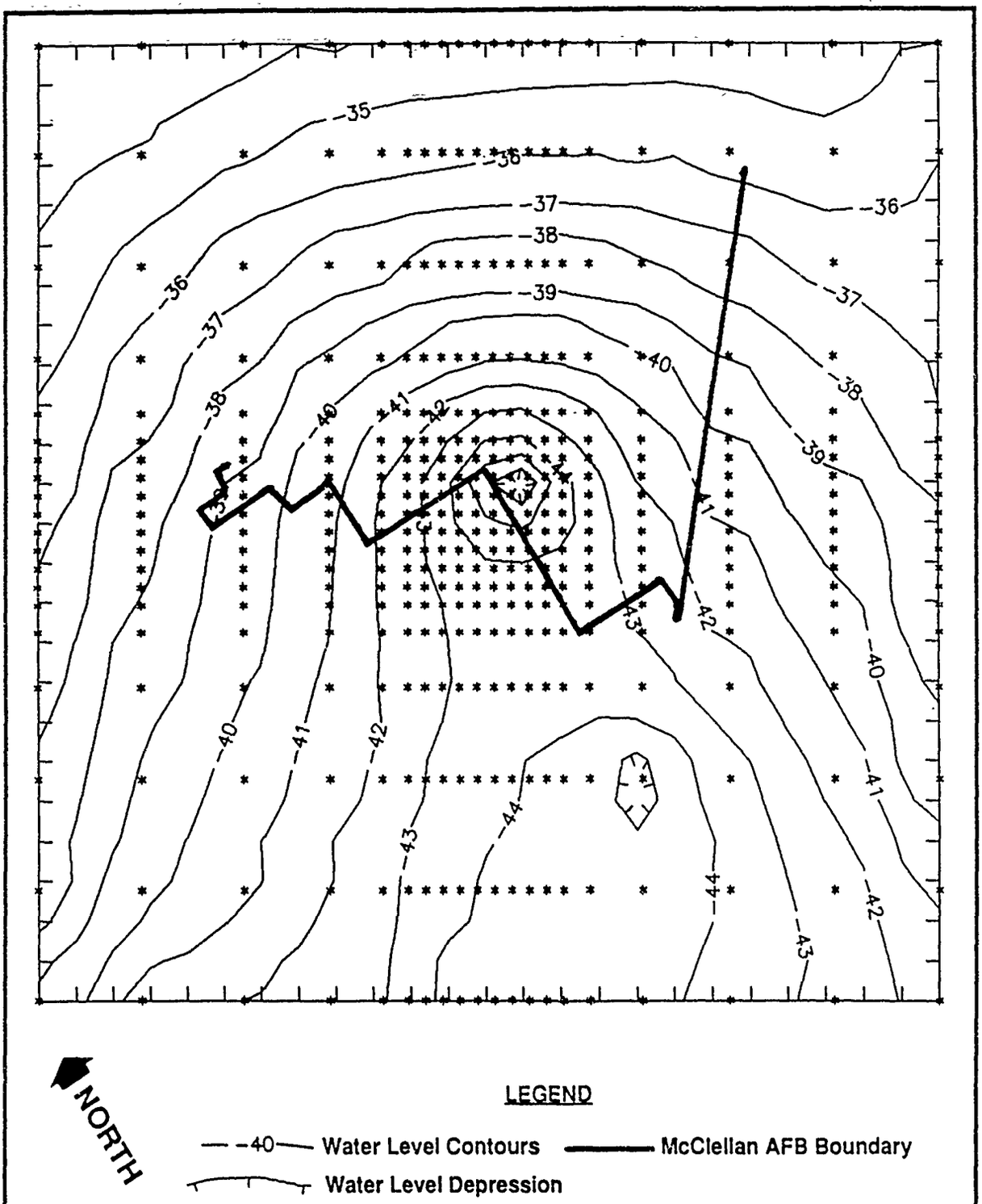

Figure A5-31. Simulation of Pumping BW-18, CW-155, ERA 1/2, and EW 3/4/5 - Zone B.

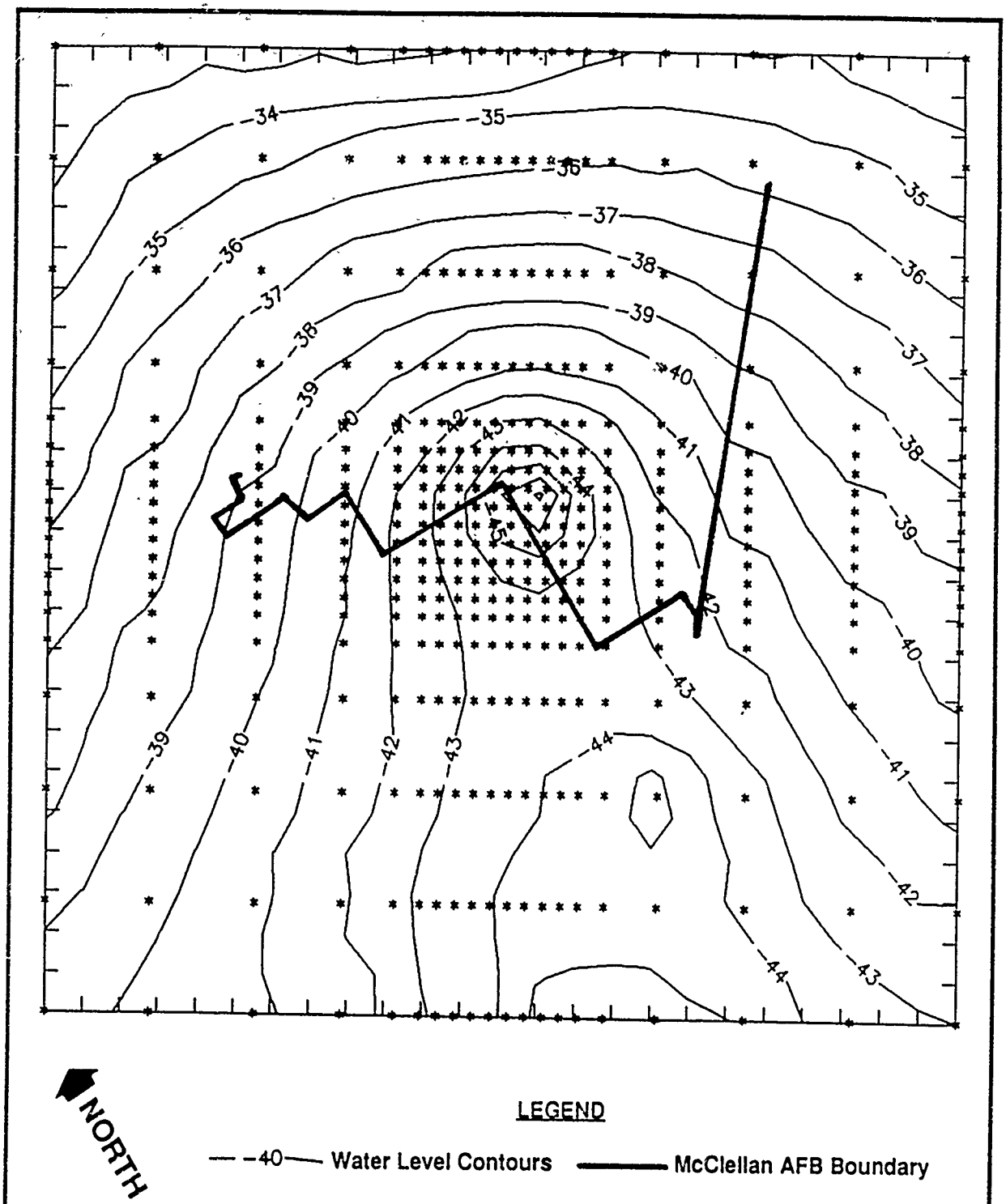

Figure A5-32. Simulation of Pumping BW-18, CW-155, ERA 1/2, and EW 3/4/5 - Zone C.

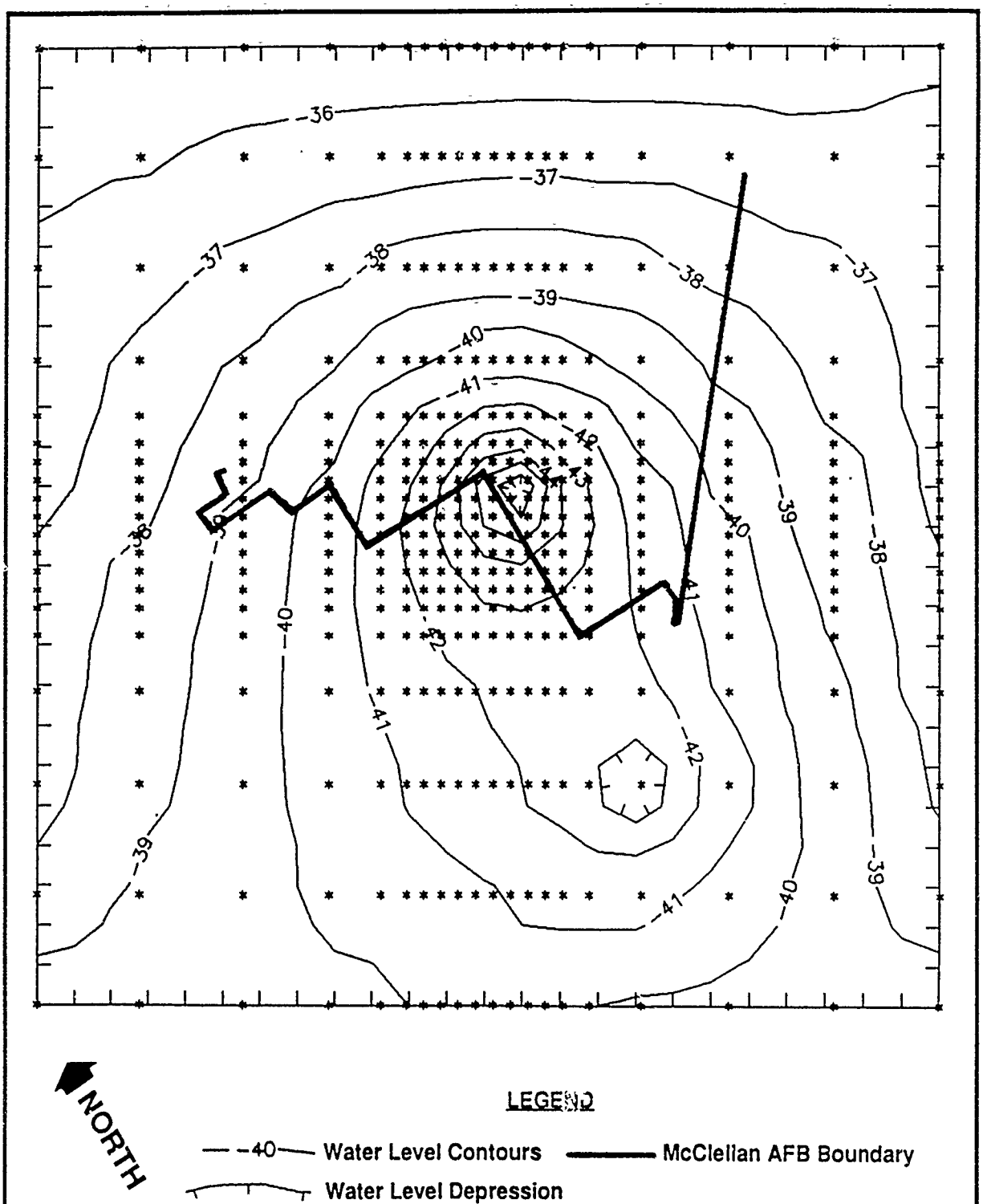

Figure A5-33. Simulation of Pumping BW-18, CW-155, ERA 1/2, and EW 3/4/5 - Zone D.

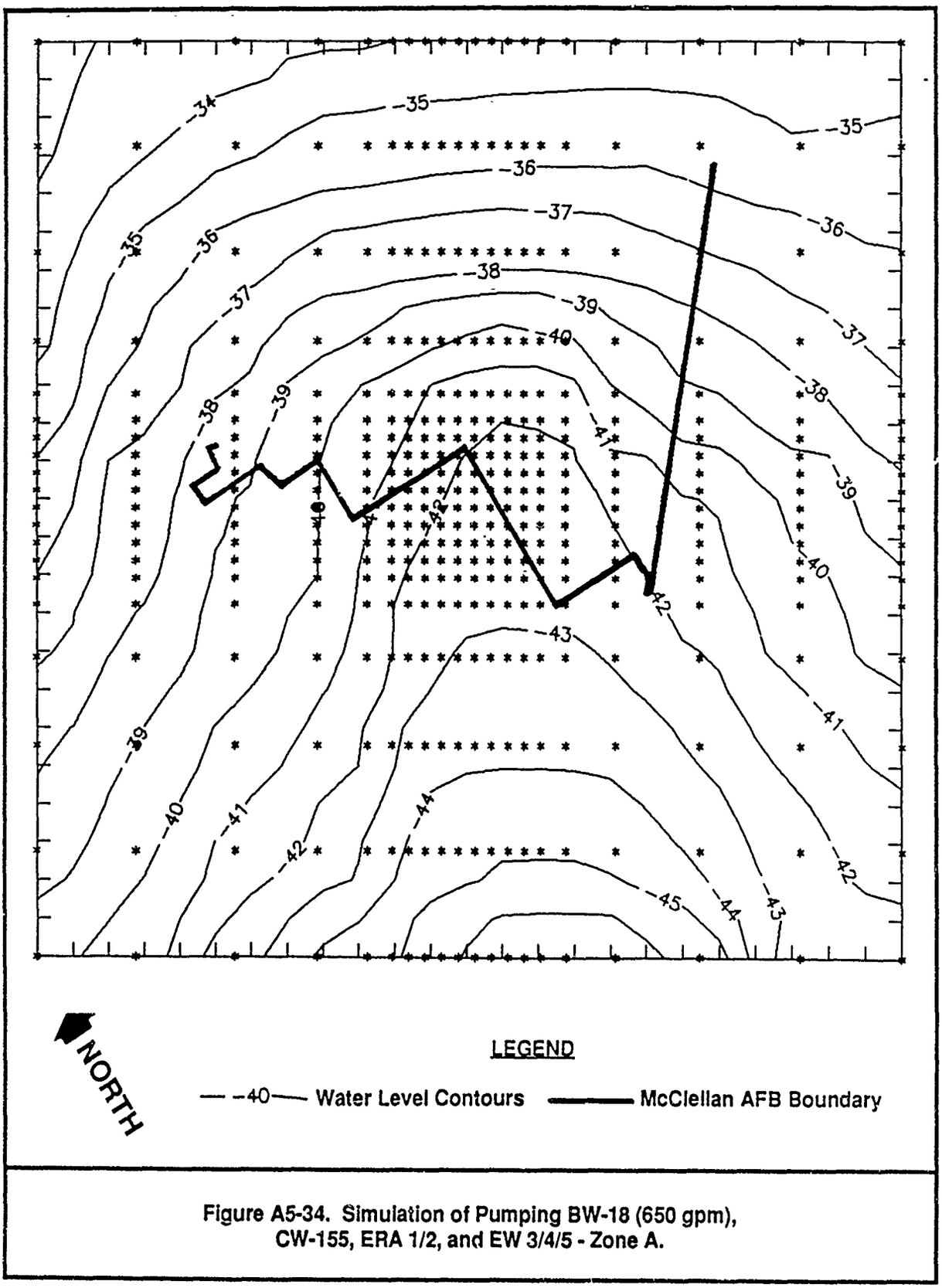

Figure A5-34. Simulation of Pumping BW-18 (650 gpm), CW-155, ERA 1/2, and EW 3/4/5 - Zone A.

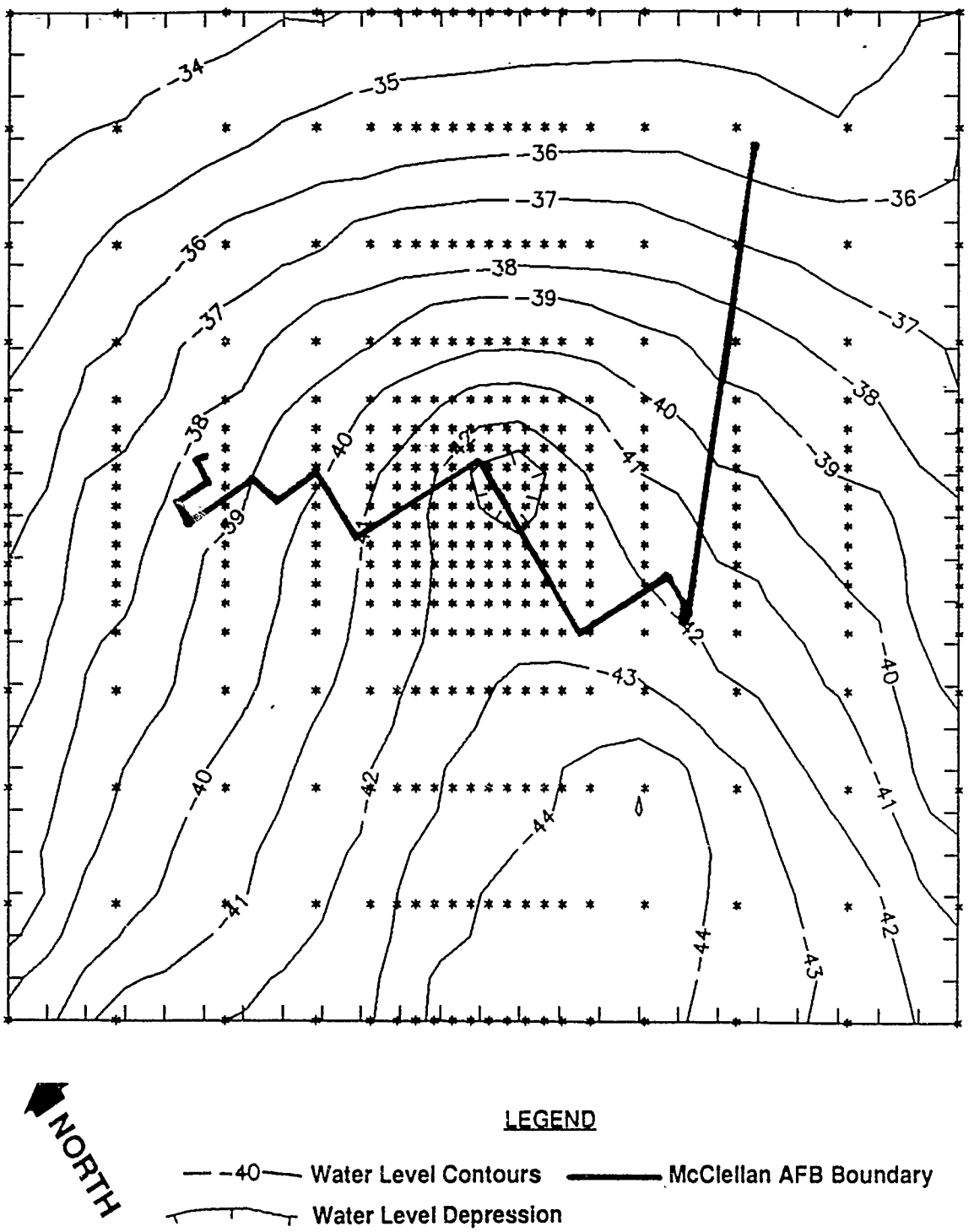

Figure A5-35. Simulation of Pumping BW-18 (650 gpm), CW-155, ERA 1/2, and EW 3/4/5 - Zone B.

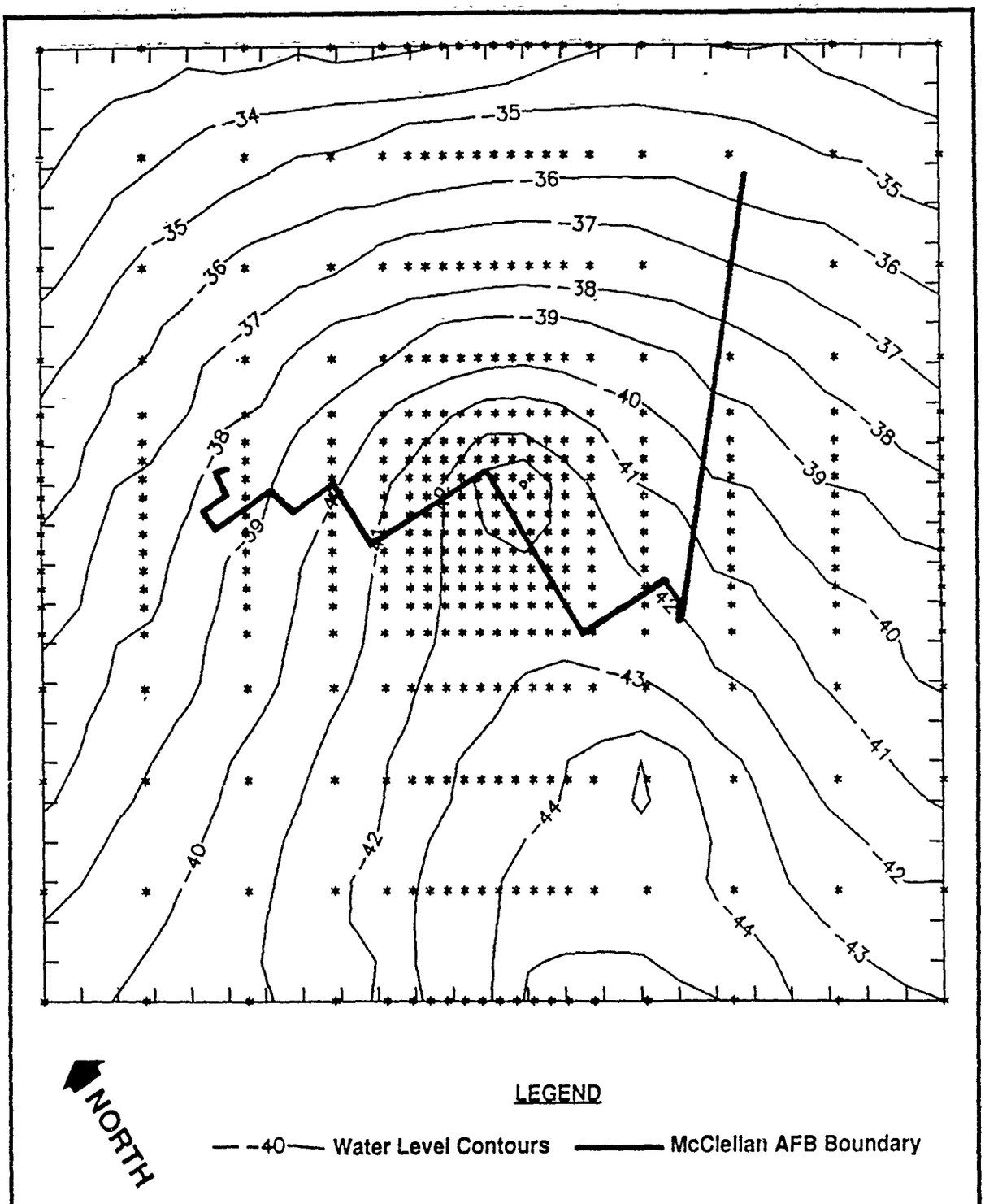

Figure A5-36. Simulation of Pumping BW-18 (650 gpm), CW-155, ERA 1/2, and EW 3/4/5 - Zone C.

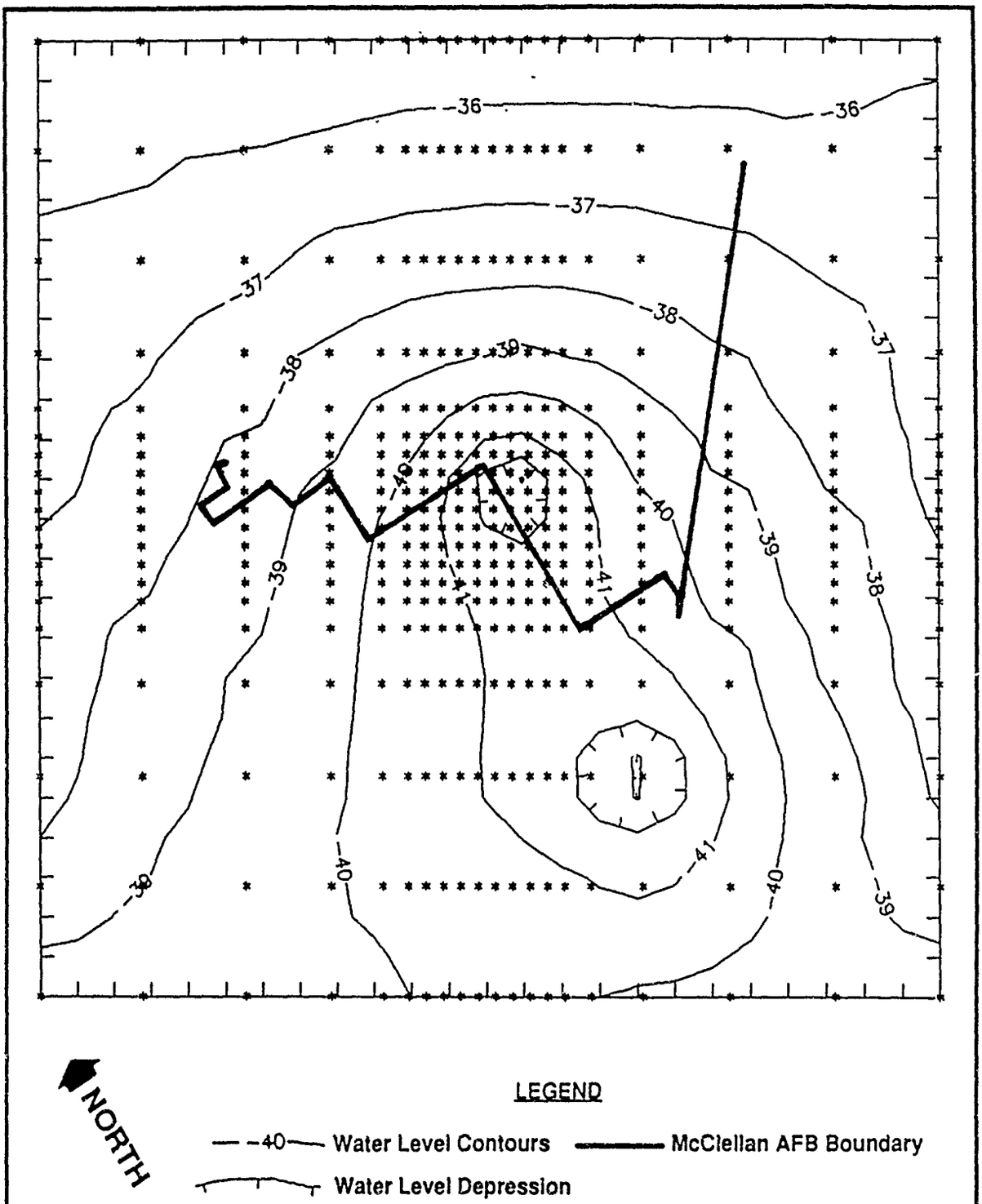

Figure A5-37. Simulation of Pumping BW-18 (650 gpm), CW-155, ERA 1/2, and EW 3/4/5 - Zone D.

TABLE A5-1. ESTIMATED HYDRAULIC PARAMETERS OF GEOHYDROLOGIC ZONES AT LOCATIONS WITHIN OU B

Area/Plume	Geohydrologic Zone	Test Interval (ft)	Hydraulic Conductivity of Test Interval (ft/day)	Saturated Thickness of Zone (feet)	Estimated Transmissivity of Zone (ft^2/day)	Storage Coefficient of Zone ($x10^{-3}$)
TCE/PCE Plume (Building 666 Area)	A	11.5 - 13.4	5 - 20 (100)[a]	30(-40 to -70)	150 - 600	1.0
	B	-	NT	66(-71 to -137)	200 - 400	0.5[b]
	C	-	NT	67(-138 to -205)	4,000 - 8,000	0.1[b]
	D	-	NT	98(-206 to -304)	2,000 - 4,000	0.1[b]
Northern TCE/1,2-DCE Plume (E - W boundary area)	A	10	30 - 55	30(-43 to -73)	900 - 1,650	1.0
	B	10	12[c] - 44	40(-79 to -119)	600[c] - 2,200	0.4
	C	70	59 - 74	70(-128 to -198)	4,100 to 5,200	0.1
	D	60	28	64(-196 to -260)	1,790 - 3,200	0.1
Southern TCE/1,2-DCE Plume (Southwest, off base)	A	30	18 - 39	43(-44 to -87)	770 - 1,680	0.9
	B	25	16	44(-88 to -132)	700 - 800	1.1
	C	-	NT	81(-132 to 213)	3,000 - 5,000	0.1
	D	-	NT	51(-214 to -265)	4,000 - 6,000	0.1
Near BW-18, off base	B	17 - 20	4 - 5	50(-67 to -114)	200 - 500	0.1
Near BW-18, on base	B	20	8 - 13	50(-67 to -114)	160 - 260	0.1 - 0.01
Northern OU B	B	30	36	30(-75 to -105)	1,070	0.1
	C	31	52	31 (-130 to -160)	1,600	0.16

NT = Not tested
a = Value estimated from grain size distribution or lithologic characteristics.
b = Estimated from measured values in other locations in OU B.
c = Value from previous single well testing in the area.

RADIAN CORPORATION

Table A5-2

Layer 1 Hydraulic Conductivity Original Input Data

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																				
2																				
3			30	30	30	30	30	30	30	30	20	20	20	20	20	20	20	20		
4			30	30	30	30	30	30	30	30	20	20	20	20	20	20	20	20		
5			30	30	30	30	30	30	30	30	20	20	7	7	7	20	20	20		
6			30	30	30	30	30	30	30	30	20	20	7	7	7	20	20	20		
7			30	30	30	30	30	40	40	40	40	40	7	7	7	20	20	20		
8			30	30	30	40	40	40	40	40	40	40	20	20	20	20	20	20		
9			40	40	40	40	40	40	40	40	40	40	20	20	20	20	20	20		
10			40	40	40	40	40	40	40	40	40	40	50	50	50	50	50	50		
11			40	40	40	40	40	40	40	40	40	50	50	50	50	50	50	50		
12			40	40	40	40	40	40	40	40	40	50	50	50	50	50	50	50		
13			40	40	40	40	40	40	40	40	60	60	60	50	50	50	50	50		
14			40	40	40	40	40	40	40	60	60	60	60	60	50	50	50	50		
15			40	40	40	40	40	40	40	60	60	60	60	60	60	60	60	60		
16			40	40	40	40	40	40	60	60	60	60	60	60	60	60	60	60		
17			40	40	40	40	40	60	60	60	60	60	60	60	60	60	60	60		
18			40	40	40	40	40	60	60	60	60	60	60	60	60	60	60	60		
19																				
20																				

* The original grid was 16 x 16. When the grid was extended, the parameter values were estimated based on the value at the nearest cell.

Table A5-3

Layer 2 Transmissivity Original Input data

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																				
2																				
3			1100	1100	1100	1100	1100	1100	1100	1100	600	600	600	600	600	600	600	600		
4			1100	1100	1100	1100	1100	1100	1100	1100	600	600	600	600	600	600	600	600		
5			1100	1100	1100	1100	1100	1100	1100	1100	600	600	600	600	600	600	600	600		
6			1100	1100	1100	1100	1100	1100	1100	1100	600	600	600	600	600	600	600	600		
7			1100	1100	1100	400	400	400	400	400	200	200	200	200	200	600	600	600		
8			400	400	400	400	400	400	400	400	200	200	200	200	200	600	600	600		
9			400	400	400	400	400	400	400	400	200	200	200	200	200	600	600	600		
10			400	400	400	400	400	400	400	400	200	200	200	200	200	600	600	600		
11			400	400	400	400	400	400	400	400	200	200	200	200	200	600	600	600		
12			400	400	400	400	400	400	400	400	400	400	400	400	400	600	600	600		
13			400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400		
14			400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400		
15			400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400		
16			400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400		
17			400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400		
18			400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400		
19																				
20																				

* The original grid was 16 x 16. When the grid was extended, the parameter values were estimated based on the value at the nearest cell.

Table A5-4

Layer 3 Transmissivity Original Input Data

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																				
2																				
3			1600	1600	1600	1600	1600	1600	1600	1600	1600	4300	4300	4300	4300	4300	4300	4300		
4			1600	1600	1600	1600	1600	1600	1600	1600	1600	4300	4300	4300	4300	4300	4300	4300		
5			1600	1600	1600	1600	1600	1600	1600	1600	1600	4300	4300	4300	6000	6000	6000	6000		
6			1600	1600	1600	1600	1600	1600	1600	1600	4300	4300	6000	6000	6000	6000	6000	6000		
7			1600	1600	1600	1600	1600	4300	4300	4300	4300	4300	6000	6000	6000	6000	6000	6000		
8			1600	1600	1600	1600	4300	4300	4300	4300	4300	6000	6000	6000	6000	4000	4000	4000		
9			1600	1600	4300	4300	4300	4300	4300	4300	6000	6000	6000	6000	6000	4000	4000	4000		
10			4300	4300	4300	4300	4300	4300	4300	6000	6000	6000	6000	4000	4000	4000	4000	4000		
11			4300	4300	4300	4300	4300	6000	6000	6000	6000	6000	6000	4000	4000	4000	4000	4000		
12			4300	4300	6000	6000	6000	6000	6000	6000	6000	4000	4000	4000	4000	4000	4000	4000		
13			6000	6000	6000	6000	6000	6000	6000	6000	4000	4000	4000	4000	4000	4000	4000	4000		
14			6000	6000	6000	6000	6000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000		
15			4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000		
16			4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000		
17			4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000		
18			4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000		
19																				
20																				

* The original grid was 16 x 16. When the grid was extended, the parameter values were estimated based on the value at the nearest cell.

RADIAN CORPORATION

Table A5-5

Layer 4 Transmissivity Original Input Data

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																				
2																				
3			4000	4000	4000	4000	4000	4000	4000	4000	4000	2000	2000	2000	2000	2000	2000	2000		
4			4000	4000	4000	4000	4000	4000	4000	4000	4000	2000	2000	2000	2000	2000	2000	2000		
5			4000	4000	4000	4000	4000	4000	4000	4000	4000	2000	2000	2000	2000	2000	2000	2000		
6			4000	4000	4000	4000	4000	4000	4000	4000	4000	2000	2000	2000	2000	2000	2000	2000		
7			4000	4000	4000	4000	3000	3000	3000	3000	3000	2000	2000	2000	2000	2000	2000	2000		
8			3000	3000	3000	3000	3000	3000	3000	3000	3000	2000	2000	2000	2000	2000	2000	2000		
9			3000	3000	3000	3000	3000	3000	3000	3000	3000	2000	2000	2000	2000	2000	2000	2000		
10			3000	3000	3000	3000	3000	3000	3000	3000	3000	2000	2000	2000	2000	2000	2000	2000		
11			3000	3000	3000	3000	3000	3000	3000	3000	3000	4500	4500	4500	4500	4500	4500	4500		
12			3000	3000	3000	3000	3000	3000	3000	4500	4500	4500	4500	4500	4500	4500	4500	4500		
13			3000	3000	3000	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500		
14			4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500		
15			4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500		
16			4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500		
17			4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500		
18			4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500		
19																				
20																				

* The original grid was 16 x 16. When the grid was extended, the parameter values were estimated based on the value at the nearest cell.

RADIAN CORPORATION

Table A5-6

Layers 1 and 2 Aquitard VCONT Original Input Data

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																				
2																				
3			0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006		
4			0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006		
5			0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.163	0.163	0.163	0.006	0.006	0.006	0.006		
6			0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.163	0.163	0.163	0.006	0.006	0.006	0.006		
7			0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006		
8			0.005	0.005	0.040	0.040	0.040	0.048	0.048	0.048	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006		
9			0.040	0.040	0.040	0.040	0.040	0.048	0.048	0.048	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006		
10			0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006		
11			0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.011	0.011	0.011	0.011	0.011		
12			0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.011	0.011	0.011	0.011	0.011		
13			0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.011	0.011	0.011	0.011	0.011		
14			0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.011	0.011	0.011	0.011	0.011		
15			0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.011	0.011	0.011	0.011	0.011		
16			0.040	0.040	0.040	0.040	0.040	0.040	0.040	1.440	1.440	1.440	1.440	1.440	0.011	0.011	0.011	0.011		
17			0.040	0.040	0.040	0.040	0.040	0.040	0.040	1.440	1.440	1.440	1.440	1.440	0.011	0.011	0.011	0.011		
18			0.040	0.040	0.040	0.040	0.040	0.040	0.040	1.440	1.440	1.440	1.440	1.440	0.011	0.011	0.011	0.011		
19																				
20																				

* The original grid was 16 x 16. When the grid was extended, the parameter values were estimated based on the value at the nearest cell.

RADIAN CORPORATION

Table A5-7

Layers 2 and 3 Aquitard VCONT Original Input Data

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																				
2			0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.022	0.022	0.022	0.022	0.022	0.022	0.022		
3			0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022		
4			0.006	0.006	0.006	0.028	0.028	0.028	0.028	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022		
5			0.006	0.028	0.028	0.028	0.028	0.028	0.028	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022		
6			0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022		
7			0.028	0.028	0.028	0.028	0.006	0.006	0.006	0.017	0.017	0.017	0.017	0.017	0.017	0.022	0.022	0.022		
8			0.028	0.028	0.028	0.028	0.006	0.006	0.006	0.017	0.017	0.017	0.017	0.017	0.017	0.022	0.022	0.022		
9			0.028	0.028	0.028	0.054	0.054	0.054	0.054	0.017	0.017	0.017	0.017	0.042	0.042	0.042	0.042	0.042		
10			0.028	0.028	0.028	0.054	0.054	0.054	0.054	0.031	0.031	0.031	0.042	0.042	0.042	0.042	0.042	0.042		
11			0.028	0.028	0.028	0.054	0.054	0.054	0.031	0.031	0.031	0.031	0.042	0.272	0.272	0.042	0.042	0.042		
12			0.028	0.028	0.028	0.028	0.028	0.031	0.031	0.031	0.031	0.042	0.042	0.272	0.272	0.042	0.042	0.042		
13			0.028	0.028	0.028	0.028	0.028	0.031	0.031	0.031	0.042	0.042	0.042	0.272	0.272	0.042	0.042	0.042		
14			0.028	0.028	0.028	0.031	0.031	0.031	0.031	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042		
15			0.028	0.028	0.028	0.031	0.031	0.031	0.031	0.031	1.040	1.040	1.040	0.042	0.042	0.042	0.042	0.042		
16			0.028	0.028	0.028	0.031	0.031	0.031	0.031	0.031	1.040	1.040	1.040	0.042	0.042	0.042	0.042	0.042		
17			0.028	0.028	0.028	0.031	0.031	0.031	0.031	0.031	1.040	1.040	1.040	0.042	0.042	0.042	0.042	0.042		
18			0.028	0.028	0.028	0.031	0.031	0.031	0.031	0.031	1.040	1.040	1.040	0.042	0.042	0.042	0.042	0.042		
19																				
20																				

* The original grid was 16 x 16. When the grid was extended, the parameter values were estimated based on the value at the nearest cell.

RADIAN CORPORATION

Table A5-8

Layers 3 and 4 Aultard VCONT Original Input Data

1																			
2																			
3			0.002	0.002	0.002	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	
4			0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.029	0.084	0.084	0.084	0.029	0.006	0.006	0.006	
5			0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.029	0.029	0.084	0.084	0.084	0.029	0.006	0.006	0.006	
6			0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.029	0.029	0.084	0.084	0.084	0.029	0.006	0.006	0.006	
7			0.004	0.004	0.004	0.004	0.004	0.007	0.007	0.029	0.029	0.029	0.029	0.029	0.029	0.006	0.006	0.006	
8			0.004	0.004	0.007	0.007	0.007	0.007	0.007	0.029	0.029	0.029	0.029	0.029	0.029	0.006	0.006	0.006	
9			0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.029	0.029	0.029	0.029	0.029	0.029	0.006	0.006	0.006	
10			0.007	0.007	0.007	0.007	0.007	0.007	0.010	0.010	1.000	1.000	1.000	0.006	0.006	0.006	0.006	0.006	
11			0.007	0.007	0.007	0.007	0.007	0.007	0.010	0.010	1.000	1.000	1.000	0.006	0.006	0.006	0.006	0.006	
12			0.007	0.007	0.007	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.006	0.006	0.006	0.006	0.006	
13			0.007	0.007	0.007	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.006	0.006	0.006	0.006	0.006	
14			0.004	0.004	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.006	0.006	0.006	0.006	0.006	
15			0.004	0.004	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.006	0.006	0.006	0.006	0.006	
16			0.004	0.004	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.006	0.006	0.006	0.006	0.006	
17			0.004	0.004	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.006	0.006	0.006	0.006	0.006	
18			0.004	0.004	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.006	0.006	0.006	0.006	0.006	
19																			
20																			

* The original grid was 16 x 16. When the grid was extended, the parameter values were estimated based on the value at the nearest cell.

RADIAN CORPORATION

Table A5-9

Layer 1 Bottoms

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-72.0	-72.0	-72.0	-72.0	-72.0	-72.0	-70.0	-70.0	-70.0	-71.0	-72.0	-73.0	-75.0	-73.0	-70.0	-70.0	-71.0	-71.0	-71.0	-71.0
2	-72.0	-72.0	-72.0	-72.0	-72.0	-72.0	-70.0	-70.0	-70.0	-71.0	-72.0	-73.0	-75.0	-73.0	-70.0	-70.0	-71.0	-71.0	-71.0	-71.0
3	-72.0	-72.0	-72.0	-72.0	-72.0	-72.0	-70.0	-70.0	-70.0	-71.0	-72.0	-73.0	-75.0	-73.0	-70.0	-70.0	-71.0	-71.0	-71.0	-71.0
4	-71.0	-71.0	-71.0	-74.0	-74.0	-74.0	-70.0	-73.0	-70.0	-70.0	-72.0	-73.0	-75.0	-75.0	-73.0	-70.0	-70.0	-71.0	-71.0	-71.0
5	-70.0	-70.0	-70.0	-70.0	-70.0	-75.0	-75.0	-73.0	-73.0	-73.0	-75.0	-77.0	-77.0	-77.0	-75.0	-73.0	-70.0	-70.0	-70.0	-70.0
6	-75.0	-75.0	-75.0	-75.0	-77.0	-77.0	-75.0	-75.0	-75.0	-75.0	-80.0	-80.0	-80.0	-79.0	-77.0	-75.0	-73.0	-70.0	-70.0	-70.0
7	-75.0	-75.0	-75.0	-75.0	-77.0	-77.0	-77.0	-75.0	-75.0	-77.0	-80.0	-80.0	-80.0	-80.0	-77.0	-75.0	-73.0	-70.0	-70.0	-70.0
8	-75.0	-75.0	-75.0	-77.0	-77.0	-75.0	-75.0	-73.0	-70.0	-70.0	-75.0	-77.0	-77.0	-77.0	-77.0	-75.0	-73.0	-70.0	-70.0	-70.0
9	-77.0	-77.0	-77.0	-77.0	-79.0	-77.0	-70.0	-71.0	-67.0	-71.0	-70.0	-76.0	-77.0	-77.0	-77.0	-77.0	-75.0	-70.0	-70.0	-70.0
10	-81.0	-81.0	-81.0	-81.0	-81.0	-81.0	-77.0	-70.0	-71.0	-67.0	-71.0	-70.0	-75.0	-75.0	-75.0	-77.0	-77.0	-75.0	-75.0	-75.0
11	-81.0	-81.0	-81.0	-81.0	-81.0	-81.0	-75.0	-70.0	-73.0	-73.0	-71.0	-70.0	-73.0	-77.0	-77.0	-79.0	-79.0	-77.0	-77.0	-77.0
12	-83.0	-83.0	-83.0	-83.0	-81.0	-81.0	-75.0	-70.0	-70.0	-70.0	-73.0	-75.0	-77.0	-81.0	-81.0	-81.0	-79.0	-79.0	-79.0	-79.0
13	-83.0	-83.0	-83.0	-83.0	-81.0	-79.0	-77.0	-75.0	-73.0	-73.0	-70.0	-73.0	-77.0	-79.0	-79.0	-81.0	-81.0	-79.0	-79.0	-79.0
14	-83.0	-83.0	-83.0	-83.0	-81.0	-77.0	-75.0	-75.0	-75.0	-75.0	-70.0	-75.0	-73.0	-75.0	-77.0	-79.0	-81.0	-81.0	-81.0	-81.0
15	-83.0	-83.0	-83.0	-83.0	-81.0	-79.0	-77.0	-77.0	-77.0	-77.0	-75.0	-70.0	-75.0	-77.0	-79.0	-81.0	-81.0	-81.0	-81.0	-81.0
16	-85.0	-85.0	-85.0	-83.0	-83.0	-81.0	-79.0	-79.0	-79.0	-79.0	-77.0	-75.0	-77.0	-77.0	-79.0	-81.0	-81.0	-81.0	-81.0	-81.0
17	-85.0	-85.0	-85.0	-85.0	-83.0	-83.0	-81.0	-81.0	-81.0	-79.0	-79.0	-78.0	-79.0	-77.0	-79.0	-81.0	-81.0	-81.0	-81.0	-81.0
18	-85.0	-85.0	-85.0	-85.0	-85.0	-85.0	-83.0	-83.0	-81.0	-79.0	-79.0	-79.0	-79.0	-79 0	-79.0	-81.0	-81.0	-81.0	-81.0	-81.0
19	-85.0	-85.0	-85.0	-85.0	-85.0	-85.0	-83.0	-83.0	-81.0	-79.0	-79.0	-79.0	-79.0	-79.0	-79.0	-81.0	-81.0	-81.0	-81.0	-81.0
20	-85.0	-85.0	-85.0	-85.0	-85.0	-85.0	-83.0	-83.0	-81.0	-79.0	-79.0	-79.0	-79.0	-79.0	-79.0	-81.0	-81.0	-81.0	-81.0	-81.0

* Shaded Boxes Control Point Locations (Cells w/ Monitoring Well Data)

Table A5-10

Layer 2 Bottoms

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-103.0	-103.0	-103.0	-103.0	-97.0	-97.0	-95.0	-93.0	-93.0	-90.0	-88.0	-88.0	-86.0	-86.0	-84.0	-84.0	-82.0	-82.0	-82.0	-82.0
2	-103.0	-103.0	-103.0	-103.0	-97.0	-97.0	-95.0	-93.0	-93.0	-90.0	-88.0	-88.0	-86.0	-86.0	-84.0	-84.0	-82.0	-82.0	-82.0	-82.0
3	-103.0	-103.0	-103.0	-103.0	-97.0	-97.0	-95.0	-93.0	-93.0	-90.0	-88.0	-88.0	-86.0	-86.0	-84.0	-84.0	-82.0	-82.0	-82.0	-82.0
4	-105.0	-105.0	-105.0	-103.0	-99.0	-97.0	-95.0	-95.0	-93.0	-90.0	-90.0	-88.0	-86.0	-86.0	-84.0	-84.0	-82.0	-82.0	-82.0	-82.0
5	-105.0	-105.0	-105.0	-103.0	-99.0	-97.0	-95.0	-95.0	-93.0	-93.0	-90.0	-90.0	-88.0	-88.0	-86.0	-84.0	-82.0	-82.0	-82.0	-82.0
6	-105.0	-105.0	-105.0	-105.0	-103.0	-98.0	-95.0	-95.0	-93.0	-93.0	-90.0	-90.0	-88.0	-88.0	-86.0	-86.0	-84.0	-84.0	-84.0	-84.0
7	-103.0	-103.0	-103.0	-101.0	-99.0	-97.0	-97.0	-95.0	-95.0	-95.0	-93.0	-90.0	-90.0	-90.0	-90.0	-88.0	-86.0	-86.0	-86.0	-86.0
8	-105.0	-105.0	-105.0	-103.0	-99.0	-97.0	-99.0	-97.0	-97.0	-97.0	-95.0	-93.0	-90.0	-90.0	-90.0	-90.0	-88.0	-88.0	-88.0	-88.0
9	-103.0	-103.0	-103.0	-99.0	-97.0	-95.0	-97.0	-103.0	-103.0	-97.0	-95.0	-93.0	-93.0	-93.0	-90.0	-90.0	-88.0	-88.0	-88.0	-88.0
10	-99.0	-99.0	-99.0	-97.0	-93.0	-88.0	-93.0	-97.0	-99.0	-97.0	-95.0	-95.0	-95.0	-93.0	-90.0	-90.0	-90.0	-88.0	-88.0	-88.0
11	-101.0	-101.0	-101.0	-99.0	-95.0	-99.0	-97.0	-97.0	-99.0	-99.0	-97.0	-97.0	-95.0	-95.0	-93.0	-92.0	-90.0	-90.0	-90.0	-90.0
12	-103.0	-103.0	-103.0	-101.0	-99.0	-101.0	-99.0	-99.0	-101.0	-103.0	-103.0	-97.0	-97.0	-95.0	-95.0	-95.0	-93.0	-93.0	-93.0	-93.0
13	-105.0	-105.0	-105.0	-103.0	-101.0	-101.0	-101.0	-101.0	-103.0	-103.0	-103.0	-97.0	-96.0	-96.0	-95.0	-95.0	-95.0	-93.0	-93.0	-93.0
14	-105.0	-105.0	-105.0	-103.0	-103.0	-103.0	-103.0	-103.0	-103.0	-103.0	-101.0	-99.0	-97.0	-97.0	-95.0	-95.0	-95.0	-95.0	-95.0	-95.0
15	-105.0	-105.0	-105.0	-105.0	-105.0	-105.0	-105.0	-105.0	-105.0	-103.0	-101.0	-99.0	-99.0	-99.0	-97.0	-97.0	-97.0	-95.0	-95.0	-95.0
16	-107.0	-107.0	-107.0	-107.0	-107.0	-107.0	-107.0	-107.0	-105.0	-105.0	-103.0	-103.0	-103.0	-103.0	-99.0	-99.0	-99.0	-97.0	-97.0	-97.0
17	-109.0	-109.0	-109.0	-109.0	-109.0	-109.0	-109.0	-109.0	-107.0	-107.0	-107.0	-107.0	-105.0	-103.0	-101.0	-101.0	-99.0	-99.0	-99.0	-99.0
18	-111.0	-111.0	-111.0	-111.0	-111.0	-111.0	-111.0	-109.0	-109.0	-109.0	-107.0	-107.0	-105.0	-103.0	-101.0	-101.0	-101.0	-99.0	-99.0	-99.0
19	-111.0	-111.0	-111.0	-111.0	-111.0	-111.0	-111.0	-109.0	-109.0	-109.0	-107.0	-107.0	-105.0	-103.0	-101.0	-101.0	-101.0	-99.0	-99.0	-99.0
20	-111.0	-111.0	-111.0	-111.0	-111.0	-111.0	-111.0	-109.0	-109.0	-109.0	-107.0	-107.0	-105.0	-103.0	-101.0	-101.0	-101.0	-99.0	-99.0	-99.0

* Shaded Boxes Control Point Locations (Cells w/ Monitoring Well Data)

Table A5-11

Layer 3 Bottoms

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0
2	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0
3	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0
4	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-145.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0
5	-145.0	-145.0	-145.0	-145.0	-143.0	-143.0	-143.0	-143.0	-143.0	-143.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0
6	-145.0	-145.0	-145.0	-145.0	-143.0	-143.0	-143.0	-143.0	-143.0	-143.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0
7	-145.0	-145.0	-145.0	-145.0	-143.0	-143.0	-143.0	-143.0	-143.0	-143.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0	-152.0
8	-145.0	-145.0	-145.0	-145.0	-143.0	-143.0	-143.0	-143.0	-143.0	-143.0	-149.0	-149.0	-149.0	-152.0	-152.0	-188.0	-188.0	-188.0	-188.0	-188.0
9	-145.0	-145.0	-145.0	-145.0	-143.0	-143.0	-143.0	-143.0	-143.0	-149.0	-149.0	-149.0	-149.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0
10	-163.0	-163.0	-163.0	-163.0	-163.0	-163.0	-163.0	-163.0	-149.0	-149.0	-149.0	-149.0	-152.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0
11	-163.0	-163.0	-163.0	-163.0	-163.0	-163.0	-163.0	-163.0	-152.0	-152.0	-152.0	-152.0	-152.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0
12	-163.0	-163.0	-163.0	-163.0	-163.0	-163.0	-163.0	-163.0	-152.0	-152.0	-152.0	-152.0	-160.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0
13	-163.0	-163.0	-163.0	-163.0	-163.0	-163.0	-163.0	-152.0	-152.0	-152.0	-160.0	-160.0	-160.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0
14	-163.0	-163.0	-163.0	-163.0	-163.0	-160.0	-160.0	-152.0	-152.0	-152.0	-160.0	-160.0	-160.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0
15	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-152.0	-152.0	-152.0	-160.0	-160.0	-160.0	-160.0	-188.0	-188.0	-188.0	-188.0	-188.0	-188.0
16	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-157.0	-157.0	-157.0	-157.0	-157.0	-188.0	-188.0	-188.0	-188.0	-188.0
17	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-157.0	-157.0	-157.0	-157.0	-157.0	-157.0	-188.0	-188.0	-188.0	-188.0	-188.0
18	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-157.0	-157.0	-157.0	-157.0	-157.0	-157.0	-188.0	-188.0	-188.0	-188.0	-188.0
19	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-157.0	-157.0	-157.0	-157.0	-157.0	-157.0	-188.0	-188.0	-188.0	-188.0	-188.0
20	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-160.0	-157.0	-157.0	-157.0	-157.0	-157.0	-157.0	-188.0	-188.0	-188.0	-188.0	-188.0

* Shaded Boxes Control Point Locations (Cells w/ Monitoring Well Data)

Table A5-12

Layer 4 Bottoms

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
2	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
3	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
4	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
5	-230.0	-230.0	-230.0	-230.0	-213.0	-213.0	-213.0	-213.0	-213.0	-240.0	-240.0	-240.0	-240.0	-240.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
6	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-240.0	-240.0	-240.0	-240.0	-240.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
7	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-240.0	-240.0	-240.0	-240.0	-233.0	-233.0	-230.0	-230.0	-230.0	-230.0	-230.0
8	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-240.0	-233.0	-233.0	-233.0	-233.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
9	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-233.0	-233.0	-233.0	-233.0	-233.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
10	-220.0	-220.0	-220.0	-220.0	-220.0	-220.0	-220.0	-220.0	-233.0	-233.0	-233.0	-233.0	-233.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
11	-220.0	-220.0	-220.0	-220.0	-220.0	-220.0	-220.0	-233.0	-233.0	-213.0	-213.0	-213.0	-213.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
12	-220.0	-220.0	-220.0	-220.0	-220.0	-220.0	-233.0	-233.0	-213.0	-213.0	-213.0	-213.0	-213.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
13	-220.0	-220.0	-220.0	-220.0	-220.0	-220.0	-233.0	-233.0	-213.0	-213.0	-213.0	-213.0	-213.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
14	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-213.0	-213.0	-213.0	-213.0	-213.0	-213.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0	-230.0
15	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-213.0	-213.0	-213.0	-213.0	-222.0	-222.0	-222.0	-222.0	-230.0	-230.0	-230.0	-230.0	-230.0
16	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-213.0	-213.0	-213.0	-213.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0
17	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-213.0	-213.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0
18	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-213.0	-213.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0
19	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-213.0	-213.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0
20	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-225.0	-213.0	-213.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0	-222.0

* Shaded Boxes Control Point Locations (Cells w/ Monitoring Well Data)

Table A5-13

Layer 1 Initial Head

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-32.7	-33.1	-33.3	-33.9	-33.9	-34.0	-34.0	-34.1	-34.1	-34.1	-34.2	-34.2	-34.3	-34.3	-34.4	-34.4	-34.5	-34.5	-34.6	-34.6
2	-32.8	-33.8	-34.5	-34.9	-35.0	-35.0	-35.1	-35.1	-35.1	-35.2	-35.2	-35.2	-35.3	-35.3	-35.3	-35.3	-35.3	-35.2	-34.9	-35.1
3	-33.5	-34.9	-35.9	-36.4	-36.5	-36.5	-36.6	-36.6	-36.7	-36.7	-36.7	-36.8	-36.8	-36.8	-36.8	-36.8	-36.7	-36.0	-36.1	-36.0
4	-33.7	-35.7	-36.8	-37.8	-37.9	-38.0	-38.2	-38.3	-38.4	-38.5	-38.5	-38.5	-38.6	-38.6	-38.6	-38.5	-37.9	-37.6	-37.2	-36.6
5	-34.4	-36.2	-37.3	-38.5	-38.8	-38.9	-39.1	-39.2	-39.3	-39.4	-39.4	-39.4	-39.6	-39.4	-39.6	-39.4	-38.6	-37.5	-37.8	-37.1
6	-34.5	-36.5	-37.6	-38.7	-38.9	-39.1	-39.3	-39.5	-39.5	-39.6	-39.6	-39.7	-40.3	-40.3	-39.8	-40.0	-39.0	-38.6	-38.1	-37.3
7	-34.7	-36.7	-37.8	-38.8	-39.0	-39.2	-39.5	-39.6	-39.7	-39.7	-39.8	-39.8	-40.6	-40.0	-40.1	-40.1	-39.2	-38.8	-38.3	-37.5
8	-35.0	-36.9	-38.1	-38.9	-39.1	-39.4	-39.6	-39.7	-39.8	-39.8	-39.9	-40.0	-40.2	-40.3	-40.3	-40.4	-39.4	-39.1	-38.6	-37.8
9	-35.3	-37.1	-38.3	-38.9	-39.2	-39.6	-39.7	-39.8	-39.9	-40.0	-40.1	-40.2	-40.4	-40.5	-40.5	-40.6	-40.8	-40.4	-39.6	-38.2
10	-35.4	-37.2	-38.0	-38.9	-39.3	-39.8	-39.8	-39.9	-40.1	-40.2	-40.3	-40.7	-40.6	-40.7	-40.7	-40.8	-40.8	-40.4	-39.6	-38.3
11	-35.5	-37.2	-38.4	-39.0	-39.4	-39.8	-39.9	-40.1	-40.2	-40.4	-40.9	-40.6	-40.7	-40.8	-40.8	-40.9	-40.9	-40.5	-39.7	-38.5
12	-35.6	-37.3	-38.5	-39.0	-39.5	-40.0	-40.1	-40.2	-40.4	-40.5	-40.7	-40.8	-40.9	-40.9	-41.0	-41.0	-41.0	-40.6	-39.7	-38.7
13	-35.8	-37.4	-38.5	-39.1	-39.6	-40.2	-40.3	-40.3	-40.6	-40.7	-40.9	-41.0	-41.0	-41.3	-41.1	-41.2	-41.1	-40.7	-39.8	-38.8
14	-35.9	-37.5	-38.6	-37.6	-39.8	-40.4	-40.4	-40.3	-40.8	-40.9	-41.0	-41.1	-41.2	-41.3	-41.3	-41.4	-41.3	-40.8	-39.9	-39.0
15	-36.0	-37.6	-38.7	-39.3	-40.0	-40.6	-40.6	-40.8	-41.0	-41.1	-41.2	-41.3	-41.4	-41.5	-41.5	-41.5	-41.4	-40.9	-40.0	-39.1
16	-36.3	-37.7	-38.9	-39.5	-40.2	-40.8	-40.9	-41.2	-41.4	-41.5	-41.6	-41.7	-41.7	-41.8	-41.8	-42.7	-41.7	-40.5	-40.2	-39.3
17	-36.9	-38.1	-39.2	-40.0	-40.7	-41.2	-41.4	-42.0	-42.1	-42.2	-42.2	-42.4	-42.4	-42.4	-42.5	-42.5	-42.3	-41.7	-40.6	-39.7
18	-37.9	-38.9	-40.0	-40.8	-41.6	-42.3	-42.6	-43.0	-43.2	-43.3	-43.4	-43.4	-43.4	-43.4	-43.4	-43.4	-43.2	-42.6	-41.5	-40.6
19	-38.4	-39.7	-41.0	-42.0	-42.8	-43.4	-43.8	-44.1	-44.4	-44.5	-44.6	-44.6	-44.7	-44.7	-44.7	-44.6	-44.5	-43.7	-42.2	-41.4
20	-39.7	-40.5	-42.5	-44.1	-44.6	-44.9	-45.1	-45.4	-45.6	-46.0	-46.2	-46.4	-46.6	-46.6	-46.6	-46.7	-46.6	-45.6	-42.4	-42.6

* Shaded Boxes are Control Point Locations (Cells w/ Monitoring Well Data)

Table A5-14

Layer 2 Initial Head

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-33.1	-33.3	-33.7	-33.9	-34.1	-34.2	-34.2	-34.2	-34.3	-34.3	-34.4	-34.4	-34.5	-34.5	-34.5	-34.5	-34.6	-34.6	-34.5	-35.0
2	-33.7	-33.8	-34.4	-34.8	-34.9	-35.0	-35.0	-35.1	-35.1	-35.1	-35.2	-35.2	-35.2	-35.3	-35.3	-35.3	-35.3	-35.2	-34.9	-36.0
3	-34.1	-34.8	-35.7	-36.2	-36.4	-36.5	-36.6	-36.6	-36.6	-36.7	-36.7	-36.7	-36.8	-36.8	-36.8	-36.7	-36.7	-36.5	-36.1	-36.2
4	-34.7	-35.7	-36.7	-37.4	-37.7	-37.9	-37.9	-38.0	-37.4	-38.1	-38.2	-38.2	-38.2	-38.2	-38.2	-38.1	-37.9	-37.6	-37.2	-36.9
5	-35.1	-36.2	-37.3	-37.6	-38.4	-38.6	-38.7	-38.8	-38.9	-38.9	-39.0	-39.0	-39.0	-39.0	-38.9	-38.9	-38.7	-38.3	-37.8	-37.0
6	-35.2	-36.5	-37.5	-38.4	-38.7	-38.9	-39.0	-39.1	-39.2	-39.3	-39.3	-39.3	-39.3	-39.3	-39.3	-39.2	-39.0	-38.6	-38.1	-37.2
7	-35.3	-36.6	-37.7	-38.5	-38.9	-39.1	-39.3	-39.4	-39.5	-39.5	-39.5	-39.5	-39.5	-39.5	-39.5	-39.4	-39.2	-38.8	-38.3	-37.3
8	-35.4	-36.8	-37.9	-38.7	-39.1	-39.4	-39.5	-39.2	-39.6	-39.7	-39.7	-39.8	-39.7	-39.7	-39.7	-39.6	-39.4	-39.1	-38.5	-37.6
9	-35.5	-37.0	-38.1	-38.9	-39.3	-39.5	-39.6	-39.7	-39.8	-39.9	-39.9	-40.0	-40.0	-39.9	-39.9	-39.9	-39.7	-39.4	-38.8	-38.1
10	-35.7	-37.2	-38.3	-39.0	-39.0	-39.6	-39.8	-39.9	-40.0	-40.0	-40.2	-40.2	-40.3	-40.2	-40.1	-40.1	-40.0	-39.6	-39.0	-38.2
11	-35.8	-37.3	-38.4	-39.1	-39.6	-39.8	-39.9	-40.0	-40.1	-40.2	-40.3	-40.4	-40.3	-40.4	-40.4	-40.3	-40.2	-39.8	-39.2	-38.3
12	-35.9	-37.4	-38.4	-39.2	-39.7	-39.9	-40.0	-40.1	-40.2	-40.4	-40.5	-40.6	-40.7	-40.4	-40.6	-40.5	-40.4	-40.0	-39.4	-38.5
13	-36.0	-37.5	-38.5	-39.3	-39.8	-40.0	-40.1	-40.2	-40.4	-40.5	-40.7	-40.8	-40.9	-40.8	-40.8	-40.7	-40.6	-40.2	-39.6	-38.1
14	-36.1	-37.6	-38.6	-39.4	-39.9	-40.1	-40.2	-40.4	-40.5	-40.7	-40.9	-41.0	-41.1	-41.0	-41.0	-40.9	-40.8	-40.4	-39.7	-38.1
15	-36.2	-37.7	-38.7	-39.5	-40.0	-40.3	-40.4	-40.6	-40.7	-40.9	-41.1	-41.2	-41.3	-41.2	-41.2	-41.1	-41.0	-40.6	-39.9	-38.2
16	-36.4	-37.8	-38.9	-39.7	-40.2	-40.5	-40.7	-40.9	-41.0	-41.2	-41.4	-41.5	-41.6	-41.5	-41.5	-41.4	-41.3	-40.9	-40.1	-38.3
17	-36.7	-38.2	-39.2	-40.1	-40.7	-41.0	-41.2	-41.4	-41.6	-41.8	-42.1	-42.5	-42.2	-42.1	-42.1	-42.0	-41.9	-41.4	-40.6	-38.8
18	-37.2	-38.9	-39.9	-40.8	-41.5	-41.8	-42.1	-42.3	-42.4	-42.6	-42.7	-42.8	-42.9	-42.9	-42.9	-42.9	-42.8	-42.3	-41.4	-39.2
19	-37.5	-39.6	-40.7	-41.6	-42.3	-42.7	-42.9	-43.2	-43.4	-43.5	-43.7	-43.8	-43.9	-44.0	-44.0	-44.0	-44.0	-43.5	-42.4	-40.8
20	-39.2	-41.2	-42.0	-42.6	-42.8	-43.4	-43.8	-44.3	-44.5	-44.6	-44.7	-44.7	-44.7	-44.6	-44.5	-44.4	-44.2	-43.7	-42.7	-41.7

* Shaded Boxes are Control Point Locations (Cells w/ Monitoring Well Data)

Table A5-15

Layer 3 Initial Head

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-32.4	-32.5	-32.6	-32.7	-32.8	-32.9	-32.9	-33.0	-33.1	-33.3	-33.4	-33.5	-33.6	-33.7	-33.8	-33.9	-34.2	-33.9	-33.7	-33.4
2	-32.8	-33.8	-34.4	-34.8	-34.9	-35.0	-35.0	-35.1	-35.1	-35.1	-35.2	-35.2	-35.2	-35.3	-35.3	-35.3	-35.3	-35.2	-34.9	-34.1
3	-33.7	-34.8	-35.7	-36.2	-36.4	-36.5	-36.6	-36.6	-36.6	-36.7	-36.7	-36.7	-36.8	-36.8	-36.8	-36.7	-36.7	-36.5	-36.1	-35.7
4	-34.7	-35.7	-36.7	-37.4	-37.7	-37.9	-37.9	-38.0	-38.1	-38.1	-38.2	-38.2	-38.2	-38.2	-38.1	-38.1	-37.9	-37.6	-37.2	-36.6
5	-35.1	-36.2	-37.3	-38.1	-38.4	-38.6	-38.7	-38.8	-38.9	-38.9	-39.0	-39.0	-39.0	-38.9	-38.9	-38.9	-38.7	-38.3	-37.8	-37.2
6	-35.4	-36.5	-37.5	-38.4	-38.7	-38.9	-39.0	-39.2	-39.3	-39.3	-39.3	-39.3	-39.3	-39.3	-39.2	-39.2	-39.0	-38.6	-38.1	-37.6
7	-35.6	-36.6	-37.7	-38.5	-38.9	-39.1	-39.3	-39.4	-39.5	-39.5	-39.5	-39.5	-39.5	-39.5	-39.4	-39.4	-39.2	-38.8	-38.3	-37.8
8	-35.7	-36.8	-37.9	-38.7	-39.2	-39.4	-39.5	-39.6	-39.7	-39.7	-39.7	-39.7	-39.7	-39.7	-39.7	-39.6	-39.4	-39.0	-38.5	-38.1
9	-35.6	-37.0	-38.1	-38.9	-39.3	-39.5	-39.6	-39.7	-39.8	-39.9	-39.9	-39.9	-39.9	-39.9	-39.9	-39.8	-39.7	-39.3	-38.8	-38.3
10	-35.9	-37.2	-38.3	-39.0	-39.4	-39.1	-39.8	-39.9	-40.0	-40.0	-40.1	-40.1	-40.1	-40.1	-40.1	-40.1	-39.9	-39.6	-39.0	-38.5
11	-36.1	-37.3	-38.4	-39.1	-39.6	-39.8	-39.9	-40.0	-40.1	-39.5	-40.3	-40.3	-40.3	-40.3	-40.3	-40.3	-40.2	-39.8	-39.2	-38.8
12	-36.4	-37.4	-38.4	-39.2	-39.7	-39.9	-40.0	-40.1	-40.2	-40.3	-40.4	-40.5	-40.4	-40.0	-40.5	-40.5	-40.4	-40.0	-39.4	-38.9
13	-36.5	-37.5	-38.5	-39.3	-39.8	-40.0	-40.1	-40.2	-40.4	-40.5	-40.6	-39.8	-40.8	-40.8	-40.7	-40.7	-40.6	-40.2	-39.6	-39.2
14	-36.6	-37.6	-38.6	-39.4	-39.9	-40.1	-40.2	-40.4	-40.5	-40.7	-40.8	-40.9	-41.0	-41.0	-40.9	-40.9	-40.8	-40.4	-39.7	-39.2
15	-36.7	-37.7	-38.7	-39.5	-40.0	-40.2	-40.4	-40.6	-40.7	-40.9	-41.0	-41.1	-41.2	-41.2	-41.2	-41.1	-41.0	-40.6	-39.9	-39.4
16	-36.9	-37.8	-38.9	-39.7	-40.2	-40.5	-40.7	-40.8	-41.0	-41.2	-41.3	-41.4	-41.5	-41.5	-41.5	-41.4	-41.3	-40.9	-40.1	-39.6
17	-37.4	-38.2	-39.3	-40.1	-40.7	-41.0	-41.2	-41.4	-41.6	-41.8	-41.9	-41.9	-42.1	-42.1	-42.0	-42.0	-41.9	-41.4	-40.6	-39.9
18	-37.8	-38.9	-39.9	-40.8	-41.5	-41.8	-42.0	-42.2	-42.4	-42.5	-42.7	-42.7	-42.8	-42.9	-42.9	-42.9	-42.8	-42.3	-41.4	-40.7
19	-38.9	-39.6	-40.7	-41.6	-42.3	-42.7	-42.9	-43.1	-43.3	-43.5	-43.6	-43.8	-43.9	-43.9	-44.0	-44.0	-43.9	-43.5	-42.4	-42.0
20	-39.7	-40.1	-40.9	-41.4	-42.2	-42.9	-43.1	-43.4	-43.6	-43.9	-44.0	-45.1	-45.2	-45 3	-45.3	-45.3	-45.2	-45.0	-43.4	-43.0

* Shaded Boxes are Control Point Locations (Cells w/ Monitoring Well Data)

Table A5-16

Layer 4 Initial Head

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-35.2	-35.2	-35.2	-35.2	-35.2	-35.2	-35.2	-35.2	-35.2	-35.2	-35.3	-35.3	-35.3	-35.3	-35.3	-35.3	-35.3	-35.4	-35.4	-35.9
2	-35.7	-35.7	-35.7	-35.7	-35.7	-35.7	-35.8	-35.8	-35.8	-35.8	-35.8	-35.8	-35.8	-35.8	-35.8	-35.8	-35.9	-35.9	-36.0	-36.4
3	-36.2	-36.1	-36.2	-36.3	-36.3	-36.3	-36.3	-36.3	-36.4	-36.4	-36.4	-36.4	-36.4	-36.4	-36.4	-36.4	-36.4	-36.4	-36.5	-36.6
4	-36.3	-36.5	-36.6	-36.7	-36.8	-36.8	-36.8	-36.8	-36.8	-36.9	-36.9	-36.9	-36.9	-36.9	-36.9	-36.9	-36.9	-36.8	-36.8	-36.7
5	-36.4	-36.7	-36.9	-37.0	-37.1	-37.1	-37.1	-37.1	-37.1	-37.1	-37.2	-37.2	-37.2	-37.2	-37.2	-37.2	-37.2	-37.1	-36.9	-36.7
6	-36.5	-36.8	-37.0	-37.1	-37.2	-37.2	-37.3	-37.3	-37.3	-37.3	-37.3	-37.3	-37.3	-37.3	-37.3	-37.3	-37.3	-37.2	-37.0	-36.8
7	-36.6	-36.9	-37.1	-37.2	-37.3	-37.3	-37.4	-37.4	-37.4	-37.4	-37.4	-37.4	-37.4	-37.4	-37.4	-37.4	-37.4	-37.3	-37.1	-36.8
8	-36.7	-37.0	-37.2	-37.3	-37.4	-37.4	-37.4	-37.5	-37.5	-37.5	-37.5	-37.5	-37.5	-37.5	-37.5	-37.5	-37.5	-37.4	-37.2	-36.8
9	-36.8	-37.0	-37.3	-37.4	-37.5	-37.5	-37.5	-37.4	-37.6	-37.6	-37.6	-37.6	-37.6	-37.6	-37.6	-37.6	-37.6	-37.5	-37.2	-36.8
10	-36.9	-37.1	-37.4	-37.5	-37.6	-37.6	-37.6	-37.7	-37.7	-37.7	-37.7	-37.7	-37.7	-37.7	-37.7	-37.7	-37.7	-37.5	-37.3	-36.9
11	-37.0	-37.2	-37.4	-37.6	-37.7	-37.7	-37.7	-37.8	-37.8	-37.4	-37.8	-37.8	-37.8	-37.8	-37.8	-37.8	-37.7	-37.6	-37.4	-36.9
12	-37.1	-37.3	-37.5	-37.7	-37.8	-37.8	-37.8	-37.8	-37.9	-37.9	-37.9	-37.9	-37.9	-37.9	-37.9	-37.9	-37.8	-37.7	-37.4	-37.0
13	-37.2	-37.4	-37.6	-37.8	-37.9	-37.9	-37.9	-37.9	-38.0	-38.0	-38.0	-37.5	-38.0	-38.0	-38.0	-38.0	-37.9	-37.8	-37.5	-37.1
14	-37.3	-37.5	-37.7	-37.9	-38.0	-38.0	-38.0	-38.0	-38.1	-38.1	-38.1	-38.1	-38.1	-38.1	-38.1	-38.1	-38.0	-37.9	-37.6	-37.2
15	-37.4	-37.5	-37.8	-38.0	-38.1	-38.1	-38.1	-38.1	-38.1	-38.2	-38.2	-38.2	-38.2	-38.2	-38.2	-38.2	-38.1	-38.0	-37.7	-37.3
16	-37.5	-37.7	-37.9	-38.1	-38.2	-38.2	-38.3	-38.3	-38.3	-38.3	-38.3	-38.3	-38.3	-38.3	-38.3	-38.3	-38.3	-38.1	-37.8	-37.4
17	-37.6	-37.9	-38.2	-38.4	-38.5	-38.5	-38.5	-38.6	-38.6	-38.6	-38.6	-37.9	-38.6	-38.6	-38.6	-38.6	-38.5	-38.4	-38.0	-37.5
18	-37.7	-38.2	-38.6	-38.8	-38.9	-39.0	-39.0	-39.0	-39.1	-39.1	-39.1	-39.1	-39.1	-39.1	-39.1	-39.0	-39.0	-38.8	-38.4	-37.8
19	-38.2	-38.8	-39.1	-39.4	-39.5	-39.5	-39.6	-39.6	-39.6	-39.7	-39.7	-39.7	-39.7	-39.6	-39.6	-39.6	-39.5	-39.3	-38.9	-38.2
20	-39.5	-39.6	-39.7	-39.8	-39.9	-40.0	-40.1	-40.2	-40.3	-40.4	-40.5	-40.4	-40.3	-40.2	-40.1	-40.0	-39.9	-39.8	-39.7	-39.6

* Shaded Boxes are Control Point Locations (Cells w/ Monitoring Well Data)

RADIAN CORPORATION

Table A5-17

LAYER 1 CONDUCTIVITY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	30.0	30.0	30.0	30.0	30.0	36.0	45.0	4.5	4.5	4.5	3.0	3.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
2	30.0	30.0	30.0	30.0	30.0	36.0	45.0	4.5	4.5	4.5	3.0	3.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
3	30.0	30.0	90.0	90.0	90.0	36.0	45.0	4.5	4.5	4.5	3.0	3.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
4	30.0	30.0	90.0	90.0	90.0	36.0	45.0	45.0	45.0	45.0	30.0	30.0	60.0	60.0	60.0	60.0	6.0	6.0	6.0	6.0
5	30.0	30.0	90.0	600.0	600.0	108.0	135.0	200.0	200.0	200.0	200.0	200.0	70.0	70.0	70.0	50.0	1.0	1.0	3.0	3.0
6	30.0	30.0	30.0	600.0	600.0	108.0	135.0	300.0	300.0	300.0	300.0	300.0	70.0	70.0	70.0	200.0	0.1	0.1	0.3	0.3
7	30.0	30.0	30.0	600.0	600.0	108.0	135.0	400.0	400.0	400.0	200.0	200.0	70.0	70.0	70.0	200.0	0.1	0.1	0.3	0.3
8	30.0	30.0	30.0	600.0	600.0	72.0	180.0	400.0	400.0	400.0	200.0	200.0	200.0	200.0	200.0	200.0	0.1	0.1	0.3	0.3
9	60.0	60.0	60.0	600.0	600.0	600.0	1200.0	500.0	400.0	400.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	600.0	600.0
10	300.0	300.0	300.0	300.0	90.0	300.0	1200.0	400.0	400.0	400.0	400.0	200.0	400.0	500.0	500.0	500.0	500.0	500.0	1500.0	1500.0
11	300.0	300.0	300.0	300.0	90.0	300.0	1200.0	400.0	400.0	400.0	400.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	1500.0	1500.0
12	300.0	300.0	300.0	300.0	90.0	150.0	600.0	400.0	400.0	400.0	400.0	625.0	500.0	500.0	500.0	500.0	500.0	500.0	1500.0	1500.0
13	300.0	300.0	300.0	300.0	9.0	150.0	600.0	200.0	400.0	400.0	600.0	750.0	600.0	500.0	500.0	500.0	500.0	500.0	1500.0	1500.0
14	300.0	300.0	300.0	300.0	9.0	150.0	600.0	200.0	320.0	600.0	600.0	750.0	750.0	750.0	625.0	500.0	500.0	500.0	1500.0	1500.0
15	300.0	300.0	300.0	300.0	9.0	150.0	150.0	100.0	320.0	300.0	300.0	750.0	750.0	750.0	750.0	600.0	600.0	600.0	1800.0	1800.0
16	300.0	300.0	300.0	300.0	9.0	150.0	150.0	50.0	320.0	300.0	300.0	750.0	750.0	750.0	750.0	750.0	600.0	600.0	1800.0	1800.0
17	300.0	300.0	300.0	300.0	90.0	150.0	150.0	50.0	320.0	300.0	300.0	750.0	750.0	750.0	750.0	750.0	600.0	600.0	1800.0	1800.0
18	300.0	300.0	300.0	300.0	90.0	150.0	150.0	150.0	960.0	900.0	900.0	1800.0	1800.0	2250.0	2250.0	2250.0	1800.0	1800.0	1800.0	1800.0
19	300.0	300.0	300.0	300.0	90.0	150.0	150.0	150.0	960.0	900.0	900.0	1800.0	1800.0	2250.0	2250.0	2250.0	1800.0	1800.0	1800.0	1800.0
20	300.0	300.0	300.0	300.0	90.0	150.0	150.0	150.0	960.0	900.0	900.0	1800.0	1800.0	2250.0	2250.0	2250.0	1800.0	1800.0	1800.0	1800.0

* Shaded Boxes are Control Point Locations (Cells w/ Monitoring Well Data)

RADIAN CORPORATION

Table A5-18

LAYER 2 TRANSMISSIVITY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7
2	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7
3	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7
4	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7
5	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	1358.0	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7	740.7
6	1697.5	1697.5	1697.5	1697.5	1697.5	1697.5	1697.5	1697.5	1697.5	1697.5	925.9	925.9	925.9	925.9	925.9	925.9	925.9	925.9	925.9	925.9
7	1697.5	1697.5	1697.5	1697.5	1697.5	617.3	617.3	617.3	617.3	617.3	308.6	308.6	308.6	308.6	308.6	925.9	925.9	925.9	925.9	925.9
8	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	308.6	308.6	308.6	308.6	308.6	925.9	925.9	925.9	925.9	925.9
9	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	308.6	308.6	308.6	308.6	308.6	925.9	925.9	925.9	925.9	925.9
10	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	308.6	308.6	308.6	308.6	308.6	925.9	925.9	925.9	925.9	925.9
11	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	308.6	308.6	308.6	308.6	308.6	925.9	925.9	925.9	925.9	925.9
12	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	925.9	925.9	925.9	925.9	925.9
13	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	925.9	925.9	925.9	925.9	925.9
14	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3
15	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3
16	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3	617.3
17	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8
18	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8
19	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8
20	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8	493.8

* Shaded Boxes are Control Point Locations (Cells w/ Monitoring Well Data)

RADIAN CORPORATION

Table A5-19

LAYER 3 TRANSMISSIVITY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4
2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4
3	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4
4	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4
5	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	6125.4	6125.4	6125.4	8547.0	8547.0	8547.0	8547.0	8547.0	8547.0
6	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	6125.4	6125.4	8547.0	8547.0	8547 0	8547.0	8547.0	8547.0	8547.0	8547.0
7	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	6125.4	6125.4	6125.4	6125.4	6125.4	8547.0	8547.0	8547.0	8547.0	8547.0	8547.0	3547.0	8547.0
8	2279.2	2279.2	2279.2	2279.2	2279.2	2279.2	6125.4	6125.4	6125.4	6125.4	6125.4	8547.0	8547.0	8547.0	8547.0	5698.0	5698.0	5698.0	5698.0	5698.0
9	2279.2	2279.2	2279.2	2279.2	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	8547.0	8547.0	8547.0	8547.0	8547.0	5698.0	5698.0	5698.0	5696.0	5698.0
10	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	8547.0	8547.0	8547.0	8547.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0
11	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	6125.4	8547.0	8547.0	8547.0	8547.0	8547.0	8547.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0
12	6125.4	6125.4	6125.4	6125.4	8547.0	8547.0	8547.0	8547.0	8547.0	8547.0	8547.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0
13	8547.0	8547.0	8547.0	8547.0	8547.0	8547.0	8547.0	8547.0	8547.0	8547.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0
14	8547.0	8547.0	8547.0	8547.0	8547.0	8547.0	8547.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0
15	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0
16	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0
17	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0
18	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0
19	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0
20	5698.0	5698.0	5098.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0	5698.0

* Shaded Boxes are Control Point Locations (Cells w/ Monitoring Well Data)

RADIAN CORPORATION

Table A5-20

LAYER 4 TRANSMISSIVITY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
2	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
3	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
4	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
5	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
6	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
7	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
8	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
9	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
10	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
11	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
12	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
13	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
14	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
15	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
16	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
17	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
18	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
19	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0
20	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0	5000.0

* Shaded Boxes are Control Point Locations (Cells w/ Monitoring Well Data)

RADIAN CORPORATION

Table A5-21

VCONT for Layers 1 and 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
2	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
3	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
4	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
5	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
6	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
7	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
8	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
9	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
10	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.04	0.04	0.04	0.004	0.004	0.004	0.004	0.004	0.004	0.004
11	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.04	0.04	0.04	0.004	0.004	0.004	0.004	0.004	0.004	0.004
12	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.04	0.04	0.04	0.004	0.004	0.004	0.004	0.004	0.004	0.004
13	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.04	0.04	0.04	0.004	0.004	0.004	0.004	0.004	0.004	0.004
14	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.04	0.04	0.04	0.004	0.004	0.004	0.004	0.004	0.004	0.004
15	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.04	0.04	0.04	0.004	0.004	0.004	0.004	0.004	0.004	0.004
16	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.04	0.04	0.04	0.004	0.004	0.004	0.004	0.004	0.004	0.004
17	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.04	0.04	0.04	0.004	0.004	0.004	0.004	0.004	0.004	0.004
18	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
19	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
20	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004

* Shaded Boxes are Control Point Locations (Cells w/ Monitoring Well Data)

RADIAN CORPORATION

Table A5-22

VCONT for Layers 2 and 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
3	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
4	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
5	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
6	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
7	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
8	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
9	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
10	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
11	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
12	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
13	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
14	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
15	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
16	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
17	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
18	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
19	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
20	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06

* Shaded Boxes are Control Point Locations (Cells w/ Monitoring Well Data)

RADIAN CORPORATION

Table A5-23

VCONT for Layers 3 and 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
2	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
3	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
4	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
5	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0 0001
7	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
8	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
9	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
10	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
11	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
12	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
13	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
14	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
15	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
16	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
17	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
18	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
19	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
20	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

* Shaded Boxes are Control Point Locations (Cells w/ Monitoring Well Data)

A6.0 DETAILS OF PROPOSED EXTRACTION WELL FIELDS

Two extraction well fields are included in the Recommended Removal Action Alternatives. One field, consisting of two extraction wells, is proposed for construction in the trichloroethene/tetrachloroethene (TCE/PCE) plume downgradient from the foundation of Building 666. The second extraction well field consists of three wells to be constructed near the east-west McClellan Air Force Base (AFB) boundary in the northern trichloroethene/1,2-dichloroethene (TCE/1,2-DCE) plume. Each of the well fields is designed to initially withdraw groundwater from the central part of the plume in which contaminant concentrations are expected to be greatest.

The following sections explain the background hydrogeology, analytical data, and calculations that have led to the siting and design of the well fields. Section A6.1 describes the extraction well field in the TCE/PCE plume. Section A6.2 describes the well field in the northern TCE/1,2-DCE plume.

A6.1 Proposed Extraction Well Field for TCE/PCE Plume

An extraction well field consisting of two wells screened in the A geohydrologic zone is proposed for the TCE/PCE plume migrating in the Building 666 area of Operable Unit (OU) B. The spacing, depth, and design of the two wells are based upon data collected during the OU B Groundwater Remedial Investigation (OUBGRI) and the Preliminary Groundwater Operable Unit Remedial Investigation (PGOURI) field investigations, March 1989 through April 1990. The following sections outline the analysis procedures used to arrive at the well field configuration.

A6.1.1 Depth Determination

The principal data interpreted to determine the depth of each of the two proposed extraction wells were taken from lithologic logs of the borings for monitoring wells in the plume area. The monitoring wells (MWs) are MW-11A, MW-41S, MW-157, MW-158, MW-159, and MW-153. Well locations are shown in Figure A6-1.

The A geohydrologic zone includes the deposits from the water table at approximately 100 feet below ground surface (BGS) (-40 feet mean sea level [msl]) to 135 feet BGS (-75 feet msl).

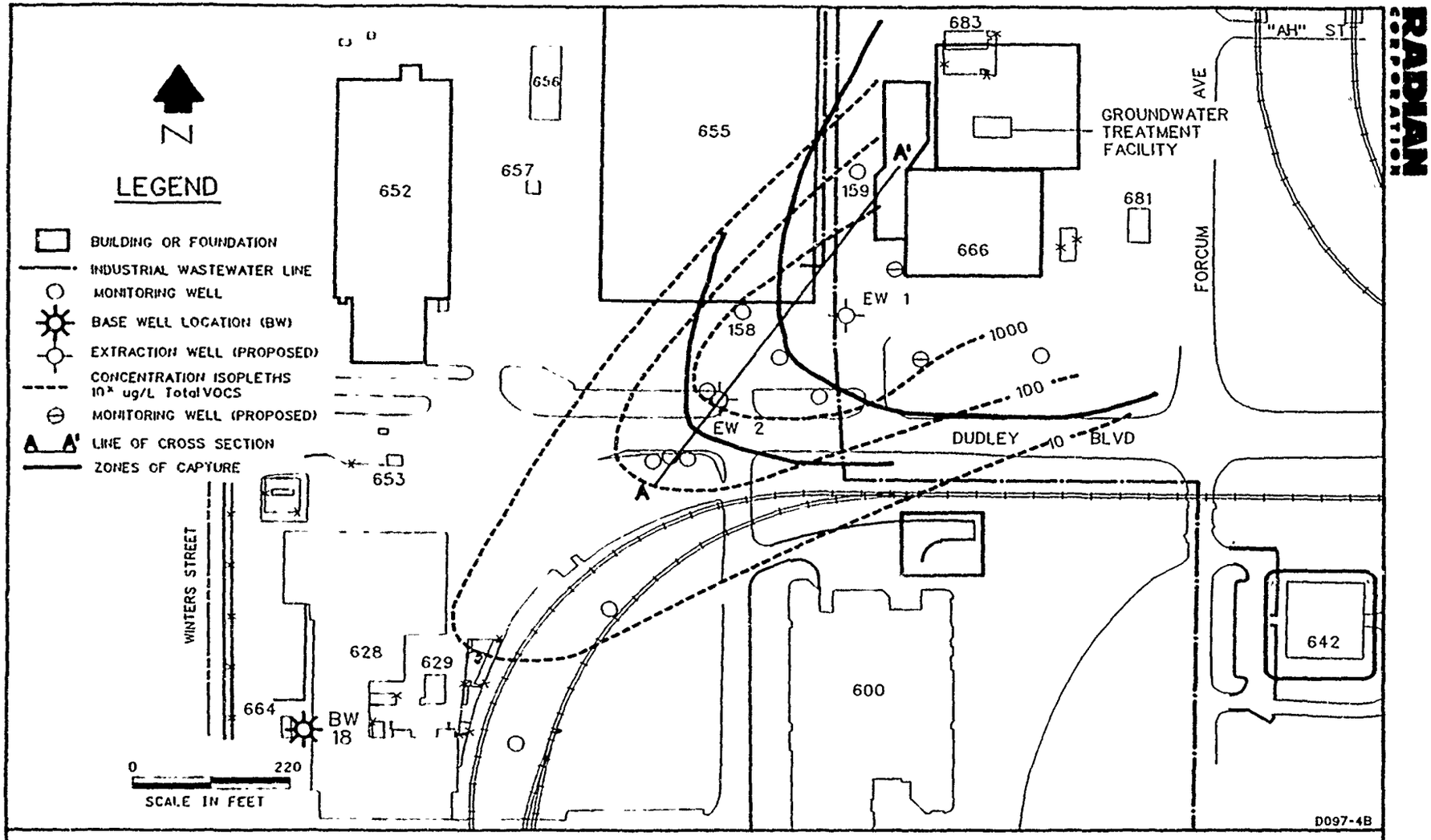

Figure A6-1. Location of Extraction Wells for Expedited Removal Action, TCE-PCE Plume, Operable Unit B.

In the area where the TCE/PCE plume has its highest concentrations, MW-41S, MW-157, MW-158, and MW-159 penetrate only the fine silty sands, silts, and clays of the A zone to a depth of 117 feet (-54 feet msl). Aquifer tests at MW-157 and MW-158 were conducted in these fine-grained deposits.

Downgradient MW-153 has a screen interval from 116.5 to 126.5 feet BGS (-53.98 feet to -63.98 feet msl) in fine-grained silty sand and fine to coarse-grained gravelly sand underlain by a sandy to silty clay. The log from MW-154 indicates the clay is 7 feet thick, with a bottom contact at -70.5 feet msl. Underlying this clay, a coarse-grained sand with abundant pebble gravel approximately 10 feet thick was described. See cross section A-A′ in Figure A6-2.

Borings for MW-41S, MW-157, and MW-158, in the most concentrated part of the plume, did not penetrate deeply enough to indicate the presence of the fine-grained sand, 7-foot clay, 10-foot gravelly sand penetrated at MW-154. However, MW-11A, drilled in April 1990 near the proposed location of the downgradient extraction well, did not penetrate 7 feet of clay or the underlying 10 feet of gravelly sand in the depth interval from -65 to -75 feet msl. Lithologies reported on the log for MW-11A are 2 feet of gravel from -66 to -68 feet, 2 feet of silty to sandy (as interbeds) gravel, 2 feet of sandy clay (-70 to -72 feet msl), and 3 feet of silt or sandy silt from -72 to -75 feet msl, total depth. As depicted in cross section A-A′, the clay and underlying gravel are interpreted to be thinner and deeper than those reported at MW-154. The potential exists that the deposits have graded laterally into other lithologies. Gradational changes in deposits are not unusual for the alluvial plain depositional environment of the A zone.

Contaminants with a total volatile organic compound (VOC) concentration of 160 μg/L have been detected in the fine-grained sand and gravelly sand at MW-153. The presence of the VOCs suggests that there is some migration of groundwater containing contaminants between the plume upgradient at MW-158 and MW-157 (which has higher VOC concentrations) and MW-153.

The presence of VOC contaminants in the sands at MW-153 and the apparent migration through sandy silts and silty sands are the principal reasons for proposing to screen the downgradient TCE/PCE extraction well through the sands and silts shown in cross section A-A′. The bottom of the screen will be placed at

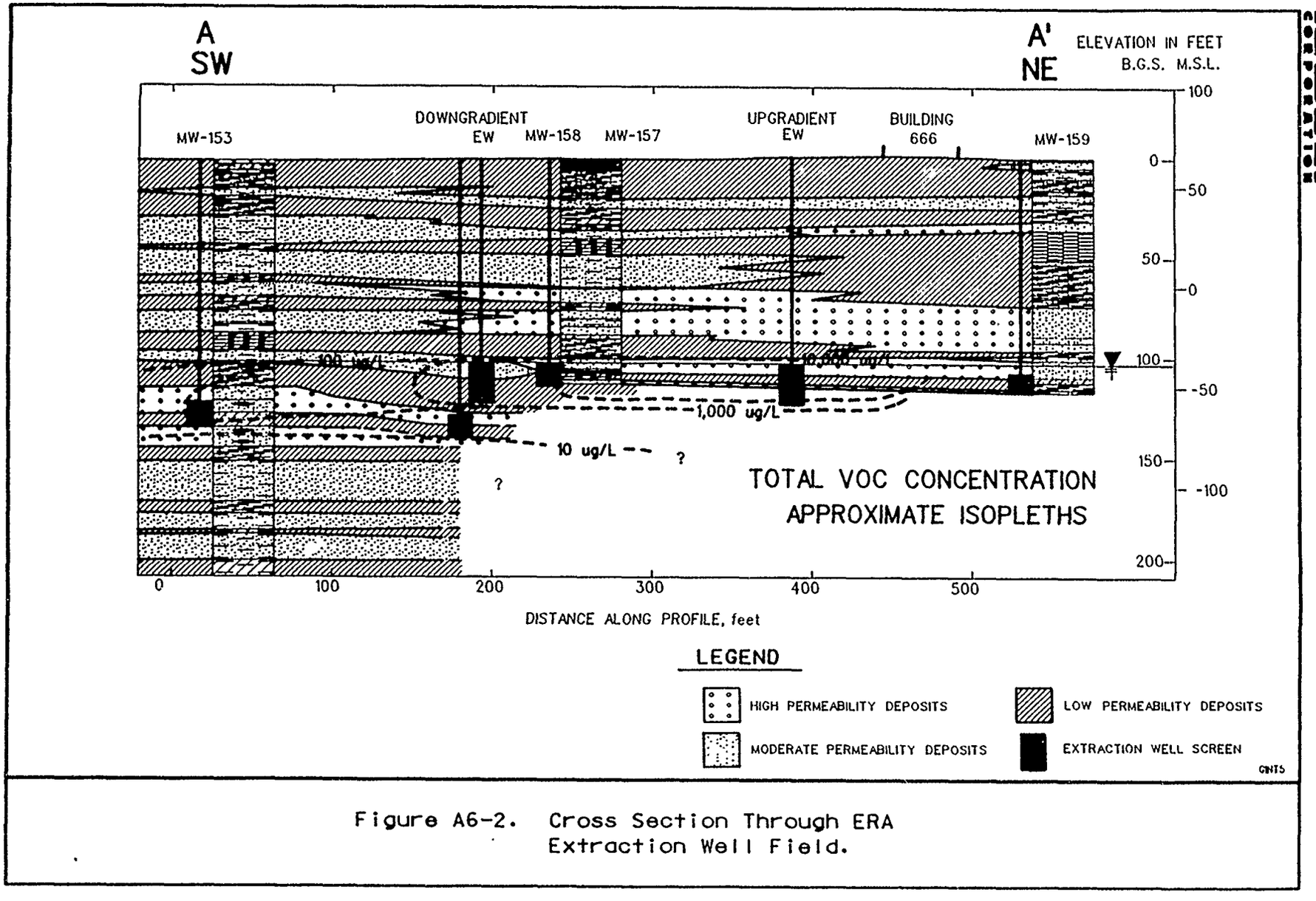

Figure A6-2. Cross Section Through ERA Extraction Well Field.

approximately -62 feet msl. The screen interval for the well will extend upward to -42 feet msl, approximately 2.5 to 3.0 feet below the static water table. The saturated interval affected by pumping of the well will be approximately 23 feet.

The upgradient well in the TCE/PCE extraction well field will be screened through fine-grained silty sands, silts, and sandy clay deposits that are expected to be gradational, but continuous, from MW-157 to the foundation of Building 666. It is anticipated that at a horizontal distance of 120 to 140 feet northeast of MW-157, the fine-grained sediments will contain groundwater with the highest concentrations present in the TCE/PCE plume. Concentrations are likely to exceed 20,000 μg/L total VOCs because concentrations at MW-157 were 11,600 μg/L in April. The upgradient extraction well in the TCE/PCE extraction well field will be screened from approximately -60 to -45 feet msl to extract the contaminated groundwater from a saturated thickness to 17 feet below the static water table.

A6.1.2 Aquifer Tests and Hydraulic Conductivities

The pumping rate of each extraction well was determined on the basis of hydraulic conductivities, in the saturated interval over which vertical hydraulic control is needed, optimum drawdown, and horizontal zone of capture needed to control contaminated groundwater flow.

Two aquifer tests were conducted at wells in the TCE/PCE plume during the OUBGRI. Monitoring Wells 157 and 158 were each pumped for approximately 24 hours in individual tests. The wells are approximately 77 feet apart, and each was monitored while the other was being pumped. During the tests of the wells, Base Well (BW) 18 was not operating.

Neuman (1975) equations were used to calculate the transmissivity (T) and storage coefficient (S) values for observation wells and T values for pumped wells (Section A5.1). Hydraulic conductivity values (K) were calculated by dividing the T value by the test interval(b), the saturated interval affected by the aquifer test. The following summarizes results of the calculations:

Pumped Well MW-157	Pumped Well MW-158
b = 13.4 ft.	b = 11.5 ft
T = 67 to 214 ft^2/day	T = 94 to 155 ft^2/day
K = T/b	K = T/b
K = 5 to 16 ft/day	K = 8 to 13.5 ft/day

On the basis of these calculations, a mean hydraulic conductivity of 20 feet/day was estimated for the upgradient TCE/PCE extraction well. The well will extract water from an estimated saturated interval consisting of 17 feet of fine-grained silty sand, silt, and clay. Rounding the hydraulic conductivity (k) values from the aquifer tests upward to 20 ft/day, the total transmissivity (T) estimate for the saturated interval (b) is:

$T = Kb$
$T = (20\ ft/day)\ (17\ feet)$
$T = 340\ ft^2/day$

Aquifer tests were not conducted in any monitoring wells near the proposed location of the downgradient well in the TCE/PCE plume. Because the deposits in the A geohydrologic zone increase in sand and gravel content near the proposed location (Figure A6-2), a method that does not require an aquifer test was used to estimate the transmissivity at the well location. Masch and Denny (1966) developed curves for fine- to medium-grained sand deposits that may be used to estimate transmissivity from particle size distribution curves. Particle size distribution curves were developed for three samples collected from depths of 100 to 125 feet BGS during the drilling of the boring for MW-11A (Appendix D). Grain diameter dimensions (d) representing weight percentages of the samples were determined from the curves. From the curves, values were obtained for the values Σ_i and d_{50}. Σ_i is the result of the equation:

$$\Sigma_i = \frac{d_{16} - d_{84}}{4} + \frac{d_5 - d_{95}}{6.6}$$

where d_{16}, d_{84}, d_5, d_{95} are grain diameter dimensions (millimeters [mm]) that are exceeded by 16 percent, 84 percent, 5 percent, and 95 percent, respectively, of the grains in the sample. For example, if d_{16} = 2 mm, 16 percent of the sample grains have diameters greater than 2 mm.

By the Masch and Denny method, the d_{50} value for the sample is converted to a θ unit, where:

$$\theta = \ln d_{50}$$

For the samples analyzed, the Σ_I and θ unit values were used with the Masch and Denny curve to estimate K (cm/min). Results of Σ_I, θ units, K (cm/min), and K in ft/day are:

Sample	Σ_I	d_{50} (mm)	θ Unit	K (cm/min)	K (ft/day)
100 - 110	1.17	0.50	0.69	1.0	47
110 - 121	1.49	0.47	0.76	.7	32
121 - 125	2.86	3.5	-1.25	off curve	--

The sample from 121 to 125 feet was too coarse to yield meaningful results with the curve. The ln d_{50} must be negative to be used on the curve; therefore, d_{50} must be less than 2.73. Because the curve could not yield a K value for the interval from 121 to 125 feet, a value of 360 ft/day was estimated from published ranges for a silty coarse sand.

The estimated transmissivity for the 20 feet of screened interval in the downgradient well is:

5 feet x 47 ft/day	=	235 ft^2/day
11 feet x 32 ft/day	=	352 ft^2/day
4 feet x 360 ft day	=	1,440 ft^2/day
TOTAL		2,027

Mean K = 2,027/20 ft = 100 ft/day

The pumping rate for each of the wells was selected on the basis of the drawdown required to control the migration of the plume toward MW-153 and the need to minimize the lowering of the water table to prolong the usefulness of each well. The drawdown required to control flow between MW-157 and MW-153 is estimated to be a

minimum of 1 foot at the location of the extraction well located between the two monitoring wells. The slope of the groundwater surface between MW-157 and MW-153 is 0.0033 when BW-18 is pumping. Difference in head between the wells is approximately 0.7 feet. With 1 foot of drawdown at the extraction well located 110 feet upgradient from MW-153, the curved drawdown surface produced by the extraction well would intersect the static surface approximately 50 feet downgradient from the extraction well. The static surface is sloping toward the cone of depression created by a base supply well. Calculation of the drawdown surface for the well is based on the attainment of equilibrium after pumping has been maintained at a rate of 15 gpm (2,900 ft^3/d) for a period of 2 to 3 months.

After the drawdown surface has stabilized at the downgradient extraction well, there should be no drawdown at a radial distance of 100 feet upgradient from the well. Therefore, there will be no significant drawdown at MW-157, which will be approximately 100 feet upgradient, although groundwater from the vicinity of MW-157 will flow toward the extraction well under the influence of the natural gradient.

The pumping rate selected for the upgradient extraction well, 5 gpm (960 ft^3/d), will cause a drawdown of approximately 3 feet at the well. The slope of the static water table surface at the proposed location for the well is estimated to be 0.004 when BW-18 is pumping. After the drawdown surface has stabilized at the upgradient extraction well, there will be drawdown of 0.7 foot at a distance of 100 feet in the downgradient direction. Groundwater beneath the point where the drawdown is 0.7 feet will be drawn upgradient to the extraction well at a very low (0.1 ft/d) velocity. Therefore, if the upgradient extraction well is located approximately 110 feet northeast of and upgradient from MW-157, and 200 feet from the downgradient extraction well, there will be no compound drawdown at MW-157 from the wells, and the upgradient extraction well will draw groundwater from a point upgradient of MW-157.

A6.1.3 Extraction Field - Well Siting

The preliminary siting of wells in the extraction well field for the TCE/PCE plume was based on: the probable extent of contaminant concentrations exceeding 1,000 $\mu g/L$; the pumping-induced gradients expected at distances from the wells when equilibrium is attained; and the desired effectiveness that each well will have at equilibrium.

The probable extent of contaminant concentrations greater than 1,000 μg/L in the A zone is shown on Figure A6-1 by the 1,000 μg/L isopleth. The isopleth is dashed because its location is approximate. The isopleth is interpolated between monitoring wells in the A zone where concentrations are known, and its longitudinal axis is aligned with the flow direction toward BW-18. The "front" or downgradient edge of the 1,000 μg/L isopleth is estimated to be approximately 110 feet southwest or downgradient from MW-157, which had the highest concentration (11,600 μg/L total VOCs) in the TCE/PCE plume. The downgradient extraction well would be sited 50 to 60 feet northeast of the estimated location of the front edge of the 1,000 μg/L isopleth.

The wells have been sited such that their drawdowns will be sufficient to exceed the existing groundwater gradients which result from the pumping of BW-18. Drawdown of at least 1 foot at the downgradient extraction well will induce a gradient sufficient to capture groundwater with total VOC concentrations of 1,000 to 3,000 μg/L that would normally flow toward MW-153 and BW-18. Drawdown of at least 3 feet at the upgradient extraction well will produce a gradient that will capture groundwater with concentrations estimated at 20,000 μg/L or greater around the well.

The two extraction wells have been sited along the approximate longitudinal axis of the TCE/PCE plume. The positions along the longitudinal axis were selected to optimize the effectiveness of extraction and treatment of groundwater. The purpose of the well field is control of groundwater with concentrations of 1,000 μg/L total VOCs or greater. The systems considered for treatment of the extracted water are the most cost-effective when concentrations are 1,000 to 4,000 μg/L total VOCs. Therefore, wells in the extraction field have been sited to control the more concentrated part of the plume and to capture, in the first one to two years of extraction, groundwater along the axis without significant dilution from groundwater with concentrations of 1 of 10 μg/L. To accomplish this control and capture, the zone of capture for each well was considered in the siting.

The pumping rate for each of the wells was determined from equations for calculation of the zone of capture for a pumping well. The equation of Keely and Tsang (1983) is the basis for determining well pumping rates. The equation, normally solved to determine the zone of capture (Z_c) for a well under pumping conditions, can be solved for total discharge rate (Q) when a specific Z_c is desired. The equation to solve for maximum Z_c in a confined aquifer at a point upgradient from the well is:

$$Z_c = 2\pi r = \frac{Q}{hKI}$$

where:

r = Radial distance of influence downgradient, in feet
Q = Total discharge rate in ft^3/day

h = Thickness of the saturated interval (here the thickness of the zone) in feet
K = Hydraulic conductivity in ft/day
I = Hydraulic gradient in feet/foot

For a pumping well operating in a geohydrologic zone that has a natural or induced hydraulic gradient which is the case in OU B, the Z_c is shaped like a parabola with its vertex on the downgradient side of the pumping well. Therefore, the Z_c is less than its maximum width on the downgradient end nearest the well and widens to its maximum, Z_{CM}, at a distance upgradient. At the location of the well, the Z_c may be designated Z_{CW} and is one-half the width of Z_{CM}. Therefore,

$$Z_{CW} = \pi r = \frac{Q}{2\,hKI}$$

Downgradient Well

$$Z_{CM} \text{ (zone of capture)} = 2\pi r = \frac{Q}{hKI}$$

where:

Q (flow rate) = 2900 ft^3/d; K (hydraulic conductivity) = 100 ft/d
h (saturated thickness) = 23 feet; I (gradient) = 0.0033
r = radius of influence downgradient

therefore:

Z_{CD} = 382 feet at a distance upgradient from well
Z_{CW} = 191 feet at the extraction well

Upgradient Well

where:

Q = 960 ft^3/d; h = 18 feet
K = 20 ft/d; I = 0.004

therefore:

Z_{CM} = 667 feet at a distance upgradient from well
Z_{CW} = 333 feet at the extraction well

The zones of capture equations used are based on assumptions of confined conditions, homogeneity, and isotropy in the saturated thickness. These assumptions do not hold for the saturated thickness in the TCE/PCE plume area. Therefore, the Z_{CD} values are expected to be less than calculated values when the extraction wells reach a steady state. However, the width of the plume with concentrations of 500 to 1000 μg/L total VOCs is estimated to be 250 to 300 feet in the vicinity of the extraction wells. Therefore, conservative zones of capture of 300 feet and 400 feet for the downgradient and upgradient wells, respectively, are considered realistic. Existing and new monitoring wells will be used to verify the actual zone of capture for the wells.

It is apparent from Figure A6-1 that the zone of capture created by the downgradient extraction well alone would capture the portion of the TCE/PCE plume that exceeds 1,000 μg/L. The upgradient well was included in the well field to draw in more highly contaminated groundwater closer to the probable source area. Concentrations of total VOCs in groundwater at the upgradient well location may exceed 10,000 μg/L. A well extracting groundwater containing greater concentrations, closer to a source, is a "source control" well. A source control extraction well limits the potential for horizontal and vertical spreading of the contaminants away from the source. The use of a source control well along with a downgradient well will also decrease the time needed to extract the contaminants because the more highly contaminated groundwater will travel a shorter distance to the source control well.

The results of calculated and more conservative, estimated zones of capture for the proposed extraction wells indicate that no more than two wells, sited along the axis of the TCE/PCE plume, are necessary to meet the purpose of the well field. If additional wells were to be placed in the approximate width of the contaminant plume, pumping rates would have to be lower than those proposed for the two extraction wells. Lower pumping rates would be required to achieve smaller zones of capture for each of the wells. To have a combined zone of capture equivalent to the proposed downgradient well, two wells pumping at a rate of 7.5 gpm would be needed near the front edge of the TCE/PCE plume. If both wells were pumped at rates greater than 7.5 gpm, the zone of capture for each well would extend outward beyond the more concentrated part of the plume. These zones of capture would draw less concentrated groundwater into the wells, thereby causing extraction of less concentrated water for treatment. The zones of capture from those two wells would partially overlap, and there is potential that part of the plume lying at a point between the wells could migrate downgradient without being captured. An additional disadvantage of siting two wells where one is adequate is the greater cost of drilling, screening, and installing the wellhead and underground piping.

A6.1.4 Well Construction

Each of the extraction wells will be constructed such that the boring for the well can be reentered and deepened when the water table is drawn down to the depth of the pump intake. The well construction details are shown in Figure A6-3. The steel components in the well casing and screen will be constructed of materials with sufficient strength to withstand removal when the borings must be deepened in 5 to 7 years.

A6.1.5 Initial Contaminant Concentration

The initial contaminant concentrations for each extraction well are based on the expected concentration of total VOCs that will be extracted by each well during its first year of operation. The initial concentration is considered the "worst case" in terms of the impact on the treatment system. It is anticipated that concentrations of groundwater extracted by each well will decrease after one year (or less) of operation because groundwater with contaminant concentrations less than 1000 μg/L will enter the zone of capture and dilute the concentration as the wells continue to operate.

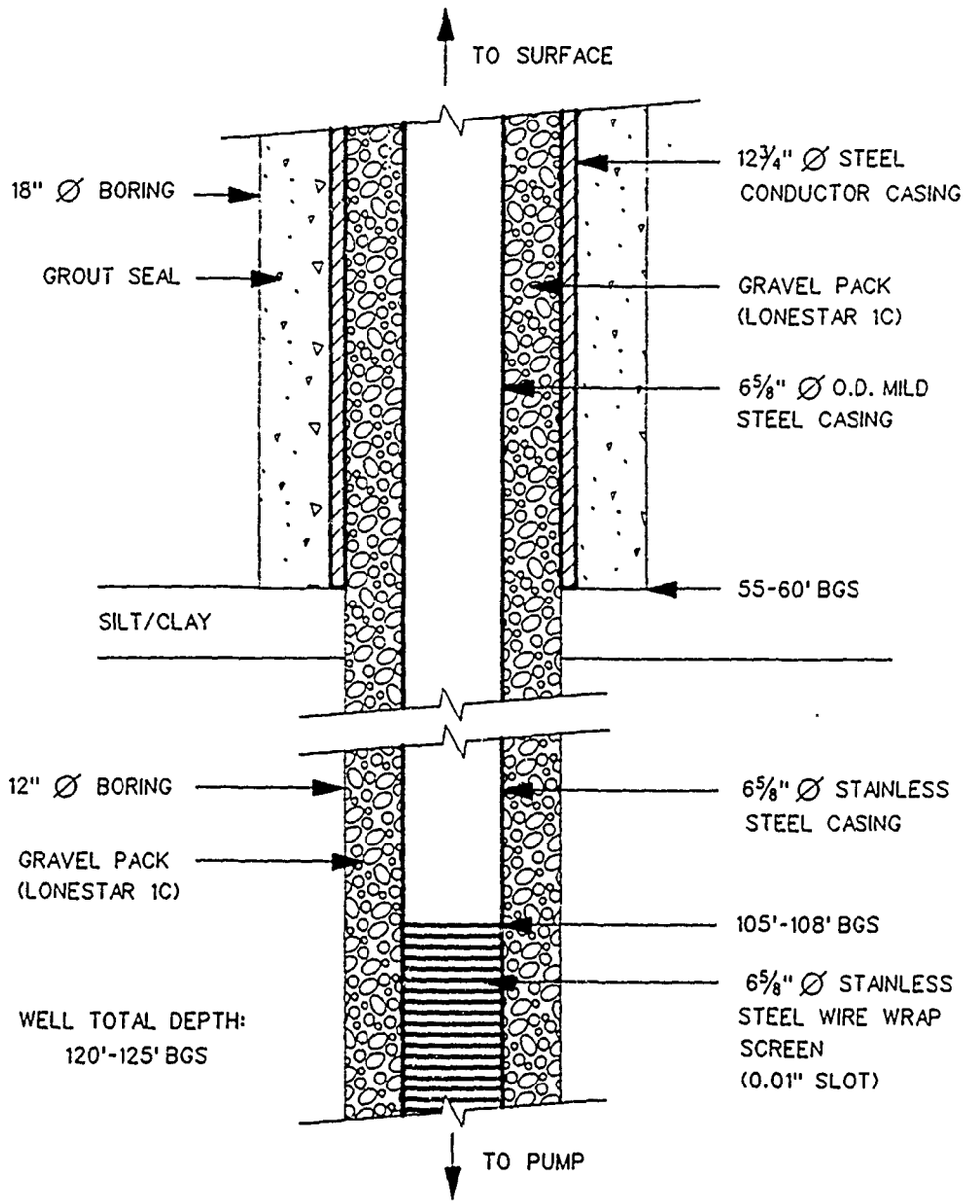

Figure A6-3. Construction Detail Typical Extraction Well TCE/PCE Plume.

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The assumptions used to establish the chemical-treatment design were:

- The upgradient well will have an average flow rate of 5 gpm and the downgradient well will have an average flow rate of 15 gpm.

- All VOC contaminants are dissolved in groundwater. There are no separate-phase VOCs present in the A zone plume.

- Concentrations of VOCs in groundwater at the proposed extraction well locations were estimated on the basis of contaminant concentrations analyzed in samples from 6 A-zone monitoring wells. The wells analyzed were: MW-41S MW-65, MW-153, MW-157, MW-158, and MW-159. There are no wells constructed in the locations of the proposed extraction wells that would yield samples representing concentrations in the plume at those locations.

The VOCs that have been detected in the plume in samples from the six wells are listed below with a range of concentrations measured in 1990.

- Trichloroethane (TCE): 60 - 9,600 μg/L (18,000 μg/L - not confirmed);

- Tetrachloroethene (PCE): 1 - 2,000 μg/L;

- 1,2-Dichloroethene (1,2-DCE): 4 - 45 μg/L;

- Chloroform: Not detected (ND) - 4 μg/L;

- Methylene chloride: ND - 540 μg/L (540 μg/L below detection limit -1 sample); and

- 1,1,1-Trichloroethane (1,1,1-TCA): ND - 15 μg/L.

Volatile organic compounds used in the source area or detected in soils below the source area, but not detected in groundwater samples are:

- Acetone;
- Methyl ethyl ketone;

- Trichlorotrifluoroethane;
- 2-Hexanone;
- Benzene;
- Toluene; and
- Xylenes.

To calculate expected extraction concentrations in groundwater, the TCE concentration, which is greater than that of any other VOC, was used as an indicator. The concentrations of other VOCs that are known to be in groundwater were estimated from the ratio of their concentrations to TCE were from samples in which the other VOCs were detected. They concentration ratios used were:

PCE = 0.2 TCE
1,2-DCE = .03 TCE
Chloroform = .002 TCE
Methylene chloride = .05 TCE
1,1,1-TCA = .001 TCE

For each extraction well, TCE concentrations were assumed to be more concentrated in the upgradient flow to the well and less concentrated in the downgradient flow to the well. The more concentrated upgradient and less concentrated downgradient flows were each estimated to represent one half of the groundwater extracted from the well.

The concentration of flow to each well were estimated as follows:

<u>Downgradient Well (pumped at 15 gpm)</u>
1/2 of flow = 7.5 gpm with 1,000 μg/L TCE
1/2 of flow = 7.5 gpm with 3,000 μg/L TCE
Total flow = 1/2 (1,000 μg/L) + 1/2 (3,000 μg/L)
= 2,000 μg/L TCE

<u>Upgradient Well (pumped at 5 gpm)</u>
1/2 of flow = 2.5 gpm with 30,000 μg/L TCE
1/2 of flow = 2.5 gpm with 60,000 μg/L TCE
Total flow = 1/2 (30,000 μg/L) + 1/2 (60,000 μg/L)
= 45,000 μg/L TCE

Because both wells would be pumping continuously and the flow from each would be mixed with the other in a holding tank before treatment, the following are estimated to be the mean concentrations of TCE in the holding tank due to the mixing of the flows:

Upgradient Well (5 gpm)
TCE concentration = 45,000 μg/L

Downgradient Well (15 gpm)
TCE concentration = 2000 μg/L

Total flow per minute = 15 gallons + 5 gallons = 20 gallons

C_T = mean concentration of total flow

C_T = 5 g (45,000 μg/L) + 15g (2,000 μg/L)/20 g

C_T = 12,750 μg/L TCE

To obtain the total VOC loading expected from the VOCs detected in groundwater, the following calculations were made:

Mean TCE	= 12,750 μg/L
Mean PCE = 12,750 x .2	= 2550 μg/L
Mean 1,2-DCE = 12,750 x .03	= 383 μg/L
Mean chloroform = 12,750 x .002	= 25 μg/L
Mean methylene chloride = 12,750 x .05	= 638 μg/L
Mean 1,1,1-TCA = 12,750 x .001	= 12 μg/L
Total Mean VOC Concentration	= 16,360 μg/L

The flow rate planned for each of the extraction wells is based upon the data available for the hydrologic parameters for the A geohydrologic zone in the area of TCE/PCE plume. Because the nature of the natural deposits in the zone changes significantly over relatively short vertical and horizontal distances, it is recommended that the pumps to be used in the wells have a range of pumping rates available to allow adjustment of the flow rate after the wells are constructed.

The estimated concentrations of contaminants that will enter each extraction well in the first months of pumping are based on data from previously constructed extraction wells at McClellan AFB and the assumption that all contaminants in the TCE/PCE plume are dissolved in groundwater. The assumption that no separate phase of VOC contaminants present is based on the fact that separate phase contaminants have not been detected in monitoring wells or extraction wells in areas such as OU D where drums of waste solvent were discharged into sludge pits. In the probable source area for the TCE/PCE plume, relatively small quantities of VOC were used for metal degreasing and were collected in trenches and sumps where they could mix with water before discharge. Therefore, the assumption that no separate phase contaminants are present is drawn from the evidence that separate phase liquids have not entered the groundwater beneath McClellan AFB even in those locations where greater volumes of VOC contaminants were discharged. Samples of groundwater drawn into the extraction wells will be analyzed during the the operation of the extraction well field. An increasing trend in VOC concentration at the upgradient well would indicate the approach of separate phase VOCs. The identification of separate phase VOCs in the well from increasing concentrations would require evaluation of the treatment system. Furthermore, additional drilling of borings and construction and sampling of monitoring wells in the OU B RI will address the potential occurrence of separate phase liquids.

A6.2 Proposed Extraction Well Field--Northern TCE/1,2-DCE Plume

An extraction well field consisting of three wells, each screened in a separate geohydrologic zone, is proposed for the northern TCE/1,2-DCE plume. The purpose of the extraction well field is to initially capture the groundwater in the northern plume that contains the greatest concentration of total VOCs. As pumping proceeds in the well field, groundwater with lower concentrations of VOCS will be captured as it migrates southward to the wells. The location, depth, and design of the three wells are based upon data collected in the OUBGRI and PGOURI programs from March 1989 through May 1990.

Contaminant concentrations exceeding 100 μg/L total VOCs have been detected in groundwater samples from the A, B, and C geohydrologic zones near the east-west McClellan AFB boundary (Section A4.2). Concentration isopleths for each zone are shown in Figures A6-4, A6-5, and A6-6. The groundwater in each of those zones is migrating toward the capture zone created by the operation of BW-18 (Section A3.2).

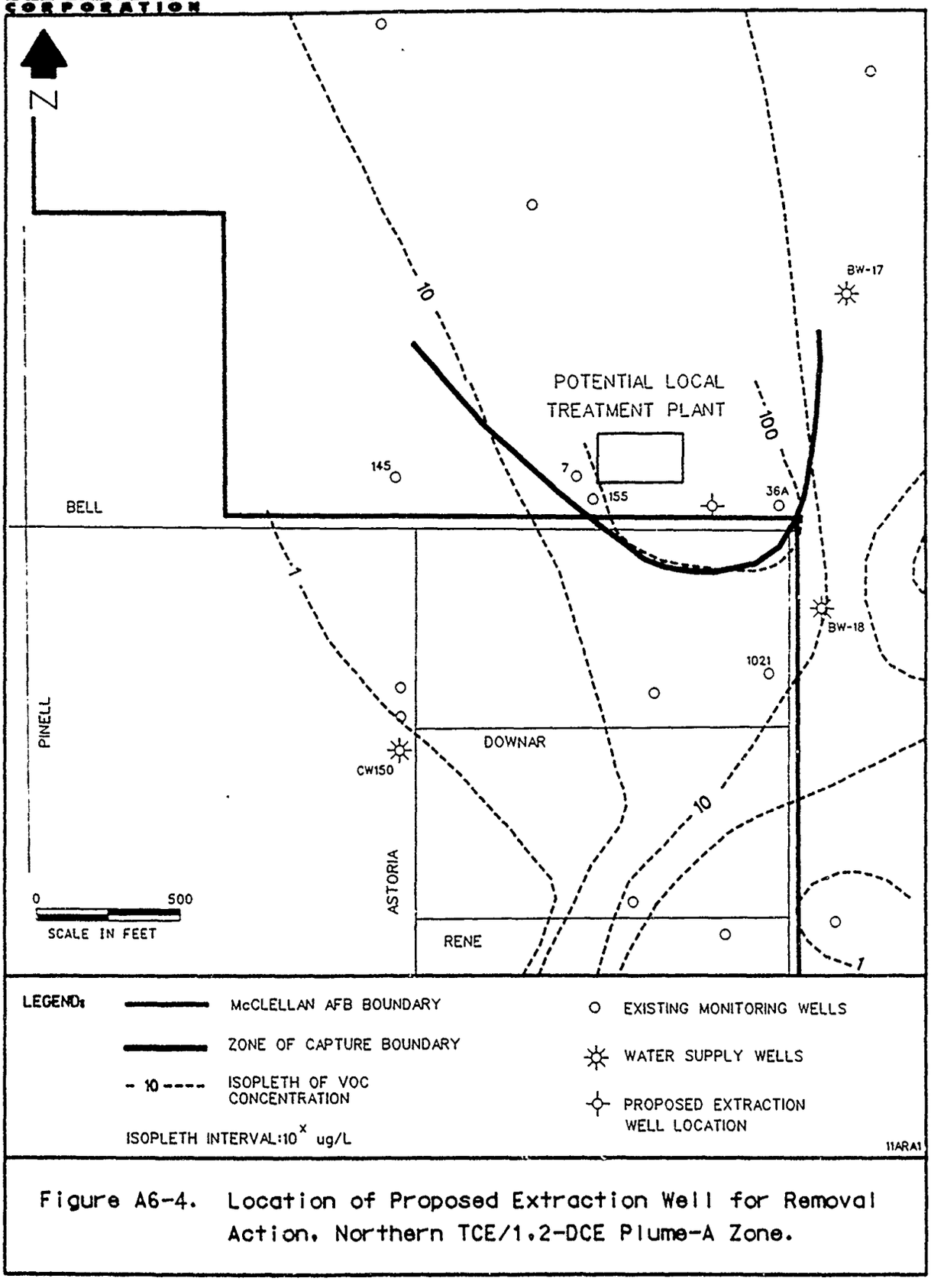


Figure A6-4. Location of Proposed Extraction Well for Removal Action, Northern TCE/1,2-DCE Plume-A Zone.

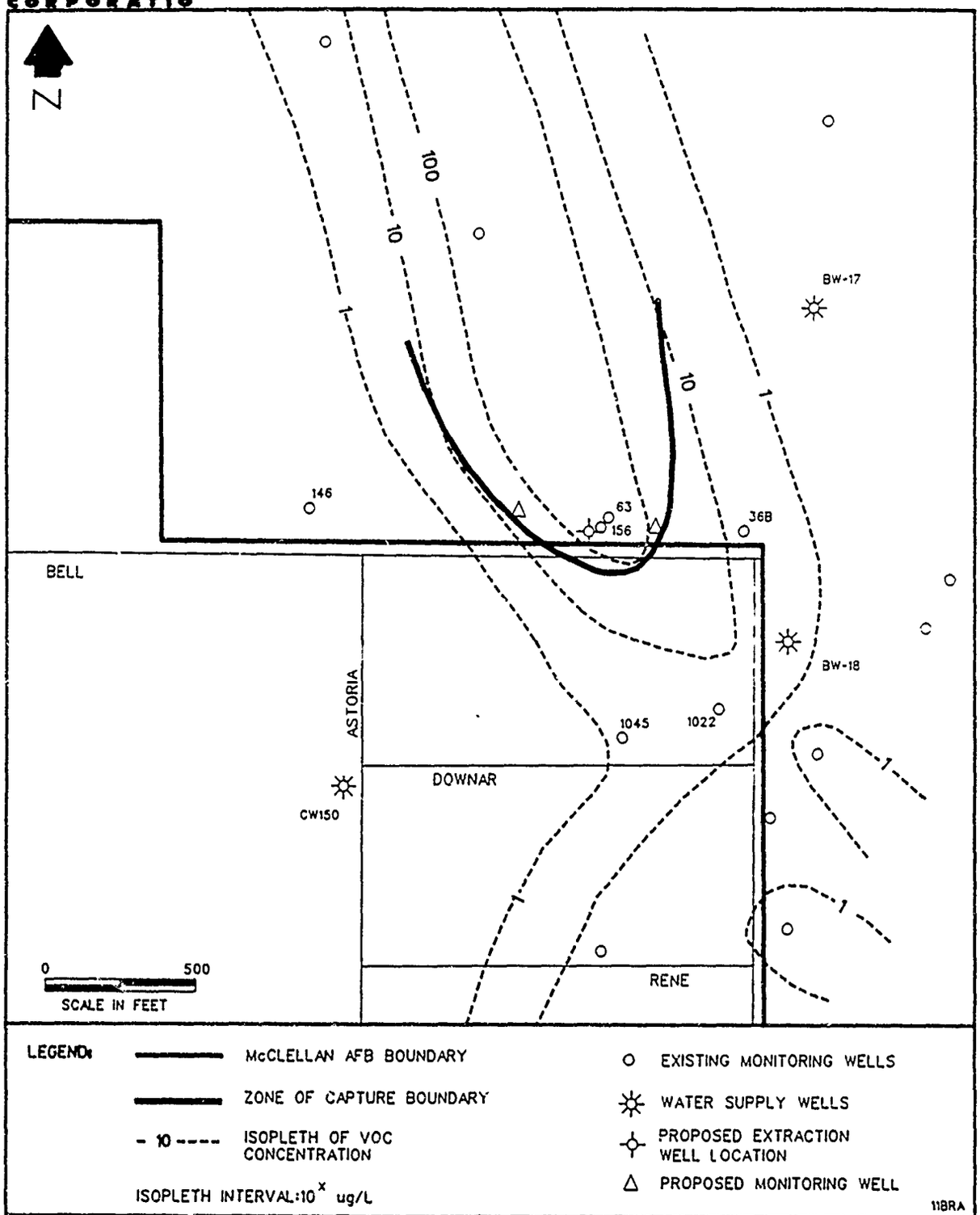


Figure A6-5. Location of Proposed Extraction Well for Removal Action, Northern TCE/1,2-DCE Plume-B Zone.

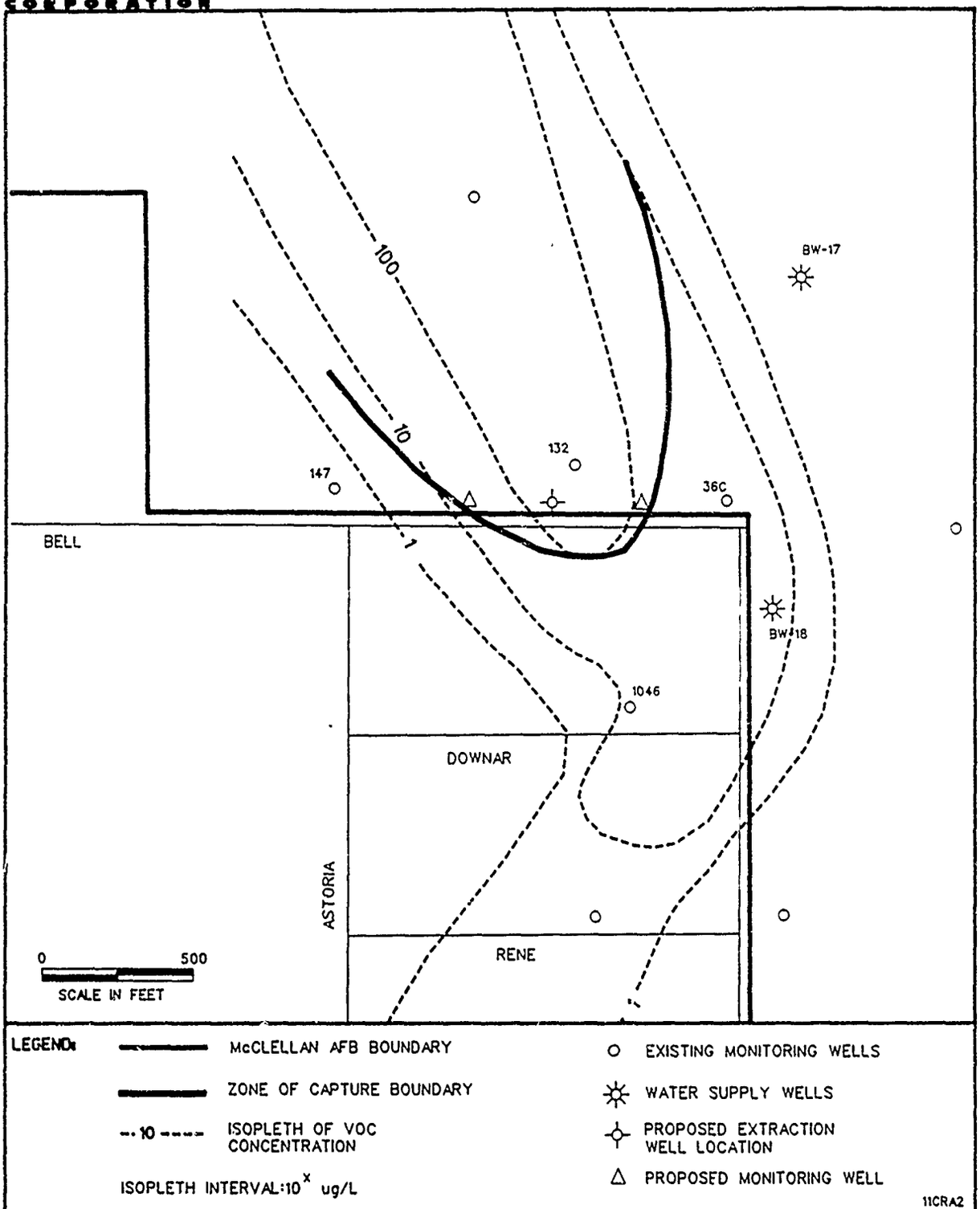


Figure A6-6. Location of Proposed Extraction Well for Removal Action, Northern TCE/1,2-DCE Plume-C Zone.

To capture the groundwater containing contaminant concentrations greater than 100 μg/L total VOCs before it migrates into the capture zone of BW-18, control of migration in the A, B, and C zones with extraction wells will be necessary. Three extraction wells, one constructed in each of the zones, are the most effective method of controlling the migration of the plume.

A6.2.1 Determination of Number and Depth of Wells

The elevations of geohydrologic zones containing groundwater greater than 100 μg/L VOCs are: the A zone, -43 to -78 ft msl; B zone, -79 to -124 ft msl; and C zone, -125 to -198 ft msl. Concentrations are approximately equally distributed in groundwater over a 150-foot depth interval. One well with a long screen interval could be constructed to extract from all three zones. However, each of the zones has a suite of deposits and hydraulic parameters that are different than the zone above or below. Each zone responds uniquely to hydraulic conditions created by the pumping of BW-18 and will respond uniquely to the pumping of wells with less capacity. Three separate wells are proposed to extract groundwater because of the differences in hydraulic response that exist between zones.

Three separate wells offer several advantages over the construction of one or two extraction wells. The advantages are:

- Each well's discharge may be fine-tuned to achieve the withdrawal contaminants out of fine-grained deposits that occur in the zone. One well with a single well screen would draw most of its discharge from the most permeable deposits. Fine-grained deposits will yield contaminants at a slower rate.

- With one well in each zone, the horizontal zone of capture may be tailored for the characteristics of the zone. The zones differ in the thickness and permeability of deposits. The well discharge in each zone may be changed during initial testing or in the future to increase or decrease the zone of capture.

- If one of the wells must be shut down for maintenance or repair, there will be decreased potential for cross contamination between zones through well casing or gravel pack. All three zones now have approximately equal concentrations of total VOCs. However, if in

the future, the concentration in one zone is reduced below those of others, the well with lower concentrations may be shut down without increasing the potential for cross contamination.

- Aquifer test data indicate that there is hydraulic communication between the C and D zones. A separate C zone well may have sufficient hydraulic effects to draw contaminants upward from the D zone. This effect is noticeable in the upward gradient produced by pumping of BW-18. With one long well screen, the hydraulic impact of the C zone extraction well on the D zone may be lessened.

The extraction well to be constructed in each of the zones will have a screen designed for the specific zone. Actual screen lengths to be installed in the wells will be determined from pilot hole borings drilled and sampled at the extraction well locations. The approximate screen length and elevations for each well have been selected from lithologic data from the boring drilled in MW-149 and adjacent wells. The lithology of deposits in the boring are shown in Plate 2.

The approximate screen intervals selected for each zone's extraction well are: the A zone, 110 feet (-48 ft msl) in a sand 5 feet below the dry season water table surface to 140 feet (-78 ft msl) in a clay below the bottom sand in the A zone; the B zone, 147 feet (-85 ft msl) in a clay to 187 feet (-125 ft msl) in a clay below the bottom sand in the B zone; and the C zone, 190 feet (-128 ft msl) in a clay to 260 feet (-198 ft msl) in a clay below the bottom sand in the C zone. The wells screen intervals are designed to fully penetrate all sands within the zone as well as fine-grained deposits between sands.

Approximately 5 feet of a fine-grained deposit will be left between the bottom of upper zone's screen and the top of the next lower zone's screen to reduce interference and vertical gradients between the zones near extraction wells. Extraction wells constructed in vertically adjacent zones such as A and B or B and C will be located 100 to 250 feet apart, thereby further reducing the interference between hydraulic responses in adjacent zones. The results from the monitoring of adjacent zones during aquifer testing indicated that hydraulic responses occur in unpumped zones when the adjacent zone is pumped (Section A5.1). Limited vertical gradient development at zone boundaries is favorable for removal of contaminants from fine-grained deposits between zones.

The screen intervals selected for each zone were designed to draw groundwater containing contaminants from all deposits in zone. It is expected that groundwater flow in the more permeable deposits will be horizontal. There is potential for vertical flow upward from the D zone to the C zone. Contaminant concentrations are lower in the D zone near the extraction wells at this time. However, if groundwater containing greater VOC concentrations continues to move to the south, the C zone well may provide a vertical gradient in the D zone that will be sufficient to capture the contaminant plume in the zone. The vertical gradient and any capture from the D zone will be monitored during operation of the wells.

A6.2.2 Hydraulic Parameters and Pumping Rates

The pumping rate of each extraction well was determined from estimated hydraulic conductivities for each zone, the saturated thickness over which vertical hydraulic control is needed, and the horizontal zone of capture needed to control the flow of contaminated groundwater. The hydraulic conductivity values used for each zone should be confirmed with longer term pump testing prior to selection of optimum rates for extraction, treatment, and discharge.

Four aquifer tests, one in each of the A, B, C, and D zones, were conducted in monitoring wells located within 300 feet of the recommended extraction well locations (Figures A6-4, A6-5, and A6-6). Transmissivity and hydraulic conductivity values for the vertical test interval affected by the pump test were calculated from aquifer test analyses. Because none of the wells used for aquifer test was screened over the entire geohydrologic zone, the transmissivity and hydraulic conductivity values obtained from the analysis were used to estimate transmissivity values for the entire zone. Differences in the characteristics of deposits in the full thickness of the geohydrologic zone were factored into the estimates of transmissivity and hydraulic conductivity used in the pumping rate calculation (Section A5.1).

The transmissivity (T), hydraulic conductivity (K), and storage coefficient (S) values estimated for each entire zone from the aquifer test data are:

A Zone:

$T = 1200\ ft^2/day$,
$K = 40\ ft/day$,
$S = 1 \times 10^{-3}$.

B Zone:

T = 1600 ft^2/day,
K = 40 ft/day,
S = 4 x 10^{-4}.

C Zone:

T = 4300 ft^2/day,
K = 61 ft/day,
S = 1 x 10^{-4}.

D Zone:

T = 3000 ft^2/day,
K = 47 ft/day,
S = 1 x 10^{-4}.

The D zone will not have an extraction well because total VOC concentrations in the zone near the east-west McClellan AFB are one-tenth or less of concentrations in the A, B, C, and D zones. Therefore, calculations of flow rate or zone of capture were not completed for the D zone.

The pumping rate for each of the wells was determined from equations for calculation of the zone of capture for a pumping well. The equation of Keely and Tsang (1983) is the basis for the determining well pumping rates. The equation, normally solved to determined the zone of capture (Z_c) for a well under pumping conditions, can be solved for total discharge rate (Q) when a specific Z_c is desired. The equation to solve for maximum Z_c in a confined aquifer at a point upgradient from the well is:

$$Z_c = 2\pi r = Q/hKI$$

Where:

r = Radial distance from the well in feet;

Q = Total discharge rate in ft^3/day;

h = Thickness of the saturated interval (here the thickness of the zone) in feet;

K = Hydraulic conductivity in ft/day; and

I = Hydraulic gradient in feet/foot.

For a pumping well operating in a geohydrologic zone that has a natural or induced hydraulic gradient, which is the case in OU B, the Z_c is shaped like a parabola with its vertex on the downgradient side of the pumping well. Therefore, the Zc is less than its maximum width on the downgradient end nearest the well and widens to its maximum, Z_{CM}, at a distance upgradient. At the location of the well, the Z_c may be designated Z_{cw} and it is one-half the width of Z_{CM}. Therefore,

$$Z_{cw} = \pi r = \frac{Q}{2hKI}$$

To achieve a Z_{cw} equivalent to the width of the 100 μg/L area of the plume at the well in each zone, the discharge from the well is determined by:

$$Q = 2\ KhI\ Z_{cw}$$

The width of the area of the plume exceeding 100 μg/L is shown for each zone in Figures A6-4, A6-5, and A6-6. The plume widths by zone are:

A Zone: Z_{cw} = 700 feet
B Zone: Z_{cw} = 400 feet
C Zone: Z_{cw} = 600 feet

Therefore, the well discharge needed to capture the full width of the plume at the well in each zone is determined from the following:

$$Q = 2\ KhI\ Z_{cw}$$

A Zone: Q_A = 2 (40 ft/day) (30 ft) I (700 ft)
Q_A = 5880 ft^3/day or 30 gallons per minute (gpm)

where:

I = 3.5×10^{-3} in the zone

B Zone: $Q_B = 2$ (40 ft/day) (40 ft) (I) (400 ft)
$Q_B = 4730$ ft^2/day or 25 gpm
where:
I = 3.7×10^{-3} in the zone

C Zone: $Q_C = 2$ (61 ft/day) (70 ft) I (600 ft)
$Q_B = 18{,}960$ ft^3/day or 100 gpm
where:
I = 3.7×10^{-3} in the zone

The well discharges for each zone are estimated values that will create the desired Z_{CW} at the location of each extraction well. In the upgradient direction, to the northwest, the maximum Z_C, Z_{CM}, will widen to capture the area of the plume in each zone that contains concentrations of 10 μg/L or less. The Z_{CM} upgradient for the well in each zone is:

A Zone: $2\ Z_{CW} = 1400$ feet
B Zone: $2\ Z_{CW} = 800$ feet
C Zone: $2\ Z_{CW} = 1200$ feet

The Z_{cw} and Z_{sm} for each zone are illustrated as parabolic shapes open to the northwest in Figures A6-4, A6-5, and A6-6. The discharges for each well to achieve Z_{CW} and Z_{CM} needed are dependent on the K and I values for each zone. The I value, hydraulic gradient, used are those determined from the April 1990 potentiometric surface. If the gradient increases, the pumping rate must increase to maintain the Z_{CW} and Z_{CM}. If the gradient decreases, and pumping rates are held constant, Z_{CW} and Z_{CM} will widen to draw in more of the plume. The K values used in the equation are estimated values for the geohydrologic zone. If the actual K values are greater, the well discharge, Q, needed to maintain the Z_{CW} and Z_{CM} must be increased.

To determine the Q needed for each zone, a thoroughly monitored aquifer test should be performed with a fully penetrating well screen in each zone to determine the K value and optimum pumping rate, Q.

A6.2.3 Extraction Well Siting

The extraction well locations, shown in Figures A6-4, A6-5, and A6-6, were selected on the basis of two criteria: to capture the largest possible volume of the 100 μg/L concentration of total VOCs in the northern TCE/1,2-DCE plume moving southwesterly toward BW-18, and to have the extraction wells located within the McClellan AFB boundary. The first criterion was established for the extraction wells to prevent contaminant concentrations, that could increase health risks to users of BW-18 water, from migrating toward the well. The second criterion was established for three reasons: extraction wells on McClellan AFB will prevent additional migration of the northern plume beyond its east-west boundary; the land between the McClellan AFB boundary and BW-18 already has private homes, businesses, and thoroughfares that would be disrupted by the construction of extraction wells and pipelines if off-base locations were selected; and the area of the proposed wells and pipelines on McClellan AFB is not presently being used and will, in the future, provide closer access to the existing pipeline leading to the groundwater treatment plant on base.

In siting the extraction wells for the northern TCE/1,2-DCE plume, the second criterion was given greater weight because: BW-18 has a treatment system in operation to remove contaminants from the groundwater extracted; the extraction wells will be able to draw most, if not all, of the contaminant plume greater than 100 μg/L back from off-base areas; and citing extraction wells close to BW-18 would require greater well discharge rates in each zone to capture the plume.

To capture the largest volume of the plume exceeding a concentration of 100 μg/L total VOCs in each zone, each extraction well location was selected with the requirements that its Z_{cw} extend over the full width of the 100 μg/L isopleth at the McClellan AFB boundary. Locations of wells were also placed along the line representing the most direct line of groundwater flow in each zone. Extraction well locations were selected with the requirement of extending the zone of capture, Z_c, the greatest distance possible in the downgradient direction. The selected well locations and calculated zones of capture are shown in Figures A6-4, A6-5, and A6-6. The figures illustrate that 90 to 100 percent of the 100 μg/L in each zone will be captured by the wells.

The southern extent of the Z_c in each zone was determined from the equations used to determine flow rates. The southern extent of the Z_c, also referred to

as the stagnation point, r, is calculated from the equation:

$$r = \frac{Z_{CM}}{2\pi}$$

For each zone, the r value is:

$$\text{A Zone: } r_A = \frac{1400 \text{ feet}}{2\pi} = 223 \text{ feet}$$

$$\text{B Zone: } r_B = \frac{800 \text{ feet}}{2\pi} = 127 \text{ feet}$$

$$\text{C Zone: } r_C = \frac{1200 \text{ feet}}{2\pi} = 191 \text{ feet}$$

The r values for each zone will vary with well discharge or changes in K and I. If K or I are greater than the values stated and Q remains constant, r will be smaller as will Z_{CW} and Z_{CM}. If K or I are less than the values stated above, r, Z_{CW}, and Z_{CM} will be greater with the same pumping rates, Q.

A6.2.4 Well Construction

The extraction well constructed in each zone will be identical to that in adjacent zones except that well screen intervals and gravel pack intervals will be longer and deeper in the B and C zones. The screen interval will fully penetrate each of the zones. The design for the wells in the northern TCE/1,2-DCE plume will not require that the wells be deepened at a future date because of decreasing water levels. With full penetration of each zone, the wells will be operable as long as groundwater is moving through the zone.

Each well will be six inches in inside diameter, and constructed with stainless steel casing and screen below the water level. The screen slot size and gravel pack of each well will be determined on the basis of grain size analyses of samples from the deposits penetrated in the zone. Samples for grain size analysis will be taken from the pilot borings drilled in the extraction well locations. The typical extraction well design to be used for each well is shown in Figure A6-7.

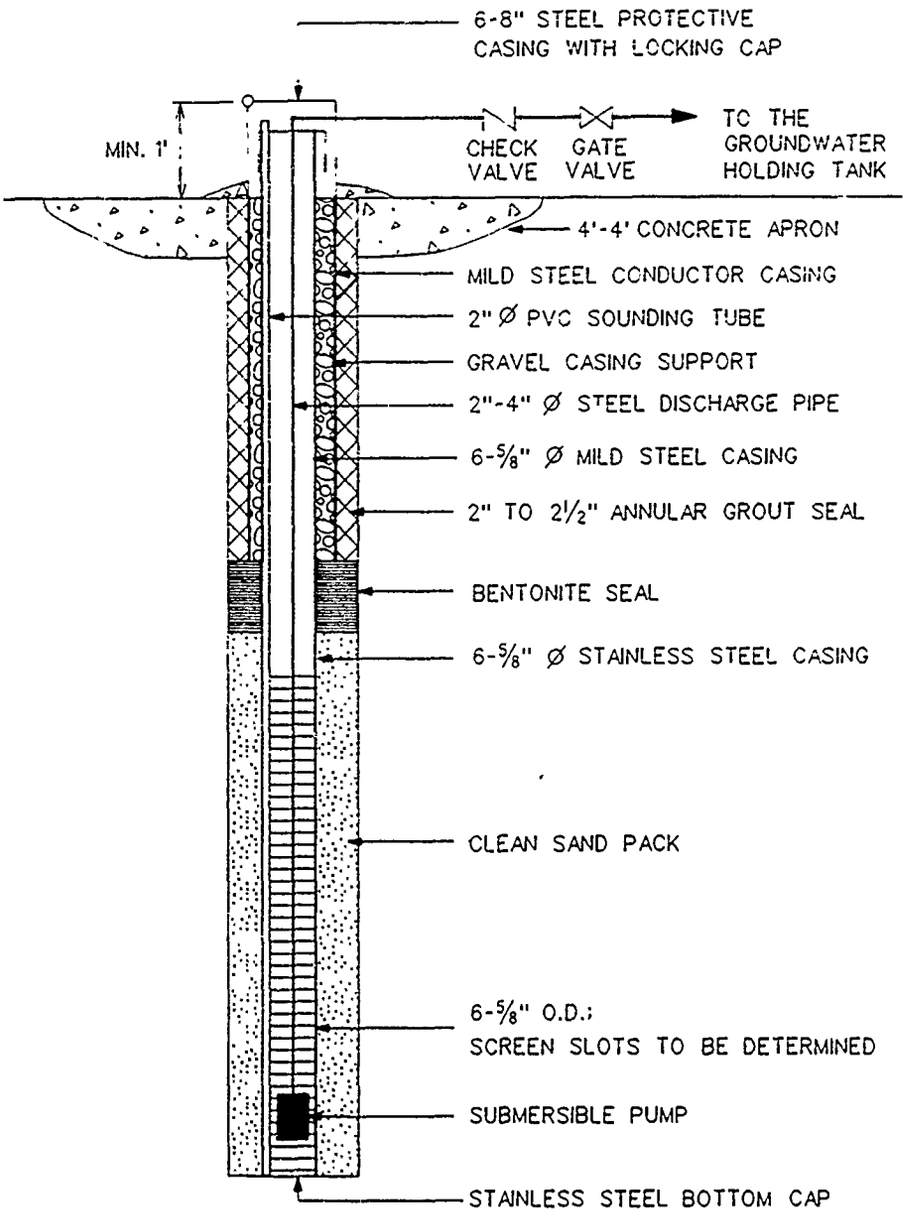


Figure A6-7. Typical Extraction Well Design.

MAFB 0011 WELL4

A6.2.5 Initial Contaminant Concentration

The initial contaminant concentrations for each extraction well are based on the concentrations of each VOC that will be drawn to the well in groundwater from the central, more-concentrated volume of the plume during the first year of operation. The initial concentrations are considered the "worst case" in terms of impact on the treatment system. It is anticipated that concentrations of VOCs in groundwater extracted by each well will decrease after one year (or less) of operation because groundwater with lower contaminant concentrations will be drawn into the well as water in the larger zone of capture moves toward the well. The concentrations of contaminants in the larger zone of capture are lower than those near the extraction well, and groundwater volumes with lower concentrations will dilute the groundwater drawn in from the more concentrated volume of the plume.

The assumptions used to establish the initial contaminant concentrations for each well were:

- All VOC contaminants are dissolved in groundwater; there are no separate-phase VOCs present in any zone.
- The concentrations of VOCs detected in the first quarter of 1990 groundwater samples from eight monitoring wells represent the concentrations in the plume at the location of the extraction wells. The wells from which sample analytical data were used are: A zone, MW-7, MW-155, and MW-36A; B zone, MW-63, MW-156, and MW-36B; and C zone, MW-132 and MW-36C. (Data from MWs 36A, 36B, 36C are used qualitatively; they are not yet validated.)
- Concentrations of VOCs are uniformly distributed through each zone.

Estimated contaminant concentrations influent to the wells in the first year of operation based on the most recent monitoring well analyses are:

A Zone:

TCE	65 μg/L
1,2-DCE	75 μg/L

Chloroform	10 μg/L
1,2-DCA	1 μg/L
Methylene chloride	2 μg/L

B Zone:

TCE	100 μg/L
1,2-DCE	72 μg/L
1,2-DCA	2 μg/L

C Zone:

TCE	130 μg/L
1,2-DCE	40 μg/L
Chloroform	2 μg/L
1,2-DCA	2 μg/L
PCE	3 μg/L
Methylene chloride	2 μg/L
Acetone	2 μg/L
1,1-DCE	2 μg/L

These are considered startup concentrations and they are anticipated to decrease with time. However, groundwater sample concentrations in the northern TCE/1,2-DCE plume near the east-west McClellan AFB boundary.

Total initial influent concentrations from each zone with wells operating at design rates are estimated to be:

A zone well: 30 gpm

Percent of total flow: 19.4%		Concentrations (μg/L)
TCE	65 x .194	12.6
1,2-DCE	75 x .194	14.6
Chloroform	10 x .194	1.9
1,2-DCA	1 x .194	.2
Methylene chloride	2 x .194	.4
	Total VOC	29.7

B Zone well: 25 gpm
Percent of total flow: 16.1%

TCE	110 x .161		17.7
1,2-DCE	72 x .161		11.6
1,2-DCA	2 x .161		.3
		Total VOC	29.6

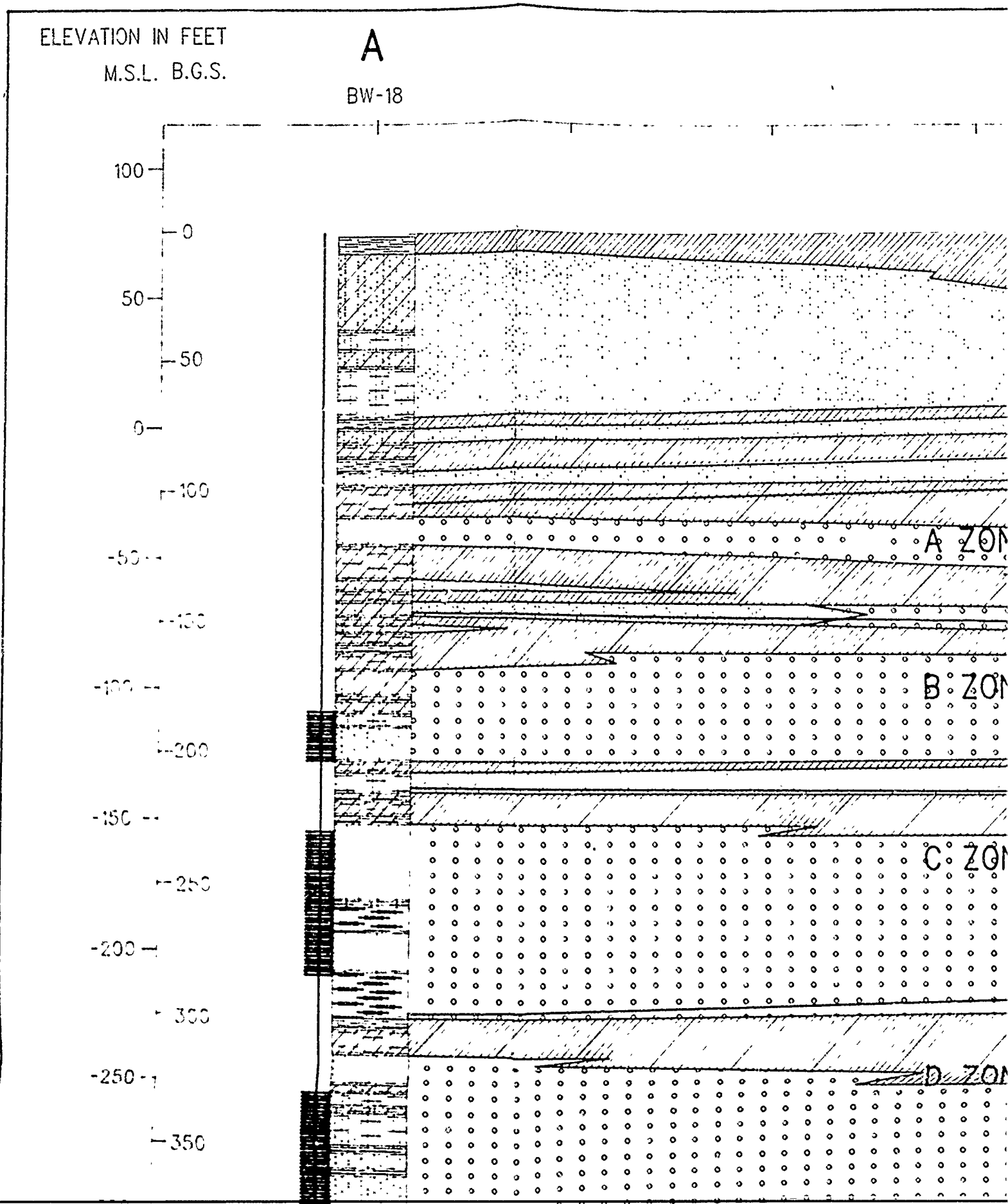
C Zone well: 100 gpm
Percent of total flow: 64.5%

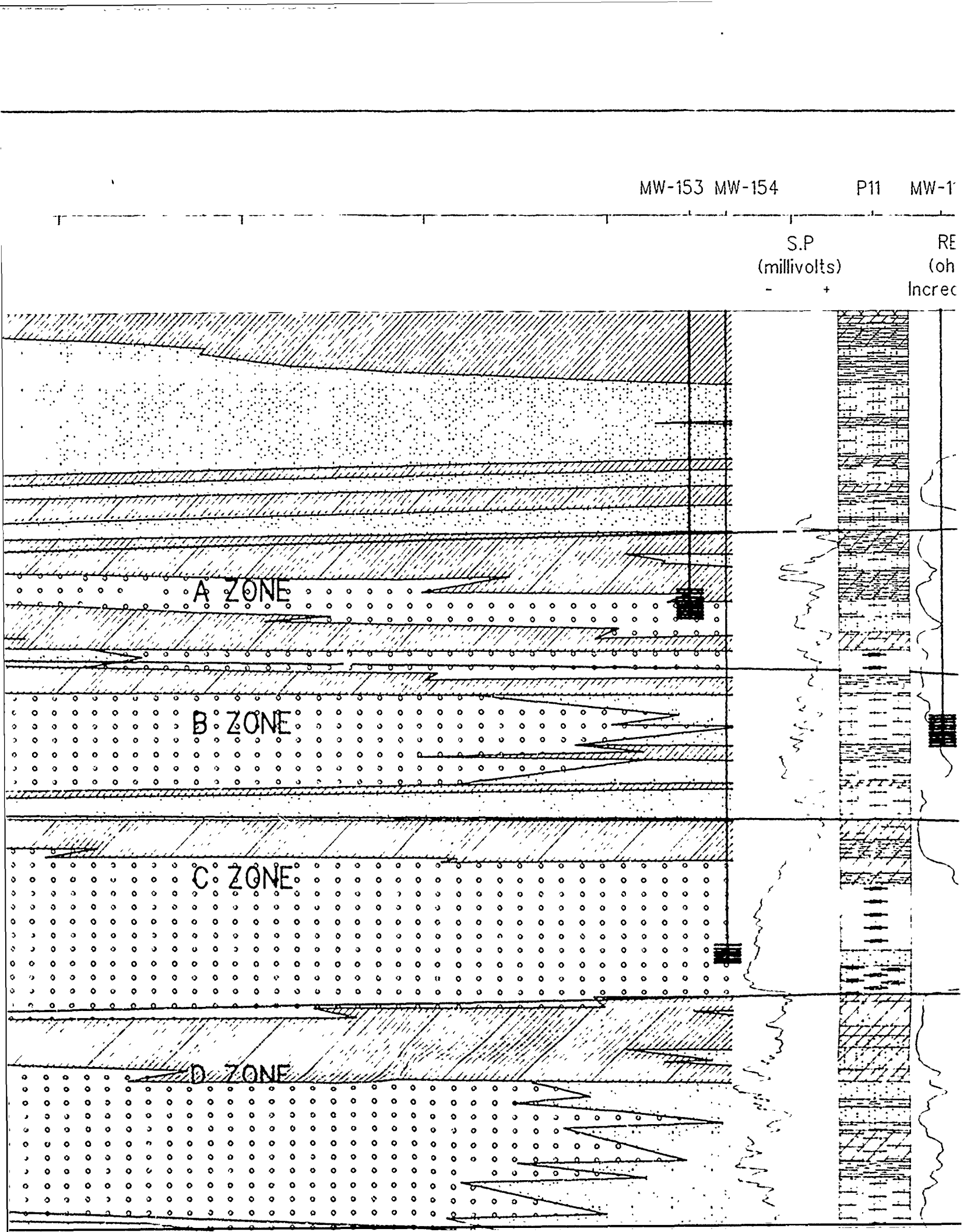
TCE	130 x .645		83.9
1,2-DCE	40 x .645		25.8
Chloroform	2 x .645		1.3
1,2-DCA	2 x .645		1.3
PCE	3 x .645		1.3
Methylene chloride	2 x .645		1.9
Acetone	3 x .645		1.9
1,1-DCE	2 x .645		1.3
		Total VOC	118.7

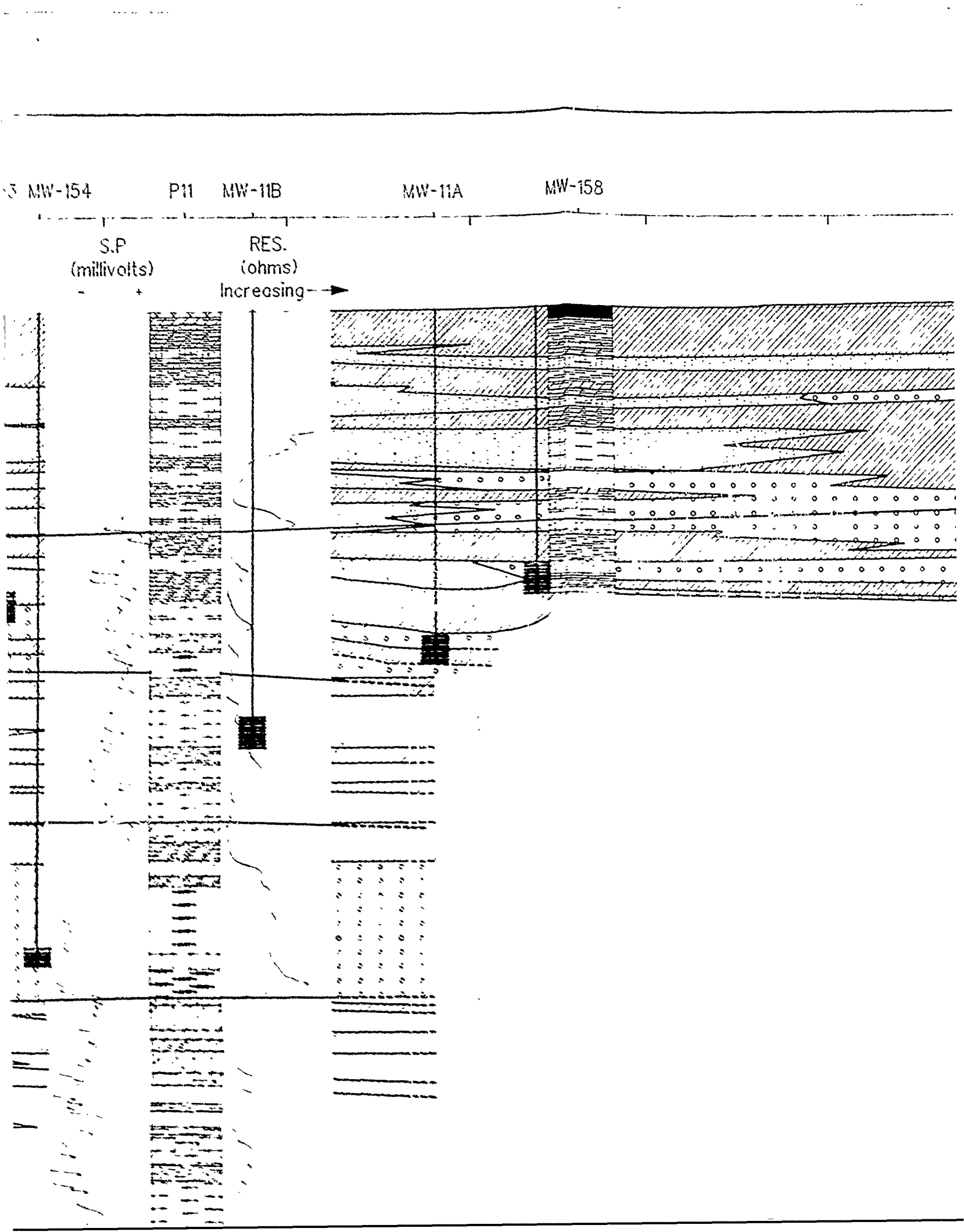
Estimated total initial influent concentration from all wells:

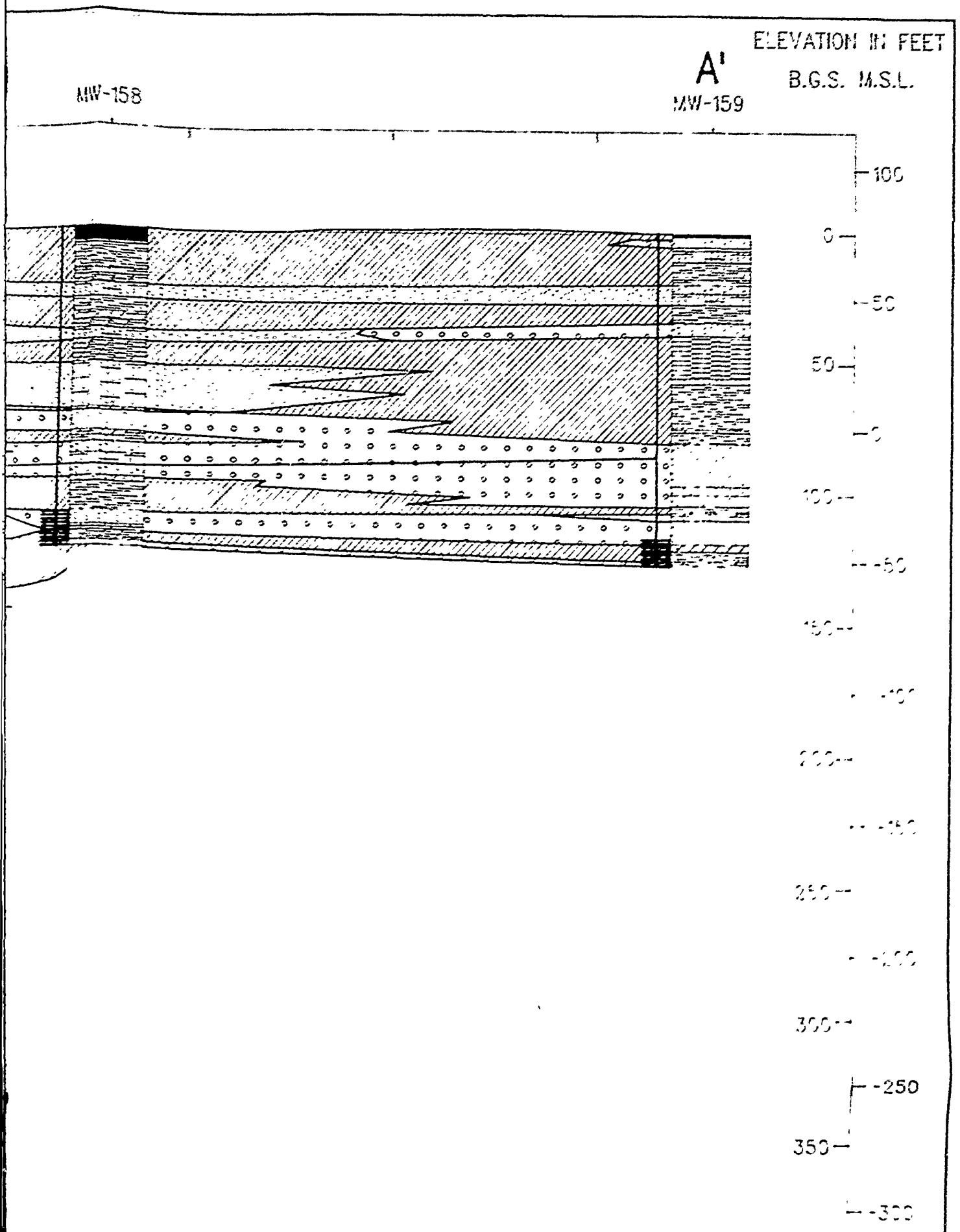
TCE		114.2
1,2-DCE		52.
Chloroform		3.2
1,2-DCA		1.8
PCE		1.7
Methylene chloride		1.9
Acetone		1.3
1,1-DCE		1.9
	Total VOC	178.0

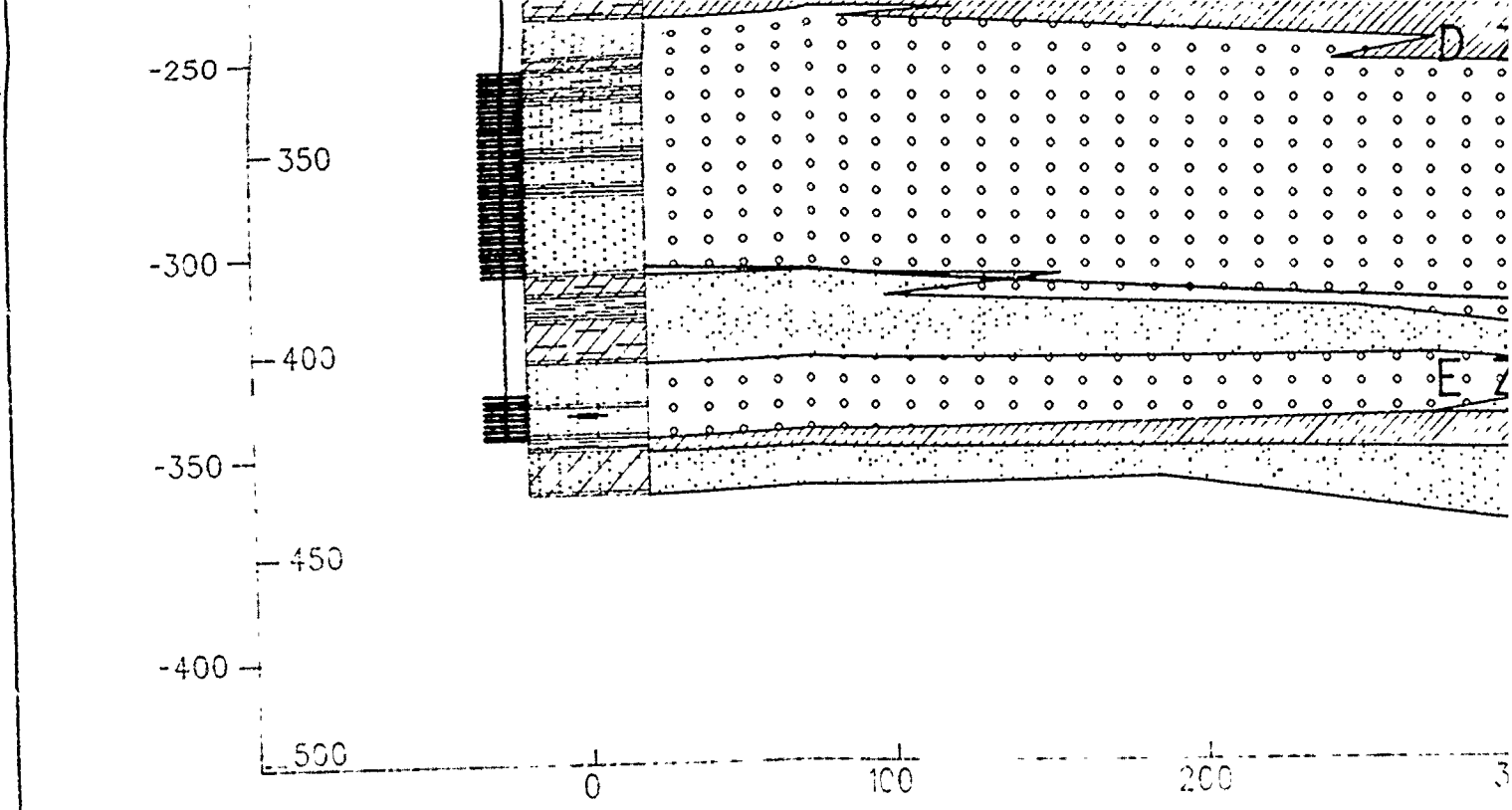
Metals analytical data for groundwater in all of the monitoring wells were evaluated. None of the metals concentrations detected in 1989 or 1990 analyses exceeded the established MCLs.

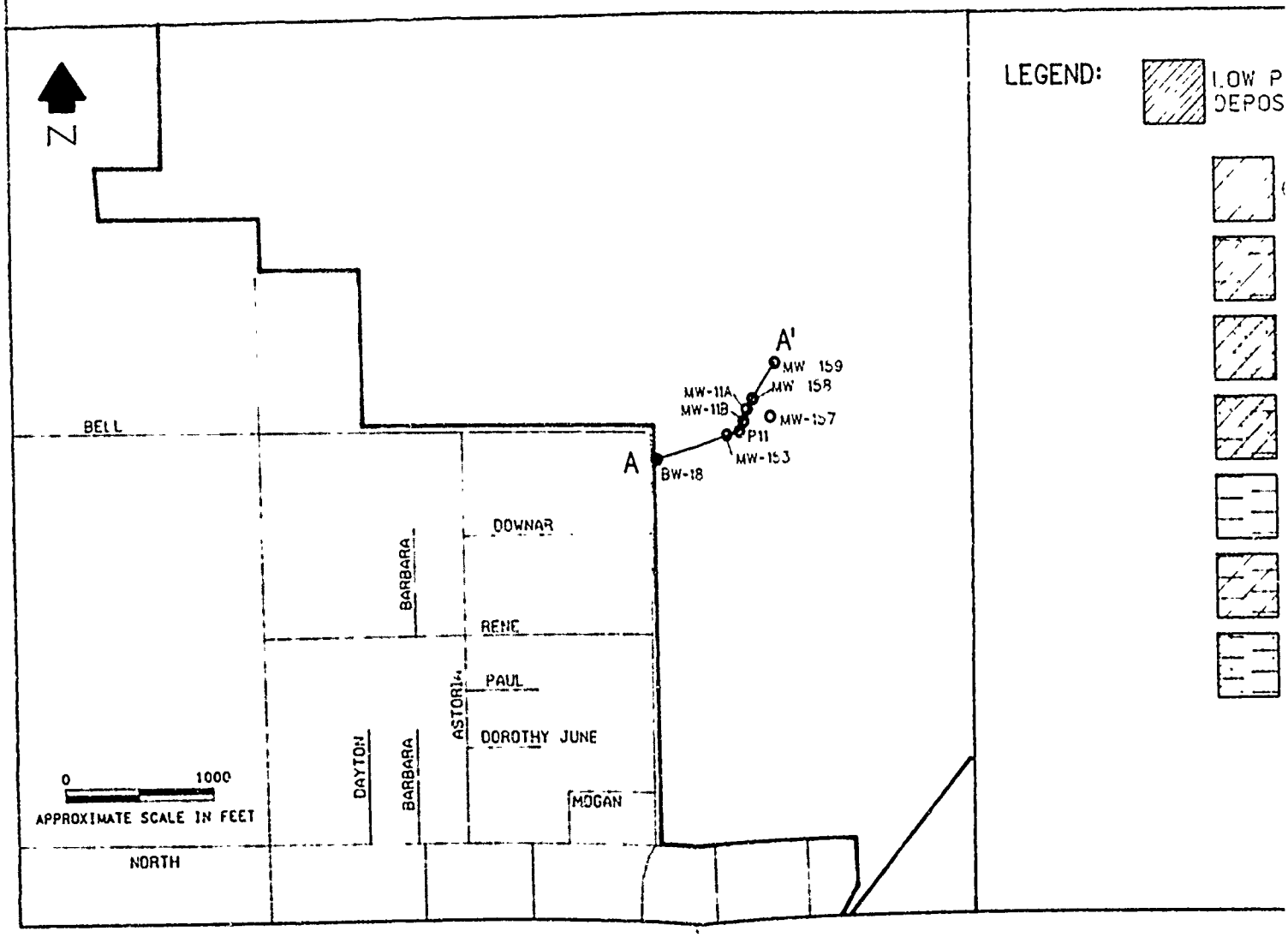

ELEVATION IN FEET
M.S.L. B.G.S.
A
BW-18
100
0
50
50
0
-100
-50
-150
-100
-200
-150
-250
-200
-300
-250
-350
A ZON
B ZON
C ZON
D ZON

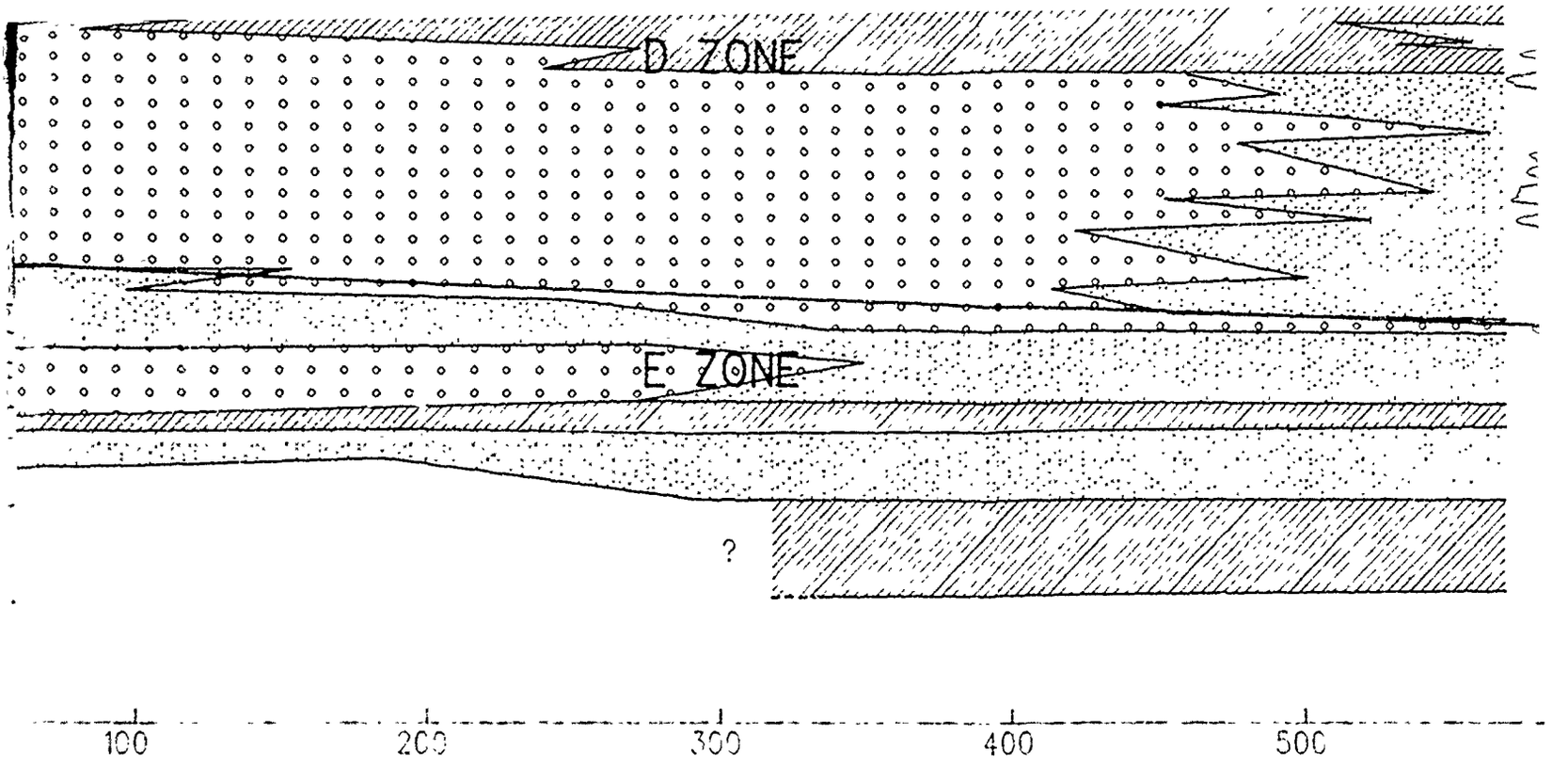

MW-153
MW-154
P11
MW-1
S.P
(millivolts)
- +
RE
(oh
Increc
A ZONE
B ZONE
C ZONE
D ZONE


MW-154
P11
MW-11B
MW-11A
MW-158
S.P
(millivolts)
- +
RES.
(ohms)
Increasing


ELEVATION IN FEET
B.G.S. M.S.L.
A'
MW-158
MW-159
100
0
-50
50
-0
100
-150
150
-200
200
-250
250
-300
300
-250
350
-300


-250
350
-300
400
-350
450
-400
500
0
100
200
D
E


N
LEGEND:
A'
MW 159
MW 158
MW-11A
MW-11B
MW-157
P11
MW-153
A
BW-18
BELL
DOWNAR
BARBARA
RENE
PAUL
ASTORIA
DOROTHY JUNE
DAYTON
BARBARA
MOGAN
0
1000
APPROXIMATE SCALE IN FEET
NORTH



100 200 300 400 500

DISTANCE ALONG PR(

LEGEND:

LOW PERMEABILITY DEPOSITS

MODERATE PERMEABILITY DEPOSITS

HIGI DEPI

CLAY

SILTY SANDY CLAY

SILTY CLAY

SANDY CLAY

SILT

CLAYEY SILT

SANDY SILT

GRAVELLY SILT

CLAYEY SAND

SILTY SAND

SILTY CLAYEY SAND

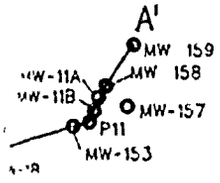
SILTY GRAVEL

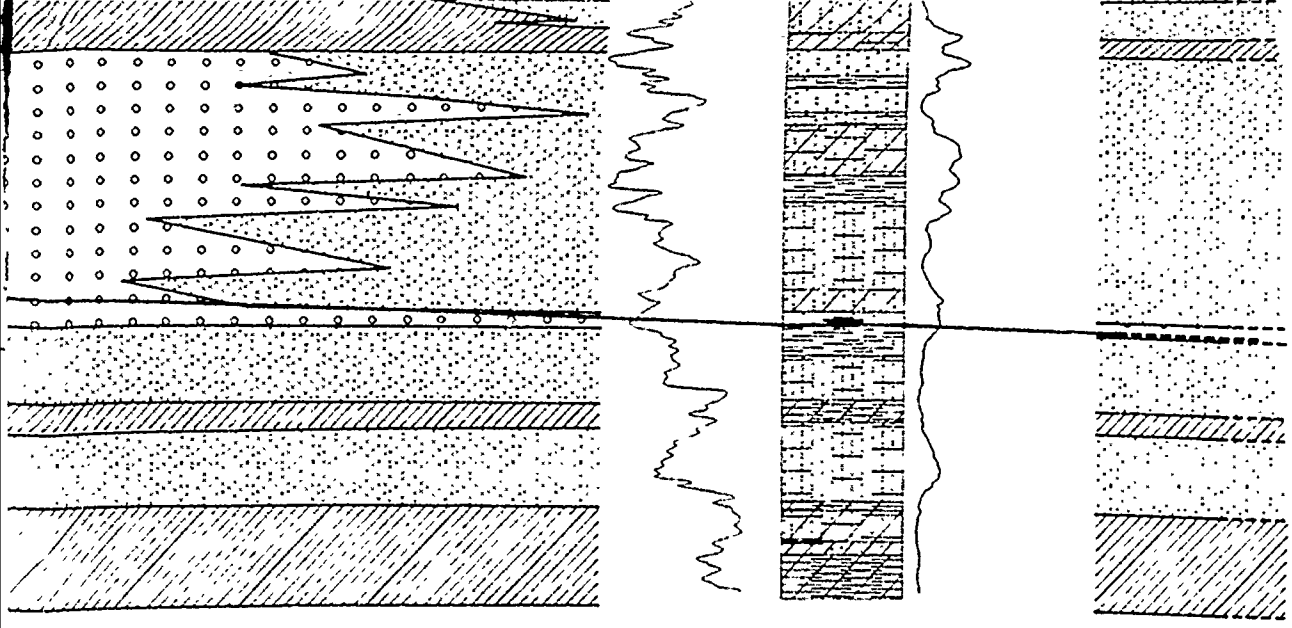
CLAYEY GRAVEL

NO F

FILI

ASPH





400 500 600 700 800 90

DISTANCE ALONG PROFILE, feet

MODERATE PERMEABILITY DEPOSITS

GRAVELLY SILT

CLAYEY SAND

SILTY SAND

SILTY CLAYEY SAND

SILTY GRAVEL

CLAYEY GRAVEL

HIGH PERMEABILITY DEPOSITS

SAND

GRAVELLY SAND

GRAVEL

SANDY GRAVEL

NO RETURN

FILL

ASPHALT

MONITORING WELL SCREEN

STATIC WATER LEVEL

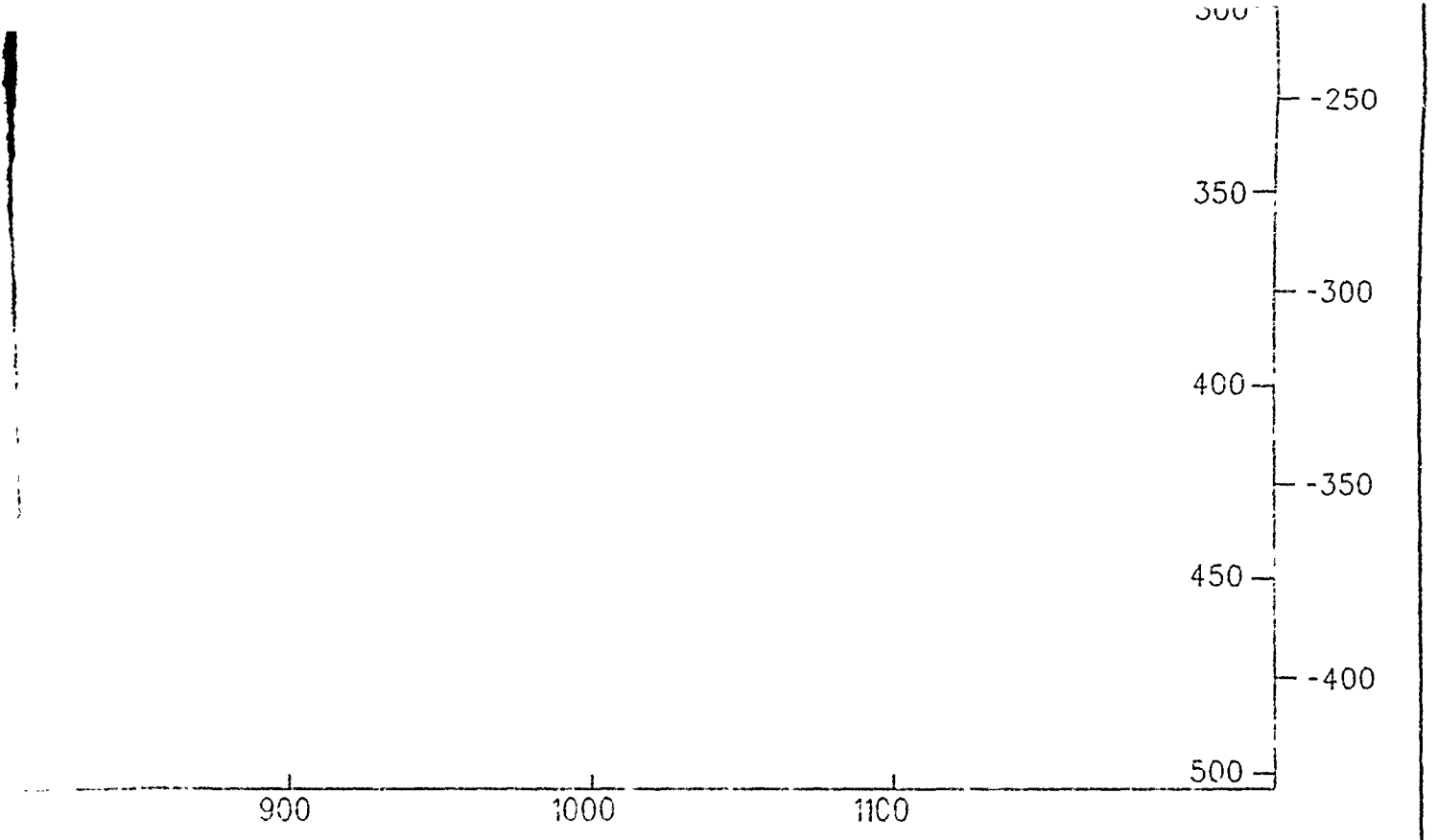
S.P. SPONTANEOUS POTENTIAL

RES. RESISTIVITY LOG

M.S.L. MEAN SEA LEVEL

B.G.S. BELOW GROUND SURFACE

------ CONTACTS ARE DASHED WHE



ORING WELL SCREEN INTERVALS

C WATER LEVEL

ANLOUS POTENTIAL LOG

TIVITY LOG

SEA LEVEL

GROUND SURFACE

CTS ARE DASHED WHERE APPROXIMATE

PLATE 1

GEOLOGIC CROSS SECTION A-A'

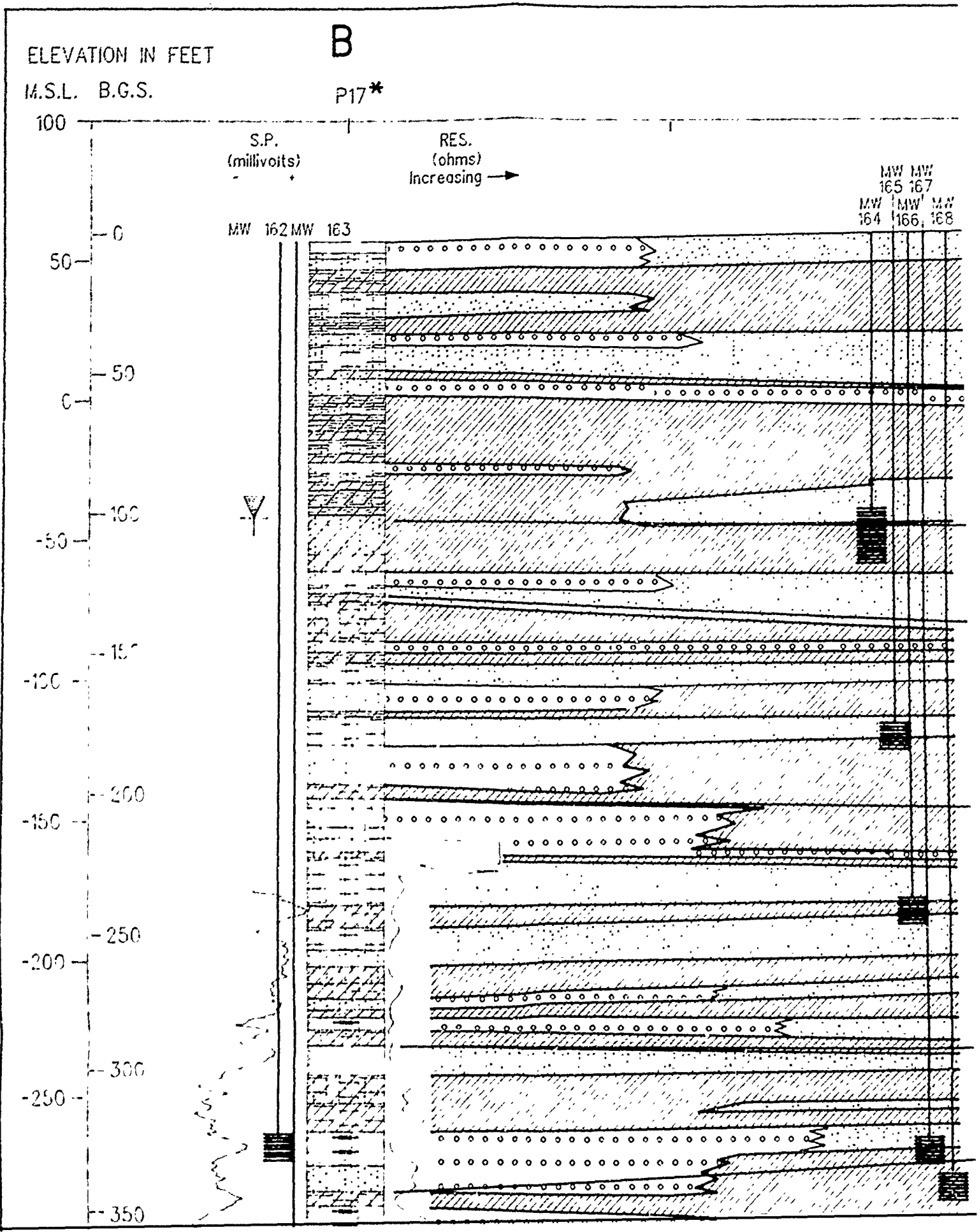
OPERABLE UNIT B GROUNDWATER REMEDIAL INVESTIGATION

McClellan AFB

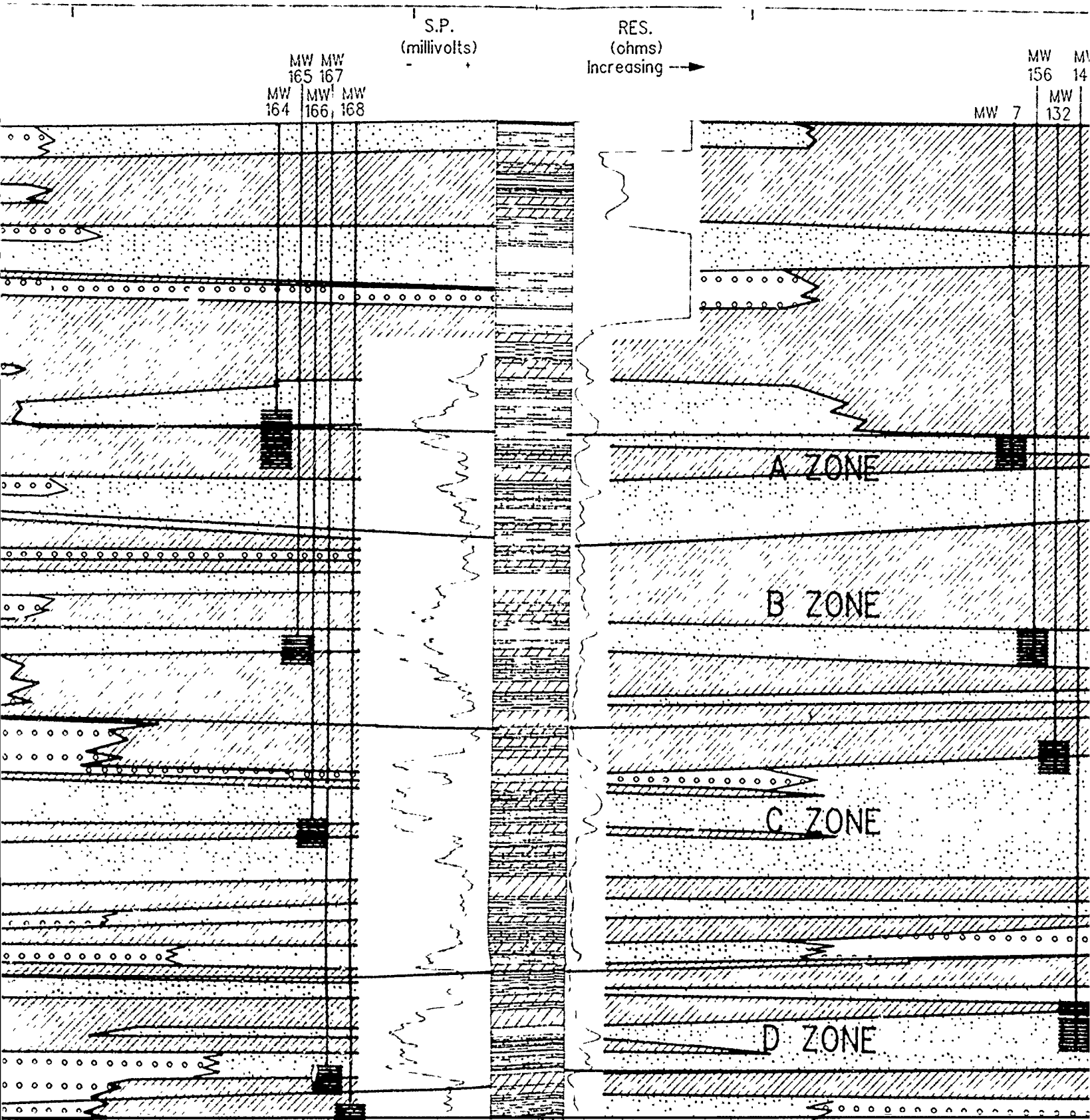
1990

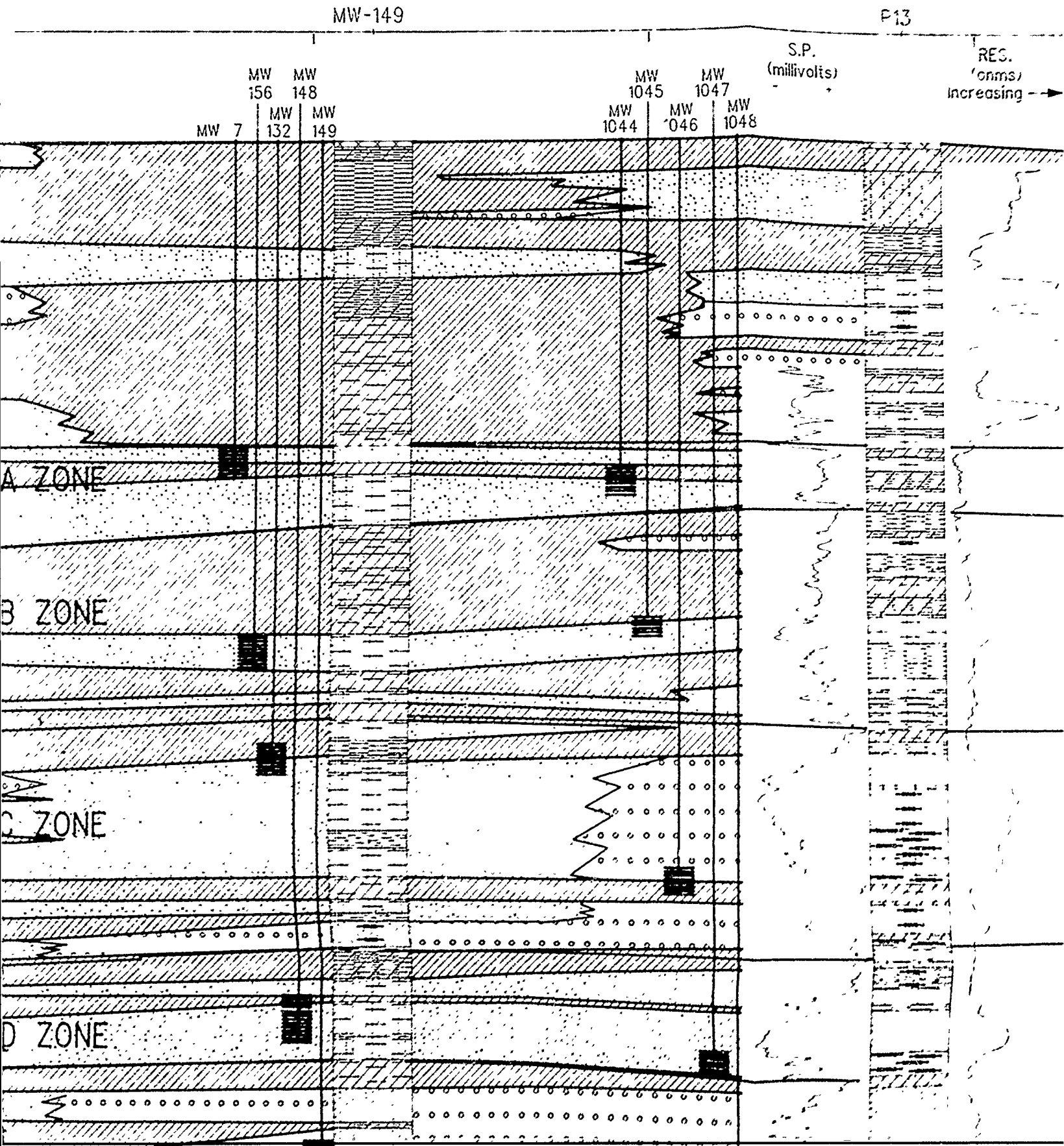
RADIAN CORPORATION

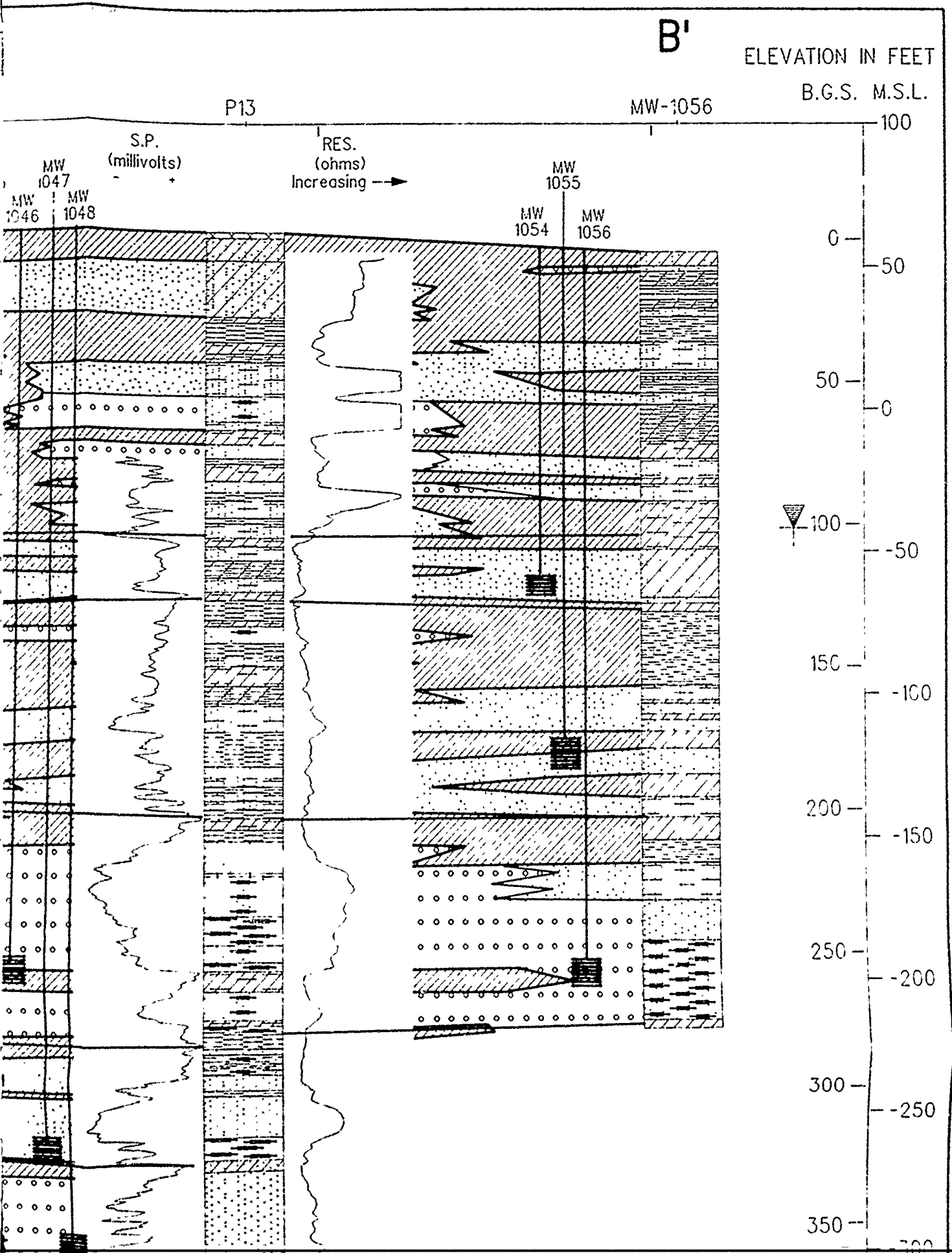
MAFB D011 GINT GINT11B


B
ELEVATION IN FEET
M.S.L. B.G.S.
P17*
100
S.P.
(millivolts)
RES.
(ohms)
Increasing
MW 165
MW 167
MW 164
MW 166
MW 168
MW 162
MW 163
0
50
50
0
100
-50
150
-100
200
-150
250
-200
300
-250
350

P21*


S.P.
(millivolts)
- +
RES.
(ohms)
Increasing →
MW 164
MW 165
MW 166
MW 167
MW 168
MW 7
MW 156
MW 132
A ZONE
B ZONE
C ZONE
D ZONE


MW-149
P13
S.P.
(millivolts)
RES.
(ohms)
increasing
MW 7
MW 156
MW 132
MW 148
MW 149
MW 1044
MW 1045
MW 1046
MW 1047
MW 1048
A ZONE
B ZONE
C ZONE
D ZONE


B'
ELEVATION IN FEET
B.G.S. M.S.L.
P13
MW-1056
S.P.
(millivolts)
- +
RES.
(ohms)
Increasing →
MW 1046
MW 1047
MW 1048
MW 1054
MW 1055
MW 1056
100
0
50
50
0
100
-50
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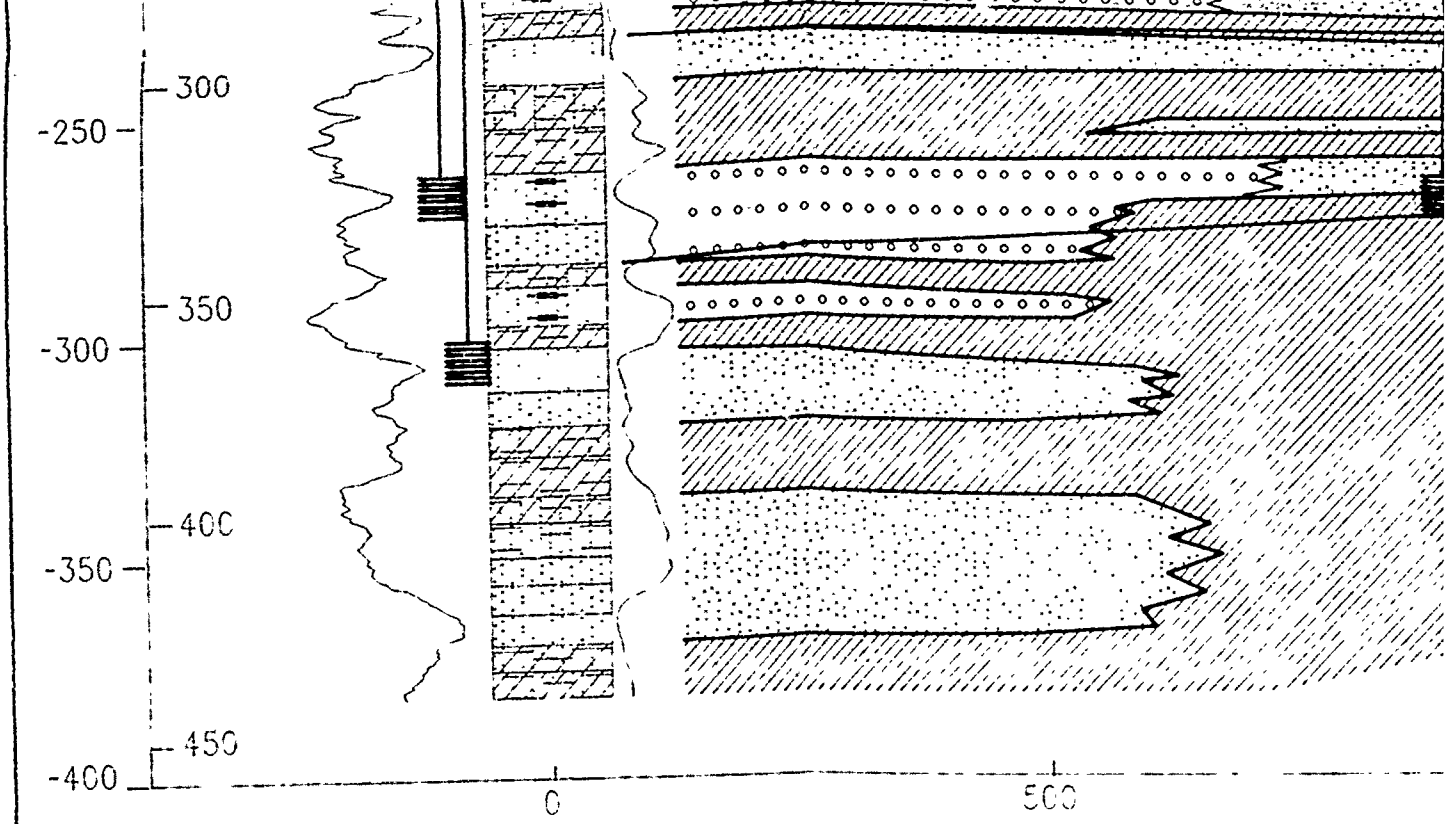
-200
300
-250
350


300
-250
350
-300
400
-350
450
-400
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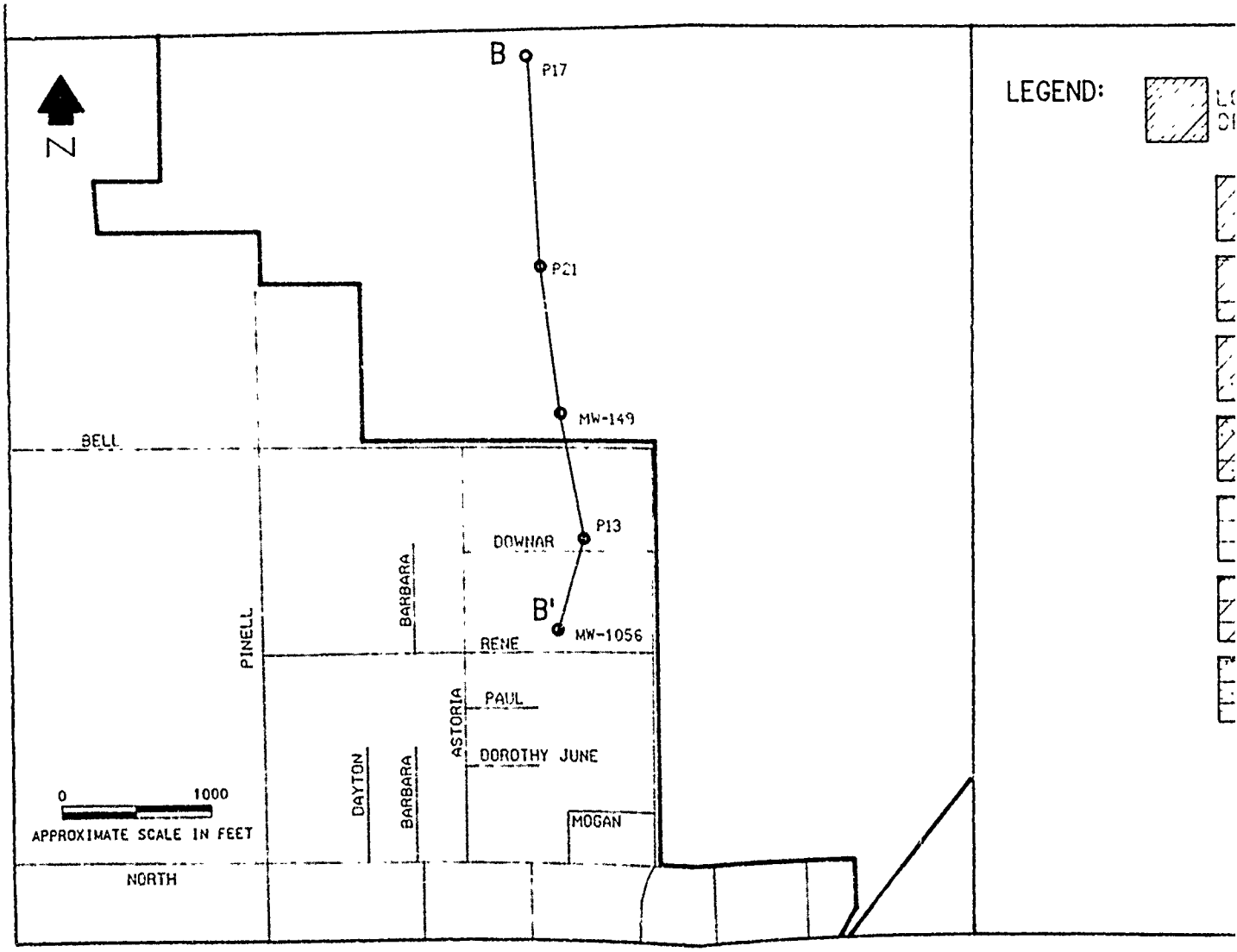
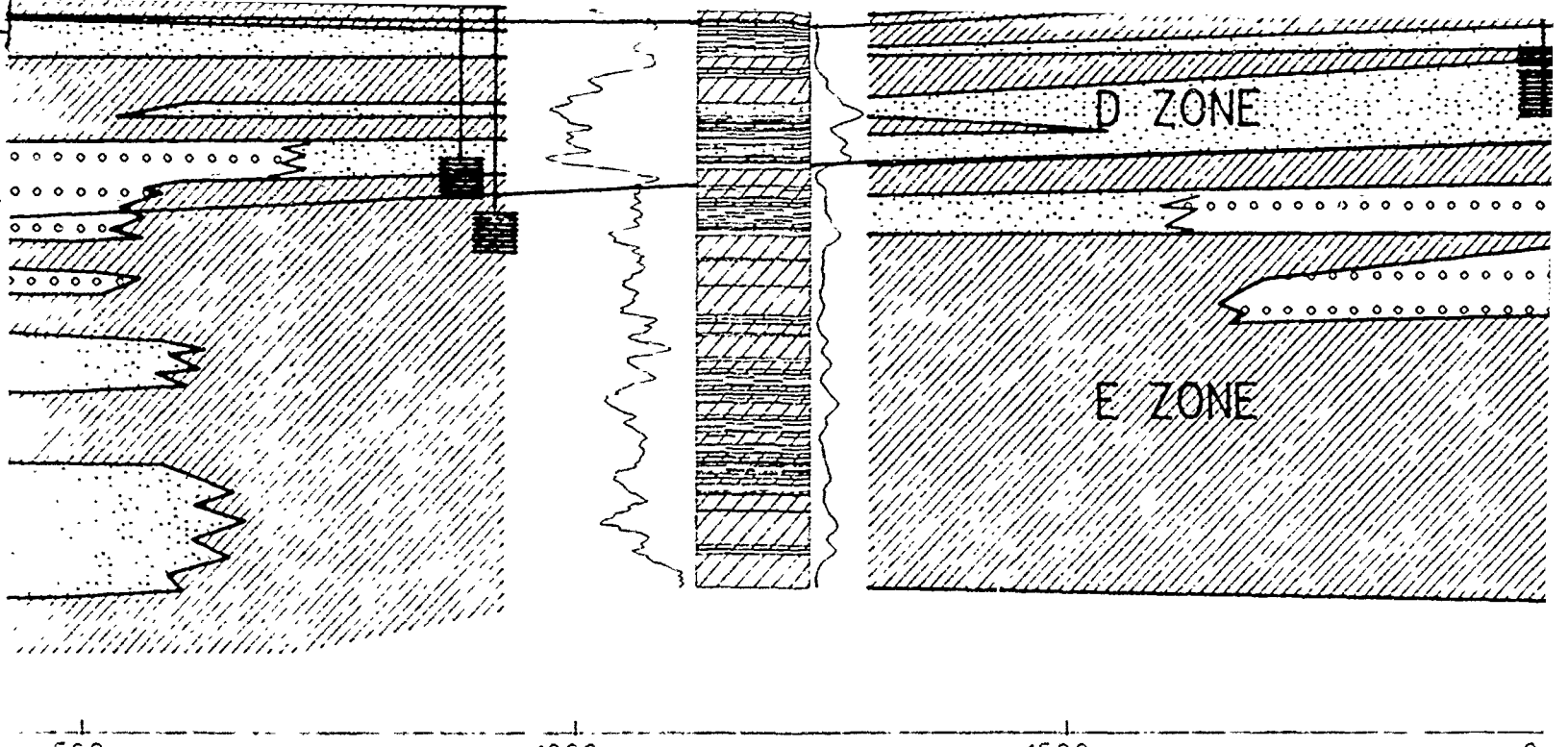
500


B
P17
P21
MW-149
P13
B'
MW-1056
N
LEGEND:
BELL
DOWNAR
BARBARA
PINELL
RENE
PAUL
ASTORIA
DOROTHY JUNE
DAYTON
BARBARA
MOGAN
0
1000
APPROXIMATE SCALE IN FEET
NORTH



500 1000 1500 2

DISTANCE ALONG PROFILE, fe

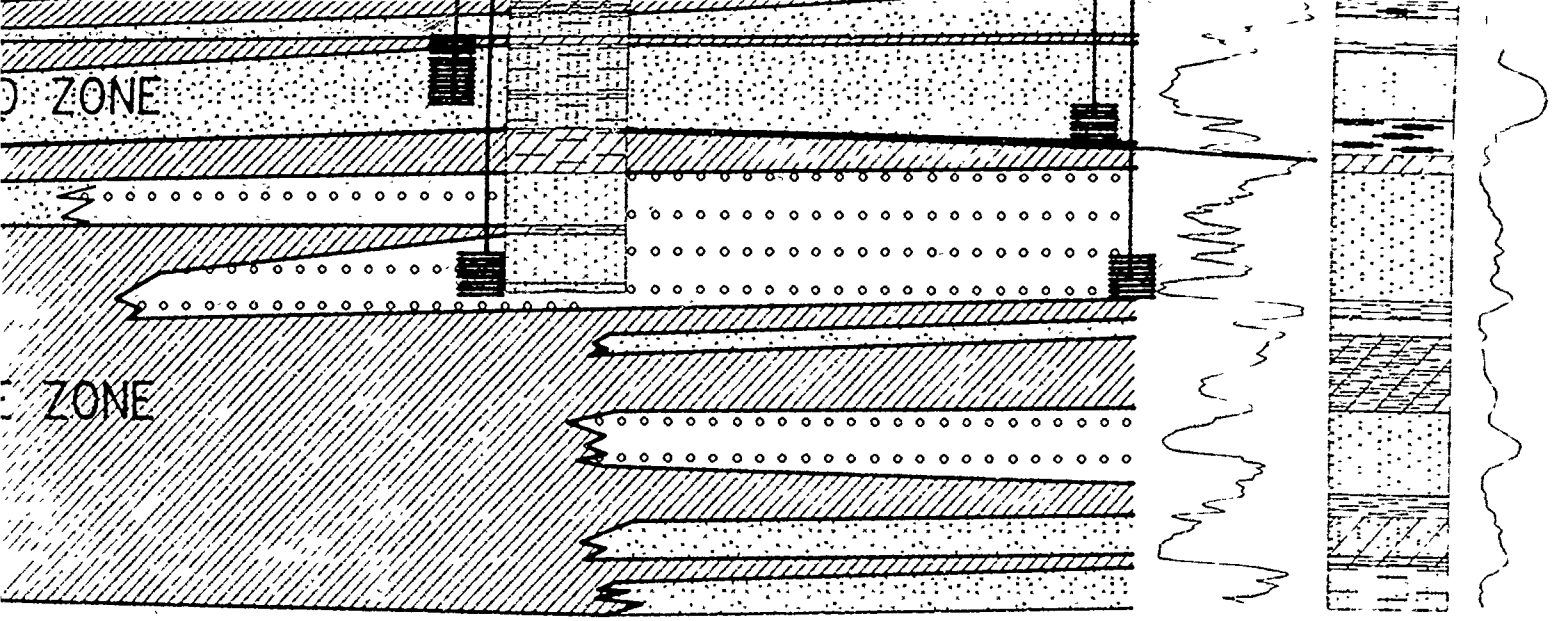
LEGEND:

LOW PERMEABILITY DEPOSITS
- CLAY
- SILTY SANDY CLAY
- SILTY CLAY
- SANDY CLAY
- SILT
- CLAYEY SILT
- SANDY SILT

MODERATE PERMEABILITY DEPOSITS
- GRAVELLY SILT
- CLAYEY SAND
- SILTY SAND
- SILTY CLAYEY SAND
- SILTY GRAVEL
- CLAYEY GRAVEL

HIGH PERMEABI DEPOSITS
- SAND
- GRAVELLY
- GRAVEL
- SANDY GF

- NO RETURN
- FILL
- ASPHALT



2000 2500 3000

ALONG PROFILE, feet

ILITY

HIGH PERMEABILITY DEPOSITS

.T

SAND

GRAVELLY SAND

GRAVEL

SAND

SANDY GRAVEL

NO RETURN

EL

FILL

ASPHALT

MONITORING WELL SCREEN INTERVALS

STATIC WATER LEVEL

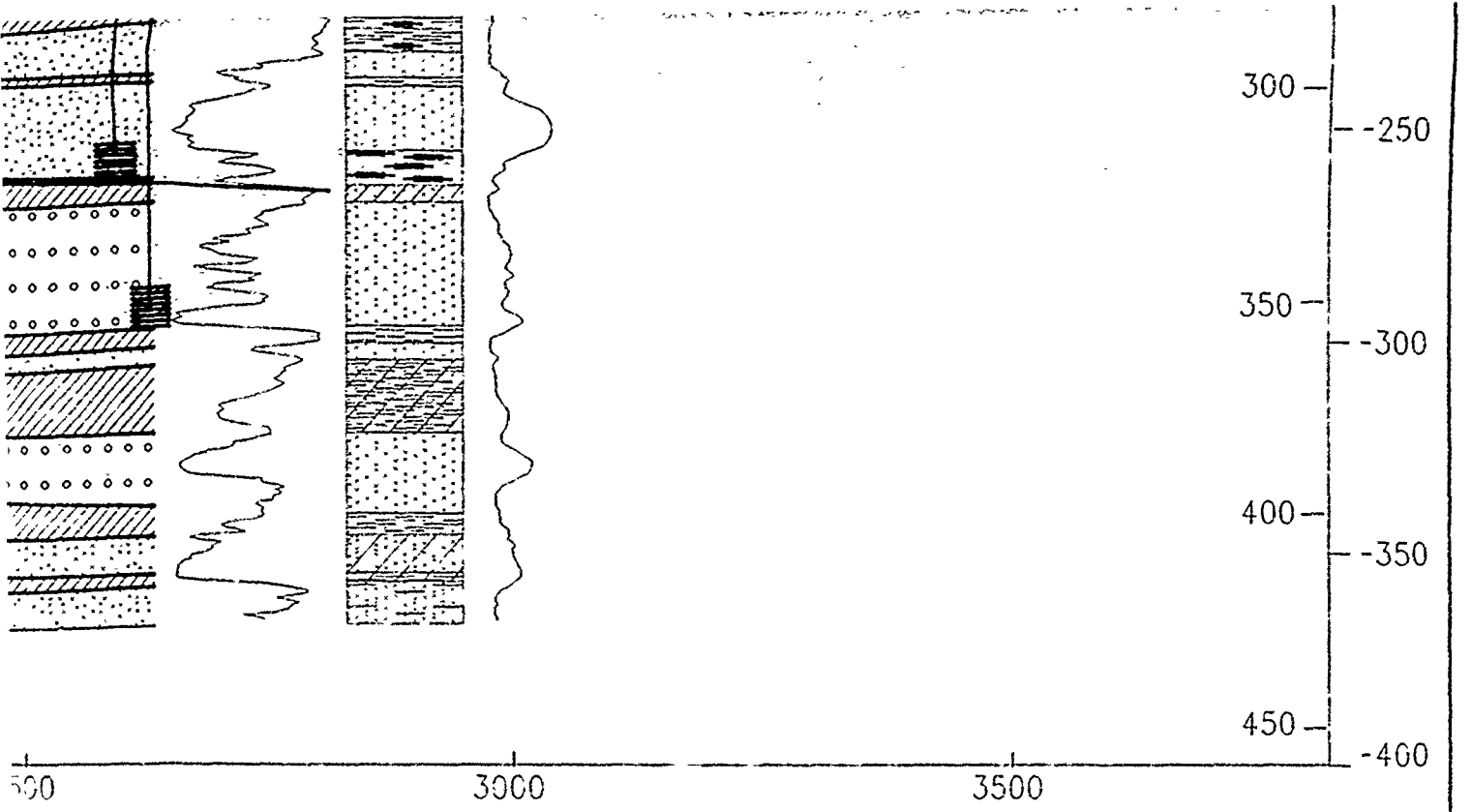
* MONITORING WELLS IN CLUSTERS P17 AND P21 WE
INSTALLED FOR THE PRELIMINARY GROUNDWATER
OPERABLE UNIT REMEDIAL INVESTIGATION (POUR

S.P. SPONTANEOUS POTENTIAL LOG

RES. RESISTIVITY LOG

M.S.L. MEAN SEA LEVEL

B.G.S. BELOW GROUND SURFACE



ITORING WELL SCREEN INTERVALS

TIC WATER LEVEL

ITORING WELLS IN CLUSTERS P17 AND P21 WERE
TALLED FOR THE PRELIMINARY GROUNDWATER
RABLE UNIT REMEDIAL INVESTIGATION (PGOURI)

NTANEOUS POTENTIAL LOG

ISTIVITY LOG

N SEA LEVEL

OW GROUND SURFACE

PLATE 2

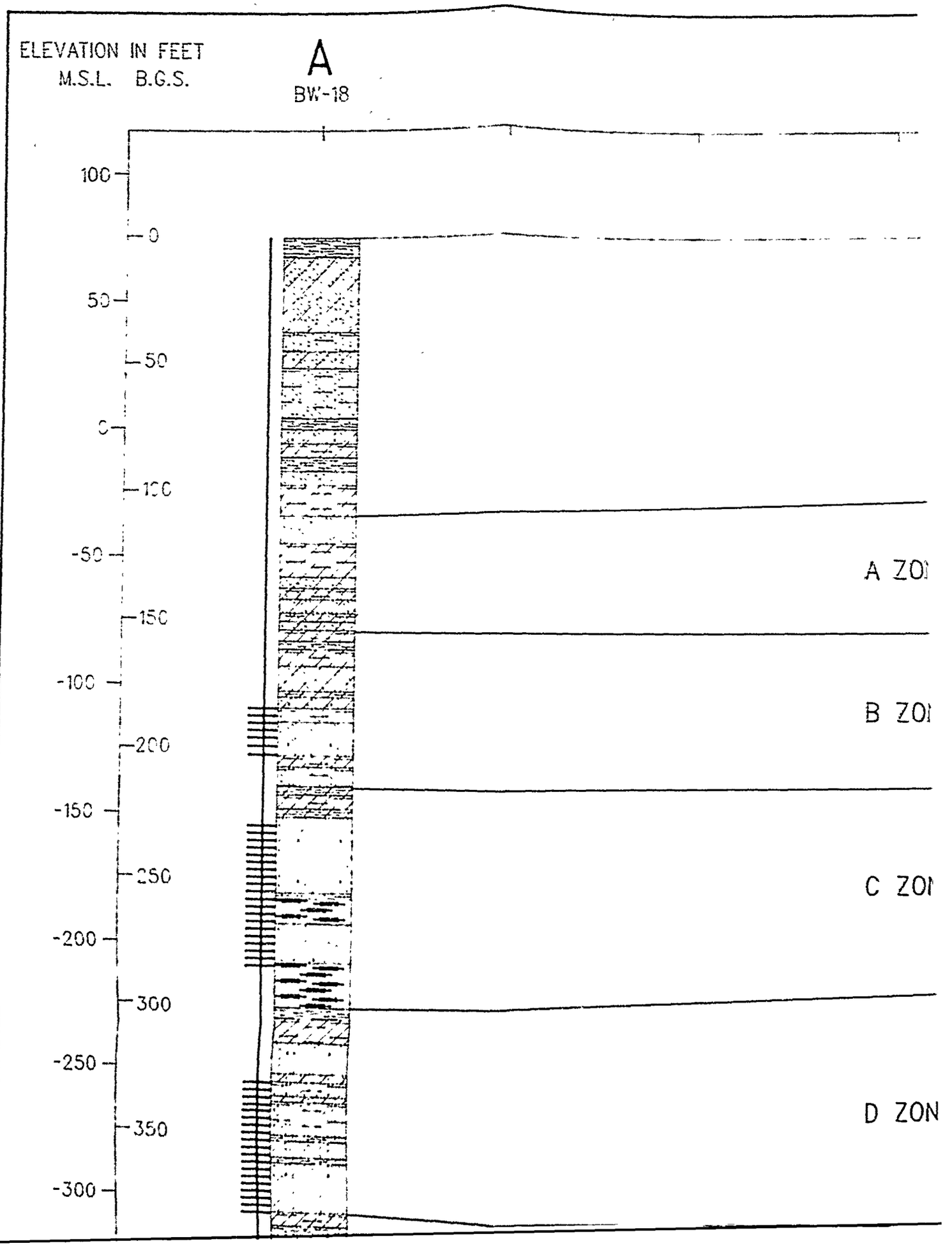
GEOLOGIC CROSS SECTION B-B'

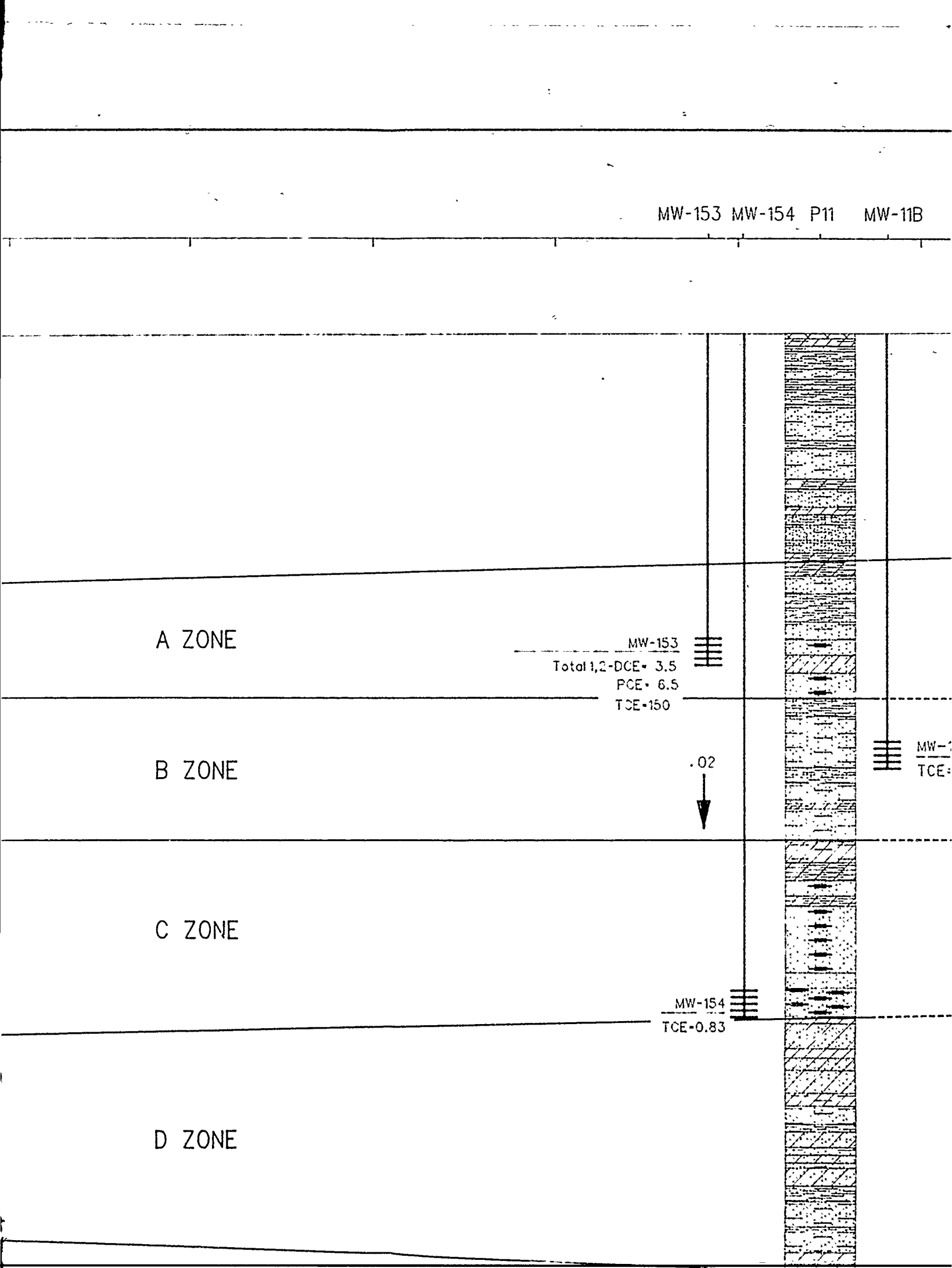
McClellan AFB
OPERABLE UNIT B
GROUNDWATER
REMEDIAL INVESTIGATION

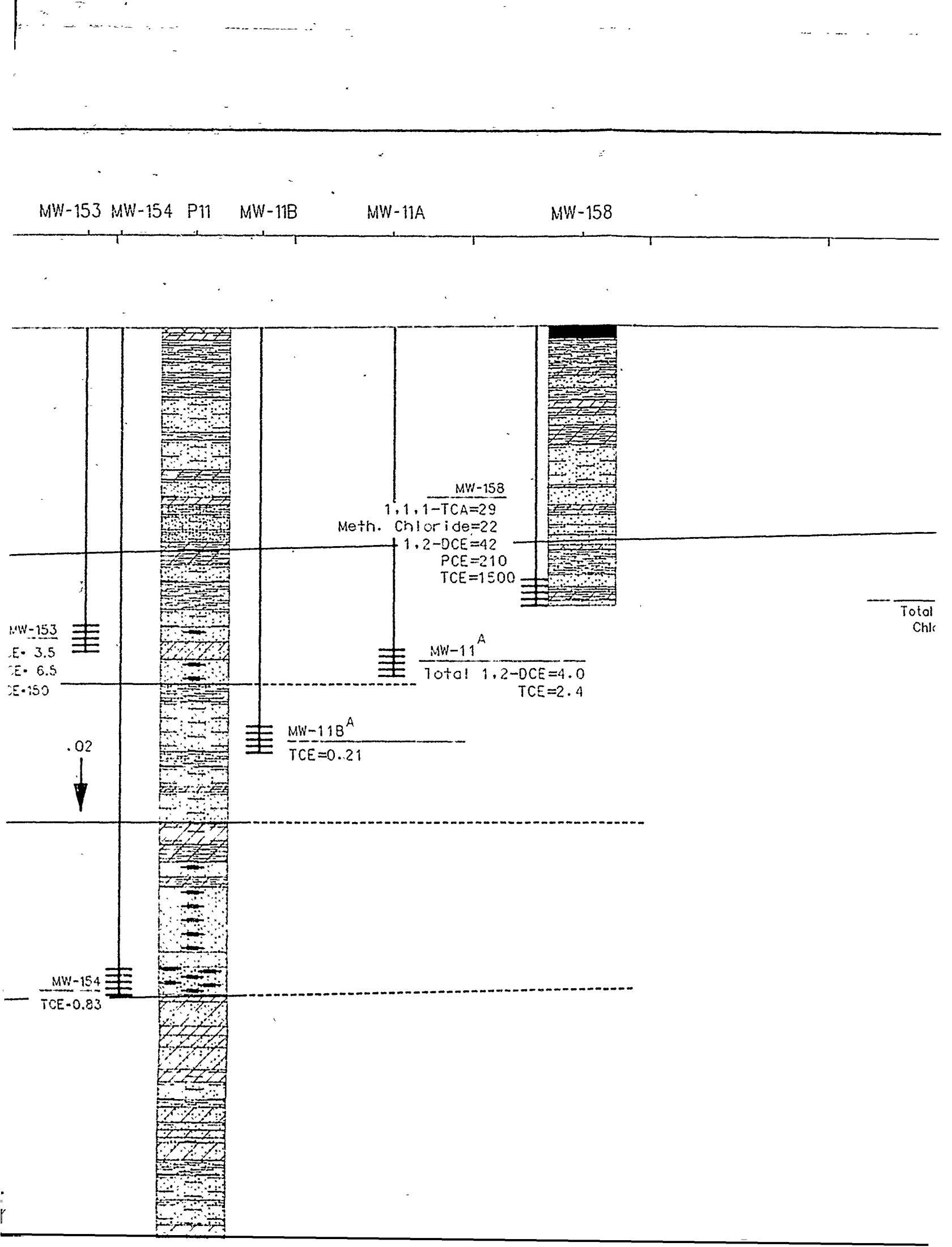
1990

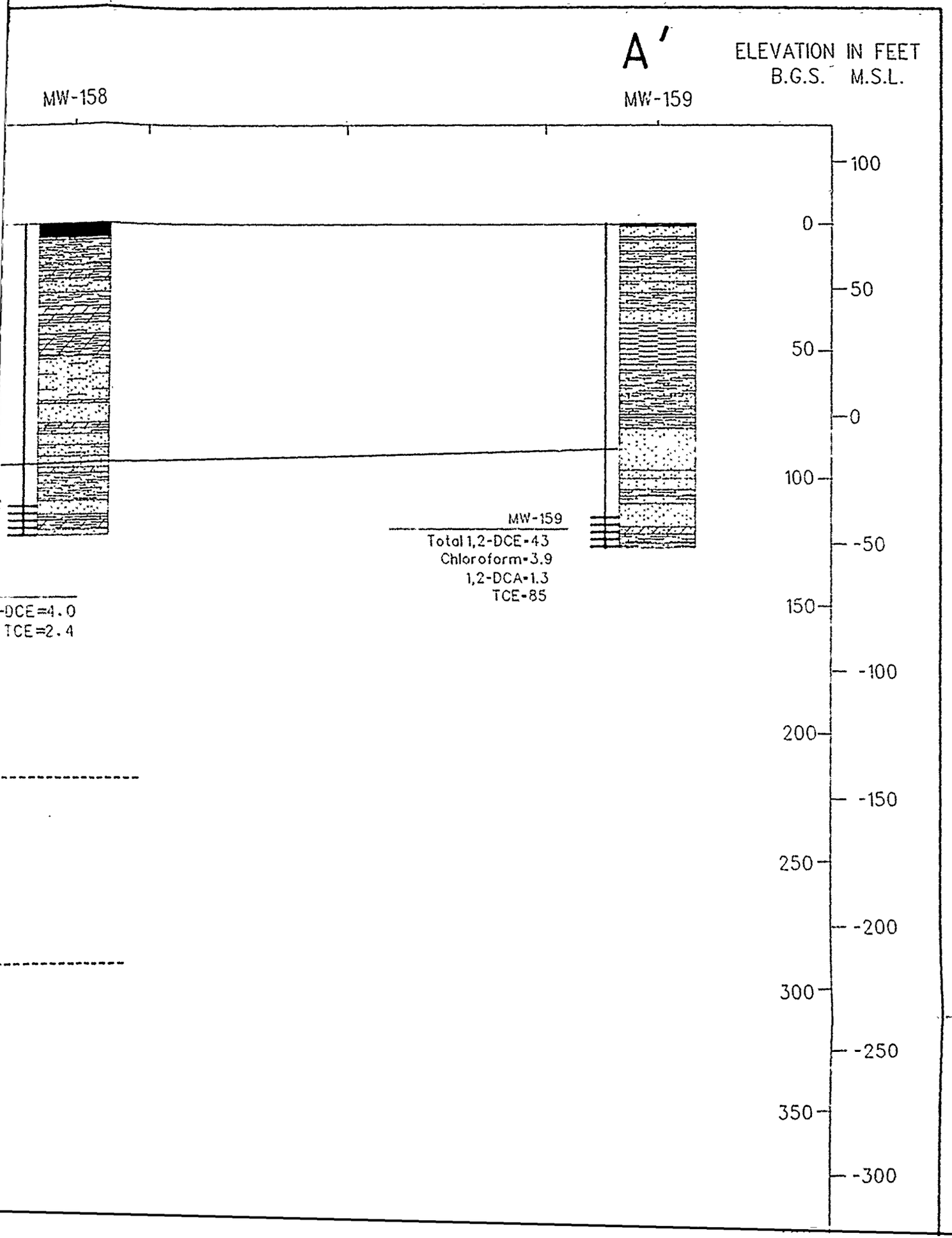
RADIAN CORPORATION

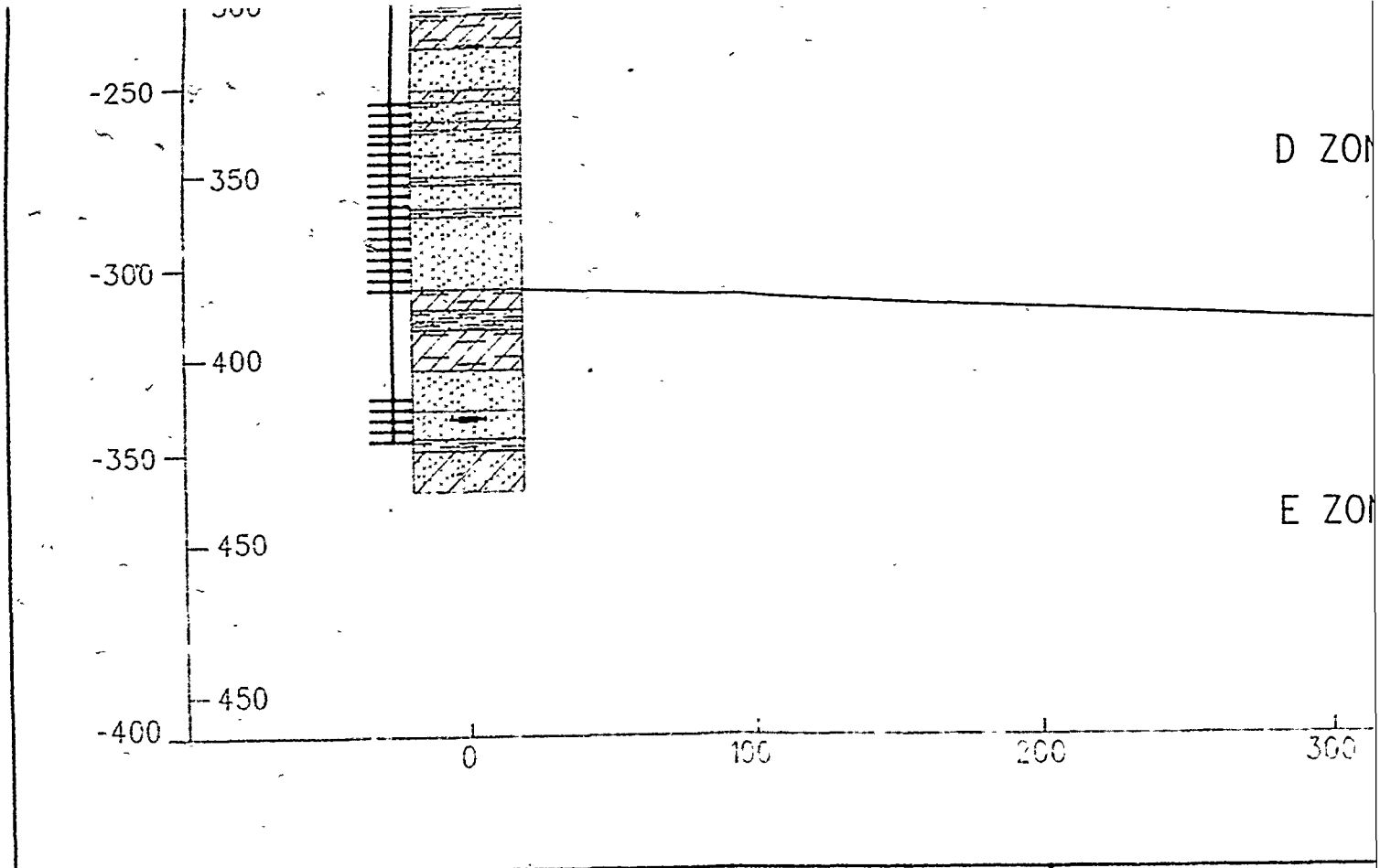
MAFB do11 GINT GINT10B

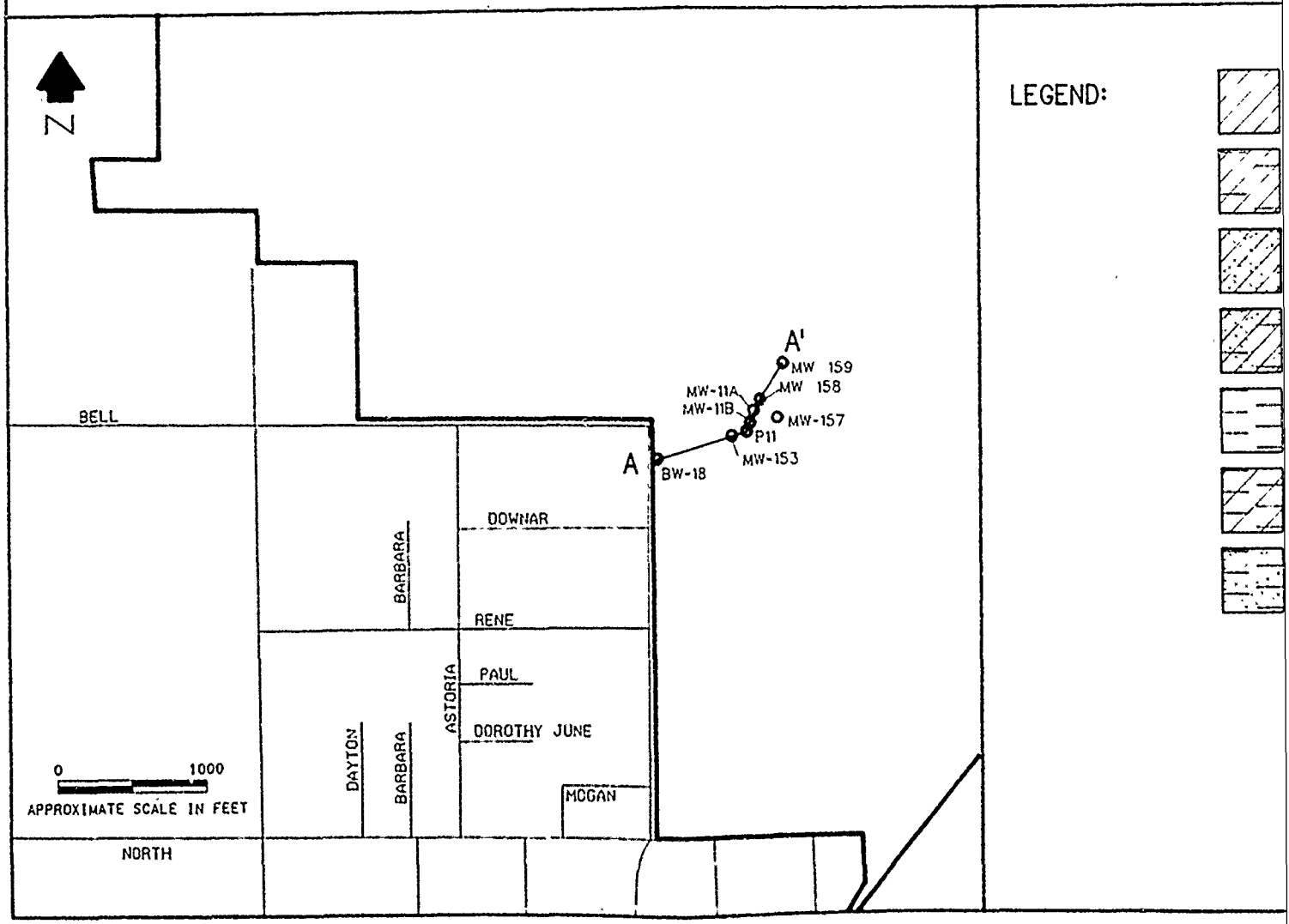

ELEVATION IN FEET
M.S.L. B.G.S.
A
BW-18
100
0
50
50
0
100
-50
150
-100
200
-150
250
-200
300
-250
350
-300
A ZO
B ZO
C ZO
D ZON

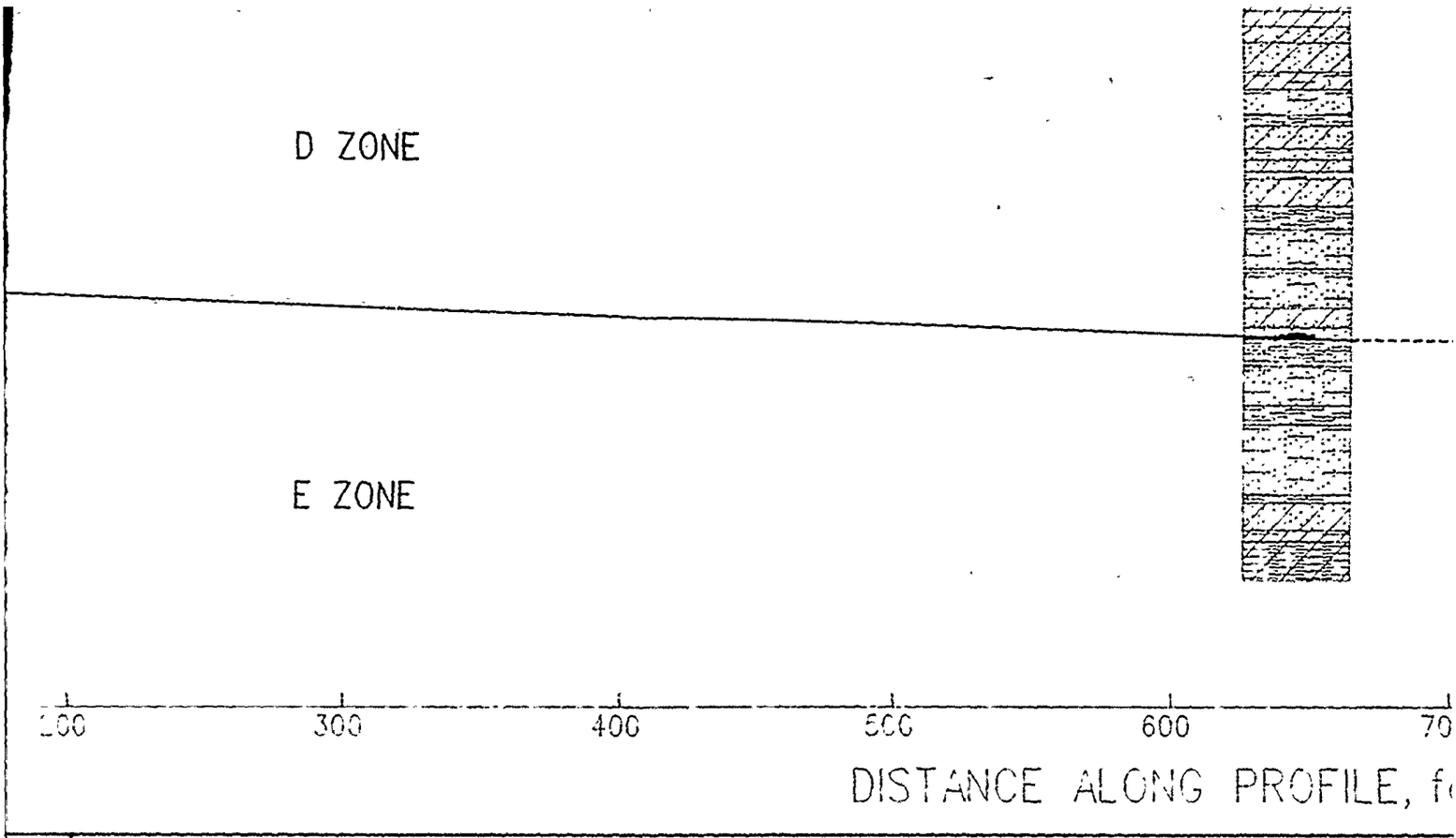

MW-153
MW-154
P11
MW-11B
A ZONE
B ZONE
C ZONE
D ZONE
MW-153
Total 1,2-DCE- 3.5
PCE- 6.5
TCE-150
.02
MW-154
TCE-0.83


MW-153
MW-154
P11
MW-11B
MW-11A
MW-158
MW-158
1,1,1-TCA=29
Meth. Chloride=22
1,2-DCE=42
PCE=210
TCE=1500
Total
Chl
MW-153
E- 3.5
E- 6.5
E-150
MW-11A
Total 1,2-DCE=4.0
TCE=2.4
MW-11B
TCE=0.21
.02
MW-154
TCE-0.83


A'
ELEVATION IN FEET
B.G.S. M.S.L.
MW-158
MW-159
100
0
50
50
0
100
-50
150
-100
200
-150
250
-200
300
-250
350
-300
MW-159
Total 1,2-DCE-43
Chloroform-3.9
1,2-DCA-1.3
TCE-85
-DCE=4.0
TCE=2.4


-250
350
-300
400
-350
450
-400
450
0
100
200
300
D ZON
E ZON


N
LEGEND:
A'
MW 159
MW 158
MW-11A
MW-11B
MW-157
P11
MW-153
A
BW-18
BELL
DOWNAR
BARBARA
RENE
ASTORIA
PAUL
DOROTHY JUNE
DAYTON
BARBARA
MOGAN
0
1000
APPROXIMATE SCALE IN FEET
NORTH



LEGEND:

- CLAY
- SILTY SANDY CLAY
- SILTY CLAY
- SANDY CLAY
- SILT
- CLAYEY SILT
- SANDY SILT
- GRAVELLY SILT
- CLAYEY SAND
- SILTY SAND
- SILTY CLAYEY SAND
- SILTY GRAVEL
- CLAYEY GRAVEL
- SAND
- GRAVELLY SAND
- GRAVEL
- SANDY GRAVEL
- NO RETURN
- FILL
- ASPHALT

700 800 900 1000 1100

; PROFILE, feet

SAND

GRAVELLY SAND

GRAVEL

SANDY GRAVEL

NO RETURN

FILL

ASPHALT

MONITORING WELL SCREEN INTERVALS

STATIC WATER LEVEL

M.S.L. MEAN SEA LEVEL

B.G.S. BELOW GROUND SURFACE

------ CONTACTS ARE DASHED WHERE APPROXIMATE

ND NOT DETECTED

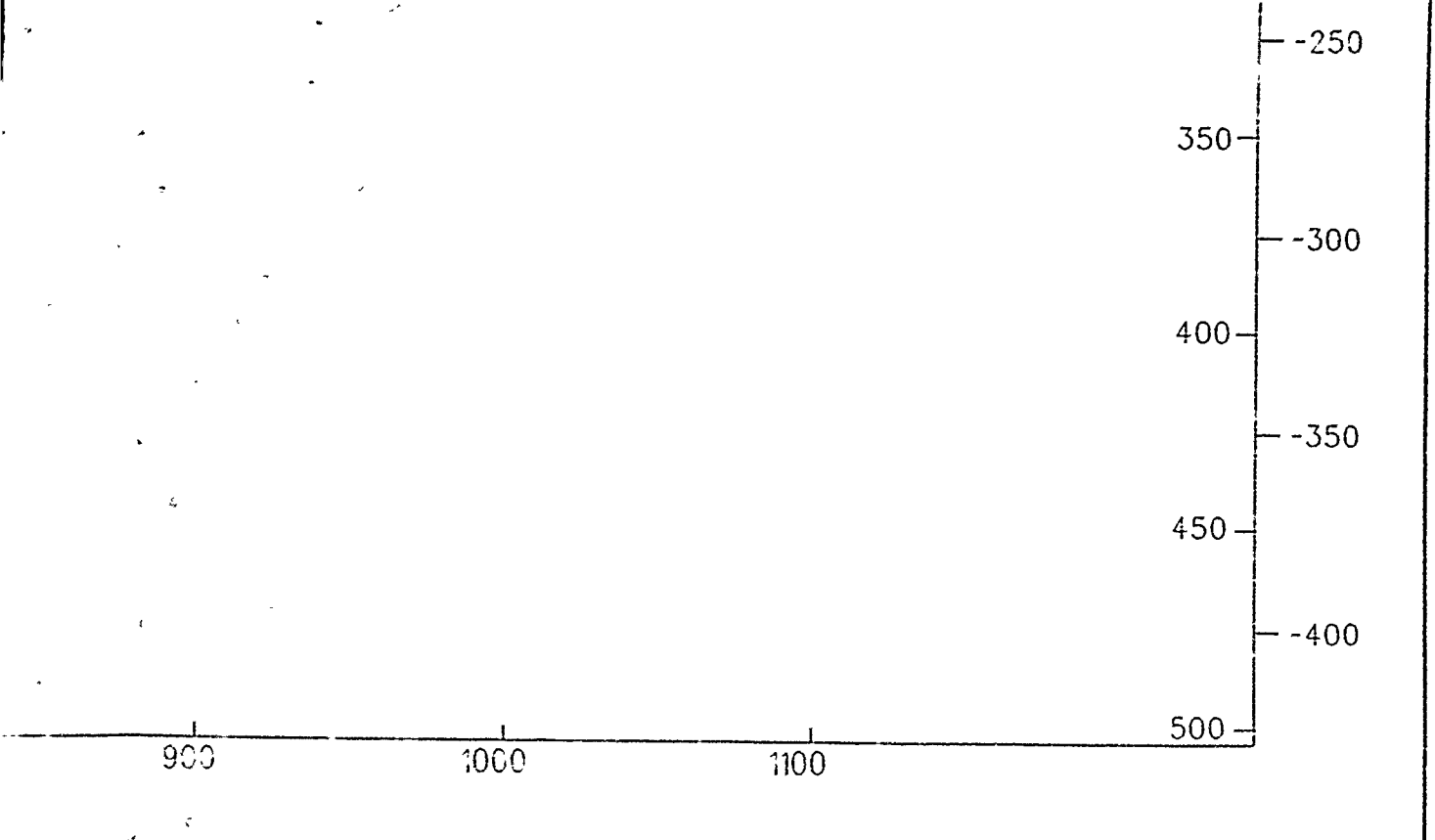
CONCENTRATIONS ARE IN MICROGRAMS PER LITER FOR FORTH QUARTER 1989 AND FIRST QUARTER 1990 ANALYSES, EXCEPT WHERE NOTED.

[A] ANALYSES FOR THIS WELL PERFORMED MARCH OR APRIL 1990.

0.013 ↓ VERTICAL GRADIENT MAGNITUDE AND DIRECTION BETWEEN WELLS SCREENED IN SEPARATE ZONES, APRIL 1990 DATA.

SO

RE



ORING WELL SCREEN INTERVALS

C WATER LEVEL

SEA LEVEL

GROUND SURFACE

CTS ARE DASHED WHERE APPROXIMATE

ETECTED

NTRATIONS ARE IN MICROGRAMS PER
FOR FORTH QUARTER 1989 AND
QUARTER 1990 ANALYSES, EXCEPT WHERE NOTED.

SES FOR THIS WELL PERFORMED
OR APRIL 1990.

CAL GRADIENT MAGNITUDE AND DIRECTION BETWEEN
SCREENED IN SEPARATE ZONES, APRIL 1990 DATA.

PLATE 3

VERTICAL CONTAMINANT DISTRIBUTION IN SOUTHWEST TO NORTHEAST CROSS SECTION

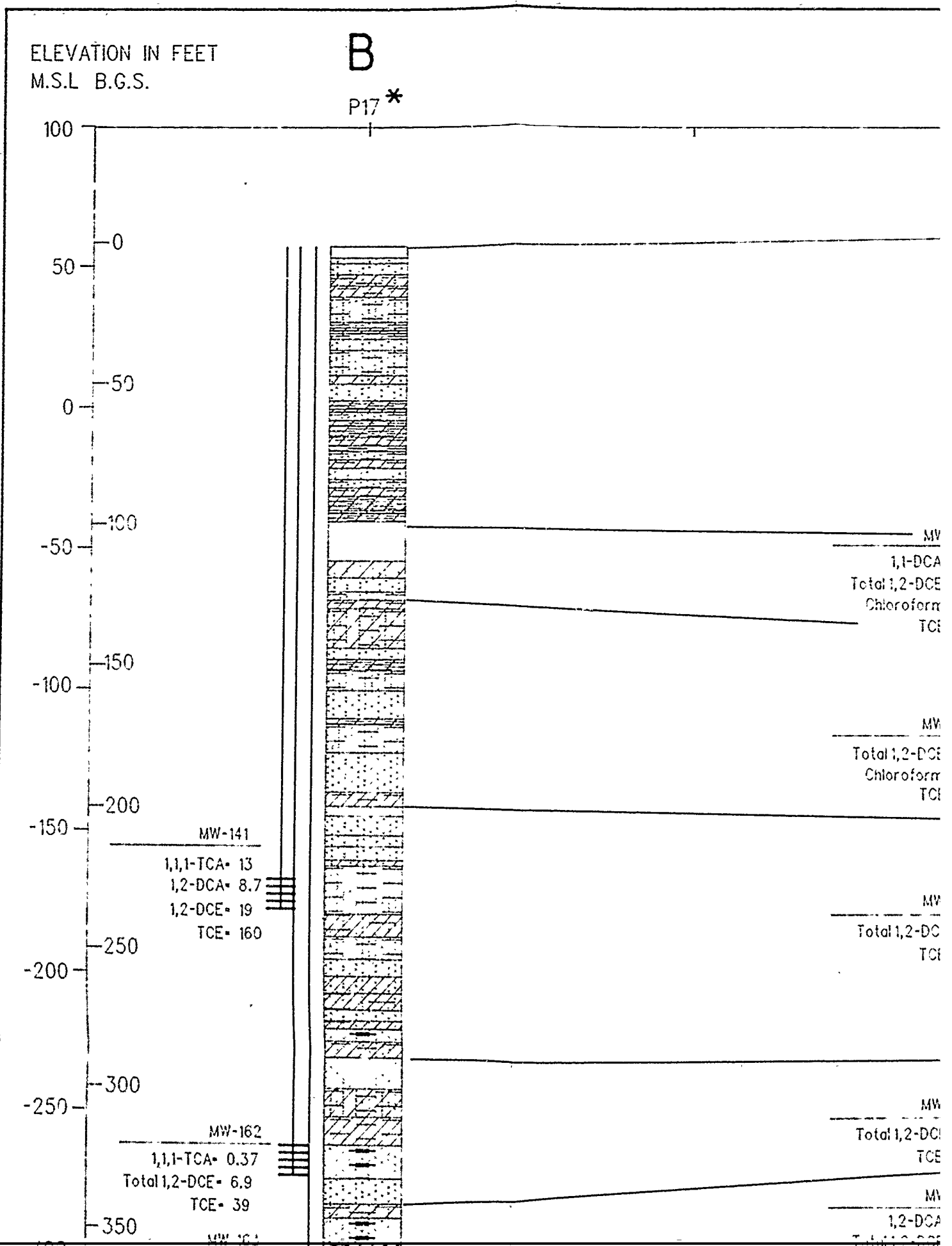
RESULTS
OF EPA METHOD
8010 ANALYSES

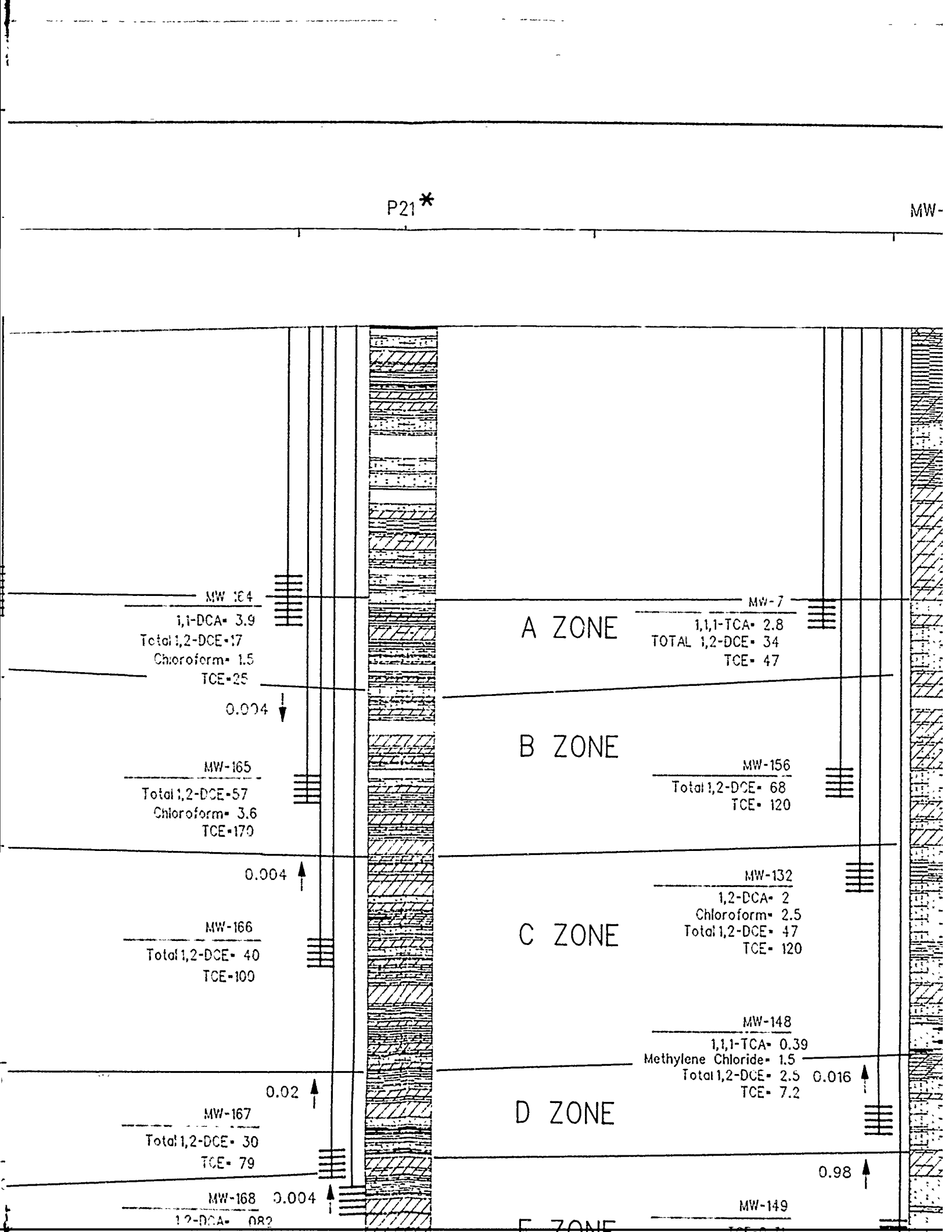
OPERABLE UNIT B
GROUNDWATER
REMEDIAL INVESTIGATION
McClellan AFB

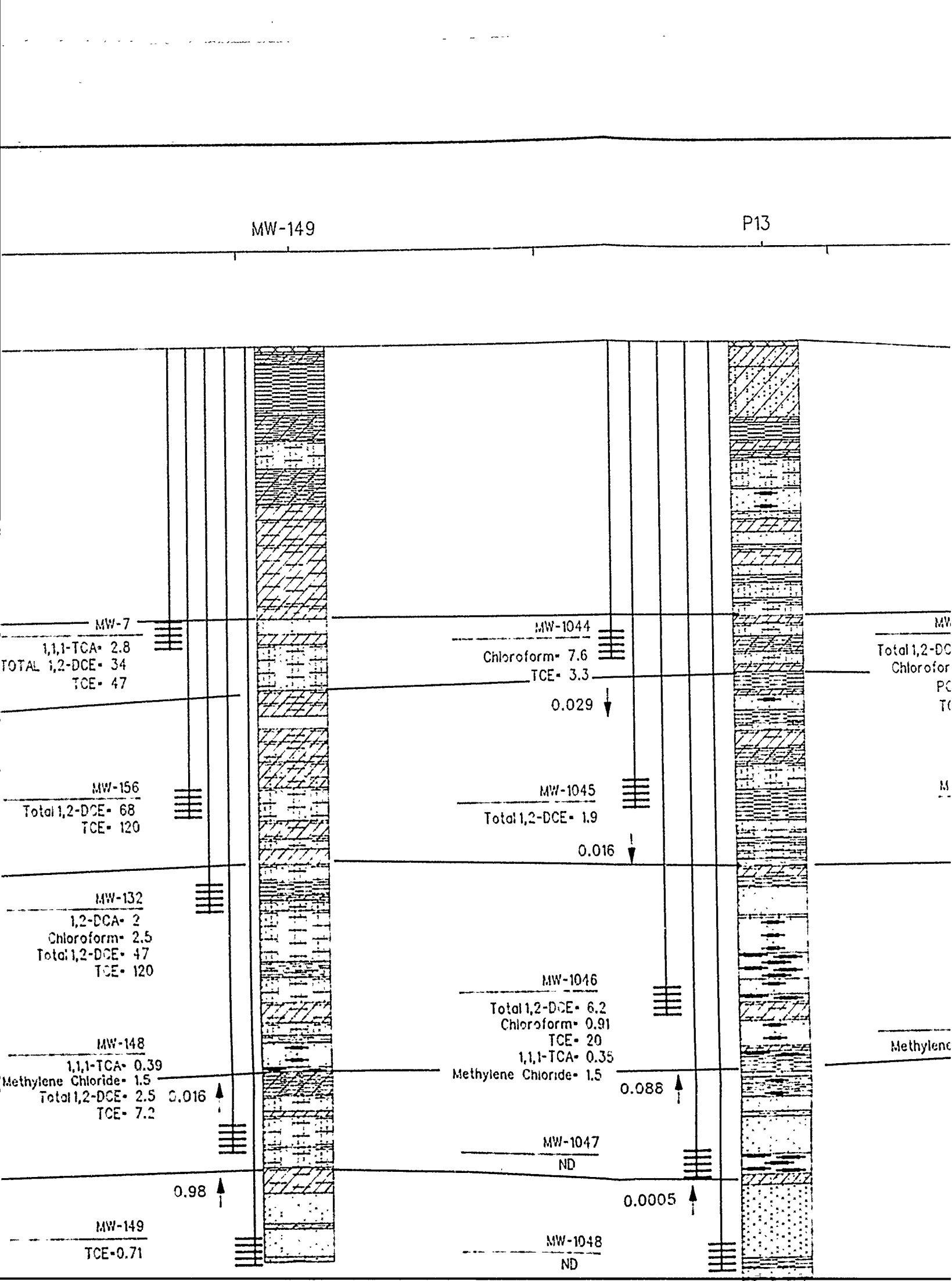
1990

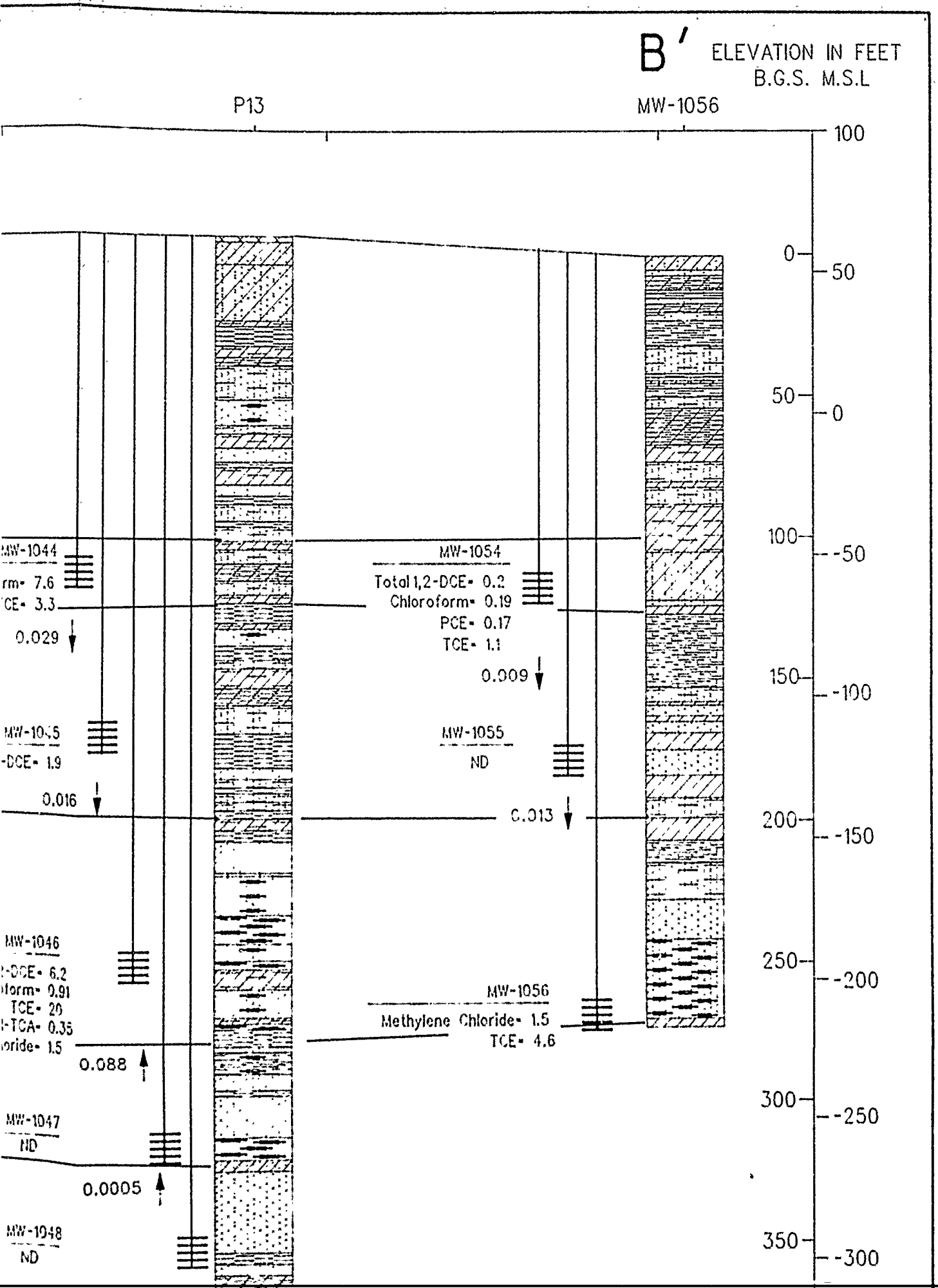
RADIAN CORPORATION

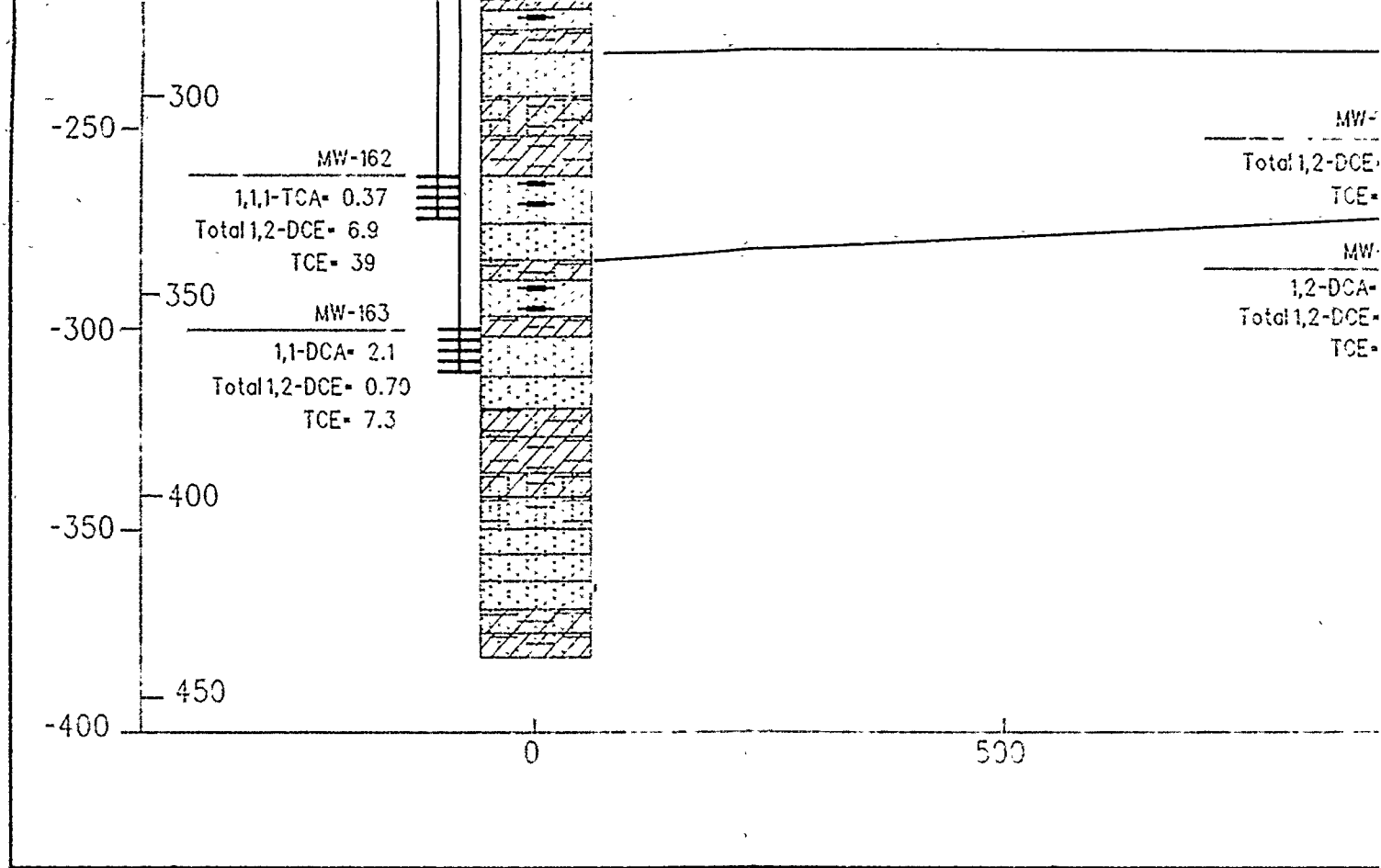
MAFB D011 GINT GINT7B

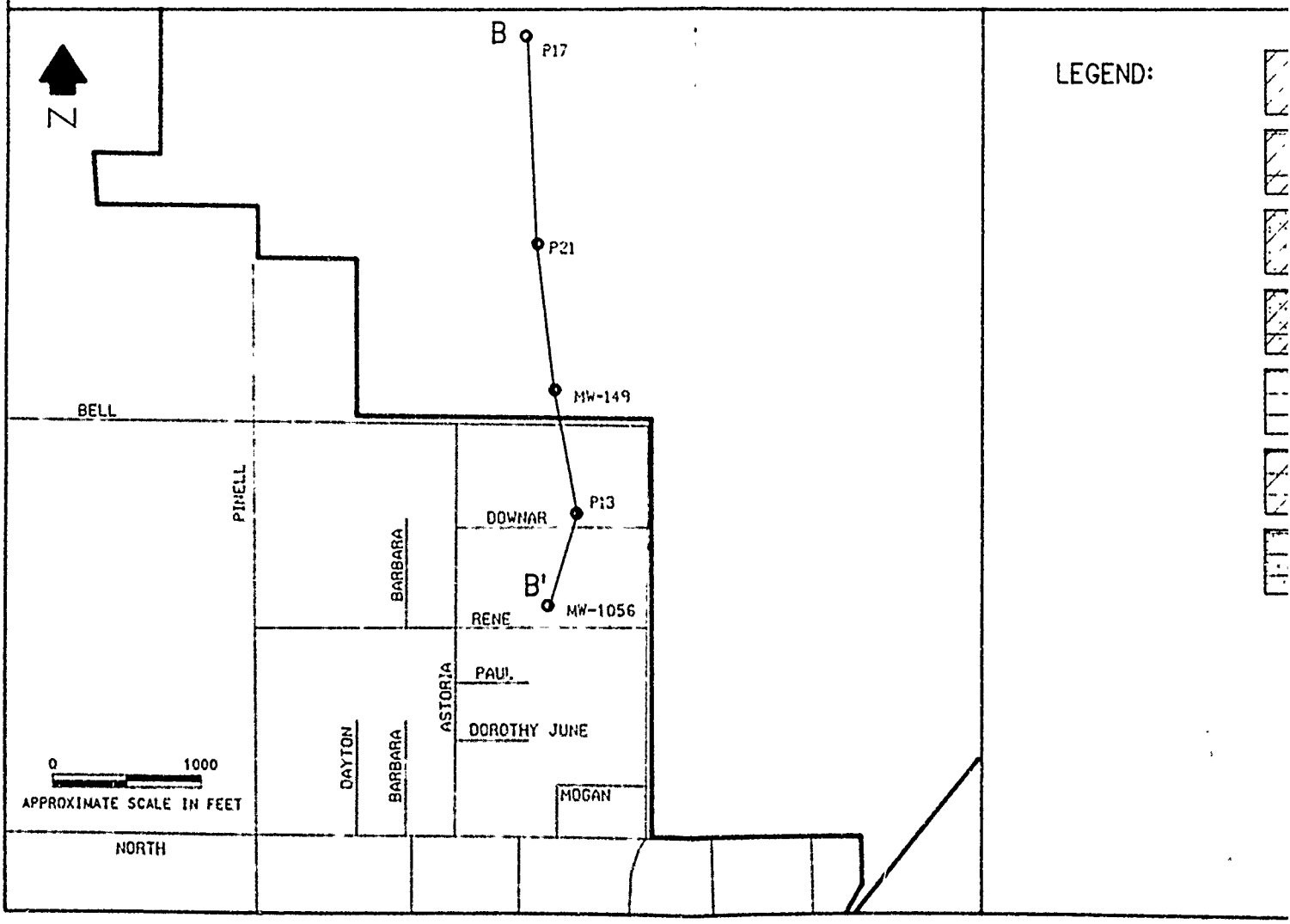

ELEVATION IN FEET
M.S.L B.G.S.
B
P17 *
100
50
0
-50
-100
-150
-200
-250
0
50
100
150
200
250
300
350
MW-141
1,1,1-TCA= 13
1,2-DCA= 8.7
1,2-DCE= 19
TCE= 160
MW-162
1,1,1-TCA= 0.37
Total 1,2-DCE= 6.9
TCE= 39
MW
1,1-DCA
Total 1,2-DCE
Chloroform
TCE
MW
Total 1,2-DCE
Chloroform
TCE
MW
Total 1,2-DC
TCE
MW
Total 1,2-DC
TCE
MW
1,2-DCA

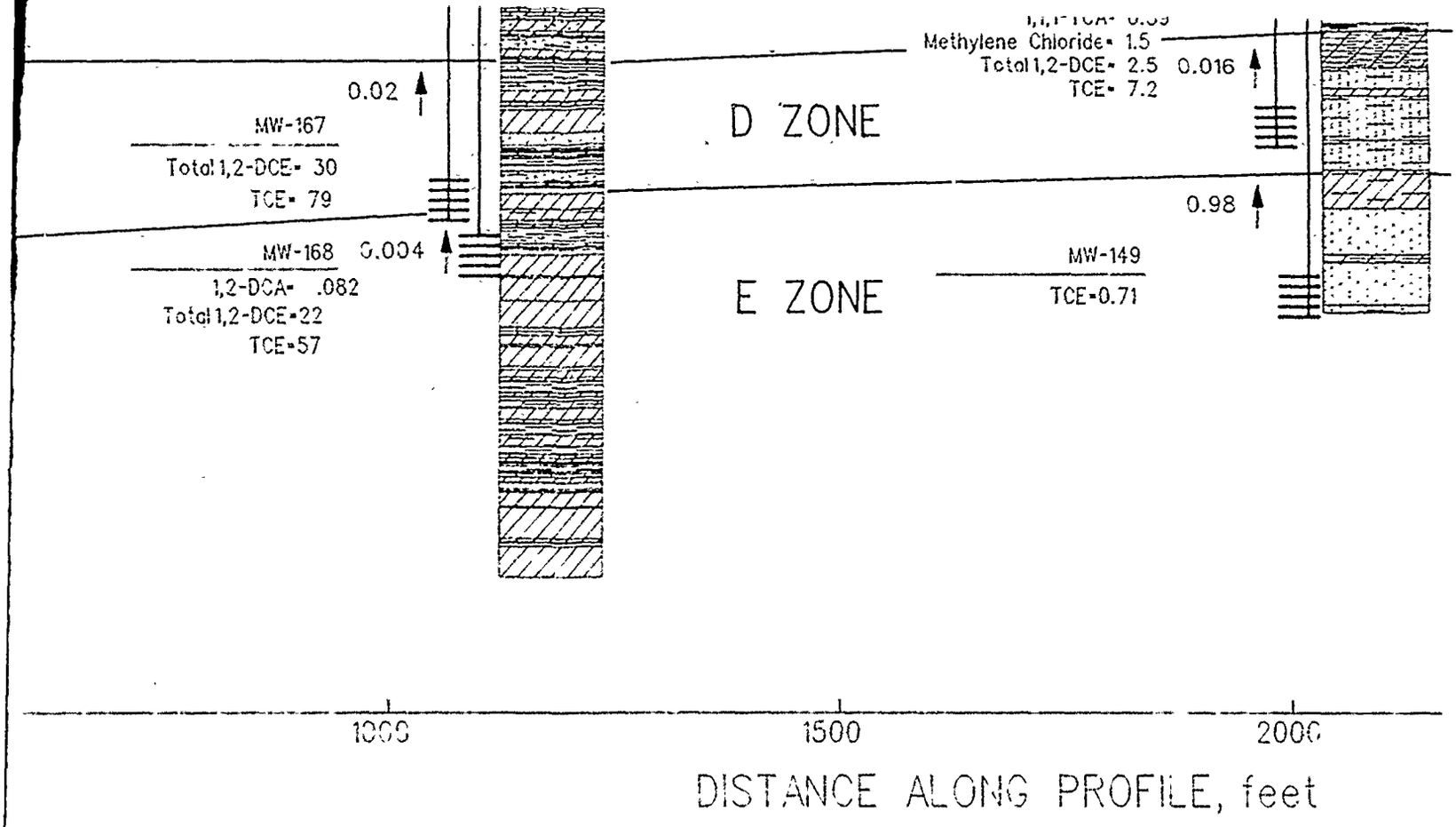

P21*
MW-
MW-164
1,1-DCA- 3.9
Total 1,2-DCE-17
Chloroform- 1.5
TCE-25
0.004
MW-165
Total 1,2-DCE-57
Chloroform- 3.6
TCE-170
0.004
MW-166
Total 1,2-DCE- 40
TCE-100
0.02
MW-167
Total 1,2-DCE- 30
TCE- 79
MW-168
0.004
1,2-DCA- 082
A ZONE
B ZONE
C ZONE
D ZONE
E ZONE
MW-7
1,1,1-TCA- 2.8
TOTAL 1,2-DCE- 34
TCE- 47
MW-156
Total 1,2-DCE- 68
TCE- 120
MW-132
1,2-DCA- 2
Chloroform- 2.5
Total 1,2-DCE- 47
TCE- 120
MW-148
1,1,1-TCA- 0.39
Methylene Chloride- 1.5
Total 1,2-DCE- 2.5
TCE- 7.2
0.016
0.98
MW-149


MW-149
P13
MW-7
1,1,1-TCA- 2.8
TOTAL 1,2-DCE- 34
TCE- 47
MW-156
Total 1,2-DCE- 68
TCE- 120
MW-132
1,2-DCA- 2
Chloroform- 2.5
Total 1,2-DCE- 47
TCE- 120
MW-148
1,1,1-TCA- 0.39
Methylene Chloride- 1.5
Total 1,2-DCE- 2.5
TCE- 7.2
0.016
0.98
MW-149
TCE-0.71
MW-1044
Chloroform- 7.6
TCE- 3.3
0.029
MW-1045
Total 1,2-DCE- 1.9
0.016
MW-1046
Total 1,2-DCE- 6.2
Chloroform- 0.91
TCE- 20
1,1,1-TCA- 0.35
Methylene Chloride- 1.5
0.088
MW-1047
ND
0.0005
MW-1048
ND


B'
ELEVATION IN FEET
B.G.S. M.S.L
P13
MW-1056
100
0
50
50
0
100
-50
150
-100
200
-150
250
-200
300
-250
350
-300
MW-1044
rm- 7.6
CE- 3.3
0.029
MW-1045
-DCE- 1.9
0.016
MW-1046
-DCE- 6.2
loform- 0.91
TCE- 20
-TCA- 0.35
oride- 1.5
0.088
MW-1047
ND
0.0005
MW-1048
ND
MW-1054
Total 1,2-DCE- 0.2
Chloroform- 0.19
PCE- 0.17
TCE- 1.1
0.009
MW-1055
ND
0.013
MW-1056
Methylene Chloride- 1.5
TCE- 4.6

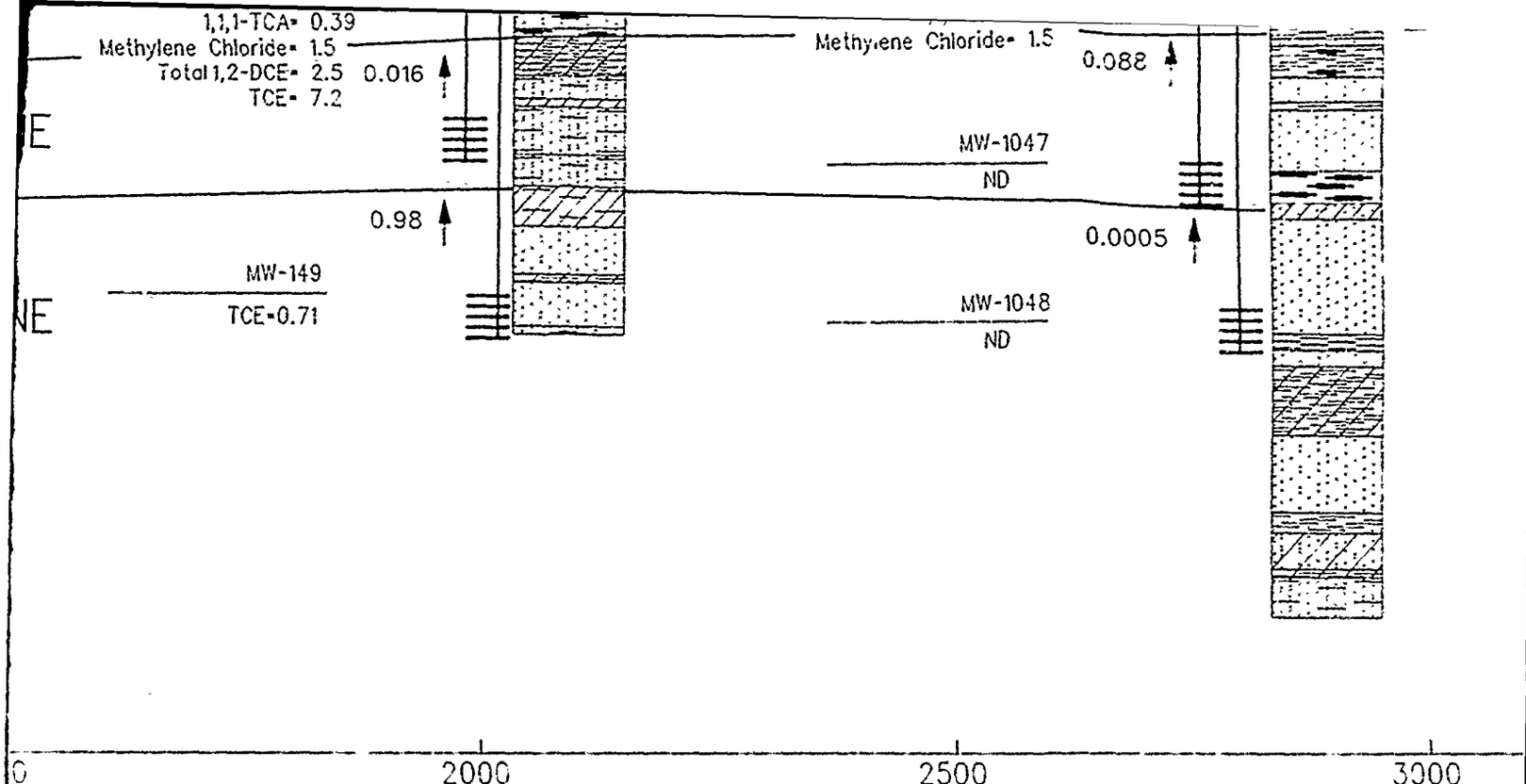

300
-250
350
-300
400
-350
450
-400
0
500
MW-162
1,1,1-TCA= 0.37
Total 1,2-DCE= 6.9
TCE= 39
MW-163
1,1-DCA= 2.1
Total 1,2-DCE= 0.70
TCE= 7.3
MW-
Total 1,2-DCE
TCE=
MW-
1,2-DCA=
Total 1,2-DCE
TCE=


N
B
P17
P21
MW-149
P13
B'
MW-1056
BELL
PINELL
BARBARA
DOWNAR
RENE
ASTORIA
PAUL
DOROTHY JUNE
DAYTON
BARBARA
MOGAN
NORTH
0
1000
APPROXIMATE SCALE IN FEET
LEGEND:



LEGEND:

- CLAY
- SILTY SANDY CLAY
- SILTY CLAY
- SANDY CLAY
- SILT
- CLAYEY SILT
- SANDY SILT
- GRAVELLY SILT
- CLAYEY SAND
- SILTY SAND
- SILTY CLAYEY SAND
- SILTY GRAVEL
- CLAYEY GRAVEL
- SAND
- GRAVELLY SAND
- GRAVEL
- SANDY GRAVEL
- NO RETURN
- FILL
- ASPHALT



CE ALONG PROFILE, feet

SILT

AND

ND

AYEY SAND

AVEL

RAVEL

SAND

GRAVELLY SAND

GRAVEL

SANDY GRAVEL

NO RETURN

FILL

ASPHALT

MONITORING WELL SCREEN INTERVALS

STATIC WATER LEVEL

M.S.L. MEAN SEA LEVEL

B.G.S. BELOW GROUND SURFACE

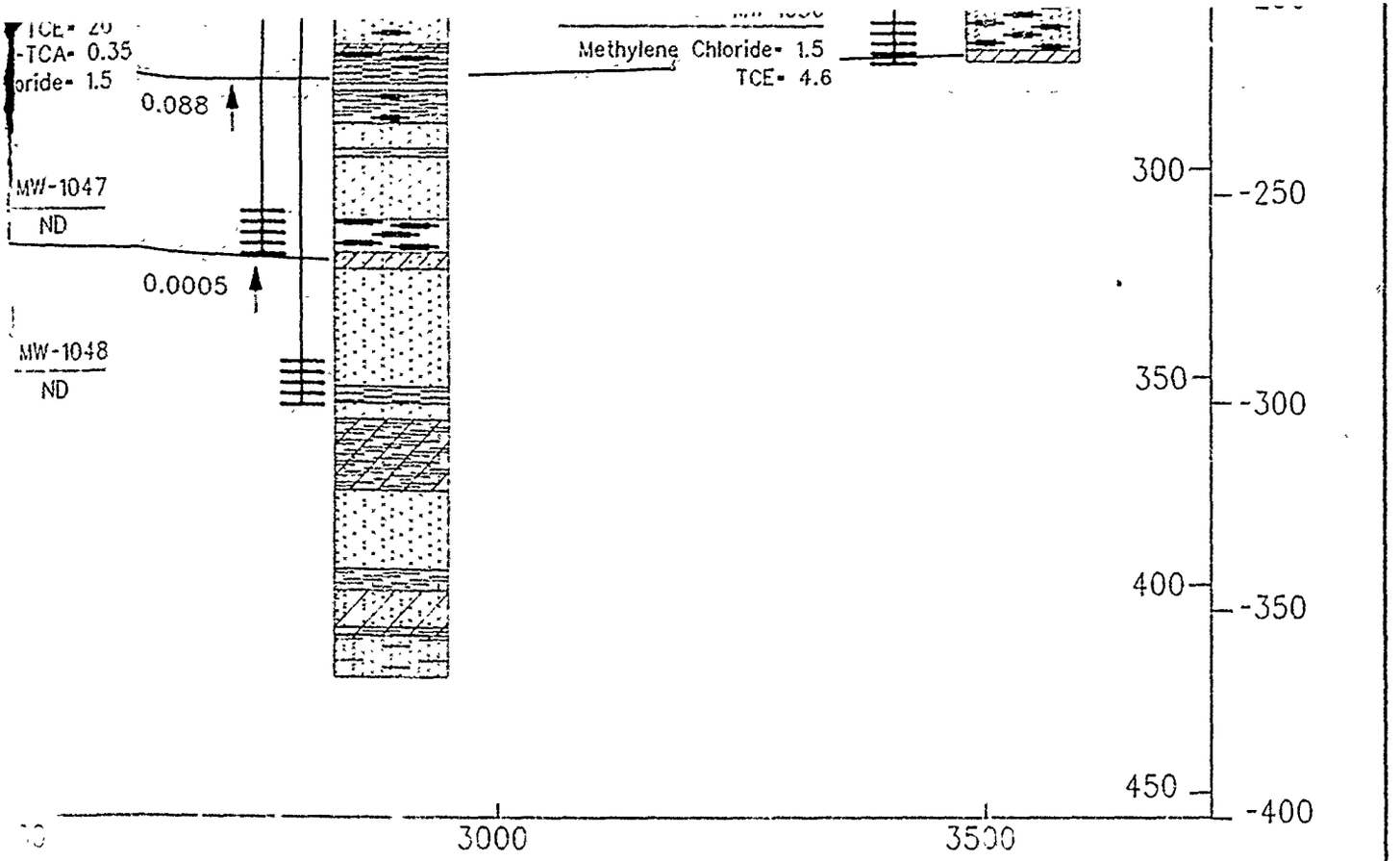
------ CONTACTS ARE DASHED WHERE APPROXIMATE

ND NOT DETECTED

CONCENTRATIONS ARE IN MICROGRAMS PER LITER FOR FORTH QUARTER 1989 AND FIRST QUARTER 1990 ANALYSES, EXCEPT WHE

* MONITORING WELLS IN CLUSTERS P17 AND P2 INSTALLED FOR THE PRELIMINARY GROUNDWAT OPERABLE UNIT REMEDIAL INVESTIGATION (F

0.013 ↓ VERTICAL GRADIENT MAGNITUDE AND DIRECT WELLS SCREENED IN SEPARATE ZONES, APRIL



ITORING WELL SCREEN INTERVALS

TIC WATER LEVEL

N SEA LEVEL

OW GROUND SURFACE

TACTS ARE DASHED WHERE APPROXIMATE

DETECTED

CENTRATIONS ARE IN MICROGRAMS PER
ER FOR FORTH QUARTER 1989 AND
ST QUARTER 1990 ANALYSES, EXCEPT WHERE NOTED.

TORING WELLS IN CLUSTERS P17 AND P21 WERE
ALLED FOR THE PRELIMINARY GROUNDWATER
ABLE UNIT REMEDIAL INVESTIGATION (PGOURI)

TICAL GRADIENT MAGNITUDE AND DIRECTION BETWEEN
S SCREENED IN SEPARATE ZONES, APRIL 1990 DATA.

PLATE 4

McClellan AFB
VERTICAL CONTAMINANT DISTRIBUTION IN NORTHWEST TO SOUTHEAST CROSS SECTION RESULTS OF EPA METHOD 8010 ANALYSES

OPERABLE UNIT B GROUNDWATER REMEDIAL INVESTIGATION

JULY 1990

RADIAN CORPORATION

MAFB GINT8B

RADIAN
CORPORATION

APPENDIX B

BASELINE RISK ASSESSMENT

RADIAN CORPORATION

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RADIAN CORPORATION

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RADIAN CORPORATION

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1.0 INTRODUCTION

McClellan Air Force Base (AFB) is located approximately seven miles northeast of downtown Sacramento, California, as shown in Figure 1-1. During environmental investigations at McClellan AFB possible sources of contamination were grouped into four geographic on-base areas and five geographic off-base areas. In 1989, McClellan AFB was divided into operable units (OUs) to further facilitate groundwater investigations. The Operable Unit B (OU B) was implemented to determine the potential for contaminant migration to off-base municipal water supplies. OU B includes Area B and a portion of the adjacent off-base Southwest Area. Analytical data from monitoring wells in OU B indicate that chlorinated organic compounds and heavy metals have migrated from locations beneath McClellan AFB to off-base monitoring wells.

1.1 Overview

The purpose of the OU B baseline risk assessment is to identify and characterize the current or "baseline" risks to the human populace living and working in and around OU B at McClellan. The baseline risk assessment can identify the need for a removal action, it can identify health based clean-up criteria, or it can support a no action decision. It provides information required to identify, evaluate, and select removal actions. Therefore, it is an important part of any Engineering Evaluation and Cost Analysis-Environmental Assessment (EE/CA-EA).

Site-Specific Objectives of the Baseline Risk Assessment

The site specific objectives for the OU B groundwater baseline risk assessment are to identify the potential receptors, contaminants of concern, exposure pathways, and health risks that may result from groundwater use. Two major water supply wells are located within the limits of the OU B. Base Water Supply Well 18 (BW-18) serves on-base military personnel and their dependents, as well, as civilian personnel working on base. City Well 132 (CW-132) is located in the southern portion of the operable unit and is part of a City of Sacramento well field serving primarily off-base residential, commercial, and industrial users through the city water system. The baseline risk assessment will identify and characterize the potential risks to residential, military, and civilian personnel in the operable unit associated with use of contaminated groundwater.

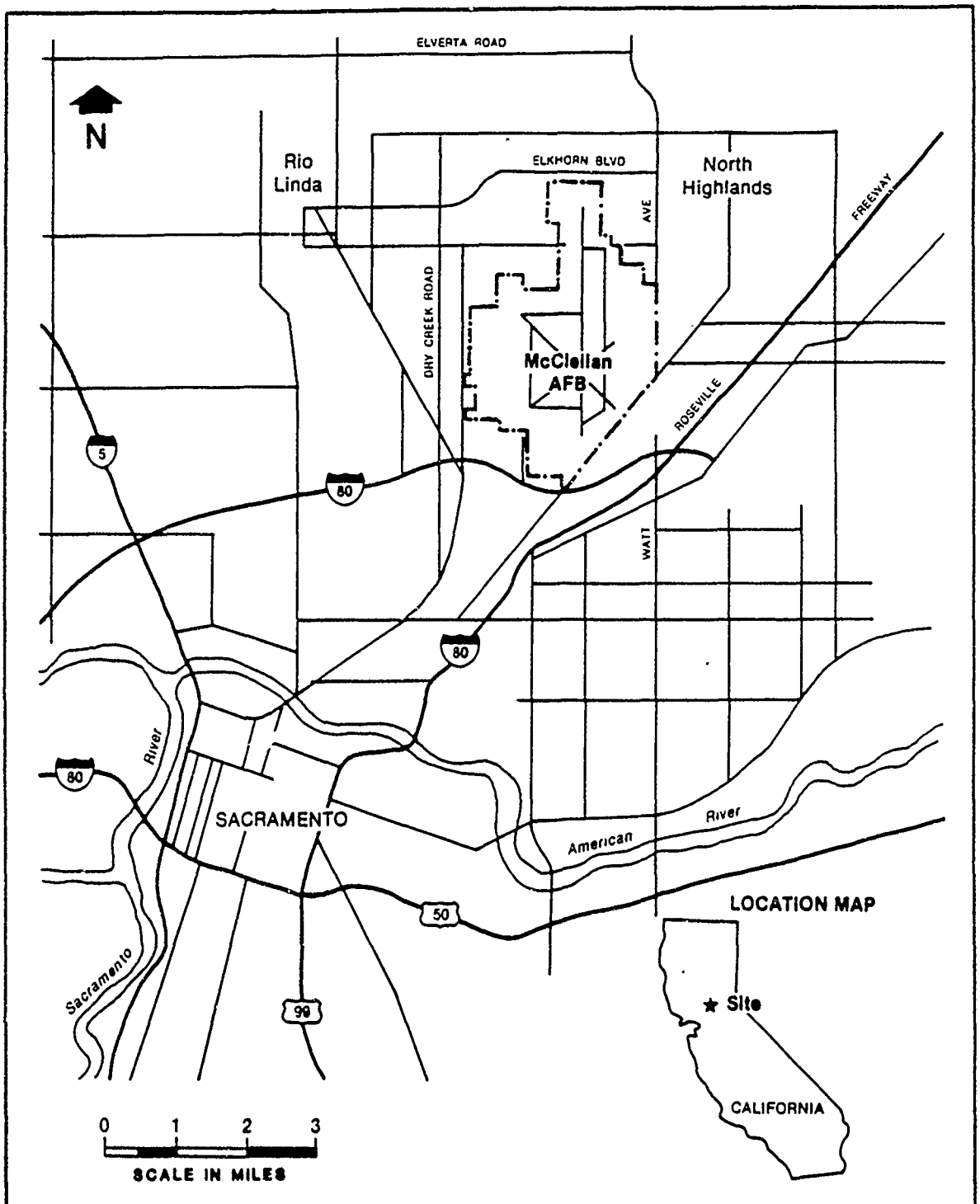

Figure 1-1. Location of McClellan Air Force Base, California

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Use of contaminated groundwater was based on two hydrologic scenarios: (1) BW-18 pumping and CW-132 off, and (2) BW-18 off and CW-132 pumping. Exposure assumptions were proposed and algorithms developed for the following: the average and upper bound (9 and 30-year) exposure periods for resident adults and children; the 3-year exposure period associated with one tour of military duty; and the 30-year occupational exposure scenario for civilians working at the base. The baseline risk was calculated using the two hydrologic scenarios and exposure assumptions and modeled concentrations of contaminants in groundwater at the wells.

1.2 Site Background

Appendix A contains general site background information including the site description, history of McClellan AFB operations, and the history of OU B.

1.2.1 Groundwater Operable Unit Remedial Investigation

In 1989, 29 monitoring wells were constructed to characterize the hydrologic conditions, the subsurface geology and the groundwater quality in OU B. A principal objective of the groundwater remedial investigation was to evaluate the magnitude and extent of groundwater contamination between McClellan AFB and active municipal wells to the southwest. Several clusters of wells, therefore, were constructed downgradient from BW-18 and upgradient from CW-132 (Figure 1-2). Groundwater monitoring well locations and approximate completion depths were reviewed and accepted prior to drilling by the California Department of Health Services (DHS), the California Regional Water Quality Control Board (RWQCB), and the U.S. Environmental Protection Agency (U.S. EPA) Regional Office. The drilling and construction of three to five wells per cluster was the method used to determine the vertical extent of groundwater contamination at any particular location. Geologic data from well borings and water level measurements from the wells were used to define five geohydrologic zones (A, B, C, D, and E) from the water table to a depth of 360 feet. The five geohydrologic zones are only semiconfined. Water-level measurements were used to develop potentiometric surface maps and to determine groundwater flow directions and hydraulic gradients under pumping and nonpumping conditions in OU B. When base wells are inactive, groundwater flow in all five zones is southwesterly to off-base areas in response to pumping by City of Sacramento water supply wells. When BW-18 is pumping, groundwater in all zones is strongly influenced by its activity. Under the current pumping rate of 1.5 to 1.6 million gallons per day, a large portion of flow

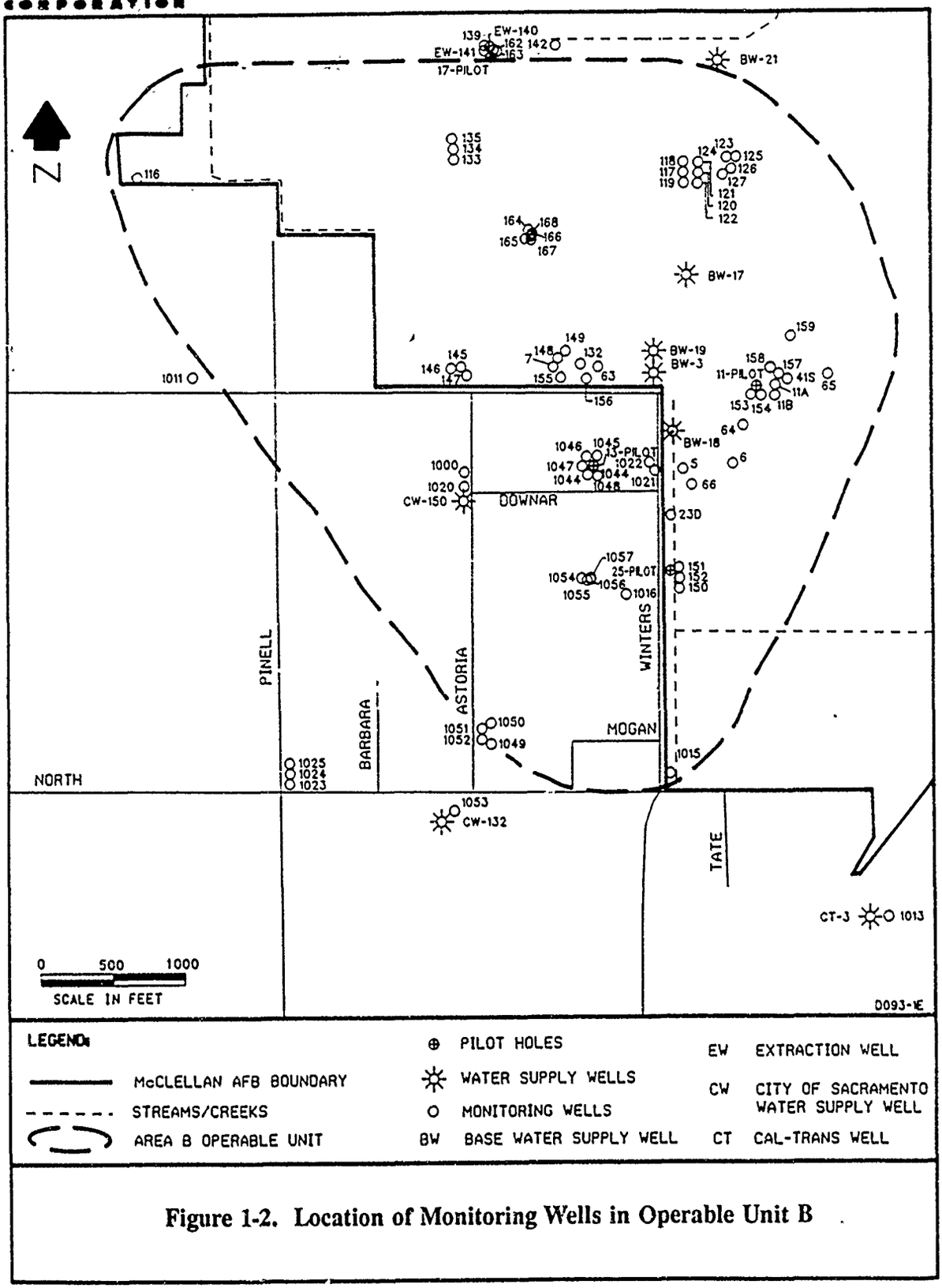

Figure 1-2. Location of Monitoring Wells in Operable Unit B

through the A, B, C, D, and E geohydrologic zones is captured by BW-18. Monitoring wells were initially sampled immediately following well development. Subsequent resampling for analysis of volatile organic compounds occurs quarterly as part of McClellan AFB Groundwater Sampling and Analysis Program.

1.2.2 Groundwater Quality Beneath OU B

Analytical data from monitoring wells in OU B indicate that volatile organic compounds (VOCs) and metals are present in the groundwater beneath the area. Results indicate that contaminants have migrated both vertically and horizontally beneath OU B. Contaminants originating from locations beneath McClellan AFB have migrated beyond the base boundary to off-base areas where they are detectable at lower concentrations. The locations of monitoring wells within OU B are shown in Figure 1-2. Contaminants have been detected at levels above California DHS Maximum Contaminant Levels (MCLs) in on-base monitor wells within OU B in all five hydrologic zones. In off-base wells within OU B, contaminants have only been detected in the shallower A, B, and C geohydrologic zones at much lower concentrations.

Based on recent and historical analytical data three distinct contaminant plumes have been identified within OU B (Figure 1-3). They consist of a large trichloroethene-1,2-dichloroethene (TCE-1,2-DCE) plume that trends north/south through most of OU B, a trichloroethene-perchloroethene (TCE-PCE) plume in the Building 666 area that trends northeast/southwest, and a PCE plume that is to the south of BW-18.

The TCE-1,2-DCE plume has been detected in all geohydrologic zones within OU B. In the A, B, and C zones it extends from Operable Unit C (OU C) to the northern boundary of OU B to the southwest boundary of OU B. Fewer wells are completed in the deeper D and E geohydrologic zones, and therefore, the areal extent of the TCE-1,2-DCE plume in these zones is unknown. Volatile organic compound concentrations are higher north of BW-18 and generally increase to the north (Figure 1-3). The B and C zones contain the highest contaminant concentrations; next highest are in the A zone, while the D and E zones contain the lowest.

The TCE-PCE plume is smaller in areal extent than the TCE-1,2-DCE plume, but contains higher levels of contaminants. The TCE-PCE plume trends northeast/southwest with concentrations increasing northeast away from BW-18 to their highest levels near Building 666 (Figure 1-3). The presence or extent of this plume in

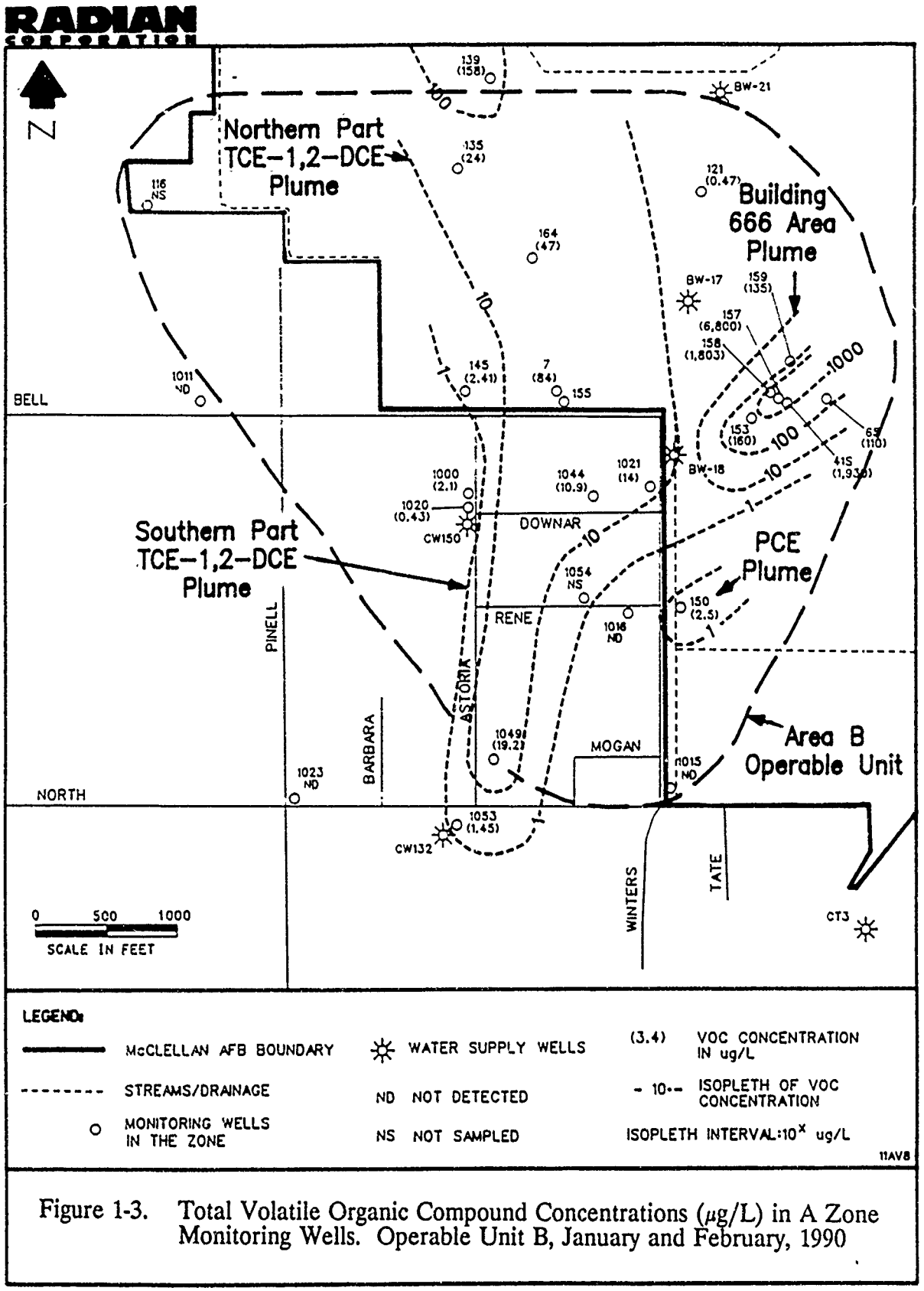

Figure 1-3. Total Volatile Organic Compound Concentrations (μg/L) in A Zone Monitoring Wells. Operable Unit B, January and February, 1990

zones other than the A zone cannot currently be determined due to a lack of data for the deeper zones. The third and smallest plume, a PCE plume, has been detected in the A and B zones at one cluster of wells only. This plume has not been detected in any other nearby wells. The areal extent of this plume has not been determined.

1.3 Scope of Risk Assessment

The EE/CA-EA for OU B is limited to the groundwater pathway; therefore, the scope of the baseline risk assessment has also been limited to exposure occurring via groundwater. It is recognized that other exposure pathways may exist at OU B, such as direct contact with potentially contaminated soils. However, these other pathways will be addressed by the Remedial Investigation/Feasibility Study (RI/FS) process rather than the EE/CA-EA.

Substantial data were available prior to beginning the baseline risk assessment for OU B. For example, the study area had already been defined as a separate Operable Unit. Sampling and analytical data were available for several years from monitoring wells, as well as, some of the McClellan AFB wells. These data made it possible to scope the risk assessment without additional site visits or specific sampling events.

1.3.1 Complexity of Assessment and Rationale

Because the risk assessment was limited to the groundwater pathway, direct and indirect pathways involving soil and air releases were not included. All groundwater pathways were investigated and exposure was quantitated to the extent possible. Environmental fate and transport modeling was used to estimate contaminant movement in the aquifers. The chemicals considered were those for which routine analyses were being conducted in the Groundwater Sampling and Analysis Program. Additional sampling for other contaminants was not conducted.

As described above, the EE/CA-EA is intended to evaluate and select removal actions for the existing groundwater contamination. An expedited schedule has been used so that removal activity can be initiated before substantial additional spread of contaminants can occur. Thus, the baseline risk assessment was limited in depth (considering groundwater only) and breadth (considering only those chemicals with substantial recent history of movement) so as to meet the requirements of the EE/CA-EA schedule.

1.3.2 Overview of Risk Assessment Design

The risk assessment was designed to quantitate the risks associated with the use of BW-18, a well located on McClellan AFB within OU B, and a City of Sacramento public water supply well, designated CW-132. Exposure pathways were investigated, including direct and indirect exposure to contamination in groundwater. Environmental fate and transport modeling was used to predict the magnitude of contamination which could migrate with time to the two wells. Because the water from BW-18 is treated to remove contaminants prior to distribution in the water supply, only treated water was included in the chronic exposure scenarios. Use of the contaminated water after a hypothetical failure of the treatment plant was included as a subchronic exposure scenario. For CW-132, evaluation of chronic exposure to contaminated water included direct and indirect pathways.

1.4 Organization of the Risk Assessment Report

This report is divided into six sections. This section, Section 1, presents the introduction. Section 2 identifies the chemicals of potential concern. The exposure assessment is presented in Section 3. Section 4 includes the toxicity assessment. The risk characterization is presented in Section 5. Finally, Section 6 contains the summary of the risk assessment. Appendices have been included in this report to present detailed information such as supporting background information, individual analytical results and specific methodologies.

2.0 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

This section will describe the process and criteria used to narrow the list of all of the contaminants detected in groundwater samples collected at OU B to a list of chemicals which have the potential to pose a significant threat to human health and welfare.

2.1 General Considerations

The general considerations used for the identification of the chemicals of potential concern are outlined in the following subsections.

2.1.1 Availability of Data

As described previously, sampling and analysis of groundwater have been underway in OU B for several years. The analytical program has been streamlined to conserve the budget, as well as, to concentrate data collection efforts on those chemicals that have historically been detected with some consistency in OU B. This allows the evaluation to focus on chemicals that are more likely to pose a serious threat due to their persistence at the site rather than on transient chemicals. As a result, the data available are limited to results from EPA Methods 8010 (a gas chromatographic method for volatile organic compounds), 8240 (a method using mass spectroscopic confirmation of gas chromatographic results for volatile organic compounds), and 6010 (an inductively coupled plasma emission spectrometry method for metals).

2.1.2 Schedule for the EE/CA-EA

An EE/CA-EA is a comprehensive analysis of removal action options for a Superfund hazardous waste site. The EE/CA-EA process is the procedure used by response personnel to develop, evaluate, and select a removal action. Removal actions are, relative to remedial actions, relatively short-term. Therefore, the EE/CA-EA process must be performed and completed within an abbreviated schedule. Any tasks performed in support of the EE/CA-EA must also be performed within the EE/CA-EA schedule. The baseline risk assessment will identify and characterize health-related risks to nearby receptors. It will also provide risk based clean-up criteria for the removal action. While any risk assessment can be improved by collection of additional data, the schedule requirements of the EE/CA-EA preclude any additional sampling and analysis.

2.1.3 The RI/FS Process

An RI/FS is planned for McClellan AFB as a whole, to include OU B. The RI/FS will be comprehensive in scope and contaminants, other than those for which data are currently available, can be addressed at that time. Therefore, it was not considered necessary to conduct additional analytical work at this time.

2.2 Data Evaluation

Standard U.S. EPA Methods 8010 and 6010 from Test Methods for Evaluating Solid Waste (U.S. EPA SW-846) were used to analyze the samples for VOCs and metals that were used for the baseline risk assessment. The analyses were performed according to Standard Operating Procedures (SOPs) developed by the Radian laboratory. The SOPs establish procedures and specifications for sample preparation, analysis, and data reduction. These include instrument settings; calibration procedures and specifications; QA/QC procedures including analysis of blank, duplicate, and spiked samples to monitor system performance; requirements for control charts to document that the analytical system is in statistical control; and data reduction and reporting protocols. Appendix B details the specific methods and protocols included in the SOPs developed by the Radian laboratory.

2.3 Selection of Contaminants of Potential Concern

The contaminants of potential concern in OU B were selected on the basis of the quality of the available data and whether or not the compounds were potentially site-related.

A "snap-shot" approach was implemented to select a specific data set to be used in the quantitative risk assessment. The most recent data, from January, 1990, was selected as the primary data set. All other data were used in a qualitative analysis to determine if there were any historically significant changes in concentrations.

Some contaminants detected in the January, 1990, sampling and analysis effort were eliminated from the quantitative risk assessment after the data were evaluated. This evaluation included comparison of background levels, frequency of detection, and evaluation of quantitation limits.

2.3.1 Justification for Elimination of Contaminants

The data set compiled from the January, 1990, results contained chemicals for which positive data (detected concentrations) were available in at least one sample. Those contaminants analyzed for, but not detected in any samples, were immediately eliminated.

The list of contaminants was narrowed down further by taking into consideration the frequency of detection, evaluation of quantitation limits, unvalidated data, and actual use of aquifer zones. The list of contaminants is then limited only to those contaminants that would most likely contribute significantly to the total risk, and eliminates contaminants that may detract from the dominant risk presented by the site.

The frequency of detection for any compound was calculated by dividing the number of samples in which the contaminant was detected by the number of samples available. Contaminants present in less than 5% of the samples are often eliminated from further assessment (USEPA, 1989c). Another elimination criterion was to multiply the detection limit by a factor of five to obtain a quantitation limit. The quantitation limit is considered to be the lowest level at which a chemical may be accurately and reproducibly quantified. Reproducible quantitation of a chemical may not be possible at the detection limit, due to the irregular nature of instrument or method noise (USEPA, 1989a).

Usually, only validated data are used in a quantitative risk assessment, but in this risk assessment a limited number of unconfirmed results was used due to limited data availability. The E zone results were eliminated due to the fact that none of the drinking water wells penetrate to the E zone level. Most of the water used from BW-18 and CW-132 is taken from the B through D zones, therefore, the E zone would not contribute contaminants to these drinking water wells.

2.3.2 Criteria Used for Volatile Organic Compounds (VOCs)

The January data set contained VOCs for which positive data were available in at least one sample (all VOCs reported as non-detected were eliminated). Table 2-1 presents potential VOCs of concern.

For the standard criterion of <5% detection limit to be used, more than 20 samples had to be available from each zone for a single sample result to be eliminated.

TABLE 2-1. CHEMICALS SAMPLED IN GROUNDWATER (VOCs)

Chemicals	Frequency of Detection(a) Zone A	Zone B	Zone C	Zone D	Range of Detection Limits (µg/L)	Range of Detection Concentrations (µg/L) (b)
1,1,1-Trichloroethane**	14/37(38%)	6/23(26%)	4/11(36%)	3/8(38%)	0.20 - 10	0.23* - 29*
1,1,2-Trichloroethane**	3/37(8%)	1/23(4%)	1/11(9%)	1/8(13%)	0.2 - 2.0	0.42*X - 7.5*X
1,1,2,2-Tetrachloroethane**	3/37(8%)	0/23(9%)	0/11(0%)	1/8(13%)	0.15 - 0.15	0.23*X - 1.2X
1,2-Dichloropropane	1/37(3%)	0/23(0%)	0/11(0%)	0/8(0%)	0.1	0.54X
1,4-Dichlorobenzene	0/37(0%)	2/23(9%)	0/11(0%)	0/8(0%)	0.24 - 0.24	0.24*X -0.28*X
2-Chloroethylvinylether	0/37(0%)	1/23(4%)	1/11(9%)	0/8(0%)	0.5 - 0.5	0.64*X - 0.99*X
Benzene	0/37(0%)	0/23(0%)	1/11(9%)	0/8(0%)	0.2	0.2*X
Bromoform	1/37(3%)	0/23(0%)	0/11(0%)	0/8(0%)	25	40*X
Chloroethane	1/37(3%)	0/23(0%)	0/11(0%)	1/8(13%)	0.52 - 26	1.2*X - 31*X
Chloromethane	1/37(3%)	0/23(0%)	1/11(9%)	0/8(0%)	1.5	5.8*X
Dibromochloromethane	2/37(5%)	1/23(4%)	0/11(0%)	0/8(0%)	0.2 - 100	0.23*X - 250*X
Methylene chloride**	11/37(30%)	9/23(39%)	4/11(36%)	3/8(38%)	0.4 - 0.4	0.41* - 2.3
Toluene	0/37(0%)	0/23(0%)	1/11(9%)	0/8(0%)	0.2	0.21*X
trans-1, 3-Dichloropropene	1/37(3%)	0/23(0%)	1/11(9%)	0/8(0%)	0.34 - 1.7	0.51*X - 2.4*X
Vinyl chloride	1/37(3%)	0/23(0%)	0/11(0%)	0/8(0%)	2.0	2.8*X
Xylenes (total)	0/37(0%)	0/23(0%)	1/11(9%)	0/8(0%)	0.2	0.58*X
Bromodichloromethane	1/37(3%)	2/23(9%)	0/11(0%)	0/8(0%)	0.1 - 1.0	0.11*X - 1.1*X
Carbon tetrachloride**	6/37(16%)	1/23(4%)	0/11(0%)	1/8(13%)	0.12 - 0.12	0.12*X - 2.6X
Chloroform**	5/37(14%)	2/23(9%)	3/11(27%)	1/8(13%)	0.1 - 0.1	0.16* - 7.6
1,1-Dichloroethane	0/37(0%)	0/23(0%)	0/11(0%)	0/8(0%)		
1,2-Dichloroethane**	12/37(32%)	7/23(30%)	2/11(18%)	1/8(13%)	0.1 - 0.5	0.14* - 2.9
1,1-Dichloroethene**	4/37(11%)	0/23(0%)	1/11(9%)	1/8(13%)	0.2 - 1.0	20X - 6.2X
1,2-Dichloroethene**	12/37(32%)	5/23(22%)	3/11(27%)	1/8(13%)	0.2 - 2.0	0.21* - 51
Tetrachloroethene**	14/37(38%)	3/23(13%)	2/11(18%)	2/8(25%)	0.1 - 50	0.39* - 2300
Trichloroethene**	18/37(49%)	8/23(35%)	4/11(36%)	3/8(38%)	0.2 - 10	0.48* - 1500

(a) Number of samples in which the chemical was positively detected (confirmed and unconfirmed) over the number of samples available.
(b) Used unconfirmed concentrations when confirmed concentrations were unavailable.
X Unconfirmed
* Detected at less than five times the detection limit.
** Chemical of potential concern after data evaluation (see text).

Therefore, the frequency of detection criterion was modified to compensate for the limited number of samples taken in OU B. When the frequency of detection was >5%, but less than 15% then the following criterion was used: if the sample concentration was less than five times the detection limit and unconfirmed then the compound was eliminated from the risk assessment.

Two compounds designated by the U.S. EPA as Group A - Human Carcinogen, benzene and vinyl chloride, were eliminated from the initial contaminant list because of their low concentrations, infrequent occurrence, and unconfirmed analytical results. Benzene was found in only 1% of the total samples analyzed at a concentration equal to the detection limit. The benzene results were also unconfirmed. Vinyl chloride was found in only 1% of the total samples analyzed. It was present at a concentration less than five times the detection limit and these results were also unconfirmed. Therefore, these two contaminants, because of their low concentrations and low frequency of occurrence, were eliminated from the risk assessment.

2.3.3 Criteria for Metals

The preliminary data set for metals contained only positive data available in at least one sample, excluding those metals reported as non-detectable. Table 2-2 presents potential metals of concern.

The frequency of detection criterion of <5% could not be used on this data set due to limited sample availability. Instead the metals of concern were compared to baseline values for metals in the groundwater beneath OU B. The monitoring wells used to obtain these baseline concentrations are located up gradient (north and northeast) from potential sources of contamination on McClellan AFB OU B. See Appendix C for calculation of metal baseline concentrations. These baseline concentrations were only applicable to a few of the metals of concern. The metals that were not reported in the baseline evaluation were further eliminated according to surrounding land conditions, toxicity, and essential nutrient value for humans.

Aluminum was eliminated from the risk assessment due to its low concentration and infrequent occurrence. It was present in one sample out of eleven total samples, with a concentration less than two times the detection limit. Aluminum is one of the most abundant metals found in the earth's crust, therefore, it is appropriate to assume that the analyzed concentration is a result of background concentrations not

TABLE 2-2. CHEMICALS SAMPLED IN GROUNDWATER (METALS)

Chemical	Frequency of Detection (a) Zone A	Zone B	Zone C	Zone D	Detection Limits (mg/L)	Range of Detection Concentrations (mg/L) (b)	Baseline Concentrations (mg/L)
Aluminum	1/7(14%)	0/2(%)	0/0(0%)	0/2(0%)	0.045	0.049*	N/A
Barium	7/7(100%)	2/2(100%)	0/0(0%)	2/2(100%)	0.002	0.012 - 0.078	0.12
Boron**	7/7(100%)	2/2(100%)	0/0(0%)	2/2(100%)	0.006	0.048 - 0.35	NA
Calcium(n)	7/7(100%)	2/2(100%)	0/0(0%)	2/2(100%)	0.01	9.2 - 33	NA
Chromium	3/7(43%)	2/2(100%)	0/0(0%)	1/2(50%)	0.007	0.010* - 0.02*	0.025(c)
Copper	6/7(86%)	1/2(50%)	0/0(0%)	2/2(100%)	0.006	0.008* - 0.025	0.060
Iron(n)	7/7(100%)	2/2(100%)	0/0(0%)	2/2(100%)	0.007	0.012* - 0.96	NA
Magnesium(n)	7/7(100%)	2/2(100%)	0/0(0%)	2/2(100%)	0.03	4.8 - 17	NA
Maganese	4/7(57%)	1/2(50%)	0/0(0%)	2/2(100%)	0.002	0.002* - 0.15	NA
Nickel	2/7(29%)	1/2(50%)	0/0(0%)	1/2(50%)	0.015	0.016* - 0.047	0.060
Potassium(n)	1/7(14%)	0/2(0%)	0/0(0%)	0/2(0%)	3.0	7.2*	NA
Silicon	7/7(100%)	2/2(100%)	0/0(0%)	2/2(100%)	0.058	14 - 38	NA
Sodium(n)	7/7(100%)	2/2(100%)	0/0(0%)	2/2(100%)	0.029	18 - 23	NA
Vanadium**	6/7(86%)	2/2(100%)	0/0(0%)	1/2(50%)	0.008	0.009* - 0.037*	NA
Zinc**	7/7(100%)	2/2(100%)	0/0(0%)	2/2(100%)	0.002	0.004* - 0.038	0.07

(a) Number of Samples in which the chemical was detected (confirmed and unconfirmed) over the number of samples available.
(b) Used unconfirmed concentrations when confirmed concentrations were unavailable.
(c) One-half U.S. EPA Primary Maximum Contaminant Level used for baseline.
(n) Essential human nutrient.

X - Unconfirmed
* - Detected at less than five times the detection limit
** - Chemical of potential concern after data evaluation (see text)

contamination coming from the site. The groundwater concentrations of silicon are likely to be dissolved from the surrounding soil and are also considered to be background concentrations. Silicon is an inert compound, with low toxicity, therefore, it was eliminated from the risk assessment.

Manganese is an essential element in the human body. The human daily intake ranges from 2 to 9 mg, with a gastrointestinal absorption factor of less than 5% (Klaassen et al., 1986). The highest manganese concentration reported is 0.15 mg/L which is 8% of the minimum daily intake and less than 2% of the maximum daily intake. Therefore, the exclusion of this compound was based on its low toxicity and low concentrations.

The compounds that are essential human nutrients (calcium, iron, magnesium, potassium, and sodium) are present in low concentrations that pose no threat to human health or welfare.

2.4 Summary of Chemicals of Potential Concern

The initial contaminant list was analyzed through data evaluation (i.e., background comparisons, frequency of detection, evaluation of quantitation limits) to eliminate those compounds that contributed no significant risks to the total risk assessment. This enabled the risk assessors to focus on those contaminants that might pose a significant threat to human health and welfare. Table 2-3 presents a summary of chemicals of potential concern at the McClellan AFB OU B.

TABLE 2-3. SUMMARY OF CHEMICALS OF POTENTIAL CONCERN AT McCLELLAN AFB OU B

Chemicals	CAS Number
Carbon Tetrachloride	56-23-5
Chloroform	67-66-3
Dichloroethane, 1,2-	107-06-2
Dichloroethene, 1,1-	75-35-4
Dichloroethene, 1,2-	156-60-5
Methylene Chloride	75-09-2
Tetrachloroethane, 1,1,2,2-	79-34-5
Tetrachloroethene	127-18-4
Trichloroethane, 1,1,1-	71-55-6
Trichloroethane, 1,1,2-	79-00-5
Trichloroethene	79-01-6
Boron	7440-42-8
Vanadium	7440-62-2
Zinc	7440-66-6

3.0 EXPOSURE ASSESSMENT

Exposure assesment is the determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, and route of human exposures to the chemicals of potential concern that are present at or migrating from the site. The scope of this assessment is limited to the transport of compounds in the groundwater beneath and downgradient from the site to points at which human exposure can occur. It does not consider pathways of exposure that do not originate from chemicals in the groundwater (e.g., direct contact with contaminated soil or waste, volatilization of chemicals to the ambient air from a waste source).

The subsections which follow briefly discuss the exposure setting (Section 3.1), the exposure pathways (Section 3.2), modeling of groundwater flow (Section 3.3), quantification of exposure (Section 3.4), and the uncertainties associated with the estimates of exposure (Section 3.5). A summary of the exposure assessment is provided in Section 3.6.

3.1 Characterization of Exposure Setting

In this section, the site is characterized with respect to its physical characteristics, as well as, those of the human populations on or near the site.

3.1.1 Physical Setting

A brief description of the physiography, geology, hydrology, meteorology, and biota in the vicinity of McClellan AFB follows. Appendix D contains additional information on the physical setting of OU B.

Physiography

McClellan AFB is located in the northern part of the Great Valley Physiographic Province in the Sacramento Valley. Specifically, it is situated on the east side of the Victor Plain, an alluvial plain which lies along the eastern side of the Sacramento Valley. (CDWR, 1974 and 1978) The land surface at McClellan AFB slopes gently to the west. Elevations range from 75 feet above mean sea level (msl) on the east side to 50 feet msl on the west. The topographic relief is very low.

Geology and Soils

The upper surface of the Victor Plain, in most places, represents the upper surface of the Victor Formation, one of four units overlying the volcanoclastic Mehrten Formation. The four units are the Victor Formation, Arroyo Seco Gravels, and the Laguna and Fair Oaks formations. Three of these units, the Victor Formation, the Laguna Formation, and the Fair Oaks Formation, are present in the shallow subsurface at McClellan AFB.

The Victor Formation is underlain by the Fair Oaks Formation. The sedimentary deposits of the Fair Oaks Formation consist primarily of poorly bedded sand, silt, and clay, with less common gravel lenses. This formation is characterized by beds of volcanic tuff up to one foot thick which have been altered to white clay. The Fair Oaks Formation dips to the west at approximately 15 feet per mile ranging in thickness from 0 to 400 feet; in the vicinity of McClellan AFB it is thought to be approximately 100 feet thick.

The Fair Oaks Formation interfingers with the contemporaneous Laguna Formation in the vicinity of McClellan AFB. The Laguna Formation is predominantly fine-grained, poorly bedded, and moderately compacted. The formation is heterogeneous, with irregular accumulations of silt, sand, clay, and lenticular gravel beds. The most common deposits are light-gray to yellowbrown clayey silt, to silty, fine-grained sand. Clean, well-sorted sand occurs chiefly in relatively thin, laterally extensive beds. Gravel beds are scarce, poorly sorted, and of relatively low hydraulic conductivity. The sands have been eroded from granitic rock and contain abundant weathered feldspars, mica, and quartz grains. Mica particles are locally abundant and serve as a distinguishing characteristic for most of the formation. In the vicinity of McClellan AFB the formation is about 125 to 200 feet thick (CDWR, 1974). The sediments of the Laguna and Fair Oaks formations are very similar in the vicinity of McClellan AFB. The presence of the white clay layers in the Fair Oaks Formation is the primary characteristic distinguishing it from the Laguna Formation in this area.

The Mehrten Formation underlies the Fair Oaks and Laguna formations. The Mehrten Formation consists of an upper unit of gray to black sand interbedded with blue to brown clay and a lower unit of hard, gray volcanic tuff breccia. The Mehrten Formation may reach thicknesses up to 1,200 feet in the Sacramento Valley (CDWR, 1974), however, its thickness beneath McClellan AFB has not been determined.

Soils in the vicinity of McClellan AFB are extremely variable. Soil permeabilities range from 0.6 to 2.0 inches per year depending on local amounts of clay and hardpan. The local soils are generally classified as San Joaquin fine sandy loam, Fiddyment fine, sand loam, or San Joaquin-Xeralfic Arents complex. These soils have a low shrink-swell potential, a slight erosion potential, and a very low available water capacity of approximately 0.10 to 0.14 inches per inch.

Groundwater

Groundwater in the vicinity of the base occurs in multiple zones, distinguished by depth, and under both unconfined and confined conditions. Aquifer zone characteristics and background water quality are discussed in the following subsections.

Groundwater Hydrology

The groundwater system in the vicinity of McClellan AFB has been divided into two zones: an upper zone composed of the Fair Oaks, Laguna, and Victor formations and a lower zone composed of the Mehrten and underlying waterbearing formations (CDWR, 1974). The two zones are separated by a buried erosional surface of moderate to high relief.

In the vicinity of the base, groundwater occurs primarily in the Fair Oaks, Laguna, and Mehrten formations. Most groundwater production wells in the area are screened in the Mehrten Formation (Engineering-Science, 1983). Groundwater recharge in the eastern portion of the Sacramento Valley occurs as a result of leakage from streams and rivers, percolation of precipitation and irrigation water through soils, and migration of runoff along fracture zones and formation contacts in the foothills of the Sierra Nevada. The upper waterbearing zone in the Sacramento Valley is recharged predominantly through percolation of water from the ground surface. This process is generally inhibited by the presence of hardpan throughout much of the valley. Therefore, groundwater recharge to the upper zone occurs predominantly through past and present stream channels consisting of permeable sands and gravel which allow percolation of surface waters into the saturated zone. According to the CDWR (1974), the permeable buried stream channels interlayed with less permeable sediments has resulted in a network of tabular, shallow aquifers throughout the county. Hardpan locally restricts downward migration of water to the deeper aquifers.

Groundwater discharge in the Sacramento Valley occurs predominantly through pumping. Since the turn of the century, the extraction of groundwater for irrigation, industrial, municipal, and domestic uses has substantially altered the groundwater levels and gradients. The regional groundwater flow direction in the vicinity of Sacramento is southerly toward a pumping trough south of Sacramento.

Where saturated, the Victor Formation has only moderate hydraulic conductivity and generally yields little water to wells unless stream channel deposits are penetrated. The Fair Oaks and Laguna formations have generally low to moderate hydraulic conductivity except where coarse-grained channel deposits are present. In the more permeable materials, well yields may reach 3,500 gallons per minute (gpm) with drawdowns of approximately 30 feet, yielding a specific capacity of about 120 gpm per foot (gpm/ft) of drawdown (CDWR, 1974). The black sands of the Mehrten Formation generally have a specific capacity of approximately 45 gpm/ft. Specific capacities as high as 100 gpm/ft, however, have been noted in the Mehrten Formation (CDWR, 1974). Table D-1 (see Appendix D) summarizes the hydraulic characteristics of the Victor, Fair Oaks, Laguna, and Mehrten formations.

The water table in the region surrounding McClellan AFB is typically 90 to 110 feet below the ground surface. Variations in the depth to water depend predominantly on local topography and locations of cones of depression from high-capacity extraction wells.

Deeper waterbearing zones are semiconfined to confined and are believed to be locally interconnected with the unconfined zone due to the absence of continuous confining layers. Lateral discontinuity and facies changes within confining layers allow for local vertical groundwater movement between the various waterbearing zones.

The water table in the vicinity of McClellan AFB fluctuates as much as two feet per year. The annual mean water level is declining as a result of groundwater extraction for private, public, industrial, and domestic purposes. The water table declined by 0.9 to 1.7 feet each year between 1955 and 1985 (Radian, 1986). Groundwater levels are expected to continue declining in future years due to overdrafting of the local groundwater aquifers.

Extensive groundwater pumping near McClellan AFB has also altered the flow direction of the local groundwater system. In 1955, groundwater flow was generally to the southwest toward a pumping depression located southwest of the base. By 1965,

this depression had deepened and a second pumping depression developed directly south of the base due to the operation of production wells located near the McClellan AFB boundary. As a result, flow directions were altered as groundwater on-base began to flow to the south and groundwater west of the base began to flow in an east and south-east direction in the late 1950s or early 1960s (Radian, 1986).

Groundwater Quality

Natural groundwater quality in the area of McClellan AFB is excellent for irrigation and domestic use. The groundwater is characterized as a calcium-sodium bicarbonate type. In Sacramento County, the fresh groundwater zone ranges in thickness from several hundred feet near the eastern portion of the county, to an estimated 2,000 feet near the Sacramento River. The fresh water zone at McClellan AFB is approximately 1,385 feet thick (CH2M Hill, 1981).

Surface Water

Surface water in the Sacramento Valley originates in the Cascade Range and Sierra Nevada to the north and east and from the east side of the Coast Ranges to the west. The Sacramento and American rivers are the major drainages in the vicinity of McClellan AFB (Figure 3-1). The drainage patterns of these rivers are described in Appendix D.

Surface water drainage in the vicinity of McClellan AFB occurs predominantly through Magpie, Don Julio, Rio Linda, and Arcade creeks, shown in Figure 3-2. Magpie Creek enters the base from the east and is joined by several small tributaries before leaving the base to the west. On-base drainages have been modified by construction of a series of storm drains and channels across the base. Runoff from streets and runways is directed into the storm drainage system and exits the base via Magpie Creek. Old channels occupied by Magpie Creek before construction of the storm drainage system are presented in Figure 3-2.

Rio Linda Creek crosses the northern portion of the base. Magpie Creek crosses the southeast and central portions. Arcade Creek is located just south of base property. All three of these drainages flow into the Natomas East Drainage Canal west of the base. The canal flows south and west until it discharges into the American River, just east of the confluence of the American and Sacramento rivers.

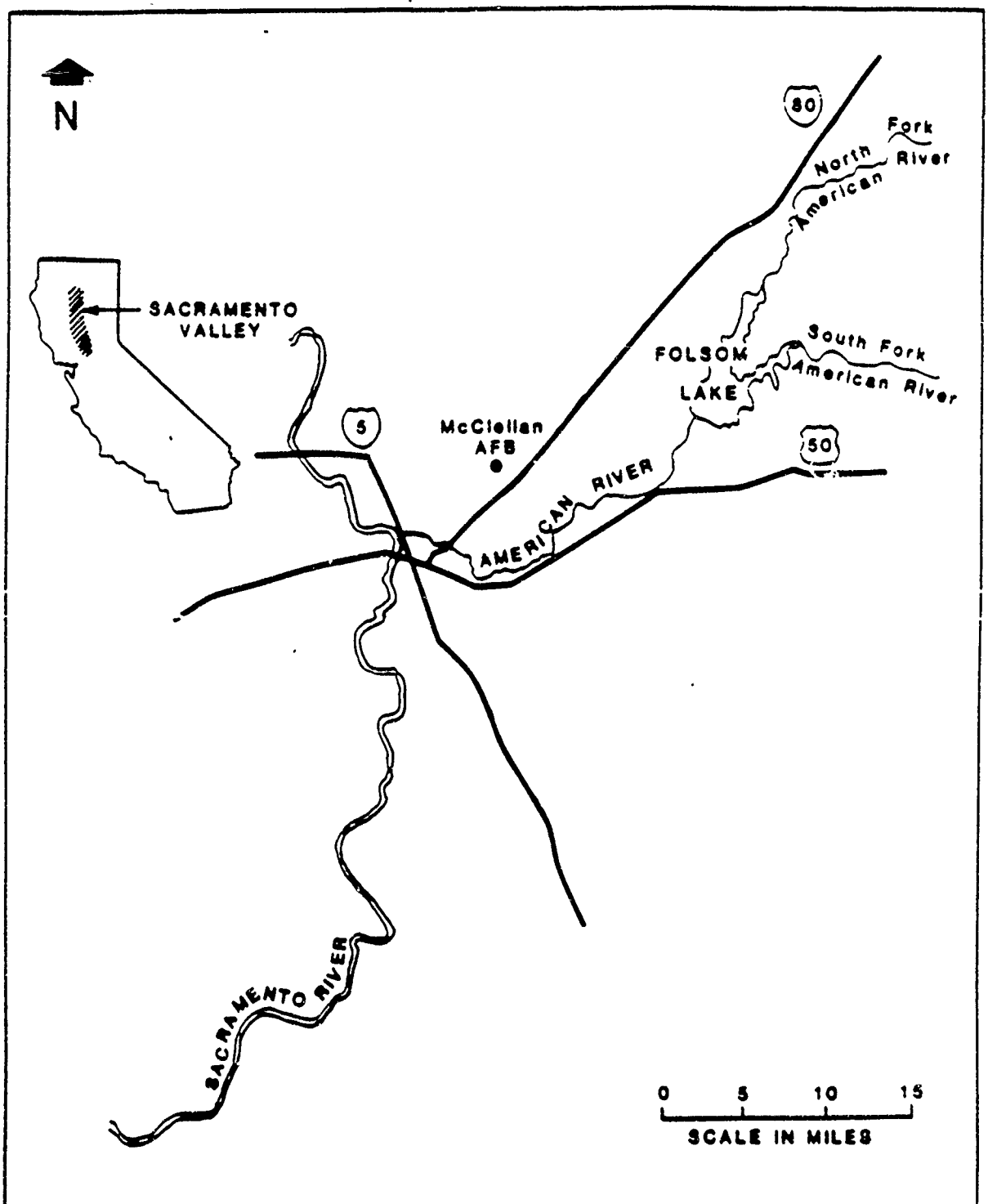

Figure 3-1. Bureau Water Drainage in the Sacramento Valley

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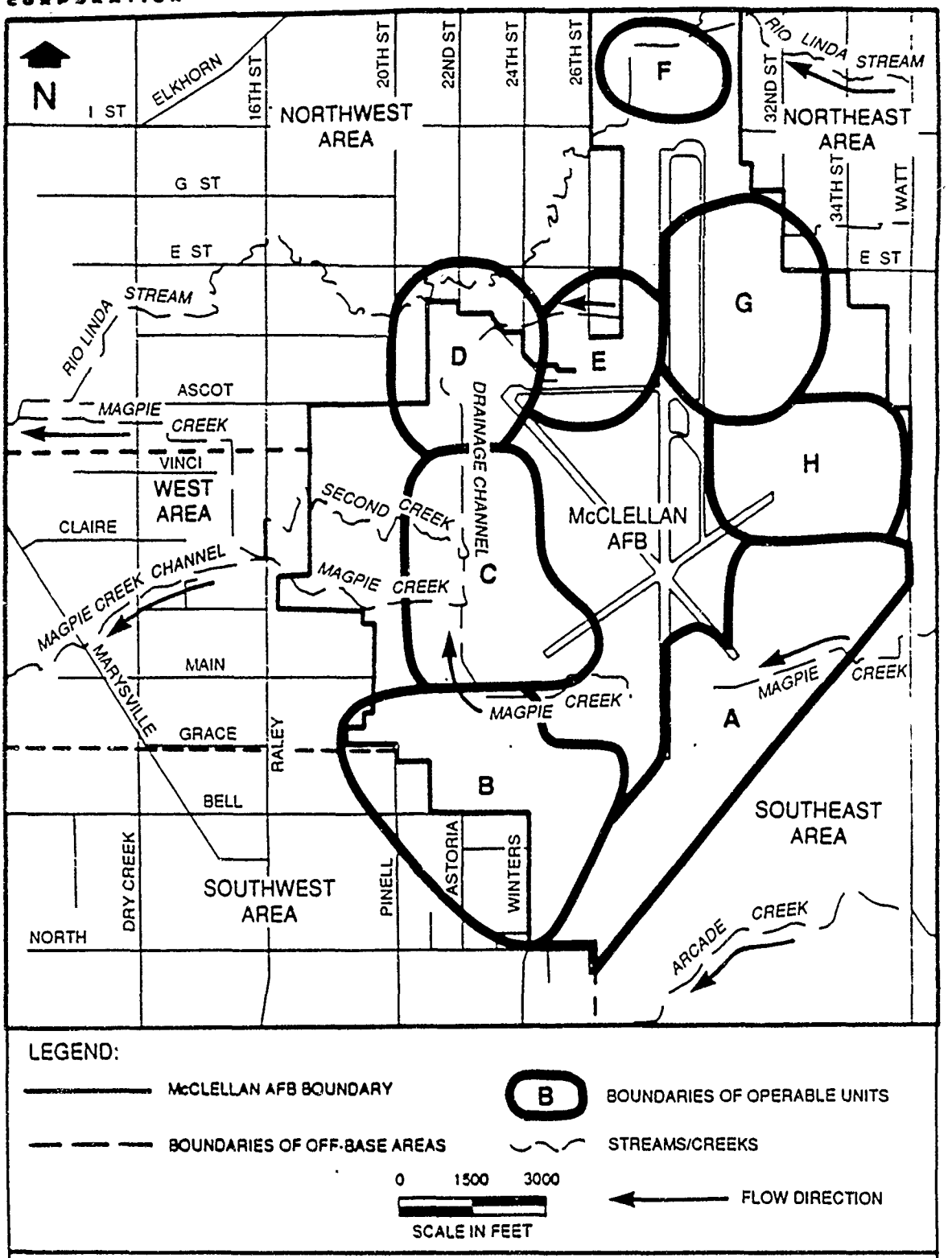


Figure 3-2. Old Channels Occupied by Magpie Creek Before Construction of the Storm Drainage System

Meteorology

McClellan AFB and the surrounding Sacramento Valley have a Mediterranean-Subtropical type of climate characterized by hot, dry summers and cool, moist winters. Average temperatures of the area range from the mid-40s during winter months to the mid-70s during the summer, with an average annual temperature of approximately 60°F.

Most of the precipitation falls during winter and spring months, with over one-half of the total annual rainfall occurring during December, January, and February. Of an average annual rainfall of approximately 19 inches, 17 inches are usually recorded for November through April and two inches for May through October. Snowfall is rare. The mean annual evapotranspiration rate for the Sacramento area is approximately 45 inches/year. The net precipitation for the area (mean annual precipitation minus mean annual evapotranspiration) is approximately -26 inches per year.

Biota

Grasslands are the predominant plant community at the base and most of the surrounding undeveloped region. Small riparian forests and vernal pools also occur within the general area.

A field survey of fauna present at McClellan AFB was conducted during April of 1981 (CH2M Hill, 1981). During the survey, one fish, one amphibian, one reptile, two mammal, and 24 bird species were sighted. The blacktail hare was the largest mammal permanently residing on base. Muskrats were also observed at a number of locations along Magpie Creek. Game bird species, such as pheasant, mourning dove, and California quail were common on the base. Mallards were observed in Magpie Creek.

The vertebrate fauna of Magpie Creek are limited primarily to mosquitofish, waterfowl, muskrats, and amphibians. A study done in 1973 (Pauls and Doane) documented the macroinvertebrate fauna of the creek. Species density and diversity were limited in the portions of the creek lined with concrete where little natural substrate was available. Sludge worms (Tubiflex) were the only species found upstream of McClellan AFB where the San Six Wastewater Treatment Plant provides most of the flow. Further downstream, damselfly (Ischnura), Psychoda fly, and mosquito larvae were prevalent.

Only two endangered plant species are known to occur within Sacramento County, the Sacramento orcutt grass (Orcuttia viscida), which occurs in the vicinity of Phoenix Field and Boggs Lake hedge hyssop (Gratiola heterosepala), which is found in the vicinity of Rio Linda (CH2M Hill, 1981).

Only three endangered wildlife species are expected to occur within 25 miles of the base: the bald eagle, the peregrine falcon, and the giant garter snake. The nearest eagle nest sites are near Lake Pillsbury (Mendocino County) and in the vicinity of Chico (Butte County) (CH2M Hill, 1981). However, juvenile or non-breeding eagles occasionally pass through the Sacramento area. Peregrine falcons regularly migrate through Sacramento County and it is possible that some may reside in the area. The giant garter snake is confined to sloughs, marshes, and other permanent freshwater areas. The nearest known location of the giant garter snake is in rivers and associated wetlands south of Sacramento.

Most of the undeveloped grassland areas on the base have been disturbed in the past. Much of the Magpie Creek has been cleared of former riparian vegetation and channelized. Some of the vernal pool areas of the creek have been drained or filled. Most of these actions took place years ago, however, and vegetation growing on the unimproved areas of the base is generally healthy, vigorous, and supporting the appropriate fauna.

In addition to its physical modification, Magpie Creek has been affected by the effluent from the San Six County Wastewater Treatment Plant located north of the base. In 1977, a fish kill of 100 to 150 minnows in Magpie Creek was traced to high chlorine residuals originating from the treatment plant. This problem has since been corrected.

The historical use of persistent, and later non-persistent, pesticides for mosquito control on-base affected the natural invertebrate fauna of Magpie Creek and the vernal pools. However, this impact is considered minor as CH2M Hill found no evident stress on biota due to the use and disposal of waste pesticides at McClellan AFB.

3.1.2 Potentially Exposed Populations

McClellan AFB is surrounded by three communities, each of which contains residential, commercial, and industrial zones. The communities surrounding

McClellan AFB (Figure 3-3) include Rio Linda and Elverta to the northwest, North Sacramento to the west and southwest, and North Highlands to the east. All of these communities are in Sacramento County. Rio Linda and North Highlands are unincorporated.

The population of the surrounding communities as determined by the 1980 census is 107,822. A summary of population by community and tract number, as well as projected populations in the year 2005, is presented in Table 3-1. The tract areas presented in this table are shown in Figure 3-3.

The total number of military personnel assigned to McClellan AFB is approximately 3500. There are 105 family housing units (42 are 2-bedroom units and 63 are 3-bedroom units) and 719 dorm spaces located on-base. McClellan AFB employs approximately 13,500 civilian workers.

Land Use

The current and future land use in the vicinity of McClellan AFB is discussed in the following subsections.

Current Land Use

Land use in the vicinity of McClellan AFB (presented in Figure 3-4) consists of a combination of military, industrial, commercial, residential, and agricultural zones.

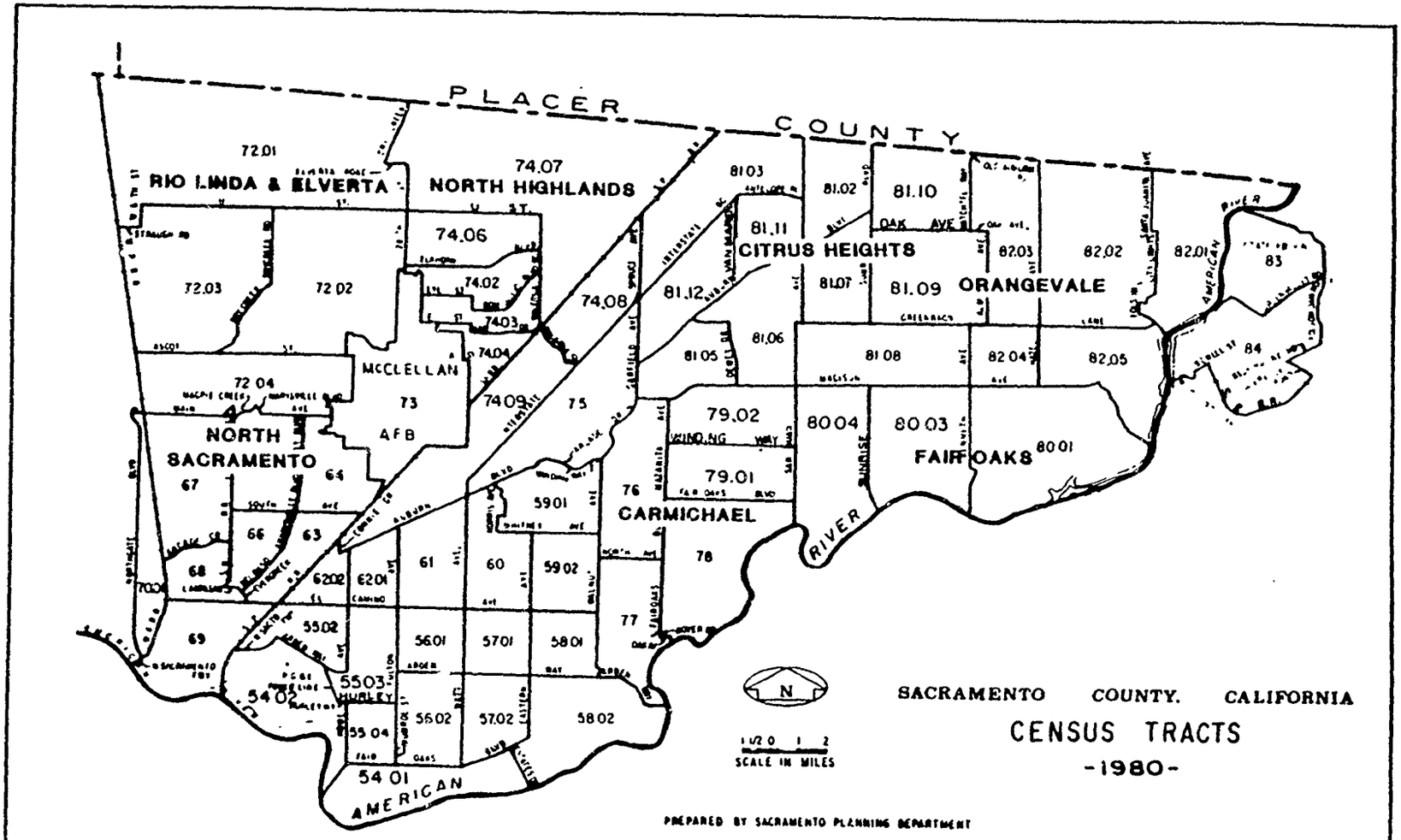
Much of the land use around the base is residential. In the Rio Linda area northwest of the base, most of the land is categorized as agricultural-residential. This land category identifies areas which are reserved for large lot rural residential uses where animals may be kept and crops raised for recreational, educational, personal consumption or income supplement purposes (Sacramento County, 1985). Many of these residences use private well water for nonpotable uses.

Several Rio Linda lots directly adjacent to the base have been zoned as industrial-intensive. This land category identifies areas reserved for research, manufacturing, processing, and warehousing activities. Necessary public services, such as sewer and water systems, are available in industrial intensive areas.

TABLE 3-1. POPULATION DATA AND PROJECTIONS FOR THE COMMUNITIES SURROUNDING McCLELLAN AFB

Tract Community	1980 Census Number	1980 Population	Projected 2005 Population
Rio Linda and Elverta	72.01	3,689	
	72.02	3,547	
	72.03	6,737	
	TOTAL	13,973	26,529
North Highlands	73.00	1,541	
	74.02	6,207	
	74.03	4,451	
	74.04	3,511	
	74.06	7,044	
	74.07	7,959	
	74.08	9,819	
	74.09	7,262	
	75.00	11,010	
	TOTAL	58,804	118,861
North Sacramento	72.04	1,613	
	63.00	3,578	
	64.00	4,514	
	65.00	3,406	
	66.00	4,621	
	67.00	7,365	
	68.00	5,644	
	69.00	4,304	
	TOTAL	35,045	52,682

SOURCE: Sacramento County, 1985



SOURCE: Sacramento County, 1986.

Figure 3-3. Urban Area Surrounding McClellan Air Force Base (Numbered and Outlined Areas are Census Tracts)

RADIAN CORPORATION

Most of the land use to the southwest and east of the base consists of low density residential zones. These areas are reserved for a planned population density range of 5 to 30 persons per acre or a housing density range of 1 to 12 dwelling units per acre. While some of these residences may have private wells, the majority have municipal water supplies. Investigations in the area of OU B, however, have shown that there are currently no private wells in use for either drinking water or for irrigation.

To the southwest and east of McClellan AFB are parcels designated for commercial and office use which includes shopping centers, large office complexes, and major concentrations of strip commercial development.

Del Paso Park, designated as a recreational area, is located within one mile of the southeast edge of the base. Additional recreational/agricultural-recreational reserve areas are located along Dry Creek, approximately two miles west of the base.

Potential Alternative Future Land Uses

Potential future land uses include development of land currently zoned industrial-intensive adjacent to the base to the north into research, manufacturing, processing and/or warehousing operations. Parcels designated for commerical and office use to the west and east of the base will potentially develop into shopping centers and large office complexes. Low density residential zones to the southwest and east of the base will probably develop to a higher density.

Community Water Resources

The communities in the vicinity of McClellan AFB receive water from private wells and municipal water supplies. North Sacramento receives water from the City of Sacramento Water Department. Many private wells are still in use in the area north of El Camino Avenue in North Sacramento.

In 1986, the Rio Linda Water District and the City of Sacramento Water Department began connecting Rio Linda, Elverta, and North Sacramento residences in adjacent areas to the west of the base to municipal water supplies. The residents in this area previously used private wells for their water needs. The connection of the residences to municipal water supplies was a remedial action initiated by McClellan AFB.

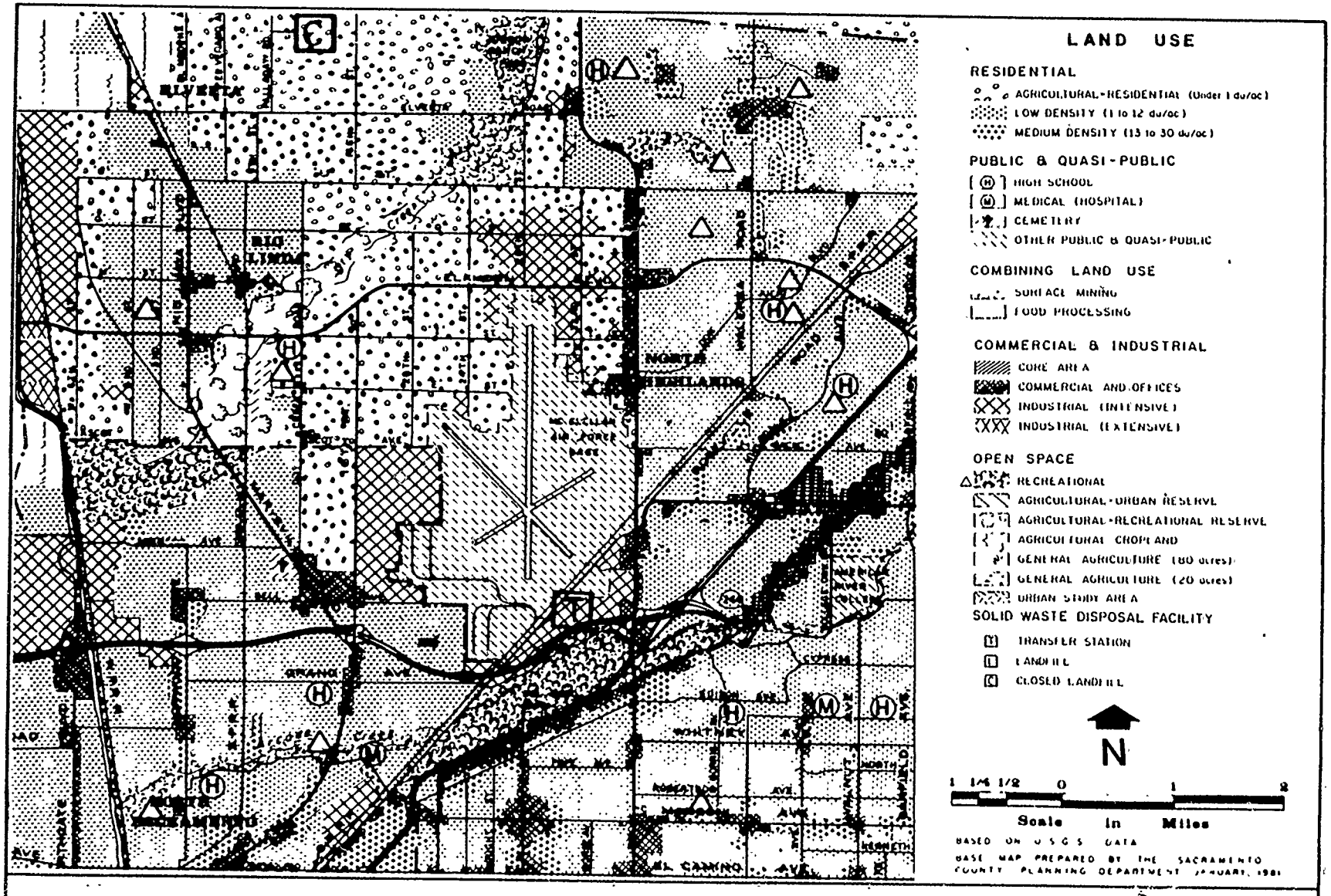


Figure 3-4. Land Use Map of the Vicinity McClellan Air Force Base

On-base residents receive water from the McClellan AFB water supply system, which draws from wells located on the base.

Subpopulations of Potential Concern

Potentially sensitive members of the population with respect to exposure to chemicals originating at the site include those with pre-existing conditions which may be aggravated by exposure to the chemicals of concern, the very young, the unborn fetus, hypersensitive individuals, the ill, and the infirm elderly. Locations at which the more sensitive members of the population might congregate include hospitals, retirement/ nursing homes, schools, nurseries, and day care centers.

3.2 Identification of Exposure Pathways

An exposure pathway describes the movement or translocation of a chemical or physical agent from the source to the exposed individual. An exposure pathway generally consists of:

- A source and mechanism of chemical release;
- A retention or transport medium (or media in cases involving multimedia transfer of chemicals);
- A point of potential human contact with the contaminated medium; and
- An exposure route (e.g., ingestion).

The subsections which follow provide information on contaminant sources and receiving media at the site, the fate and transport of chemicals of concern, and exposure points and exposure routes.

3.2.1 Sources and Receiving Media

Results of chemical analyses of groundwater samples collected during the EE/CA-EA investigation show that contaminants are present in the groundwater to depths of 360 feet below surface beneath OU B. Section 2.3 summarizes the analytical data characterizing groundwater contamination at the site. It identifies the chemicals detected in the groundwater above detection limits and discusses the selection of contaminants of potential concern. For the purposes of this risk assessment, the source of

contamination is groundwater containing the following dissolved organic compounds and inorganic species:

- Carbon tetrachloride;
- Chloroform;
- 1,2-Dichloroethane;
- 1,1-Dichloroethene;
- 1,2-Dichloroethene;
- Methylene chloride;
- 1,1,2,2-Tetrachloroethane;
- Tetrachloroethene;
- 1,1,1-Trichloroethane;
- 1,1,2-Trichloroethane;
- Trichloroethene;
- Boron;
- Vanadium; and
- Zinc.

The original release sources (e.g., contaminated soil, surface or buried waste, spills or leaks) which contributed contaminants to the groundwater via site leaching are considered only indirectly in this assessment.

3.2.2 Fate and Transport in Release Media

Potentially significant contaminant transport and fate mechanisms in the groundwater medium include: 1) groundwater migration; 2) discharge to the surface and transport in surface water; 3) uptake by plants and animals; and 4) volatilization to the atmosphere.

Groundwater Migration

The regional groundwater flow direction in the vicinity of Sacramento is southerly toward a pumping trough south of Sacramento. As described in Section 3.1, extensive pumping near McClellan AFB has altered the flow direction of the local groundwater system. Due to the operation of production wells located near the base boundary, groundwater on-base which originally flowed to the southwest now flows to the south. Groundwater to the west of McClellan AFB flows in an easterly and southeasterly direction.

Analysis of groundwater samples from monitoring wells on and off the base indicates that the contaminant plumes are moving in a southerly direction and have crossed the base boundary to the southwest. The closest off-base production wells (City Wells 150 and 132) are located downgradient of McClellan AFB and are within 1500 feet of the southwest base boundary. Neither well is currently operating. No agricultural wells are in operation in a downgradient direction in the vicinity of the base.

Discharge to the Surface and Transport in Surface Water

Surface waters do not receive baseflow from groundwater and therefore are not at risk of contamination from this source. Streams and rivers in the eastern portion of the Sacramento Valley, where the base is located, provide recharge to the groundwater. Groundwater discharge in the Sacramento Valley occurs predominantly through pumping.

Uptake by Biota

The groundwater is sufficiently below the ground surface that direct uptake of contaminated groundwater by plants and animals is not likely. The water table in the region surrounding the base is typically 90 to 110 feet below the ground surface.

Since the groundwater does not discharge to the surface, fish and other biota in contact with the surface water in the vicinity of the base are not at risk of contamination from chemicals in the groundwater beneath OU B. Likewise, since there are no agricultural wells in operation downgradient from OU B, there is little potential for use of contaminated groundwater to irrigate commercially grown crops or as stock water.

Groundwater drawn to the surface by municipal wells can be used to irrigate home gardens. However, 11 of the 14 chemicals of concern are volatile and will tend to evaporate from the soil surface before significant plant uptake can occur.

Investigations in the area of OU B have shown that there are currently no domestic wells in use either for drinking water or for irrigation puposes.

Volatilization to the Atmosphere

The groundwater plume is sufficiently below the ground surface that volatilization of volatile chemicals to the soil pores and eventually to the atmosphere is not considered a significant transport and fate mechanism. When the groundwater is drawn to the surface, however, the volatile chemicals of concern can volatilize to the air during home use of the water. Activities involving the use of heated water (e.g., showering, washing clothes and dishes) will increase the tendency of volatile chemicals to volatilize.

3.2.3 Exposure Points and Exposure Routes

The primary point at which human exposure to contaminants detected beneath OU B may occur is at the tap in homes and workplaces on-base and off-base that are serviced by water drawn from wells in the path of the migrating contaminant plumes. Use of the water by residents can lead to exposure via ingestion of the water, skin contact with the water, and inhalation of vapors released from the water as it leaves the tap. Use of the water by workers can lead to exposure by the same routes; however, skin contact and inhalation of vapors are less significant for workers. Activity patterns of on-base civilian workers and off-base office and industrial workers do not typically include showering, washing dishes, and washing clothes. These primarily domestic activities involve the greatest potential for skin contact with the water and the release of vapors which can be inhaled.

Probable future land uses in the vicinity of the base -- increased industrial/commercial development and increased density of residential housing will not alter these exposure points and exposure routes unless the source of potable water distributed to on-base and off-base residences and workplaces changes. The size of the potentially exposed population off-base will increase, however.

3.2.4 Exposure Pathways

Figure 3-5 depicts potential pathways for contaminants originating in the groundwater at the site to move from point of release to point of human exposure. Pathways which are not complete have been crossed out; footnotes summarize the rationale for considering the pathway incomplete. Pathways which are complete but

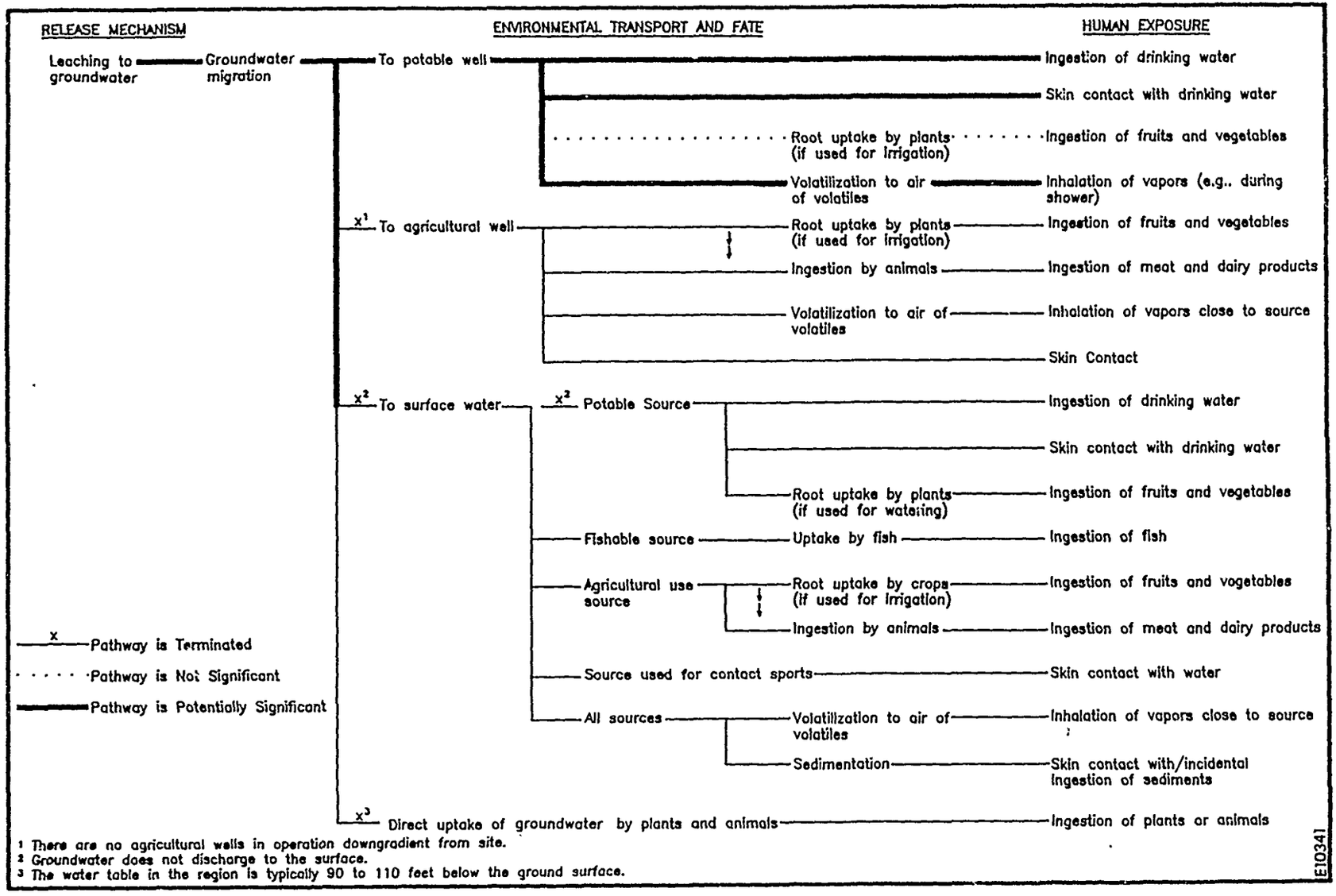


Figure 3-5. Potential Groundwater Migration Pathways and Receptors

judged insignificant are also indicated with a dashed line. Complete pathways that exist at the site include:

- Groundwater migration to potable well; ingestion of drinking water;
- Groundwater migration to potable well; skin contact with water while showering;
- Groundwater migration to potable well; volatilization of volatiles during home use; inhalation of vapors (e.g., while showering, washing clothes, and washing dishes); and
- Groundwater migration to potable well; use of water to irrigate backyard garden; root uptake by plants; ingestion of fruits and vegetables.

Of these pathways, the first three are considered potentially significant. The significance of the fourth pathway is low by comparison because most of the chemicals of concern are volatile and will tend to volatilize from the soil surface before significant plant uptake can occur. The exposure resulting from ingesting plants grown in a backyard garden which is watered with tap water is much less than that from drinking the water.

Populations which use the groundwater from areas potentially impacted by the contaminant plume as potable water include both on-base residents and workers and residents and workers in the surrounding community. Exposures to contaminants in the groundwater can occur over long periods of time for these populations, although the typical tour of duty for military personnel at the base is three years.

The base maintains a monitoring and treatment system to detect and remove organic contaminants from groundwater drawn from the on-base production well (BW-18). The potential exposure for on-base residents and workers therefore includes both:

- Chronic (long-term) exposure to contaminants in the groundwater at post-treatment concentrations (assumed to be below the monitoring program detection limits); and

- Subchronic (two-week to seven year) exposure to contaminants in the groundwater at pre-treatment concentrations (assuming that the treatment system fails for a period of time). Off-base residents and workers are not subject to subchronic exposures which are higher than chronic exposures.

Table 3-2 summarizes the pertinent information on all complete exposure pathways at the site. It identifies the potentially exposed populations, exposure media, exposure points, and exposure routes. It also notes if the pathway has been selected for quantitative evaluation and summarizes the justification for including or excluding each pathway in the analysis.

It should be emphasized that water distributed to on-base residents and workplaces is treated to remove organic constituents. Off-base, the closest municipal production wells have been taken out of operation. The contaminant plume has not yet migrated to other area production wells.

3.2.5 Summary of Exposure Pathways to be Quantified

Table 3-3 outlines the exposure scenarios that are evaluated in this assessment. Chronic exposure is evaluated for four scenarios:

1. On-base Residential/Lifetime

   - child
   - adult;

2. On-base Residential/3-Year Tour of Duty

   - child
   - adult;

3. On-base Worker (adult only); and

4. Off-base Residential

   - child
   - adult.

TABLE 3-2. COMPLETE EXPOSURE PATHWAYS AT THE SITE[a]

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected for Evaluation	Reason for Selection or Exclusion
Current Land Use			
Residents • On-Base • Off-Base	Ingestion of groundwater from wells downgradient from areas of known contamination.	Yes	Base and city drinking water systems draw groundwater from local wells.
Residents • On-Base • Off-Base	Dermal contact with chemicals in groundwater during home use.	Yes	Groundwater is used for bathing/showering by residents.
Residents • On-Base • Off-Base	Inhalation of chemicals volatilized from groundwater during home use.	Yes	Most of the chemicals of potential concern in the groundwater are volatile.
Residents • On-Base • Off-Base	Ingestion of fruits and vegetables grown in a home garden and watered with groundwater.	No	The potential for significant exposure via this pathway is low because most of the chemicals of concern are volatile and will tend to volatilize from the soil surface before significant plant uptake can occur.
On-Base Workers	Ingestion of groundwater while at work.	Yes	On-base work environments use water from the base drinking water distribution system.

(Continued)

TABLE 3-2. CONTINUED

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected for Evaluation	Reason for Selection or Exclusion
Future Land Use			
On- and off-base residents and on-base workers	Same as above for current land use.	-	Current land use represents worst-case exposure to chemicals in ground water.

[a]This risk assessment was limited in scope to an evaluation of the groundwater pathway.

TABLE 3-3. EXPOSURE SCENARIOS

Description	Brief Rationale
Chronic Exposure	
On-Base Residential/Lifetime • Child • Adult	The base houses a residential community for military personnel and families. The base water system draws from the groundwater at the site.
On-Base Residential/3-Year Tour of Duty • Child • Adult	Three years is the typical tour of duty for military personnel. It is unlikely that any one person will reside on-base for a lifetime.
On-Base Worker (Adult)	Civilian personnel work on base, but reside off base.
Off-Base Residential • Child • Adult	The city water system draws from the groundwater downgradient from the base.
Subchronic Exposure	
On-Base Residential (Applicable to Both Lifetime and 3-Year Tour of Duty Scenarios) • Child • Adult	The base monitoring and treatment system could fail, allowing untreated groundwater to be distributed to residences and work stations for a period of time before the failure is detected and corrected.
On-Base Worker (Adult)	Same as above.

The "On-base Residential/Lifetime" scenario assumes that families with children live on-base for a period of time corresponding to national statistics on time spent at one residence. This scenario is not realistic for military families residing on-base. It is included only to provide a worst-case analysis using standard residential exposure assumptions. The "On-base Residential/3-Year Tour of Duty" scenario better represents the typical military family residing on-base. It assumes a residence time of three years, corresponding to the typical duration of a tour of duty for military personnel.

The "On-base Worker" scenario represents civilian personnel working on- base, but residing off-base. A typical working lifetime of 30 years for an adult worker is assumed.

The "Off-base Residential" scenario represents families with children living off-base in an area serviced by water drawn from CW-132. Although CW-132 is not currently in service, it was selected to represent worst-case conditions due to its location downgradient and close proximity to the base. Risks associated with exposure to water drawn from other wells in the vicinity are likely to be lower than estimated risks associated with exposure to water drawn from CW-132.

Subchronic exposure is evaluated for two scenarios:

1. On-base Residential (applicable to both lifetime and 3-year tour of duty scenarios)

    - child
    - adult; and

2. On-base Worker (adult).

Both scenarios represent the short-term exposure associated with a theoretical failure of the base water treatment system. A subchronic exposure evaluation is not necessary for off-base consumers of the groundwater, since no pretreatment of the water to remove organics prior to distribution is assumed.

The following section (Section 3.3) summarizes the groundwater flow model used to estimate concentrations of contaminants of concern in the water at the tap for on-base and off-base scenarios. The model predicts concentrations at the wellheads of

BW-18 (for on-base scenarios) and CW-132 (for off-base scenarios). The exposure assumptions and intake algorithms used to quantify exposure for each of the exposure scenarios are specified in Section 3.4.

3.3 Flow Model

Analytical groundwater flow models were used to develop flow nets for individual geohydrologic zones in OU B in the vicinity of BW-18 and CW-132. The purpose of the models was to estimate concentrations of groundwater contaminants that could reach supply wells. The modeling approach was to develop solutions to the two-dimensional Laplace equation for steady flow to a fully penetrating well discharging from a homogeneous, isotropic aquifer of infinite areal extent.

Solutions to the Laplace equation were applied to the individual geohydrologic zones A, B, C, and D in order to construct flow nets for each of the zones. The flow nets were used in conjunction with contaminant concentration isopleths to calculate, by a flow weighted averaging technique, expected contaminant concentrations at the BW-18 and CW-132 wellheads. The concentration isopleths were derived from January, 1990, data. These calculations produce steady-state wellhead concentrations of individual contaminants, in which the January, 1990, concentration distributions in OU B are assumed to be time invariant. Thus, the modeling procedure generates the expected, long-term concentration of different contaminants at BW-18 and CW-132 from a contamination distribution that is taken to be fixed at its January, 1990, condition.

Results of these calculations are presented as Table 3-4. In the case of BW-18, an expected concentration and a maximum probable concentration is given for each contaminant. The dual concentration values were calculated because there was uncertainty about the pattern of groundwater flow in the D geohydrologic zone which contributed to uncertainty about the contaminant concentration of water produced from that zone. A complete description of the model, assumptions, calculation procedures, and results is presented in Appendix E.

3.4 Applicable or Relevant and Appropriate Requirements (ARARs)

Chemical-specific applicable or relevant and appropriate requirements (ARARs) are usually health- or risk-based numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged

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TABLE 3-4. ANALYTICAL MODELING RESULTS - PREDICTED CONCENTRATIONS OF INDICATOR COMPOUNDS AT BW-18 AND CW-132, OPERABLE UNIT B, MCCLELLAN AFB, CA

Indicator Compound	Wellhead Concentration (μg/L)		
	BW-18		CW-132
	Expected[1]	Maximum[2]	
Carbon Tetrachloride	0.09[3]	0.09[3]	0.01[3]
Chloroform	0.16	0.16	0.09
1,2-Dichloroethane	0.10	0.10	0.05
1,1-Dichloroethene	0.14[3]	0.14[3]	0.07[3]
1,2-Dichloroethene	6.70	15.67	2.55
Methylene Chloride	0.27	0.38	0.11
1,1,2,2-Tetrachloroethane	0.08[3]	0.16[3]	0.003[3]
Tetrachloroethene	0.81	0.81	2.63
1,1,1-Trichloroethane	0.14	0.19	0.05
1,1,2-Trichloroethane	0.10[3]	0.15[3]	0.001[3]
Trichloroethene	38.66	60.58	22.29
Boron	90	160	30
Vanadium	10	20	2
Zinc	10	10	10

[1]Values calculated using an averaged concentration in Geohydrologic Zone D.

[2]Values calculated using a maximum concentration in Geohydrologic Zone D.

[3]Values are based on isopleths drawn from unconfirmed data. If an unconfirmed compound was detected in both the original and the confirmation column, the original value was used. Because the data was suspect, the values were used for contouring only if they were found within known plumes (determined by VOC isopleths.)

to, the ambient environment. If a chemical has more than one such regulation that is ARAR, the most stringent generally should be used. At sites where some indicator chemicals do not have ARARs, a complete risk characterization process for all indicator chemicals must be performed. Table 3-5 presents a comparison of the Resource Conservation and Recovery Act (RCRA), Safe Drinking Water Act (SDWA), and Clean Water Act (CWA) chemical-specific requirements (EPA, 1988).

3.5 Quantification of Exposures

This section describes the methodology used to estimate the magnitude, frequency, and duration of exposures for the populations and exposure pathways selected for quantitative evaluation. For each exposure scenario, an average and a reasonable maximum exposure is estimated. Section 3.4.1 summarizes estimates of exposure concentrations. Section 3.4.2 describes exposure assumptions and algorithms used to calculate intake into the body.

3.5.1 Exposure Concentrations

Tables 3-6, 3-7, and 3-8 provide a summary of exposure concentrations for on-base chronic exposures, off-base chronic exposures, and on-base subchronic exposures, respectively. Each table specifies: 1) the estimated concentration at the tap used to quantify ingestion of and dermal contact with water; and 2) the estimated concentration in air used to quantify inhalation of chemicals volatilized from the tap water while showering, washing clothes, and washing dishes.

Concentrations in Tap Water

The exposure concentrations for water at the tap are based on the results of the groundwater flow modeling described in Section 3.3 without any allowance for dilution. It should be emphasized that the modeled concentrations are hypothetical concentrations for use in the exposure assessment and are not actually present in the supply wells.

For on-base chronic exposures, the exposure concentration is the lower of the modeled concentration at BW-18 or the analytical detection limits for individual chemicals. If the modeled concentration is lower than the detection limit, it is assumed that this concentration reaches the tap at residences and workplaces on-base. If the modeled

TABLE 3-5. SELECTED CHEMICAL-SPECIFIC POTENTIAL APPLICATION OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

Chemicals	Potential ARARs[a]						For Use in Special Circumstances
			CWA Water Quality Criteria for Protection of Human Health		CWA Ambient Water Quality Criteria for Protection of Aquatic Life[b]		
	RCRA Maximum Concentration Limits (mg/L)	SDWA Maximum Contaminant Levels (mg/L)	Water and Fish Ingestion (mg/L)	Fish Consumption Only (mg/L)	Freshwater Acute/Chronic (mg/L)	Marine Acute/Chronic (mg/L)	SDWA/MCL Goal (mg/L)[c]
Carbon Tetrachloride		5.0E-03	4.0E-04	6.9E-03	3.5E+01	5.0E+01	0.0E+00
Chloroform			1.9E-04	1.8E-02	2.8E+01*/1.2*		
Dichloroethane, 1,2-		5.0E-03	9.4E-04	2.4E-01	1.1E+02*/2.0E+01*	1.1E+02*	0.0E+00
Dichloroethene, 1,1-		7.0E-03	3.1E+00		1.1E+01*	2.2E+02*	7.0E-03
Dichloroethene, 1,2[d]			3.3E-05	1.9E-03	1.1E+01*	2.2E+02*	
Methylene chloride							
Tetrachloroethane, 1,1,2,2-			1.7E-04	1.1E-02	2.4*	9.0*	
Tetrachloroethene		5.0E-03[e]	8.0E-04	8.9E-03	5.2*/8.4E-1*	1.0E+1*/4.5E-1*	0.0E+00[e]
Trichloroethane, 1,1,1-		2.0E-01	1.8E+01	1.0E+03		3.1E+01*	2.0E-01
Trichloroethane, 1,1,2-		5.0E-03[f]	6.0E-04	4.2E-02	9.4*		3.0E-03[f]
Trichloroethene		5.0E-03	2.7E-03	8.1E-02	4.5E+01*/2.1E+01*	2.0*	0.0E-00
Boron							
Vanadium							
Zinc					1.3E-01/1.1E-01	9.6E-02/8.6E-02	

(continued)

TABLE 3-5. (Continued)

* Lowest Observed Effect Level
(a) When two or more values conflict, the lower value generally should be used.
(b) Federal water quality criteria (FWQC) are not legally enforceable standards, but are potentially relevant and appropriate to CERCLA actions.
(c) For water that is to be used for drinking, the MCLs set under the SDWA are generally the applicable or relevant and appropriate standard. A standard for drinking water more stringent than an MCL may be needed in special circumstances, such as where multiple contaminants in groundwater or multiple pathways of exposure present extraordinary risks. In setting a level more stringent than the MCL in such cases, a site-specific determination should be made by considering MCLGs, the Agency's policy on the use of appropriate risk ranges for carcinogens, levels of quantification, and other pertinent guidelines. Prior consultation with Headquarters is encouraged in such cases.
(d) Chemical-specific requirements for dichloroethylenes.
(e) Proposed, May 22, 1989.
(f) Proposed, July 25, 1990.

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TABLE 3-6. SUMMARY OF ON-BASE CHRONIC EXPOSURE CONCENTRATIONS

	Exposure Concentration							
			Inhalation of Chemicals Volatilized from Groundwater ($\mu g/m^3$)					
	Ingestion of and Dermal Contact with Groundwater[a] ($\mu g/L$)		Showering[b]		Washing Clothes[c]		Washing Dishes[c]	
	Average	Reasonable Maximum	Average	Reasonable Maximum	Average[d]	Reasonable Maximum[d]	Average[e]	Reasonable Maximum[e]
Carbon tetrachloride	0.09	0.09	1.9	3.5	0.1/0.052	0.1/0.052	0.02/0.013	0.02/0.013
Chloroform	0.16	0.16	3.3	6.3	0.18/0.092	0.18/0.092	0.035/0.023	0.035/0.023
1,2-Dichloroethane	0.10	0.10	2.1	3.9	0.11/0.058	0.11/0.058	0.022/0.014	0.022/0.014
1,1-Dichloroethene	0.14	0.14	2.9	5.5	0.16/0.081	0.16/0.081	0.031/0.02	0.031/0.02
1,2-Dichloroethene	0.5[f]	0.5[f]	10.0	20.0	0.57/0.29	0.57/0.29	0.11/0.071	0.11/0.071
Methylene chloride	0.27	0.38	5.5	15.0	0.31/0.16	0.43/0.22	0.059/0.038	0.083/0.054
1,1,2,2-Tetrachloroethane	0.08	0.16	1.6	6.3	0.091/0.046	0.18/0.092	0.017/0.011	0.035/0.023
Tetrachloroethene	0.5[f]	0.5[f]	10.0	20.0	0.57/0.29	0.57/0.29	0.11/0.071	0.11/0.071
1,1,1-Trichloroethane	0.14	0.19	2.9	7.5	0.16/0.081	0.22/0.11	0.031/0.02	0.042/0.027
1,1,2-Trichloroethane	0.10	0.15	2.1	5.9	0.11/0.058	0.17/0.087	0.022/0.014	0.033/0.021
Trichloroethene	0.5[f]	0.5[f]	10.0	20.0	0.57/0.29	0.57/0.29	0.11/0.071	0.11/0.071
Boron	90.0	160.0	0	0	0	0	0	0
Vanadium	10.0	20.0	0	0	0	0	0	0
Zinc	10.0	10.0	0	0	0	0	0	0

[a]Concentrations are the lesser of the analytical detection limits for monitoring program at Base Well 18 or modeled pretreatment concentrations at well.
[b]Concentrations are based on estimates of volatilization from tap water in a bathroom while showering.
[c]Concentrations are based on estimates of volatilization from process (tap) water in a kitchen while operating a dishwashing machine or clothes washing machine.
[d]35-minute average concentration over operating cycle/90-minute average concentration after completion of final cycle.
[e]72-minute average concentration over operating cycle/48-minute average concentration after completion of final cycle.
[f]Concentrations are the analytical detection limits for monitoring program at Base Well 18.

TABLE 3-7. SUMMARY OF OFF-BASE CHRONIC EXPOSURE CONCENTRATIONS

	Exposure Concentration							
	Ingestion of and Dermal Contact with Groundwater[a] ($\mu g/L$)		Inhalation of Chemicals Volatilized from Groundwater ($\mu g/m^3$)					
			Showering[b]		Washing Clothes[c]		Washing Dishes[c]	
	Average	Reasonable Maximum	Average	Reasonable Maximum	Average[d]	Reasonable Maximum[d]	Average[e]	Reasonable Maximum[e]
Carbon tetrachloride	0.01	0.01	0.21	0.39	0.01/0.0058	0.01/0.0058	0.0022/0.0014	0.0022/0.0014
Chloroform	0.09	0.09	1.8	3.5	0.1/0.052	0.1/0.052	0.02/0.013	0.02/0.013
1,2-Dichloroethane	0.05	0.05	1.0	2.0	0.057/0.029	0.057/0.029	0.011/0.0071	0.011/0.0071
1,1-Dichloroethene	0.07	0.07	1.4	2.8	0.08/0.04	0.08/0.04	0.015/0.0099	0.015/0.0099
1,2-Dichloroethene	2.5	2.5	52.0	100.0	2.9/1.4	2.9/1.4	0.55/0.35	0.55/0.35
Methylene chloride	0.11	0.11	2.3	4.3	0.13/0.063	0.13/0.063	0.024/0.016	0.024/0.016
1,1,2,2-Tetrachloroethane	0.003	0.003	0.062	0.12	0.0034/0.0017	0.0034/0.0017	0.00066/0.00042	0.00066/0.00042
Tetrachloroethene	2.6	2.6	54.0	100.0	3.0/1.5	3.0/1.5	0.57/0.37	0.57/0.37
1,1,1-Trichloroethane	0.05	0.05	1.0	2.0	0.057/0.029	0.057/0.029	0.011/0.0071	0.011/0.0071
1,1,2-Trichloroethane	0.001	0.001	0.021	0.039	0.0011/0.00058	0.0011/0.00058	0.00022/0.00014	0.00022/0.00014
Trichloroethene	22.0	22.0	460.0	880.0	25/13	25/13	4.8/3.1	4.8/3.1
Boron	30.0	30.0	0	0	0	0	0	0
Vanadium	2.0	2.0	0	0	0	0	0	0
Zinc	10.0	10.0	0	0	0	0	0	0

[a]Concentrations are the modeled concentrations at City Well 132.
[b]Concentrations are based on estimates of volatilization from tap water in a bathroom while showering.
[c]Concentrations are based on estimates of volatilization from process (tap) water in a kitchen while operating a dishwashing machine or clothes washing machine.
[d]35-minute average concentration over operating cycle/90-minute average concentration after completion of final cycle.
[e]72-minute average concentration over operating cycle/48-minute average concentration after completion of final cycle.

TABLE 3-8. SUMMARY OF ON-BASE SUBCHRONIC EXPOSURE CONCENTRATIONS

	Exposure Concentration							
			Inhalation of Chemicals Volatilized from Groundwater ($\mu g/m^3$)					
	Ingestion of and Dermal Contact with Groundwater[a] ($\mu g/L$)		Showering[b]		Washing Clothes[c]		Washing Dishes[c]	
	Average	Reasonable Maximum	Average	Reasonable Maximum	Average[d]	Reasonable Maximum[d]	Average[e]	Reasonable Maximum[e]
Carbon tetrachloride	0.09	0.09	1.9	3.5	0.1/0.052	0.1/0.052	0.02/0.013	0.02/0.013
Chloroform	0.16	0.16	3.3	6.3	0.18/0.092	0.18/0.092	0.035/0.023	0.035/0.023
1,2-Dichloroethane	0.10	0.10	2.1	3.9	0.11/0.058	0.11/0.058	0.022/0.014	0.022/0.014
1,1-Dichloroethene	0.14	0.14	2.9	5.5	0.16/0.081	0.16/0.081	0.031/0.02	0.031/0.02
1,2-Dichloroethene	6.7	16.0	140.0	620.0	7.7/3.9	18/9.2	1.5/0.95	3.5/2.3
Methylene chloride	0.27	0.38	5.5	15.0	0.31/0.16	0.43/0.22	0.059/0.038	0.083/0.054
1,1,2,2-Tetrachloroethane	0.08	0.16	1.6	6.3	0.091/0.046	0.18/0.092	0.017/0.011	0.035/0.023
Tetrachloroethene	0.81	0.81	17.0	32.0	0.93/0.47	0.93/0.47	0.18/0.12	0.18/0.12
1,1,1-Trichloroethane	0.14	0.19	2.9	7.5	0.16/0.081	0.22/0.11	0.031/0.02	0.042/0.027
1,1,2-Trichloroethane	0.10	0.15	2.1	5.9	0.11/0.058	0.17/0.087	0.022/0.014	0.033/0.021
Trichloroethene	39.0	61.0	790.0	2400.0	45/22	70/35	8.5/5.5	13/8.6
Boron	90.0	160.0	0	0	0	0	0	0
Vanadium	10.0	20.0	0	0	0	0	0	0
Zinc	10.0	10.0	0	0	0	0	0	0

[a]Concentrations are the modeled pretreatment concentrations at Base Well 18, assuming total failure of the base treatment system.
[b]Concentrations are based on estimates of volatilization from tap water in a bathroom while showering.
[c]Concentrations are based on estimates of volatilization from process (tap) water in a kitchen while operating a dishwashing machine or clothes washing machine.
[d]35-minute average concentration over operating cycle/90-minute average concentration after completion of final cycle.
[e]72-minute average concentration over operating cycle/48-minute average concentration after completion of final cycle.

concentration is greater than the detection limit, it is assumed that the base treatment system will detect the presence of the chemical in the water and reduce the concentration to below the detection limit. The detection limit is considered the worst-case post-treatment concentration and probably overestimates actual concentrations.

For off-base chronic exposures, the exposure concentration is the modeled concentration at CW-132. It is assumed that no treatment of the groundwater occurs either prior to or after its distribution to residential and other users.

For on-base subchronic exposures, the exposure concentration is the modeled concentration at BW-18. It is assumed that the base treatment system fails and estimated concentrations in the groundwater pass through the system with no removal for a period of time before the failure is detected and corrected.

The methodologies used to estimate concentrations in air while showering and operating the dishwasher and the washing machine are provided in Appendix F.

3.5.2 Estimation of Chemical Intakes for Individual Pathways

Exposure is defined as the contact rate of an organism with a chemical or physical agent. Intake is exposure normalized for time and body weight and is expressed in units of mg chemical/kg body weight-day (U.S. EPA, 1989a).

The generic equation for calculating chemical intakes is (U.S. EPA, 1989a):

$$I = C \times CR \times EFD/BW \times 1/AT \qquad (3\text{-}1)$$

where:

I = intake; the amount of chemical at the exchange boundary (mg/kg body weight-day)

Chemical-related variable

C = chemical concentration; the average concentration contacted over the exposure period (e.g., mg/liter water)

Variables that describe the exposed population

CR = contact rate; the amount of contaminated medium contacted per unit time or event (e.g., liters/day)

EFD = exposure frequency and duration; describes how long and how often exposure occurs. Often calculated using two terms (EF and ED):

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight; the average body weight over the exposure period (kg)

Assessment-determined variable

AT = averaging time; period over which exposure is averaged (days)

There are three categories of variables that are used to estimate intake: 1) chemical-related variables (exposure concentration); 2) variables that describe the exposed population (contact rate, exposure frequency and duration, and body weight); and 3) assessment-determined variables (averaging time). The chemical-related variables (exposure concentration) used to estimate intake are listed for each chemical of concern, each pathway of exposure, and each exposure scenario in Tables 3-6, 3-7, and 3-8. The methodology used to derive these estimated exposure concentrations is discussed in the previous subsection.

The values used to estimate chronic and subchronic exposure for each exposure scenario are found in Appendix G in tabular form. The tables list both the average and reasonable maximum value used for each variable and provide a brief rationale for the value selected.

These values were input to the following equations for calculating pathway specific intakes:

Ingestion of Drinking Water

Intake (mg/kg-day) = (CW x IR x EF x ED)/(BW x AT) (3-2)

where:

CW = Chemical Concentration in Water (mg/liter)
IR = Ingestion Rate (liters/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged - days)

Dermal Contact With Water

Absorbed Dose (mg/kg-day) =
(CW x SA x PC x ET x EF x ED x CF)/(BW x AT) (3-3)

where:

CW = Chemical Concentration in Water (mg/liter)
SA = Skin Surface Area Available for Contact (cm^2)
PC = Chemical-specific Dermal Permeability Constant (cm/hr)
ET = Exposure Time (hours/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
CF = Volumetric Conversion Factor for Water (1 liter/1000 cm^3)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged - days)

Inhalation of Chemicals Volatilized from Water During Home Use

Intake (mg/kg-day) = (CA x IR x ET X EF x ED)/(BW x AT) (3-4)

where:

CA = Contaminant Concentration in Air (mg/m^3)
IR = Inhalation Rate (m^3/hour)
ET = Exposure Time (hours/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged - days)

An algorithm was developed to determine an average daily inhalation exposure as an air concentration. This approach eliminates the need to make an assumption regarding the efficiency of absorption of the chemical by the respiratory tract. The effective air concentration is an inhalation exposure normalized for time and inhalation rate and is expressed in units of mg chemical/m^3 inhalation rate. The following equation was used to calculate the pathway-specific effective air concentrations (EAC):

$$EAC\ (mg/m^3) = (CA \times IRS \times ET \times EF \times ED)/(IRD \times CF \times AT) \quad (3\text{-}5)$$

CA = Contamination Concentration in Air (mg/m^3)
IRS = Inhalation Rate during exposure (m^3/hour)
ET = Exposure Time (hours/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
IRD = Inhalation Rate the remainder of the day (m^3/hour)
CF = Conversion Factor (hour/day)
AT = Averaging Time (period over which exposure is averaged-days)

Appendix H contains the spreadsheets which document all the algorithms, the input variables, and the resulting intakes. Appendix I provides a hand calculation of each intake for one chemical. The calculated intakes are summarized in Section 5.0 in the context of characterizing the associated risks.

3.6 Identification of Uncertainties

The major areas of the exposure assessment in which sources of uncertainity may have been introduced include the environmental analysis and sampling program, fate and transport modeling, and exposure parameter estimation. Table 3-9 summarizes the major sources of uncertainty and also ranks each source of exposure for the potential magnitude of its effect on the exposure estimates and the direction of the effect (i.e., whether the assumption made or value selected will tend to overestimate exposure, underestimate exposure, or over- or underestimate exposure). In general, sources of uncertainty marked as "low" may affect estimates of exposure by less than one order of magnitude, sources of uncertainty marked as "moderate" may affect estimates of exposure by between one and two orders of magnitude, and sources of uncertainty marked as "high" may affect estimates of exposure by more than two orders of magnitude.

The subsections which follow discuss the major sources of uncertainty for the exposure assessment.

3.6.1 Environmental Sampling and Analysis

The EE/CA-EA monitoring was limited to the groundwater medium. Characteristics of the original source(s) for the contaminants in the groundwater have not been identified. For example, residual contamination in soils at the site is not known. If the original source(s) for the contaminants in groundwater still contribute to its contamination and concentrations in the groundwater detected by the latest available sampling data do not represent maximum concentrations, the exposure estimates may be underestimated. If, however, the original source(s) no longer release chemicals to the groundwater and concentrations of chemicals in the groundwater will decrease in the future as the chemicals are flushed from the site, the exposure estimates may be overestimated. The assessment assumed steady state for concentrations of chemicals in groundwater at the site -- concentrations of chemicals in the groundwater at the site will remain constant over the assumed periods of time for exposure duration.

Another source of uncertainty in the assessment relates to the lack of sufficient data to adequately characterize background concentrations for inorganics. The selection of inorganic species to include in the assessment was based, in part, on "baseline" concentrations (see Section 2.3.3). There are insufficient data available to state that base

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TABLE 3-9. SUMMARY OF UNCERTAINTIES ASSOCIATED WITH THE EXPOSURE ASSESSMENT

	Effect on Exposure[a]		
	Potential Magnitude for Over-Estimation of Exposure	Potential Magnitude for Under-Estimation of Exposure	Potential Magnitude for Over- or Under-Estimation of Exposure
Environmental Sampling and Analysis			
Monitoring program was limited to the groundwater medium. Characteristics of the original source for the contaminants in groundwater have not been identified. Residual contamination in soils is not known.			Moderate
Systemic or random errors in the chemical analyses may yield erroneous data.			Low
Insufficient data was available to adequately characterize background concentrations:			
- Selection of inorganics to include in assessment.			Moderate
- Inability to attribute a portion of estimated exposures to background concentrations.	Moderate		
Fate and Transport Modeling - Groundwater Flow			
Model assumes homogeneous aquifer properties.			Moderate
Sufficient data to determine aquifer transmissivity not available.			Low
Potential wellhead contaminants drawn only from OU B.		Moderate	
Nature and extent of groundwater contamination southeast of BW-18 not well characterized.		Low	

(Continued)

TABLE 3-9. CONTINUED

	Effect on Exposure[a]		
	Potential Magnitude for Over-Estimation of Exposure	Potential Magnitude for Under-Estimation of Exposure	Potential Magnitude for Over- or Under-Estimation of Exposure
Fate and Transport Modeling - Groundwater Flow (continued)			
Contribution of groundwater from geohydrologic zones D and E at CW-132, and geohydrologic zone E at BW-18 was neglected.	Low		
Level of groundwater contamination will not change from that observed during January 1990 sampling.			Unknown
Fate and Transport Modeling - Volatilization from Water During Home Use-Showering			
100% volatilization was assumed.	Moderate		
Dimensions of the shower stall.			Low
Air exchange rate used (=1 assumed)	Low		
Volatilization rate as a function of time.			Low
Use of the maximum concentrations from the model to predict exposures.	Moderate		
Fate and Transport Modeling - Volatilization from Water During Home Use - Operating Dishwasher and Washing Machine			
100% volatilization was assumed.	Moderate		
The dimensions of the room where washer and dryer are located.			Low
Air exchange rate used (2 = assumed).	Moderate		

(Continued)

TABLE 3-9. CONTINUED

	Effect on Exposure[a]		
	Potential Magnitude for Over-Estimation of Exposure	Potential Magnitude for Under-Estimation of Exposure	Potential Magnitude for Over- or Under-Estimation of Exposure
Fate and Transport Modeling - Volatilization from Water During Home Use - Operating Dishwasher and Washing Machine (continued)			
Use of first order decay to estimate concentrations.			Low
Exposure Parameter Estimation			
The standard assumptions regarding body weight, period exposed, life expectancy, population characteristics, and lifestyle may not be representative of any actual exposure situation.			Moderate
The amount of media intake is assumed to be constant and representative of the exposed population.	Moderate		
100% of water ingestion is assumed to be tap water from the residence for residential exposures and from the work place for occupational exposures.	Low		
Frequency of exposure is assumed to be 365 days/year for chronic exposure scenarios.	Moderate		
Total body surface area used for dermal contact exposures.	Low		
Duration exposure for inhalation of volatiles from washing machine and dishwasher assumes that the exposed individual stays in close proximity to the machines for 120 minutes (including operation of the machine plus time after the completion of the final cycle), every time the machine is operated.	Moderate		

(Continued)

TABLE 3-9. CONTINUED

	Effect on Exposure[a]		
	Potential Magnitude for Over-Estimation of Exposure	Potential Magnitude for Under-Estimation of Exposure	Potential Magnitude for Over- or Under-Estimation of Exposure
Exposure Parameter Estimation (continued)			
Occupation exposures assume 30 years of work at the same location.	Low		

[a] In general, assumptions marked as "low" may affect estimates of exposure by less than one order of magnitude, assumptions marked as "moderate" may affect estimates of exposure by between one and two orders of magnitude, and assumptions marked as "high" may affect estimates of exposure by more than two orders of magnitude.

line values are equivalent to background concentrations (Radian, 1990). If the "baseline" concentrations are lower than background, some inorganics included in the analysis may be present at the site due to a source other than the site under evaluation (either a natural source or other anthropogenic sources). This case would lead to overestimates of exposures which can be attributed to the site. On the other hand, if the "baseline" concentrations are higher than background, some inorganics which can be attributed to the site may have been excluded from the assessment.

Because background concentrations could not be identified with confidence, the assessment attributes 100% of estimated exposures to the site. To the extent that background concentrations might be present in the groundwater, particularly for the organic compounds, the exposure assessment overestimates exposures which are due to contaminants detected at the site.

Finally, systemic or random errors in the chemical analyses may yield erroneous data. If the analytical data do not provide an accurate representation of concentrations of contaminants in the groundwater at the time the sampling occurred, the exposure estimates may be either under- or overestimated.

3.6.2 Fate and Transport Modeling

To model the migration of contaminants in the groundwater from the site to selected production wells required the use of simplifying assumptions to simulate the subsurface environment. For example, the model assumes homogeneous aquifer properties. Also, aquifer transmissivity is a model input variable which had to be assumed due to lack of sufficient data on transmissivity of the aquifer under evaluation. The assumption of a homogeneous aquifer and the value selected to represent transmissivity may lead either to overestimates or underestimates of exposures.

Other assumptions may lead to underestimates of exposure. These include the assumption that potential wellhead contaminants are drawn only from OU B. If other sources of contamination exist in the well's zone of influence, the total exposure (from all sources including OU B) may be underestimated. For example, the nature and extent of groundwater contamination in the PCE plume southeast of BW-18 is not well characterized. This plume was not included in the estimates of wellhead concentrations.

Assumptions which may lead to overestimates of exposure also were included in the assessment due to lack of sufficient data. The contribution of groundwater from

geohydrologic zones D and E at CW-132, and geohydrologic zone E at BW-18, was neglected, for example. Inclusion of water drawn from these zones would dilute or reduce the estimated concentrations at the wellhead.

Volatilization From Water During Home Use

To estimate concentrations of contaminants in the air from showering, operating a dishwasher, and operating a washing machine, 100% volatilization of volatiles from the water was assumed. Volatilization rates will vary for the contaminants of concern and will likely be lower than 100%. The assumption of 100% volatilization will result in overestimates of exposures. A fairly low air exchange rate was also assumed, which will also likely result in overestimates of exposure. For the showering pathway, maximum predicted concentrations from the model were used to estimate exposure, which will result in overestimates as well.

Other factors may result in either an over- or an underestimate of exposures for the air pathways. These include: 1) the dimensions of the shower stall for showering and the room in which the dishwasher and washing machine is located; 2) the volatilization rate as a function of time for the shower pathway; and 3) the use of first order decay to estimate concentrations in the room after the end of the dishwasher and washing machine cycles.

3.6.3 Exposure Parameter Estimation

The standard assumptions regarding body weight, period exposed, life expectancy, population characteristics, and lifestyle may not be representative of any actual exposure situation. These assumptions may over- or underestimate exposures.

Other assumptions made in the exposure assessment tend to be conservative and thus overestimate exposures. These include:

- The amount of media intake is assumed to be constant and representative of the exposed population;
- 100% of water ingestion is assumed to be tap water from the residence for residential exposures and from the workplace for occupational exposures;
- The frequency of exposure is assumed to be 365 days/year for chronic exposure scenarios;

- The total body surface area is used for dermal contact exposures;

- The duration of exposure for inhalation of volatiles from the washing machine and dishwasher assumes that the exposed individual stays in close proximity to the machines during the operation of the machines and up to 90 minutes after the completion of the final cycle every time the machine is operated; and

- Occupational exposures assume 30 years of work at the same location.

No assumptions which tend to underestimate exposures have been identified with respect to exposure parameter estimation.

3.6.4 Exposure Pathways Evaluated

This assessment was limited in scope to exposure pathways originating with contaminants in the groundwater. Because the original source(s) for the contaminants in the groundwater have not been identified and evaluated, potential pathways of exposure unrelated to the groundwater medium have not been examined. Potentially applicable transport and fate mechanisms could include, for example, volatilization of chemicals to the air and fugitive dust generation from shallow contaminants and surface soils and surface runoff.

However, much of the surface soil at the site is either covered by buildings or asphalt. Exposed surface soils are not considered contaminated. These factors tend to reduce the potential for significant human exposures via volatilization from the soil, fugitive dust generation, surface runoff, or direct contact with the soil.

Of the exposure pathways identified as complete pathways, one was not quantified: migration of groundwater to potable well; use of the water to irrigate backyard garden; root uptake by plants; ingestion of plants. Since the majority of chemicals of concern are volatile, they will tend to volatilize from the soil surface before significant root uptake can occur. This pathway was considered to have a much lower potential for human exposure than drinking water from the same source, which was quantified.

3.6.5 Current and Future Land Use

Current land use was represented in the assessment by on-base and off-base residential exposure scenarios and an on-base occupational exposure scenario. Future land use, which will probably involve greater density of residential, commercial, and industrial development in the vicinity of the base, will not result in exposures of greater magnitude. It may result in an increase in the size of the population at risk of exposure.

3.7 Summary of Exposure Assessment

This assessment was limited in scope to exposure pathways originating in the groundwater beneath OU B and associated with the use of BW-18 and CW-132. Because the original source(s) for the contaminants in the groundwater have not been identified and evaluated, potential pathways of exposure unrelated to the groundwater medium were not examined. The primary point at which human exposure to contaminants may occur is at the tap in homes and workplaces on-base and off-base that are serviced by water drawn from BW-18 and CW-132. Environmental fate and transport modeling was used to predict the magnitude of contaminants which could migrate to these two wells. Table 3-2 summarizes the pertinent information on all complete exposure pathways at the site. Table 3-3 outlines the exposure scenarios which were evaluated in this assessment. Tables 3-6 thru 3-8 provide a summary of the modeled concentrations used for each exposure scenario.

4.0 TOXICITY ASSESSMENT

The available toxicity information for each of the chemicals of concern is presented in this section. This information includes a listing of standard EPA toxicity values (reference doses and slope factors), as well as, a description of the carcinogenic and noncarcinogenic effects associated with exposure to each of the chemicals.

4.1 Toxicity Information for Noncarcinogenic and Carcinogenic Effects

This section summarizes the types of toxicological information considered for use in this risk assessment. The following subsections include toxicity information used in determining the risks associated with noncarcinogenic effects (EPA reference doses), information used in determining carcinogenic risk (slope factors and weight-of-evidence classifications), and information used for in determining the risks for both types of effects.

4.1.1 Exposure Periods

The risk assessment encompasses two durations of exposure for noncarcinogenic effects: chronic and subchronic. The chronic exposure scenarios include residential and occupational exposure occurring from use of water from BW-18, and residential exposure from use of water from CW-132. The chronic reference dose (RfD) values presented in Table 4-1 were used for calculating Hazard Indices for these scenarios. The subchronic exposure scenario includes exposure for a maximum of 30 days to water from BW-18 that is contaminated due to a failure of the treatment system. The subchronic RfD values (RfD_s), also presented in Table 4-1, were used in calculation of Hazard Indices for the subchronic exposure scenario. Use of the RfD_s is considered appropriate for exposure periods of two weeks to seven years (EPA, 1989a).

For carcinogenic effects, exposure was averaged over a lifetime, as per EPA guidance (EPA, 1989a).

4.1.2 RfD Values for Chemicals of Concern

The RfD values for the chemicals of concern identified in Section 2.3 are presented in Table 4-1. These values were obtained from an Integrated Risk Information System (IRIS) search dated May 21, 1990, or from the EPA Health Effects

TABLE 4-1. TOXICITY VALUES: POTENTIAL NONCARCINOGENIC EFFECTS

Chemical	Chronic RfD (mg/kg-day)	RfDs (mg/kg-day)	Confidence Level	Critical Effect	RfD Study Type/ RfD Source	Uncertainty and Modifying Factors (UF-RfD;RfDs)
Oral Route						
Carbon tetrachloride	7.0E-04	7.0E-03	Medium	Liver Lesions	Gavage/ IRIS a	UF=1000; 100 MF=1
Chloroform	1.0E-02	1.0E-02	Medium	Fatty cyst formation in liver	Oral/ IRIS a	UF=1000; 1000 MF=1
Dichloroethene, 1,1-	9.0E-03	9.0E-03	Medium	Hepatic lesions	Water/ IRIS a	UF=1000; 1000 MF=1
Dichloroethene, 1,2-	2.0E-02	2.0E-01	Low	Increased serum alkaline phosphatase in male mice	Water/ IRIS a	UF=1000; 100 MF=1
Methylene chloride	6.0E-02	6.0E-02	Medium	Liver toxicity	Water/ IRIS a	UF=100; 100 MF=1
Tetrachloroethene	1.0E-02	1.0E-01	Medium	Hepatotoxicity in mice, weight gain in rats	Gavage/ IRIS a	UF=1000; 100 MF=1
Trichloroethane, 1,1,1-	9.0E-02	9.0E-01	Medium	No adverse effects Slight growth retardation	Inhalation/ IRIS a	UF=1000; 100 MF=1
Trichloroethane, 1,1,2-	4.0E-03	4.0E-02	Medium	Clinical serum chemistry	Water/ IRIS a	UF=1000; 100 MF=1
Boron	9.0E-02	9.0E-02	Medium	Testicular lesions	Diet/ IRIS a	UF=100; 100

(Continued)

TABLE 4-1. CONTINUED

Chemical	Chronic RfD (mg/kg-day)	RfDs (mg/kg-day)	Confidence Level	Critical Effect	RfD Study Type/ RfD Source	Uncertainty and Modifying Factors (UF-RfD;RfDs)
Vanadium	7.0E-03	7.0E-03		None observed	Water/HEAST[c]	UF=100; 100
Zinc	2.0E-01	2.0E-01		Anemia	Therapeutic dosage/HEAST[c]	UF=10; 10
Inhalation route	(mg/m^3)	(mg/m^3)				
Methylene chloride	3.0E+00	3.0E+00		NA	Inhalation/ HEAST[c]	UF=100; 100
(equivalent oral RfD)b	9.0E-01	9.0E-01				MF=1
Trichloroethane, 1,1,1-	1.0E+00	1.0E+01		Hepatotoxicity	Inhalation/ HEAST[c]	UF=1000; 100
(equivalent oral RfD)b	3.0E-01	3.0E+00				MF=1

a Integrated Risk Information Service, search dated May 21, 1990.
b Equivalent oral RfD calculated assuming 20 m^3 daily inhalation volume and 70 kg body weight.
c US EPA Health Effects Assessment Summary Tables (HEAST), 4th Quarter 1989.

Assessment Summary Tables (HEAST, 4th Quarter, 1989). No oral RfD values are currently available for 1,2-dichloroethane, 1,1,2,2-tetrachloroethane, or trichloroethene; inhalation RfD values are only available for methylene chloride and 1,1,1-trichloroethane. The oral RfD for 1,1,1-trichloroethane was calculated from the inhalation RfD based on route-to-route extrapolation. It should be noted that the RfD for vanadium is based on a dosage at which no effects were observed; an uncertainty factor of 100 was also applied to this dosage.

Use of Inhalation RfD Values

Because inhalation RfD (RfD_i) values were available for methylene chloride and 1,1,1-trichloroethane, it was considered more consistent toxicologically to use the RfD_i values for the inhalation exposure from showering. Like the other organic chemicals, it was assumed that these chemicals had the potential to volatilize from the water to the air during showering. This approach eliminates the need to make an assumption regarding the efficiency of absorption of the chemical by the respiratory tract. As described in Section 3.4, an algorithm was developed to determine an average daily inhalation exposure due to showering as an air concentration. This air concentration was then compared to the RfD_i to determine the Hazard Index of that portion of the exposure. For the remaining chemicals, intake was calculated as described in Section 3.4 and these values were compared to oral RfD values.

4.1.3 Absorption Efficiency

Absorption of chemicals by the gastrointestinal tract was assumed to be 100%. This is probably an overestimate, particularly for the metals. However, use of this assumption lends additional conservatism to the assessment. Absorption of chemicals by inhalation was also assumed to be 100% for those for which intake was calculated for comparison to an oral RfD value. For absorption of chemicals by dermal contact, a literature search was performed in an attempt to obtain chemical-specific dermal permeability constants for the chemicals. None were found, however, so the dermal permeability constant for water was used for all chemicals.

4.1.4 Slope Factors and Weight-of-Evidence Classifications

The slope factors and weight-of-evidence classifications for all chemicals of concern that have been classified as carcinogens by EPA are presented in

Table 4-2. The values presented were obtained from an IRIS search dated May 21, 1990. Several chemicals on the list have not been classified as carcinogens; these include 1,2-dichloroethene, boron, vanadium, and zinc. Three of the chemicals have been classified in Group C - Possible Human Carcinogen; the remainder were classified by EPA as Group B2 - Probable Human Carcinogen (sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans). EPA has classified 1,1,1-trichloroethane in Group D - Not Classifiable as to Human Carcinogenicity. It has been tested in two species with no evidence of a carcinogenic effect.

4.1.5 Elimination of Group A Carcinogens from the Risk Assessment

Two chemicals that EPA has classified as Group A - Human Carcinogen were eliminated from the list of chemicals of concern. Since these chemicals were found only once at two different wells, were found at less than 5 times the detection limit, and were not confirmed by the second column analysis, exclusion of these compounds from the risk assessment was considered justifiable.

4.1.6 California Proposition 65 Developmental Toxins

The State of California has established a list of chemicals that are considered to be potential developmental/reproductive toxins under the Safe Drinking Water and Toxic Enforcement Act. None of the chemicals of concern for McClellan AFB OU B appear on this list.

4.2 Toxicity and Carcinogenicity of Chemicals of Concern

This section will summarize the toxicity information available for the noncarcinogenic and carcinogenic effects associated with the chemicals of concern. Toxicity information on noncarcinogenic effects is provided for each chemical that has an RfD value and includes the data that form the basis for determination of the RfD. The evaluation of potential carcinogenic risks includes only those chemicals which EPA has classified as carcinogenic. Unless noted otherwise, the information presented below on each of these chemicals is summarized from the information available on IRIS as of May 21, 1990.

TABLE 4-2. TOXICITY VALUES: POTENTIAL CARCINOGENIC EFFECTS

Chemical	Slope Factor (SF) 1/(mg/kg-day)	Inhalation Slope Factor (SF) $1/\mu g/m^3$ [1/(mg/kg-day)]	EPA Weight-of-Evidence Classification	Type of Cancer	SF Study Type (Inhalation;Oral)/ SF Source
Carbon tetrachloride	1.3E-01[a]	1.5E-05[a,b,g] [1.3E-01][a,b] [5.2E-02][g]	B2	Hepatocellular carcinomas/ hepatomas	Gavage; gavage/ IRIS *
Chloroform	6.1E-03[a]	2.3E-05[h] [8.1E-02][a]	B2	Kidney tumor	Oral; oral/IRIS
Dichloroethane, 1,2-	9.1E-02[a]	2.6E-05 [9.1E-02][a,b]	B2	Several tumor types	Gavage; gavage/IRIS
Dichloroethene, 1,1-	6.0E-01[a]	5.0E-05 [1.2E+00][a]	C	Adrenal pheochromocy-tomas	Inhalation; gavage/IRIS
Methylene chloride	7.5E-03[f]	4.1E-06[c]	B2	Hepatocellular adenomas or carcinomas	Inhalation; inhalation and water/IRIS
Tetrachloroethane, 1,1,2,2-	2.0E-01[a]	5.8E-05 [2.0E-01][a,b]	C	Hepatocellular carcinoma	Gavage; gavage/ IRIS
Tetrachloroethene	5.1E-02[d]	9.5E-07 [3.3E-03]	B2	Leukemia liver tumors	Inhalation; gavage/HEAST**

(Continued)

TABLE 4-2. CONTINUED

Chemical	Slope Factor (SF) 1/(mg/kg-day)	Inhalation Slope Factor (SF) $1/\mu g/m^3$ [1/(mg/kg-day)]	EPA Weight-of-Evidence Classification	Type of Cancer	SF Study Type (Inhalation;Oral)/ SF Source
Trichloroethane, 1,1,2-	5.7E-02[a]	1.6E-05 [5.7E-02][a,b]	C	Hepatocellular carcinomas and pheochromocytomas	Gavage; gavage/IRIS
Trichloroethene	1.1E-02[e]	1.7E-06 [1.7E-02][e]	B2	Lung, liver	Inhalation, gavage/HEAST

* Integrated Risk Information Service, search dated May 21, 1990.
** US EPA Health Effects Assessment Summary Tables, 4th Quarter, 1989.
a Verified, on IRIS.
b Based on route-to-route extrapolation.
c Value from IRIS, HEAST shows value of 1/4.7E-07 $\mu g/m^3$.
d Under review by CRAVE.
e Values removed from IRIS pending further review.
f Verified on IRIS, but under review.
g Incorporates an absorption factor of 0.4. Inhalation potency slope of 1.3E-01 [1/(mg/kg/day)] as absorbed dose.
h Based on oral data (IRIS).

Carbon Tetrachloride

Studies in many species have identified the liver as the major target organ for toxicity of carbon tetrachloride. The oral RfD is based on a study in rats in which carbon tetrachloride was administered in corn oil by gavage for 12 weeks. The No Observed Adverse Effects Level (NOAEL) for this study was 1 mg/kg, converted to 0.71 mg/kg/day to allow for dosing only five days per week instead of seven. The study was supported by four other subchronic studies demonstrating similar effects in the same approximate range of dosages. An uncertainty factor of 1000 (10x for interspecies conversion, 10x for protection of sensitive populations, and 10x for subchronic rather than chronic duration) was applied to the NOAEL to establish an RfD of $7x10^{-4}$ mg/kg for chronic exposure. Although not listed in IRIS, the EPA HEAST presents an RfD_s of $7x10^{-3}$ mg/kg. Confidence in the RfD is medium based on weaknesses in the database, such as the lack of information on developmental and reproductive endpoints.

There is sufficient evidence of the carcinogenicity of carbon tetrachloride in experimental animals. Carbon tetrachloride has been shown to be carcinogenic in all species tested including rats, mice, and hamsters. Hepatocellular carcinomas are produced in all these species. The oral slope factor was calculated using the geometric mean of those calculated from one study in rats, one study in hamsters, and two studies in mice. All four studies were used because all were deficient in some respect, so a single study could not be used for this determination. Data from males and females were combined for all studies because sample sizes were small. The unit risks calculated from these studies ranged from $3.1x10^{-7}$ to $3.4x10^{-5}$ $(ug/L)^{-1}$. Because this range is fairly small and because the same biological mechanism was found to lead to the same tumor type in each study, it was considered appropriate to use the geometric mean. The oral slope factor was calculated to be $1.3x10^{-1}$ $(mg/kg/day)^{-1}$. Carbon tetrachloride has been classified as Group B2 - Probable Human Carcinogen. Carbon tetrachloride also appears on the list of chemicals known to cause cancer established under the California Safe Drinking Water and Toxic Enforcement Act.

Chloroform

The oral RfD is based on a chronic study in dogs in which chloroform was administered in gelatin capsules mixed with toothpaste. Effects on the liver were observed including fatty cysts, nodules of altered hepatocytes and increases in serum enzymes associated with disturbances in liver function [serum glutamic-pyruvic transaminase (SGPT) and serum glutamic-oxaloacetic transaminase (SGOT)]. A

NOAEL was not identified; the Lowest Observed Adverse Effect Level (LOAEL) was 15 mg/kg. This value was adjusted to 12.9 mg/kg/day to account for dosing only six days per week rather than seven. An uncertainty factor of 1000 (10x for interspecies conversion, 10x for protection of sensitive populations, and 10x for LOAEL rather than NOAEL) was used to establish the RfD of $1x10^{-2}$ mg/kg/day. The RfD_s for chloroform is the same value. The level of confidence in the RfD is medium; several studies support the LOAEL, but a NOAEL was not found.

There is sufficient evidence for the carcinogenic activity of chloroform in experimental animals. Chloroform has been tested for carcinogenicity in eight strains of mice, two strains of rats and in beagle dogs. Administration of chloroform typically results in kidney tumors in rats and liver tumors in mice. Kidney tumors have also been reported in male mice. The oral slope factor was calculated based on the incidence of kidney tumors in male Osborne-Mendel rats after administration of chloroform in drinking water. The oral slope factor was $6.1x\ 10^{-3}$ $(mg/kg/day)^{-1}$. The inhalation slope factor was calculated from a study in B6C3F1 female mice treated with chloroform by gavage. The inhalation slope factor was $2.3x1^{-5}$ $(ug/m^3)^{-1}$. EPA has classified chloroform in Group B2 - Probable Human Carcinogen. Chloroform also appears on the list of chemicals known to cause cancer established under the California Safe Drinking Water and Toxic Enforcement Act.

1,2-Dichloroethane

An RfD value is currently not available for 1,2-dichloroethane. The potential noncarcinogenic effects from exposure could not be evaluated.

Administration of 1,2-dichloroethane in corn oil by gavage resulted in increased incidences of several tumor types in male and female rats and male and female mice. Tumors were observed in the stomach, circulatory system, mammary gland, lung, liver, and uterus. The oral slope factor was calculated based on the incidence of hemangiosarcomas in male rats. The oral slope factor was $9.1x10^{-2}$ $(mg/kg/day)^{-1}$. An inhalation slope factor was calculated from the same data, assuming 100% absorption and metabolism at the low dose. The inhalation slope factor was $2.6x10^{-5}$ $(ug/m^3)^{-1}$. EPA has classified 1,2-dichloroethane in Group B2 - Probable Human Carcinogen.

1,1-Dichloroethene

The liver is the target organ for toxicity of this chemical and the available data indicate that rats are the most sensitive experimental species. The RfD is based on a study in which 1,1-dichloroethene was administered to rats in drinking water for two years. The only pathologic findings were hepatic lesions characterized by hepatocellular fatty change and swelling. A NOAEL was not found. The LOAEL was 50 ppm 1,1-dichloroethene in water. This was converted to a daily dosage of 9 mg/kg. An uncertainty factor of 1000 was used (10x for interspecies conversion, 10x for protection of sensitive populations, and 10x for lack of a NOAEL) to establish the RfD of $9x10^{-3}$ mg/kg. The RfD_s for 1,1-dichloroethene is the same value. The confidence in the RfD is considered medium. However, IRIS indicates the Oral RfD Working Group is conducting further review on this chemical and the RfD may change in the near future.

There is limited evidence for the carcinogenic activity of 1,1-dichloroethene in experimental animals. Although 18 studies have been conducted to assess the carcinogenic activity of this chemical (11 by inhalation, 5 oral, 1 by dermal application and 1 by subcutaneous injection), only one inhalation study provided evidence that this chemical can act as a complete carcinogen. Four slope factors were calculated from two studies that did not show a statistically significant increase in tumor incidence attributable to oral exposure to 1,1-dichloroethene. The highest of the four factors was selected for use. The oral slope factor was $6x10^{-1}$ $(mg/kg/day)^{-1}$. The inhalation study in mice that provided evidence of a carcinogenic effect was used as the basis for the inhalation slope factor of $5.0x10^{-5}$ $(ug/m^3)^{-1}$. Because of the limited evidence for carcinogenic activity in experimental animals, 1,1-dichloroethene has been classified by EPA in Group C - Possible Human Carcinogen.

1,2-Dichloroethene

The oral RfD is based primarily on a study in which 1,2-dichloroethene was administered in drinking water to mice for 90 days. Changes in several parameters were observed, including decreases in serum transaminases and aniline hydroxylase, but no changes were found in levels of liver microsomal enzymes. The most sensitive toxicologically significant effect was an increase in serum alkaline phosphatase activity in male mice. The NOAEL was 0.1 mg/L in drinking water, converted to an oral dosage of 17 mg/kg. An uncertainty factor of 1000 was used (10x for interspecies conversion, 10x for protection of sensitive populations, and 10x for

subchronic rather than chronic duration) to establish an oral RfD of $2x10^{-2}$ mg/kg/day. The confidence in the RfD is low, based primarily on the lack of data on chronic effects and developmental and reproductive toxicity. Although not listed on IRIS, HEAST presents a RfD_s value of $2x10^{-1}$ mg/kg/day.

EPA has not classified 1,2-dichloroethene as to its carcinogenic potential.

Methylene Chloride

The oral RfD is based on a study in which methylene chloride was administered to rats in drinking water for 24 months. Treatment-related histologic lesions of the liver were observed at nominal dosages of 50 mg/kg/day and higher. The NOAELs were 5.85 and 6.47 mg/kg/day for males and females, respectively. An uncertainty factor of 100 (10x for interspecies conversion and 10x for protection of sensitive populations) was applied to the NOAEL to establish an RfD of $6x10^{-2}$ mg/kg/day. This value is also used for the RfD_s. The level of confidence in the RfD is medium because only a few studies support the NOAEL.

Although not listed in IRIS, HEAST presents chronic and subchronic RfD_i values of 3 mg/m^3. These are based on a two-year inhalation study in rats exposed to methylene chloride at 200 ppm (695 mg/m^3) 6 hours/day, 5 days/week. An uncertainty factor of 100 is listed.

There is sufficient evidence for the carcinogenic activity of methylene chloride in experimental animals. One study in which methylene chloride was administered in drinking water produced significant carcinogenic effects in female rats, but not in male rats or mice of either sex. Inhalation exposure of mice to methylene chloride resulted in increased incidences of liver and lung tumors. The oral slope factor was calculated as the arithmetic mean of the slope factors calculated from the study using oral exposure and inhalation exposure (excluding the lung tumors). The oral slope factor was $7.5x10^{-3}$ $(mg/kg/day)^{-1}$. The inhalation slope factor was calculated from the study in mice using the combined incidence of lung and liver tumors. The inhalation slope factor was $4.1x10^{-6}$ $(ug/m^3)^{-1}$. EPA has classified methylene chloride in Group B2 - Probable Human Carcinogen. Methylene chloride also appears on the list of chemicals known to cause cancer established under the California Safe Drinking Water and Toxic Enforcement Act.

1,1,2,2-Tetrachloroethane

An RfD value is currently not available for 1,1,2,2-tetrachloroethane. Potential noncarcinogenic effects were not evaluated.

Administration of 1,1,2,2-tetrachloroethane in corn oil by gavage resulted in a highly significant increase in the incidence of liver tumors in mice of both sexes. No evidence of carcinogenicity was observed in rats of either sex. The oral slope factor was calculated based on the incidence of liver tumors in female mice. The oral slope factor was 2.0×10^{-1} $(mg/kg/day)^{-1}$. An inhalation slope factor was calculated from the same data as 5.8×10^{-5} $(ug/m^3)^{-1}$. EPA has classified this chemical in Group C - Possible Human Carcinogen.

Tetrachloroethene

The oral RfD is based primarily on a study in which tetrachloroethene in corn oil was administered by gavage to mice, five days per week for six weeks. Increased liver triglycerides were first seen at 100 mg/kg. At higher doses, hepatotoxic effects included decreased DNA content; changes in enzyme levels; and hepatocellular necrosis, degeneration and polyploidy. The NOAEL was 20 mg/kg, converted to 14 mg/kg to account for administration only five days per week. The NOAEL was supported by similar results in a study in rats. An uncertainty factor of 1000 (10x for interspecies conversion, 10x for protection of sensitive populations, and 10x for lack of chronic data) was used to establish the RfD of 1×10^{-2} mg/kg/day. Although not listed in IRIS, HEAST presents an RfD_s of 1×10^{-1} mg/kg/day. Confidence in the oral RfD is rated as medium based on the lack of reproductive and developmental data and a NOAEL in a chronic study.

Information on tetrachloroethene is not available on IRIS. The EPA HEAST, 4th Quarter 1989, lists this chemical in Table B: Carcinogenicity with an oral slope factor of 5.1×10^{-2} $(mg/kg/day)^{-1}$. The table refers to a gavage study in mice resulting in liver tumors as the basis for the slope factor. An inhalation study in rats and mice was used to determine an inhalation slope factor of 3.2×10^{-4} $(ug/m^3)^{-1}$ based on liver tumors and leukemia. According to HEAST, EPA has classified tetrachloroethene in Group B2 - Probable Human Carcinogen. Tetrachloroethene also appears on the list of chemicals known to cause cancer established under the California Safe Drinking Water and Toxic Enforcement Act.

1,1,1-Trichloroethane

The oral RfD is based on a study in which female guinea pigs were exposed to 1,1,1-trichloroethane by inhalation for 7 hours per day, 5 days per week for 6 months. Fatty changes in the liver and increased liver weights were observed. The NOAEL was 500 ppm in air. This was converted to a daily oral dose by adjusting for exposure duration and the assumed ventilation rate and body weight of the animals. It was also assumed that 30% of the inhaled material was absorbed. This resulted in an adjusted NOAEL of 90 mg/kg/day. An uncertainty factor of 1000 (10x for interspecies conversion, 10x for protection of sensitive populations, and 10x for lack of chronic data) was used to establish the oral RfD of $9x10^{-2}$ mg/kg/day. Although not listed on IRIS, HEAST presents an RfD_s of $9x10^{-1}$ mg/kg/day. The level of confidence in the oral RfD is medium. Although the database is fairly comprehensive, the results from these studies are somewhat inconsistent.

According to IRIS, a risk assessment for inhalation exposure to 1,1,1-trichloroethane in under review by an EPA work group. However, HEAST lists an RfD_i of 1 mg/m^3 based on the same study that forms the basis for the oral RfD. HEAST also lists an RfD_{si} of 10 mg/m^3, based on the same study. These values were used for the risk assessment.

EPA has classified 1,1,1-trichloroethane in Group D - Not Classified as to Human Carcinogenicity. The compound has been tested in two species with no evidence of a carcinogenic effect.

1,1,2-Trichloroethane

The oral RfD is based on two studies in which 1,1,2-trichloroethane was administered to mice in drinking water for 90 days. Clinical chemistry indications of adverse effects on the liver were seen at 2000 mg/L, while effects on the blood and immune status were seen at 200 and 2000 mg/L. The NOAEL was 20 mg/L, which was converted to an oral dosage of 3.9 mg/kg/day. An uncertainty factor of 1000 was used (10x for interspecies conversion, 10x for protection of sensitive populations, and 10x for lack of chronic data) to establish the RfD of $4x10^{-3}$ mg/kg/day. Although not listed in IRIS, HEAST presents an RfD_s of $4x10^{-2}$ mg/kg/day. The confidence in the oral RfD is rated as medium, based on the lack of chronic toxicity data.

1,1,2-Trichloroethane was administered in corn oil by gavage to male and female rats and mice. Significant increases in liver tumors were observed in mice of both sexes as well as adrenal tumors in female mice. Significant increases in tumor incidence were not found in rats of either sex. The incidence of liver tumors in male mice was used as the basis for calculation of the oral slope factor. The oral slope factor was $5.7x10^{-2}$ $(mg/kg/day)^{-1}$. The same data were used to calculate an inhalation slope factor of $1.6x10^{-5}$ $(ug/m^3)^{-1}$. Because a carcinogenic response was found in only one species, EPA has classified 1,1,2-trichloroethane in Group C - Possible Human Carcinogen.

Trichloroethene

An RfD is not available for trichloroethene. Potential noncarcinogenic effects were not evaluated.

IRIS reports only that the risk assessment for this chemical is under review. HEAST lists trichloroethene in Table B: Carcinogenicity with an oral slope factor of $1.1x10^{-2}$ $(mg/kg/day)^{-1}$. There is a reference to two gavage studies conducted in mice, and liver tumors formed the basis for the oral slope factor. An inhalation slope factor of $1.7x10^{-6}$ $(ug/m^3)^{-1}$ is listed based on two inhalation studies in mice which resulted in lung tumors. HEAST lists trichloroethene in Group B2 - Probable Human Carcinogen. Trichloroethene also appears on the list of chemicals known to cause cancer established under the California Safe Drinking Water and Toxic Enforcement Act.

Boron

The oral RfD is based on a study in which dogs and rats were fed boron as borax and boric acid for two years. Dogs were found to be the more sensitive species. Testicular atrophy and spermatogenic arrest were seen in both species at 1170 ppm in the diet. The NOAEL was 350 ppm boron equivalents, or 8.8 mg/kg/day in dogs and 17.5 mg/kg/day in rats. An uncertainty factor of 100 (10x for interspecies conversion and 10x for protection of sensitive populations) was used to establish the RfD of $9x10^{-2}$ mg/kg/day. According to HEAST, this value is also used as the RfD_s. The confidence in the RfD is medium, based on the limited numbers of animals used in the study and the lack of data on developmental toxicity.

Boron has not been classified by the EPA as to its carcinogenic potential.

Vanadium

Vanadium is not listed in IRIS. However, HEAST lists chronic and subchronic RfD values of $7x10^{-3}$ mg/kg/day. These are based on a study in which vanadium was administered as vanadium sulfate in drinking water to rats for lifetime exposure. According to HEAST, no effects were observed at the only dose tested (0.7 mg/kg/day). HEAST lists an uncertainty factor of 100.

Vanadium has not been classified by the EPA as to its carcinogenic potential.

Zinc

Zinc is also not listed in IRIS. HEAST lists chronic and subchronic RfD values of $2x10^{-1}$ mg/kg/day. These are based on a study in humans in which 2.14 mg/kg/day was used as a therapeutic dosage. The effect of concern was anemia. HEAST lists an uncertainty factor of 10.

Zinc has not been classified by the EPA as to its carcinogenic potential.

4.3 Uncertainties Related to Toxicity Information

As shown in Table 4-1, the confidence level in the RfD for 1,2-dichloroethene was low. This is because the database for this chemical is weak due to the lack of chronic studies and the lack of data on reproductive and developmental toxicity. The principal study on which the RfD was based was well-designed, although the doses were not logarithmically spaced, and allowed identification of both a LOAEL and a NOAEL. The confidence level in the remaining RfD values was medium.

Of the nine chemicals classified as carcinogens, three are in Group C - Possible Human Carcinogen. The Group C carcinogens are 1,1-dichloroethene, 1,1,2,2-tetrachloroethane, and 1,1,2-trichloroethane. In some cases (for pesticides registered under the Federal Insecticide, Fungicide, and Rodenticide Act, for example), quantitative risk assessment is not considered appropriate for carcinogens in Group C. This is because the confidence in the carcinogenicity data is not considered sufficient for the low-dose extrapolation procedures required for determination of a cancer potency

slope factor. Nonetheless, these three chemicals were included in the baseline risk assessment.

4.4 Summary of Toxicity Information

RfD values are available for 11 of the 14 chemicals of concern. The level of confidence in the RfD values ranges from low (only one chemical) to medium. Subchronic RfD values were available for all 11 chemicals. Inhalation RfD values were available for two. Nine of the chemicals of concern are classified as carcinogens by EPA. Of the nine, three are Group C - Possible Human Carcinogens; the remainder are Group B2 - Probable Human Carcinogens. Inhalation slope factors were available for three of these chemicals. Thus the risk assessment considered the potential for subchronic noncarcinogenic effects, chronic noncarcinogenic effects, and carcinogenic effects.

5.0 RISK CHARACTERIZATION

This section integrates the exposure assessment for each scenario with the toxicity assessment. For carcinogenic effects, the risk characterization is expressed as the probability of an individual developing cancer in his/her lifetime. For noncarcinogenic effects, a Hazard Index has been calculated to compare the calculated exposure to the EPA RfD. The following sections present the risk characterization for current land uses, assuming that contamination migrates to the wells in the future.

5.1 Current Land Use Conditions

The current land use conditions are those that are being considered for this baseline risk assessment. The area within and around OU B is currently being used for residential, commercial, and light industrial purposes. The residents on McClellan AFB, as well as the civilians working on the base, are currently users of the water from BW-18. Thus, this population represents the worst-case exposure scenario for BW-18. The residents living in the City of Sacramento adjacent to McClellan AFB OU B, who could be users of the water from CW-132 if it were in operation, represent the worst-case exposed population for this well.

5.1.1 Justification for Combining Pathways

In the residential exposure scenarios, the possible exposure pathways include ingestion of contaminated water, dermal absorption of contaminants from water while showering, and inhalation of contaminants volatilized to air from water during showering, running the dishwasher, or washing the laundry. The ingestion pathway assumes that all of the daily water intake is from the contaminated source. If that assumption is accepted, then it is entirely possible that a single individual could be exposed by all three of these pathways. Therefore it is appropriate to add all pathways together. The following discussion will present the risk characterization for each pathway separately, and then will combine the pathways for each scenario.

5.1.2 Carcinogenic Risk

Carcinogenic risks are expressed as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to potential carcinogens. Chemical-specific data are presented, as well as, total risks for each

pathway and for each exposure scenario. Tables presenting the chronic daily intake and resulting carcinogenic risk are found in Appendix H.

Base Well 18 Residential Exposure

This exposure scenario assumes that contaminated water from BW-18 is treated to remove contaminants before distribution. It also assumes that some exposure is taking place to contaminants that are present in the water, but not detected during testing after treatment. Table 5-1 summarizes chemical-specific and pathway-specific risks associated with residential exposure to water from BW-18. Total ingestion pathway risk using average water concentrations and average exposure assumptions is $6x10^{-7}$; using upper bound water concentrations and assumptions, total pathway risk is $2x10^{-6}$. Using average water concentrations and assumptions, the total pathway risk associated with dermal contact with contaminants in water during showering is $6x10^{-10}$; using the upper bound values, the total pathway risk is $5x10^{-9}$. Total inhalation pathway risk using average water contamination and exposure assumptions is $4x10^{-7}$; using upper bound values, the risk is $6x10^{-6}$. The greatest contribution to the inhalation pathway is the exposure resulting from the use of the washing machine, followed by use of the dish washer; exposure during showering provides a relatively small contribution (see Appendix H). Using average assumptions, the total risk for residential exposure to water from BW-18 is $9x10^{-7}$; using upper bound values, the risk for this exposure scenario is $8x10^{-6}$. As can be seen from the table, the greatest contribution to the risk is provided by the inhalation pathway. The chemical that provides the greatest contribution to the risk is 1,1-dichloroethene.

Base Well 18 Residential Exposure - 3-Year Tour of Duty

This scenario calculates exposures for military residents living on-base for a single tour of duty, which typically lasts for three years. The chemical-specific and total pathway risks for this exposure scenario are shown in Table 5-2. Since there are no differences between the average and upper bound exposure assumptions for the ingestion pathway and the differences between the average and upper bound groundwater concentrations are very small, there is essentially no difference in the total ingestion pathway risk. Total ingestion pathway risk is $2x10^{-7}$. For exposure resulting from dermal contact with contaminants while showering, the risks remain very small

TABLE 5-1. CARCINOGENIC RISK FOR BASE WELL 18 RESIDENTIAL EXPOSURE

	Exposure Pathway									
	Average					Upper Bound				
	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution
Carbon tetrachloride	4E-08	4E-11	5E-08	9E-08	10	1E-07	3E-10	8E-07	9E-07	11
Chloroform	4E-09	4E-12	6E-08	6E-08	7	1E-08	3E-11	9E-07	9E-07	11
1,2-Dichloroethane	3E-08	3E-11	4E-08	7E-08	8	1E-07	3E-10	6E-07	7E-07	9
1,1-Dichloroethene	3E-07	3E-10	1E-07	4E-07	43	1E-06	3E-09	1E-06	2E-06	25
Methylene Chloride	7E-09	7E-12	2E-08	3E-08	3	4E-08	8E-11	3E-07	3E-07	4
1,1,2,2-Tetrachloroethane	6E-08	6E-11	7E-08	1E-07	11	4E-07	9E-10	2E-06	2E-06	25
Tetrachloroethene	9E-08	9E-11	8E-09	1E-07	11	3E-07	8E-10	8E-08	4E-07	5
1,1,2-Trichloroethane	2E-08	2E-11	3E-08	5E-08	5	1E-07	3E-10	6E-07	7E-07	9
Trichloroethene	2E-08	2E-11	1E-08	3E-08	3	7E-08	2E-10	1E-07	2E-07	2
Total by Pathway	6E-07	6E-10	4E-07			2E-06	5E-09	6E-06		
Scenario Total				9E-07					8E-06	

TABLE 5-2. CARCINOGENIC RISK FOR BASE WELL 18 3-YEAR TOUR EXPOSURE

	Exposure Pathway									
	Average					Upper Bound				
	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution
Carbon tetrachloride	1E-08	1E-11	2E-08	3E-08	8	1E-08	3E-11	8E-08	9E-08	10
Chloroform	1E-09	1E-12	2E-08	2E-08	8	1E-09	3E-12	9E-08	9E-08	10
1,2-Dichloroethane	1E-08	1E-11	1E-08	2E-08	8	1E-08	3E-11	6E-08	7E-08	8
1,1-Dichloroethene	1E-07	1E-10	4E-08	1E-07	39	1E-07	3E-10	1E-07	2E-07	22
Methylene Chloride	3E-09	7E-12	6E-09	9E-09	3	4E-08	8E-12	3E-08	7E-08	8
1,1,2,2-Tetrachloroethane	2E-08	2E-11	2E-08	4E-08	15	4E-08	9E-11	2E-07	2E-07	22
Tetrachloroethene	3E-08	3E-11	3E-09	3E-08	12	3E-08	8E-11	8E-09	2E-08	2
1,1,2-Trichloroethane	7E-09	7E-12	9E-09	1E-08	4	1E-08	3E-11	6E-08	1E-07	11
Trichloroethene	7E-09	7E-12	5E-09	1E-08	4	7E-09	2E-11	1E-08	2E-08	2
Total by Pathway	2E-07	2E-10	1E-07			2E-07	5E-10	6E-07		
Scenario Total				3E-07					9E-07	

regardless of whether average or upper bound assumptions are used, ranging from 2 to $5x10^{-10}$. Using average water concentrations and exposure assumptions, the risk associated with inhalation exposure is $1x10^{-7}$; using upper bound values, the risk is $6x10^{-7}$. The total risks associated with this scenario are estimated to be $3x10^{-7}$; using upper bound values the estimate is $9x10^{-7}$. Again, the greatest contribution to the risk is provided by the inhalation pathway. The two chemicals responsible for most of the risks are 1,1-dichloroethene and 1,1,2,2-tetrachloroethane.

Base Well 18 Occupational Exposure

This scenario considers exposure of civilians working on the base for 30 years until retirement. The only pathway included is ingestion of drinking water while at work. The chemical-specific and total risks are summarized in Table 5-3. Using average water concentrations, the total pathway risk is $1x10^{-6}$; using upper bound water concentrations, the total pathway risk is $2x10^{-6}$. This probably represents an overestimate, however, since it was assumed that the entire 2-liter volume of fluid ingested each day consisted of water or beverages made from water on the base.

City Well 132 Residential Exposure

This scenario estimates risks for residents of the City of Sacramento if water from CW-132 was distributed in the public water supply after contamination arrived at the well. The chemical-specific and total pathway risks for this exposure scenario are presented in Table 5-4. Using average exposure assumptions, the total ingestion pathway risk is estimated at $2x10^{-6}$; using upper bound assumptions the risk is estimated to be $5x10^{-6}$. Chemical-specific and total pathway risks for exposure resulting from dermal contact while showering using average exposure assumptions are estimated to be $2x10^{-9}$; using upper bound assumptions, it is estimated at $1x10^{-8}$. Using average exposure assumptions, the risk associated with the inhalation pathway is estimated to be $8x10^{-7}$. Using the upper bound exposure assumptions, the risk is estimated to be $8x10^{-6}$. The greatest contribution to the risk associated with the inhalation pathway is provided by exposure while using the washing machine, followed by that while using the dishwasher (see Appendix H). The total risk for this exposure scenario using average assumptions is estimated to be $3x10^{-6}$; using upper bound exposure assumptions the total risk would be $1x10^{-5}$. The greatest contribution to the risk is provided by the inhalation pathway; the most important chemicals are trichloroethene and tetrachloroethene.

TABLE 5-3. CARCINOGENIC RISK FOR INGESTION PATHWAY; OCCUPATIONAL EXPOSURE: BW 18

Chemical	SF $(mg/kg/day)^{-1}$	Weight of Evidence	SF Source	CDI (mg/kg/day) Average	CDI (mg/kg/day) Upper Bound	Chemical-Specific Risk Average	Chemical-Specific Risk Upper Bound
Carbon tetrachloride	1.3E-01	B2	IRIS	7.2E-07	7.2E-07	9E-08	9E-08
Chloroform	6.1E-03	B2	IRIS	1.3E-06	1.3E-06	8E-09	8E-09
1,2-Dichloroethane	9.1E-02	B2	IRIS	8.1E-07	8.1E-07	7E-08	7E-08
1,1-Dichloroethene	6.0E-01	C	IRIS	1.1E-06	1.1E-06	7E-07	7E-07
Methylene chloride	7.5E-03	B2	IRIS	2.2E-06	3.1E-06	2E-08	2E-08
1,1,2,2-Tetrachloroethane	2.0E-01	C	IRIS	6.4E-07	1.3E-06	1E-07	3E-07
Tetrachloroethene	5.1E-02	B2	HEAST	4.0E-06	4.0E-06	2E-07	2E-07
1,1,2-Trichloroethane	5.7E-02	C	IRIS	8.1E-07	1.2E-06	5E-08	7E-08
Trichloroethene	1.1E-02	B2	HEAST	4.0E-06	4.0E-06	4E-08	4E-08
					Total Pathway Risk	1E-06	2E-06

TABLE 5-4. CARCINOGENIC RISK FOR CW-132 RESIDENTIAL EXPOSURE

	Exposure Pathway									
	Average					Upper Bound				
	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution
Carbon tetrachloride	5E-09	5E-12	6E-09	1E-08	0.4	2E-08	4E-11	9E-08	1E-07	1
Chloroform	2E-09	2E-12	3E-08	3E-08	1	7E-09	2E-11	5E-07	5E-07	5
1,2-Dichloroethane	2E-08	2E-11	2E-08	4E-08	1	6E-08	1E-10	3E-07	4E-07	4
1,1-Dichloroethene	2E-07	2E-10	6E-08	3E-07	10	5E-07	1E-09	6E-07	1E-06	10
Methylene Chloride	3E-09	3E-12	8E-09	1E-08	0.3	1E-08	2E-11	7E-08	8E-08	0.8
1,1,2,2-Tetrachloroethane	2E-09	2E-12	3E-09	5E-09	0.2	7E-09	2E-11	4E-08	5E-08	0.5
Tetrachloroethene	5E-07	5E-10	4E-08	5E-07	17	2E-06	4E-09	4E-07	2E-06	20
1,1,2-Trichloroethane	2E-10	2E-13	3E-10	5E-10	<0.1	7E-10	2E-12	4E-09	5E-09	<0.1
Trichloroethene	9E-07	9E-10	6E-07	2E-06	69	3E-06	7E-09	6E-06	9E-06	90
Total by Pathway	2E-06	2E-09	8E-07			5E-06	1E-08	8E-06		
Scenario Total				3E-06					1E-05	

5.1.3 Chronic Noncarcinogenic Effects

Unlike carcinogenic risks, noncarcinogenic effects are not presented as a probability of an individual suffering an adverse effect. Instead, the potential for noncarcinogenic effects is evaluated by comparing the daily intake over a specified time period with a reference dose derived for a similar exposure period. This comparison is made by dividing the daily intake by the RfD value; the quotient is defined as the Hazard Index. If the daily intake is equal to the RfD, the Hazard Index is equal to 1. If the Hazard Index is less than 1, it is unlikely that even sensitive populations would experience adverse health effects.

Base Well 18 Residential Exposure

Noncarcinogenic effects associated with water from BW-18 for adults are summarized in Table 5-5. Using the average water concentrations and assumptions, the Hazard Index associated with the ingestion pathway is 0.08; using upper bound values, the Hazard Index is 0.1. For dermal contact with contaminants during showering, using either average or upper bound values, the Hazard Index is extremely small ranging from $7x10^{-6}$ to $2x10^{-5}$. Using average water concentrations and exposure assumptions, the Hazard Index for the inhalation pathway is 0.009; using upper bound values, the Hazard Index is 0.04. The total Hazard Index for adults for all exposure pathways for this scenario is 0.09 using average water concentrations and exposure assumptions; using upper bound values, the Hazard Index is 0.2. These results indicate that the predicted exposures are not likely to result in adverse health effects in adults.

Noncarcinogenic effects for children for this exposure scenario are presented in Table 5-6. The total ingestion pathway Hazard Index for average water concentrations and exposure assumptions is 0.2; using upper bound values the total pathway Hazard Index is 0.3. As with the adult exposures, for the dermal contact pathway the Hazard Indices are very low, ranging from $1x10^{-5}$ to $3x10^{-5}$. Using average water concentrations and exposure assumptions, the Hazard Index for the inhalation pathway is 0.05. Using upper bound values, the Hazard Index is 0.2. The total Hazard Index for children for all pathways of chronic residential exposure using average values is 0.2; that using upper bound values is 0.5. These results indicate that chronic residential exposure of children to water from BW-18 is unlikely to result in adverse health effects.

TABLE 5-5. NONCARCINOGENIC RISK FOR ADULTS, BASE WELL 18 RESIDENTIAL EXPOSURE

	Exposure Pathway									
	Average					Upper Bound				
	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution
Carbon tetrachloride	4E-03	4E-06	5E-03	9E-03	10	4E-03	9E-06	2E-02	2E-02	11
Chloroform	5E-04	5E-07	6E-04	1E-03	1	5E-04	1E-06	3E-03	4E-03	2
1,1-Dichloroethene	4E-04	4E-07	6E-04	1E-03	1	4E-04	1E-06	2E-03	2E-03	1
1,2-Dichloroethene	7E-04	7E-07	9E-04	2E-03	2	7E-04	2E-06	4E-03	5E-03	3
Methylene Chloride	1E-04	1E-07	1E-05	1E-04	0.1	2E-04	4E-07	5E-05	3E-04	0.1
Tetrachloroethene	1E-03	1E-06	2E-03	3E-03	3	1E-03	3E-06	8E-03	9E-03	5
1,1,1-Trichlorethane	4E-05	4E-08	2E-05	6E-05	0.1	6E-05	1E-07	7E-05	1E-04	0.1
1,1,2-Trichloroethane	7E-04	7E-07	9E-04	2E-03	2	1E-03	3E-06	6E-03	7E-03	4
Boron	3E-02	-	-	3E-02	33	5E-02	-	-	5E-02	28
Vanadium	4E-02	-	-	4E-02	45	8E-02	-	-	8E-02	45
Zinc	1E-03	-	-	1E-03	1	1E-03	-	-	1E-03	1
Total Hazard Index by Pathway	8E-02	7E-06	9E-03			1E-01	2E-05	4E-02		
Total Hazard Index by Scenario				9E-02					2E-01	

TABLE 5-6. NONCARCINOGENIC RISK FOR CHILDREN, BASE WELL 18 RESIDENTIAL EXPOSURE

	Exposure Pathway									
	Average					Upper Bound				
	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution
Carbon tetrachloride	8E-03	6E-06	2E-02	3E-02	14	8E-03	2E-05	9E-02	1E-01	20
Chloroform	1E-03	7E-07	3E-03	4E-03	2	1E-03	2E-06	1E-02	1E-02	2
1,1-Dichloroethene	1E-03	7E-07	3E-03	4E-03	2	1E-03	2E-06	1E-02	1E-02	2
1,2-Dichloroethene	2E-03	1E-06	4E-03	6E-03	3	2E-03	3E-06	2E-02	2E-02	4
Methylene Chloride	3E-04	2E-07	1E-05	3E-04	0.1	4E-04	7E-07	5E-05	5E-04	0.1
Tetrachloroethene	3E-03	2E-06	9E-03	1E-02	5	3E-03	6E-06	3E-02	3E-02	6
1,1,1-Trichloroethane	1E-04	7E-08	2E-05	1E-04	<0.1	1E-04	2E-07	7E-05	2E-04	<0.1
1,1,2-Trichloroethane	2E-03	1E-06	4E-03	6E-03	3	2E-03	4E-06	3E-02	3E-02	6
Boron	6E-02	-	-	6E-02	28	1E-01	-	-	1E-01	20
Vanadium	9E-02	-	-	9E-02	42	2E-01	-	-	2E-01	40
Zinc	3E-03	-	-	3E-03	1	3E-03	-	-	3E-03	1
Total Hazard Index by Pathway	2E-01	1E-05	5E-02			3E-01	3E-05	2E-01		
Total Hazard Index by Scenario				2E-01					5E-01	

For both adults and children the exposure pathway providing the largest contribution to the possibility of noncarcinogenic effects is the ingestion pathway. The chemicals contributing the largest percentage to the Hazard Index are vanadium and boron, followed by carbon tetrachloride, for both adults and children.

Base Well 18 Military Exposure - 3-Year Tour of Duty

Noncarcinogenic effects in adults associated with exposure during a three-year tour of duty are presented in Table 5-7. The Hazard Index for the ingestion pathway using average water concentrations and exposure assumptions is 0.07; that using upper bound values is 0.1. Noncarcinogenic effects in adults resulting from dermal contact with contaminants while showering are very small, with Hazard Indices ranging from $2x10^{-6}$ to $4x10^{-6}$. The Hazard Index resulting from inhalation exposure using average exposure assumptions and water concentrations is 0.002; using upper bound assumptions the Hazard Index is 0.009. The total Hazard Index for all exposure pathways for adults during a three-year tour of duty is 0.07 using average water concentrations and exposure assumptions. Using upper bound values, the total Hazard Index is 0.1. These results indicate this exposure scenario is unlikely to result in adverse health effects in adults.

Noncarcinogenic effects in children associated with ingestion of contaminants are presented in Table 5-8. The Hazard Index for the ingestion pathway using average water concentrations and exposure assumptions is 0.2; that using upper bound values is 0.3. As expected, the Hazard Indices for the dermal contact pathway are very small, ranging from $3x10^{-6}$ to $7x10^{-6}$. The Hazard Index calculated for the inhalation pathway using average water concentrations and assumptions is 0.01; that calculated using upper bound assumptions is 0.04. The total Hazard Index for children exposed during a three-year tour of duty is 0.2 for average assumptions; that for upper bound assumptions is 0.3. These results indicate that this exposure scenario is not likely to result in adverse health effects in children.

For both adults and children exposed during a three-year tour of duty, the largest exposure is provided by the ingestion pathway. The greatest contribution to the Hazard Index is provided by vanadium and boron, followed by carbon tetrachloride, chloroform, and 1,1-dichloroethene.

TABLE 5-7. NONCARCINOGENIC RISK FOR ADULTS, BASE WELL 18 3-YEAR TOUR EXPOSURE

	Exposure Pathway									
	Average					Upper Bound				
	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution
Carbon tetrachloride	4E-04	4E-07	5E-04	9E-04	1	4E-04	9E-07	2E-03	2E-03	1
Chloroform	5E-04	5E-07	6E-04	1E-03	1	5E-04	1E-06	3E-03	4E-03	3
1,1-Dichloroethene	4E-04	4E-07	6E-04	1E-03	1	4E-04	1E-06	2E-03	2E-03	1
1,2-Dichloroethene	7E-05	7E-08	9E-05	2E-04	0.2	7E-05	2E-07	4E-04	5E-04	0.4
Methylene Chloride	1E-04	1E-07	1E-05	1E-04	0.1	2E-04	4E-07	5E-05	3E-04	0.2
Tetrachloroethene	1E-04	1E-07	2E-04	3E-04	0.4	1E-04	3E-07	8E-04	9E-04	0.6
1,1,1-Trichloroethane	4E-06	4E-09	2E-06	6E-06	<0.1	6E-06	1E-08	7E-06	1E-05	<0.1
1,1,2-Trichloroethane	7E-05	7E-08	9E-05	2E-04	0.3	1E-04	3E-07	6E-04	7E-04	0.5
Boron	3E-02	-	-	3E-02	40	5E-02	-	-	5E-02	35
Vanadium	4E-02	-	-	4E-02	54	8E-02	-	-	8E-02	57
Zinc	1E-03	-	-	1E-03	1	1E-03	-	-	1E-03	1
Total Hazard Index by Pathway	7E-02	2E-06	2E-03			1E-01	4E-06	9E-03		
Total Hazard Index by Scenario				7E-02					1E-01	

TABLE 5-8. NONCARCINOGENIC RISK FOR CHILDREN, BASE WELL 18 3-YEAR TOUR EXPOSURE

	Exposure Pathway									
	Average					Upper Bound				
	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution
Carbon tetrachloride	8E-04	6E-07	2E-03	3E-03	2	8E-04	2E-06	9E-03	1E-02	3
Chloroform	1E-03	7E-07	3E-03	4E-03	2	1E-03	2E-06	1E-02	1E-02	3
1,1-Dichloroethene	1E-03	7E-07	3E-03	4E-03	2	1E-03	2E-06	1E-02	1E-02	3
1-2-Dichloroethene	2E-04	1E-07	4E-04	6E-04	0.4	2E-04	3E-07	2E-03	2E-03	0.6
Methylene Chloride	3E-04	2E-07	1E-05	3E-04	0.2	4E-04	7E-07	5E-05	5E-04	0.1
Tetrachloroethene	3E-04	2E-07	9E-04	1E-03	0.6	3E-04	6E-07	3E-03	3E-03	0.9
1,1,1-Trichloroethane	1E-05	7E-09	2E-06	1E-05	<0.1	1E-05	2E-08	7E-06	2E-05	<0.1
1,1,2-Trichloroethane	2E-04	1E-07	4E-04	6E-04	0.4	2E-04	4E-07	3E-03	3E-03	0.9
Boron	6E-02	-	-	6E-02	36	1E-01	-	-	1E-01	29
Vanadium	9E-02	-	-	9E-02	54	2E-01	-	-	2E-01	59
Zinc	3E-03	-	-	3E-03	2	3E-03	-	-	3E-03	0.9
Total Hazard Index by Pathway	2E-01	3E-06	1E-02			3E-01	7E-06	4E-02		
Total Hazard Index by Scenario				2E-01					3E-01	

Base Well 18 Occupational Exposure

Noncarcinogenic effects in the population occupationally exposed by ingestion of contaminants while working on the base are presented in Table 5-9. Using average water concentrations, the Hazard Index is 0.05. Using upper bound concentrations, the Hazard Index is 0.09. These results indicate that exposure of civilians working on the base for an entire 30-year working lifetime is unlikely to result in adverse health effects.

City Well 132 Residential Exposure

Noncarcinogenic effects in adults exposed to contaminants by use of water supplied by CW-132, if it were in operation and following migration of contaminants to the well, are presented in Table 5-10. Only average water concentrations are available for CW-132, because upper bound values could not be reliably modeled. The Hazard Index for the ingestion pathway is 0.03; the value is the same for both the average case and the upper bound case because the volume of water ingested is the same for each. For the dermal exposure pathway the Hazard Indices are very small, ranging from $1x10^{-5}$ to $3x10^{-5}$. The Hazard Index for the inhalation pathway calculated using average exposure assumptions is 0.02; that using upper bound assumptions is 0.07. The total Hazard Index associated with this exposure scenario in adults using average assumptions is 0.05; using upper bound assumptions the Hazard Index is 0.08. These results indicate that this exposure scenario is unlikely to result in adverse health effects in adults.

Noncarcinogenic effects in children using water from CW-132 are presented in Table 5-11. The Hazard Index for the ingestion pathway is 0.07 for both the average and upper bound case. The Hazard Indices for the dermal contact pathway are very small, ranging from $2x10^{-5}$ to $5x10^{-5}$. The Hazard Index for the inhalation pathway calculated using average exposure assumptions is 0.07; that using upper bound assumptions is 0.3. The total Hazard Index for this scenario using average assumptions is 0.2; that using upper bound assumptions is 0.4. This indicates that exposure of children to water from CW-132 is unlikely to result in adverse health effects.

For exposure of adults and children to water from CW-132, assuming the well is put back in service and that migration of contaminants to the well has occurred,

TABLE 5-9. NONCARCINOGENIC EFFECTS ASSOCIATED WITH CHRONIC OCCUPATIONAL EXPOSURE

Chemical	RFD (mg/kg/day)	RFD Source	Level of Confidence	CDI (mg/kg/day)		Hazard Index	
				Average	Upper Bound	Average	Upper Bound
Carbon Tetrachloride	7.0E-04	IRIS	Medium	1.7E-06	1.7E-06	2E-03	2E-03
Chloroform	1.0E-02	IRIS	Medium	3.0E-06	3.0E-06	3E-04	3E-04
1,1-Dichloroethene	9.0E-03	IRIS	Medium	2.6E-06	2.6E-06	3E-04	3E-04
1,2-Dichloroethene	2.0E-02	IRIS	Low	9.4E-06	9.4E-06	5E-04	5E-04
Methylene Chloride	6.0E-02	IRIS	Medium	5.1E-06	7.1E-06	9E-05	1E-04
Tetrachloroethene	1.0E-02	IRIS	Medium	9.4E-06	9.4E-06	9E-04	9E-04
1,1,1-Trichloroethane	9.0E-02	IRIS	Medium	2.6E-06	3.6E-06	3E-05	4E-05
1,1,2-Trichloroethane	4.0E-03	IRIS	Medium	1.9E-06	2.8E-06	5E-04	7E-04
Boron	9.0E-02	IRIS	Medium	1.7E-03	3.0E-03	2E-02	3E-02
Vanadium	7.0E-03	HEAST	-	1.9E-04	3.8E-04	3E-02	5E-02
Zinc	2.0E-01	HEAST	-	1.9E-04	1.9E-04	9E-04	9E-04
				Total Hazard Index		5E-02	9E-02

TABLE 5-10. NONCARCINOGENIC RISK FOR ADULTS, CW-132 RESIDENTIAL EXPOSURE

	Exposure Pathway									
	Average					Upper Bound				
	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution
Carbon tetrachloride	4E-04	4E-07	5E-04	9E-04	2	4E-04	1E-06	2E-03	2E-03	3
Chloroform	3E-04	3E-07	3E-04	6E-04	1	3E-04	6E-07	1E-03	1E-03	1
1,1-Dichloroethene	2E-04	2E-07	3E-04	5E-04	1	2E-04	5E-07	1E-03	1E-03	1
1,2-Dichloroethene	4E-03	4E-06	4E-03	8E-03	17	4E-03	9E-06	2E-02	5E-03	6
Methylene Chloride	5E-05	5E-08	5E-06	6E-05	0.1	5E-05	1E-07	1E-05	6E-05	0.1
Tetrachloroethene	8E-03	7E-06	9E-03	2E-02	42	8E-03	2E-05	4E-02	5E-02	65
1,1,1-Trichloroethane	2E-05	2E-08	6E-06	3E-05	0.1	2E-05	4E-08	2E-05	4E-05	0.1
1,1,2-Trichloroethane	7E-06	7E-09	9E-06	2E-05	<0.1	7E-06	2E-08	4E-05	5E-05	0.1
Boron	1E-02	-	-	1E-02	20	1E-02	-	-	1E-02	13
Vanadium	8E-03	-	-	9E-03	17	8E-03	-	-	8E-03	10
Zinc	1E-03	-	-	1E-03	2	1E-03	-	-	1E-03	1
Total Hazard Index by Pathway	3E-02	1E-05	2E-02			3E-02	3E-05	7E-02		
Total Hazard Index by Scenario				5E-02					8E-02	

TABLE 5-11. NONCARCINOGENIC RISK FOR CHILDREN, CW-132 RESIDENTIAL EXPOSURE

	Exposure Pathway									
	Average					Upper Bound				
	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution
Carbon tetrachloride	9E-04	7E-07	3E-03	4E-03	3	9E-04	2E-06	1E-02	1E-02	3
Chloroform	6E-04	4E-07	2E-03	3E-03	2	6E-04	1E-06	6E-03	7E-03	2
1,1-Dichloroethene	5E-04	4E-07	1E-03	2E-03	1	5E-04	9E-07	5E-03	6E-03	2
1,2-Dichloroethene	8E-03	6E-06	2E-02	3E-02	20	8E-03	2E-05	9E-02	1E-01	27
Methylene Chloride	1E-04	8E-08	5E-06	1E-04	0.1	1E-04	2E-07	1E-05	1E-04	<0.1
Tetrachloroethene	2E-02	1E-05	5E-02	7E-02	46	2E-02	3E-05	2E-01	2E-01	55
1,1,1-Trichloroethane	4E-05	3E-08	7E-06	5E-05	<0.1	4E-05	6E-08	2E-05	6E-05	<0.1
1,1,2-Trichloroethane	2E-05	1E-08	4E-05	6E-05	<0.1	2E-05	3E-08	2E-04	2E-04	0.1
Boron	2E-02	-	-	2E-02	13	2E-02	-	-	2E-02	5
Vanadium	2E-02	-	-	2E-02	13	2E-02	-	-	2E-02	5
Zinc	3E-03	-	-	3E-03	2	3E-03	-	-	3E-03	1
Total Hazard Index by Pathway	7E-02	2E-05	7E-02			7E-02	5E-05	3E-01		
Total Hazard Index by Scenario				2E-01					4E-01	

the greatest contribution to the potential for noncarcinogenic effects is provided by the ingestion pathway. The chemical that provides the greatest percentage contribution to the overall Hazard Index is tetrachloroethene, followed by boron and vanadium.

5.1.4 Subchronic Exposure

Subchronic exposure may occur if the treatment system for BW-18 fails, and water containing contaminants is allowed to enter the distribution system. The resulting noncarcinogenic effects in adults living on the base are presented in Table 5-12. Using the average water concentrations, the Hazard Index for the ingestion pathway is 0.07; using upper bound values, the Hazard Index is 0.1. The dermal contact Hazard Index ranges from $3x10^{-6}$ to $1x10^{-5}$. The Hazard Index for the inhalation pathway using average water concentrations is 0.003; that using upper bound assumptions is 0.01. The total Hazard Index for subchronic exposure in adults using average water concentrations is 0.08; that for upper bound concentrations is 0.1. This indicates that subchronic exposure resulting from failure of the BW-18 treatment system is unlikely to result in adverse health effects in adults.

For children, noncarcinogenic effects resulting from subchronic exposure are summarized in Table 5-13. The Hazard Index using the average water concentrations for the ingestion pathway is 0.2; that using the upper bound concentration is 0.3. For the dermal contact pathway, the Hazard Index ranges from $4x10^{-6}$ to $2x10^{-5}$. The Hazard Index calculated for the inhalation pathway using average predicted water concentrations is 0.02; that using upper bound concentrations is 0.06. The total Hazard Index calculated for children using average water concentrations is 0.2; that using upper bound concentrations is 0.4. These results indicate this exposure scenario will probably not result in unacceptable exposures for children.

The noncarcinogenic effects associated with subchronic occupational exposure are presented in Table 5-14. Using average modeled water concentrations, the Hazard Index is 0.05. Using the upper bound water concentrations, the Hazard Index is 0.1. These results indicate that a failure of the treatment system for BW-18 will not result in adverse health effects for civilians working on the base.

For all subchronic exposure scenarios, the greatest contribution to the potential for noncarcinogenic effects is provided by the ingestion pathway.

TABLE 5-12. NONCARCINOGENIC RISK FOR ADULTS, BASE WELL 18 SUBCHRONIC EXPOSURE

	Exposure Pathway									
	Average					Upper Bound				
	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution
Carbon tetrachloride	4E-04	4E-07	5E-04	9E-04	1	4E-04	9E-07	2E-03	2E-03	1
Chloroform	5E-04	5E-07	6E-04	1E-03	1	5E-04	1E-06	2E-03	3E-03	2
1,1-Dichloroethene	4E-04	4E-07	6E-04	1E-03	1	4E-04	1E-06	2E-03	2E-03	1
1,2-Dichloroethene	1E-03	9E-07	1E-03	2E-03	3	2E-03	5E-06	7E-03	9E-03	6
Methylene Chloride	1E-04	1E-07	1E-05	1E-04	0.1	2E-04	4E-07	5E-05	3E-04	0.2
Tetrachloroethene	2E-04	2E-07	3E-04	5E-04	0.7	2E-04	6E-07	1E-03	1E-03	0.7
1,1,1-Trichloroethane	4E-06	4E-09	2E-06	6E-06	<0.1	6E-06	1E-08	7E-06	1E-05	<0.1
1,1,2-Trichloroethane	7E-05	7E-08	1E-04	2E-04	0.3	1E-04	3E-07	4E-04	5E-04	0.3
Boron	3E-02	-	-	3E-02	39	5E-02	-	-	5E-02	34
Vanadium	4E-02	-	-	4E-02	52	8E-02	-	-	8E-02	54
Zinc	1E-03	-	-	1E-03	1	1E-03	-	-	1E-03	0.7
Total Hazard Index by Pathway	7E-02	3E-06	3E-03			1E-01	1E-05	1E-02		
Total Hazard Index by Scenario				8E-02					1E-01	

TABLE 5-13. NONCARCINOGENIC RISK FOR CHILDREN, BASE WELL 18 SUBCHRONIC EXPOSURE

	Exposure Pathway									
	Average					Upper Bound				
	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution	Ingestion	Dermal Contact	Inhalation	Total	Percent Contribution
Carbon tetrachloride	8E-04	6E-07	2E-03	3E-03	2	8E-04	2E-06	6E-03	7E-03	2
Chloroform	1E-03	7E-07	3E-03	4E-03	2	1E-03	2E-06	8E-03	9E-03	2
1,1-Dichloroethene	1E-03	7E-07	3E-03	4E-03	2	1E-03	2E-06	8E-03	9E-03	2
1,2-Dichloroethene	2E-03	2E-06	6E-03	8E-03	5	5E-03	9E-06	3E-02	4E-02	11
Methylene Chloride	3E-04	2E-07	1E-05	3E-04	0.2	4E-04	7E-07	5E-05	5E-04	0.1
Tetrachloroethene	5E-04	4E-07	2E-03	3E-03	2	5E-04	9E-07	4E-03	5E-03	1
1,1,1-Trichloroethane	1E-05	7E-09	2E-06	1E-05	<0.1	1E-05	2E-08	7E-06	2E-05	<0.1
1,1,2-Trichloroethane	2E-04	1E-07	5E-04	7E-04	0.4	2E-04	4E-07	2E-03	2E-03	0.5
Boron	6E-02	-	-	6E-02	34	1E-01	-	-	1E-01	27
Vanadium	9E-02	-	-	9E-02	51	2E-01	-	-	2E-01	53
Zinc	3E-03	-	-	3E-03	2	3E-03	-	-	3E-03	0.8
Total Hazard Index by Pathway	2E-01	4E-06	2E-02			3E-01	2E-05	6E-02		
Total Hazard Index by Scenario				2E-01					4E-01	

TABLE 5-14. NONCARCINOGENIC EFFECTS ASSOCIATED WITH SUBCHRONIC OCCUPATIONAL INGESTION EXPOSURE

Chemical	RFDs (mg/kg/day)	RFDs Source	Level of Confidence	CDI (mg/kg/day) Average	CDI (mg/kg/day) Upper Bound	Hazard Index Average	Hazard Index Upper Bound
Carbon Tetrachloride	7.0E-03	HEAST	Medium	1.8E-06	1.8E-06	3E-04	3E-04
Chloroform	1.0E-02	HEAST	Medium	3.3E-06	3.3E-06	3E-04	3E-04
1,1-Dichloroethene	9.0E-03	HEAST	Medium	2.9E-06	2.9E-06	3E-04	3E-04
1,2-Dichloroethene	2.0E-01	HEAST	Low	1.4E-04	3.2E-04	7E-03	2E-03
Methylene Chloride	6.0E-02	HEAST	Medium	5.5E-06	7.8E-06	9E-05	1E-04
Tetrachloroethene	1.0E-01	HEAST	Medium	1.7E-05	1.7E-05	2E-04	2E-04
1,1,1-Trichloroethane	9.0E-01	HEAST	Medium	2.9E-06	3.9E-06	3E-06	4E-06
1,1,2-Trichloroethane	4.0E-01	HEAST	Medium	2.0E-06	3.1E-06	5E-05	8E-05
Boron	9.0E-02	HEAST	Medium	1.8E-03	3.3E-03	2E-02	4E-02
Vanadium	7.0E-03	HEAST	-	2.0E-04	4.1E-04	3E-02	6E-02
Zinc	2.0E-01	HEAST	-	2.0E-04	2.0E-04	1E-03	1E-03
				Total Hazard Index		5E-02	1E-01

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5.2 Future Land Use Conditions

Substantial changes in land-use patterns for the area within and adjacent to OU B are not expected. This baseline risk assessment considers current land-use conditions, but with contamination conditions expected to occur in the future, if the migration of contaminants in OU B is left unchecked. Thus, the scenarios presented represent future conditions as they are modeled to occur, rather than current conditions. However, it is expected that the population residing and working in the off-base areas will increase. Thus, the population exposed and potentially at-risk could increase, even if the overall land-use conditions do not change.

5.3 Uncertainties

This section discusses the uncertainties associated with the risk characterization. These include site-specific factors, as well as, uncertainties arising in the risk characterization due to the inherent uncertainties in the toxicity assessment.

5.3.1 Key Site-specific Uncertainties

One important source of uncertainty relates to modeling the movement of contaminants toward CW-132. Sufficient data were available for an analytical modeling approach for the movement of contaminants toward BW-18. In fact, the approach used presented both a reasonable-case estimate and an upper bound estimate of the level of contamination expected at BW-18. The data were not sufficient to model conditions surrounding CW-132 with the same degree of precision, however. Thus uncertainty exists as to the magnitude of contamination that can be expected to arise there.

Another source of uncertainty is the amount of contamination that is present in OU B and the effect this will have on the future contamination of the groundwater in this area. For wells in the A, B, and C geohydrologic zones for which sequential data are available, a trend toward increasing concentrations of trichloroethene is evident (see Appendix B). Data for the D geohydrologic zone suggest the level of contamination in this zone is stable at this time. The 1990 data were used for modeling the migration of contamination toward BW-18 and CW-132. If the concentrations of contaminants in groundwater were to continue to increase, the concentrations predicted to occur at BW-18 and CW-132 would also be higher, potentially increasing the overall likelihood of carcinogenic and noncarcinogenic effects.

5.3.2 Toxicity Assessment Uncertainties

All of the organic chemicals found in the groundwater underlying OU B have the potential to affect the liver. This combination of chemicals has not been tested to ascertain the possibility of their exerting synergistic effects. However, given that all could damage the liver to some extent, and that the liver is the major site of detoxication for these as well as other chemicals, the possibility of a synergistic effect exists. The likelihood of this effect occurring, as well as its magnitude should it occur, is impossible to assess.

The effect expected to result from vanadium exposure is unknown, since no effects were identified in the study used as the basis for the RfD. The other metals that were included in the risk assessment present different types of effects and would not be expected to contribute to possible synergistic effects. Boron and vanadium contributed the greatest portion of the potential noncarcinogenic effects in all exposure scenarios. For water obtained from BW-18, the modeled concentrations of boron and vanadium used may overestimate the levels that can reasonably be detected, because information on the ability of the treatment system to remove metals is not available at this time. Since the treated water is not routinely analyzed for metals, detection limits are not available to use in the chronic and three-year tour exposure scenarios.

Evaluation of the chemical-specific tables reveals that one of the greatest contributors to the carcinogenic risk is 1,1-dichloroethene. The weight-of-evidence for this chemical is Group C - Possible Human Carcinogen. This chemical contributes as much as half of the overall risk on a per-pathway basis. To a certain extent, the fact that half of the risk is provided by a chemical with a weight-of-evidence classification no stronger than Group C reduces somewhat the strength of the overall risk assessment.

Trichloroethene is a contaminant currently found at relatively high concentrations in OU B and the concentrations of this chemical predicted to occur at BW-18 and CW-132 are the highest of any of the organics. However, an RfD is not currently available for this chemical, so it was not included in the assessment of subchronic or chronic noncarcinogenic effects. Thus, the estimates of these effects may be lower than would be possible if an RfD were available for trichloroethene.

Substantial uncertainty exists in evaluating the residential exposure scenarios, since the exposure is expected to occur over less than a lifetime. Substantial scientific debate has occurred over the existence of a threshold for carcinogenic effects.

To the extent that a threshold may exist, calculation of a carcinogenic risk based on exposures that occur over less than a lifetime may overestimate the true likelihood of a carcinogenic effect.

As described in the introductory section, this baseline risk assessment addresses only the groundwater pathway. It is possible that other pathways of exposure, such as direct or indirect contact with contaminated soil, exist within OU B that are not taken into account in this risk assessment. However, these are expected to be unimportant for off-base residents using water from CW-132, because this population is not likely to have access to the site. Other such pathways could be important for residents on-base, who could have other routes of exposure in addition to the groundwater pathway. These other possible pathways, as well as the groundwater pathway, will be considered in detail in the RI/FS process.

5.4 Comparison of Risk Characterization Results to Human Studies

An Agency for Toxic Substances and Disease Registry health assessment is not available for this site. No site-specific human studies have been conducted.

5.5 Summary Discussion and Tabulation of Risk Characterization

This section summarizes the results of the risk characterization and identifies the key exposure pathways and contaminants, the major factors driving the risk, and the major factors driving the uncertainties.

5.5.1 Key Site-related Contaminants and Key Exposure Pathways Identified

The site-related contaminants that provide the greatest contribution to the carcinogenic risk are 1,1-dichloroethene and 1,1,2,2-tetrachloroethane for BW-18 and trichloroethene and tetrachloroethene for CW-132. For potential noncarcinogenic effects, the greatest contribution is provided by vanadium and boron. The potential for noncarcinogenic effects resulting from VOCs is smaller. The greatest contributors are carbon tetrachloride, chloroform, and 1,1-dichloroethene for BW-18 chronic exposure; 1,2-dichloroethene for BW-18 subchronic exposure; and tetrachloroethene and 1,2-dichloroethene for CW-132 exposure. The most important pathway is ingestion of drinking water containing contaminants.

Types of Health Risk of Concern

As shown in Section 4.0, all of the organic chemicals have the potential to affect the liver. Therefore the type of health risk of concern involves diseases of the liver. These diseases could potentially include noncarcinogenic effects as well as development of neoplastic liver disease. Liver disease is fairly common in the US population and therefore a relatively high background rate of these diseases would be expected in the potentially exposed population. A high background rate might make it difficult to distinguish a superimposed health effect associated with exposure to contaminants originating in OU B.

Confidence in Key Exposure Estimates for Key Exposure Pathways

As indicated in each of the previous sections, there are uncertainties associated with all portions of the risk assessment. These uncertainties tend to reduce the confidence associated with each of the steps in the risk assessment. In the aggregate, the uncertainties reduce the overall confidence in the results of this baseline risk assessment. Because the level of confidence assigned by EPA to the RfD values was no greater than Medium, the level of confidence in the risk assessment as a whole can be no better than Medium. There are major uncertainties associated with a few of the exposure assumptions, notably those required for calculating exposures while using the washing machine and the dishwasher. These pathways were important contributors to the overall risk characterization. For carcinogenic risks, the inhalation pathway was most important when upper bound water concentrations and exposure assumptions were used. This may reflect the greater range of exposures possible by the inhalation pathway rather than true risk posed. The uncertainties associated with the dishwasher and washing machine exposure pathways have some importance in the level of confidence in the risk assessment as a whole because of the importance of the inhalation pathway. Because greater uncertainty was associated with an important contributor to the overall risk, the overall level of confidence in the risk assessment can be no better than Medium.

5.5.2 Magnitude of the Carcinogenic and Noncarcinogenic Risk Estimates

The risks estimated for each scenario are summarized in Table 5-15. The greatest risk is associated with the use of contaminated water from CW-132. It should be emphasized that, as yet, contamination has not been demonstrated in this well; more importantly, this well is not in service. The estimated risks associated with use of water

TABLE 5-15. SUMMARY OF CARCINOGENIC RISKS BY EXPOSURE SCENARIO

Pathway	Carcinogenic Risk	
	Average	Upper Bound
BW-18		
Residential	9E-07	8E-06
3-Year Tour-of-Duty	3E-07	9E-07
Occupational	1E-06	2E-06
CW-132		
Residential	3E-06	1E-05

from this well indicate that CW-132 should not be used for service after contamination arrives. Although higher levels of contamination are predicted to occur at BW-18 than at CW-132, the risks associated with residential use of water from BW-18 are lower. This is because of the treatment system in use to remove contaminants from the water prior to distribution. The risks estimated for the residential, three-year tour of duty, and occupational scenarios are very conservative, because concentrations of contaminants at the detection limits were assumed to be present in the water distributed. The actual concentrations in the water are expected to be much lower and therefore the risks associated with use of the water will also be lower. Since it is not possible to estimate how much lower those concentrations might be, the appropriate, conservative method for risk assessment purposes is to use the detection limit. This method may not, however, be useful for purposes of risk communication because using the detection limit overestimates the actual amount of contamination present. The risks estimated for occupational exposure are larger than those estimated for residential exposure. This is because the average residential scenario assumes nine years of exposure at a residence, as directed by the current Superfund guidance, whereas the average occupational scenario assumes 30 years of exposure at work.

The risks of noncarcinogenic effects are summarized in Table 5-16. All exposure scenarios result in predicted contaminant intakes that are unlikely to result in adverse health effects for adults and children. Hazard Indices are typically higher for children than for adults. This is due primarily to the greater volume of fluid intake per unit body weight in children than in adults and is a reflection of children's relatively higher metabolic rates. The higher Hazard Indices for children, however, are well below one, the benchmark value for acceptable exposure.

Major Factors Driving Risk

The carcinogenic risks and potential noncarcinogenic effects calculated for this baseline risk assessment are hypothetical, in that the assessment considered modeled concentrations of contaminants predicted to occur at some time in the future if no removal actions are undertaken. No contamination has yet been found at CW-132, and the risk assessment for BW-18 considered hypothetical future concentrations of contaminants.

The major factor driving the risk is the ingestion pathway. The major chemical driving the carcinogenic risk for BW-18 is 1,1-dichloroethene, followed by

TABLE 5-16. SUMMARY OF NONCARCINOGENIC RISKS BY EXPOSURE SCENARIO

Scenario	Hazard Index			
	Children		Adults	
	Average	Upper Bound	Average	Upper Bound
Chronic				
BW-18				
Residential	0.2	0.5	0.09	0.2
3-Year Tour-of-Duty	0.2	0.3	0.07	0.1
Occupational	-	-	0.05	0.09
CW-132				
Residential	0.2	0.4	0.05	0.08
Subchronic				
BW-18				
Residential	0.2	0.4	0.08	0.1
3-Year Tour-of-Duty	0.2	0.4	0.08	0.1
Occupational	-	-	0.05	0.1

1,1,2,2-tetrachloroethane. For CW-132 the major chemicals are trichloroethene and tetrachloroethene. The major chemicals driving the noncarcinogenic effects are vanadium and boron for BW-18, followed by carbon tetrachloride and tetrachloroethene. For CW-132, the most important chemical is tetrachloroethene followed by 1,2,-dichloroethene. The most important pathway for noncarcinogenic effects is ingestion for the average case and inhalation for the upper bound case.

Major Factors Driving the Uncertainties

For BW-18, the major chemicals driving the risk (1,1-dichloroethene and 1,1,2,2-tetrachloroethene) are those which have the lowest weight-of-evidence classification usable for a risk assessment. This reduces the overall confidence in the risk assessment, because of the greater degree of uncertainty associated with the prediction of carcinogenic effects for chemicals with the weaker classification. For CW-132, the major chemicals driving the risk are under review. Tetrachloroethene is under review by the Carcinogen Risk Assessment Verification Endeavor (CRAVE) Workgroup, which may result in a change in the slope factor. The slope factor for trichloroethene has been removed from IRIS pending further review (the value used was obtained from HEAST); this indicates there may also be a change in the slope factor for this chemical. This also reduces the confidence in the outcome of the risk assessment somewhat.

For the determination of noncarcinogenic effects, a major uncertainty is the lack of an RfD for trichloroethene, a contaminant predicted to occur in high concentrations relative to those of the other chemicals. Additional uncertainty is provided by the relatively large contribution of boron and vanadium to the Hazard Index. The extent to which these metals are removed by the treatment system for BW-18 is unknown. Moreover, the exposure assessment assumed 100% absorption of these chemicals from the gastrointestinal tract, which is unlikely to occur. The potential chronic effects of exposure to vanadium are unknown, since the RfD is based on a study in which no effects were observed. Finally, chronic effects attributable to exposure to boron and vanadium are likely to be different from those associated with exposure to VOCs, so adding the Hazard Indices for the metals to those of the VOCs will tend to overestimate the likelihood of adverse health effects.

6.0 SUMMARY

This section presents a summary overview of the baseline risk assessment conducted as part of the EE/CA-EA for OU B of McClellan AFB.

6.1 Chemicals of Potential Concern

The contaminants of potential concern in OU B were selected on the basis of the quality of the available data and whether or not the compounds were potentially site-related. A "snap-shot" approach was implemented to select a specific data set to be used in the quantitative risk assessment. The most recent data, from January, 1990, was selected as the primary data set. All other data were used in a qualitative analysis to determine if there were any historically significant changes in concentrations. Some contaminants detected in the January, 1990, sampling and analysis effort were eliminated from the quantitative risk assessment based on data evaluation - background comparisons, frequency of detection, and evaluation of quantitation limits. This included two EPA-designated Group A carcinogens, benzene, and vinyl chloride, which were eliminated from the initial contaminant list because of their low concentrations, infrequent occurrence, and unconfirmed analytical results.

The chemicals selected for the baseline risk assessment are listed in Table 6-1.

6.2 Exposure Assessment

This assessment was limited in scope to exposure pathways originating with contaminants in the groundwater beneath OU B and associated with the use of BW-18 and CW-132. Environmental fate and transport modeling was used to predict the magnitude of contamination which could migrate to the two supply wells. Since the original source(s) for the contaminants in the groundwater have not been identified and evaluated, potential pathways of exposure unrelated to the groundwater medium have not been examined. Potentially applicable transport and fate mechanisms could include, for example, volatilization of chemicals to the air and fugitive dust generation from shallow contaminants and surface soils and surface runoff.

Complete exposure pathways that exist at the site include: 1) groundwater migration to potable well; ingestion of drinking water; 2) groundwater migration to

TABLE 6-1. SUMMARY OF CHEMICALS OF POTENTIAL CONCERN AT McCLELLAN AFB OU B

Chemicals	CAS Number
Carbon Tetrachloride	56-23-5
Chloroform	67-66-3
Dichloroethane, 1,2-	107-06-2
Dichloroethene, 1,1-	75-35-4
Dichloroethene, 1,2-	156-60-5
Methylene Chloride	75-09-2
Tetrachloroethane, 1,1,2,2-	79-34-5
Tetrachloroethene	127-18-4
Trichloroethane, 1,1,1-	71-55-6
Trichloroethane, 1,1,2-	79-00-5
Trichloroethene	79-01-6
Boron	7440-42-8
Vanadium	7440-62-2
Zinc	7440-66-6

potable well; skin contact with drinking water; 3) groundwater migration to potable well; volatilization of volatiles during home use; inhalation of vapors (e.g., while showering, washing clothes, or washing dishes); and 4) groundwater migration to potable well; use of water to irrigate backyard garden; root uptake by plants; ingestion of fruits and vegetables.

Of these pathways, the first three are considered potentially significant. The fourth pathway was not quantified for this risk assessment because the majority of chemicals of concern are volatile and will tend to volatilize from the soil surface before significant plant uptake can occur. The exposure resulting from the irrigation pathway was considered to have a much lower potential for human exposure than drinking water from the same source, a pathway which was quantified.

The primary point at which human exposure to contaminants detected beneath OU B may occur is at the tap in homes and workplaces on-base and off-base that are serviced by water drawn from wells in the path of the migrating contaminant plumes. The exposure scenarios that were evaluated in this risk assessment were residential, 3-year tour-of-duty, and occupational. Use of water by residents can lead to exposure via ingestion of the water, skin contact with the water, and inhalation of vapors released from the water as it leaves the tap. Use of the water by workers can lead to exposure by the same routes; however, skin contact and inhalation of vapors are less significant for workers. Activity patterns of on-base civilian workers and off-base office and industrial workers do not typically include showering, washing dishes, and washing clothes. These primarily domestic activities involve the greatest potential for skin contact with the water and the release of vapors which can be inhaled.

Probable future land uses in the vicinity of the base -- increased industrial/commercial development and increased density of residential housing will not alter these exposure points and exposure routes unless the source of potable water distributed to on-base and off-base residence and workplaces changes. The size of the potentially exposed population off-base will increase, however.

Table 6-2 summarizes the exposure scenarios which were evaluated in this risk assessment.

TABLE 6-2. EXPOSURE SCENARIOS

Description	Brief Rationale
Chronic Exposure	
On-Base Residential/Lifetime • Child • Adult	The base houses a residential community for military personnel and families. The base water system draws from the groundwater at the site.
On-Base Residential/3-Year Tour of Duty • Child • Adult	Three years is the typical tour of duty for military personnel. It is unlikely that any one person will reside on-base for a lifetime.
On-Base Worker (Adult)	Civilian personnel work on base, but reside off base.
Off-Base Residential • Child • Adult	The city water system draws from the groundwater downgradient from the base.
Subchronic Exposure	
On-Base Residential (Applicable to Both Lifetime and 3-Year Tour of Duty Scenarios) • Child • Adult	The base monitoring and treatment system could fail, allowing untreated groundwater to be distributed to residences and work stations for a period of time before the failure is detected and corrected.
On-Base Worker (Adult)	Same as above.

6.3 Toxicity Assessment

Chronic and subchronic exposures were considered in this risk assessment for potential noncarcinogenic effects. The chronic exposure scenarios include residential and occupational exposure occurring from use of water from BW-18 and residential exposure from use of water from CW-132. The chronic RfD values presented in Table 6-3 were used for calculating Hazard Indices for these scenarios. The subchronic exposure scenario includes exposure for a maximum of 30 days to water from BW-18 that is contaminated due to a failure of the treatment system. The RfD_s values, also presented in Table 6-3, were used in calculation of Hazard Indices for the subchronic exposure scenario. Use of the RfD_s is considered appropriate for exposure periods of two weeks to seven years (EPA, 1989a). For carcinogenic effects, exposure was averaged over a lifetime (EPA, 1989a).

The RfD values for the chemicals of concern presented in Table 6-3 were obtained from an IRIS search dated May 21, 1990, or from the EPA Health Effects Assessment Summary Tables (HEAST 4th Quarter, 1989). No RfD values are currently available for 1,2-dichloroethane, 1,1,2,-tetrachloroethane, or trichloroethene. Inhalation RfD2 values are only available for methylene chloride and 1,1,1-trichloroethane. The oral RfD for 1,1,1-trichloroethane was calculated from the inhalation RfD based on route-to-route extrapolation. It should be noted that the RfD for vanadium is based on a dosage at which no effects were observed; an uncertainty factor of 100 was also applied to this dosage.

The slope factors and weight-of evidence classifications for all chemicals of concern that have been classified by EPA as to their carcinogenic potential are presented in Table 6-4. The values presented were obtained from an IRIS search dated May 21, 1990. Several chemicals on the list of chemicals of concern have not been classified as carcinogens. These include 1,2-dichloroethene, boron, vanadium, and zinc. Three of the chemicals have been classified in Group C - Possible Human Carcinogen; the remainder were classified by EPA as Group B2 - Probable Human Carcinogen (sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans). EPA has classified 1,1,1-trichloroethane in Group D - Not Classifiable as to Human Carcinogenicity. It has been tested in two species with no evidence of a carcinogenic effect.

In summary, RfD values were available for 11 of the 14 chemicals of concern. The level of confidence in the RfD values ranged from low (only one Table

TABLE 6-3. TOXICITY VALUES: POTENTIAL NONCARCINOGENIC EFFECTS'

Chemical	Chronic RfD (mg/kg-day)	RfDs (mg/kg-day)	Confidence Level	Critical Effect	RfD Study Type/ RfD Source	Uncertainty and Modifying Factors (UF-RfD;RfDs)
Oral Route						
Carbon tetrachloride	7.0E-04	7.0E-03	Medium	Liver Lesions	Gavage/ IRIS a	UF=1000; 100 MF=1
Chloroform	1.0E-02	1.0E-02	Medium	Fatty cyst formation in liver	Oral/ IRIS a	UF=1000; 1000 MF=1
Dichloroethene, 1,1-	9.0E-03	9.0E-03	Medium	Hepatic lesions	Water/ IRIS a	UF=1000; 1000 MF=1
Dichloroethene, 1,2-	2.0E-02	2.0E-01	Low	Increased serum alkaline phosphatase in male mice	Water/ IRIS a	UF=1000; 100 MF=1
Methylene chloride	6.0E-02	6.0E-02	Medium	Liver toxicity	Water/ IRIS a	UF=100; 100 MF=1
Tetrachloroethene	1.0E-02	1.0E-01	Medium	Hepatotoxicity in mice, weight gain in rats	Gavage/ IRIS a	UF=1000; 100 MF=1
Trichloroethane, 1,1,1-	9.0E-02	9.0E-01	Medium	No adverse effects Slight growth retardation	Inhalation/ IRIS a	UF=1000; 100 MF=1
Trichloroethane, 1,1,2-	4.0E-03	4.0E-02	Medium	Clinical serum chemistry	Water/ IRIS a	UF=1000; 100 MF=1
Boron	9.0E-02	9.0E-02	Medium	Testicular lesions	Diet/ IRIS a	UF=100; 100

(Continued)

TABLE 6-3. CONTINUED

Chemical	Chronic RfD (mg/kg-day)	RfDs (mg/kg-day)	Confidence Level	Critical Effect	RfD Study Type/ RfD Source	Uncertainty and Modifying Factors (UF-RfD;RfDs)
Vanadium	7.0E-03	7.0E-03		None observed HEAST	Water/HEAST[c]	UF=100; 100
Zinc	2.0E-01	2.0E-01		Anemia	Therapeutic dosage/HEAST	UF=10; 10
Inhalation route	(mg/m^3)	(mg/m^3)				
Methylene chloride	3.0E+00	3.0E+00		NA	Inhalation/ HEAST	UF=100; 100 MF=1
(equivalent oral RfD)b	9.0E-01	9.0E-01				
Trichloroethane, 1,1,1-	1.0E+00	1.0E+01		Hepatotoxicity	Inhalation/ HEAST	UF=1000; 100 MF=1
(equivalent oral RfD)b	3.0E-01	3.0E+00				

a Integrated Risk Information Service, search dated May 21, 1990.
b Equivalent oral RfD calculated assuming 20 m^3 daily inhalation volume and 70 kg body weight.
c US EPA Health Effects Assessment Summary Tables (HEAST), 4th Quarter 1989.

TABLE 6-4. TOXICITY VALUES: POTENTIAL CARCINOGENIC EFFECTS

Chemical	Slope Factor (SF) 1/(mg/kg-day)	Inhalation Slope Factor (SF) $1/\mu g/m^3$ [1/(mg/kg-day)]	EPA Weight-of-Evidence Classification	Type of Cancer	SF Study Type (Inhalation;Oral)/ SF Source
Carbon tetrachloride	1.3E-01[a]	1.5E-05[a,b,g] [1.3E-01][a,b] [5.2E-02][g]	B2	Hepatocellular carcinomas/ hepatomas	Gavage; gavage/ IRIS *
Chloroform	6.1E-03[a]	2.3E-05[h] [8.1E-02][a]	B2	Kidney tumor	Oral; oral/IRIS
Dichloroethane, 1,2-	9.1E-02[a]	2.6E-05 [9.1E-02][a,b]	B2	Several tumor types	Gavage; gavage/IRIS
Dichloroethene, 1,1-	6.0E-01[a]	5.0E-05 [1.2E+00][a]	C	Adrenal pheochromocytomas	Inhalation; gavage/IRIS
Methylene chloride	7.5E-03[f]	4.1E-06[c]	B2	Hepatocellular adenomas or carcinomas	Inhalation; inhalation and water/IRIS
Tetrachloroethane, 1,1,2,2-	2.0E-01[a]	5.8E-05 [2.0E-01][a,b]	C	Hepatocellular carcinoma	Gavage; gavage/ IRIS
Tetrachloroethene	5.1E-02[d]	9.5E-07 [3.3E-03]	B2	Leukemia liver tumors	Inhalation; gavage/HEAST**

(Continued)

TABLE 6-4. CONTINUED

Chemical	Slope Factor (SF) 1/(mg/kg-day)	Inhalation Slope Factor (SF) $1/\mu g/m^3$ [1/(mg/kg-day)]	EPA Weight-of-Evidence Classification	Oral Type of Cancer	SF Study Type (Inhalation;Oral)/ SF Source
Trichloroethane, 1,1,2-	5.7E-02[a]	1.6E-05 [5.7E-02][a,b]	C	Hepatocellular carcinomas and pheochromocytomas	Gavage; gavage/IRIS
Trichloroethene	1.1E-02[e]	1.7E-06 [1.7E-02][e]	B2	Lung, liver	Inhalation, gavage/HEAST

* Integrated Risk Information Service, search dated May 21, 1990.
** US EPA Health Effects Assessment Summary Tables, 4th Quarter, 1989.
a Verified, on IRIS.
b Based on route-to-route extrapolation.
c Value from IRIS, HEAST shows value of 1/4.7E-07 $\mu g/m^3$.
d Under review by CRAVE.
e Values removed from IRIS pending further review.
f Verified on IRIS, but under review.
g Incorporates an absorption factor of 0.4. Inhalation potency slope of 1.3E-01 [1/(mg/kg/day)] as absorbed dose.
h Based on oral data (IRIS).

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6-3 chemical) to medium. Subchronic RfD values were available for all 11 chemicals. Inhalation RfD values were available for two. Nine of the chemicals of concern are classified as carcinogens by EPA. Of the nine, three are Group C - Possible Human Carcinogens; the remainder are Group B2 - Probable Human Carcinogens. Inhalation slope factors were available for three of these chemicals. Thus, the risk assessment considered the potential for subchronic noncarcinogenic effects, chronic noncarcinogenic effects, and carcinogenic effects.

6.4 Risk Characterization

The carcinogenic risks estimated for each exposure scenario are summarized in Table 6-5. The greatest risk is associated with the use of contaminated water from CW-132. It should be emphasized that, as yet, contamination has not been demonstrated in this well. More importantly, this well is not in service. The estimated risks associated with use of water from this well indicate that CW-132 should not be used for service after contamination arrives. Although higher levels of contamination are predicted to occur at BW-18 than at CW-132, the risks associated with residential use of water from BW-18 are lower. This is because of the treatment system in use to remove contaminants from the water prior to distribution. The risks estimated for the residential, three-year tour of duty, and occupational scenarios are very conservative, because concentrations of contaminants at the detection limit were assumed to be present in the water distributed. The actual concentrations in the water are expected to be much lower and therefore the risks associated with use of the water will also be lower. Since it is not possible to estimate how much lower those concentrations might be, the appropriate, conservative method for risk assessment purposes is to use the detection limit. This method may not, however, be useful for purposes of risk communication because using the detection limit overestimates the actual amount of contamination present. The risks estimated for occupational exposure are larger than those estimated for residential exposure. This is because the average residential scenario assumes nine years of exposure at a residence, as directed by the current Superfund guidance, whereas the average occupational scenario assumes 30 years of exposure at work.

Noncarcinogenic effects are summarized in Table 6-6. All exposure scenarios result in predicted contaminant intakes that are unlikely to result in adverse health effects for adults and children. Hazard Indices are typically higher for children than for adults. This is due primarily to the greater volume of fluid intake per unit body weight in children than in adults and is a reflection of children's relatively higher

TABLE 6-5. SUMMARY OF CARCINOGENIC RISKS BY EXPOSURE SCENARIO

Pathway	Carcinogenic Risk	
	Average	Upper Bound
BW-18		
Residential	9E-07	8E-06
3-Year Tour-of-Duty	3E-07	9E-07
Occupational	1E-06	2E-06
CW-132		
Residential	3E-06	1E-05

TABLE 6-6. SUMMARY OF NONCARCINOGENIC RISKS BY EXPOSURE SCENARIO

	Hazard Index			
	Children		Adults	
Scenario	Average	Upper Bound	Average	Upper Bound
Chronic				
BW-18				
Residential	0.2	0.5	0.09	0.2
3-Year Tour-of-Duty	0.2	0.3	0.07	0.1
Occupational	-	-	0.05	0.09
CW-132				
Residential	0.2	0.4	0.05	0.08
Subchronic				
BW-18				
Residential	0.2	0.4	0.08	0.1
3-Year Tour-of-Duty	0.2	0.4	0.08	0.1
Occupational	-	-	0.05	0.1

metabolic rates. The higher Hazard Indices for children, however, remain well below 1, the benchmark value for acceptable exposure.

It should be emphasized that the carcinogenic risks and potential noncarcinogenic effects calculated for this baseline risk assessment are hypothetical, in that the assessment considered modeled concentrations of contaminants predicted to occur at some time in the future if no removal actions are undertaken. No contamination has yet been found at CW-132, and the risk assessment for BW-18 considered hypothetical future concentrations of contaminants.

The major factor driving the risk is the ingestion pathway. The major chemical driving the carcinogenic risk for BW-18 is 1,1-dichloroethene, followed by 1,1,2,2-tetrachloroethane. For CW-132 the major chemicals are trichloroethene and tetrachloroethene. The major chemicals driving the noncarcinogenic effects are vanadium and boron for BW-18, followed by carbon tetrachloride and tetrachloroethene. For CW-132, the most important chemical is tetrachloroethene followed by 1,2-dichloroethene. The most important patnway for noncarcinogenic effects is ingestion for the average case and inhalation for the upper bound case.

There were several major factors which contributed to the uncertainties in the risk assessment. For BW-18, the major chemicals driving the risk (1,1-dichloroethene and 1,1,2,2-tetrachloroethene) are those which have the lowest weight-of-evidence classification usable for a risk assessment. This reduces the overall confidence in the risk assessment because of the greater degree of uncertainty associated with the prediction of carcinogenic effects for chemicals with the weaker classification. For CW-132, the major chemicals driving the risk are under review. Tetrachloroethene is under review by the Carcinogen Risk Assessment Verification Endeavor (CRAVE) Workgroup, which may result in a change in the slope factor. The slope factor for trichloroethene has been removed from IRIS pending further review (the value used was obtained from HEAST). This indicates there may also be a change in the slope factor for this chemical and reduces the confidence in the outcome of the risk assessment somewhat.

For the determination of noncarcinogenic effects, a major uncertainty is the lack of an RfD for trichloroethene, a contaminant predicted to occur in high concentrations relative to those of the other chemicals. Additional uncertainty is provided by the relatively large contribution of boron and vanadium to the Hazard Index. The extent to which these metals are removed by the treatment system for BW-18 is unknown. Moreover, the exposure assessment assumed 100% absorption of these

chemicals from the gastrointestinal tract, which is unlikely to occur. The potential chronic effects of exposure to vanadium are unknown, since the RfD is based on a study in which no effects were observed. Finally, chronic effects attributable to exposure to boron and vanadium are likely to be different from those associated with exposure to VOCs, so adding the Hazard Indices for the metals to those of the VOCs will tend to overestimate the likelihood of adverse health effects.

6.5 Conclusions

The baseline risk assessment for the McClellan AFB OU B was limited in scope to exposure pathways originating with contaminants in the groundwater beneath OU B and associated with the use of BW-18 and CW-132. Environmental fate and transport modeling was used to predict the magnitude of contamination which could migrate to the two wells. Fourteen chemicals of potential concern were identified as the result of environmental sampling and modeling. The potential noncarcinogenic and carcinogenic risks associated with exposure to each chemical of concern were evaluated.

The greatest carcinogenic risk for all exposure scenarios was associated with the use of contaminated water from CW-132 in the residential exposure scenario. It should be emphasized that contamination has not been detected in CW-132, at this time, and the well is not in service. The estimated risks associated with potential use of water from this well, however, indicates that once contamination does migrate to the well, it should not be used. The carcinogenic risks associated with use of BW-18 (residential, three-year tour-of-duty, and occupational exposure scenarios) are lower than those for CW-132. This is primarily due to the fact that a treatment system at BW-18 is used to remove contaminants prior to distribution. The risks calculated for BW-18 exposures are very conservative because concentrations of contaminants at the detection limit were assumed to be present in the water distributed. The actual concentrations are expected to be much lower, which would also lower the carcinogenic risks associated with exposure.

The evaluation of noncarcinogenic effects associated with the chemicals of concern for all exposure scenarios demonstrated that the predicted contaminant intakes are unlikely to result in adverse health effects for either adults or children.

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APPENDIX A
SITE DESCRIPTION AND HISTORY

A1.0 INTRODUCTION

Appendix A provides a general description of the area surrounding McClellan AFB, the history of McCellan AFB operations, and the history of Operable Unit B.

A2.0 Site Description

McClellan AFB is an Air Force Logistics Command Center about seven miles northeast of Sacramento, California. The base property is approximately bounded by Elkhorn Boulevard to the north, Interstate 80 to the south, Watt Avenue to the east, and Raley Boulevard to the west (Figure A-1). OU B includes Area B of McClellan AFB and a portion of the adjacent off-base Southwest Area (Figure A-2).

A3.0 History of McClellan AFB Operations

McClellan AFB is owned by the Department of Defense.

Department of Defense
Pentagon Building
Washington, D.C. 20301

McClellan AFB is operated by the United States Air Force.

Sacramento Air Logistics Command
2852 Air Base Group
McClellan AFB, CA 95652

McClellan AFB was established in 1936 when Congress authorized the construction of a new aircraft repair depot and supply base. Originally named the Sacramento Air Depot, McClellan AFB shifted activities in the 1950s from a bomber to a fighter depot and became increasingly responsible for providing worldwide logistics. In the

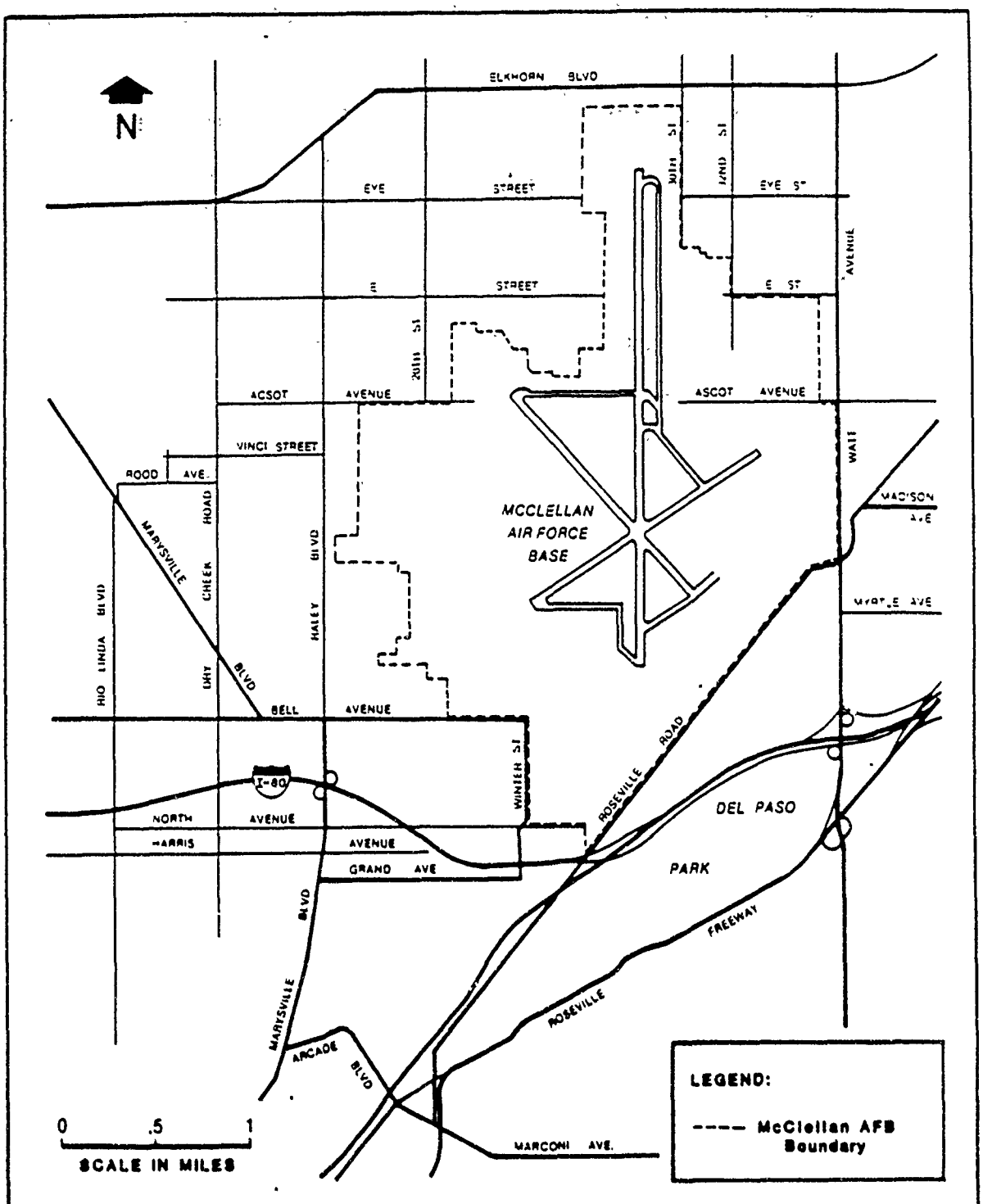

Figure A-1. McClellan Air Force Base Boundary

1288-057-8

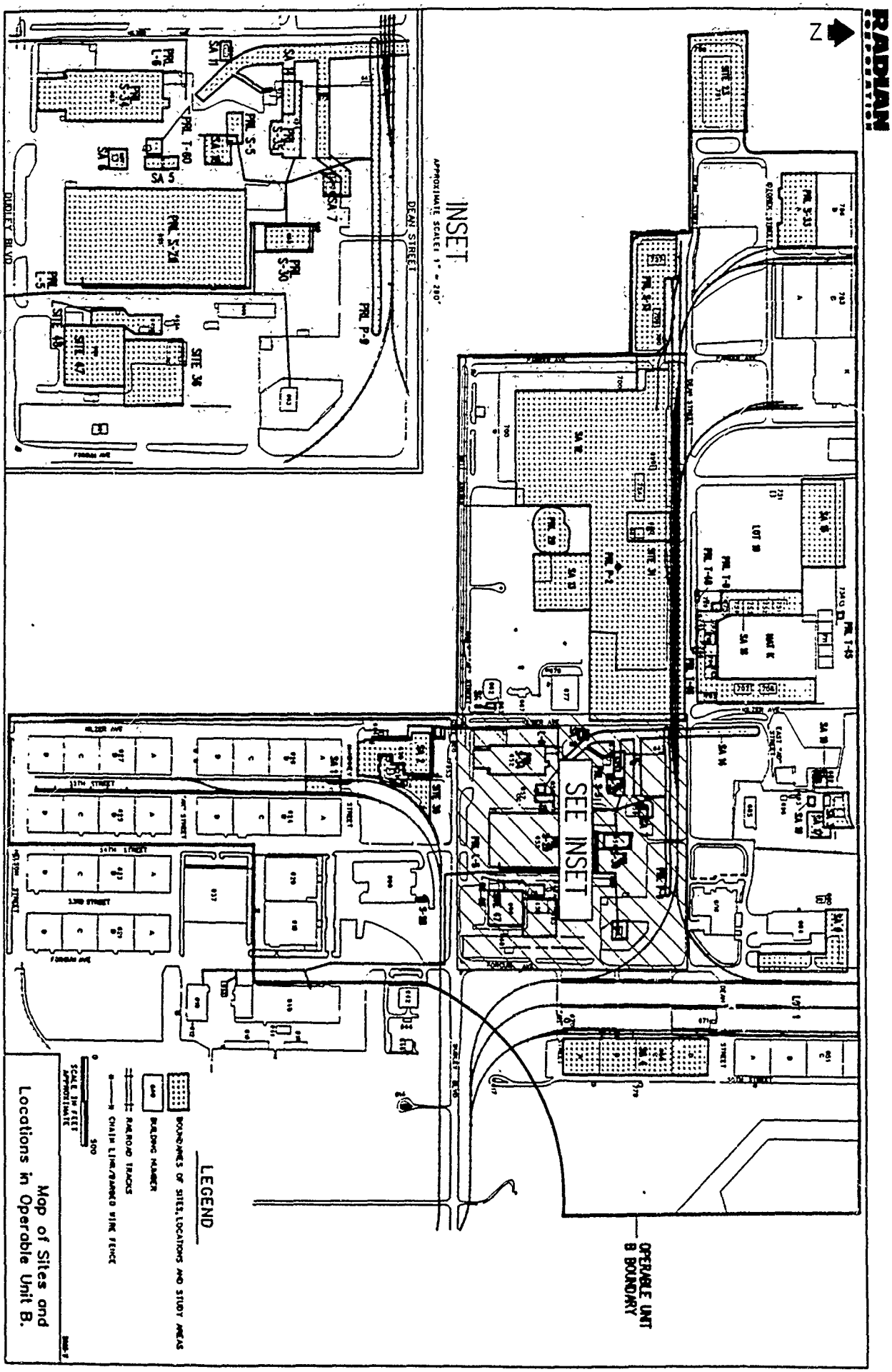

Figure A-2. Map of Sites and Locations in Operable Unit B

1960s the base gained responsibility for certain ballistic missile activities and for the F-111 fighter-bomber aircraft. Today, the center continues to be a fighter maintenance support facility and logistics planning base for the Space Shuttle Program.

Throughout its history, McClellan AFB has been engaged in a wide variety of maintenance and repair operations that require the use of toxic and hazardous materials. A summary of past waste disposal practices is presented below. The summary was compiled through a review of historical data and from published reports.

1940s: Trichloroethene, other solvents, and oils were burned at the pit in the vicinity of Building 704 (Disposal Site 22).

1950s to early 1960s: Trichloroethene was distilled on-base. Although attempts were made to reuse the chemical on-base, the distillation process was ineffective, and significant amounts of trichloroethene wastes were disposed of in the burn pit (Disposal Site 22). The burn pit used in the 1940s, 1950s, and in the early 1960s was filled and closed.

1962 to 1963: A program was initiated to reclaim commingled oils and solvents for sale through the Defense Property Disposal Office (now Defense Reutilization and Marketing Office). Trichloroethene disposal through oil/solvent reclamation was ineffective because the trichloroethene settled to the bottom of the holding tanks. It became standard practice to segregate all wastes containing trichloroethene and dispose of them at the base sludge pits (Disposal Sites 2, 4, 5, 7, and 8).

1963 to early 1970s: Trichloroethene wastes continued to be disposed of at the sludge pits. However, due to concerns related to air pollution, the use of trichloroethene at the base was significantly reduced and then phased out. Other cleaning solvents, such as tetrachloroethene, freon, and 1,1,1-trichloroethane were substituted for trichloroethene.

1976: Solvent disposal at the sludge pits was significantly reduced. Solvents were containerized and transported to off-base state-approved chemical landfills or reclamation facilities.

Late 1978: The use of trichloroethene on-base was banned due to concerns about air pollution.

Late 1981: On-base disposal of industrial wastewater sludge was discontinued. All industrial sludge was transported off-base for disposal at a Class I landfill.

1982 - Present: Waste disposal on-base has been restricted to small amounts of demolition debris, treated industrial wastewater, and sewage grit. Private contractors and Sacramento County have collected solid refuse since 1968.

A4.0 History of Operable Unit B

Operable Unit B is an area historically used for maintenance and storage activities. Some of the activities may have lead to the release of contaminants to the environment. Other activities in the area did not require the storage, handling, or use of hazardous materials, but have been included in this report in the interest of completeness. For reference, Figure A-2 shows the current features and boundaries of OU B.

Development of OU B began shortly after the dedication of McClellan Air Force Base (AFB) in 1939. Before that, the area consisted primarily of undeveloped grassland. Most of the military and industrial development took place from 1940 through 1970.

In the mid-1940s, the eastern half of OU B was used predominantly for indoor and outdoor storage. By 1946, eight large warehouses had been built. Buildings 620, 622, 624, 625, 626, and 627 are located in the area south of Dudley Boulevard and east of Kilzer

Avenue. Buildings 650 and 651 are located east of Forcum Avenue and north of Dudley Boulevard (See Figure A-2). Building 652, an automotive repair shop, was built by 1946 and was the first industrial facility to operate in OU B.

Three outdoor storage areas in the central and northeastern sections of OU B were in use by the mid-1940s. Lot 1 (between Forcum Avenue and Buildings 650 and 651) and the area bounded by Forcum Avenue, Dudley Boulevard, Dean Street, and Building 652 were used for material storage. The area north of Dean Street, between Kilzer Avenue and Forcum Avenue, was used for aircraft parking. In later decades, this area was used for material storage.

The western half of OU B was first used for storage during the 1950s. Mat K and Storage Lot 10 were paved and used for aircraft parking. Storage Lot 3 and a disposal pit on the far western side of OU B, where Building 781 presently stands, were also in use in the late 1950s.

Several changes took place during the 1970s and 1980s. In the early part of the 1970s, Buildings 684 and 685 were constructed north of Dean Street and east of Kilzer Avenue, an area previously used for open storage. Building 781 was also built at the western boundary of the base, over a former disposal pit. Industrial Wastewater Treatment Plant No. 2 ceased operating in 1974 and was dismantled in 1976. During the 1980s, the portion of OU B south of Dean Street and east of Kilzer Avenue was redeveloped. Two of the six warehouses were demolished by 1982 and Buildings 600, 618, and 620 were constructed in their place.

Three major industrial facilities were taken out of operation during the 1980s. Buildings 666 and IWTP No. 4, which treated waste from Building 666, were dismantled in 1988. Building 628, the research laboratory, was also closed in 1988. During 1989, Building 628 was being decommissioned. It will eventually be reoccupied. A field investigation is being conducted as part of the decommissioning process.

In OU B, most of the buildings, constructed for use as maintenance facilities or storage warehouses, continue to be used for those purposes. Lots 1, 3, and 10 continue to be used for open storage.

APPENDIX B
ANALYTICAL METHODS

B1.0 INTRODUCTION

Appendix B contains a detailed explanation of the standard operating procedures and specifications for sample preparation, analysis, and data reduction. Some of the procedures included are evaluation of quantitation limits; QA/QC procedures (i.e., analysis of blank, duplicate, and spiked samples); checks and reviews of analytical results; and historical comparisons of analytical data.

B2.0 Evaluation of Quantitation Limits

The limits of analyte detection or quantitation are critical issues in analyses where low levels of analytes are present. The following discussion outlines Radian's approach to interpreting detection limits and their uses. The method detection limit (MDL) is used as the analytical instrument detection criterion; an analyte is reported as detected if its concentration is at or above the MDL.

The MDL is defined as the minimum concentration of a compound that can be measured and reported with 99% confidence that the concentration is greater than zero. Method detection limits for organic analyses performed in the Radian Analytical Services Laboratory can be found in the QA/QC Letter, January-March 1990, and the Radian Analytical Services Quality Assurance Project Plan (QAPP), January 1, 1990. Most MDLs for water matrices are identical or similar to those from the United States Air Force Occupational and Environmental Health Laboratories Handbook (AFOEHL) and U.S. EPA SW-846 methods. The Radian Analytical Services Laboratory performs periodic MDL studies to demonstrate that it can meet or exceed these recommended MDLs.

Radian Analytical Services Laboratory follow the U.S. EPA methodology in determining MDLs. The U.S. EPA procedure used for establishing MDLs is described in Part 136, Appendix B, of 40 Code of Federal Regulations (1987): "Definition and

Procedure for the Determination of the Method Detection Limit - Revision 1.11". This procedure consists of analyzing seven aliquots of a standard sample spiked at three to five times an initial estimated MDL. These seven samples are taken through all the sample processing steps of the analytical method. This estimated MDL is either the recommended MDL to be verified or the previous MDL to be confirmed. The actual MDL is then defined as three times the standard deviation of the mean value for the seven analyses. These actual experimentally-determined MDLs are less than or equal to the MDLs reported on the Sampling and Analysis Management (SAM) reports and in the SAM database.

The MDL studies for the analyses used in this study were performed on the following dates: Gas Chromatography by U.S. EPA Method 8010 -- 24 February 1989; Inductively Coupled Plasma Emission Spectrometry (ICPES) by U.S. EPA Method 6010 -- 13 February 1989. The MDLs established for these methods are below the California Department of Health Services Action Levels and Federal Drinking Water Maximum Contaminant Levels which have been established as applicable or relevant and appropriate requirements (ARARs) for McClellan AFB. The ARARs are used to direct the decision-making process when determining appropriate actions for potential health threatening contamination conditions.

B3.0 Summary of Quality Assurance/Quality Control Procedures and Results

This section describes Radian's data validation process and presents the QA/QC data from the McClellan AFB Groundwater Sampling and Analysis Program for the period of January through March, 1990, for groundwater samples collected from OU B. Validation of all analyses, tables for all QC samples, and data for the other areas sampled during this period are presented in both the QA/QC Letter and the Data Summary, January-March, 1990, (Radian, 1990a). A summary of the results of the QA/QC activities is presented and a table of qualified data are presented in Table B-1.

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TABLE B-1. SUMMARY OF QUALIFIED DATA, OPERABLE UNIT B
JANUARY - MARCH 1990, McCLELLAN AFB

Sample ID	US EPA Method	Analyte(s)	Type of Qualification	Reason
MW-7	8010	Methylene chloride	E	Estimated value
MW-65	8010	Methylene chloride	E	Estimated value
		Tetrachloroethene	E	Estimated value
MW-135	8010	1,2-Dichloroethene	PF	High RPD in duplicate sample
	6010	Iron	PF	High RPD in duplicate sample
MW-149	8010	1,1,1-Trichloroethane	O	Detected in equipment blank
MW-150	8240	Methylene chloride	R	Detected in reagent blank
MW-153	8010	Trichloroethene	PL	High RPD in MS/MSD
MW-155	8010	Total 1,2-Dichloroethene	G	Estimated value
MW-157	8010	Tetrachloroethene	M	High surrogate recovery
MW-1000	8010	Methylene chloride	O	Detected in ambient blank
MW-1021	8010	Trichloroethene	PL	High RPD in MS/MSD
MW-1022	8010	Tetrachloroethene	E	Estimated value
MW-1023	8010	1,1,1-Trichloroethane	E	Estimated value
MW-1045	8010	Trichloroethene	E	Estimated value
MW-1046	8010	1,2-Dichloroethane	E	Estimated value

(Continued)

TABLE B-1. Continued

Sample ID	US EPA Method	Analyte(s)	Type of Qualification	Reason
MW-1047	6010	Boron	O	Detected in equipment blank
		Zinc	O	Detected in equipment blank
		Iron	O	Detected in equipment blank
MW-1050	8010	Methylene chloride	E	Estimated value
		Trichloroethene	E	Estimated value

PL Qualified as estimated due to high laboratory variability as measured by laboratory matrix spikes/matrix spike duplicates.
PF Qualified as estimated due to high total variability as measured by field duplicates.
RPD Relative percent difference.
R Detected in reagent blank.
O Detected in blank other than reagent blank.
M Qualified as inaccurate due to matrix spike or surrogate recoveries outside the control limits.
E Estimated value.

Quality assurance refers to the activities of planning, implementation, and oversight that are conducted to ensure that the data produced are valid and complete and that they can be used for their intended purpose.

Quality control is defined as the system or series of activities established to control the quality of a product or service so it meets the needs of the user. One measure of quality is the extent of errors. Some potential sources of errors in the McClellan AFB groundwater monitoring effort are contamination from reagents or equipment, interferences and matrix effects, and deviation from established sampling and analytical methodology. The established QA/QC procedures serve to minimize the potential for errors to occur and to quickly identify and correct any problems that arise.

The three primary objectives in Radian's QA/QC system are to:

- Ensure that correct sampling, analytical, and data reduction protocols are followed and to reduce or eliminate sources of errors affecting the quality of the data;

- Provide a quantitative assessment of the precision and accuracy of the measurement data; and

- Assess data completeness.

Radian's QA/QC system meets these objectives through a series of checks and statistical tests designed to detect any systematic error while minimizing the effects of random error. Radian's QA/QC system uses a combination of five categories of checks that establish the validity and quality of the data with respect to:

- Calibration and control standards;
- Blanks;

- Duplicates;
- Spike recoveries; and
- Transcription and reporting checks.

These tests investigate both systematic and random errors arising from the three major project activities: field sampling, laboratory analysis, and reporting.

The QA/QC data have been evaluated according to the quality assurance objectives specified in Section 4.0 of the McClellan AFB QAPP (Radian, 1990b). These are accuracy and precision objectives that are used to assess performance for each method. In addition, objectives are specified for completeness, representativeness, and comparability.

The quality assurance objectives for precision are a relative percent difference (RPD) of less than or equal to 50% for field duplicate sample results and an RPD of less than or equal to 30% for laboratory duplicate analysis results. The objectives for accuracy are analyte-specific and are listed in the SOP for each method. The objective for completeness is to have greater than 90% of all data reported as valid. The objectives for comparability and representativeness are a function of the sampling program and are evaluated in terms of program objectives. However, comparability is achieved in part by using standard methods for sampling and analysis, reporting data in standard units, and using standard and comprehensive reporting formats.

B4.0 Summary of Results

The following is a summary of the QA/QC data, qualified data, and corrective actions taken during January through March, 1990, for monitoring wells within OU B.

There were no systematic problems that affected the overall data quality reported for the period of January, February, and March, 1990. Although data from

several wells were qualified because of random errors, the majority of the data satisfied the quality assurance objectives. Qualified data for samples collected from monitoring wells within OU B are presented in Table B-1.

The term "qualified data" refers to data that fell outside the specified tolerance limits and therefore, did not meet the program's quality assurance objectives. Such data are qualified and their results should be interpreted as estimated or uncertain values. The term "corrected data" refers only to data for analytical spikes. If analytical spike recoveries are outside of method-specified control limits, a method of standard addition is performed. The results from the analysis are corrected for the original conditions that caused the analytical spike to be outside its limits. Such corrected data are considered valid. Valid data meet the quality assurance objectives of the program.

Some analytical results in this report are flagged with letters or symbols. A "C" flag indicates that the analyte was confirmed by analysis on a second chromatographic column. A "P" flag indicates that the compound was confirmed during a previous quarter by a second-column confirmation analysis; therefore, a second-column analysis was not performed. A "B" flag indicates that the compound was reported in the reagent blank analyzed the day the sample was analyzed. An "E" flag indicates that concentration of the analyte was estimated by the analyst. This flag appears in gas chromatographic data when two peaks have merged with one another or were poorly defined. A "U" flag appears when either methylene chloride or toluene were detected at a concentration less than five times the detection limit. No confirmation is required for these two analytes at these concentrations and the data are flagged as unconfirmed. All analytical qualifier flags are presented in Table B-2.

For Method 8010, there were samples in which the quantitation of some analytes was affected by interferences on the first column. Because the detected concentrations from the two columns were not within a factor of two, the analytes for both the first and second column were reported as unconfirmed. As indicated by historical results, these

TABLE B-2. GLOSSARY OF TERMS AND SYMBOLS

A	=	Analytical and/or post-digestion spike.
B	=	Detected in blank, result not corrected.
C	=	Confirmed on second column.
D	=	Sample diluted for this analyte.
DL	=	Method specified detection limit.
E	=	Estimated result, see report narrative.
G	=	Exceeds calibration range.
J	=	Detected at less than detection limit.
P	=	Previously confirmed.
Q	=	Outside control limits.
R	=	Detected in blank, result corrected.
S	=	Determined by Method of Standard Addition.
U	=	Unconfirmed, 2nd column not requested.
X	=	Not confirmed by analysis on 2nd column.
*	=	Estimated result less than 5 times the detection limit.
NA	=	Not analyzed.
N/A	=	Not available.
NC	=	Not calculated.
ND	=	Not detected at specified detection limit.
NE	=	Detection limit not established.
NR	=	Analyte not requested.
NS	=	Not spiked.
FACTOR	=	Used to calculate detection limit based on sample size, dry weight (if applicable), cleanup, or dilution.

compounds were previously confirmed, therefore, this data is reported as estimated using the values obtained from the column determined by the analyst to provide the most representative results. These data are flagged with an "E" to indicate the uncertainty associated with the analysis.

More than 98% of the data are valid, fulfilling the project objectives for accuracy and precision for the sampling program from January through March, 1990. The completeness objective of 90% valid data was attained.

Results from the data assessment and QA/QC samples are presented in the following order: general checks and reviews, laboratory control charts, blanks, field duplicates, matrix spike duplicates, matrix spike recoveries, analytical spike recoveries, and surrogate spike recoveries. A brief comparison of current and historical data for these wells is also presented. Laboratory calibration will not be discussed because those procedures are described in detail in the standard operating procedure for each method.

B5.0 Checks and Reviews

The data were checked and reviewed for errors in transcription or reporting at several points in the flow of data from analysis to reporting. While computerized data transfer and standard reporting formats preclude many reporting errors, checks were performed to ensure accurate transfer of information from field and laboratory to the reporting staff.

Part of this review and monitoring process includes tracking hold times for each sample. All samples analyzed as part of this sampling and analysis program met the method requirements for hold times.

B6.0 Control Charts

The first step in any laboratory quality assurance program is the establishment of statistical control, which is achieved through quality control of a measurement process. When an analytical system is in statistical control, the output of that process is stable and believable. When a system is not in statistical control, it cannot be considered to be measuring anything at all. The process has met the objectives when a statistically significant number of individual values (at least 30) approach a limiting value called the limiting mean. The procedure most commonly used for establishing statistical control and for determining if the process is going out of control is the use of control charts. Control charts graphically depict the behavior of the system over time. Various techniques are used to analyze the control chart data so systematic variations can be separated from the stable pattern. The charts are routinely updated to contain the most recent 30 points, or the past six months of results for the parameter being charted.

The Radian Analytical Services Laboratory uses the single measurement (X chart) type of chart to demonstrate and document statistical control. The property measured is the recovery of the internal quality control method spikes for the Gas Chromatograph (GC) and ICPES methods. All of the recoveries must fall within the control limits of plus or minus two standard deviations, which is used to indicate statistical control, or corrective actions are taken. The Radian Analytical Services Laboratory is presently using this type of control chart for method spikes and is implementing control charts to monitor reproducibility for matrix spike/matrix spike duplicate samples.

B7.0 Blanks

Several types of blanks are analyzed to assess contamination from laboratory, equipment, or ambient sources. These include reagent blanks, trip blanks, ambient blanks, and equipment blanks.

B7.1 Reagent Blanks

Reagent blanks are used to demonstrate that contamination from glassware and reagents used in the analytical procedure is under control. Each reagent blank sample is subjected to all laboratory procedures, from sample preparation to quantitation. If an analyte is detected, either an interference or contamination in the laboratory is indicated. The required frequency for analyzing reagent blanks is specified in the U.S. EPA Standard Operating Procedure (SOP) for each analytical method, and consists of at least one per day for each method/ instrument and/or one per extraction batch.

It should be noted that the required frequency of reagent blanks is one per day or extraction batch and several Sampling and Analysis Management (SAM) reporting batches may use the same reagent blank results. Each reagent blank is identified by the unique file number given on each sample report. All reagent blank data received during this sampling period are provided in the appendix of the QA/QC Letter and the database; unique reagent blanks are represented in Table 3-7 of the QA/QC Letter, January-March 1990.

Methylene chloride, toluene, and acetone are common laboratory contaminants resulting from the use of these solvents in the laboratory environment during extraction of water, soil, or solid waste for organic compounds. These three compounds may be detected in volatile analyses such as U.S. EPA Methods 8010, 8020, and 8240. No corrective action is taken if these contaminants are detected in reagent blanks at less than five times the detection limit. Overall, there were no indications of laboratory contamination or interference that affected the quality of the sample data. Results by method are discussed below.

U.S. EPA METHOD 8010--No method analytes were detected in any of the reagent blanks analyzed by Method 8010. No samples were qualified.

U.S. EPA METHOD 6010--No wells from OU B were qualified due to reagent blank contamination. A review of the data indicates that, although several metals were reported in blanks, the levels at which they were measured are much lower than levels detected in the field samples and therefore, are not considered to affect the data. The general criterion used for this assessment was if an analyte was detected at concentrations greater than five times the average blank contamination, it was not considered to be influenced by blank contamination.

B7.2 Trip Blanks

Trip blanks are used to identify volatile contaminants introduced during sample transport or handling. Trip blanks are prepared with American Society of Testing Materials (ASTM) Type I reagent-grade water, filled in a contaminant-free environment (Radian's Gas Chromatography Laboratory), sealed, carried to the field, and returned to the laboratory unopened. Type I water is of a higher quality than the Type II water required by the Air Force for this program and is certified by GC analysis as being free of organic compounds. One trip blank is collected for every 20 monitoring wells sampled.

No sample results for OU B were affected by contaminants reported in the trip blanks.

B7.3 Ambient Blanks

Ambient blanks provide a measure of contamination from airborne contaminants which may be introduced into the sample during the sampling procedure. The ambient blank, also using Type I water, is prepared and handled in a similar fashion to the trip blank except that the ambient blank is opened and poured from one container to another at the wellhead under the same conditions that exist when collecting the

samples. The container is then closed and submitted for analysis. One ambient blank is collected for each of the 10 geographically-defined areas within and surrounding McClellan AFB.

The results for the ambient blank that was analyzed by Method 8010 for OU B were qualified for methylene chloride because ambient blank contamination was indicated. Methylene chloride was detected at 0.66 ug/L in the ambient blank and 1.2 ug/L in the sample collected from MW-100.

B7.4 Equipment Blanks

Potential contamination from non-dedicated sampling equipment is monitored using equipment blanks. The sample consists of Type I reagent-grade water that is poured through the sampling device (bailer) following decontamination, but prior to sampling. One equipment blank is collected and analyzed each day samples are collected with a bailer.

One result for field data from OU B was qualified for Method 8010; 1,1,1-trichloroethane was detected in the sample collected from MW-149 at a concentration of 0.98 ug/L and the equipment blank reported the same compound at a concentration of 0.28 ug/L.

One equipment blank was collected and analyzed for metals using Method 6010. Six metals were present in the equipment blank. These metals are commonly found in Liquinox, the detergent used to wash sampling equipment between sites. Two likely reasons for contamination from this source are incomplete rinsing and use of a too concentrated cleaning solution. This could leave residue on the sampling equipment that is washed into the blanks and samples.

Results for MW-1047 were affected by this sample contamination. Three compounds that were present in the equipment blank were reported in the well sample at similar concentrations: boron, iron, and zinc. Therefore, the data for MW-1047 are qualified for these compounds and are included in Table B-1.

Two corrective actions have been implemented as a result of the equipment blank contamination: 1) effective decontamination procedures will be reviewed with the field sampling teams; and 2) the Liquinox solution will be prepared strictly according to the manufacturer's specification. In addition, a greater quantity of water will be used to rinse the sampling equipment after washing to ensure that no residue from the Liquinox solution remains on the sampling equipment.

B8.0 Duplicates

Field duplicate samples were collected and matrix spike duplicate analyses were performed, as described below.

B8.1 Field Duplicate Samples

Field duplicate samples are collected and analyzed to evaluate the precision of the measurement system and estimate variability in the sampling and analytical process. If the RPD between duplicate sample results is greater than 50%, the sources of excessive variability are investigated and the extent of samples affected is determined. Corrective actions such as qualifying the data, resampling, or reanalysis are initiated as warranted. One field duplicate is collected for every 10 wells sampled.

One field duplicate sample for OU B was qualified due to higher than expected variability in detected analyte concentrations; 1,2-dichloroethene was qualified for MW-135 for Method 8010. Iron was also qualified in MW-135 for Method 6010 because the RPD for the field duplicate pair fell outside of the quality assurance objective. This

does not appear to be a systematic problem because of the sporadic occurrence and is considered to be caused by random error. Overall, the precision, as measured by field duplicate samples for this sampling and analysis program, met the quality assurance objectives.

B8.2 Matrix Spike Duplicates

Following the recommendations in SW-846, matrix spike duplicates were performed. Matrix spike duplicates fulfill the same function as laboratory duplicate analyses, which is to estimate the precision in the analytical portion of the sampling and analytical process. Matrix spike duplicates have an advantage over duplicate analyses in that the presence of the analyte is not required in order to obtain useful results. Furthermore, both matrix effects and analytical variability can be assessed with the same sample. This allows the frequency requirement for duplicate analyses to be 5% instead of 10%. The quality assurance objective for matrix spike duplicates is to have an RPD of 30% or less.

Two wells analyzed by Method 8010 were qualified for OU B. The RPDs for trichloroethene in MW-153 and MW-1021 exceeded the quality assurance objective of 30 percent. These are most likely due to random laboratory variability.

B9.0 Spike Recoveries

Spike recovery methodologies and results are described in the following subsections.

B9.1 Matrix Spike Recoveries

A matrix spike is a solution of method analytes at known concentrations that is spiked into a field sample before extraction (if applicable). The analytical results for the

spiked sample are used to calculate the percent recovery of each spiked compound and provide a measure of the accuracy of the method. Specific acceptance criteria for each standard method and parameter measured have been established and are presented in SW-846 and in the SOPs. Because matrix spikes have been paired with duplicate analyses, the required frequency is five percent.

Matrix spikes were performed at the required frequency using the concentrations and conditions specified for each analytical method. All spike recoveries for matrix spikes in OU B samples met the acceptable recovery limits, therefore no results were qualified for the compounds of interest.

B9.2 Analytical Spikes

Analytical spikes are the first step used in clearly determining matrix effect for metals. An analytical spike solution is added to a groundwater sample and if the recovery is outside of the 75-125% control limit, the method of standard addition is used to obtain the correct concentration of the analyte.

No data was affected by analytical spikes which exceeded the quality assurance objective and therefore, no data from OU B was qualified for Method 6010.

B9.3 Surrogate Spike Recoveries

Surrogate spikes are a group of compounds, other than method analytes, selected for each organic compound analysis. The compounds have been selected to behave similarly to method analytes and recovery limits have been established for each method. The percent recovery of surrogate compounds is monitored to ensure adequate analytical performance on a measurement-by-measurement basis.

One sample in Area B was qualified because the surrogate spike recovery did not meet the method recovery limits. Detected compounds for MW-157 are qualified for Method 8010 due to high surrogate recoveries. High surrogate recoveries indicate that the reported results are higher than the actual concentration of analytes detected in the field samples.

B10.0 Historical Comparisons

The results for samples collected and analyzed during the First Quarter 1990 were also evaluated to determine if the recent sampling history of the well indicates any increasing or decreasing patterns in concentrations. The results of the evaluation for OU B wells are summarized below.

- MW-7-- Trichloroethene (TCE) and total 1,2-dichloroethene (total 1,2-DCE) increased
- MW-41S-- Tetrachloroethene (PCE) and TCE increased slightly
- MW-151-- PCE was detected
- MW-153-- TCE increased
- MW-156-- TCE and total 1,2-DCE detected above drinking water standards
- MW-157-- PCE and TCE detected above drinking water standards
- MW-158-- TCE detected above drinking water standards
- MW-1046-- 1,2-dichloroethane (1,2-DCA) detected above drinking water standards
- MW-1049-- TCE increased

APPENDIX C
BASELINE METAL CONCENTRATIONS

C1.0 INTRODUCTION

Appendix C presents the derivation of "baseline" values used in the interpretation of metal analysis in groundwater samples.

C2.0 Baseline Values

Background concentrations for metals in area groundwater were not available for the McClellan AFB OU B. In an effort to establish "baseline" concentrations for metals in the groundwater, samples were collected from monitoring wells located upgradient (to the north and northeast) from the majority of potential sources of contamination at McClellan AFB. Five of the monitoring wells are located on-base and four are located off-base. Although the original purpose of establishing baseline values was for use in determining sampling frequency at area wells, the baseline values were adapted for use in the risk assessment because true background metal concentrations were not available.

Table C-1 presents the baseline values used in the risk assessment. These baseline concentrations were derived using the following criteria:

#1 The mean* of concentrations + 3(1 standard deviation).

#2 One-half the EPA maximum contaminant level (MCL) or applicable state MCL if the value was less than #1.

#3 Method detection limit if greater than #1 or #2.

* Actual measured concentrations were used in the calculation of the mean when metals were detected in the groundwater samples. When analysis of the samples did not detect any metals, one-half of the detection limit was substituted as a conservative estimate of metal concentrations in the calculation of the mean.

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TABLE C-1. BASELINE CONCENTRATIONS OF INORGANIC ANALYTES FOR EVALUATION OF SAMPLING FREQUENCIES

Analyte	Baseline Concentration (mg/L)	Method Detection Limit (mg/L)
Antimony	0.034	0.034
Arsenic	0.025[a]	0.004
Beryllium	0.0010	0.0010
Cadmium	0.0050[a]	0.004
Chromium	0.025[a]	0.007
Copper	0.060	0.006
Lead	0.042	0.042
Mercury	0.0010[a]	0.0002
Nickel	0.060	0.015
Selenium	0.0050[a]	0.004
Silver	0.025[a]	0.007
Thallium	0.051	0.051
Zinc	0.07	0.002

[a] = One-half U.S. EPA Primary Maximum Contaminant Level used for baseline.

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APPENDIX D
PHYSIOGRAPHY AND GEOLOGY

D1.0 Introduction

Appendix D provides a more detailed description of the physiography, geology, and soils of the site and the surrounding areas.

D2.0 Physiography

McClellan AFB is located in the Great Valley Physiographic Province. This province extends north to Red Bluff and approximately 400 miles south to Bakersfield (California Department of Water Resources [CDWR], 1974). The Great Valley Province consists of the Sacramento Valley to the north and San Joaquin Valley to the south and averages 40 miles in width (CDWR, 1974 and 1978). The Sacramento Valley is bordered by the Sierra Nevada to the east and the Coast Range Mountains to the west as shown on Figure D-1.

McClellan AFB is located on the east side of the Victor Plain, an alluvial plain which is situated along the eastern side of the Sacramento Valley. The Victor Plain was created by deposition of sediments eroded from the Sierra Nevada. The Victor Plain is nearly flat and is dissected by numerous westerly-flowing streams draining the Sierra Nevada (CDWR, 1978).

The land surface at the base slopes very gently to the west. Elevations range from 75 feet above mean sea level (msl) on the east side of the base to approximately 50 feet msl on the west side. The topographic relief is very low. The major drainages in the vicinity of the Victor Plain are the Sacramento and American rivers. The Sacramento River originates from Shasta Lake in Shasta County and is fed predominantly by the Feather, Yuba, and Bear rivers from the east before reaching its junction with the American River near Sacramento. The Sacramento River collects drainage from the Cascade Range and the Sierra Nevada. It flows approximately six miles west of McClellan AFB. The American River originates in the Sierra Nevada east of the base. It consists of three forks which flow westerly and converge east of Sacramento. The American River is located approximately seven miles south of the base.

D3.0 Geology and Soils

The Sacramento Valley is a large depositional basin, filled with sediment eroded from the Sierra Nevada to the east and the Coast Range Mountains to the west.

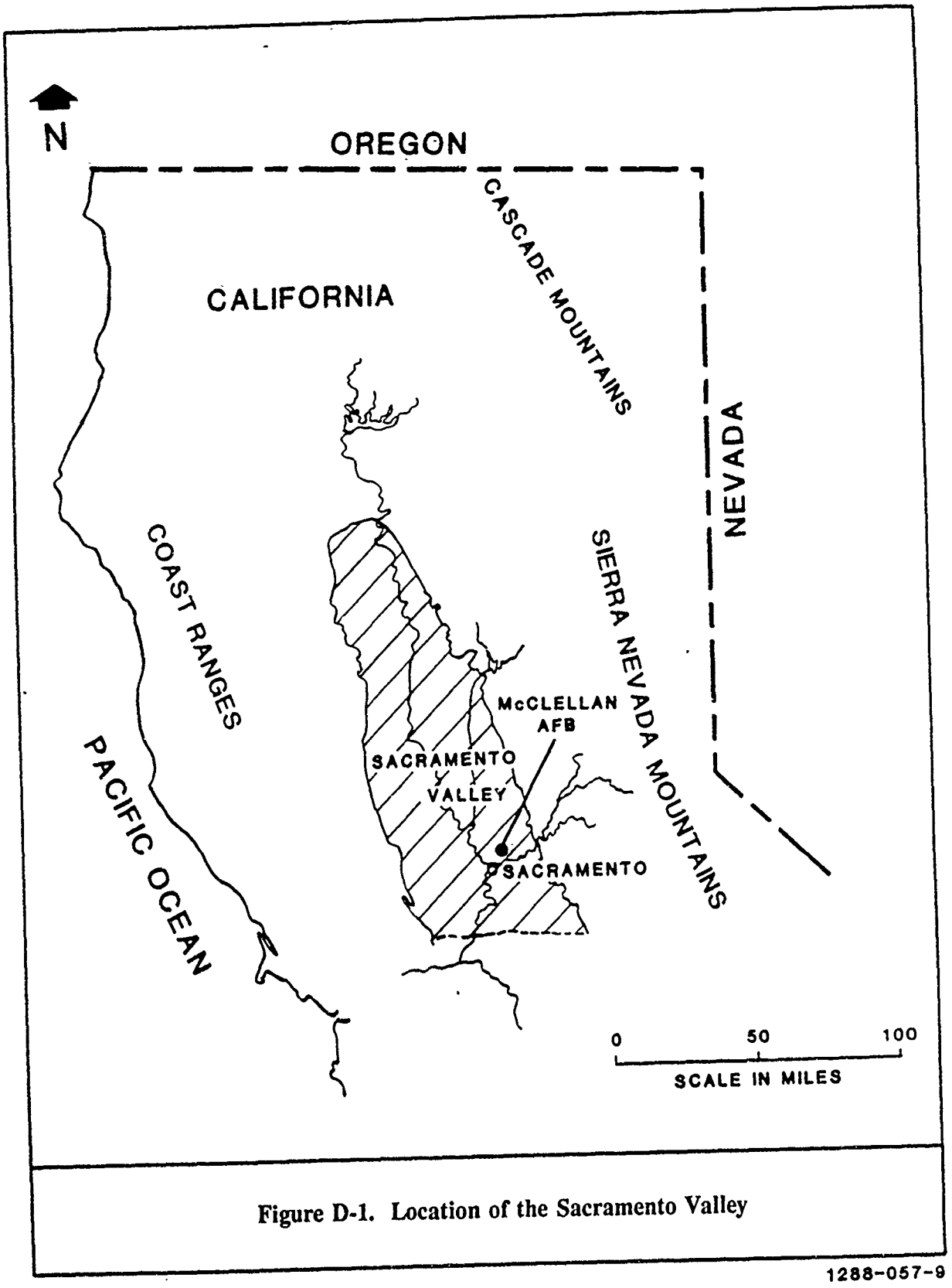

Figure D-1. Location of the Sacramento Valley

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The valley is underlain at depth by Paleozoic and Mesozoic metamorphic and igneous bedrock, overlain by Cretaceous and Eocene sandstone and shale of marine origin (CDWR, 1978). These deposits are overlain by late Eocene and post-Eocene deposits consisting of non-marine and secondary volcanic sediments primarily transported and deposited by fluvial processes. It is estimated that over 4,000 feet of sediments have been deposited in the valley since the Eocene Epoch. These sedimentary deposits are wedge-shaped with the greatest sediment thickness near the west side of the valley, as shown in Figure D-2. The deposits dip gently to the west. The regional dip ranges from 300 feet per mile near the base of the Sierra Nevada to 5 feet per mile near the center of the Sacramento Valley (CDWR, 1974).

The broad alluvial plain on which Sacramento is located is termed the Victor Plain. The upper surface of the plain, in most places, represents the upper surface of the Victor Formation, one of four units overlying the volcanoclastic Mehrten Formation. The four units are the Victor Formation, Arroyo Seco Gravels, and the Laguna and Fair Oaks formations. Three of these units are present in the shallow subsurface at the base. The uppermost unit, the Victor Formation, is the youngest unit underlying the Victor Plain. Directly beneath the Victor Formation are the Laguna and Fair Oaks formations which are thought to interfinger in the region east of Sacramento.

D3.1 Geologic Units

The dramatic variation in climatic condition and the increased quantity of sediment generated by successive periods of glacial advancement and retreat during the Pleistocene epoch in the Sierra Nevada created a very complex fluvial environment across the Sacramento Valley. By the close of the Pleistocene epoch, the valley floor had been dissected by numerous large braided streams and smaller meandering channels which had alternately deposited, eroded, and redeposited sediment along ever changing channel courses. As a result, distinct and continuous clay, silt, or sand horizons tend to be both laterally and vertically discontinuous. These interbedded deposits vary dramatically over short distances in texture, porosity, and water transmitting capabilities. However, recent work by Radian geologists using resistivity and spontaneous potential logs indicates possible local correlation of broad lithologic intervals (Radian, 1989a).

The Victor Formation is underlain by the Fair Oaks Formation. The sedimentary deposits of the Fair Oaks Formation consist primarily of poorly bedded sand, silt, and clay, with less common gravel lenses. This formation is characterized by beds

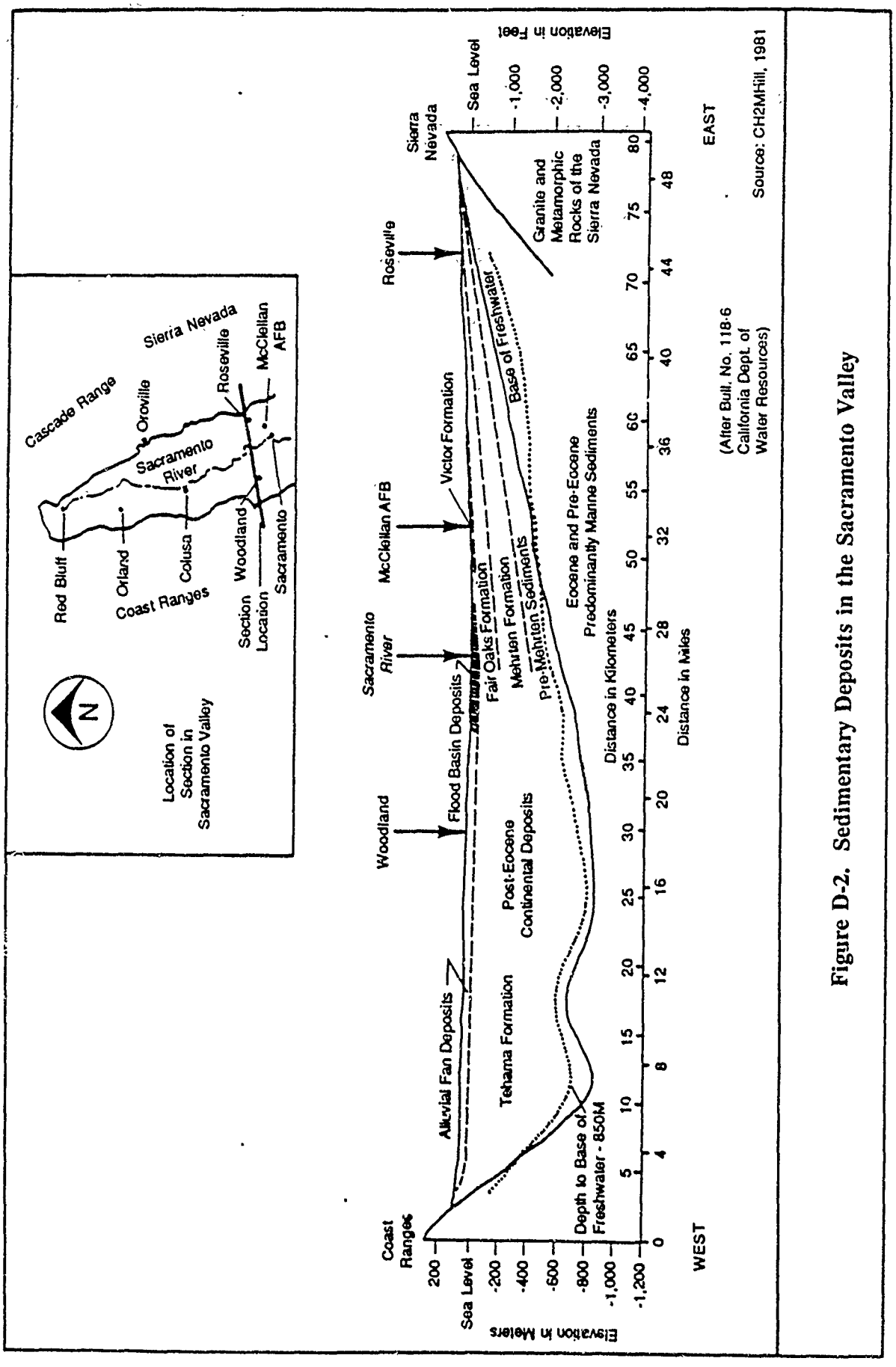

Figure D-2. Sedimentary Deposits in the Sacramento Valley

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of volcanic tuff up to one foot thick which have been altered to white clay. The Fair Oaks Formation dips to the west at approximately 15 feet per mile ranging in thickness from 0 to 400 feet; in the vicinity of McClellan AFB it is thought to be approximately 100 feet thick.

The Fair Oaks Formation interfingers with the contemporaneous Laguna Formation in the vicinity of McClellan AFB. The Laguna Formation is predominantly fine-grained, poorly bedded, and moderately compacted. The formation is heterogeneous, with irregular accumulations of silt, sand, clay, and lenticular gravel beds. The most common deposits are light-gray to yellowbrown clayey silt, to silty, fine-grained sand. Clean, well-sorted sand occurs chiefly in relatively thin, laterally extensive beds. Gravel beds are scarce, poorly sorted, and of relatively low hydraulic conductivity. The sands have been eroded from granitic rock and contain abundant weathered feldspars, mica, and quartz grains. Mica particles are locally abundant and serve as a distinguishing characteristic for most of the formation. Regionally, the formation is between 125 and 400 feet thick; in the vicinity of McClellan AFB it is about 125 to 200 feet thick (CDWR, 1974). The sediments of the Laguna and Fair Oaks formations are very similar in the vicinity of McClellan AFB. The presence of the white clay layers in the Fair Oaks Formation is the primary characteristic distinguishing it from the Laguna Formation in this area.

The Mehrten Formation underlies the Fair Oaks and Laguna formations. The Mehrten Formation consists of an upper unit of gray to black sand interbedded with blue to brown clay and a lower unit of hard, gray volcanic tuff breccia. The Mehrten Formation may reach thicknesses up to 1,200 feet in the Sacramento Valley (CDWR, 1974), however, its thickness beneath McClellan AFB has not been determined.

A summary description of the geologic formations found in Sacramento County and their waterbearing characteristics is presented in Table D-1.

D3.2 Soils

Soils in the vicinity of McClellan AFB are extremely variable. Soil permeabilities range from 0.6 to 2.0 inches per year depending on local amounts of clay and hardpan. The local soils are generally classified as San Joaquin fine sandy loam, Fiddyment fine, sand loam, or San Joaquin-Xeralfic Arents complex. These soils have a low shrink-swell potential, a slight erosion potential, and a very low available water capacity of approximately 0.10 to 0.14 inches per inch.

Table D-1. Geologic Formations in Sacramento County

Era	Period	Epoch	Formation	Thickness (ft)	Physical Characteristics	Waterbearing Characteristics
Cenozoic	Quaternary	Holocene	Alluvium	0-100±	Unconsolidated gravel, sand, silt, and clay deposited along stream channels, on terraces and floodplains, and in basins.	Gravels and sands act as important recharge areas and yield large amounts of water to wells. Silts and clays are of low permeability and yield little water.
Cenozoic	Quaternary	Pleistocene	Victor Formation	0-100±	Unconsolidated sand, silt, and clay. Hardpan present. Sand and gravel along old stream courses.	Generally yields little water. Yields larger amounts of water if old stream channels tapped.
Cenozoic	Quaternary	Pleistocene	Arroyo Seco Gravel	20-60	Sand and gravel in iron-cemented clay matrix.	Of relatively low permeability and thus would yield only small amounts of water to wells.
Cenozoic	Quaternary/ Tertiary	Pliocene to Pleistocene	Fair Oaks Formation	0-225±	Sand, silt, and clay. Hardpan present. Found principally north of American River. Cemented gravels south of the river.	Similar to the Victor Formation.
Cenozoic	Quaternary/ Tertiary	Pliocene to Pleistocene	Laguna Formation	125-200	Bedded silts, clays, and sands. Non-volcanic.	Sand beds will yield moderate amounts of water to wells; clays yield little water.
Cenozoic	Tertiary	Pliocene	Mehrten Formation	200-1,200	Beds of black volcanic sands, brown clay and sandy zones of volcanic tuff-breccia (lava). All of andesitic origin.	Volcanic sands yield large quantities of water to wells. Brown sands yield lesser amounts; clays yield little water. Tuff-breccias yield no water.
Cenozoic	Tertiary	Miocene	Valley Springs Formation	75-125	Beds of light colored sand and ash, beds of greenish-brown silty sand, few beds of gravel. All of rhyolitic origin.	Of low overall permeability. Yields only small amounts of water to wells.
Cenozoic	Tertiary	Eocene	Ione Formation	100-400	Medium-grained quartz sandstone, thick beds of white to red clay, blue to gray clay with lignite.	Of low overall permeability. Yields only small amounts of fresh to brackish water to wells.
Mesozoic	Cretaceous		Chico Formation	200-15,000±	Brown marine fossiliferous sandstone and shale. Occurs principally in the subsurface.	Usually nonwaterbearing; contains salt water. Local areas may be flushed and now contain usable groundwater.
Pre-Tertiary			Basement Complex	?	Slate and sandstone of the Mariposa Formation. Greenstone, schist, and assorted metavolcanics of the Logtown Ridge Formation. Granodiorite and other intrusive rocks of the Sierra Nevada.	Essentially nonwaterbearing. Where sufficiently decomposed and/or fractured, may yield small quantities of water to wells.

SOURCE: CDWR, 1974.

APPENDIX E
GROUNDWATER FLOW MODEL

E1.0 INTRODUCTION

An analytical model was used to estimate groundwater flow in the four geohydrologic zones in which contaminant concentrations have been detected beneath OU B. A flow model is, by definition, a system of hypotheses, data, and inferences presented as a mathematical description of the state of the groundwater system. Mathematical models have been developed to fully characterize the complex relationships of flow within an alluvial aquifer system such as the one occurring beneath OU B. Unlike the more rigorous numerical models, an analytical model must rely upon simplifying assumptions to characterize flow through an aquifer. The assumptions that each geohydrologic zone represents an infinite, homogeneous, and isotropic aquifer are simplifying assumptions made in the use of the analytical model for baseline risk assessment. Although these aquifer conditions are not present in the natural aquifer, the results of the analytical modeling provide a conservative assessment of groundwater flow and contaminant migration.

Results are conservative because the degree of inhomogeneity, anisotropy, and infinite extent of the geohydrologic zones are likely to result in decreases in the contaminant concentrations that could reach the wells under steady state or transient conditions. The inhomogeneity that exists in the deposits beneath OU B results in contaminants following more complex migration pathways that create a greater degree of mixing and attenuation of contaminants than would a homogeneous system. The condition of anisotropy that exists within the geohydrologic zones beneath OU B limits vertical migration of contaminants within or between zones. The assumptions of isotropy in the model allows for more extensive lateral or vertical distribution, and therefore, greater total contaminant mass migrating to a supply well in a zone. The assumption of isotropy in the horizontal plain would lead to erroneous calculations of migration velocity in some geohydrologic zones; however, migration velocities are not a basis for conclusions of the analytical model.

The assumption that the geohydrologic zones are infinite in extent is a common assumption in many mathematical models. The geohydrologic zones appear to be extensive throughout OU B and areas some distance beyond OU B on the basis of lithologic data. For the purpose of the modeling of contaminant migration to supply wells, the geohydrologic zones adequately meet the assumption of infinite extent.

E2.0 Flow Model

Analytical groundwater flow models were used to develop flow nets for individual geohydrologic zones in OU B in the vicinity of BW-18 and CW-132. The purpose of the models was to estimate concentrations of groundwater contaminants that could reach supply wells. The modeling approach was to develop solutions to the two-dimensional Laplace equation for steady flow to a fully penetrating well discharging from a homogeneous, isotropic aquifer of infinite areal extent. Solutions to the Laplace equation (i.e., harmonic solutions) were chosen because they allow groundwater flow to be expressed in terms of stream functions, which define channels of equal flow volume to the well from the surrounding aquifer. Using the stream functions, dilutions of aquifer contaminants were calculated and wellhead concentrations were determined. Two pumping scenarios were considered: BW-18 pumping and CW-132 turned off, and CW-132 pumping and BW-18 turned off.

E3.0 Theory

The BW-18 and CW-132 flow models are expressed in terms of two conjugate harmonic functions: potential, Φ, and the stream function, Ψ. Both functions are governed by the Laplace equation, so that:

$$\partial^2\Phi/\partial x^2 + \partial^2\Phi/\partial y^2 = 0 \qquad \text{(E-1)}$$

and

$$\partial^2\Psi/\partial x^2 + \partial^2\Psi/\partial y^2 = 0 \qquad \text{(E-2)}$$

where x and y are cartesian coordinates.

The piezometric head, ϕ, in confined groundwater systems can be extracted from the potential function, Φ, as:

$$\phi = (\Phi - C_c)/t \qquad \text{(E-3)}$$

where:

- T = transmissivity, L^2/t;
- C_c = a constant, L^3/t;
- L = unit of length; and
- t = unit of time.

In unconfined systems, piezometric head is expressed as:

$$\phi = (2(\Phi - C_u)/K)^{1/2} \quad \text{(E-4)}$$

where:

K = hydraulic conductivity, L/t; and
C_u = a constant, L^3/t.

Because the potential and stream functions are conjugates, i.e., they satisfy the Cauchy-Riemann conditions, they can be expressed as the real and imaginary parts of a comprehensive potential function, $\Omega(z)$. That is:

$$\Omega(z) = \Phi + i\Psi \quad \text{(E-5)}$$

where:

$z = x + iy$; and
$i = \sqrt{-1}$.

It is more convenient to use the complex representation of the potential function expressed in equation (E-5) than it is to solve for the potential and stream functions separately as (E-1) and (E-2), because (E-5) is simpler to implement as a computer program. After (E-5) is evaluated, it is a simple matter to extract the potential and stream functions as the real and imaginary parts of $\Omega(z)$, respectively. Except for considerations of ease of implementation and manipulation, equation (E-5) is equivalent to evaluating Φ and Ψ separately.

Since the Laplace equation is linear, expressions for $\Omega(z)$ can be superposed. That is:

$$\Omega(z) = \Omega_1(z) + \Omega_2(z) + \ldots + \Omega_n(z) \quad \text{(E-6)}$$

In equation (E-6), $\Omega_i(z)$ can be an expression for regional, uniform flow, flow towards a well, flow around an impermeable or semipermeable object (expressed as a dipole), or others.

In the BW-18 and CW-132 models, withdrawal wells were used exclusively. The expression for steady-state flow to a fully penetrating well in an infinite, isotropic, homogeneous aquifer is:

$$\Omega(z) = Q/(2\pi)\ln(z - z_w) + C \quad \text{(E-7)}$$

where:

Q = discharge of the well, L^3/t;
$z_w = x_w + iy_w$, the complex well position, L; and
C = a real constant, L^3/t.

E4.0 **BW-18 Model**

The BW-18 model was constructed as a system of four homogeneous, isotropic, confined aquifers of infinite areal extent, responding to a steady 1150 gallon per minute pumping rate at BW-18 and a regional depression of the piezometric surface, centered roughly one mile SSW of BW-18 and influencing all of OU B.

The four aquifers are designated, from top to bottom, as geohydrologic zones A, B, C, and D. Transmissivities of the zones were estimated to be (Cudzilo, pers. comm.):

- T_A = 140 to 280 ft^2/day
- T_B = 200 to 450 ft^2/day
- T_C = 3500 to 5000 ft^2/day
- T_D = 2300 to 2800 ft^2/day

A fifth zone, designated as E, underlies the D zone. Little or no contamination has been reported in groundwater sampled from this zone and BW-18 is not screened in it. It was not included in the groundwater flow model. It is possible that there is some hydraulic communication between the D and E zones by leakage across the low permeability layer that separates them. If this communication exists, then there will be a certain amount of groundwater contributed by the E zone to water pumped by BW-18. However, by neglecting this potential effect, a conservative assumption has been made because a correspondingly larger share of the total water pumped by BW-18 is attributed to the A through D zones, which are more highly contaminated. Therefore, wellhead concentrations of contaminants will be higher when neglecting the possible contribution of the E zone than would otherwise be predicted.

The approach used to model the groundwater flow system around BW-18 was to treat each zone as a separate system, hydraulically unconnected to adjacent zones. This is not strictly true, as drawdown has been observed in the A zone, for example, in response to pumping at BW-18 (Radian, 1989a), despite the fact that BW-18 is screened only in the B, C, and D zones. Leakage is thought to occur between the

other zones as well. The model accounts for this vertical component of flow across the separating layers indirectly by attributing it to an increase in the horizontal flow component. That is, groundwater that physically leaves a zone by leakage into an adjacent zone is forced, mathematically, to remain in the original layer and travel horizontally to the well. In the physical system, groundwater in different zones can mix at the zonal boundaries. In the modeled system, groundwater in different zones is mixed only at the wellhead.

The advantage of this modeling approach is that a flow net can be constructed for each zone and used to calculate the dilution of contaminants as groundwater with varying degrees of contamination is drawn into the well. If leakage across zones were treated explicitly, then it would be impossible to construct flow nets. When leakage is included, the system is no longer described by the Laplace equation, but instead, is described by the Poisson equation for which no analytic stream function exists.

Inaccuracies introduced by this approach are of two types: one involving the potentials and one involving the streamlines. First, the potential around the well is inaccurately described with this approach. The inaccuracy is largest near the well and approaches zero at large distances from the well. However, the objective of the model is not to predict water levels but to calculate wellhead concentrations. Since dilution calculations do not rely on predicted water levels, this first type of inaccuracy does not affect the modeling objective.

The second type of inaccuracy involves the flow paths themselves. By restricting groundwater movement to the horizontal plane, groundwater that might otherwise cross a boundary layer and pass through a zone of contamination in an adjacent zone is not allowed to do so. If the actual hydraulic conditions cause leakage from a zone with a higher contaminant concentration to a deeper zone with a lower contaminant concentration, then the model will produce a conservative estimate of groundwater contamination because more groundwater is retained in the more highly contaminated zone than would physically occur. If the leakage occurs from a zone of lower concentration to a zone of higher contamination, then the model will produce a nonconservative estimate, because the groundwater that would otherwise leak across the boundary and pass through the region of higher contamination is not allowed to do so in the model. In OU B, the A zone is most highly contaminated and levels of contamination generally decrease in deeper zones. When pumped, BW-18 produces a downward gradient between the A and B zones. Since the A zone is more highly

contaminated than the B zone, we conclude that the proposed modeling approach is conservative.

Water level elevations representing pumping and nonpumping conditions at BW-18 are presented in Table E-1. The May, 1989, elevation data show that a roughly circular cone of depression is formed in each of the zones in response to BW-18 pumping, and that the cone of depression is centered on the well. This response is observed in all zones, including the A zone. Evidently, groundwater in the A zone responds to BW-18 pumping as if the well were screened in it.

The discrepancy between the stated approach of modeling each layer as an isolated groundwater flow system (i.e., with no hydraulic communication between layers) and the observed condition of some hydraulic communication is not critical, provided the model correctly apportions well discharge between the layers. In the B, C, and D zones, groundwater is modeled as flowing to wells in each of the zones. The discharge of these modeled wells in the B, C, and D zones is equal to the combined contribution of groundwater in the zone being modeled and groundwater entering from adjacent zones. In the A zone, the modeled groundwater moves in response to a virtual well with a discharge equal to the effect of leakage from the A zone into the B zone. The data presented in Table E-1 allow the discharge of BW-18 to be apportioned between the four zones. If the groundwater flow system is assumed to be steady-state, isotropic, homogeneous, confined, and infinite in areal extent, the zones are assumed to be hydraulically separate, and wells in each zone are assumed to be fully penetrating, then equations (E-3) and (E-7) correctly define the aquifer response to pumping in each zone. Thus, a graphical plot of the change in potential, ϕ, as a function of $\ln(r)/(2\pi)$ (where r is radial distance from the well) will describe a straight line with a slope of Q/T and a y-intercept of C/T, if the assumptions are correct. The data in Table E-1 are shown plotted this way in Figure E-1, for the A, B, and C zones. The graphs show a very strong linear correlation between ϕ and $\ln(r)/(2\pi)$ which indicates that the conceptual model is acceptable. Therefore, the hydraulic influence of BW-18 can be represented by a series of wells pumping from unconnected hydraulic units, each of which have aquifer properties of isotropy, homogeneity, etc. Since there was only a single drawdown value available in the D zone for the May, 1989, measurements, this method could not be applied to that zone.

Additional data (January and April, 1990) were analyzed in which drawdown in the D zone was measured at multiple locations. When the linear regression described above was applied to these data, it was found that the conceptual

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TABLE E-1. WATER LEVELS FOR WELLS NEAR BASE WELL 18 COMPARING EFFECTS WITH/WITHOUT PUMPING

Well Number	Without Pumping April 1989	With Pumping May 1989	Difference (May - April)	Distance From BW 18 (feet)
A ZONE				
MW-1021	-39.64	-42.79	-3.15	280
MW-1044	-40.13	-41.99	-1.86	680
MW-41S	-38.62	-38.72	-.10[a]	880
MW-7	-39.47	-40.77	-1.3	900
MW-150	-40.31	-41.70	-1.39	980
MW-145	-39.12	-44.41[a]	-5.06	1,520
MW-1016	-40.12	-42.23	-1.60	1,140
MW-1000	-40.09	-41.77	-1.68	1,480
MW-120	-36.84	-37.12	-.28	1,720
MW-1015	-40.94	-41.72	-.78	2,260
MW-135	-37.75	-38.32	-.57	2,500
B ZONE				
MW-1022	-39.10	-47.77	-8.67	300
MW-66	-47.99	-46.36	+1.63[a]	380
MW-1045	-39.67	-44.69	-5.02	680
MW-63	-38.92	-43.07	-4.15	700
MW-23D	-39.15	-45.53	-6.38	590
MW-151	-39.66	-43.93	-4.27	940
MW-146	-38.84	-44.98	-6.14	1,520
MW-122	-36.37	-39.53	-3.16	1,700
MW-134	-37.61	-38.32	-.71	400
C ZONE				
MW-1046	-39.24	-46.64	-7.4	680
MW-132	-38.84	-44.45	-5.61	800
MW-152	-39.26	-46.29	-7.03	960
MW-147	-38.59	-41.46	-2.87[a]	1,520
MW-133	-37.89	-39.22	-1.33	2,400
D ZONE				
MW-1047	-36.84	-40.33	-3.49	680
E ZONE				
MW-1048	-38.24	-40.23	-1.99	680

[a]These measurements are suspect and have not been used in hydrologic evaluations.

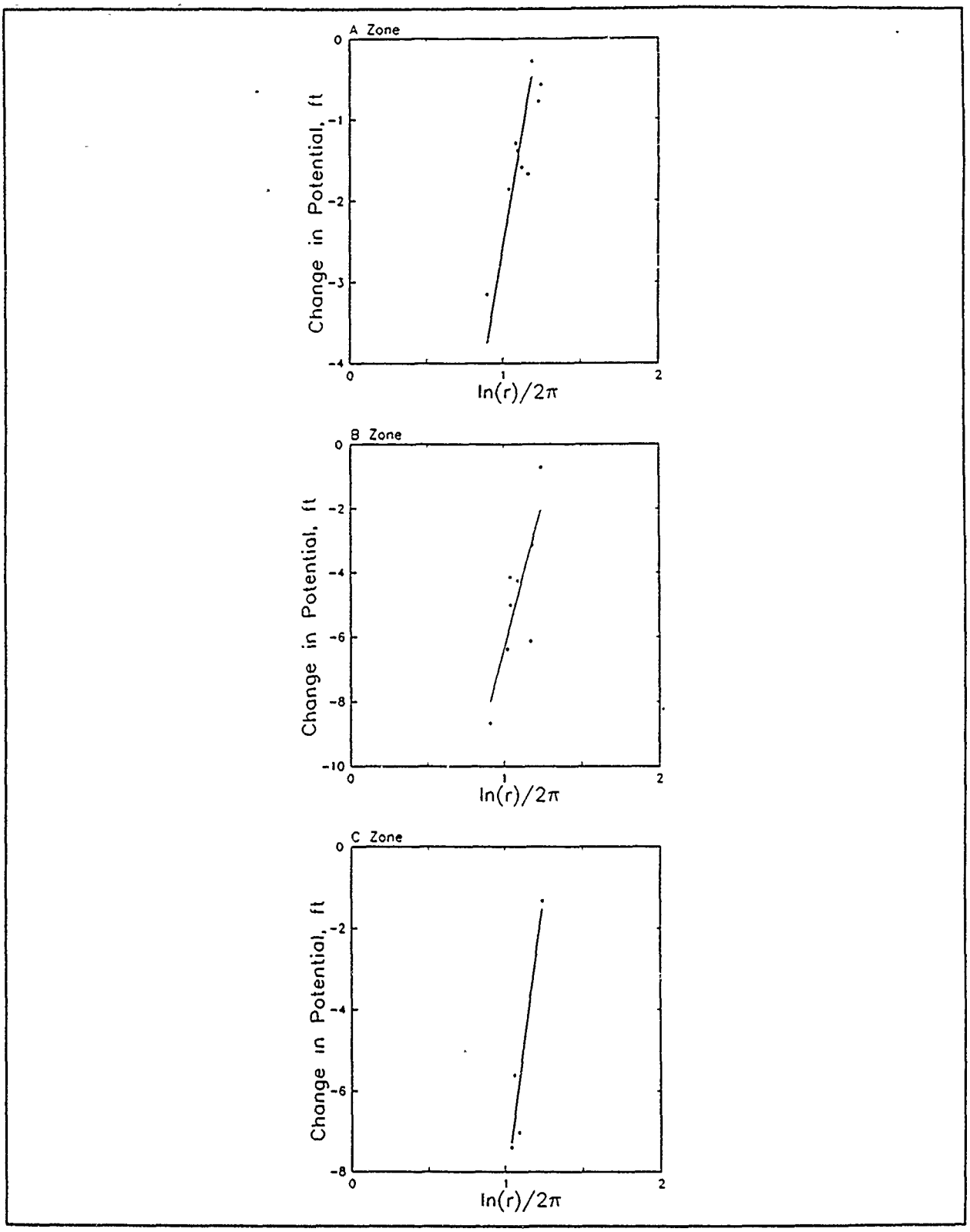

Figure E-1. Drawndown in the Vicinity of BW-18 for the A, B, and C Geohydrologic Zones, OU B, McClellan AFB, CA

model did not explain the measured drawdown. We concluded that one or more of the assumptions of the conceptual model is violated in that zone. As a result, flow nets representing flow to a well in the D zone could not be constructed to calculate wellhead concentrations in the D zone. The alternative method used for the D zone is described in Section E6.0.

Average values of transmissivity in the A, B, and C zones were used to calculate a value of the well discharge, Q, in each zone. The sum of these discharges is 682 gpm, compared to a total average discharge at BW-18 of 1150 gpm. The difference of 468 gpm is assumed to be pumped from the D zone. With Q quantified for each zone, equation (E-7) can be evaluated. Results of the calculations for Q are as follows:

Zone	Q/T (ft)	T (ft^2/day)	Q (gpm)
A	11.7	210	13
B	18.2	325	31
C	28.9	4250	638
D	-	-	468

Regional maps of the piezometric surface indicate a persistent depression south of McClellan AFB, as shown in Figure E-2. Presumably, the depression is caused by pumping in the water supply wellfield south of McClellan AFB. Whatever its cause, this prominent feature of the piezometric surface must be incorporated in the model to simulate groundwater flow in the vicinity of BW-18. To do so, a hypothetical well was used to generate the depression. The well was located 5000 feet south and 3000 feet west of BW-18. Noting that the depression is roughly circular in the vicinity of the BW-18, equations (E-7) and (E-3) were used to calculate Q and C for this hypothetical well in each of the modeled zones. The same conditions of full well penetration, steady-state conditions, homogeneity, etc. were assumed to apply to this hypothetical well as they are to BW-18. Estimated discharges of modeled wells in the A, B, and C zones were 160, 300, and 2900 gpm, respectively.

The model used to generate a flow net for the A, B, and C zones in the vicinity of BW-18 simulates the effect of BW-18 and the hypothetical well southwest of the base. The model is:

$$\Omega(z) = Q_{BW-18}/(2\pi)\ln(z-z_{BW-18}) + Q_{virt}/(2\pi)\ln(z-z_{virt}) + C \qquad \text{(E-8)}$$

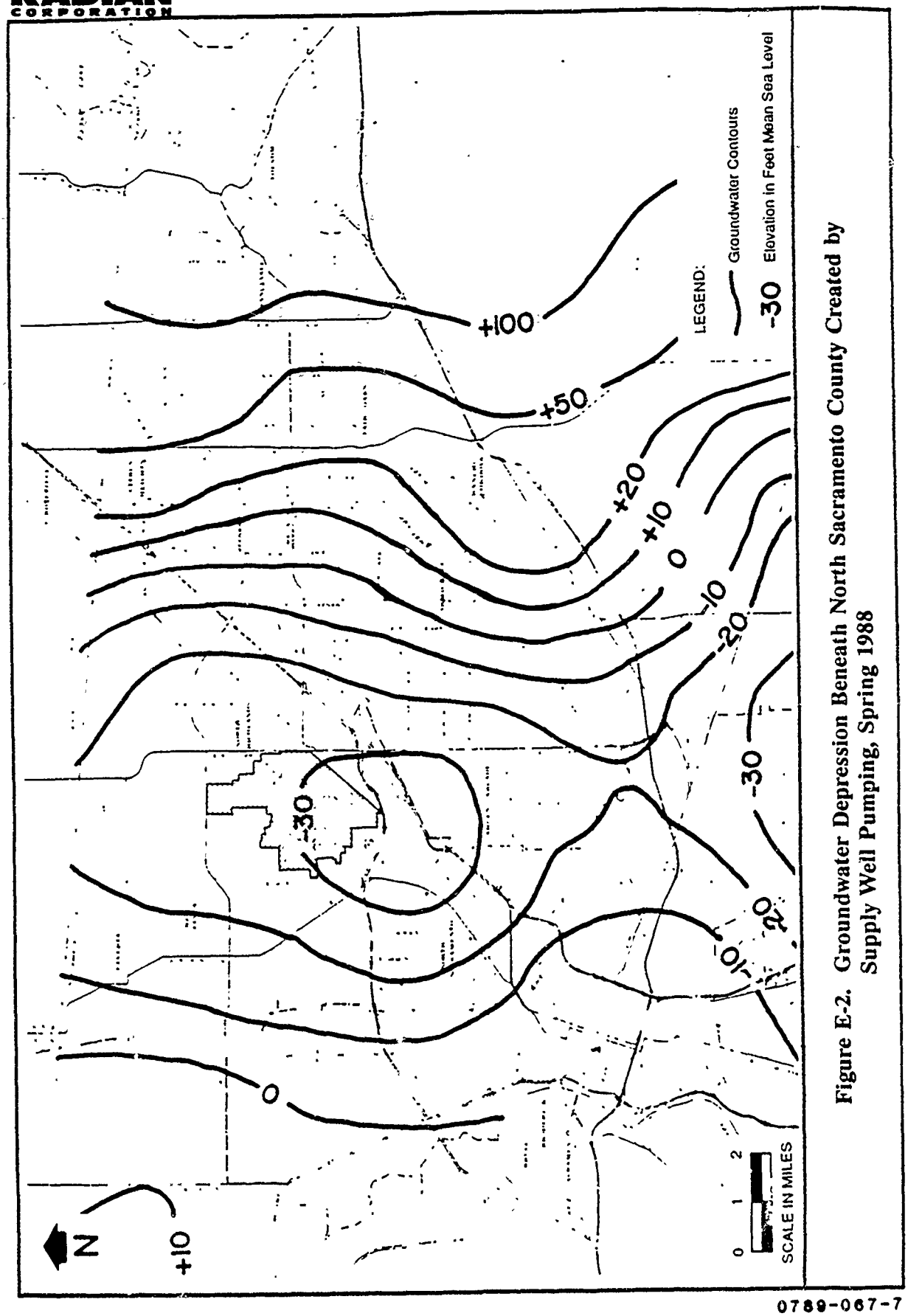

Figure E-2. Groundwater Depression Beneath North Sacramento County Created by Supply Well Pumping, Spring 1988

SOURCE Water Resources Division, Department of Public Works, County of Sacramento

where the subscript 'BW-18' refers to BW-18 and the subscript 'virt' refers to the hypothetical well used to create the depression in the regional piezometric surface. Equation (E-8) was applied to each of the four zones using the values for Q_{BW-18}, z_{BW-18}, Q_{virt}, and z_{virt} described above. It should be noted that because the constant, C, is a real number, it affects the value of the potential but has no effect on the value of the stream function. It can be interpreted as an adjustment to the datum from which piezometric heads are measured. It has no effect on the predicted speed or direction of groundwater flow.

Equation (E-8) was implemented as a FORTRAN computer program which evaluated $\Omega(z)$ at 5151 locations (values of z) on a regular, 51x101 rectangular grid. The real and imaginary parts of Ω, which correspond to the potential and stream functions, respectively, were evaluated and imported into a contouring software package to produce the flow nets shown in Figures E-3, E-5, and E-7. There is good agreement between the flow nets generated by equation (E-8) and the potentiometric maps developed from field measurements and shown in Figures E-4, E-6, and E-8

The streamlines in the flow nets are spaced such that exactly 5% of the net flow to the well passes between adjacent streamlines. The nets can be used to accurately calculate the physical dilution that occurs when contaminated groundwater and uncontaminated groundwater are simultaneously drawn into the well. A description of this procedure and the results of its application to the region near BW-18 are presented in Section E6.0.

E5.0 CW-132 Model

Flow to CW-132 was modeled in the same manner as BW-18; however, the type of drawdown data used to apportion flow between various zones in the BW-18 model was not available in useable form for CW-132. Although drawdown data exist for conditions with and without CW-132 pumping, the piezometers at which drawdown was measured are too far from CW-132 to provide useful information. When the available data are analyzed by the method illustrated in Figure E-1, no linear relationship emerges and we conclude that the piezometers are outside the zone of influence of CW-132.

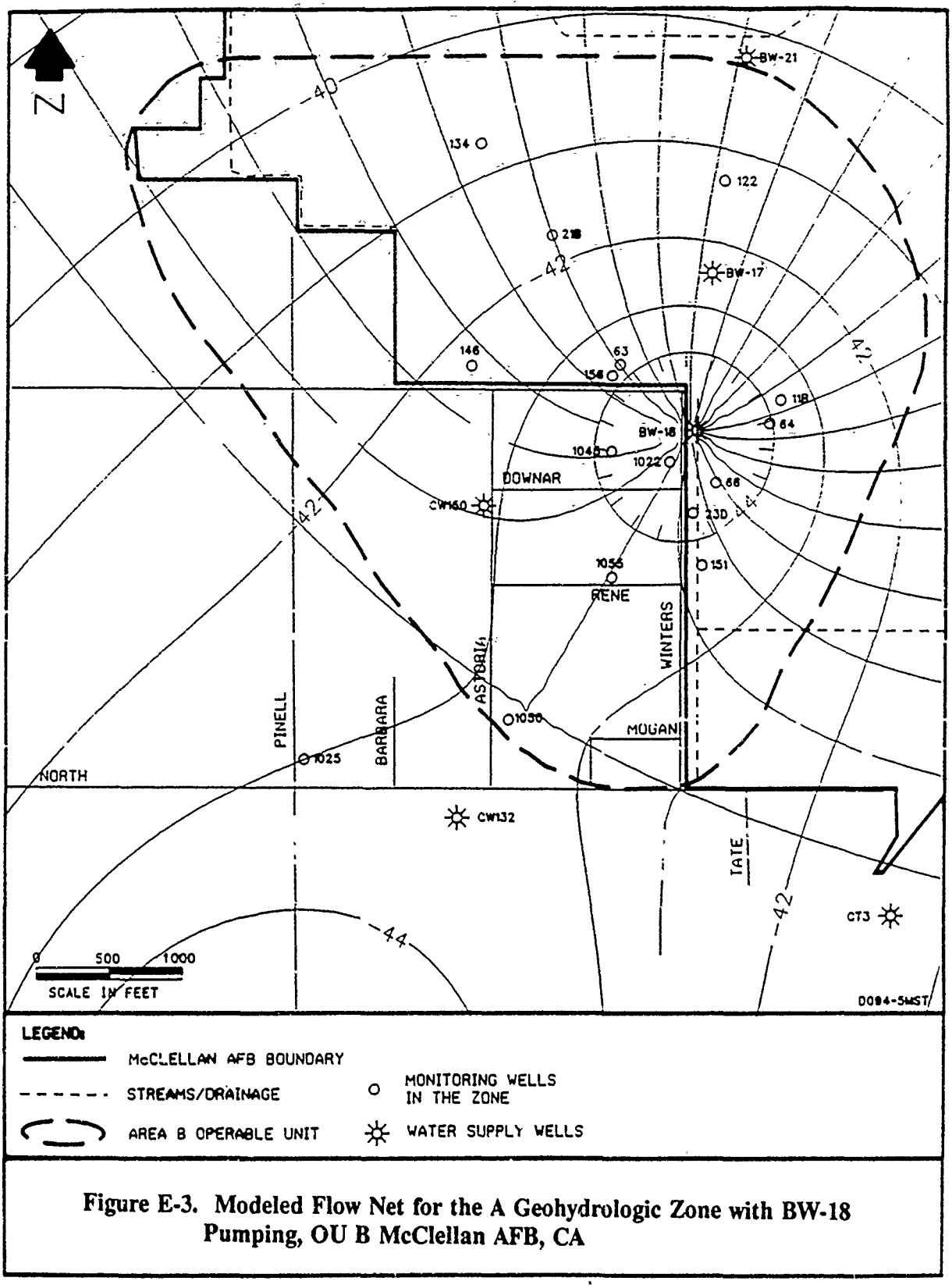

Figure E-3. Modeled Flow Net for the A Geohydrologic Zone with BW-18 Pumping, OU B McClellan AFB, CA

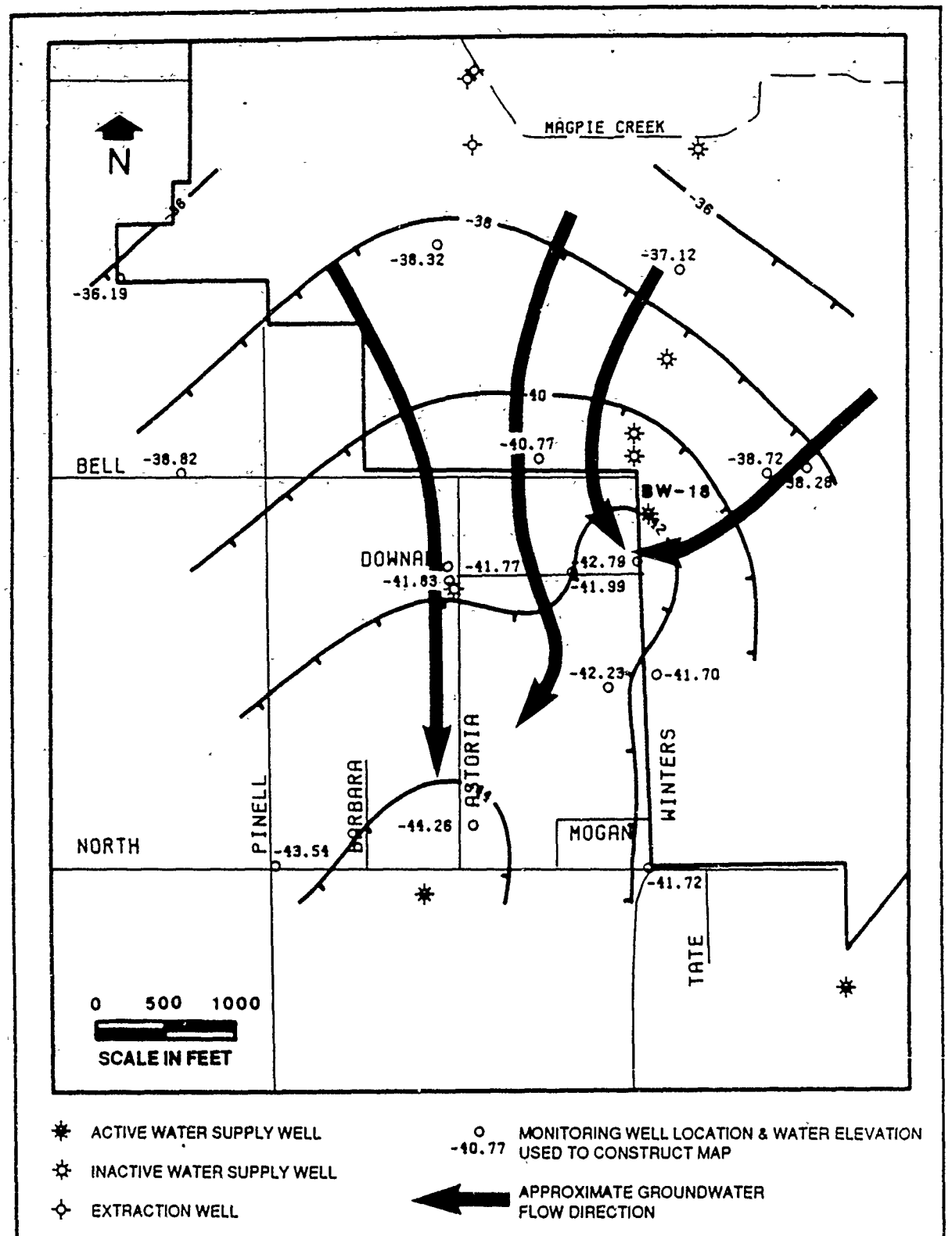

Figure E-4. Potentiometric Surface Map for the A Geohydrologic Zone with BW-18 Pumping, May 1989, Area B Goundwater Operable Unit

0789-067-11

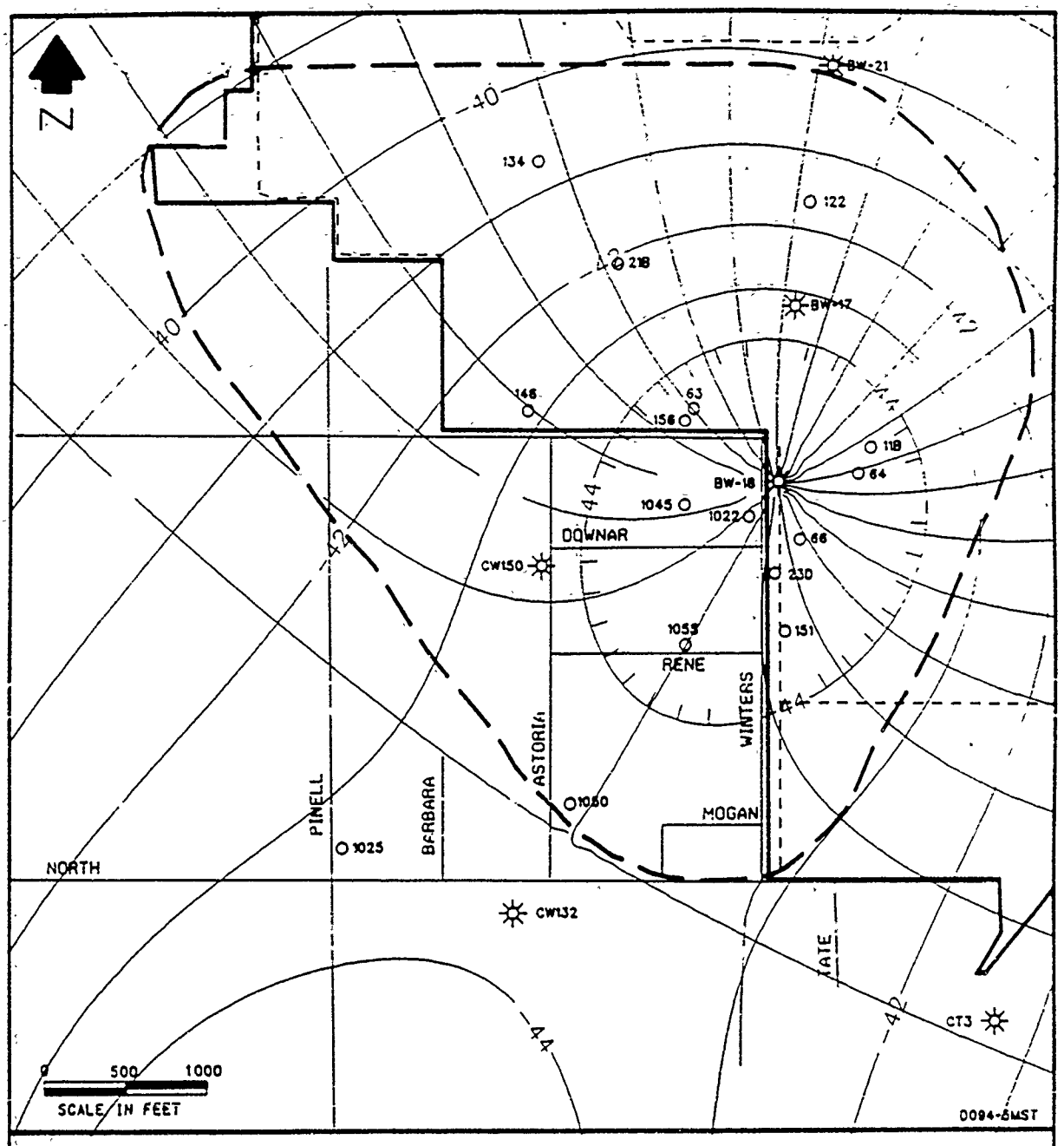

Figure E-5. Modeled Flow Net for the B Geohydrologic Zone with BW-18 Pumping, OU B, McClellan AFB, CA

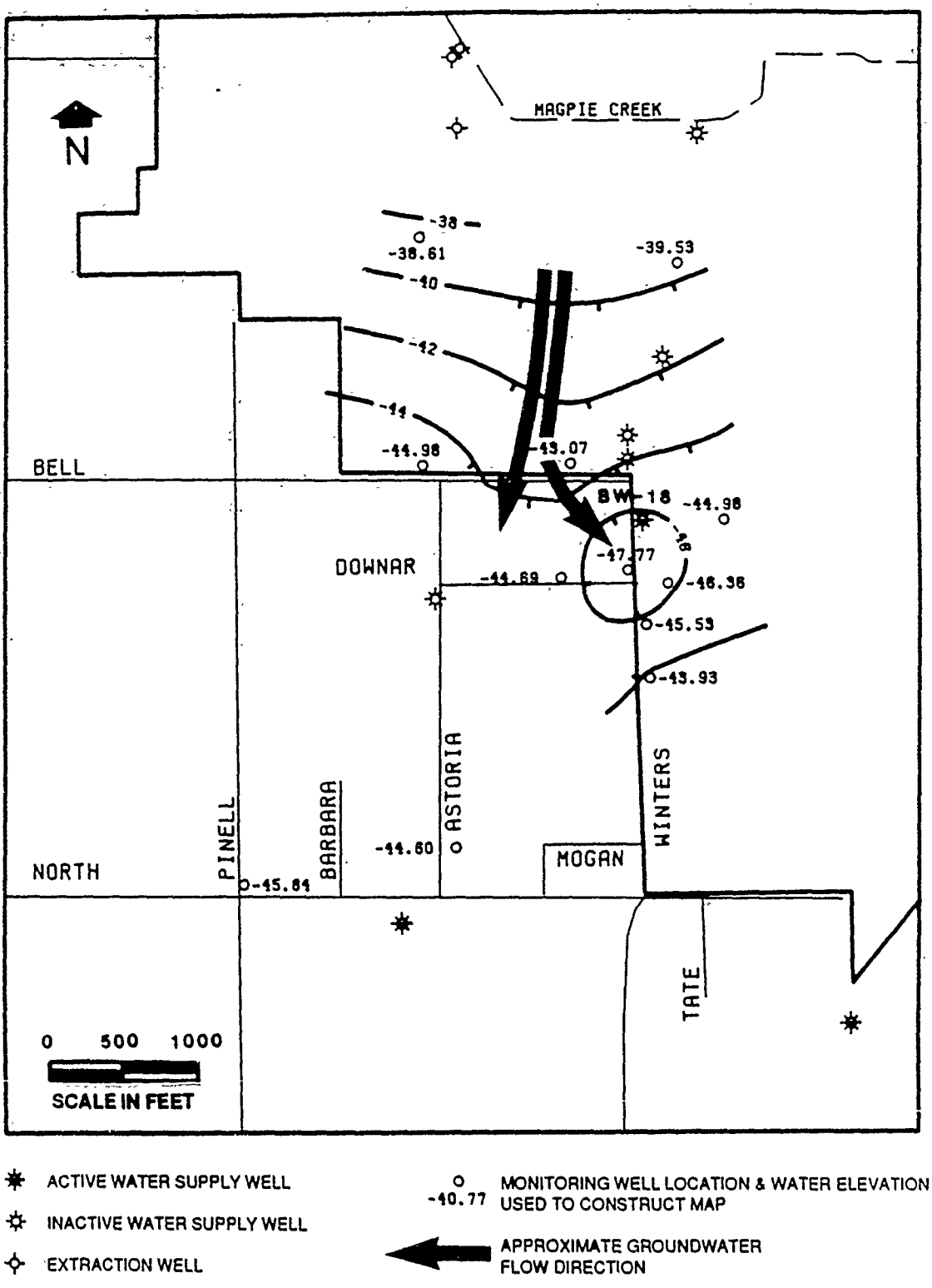

Figure E-6. Potentiometric Surface Map for the B Geohydrologic Zone, with BW-18 Pumping, May 1989, Area B Groundwater Operable Unit

0789-067-12

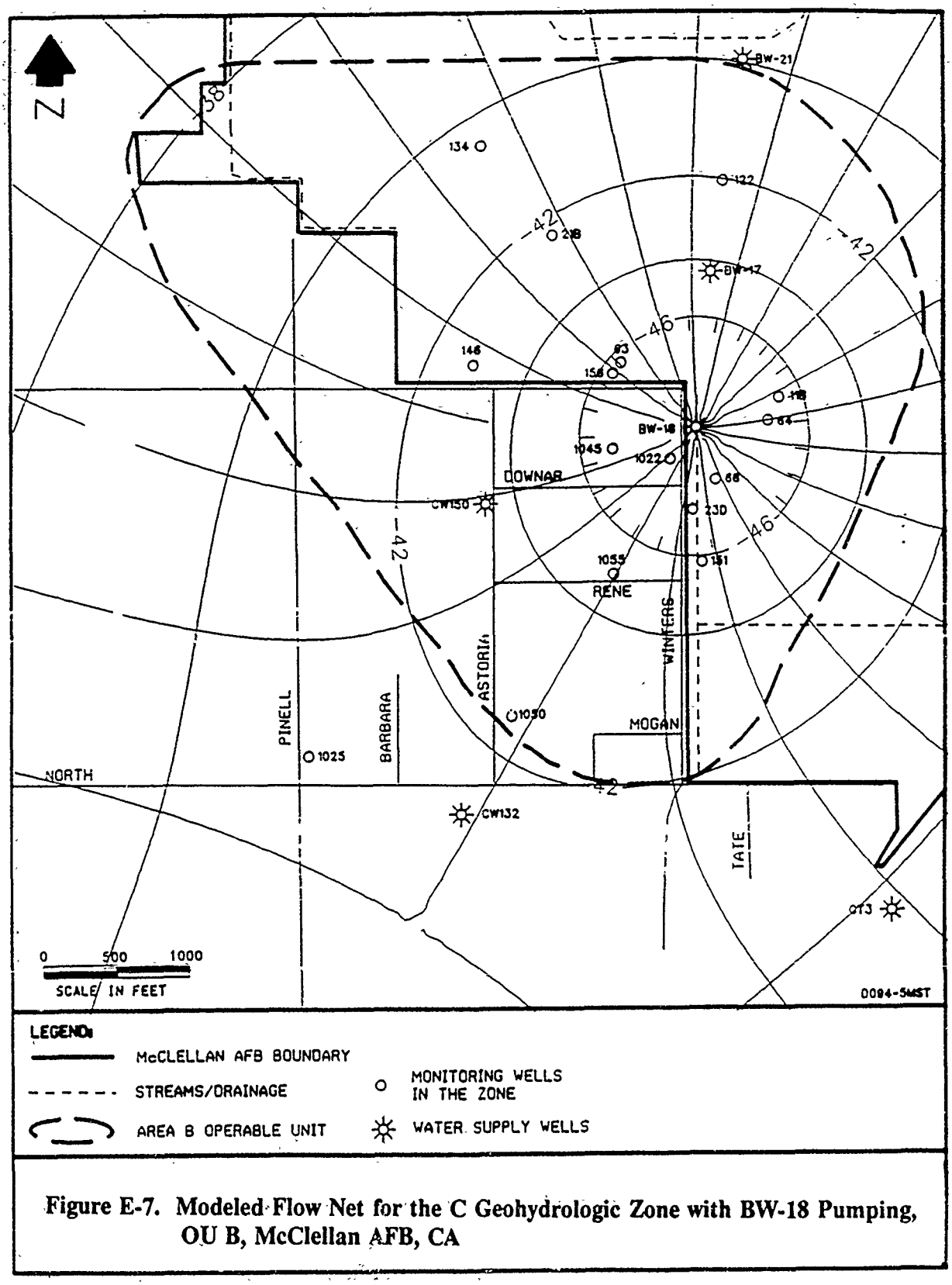

Figure E-7. Modeled Flow Net for the C Geohydrologic Zone with BW-18 Pumping, OU B, McClellan AFB, CA

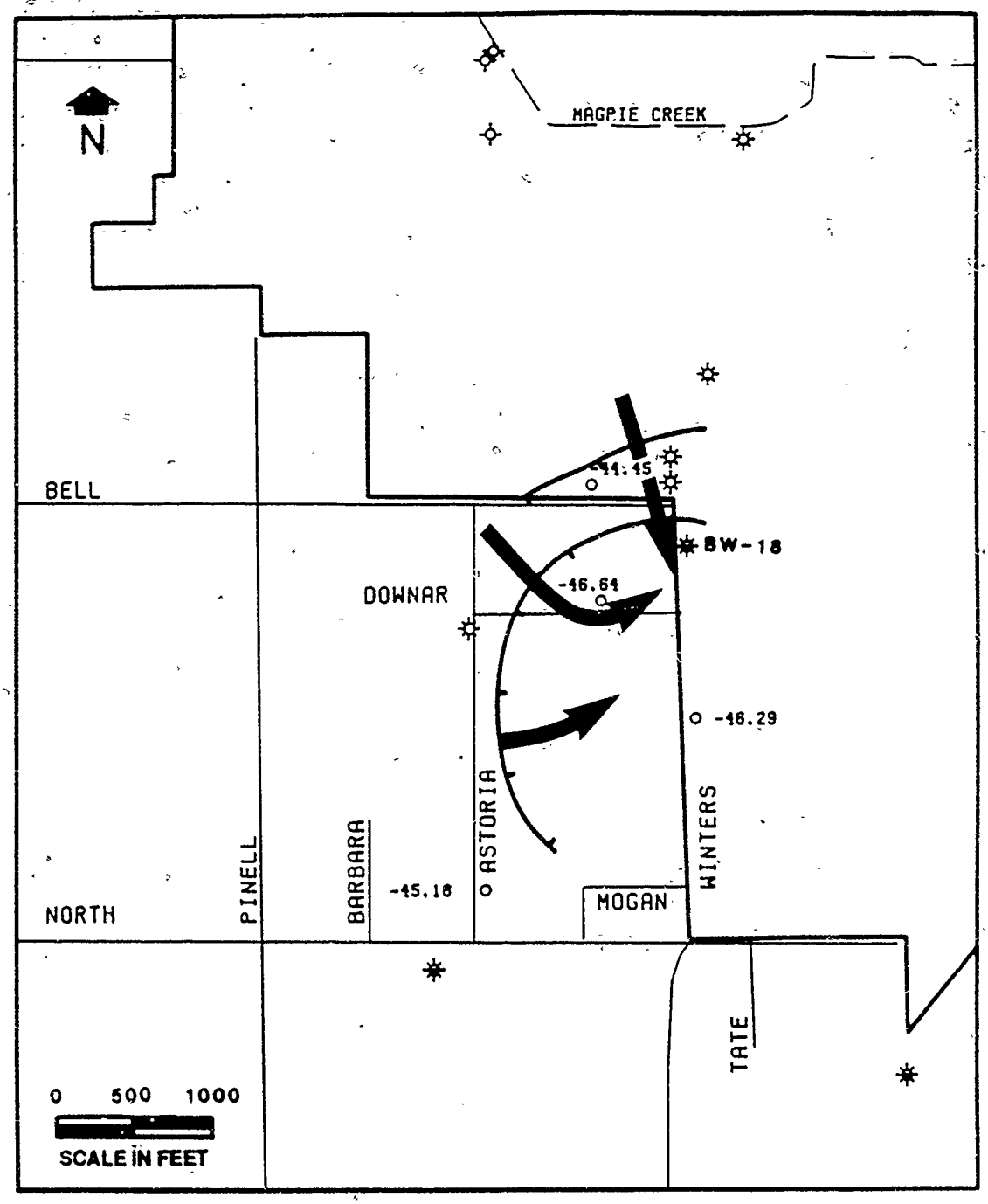

Figure E-8. Potentiometric Surface Map for the C Geohydrologic Zone, with BW-18 Pumping, May 1989, Area B Groundwater Operable Unit

0789-067-13

CW-132 is screened only in the C zone. The extent to which CW-132 withdraws groundwater from the other zones can be determined by explicitly treating the system of aquifers as leaky aquifers and predicting the drawdown that would be produced in each of the zones in response to leakage across semiconfining layers. Once the drawdown in each zone is estimated, then a hypothetical well can be placed in each aquifer to produce solutions to the groundwater flow problem in the form of equation (E-7).

To apply this method, however, the resistance to flow must be determined for the semiconfining layers. Specifically, the leakance of the semiconfining layers must be determined, where leakance, L, is defined as:

$$L = K/H \qquad \text{(E-9)}$$

where:

- L = leakance, t^{-1};
- K = saturated hydraulic conductivity of the low permeability zone, L/t; and
- H = thickness of the low permeability zone L.

Leakance for the semiconfining layer separating geohydrologic zones A and B was estimated using the drawdown data presented in Table E-1 for response to BW-18 pumping, the BW-18 pumping rates from zones A and B derived in Section E4.0, and a mathematical model for drawdown in a system of aquiters separated by a semiconfining layer. That model, which predicts potential in a system of two isotropic, homogeneous aquifers of infinite areal extent, separated by a semiconfining layer of leakance L, and with a fully penetrating well in the lower aquifer, is (Strack, 1989):

$$\Phi_1 = Q/(2\pi(1+\gamma))[\ln(r)+K_0(\omega r)]+C/(1+\gamma) \qquad \text{(E-10)}$$

$$\Phi_2 = Q/(2\pi(1+\gamma))[\gamma\ln(r)-K_0(\omega r)]+\gamma C/(1+\gamma) \qquad \text{(E-11)}$$

where Φ_1 = potential in the upper aquifer, L^3/t,
Φ_2 = potential in the lower aquifer, L^3/t,
Q = well discharge, L^3/t,
$\gamma = T_2/T_1$,
T_1 = transmissivity of the upper aquifer, L^2/t,
T_2 = transmissivity of the lower aquifer, L^2/t,
r = radial distance from the well, L,

K_0 = modified Bessel function of the second kind, order zero,
$\omega = [L(1/T_1+1/T_2)]^{0.5}$, L^{-1}, and
C = a constant, L^3/t.

Using a value of Q = 13 + 31 = 44 gpm as the combined pumping rate for the A and B zones derived in Section E4.0, trial values of leakance were used and compared to the drawdown data for the A and B zones presented in Table E-1. A value of $L = 3.6x10^{-4}$ day^{-1} produced the best agreement (least root mean square error) between predicted and observed drawdown. Plots of these data are shown as Figure E-9.

It was not possible to perform the same type of analysis for the semiconfining layer separating the B and C zones because BW-18 is screened in both zones and the contribution of groundwater from leakage across the semiconfining layer cannot be separated from the groundwater flow directly to the screened portion of the well in the two zones. Instead, the leakance of this semiconfining layer was estimated to be 50 to 100 times greater than that of the layer separating the A and B zones, based on lithology and thickness of the two semiconfining layers (Cudzilo, pers. comm.). This yields a leakance of roughly 0.03 day^{-1}.

Inspection of equations (E-10) and (E-11) shows that the potentials Φ_1 and Φ_2 approach $Q/(2\pi(1+\gamma))\ln(r)+C/(1+\gamma)$ and $\gamma Q/(2\pi(1+\gamma))\ln(r)+\gamma C/(1+\gamma)$ rapidly with increasing distance, r. This occurs because the Bessel function, K_0, approaches zero for large arguments. That is, for large arguments, the potentials Φ_1 and Φ_2 reduce to equation (E-7) with discharges of $Q_1 = Q/(1+\gamma)$ and $Q_2 = \gamma Q/(1+\gamma)$. The radial distance at which these solutions converge depends on the leakance, which is contained in the term ω. For the A and B zones, the potentials derived by equation (E-7) and those derived by equations (E-10) and (E-11) agree to within 5% for radial distances greater than about 800 feet. For the B and C zones, the potentials agree to within 5% for radial distances greater than about 160 feet.

This observation was used to apportion flow between the A, B, and C zones in response to pumping at CW-132, which is screened entirely in geohydrologic C zone. A conservative assumption was made that the D zone does not contribute groundwater to the well. For an average CW-132 discharge of 700 gallons per minute and for trans

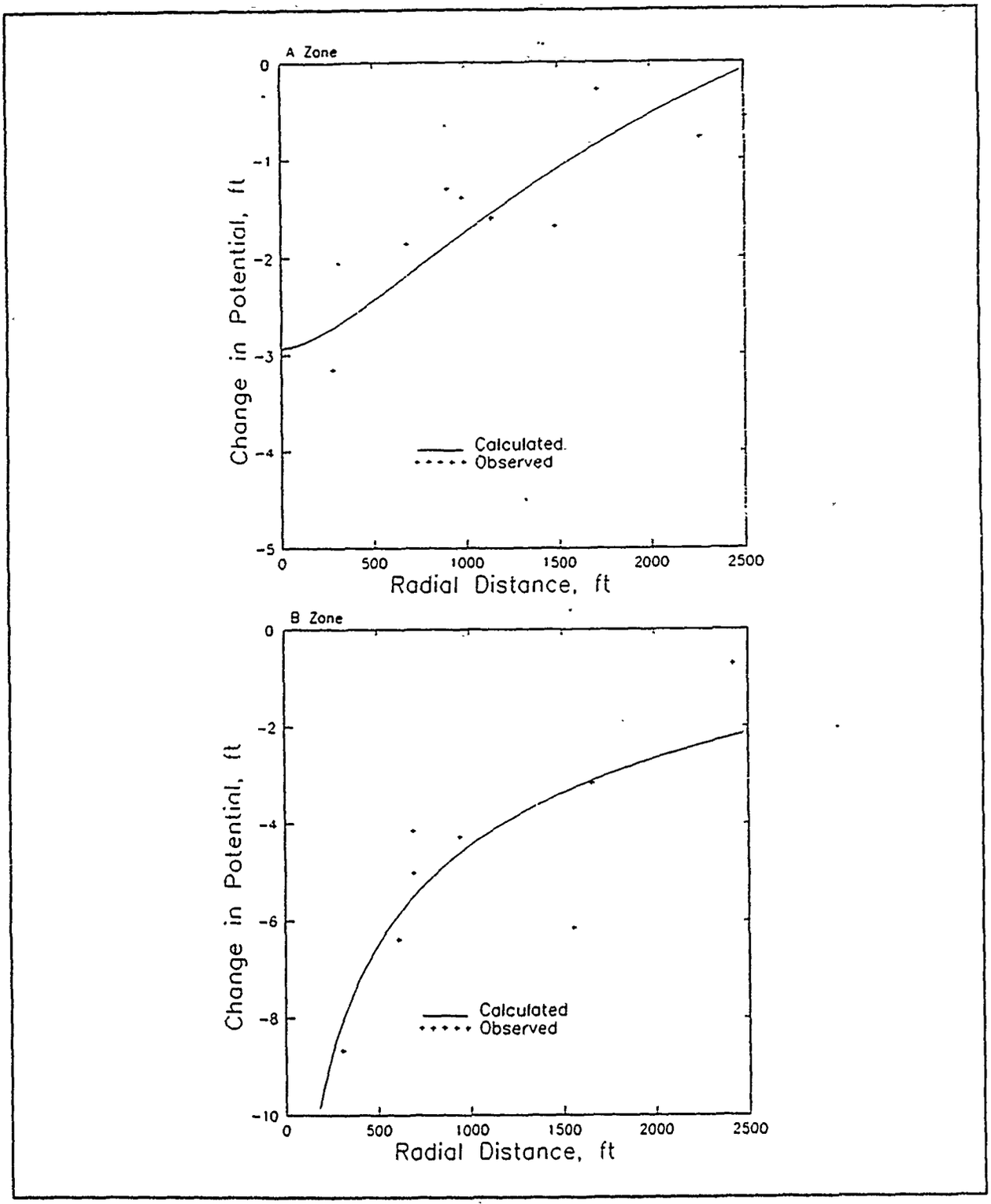

Figure E-9. Comparison of Leaky Aquifer Model to Observed Drawdown in the A and B Geohydrologic Zones, OU B, McClellan AFB, CA

missivities of the three layers taken as 210, 325, and 4250 ft^2/day for the A, B, and C zones, respectively, the discharges from the three zones are as follows:

$$Q_A = QT_A/(T_A+T_B+T_C) = 30 \text{ gallons per minute}$$
$$Q_B = QT_B/(T_A+T_B+T_C) = 48 \text{ gallons per minute}$$
$$Q_C = QT_C/(T_A+T_B+T_C) = 622 \text{ gallons per minute}$$

where:

Q_A = discharge from the A zone, L^3/t;
Q_B = discharge from the B zone, L^3/t;
Q_C = discharge from the C zone, L^3/t;
Q = CW-132 discharge, L^3/t;
T_A = transmissivity of the A zone, L^2/t;
T_B = transmissivity of the B zone, L^2/t; and
T_C = transmissivity of the C zone, L^2/t.

Except for the method by which flow from the various geohydrologic zones was calculated, the analysis of groundwater flow around CW-132 followed the same procedure as that described in Section E4.0 for BW-18. Equation (E-8) was used (with the subscript BW-18 replaced by CW-132) to produce flow nets for the A, B, and C zones in response to pumping at CW-132. These flow nets are shown as Figures E-10, E-11, and E-12.

E6.0 Contaminant Concentrations at Wellheads

The flow nets and zonal pumping distribution developed in Sections E4.0 and E5.0 were used to calculate dilution of groundwater contaminants in BW-18 and CW-132 discharge water. The flow nets were overlayed onto maps showing the concentration distribution of each contaminant. The number of streamlines passing through areas having isopleths of equal contaminant concentrations were counted. Contaminant concentrations represented by isopleths were assumed to be uniform through the thickness of the geohydrologic zone. Since the flow nets were constructed such that each pair of adjacent streamlines defines 5% of the total well discharge from that zone, the concentration of contaminant in well water from the j^{th} zone is:

$$c_j = 0.05\sum_{i=1}^{20}(c_i) \qquad \text{(E-12)}$$

$$(j = 1,2,3,4)$$

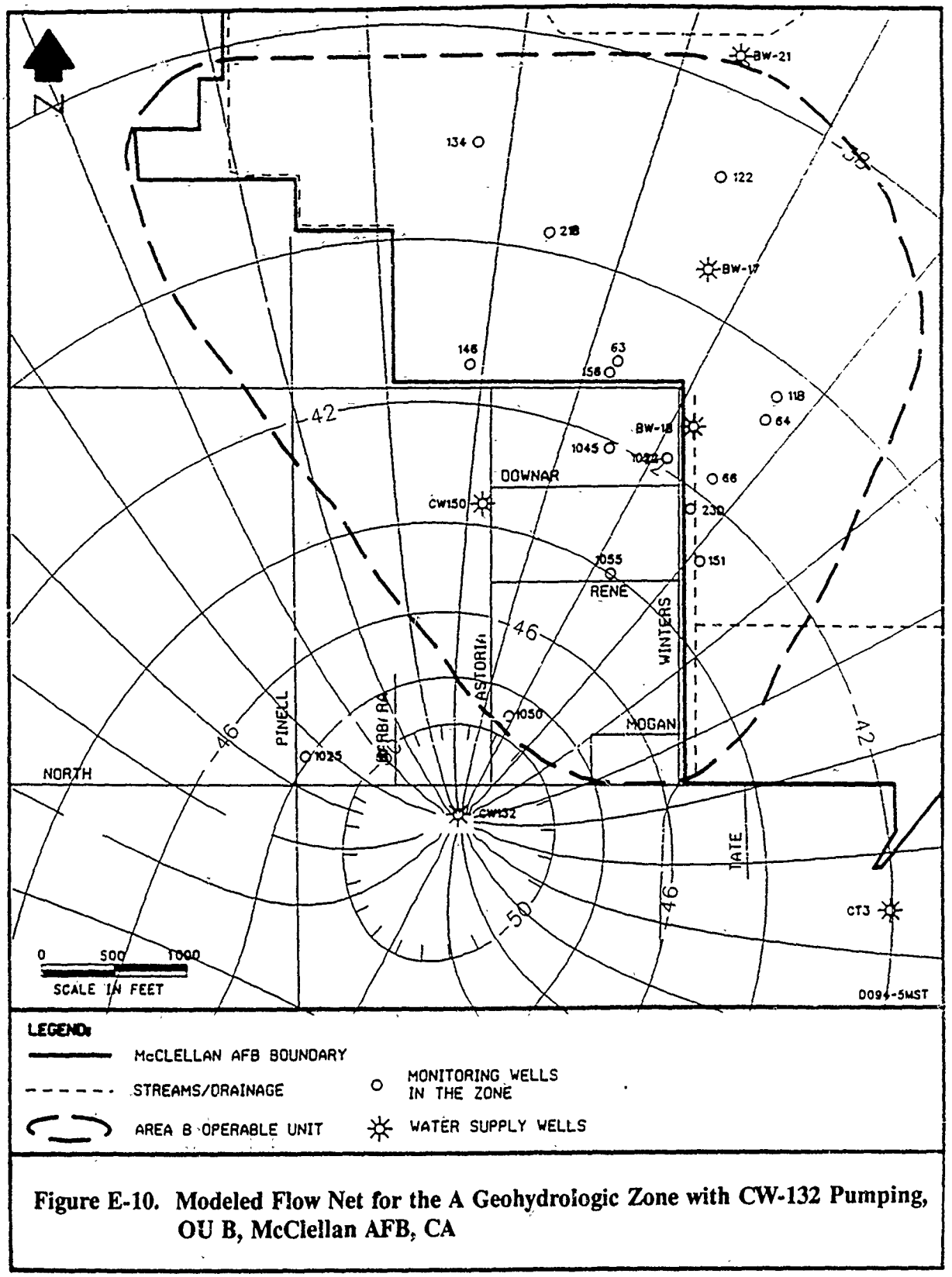

Figure E-10. Modeled Flow Net for the A Geohydrologic Zone with CW-132 Pumping, OU B, McClellan AFB, CA

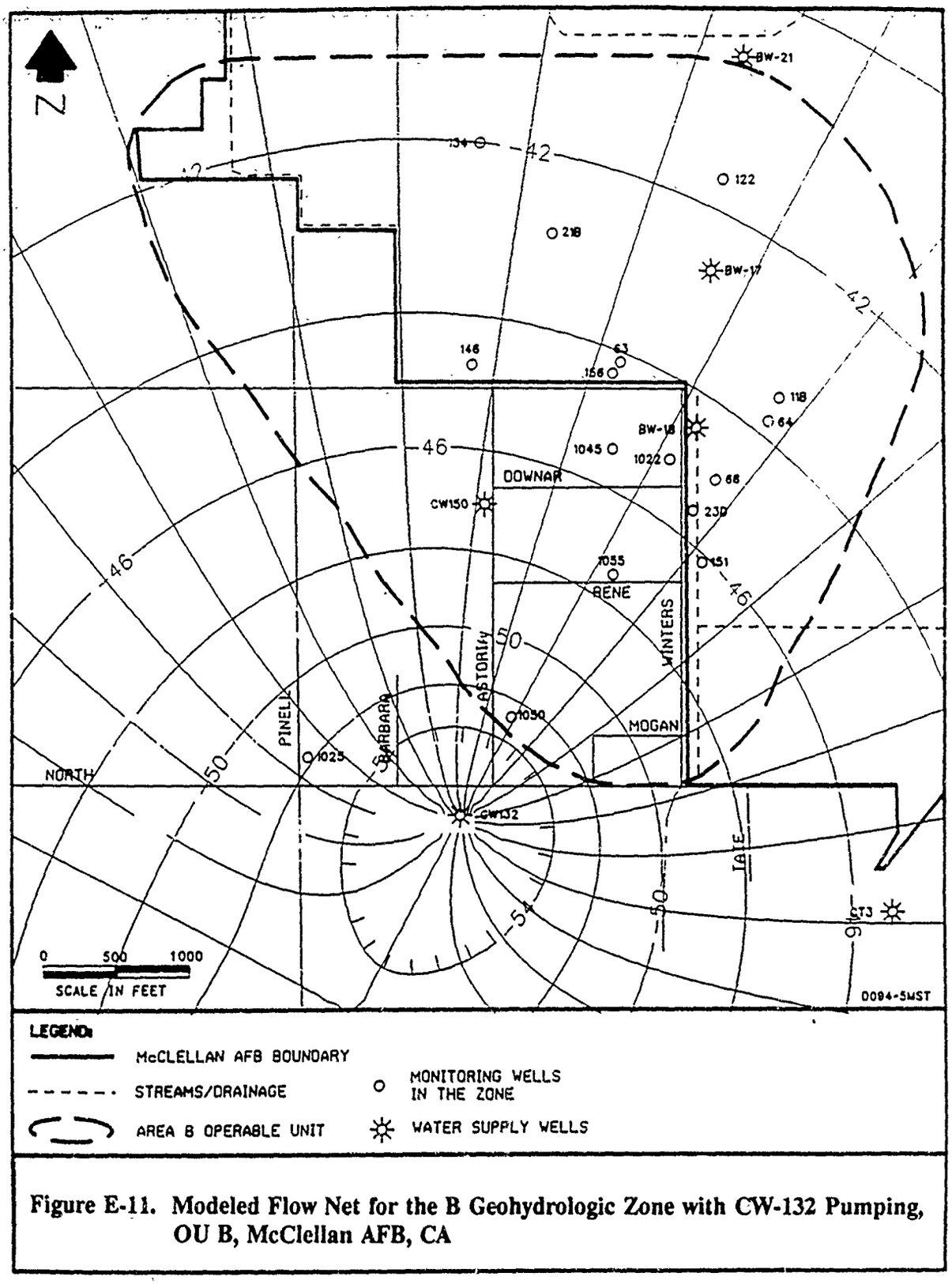

Figure E-11. Modeled Flow Net for the B Geohydrologic Zone with CW-132 Pumping, OU B, McClellan AFB, CA

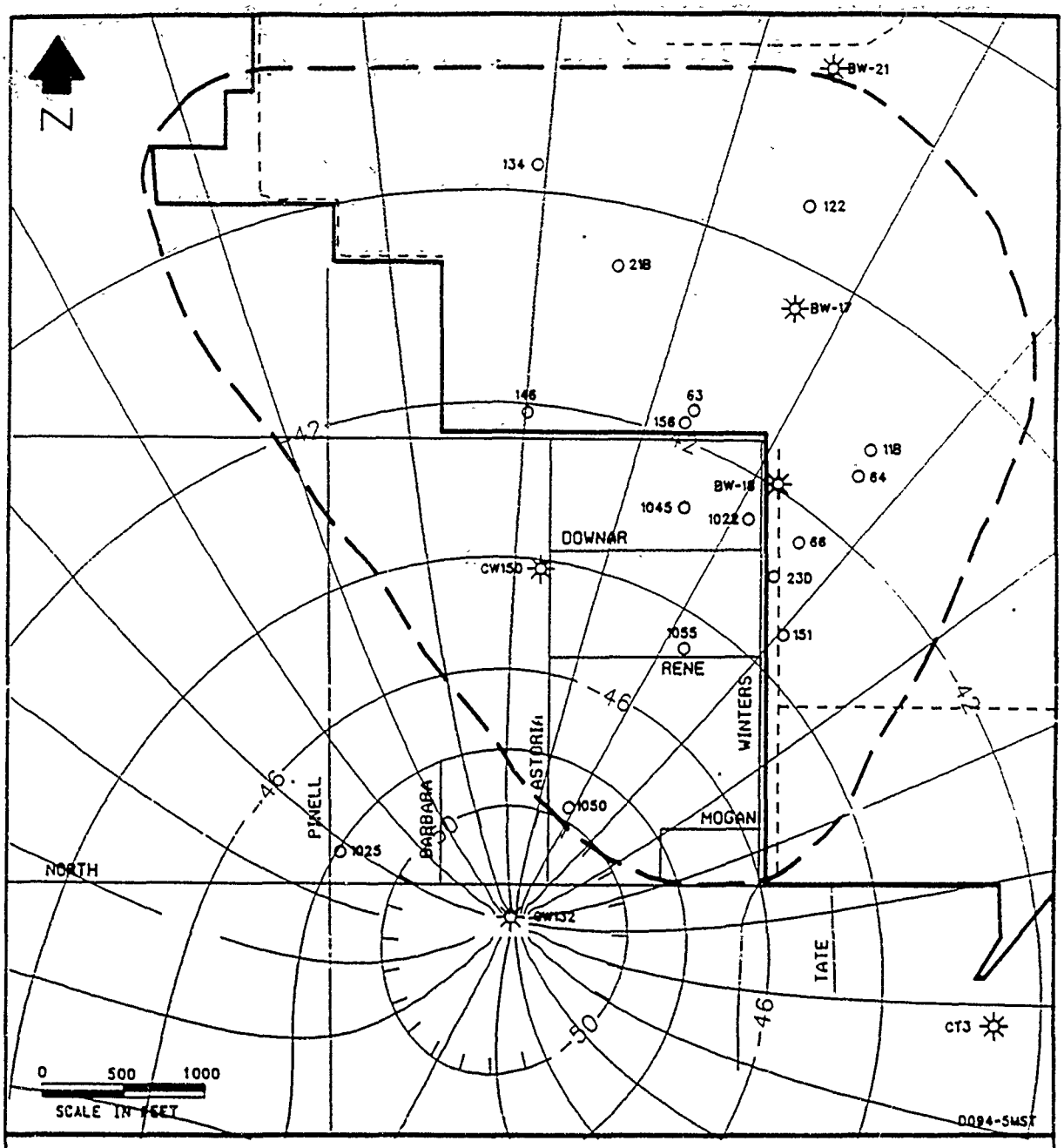

Figure E-12: Modeled Flow Net for the C Geohydrologic Zone with CW-132 Pumping, OU B, McClellan AFB, CA

where c_i = average contaminant concentration between the i^{th} pair of streamlines, M/L^3, and
c_j = contaminant concentration in well water pumped from zone A, B, C, or D, M/L^3.

Since it was concluded that the model used to generate flow nets in the A, B, and C zones was not applicable to the D zone in the vicinity of BW-18, equation (E-12) was not used in that zone for calculations involving BW-18. Instead, an assumed concentration was attributed to the groundwater entering the well casing in the D zone. The highest reported concentration from any of the samples collected in the D zone within OU B was used as the upper-bound value and this value was used as the D zone concentration for the worst case scenario. This is a highly conservative assumption for contaminant concentrations in that zone. A more reasonable assumption is that the concentration at the well casing in the D zone is the arithmetic average of all the samples collected in the D zone.

In separate calculations, the two estimates of the D zone concentrations were used with concentrations derived from the flow net analyses to calculate upper-bound and expected values of BW-18. At CW-132, the D zone was not included in the analysis and concentrations derived from the flow net analyses of the A, B, and C zones were used exclusively. The wellhead concentration is the concentration of water pumped from each zone weighted by the ratio of the total discharge from the well to the discharge from each zone:

$$c = \sum_{j=1}^{4}(Q_j c_j)/\sum_{j=1}^{4}(Q_j) \qquad \text{(E-13)}$$

where c = contaminant concentration at wellhead, M/L^3;
Q_j = discharge from zones A, B, C, or D at BW-18, or zones A, B, and C at CW-132, L^3/t; and
C_j = contaminant concentration in well water pumped from the j^{-th} zone.

These analyses were performed for flow nets at BW-18 and CW-132, and for 20 organic and inorganic contaminants. Results of the analyses are presented in Section 3.3 of the report in Table 3-4.

RADIAN CORPORATION

APPENDIX F
METHODOLOGIES TO ESTIMATE AIR CONCENTRATIONS

F1.0 Introduction

Appendix F describes in detail the methodologies used to estimate air concentrations while showering, washing dishes, and washing clothes.

F2.0 Concentration in Air While Showering

The methodology used to estimate concentrations in air while showering is based on results of shower volatilization experiments (Andelman, et.al., 1986). The experiments involved pumping aqueous trichloroethene solution through an experimental shower chamber and measuring resulting concentrations of trichloroethene in the air. The experiments revealed the following: the trichloroethene concentration increased approximately in a linear fashion over time; the volatilization was higher at higher water temperatures; and the volatilization rate increased when the height of the shower water drop path increased. The percent volatilized during the experiment ranged from 43% to 79 percent.

A kinetic-mass-balance relationship which predicts air concentrations as a function of time was developed (Andelman, et.al., 1986). The basic mass balance equation is:

$$V_A(dC_A/dt) = R - F_A C_A \qquad \text{(F-1)}$$

where:

V_A = Chamber volume;
dC_A/dt = Rate of change in concentration in air;
R = Mass of chemicals volatized per unit time;
F_A = Air flow rate; and
C_A = Concentration of a particular volatile compound in air.

$$R = k(C_w - C_A/H) \qquad \text{(F-2)}$$

where:

C_w = Concentration of a particular volatile compound in water
H = Henry's law constant (dimensionless); and
k = volatilization transfer coefficient (volume per time).

Combining equation F-1 and equation F-2 and neglecting k/H as not being significant, the equation reduces to:

$$V_A (dC_A/dt) = kC_W - F_A C_A \qquad \text{(F-3)}$$

Integrating equation (F-3) results in:

$$\ln(1-F_A C_A/kC_W) = -(F_A/V_A)t \qquad \text{(F-4)}$$

Equation F-4 has been used to predict concentrations as a function of time in the shower. The value for k is assumed to be equal to F_w (the water flow rate) at 100% volatilization. This is the maximum value for k (Andelman et.al., 1986). In the absence of experimental data, $k = F_w$ will give the worst-case concentration in the shower at different times.

Other assumptions include:

1. Water flow rate = 20 liters/minute (based on a U.S. Department of Housing and Urban Development survey which found the mean and maximum value for water flow rate in showers to be between 10 liters/minute and 30 liters/minute (Andelman et.al., 1989);

2. Air exchange rate = 1 per hour (a conservative value suggested by Andelman et.al., 1986);

3. Dimensions of the shower stall = 5.5 x 3 x 8 feet (volume = 3.736 cubic meters); and

4. Time in shower = 7 minutes for the average shower duration and 15 minutes for the reasonable maximum (U.S. EPA, 1989a).

F3.0 Concentration in Air While Operating Dishwasher

Volatile organic compounds (VOCs) in the dishwasher water will volatilize to the available air space in the machine while the machine is operating. The volatilization is due to the temperature and well mixed zone available in the machine. Although volatilization is a function of vapor pressure, 100% volatilization was assumed for this model to provide a more conservative estimate. Since the machine is not a

closed system, the VOCs will tend to leak out of the machine into the room in which the machine is located (presumably the kitchen). Due to the leakage of the dishwasher sytem, there is a continuous buildup of VOC concentrations in the kitchen during the operating cycle of the machine. When the machine has finished its final cycle, the concentrations in the room can then be expected to steadily decrease due to dilution by incoming air.

The equations were derived using a mass balance approach and are the same as those used in the shower model.

The dishwasher model uses two equations.

The first equation models the buildup of VOC concentrations in the kitchen, (taking into account the air exchange) during the operating cycle of the machine.

- $\ln (1-F_A C_A/kC_W) = -(F_A/V_A)t$ (F-5)

Equation (F-5) may also be expressed as:

$C_A = [(kC_W)/F_A] \ (1-e^{-(FA/VA)t})$ (F-6)

where:

C_A	=	Concentration is air
k	=	Volatilization coefficient (which equals F_W for 100% volatilization)
C_W	=	Concentration in water
F_A	=	Air flow rate [calculated by dividing V_A (volume of kitchen) by the air exchange rate]
F_W	=	Water flow rate
V_A	=	Volume of kitchen
t	=	Time

Concentrations are calculated for each minute for the first 72 minutes (cycle time). An average concentration over the 72 minutes is also derived.

The second equation, used in the decay phase, is a simple modification to the first equation. By substituting $kC_W = O$ (0% volatilization at the end of the cycle) the first equation becomes:

$$\ln (C_{A1}/C_{A2}) = (F_A/V_A)(t_2-t_1) \qquad \text{(F-7)}$$

where:

C_{A1} = Concentration in air at time t_1
C_{A2} = Concentration in air at time t_2
t_1 = End of the operating cycle of the machine
t_2 = Anytime after t_1

The concentration C_{A2} as a function of time (t_2-t_1) can be determined from the above equation.

Concentrations are calculated for each minute from the end of the final cycle (72 minutes) to an end time of 120 minutes (48 minutes for the decay phase). An average concentration over the 48 minutes is also derived.

Assumptions used to calculate air concentrations resulting from the operation of a dishwasher include:

1. Volatilization coefficient = 100% volatilization;

2. Dimensions of kitchen = 15 x 15 x 10 feet (63.713 cubic meters);

3. Air exchange rate = 2 per hour;

4. Volume of water used during each cycle = 53 liters (U.S. DHUD, 1984);

5. Cycle time = 72 minutes (Consumer Report, June 1987); and

6. Decay time (t_2) = 48 minutes (120 minutes - 72 minutes = 48 mintues).

F4.0 Concentration in Air While Operating Washing Machine

Volatile compounds in the washing machine water will also volatilize to the air space in the machine while the machine is operating. Therefore, the same

methodology as that for the dishwasher was used to estimate concentrations in air resulting from operation of a washing machine. Assumptions regarding 100% volatilization, location of the machine (in the kitchen), the dimensions of the room, and the air exchange rate also apply in this case. For the first equation (operating cycle of the machine), concentrations are calculated for each minute for the first 35 minutes. An average concentration over the 35 minutes is also derived.

For the decay phase, concentrations are calculated for each minute starting at the end of the final cycle (35 minutes) and ending at 120 minutes (90 minutes decay phase). An average concentration over the 90 minutes is also derived.

Assumptions which differ include:

1. Capacity of the machine = 76.5 liters (manufacturer specifications for a standard size machine);

2. Volume of water used during each cycle = 208 liters (U.S. DHUD, 1984);

3. Cycle time = 35 minutes (General Electric, 1990); and

4. Decay time (t_2) = 90 minutes (120 minutes - 35 minutes = 90 minutes).

APPENDIX G

EXPOSURE ASSUMPTION TABLES

TABLE G-1. SUMMARY OF VALUES USED TO ESTIMATE CHRONIC EXPOSURE FOR THE ON-BASE, RESIDENTIAL/LIFETIME AND OFF-BASE RESIDENTIAL EXPOSURE SCENARIOS

Variable	Average Value Used	Brief Rationale	Reasonable Maximum Value Used	Brief Rationale
Ingestion of Groundwater				
Ingestion Rate (liters/day)				
• Child	1	Individuals of 10 kg body mass or less.[a]	1	Insufficient data to support distinction between "average" and "reasonable maximum."
• Adult	2	EPA Region IX guidance (U.S. EPA, 1989c) recommends using 2 liters/day for both "average" and "reasonable maximum" exposure scenarios. U.S. EPA guidance (U.S. EPA, 1989a) cites 1.4 liters/day (adult average) for use in "average" scenario.	2	Adult, 90th percentile.[a]
Exposure Frequency (days/year)				
• Child	365	Although average frequency of exposure is probably less than 365 days/year, statistical data are not currently available to identify average frequency.	365	Exposure every day of the year.[b]
• Adult	365	Same as above.	365	Exposure every day of the year.[b]

(Continued)

TABLE G-1. CONTINUED

Variable	Average Value Used	Brief Rationale	Reasonable Maximum Value Used	Brief Rationale
Ingestion of Groundwater (Cont.)				
Exposure Duration (years)				
• Child	5	1 through 6 years of age.	5	1 through 6 years of age.
• Adult	9	National 50th percentile time at one residence.[a]	30	National 90th percentile time at one residence.[a]
Body Weight (kg)				
• Child	16	1 through 6 years of age.[b]	16	1 through 6 years of age.[b]
• Adult	70	Adult, average.[a]	70	EPA guidance recommends using 70 kg for both average and reasonable maximum exposures.[a,c]
Averaging Time (days)				
- Noncarcinogenic Effects				
• Child	1,825	5 years (exposure duration) x 365 days/year.[b]	1,825	5 years (exposure duration) x 365 days/year.[b]
• Adult	3,285	9 years (exposure duration) x 365 days/year.[b]	10,950	30 years (exposure duration) x 365 days/year.[b]
- Carcinogenic Effects	25,550	70 years x 365 days/year.[b]	25,550	70 years x 365 days/year.[b]

(Continued)

TABLE G-1. CONTINUED

Variable	Average Value Used	Brief Rationale	Reasonable Maximum Value Used	Brief Rationale
Dermal Contact with Groundwater				
Skin Surface Area Available for Contact (cm^2)				
• Child	7,280	50th percentile total body surface area, 3<6 years of age, male.[a]	8,760	95th percentile total body surface area, 3<6 years of age, male.[a]
• Adult	19,400	50th percentile total body surface area, adult male.[a]	22,800	95th percentile total body surface area, adult male.[a]
Chemical-specific Dermal Permeability Constant (cm/hr)				
• Organics	0.00084	Permeability constant for water.[b]	0.00084	Permeability constant for water.[b]
• Inorganics	0	No permeability.	0	No permeability.
Exposure Time (hours/day)				
• Child and Adult	0.12	Median shower duration, Australian study.[a]	0.25	95th percentile shower duration, Australian study.[a]

(Continued)

TABLE G-1. CONTINUED

Variable	Average Value Used	Brief Rationale	Reasonable Maximum Value Used	Brief Rationale
Dermal Contact with Groundwater (Cont.)				
Exposure Frequency (days/year)				
• Child and Adult	365	90% of American population take bath/shower every day.[a]	365	90% of American population take bath/shower every day.[a]
Exposure Duration (years)				
• Child	5	1 through 6 years of age.[b]	5	1 through 6 years of age.[b]
• Adult	9	National 50th percentile time at one residence.[a]	30	National 90th percentile time at one residence.[a]
Volumetric Conversion Factor for Water (liters/cm^3)	0.001	-	0.001	-
Body Weight (kg)				
• Child	16	1 through 6 years of age.[b]	16	1 through 6 years of age.[b]
• Adult	70	Adult, average.[a]	70	EPA guidance recommends using 70 kg for both average and reasonable maximum exposures.[a,c]

(Continued)

TABLE G-1. CONTINUED

Variable	Average Value Used	Brief Rationale	Reasonable Maximum Value Used	Brief Rationale
Dermal Contact with Groundwater (Cont.)				
Averaging Time (days)				
-Noncarcinogenic Effects				
• Child	1,825	5 years (exposure duration) x 365 days/year.[b]	1,825	5 years (exposure duration) x 365 days/year.[b]
• Adult	3,285	9 years (exposure duration) x 365 days/year.[b]	10,950	30 years (exposure duration) x 365 days/year.[b]
-Carcinogenic Effects	25,550	70 years x 365 days/year.[b]	25,550	70 years x 365 days/year.[b]
Inhalation of Chemicals Volatilized from Groundwater During Home Use - Showering				
Inhalation Rate (m^3/hour)				
• Child and Adult	0.6	Showering, all age groups.[a]	0.6	Showering, all age groups.[a]
Exposure Time (hours/day)				
• Child and Adult	0.12	Median shower duration, Australian study.[a]	0.25	95th percentile shower duration, Australian study.[a]

(Continued)

TABLE G-1. CONTINUED

Variable	Average Value Used	Brief Rationale	Reasonable Maximum Value Used	Brief Rationale
Inhalation of Chemicals Volatilized from Groundwater During Home Use - Showering (Cont.)				
Exposure Frequency (days/year)				
• Child and Adult	365	90% of American population take bath/shower every day.[a]	365	90% of American population take a bath/shower every day.[a]
Exposure Duration (years)				
• Child	5	1 through 6 years of age.[b]	5	1 through 6 years of age.[b]
• Adult	9	National 50th percentile time at one residence.[a]	30	National 90th percentile time at one residence.[a]
Body Weight (kg)				
• Child	16	1 through 6 years of age.[b]	16	1 through 6 years of age.[b]
• Adult	70	Adult, average.[a]	70	EPA guidance recommends using 70 kg for both average and reasonable maximum exposures.[a,c]

(Continued)

TABLE G-1. CONTINUED

Variable	Average Value Used	Brief Rationale	Reasonable Maximum Value Used	Brief Rationale
Inhalation of Chemicals Volatilized from Groundwater During Home Use - Showering (Cont.)				
Averaging Time (days)				
-Noncarcinogenic Effects				
• Child	1,825	5 years (exposure duration) x 365 days/year.[b]	1,825	5 years (exposure duration) x 365 days/year.[b]
• Adult	3,285	9 years (exposure duration) x 365 days/year.[b]	10,950	30 years (exposure duration) x 365 days/year.[b]
-Carcinogenic Effects	25,550	70 years x 365 days/year.[b]	25,550	70 years x 365 days/year.[b]
Inhalation of Chemicals Volatilized From Groundwater During Home Use - Clothes Washing				
All variables same as above for showering, except:				
Inhalation Rate (m^3/hour)				
• Child	0.8	Child, age 6, for light activity.[a]	2.0	Child, age 6, for moderate activity.[a]
• Adult	0.6	Average, adult, for light activity.[a]	2.1	Average, adult, for moderate activity (e.g., heavy, indoor cleanup).[a]

(Continued)

TABLE G-1. CONTINUED

Variable	Average Value Used	Brief Rationale	Reasonable Maximum Value Used	Brief Rationale
Inhalation of Chemicals Volatilized from Groundwater During Home Use - Clothes Washing (Cont.)				
Exposure Time (hours/cycle)				
• Child and Adult	2	35-minute[e] average exposure to operating cycle plus 90-minute average exposure after completion of final cycle (120 minutes total).	2	35-minute[e] average exposure to operating cycle plus 90-minute average exposure after completion of final cycle (120 minutes total).
Exposure Frequency (cycles/year)				
• Child and Adult	312	Average cycles per week for washing machine (6).[d] Operation of dishwasher and washing machine, 1 cycle per day, 6 days per week.	468	Operation of dishwasher and washing machine 1 cycle per day on week days and 2 cycles per day on weekend days (9 cycles total per week).

(Continued)

TABLE G-1. CONTINUED

Variable	Average Value Used	Brief Rationale	Reasonable Maximum Value Used	Brief Rationale
Inhalation of Chemicals Volatilized from Groundwater During Home Use - Dish Washing				
All variables sames as above for clothes washing, except:				
Exposure Time (hours/cycle)				
• Child and Adult	2	72-minute[d] average exposure to operating cycle plus 48-minute average exposure after completion of final cycle (120 minutes total).	2	72-minute[d] average exposure to operating cycle plus 48-minute average exposure after completion of final cycle (120 minutes total).

[a]U.S. EPA, 1989b.

[b]U.S. EPA, 1989a.

[c]U.S. EPA, 1989c.

[d]Consumer Reports, 1988.

[e]General Electric, 1990.

TABLE G-2. COMPARISON OF VALUES USED TO ESTIMATE CHRONIC EXPOSURE FOR ALL EXPOSURE SCENARIOS

Variable	Average Value Used			Reasonable Maximum Value Used		
	On- and Off-Base Residential/ Lifetime[a]	On-Base Residential/ 3-Year Tour	On-Base Worker	On- and Off-Base Residential/ Lifetime[a]	On-Base Residential/ 3-Year Tour	On-Base Worker
Ingestion of Groundwater						
Ingestion Rate (liters/day)						
• Child	1	1	NA	1	1	NA
• Adult	2	2	2[b]	2	2	2[b]
Exposure Frequency (days/year)						
• Child	365	365	NA	365	365	NA
• Adult	365	365	240[c]	365	365	240[c]
Exposure Duration (years)						
• Child	5	3[d]	NA	5	3[d]	NA
• Adult	9	3[d]	30[e]	9	3[d]	30[e]
Body Weight (kg)						
• Child	16	16	NA	16	16	NA
• Adult	70	70	70	70	70	70

(Continued)

TABLE G-2. CONTINUED

Variable	Average Value Used			Reasonable Maximum Value Used		
	On- and Off-Base Residential/ Lifetime[a]	On-Base Residential/ 3-Year Tour	On-Base Worker	On- and Off-Base Residential/ Lifetime[a]	On-Base Residential/ 3-Year Tour	On-Base Worker
Ingestion of Groundwater (Cont.)						
Averaging Time (days)						
- Noncarcinogenic Effects						
• Child	1,825	1,095[f]	NA	1,825	1,095[f]	NA
• Adult	3,285	1,095[f]	10,950[g]	10,950	1,095[f]	10,950[g]
- Carcinogenic Effects	25,550	25,550	25,550	25,550	25,550	25,550
Dermal Contact with Groundwater						
Skin Surface Area Available for Contact (cm^2)						
• Child	7,280	7,280	NA	8,760	8,760	NA
• Adult	19,400	19,400	NA	22,800	22,800	NA
Chemical-specific Dermal Permeability Constant (cm/hr)						
• Organics	0.00084	0.00084	NA	0.00084	0.00084	NA
• Inorganics	0	0	NA	0	0	NA

(Continued)

TABLE G-2. CONTINUED

Variable	Average Value Used			Reasonable Maximum Value Used		
	On- and Off-Base Residential/ Lifetime[a]	On-Base Residential/ 3-Year Tour	On-Base Worker	On- and Off-Base Residential/ Lifetime[a]	On-Base Residential/ 3-Year Tour	On-Base Worker
Dermal Contact with Groundwater (Cont.)						
Exposure Time (hours/day)						
• Child and Adult	0.12	0.12	NA	0.25	0.25	NA
Exposure Frequency (days/year)						
• Child and Adult	365	365	NA	365	365	NA
Exposure Duration (years)						
• Child	5	3[d]	NA	5	3[d]	NA
• Adult	9	3[d]	NA	30	3[d]	NA
Volumetric Conversion Factor for Water (liters/cm^3)	0.001	0.001	NA	0.001	0.001	NA
Body Weight (kg)						
• Child	16	16	NA	16	16	NA
• Adult	70	70	NA	70	70	NA

(Continued)

TABLE G-2. CONTINUED

Variable	Average Value Used: On- and Off-Base Residential/ Lifetime[a]	Average Value Used: On-Base Residential/ 3-Year Tour	Average Value Used: On-Base Worker	Reasonable Maximum Value Used: On- and Off-Base Residential/ Lifetime[a]	Reasonable Maximum Value Used: On-Base Residential/ 3-Year Tour	Reasonable Maximum Value Used: On-Base Worker
Dermal Contact with Groundwater (Cont.)						
Averaging Time (days)						
- Noncarcinogenic Effects						
• Child	1,825	1,095[f]	NA	1,825	1,095[f]	NA
• Adult	3,285	1,095[f]	NA	10,950	1,095[f]	NA
- Carcinogenic Effects	25,550	25,550	NA	25,550	25,550	NA
Inhalation of Chemicals Volatilized from Groundwater During Home Use - Showering						
Inhalation Rate (m^3/hour)						
• Child and Adult	0.6	0.6	NA	0.6	0.6	NA
Exposure Time (hours/day)						
• Child and Adult	0.12	0.12	NA	0.25	0.25	NA

(Continued)

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TABLE G-2. CONTINUED

Variable	Average Value Used			Reasonable Maximum Value Used		
	On- and Off-Base Residential/ Lifetime[a]	On-Base Residential/ 3-Year Tour	On-Base Worker	On- and Off-Base Residential/ Lifetime[a]	On-Base Residential/ 3-Year Tour	On-Base Worker
Inhalation of Chemicals Volatilized from Groundwater During Home Use - Showering (Cont.)						
Exposure Frequency (days/year)						
• Child and Adult	365	365	NA	365	365	NA
Exposure Duration (years)						
• Child	5	3[d]	NA	5	3[d]	NA
• Adult	9	3[d]	NA	30	3[d]	NA
Body Weight (kg)						
• Child	16	16	NA	16	16	NA
• Adult	70	70	NA	70	70	NA
Averaging Time (days)						
- Noncarcinogenic Effects						
• Child	1,825	1,095[f]	NA	1,825	1,095[f]	NA
• Adult	3,285	1,095[f]	NA	10,950	1,095[f]	NA
- Carcinogenic Effects	25,550	25,550	NA	25,550	25,550	NA

(Continued)

TABLE G-2. CONTINUED

Variable	Average Value Used: On- and Off-Base Residential/ Lifetime[a]	Average Value Used: On-Base Residential/ 3-Year Tour	Average Value Used: On-Base Worker	Reasonable Maximum Value Used: On- and Off-Base Residential/ Lifetime[a]	Reasonable Maximum Value Used: On-Base Residential/ 3-Year Tour	Reasonable Maximum Value Used: On-Base Worker
Inhalation of Chemicals Volatilized from Groundwater During Home Use - Clothes and Dish Washing						
All variables same as above for showering, except:						
Inhalation Rate (m^3/hour)						
• Child	0.8	0.8	NA	2.0	2.0	NA
• Adult	0.6	0.6	NA	2.1	2.1	NA
Exposure Time (hours/cycle)						
• Child and Adult	2	2	NA	2	2	NA
Exposure Frequency (cycles/year)						
• Child and Adult	312	312	NA	468	468	NA

[a]The rationale for values used for the On-Base Residential/Lifetime and the Off-Base Residential Exposure Scenarios is provided in Table 3-11.
[b]Same as for On- and Off-Base Residential/Lifetime Exposure Scenarios (adult), although it is unlikely that workers ingest 100% of their daily drinking water intake while on the job.
[c]5 working day/week, 20 days for vacation and holidays.
[d]Limited to 3 years of exposure due to duration of tour of duty.
[e]Number of years on the job.
[f]Exposure duration (3 years) x 365 days/year.
[g]Exposure duration (30 years) x 365 days/year.

TABLE G-3. COMPARISON OF VALUES USED TO ESTIMATE SUBCHRONIC EXPOSURE FOR ALL EXPOSURE SCENARIOS[2]

Variable	Average Value Used			Reasonable Maximum Value Used		
	On-Base Residential/ Lifetime	On-Base Residential/ 3-Year Tour	On-Base Worker	On-Base Residential/ Lifetime	On-Base Residential/ 3-Year Tour	On-Base Worker
Ingestion of Groundwater						
Ingestion Rate (liters/day)						
• Child	1	1	NA	1	1	NA
• Adult	2	2	2	2	2	2
Exposure Frequency (days/year)						
• Child	30[a]	30[a]	NA	30[a]	30[a]	NA
• Adult	30[a]	30[a]	20[b]	30[a]	30[a]	20[b]
Exposure Duration (years)						
• Child	1	1	NA	1	1	NA
• Adult	1	1	1	1	1	1
Body Weight (kg)						
• Child	16	16	NA	16	16	NA
• Adult	70	70	70	70	70	70

(Continued)

TABLE G-3. CONTINUED

Variable	Average Value Used			Reasonable Maximum Value Used		
	On-Base Residential/ Lifetime	On-Base Residential/ 3-Year Tour	On-Base Worker	On-Base Residential/ Lifetime	On-Base Residential/ 3-Year Tour	On-Base Worker
Ingestion of Groundwater (Cont.)						
Averaging Time (days)						
- Noncarcinogenic Effects						
• Child	30[c]	30[c]	NA	30[c]	30[c]	NA
• Adult	30[c]	30[c]	20[d]	30[c]	30[c]	20[d]
- Carcinogenic Effects	NA	NA	NA	NA	NA	NA
Dermal Contact with Groundwater						
Skin Surface Area Available for Contact (cm^2)						
• Child	7,280	7,280	NA	8,760	8,760	NA
• Adult	19,400	19,400	NA	22,800	22,800	NA
Chemical-specific Dermal Permeability Constant (cm/hr)						
• Organics	0.00084	0.00084	NA	0.00084	0.00084	NA
• Inorganics	0	0	NA	0	0	NA

(Continued)

TABLE G-3. CONTINUED

Variable	Average Value Used			Reasonable Maximum Value Used		
	On-Base Residential/ Lifetime	On-Base Residential/ 3-Year Tour	On-Base Worker	On-Base Residential/ Lifetime	On-Base Residential/ 3-Year Tour	On-Base Worker
Dermal Contact with Groundwater (Cont.)						
Exposure Time (hours/day)						
• Child and Adult	0.12	0.12	NA	0.25	0.25	NA
Exposure Frequency (days/year)						
• Child and Adult	30[a]	30[a]	NA	30[a]	30[a]	NA
Exposure Duration (years)						
• Child	1	1	NA	1	1	NA
• Adult	1	1	NA	1	1	NA
Volumetric Conversion Factor for Water (liters/cm^3)	0.001	0.001	NA	0.001	0.001	NA
Body Weight (kg)						
• Child	16	16	NA	16	16	NA
• Adult	70	70	NA	70	70	NA

(Continued)

TABLE G-3. CONTINUED

Variable	Average Value Used			Reasonable Maximum Value Used		
	On-Base Residential/ Lifetime	On-Base Residential/ 3-Year Tour	On-Base Worker	On-Base Residential/ Lifetime	On-Base Residential/ 3-Year Tour	On-Base Worker
Dermal Contact with Groundwater (Cont.)						
Averaging Time (days)						
- Noncarcinogenic Effects						
• Child	30[c]	30[c]	NA	30[c]	30[c]	NA
• Adult	30[c]	30[c]	NA	30[c]	30[c]	NA
- Carcinogenic Effects	NA	NA	NA	NA	NA	NA
Inhalation of Chemicals Volatilized from Groundwater During Home Use - Showering						
Inhalation Rate (m^3/hour)						
• Child and Adult	0.6	0.6	NA	0.6	0.6	NA
Exposure Time (hours/day)						
• Child and Adult	0.12	0.12	NA	0.25	0.25	NA

(Continued)

TABLE G-3. CONTINUED

Variable	Average Value Used			Reasonable Maximum Value Used		
	On-Base Residential/ Lifetime	On-Base Residential/ 3-Year Tour	On-Base Worker	On-Base Residential/ Lifetime	On-Base Residential/ 3-Year Tour	On-Base Worker
Inhalation of Chemicals Volatilized from Groundwater During Home Use - Showering (Cont.)						
Exposure Frequency (days/year)						
• Child and Adult	30[a]	30[a]	NA	30[a]	30[a]	NA
Exposure Duration (years)						
• Child	1	1	NA	1	1	NA
• Adult	1	1	NA	1	1	NA
Body Weight (kg)						
• Child	16	16	NA	16	16	NA
• Adult	70	70	NA	70	70	NA
Averaging Time (days)						
- Noncarcinogenic Effects						
• Child	30[c]	30[c]	NA	30[c]	30[c]	NA
• Adult	30[c]	30[c]	NA	30[c]	30[c]	NA
- Carcinogenic Effects	NA	NA	NA	NA	NA	NA

(Continued)

TABLE G-3. CONTINUED

Variable	Average Value Used: On-Base Residential/ Lifetime	Average Value Used: On-Base Residential/ 3-Year Tour	Average Value Used: On-Base Worker	Reasonable Maximum Value Used: On-Base Residential/ Lifetime	Reasonable Maximum Value Used: On-Base Residential/ 3-Year Tour	Reasonable Maximum Value Used: On-Base Worker
Inhalation of Chemicals Volatilized from Groundwater During Home Use - Clothes and Dish Washing						
All variables same as above for showering, except:						
Inhalation Rate (m^3/hour)						
• Child	0.8	0.8	NA	2.0	0.8	NA
• Adult	0.6	0.6	NA	2.1	0.6	NA
Exposure Time (hours/cycles)						
• Child and Adult	2	2	NA	2	2	NA
Exposure Frequency (cycles/year)						
• Child and Adult	24[e]	24[e]	NA	38[f]	38[f]	NA
Averaging Time (days)						
- Noncarcinogenic Effects						
• Child	24[g]	24[g]	NA	30[h]	30[h]	NA
• Adult	24[g]	24[g]	NA	30[h]	30[h]	NA
- Carcinogenic Effects	NA	NA	NA	NA	NA	NA

[a]Assumes failure of on-base water pretreatment system following a sampling event, 1 week until the next sampling event, 1 week until samples are analyzed, and 2 weeks for communication/resolution of treatment system failure (or provision of alternate water supply).
[b]5 days/week for 1 month.
[c]Exposure frequency (30 days/year) x exposure duration (1 year).
[d]Exposure frequency (20 days/year) x exposure duration (1 year).
[e]Average cycles per week for washing machine (6). Operation of dishwasher and washing machine, 1 cycle per day, 6 days per week, for a 30-day period.
[f]Operation of dishwasher and washing machine, 1 cycle per day, on week days and 2 cycles per day on weekend days, for a 30-day period.
[g]Exposure frequency (24 days/year) x exposure duration (1 year).
[h]Exposure each day for the 30 day exposure duration.

APPENDIX H

EXPOSURE ASSUMPTION CALCULATIONS

RADIAN CORPORATION

INGESTION OF DRINKING WATER - CHRONIC 17:13:38
RESIDENTIAL 07/06/90

Intake(mg/kg-day) = (CW x IR x EF x ED)/(BW x AT) (EPA, 1989a)

		Assumptions
CW = Chemical Concentration in Water (mg/liter)		----------
-Base Well 18		Use the lesser of monitoring detection limits or modeled pretreatment concentrations
-City Well 132		Use modeled concentrations
IR = Ingestion Rate (liters/day)		
-Children	1.0E+00	(EPA, 1989b)
-Adult	2.0E+00	(adult, 90th percentile; EPA, 1989c) (1)
EF = Exposure Frequency (days/year)	3.7E+02	(EPA,1989a)
ED = Exposure Duration (years)		
-Children	5.0E+00	(1 through 6 years old)
-Adult, Average	9.0E+00	(national median time--50th percentile-- at one residence; EPA, 1989b)
-Adult, Upper bound (reasonable maximum)	3.0E+01	(national upper bound time-- 90th percentile; EPA, 1989b) (2)
BW = Body Weight (kg)		
-Children	1.6E+01	(1 through 6 years old, EPA, 1989a)
-Adult	7.0E+01	(adult, average; EPA, 1989b)
AT = Averaging Time (period over which exposure is averaged-days)		
-Noncarcinogenic effects		
-Children	1.8E+03	(ED x 365 days/year)
-Adult, Average	3.3E+03	
-Adult, Upper bound	1.1E+04	
-Carcinogenic effects	2.6E+04	(70 years x 365 days/year)

(1) EPA Region IX guidance (EPA, 1989c) recommends using 2 liters/day for both "average" and "reasonable maximum" scenarios. The EPA Risk Assessment Guidance for Superfund (EPA,1989a) cites 1.4 liters/day (adult, average) for use in the "average" scenario.

(2) EPA Region IX guidance (EPA, 1989c) affirms the use of 30 years for the "reasonable maximum" scenario instead of the conventional 70 years.

Ingestion of Drinking Water - Chronic - Residential - Estimated Intake Dose (mg/kg-day)

12:22:55
06/14/90

Chemical	CW (mg/liter)			Base Well 18						City Well 132				
	Base Well 18			Children		Adult				Adult				
				Noncarcinogen		Noncarcinogen		Carcinogen		Children	Noncarcinogen		Carcinogen	
	Average	Upper Bound	City Well 132	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Noncarc.	Average	Upper Bound	Average	Upper Bound
Carbon tetrachloride	9.0E-05	9.0E-05	1.0E-05	5.6E-06	5.6E-06	2.6E-06	2.6E-06	3.3E-07	1.1E-06	6.3E-07	2.9E-07	2.9E-07	3.7E-08	1.2E-07
Chloroform	1.6E-04	1.6E-04	9.0E-05	1.0E-05	1.0E-05	4.6E-06	4.6E-06	5.9E-07	2.0E-06	5.6E-06	2.6E-06	2.6E-06	3.3E-07	1.1E-06
Dichloroethane, 1,2-	1.0E-04	1.0E-04	5.0E-05	6.3E-06	6.3E-06	2.9E-06	2.9E-06	3.7E-07	1.2E-06	3.1E-06	1.4E-06	1.4E-06	1.8E-07	6.1E-07
Dichloroethene, 1,1-	1.4E-04	1.4E-04	7.0E-05	8.8E-06	8.8E-06	4.0E-06	4.0E-06	5.1E-07	1.7E-06	4.4E-06	2.0E-06	2.0E-06	2.6E-07	8.6E-07
Dichloroethene, 1,2-	5.0E-04	5.0E-04	2.5E-03	3.1E-05	3.1E-05	1.4E-05	1.4E-05	1.8E-06	6.1E-06	1.6E-04	7.3E-05	7.3E-05	9.4E-06	3.1E-05
Methylene chloride	2.7E-04	3.8E-04	1.1E-04	1.7E-05	2.4E-05	7.7E-06	1.1E-05	9.9E-07	4.7E-06	6.9E-06	3.1E-06	3.1E-06	4.0E-07	1.3E-06
Tetrachloroethane,1,1,2,2-	8.0E-05	1.6E-04	3.0E-06	5.0E-06	1.0E-05	2.3E-06	4.6E-06	2.9E-07	2.0E-06	1.9E-07	8.6E-08	8.6E-08	1.1E-08	3.7E-08
Tetrachloroethene	5.0E-04	5.0E-04	2.6E-03	3.1E-05	3.1E-05	1.4E-05	1.4E-05	1.8E-06	6.1E-06	1.6E-04	7.5E-05	7.5E-05	9.7E-06	3.2E-05
Trichloroethane,1,1,1-	1.4E-04	1.9E-04	5.0E-05	8.8E-06	1.2E-05	4.0E-06	5.4E-06	5.1E-07	2.3E-06	3.1E-06	1.4E-06	1.4E-06	1.8E-07	6.1E-07
Trichloroethane,1,1,2-	1.0E-04	1.5E-04	1.0E-06	6.3E-06	9.4E-06	2.9E-06	4.3E-06	3.7E-07	1.8E-06	6.2E-08	2.9E-08	2.9E-08	3.7E-09	1.2E-08
Trichloroethene	5.0E-04	5.0E-04	2.2E-02	3.1E-05	3.1E-05	1.4E-05	1.4E-05	1.8E-06	6.1E-06	1.4E-03	6.4E-04	6.4E-04	8.2E-05	2.7E-04
Boron	9.0E-02	1.6E-01	3.0E-02	5.6E-03	1.0E-02	2.6E-03	4.6E-03	3.3E-04	2.0E-03	1.9E-03	8.6E-04	8.6E-04	1.1E-04	3.7E-04
Vanadium	1.0E-02	2.0E-02	2.0E-03	6.3E-04	1.3E-03	2.9E-04	5.7E-04	3.7E-05	2.4E-04	1.3E-04	5.7E-05	5.7E-05	7.3E-06	2.4E-05
Zinc	1.0E-02	1.0E-02	1.0E-02	6.3E-04	6.3E-04	2.9E-04	2.9E-04	3.7E-05	1.2E-04	6.3E-04	2.9E-04	2.9E-04	3.7E-05	1.2E-04

RADIAN CORPORATION

MRA/071390/pwj

Ingestion of Drinking Water - Chronic - Residential - Risk Characterization

12:22:55
06/14/90

Chemicals	Oral RfD (mg/kg/day)	Oral SF 1/(mg/kg/day)	Base Well 18						City Well 132				
			Children		Adult				Adult				
			Noncarcinogen		Noncarcinogen		Carcinogen		Children	Noncarcinogen		Carcinogen	
			Average Hazard Index	Upper Bound Hazard Index	Average Hazard Index	Upper Bound Hazard Index	Average Total Pathway Risk	Upper Bound Total Pathway Risk	Noncarc. Hazard Index	Average Hazard Index	Upper Bound Hazard Index	Average Total Pathway Risk	Upper Bound Total Pathway Risk
Carbon tetrachloride	7.0E-04	1.3E-01	8.0E-03	8.0E-03	3.7E-03	3.7E-03	4.3E-08	1.4E-07	8.9E-04	4.1E-04	4.1E-04	4.8E-09	1.6E-08
Chloroform	1.0E-02	6.1E-03	1.0E-03	1.0E-03	4.6E-04	4.6E-04	3.6E-09	1.2E-08	5.6E-04	2.6E-04	2.6E-04	2.0E-09	6.7E-09
Dichloroethane, 1,2-		9.1E-02					3.3E-08	1.1E-07				1.7E-08	5.6E-08
Dichloroethene, 1,1-	9.0E-03	6.0E-01	9.7E-04	9.7E-04	4.4E-04	4.4E-04	3.1E-07	1.0E-06	4.9E-04	2.2E-04	2.2E-04	1.5E-07	5.1E-07
Dichloroethene, 1,2-	2.0E-02		1.6E-03	1.6E-03	7.1E-04	7.1E-04			8.0E-03	3.6E-03	3.6E-03		
Methylene chloride	6.0E-02	7.5E-03	2.8E-04	4.0E-04	1.3E-04	1.8E-04	7.4E-09	3.5E-08	1.1E-04	5.2E-05	5.2E-05	3.0E-09	1.0E-08
Tetrachloroethane, 1,1,2,2-		2.0E-01					5.9E-08	3.9E-07				2.2E-09	7.3E-09
Tetrachloroethene	1.0E-02	5.1E-02	3.1E-03	3.1E-03	1.4E-03	1.4E-03	9.4E-08	3.1E-07	1.6E-02	7.5E-03	7.5E-03	4.9E-07	1.6E-06
Trichloroethane, 1,1,1-	9.0E-02		9.7E-05	1.3E-04	4.4E-05	6.0E-05			3.5E-05	1.6E-05	1.6E-05		
Trichloroethane, 1,1,2-	4.0E-03	5.7E-02	1.6E-03	2.3E-03	7.1E-04	1.1E-03	2.1E-08	1.0E-07	1.6E-05	7.1E-06	7.1E-06	2.1E-10	7.0E-10
Trichloroethene		1.1E-02					2.0E-08	6.7E-08				9.0E-07	3.0E-06
Boron	9.0E-02		6.2E-02	1.1E-01	2.9E-02	5.1E-02			2.1E-02	9.5E-03	9.5E-03		
Vanadium	7.0E-03		8.9E-02	1.8E-01	4.1E-02	8.2E-02			1.8E-02	8.2E-03	8.2E-03		
Zinc	2.0E-01		3.1E-03	3.1E-03	1.4E-03	1.4E-03			3.1E-03	1.4E-03	1.4E-03		
			1.7E-01	3.1E-01	7.8E-02	1.4E-01	5.9E-07	2.2E-06	6.8E-02	3.1E-02	3.1E-02	1.6E-06	5.3E-06

RADIAN CORPORATION

MRA/071390/pwj

RADIAN CORPORATION

INGESTION OF DRINKING WATER - CHRONIC 17:16:07
3-YEAR TOUR OF DUTY - RESIDENTIAL 07/06/90

Intake(mg/kg-day) = (CW x IR x EF x ED)/(BW x AT) (EPA, 1989a)

		Assumptions
CW = Chemical Concentration in Water (mg/liter)		
-Base Well 18		Use the lesser of monitoring detection limits or modeled pretreatment concentrations
IR = Ingestion Rate (liters/day)		
-Children	1.0E+00	(EPA, 1989b)
-Adult	2.0E+00	(adult, 90th percentile; EPA, 1989c) (1)
EF = Exposure Frequency (days/year)	3.7E+02	(EPA,1989a)
ED = Exposure Duration (years)	3.0E+00	(tour of duty)
BW = Body Weight (kg)		
-Children	1.6E+01	(1 through 6 years old; EPA, 1989a)
-Adult	7.0E+01	(adult, average; EPA, 1989b)
AT = Averaging Time (period over which exposure is averaged-days)		
-Noncarcinogenic effects	1.1E+03	(ED x 365 days/year)
-Carcinogenic effects	2.6E+04	(70 years x 365 days/year)

(1) EPA Region IX guidance (EPA, 1989c) recommends using 2 liters/day for both "average" and "reasonable maximum" scenarios. The EPA Risk Assessment Guidance for Superfund (EPA,1989a) cites 1.4 liters/day (adult, average) for use in the "average" scenario.

RADIAN CORPORATION

Ingestion of Drinking Water - Chronic - 3 Year Tour of Duty

11:16:16
06/20/90

Chemical	CW (mg/liter) Base Well 18 Average	CW (mg/liter) Base Well 18 Upper Bound	Estimated Intake Dose (mg/kg-day) Children Average	Children Upper Bound	Adult Noncarcinogen Average	Adult Noncarcinogen Upper Bound	Carcinogen Average	Carcinogen Upper Bound
Carbon tetrachloride	9.0E-05	9.0E-05	5.6E-06	5.6E-06	2.6E-06	2.6E-06	1.1E-07	1.1E-07
Chloroform	1.6E-04	1.6E-04	1.0E-05	1.0E-05	4.6E-06	4.6E-06	2.0E-07	2.0E-07
Dichloroethane, 1,2-	1.0E-04	1.0E-04	6.3E-06	6.3E-06	2.9E-06	2.9E-06	1.2E-07	1.2E-07
Dichloroethene, 1,1-	1.4E-04	1.4E-04	8.8E-06	8.8E-06	4.0E-06	4.0E-06	1.7E-07	1.7E-07
Dichloroethene, 1,2-	5.0E-04	5.0E-04	3.1E-05	3.1E-05	1.4E-05	1.4E-05	6.1E-07	6.1E-07
Methylene chloride	2.7E-04	3.8E-04	1.7E-05	2.4E-05	7.7E-06	1.1E-05	3.3E-07	4.7E-07
Tetrachloroethane, 1,1,2,2-	8.0E-05	1.6E-04	5.0E-06	1.0E-05	2.3E-06	4.6E-06	9.8E-08	2.0E-07
Tetrachloroethene	5.0E-04	5.0E-04	3.1E-05	3.1E-05	1.4E-05	1.4E-05	6.1E-07	6.1E-07
Trichloroethane, 1,1,1-	1.4E-04	1.9E-04	8.8E-06	1.2E-05	4.0E-06	5.4E-06	1.7E-07	2.3E-07
Trichloroethane, 1,1,2-	1.0E-04	1.5E-04	6.3E-06	9.4E-06	2.9E-06	4.3E-06	1.2E-07	1.8E-07
Trichloroethene	5.0E-04	5.0E-04	3.1E-05	3.1E-05	1.4E-05	1.4E-05	6.1E-07	6.1E-07
Boron	9.0E-02	1.6E-01	5.6E-03	1.0E-02	2.6E-03	4.6E-03	1.1E-04	2.0E-04
Vanadium	1.0E-02	2.0E-02	6.3E-04	1.3E-03	2.9E-04	5.7E-04	1.2E-05	2.4E-05
Zinc	1.0E-02	1.0E-02	6.3E-04	6.3E-04	2.9E-04	2.9E-04	1.2E-05	1.2E-05

Ingestion of Drinking Water - Chronic - 3 Year Tour of Duty - Risk Characterization

Chemicals	Oral RfDs (mg/kg/day)	Oral SF 1/(mg/kg/day)	Children Noncarcinogen Average Hazard Index	Children Noncarcinogen Upper Bound Hazard Index	Adult Noncarcinogen Average Hazard Index	Adult Noncarcinogen Upper Bound Hazard Index	Carcinogen Average Total Pathway Risk	Carcinogen Upper Bound Total Pathway Risk
Carbon tetrachloride	7.0E-03	1.3E-01	8.0E-04	8.0E-04	3.7E-04	3.7E-04	1.4E-08	1.4E-08
Chloroform	1.0E-02	6.1E-03	1.0E-03	1.0E-03	4.6E-04	4.6E-04	1.2E-09	1.2E-09
Dichloroethane, 1,2-		9.1E-02					1.1E-08	1.1E-08
Dichloroethene, 1,1-	9.0E-03	6.0E-01	9.7E-04	9.7E-04	4.4E-04	4.4E-04	1.0E-07	1.0E-07
Dichloroethene, 1,2-	2.0E-01		1.6E-04	1.6E-04	7.1E-05	7.1E-05		
Methylene chloride	6.0E-02	7.5E-03	2.8E-04	4.0E-04	1.3E-04	1.8E-04	2.5E-09	3.5E-09
Tetrachloroethane, 1,1,2,2-		2.0E-01					2.0E-08	3.9E-08
Tetrachloroethene	1.0E-01	5.1E-02	3.1E-04	3.1E-04	1.4E-04	1.4E-04	3.1E-08	3.1E-08
Trichloroethane, 1,1,1-	9.0E-01		9.7E-06	1.3E-05	4.4E-06	6.0E-06		
Trichloroethane, 1,1,2-	4.0E-02	5.7E-02	1.6E-04	2.3E-04	7.1E-05	1.1E-04	7.0E-09	1.0E-08
Trichloroethene		1.1E-02					6.7E-09	6.7E-09
Boron	9.0E-02		6.2E-02	1.1E-01	2.9E-02	5.1E-02		
Vanadium	7.0E-03		8.9E-02	1.8E-01	4.1E-02	8.2E-02		
Zinc	2.0E-01		3.1E-03	3.1E-03	1.4E-03	1.4E-03		
			1.6E-01	3.0E-01	7.3E-02	1.4E-01	2.0E-07	2.2E-07

RADIAN CORPORATION

INGESTION OF DRINKING WATER - SUBCHRONIC 16:52:36
(due to failure of Base Treatment System) 06/01/90
RESIDENTIAL
(Applicable to Residential and 3 year tour of duty)

Intake(mg/kg-day) = (CW x IR x EF x ED)/(BW x AT) (EPA, 1989a)

		Assumptions
CW = Chemical Concentration in Water (mg/liter) due to upset or failure of base treatment system		Use modeled concentrations (pretreatment) at well (1)
IR = Ingestion Rate (liters/day)		
-Children	1.0E+00	(EPA, 1989b)
-Adult	2.0E+00	(Adult, 90th percentile; EPA, 1989c)
EF = Exposure Frequency (days/year)	3.0E+01	(2)
ED = Exposure Duration (years)	1.0E+00	
BW = Body Weight (kg)		
-Children	1.6E+01	(1 through 6 years old; EPA, 1989b)
-Adult	7.0E+01	(adult, average; EPA, 1989b)
At = Averaging Time (period over which exposure is averaged - days)	3.0E+01	(EF x ED)

(1) Assumes total failure of the treatment system rather than reduced efficiency of the treatment system.

(2) Assumes failure immediately following a sampling event, 1 week until next sampling event, 1 week until samples are analyzed, and 2 weeks for communication/resolution of treatment system failure (or provision of alternate water supply).

Ingestion of Drinking water - Subchronic - Residential and 3 Year Tour of Duty

11:30:33 06, 13/90 Chemical	CW (mg/liter) Average	 Upper Bound	Estimated Intake Dose (mg/kg-day) Child Average	 Upper Bound	 Adult Average	 Upper Bound	Oral RfDs (mg/kg/day)	Children Average Hazard Index	 Upper Bound Hazard Index	Adult Average Hazard Index	 Upper Bound Hazard Index
Carbon tetrachloride	9.0E-05	9.0E-05	5.6E-06	5.6E-06	2.6E-06	2.6E-06	7.0E-03	8.0E-04	8.0E-04	3.7E-04	3.7E-04
Chloroform	1.6E-04	1.6E-04	1.0E-05	1.0E-05	4.6E-06	4.6E-06	1.0E-02	1.0E-03	1.0E-03	4.6E-04	4.6E-04
Dichloroethane, 1,2-	1.0E-04	1.0E-04	6.3E-06	6.3E-06	2.9E-06	2.9E-06					
Dichloroethene, 1,1-	1.4E-04	1.4E-04	8.8E-06	8.8E-06	4.0E-06	4.0E-06	9.0E-03	9.7E-04	9.7E-04	4.4E-04	4.4E-04
Dichloroethene, 1,2-	6.7E-03	1.6E-02	4.2E-04	9.8E-04	1.9E-04	4.5E-04	2.0E-01	2.1E-03	4.9E-03	9.6E-04	2.2E-03
Methylene chloride	2.7E-04	3.8E-04	1.7E-05	2.4E-05	7.7E-06	1.1E-05	6.0E-02	2.8E-04	4.0E-04	1.3E-04	1.8E-04
Tetrachloroethane,1,1,2,2-	8.0E-05	1.6E-04	5.0E-06	1.0E-05	2.3E-06	4.6E-06					
Tetrachloroethene	8.1E-04	8.1E-04	5.1E-05	5.1E-05	2.3E-05	2.3E-05	1.0E-01	5.1E-04	5.1E-04	2.3E-04	2.3E-04
Trichloroethane,1,1,1-	1.4E-04	1.9E-04	8.8E-06	1.2E-05	4.0E-06	5.4E-06	9.0E-01	9.7E-06	1.3E-05	4.4E-06	6.0E-06
Trichloroethane,1,1,2-	1.0E-04	1.5E-04	6.3E-06	9.4E-06	2.9E-06	4.3E-06	4.0E-02	1.6E-04	2.3E-04	7.1E-05	1.1E-04
Trichloroethene	3.9E-02	6.1E-02	2.4E-03	3.8E-03	1.1E-03	1.7E-03					
Boron	9.0E-02	1.6E-01	5.6E-03	1.0E-02	2.6E-03	4.6E-03	9.0E-02	6.2E-02	1.1E-01	2.9E-02	5.1E-02
Vanadium	1.0E-02	2.0E-02	6.3E-04	1.3E-03	2.9E-04	5.7E-04	7.0E-03	8.9E-02	1.8E-01	4.1E-02	8.2E-02
Zinc	1.0E-02	1.0E-02	6.3E-04	6.3E-04	2.9E-04	2.9E-04	2.0E-01	3.1E-03	3.1E-03	1.4E-03	1.4E-03
								1.6E-01	3.0E-01	7.3E-02	1.4E-01

RADIAN CORPORATION

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INGESTION OF ORINKING WATER - CHRONIC 17:17:20
CIVIL SERVICE WORKING ON BASE 07/06/90

Intake(mg/kg-day) = (CW x IR x EF x ED)/(BW x AT) (EPA, 1989a)

		Assumptions
CW = Chemical Concentration in Water (mg/liter)		---
-Base Well 18		Use the lesser of monitoring detection limits or modeled pretreatment concentrations
IR = Ingestion Rate (liters/day)	2.0E+00	(half of adult 90th percentile ingestion rate)
EF = Exposure Frequency (days/year)	2.4E+02	(5 working days/week, 20 days for vacation and holidays)
ED = Exposure Duration (years)	3.0E+01	(number of years spent working)
BW = Body Weight (kg)	7.0E+01	(adult, average; EPA, 1989b)
AT = Averaging Time (period over which exposure is averaged-days)		
-Noncarcinogenic effects	1.1E+04	(ED x 365 days/year)
-Carcinogenic effects	2.6E+04	(70 years x 365 days/year)

Ingestion of Drinking Water - Chronic - Civil Service Working on Base

14:01:32 06/13/90	CW (mg/liter) Base Well 18		Estimated Intake Dose (mg/kg-day)						Adult			
			Noncarcinogen		Carcinogen				Noncarcinogen		Carcinogen	
Chemical	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Oral RfD (mg/kg/day)	Oral SF 1/(mg/kg/day)	Average Hazard Index	Upper Bound Hazard Index	Average Total Pathway Risk	Upper Bound Total Pathway Risk
Carbon tetrachloride	9.0E-05	9.0E-05	1.7E-06	1.7E-06	7.2E-07	7.2E-07	7.0E-04	1.3E-01	2.4E-03	2.4E-03	9.4E-08	9.4E-08
Chloroform	1.6E-04	1.6E-04	3.0E-06	3.0E-06	1.3E-06	1.3E-06	1.0E-02	6.1E-03	3.0E-04	3.0E-04	7.9E-09	7.9E-09
Dichloroethane, 1,2-	1.0E-04	1.0E-04	1.9E-06	1.9E-06	8.1E-07	8.1E-07		9.1E-02			7.3E-08	7.3E-08
Dichloroethene, 1,1-	1.4E-04	1.4E-04	2.6E-06	2.6E-06	1.1E-06	1.1E-06	9.0E-03	6.0E-01	2.9E-04	2.9E-04	6.8E-07	6.8E-07
Dichloroethene, 1,2-	5.0E-04	5.0E-04	9.4E-06	9.4E-06	4.0E-06	4.0E-06	2.0E-02		4.7E-04	4.7E-04		
Methylene chloride	2.7E-04	3.8E-04	5.1E-06	7.1E-06	2.2E-06	3.1E-06	6.0E-02	7.5E-03	8.5E-05	1.2E-04	1.6E-08	2.3E-08
Tetrachloroethane,1,1,2,2-	8.0E-05	1.6E-04	1.5E-06	3.0E-06	6.4E-07	1.3E-06		2.0E-01			1.3E-07	2.6E-07
Tetrachloroethene	5.0E-04	5.0E-04	9.4E-06	9.4E-06	4.0E-06	4.0E-06	1.0E-02	5.1E-02	9.4E-04	9.4E-04	2.1E-07	2.1E-07
Trichloroethane,1,1,1-	1.4E-04	1.9E-04	2.6E-06	3.6E-06	1.1E-06	1.5E-06	9.0E-02		2.9E-05	4.0E-05		
Trichloroethane,1,1,2-	1.0E-04	1.5E-04	1.9E-06	2.8E-06	8.1E-07	1.2E-06	4.0E-03	5.7E-02	4.7E-04	7.0E-04	4.6E-08	6.9E-08
Trichloroethene	5.0E-04	5.0E-04	9.4E-06	9.4E-06	4.0E-06	4.0E-06		1.1E-02			4.4E-08	4.4E-08
Boron	9.0E-02	1.6E-01	1.7E-03	3.0E-03	7.2E-04	1.3E-03	9.0E-02		1.9E-02	3.3E-02		
Vanadium	1.0E-02	2.0E-02	1.9E-04	3.8E-04	8.1E-05	1.6E-04	7.0E-03		2.7E-02	5.4E-02		
Zinc	1.0E-02	1.0E-02	1.9E-04	1.9E-04	8.1E-05	8.1E-05	2.0E-01		9.4E-04	9.4E-04		
									5.2E-02	9.3E-02	1.3E-06	1.5E-06

RADIAN CORPORATION

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INGESTION OF DRINKING WATER - SUBCHRONIC 16:02:07
(due to failure of Base Treatment System) 06/22/90
CIVIL SERVICE WORKING ON BASE

Intake(mg/kg-day) = (CW x IR x EF x ED)/(BW x AT) (EPA, 1989a)

		Assumptions
CW = Chemical Concentration in Water (mg/liter) due to upset or failure of base treatment system		Use modeled concentrations (pretreatment) at well (1)
IR = Ingestion Rate (liters/day)	2.0E+00	(Half of adult 90th percentile ingestion rate)
EF = Exposure Frequency (days/year)	2.0E+01	(5 days/week) (2)
ED = Exposure Duration (years)	1.0E+00	
BW = Body Weight (kg)	7.0E+01	(adult, average; EPA, 1989b)
At = Averaging Time (period over which exposure is averaged - days)	2.8E+01	

(1) Assumes total failure of the treatment system rather than reduced efficiency of the treatment system.

(2) Assumes failure immediately following a sampling event, 1 week until next sampling event, 1 week until samples are analyzed, and 2 weeks for communication/resolution of treatment system failure (or provision of alternate water supply).

Ingestion of Drinking water - Subchronic - Civil Service Working on Base

16:02:26 06/22/90 Chemical	CW (mg/liter) Average	CW (mg/liter) Upper Bound	Estimated Intake Dose (mg/kg-day) Average	Estimated Intake Dose (mg/kg-day) Upper Bound	Oral RfDs (mg/kg/day)	Adult Average Hazard Index	Adult Upper Bound Hazard Index
Carbon tetrachloride	9.0E-05	9.0E-05	1.8E-06	1.8E-06	7.0E-03	2.6E-04	2.6E-04
Chloroform	1.6E-04	1.6E-04	3.3E-06	3.3E-06	1.0E-02	3.3E-04	3.3E-04
Dichloroethane, 1,2-	1.0E-04	1.0E-04	2.0E-06	2.0E-06			
Dichloroethene, 1,1-	1.4E-04	1.4E-04	2.9E-06	2.9E-06	9.0E-03	3.2E-04	3.2E-04
Dichloroethene, 1,2-	6.7E-03	1.6E-02	1.4E-04	3.2E-04	2.0E-01	6.8E-04	1.6E-03
Methylene chloride	2.7E-04	3.8E-04	5.5E-06	7.8E-06	6.0E-02	9.2E-05	1.3E-04
Tetrachloroethane,1,1,2,2-	8.0E-05	1.6E-04	1.6E-06	3.3E-06			
Tetrachloroethene	8.1E-04	8.1E-04	1.7E-05	1.7E-05	1.0E-01	1.7E-04	1.7E-04
Trichloroethane,1,1,1-	1.4E-04	1.9E-04	2.9E-06	3.9E-06	9.0E-01	3.2E-06	4.3E-06
Trichloroethane,1,1,2-	1.0E-04	1.5E-04	2.0E-06	3.1E-06	4.0E-02	5.1E-05	7.7E-05
Trichloroethene	3.9E-02	6.1E-02	7.9E-04	1.2E-03			
Boron	9.0E-02	1.6E-01	1.8E-03	3.3E-03	9.0E-02	2.0E-02	3.6E-02
Vanadium	1.0E-02	2.0E-02	2.0E-04	4.1E-04	7.0E-03	2.9E-02	5.8E-02
Zinc	1.0E-02	1.0E-02	2.0E-04	2.0E-04	2.0E-01	1.0E-03	1.0E-03
						5.2E-02	9.8E-02

RADIAN CORPORATION

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DERMAL CONTACT WITH CHEMICALS IN WATER WHILE SHOWERING - CHRONIC RESIDENTIAL 11:16:12 06/11/90

Absorbed Dose(mg/kg-day) = (CW x SA x PC x ET x EF x ED x CF)/(BW x AT) (EPA, 1989a)

		Assumptions
CW = Chemical Concentration in Water (mg/liter)		
-Base Well 18		Use the lesser of monitoring detection limits or modeled pretreatment concentrations
-City Well 132		Use modeled concentrations
SA = Skin Surface Area Available for Contact (cm2)		
-Children, Average	7.3E+03	(50th percentile total body surface area; 3<6 years, male, EPA, 1989b)
-Children, Upper bound	8.8E+03	(95th percentile total body surface area; 3<6 years, male, EPA, 1989b)
-Adult, Average	1.9E+04	(50th percentile total body surface area; adult male; EPA, 1989b)
-Adult, Upper bound	2.3E+04	(95th percentile total body surface area; adult male; EPA, 1989b)
PC = Chemical-specific Dermal Permeability Constant (cm/hr)	8.4E-04	(EPA, 1989a)
	0.0E+00	(PC for inorganic compounds)
ET = Exposure Time (hours/day)		
-Average	1.2E-01	(median shower length, Australian study; EPA, 1989b)
-Upper bound (reasonable maximum)	2.5E-01	(95th percentile shower length, Australian study; EPA, 1989b)
EF = Exposure Frequency (days/year)	3.7E+02	(90% of American population take bath/shower every day; EPA, 1989b).
ED = Exposure Duration (years)		
-Children	5.0E+00	(1 through 6 years old)
-Adult, Average	9.0E+00	(national median time--50th percentile-- at one residence; EPA, 1989b)
-Adult, Upperbound (reasonable maximum)	3.0E+01	(national upper bound time-- 90th percentile; EPA, 1989b)
CF = Volumetric Conversion Factor for Water	1.0E-03	liter/cm3
BW = Body Weight (kg)		
-Children	1.6E+01	(1 through 6 years old; EPA, 1989a)
-Adult	7.0E+01	(adult, average; EPA, 1989b)
AT = Averaging Time (period over which exposure is averaged-days)		
-Noncarcinogenic effects		
-Children	1.8E+03	(ED x 365 days/year)
-Adult, Average	3.3E+03	
-Adult, Upper bound	1.1E+04	
-Carcinogenic effects	2.6E+04	(70 years x 365 days/year)

Dermal Contact with Chemicals in Water While Showering - Chronic - Residential - Estimated Absorbed Dose (mg/kg-day)

11:31:07
06/15/90

Chemical	CW(mg/liter)			Base Well 18						City Well 132					
				Children		Adult				Children		Adult			
	Base Well 18														
	Average	Upper Bound	City Well 132	Average	Upper Bound	Noncarcinogen Average	Noncarcinogen Upper Bound	Carcinogen Average	Carcinogen Upper Bound	Average	Upper Bound	Noncarcinogen Average	Noncarcinogen Upper Bound	Carcinogen Average	Carcinogen Upper Bound
Carbon tetrachloride	9.0E-05	9.0E-05	1.0E-05	4.1E-09	1.0E-08	2.5E-09	6.2E-09	3.2E-10	2.6E-09	4.6E-10	1.1E-09	2.8E-10	6.8E-10	3.6E-11	2.9E-10
Chloroform	1.6E-04	1.6E-04	9.0E-05	7.3E-09	1.8E-08	4.5E-09	1.1E-08	5.7E-10	4.7E-09	4.1E-09	1.0E-08	2.5E-09	6.2E-09	3.2E-10	2.6E-09
Dichloroethane, 1,2-	1.0E-04	1.0E-04	5.0E-05	4.6E-09	1.1E-08	2.8E-09	6.8E-09	3.6E-10	2.9E-09	2.3E-09	5.7E-09	1.4E-09	3.4E-09	1.8E-10	1.5E-09
Dichloroethene, 1,1-	1.4E-04	1.4E-04	7.0E-05	6.4E-09	1.6E-08	3.9E-09	9.6E-09	5.0E-10	4.1E-09	3.2E-09	8.0E-09	2.0E-09	4.8E-09	2.5E-10	2.1E-09
Dichloroethene, 1,2-	5.0E-04	5.0E-04	2.5E-03	2.3E-08	5.7E-08	1.4E-08	3.4E-08	1.8E-09	1.5E-08	1.2E-07	2.9E-07	7.1E-08	1.7E-07	9.2E-09	7.5E-08
Methylene chloride	2.7E-04	3.8E-04	1.1E-04	1.2E-08	4.4E-08	7.5E-09	2.6E-08	9.7E-10	1.1E-08	5.0E-09	1.3E-08	3.1E-09	7.5E-09	4.0E-10	3.2E-09
Tetrachloroethane,1,1,2,2-	8.0E-05	1.6E-04	3.0E-06	3.7E-09	1.8E-08	2.2E-09	1.1E-08	2.9E-10	4.7E-09	1.4E-10	3.4E-10	8.4E-11	2.1E-10	1.1E-11	8.8E-11
Tetrachloroethene	5.0E-04	5.0E-04	2.6E-03	2.3E-08	5.7E-08	1.4E-08	3.4E-08	1.8E-09	1.5E-08	1.2E-07	3.0E-07	7.3E-08	1.8E-07	9.4E-09	7.7E-08
Trichloroethane,1,1,1-	1.4E-04	1.9E-04	5.0E-05	6.4E-09	2.2E-08	3.9E-09	1.3E-08	5.0E-10	5.6E-09	2.3E-09	5.7E-09	1.4E-09	3.4E-09	1.8E-10	1.5E-09
Trichloroethane,1,1,2-	1.0E-04	1.5E-04	1.0E-06	4.6E-09	1.7E-08	2.8E-09	1.0E-08	3.6E-10	4.4E-09	4.6E-11	1.1E-10	2.8E-11	6.8E-11	3.6E-12	2.9E-11
Trichloroethene	5.0E-04	5.0E-04	2.2E-02	2.3E-08	5.7E-08	1.4E-08	3.4E-08	1.8E-09	1.5E-08	1.0E-06	2.6E-06	6.2E-07	1.5E-06	8.0E-08	6.5E-07
Boron	9.0E-02	1.6E-01	3.0E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	1.0E-02	2.0E-02	2.0E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	1.0E-02	1.0E-02	1.0E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

RADIAN CORPORATION

Dermal Contact with Chemicals in Water While Showering - Chronic - Residential - Risk Characterization

11:31:07
06/15/90

Chemicals	Oral RfD (mg/kg/day)	Oral SF 1/(mg/kg/day)	Base Well 18						City Well 132					
			Children Noncarcinogen		Adult Noncarcinogen		Carcinogen		Children Noncarcinogen		Adult Noncarcinogen		Carcinogen	
			Average Hazard Index	Upper Bound Hazard Index	Average Hazard Index	Upper Bound Hazard Index	Average Total Pathway Risk	Upper Bound Total Pathway Risk	Average Hazard Index	Upper Bound Hazard Index	Average Hazard Index	Upper Bound Hazard Index	Average Total Pathway Risk	Upper Bound Total Pathway Risk
Carbon tetrachloride	7.0E-04	1.3E-01	5.9E-06	1.5E-05	3.6E-06	8.8E-06	4.2E-11	3.4E-10	6.6E-07	1.6E-06	4.0E-07	9.8E-07	4.7E-12	3.8E-11
Chloroform	1.0E-02	6.1E-03	7.3E-07	1.8E-06	4.5E-07	1.1E-06	3.5E-12	2.9E-11	4.1E-07	1.0E-06	2.5E-07	6.2E-07	2.0E-12	1.6E-11
Dichloroethane, 1,2-		9.1E-02					3.3E-11	2.7E-10					1.6E-11	1.3E-10
Dichloroethene, 1,1-	9.0E-03	6.0E-01	7.1E-07	1.8E-06	4.3E-07	1.1E-06	3.0E-10	2.5E-09	3.6E-07	8.9E-07	2.2E-07	5.3E-07	1.5E-10	1.2E-09
Dichloroethene, 1,2-	2.0E-02		1.1E-06	2.9E-06	7.0E-07	1.7E-06			5.8E-06	1.5E-05	3.6E-06	8.7E-06		
Methylene chloride	6.0E-02	7.5E-03	2.1E-07	7.3E-07	1.3E-07	4.3E-07	7.3E-12	8.4E-11	8.4E-08	2.1E-07	5.1E-08	1.3E-07	3.0E-12	2.4E-11
Tetrachloroethane,1,1,2,2-		2.0E-01					5.7E-11	9.4E-10					2.2E-12	1.8E-11
Tetrachloroethene	1.0E-02	5.1E-02	2.3E-06	5.7E-06	1.4E-06	3.4E-06	9.2E-11	7.5E-10	1.2E-05	3.0E-05	7.3E-06	1.8E-05	4.8E-10	3.9E-09
Trichloroethane,1,1,1-	9.0E-02		7.1E-08	2.4E-07	4.3E-08	1.4E-07			2.5E-08	6.4E-08	1.6E-08	3.8E-08		
Trichloroethane,1,1,2-	4.0E-03	5.7E-02	1.1E-06	4.3E-06	7.0E-07	2.6E-06	2.0E-11	2.5E-10	1.1E-08	2.9E-08	7.0E-09	1.7E-08	2.0E-13	1.7E-12
Trichloroethene		1.1E-02					2.0E-11	1.6E-10					8.8E-10	7.2E-09
Boron	9.0E-02		0.0E+00	0.0E+00	0.0E+00	0.0E+00			0.0E+00	0.0E+00	0.0E+00	0.0E+00		
Vanadium	7.0E-03		0.0E+00	0.0E+00	0.0E+00	0.0E+00			0.0E+00	0.0E+00	0.0E+00	0.0E+00		
Zinc	2.0E-01		0.0E+00	0.0E+00	0.0E+00	0.0E+00			0.0E+00	0.0E+00	0.0E+00	0.0E+00		
			1.2E-05	3.2E-05	7.4E-06	1.9E-05	5.8E-10	5.3E-09	1.9E-05	4.9E-05	1.2E-05	2.9E-05	1.5E-09	1.3E-08

RADIAN CORPORATION

H-15

MRA/071390/pwj

RADIAN CORPORATION

DERMAL CONTACT WITH CHEMICALS IN WATER WHILE SHOWERING - CHRONIC 11:39:19
3 YEAR TOUR OF DUTY - RESIDENTIAL 06/11/90

Absorbed Dose(mg/kg-day) = (CW x SA x PC x ET x EF x ED x CF)/(BW x AT) (EPA, 1989a)

		Assumptions
CW = Chemical Concentration in Water (mg/liter)		
-Base Well 18		Use the lesser of monitoring detection limits or modeled pretreatment concentrations
SA = Skin Surface Area Available for Contact (cm2)		
-Children, Average	7.3E+03	(50th percentile total body surface area; 3<6 years, male, EPA, 1989b)
-Children, Upper bound	8.8E+03	(95th percentile total body surface area, 3<6 years, male, EPA, 1989b)
-Adult, Average	1.9E+04	(50th percentile total body surface area; adult male; EPA, 1989b)
-Adult, Upper bound	2.3E+04	(95th percentile total body surface area; adult male; EPA, 1989b)
PC = Chemical-specific Dermal Permeability Constant (cm/hr)	8.4E-04	(EPA, 1989a)
	0.0E+00	(PC for inorganic compounds)
ET = Exposure Time (hours/day)		
-Average	1.2E-01	(median shower length, Australian study; EPA, 1989b)
-Upper bound (reasonable maximum)	2.5E-01	(95th percentile shower length, Australian study; EPA, 1989b)
EF = Exposure Frequency (days/year)	3.7E+02	(90% of American population take bath/shower every day; EPA, 1989b).
ED = Exposure Duration (years)	3.0E+00	(tour of duty)
CF = Volumetric Conversion Factor for Water	1.0E-03	liter/cm3
BW = Body Weight (kg)		
-Children	1.6E+01	(1 through 6 years old; EPA, 1989a)
-Adult	7.0E+01	(adult, average; EPA, 1989b)
AT = Averaging Time (period over which exposure is averaged-days)		
-Noncarcinogenic effects	1.1E+03	(ED x 365 days/year)
-Carcinogenic effects	2.6E+04	(70 years x 365 days/year)

Dermal Contact with Water While Showering - Chronic - 3 Year Tour of Duty
Estimated Absorbed Dose (mg/kg-day)

09:13:18
06/18/90

Chemical	CW(mg/liter) Base Well 18 Average	CW(mg/liter) Base Well 18 Upper Bound	Children Noncarcinogen Average	Children Noncarcinogen Upper Bound	Adult Noncarcinogen Average	Adult Noncarcinogen Upper Bound	Adult Carcinogen Average	Adult Carcinogen Upper Bound
Carbon tetrachloride	9.0E-05	9.0E-05	4.1E-09	1.0E-08	2.5E-09	6.2E-09	1.1E-10	2.6E-10
Chloroform	1.6E-04	1.6E-04	7.3E-09	1.8E-08	4.5E-09	1.1E-08	1.9E-10	4.7E-10
Dichloroethane, 1,2-	1.0E-04	1.0E-04	4.6E-09	1.1E-08	2.8E-09	6.8E-09	1.2E-10	2.9E-10
Dichloroethene, 1,1-	1.4E-04	1.4E-04	6.4E-09	1.6E-08	3.9E-09	9.6E-09	1.7E-10	4.1E-10
Dichloroethene, 1,2-	5.0E-04	5.0E-04	2.3E-08	5.7E-08	1.4E-08	3.4E-08	6.0E-10	1.5E-09
Methylene chloride	2.7E-04	3.8E-04	1.2E-08	4.4E-08	7.5E-09	2.6E-08	3.2E-10	1.1E-09
Tetrachloroethane,1,1,2,2-	8.0E-05	1.6E-04	3.7E-09	1.8E-08	2.2E-09	1.1E-08	9.6E-11	4.7E-10
Tetrachloroethene	5.0E-04	5.0E-04	2.3E-08	5.7E-08	1.4E-08	3.4E-08	6.0E-10	1.5E-09
Trichloroethane,1,1,1-	1.4E-04	1.9E-04	6.4E-09	2.2E-08	3.9E-09	1.3E-08	1.7E-10	5.6E-10
Trichloroethane,1,1,2-	1.0E-04	1.5E-04	4.6E-09	1.7E-08	2.8E-09	1.0E-08	1.2E-10	4.4E-10
Trichloroethene	5.0E-04	5.0E-04	2.3E-08	5.7E-08	1.4E-08	3.4E-08	6.0E-10	1.5E-09
Boron	9.0E-02	1.6E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	1.0E-02	2.0E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	1.0E-02	1.0E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Risk Characterization

09:12:02
06/18/90

Chemicals	RfDs (mg/kg/day)	ERR Oral SF 1/(mg/kg/day)	Base Well 18 Children Noncarcinogen Average Hazard Index	Children Noncarcinogen Upper Bound Hazard Index	Adult Noncarcinogen Average Hazard Index	Adult Noncarcinogen Upper Bound Hazard Index	Carcinogen Average Total Pathway Risk	Carcinogen Upper Bound Total Pathway Risk
Carbon tetrachloride	7.0E-03	1.3E-01	5.9E-07	1.5E-06	3.6E-07	8.8E-07	1.4E-11	3.4E-11
Chloroform	1.0E-02	6.1E-03	7.3E-07	1.8E-06	4.5E-07	1.1E-06	1.2E-12	2.9E-12
Dichloroethane, 1,2-		9.1E-02					1.1E-11	2.7E-11
Dichloroethene, 1,1-	9.0E-03	6.0E-01	7.1E-07	1.8E-06	4.3E-07	1.1E-06	1.0E-10	2.5E-10
Dichloroethene, 1,2-	2.0E-01		1.1E-07	2.9E-07	7.0E-08	1.7E-07		
Methylene chloride	6.0E-02	7.5E-03	2.1E-07	7.3E-07	1.3E-07	4.3E-07	2.4E-12	8.4E-12
Tetrachloroethane,1,1,2,2-		2.0E-01					1.9E-11	9.4E-11
Tetrachloroethene	1.0E-01	5.1E-02	2.3E-07	5.7E-07	1.4E-07	3.4E-07	3.1E-11	7.5E-11
Trichloroethane,1,1,1-	9.0E-01		7.1E-09	2.4E-08	4.3E-09	1.4E-08		
Trichloroethane,1,1,2-	4.0E-02	5.7E-02	1.1E-07	4.3E-07	7.0E-08	2.6E-07	6.8E-12	2.5E-11
Trichloroethene		1.1E-02					6.6E-12	1.6E-11
Boron	9.0E-02							
Vanadium	7.0E-03							
Zinc	2.0E-01							
			2.7E-06	7.2E-06	1.7E-06	4.3E-06	1.9E-10	5.3E-10

RADIAN CORPORATION

DERMAL CONTACT WITH CHEMICALS IN WATER WHILE SHOWERING - SUBCHRONIC 11:46:21
RESIDENTIAL 06/11/90
(Applicable to Residential and 3 year tour of duty)

Absorbed Dose(mg/kg-day) = (CW x SA x PC x ET x EF x ED x CF)/(BW x AT) (EPA, 1989a)

	Assumptions
CW = Chemical Concentration in Water (mg/liter)	Use modeled concentrations (pretreatment) at well
SA = Skin Surface Area Available for Contact (cm2)	
-Children, Average	7.3E+03 (50th percentile total body surface area; 3<6 years; male; EPA, 1989b)
-Children, Upper bound	8.8E+03 (95th percentile total body surface area; 3<6 years; male; EPA, 1989b)
-Adult, Average	1.9E+04 (50th percentile total body surface area; adult male; EPA, 1989b)
-Adult, Upper bound	2.3E+04 (95th percentile total body surface area; adult male; EPA, 1989b)
PC = Chemical-specific Dermal Permeability Constant (cm/hr)	8.4E-04 (EPA, 1989a) 0.0E+00 (PC for inorganic compounds)
ET = Exposure Time (hours/day)	
-Average	1.2E-01 (median shower length, Australian study; EPA, 1989b)
-Upper bound (reasonable maximum)	2.5E-01 (95th percentile shower length, Australian study; EPA, 1989b)
EF = Exposure Frequency (days/year)	3.0E+01
ED = Exposure Duration (years)	1.0E+00
CF = Volumetric Conversion Factor for Water	1.0E-03 liter/cm3
BW = Body Weight (kg)	
-Children	1.6E+01 (1 through 6 years old; EPA, 1989a)
-Adult	7.0E+01 (adult, average; EPA, 1989b)
AT = Averaging Time (period over which exposure is averaged-days)	
-Noncarcinogenic effects	3.0E+01 (EF x ED)

Dermal Contact with Chemicals in Water While Showering - Subchronic - Residential and 3 Year Tour of Duty

09:19:13
06/18/90

Chemical	CW(mg/liter) Average	CW(mg/liter) Upper Bound	Estimated Absorbed Dose (mg/kg-day) Children Average	Children Upper Bound	Adult Average	Adult Upper Bound	Oral RfDs (mg/kg/day)	Children Average Hazard Index	Children Upper Bound Hazard Index	Adult Average Hazard Index	Adult Upper Bound Hazard Index
Carbon tetrachloride	9.0E-05	9.0E-05	4.1E-09	1.0E-08	2.5E-09	6.2E-09	7.0E-03	5.9E-07	1.5E-06	3.6E-07	8.8E-07
Chloroform	1.6E-04	1.6E-04	7.3E-09	1.8E-08	4.5E-09	1.1E-08	1.0E-02	7.3E-07	1.8E-06	4.5E-07	1.1E-06
Dichloroethane, 1,2-	1.0E-04	1.0E-04	4.6E-09	1.1E-08	2.8E-09	6.8E-09					
Dichloroethene, 1,1-	1.4E-04	1.4E-04	6.4E-09	1.6E-08	3.9E-09	9.6E-09	9.0E-03	7.1E-07	1.8E-06	4.3E-07	1.1E-06
Dichloroethene, 1,2-	6.7E-03	1.6E-02	3.1E-07	1.8E-06	1.9E-07	1.1E-06	2.0E-01	1.5E-06	9.0E-06	9.4E-07	5.4E-06
Methylene chloride	2.7E-04	3.8E-04	1.2E-08	4.4E-08	7.5E-09	2.6E-08	6.0E-02	2.1E-07	7.3E-07	1.3E-07	4.3E-07
Tetrachloroethane,1,1,2,2-	8.0E-05	1.6E-04	3.7E-09	1.8E-08	2.2E-09	1.1E-08					
Tetrachloroethene	8.1E-04	8.1E-04	3.7E-08	9.3E-08	2.3E-08	5.5E-08	1.0E-01	3.7E-07	9.3E-07	2.3E-07	5.5E-07
Trichloroethane,1,1,1-	1.4E-04	1.9E-04	6.4E-09	2.2E-08	3.9E-09	1.3E-08	9.0E-01	7.1E-09	2.4E-08	4.3E-09	1.4E-08
Trichloroethane,1,1,2-	1.0E-04	1.5E-04	4.6E-09	1.7E-08	2.8E-09	1.0E-08	4.0E-02	1.1E-07	4.3E-07	7.0E-08	2.6E-07
Trichloroethene	3.9E-02	6.1E-02	1.8E-06	7.0E-06	1.1E-06	4.1E-06					
Boron	9.0E-02	1.6E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.0E-02				
Vanadium	1.0E-02	2.0E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.0E-03				
Zinc	1.0E-02	1.0E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-01				
								4.3E-06	1.6E-05	2.6E-06	9.7E-06

RADIAN CORPORATION

MRA/071390/pwj

RADIAN CORPORATION

INHALATION OF VAPOR PHASE CHEMICALS WHILE
SHOWERING WITH RESIDENTIAL WATER - CHRONIC
RESDENTIAL

Intake(mg/kg-day) = (CA x IR x ET x EF X ED)/(BW x AT) (EPA, 1989a)

		Assumptions
CA = Contaminant Concentration in Air (mg/m3)		Chemical-specific; calculated from concentration in tap water (Base Well 18 and City Well 132)
IR = Inhalation Rate (m3/hour)	6.0E-01	(Showering; all age groups; EPA, 1989b)
ET = Exposure Time (hours/day)		
-Average	1.2E-01	(50th percentile shower duration; EPA, 1989b)
-Upper Bound (reasonable maximum)	2.5E-01	(95th percentile shower duration; EPA, 1989b) (1)
EF = Exposure Frequency (days/year)	3.7E+02	(90% of American population take bath/shower every day; EPA, 1989b)
ED = Exposure Duration (years)		
-Children	5.0E+00	(1 through 6 years old)
-Adult, Average	9.0E+00	(national median time--50th percentile-- at one residence; EPA, 1989b)
-Adult, Upper bound (reasonable maximum)	3.0E+01	(national upper bound time-- 90th percentile; EPA, 1989b)
BW = Body Weight (kg)		
-Children	1.6E+01	(1 through 6 years old; EPA, 1989a)
-Adult	7.0E+01	(adult, average; EPA, 1989b)
AT = Averaging Time (period over which exposure is averaged-days)		
-Noncarcinogenic effects		
-Children	1.8E+03	(ED x 365 days/year)
-Adult, Average	3.3E+03	
-Adult, Upper bound	1.1E+04	
-Carcinogenic effects	2.6E+04	(70 years x 365 days/year)

(1) EPA, 1989a cites the 90th percentile (0.2); however, text elsewhere recommends use of 95th percentile when it is available.

RADIAN CORPORATION

INHALATION OF VAPOR PHASE CHEMICALS WHILE
SHOWERING WITH RESIDENTIAL WATER - CHRONIC
RESDENTIAL

Effective Air Concentration (EAC), (mg/m3) = (CA x IRS x ET x EF X ED)/(IRD X CF X AT)

		Assumptions
CA = Contaminant Concentration in Air (mg/m3)		Chemical-specific; calculated from concentration in tap water (Base Well 18 and City Well 132)
IRS = Inhalation Rate in the Shower (m3/hour)	6.0E-01	(Showering; all age groups; EPA, 1989b)
ET = Exposure Time (hours/day)		
-Average	1.2E-01	(50th percentile shower duration; EPA, 1989b)
-Upper Bound (reasonable maximum)	2.5E-01	(95th percentile shower duration; EPA, 1989b) (1)
EF = Exposure Frequency (days/year)	3.7E+02	(90% of American population take bath/shower every day; EPA, 1989b)
ED = Exposure Duration (years)		
-Children	5.0E+00	(1 through 6 years old)
-Adult, Average	9.0E+00	(national median time--50th percentile-- at one residence; EPA, 1989b)
-Adult, Upper bound (reasonable maximum)	3.0E+01	(national upper bound time-- 90th percentile; EPA, 1989b)
IRD = Inhalation Rate per Day (m3/hour)		
-Average	8.0E-01	(EPA, 1989a)
-Upper Bound	1.3E+00	(EPA, 1989a)
CF = Conversion Factor (hour/day)	2.4E+01	
AT = Averaging Time (period over which exposure is averaged-days)		
-Noncarcinogenic effects		
-Children	1.8E+03	(ED x 365 days/year)
-Adult, Average	3.3E+03	
-Adult, Upper bound	1.1E+04	
-Carcinogenic effects	2.6E+04	(70 years x 365 days/year)

(1) EPA, 1989a cites the 90th percentile (0.2); however, text elsewhere recommends use of 95th percentile when it is available.

Inhalation of Vapor Phase Chemicals While Showering with Residential Water - Chronic - Residential - Estimated Intake Dose (mg/kg-day)

09:01:13
06/19/90

Chemical	CA(mg/m3)				Base Well 18						City Well 132					
					Children		Adult				Children		Adult			
	Base Well 18		City Well 132		Noncarcinogenic		Noncarcinogenic		Carcinogenic		Noncarcinogenic		Noncarcinogenic		Carcinogenic	
	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound
Carbon tetrachloride	1.9E-03	3.5E-03	2.1E-04	3.9E-04	8.3E-06	3.3E-05	1.9E-06	7.6E-06	2.4E-07	3.3E-06	9.4E-07	3.7E-06	2.2E-07	8.4E-07	2.8E-08	3.6E-07
Chloroform	3.3E-03	6.3E-03	1.8E-03	3.5E-03	1.5E-05	5.9E-05	3.4E-06	1.4E-05	4.4E-07	5.8E-06	8.1E-06	3.3E-05	1.9E-06	7.5E-06	2.4E-07	3.2E-06
Dichloroethane, 1,2-	2.1E-03	3.9E-03	1.0E-03	2.0E-03	9.4E-06	3.7E-05	2.2E-06	8.4E-06	2.8E-07	3.6E-06	4.5E-06	1.9E-05	1.0E-06	4.3E-06	1.3E-07	1.8E-06
Dichloroethene, 1,1-	2.9E-03	5.5E-03	1.4E-03	2.8E-03	1.3E-05	5.2E-05	3.0E-06	1.2E-05	3.8E-07	5.1E-06	6.3E-06	2.6E-05	1.4E-06	6.0E-06	1.9E-07	2.6E-06
Dichloroethene, 1,2-	1.0E-02	2.0E-02	5.2E-02	1.0E-01	4.5E-05	1.9E-04	1.0E-05	4.3E-05	1.3E-06	1.8E-05	2.3E-04	9.4E-04	5.3E-05	2.1E-04	6.9E-06	9.2E-05
Methylene chloride	5.5E-03	1.5E-02	2.3E-03	4.3E-03	2.5E-05	1.4E-04	5.7E-06	3.2E-05	7.3E-07	1.4E-05	1.0E-05	4.0E-05	2.4E-06	9.2E-06	3.0E-07	3.9E-06
Tetrachloroethane,1,1,2,2-	1.6E-03	6.3E-03	6.2E-05	1.2E-04	7.2E-06	5.9E-05	1.6E-06	1.4E-05	2.1E-07	5.8E-06	2.8E-07	1.1E-06	6.4E-08	2.6E-07	8.2E-09	1.1E-07
Tetrachloroethene	1.0E-02	2.0E-02	5.4E-02	1.0E-01	4.5E-05	1.9E-04	1.0E-05	4.3E-05	1.3E-06	1.8E-05	2.4E-04	9.4E-04	5.6E-05	2.1E-04	7.1E-06	9.2E-05
Trichloroethane,1,1,1-	2.9E-03	7.5E-03	1.0E-03	2.0E-03	1.3E-05	7.0E-05	3.0E-06	1.6E-05	3.8E-07	6.9E-06	4.5E-06	1.9E-05	1.0E-06	4.3E-06	1.3E-07	1.8E-06
Trichloroethane,1,1,2-	2.1E-03	5.9E-03	2.1E-05	3.9E-05	9.4E-06	5.5E-05	2.2E-06	1.3E-05	2.8E-07	5.4E-06	9.4E-08	3.7E-07	2.2E-08	8.4E-08	2.8E-09	3.6E-08
Trichloroethene	1.0E-02	2.0E-02	4.6E-01	8.8E-01	4.5E-05	1.9E-04	1.0E-05	4.3E-05	1.3E-06	1.8E-05	2.1E-03	8.3E-03	4.7E-04	1.9E-03	6.1E-05	8.1E-04
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Showering with Residential Water - Chronic - Residential - Effective Air Concentration (mg/m3)

09:01:13
06/19/90

Chemical	CA(mg/m3)				Base Well 18						City Well 132					
					Children		Adult				Children		Adult			
	Base Well 18		City Well 132		Noncarcinogenic		Noncarcinogenic		Carcinogenic		Noncarcinogenic		Noncarcinogenic		Carcinogenic	
	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound
Carbon tetrachloride	1.9E-03	3.5E-03	2.1E-04	3.9E-04	6.9E-06	1.8E-05	6.9E-06	1.8E-05	8.9E-07	7.6E-06	7.9E-07	1.9E-06	7.9E-07	1.9E-06	1.0E-07	8.4E-07
Chloroform	3.3E-03	6.3E-03	1.8E-03	3.5E-03	1.2E-05	3.1E-05	1.2E-05	3.1E-05	1.6E-06	1.4E-05	6.7E-06	1.8E-05	6.7E-06	1.8E-05	8.7E-07	7.5E-06
Dichloroethane, 1,2-	2.1E-03	3.9E-03	1.0E-03	2.0E-03	7.9E-06	1.9E-05	7.9E-06	1.9E-05	1.0E-06	8.4E-06	3.8E-06	1.0E-05	3.8E-06	1.0E-05	4.8E-07	4.3E-06
Dichloroethene, 1,1-	2.9E-03	5.5E-03	1.4E-03	2.8E-03	1.1E-05	2.7E-05	1.1E-05	2.7E-05	1.4E-06	1.2E-05	5.2E-06	1.4E-05	5.2E-06	1.4E-05	6.7E-07	6.0E-06
Dichloroethene, 1,2-	1.0E-02	2.0E-02	5.2E-02	1.0E-01	3.7E-05	1.0E-04	3.7E-05	1.0E-04	4.8E-06	4.3E-05	1.9E-04	5.0E-04	1.9E-04	5.0E-04	2.5E-05	2.1E-04
Methylene chloride	5.5E-03	1.5E-02	2.3E-03	4.3E-03	2.1E-05	7.5E-05	2.1E-05	7.5E-05	2.7E-06	3.2E-05	8.6E-06	2.2E-05	8.6E-06	2.2E-05	1.1E-06	9.2E-06
Tetrachloroethane, 1,1,2,2-	1.6E-03	6.3E-03	6.2E-05	1.2E-04	6.0E-06	3.1E-05	6.0E-06	3.1E-05	7.7E-07	1.4E-05	2.3E-07	6.0E-07	2.3E-07	6.0E-07	3.0E-08	2.6E-07
Tetrachloroethene	1.0E-02	2.0E-02	5.4E-02	1.0E-01	3.7E-05	1.0E-04	3.7E-05	1.0E-04	4.8E-06	4.3E-05	2.0E-04	5.0E-04	2.0E-04	5.0E-04	2.6E-05	2.1E-04
Trichloroethane, 1,1,1-	2.9E-03	7.5E-03	1.0E-03	2.0E-03	1.1E-05	3.7E-05	1.1E-05	3.7E-05	1.4E-06	1.6E-05	3.8E-06	1.0E-05	3.8E-06	1.0E-05	4.8E-07	4.3E-06
Trichloroethane, 1,1,2-	2.1E-03	5.9E-03	2.1E-05	3.9E-05	7.9E-06	2.9E-05	7.9E-06	2.9E-05	1.0E-06	1.3E-05	7.9E-08	2.0E-07	7.9E-08	2.0E-07	1.0E-08	8.4E-08
Trichloroethene	1.0E-02	2.0E-02	4.6E-01	8.8E-01	3.7E-05	1.0E-04	3.7E-05	1.0E-04	4.8E-06	4.3E-05	1.7E-03	4.4E-03	1.7E-03	4.4E-03	2.2E-04	1.9E-03
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Showering with Residential Water - Chronic - Residential - Risk Characterization

14:00:59
07/06/90

Chemical	Oral RfD (mg/kg/day)	Inhal. RfD (mg/m3)	Inhal. Unit Risk 1/(ug/m3)	Inhal. SF (mg/kg/day)	Base Well 18						City Well 132					
					Children		Adult				Children		Adult			
					Noncarcinogenic		Noncarcinogenic		Carcinogenic		Noncarcinogenic		Noncarcinogenic		Carcinogenic	
					Average Hazard Index	Upper Bound Hazard Index	Average Hazard Index	Upper Bound Hazard Index	Average Total Pathway Risk	Upper Bound Total Pathway Risk	Average Hazard Index	Upper Bound Hazard Index	Average Hazard Index	Upper Bound Hazard Index	Average Total Pathway Risk	Upper Bound Total Pathway Risk
Carbon tetrachloride	7.0E-04			1.3E-01	1.2E-02	4.7E-02	2.7E-03	1.1E-02	3.2E-08	4.2E-07	1.4E-03	5.2E-03	3.1E-04	1.2E-03	3.6E-09	4.7E-08
Chloroform	1.0E-02			8.1E-02	1.5E-03	5.9E-03	3.4E-04	1.3E-03	3.5E-08	4.7E-07	8.1E-04	3.3E-03	1.9E-04	7.5E-04	1.9E-08	2.6E-07
Dichloroethane, 1,2-				9.1E-02					2.5E-08	3.3E-07					1.2E-08	1.7E-07
Dichloroethene, 1,1-	9.0E-03		5.0E-05		1.5E-03	5.7E-03	3.3E-04	1.3E-03	7.0E-08	5.9E-07	7.0E-04	2.9E-03	1.6E-04	6.7E-04	3.4E-08	3.0E-07
Dichloroethene, 1,2-	2.0E-02				2.3E-03	9.4E-03	5.1E-04	2.1E-03			1.2E-02	4.7E-02	2.7E-03	1.1E-02		
Methylene chloride	6.0E-02	3.0E+00	4.1E-06		6.9E-06	2.5E-05	6.9E-06	2.5E-05	1.1E-08	1.3E-07	2.9E-06	7.2E-06	2.9E-06	7.2E-06	4.5E-09	3.8E-08
Tetrachloroethane, 1,1,2,2-				2.0E-01					4.2E-08	1.2E-06					1.6E-09	2.2E-08
Tetrachloroethene	1.0E-02		9.5E-07		4.5E-03	1.9E-02	1.0E-03	4.3E-03	4.6E-09	4.1E-08	2.4E-02	9.4E-02	5.6E-03	2.1E-02	2.5E-08	2.0E-07
Trichloroethane, 1,1,1-	9.0E-02	1.0E+00			1.1E-05	3.7E-05	1.1E-05	3.7E-05			3.7E-06	1.0E-05	3.7E-06	1.0E-05		
Trichloroethane, 1,1,2-	4.0E-03	ND		5.7E-02	2.4E-03	1.4E-02	5.4E-04	3.2E-03	1.6E-08	3.1E-07	2.4E-05	9.1E-05	5.4E-06	2.1E-05	1.6E-10	2.0E-09
Trichloroethene			1.7E-06						8.2E-09	7.3E-08					3.8E-07	3.2E-06
Boron	9.0E-02	ND														
Vanadium	7.0E-03	ND														
Zinc	2.0E-01	ND														
					2.4E-02	1.0E-01	5.5E-03	2.3E-02	2.4E-07	3.5E-06	3.9E-02	1.5E-01	8.9E-03	3.5E-02	4.8E-07	4.2E-06

RADIAN CORPORATION

MRA/071390/pwj

RADIAN CORPORATION

INHALATION OF VAPOR PHASE CHEMICALS WHILE
SHOWERING WITH RESIDENTIAL WATER - CHRONIC
3 YEAR TOUR OF DUTY - RESIDENTIAL

Intake(mg/kg-day) = (CA x IR x ET x EF X ED)/(BW x AT) (EPA, 1989a)

	Assumptions
CA = Contaminant Concentration in Air (mg/m3)	Chemical-specific; calculated from concentration in tap water (Base Well 18 and City Well 132)
IR = Inhalation Rate (m3/hour)	6.0E-01 (Showering; all age groups; EPA, 1989b)
ET = Exposure Time (hours/day)	
-Average	1.2E-01 (50th percentile shower duration; EPA, 1989b)
-Upper Bound (reasonable maximum)	2.5E-01 (95th percentile shower duration; EPA, 1989b) (1)
EF = Exposure Frequency (days/year)	3.7E+02 (90% of American population take bath/shower every day; EPA, 1989b)
ED = Exposure Duration (years)	3.0E+00 (tour of duty)
BW = Body Weight (kg)	
-Children	1.6E+01 (1 through 6 years old; EPA, 1989a)
-Adult	7.0E+01 (adult, average; EPA, 1989b)
AT = Averaging Time (period over which exposure is averaged-days)	
-Noncarcinogenic effects	1.1E+03 (ED x 365 days/year)
-Carcinogenic effects	2.6E+04 (70 years x 365 days/year)

(1) EPA, 1989a cites the 90th percentile (0.2); however, text elsewhere recommends use of 95th percentile when it is available.

RADIAN CORPORATION

INHALATION OF VAPOR PHASE CHEMICALS WHILE
SHOWERING WITH RESIDENTIAL WATER - CHRONIC
3 YEAR TOUR OF DUTY - RESIDENTIAL

Effective Air Concentration (EAC), (mg/m3) = (CA X IRS X ET X EF X ED)/(IRD X CF X AT)

	Assumptions
CA = Contaminant Concentration in Air (mg/m3)	Chemical-specific; calculated from concentration in tap water (Base Well 18 and City Well 132)
IR = Inhalation Rate (m3/hour)	6.0E-01 (Showering; all age groups; EPA, 1989b)
ET = Exposure Time (hours/day)	
-Average	1.2E-01 (50th percentile shower duration; EPA, 1989b)
-Upper Bound (reasonable maximum)	2.5E-01 (95th percentile shower duration; EPA, 1989b) (1)
EF = Exposure Frequency (days/year)	3.7E+02 (90% of American population take bath/shower every day; EPA, 1989b)
ED = Exposure Duration (years)	3.0E+00 (tour of duty)
IRD = Inhalation Rate per Day (m3/hour)	
-Average	8.0E-01 (EPA, 1989a)
-Upper Bound	1.3E+00 (EPA, 1989a)
CF = Conversion Factor (hour/day)	2.4E+01
AT = Averaging Time (period over which exposure is averaged-days)	
-Noncarcinogenic effects	1.1E+03 (ED x 365 days/year)
-Carcinogenic effects	2.6E+04 (70 years x 365 days/year)

(1) EPA, 1989a cites the 90th percentile (0.2); however, text elsewhere recommends use of 95th percentile when it is available.

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Showering with Residential Water - Chronic - 3 Year Tour of Duty

08:53:51
06/19/90

Base Well 18

Estimated Intake Dose (mg/kg-day)

Chemical	CA(mg/m3) Base Well 18 Average	CA(mg/m3) Base Well 18 Upper Bound	Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	1.9E-03	3.5E-03	8.3E-06	3.3E-05	1.9E-06	7.6E-06	8.2E-08	3.3E-07
Chloroform	3.3E-03	6.3E-03	1.5E-05	5.9E-05	3.4E-06	1.4E-05	1.5E-07	5.8E-07
Dichloroethane, 1,2-	2.1E-03	3.9E-03	9.4E-06	3.7E-05	2.2E-06	8.4E-06	9.3E-08	3.6E-07
Dichloroethene, 1,1-	2.9E-03	5.5E-03	1.3E-05	5.2E-05	3.0E-06	1.2E-05	1.3E-07	5.1E-07
Dichloroethene, 1,2-	1.0E-02	2.0E-02	4.5E-05	1.9E-04	1.0E-05	4.3E-05	4.4E-07	1.8E-06
Methylene chloride	5.5E-03	1.5E-02	2.5E-05	1.4E-04	5.7E-06	3.2E-05	2.4E-07	1.4E-06
Tetrachloroethane,1,1,2,2-	1.6E-03	6.3E-03	7.2E-06	5.9E-05	1.6E-06	1.4E-05	7.1E-08	5.8E-07
Tetrachloroethene	1.0E-02	2.0E-02	4.5E-05	1.9E-04	1.0E-05	4.3E-05	4.4E-07	1.8E-06
Trichloroethane,1,1,1-	2.9E-03	7.5E-03	1.3E-05	7.0E-05	3.0E-06	1.6E-05	1.3E-07	6.9E-07
Trichloroethane,1,1,2-	2.1E-03	5.9E-03	9.4E-06	5.5E-05	2.2E-06	1.3E-05	9.3E-08	5.4E-07
Trichloroethene	1.0E-02	2.0E-02	4.5E-05	1.9E-04	1.0E-05	4.3E-05	4.4E-07	1.8E-06
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Inhalation of Vapor Phase Chemicals While Showering with Residential Water - Chronic - 3 Year Tour of Duty

08:53:51
06/19/90

Base Well 18

Effective Air Concentration (mg/m3)

Chemical	CA(mg/m3) Base Well 18 Average	CA(mg/m3) Base Well 18 Upper Bound	Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	1.9E-03	3.5E-03	6.9E-06	1.8E-05	6.9E-06	1.8E-05	3.0E-07	7.6E-07
Chloroform	3.3E-03	6.3E-03	1.2E-05	3.1E-05	1.2E-05	3.1E-05	5.3E-07	1.3E-06
Dichloroethane, 1,2-	2.1E-03	3.9E-03	7.9E-06	1.9E-05	7.9E-06	1.9E-05	3.4E-07	8.4E-07
Dichloroethene, 1,1-	2.9E-03	5.5E-03	1.1E-05	2.7E-05	1.1E-05	2.7E-05	4.7E-07	1.2E-06
Dichloroethene, 1,2-	1.0E-02	2.0E-02	3.7E-05	1.0E-04	3.7E-05	1.0E-04	1.6E-06	4.3E-06
Methylene chloride	5.5E-03	1.5E-02	2.1E-05	7.5E-05	2.1E-05	7.5E-05	8.8E-07	3.2E-06
Tetrachloroethane, 1,1,2,2-	1.6E-03	6.3E-03	6.0E-06	3.1E-05	6.0E-06	3.1E-05	2.6E-07	1.3E-06
Tetrachloroethene	1.0E-02	2.0E-02	3.7E-05	1.0E-04	3.7E-05	1.0E-04	1.6E-06	4.3E-06
Trichloroethane, 1,1,1-	2.9E-03	7.5E-03	1.1E-05	3.7E-05	1.1E-05	3.7E-05	4.7E-07	1.6E-06
Trichloroethane, 1,1,2-	2.1E-03	5.9E-03	7.9E-06	2.9E-05	7.9E-06	2.9E-05	3.4E-07	1.3E-06
Trichloroethene	1.0E-02	2.0E-02	3.7E-05	1.0E-04	3.7E-05	1.0E-04	1.6E-06	4.3E-06
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Showering with Residential Water - Chronic - 3 Year Tour of Duty
Risk Characterization

15:42:21
07/06/90

Base Well 18

Chemical	Oral RfDs (mg/kg/day)	Inhalation RFDs (mg/m3)	Inhalation Unit Risk 1/(ug/m3)	Inhalation SF 1/(mg/kg/day)	Children Noncarcinogenic Average Hazard Index	Children Noncarcinogenic Upper Bound Hazard Index	Adult Noncarcinogenic Average Hazard Index	Adult Noncarcinogenic Upper Bound Hazard Index	Carcinogenic Average Total Pathway Risk	Carcinogenic Upper Bound Total Pathway Risk
Carbon tetrachloride	7.0E-03			1.3E-01	1.2E-03	4.7E-03	2.7E-04	1.1E-03	1.1E-08	4.2E-08
Chloroform	1.0E-02			8.1E-02	1.5E-03	5.9E-03	3.4E-04	1.3E-03	1.2E-08	4.7E-08
Dichloroethane, 1,2-				9.1E-02					8.4E-09	3.3E-08
Dichloroethene, 1,1-	9.0E-03		5.0E-05		1.5E-03	5.7E-03	3.3E-04	1.3E-03	2.3E-08	5.9E-08
Dichloroethene, 1,2-	2.0E-01				2.3E-04	9.4E-04	5.1E-05	2.1E-04		
Methylene chloride	6.0E-02	3.0E+00	4.1E-06		6.9E-06	2.5E-05	6.9E-06	2.5E-05	3.6E-09	1.3E-08
Tetrachloroethane, 1,1,2,2-				2.0E-01					1.4E-08	1.2E-07
Tetrachloroethene	1.0E-01		9.5E-07		4.5E-04	1.9E-03	1.0E-04	4.3E-04	1.5E-09	4.1E-09
Trichloroethane, 1,1,1-	9.0E-01	1.0E+01			1.1E-06	3.7E-06	1.1E-06	3.7E-06		
Trichloroethane, 1,1,2-	4.0E-02	ND		5.7E-02	2.4E-04	1.4E-03	5.4E-05	3.2E-04	5.3E-09	3.1E-08
Trichloroethene			1.7E-06						2.7E-09	7.3E-09
Boron	9.0E-02	ND								
Vanadium	7.0E-03	ND								
Zinc	2.0E-01	ND								
					5.0E-03	2.1E-02	1.2E-03	4.7E-03	8.1E-08	3.5E-07

RADIAN CORPORATION

INHALATION OF VAPOR PHASE CHEMICALS WHILE SHOWERING 09:39:49
WITH RESIDENTIAL WATER - SUBCHRONIC 06/20/90
(Applicable to Residential and 3 year tour of duty)

Intake(mg/kg-day) = (CA x IR x ET x EF X ED)/(BW x AT) (EPA, 1989a)

		Assumptions
CA = Contaminant Concentration in Air (mg/m3)		Chemical-specific; calculated from concentration in tap water (use modeled concentrations (pretreatment) at well)
IR = Inhalation Rate (m3/hour)	6.0E-01	(Showering; all age groups; EPA, 1989b)
ET = Exposure Time (hours/day)		
-Average	1.2E-01	(50th percentile shower duration; EPA, 1989b)
-Upper Bound (reasonable maximum)	2.5E-01	(95th percentile shower duration; EPA, 1989b)
EF = Exposure Frequency (days/year)	3.0E+01	
ED = Exposure Duration (years)	1.0E+00	
BW = Body Weight (kg)		
-Children	1.6E+01	(1 through 6 years old; EPA, 1989a)
-Adult	7.0E+01	(adult, average; EPA, 1989b)
AT = Averaging Time (period over which exposure is averaged-days)		
-Noncarcinogenic effects	3.0E+01	(EF x ED)

RADIAN CORPORATION

INHALATION OF VAPOR PHASE CHEMICALS WHILE SHOWERING 11:53:03
WITH RESIDENTIAL WATER - SUBCHRONIC 06/11/90
(Applicable to Residential and 3 year tour of duty)

Effective Air Concentration (EAC), (mg/m3) = (CA X IRS X ET X EF X ED)/(IRD X CF X AT)

		Assumptions
CA = Contaminant Concentration in Air (mg/m3)		Chemical-specific; calculated from concentration in tap water (use modeled concentrations (pretreatment) at well)
IRS = Inhalation Rate in the Shower (m3/hour)	6.0E-01	(Showering; all age groups; EPA, 1989b)
ET = Exposure Time (hours/day)		
-Average	1.2E-01	(50th percentile shower duration; EPA, 1989b)
-Upper Bound (reasonable maximum)	2.5E-01	(95th percentile shower duration; EPA, 1989b)
EF = Exposure Frequency (days/year)	3.0E+01	
ED = Exposure Duration (years)	1.0E+00	
IRD = Inhalation Rate per Day (m3/hour)		
-Average	8.0E-01	(EPA, 1989a)
-Upper Bound	1.3E+00	(EPA, 1989a)
CF = Conversion Factor (hour/day)	2.4E+01	
AT = Averaging Time (period over which exposure is averaged-days)		
-Noncarcinogenic effects	3.0E+01	(EF x ED)

Inhalation of Vapor Phase Chemicals While Showering with Residential Water - Subchronic - Residenti

12:23:54
06/26/90

Chemical	CA(mg/m3)		Estimated Intake Dose (mg/kg-day) Children		Adult	
	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound
Carbon tetrachloride	1.9E-03	3 5E-03	8.3E-06	3.3E-05	1.9E-06	7.6E-06
Chloroform	3 3E-03	6.3E-03	1.5E-05	5.9E-05	3.4E-06	1.4E-05
Dichloroethane, 1,2-	2 1E-03	3.9E-03	9.4E-06	3.7E-05	2.2E-06	8.4E-06
Dichloroethene, 1,1-	2.9E-03	5.5E-03	1.3E-05	5.2E-05	3.0E-06	1.2E-05
Dichloroethene, 1,2-	1 4E-01	6.2E-01	6.3E-04	5.8E-03	1.4E-04	1.3E-03
Methylene chloride	5 5E-03	1.5E-02	2.5E-05	1 4E-04	5.7E-06	3.2E-05
Tetrachloroethane,1,1,2,2-	1 6E-03	6.3E-03	7.2E-06	5.9E-05	1.6E-06	1.4E-05
Tetrachloroethene	1 7E-02	3.2E-02	7.7E-05	3.0E-04	1.7E-05	6.9E-05
Trichloroethane,1,1,1-	2.9E-03	7.5E-03	1.3E-05	7.0E-05	3.0E-06	1.6E-05
Trichloroethane,1,1,2-	2.1E-03	5.9E-03	9 4E-06	5.5E-05	2.2E-06	1.3E-05
Trichloroethene	7.9E-01	2.4E+00	3.6E-03	2.2E-02	8.1E-04	5.1E-03
Boron	0 0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0 0E+00	0 0E+00	0 0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0 0E+00	0 0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Showering with Residential Water - Subchronic - Residential and 3 Year Tour of Duty

12:23:54 06/26/90	CA(mg/m3)		Effective Air Concentration (mg/m3) Children		Adult				Children		Adult	
Chemical	Average	Upper Bound	Average	Upper Bound	Average	Upper Bound	Oral RfDs (mg/kg/d)	Inhalation RFDs (mg/m3)	Average Hazard Index	Upper Bound Hazard Index	Average Hazard Index	Upper Bound Hazard Index
Carbon tetrachloride	1.9E-03	3.5E-03	6.9E-06	1.8E-05	6.9E-06	1.8E-05	7.0E-03		1.2E-03	4.7E-03	2.7E-04	1.1E-03
Chloroform	3.3E-03	6.3E-03	1.2E-05	3.1E-05	1.2E-05	3.1E-05	1.0E-02		1.5E-03	5.9E-03	3.4E-04	1.4E-03
Dichloroethane, 1,2-	2.1E-03	3.9E-03	7.9E-06	1.9E-05	7.9E-06	1.9E-05						
Dichloroethene, 1,1-	2.9E-03	5.5E-03	1.1E-05	2.7E-05	1.1E-05	2.7E-05	9.0E-03		1.4E-03	5.7E-03	3.3E-04	1.3E-03
Dichloroethene, 1,2-	1.4E-01	6.2E-01	5.3E-04	3.1E-03	5.3E-04	3.1E-03	2.0E-01		3.2E-03	2.9E-02	7.2E-04	6.6E-03
Methylene chloride	5.5E-03	1.5E-02	2.1E-05	7.5E-05	2.1E-05	7.5E-05	6.0E-02	3.0E+00	6.9E-06	2.5E-05	6.9E-06	2.5E-05
Tetrachloroethane,1,1,2,2-	1.6E-03	6.3E-03	6.0E-06	3.1E-05	6.0E-06	3.1E-05						
Tetrachloroethene	1.7E-02	3.2E-02	6.4E-05	1.6E-04	6.4E-05	1.6E-04	1.0E-01		7.6E-04	3.0E-03	1.7E-04	6.9E-04
Trichloroethane,1,1,1-	2.9E-03	7.5E-03	1.1E-05	3.7E-05	1.1E-05	3.7E-05	9.0E-01	1.0E+01	1.1E-06	3.7E-06	1.1E-06	3.7E-06
Trichloroethane,1,1,2-	2.1E-03	5.9E-03	7.9E-06	2.9E-05	7.9E-06	2.9E-05	4.0E-02	ND	2.4E-04	1.4E-03	5.4E-05	3.2E-04
Trichloroethene	7.9E-01	2.4E+00	3.0E-03	1.2E-02	3.0E-03	1.2E-02						
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.0E-02	ND				
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.0E-03	ND				
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-01	ND				
									8.3E-03	5.0E-02	1.9E-03	1.1E-02

RADIAN CORPORATION

RADIAN CORPORATION

INHALATION OF VAPOR PHASE CHEMICALS WHILE USING A DISHWASHER AND A WASHING MACHINE WITH RESIDENTIAL WATER - CHRONIC RESDENTIAL

10:34:24
06/26/90

Intake(mg/kg-day) = (CA x IR x EF X ED)/(BW x AT) (EPA, 1989a)

	Assumptions
CA = Contaminant Concentration in Air (mg/m3)	Chemical-specific; calculated from concentration in tap water (Base Well 18 and City Well 132)
IR = Inhalation Rate (m3/hour)	
-Children, Average	8.0E-01 (child, age 6, for light activity; EPA, 1989b)
-Children, Upper bound	2.0E+00 (child, age 6, for moderate activity; EPA, 1989b)
-Adult, Average	6.0E-01 (average, adult, for light activity; EPA, 1989b)
-Adult, Upper bound	2.1E+00 (average, adult, for moderate activity; EPA, 1989b)
EF = Exposure Frequency (days/year)	
-Average	3.1E+02 (average cycle time for dishwasher (6); Consumer Report, 1987. Operation of dishwasher and washing machine simultaneously, 1 cycle per day, 6 days per week)
-Upper bound	4.7E+02 (Operation of dishwasher and washing machine simultaneously, 1 cycle per day, 9 days per week)
ED = Exposure Duration (years)	
-Children	5.0E+00 (1 through 6 years old)
-Adult, Average	9.0E+00 (national median time--50th percentile--at one residence; EPA, 1989b)
-Adult, Upper bound (reasonable maximum)	3.0E+01 (national upper bound time--90th percentile; EPA, 1989b)
BW = Body Weight (kg)	
-Children	1.6E+01 (1 through 6 years old; EPA, 1989a)
-Adult	7.0E+01 (adult, average; EPA, 1989b)
AT = Averaging Time (period over which exposure is averaged-days)	
-Noncarcinogenic effects	
-Children	1.8E+03 (ED x 365 days/year)
-Adult, Average	3.3E+03
-Adult, Upper bound	1.1E+04
-Carcinogenic effects	2.6E+04 (70 years x 365 days/year)

(1) EPA, 1989a cites the 90th percentile (0.2); however, text elsewhere recommends use of 95th percentile when it is available.

RADIAN CORPORATION

INHALATION OF VAPOR PHASE CHEMICALS WHILE USING A DISHWASHER AND A WASHING MACHINE WITH RESIDENTIAL WATER - CHRONIC RESDENTIAL

16:23:43
07/12/90

Effective Air Concentration (EAC), (mg/m3) = (CA x IRS x EF X ED)/(IRD X CF X AT)

	Assumptions
CA = Contaminant Concentration in Air (mg/m3)	Chemical-specific; calculated from concentration in tap water (Base Well 18 and City Well 2)
IRS = Inhalation Rate (m3/hour)	
-Children, Average	8.0E-01 (child, age 6, for light activity; EPA, 1989b)
-Children, Upper bound	2.0E+00 (child, age 6, for moderate activity; EPA, 1989b)
-Adult, Average	6.0E-01 (average, adult, for light activity; EPA, 1989b)
-Adult, Upper bound	2.1E+00 (average, adult, for moderate activity; EPA, 1989b)
EF = Exposure Frequency (days/year)	
-Average	3.1E+02 (average cycles per week for washing machine (6); Consumer Report, 1987. Operation of dishwasher and washing machine simultaneously, 1 cycle per day, 6 days per week)
-Upper bound	4.7E+02 (operation of dishwasher and washing machine simultaneously, 1 cycle per day, 9 days per week)
ED = Exposure Duration (years)	
-Children	5.0E+00 (1 through 6 years old)
-Adult, Average	9.0E+00 (national median time--50th percentile--at one residence; EPA, 1989b)
-Adult, Upper bound (reasonable maximum)	3.0E+01 (national upper bound time--90th percentile; EPA, 1989b)
IRD = Inhalation Rate per Day (m3/hour)	
-Average	8.0E-01 (EPA, 1989a)
-Upper Bound	1.3E+00 (EPA, 1989a)
CF = Conversion Factor (hour/day)	2.4E+01
AT = Averaging Time (period over which exposure is averaged-days)	
-Noncarcinogenic effects	
-Children	1.8E+03 (ED x 365 days/year)
-Adult, Average	3.3E+03
-Adult, Upper bound	1.1E+04
-Carcinogenic effects	2.6E+04 (70 years x 365 days/year)

(1) EPA, 1989a cites the 90th percentile (0.2); however, text elsewhere recommends use of 95th percentile when it is available.

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using a Washing Machine with Residential Water - Chronic - Residential - Base Wel

10:35:15
06/26/90

Estimated Intake Dose (mg/kg-day)

Chemical	CA(mg/m3) Average 35 min	CA(mg/m3) Average 90 min	CA(mg/m3) Upper Bound 35 min	CA(mg/m3) Upper Bound 90 min	Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	1.0E-04	5.2E-05	1.0E-04	5.2E-05	5.9E-06	2.2E-05	1.0E-06	5.3E-06	1.3E-07	2.3E-06
Chloroform	1.8E-04	9.2E-05	1.8E-04	9.2E-05	1.0E-05	3.9E-05	1.8E-06	9.4E-06	2.3E-07	4.0E-06
Dichloroethane, 1,2-	1.1E-04	5.8E-05	1.1E-04	5.8E-05	5E-06	2.4E-05	1.1E-06	5.9E-06	1.4E-07	2.5E-06
Dichloroethene, 1,1-	1.6E-04	8.1E-05	1.6E-04	8.1E-05	9.2E-06	3.4E-05	1.6E-06	8.2E-06	2.0E-07	3.5E-06
Dichloroethene, 1,2-	5.7E-04	2.9E-04	5.7E-04	2.9E-04	3.3E-05	1.2E-04	5.6E-06	2.9E-05	7.2E-07	1.3E-05
Methylene chloride	3.1E-04	1.6E-04	4.3E-04	2.2E-04	1.8E-05	9.3E-05	3.0E-06	2.2E-05	3.9E-07	9.6E-06
Tetrachloroethane,1,1,2,2-	9.1E-05	4.6E-05	1.8E-04	9.2E-05	5.2E-06	3.9E-05	9.0E-07	9.4E-06	1.2E-07	4.0E-06
Tetrachloroethene	5.7E-04	2.9E-04	5.7E-04	2.9E-04	3.3E-05	1.2E-04	5.6E-06	2.9E-05	7.2E-07	1.3E-05
Trichloroethane,1,1,1-	1.6E-04	8.1E-05	2.2E-04	1.1E-04	9.2E-06	4.7E-05	1.6E-06	1.1E-05	2.0E-07	4.8E-06
Trichloroethane,1,1,2-	1.1E-04	5.8E-05	1.7E-04	8.7E-05	6.5E-06	3.7E-05	1.1E-06	8.8E-06	1.4E-07	3.8E-06
Trichloroethene	5.7E-04	2.9E-04	5.7E-04	2.9E-04	3.3E-05	1.2E-04	5.6E-06	2.9E-05	7.2E-07	1.3E-05
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Inhalation of Vapor Phase Chemicals While Using a Washing Machine with Residential Water - Chronic - Residential - Base Wel

10:35:15
06/26/90

Effective Air Concentration (mg/m3)

Chemical	CA(mg/m3) Average 35 min	CA(mg/m3) Average 90 min	CA(mg/m3) Upper Bound 35 min	CA(mg/m3) Upper Bound 90 min	Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	1.0E-04	5.2E-05	1.0E-04	5.2E-05	4.9E-06	1.2E-05	3.7E-06	1.2E-05	4.7E-07	5.3E-06
Chloroform	1.8E-04	9.2E-05	1.8E-04	9.2E-05	8.7E-06	2.1E-05	6.5E-06	2.2E-05	8.4E-07	9.4E-06
Dichloroethane, 1,2-	1.1E-04	5.8E-05	1.1E-04	5.8E-05	5.4E-06	1.3E-05	4.1E-06	1.4E-05	5.2E-07	5.9E-06
Dichloroethene, 1,1-	1.6E-04	8.1E-05	1.6E-04	8.1E-05	7.6E-06	1.8E-05	5.7E-06	1.9E-05	7.4E-07	8.2E-06
Dichloroethene, 1,2-	5.7E-04	2.9E-04	5.7E-04	2.9E-04	2.7E-05	6.5E-05	2.0E-05	6.9E-05	2.6E-06	2.9E-05
Methylene chloride	3.1E-04	1.6E-04	4.3E-04	2.2E-04	1.5E-05	5.0E-05	1.1E-05	5.2E-05	1.4E-06	2.2E-05
Tetrachloroethane, 1,1,2,2-	9.1E-05	4.6E-05	1.8E-04	9.2E-05	4.4E-06	2.1E-05	3.3E-06	2.2E-05	4.2E-07	9.4E-06
Tetrachloroethene	5.7E-04	2.9E-04	5.7E-04	2.9E-04	2.7E-05	6.5E-05	2.0E-05	6.9E-05	2.6E-06	2.9E-05
Trichloroethane, 1,1,1-	1.6E-04	8.1E-05	2.2E-04	1.1E-04	7.6E-06	2.5E-05	5.7E-06	2.6E-05	7.4E-07	1.1E-05
Trichloroethane, 1,1,2-	1.1E-04	5.8E-05	1.7E-04	8.7E-05	5.4E-06	2.0E-05	4.1E-06	2.1E-05	5.2E-07	8.8E-06
Trichloroethene	5.7E-04	2.9E-04	5.7E-04	2.9E-04	2.7E-05	6.5E-05	2.0E-05	6.9E-05	2.6E-06	2.9E-05
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using a Washing Machine with Residential Water - Chronic - Residential -

14:21:09
07/06/90

Base Well 18

Chemical	Oral RfD (mg/kg/day)	Inhal. RfD (mg/m3)	Inhal. Unit Risk 1/(ug/m3)	Inhal. SF 1/(mg/kg/day)	Children Noncarcinogenic Average Hazard Index	Children Noncarcinogenic Upper Bound Hazard Index	Adult Noncarcinogenic Average Hazard Index	Adult Noncarcinogenic Upper Bound Hazard Index	Carcinogenic Average Total Pathway Risk	Carcinogenic Upper Bound Total Pathway Risk
Carbon tetrachloride	7.0E-04			1.3E-01	8.4E-03	3.2E-02	1.4E-03	7.6E-03	1.7E-08	3.0E-07
Chloroform	1.0E-02			8.1E-02	1.0E-03	3.9E-03	1.8E-04	9.4E-04	1.9E-08	3.3E-07
Dichloroethane, 1,2-				9.1E-02					1.3E-08	2.3E-07
Dichloroethene, 1,1-	9.0E-03		5.0E-05		1.0E-03	3.8E-03	1.7E-04	9.2E-04	3.7E-08	4.1E-07
Dichloroethene, 1,2-	2.0E-02				1.6E-03	6.1E-03	2.8E-04	1.5E-03		
Methylene chloride	6.0E-02	3.0E+00	4.1E-06		4.9E-06	1.7E-05	3.7E-06	1.7E-05	5.8E-09	9.2E-08
Tetrachloroethane, 1,1,2,2-				2.0E-01					2.3E-08	8.1E-07
Tetrachloroethene	1.0E-02		9.5E-07		3.3E-03	1.2E-02	5.6E-04	2.9E-03	2.5E-09	2.8E-08
Trichloroethane, 1,1,1-	9.0E-02	1.0E+00			7.6E-06	2.5E-05	5.7E-06	2.6E-05		
Trichloroethane, 1,1,2-	4.0E-03	ND		5.7E-02	1.6E-03	9.2E-03	2.8E-04	2.2E-03	8.2E-09	2.2E-07
Trichloroethene			1.7E-06						4.5E-09	5.0E-08
Boron	9.0E-02	ND								
Vanadium	7.0E-03	ND								
Zinc	2.0E-01	ND								
					1.7E-02	6.7E-02	2.9E-03	1.6E-02	1.3E-07	2.5E-06

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using a Washing Machine with Residential Water - Chronic - Residential - City Well

11:30:42
06/26/90

Estimated Intake Dose (mg/kg-day)

Chemical	CA(mg/m3) Average 35 min	CA(mg/m3) Average 90 min	CA(mg/m3) Upper Bound 35 min	CA(mg/m3) Upper Bound 90 min	Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	1.1E-05	5.8E-06	1.1E-05	5.8E-06	6.5E-07	2.4E-06	1.1E-07	5.9E-07	1.4E-08	2.5E-07
Chloroform	1.0E-04	5.2E-05	1.0E-04	5.2E-05	5.9E-06	2.2E-05	1.0E-06	5.3E-06	1.3E-07	2.3E-06
Dichloroethane, 1,2-	5.7E-05	2.9E-05	5.7E-05	2.9E-05	3.3E-06	1.2E-05	5.6E-07	2.9E-06	7.2E-08	1.3E-06
Dichloroethene, 1,1-	8.0E-05	4.0E-05	8.0E-05	4.0E-05	4.6E-06	1.7E-05	7.8E-07	4.1E-06	1.0E-07	1.8E-06
Dichloroethene, 1,2-	2.9E-03	1.4E-03	2.9E-03	1.4E-03	1.6E-04	6.1E-04	2.8E-05	1.5E-04	3.6E-06	6.3E-05
Methylene chloride	1.3E-04	6.3E-05	1.3E-04	6.3E-05	7.2E-06	2.7E-05	1.2E-06	6.5E-06	1.6E-07	2.8E-06
Tetrachloroethane,1,1,2,2-	3.4E-06	1.7E-06	3.4E-06	1.7E-06	2.0E-07	7.3E-07	3.4E-08	1.8E-07	4.3E-09	7.6E-08
Tetrachloroethene	3.0E-03	1.5E-03	3.0E-03	1.5E-03	1.7E-04	6.4E-04	2.9E-05	1.5E-04	3.7E-06	6.5E-05
Trichloroethane,1,1,1-	5.7E-05	2.9E-05	5.7E-05	2.9E-05	3.3E-06	1.2E-05	5.6E-07	2.9E-06	7.2E-08	1.3E-06
Trichloroethane,1,1,2-	1.1E-06	5.8E-07	1.1E-06	5.8E-07	6.5E-08	2.4E-07	1.1E-08	5.9E-08	1.4E-09	2.5E-08
Trichloroethene	2.5E-02	1.3E-02	2.5E-02	1.3E-02	1.4E-03	5.4E-03	2.5E-04	1.3E-03	3.2E-05	5.5E-04
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Inhalation of Vapor Phase Chemicals While Using a Washing Machine with Residential Water - Chronic - Residential - City Well

11:30:42
06/26/90

Effective Air Concentration (mg/m3)

Chemical	CA(mg/m3) Average 35 min	CA(mg/m3) Average 90 min	CA(mg/m3) Upper Bound 35 min	CA(mg/m3) Upper Bound 90 min	Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	1.1E-05	5.8E-06	1.1E-05	5.8E-06	5.4E-07	1.3E-06	4.1E-07	1.4E-06	5.2E-08	5.9E-07
Chloroform	1.0E-04	5.2E-05	1.0E-04	5.2E-05	4.9E-06	1.2E-05	3.7E-06	1.2E-05	4.7E-07	5.3E-06
Dichloroethane, 1,2-	5.7E-05	2.9E-05	5.7E-05	2.9E-05	2.7E-06	6.5E-06	2.0E-06	6.9E-06	2.6E-07	2.9E-06
Dichloroethene, 1,1-	8.0E-05	4.0E-05	8.0E-05	4.0E-05	3.8E-06	9.1E-06	2.9E-06	9.6E-06	3.7E-07	4.1E-06
Dichloroethene, 1,2-	2.9E-03	1.4E-03	2.9E-03	1.4E-03	1.4E-04	3.3E-04	1.0E-04	3.4E-04	1.3E-05	1.5E-04
Methylene chloride	1.3E-04	6.3E-05	1.3E-04	6.3E-05	6.0E-06	1.4E-05	4.5E-06	1.5E-05	5.8E-07	6.5E-06
Tetrachloroethane, 1,1,2,2-	3.4E-06	1.7E-06	3.4E-06	1.7E-06	1.6E-07	3.9E-07	1.2E-07	4.1E-07	1.6E-08	1.8E-07
Tetrachloroethene	3.0E-03	1.5E-03	3.0E-03	1.5E-03	1.4E-04	3.4E-04	1.1E-04	3.6E-04	1.4E-05	1.5E-04
Trichloroethane, 1,1,1-	5.7E-05	2.9E-05	5.7E-05	2.9E-05	2.7E-06	6.5E-06	2.0E-06	6.9E-06	2.6E-07	2.9E-06
Trichloroethane, 1,1,2-	1.1E-06	5.8E-07	1.1E-06	5.8E-07	5.4E-08	1.3E-07	4.1E-08	1.4E-07	5.2E-09	5.9E-08
Trichloroethene	2.5E-02	1.3E-02	2.5E-02	1.3E-02	1.2E-03	2.9E-03	9.0E-04	3.0E-03	1.2E-04	1.3E-03
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using a Washing Machine with Residential Water - Chronic - Residential - Risk Cha

14:11:11
07/06/90

City Well 132

Chemical	Oral RfD (mg/kg/d	Inhal. RfD (mg/m3)	Inhal. Unit Ris	Inhal. SF 1/(ug/m31/(mg/kg/day)	Children Noncarcinogenic Average Hazard Index	Children Noncarcinogenic Upper Bound Hazard Index	Adult Noncarcinogenic Average Hazard Index	Adult Noncarcinogenic Upper Bound Hazard Index	Adult Carcinogenic Average Total Pathway Risk	Adult Carcinogenic Upper Bound Total Pathway Risk
Carbon tetrachloride	7.0E-04			1.3E-01	9.3E-04	3.5E-03	1.6E-04	8.4E-04	1.9E-09	3.3E-08
Chloroform	1.0E-02			8.1E-02	5.9E-04	2.2E-03	1.0E-04	5.3E-04	1.1E-08	1.8E-07
Dichloroethane, 1,2-				9.1E-02					6.6E-09	1.1E-07
Dichloroethene, 1,1-	9.0E-03		5.0E-05		5.1E-04	1.9E-03	8.7E-05	4.6E-04	1.8E-08	2.1E-07
Dichloroethene, 1,2-	2.0E-02				8.2E-03	3.1E-02	1.4E-03	7.3E-03		
Methylene chloride	6.0E-02	3.0E+00	4.1E-06		2.0E-06	4.8E-06	1.5E-06	5.0E-06	2.4E-09	2.7E-08
Tetrachloroethane, 1,1,2,2-				2.0E-01					8.6E-10	1.5E-08
Tetrachloroethene	1.0E-02		9.5E-07		1.7E-02	6.4E-02	2.9E-03	1.5E-02	1.3E-08	1.5E-07
Trichloroethane, 1,1,1-	9.0E-02	1.0E+00			2.7E-06	6.5E-06	2.0E-06	6.9E-06		
Trichloroethane, 1,1,2-	4.0E-03	ND		5.7E-02	1.6E-05	6.1E-05	2.8E-06	1.5E-05	8.2E-11	1.4E-09
Trichloroethene			1.7E-06						2.0E-07	2.2E-06
Boron	9.0E-02	ND								
Vanadium	7.0E-03	ND								
Zinc	2.0E-01	ND								
					2.7E-02	1.0E-01	4.7E-03	2.4E-02	2.5E-07	2.9E-06

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using a Dishwasher with Residential Water - Chronic - Residential - City Well 132

11:13:23
06/26/90

Estimated Intake Dose (mg/kg-day)

Chemical	CA(mg/m3) Average 72 min	CA(mg/m3) Average 48 min	CA(mg/m3) Upper Bound 72 min	CA(mg/m3) Upper Bound 48 min	Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	2.2E-06	1.4E-06	2.2E-06	1.4E-06	1.6E-07	6.0E-07	2.8E-08	1.4E-07	3.5E-09	6.2E-08
Chloroform	2.0E-05	1.3E-05	2.0E-05	1.3E-05	1.4E-06	5.4E-06	2.5E-07	1.3E-06	3.2E-08	5.6E-07
Dichloroethane, 1,2-	1.1E-05	7.1E-06	1.1E-05	7.1E-06	8.0E-07	3.0E-06	1.4E-07	7.2E-07	1.8E-08	3.1E-07
Dichloroethene, 1,1-	1.5E-05	9.9E-06	1.5E-05	9.9E-06	1.1E-06	4.2E-06	1.9E-07	1.0E-06	2.5E-08	4.3E-07
Dichloroethene, 1,2-	5.5E-04	3.5E-04	5.5E-04	3.5E-04	4.0E-05	1.5E-04	6.9E-06	3.6E-05	8.8E-07	1.5E-05
Methylene chloride	2.4E-05	1.6E-05	2.4E-05	1.6E-05	1.8E-06	6.6E-06	3.0E-07	1.6E-06	3.9E-08	6.8E-07
Tetrachloroethane,1,1,2,2-	6.6E-07	4.2E-07	6.6E-07	4.2E-07	4.8E-08	1.8E-07	8.3E-09	4.3E-08	1.1E-09	1.9E-08
Tetrachloroethene	5.7E-04	3.7E-04	5.7E-04	3.7E-04	4.2E-05	1.6E-04	7.2E-06	3.8E-05	9.2E-07	1.6E-05
Trichloroethane,1,1,1-	1.1E-05	7.1E-06	1.1E-05	7.1E-06	8.0E-07	3.0E-06	1.4E-07	7.2E-07	1.8E-08	3.1E-07
Trichloroethane,1,1,2-	2.2E-07	1.4E-07	2.2E-07	1.4E-07	1.6E-08	6.0E-08	2.8E-09	1.4E-08	3.5E-10	6.2E-09
Trichloroethene	4.8E-03	3.1E-03	4.8E-03	3.1E-03	3.5E-04	1.3E-03	6.1E-05	3.2E-04	7.8E-06	1.4E-04
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Inhalation of Vapor Phase Chemicals While Using a Dishwasher with Residential Water - Chronic - Residential - City Well 132

11:13:23
06/26/90

Effective Air Concentration (mg/m3)

Chemical	CA(mg/m3) Average 72 min	CA(mg/m3) Average 48 min	CA(mg/m3) Upper Bound 72 min	CA(mg/m3) Upper Bound 48 min	Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	2.2E-06	1.4E-06	2.2E-06	1.4E-06	1.3E-07	3.2E-07	1.0E-07	3.4E-07	1.3E-08	1.4E-07
Chloroform	2.0E-05	1.3E-05	2.0E-05	1.3E-05	1.2E-06	2.9E-06	9.0E-07	3.0E-06	1.2E-07	1.3E-06
Dichloroethane, 1,2-	1.1E-05	7.1E-06	1.1E-05	7.1E-06	6.7E-07	1.6E-06	5.0E-07	1.7E-06	6.4E-08	7.2E-07
Dichloroethene, 1,1-	1.5E-05	9.9E-06	1.5E-05	9.9E-06	9.4E-07	2.2E-06	7.0E-07	2.4E-06	9.0E-08	1.0E-06
Dichloroethene, 1,2-	5.5E-04	3.5E-04	5.5E-04	3.5E-04	3.3E-05	8.0E-05	2.5E-05	8.4E-05	3.2E-06	3.6E-05
Methylene chloride	2.4E-05	1.6E-05	2.4E-05	1.6E-05	1.5E-06	3.5E-06	1.1E-06	3.7E-06	1.4E-07	1.6E-06
Tetrachloroethane, 1,1,2,2-	6.6E-07	4.2E-07	6.6E-07	4.2E-07	4.0E-08	9.6E-08	3.0E-08	1.0E-07	3.9E-09	4.3E-08
Tetrachloroethene	5.7E-04	3.7E-04	5.7E-04	3.7E-04	3.5E-05	8.4E-05	2.6E-05	8.8E-05	3.4E-06	3.8E-05
Trichloroethane, 1,1,1-	1.1E-05	7.1E-06	1.1E-05	7.1E-06	6.7E-07	1.6E-06	5.0E-07	1.7E-06	6.4E-08	7.2E-07
Trichloroethane, 1,1,2-	2.2E-07	1.4E-07	2.2E-07	1.4E-07	1.3E-08	3.2E-08	1.0E-08	3.4E-08	1.3E-09	1.4E-08
Trichloroethene	4.8E-03	3.1E-03	4.8E-03	3.1E-03	2.9E-04	7.1E-04	2.2E-04	7.4E-04	2.8E-05	3.2E-04
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using a Dishwasher with Residential Water - Chronic - Residential
Risk Characterization

14:53:16
07/06/90

City Well 132

Chemical	Oral RfD (mg/kg/day)	Inhal. RfD (mg/m3)	Inhal. Unit Risk 1/(ug/m3)	Inhal. SF 1/(mg/kg/day)	Children Noncarcinogenic Average Hazard Index	Children Noncarcinogenic Upper Bound Hazard Index	Adult Noncarcinogenic Average Hazard Index	Adult Noncarcinogenic Upper Bound Hazard Index	Adult Carcinogenic Average Total Pathway Risk	Adult Carcinogenic Upper Bound Total Pathway Risk
Carbon tetrachloride	7.0E-04			1.3E-01	2.3E-04	8.6E-04	3.9E-05	2.1E-04	4.6E-10	8.0E-09
Chloroform	1.0E-02			8.1E-02	1.4E-04	5.4E-04	2.5E-05	1.3E-04	2.6E-09	4.5E-08
Dichloroethane, 1,2-				9.1E-02					1.6E-09	2.8E-08
Dichloroethene, 1,1-	9.0E-03		5.0E-05		1.2E-04	4.7E-04	2.1E-05	1.1E-04	4.5E-09	5.1E-08
Dichloroethene, 1,2-	2.0E-02				2.0E-03	7.5E-03	3.4E-04	1.8E-03		
Methylene chloride	6.0E-02	3.0E+00	4.1E-06		4.9E-07	1.2E-06	3.7E-07	1.2E-06	5.8E-10	6.5E-09
Tetrachloroethane, 1,1,2,2-				2.0E-01					2.1E-10	3.7E-09
Tetrachloroethene	1.0E-02		9.5E-07		4.2E-03	1.6E-02	7.2E-04	3.8E-03	3.2E-09	3.6E-08
Trichloroethane, 1,1,1-	9.0E-02	1.0E+00			6.7E-07	1.6E-06	5.0E-07	1.7E-06		
Trichloroethane, 1,1,2-	4.0E-03	ND		5.7E-02	4.0E-06	1.5E-05	6.9E-07	3.6E-06	2.0E-11	3.5E-10
Trichloroethene			1.7E-06						4.8E-08	5.4E-07
Boron	9.0E-02	ND								
Vanadium	7.0E-03	ND								
Zinc	2.0E-01	ND								
					6.7E-03	2.5E-02	1.1E-03	6.0E-03	6.1E-08	7.2E-07

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using a Dishwasher with Residential Water - Chronic - Residential - Base Well 18

10:36:16
06/26/90

Chemical	CA(mg/m3) Average 72 min	CA(mg/m3) Average 48 min	CA(mg/m3) Upper Bound 72 min	CA(mg/m3) Upper Bound 48 min	Estimated Intake Dose (mg/kg-day) Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	2.0E-05	1.3E-05	2.0E-05	1.3E-05	1.4E-06	5.4E-06	2.5E-07	1.3E-06	3.2E-08	5.6E-07
Chloroform	3.5E-05	2.3E-05	3.5E-05	2.3E-05	2.6E-06	9.6E-06	4.4E-07	2.3E-06	5.7E-08	9.9E-07
Dichloroethane, 1,2-	2.2E-05	1.4E-05	2.2E-05	1.4E-05	1.6E-06	6.0E-06	2.8E-07	1.4E-06	3.5E-08	6.2E-07
Dichloroethene, 1,1-	3.1E-05	2.0E-05	3.1E-05	2.0E-05	2.3E-06	8.4E-06	3.9E-07	2.0E-06	5.0E-08	8.7E-07
Dichloroethene, 1,2-	1.1E-04	7.1E-05	1.1E-04	7.1E-05	8.0E-06	3.0E-05	1.4E-06	7.2E-06	1.8E-07	3.1E-06
Methylene chloride	5.9E-05	3.8E-05	8.3E-05	5.4E-05	4.3E-06	2.3E-05	7.4E-07	5.5E-06	9.6E-08	2.4E-06
Tetrachloroethane,1,1,2,2-	1.7E-05	1.1E-05	3.5E-05	2.3E-05	1.3E-06	9.6E-06	2.2E-07	2.3E-06	2.8E-08	9.9E-07
Tetrachloroethene	1.1E-04	7.1E-05	1.1E-04	7.1E-05	8.0E-06	3.0E-05	1.4E-06	7.2E-06	1.8E-07	3.1E-06
Trichloroethane,1,1,1-	3.1E-05	2.0E-05	4.2E-05	2.7E-05	2.3E-06	1.1E-05	3.9E-07	2.7E-06	5.0E-08	1.2E-06
Trichloroethane,1,1,2-	2.2E-05	1.4E-05	3.3E-05	2.1E-05	1.6E-06	9.0E-06	2.8E-07	2.2E-06	3.5E-08	9.3E-07
Trichloroethene	1.1E-04	7.1E-05	1.1E-04	7.1E-05	8.0E-06	3.0E-05	1.4E-06	7.2E-06	1.8E-07	3.1E-06
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Inhalation of Vapor Phase Chemicals While Using a Dishwasher with Residential Water - Chronic - Residential - Base Well 18

10:36:16
06/26/90

Chemical	CA(mg/m3) Average 1 min	CA(mg/m3) Average 14 min	CA(mg/m3) Upper Bound 1 min	CA(mg/m3) Upper Bound 14 min	Effective Air Concentration (mg/m3) Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	2.0E-05	1.3E-05	2.0E-05	1.3E-05	1.2E-06	2.9E-06	9.0E-07	3.0E-06	1.2E-07	1.3E-06
Chloroform	3.5E-05	2.3E-05	3.5E-05	2.3E-05	2.1E-06	5.1E-06	1.6E-06	5.4E-06	2.1E-07	2.3E-06
Dichloroethane, 1,2-	2.2E-05	1.4E-05	2.2E-05	1.4E-05	1.3E-06	3.2E-06	1.0E-06	3.4E-06	1.3E-07	1.4E-06
Dichloroethene, 1,1-	3.1E-05	2.0E-05	3.1E-05	2.0E-05	1.9E-06	4.5E-06	1.4E-06	4.7E-06	1.8E-07	2.0E-06
Dichloroethene, 1,2-	1.1E-04	7.1E-05	1.1E-04	7.1E-05	6.7E-06	1.6E-05	5.0E-06	1.7E-05	6.4E-07	7.2E-06
Methylene chloride	5.9E-05	3.8E-05	8.3E-05	5.4E-05	3.6E-06	1.2E-05	2.7E-06	1.3E-05	3.5E-07	5.5E-06
Tetrachloroethane, 1,1,2,2-	1.7E-05	1.1E-05	3.5E-05	2.3E-05	1.1E-06	5.1E-06	8.0E-07	5.4E-06	1.0E-07	2.3E-06
Tetrachloroethene	1.1E-04	7.1E-05	1.1E-04	7.1E-05	6.7E-06	1.6E-05	5.0E-06	1.7E-05	6.4E-07	7.2E-06
Trichloroethane, 1,1,1-	3.1E-05	2.0E-05	4.2E-05	2.7E-05	1.9E-06	6.1E-06	1.4E-06	6.4E-06	1.8E-07	2.7E-06
Trichloroethane, 1,1,2-	2.2E-05	1.4E-05	3.3E-05	2.1E-05	1.3E-06	4.8E-06	1.0E-06	5.1E-06	1.3E-07	2.2E-06
Trichloroethene	1.1E-04	7.1E-05	1.1E-04	7.1E-05	6.7E-06	1.6E-05	5.0E-06	1.7E-05	6.4E-07	7.2E-06
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using a Dishwasher with Residential Water - Chronic - Residential
Risk Characterization

14:41:43
07/06/90

Base Well 18

Chemical	Oral RfD (mg/kg/day)	Inhal. RfD (mg/m3)	Inhal. Unit Risk 1/(ug/m3)	Inhal. SF 1/(mg/kg/day)	Children Noncarcinogenic Average Hazard Index	Children Noncarcinogenic Upper Bound Hazard Index	Adult Noncarcinogenic Average Hazard Index	Adult Noncarcinogenic Upper Bound Hazard Index	Adult Carcinogenic Average Total Pathway Risk	Adult Carcinogenic Upper Bound Total Pathway Risk
Carbon tetrachloride	7.0E-04			1.3E-01	2.1E-03	7.7E-03	3.5E-04	1.9E-03	4.1E-09	7.2E-08
Chloroform	1.0E-02			8.1E-02	2.6E-04	9.6E-04	4.4E-05	2.3E-04	4.6E-09	8.0E-08
Dichloroethane, 1,2-				9.1E-02					3.2E-09	5.6E-08
Dichloroethene, 1,1-	9.0E-03		5.0E-05		2.5E-04	9.4E-04	4.3E-05	2.3E-04	9.0E-09	1.0E-07
Dichloroethene, 1,2-	2.0E-02				4.0E-04	1.5E-03	6.9E-05	3.6E-04		
Methylene chloride	6.0E-02	3.0E+00	4.1E-06		1.2E-06	4.1E-06	9.0E-07	4.3E-06	1.4E-09	2.3E-08
Tetrachloroethane, 1,1,2,2-				2.0E-01					5.7E-09	2.0E-07
Tetrachloroethene	1.0E-02		9.5E-07		8.0E-04	3.0E-03	1.4E-04	7.2E-04	6.1E-10	6.8E-09
Trichloroethane, 1,1,1-	9.0E-02	1.0E+00			1.9E-06	6.1E-06	1.4E-06	6.4E-06		
Trichloroethane, 1,1,2-	4.0E-03	ND		5.7E-02	4.0E-04	2.3E-03	6.9E-05	5.4E-04	2.0E-09	5.3E-08
Trichloroethene			1.7E-06						1.1E-09	1.2E-08
Boron	9.0E-02	ND								
Vanadium	7.0E-03	ND								
Zinc	2.0E-01	ND								
					4.2E-03	1.6E-02	7.2E-04	3.9E-03	3.2E-08	6.0E-07

RADIAN CORPORATION

INHALATION OF VAPOR PHASE CHEMICALS WHILE USING A DISHWASHER AND A WASHING MACHINE WITH RESIDENTIAL WATER - CHRONIC 3 YEAR TOUR OF DUTY - RESIDENTIAL

12:30:16
06/26/90

Intake(mg/kg-day) = (CA x IR x EF X ED)/(BW x AT) (EPA, 1989a)

	Assumptions
CA = Contaminant Concentration in Air (mg/m3)	Chemical-specific; calculated from concentration in tap water (Base Well 18 and City Well 132)
IR = Inhalation Rate (m3/hour)	
-Children, Average	8.0E-01 (child, age 6, for light activity; EPA, 1989b)
-Children, Upper bound	2.0E+00 (child, age 6, for moderate activity; EPA, 1989b)
-Adult, Average	6.0E-01 (average, adult, for light activity; EPA, 1989b)
-Adult, Upper bound	2.1E+00 (average, adult, for moderate activity; EPA, 1989b)
EF = Exposure Frequency (days/year)	
-Average	3.1E+02 (average cycles per week for washing machine (6); Consumer Report, 1987 Operation of dishwasher and washing machine simultaneously, 1 cycle per day, 6 days per week)
-Upper bound	4.7E+02 (operation of dishwasher and washing machine simultaneously, 1 cycle per day, 9 days per week)
ED = Exposure Duration (years)	3.0E+00 (tour of duty)
BW = Body Weight (kg)	
-Children	1.6E+01 (1 through 6 years old; EPA, 1989a)
-Adult	7.0E+01 (adult, average; EPA, 1989b)
AT = Averaging Time (period over which exposure is averaged-days)	
-Noncarcinogenic effects	1.1E+03 (ED x 365 days/year)
-Carcinogenic effects	2.6E+04 (70 years x 365 days/year)

(1) EPA, 1989a cites the 90th percentile (0.2); however, text elsewhere recommends use of 95th percentile when it is available.

RADIAN CORPORATION

INHALATION OF VAPOR PHASE CHEMICALS WHILE USING A DISHWASHER AND WASHING MACHINE WITH RESIDENTIAL WATER - CHRONIC 3 YEAR TOUR OF DUTY - RESIDENTIAL

12:31:57
06/26/90

Effective Air Concentration (EAC), (mg/m3) = (CA X IRS X EF X ED)/(IRD X CF X AT)

	Assumptions
CA = Contaminant Concentration in Air (mg/m3)	Chemical-specific; calculated from concentration in tap water (Base Well 18 and City Well 132)
IR = Inhalation Rate (m3/hour)	
-Children, Average	8.0E-01 (child, age 6, for light activity; EPA, 1989b)
-Children, Upper bound	2.0E+00 (child, age 6, for moderate activity; EPA, 1989b)
-Adult, Average	6.0E-01 (average, adult, for light activity; EPA, 1989b)
-Adult, Upper bound	2.1E+00 (average, adult, for moderate activity; EPA, 1989b)
EF = Exposure Frequency (days/year)	
-Average	3.1E+02 (average cycles per week for washing machine (6); Consumer Report, 1987 Operation of dishwasher and washing machine simultaneously, 1 cycle per day, 6 days per week)
-Upper bound	4.7E+02 (operation of dishwasher and washing machine simultaneously, 1 cycle per day, 9 days per week)
ED = Exposure Duration (years)	3.0E+00 (tour of duty)
IRD = Inhalation Rate per Day (m3/hour)	
-Average	8.0E-01 (EPA, 1989a)
-Upper Bound	1.2E+00 (EPA, 1989a)
CF = Conversion Factor (hour/day)	2.4E+01
AT = Averaging Time (period over which exposure is averaged-days)	
-Noncarcinogenic effects	1.1E+03 (ED x 365 days/year)
-Carcinogenic effects	2.6E+04 (70 years x 365 days/year)

(1) EPA, 1989a cites the 90th percentile (0.2); however, text elsewhere recommends use of 95th percentile when it is available.

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using a Dishwasher with Residential Water - Chronic - 3 Year Tour of Duty

12:37:06
06/26/90

Base Well 18

Estimated Intake Dose (mg/kg-day)

Chemical	CA(mg/m3) Average 72 min	CA(mg/m3) Average 48 min	CA(mg/m3) Upper Bound 72 min	CA(mg/m3) Upper Bound 48 min	Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	2.0E-05	1.3E-05	2.0E-05	1.3E-05	1.4E-06	5.4E-06	2.5E-07	1.3E-06	1.1E-08	5.6E-08
Chloroform	3.5E-05	2.3E-05	3.5E-05	2.3E-05	2.6E-06	9.6E-06	4.4E-07	2.3E-06	1.9E-08	9.9E-08
Dichloroethane, 1,2-	2.2E-05	1.4E-05	2.2E-05	1.4E-05	1.6E-06	6.0E-06	2.8E-07	1.4E-06	1.2E-08	6.2E-08
Dichloroethene, 1,1-	3.1E-05	2.0E-05	3.1E-05	2.0E-05	2.3E-06	8.4E-06	3.9E-07	2.0E-06	1.7E-08	8.7E-08
Dichloroethene, 1,2-	1.1E-04	7.1E-05	1.1E-04	7.1E-05	8.0E-06	3.0E-05	1.4E-06	7.2E-06	5.9E-08	3.1E-07
Methylene chloride	5.9E-05	3.8E-05	8.3E-05	5.4E-05	4.3E-06	2.3E-05	7.4E-07	5.5E-06	3.2E-08	2.4E-07
Tetrachloroethane,1,1,2,2-	1.7E-05	1.1E-05	3.5E-05	2.3E-05	1.3E-06	9.6E-06	2.2E-07	2.3E-06	9.4E-09	9.9E-08
Tetrachloroethene	1.1E-04	7.1E-05	1.1E-04	7.1E-05	8.0E-06	3.0E-05	1.4E-06	7.2E-06	5.9E-08	3.1E-07
Trichloroethane,1,1,1-	3.1E-05	2.0E-05	4.2E-05	2.7E-05	2.3E-06	1.1E-05	3.9E-07	2.7E-06	1.7E-08	1.2E-07
Trichloroethane,1,1,2-	2.2E-05	1.4E-05	3.3E-05	2.1E-05	1.6E-06	9.0E-06	2.8E-07	2.2E-06	1.2E-08	9.3E-08
Trichloroethene	1.1E-04	7.1E-05	1.1E-04	7.1E-05	8.0E-06	3.0E-05	1.4E-06	7.2E-06	5.9E-08	3.1E-07
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Inhalation of Vapor Phase Chemicals While Using a Dishwasher with Residential Water - Chronic - 3 Year Tour of Duty

12:37:06
06/26/90

Base Well 18

Effective Air Concentration (mg/m3)

Chemical	CA(mg/m3) Average 72 min	CA(mg/m3) Average 48 min	CA(mg/m3) Upper Bound 72 min	CA(mg/m3) Upper Bound 48 min	Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	2.0E-05	1.3E-05	2.0E-05	1.3E-05	1.2E-06	2.9E-06	9.0E-07	3.0E-06	3.9E-08	1.3E-07
Chloroform	3.5E-05	2.3E-05	3.5E-05	2.3E-05	2.1E-06	5.1E-06	1.6E-06	5.4E-06	6.9E-08	2.3E-07
Dichloroethane, 1,2-	2.2E-05	1.4E-05	2.2E-05	1.4E-05	1.3E-06	3.2E-06	1.0E-06	3.4E-06	4.3E-08	1.4E-07
Dichloroethene, 1,1-	3.1E-05	2.0E-05	3.1E-05	2.0E-05	1.9E-06	4.5E-06	1.4E-06	4.7E-06	6.0E-08	2.0E-07
Dichloroethene, 1,2-	1.1E-04	7.1E-05	1.1E-04	7.1E-05	6.7E-06	1.6E-05	5.0E-06	1.7E-05	2.1E-07	7.2E-07
Methylene chloride	5.9E-05	3.8E-05	8.3E-05	5.4E-05	3.6E-06	1.2E-05	2.7E-06	1.3E-05	1.2E-07	5.5E-07
Tetrachloroethane, 1,1,2,2-	1.7E-05	1.1E-05	3.5E-05	2.3E-05	1.1E-06	5.1E-06	8.0E-07	5.4E-06	3.4E-08	2.3E-07
Tetrachloroethene	1.1E-04	7.1E-05	1.1E-04	7.1E-05	6.7E-06	1.6E-05	5.0E-06	1.7E-05	2.1E-07	7.2E-07
Trichloroethane, 1,1,1-	3.1E-05	2.0E-05	4.2E-05	2.7E-05	1.9E-06	6.1E-06	1.4E-06	6.4E-06	6.0E-08	2.7E-07
Trichloroethane, 1,1,2-	2.2E-05	1.4E-05	3.3E-05	2.1E-05	1.3E-06	4.8E-06	1.0E-06	5.1E-06	4.3E-08	2.2E-07
Trichloroethene	1.1E-04	7.1E-05	1.1E-04	7.1E-05	6.7E-06	1.6E-05	5.0E-06	1.7E-05	2.1E-07	7.2E-07
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using the Dishwasher with Residential Water - Chronic - 3 Year Tour of Duty
Risk Characterization

15:05:51
07/06/90

					Base Well 18					
					Children		Adult			
					Noncarcinogenic		Noncarcinogenic		Carcinogenic	
Chemical	Oral RfDs (mg/kg/day)	Inhalation RFDs (mg/m3)	Inhalation Unit Risk 1/(ug/m3)	Inhalation SF 1/(mg/kg/day)	Average Hazard Index	Upper Bound Hazard Index	Average Hazard Index	Upper Bound Hazard Index	Average Total Pathway Risk	Upper Bound Total Pathway Risk
Carbon tetrachloride	7.0E-03			1.3E-01	2.1E-04	7.7E-04	3.5E-05	1.9E-04	1.4E-09	7.2E-09
Chloroform	1.0E-02			8.1E-02	2.6E-04	9.6E-04	4.4E-05	2.3E-04	1.5E-09	8.0E-09
Dichloroethane, 1,2-				9.1E-02					1.1E-09	5.6E-09
Dichloroethene, 1,1-	9.0E-03		5.0E-05		2.5E-04	9.4E-04	4.3E-05	2.3E-04	3.0E-09	1.0E-08
Dichloroethene, 1,2-	2.0E-01				4.0E-05	1.5E-04	6.9E-06	3.6E-05		
Methylene chloride	6.0E-02	3.0E+00	4.1E-06		1.2E-06	4.1E-06	9.0E-07	4.3E-06	4.8E-10	2.3E-09
Tetrachloroethane, 1,1,2,2-				2.0E-01					1.9E-09	2.0E-08
Tetrachloroethene	1.0E-01		9.5E-07		8.0E-05	3.0E-04	1.4E-05	7.2E-05	2.0E-10	6.8E-10
Trichloroethane, 1,1,1-	9.0E-01	1.0E+01			1.9E-07	6.1E-07	1.4E-07	6.4E-07		
Trichloroethane, 1,1,2-	4.0E-02	ND		5.7E-02	4.0E-05	2.3E-04	6.9E-06	5.4E-05	6.7E-10	5.3E-09
Trichloroethene			1.7E-06						3.6E-10	1.2E-09
Boron	9.0E-02	ND								
Vanadium	7.0E-03	ND								
Zinc	2.0E-01	ND								
					8.7E-04	3.4E-03	1.5E-04	8.1E-04	1.1E-08	6.0E-08

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using a Washing Machine with Residential Water - Chronic - 3 Year Tour of Duty

12:42:33
06/26/90

Base Well 18

Estimated Intake Dose (mg/kg-day)

Chemical	CA(mg/m3) Average 35 min	CA(mg/m3) Average 90 min	CA(mg/m3) Upper Bound 35 min	CA(mg/m3) Upper Bound 90 min	Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	1.0E-04	5.2E-05	1.0E-04	5.2E-05	5.9E-06	2.2E-05	1.0E-06	5.3E-06	4.3E-08	2.3E-07
Chloroform	1.8E-04	9.2E-05	1.8E-04	9.2E-05	1.0E-05	3.9E-05	1.8E-06	9.4E-06	7.7E-08	4.0E-07
Dichloroethane, 1,2-	1.1E-04	5.8E-05	1.1E-04	5.8E-05	6.5E-06	2.4E-05	1.1E-06	5.9E-06	4.8E-08	2.5E-07
Dichloroethene, 1,1-	1.6E-04	8.1E-05	1.6E-04	8.1E-05	9.2E-06	3.4E-05	1.6E-06	8.2E-06	6.7E-08	3.5E-07
Dichloroethene, 1,2-	5.7E-04	2.9E-04	5.7E-04	2.9E-04	3.3E-05	1.2E-04	5.6E-06	2.9E-05	2.4E-07	1.3E-06
Methylene chloride	3.1E-04	1.6E-04	4.3E-04	2.2E-04	1.8E-05	9.3E-05	3.0E-06	2.2E-05	1.3E-07	9.6E-07
Tetrachloroethane,1,1,2,2-	9.1E-05	4.6E-05	1.8E-04	9.2E-05	5.2E-06	3.9E-05	9.0E-07	9.4E-06	3.8E-08	4.0E-07
Tetrachloroethene	5.7E-04	2.9E-04	5.7E-04	2.9E-04	3.3E-05	1.2E-04	5.6E-06	2.9E-05	2.4E-07	1.3E-06
Trichloroethane,1,1,1-	1.6E-04	8.1E-05	2.2E-04	1.1E-04	9.2E-06	4.7E-05	1.6E-06	1.1E-05	6.7E-08	4.8E-07
Trichloroethane,1,1,2-	1.1E-04	5.8E-05	1.7E-04	8.7E-05	6.5E-06	3.7E-05	1.1E-06	8.8E-06	4.8E-08	3.8E-07
Trichloroethene	5.7E-04	2.9E-04	5.7E-04	2.9E-04	3.3E-05	1.2E-04	5.6E-06	2.9E-05	2.4E-07	1.3E-06
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Inhalation of Vapor Phase Chemicals While Using a Washing Machine with Residential Water - Chronic - 3 Year Tour of Duty

12:42:33
06/26/90

Base Well 18

Effective Air Concentration (mg/m3)

Chemical	CA(mg/m3) Average 35 min	CA(mg/m3) Average 90 min	CA(mg/m3) Upper Bound 35 min	CA(mg/m3) Upper Bound 90 min	Children Noncarcinogenic Average	Children Noncarcinogenic Upper Bound	Adult Noncarcinogenic Average	Adult Noncarcinogenic Upper Bound	Adult Carcinogenic Average	Adult Carcinogenic Upper Bound
Carbon tetrachloride	1.0E-04	5.2E-05	1.0E-04	5.2E-05	4.9E-06	1.2E-05	3.7E-06	1.2E-05	1.6E-07	5.3E-07
Chloroform	1.8E-04	9.2E-05	1.8E-04	9.2E-05	8.7E-06	2.1E-05	6.5E-06	2.2E-05	2.8E-07	9.4E-07
Dichloroethane, 1,2-	1.1E-04	5.8E-05	1.1E-04	5.8E-05	5.4E-06	1.3E-05	4.1E-06	1.4E-05	1.7E-07	5.9E-07
Dichloroethene, 1,1-	1.6E-04	8.1E-05	1.6E-04	8.1E-05	7.6E-06	1.8E-05	5.7E-06	1.9E-05	2.5E-07	8.2E-07
Dichloroethene, 1,2-	5.7E-04	2.9E-04	5.7E-04	2.9E-04	2.7E-05	6.5E-05	2.0E-05	6.9E-05	8.8E-07	2.9E-06
Methylene chloride	3.1E-04	1.6E-04	4.3E-04	2.2E-04	1.5E-05	5.0E-05	1.1E-05	5.2E-05	4.7E-07	2.2E-06
Tetrachloroethane, 1,1,2,2-	9.1E-05	4.6E-05	1.8E-04	9.2E-05	4.4E-06	2.1E-05	3.3E-06	2.2E-05	1.4E-07	9.4E-07
Tetrachloroethene	5.7E-04	2.9E-04	5.7E-04	2.9E-04	2.7E-05	6.5E-05	2.0E-05	6.9E-05	8.8E-07	2.9E-06
Trichloroethane, 1,1,1-	1.6E-04	8.1E-05	2.2E-04	1.1E-04	7.6E-06	2.5E-05	5.7E-06	2.6E-05	2.5E-07	1.1E-06
Trichloroethane, 1,1,2-	1.1E-04	5.8E-05	1.7E-04	8.7E-05	5.4E-06	2.0E-05	4.1E-06	2.1E-05	1.7E-07	8.8E-07
Trichloroethene	5.7E-04	2.9E-04	5.7E-04	2.9E-04	2.7E-05	6.5E-05	2.0E-05	6.9E-05	8.8E-07	2.9E-06
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using the Washing Machine with Residential Water - Chronic - 3 Year Tour of Duty
Risk Characterization

17:09:02
07/06/90

Chemical	Oral RfDs (mg/kg/day)	Inhalation RFDs (mg/m3)	Inhalation Unit Risk 1/(ug/m3)	Inhalation SF 1/(mg/kg/day)	Base Well 18 — Children — Noncarcinogenic Average Hazard Index	Children — Noncarcinogenic Upper Bound Hazard Index	Adult — Noncarcinogenic Average Hazard Index	Adult — Noncarcinogenic Upper Bound Hazard Index	Adult — Carcinogenic Average Total Pathway Risk	Adult — Carcinogenic Upper Bound Total Pathway Risk
Carbon tetrachloride	7.0E-03			1.3E-01	8.4E-04	3.2E-03	1.4E-04	7.6E-04	5.6E-09	3.0E-08
Chloroform	1.0E-02			8.1E-02	1.0E-03	3.9E-03	1.8E-04	9.4E-04	6.2E-09	3.3E-08
Dichloroethane, 1,2-				9.1E-02					4.4E-09	2.3E-08
Dichloroethene, 1,1-	9.0E-03		5.0E-05		1.0E-03	3.8E-03	1.7E-04	9.2E-04	1.2E-08	4.1E-08
Dichloroethene, 1,2-	2.0E-01				1.6E-04	6.1E-04	2.8E-05	1.5E-04		
Methylene chloride	6.0E-02	3.0E+00	4.1E-06		4.9E-06	1.7E-05	3.7E-06	1.7E-05	1.9E-09	9.2E-09
Tetrachloroethane, 1,1,2,2-				2.0E-01					7.7E-09	8.1E-08
Tetrachloroethene	1.0E-01		9.5E-07		3.3E-04	1.2E-03	5.6E-05	2.9E-04	8.3E-10	2.8E-09
Trichloroethane, 1,1,1-	9.0E-01	1.0E+01			7.6E-07	2.5E-06	5.7E-07	2.6E-06		
Trichloroethane, 1,1,2-	4.0E-02	ND		5.7E-02	1.6E-04	9.2E-04	2.8E-05	2.2E-04	2.7E-09	2.2E-08
Trichloroethene			1.7E-06						1.5E-09	5.0E-09
Boron	9.0E-02	ND								
Vanadium	7.0E-03	ND								
Zinc	2.0E-01	ND								
					3.6E-03	1.4E-02	6.1E-04	3.3E-03	4.3E-08	2.5E-07

RADIAN CORPORATION

INHALATION OF VAPOR PHASE CHEMICALS WHILE USING A DISHWASHER AND A WASHING MACHINE WITH RESIDENTIAL WATER - SUBCHRONIC (Applicable to Residential and 3 year tour of duty)

10:44:48
07/13/90

Effective Air Concentration (EAC), (mg/m3) = (CA X IRS X EF X ED)/(IRD X CF X AT)

	Assumptions
CA = Contaminant Concentration in Air (mg/m3)	Chemical-specific; calculated from concentration in tap water (use modeled concentrations (pretreatment) at well)
IRS = Inhalation Rate (m3/hour)	
-Children, Average	8.0E-01 (child, age 6, for light activity; EPA, 1989b)
-Children, Upper bound	2.0E+00 (child, age 6, for moderate activity; EPA, 1989b)
-Adult, Average	6.0E-01 (average, adult, for light activity; EPA, 1989b)
-Adult, Upper bound	2.1E+00 (average, adult, for moderate activity; EPA, 1989b)
EF = Exposure Frequency (days/year)	
-Average	2.4E+01 (average cycles per week for washing machine (6); Consumer Report, 1987 Operation of dishwasher and washing machine simultaneously, 1 cycle per day, 6 days per week)
-Upper bound	3.8E+01 (operation of dishwasher and washing machine simultaneously, 1 cycle per day, 9 days per week)
ED = Exposure Duration (years)	1.0E+00
IRD = Inhalation Rate per Day (m3/hour)	
-Average	8.0E-01 (EPA, 1989a)
-Upper Bound	1.2E+00 (EPA, 1989a)
CF = Conversion Factor (hour/day)	2.4E+01
AT = Averaging Time (period over which exposure is averaged-days)	
-Noncarcinogenic effects	
-Average	2.4E+01 (EF x ED)
-Upper bound	3.0E+01

RADIAN CORPORATION

INHALATION OF VAPOR PHASE CHEMICALS WHILE USING A DISHWASHER AND A WASHING MACHINE WITH RESIDENTIAL WATER - SUBCHRONIC
(Applicable to Residential and 3 year tour of duty)

10:44:48
07/13/90

Effective Air Concentration (EAC), (mg/m3) = (CA X IRS X EF X ED)/(IRD X CF X AT)

	Assumptions
CA = Contaminant Concentration in Air (mg/m3)	Chemical-specific; calculated from concentration in tap water (use modeled concentrations (pretreatment) at well)
IRS = Inhalation Rate (m3/hour)	
-Children, Average	8.0E-01 (child, age 6, for light activity; EPA, 1989b)
-Children, Upper bound	2.0E+00 (child, age 6, for moderate activity; EPA, 1989b)
-Adult, Average	6.0E-01 (average, adult, for light activity; EPA, 1989b)
-Adult, Upper bound	2.1E+00 (average, adult, for moderate activity; EPA, 1989b)
EF = Exposure Frequency (days/year)	
-Average	2.4E+01 (average cycles per week for washing machine (6); Consumer Report, 1987 Operation of dishwasher and washing machine simultaneously, 1 cycle per day, 6 days per week)
-Upper bound	3.8E+01 (operation of dishwasher and washing machine simultaneously, 1 cycle per day, 9 days per week)
ED = Exposure Duration (years)	1.0E+00
IRD = Inhalation Rate per Day (m3/hour)	
-Average	8.0E-01 (EPA, 1989a)
-Upper Bound	1.2E+00 (EPA, 1989a)
CF = Conversion Factor (hour/day)	2.4E+01
AT = Averaging Time (period over which exposure is averaged-days)	
-Noncarcinogenic effects	
-Average	2.4E+01 (CF x ED)
-Upper bound	3.0E+01

Inhalation of Vapor Phase Chemicals While Using a Washing Machine with Residential Water - Subchronic - Residential and 3 Year Tour of Duty - Base Well 18

11:25:40	CA(mg/m3)				Estimated Intake Dose (mg/kg-day)			
06/26/90					Children		Adult	
	Average		Upper Bound					
					Average	Upper Bound	Average	Upper Bound
Chemical	35 min	90 min	35 min	90 min				
Carbon tetrachloride	1.0E-04	5.2E-05	1.0E-04	5.2E-05	6.9E-06	2.2E-05	1.2E-06	5.2E-06
Chloroform	1.8E-04	9.2E-05	1.8E-04	9.2E-05	1.2E-05	3.9E-05	2.1E-06	9.3E-06
Dichloroethane, 1,2-	1.1E-04	5.8E-05	1.1E-04	5.8E-05	7.6E-06	2.4E-05	1.3E-06	5.8E-06
Dichloroethene, 1,1-	1.6E-04	8.1E-05	1.6E-04	8.1E-05	1.1E-05	3.4E-05	1.8E-06	8.1E-06
Dichloroethene, 1,2-	7.7E-03	3.9E-03	1.8E-02	9.2E-03	5.1E-04	3.9E-03	8.8E-05	9.3E-04
Methylene chloride	3.1E-04	1.6E-04	4.3E-04	2.2E-04	2.1E-05	9.2E-05	3.5E-06	2.2E-05
Tetrachloroethane,1,1,2,2-	9.1E-05	4.6E-05	1.8E-04	9.2E-05	6.1E-06	3.9E-05	1.0E-06	9.3E-06
Tetrachloroethene	9.3E-04	4.7E-04	9.3E-04	4.7E-04	6.2E-05	2.0E-04	1.1E-05	4.7E-05
Trichloroethane,1,1,1-	1.6E-04	8.1E-05	2.2E-04	1.1E-04	1.1E-05	4.6E-05	1.8E-06	1.1E-05
Trichloroethane,1,1,2-	1.1E-04	5.8E-05	1.7E-04	8.7E-05	7.6E-06	3.6E-05	1.3E-06	8.7E-06
Trichloroethene	4.5E-02	2.2E-02	7.0E-02	3.5E-02	3.0E-03	1.5E-02	5.1E-04	3.5E-03
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Inhalation of Vapor Phase Chemicals While Using a Washing Machine with Residential Water - Subchronic - Residential and 3 Year Tour of Duty - Base Well 18

11:25:40 06/26/90	CA(mg/m3)				Effective Air Concentration (mg/m3)						Children		Adult	
	Average		Upper Bound		Children		Adult		Oral	Inhalation	Average	Upper Bound	Average	Upper Bound
Chemical	35 min	90 min	35 min	90 min	Average	Upper Bound	Average	Upper Bound	RfDs (mg/kg/da	RFDs (mg/m3)	Hazard Index	Hazard Index	Hazard Index	Hazard Index
Carbon tetrachloride	1.0E-04	5.2E-05	1.0E-04	5.2E-05	5.7E-06	1.2E-05	4.3E-06	1.2E-05	7.0E-03		9.8E-04	3.1E-03	1.7E-04	7.5E-04
Chloroform	1.8E-04	9.2E-05	1.8E-04	9.2E-05	1.0E-05	2.1E-05	7:6E-06	2.2E-05	1.0E-02		1.2E-03	3.9E-03	2.1E-04	9.3E-04
Dichloroethane, 1,2-	1.1E-04	5.8E-05	1.1E-04	5.8E-05	6.4E-06	1.3E-05	4.8E-06	1.4E-05						
Dichloroethene, 1,1-	1.6E-04	8.1E-05	1.6E-04	8.1E-05	8.9E-06	1.8E-05	6.7E-06	1.9E-05	9.0E-03		1.2E-03	3.8E-03	2.0E-04	9.0E-04
Dichloroethene, 1,2-	7.7E-03	3.9E-03	1.8E-02	9.2E-03	4.3E-04	2.1E-03	3.2E-04	2.2E-03	2.0E-01		2.6E-03	1.9E-02	4.4E-04	4.7E-03
Methylene chloride	3.1E-04	1.6E-04	4.3E-04	2.2E-04	1.7E-05	4.9E-05	1.3E-05	5.1E-05	6.0E-02	3.0E+00	5.7E-06	1.6E-05	4.3E-06	1.7E-05
Tetrachloroethane,1,1,2,2-	9.1E-05	4.6E-05	1.8E-04	9.2E-05	5.1E-06	2.1E-05	3.8E-06	2.2E-05						
Tetrachloroethene	9.3E-04	4.7E-04	9.3E-04	4.7E-04	5.2E-05	1.0E-04	3.9E-05	1.1E-04	1.0E-01		6.2E-04	2.0E-03	1.1E-04	4.7E-04
Trichloroethane,1,1,1-	1.6E-04	8.1E-05	2.2E-04	1.1E-04	8.9E-06	2.5E-05	6.7E-06	2.6E-05	9.0E-01	1.0E+01	8.9E-07	2.5E-06	6.7E-07	2.6E-06
Trichloroethane,1,1,2-	1.1E-04	5.8E-05	1.7E-04	8.7E-05	6.4E-06	1.9E-05	4.8E-06	2.0E-05	4.0E-02	ND	1.9E-04	9.1E-04	3.3E-05	2.2E-04
Trichloroethene	4.5E-02	2.2E-02	7.0E-02	3.5E-02	2.5E-03	7.9E-03	1.9E-03	8.3E-03						
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.0E-02	ND				
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.0E-03	ND				
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-01	ND				
											6.8E-03	3.3E-02	1.2E-03	7.9E-03

RADIAN CORPORATION

MRA/071390/pwj

Inhalation of Vapor Phase Chemicals While Using a Dishwasher with Residential Water - Subchronic - Residential and 3

11:20:51 06/26/90	CA(mg/m3)				Estimated Intake Dose (mg/kg-day)			
	Average		Upper Bound		Children		Adult	
Chemical	72 min	48 min	72 min	48 min	Average	Upper Bound	Average	Upper Bound
Carbon tetrachloride	2.0E-05	1.3E-05	2.0E-05	1.3E-05	1.7E-06	5.4E-06	2.9E-07	1.3E-06
Chloroform	3.5E-05	2.3E-05	3.5E-05	2.3E-05	3.0E-06	9.5E-06	5.1E-07	2.3E-06
Dichloroethane, 1,2-	2.2E-05	1.4E-05	2.2E-05	1.4E-05	1.9E-06	5.9E-06	3.2E-07	1.4E-06
Dichloroethene, 1,1-	3.1E-05	2.0E-05	3.1E-05	2.0E-05	2.6E-06	8.3E-06	4.5E-07	2.0E-06
Dichloroethene, 1,2-	1.5E-03	9.5E-04	3.5E-03	2.3E-03	1.3E-04	9.5E-04	2.2E-05	2.3E-04
Methylene chloride	5.9E-05	3.8E-05	8.3E-05	5.4E-05	5.1E-06	2.3E-05	8.7E-07	5.4E-06
Tetrachloroethane,1,1,2,2-	1.7E-05	1.1E-05	3.5E-05	2.3E-05	1.5E-06	9.5E-06	2.6E-07	2.3E-06
Tetrachloroethene	1.8E-04	1.2E-04	1.8E-04	1.2E-04	1.5E-05	4.8E-05	2.6E-06	1.2E-05
Trichloroethane,1,1,1-	3.1E-05	2.0E-05	4.2E-05	2.7E-05	2.6E-06	1.1E-05	4.5E-07	2.7E-06
Trichloroethane,1,1,2-	2.2E-05	1.4E-05	3.3E-05	2.1E-05	1.9E-06	8.9E-06	3.2E-07	2.1E-06
Trichloroethene	8.5E-03	5.5E-03	1.3E-02	8.6E-03	7.3E-04	3.6E-03	1.3E-04	8.7E-04
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

RADIAN CORPORATION

Inhalation of Vapor Phase Chemicals While Using a Dishwasher with Residential Water - Subchronic - Residential and 3 Year Tour of Duty - Base Well 18.

11:20:51
06/26/90

Chemical	CA(mg/m3) Average 72 min	CA(mg/m3) Average 48 min	CA(mg/m3) Upper Bound 72 min	CA(mg/m3) Upper Bound 48 min	Effective Air Concentration (mg/m3) Children Average	Children Upper Bound	Adult Average	Adult Upper Bound	Oral RfDs (mg/kg/da	Inhalation RFDs (mg/m3)	Children Average Hazard Index	Children Upper Bound Hazard Index	Adult Average Hazard Index	Adult Upper Bound Hazard Index
Carbon tetrachloride	2.0E-05	1.3E-05	2.0E-05	1.3E-05	1.4E-06	2.9E-06	1.1E-06	3.0E-06	7.0E-03		2.4E-04	7.6E-04	4.1E-05	1.8E-04
Chloroform	3.5E-05	2.3E-05	3.5E-05	2.3E-05	2.5E-06	5.1E-06	1.9E-06	5.3E-06	1.0E-02		3.0E-04	9.5E-04	5.1E-05	2.3E-04
Dichloroethane, 1,2-	2.2E-05	1.4E-05	2.2E-05	1.4E-05	1.6E-06	3.2E-06	1.2E-06	3.3E-06						
Dichloroethene, 1,1-	3.1E-05	2.0E-05	3.1E-05	2.0E-05	2.2E-06	4.4E-06	1.6E-06	4.7E-06	9.0E-03		2.9E-04	9.3E-04	5.0E-05	2.2E-04
Dichloroethene, 1,2-	1.5E-03	9.5E-04	3.5E-03	2.3E-03	1.1E-04	5.1E-04	7.9E-05	5.3E-04	2.0E-01		6.3E-04	4.8E-03	1.1E-04	1.1E-03
Methylene chloride	5.9E-05	3.8E-05	8.3E-05	5.4E-05	4.2E-06	1.2E-05	3.2E-06	1.3E-05	6.0E-02	3.0E+00	1.4E-06	4.0E-06	1.1E-06	4.2E-06
Tetrachloroethane,1,1,2,2-	1.7E-05	1.1E-05	3.5E-05	2.3E-05	1.3E-06	5.1E-06	9.4E-07	5.3E-06						
Tetrachloroethene	1.8E-04	1.2E-04	1.8E-04	1.2E-04	1.3E-05	2.6E-05	9.5E-06	2.7E-05	1.0E-01		1.5E-04	4.8E-04	2.6E-05	1.2E-04
Trichloroethane,1,1,1-	3.1E-05	2.0E-05	4.2E-05	2.7E-05	2.2E-06	6.0E-06	1.6E-06	6.3E-06	9.0E-01	1.0E+01	2.2E-07	6.0E-07	1.6E-07	6.3E-07
Trichloroethane,1,1,2-	2.2E-05	1.4E-05	3.3E-05	2.1E-05	1.6E-06	4.8E-06	1.2E-06	5.0E-06	4.0E-02	ND	4.7E-05	2.2E-04	8.0E-06	5.4E-05
Trichloroethene	8.5E-03	5.5E-03	1.3E-02	8.6E-03	6.1E-04	1.9E-03	4.6E-04	2.0E-03						
Boron	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.0E-02	ND				
Vanadium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.0E-03	ND				
Zinc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-01	ND				
											1.7E-03	8.1E-03	2.9E-04	1.9E-03

RADIAN CORPORATION

MRA/071390/pwj

RADIAN
CORPORATION

APPENDIX I

HAND CALCULATIONS

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 1

SIGNATURE Jan Beck DATE 5/8/90 CHECKED TEJ DATE 900712

PROJECT McClellan AFB EE/LA HRA JOB NO.

SUBJECT Ingestion of drinking water - Chronic - residential SHEET OF 4 SHEETS

Intake (mg/kg-day) = CW x IR x EF x ED / BW x AT

Methylene Chloride

Base Well 18

Non carcinogenic Effects

Children Average

Intake = $\frac{2.7E-04 \times 1.0 \times 365 \times 5.0}{1.6E+01 (5.0 \times 365)}$ = 1.7E-05

Child Upper bound

Intake = $\frac{3.8E-04 \times 1.0 \times 365 \times 5}{16 (5 \times 365)}$ = 2.4E-05

Adult - Average

Intake = $\frac{2.7E-04 \times 2.0 \times 365 \times 9.0}{7.0E+01 (9.0 \times 365)}$ = 7.7E-06

Adult - Upper bound

Intake = $\frac{3.8E-04 \times 2.0 \times 365 \times 3.0E+01}{7.0E+01 (3.0E+01 \times 365)}$ = 1.1E-05

Carcinogenic Effects

Adult - Average

Intake = $\frac{2.7E-04 \times 2.0 \times 365 \times 9.0}{7.0E+01 (70 \times 365)}$ = 9.9E-07

Adult - Upper bound

Intake = $\frac{3.8E-04 \times 2.0 \times 365 \times 3.0E+01}{7.0E+01 (70 \times 365)}$ = 4.7E-06

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 1

SIGNATURE _____ DATE _____ CHECKED [signature] DATE 900717

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 4 SHEETS

Methylene Chloride

City Well 132

Noncarcinogenic Effects

Children (6.89E-06)

Intake = $\frac{1.1E-04 \times 1.0 \times 365 \times 5.0}{1.4E+01 \times (5.0 \times 365)}$ = 6.9E-06

Adult - Average

Intake = $\frac{1.1E-04 \times 2.0 \times 365 \times 9.0}{7.0E+01 \times (9.0 \times 365)}$ = 3.1E-06

Adult - Upper bound

Intake = $\frac{1.1E-04 \times 2.0 \times 365 \times 3.0E+01}{7.0E+01 \times (30 \times 365)}$ = 3.1E-06

Carcinogenic effects

Adult - Average

Intake = $\frac{1.1E-04 \times 2.0 \times 365 \times 9.0}{7.0E+01 \times (70 \times 365)}$ = 4.0E-07

Adult - Upper bound

Intake = $\frac{1.1E-04 \times 2.0 \times 365 \times 3.0E+01}{7.0E+01 \times (70 \times 365)}$ = 1.3E-06

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 1

SIGNATURE _____ DATE _____ CHECKED TCG DATE 9/6/12

PROJECT _____ JOB NO. _____

SUBJECT Risk Characterization SHEET 3 OF 4 SHEETS

Noncarcinogenic effects

: Hazard Index (HI) = average intake / reference dose

Baseline 18

Children Average

$HI = \frac{1.7E-05}{6.0E-02} = 2.8E-04$

Childhood Upperbound

$HI = \frac{2.4E-05}{6.0E-02} = 4.0E-04$

Adult Average

$HI = \frac{7.7E-06}{6.0E-02} = 1.3E-04$

Upper bound

$HI = \frac{1.1E-05}{6.0E-02} = 1.8E-04$

City Well 132

Children

(6.88E-06)

$HI = \frac{6.9E-06}{6.0E-02} = 1.1E-04$

Adult

Average

$HI = \frac{3.1E-06}{6.0E-02} = 5.2E-05$

Upperbound

$HI = \frac{3.1E-06}{6.0E-02} = 5.2E-05$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 1

SIGNATURE _____ DATE _____ CHECKED TEJ DATE 900712

PROJECT _____ JOB NO. _____

SUBJECT Risk Characterization SHEET 4 OF 4 SHEETS

Carcinogenic Effects

Total Pathway Risk (TPR) = intake X cancer slope factor

Base Well 18

Adult - Average

TPR = 9.9E-07 X 7.5E-03 = 7.4E-09

Adult - Upper bound

TPR = 4.7E-06 X 7.5E-03 = 3.5E-08

City Well 32

Adult - Average

TPR = 4.0E-07 X 7.5E-03 = 3.0E-09

Adult - Upper bound

(1.35E-06)

TPR = 1.3E-06 X 7.5E-03 = 1.0E-08

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 2

SIGNATURE Jan Beck DATE 5/8/90 CHECKED TEJ DATE 900717

PROJECT McClellan AFB JOB NO.

SUBJECT Ingestion of drinking water SHEET 1 OF 2 SHEETS
Chronic - 3 yr out of duty

Intake (mg/kg-day) = (Cw x IR x EF x ED) / (Bw x AT)

Methylene Chloride

Base Well 18

Noncarcinogenic Effects

Children - average

$$\text{Intake} = \frac{2.7E\text{-}04 \times 1.0 \times 365 \times 3.0}{16\ (3.0 \times 365)} = 1.7E\text{-}05$$

Children - Upper bound

$$\text{Intake} = \frac{3.8E\text{-}04 \times 1.0 \times 365 \times 3}{16 \times 3.0 \times 365} = 2.4E\text{-}05$$

Adult Average

$$\text{Intake} = \frac{2.7E\text{-}04 \times 2.0 \times 365 \times 3.0}{70\ (3.0 \times 365)} = 7.7E\text{-}06$$

Adult Upper bound

$$\text{Intake} = \frac{3.8E\text{-}04 \times 2.0 \times 365 \times 3}{70 \times 3.0 \times 365} = 1.1E\text{-}05$$

Carcinogenic effects

Adult Average

$$\text{Intake} = \frac{2.7E\text{-}04 \times 2.0 \times 365 \times 3.0}{70\ (70 \times 365)} = 3.3E\text{-}07$$

Adult Upper bound

$$\text{Intake} = \frac{3.8E\text{-}04 \times 2 \times 365 \times 3}{70\ (70 \times 365)} = 4.7E\text{-}07$$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 2

SIGNATURE _____ DATE _____ CHECKED TEJ DATE 10/07/2

PROJECT _____ JOB NO _____

SUBJECT _____ SHEET 2 OF 2 SHEETS

Methylene Chloride

Noncarcinogenic effects:

Hazard Index (HI) = intake dose / reference dose

Children Average

$HI = \frac{1.7E-05}{6.0E-02} = 2.8E-04$

Children Upperbound

$HI = \frac{2.4E-05}{6.0E-02} = 4.0E-04$

Adult Average

$HI = \frac{7.7E-06}{6.0E-02} = 1.3E-04$

Adult Upperbound

$HI = \frac{1.1E-05}{6.0E-02} = 1.8E-04$

Carcinogenic effects

Total Pathway Risk (TPR) = intake dose × cancer slope factor

Adult Average

$TPR = 3.3E-07 \times 7.5E-03 = 2.5E-09$

Adult Upperbound

$TPR = 4.7E-07 \times 7.5E-03 = 3.5E-09$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 3

SIGNATURE Jan Beck DATE 5/8/90 CHECKED TEJ DATE 9/07/90

PROJECT McClellan AFB JOB NO.

SUBJECT Ingestion of drinking water - Subchronic = Residential and 3 yr tour of duty SHEET 1 OF 1 SHEETS

Intake (mg/kg-day) = (Cw x IR x EF x ED)/(Bw x AT)

Methylene Chloride

Noncarcinogenic Effects

Children Average

Intake = $\frac{2.7E-04 \times 1.9 \times 30 \times 1.0}{16 \times 30 \times 1}$ = 1.7E-05

Child Upper bound

Intake = $\frac{3.8E-04 \times 1.0 \times 30 \times 1.0}{16 \times 30 \times 1}$ = 2.4E-05

Adult Average

Intake = $\frac{2.7E-04 \times 2.0 \times 30 \times 1.0}{70 \times 30 \times 1}$ = 7.7E-06

Adult Upperbound

Intake = $\frac{3.8E-04 \times 2.0 \times 30 \times 1.0}{70 \times 30 \times 1}$ = 1.1E-05

Hazard Index (HI) = intake dose / reference dose

Children Average

HI = $\frac{1.7E-05}{6.0E-02}$ = 2.8E-04

Children Upper bound

HI = $\frac{2.4E-05}{6.0E-02}$ = 4.0E-04

Adult Average

HI = $\frac{7.7E-06}{6.0E-02}$ = 1.3E-04

Adult Upperbound

HI = $\frac{1.1E-05}{6.0E-02}$ = 1.8E-04

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 4

SIGNATURE Jan Beck DATE 5/10/90 CHECKED JEJ DATE 9/6/12

PROJECT McClellan AFB EE/CA HRA JOB NO.

SUBJECT Ingestion of Drinking Water SHEET 1 OF 1 SHEETS
Chronic - Civil Worker

Intake (mg/kg-day) = (CW x IR x EF x ED)/(BW x AT)

Methylene Chloride

Base Well 18

Noncarcinogenic Effects

Adult Average

Adult = $\frac{2.7E-04 \times 2.0 \times 240 \times 30}{70 (30 \times 365)}$ = 5.1E-06

Adult Upperbound

Intake = $\frac{3.8E-04 \times 2.0 \times 240 \times 30}{70 (30 \times 365)}$ = 7.1E-06

Carcinogenic effects

Adult average = $\frac{2.7E-04 \times 2.0 \times 240 \times 30}{70 (70 \times 365)}$ = 2.2E-06

Adult Upperbound

Intake = $\frac{3.8E-04 \times 2.0 \times 240 \times 30}{70 (70 \times 365)}$ = 3.1E-06

Adult Average

Hazard Index (HI) = $\frac{5.1E-06}{6.0E-02}$ = 8.5E-05

Adult Upperbound

HI = $\frac{7.1E-06}{6.0E-02}$ = 1.2E-04

Adult Cancer Risk (2.17E-06)

Total Pathway Risk = 3.2E-06 x 7.5E-03 = 1.6E-08

Adult Upperbound

TPR = 3.1E-06 x 7.5E-03 = 2.3E-08

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 5

SIGNATURE Jan Beale DATE 5/16/90 CHECKED TEJ DATE 6/07/12

PROJECT McClellan AFB JOB NO

SUBJECT Ingestion of drinking water SHEET 1 OF 1 SHEETS
Surface + Grid Wells

Intake (mg/kg-day) = (Cw X IR X EF X ED)/(BW X AT)

Trichloroethene Chloride
Base Well 18

Noncarcinogenic

Adult Average

Intake = $\frac{2.7E-04 \times 2.0 \times 20 \times 1.0}{70 (28 \times 1.0)} = 5.5E-06$

Adult Upper Bound

Intake = $\frac{3.9E-04 \times 2.0 \times 20 \times 1.0}{70 (28 \times 1.0)} = 7.8E-06$

Adult Average

Hazard Index = $\frac{5.5E-06}{6.0E-02} = 9.2E-05$

Adult Upper Bound

HI = $\frac{7.8E-06}{6.0E-02} = 1.3E-04$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 6

SIGNATURE Jan Beck DATE 5/10/90 CHECKED REJ DATE 9/07/12

PROJECT McClellan AFB JOB NO.

SUBJECT Dermal Contact in water while showering - Chronic - Residential SHEET 1 OF 6 SHEETS

Absorbed Dose (mg/kg-day) = $\frac{(CW \times SA \times PC \times ET \times EF \times ED \times CF)}{(BW \times AT)}$

Methylene Chloride
Base Well 18

Non-carcinogenic effects

Children - Average

Absorbed Dose: $\frac{2.7E-04 \times 7.28E+03 \times 8.4E-04 \times 0.12 \times 365 \times 5.0 \times 0.001}{16\ (5.0 \times 365)}$

$(1.24E-08)$

$\doteq 1.2E-08$

Children - Upper bound

Absorbed Dose = $\frac{3.8E-04 \times 8.8E+03 \times 8.4E-04 \times 2.5E-01 \times 365 \times 5 \times 0.001}{16\ (5.0 \times 365)}$

$= 4.4E-08$

Adult - Average

Absorbed Dose = $\frac{2.7E-04 \times 1.9E+04 \times 8.4E-04 \times 1.2E-01 \times 365 \times 9.0 \times 0.001}{70\ (9.0 \times 365)}$

$\doteq 7.5E-09$

Adult - Upper bound

Absorbed Dose = $\frac{3.8E-04 \times 2.3E+04 \times 8.4E-04 \times 2.5E-01 \times 365 \times 30 \times 0.001}{70\ (30 \times 365)}$

$= 2.6E-08$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 6

SIGNATURE _____ DATE _____ CHECKED TEJ DATE 9/20/12

PROJECT _____ JOB NO: _____

SUBJECT _____ SHEET 2 OF 6 SHEETS

Carcinogenic effects
Base: Well 18
Methylene Chloride

Adult - Average

Absorbed Dose = $\frac{2.7E-04 \times 1.94E+04 \times 8.4E-04 \times 1.2E-01 \times 365 \times 9 \times 0.001}{70\ (70 \times 365)}$

= 9.7E-10

Adult - Upperbound

Absorbed Dose = $\frac{3.8E-04 \times 2.3E+04 \times 8.4E-04 \times 2.5E-01 \times 365 \times 30 \times 0.001}{70\ (70 \times 365)}$

(1.12E-08)

= 1.1E-08

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 6

SIGNATURE _____ DATE _____ CHECKED REG DATE 9/20/12

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 3 OF 6 SHEETS

Methylene Chloride
City Well 132

Noncarcinogenic effects

Children - Average

Absorbed Dose = $\frac{1.1E-04 \times 7.28E+03 \times 8.4E-04 \times 1.2E-01 \times 365 \times 5.0 \times 0.001}{16 \times (5.0 \times 365)}$

$(5.04E-09)$

$= 5.0E-09$

Children - Worst Round

Absorbed Dose = $\frac{1.1E-04 \times 8.8E+03 \times 8.4E-04 \times 2.5E-01 \times 365 \times 5.0 \times 0.001}{16 \times (5.0 \times 365)}$

$(1.27E-08)$

$= 1.3E-08$

Adult - Average

Absorbed Dose = $\frac{1.1E-04 \times 1.9E+04 \times 8.4E-04 \times 1.2E-01 \times 365 \times 9.0 \times 0.001}{70 \times (9.0 \times 365)}$

$(3.07E-09)$

$= 3.1E-09$

Adult - Upper Bound

Absorbed Dose = $\frac{1.1E-04 \times 2.2E+04 \times 8.4E-04 \times 2.5E-01 \times 365 \times 30 \times 0.001}{70 \times (30 \times 365)}$

$= 7.5E-09$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 6

SIGNATURE _____ DATE _____ CHECKED JEJ DATE 920717

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 4 OF 6 SHEETS

Carcinogenic effects
City Well 132
Methylene Chloride

Adult - Average

Absorbed Dose = $\frac{1.1E-04 \times 1.9E+04 \times 8.4E-04 \times 1.2E-01 \times 365 \times 9 \times 0.001}{70 \ (70 \times 365)}$

= 4.0E-10

Adult - Upper bound

Absorbed Dose = $\frac{1.1E-04 \times 2.28E+04 \times 8.4E-04 \times 2.5E-01 \times 365 \times 30 \times 0.001}{70 \ (70 \times 365)}$

= 3.2E-09

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 6

SIGNATURE _____ DATE _____ CHECKED TBA DATE 9/30/92

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 5 OF 6 SHEETS

Noncarcinogenic effects
Base well 18
Methylene Chloride
Children - Average

HI = 1.2E-08 (1.24E-08) / 6.0E-02 = 2.1E-07

Children - Upper bound

HI = 4.4E-08 / 6.0E-02 = 7.3E-07

Adult - Average

HI = 7.5E-09 / 6.0E-02 = 1.3E-08

Adult - Upper bound

HI = 2.6E-08 / 6.0E-02 = 4.3E-07

Carcinogenic
Base Well 18

Adult - Average

TPR = 9.7E-10 X 7.5E-03 = 7.3E-12

Adult - Upper bound

TPR = 1.1E-09 (1.1ME-09) X 7.5E-03 = 8.4E-11

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 6

SIGNATURE _____ DATE _____ CHECKED REJ DATE 900712

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 6 OF 6 SHEETS

Noncarcinogenic effects

Chemical 132

Methylene Chloride

Child - Average

$HI = \frac{5.0E-09 \text{ (5.0E-09)}}{6.0E-02} = 8.4E-08$

Child - Upper bound

$HI = \frac{1.3E-08 \text{ (1.3E-08)}}{6.0E-02} = 2.1E-07$

Adult - Average

$HI = \frac{3.1E-09 \text{ (3.0E-09)}}{6.0E-02} = 5.1E-08$

Adult - Upper bound

$HI = \frac{7.5E-09}{6.0E-02} = 1.3E-07$

Carcinogenic effects

Adult - Average

$TPR = 4.0E-10 \times 7.5E-03 = 3.0E-12$

Adult - Upper bound

$TPR = 3.2E-09 \times 7.5E-03 = 2.4E-11$

10-88-20722

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 7

SIGNATURE Jan Beck DATE 5/11/90 CHECKED REJ DATE 900717

PROJECT McClellan AFB JOB NO.

SUBJECT Dermal contact with chemicals in water while showering - chronic - 3yr tour - residential SHEET 1 OF 3 SHEETS

Absorbed Dose (mg/kg-day) = $\frac{C_w \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$

Methylene Chloride

Basis: Well 18

Noncarcinogenic Effects

Children - Average

Absorbed Dose = $\frac{2.7E-04 \times 7.28E+03 \times 8.4E-04 \times 1.2E-01 \times 365 \times 3.0 \times 0.0}{16 \times (3.0 \times 365)}$

$(1.238E-08)$

$= 1.2E-08$

Children - Upper Bound

Absorbed Dose = $\frac{3.8E-04 \times 8.8E+03 \times 8.4E-04 \times 2.5E-01 \times 365 \times 3.0 \times 0.00}{16 \times (3.0 \times 365)}$

$(4.38E-08)$

$= 4.4E-08$

Adult - Average

Absorbed Dose = $\frac{2.7E-04 \times 1.9E+04 \times 8.4E-04 \times 1.2E-01 \times 365 \times 3.0 \times 0.001}{70 \times (3.0 \times 365)}$

$(7.9E-09)$

$= 7.5E-09$

Adult - Upper Bound

Absorbed Dose = $\frac{3.8E-04 \times 2.8E+04 \times 8.4E-04 \times 2.5E-01 \times 365 \times 3.0 \times 0.001}{70 \times (3.0 \times 365)}$

$= 2.6E-08$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 7

SIGNATURE _____ DATE _____ CHECKED TEJ DATE 9-10-15

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 3 SHEETS

Incremental effects
Pollutant Chromium
Hazel Well 18

Adult Cancer

Alcohol: $\frac{2.7E-04 \times 1.9E+04 \times 8.4E-04 \times 1.2E-01 \times 365 \times 3 \times 0.5}{70 \times (70 \times 365)}$

$= 3.2E-10$ ✓

Adult Upper Bound

Alcohol: $\frac{3.8E-04 \times 2.3E+04 \times 8.4E-04 \times 2.5E-01 \times 365 \times 3.0 \times 0.001}{70 \times (70 \times 365)}$

$= \frac{(1.2E-09)}{1.1E-09}$ ✓

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 7

SIGNATURE _____ DATE _____ CHECKED TEG. DATE 9/10/12

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 3 OF 3 ! SHEETS

Risk Characterization
Petroleum Orchards
Base Well 18

Noncarcinogenic

Children - Average
HI = 1.2E-08 (1.23E-08) + 2.1E-07
6.0E-02

Children - Upper bound
HI = 4.4E-08 + 7.3E-07
6.0E-02

Adult - Average
HI = 7.5E-09 + 1.3E-07
6.0E-02

Adult Upperbound
HI = 2.6E-08 + 4.3E-07
6.0E-02

Carcinogenic

Adult - Average
TPR = 3.2E-10 x 7.5E-03 = 2.4E-12

Adult - Upperbound
TPR = 1.1E-09 (1.12E-09) x 7.5E-03 = 8.4E-12

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 8

SIGNATURE Jan Becke DATE _____ CHECKED TEA DATE 9/26/91

PROJECT McClellan AFB JOB NO. _____

SUBJECT Dermal contact with chemicals in water while showering = Subsurface - Resident SHEET 1 OF 2 SHEETS

3yr tour of duty

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

Methylene Chloride

Based with 18

Noncarcinogenic Effects

Child/teen - Average

Absorbed Dose = 2.7E-04 × 7.28E+03 × 8.4E-04 × 1.2E-01 × 30 × 1 × 0.001 / 16 (1.0 × 30)

(1.24E-08)

≈ 1.2E-08

Child/teen - Upper bound

Absorbed Dose = 3.8E-04 × 8.8E+03 × 8.4E-04 × 2.5E-01 × 30 × 1 × 0.001 / 16 (1.0 × 30)

(4.39E-08)

≈ 4.4E-08

Adult - Average

Absorbed Dose = 2.7E-04 × 1.9E+04 × 8.4E-04 × 6.2E+01 × 30 × 1 × 0.001 / 70 (1.0 × 30)

= 7.5E-09

(7.54E-09)

Adult - Upper bound

Absorbed Dose = 3.8E-04 × 2.3E+04 × 8.4E-04 × 2.5E-01 × 30 × 1 × 0.001 / 70 (1.0 × 30)

(9.62E-08)

≈ 2.6E-08

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 8

SIGNATURE _____ DATE _____ CHECKED [illegible] DATE 9/20/93

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 2 SHEETS

Risk Characterization

Noncarcinogenic effects

Baseline Risks

Children - Average

(1.24E-08)

HI = 1.2E-08 / 6.0E-02 = 2.1E-07 ✓

Children - Upper bound

HI = 4.4E-08 / 6.0E-02 = 7.3E-07

Adult - Average

HI = 7.5E-09 / 6.0E-02 = 1.3E-07

Adult - Upper bound

HI = 2.6E-08 / 6.0E-02 = 4.3E-07

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 9

SIGNATURE Jan Beck DATE _____ CHECKED TEJ DATE 5/07/2

PROJECT Pic Clifton FE JOB NO. _____

SUBJECT Inhalation of vapor phase contaminants while [illegible] SHEET 1 OF 8 SHEETS

Intake (mg/kg-day) = $\frac{CA \times TR \times ET \times EF \times ED}{BW \times AT}$

Residential Child

Base Well #7

Noncarcinogenic effects

Children - Average (2.48)

Intake = $\frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 5.0}{16 (5.0 \times 365)}$ = 2.5E-05

Children - Upper bound (1.41E-04)

Intake = $\frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 365 \times 5.0}{16 (5.0 \times 365)}$ = 1.4E-04

Adult - Average (5.66E-06)

Intake = $\frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 9.0}{70 (9.0 \times 365)}$ = 5.7E-06

Adult - Upper bound (3.21E-05)

Intake = $\frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 365 \times 30}{70 (30 \times 365)}$ = 3.2E-05

Carcinogenic effects

Adult - Average (7.77E-07)

Intake = $\frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 9.0}{70 (70 \times 365)}$ = 7.3E-07

Adult - Upper bound (1.38E-05)

Intake = $\frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 365 \times 30}{70 (70 \times 365)}$ = 1.4E-05

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 9

SIGNATURE _____ DATE _____ CHECKED TEJ DATE 9/6/12

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 8 SHEETS

Methylene chloride
City Well 132

Noncarcinogenic effects

Child - Current (1.04E-05)

Intake = $\frac{2.3E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 5.0}{16 \times (5.0 \times 365)}$ = 1.0E-05

Children - Future (4.03E-05)

Intake = $\frac{4.3E-03 \times 6.0E-01 \times 2.5E-01 \times 365 \times 5.0}{16 \times (5.0 \times 365)}$ = 4.0E-05

Adult - Average (2.37E-06)

Intake = $\frac{2.3E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 9.0}{70 \times (9.0 \times 365)}$ = 2.4E-06

Adult - Future (9.21E-06)

Intake = $\frac{4.3E-03 \times 6.0E-01 \times 2.5E-01 \times 365 \times 30}{70 \times (30 \times 365)}$ = 9.0E-06

Carcinogenic effects

Adult - Average (3.04E-07)

Intake = $\frac{2.3E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 9.0}{70 \times (70 \times 365)}$ = 3.0E-07

Adult - Future (3.94E-06)

Intake = $\frac{4.3E-03 \times 6.0E-01 \times 2.5E-01 \times 365 \times 30}{70 \times (70 \times 365)}$ = 3.9E-06

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 9

SIGNATURE _____ DATE _____ CHECKED REG DATE 9-20-12

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 3 OF 8 SHEETS

Effective Air Concentration (mg/m³) = $\frac{CA \times IRS \times ET \times EF \times ED}{IRD \times CF \times AT}$ (EAC)

Methylene Chloride

Base: Well 18

Non-carcinogenic effects

Children - Average

$EAC = \frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 5.0}{8.0E-01 \times 2.4E+01 \times (5.0 \times 365)} = 2.1E-05$ (2.06E-05) ✓

Children - Upper bound

$EAC = \frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 365 \times 5.0}{1.25 \times 2.4E+01 \times (5.0 \times 365)} = 7.5E-05$ ✓

Adult - Average

$EAC = \frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 9.0}{8.0E-01 \times 2.4E+01 \times (9.0 \times 365)} = 2.1E-05$ (2.06E-05) ✓

Adult - Upper bound

$EAC = \frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 365 \times 30}{1.25 \times 2.4E+01 \times (30 \times 365)} = 7.5E-05$ ✓

Carcinogenic effects

Adult - Average

$EAC = \frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 9.0}{8.0E-01 \times 2.4E+01 \times (70 \times 365)} = 2.7E-06$

$= 2.7E-03$ ug/m³

(3.21E-05)

Adult - Upper bound

$EAC = \frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 365 \times 30}{1.25 \times 2.4E+01 \times (70 \times 365)} = 3.2E-05$

$= 3.2E-02$ ug/m³

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 9

SIGNATURE _____ DATE _____ CHECKED TRA DATE 9/26/12

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 4 OF 8 SHEETS

Methylene Chloride
City Well 13

Noncarcinogenic effects

Children - Average

EAC = $\frac{2.3E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 5.0}{8.0E-01 \times 24 \times 1E+01 (5.0 \times 365)}$ = 8.6E-06 (8.63E-06)

Children - Upperbound

EAC = $\frac{4.3E-03 \times 6.0E-01 \times 2.5E-01 \times 365 \times 5}{1.25 \times 24 (5.0 \times 365)}$ = 2.2E-05 (2.15E-05)

Adult - Average

EAC = $\frac{2.3E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 9.0}{8.0E-01 \times 24 (9.0 \times 365)}$ = 8.6E-06 (8.63E-06)

Adult - Upperbound

EAC = $\frac{4.3E-03 \times 6.0E-01 \times 2.5E-01 \times 365 \times 30}{1.25 \times 24 (30 \times 365)}$ = 2.2E-05 (2.15E-05)

Carcinogenic effects

Adult - Average

EAC = $\frac{2.3E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 9}{8.0E-01 \times 24 (70 \times 365)}$ = 1.1E-06 (1.11E-06)

= 1.1E-03 ug/m3

Adult Upperbound

EAC = $\frac{4.3E-03 \times 6.0E-01 \times 2.5E-01 \times 365 \times 30}{1.25 \times 24 (70 \times 365)}$ = 9.2E-06 (9.2E-06)

= 9.2E-03 ug/m3

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 9

SIGNATURE _____ DATE _____ CHECKED REJ DATE 9/6/7-12

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 5 OF 8 SHEETS

Risk Characterization

Methylene Chloride HI = EAC / RFD

Base Well 18

Children Average

HI = $\frac{2.1E-05\ (2.06E-05)}{3.0}$ = 6.9E-06

Children - Upper Bound

HI = $\frac{7.5E-05}{3.0}$ = 2.5E-05

Adult Average

HI = $\frac{2.1E-05\ (2.06E-05)}{3.0}$ = 6.9E-06

Adult - Upper Bound

HI = $\frac{7.5E-05}{3.0}$ = 2.5E-05

Carcinogenic effects TPR = EAC X Unit Risk

Adult - Average

TPR = 2.7E-03 X 4.2E-06 = 1.1E-08

Adult - Upper Bound

TPR = 3.2E-02 X 4.7E-06 = 1.3E-07

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 9

SIGNATURE _____ DATE _____ CHECKED TCG DATE 9/26/12

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 6 OF 8 SHEETS

Risk Characterization

Methylene Chloride HI = EAC / RfD

City Well 13.2

Children - Average

HI = 8.6E-06 / 3.0 = 2.9E-06

Children - Upper bound

HI = (2.1E-05) 2.2E-05 / 3.0 = 7.2E-06

Adult - Average

HI = 8.6E-06 / 3.0 = 2.9E-06

Adult - Upper bound

HI = (2.1E-05) 2.2E-05 / 3.0 = 7.2E-06

Carcinogenic effects TPR = EAC x Unit Risk

Adult - Average

TPR = 1.1E+03 x 4.1E-06 = 4.5E-09

Adult - Upper bound

TPR = 9.2E-03 x 4.1E-06 = 3.8E-08

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 9

SIGNATURE _____ DATE _____ CHECKED REA DATE [illegible]

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 7 OF 8 SHEETS

Risk Characterization
Carbon Tetrachloride

Noncarcinogenic effects

Hazard Index (HI) = ~~Intake/oral RfD~~

Base Well 18

Child Average

HI = $\frac{8.3E-06}{7.0E-04}$ = 1.2E-02

Child Upperbound

HI = $\frac{3.3E-05}{7.0E-04}$ = 4.7E-02

Adult Average

HI = $\frac{1.9E-06}{7.0E-04}$ = 2.7E-03

Adult Upperbound

HI = $\frac{7.6E-06}{7.0E-04}$ = 1.1E-02

City Well 132

Child Average

HI = $\frac{9.4E-07}{7.0E-04}$ = 1.3E-03

Child Upperbound

HI = $\frac{3.7E-06}{7.0E-04}$ = 5.3E-03

Adult Average

HI = $\frac{2.2E-07}{7.0E-04}$ = 3.1E-04

Adult Upperbound

HI = $\frac{8.4E-07}{7.0E-04}$ = 1.2E-03

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 9

SIGNATURE _____ DATE _____ CHECKED EJ DATE 5/20/92

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 8 OF 8 SHEETS

Risk Characterization

Carbon tetrachloride

Carcinogenic effects TPR = Intake X SF

Base Well 18

Adult - Average

TPR = 2.4E-07 X 1.3E-01 = 3.1E-08

Adult - Upper bound

TRR - 3.3E-06 X 1.3E-01 = 4.3E-07

City Well

Adult - Average

TPR - 2.8E-08 X 1.3E+0 = 3.6E-09

Adult - Upper bound

TPR = 3.6E-07 X 1.3E-01 4.7E-08

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 10

SIGNATURE Jan Beck DATE 5/14/90 CHECKED TEJ DATE 5/17/90

PROJECT McClellan AFB JOB NO.

SUBJECT Inhalation of Vapor Phase Chemicals while SHEET 1 OF 4 SHEETS
showering w/ residential water - chronic - 3yr time of duty

Intake (mg/kg-day) = $\frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$

Noncarcinogenic effects

Methylene Chloride

Base Well 13

Variables

Intake = $\frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 3.65 \times 3.0}{16 (3.0 \times 365)}$ = 2.5E-05 (2.48E-05)

Children - Upper bound

Intake = $\frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 365 \times 3.0}{16 (3.0 \times 365)}$ = 1.4E-04 (1.41E-04)

Adult - Average

Intake = $\frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 3.0}{70 (3.0 \times 365)}$ = 5.7E-06 (5.66E-06)

Adult - Upper bound

Intake = $\frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 365 \times 3.0}{70 (3.0 \times 365)}$ = 3.2E-05 (3.21E-05)

Carcinogenic effects

adult - Average

Intake = $\frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 3.0}{70 (70 \times 365)}$ = 2.4E-07

Adult - Upper bound

Intake = $\frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 365 \times 3.0}{70 (70 \times 365)}$ = 1.4E-06 (1.38E-06)

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 10

SIGNATURE _____ DATE _____ CHECKED REJ DATE 9.C712

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 4 SHEETS

(mg/m³)

Effective Air Conc. (EAC) = $\frac{CA \times IRS \times ET \times EF \times ED}{IRD \times CF \times AT}$

Noncarcinogenic effects

Methylene Chloride

Base Well 15

Children - Average

EAC = $\frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 3.0}{8.0E-01 \times 24 (3.0 \times 365)}$ = 2.1E-05 (2.06E-05)

Children - Upper bound

EAC = $\frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 365 \times 3.0}{1.25 \times 24 (3.0 \times 365)}$ = 7.5E-05

Adult - Average

EAC = $\frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 3.0}{8.0E-01 \times 24 (3.0 \times 365)}$ = 2.1E-05 (2.06E-05)

Adult - Upper bound

EAC = $\frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 365 \times 3.0}{1.25 \times 24 (3.0 \times 365)}$ = 7.5E-05.

Carcinogenicity

Adult - Average

EAC = $\frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 365 \times 3.0}{8.0E-01 \times 24 (70 \times 365)}$ = 8.8E-07 (8.84E-07)

= 8.8E-04 ug/m³

Adult - Upper bound

EAC = $\frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 365 \times 3.0}{1.25E+00 \times 24 (70 \times 365)}$ = 3.2E-06 (3.21E-06)

= 3.2E-03 ug/m³

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 10

SIGNATURE _____ DATE _____ CHECKED [illegible] DATE 9/27/12

PROJECT _____ JOB NO _____

SUBJECT _____ SHEET 3 OF 21 SHEETS

Risk Characterization

Noncarcinogenic effects Hazard Index = EAC mg/m^3 / RFD mg/m^3

Methylene Chloride

Base Well 18

Children - Average

HI = $\frac{2.1E-05}{3.0}$ (2.06E-05) = 6.9E-06

Children - Upper bound

HI = $\frac{7.5E-05}{3.0}$ = 2.5E-05

Adult Average

HI = $\frac{2.1E-05}{3.0}$ (2.06E-05) = 6.9E-06

Adult - Upper bound

HI = $\frac{7.5E-05}{3.0}$ = 2.5E-05

Carcinogenic effects TPR = EAC ug/m^3 * Unit risk ug/m^3

Adult - Average

TPR = 8.8E-04 X 4.1E-06 = 3.6E-09

Adult - Upper bound

TPR = 3.2E-03 X 4.1E-06 = 1.3E-08

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 10

SIGNATURE _____ DATE _____ CHECKED [illegible] DATE 5/6/12

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 4 OF 4 SHEETS

Risk Characterization

Carbon tetrachloride

Base Well 18 mg/kg-day mg/kg/day

Carcinogenic effects TPR = Intake X SF

Adult - Average

TPR = 8.2E-08 X 1.3E-01 = 1.1E-08

Adult - Upperbound

TPR = 3.3E-07 X 1.3E-01 = 4.3E-08

Noncarcinogenic effects Hazard Index (HI) = intake dose/oral RfD

Base Well 18

Child Average

HI = 8.3E-06 / 7.0E-03 = 1.2E-03

Child Upperbound

HI = 3.3E-05 / 7.0E-03 = 4.7E-03

Adult Average

HI = 1.9E-06 / 7.0E-03 = 2.7E-04

Adult Upperbound

HI = 7.6E-06 / 7.0E-03 = 1.1E-03

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 11

SIGNATURE Jan Beck DATE 5/11/90 CHECKED [illegible] DATE 9/17/12

PROJECT McClellan AFB JOB NO.

SUBJECT Inhalation exposure due to use of water SHEET 1 OF 2 SHEETS
while showering w/ residential water - subchronic

(mg/m³)

Effective air conc = CA x IRS x ET x EF x ED / IRD x CF x AT
(EAC)

Methylene Chloride
Base Well 18
Noncancer chronic effects
Children - Average / Adult Average

EAC = $\frac{5.5E-03 \times 6.0E-01 \times 1.2E-01 \times 30 \times 1.0}{8.0E-01 \times 24 \times (30)}$ = 2.1E-05 (2.06E-05)

Children: Upperbound / Adult Upperbound

EAC = $\frac{1.5E-02 \times 6.0E-01 \times 2.5E-01 \times 30 \times 1.0}{1.25 \times 24 \times (30)}$ = 7.5E-05

Risk Characterization Hazard Index = $\frac{EAC}{RfDs}$

Child Average / Adult Average

HI = $\frac{2.1E-05}{3.0}$ = 6.9E-06 (5.04E-06)

Child Upperbound / Adult Upperbound

HI = $\frac{7.5E-05}{3.0}$ = 2.5E-05

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 11

SIGNATURE _____ DATE _____ CHECKED TEJ DATE 7-30-

PROJECT _____ JOB NO _____

SUBJECT _____ SHEET 2 OF 2 SHEETS

Intake (mg/kg day) = (CA x IR x ET x EF x ED)/(BW x AT)

Methylene Chloride

Base Well 18

Noncarcinogenic effects

Child average

Intake = $\frac{5.5E-03 \times 2.6 \times .12 \times 30 \times 1}{16 \times 30}$ = 2.5E-05 (2.48E-05)

Child upperbound

Intake = $\frac{1.5E-02 \times 0.6 \times .25 \times 30 \times 1}{16 \times 30}$ = 1.4E-04

Adult Average

Intake = $\frac{5.5E-03 \times 0.6 \times .12 \times 30 \times 1}{70 \times 30}$ = 5.7E-06 (5.66E-06)

Adult Upperbound

Intake = $\frac{1.5E-02 \times 0.6 \times .25 \times 30 \times 1}{70 \times 30}$ = 3.2E-05 (3.2E-05)

Risk Characterization - Carbon tetrachloride

Hazard Index (HI) = intake/oral RfDs

Child Average

HI = $\frac{8.3E+06}{7.0E+05}$ = 1.2E-03

Child Upperbound

HI = $\frac{3.3E-05}{7.0E-03}$ = 4.7E-03

Adult Average

HI = $\frac{1.9E-06}{7.0E-03}$ = 2.7E-04

Adult Upperbound

HI = $\frac{7.6E-06}{7.0E-03}$ = 1.1E-03

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 12

SIGNATURE Jan Beck DATE 7/5/90 CHECKED RCG DATE 9/6/90

PROJECT McClellan AFB EE/CA HRA JOB NO.

BW-18

SUBJECT Inhalation of vapor phase Chemicals while using a washing machine with residential water - Chronic SHEET 1 OF 6 SHEETS

Intake (mg/kg-day) = (CA x IR x EF x ED)/(BW x AT)

Methylene Chloride

Base Well 18

Noncarcinogenic effects

Children Average

Intake = CA x $\frac{0.8\ m^3/hour \times 3.12\ days/year \times 5.0\ years}{16\ kg \times (5\ years \times 365\ days/year)}$

= CA x 0.043 m^3/hour · kg

= $(3.1E\text{-}04\ mg/m^3 \times 0.58\ \frac{hours}{day} \times 0.043\ m^3/hour \cdot kg) +$

$(1.6E\text{-}04\ mg/m^3 \times 1.5\ \frac{hours}{day} \times 0.043\ m^3/hour \cdot kg)$

= 7.7E-06 mg/kg-day + 1.0E-05 mg/kg-day = 1.8E-05 mg/kg-day

Children Upper (round)

Intake = CA x $\frac{2.0 \times 468 \times 5.0}{16 \times (5 \times 365)}$ = CA x 0.16

= (4.3E-04 x 0.58 x 0.16) + (2.2E-04 x 1.5 x 0.16)

= 9.3E-05 mg/kg-day

Adult Average

Intake = CA x $\frac{0.6 \times 312 \times 9}{70 \times (9 \times 365)}$ = CA x 0.00733

= (3.1E-04 x 0.58 x 0.00733) + (1.6E-04 x 1.5 x 0.00

= 3.1E-06

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 12

SIGNATURE _____ DATE _____ CHECKED TCP DATE 6/--/-

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 6 SHEETS

Adult Upperbound

Intake = CA x 2.1 x 468 x 30 = CA x 0.038
70 x (30 x 365)

= (4.3E-04 x 0.038 x 0.58) + (2.2E-04 x 1.5 x 0.0

= 2.3E-05 ✓

Carcinogenic Effects

Adult Average

Intake CA x .6 x 312 x 9 = CA x 9.4E-04
70 x (70 x 365)

= (3.1E-04 x 0.58 x 9.4E-04) + (1.6E-04 x 1.5 x 9.4-04)

= 4.0E-07 ✓

Adult Upperbound

Intake = CA x 2.1 x 468 x 30 = CA x 0.0165
70 x 70 x 365

= (4.3E-04 x 0.58 x 0.0165) + (2.2E-04 x 1.5 x 0.0165) ✓

= 9.6E-06

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 12

SIGNATURE _____ DATE _____ CHECKED JH DATE 7/12/90

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 3 OF 6 SHEETS

Base Well 18

Effective Air Conc EAC), (mg/m^3) = $\frac{CA \times IRS \times EF \times ED}{IRD \times CF \times AT}$

Methylene Chloride

Child Average

EAC = CA x 0.8 m^3/hr x 312 days/year x 5 years
0.8 m^3/hour x 24 hour/day x 5.0 years x 365 days/year

EAC = CA x 0.036 $\frac{days}{hour}$ = (3.1E-04 $\frac{mg}{m^3}$ x 0.036 $\frac{days}{hour}$ x 0.58 $\frac{Hour}{day}$) + (1.6E-04 x 1.5 x 0.03

= 1.5E-05 mg/m^3 ✓

Child Upper bound

EAC = CA x 2.0 x 468 x 5.0 = CA x 0.089 = (4.3E-04 x 0.58 x 0.089) + (2.2E-04 x 1.5 x 0.089
1.2 x 24 x 5 x 365 = 5.1E-05 ✓

Adult Average

EAC = CA x 0.6 x 312 x 9.0 = CA x 0.0267 = (3.1E-04 x 0.58 x 0.0267) + (1.6E-04 x 1.5 x 0.02
0.8 x 24 x 9 x 365

= 1.1E-05 ✓

Adult Upperbound

EAC = CA x 2.1 x 468 x 30 = CA x 0.0935 = (4.3E-04 x 0.58 x 0.0935) + (2.2E-04 x 1.5 x 0.0
1.2 x 24 x 30 x 365

= 5.3E-05 ✓

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 12

SIGNATURE _____ DATE _____ CHECKED JH DATE 7/13/90

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 4 OF 6 SHEETS

Base Well 18

Carcinogenic effects

Methylene Chloride

Adult Average

$EAC = \frac{CA \times 0.6 \times 312 \times 9}{0.8 \times 24 \times 70 \times 365} = CA \times 0.0034 = (3.1E-04 \times 0.58 \times 0.0034) + (1.6E-04 \times 1.5 \times 0.003$

$= 1.4E-06\ mg/m^3 = 1.4E-03\ ug/m^3$ ✓

Adult - Upperbound

$EAC = \frac{CA \times 2.1 \times 468 \times 30}{1.2 \times 24 \times 70 \times 365} = CA \times 0.04 = (4.3E-04 \times 0.58 \times 0.04) + (2.2E-04 \times 1.5 \times 0.0$

$= 2.3E-05 = 2.3E-02\ ug/m^3$ ✓

Risk Characterization - Methylene Chloride

Noncarcinogenic Effects

Hazard Index (HI) = EAC / RfD

Child Average

$HI = \frac{1.5E-05\ mg/m^3}{3.0E+00\ mg/m^3} = 5.0E-06$ ✓

Child Upperbound

$HI = \frac{5.1E-05}{3.0} = 1.7E-05$ ✓

Adult Average

$HI = \frac{1.1E-05}{3.0} = 3.7E-06$ ✓

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 12

SIGNATURE _____ DATE _____ CHECKED JH DATE 7/13/90

PROJECT _____ JOB NO _____

SUBJECT _____ SHEET 5 OF 6 SHEETS

Adult Upperbound

HI = 5.3E-05 / 3.0 = 1.7E-05

Carcinogenic Effects
Methylene Chloride

Total Pathway Risk (TPR) = EAC x Unit Risk

Adult Average

TPR = 1.4E-03 $\frac{ug}{m^3}$ x 4.6E-06 $\frac{1}{ug/m^3}$ = 5.8E-09

Adult Upperbound

TPR = 2.3E-02 x 4.1E-06 = 9.3E-08

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 12

SIGNATURE _____ DATE _____ CHECKED JH DATE 7/21/95

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 6 OF 6 SHEETS

Risk Characterization - Carbon tetrachloride

Noncarcinogenic Effects

Hazard Index (HI): Intake dose / oral RfD

Child Average

$HI = \frac{5.9E-06 \text{ mg/kg-day}}{7.0E-04 \text{ mg/kg-day}} = 8.4E-03$

Child Upperbound

$HI = \frac{2.2E-05}{7.0E-04} = 3.1E-02$

Adult Average

$HI = \frac{1.0E-06}{7.0E-04} = 1.4E-03$

Adult Upperbound

$HI = \frac{5.3E-06}{7.0E-04} = 7.6E-03$

Carcinogenic Effects - Carbon tetrachloride

Total Pathway Risk (TPR): Intake Dose X Inhalation Slope Factor

Adult Average

$TPR = 1.3E-07 \text{ mg/kg-day} \times 1.3E-01 \left\| \frac{1}{\text{mg/kg-day}} \right\| = 1.7E-08$

Adult Upperbound

$TPR = 2.3E-06 \times 1.3E-01 = 3.0E-07$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 13

SIGNATURE Jana Beck DATE 7/6/90 CHECKED EH DATE 7/13/90

PROJECT McClellan AFB EE/CA HRA JOB NO.

CW-132 SUBJECT Inhalation of vapor phase chemicals while using a washing machine w/residential water chu SHEET 1 OF 4 SHEETS

Intake (mg/kg-day) = (CA x IR x EF x ED)/(BW x AT)

Methylene Chloride
City Well 132

Noncarcinogenic Effects
Child Average

Intake = CA x .8 x 312 x 5 / 16 x 5 x 365 = CA x 0.043 = (1.3E-04 x 0.58 x 0.043) + (6.3E-05 x 1.5 x 0.04
= 7.3E-06 ✓

Child Upperbound

Intake = CA x 2 x 468 x 5 / 16 x 5 x 365 = CA x 0.16 = (1.3E-04 x 0.58 x 0.16) + (6.3E-05 x 1.5 x 0.16)
= 2.7E-05 ✓

Adult Average

Intake = CA x 0.6 x 312 x 9 / 70 x (9 x 365) = CA x 0.023 = (1.3E-04 x 0.58 x 0.023) + (6.3E-05 x 1.5 x 0.023)
= 1.2E-06 ✓

Adult Upperbound

Intake = CA x 2.1 x 468 x 30 / 70 x (30 x 365) = CA x 0.038 = (1.3E-04 x 0.58 x 0.038) + (6.3E-05 x 1.5 x 0.038)
= 6.5E-06

Carcinogenic effects
Adult Average

Intake = CA x .6 x 312 x 9 / 70 x 70 x 365 = CA x 9.4E-04 = (1.3E-04 x 0.58 x 9.4E-04) + (6.3E-05 x 1.5 x 9.4E-04
= 1.6E-07

Adult Upperbound

Intake = CA x 21 x 468 x 30 / 70 x 70 x 365 = CA x 0.065 = (1.3E-04 x 0.58 x 0.065) + (6.3E-05 x 1.5 x 0.065)
= 2.8E-06 ✓

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 13

SIGNATURE _____ DATE _____ CHECKED JH DATE 7/12/90

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 4 SHEETS

City Well 132

EAC (mg/m³) = (CA X IRS X EFXED) / (IRD X CF X AT)

Methylene Chloride

Child Average

EAC = CA X $\frac{.8 \times 312 \times 5}{.8 \times 24 \times 5 \times 365}$ = CA X 0.036 = (1.3E-04 X 0.58 X 0.036) + (6.3E-05 X 1.5 X 0.036)

= 6.1E-06

Child Upper bound

EAC = CA X $\frac{2 \times 468 \times 5}{1.2 \times 24 \times 5 \times 365}$ = CA X 0.089 = (1.3E-04 X 0.58 X 0.089) + (6.3E-05 X 1.5 X 0.089)

= 1.5E-05 ✓

Adult Average

EAC = CA X $\frac{0.6 \times 312 \times 9}{0.8 \times 24 \times 9 \times 365}$ = CA X 0.0267 = (1.3E-04 X 0.58 X 0.0267) + (6.3E-05 X 1.5 X 0.026)

= 4.5E-06

Adult Upper bound

EAC = CA X $\frac{2.1 \times 468 \times 30}{1.2 \times 24 \times 30 \times 365}$ = CA X 0.0935 = (1.3E-04 X 0.58 X 0.0935) + (6.3E-05 X 1.5 X 0.0935)

= 1.6E-05 ✓

Carcinogenic effects

Adult - Average

EAC = CA X $\frac{0.6 \times 312 \times 9}{0.8 \times 24 \times 70 \times 365}$ = CA X 0.0034 = (1.3E-04 X 0.58 X 0.0034) + (6.3E-05 X 1.5 X 0.0034)

= 5.8E-07 mg/m³ = 5.8E-04 ug/m³

Adult Upper bound

EAC = CA X $\frac{2.1 \times 468 \times 30}{1.2 \times 24 \times 70 \times 365}$ = CA X 0.04 = (1.3E-04 X 0.58 X 0.04) + (6.3E-05 X 1.5 X 0.04)

= 6.8E-06 = 6.8E-03 ug/m³

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 13

SIGNATURE _____ DATE _____ CHECKED JH DATE 7/13/90

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 3 OF 4 SHEETS

Risk Characterization - Methylene Chloride CW-132

Noncarcinogenic effects

Hazard index (HI) = EAC/RFD

Child Average

$HI = \frac{6.1E-06}{3.0} = 2.0E-06$

Child Upperbound

$HI = \frac{1.5E-05}{3.0} = 5.0E-06$

Adult Average

$HI = \frac{4.5E-06}{3.0} = 1.5E-06$

Adult Upper Bound

$HI = \frac{1.6E-05}{3.0} = 5.3E-06$

Carcinogenic Effects

Total Pathway Risk (TPR) = EAC X Unit Risk

Adult Average

$TPR = 5.8E-04 \times 4.1E-06 \approx 2.4E-09$

Adult Upperbound

$TPR = 6.8E-03 \times 4.1E-06 = 2.8E-08$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 13

SIGNATURE _____ DATE _____ CHECKED JH DATE 7/13/90

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 4 OF 4 SHEETS

Risk Characterization - Carbon tetrachloride

Noncarcinogenic effects

Hazard Index (HI) = Intake dose / oral RfD

Child Average

HI = 6.5E-07 mg/kg-day = 9.3E-04
7.0E-04 mg/kg-day

Child Upperbound

HI = 2.4E-06 = 3.4E-03
7.0E-04

Adult Average

HI = 1.1E-07 = 1.6E-04
7.0E-04

Adult Upperbound

HI = 5.9E-07 = 8.4E-04
7.0E-04

Carcinogenic effects - Carbon tetrachloride

Total pathway risk (TPR) = intake dose x inhal. slope factor

Adult Average

TPR = 1.4E-08 mg/kg-day x 1.3E-01 $\frac{1}{\text{mg/kg-day}}$ = 1.8E-09

Adult Upperbound

TPR = 2.5E-07 x 1.3E-01 = 3.3E-08

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 14

SIGNATURE Jan Beck DATE 7/6/90 CHECKED TH DATE 7/10/90

PROJECT McClellan AFB JOB NO.

SUBJECT Inhalation of Vapor Phase - 3yr tour - BW-18 SHEET 1 OF 4 SHEETS
Chemicals while using a washing machine w/ residential water

Intake (mg/kg-day) = (CA x IR x EF x ED) / (BW x AT)

Methylene Chloride
BW-18
Noncarcinogenic effects

Child Average
Intake = CA x .8 x 312 x 3 / 16 x 3 x 365 = CA x 0.043 = (3.1E-04 x 0.58 x 0.043) + (1.6E-04 x 1.5 x 0.04)
= 1.8E-05 ✓

Child Upperbound
Intake = CA x 2.0 x 468 x 3 / 16 x 3 x 365 = CA x 0.16 = (4.3E-04 x 0.58 x 0.16) + (2.2E-04 x 1.5 x 0.16)
= 9.3E-05 ✓

Adult Average
Intake = CA x .6 x 312 x 3 / 70 x 3 x 365 = CA x 0.0073 = (3.1E-04 x 0.58 x 0.0073) + (1.6E-04 x 1.5 x 0.008)
= 3.1E-06 ✓

Adult Upperbound
Intake = CA x 2.1 x 468 x 3 / 70 x 3 x 365 = CA x 0.038 = (4.3E-04 x 0.58 x 0.038) + (2.2E-04 x 1.5 x 0.038)
= 2.2E-05 ✓

Carcinogenic Effects
Adult Average
Intake = CA x .6 x 312 x 3 / 70 x 70 x 365 = CA x 0.00031 = (3.1E-04 x 0.58 x 0.00031) + (1.6E-04 x 1.5 x 0.00031)
= 1.3E-07 = 1.3E-04 ug/m³ ✓

Adult Upperbound
Intake = CA x 2.1 x 468 x 3 / 70 x 70 x 365 = CA x 0.0016 = (4.3E-04 x 0.58 x 0.0016) + (2.2E-04 x 1.5 x 0.0016)
= 9.5E-07 = 9.5E-04 ug/m³ ✓

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 14

SIGNATURE _____ DATE _____ CHECKED JH DATE 7/12/91

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 4 SHEETS

EAC (mg/m³) = CA x IRS x EF x ED / IRD x CF x AT

Methylene chloride

Bw 1.80

Noncarcinogenic effects

Child Average

EAC = CA x .8 x 312 x 3 / .8 x 24 x 3 x 365 = CA x 0.036 = (3.1E-04 x 0.58 x 0.036) + (1.6E-04 x 1.5 x 0.0

= 1.5E-05

Child Upperbound

EAC = CA x 2 x 468 x 3 / 1.2 x 24 x 3 x 365 = CA x 0.089 = (4.3E-04 x 0.58 x 0.089) + (2.2E-04 x 1.5 x 0.0

= 5.1E-05

Adult Average

EAC = CA x .6 x 312 x 3 / .8 x 24 x 3 x 365 = CA x 0.027 = (3.1E-04 x 0.58 x 0.027) + (1.6E-04 x 1.5 x 0.02

= 1.1E-05

Adult Upperbound

EAC = CA x 2.1 x 468 x 3 / 1.2 x 24 x 3 x 365 = CA x 0.093 = (4.3E-04 x 0.58 x 0.093) + (2.2E-04 x 1.5 x 0.04

= 5.4E-05

Carcinogenic effects

Adult Average

EAC = CA x .6 x 312 x 3 / .8 x 24 x 70 x 365 = CA x 0.0011 = (3.1E-04 x 0.58 x 0.0011) + (1.6E-04 x 1.5 x 0.0

= 4.6E-07 = 4.6E-04 ug/m³

Adult Upperbound

EAC = CA x 2.1 x 468 x 3 / 1.2 x 24 x 70 x 365 = CA x 0.004 = (4.3E-04 x 0.58 x 0.004) + (2.2E-04 x 1.5 x 0.0

= 2.3E-06 = 2.3E-03 ug/m³

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 14

SIGNATURE _____ DATE _____ CHECKED JA DATE 7/13/94

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 3 OF 4 SHEETS

Risk Characterization - Methylene Chloride

Noncarcinogenic effects

Hazard Index (HI) = EAC / RFD

Child Average

$HI = \frac{1.5E-05}{3.0} = 5.0E-06$

Child Upperbound

$HI = \frac{5.1E-05}{3.0} = 1.7E-05$

Adult Average

$HI = \frac{1.1E-05}{3.0} = 3.7E-06$

Adult Upperbound

$HI = \frac{5.4E-05}{3.0} = 1.8E-05$

Carcinogenic Effects: Methylene Chloride

Total Pathway Risk (TPR) = EAC x Unit Risk

Adult Average

$TPR = 4.6E-04 \times 4.1E-06 = 1.9E-09$

Adult Upperbound

$TPR = 2.3E-03 \times 4.1E-06 = 9.4E-09$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 14

SIGNATURE _____ DATE _____ CHECKED JH DATE 7/13/90

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 4 OF 4 SHEETS

Risk Characterization - Carbon tetrachloride

Noncarcinogenic effects

HI = intake dose / oral RFDs

Child Average

$HI = \frac{5.9E-06 \text{ mg/kg-day}}{7.0E-03 \text{ mg/kg-day}} = 8.4E-04$

Child Upperbound

$HI = \frac{2.2E-05}{7.0E-03} = 3.1E-03$

Adult Average

$HI = \frac{1.0E-06}{7.0E-03} = 1.4E-04$

Adult Upperbound

$HI = \frac{5.3E-06}{7.0E-03} = 7.6E-04$

Carcinogenic effects - Carbon tetrachloride

TPR = intake dose X inhalation slope factor

Adult Average

$TPR = 4.3E-08 \text{ mg/kg-day} \times 1.3E-01 \frac{1}{\text{mg/kg-day}} = 5.6E-09$

Adult Upperbound

$TPR = 2.3E-07 \times 1.3E-01 = 3.0E-08$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 15

SIGNATURE Jan Beck DATE 7/6/90 CHECKED JH DATE 7/12/90

PROJECT McClellan AFB JOB NO.

SUBJECT Inhalation of Vapor Phase Chemicals SHEET 1 OF 3 SHEETS
while using a washing machine - Subchronic - BW-18

Intake (mg/kg-day) = $\frac{CA \times IR \times EF \times ED}{BW \times AT}$

Methylene Chloride
Base Well 18
Noncarcinogenic effects

Child Average

Intake = $\frac{CA \times .8 \times 24 \times 1}{16 \times 24 \times 1}$ = CA x 0.05 = (3.1E-04 x 0.58 x 0.05) + (1.6E-04 x 1.5 x 0

= 2.1E-05 ✓

Child - Upperbound

Intake = $\frac{CA \times 2 \times 38 \times 1}{16 \times 30 \times 1}$ = CA x 0.158 = (4.3E-04 x 0.58 x 0.158) + (2.2E-04 x 1.5 x 0.1 ✓

= 9.1E-05

Adult - Average

Intake = $\frac{CA \times .6 \times 24 \times 1}{70 \times 24 \times 1}$ = CA x 0.0086 = (3.1E-04 x 0.58 x 0.0086) + (1.6E-04 x 1.5 x 0.008 ✓

= 3.6E-06

Adult Upperbound

Intake = $\frac{CA \times 2.1 \times 38 \times 1}{70 \times 30 \times 1}$ = CA x 0.038 = (4.3E-04 x 0.58 x 0.038) + (2.2E-04 x 1.5 x 0.038)

= 2.2E-05 ✓

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 15

SIGNATURE _____ DATE _____ CHECKED JH DATE 7/13/90

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 3 SHEETS

$$EAC\ (mg/m^3) = \frac{CA \times IRS \times EF \times ED}{IRD \times CF \times AT}$$

Methylene Chloride
Basel Well 18
Noncarcinogenic effects

Child Average

$EAC = CA \times \frac{.8 \times 24 \times 1}{.8 \times 24 \times 24 \times 1} = CA \times 0.042 = (3.1E-04 \times 0.58 \times 0.042) + (1.6E-04 \times 1.5 \times 0.042$

$= 1.8E-05$ ✓

Child Upperbound

$EAC = CA \times \frac{2.0 \times 38 \times 1}{1.2 \times 24 \times 30 \times 1} = CA \times 0.088 = (4.3E-04 \times 0.58 \times 0.088) + (2.2E-04 \times 1.5 \times 0.088$

$= 5.0E-05$ ✓

Adult Average

$EAC = CA \times \frac{.6 \times 24 \times 1}{.8 \times 24 \times 24 \times 1} = CA \times 0.031 = (3.1E-04 \times 0.58 \times 0.031) + (1.6E-04 \times 1.5 \times 0.031)$

$= 1.3E-05$ ✓

Adult Upperbound

$EAC = CA \times \frac{2.1 \times 38 \times 1}{1.2 \times 24 \times 30 \times 1} = CA \times 0.092 = (4.3E-04 \times 0.58 \times 0.092) + (2.2E-04 \times 1.5 \times 0.092)$

$= 5.2E-05$ ✓

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 15

SIGNATURE _____ DATE _____ CHECKED JH DATE 7/13/90

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 3 OF 3 SHEETS

Risk Characterization - Methylene chloride

Noncarcinogenic Effects

HI = EAC / RfDs

Child average

HI = 1.7E-05 / 3.0 = 5.7E-06

Child Upperbound

HI = 5.2E-05 / 3.0 = 1.7E-05

Adult Average

HI = 1.3E-05 / 3.0 = 4.3E-06

Adult Upperbound

HI = 5.2E-05 / 3.0 = 1.7E-05

Carbon tetrachloride

HI = intake dose / oral RfDs

Child Average

HI = 6.9E-05 / 7.0E-03 = 9.9E-04

Child Upperbound

HI = 2.2E-05 / 7.0E-03 = 3.1E-03

Adult Average

HI = 1.2E-06 / 7.0E-03 = 1.7E-04

Adult Upperbound

HI = 5.2E-06 / 7.0E-03 = 7.4E-04

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 16

SIGNATURE Jan Beck DATE 7/6/90 CHECKED TH DATE 7/13/90

PROJECT McClellan AFB JOB NO.

SUBJECT Inhalation of VOCs from chemicals in groundwater - Circle - City well 132 SHEET 1 OF 4 SHEETS

Intake (mg/kg-day) = (CA x IR x EF x ED) / (BW x AT)

Methylene Chloride

Basis Weight 18

Noncarcinogenic effects

Child Average

Intake = $\frac{4 \times .8 \times 312 \times 5}{16 \times 5 \times 365}$ = CA x 0.043 = (2.4E-05 x 1.2 x 0.043) + (1.6E-05 x 0.8 x 0.04)

= 1.8E-06

Child Upperbound

Intake = $\frac{CA \times 20 \times 468 \times 5}{16 \times 5 \times 365}$ = CA x 0.16 = (2.4E-05 x 1.2 x 0.16) + (1.6E-05 x 0.8 x 0.16)

= 6.6E-06

Adult Average

Intake = $\frac{CA \times 0.6 \times 312 \times 9}{70 \times 9 \times 365}$ = CA x 0.00733 = (2.4E-05 x 1.2 x 0.00733) + (1.6E-05 x 0.8 x 0.00733)

= 3.0E-07

Adult Upperbound

Intake = $\frac{CA \times 2.1 \times 468 \times 30}{70 \times 30 \times 365}$ = CA x 0.038 = (2.4E-05 x 1.2 x 0.038) + (1.6E-05 x 0.8 x 0.038)

= 1.6E-06

Carcinogenic effects

Adult Average

Intake = $\frac{CA \times .6 \times 312 \times 9}{70 \times 70 \times 365}$ = CA x 9.4E-04 = (2.4E-05 x 1.2 x 9.4E-04) + (1.6E-05 x 0.8 x 9.4E-

= 3.9E-08

Adult Upperbound

Intake = $\frac{CA \times 2.1 \times 468 \times 30}{70 \times 70 \times 365}$ = CA x 0.0165 = (2.4E-05 x 1.2 x 0.0165) + (1.6E-05 x 0.8 x C.

= 6.8E-07

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 16

SIGNATURE _____ DATE _____ CHECKED JH DATE 7/17/90

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 4 SHEETS

Base Well 18

EAC (mg/m³) = $\frac{CA \times IRS \times EF \times ED}{IRD \times CF \times AT}$

Methylene Chloride

Child Average

EAC = $\frac{CA \times .8 \times 312 \times 5}{.8 \times 24 \times 5 \times 365}$ = CA x 0.036 = (2.4E-05 x 1.2 x 0.036) + (1.6E-05 x 0.8 x 0.0

= 1.5E-06 ✓

Child Upperbound

EAC = $\frac{CA \times 2.0 \times 468 \times 5}{1.2 \times 24 \times 365 \times 5}$ = CA x 0.089 = (2.4E-05 x 1.2 x 0.089) + (1.6E-05 x 0.8 x 0.089)

= 3.6E-06

Adult Average

EAC = $\frac{CA \times 0.6 \times 312 \times 9}{0.5 \times 24 \times 9 \times 365}$ = CA x 0.0367 = (2.4E-05 x 1.2 x 0.036) + (1.6E-05 x 0.8 x 0.036)

= 1.1E-06 ✓

Adult Upperbound

EAC = $\frac{CA \times 2.1 \times 468 \times 30}{1.2 \times 24 \times 30 \times 365}$ = CA x 0.0935 = (2.4E-05 x 1.2 x 0.0935) + (1.6E-05 x 0.8 x 0.09

= 3.8E-06 ✓

Carcinogenic effects

Adult Average

EAC = $\frac{CA \times 0.6 \times 312 \times 9}{0.8 \times 24 \times 76 \times 365}$ = CA x 0.0084 = (2.4E-05 x 1.2 x 0.0034) + (1.6E-05 x 0.8 x 0.003

= 1.4E-07 = 1.4E-04 ug/m³ ✓

Adult Upperbound

EAC = $\frac{CA \times 2.1 \times 468 \times 30}{1.2 \times 24 \times 70 \times 365}$ = CA x 0.04 = (2.4E-05 x 1.2 x 0.04) + (1.6E-05 x 0.8 x 0.04)

= 1.7E-06 = 1.7E-03 ug/m³ ✓

10 88 20722

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 16

SIGNATURE _____ DATE _____ CHECKED TEG DATE 9/20/93

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 3 OF 4 SHEETS

Risk Characterization
Methylene Chloride
Noncarcinogenic effects

Hazard Index (HI) = EAC / RfD;

Child Average

$HI = \frac{1.5E-06}{3.0} = 5.0E-07$

Child Upperbound

$HI = \frac{3.7E-06}{3.0} = 1.2E-06$

Adult Average

$HI = \frac{1.1E-06}{3.0} = 3.7E-07$

Adult Upperbound

$HI = \frac{3.8E-06}{3.0} = 1.3E-06$

Carcinogenic effects

Total Pathway Risk (TPR) = EAC x Unit Risk

Adult Average

TPR = 1.4E-04 X 4.1E-06 = 5.7E-10

Adult Upperbound

TPR = 1.7E-03 X 4.1E-06 = 6.9E-09

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 16

SIGNATURE _____ DATE _____ CHECKED TES DATE 9/27/13

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 4 OF 4 SHEETS

Risk Characterization

Carbon Tetrachloride

Noncarcinogenic effects

Hazard Index (HI) = Intake dose / oral RfD

Child Average

$HI = \frac{1.6E-07}{7.0E-04} = 2.3E-04$

Child Upperbound

$HI = \frac{6.0E-07}{7.0E-04} = 8.6E-04$

Adult Average

$HI = \frac{2.8E-08}{7.0E-04} = 4.0E-05$

Adult Upperbound

$HI = \frac{1.4E-07}{7.0E-04} = 2.0E-04$

Carcinogenic effects

Total Pathway Risk (TPR) = intake dose X inhalation SF

Adult Average

$TPR = 3.5E-09 \times 1.3E-01 = 4.6E-10$

Adult Upperbound

$TPR = 6.2E-08 \times 1.3E-01 = 8.1E-09$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 17

SIGNATURE Joan Beck DATE 7/8/90 CHECKED TEJ DATE 900713

PROJECT McClellan AFB HRA JOB NO.

SUBJECT Inhalation of Vapor Phase Chemicals while using a dishwasher with residential water - Base well 18 SHEET 1 OF 4 SHEETS

Intake (mg/kg-day) = (CA x IR x EF x ED)/(BW x AT)

Methylene Chloride

BW-18

Noncarcinogenic Effects

Child Average

Intake = CA x .8 x 312 x 5 / 16 x 5 x 365 = CA x 0.043 = (5.9E-05 x 1.2 x 0.043) + (3.8E-05 x .8 x 0.043)

= 1.3E-06

Child Upperbound

Intake = CA x 2 x 468 x 5 / 16 x 5 x 365 = CA x 0.16 = (8.3E-05 x 1.2 x 0.16) + (5.4E-05 x .8 x 0.1

= 2.3E-05

Adult Average

Intake = CA x 8.6 x 312 x 9 / 70 x (9 x 365) = CA x 0.023 = (5.9E-05 x 1.2 x 0.023) + (3.8E-05 x .8 x 0.007

= 7.4E-07

Adult Upperbound

Intake = CA x 2.1 x 468 x 30 / 70 x 30 x 365 = CA x 0.038 = (8.3E-05 x 1.2 x 0.038) + (5.4E-05 x .8 x 0.03

= 5.4E-06

Carcinogenic effects

Adult Average

Intake = CA x .6 x 312 x 9 / 70 x 70 x 365 = CA x 9.4E-04 = (5.9E-05 x 1.2 x 9.4E-04) + (3.8E-05 x .8 x 9.4E-0

= 9.5E-08

Adult Upperbound

1.6E-06

Intake = CA x 2.1 x 468 x 30 / 70 x 70 x 365 = CA x 0.0165 = (8.3E-05 x 1.2 x 0.0165) + (5.4E-05 x .8 x 0

= 2.4E-06

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 17

SIGNATURE _____ DATE _____ CHECKED TCE DATE 5-25-12

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 4 SHEETS

Base Well 18

EAC (mg/m³) = (CA x IRS x EF x ED)/(IRD x CF x AT)

Methylene chloride

Child Average

EAC = CA x (.8 x 312 x 5)/(.8 x 24 x 5 x 365) = CA x 0.036 = (5.9E-05 x 1.2 x 0.036) + (3.8E-05 x .8 x 0.036)

= 2.6E-06

Child Upperbound

EAC = CA x (2 x 468 x 5)/(1.2 x 24 x 5 x 365) = CA x 0.089 = (8.3E-05 x 1.2 x 0.089) + (5.4E-05 x .8 x 0.089)

= 1.3E-05

Adult Average

EAC = CA x (.6 x 312 x 9)/(.8 x 24 x 9 x 365) = CA x 0.0267 = (5.9E-05 x 1.2 x 0.0267) + (3.8E-05 x .8 x 0.0267)

= 2.7E-06

Adult Upperbound

EAC = CA x (2.1 x 468 x 30)/(1.2 x 24 x 30 x 365) = CA x 0.0935 = (8.3E-05 x 1.2 x 0.0935) + (5.4E-05 x .8 x 0.0935)

= 1.3E-05

Carcinogenic effects

Adult Average

EAC = CA x (.4 x 312 x 9)/(.8 x 24 x 70 x 365) = CA x 0.0034 = (5.9E-05 x 1.2 x 0.0034) + (3.8E-05 x .8 x 0.0034)

= 3.4E-07 = 3.4E-04 µg/m³

Adult Upperbound

EAC = CA x (2.1 x 468 x 30)/(1.2 x 24 x 70 x 365) = CA x 0.04 = (8.3E-05 x 1.2 x 0.04) + (5.4E-05 x .8 x 0.04)

= 5.7E-06 = 5.7E-03 µg/m³

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 17

SIGNATURE _____ DATE _____ CHECKED TCJ DATE 7/27/12

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 3 OF 4 SHEETS

Risk Characterization - Methylene Chloride

- Noncarcinogenic Effects

Hazard Index (HI) = EAC/RfD:

Child Average

HI = 3.6E-06 / 3.0 = 1.2E-06

Child Upperbound =

HI = 1.3E-05 / 3.0 = 4.3E-06

Adult Average

HI = 2.7E-06 / 3.0 = 9.0E-07

Adult Upperbound

HI = 1.3E-05 / 3.0 = 4.3E-06

Carcinogenic effects

Total Pathway Risk (TPR) = EAC x Unit Risk

Adult Average

TPR = 3.4E-04 x 4.1E-06 = 1.4E-09

Adult Upperbound

TPR = 5.7E-03 x 4.1E-06 = 2.3E-08

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO 17

SIGNATURE _____ DATE _____ CHECKED TCE DATE 9/2013

PROJECT _____ JOB NO: _____

SUBJECT _____ SHEET 4 OF 4 SHEETS

Risk Characterization - Carbon tetrachloride

Noncarcinogenic effects

Hazard Index (HI) = intake dose/oral RfD

Child Average

HI = 1.4E-06 / 7.0E-04 = 2E-03

Child Upperbound

HI = 5.4E-06 / 7.0E-04 = 7.7E-03

Adult Average

HI = 2.5E-07 / 7.0E-04 = 3.6E-04

Adult Upperbound

HI = 1.3E-06 / 7.0E-04 = 1.9E-03

Carcinogenic effects

Total Pathway Risk (TPR) = intake dose x oral slope factor

Adult Average

TPR = 3.2E-08 x 1.3E-01 = 4.2E-09

Adult Upperbound

TPR = 5.6E-07 x 1.3E-01 = 7.3E-08

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 18

SIGNATURE Jan Beck DATE 7/8/90 CHECKED TEJ DATE 7/20/90

PROJECT McClellan AFB HRA JOB NO.

SUBJECT Inhalation of vapor phase chemicals while showering SHEET 1 OF 4 SHEETS

while 3yrs tours of duty

Intake (mg/kg day) = (CA x IR x EF x ED)/(BW x AT)

Methylene Chloride
EW-18D - 3yr tour of duty
Noncarcinogenic effects

Child Average

Intake = CA x $\frac{8 \times 312 \times 3}{16 \times 3 \times 365}$ CA x 0.043 = (5.9E-05 x 1.2 x 0.043) + (3.8E-05 x .8 x 0.043)

= 4.4E-06

Child Upperbound

Intake = CA x $\frac{2 \times 468 \times 3}{16 \times 3 \times 365}$ CA x 0.16 = (8.3E-05 x 1.2 x 0.16) + (5.4E-05 x .8 x 0.16)

= 2.3E-05

Adult Average

Intake = CA x $\frac{.6 \times 312 \times 3}{70 \times 3 \times 365}$ CA x 0.0073 = (5.9E-05 x 1.2 x 0.0073) + (3.8E-05 x .8 x 0.0073)

= 7.4E-07

Adult Upperbound

Intake = CA x $\frac{2.1 \times 468 \times 3}{70 \times 3 \times 365}$ CA x 0.038 = (8.3E-05 x 1.2 x 0.038) + (5.4E-05 x .8 x 0.038)

= 1.5.4E-06

Carcinogenic effects

Adult Average

Intake = CA x $\frac{.6 \times 312 \times 3}{70 \times 70 \times 365}$ CA x 0.000314 = (5.9E-05 x 1.2 x 0.000314) + (3.8E-05 x .8 x 0.000314

= 3.2E-08

Adult Upperbound

Intake = CA x $\frac{2.1 \times 468 \times 3}{70 \times 70 \times 365}$ CA x 0.0016 = (8.3E-05 x 1.2 x 0.0016) + (5.4E-05 x .8 x 0.0016)

= 2.3E-07

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 18

SIGNATURE _____ DATE _____ CHECKED REJ DATE 90071

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 4 SHEETS

EAC (mg/m³) = CA X IRS X EF X ED / IRD X CF X AT

Methylene Chloride
BW-18 3yr tour of duty
Noncarcinogenic effects

Child Average

EAC = CA X .8 X 312 X 3 / CA X 0.036 = (5.9E-05 X 1.2 X 0.036) + (3.8E-05 X .8 X 0.036)
.8 X 24 X 3 X 365

= 3.6E-06

Child Upperbound

EAC = CA X 2 X 468 X 3 / CA X 0.089 = (8.3E-05 X 1.2 X 0.089) + (5.4E-05 X .8 X 0.089)
1.2 X 24 X 3 X 365

= 1.3E-05

Adult Average

EAC = CA X .6 X 312 X 3 / CA X 0.027 = (5.9E-05 X 1.2 X 0.027) + (3.8E-05 X .8 X 0.027)
.8 X 24 X 3 X 365

= 2.7E-06

Adult Upperbound

EAC = CA X 2.1 X 468 X 3 / CA X 0.093 = (8.3E-05 X 1.2 X 0.093) + (5.4E-05 X .8 X 0.093)
1.2 X 24 X 3 X 365

= 1.3E-05

Carcinogenic effects

Adult Average

EAC = CA X .6 X 312 X 3 / CA X 0.0011 = (5.9E-05 X 1.2 X 0.0011) + (3.8E-05 X .8 X 0.0011)
.8 X 24 X 70 X 365

= 1.1E-07 = 1.1E-04 ug/m³

Adult Upperbound

EAC = CA X 2.1 X 468 X 3 / CA X 0.004 = (8.3E-05 X 1.2 X 0.004) + (5.4E-05 X .8 X 0.004)
1.2 X 24 X 70 X 365

= 5.6E-07 = 5.6E-04 ug/m³

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 18

SIGNATURE _____ DATE _____ CHECKED TEJ DATE 9/20/91

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 3 OF 4 SHEETS

Risk Characterization - Methylene Chloride

Noncarcinogenic effects

Hazard Index = EAC / RfD

Child Average

HI = $\frac{3.6E-06}{3.0}$ = 1.2E-06

Child Upperbound

HI = $\frac{1.3E-05}{3.0}$ = 4.3E-06

Adult Average

HI = $\frac{2.7E-06}{3.0}$ = 9.0E-07

Adult Upperbound

HI = $\frac{1.3E-05}{3.0}$ = 4.3E-06

Carcinogenic effects - Methylene Chloride

Total Pathway Risk (TPR) = $\sum$ EAC X unit risk

Adult Average

TPR = 1.1E-04 X 4.1E-06 = 4.5E-10

Adult Upperbound

TPR = 5.6E-04 X 4.1E-06 = 2.3E-09

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 18

SIGNATURE _____ DATE _____ CHECKED TEJ DATE 9/26/13

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 4 OF 4 SHEETS

Risk Characterization - Carbon tetrachloride

Noncarcinogenic effects

HI = intake dose / oral RfDs

Child average

$HI = \frac{1.4E-06}{7.0E-03} = 2.0E-04$

Child upperbound

$HI = \frac{5.4E-06}{7.0E-03} = 7.7E-04$

Adult Average

$HI = \frac{2.5E-07}{7.0E-03} = 3.6E-05$

Adult Upperbound

$HI = \frac{1.3E-06}{7.0E-03} = 1.9E-04$

Carcinogenic effects - Carbon tetrachloride

TPR = intake dose x inhalation slope factor

Adult Average

TPR = 1.1E-08 X 1.3E-01 = 1.4E-09

Adult Upperbound

TPR = 5.6E-08 X 1.3E-01 = 7.3E-09

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CALCULATION SHEET

CALC. NO. 19

SIGNATURE Jan Beck DATE 7/8/93 CHECKED REJ DATE 9/30/93

PROJECT McClellan AFB HRA JOB NO

SUBJECT Inhalation of vapor phase chemicals while using a dishwasher with residential well-substance SHEET 1 OF 3 SHEETS

$$\text{Intake (mg/kg-day)} = \frac{CA \times IR \times EF \times ED}{BW \times AT}$$

Methylene Chloride
Base Well 18
Noncarcinogenic effects

Child Average

Intake = $\frac{CA \times .8 \times 24 \times 1}{16 \times 24 \times 1} = CA \times 0.05 = (5.9E-05 \times 1.2 \times 0.05) + (3.8E-05 \times .8 \times 0.05)$

= 5.0E-06

Child Upperbound

Intake = $\frac{CA \times 2 \times 38 \times 1}{16 \times 30 \times 1} = CA \times 0.158 = (8.3E-05 \times 1.2 \times 0.158) + (5.4E-05 \times .8 \times 0.158)$

= 2.3E-05

Adult Average

Intake = $\frac{CA \times .6 \times 24 \times 1}{70 \times 24 \times 1} = CA \times 0.0086 = (5.9E-05 \times 1.2 \times 0.0086) + (3.8E-05 \times .8 \times 0.0086)$

= 8.7E-07

Adult Upperbound

Intake = $\frac{CA \times 2 \times 38 \times 1}{70 \times 30 \times 1} = CA \times 0.038 = (8.3E-05 \times 1.2 \times 0.038) + (5.4E-05 \times .8 \times 0.038)$

= 5.4E-06

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 19

SIGNATURE _____ DATE _____ CHECKED TEJ DATE 7-07-1[illegible]

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 3 SHEETS

$$EAC\ (mg/m^3) = \frac{CA \times IRS \times EF \times ED}{IRO \times CF \times AT}$$

Methylene Chloride
BW-18 Dalchronic
Noncarcinogenic effects

Child Average

$$EAC = \frac{CA \times .8 \times 24 \times 1}{.8 \times 24 \times 24 \times 1} = CA \times 0.042 = (5.9E-05 \times 1.2 \times 0.042) + (3.8E-05 \times .8 \times 0.042)$$

$$= 4.3E-06$$

Child Upperbound

$$EAC = \frac{CA \times 2.0 \times 38 \times 1}{1.2 \times 24 \times 30 \times 1} = CA \times 0.088 = (8.3E-05 \times 1.2 \times 0.088) + (5.4E-05 \times .8 \times 0.088)$$

$$= 1.3E-05$$

Adult Average

$$EAC = \frac{CA \times .6 \times 24 \times 1}{.8 \times 24 \times 24 \times 1} = CA \times 0.031 = (5.9E-05 \times 1.2 \times 0.031) + (3.8E-05 \times .8 \times 0.031)$$

$$= 3.1E-06$$

Adult Upperbound

$$EAC = \frac{CA \times 2.1 \times 38 \times 1}{1.2 \times 24 \times 30 \times 1} = CA \times 0.092 = (8.3E-05 \times 1.2 \times 0.092) + (5.4E-05 \times .8 \times 0.092)$$

$$= 1.3E-05$$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO. 19

SIGNATURE _____ DATE _____ CHECKED TEJ DATE 900713

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 3 OF 3 SHEETS

Risk Characterization - Methylene Chloride

Noncarcinogenic effects

HI = EAC / RfDs

Child Average

$HI = \frac{4.2E-06}{3.0} = 1.4E-06$

Child Upperbound

$HI = \frac{1.3E-05}{3.0} = 4.3E-06$

Adult Average

$HI = \frac{3.1E-06}{3.0} = 1.0E-06$

Child Upperbound

$HI = \frac{1.3E-05}{3.0} = 4.3E-06$

Carbon Tetrachloride

HI = Intake dose / oral RfDs

Child average

$HI = \frac{1.7E-06}{7.0E-03} = 2.4E-04$

Child Upperbound

$HI = \frac{5.4E-06}{7.0E-03} = 7.7E-04$

Adult Average

$HI = \frac{2.9E-07}{7.0E-03} = 4.1E-05$

Adult Upper Bound $HI = \frac{1.3E-06}{7.0E-03} = 1.8E-04$

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APPENDIX C

CONCEPTUAL DESIGN

C1.0 INTRODUCTION

The McClellan Air Force Base (AFB) Operable Unit (OU) B Engineering Evaluation and Cost Analysis-Environmental Assessment (EE/CA-EA) recommended a proposed removal action that included the extraction of contaminated groundwater from the A, B, and C geohydrologic zones, transport of the groundwater to the existing Groundwater Treatment Plant (GWTP), and discharge into Magpie Creek. Because of the length of time needed to design, construct and acquire right-of-way, an interim solution was also selected. The interim solution utilized the extraction wells from the final solution, but rather than pumping the water to the GWTP, the water would be discharged directly to the Sacramento Regional County Sanitation Department sanitary sewer.

To establish design parameters and construction concepts of the recommended alternative, this conceptual design was prepared for the northern trichloroethene/1,2-dichloroethene (TCE/1,2-DCE) plume extraction well, treatment, and discharge removal action. Section 2.0 outlines the technical approach used in the conceptual design for each of the different components of the removal action. Section 3.0 describes the conceptual design for the pipeline alternative to the GWTP. Section 4.0 describes the conceptual design for the interim pipeline to the sanitary sewer. Section 5.0 contains the cost estimates for the proposed removal actions.

C2.0 APPROACH

The following sections summarize the technical approach for each of the major components of the selected extraction, conveyance, and treatment removal action.

C2.1 Extraction Wells

Three extraction wells are proposed for the northern trichloroethene/1,2-dichloroethene (TCE-1,2-DCE) plume removal action. The extraction wells are located adjacent to "AF" Street along the southern boundary of Operable Unit (OU) B (see Figure C2-1). Each well will be constructed with its screen fully penetrating one of the three geohydrologic zones, A, B, and C. The extraction wells are located to initially capture the most highly concentrated portion of the plume in each zone. The wells will capture groundwater migrating from the north or northeast that has contaminant concentrations of 100 micrograms per liter (μg/L) or greater. Figures C2-2, C2-3, and C2-4 show the capture zones for each of the wells. The wells will not have sufficient discharge to capture groundwater that has passed to the south of the extraction well locations. For additional details of the extraction well design, see Appendix A, Section 6.0.

The expected concentrations of contaminants in groundwater that will be extracted by each well during its first year of operation were calculated from data obtained from sampling of local monitoring wells during the first quarter of 1990 and from anticipated flowrates. The resulting contaminant concentrations for the plume in each zone are summarized in Table C2-1. As the wells continue to operate, the concentrations of volatile organic compounds (VOCs) in the groundwater are anticipated to fluctuate and then steadily decrease as groundwater with concentrations of 1 to 10 μg/L is drawn into the wells from the wider zone of capture to the north.

Because extracted groundwater from each of the three wells will be combined prior to discharge, mean contaminant concentrations were also calculated to determine the water quality of the combined groundwater. The resulting mean contaminant concentrations for the northern TCE/1,2-DCE plume are summarized in Table C2-2.

C2.2 Conveyance/Treatment

Groundwater extracted from the three wells will be conveyed to the existing Groundwater Treatment Plant (GWTP) located in OU C of McClellan AFB. The

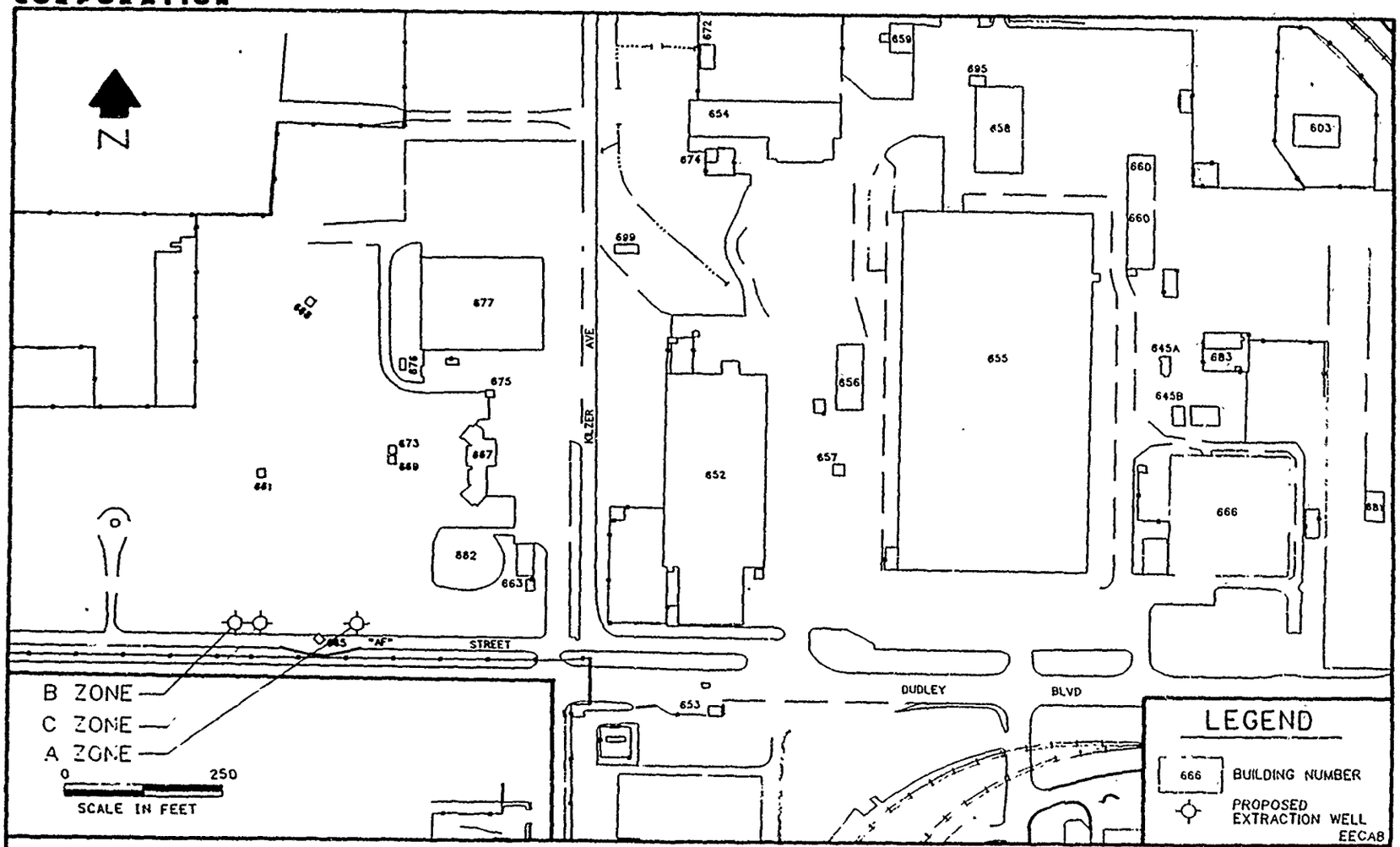

Figure C2-1. Location of Proposed Extraction Wells Northern TCE/1,2-DCE Plume Operable Unit B.

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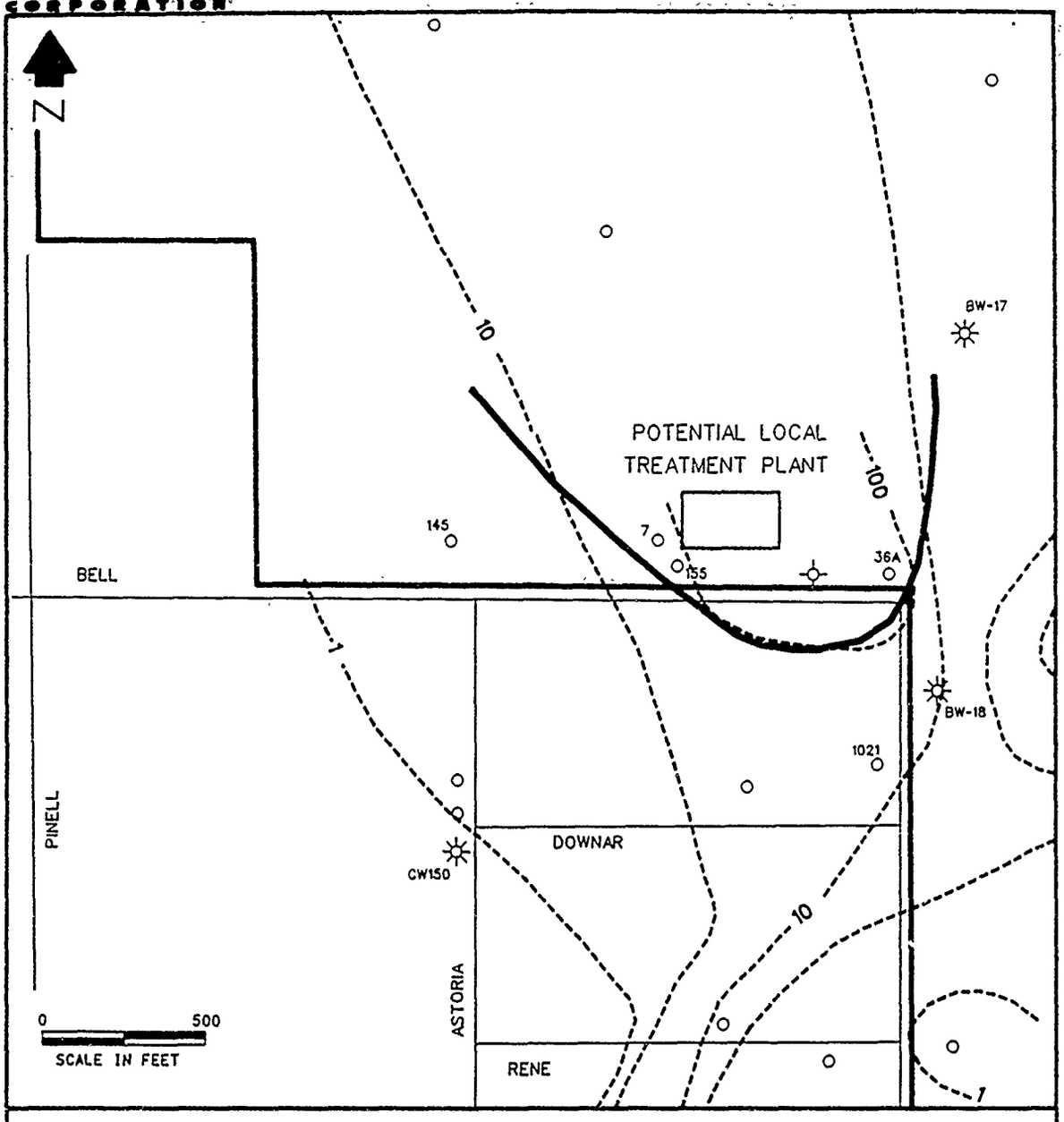

LEGEND:

- McCLELLAN AFB BOUNDARY
- ZONE OF CAPTURE BOUNDARY
- 10 ---- ISOPLETH OF VOC CONCENTRATION
- ISOPLETH INTERVAL: 10^{x} ug/L
- EXISTING MONITORING WELLS
- WATER SUPPLY WELLS
- PROPOSED EXTRACTION WELL LOCATION

11ARA4

Figure C2-2. Proposed Extraction Well Location and Zone of Capture, A Geohydrologic Zone, Northern TCE/1,2-DCE Plume.

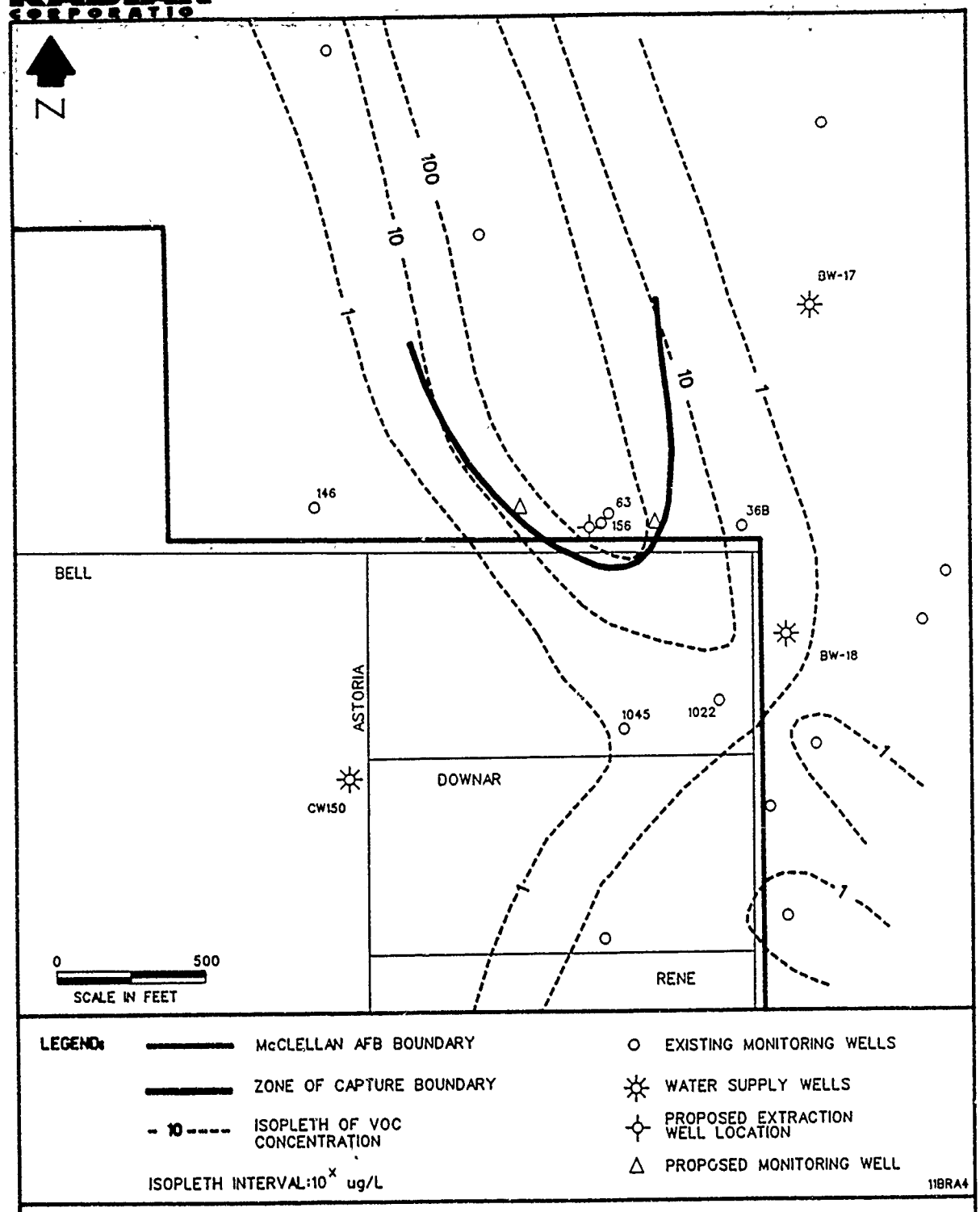

Figure C2-3. Proposed Extraction Well Location and Zone of Capture, B Geohydrologic Zone, Northern TCE/1,2-DCE Plume.

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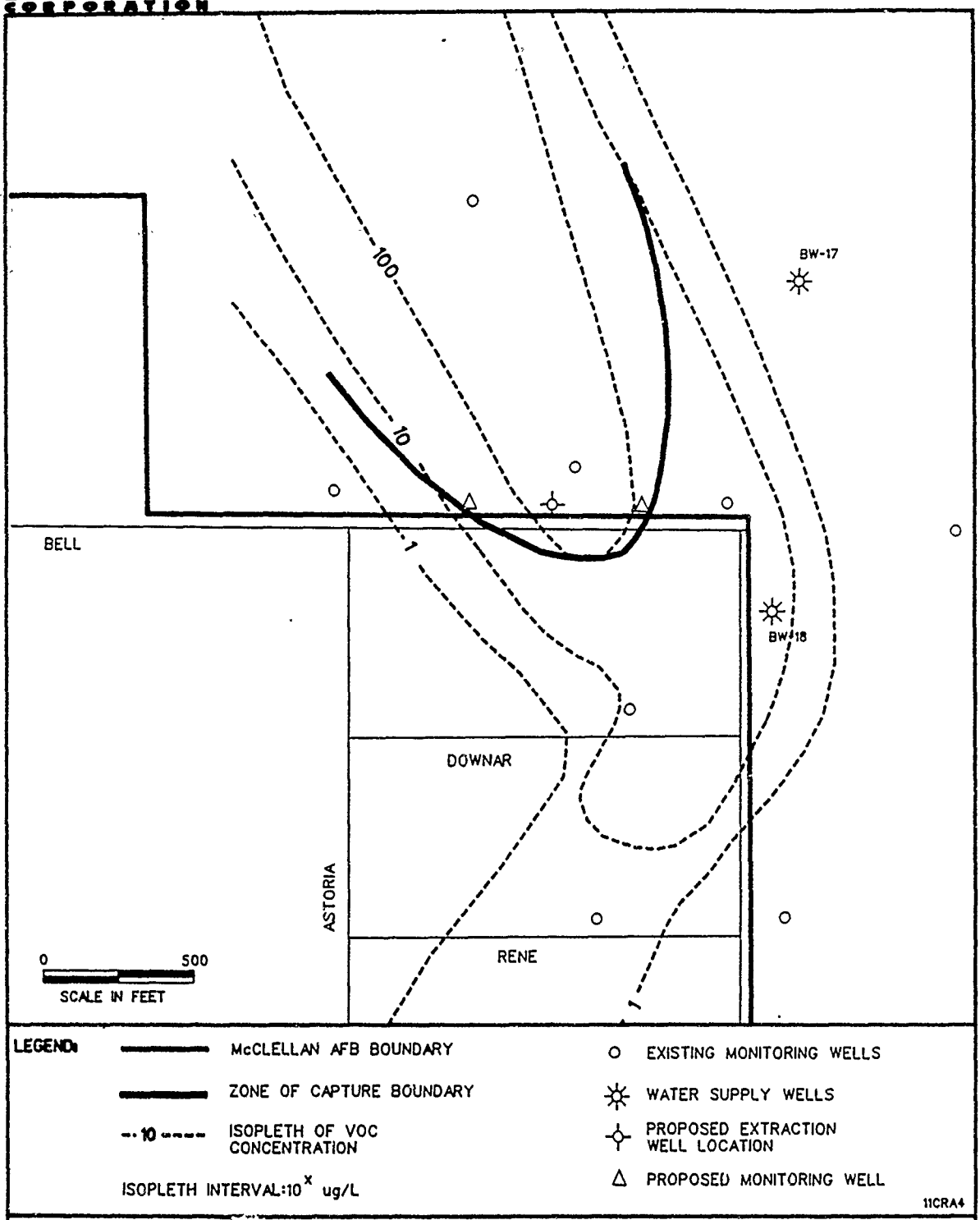

Figure C2-4. Proposed Extraction Well Location and Zone of Capture, C Geohydrologic Zone, Northern TCE/1,2-DCE Plume.

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TABLE C2-1. CONTAMINANT CONCENTRATIONS IN EACH ZONE OF THE NORTHERN TCE/1,2-DCE PLUME

Contaminant	Well: Flow:	A Zone 30 gpm	B Zone 25 gpm	C Zone 100 gpm
		Concentration (units in µg/l)		
TCE		65	110	130
1,2-DCE		75	72	40
Chloroform		10	--	2
1,2-DCA		1	2	2
1,1-DCE		--	--	2
Methylene Chloride		2	--	2
PCE		--	--	3
Acetone		--	--	3

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TABLE C2-2. MEAN CONTAMINANT CONCENTRATION OF COMBINED GROUNDWATER FROM THE NORTHERN TCE/1,2-DCE PLUME

Contaminant	Mean Concentration C*, (μg/L)
TCE	114.2
1,2-DCE	52
Chloroform	3.2
1,2-DCA	0.8
PCE	1.7
Methylene Chloride	1.9
Acetone	1.3
1,1-DCE	1.9
	178.0

* $C = \Sigma (C_A F_A + C_B F_B + C_C F_C)$

where:

C = mean contaminant concentration
F = flow of well A, B, or C
C_A = contaminant concentration in A zone
C_B = contaminant concentration in B zone
C_C = contaminant concentration in C zone

design, construction, and procurement of rights-of-way for this pipeline route will take approximately one to three years to complete. If the McClellan Air Force Base (AFB) Remedial Response Program managed removal actions according to the U.S. Environmental Protection Agency (U.S. EPA) fund-financed removal actions, the action would have to be in operation within one year to meet U.S. EPA regulatory requirements 40 CFR Sec. 300.414\5(b)(5). If U.S. EPA requirements were applied to this removal action to capture contaminant concentrations migrating toward BW-18, then another removal action would be selected which would be implemented in a shorter time period. For this reason, the extracted groundwater will be temporarily discharged to an existing sanitary sewer line. The GWTP discharge and the sanitary sewer discharge options are each discussed in the sections below.

GWTP Conveyance System

The GWTP has been in operation since 1987 treating contaminated groundwater extracted from OU C and OU D and discharging the treated water to Magpie Creek. An aboveground piping system located in OU C and OU D conveys the extracted groundwater to the GWTP. The locations of the existing extraction systems and the GWTP in relation to the proposed northern plume extraction wells are shown in Figure C2-5.

To convey the extracted groundwater from OU B to the GWTP (approximately 3000 feet to the north), a new pipeline must be constructed from the OU B extraction wells to the existing pipeline in OU C that leads to the GWTP. The proposed route for the new pipeline is presented in Figure C2-5. To pass beneath on-base railroad tracks and roads, and to allow access to facilities along Kilzer Avenue, approximately 40 percent of the pipeline will be underground. The aboveground and below ground portions of the pipeline route are shown in Figure C2-5. The proposed pipeline route is only one of several options discussed with McClellan AFB officials. The route proposed in the conceptual design was the preferred route at the time of this report. However, the actual route the pipeline follows may differ from that described pending future conditions and decisions. The cost estimates presented in Section C5.2 describe three different pipeline construction techniques, including aboveground, buried, or trenched designs for the proposed route. The costs for alternative routes of construction of the pipeline by one or a combination of these pipeline construction techniques should fall within an approximate range of costs presented for the proposed route.

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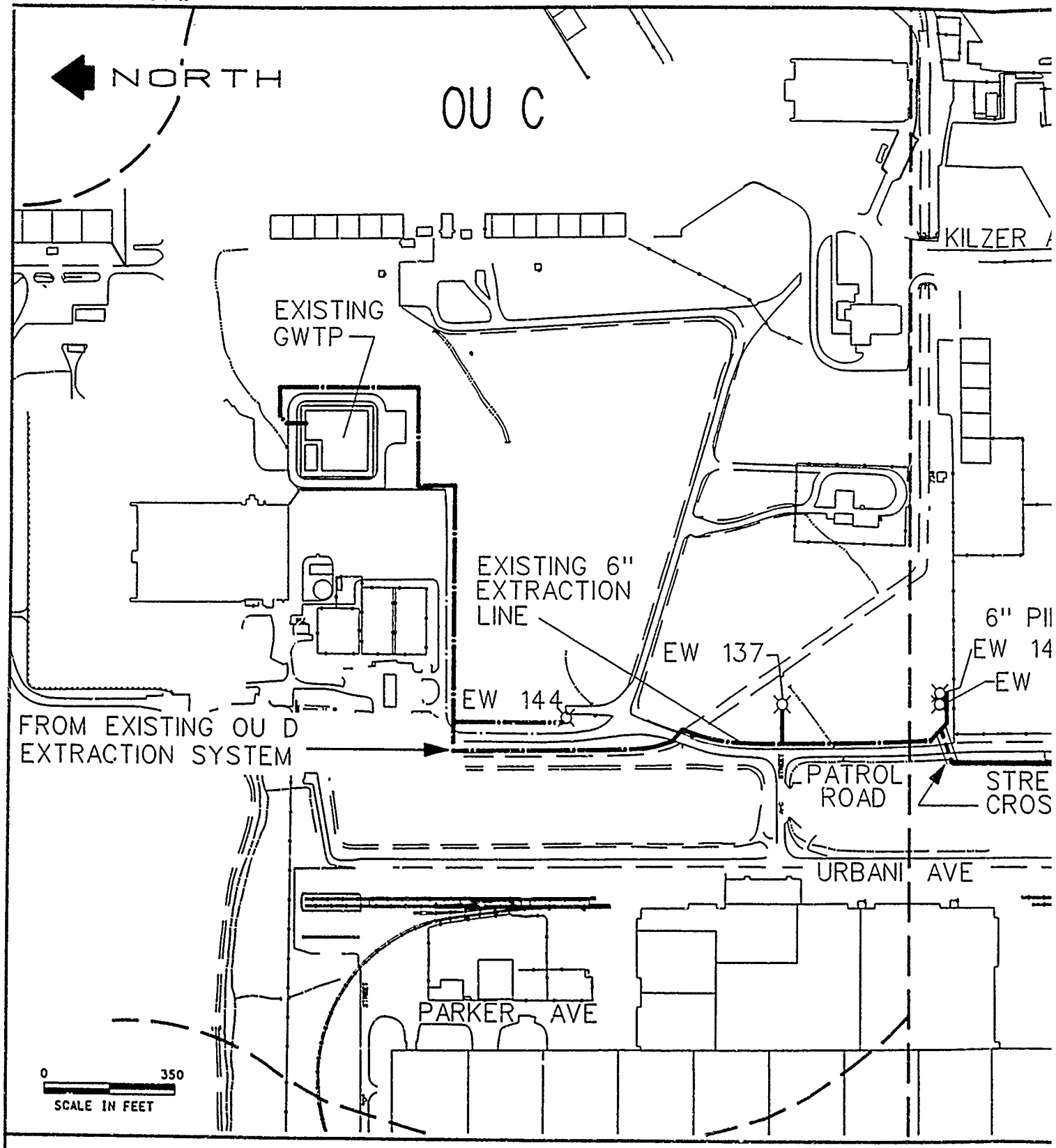

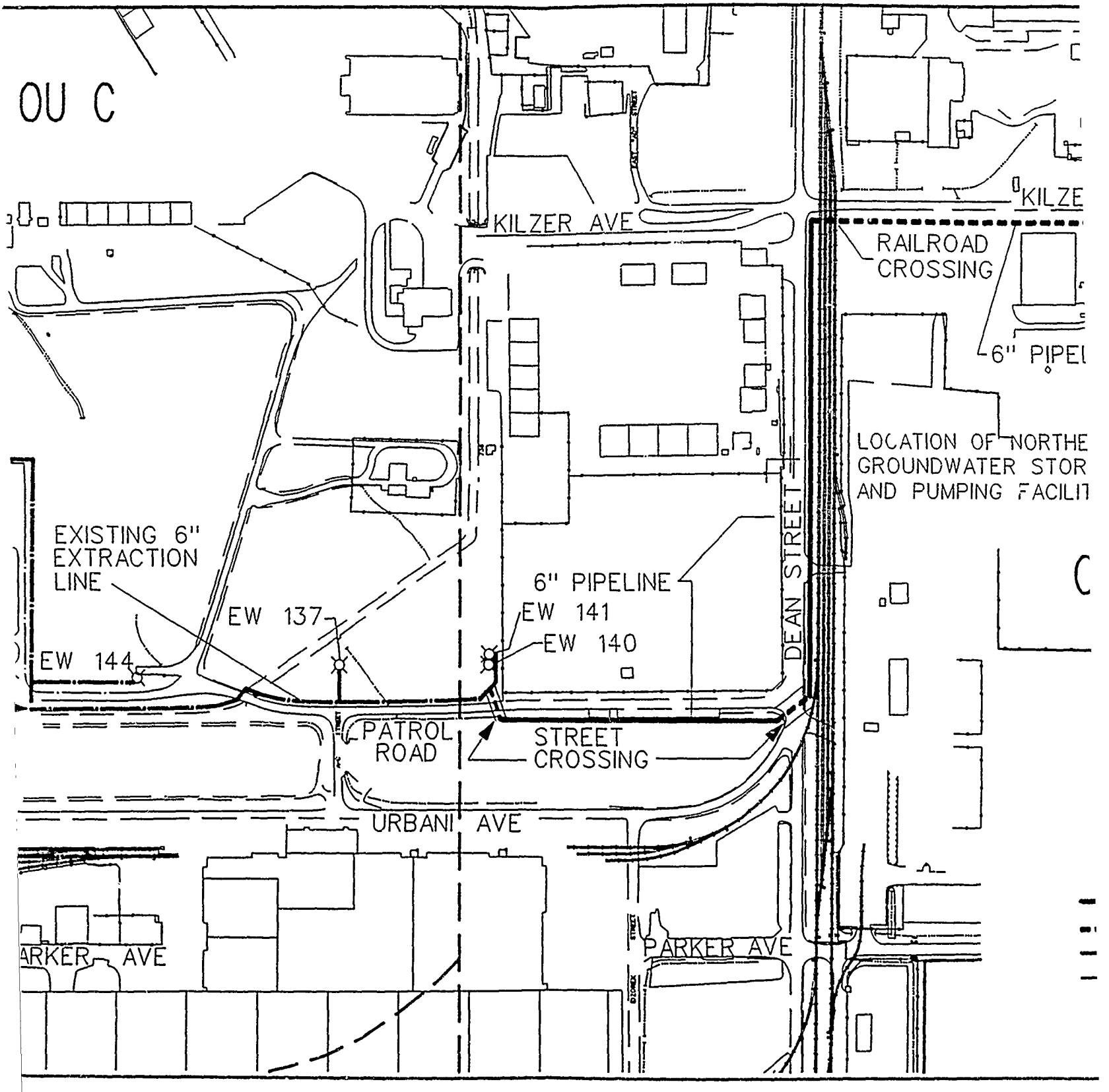
OU C
KILZER AVE
KILZE
RAILROAD CROSSING
6" PIPEL
LOCATION OF NORTHE
GROUNDWATER STOR
AND PUMPING FACILI
EXISTING 6" EXTRACTION LINE
EW 137
EW 144
6" PIPELINE
EW 141
EW 140
DEAN STREET
PATROL ROAD
STREET CROSSING
URBANI AVE
ARKER AVE
PARKER AVE

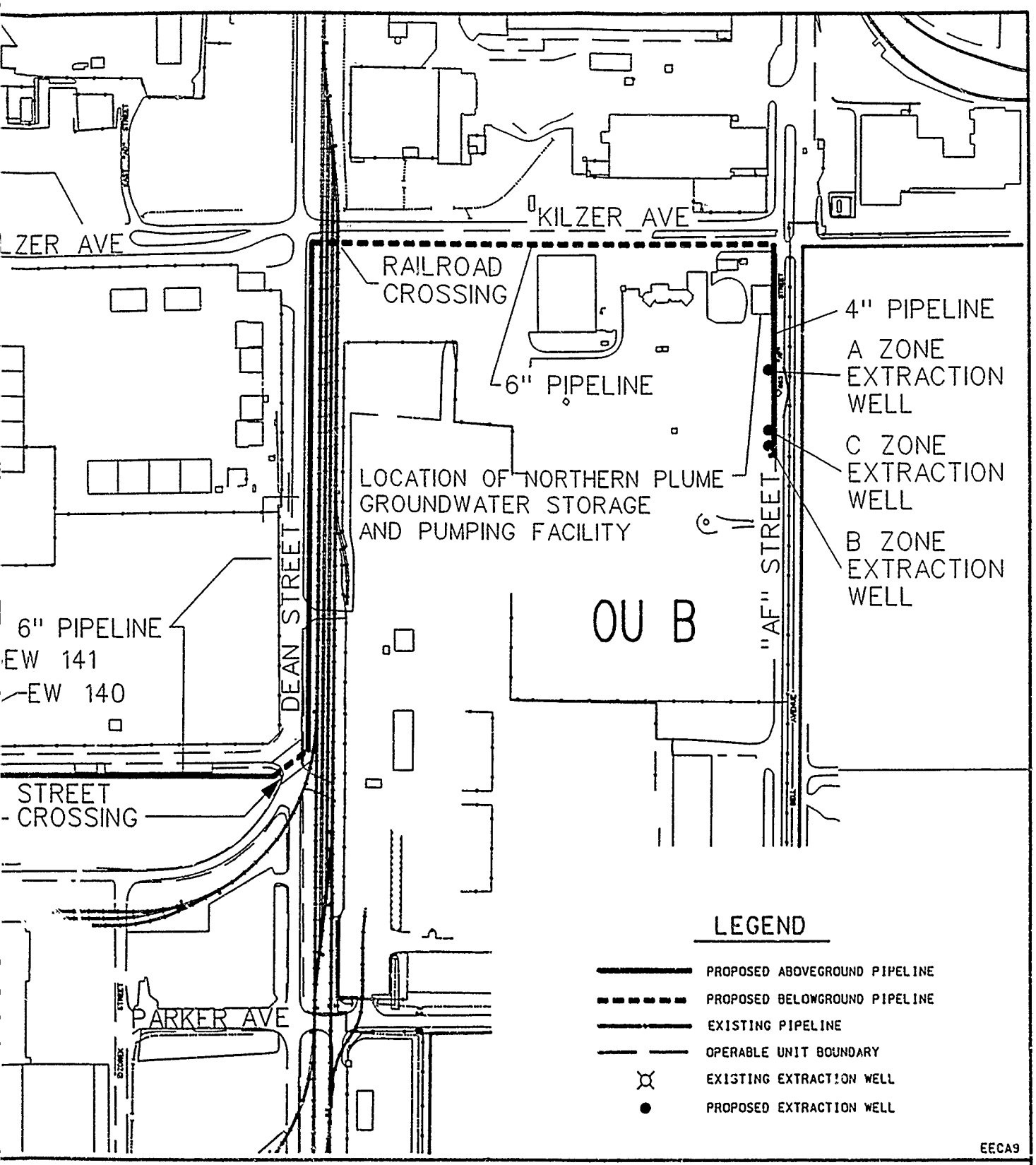

Figure C2-5. Proposed Pipeline Route to the GWTP.

Interim Sanitary Sewer Discharge

For the interim removal action, the extracted groundwater will be conveyed by above ground pipeline to an existing on-base sanitary sewer line located approximately 19 feet from Extraction Well A-1. The existing sanitary sewer line will convey the groundwater to the Sacramento Regional County Wastewater Treatment Plant, where the groundwater can be treated to remove VOC contaminant levels to nondetectable levels before discharge.

The proposed route of the aboveground pipeline connection to the existing sanitary sewer line is shown in Figure C2-6. Because groundwater will be discharged to the sanitary sewer on a temporary basis only, aboveground piping (rather than below ground piping) will be used to connect the extraction wells to the sanitary sewer line.

C2.3 Permitting Requirements

Any discharge of contaminated groundwater from the northern TCE/1,2-DCE extraction wells to the GWTP or to the sanitary sewer line must meet permit restrictions for these facilities. The following sections identify the applicable permits and discuss the impact, if any, these permit requirements will have on the design or operation of the northern TCE/1,2-DCE plume extraction system. McClellan AFB is not required to obtain federal, state, or local permits for responses conducted on-site [U.S. Code Sec. 9621(e), 40 CFR Sec. 300.400(e), and Section 19 of the Interagency Agreements].

GWTP NPDES Permit

The GWTP has a National Pollutant Discharge Elimination System (NPDES) permit allowing discharge of its treated effluent to Magpie Creek. The GWTP currently discharges approximately 0.36 million gallons per day (MGD) to Magpie Creek. However, the permit states that additional extraction systems may be added on as needed from other sites on base with the total discharge not to exceed 1.45 MGD. Treating the 155 gpm (0.22 MGD) of groundwater extracted from the northern TCE/1,2-DCE plume will exceed neither the permitted capacity of the NPDES permit nor the 1000 gpm design capacity of the GWTP.

The NPDES permit requires that the effluent from the GWTP meet strict standards, such as a monthly average of less than 1.0 mg/L of acetone, methyl ethyl

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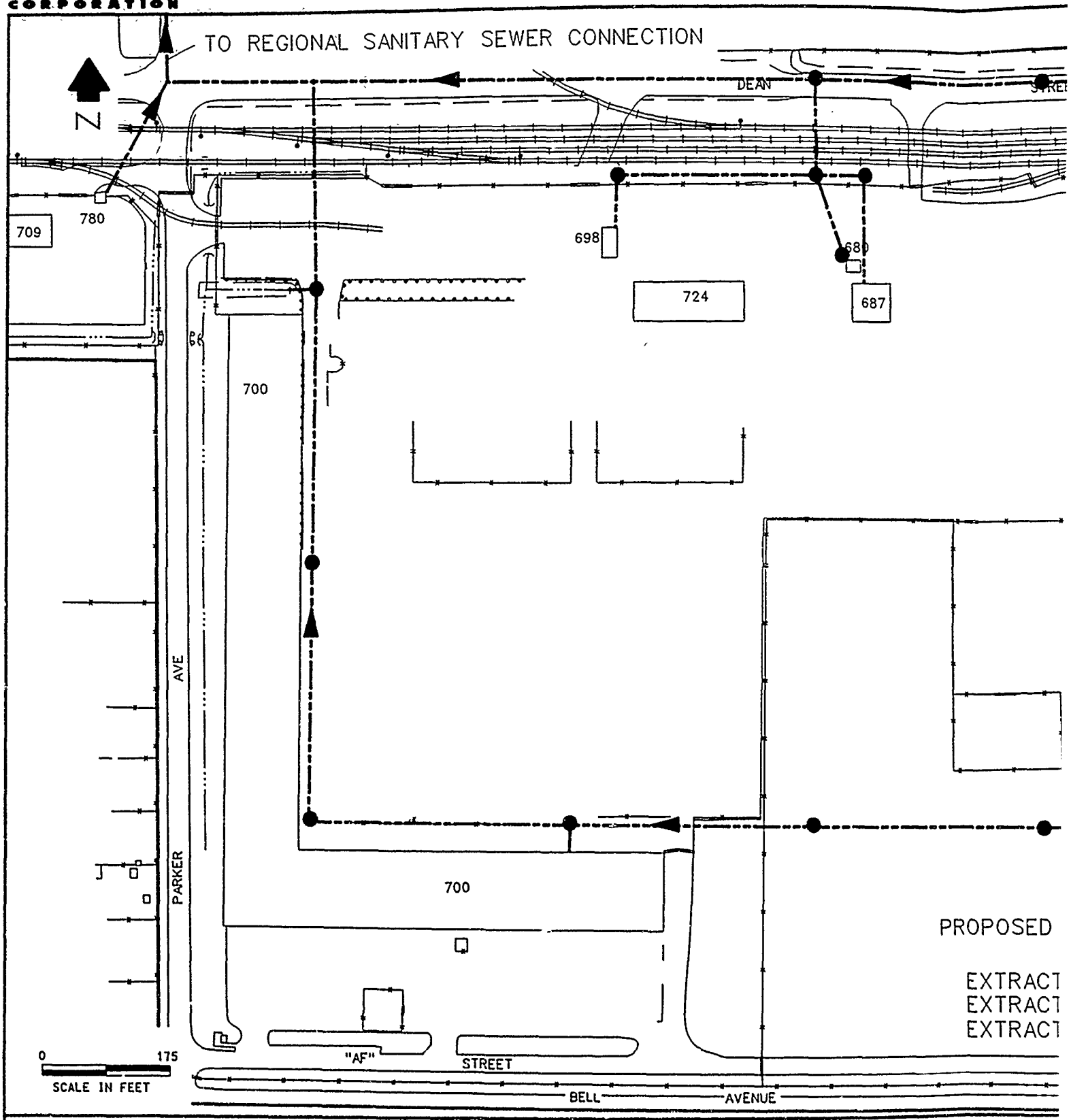

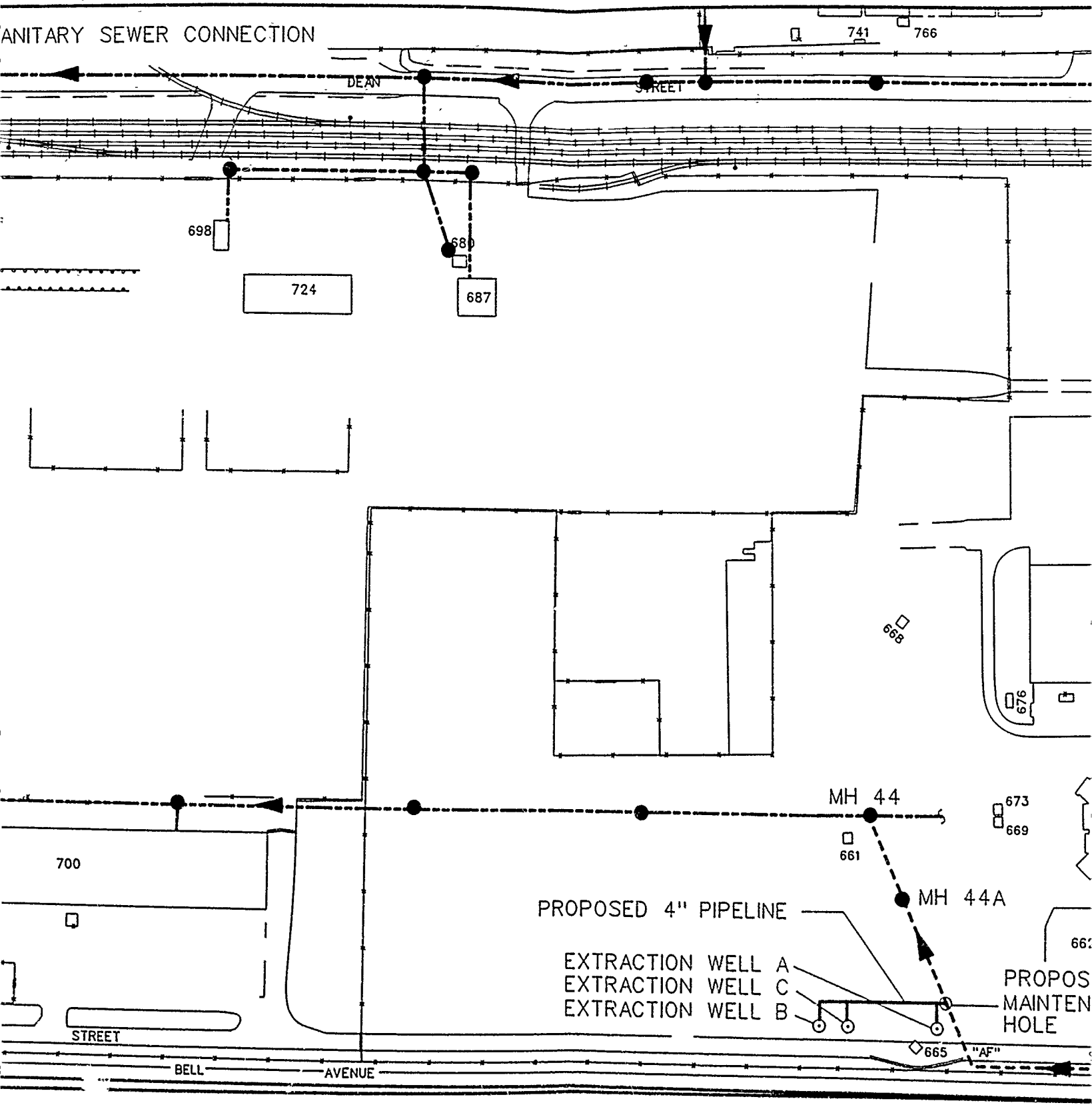
ANITARY SEWER CONNECTION
741
766
DEAN
STREET
698
680
724
687
668
676
MH 44
673
669
661
700
MH 44A
PROPOSED 4" PIPELINE
EXTRACTION WELL A
EXTRACTION WELL C
EXTRACTION WELL B
PROPOS
MAINTEN
HOLE
665
"AF"
STREET
BELL
AVENUE

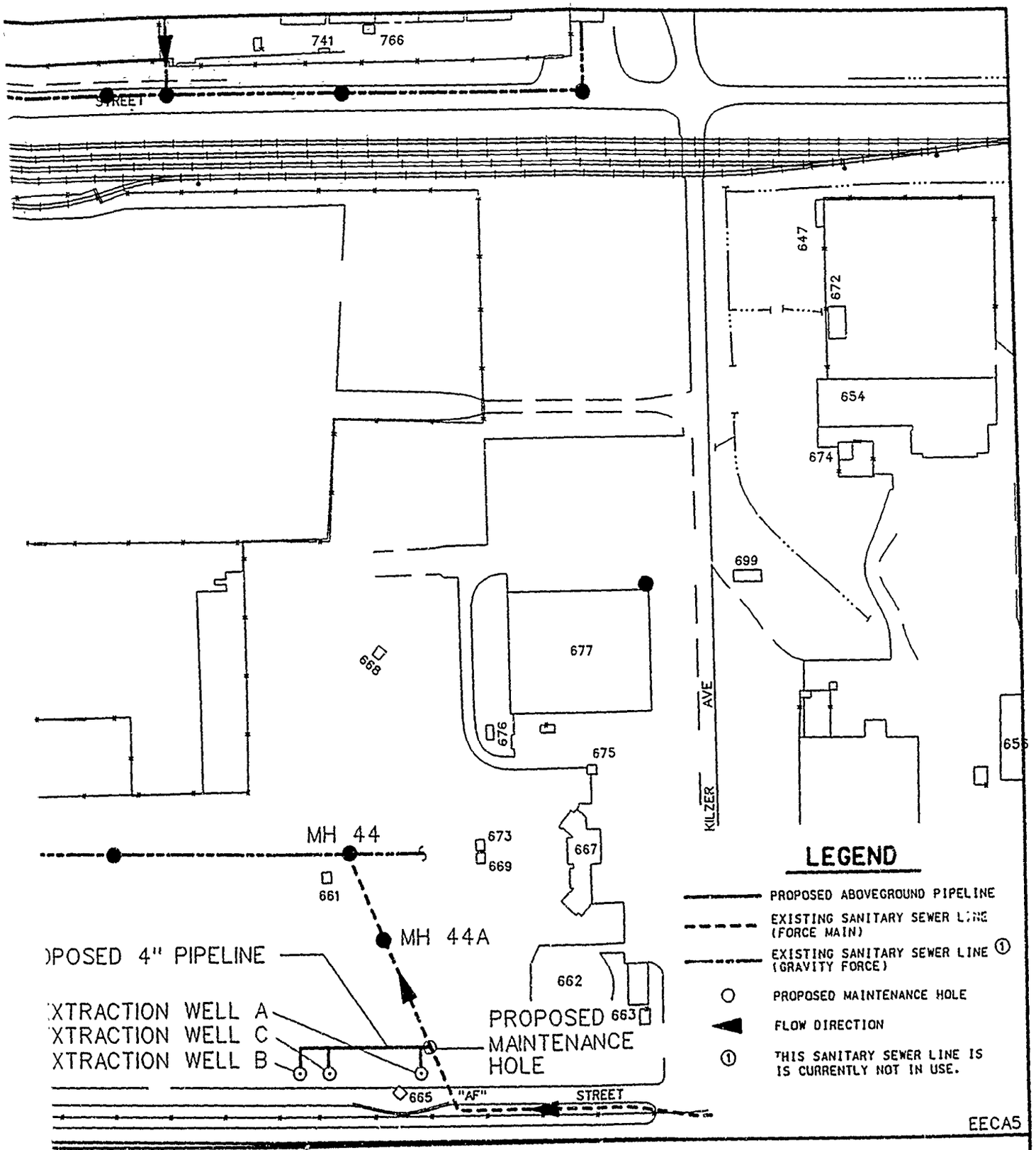

Figure C2-6. Proposed Pipeline Route to the Existing Sanitary Sewer Line.

ketone, and methyl isobutyl ketone, and nondeductible levels of other volatile organic and base neutral/acid extractable compounds. The additional flow from the north TCE/1,2-DCE plume should not cause the plant to exceed these standards. Discussions with GWTP personnel indicate that the additional flow may actually enhance the performance of the plant. Although the procedural requirements for obtaining or maintaining an NPDES permit is not required to operate the GWTP, all requirements, criteria, or limitations of this permit will be satisified.

Sanitary Sewer Use Permit

In April 1990, the Sacramento Regional County Sanitation District adopted a policy for accepting the discharge of contaminated groundwater to the Sacramento Regional County Sanitation District Sewer System. This policy states that contaminated groundwater may be accepted into the district sewer system provided it does not interfere with the regional treatment plant's ability to treat wastewater and does not result in a violation of the plant's NPDES permit. The groundwater from the northern plume extraction wells should not interfere with the regional treatment plant's operations because the 100 μg/L total VOC contaminant concentrations are low. The groundwater should therefore be accepted into the sanitary sewer system.

The Industrial Wastewater Treatment Plant (IWTP) and the sanitary sewer have a combined permitted capacity of 45 million gallons per month (MG/month). The IWTP also discharges to the Regional Sanitary Sewer System. The average combined discharge rate from the IWTP and the sanitary sewer in 1989 was 40.342 MG/month. The additional flow from the northern TCE/1,2-DCE plume extraction system will increase the flow to the sanitary sewer 6.6 MG/month, which is approximately 2 MG/month over the existing permitted capacity. McClellan AFB will therefore have to purchase additional capacity in order to discharge the northern plume groundwater.

The maximum capacity of the off-base sanitary sewer system is 60 MG/month which is adequate to handle the additional flow from the northern TCE/1,2-DCE plume extraction system. However, the rated capacity of the pipe carrying the discharge from McClellan AFB to the Regional Sewer Connection is 3 MGD, and McClellan's Sewer Use Permit allows a maximum of only 2.0 MGD of wastewater to be discharged. Therefore, during storm events or other peak demand periods, the groundwater extraction pumps may have to be shut down temporarily if the Base's daily discharge exceeds 2.0 MGD.

C3.0 GROUNDWATER EXTRACTION/CONVEYANCE TO THE GWTP

Groundwater from the northern TCE/1,2-DCE plume will be extracted via three extraction wells located along the east-west base boundary in OU B. Groundwater from the extraction wells will be pumped to a local groundwater holding/flow equalization tank and from this tank to the GWTP. The proposed pipeline route is shown in Figure C2-5; a preliminary process flow diagram is shown in Figure C3-1. Preliminary specifications for the major equipment required for the groundwater extraction/GWTP conveyance system and the sanitary sewer conveyance system are shown in Table C3-1. Each of the major components of the groundwater extraction/ GWTP conveyance system design are discussed in the sections below.

C3.1 Extraction Wells

The design specifications for each of the three extraction wells are summarized in Table C3-2. A diagram showing the key features of the extraction well design is shown in Figure C3-2. Each well will be constructed with its screen fully penetrating one of the three geohydrologic Zones, A, B, or C. The screen intervals for the A, B, and C Zone wells are 110 to 140 feet below ground surface (BGS), 145 to 180 feet BGS, and 190 to 260 feet BGS, respectively. The upper casing of each of the extraction wells will be constructed of mild steel and the lower casing will be constructed of stainless steel. Each extraction well will be designed so it can be deepened at a future date if the drawdown in the well drops to the pump intake.

Vertical stainless steel centrifugal well pumps will be used to pump the groundwater from bottom of the well to the groundwater holding/flow equalization tank. The pumps will be located between 130 and 140 feet BGS with approximately 25 feet of water above the pumps. Preliminary well pump data indicate that the A Zone well can be pumped at a rate of 30 gallons per minute (gpm), the B Zone can be pumped at a rate of 25 gpm and the C Zone well can be pumped at a rate of 100 gpm. The head calculations used to develop the specifications for the well pumps are shown in Table C3-3. The actual pumping rate from each of the three extraction wells, and thus the final pump specifications, will be determined after additional well pump test data is collected.

The extraction well components were designed with hydraulic capacities above the current requirements in order to handle potentially greater flowrates in the

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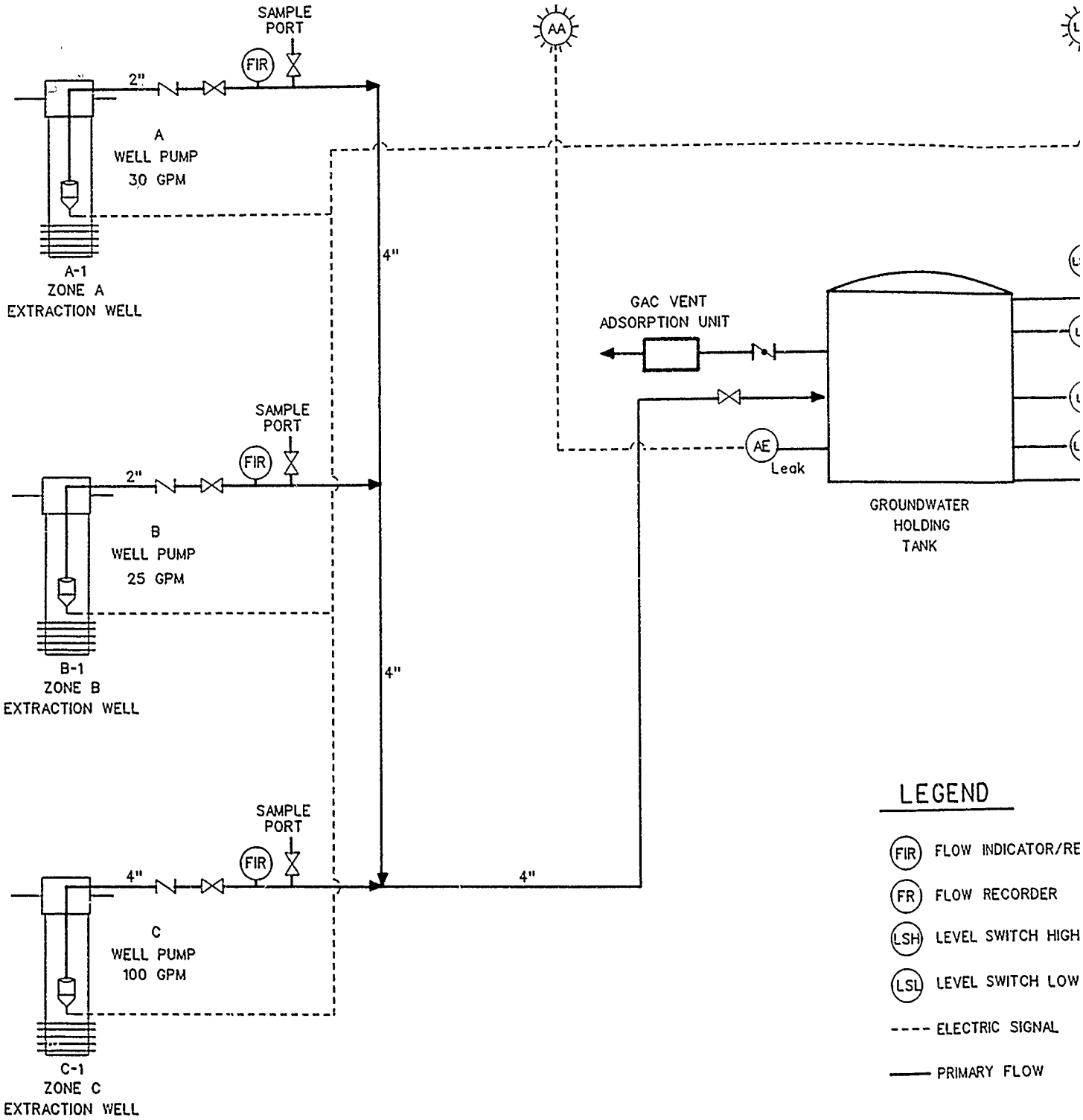
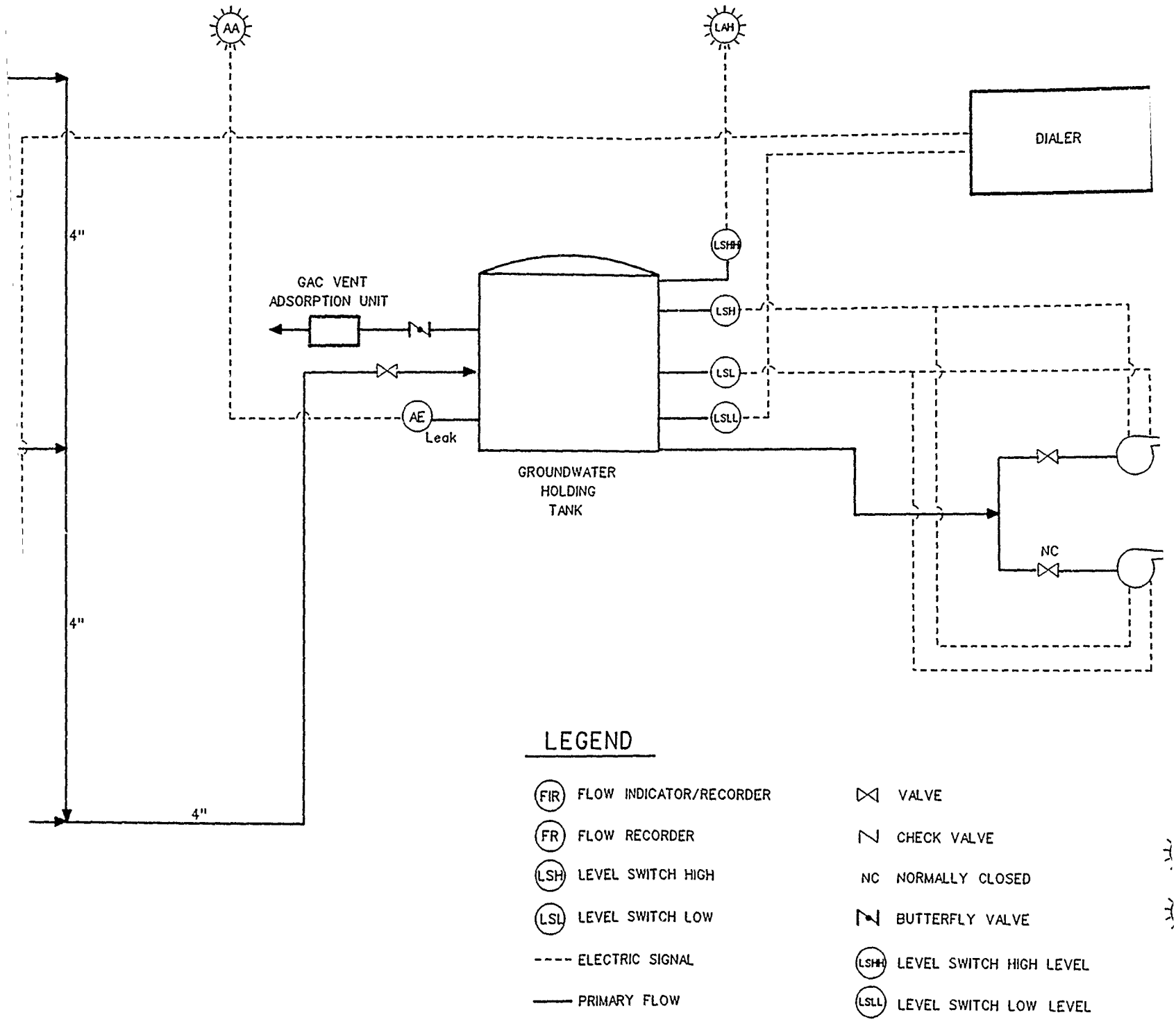
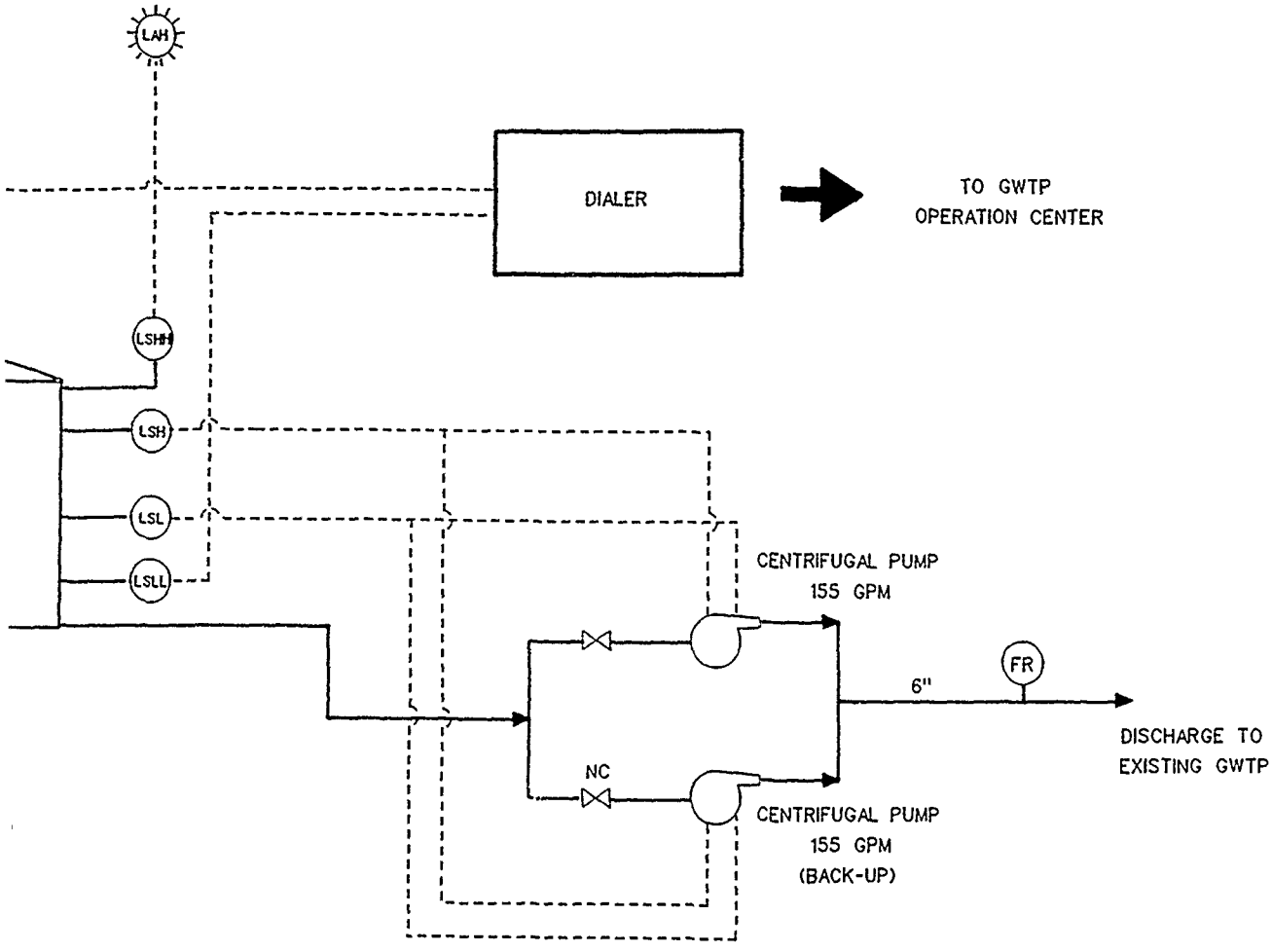




LEGEND

- FIR — FLOW INDICATOR/RECORDER
- FR — FLOW RECORDER
- LSH — LEVEL SWITCH HIGH
- LSL — LEVEL SWITCH LOW
- ---- ELECTRIC SIGNAL
- —— PRIMARY FLOW
- VALVE
- CHECK VALVE
- NC — NORMALLY CLOSED
- BUTTERFLY VALVE
- LSHH — LEVEL SWITCH HIGH LEVEL
- LSLL — LEVEL SWITCH LOW LEVEL



NDICATOR/RECORDER

ECORDER

WITCH HIGH

WITCH LOW

SIGNAL

FLOW

VALVE

CHECK VALVE

NC NORMALLY CLOSED

BUTTERFLY VALVE

LSHH LEVEL SWITCH HIGH LEVEL

LSLL LEVEL SWITCH LOW LEVEL

AE ANALYSIS ELEMENT LEAK
Leak

LAH LEVEL ALARM HIGH

AA LEAK ALARM

Figure C3-1. Preliminary Process Flow Diagram for Groundwater Extraction/Conveyance To GWTP.

MAFB 0011 FLOW8

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TABLE C3-1. PRELIMINARY EQUIPMENT SPECIFICATIONS

Equipment	Specification
Extraction Well Pump A-1	
Service	Contaminated groundwater transfer[1]
Type	Vertical centrifugal well pump
Location	Zone A extraction well
Capacity	30 gpm
TDH	166 feet
BHP Rating	2.5
Electrical Rating	3.0 hp
Extraction Well Pump B-1	
Service	Contaminated groundwater transfer[1]
Type	Vertical centrifugal well pump
Location	Zone B extraction well
Capacity	25 gpm
TDH	175 feet
BHP Rating	2.2
Electrical Rating	2.6 hp
Extraction Well Pump C-1	
Service	Contaminated groundwater transfer[1]
Type	Vertical centrifugal well pump
Location	Zone C extraction well
Capacity	100 gpm
TDH	174 feet
BHP Rating	8.8
Electrical Rating	10.4 hp
Groundwater Holding Tank	
Service	Contaminated groundwater reservoir[1]
Type	Circular, corrugated steel sidewalls with primary containment bladder
Dimensions	18.3 feet diameter, 22 feet high
Location	Concrete foundation east of northern plume extraction wells
GAC Gas Adsorption Unit	
Service	Vapor phase organic adsorption
Type	Removable with replaceable GAC cartridges
Location	Groundwater holding tank
Capacity	20 SCFM

(Continued)

TABLE C3-1. (Continued)

Equipment	Specification
Booster Pumps	
Service	Groundwater transfer to the GWTP
Type	Horizontal centrifugal pump
Location	Groundwater holding tank effluent
Capacity	155 gpm
TDH	39 feet
BHP Rating	3.0
Electrical Rating	3.6 hp

[1] Groundwater contains contaminants listed in Table C2-2.

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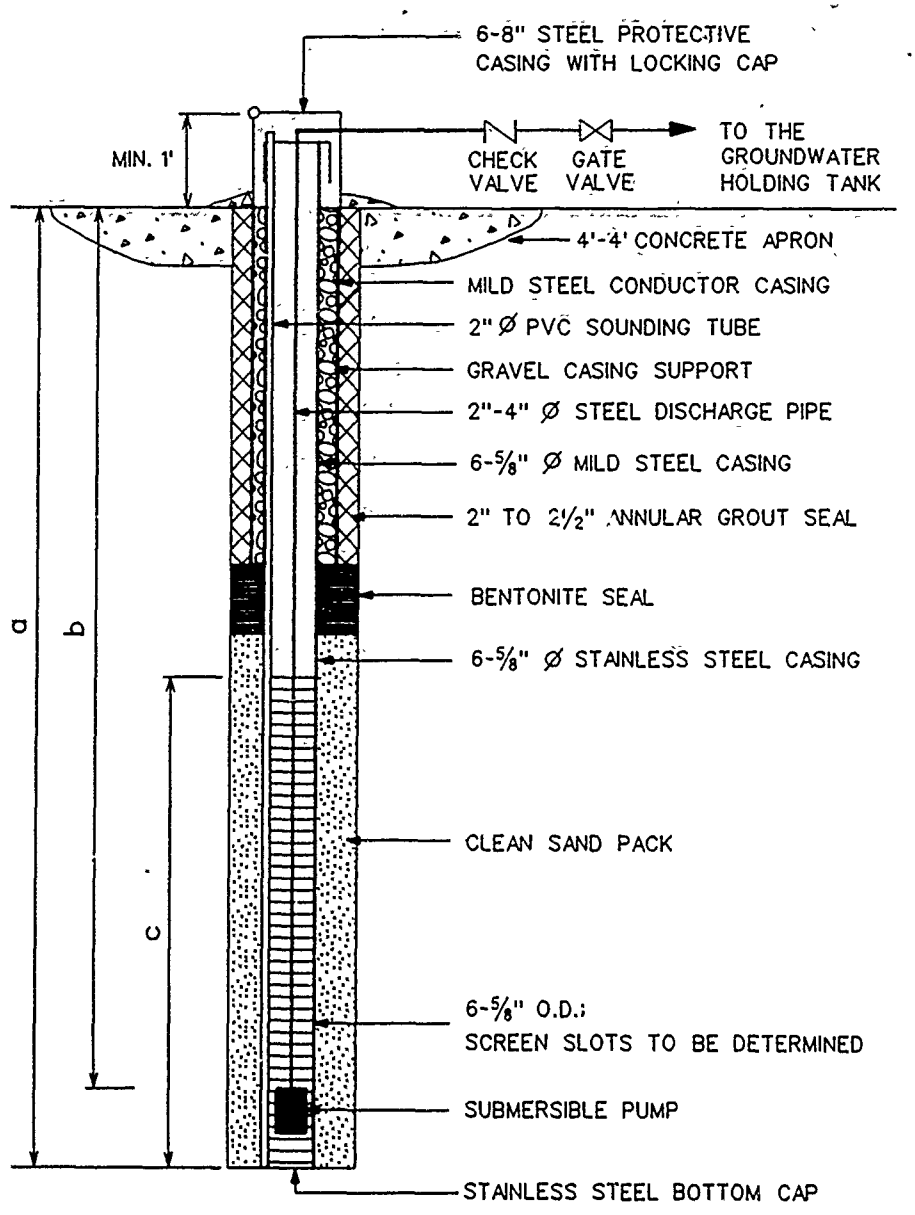
TABLE C3-2. DESIGN SPECIFICATIONS FOR EXTRACTION WELLS IN THE NORTHERN TCE/1,2 DCE PLUME

	A Zone	B Zone	C Zone
Initial depth	140' B6S	180' B6S	260' B6S
Lower borehole	13 - 14"	13 - 14"	13 - 14"
Casing diameter	6-5/8"	6-5/8"	6 - 5/8"
Upper casing	Mild steel (w/Cu)	Mild Steel (w/Cu)	Mild Steel (w/Cu)
Lower Casing	Stainless Steel	Stainless Steel	Stainless Steel
Screen interval	110-140 BGS	145-180 BGS	190 - 260 BGS
Screen diameter	6-5/8' O.D.	6-5/8' O.D.	6-5/8' O.D.
Screen slots:	TBD*	TBD*	TBD*
Gravel pack:	TBD*	TBD*	TBD*
Pumping rate:	30 gpm	25 gpm	100 gpm
Pump depth:	130	140	140
Sanitary seal:	Rubber compression seal at top of conductor casing	Rubber compression seal at top of conductor casing	Rubber compression seal at top of conductor casing

* To be determined. Gravel pack and screen slot size for each of the wells will be determined from sieve analyses of samples collected from pilot borings.



Well ID	Well Depth, a	Pump Depth, b	Screen Interval, c
A	140 ft. BGS	130 ft. BGS	110-140 ft. BGS
B	180 ft. BGS	140 ft. BGS	145-180 ft. BGS
C	260 ft. BGS	140 ft. BGS	190-260 ft. BGS

NOT TO SCALE

Figure C3-2. Typical Extraction Well Design Details.

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TABLE C3-3. EXTRACTION WELL PUMPS: HEAD LOSS CALCULATIONS

PUMP ID: A-1

Discharge Pipe Length (feet):*	130
Discharge Pipe Diameter (feet):	0.167
Header Pipe Length (feet):**	192
Header Pipe Diameter (feet):	0.333
Friction Factor:	0.015
Pump Eff.	0.5
Motor Eff.	0.85

FITTING LOSSES

Fitting	HL Coeff	Number	Total K
Discharge Pipe			
Check Valve	2	1	2
Gate Valve	0.17	1	0.17
Entrance	1	1	1
Flow Meter	60	1	60
			63.17
Header Pipe			
Tee, Run	1	1	1
90-Bend	0.75	4	3
Exit	1	1	1
			5

(Continued)

* Discharge pipe extends from pipe intake to wellhead.
** Header pipe extends from wellhead to holding tank.

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TABLE C3-3. (Continued)

EXTRACTION WELL A-1

Pump Flow GPM	Disch. Pipe Vlcy FPS	Disch. Frct Loss FT	Headr Pipe Vlcy FPS	Headr Frct Loss FT	Total Ftng Loss FT	Min Stat Loss FT	Max Stat Loss FT	Min Totl Loss FT	Max Totl Loss FT	Min BHP	Max BHP	Min Elec HP	Max Elec HP
5	0.51	0.05	3.33	1.487	1.11	127	152	130	155	0.33	0.39	0.4	0.5
10	1.02	0.19	3.46	1.603	1.94	127	152	131	156	0.66	0.79	0.8	0.9
15	1.53	0.42	3.58	1.724	3.28	127	152	132	157	1.00	1.19	1.2	1.4
20	2.04	0.75	3.71	1.850	5.13	127	152	135	160	1.36	1.61	1.6	1.9
25	2.54	1.17	3.84	1.979	7.50	127	152	138	163	1.74	2.05	2.0	2.4
30	3.05	1.69	3.97	2.114	10.37	127	152	141	166	2.14	2.52	2.5	3.0
35	3.56	2.30	4.10	2.252	13.75	127	152	145	170	2.57	3.01	3.0	3.5
40	4.07	3.00	4.22	2.395	17.64	127	152	150	175	3.03	3.54	3.6	4.2
45	4.58	3.80	4.35	2.543	22.05	127	152	155	180	3.53	4.10	4.2	4.8
50	5.09	4.69	4.48	2.694	26.96	127	152	161	186	4.07	4.71	4.8	5.5
55	5.60	5.68	4.61	2.851	32.38	127	152	168	193	4.66	5.36	5.5	6.3
60	6.11	6.76	4.74	3.011	38.32	127	152	175	200	5.31	6.06	6.2	7.1
65	6.62	7.93	4.86	3.176	44.77	127	152	183	208	6.00	6.82	7.1	8.0
70	7.12	9.20	4.99	3.345	51.72	127	152	191	216	6.76	7.65	8.0	9.0
75	7.63	10.56	5.12	3.519	59.19	127	152	200	225	7.59	8.53	8.9	10.0

(Continued)

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TABLE C3-3. (Continued)

PUMP ID: B-1

Discharge Pipe Length (feet):*	140
Discharge Pipe Diameter (feet):	0.167
Header Pipe 1 Length, (feet):**	37.5
Header Pipe 2 Length, (feet):***	150
Header Pipe 3 Length, (feet):****	192
Header Pipe Diameter (feet):	0.333
Friction Factor:	0.015
Pump Eff.	0.5
Motor Eff.	0.85

FITTING LOSSES

Fitting	HL Coeff	Number	Total K
Discharge Pipe			
Check Valve	2	1	2
Gate Valve	0.17	1	0.17
Entrance	1	1	1
Flow Meter	60	1	60
			63.17
Header Pipe 1			
90-Bend	0.75	5	3.75
			4.5
Header Pipe 2			
90-Bend	0.75	4	3
Tee, Run	1	1	1
			4
Header Pipe 3			
90-Bend	0.75	4	3
Tee, Run	1	2	2
Exit	1	1	1
			6

(Continued)

* Discharge pipe extends from pipe intake to wellhead.
** Header pipe 1 extends from Wellhead B to Wellhead C.
*** Header pipe 2 extends from Wellhead C to Wellhead A.
**** Header pipe 3 extends from Wellhead C to the holding tank.

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TABLE C3-3: (Continued)

EXTRACTION WELL B-1

Pump Flow GPM	Total Pipe Frct Loss FT	Total Ftng Loss FT	Min Stat Loss FT	Max Stat Loss FT	Min Totl Loss FT	Max Totl Loss FT	Min BHP	Max BHP	Min Elec HP	Max Elec HP
5	2.41	1.82	137	162	141	166	0.36	0.42	0.4	0.5
10	2.76	2.71	137	162	142	167	0.72	0.85	0.8	1.0
15	3.22	4.12	137	162	144	169	1.09	1.28	1.3	1.5
20	3.78	6.04	137	162	147	172	1.48	1.74	1.7	2.0
25	4.46	8.48	137	162	150	175	1.89	2.21	2.2	2.6
30	5.25	11.44	137	162	154	179	2.33	2.71	2.7	3.2
35	6.15	14.91	137	162	158	183	2.79	3.24	3.3	3.8
40	7.15	18.89	137	162	163	188	3.29	3.80	3.9	4.5
45	8.27	23.39	137	162	169	194	3.83	4.40	4.5	5.2
50	9.50	28.41	137	162	175	200	4.42	5.05	5.2	5.9
55	10.83	33.94	137	162	182	207	5.05	5.74	5.9	6.8
60	12.27	39.99	137	162	189	214	5.74	6.49	6.7	7.6
65	13.83	46.55	137	162	197	222	6.48	7.30	7.6	8.6
70	15.50	53.63	137	162	206	231	7.29	8.17	8.6	9.6
75	17.27	61.22	137	162	216	241	8.16	9.11	9.6	10.7

(Continued)

RADIAN CORPORATION

TABLE C3-3. (Continued)

PUMP ID: C-1

Discharge Pipe Length (feet):*	140
Header Pipe 2 Length, (feet):**	150
Header Pipe 3 Length, (feet):***	192
Pipe Diameter (feet):	0.333
Friction Factor:	0.015
Pump Eff.	0.5
Motor Eff.	0.85

FITTING LOSSES

Fitting	HL Coeff	Number	Total K
	Discharge Pipe		
Check Valve	2	1	2
Gate Valve	0.17	1	0.17
Entrance	1	1	1
Flow Meter	60	1	60
			63.17
	Header Pipe 2		
90-Bend	0.75	4	3
Tee, Run	1	1	1
			4
	Header Pipe 3		
90-Bend	0.75	5	3.75
Tee, Run	1	1	1
Exit	1	1	1
			5.75

(Continued)

* Discharge pipe extends from pipe intake to wellhead.
** Header pipe 2 extends from Wellhead C to Wellhead A.
*** Header pipe 3 extends from Wellhead C to the holding tank.

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TABLE C3-3. (Continued)

EXTRACTION WELL C-1

Pump Flow GPM	Total Pipe Frct Loss FT	Total Pipe Ftng Loss FT	Min Stat Loss FT	Max Stat Loss FT	Min Total Loss FT	Max Total Loss FT	Min BHP	Max BHP	Min Elec HP	Max Elec HP
5	0.38	0.26	137	162	137.6	162.6	0.35	0.41	0.41	0.48
10	0.46	0.40	137	162	137.8	162.8	0.70	0.82	0.82	0.97
15	0.55	0.49	137	162	138.0	163.0	1.05	1.23	1.23	1.45
20	0.66	0.66	137	162	138.3	163.3	1.40	1.65	1.64	1.94
25	0.77	0.87	137	162	138.6	163.6	1.75	2.07	2.06	2.43
30	0.90	1.12	137	162	139.0	164.0	2.11	2.48	2.48	2.92
35	1.03	1.40	137	162	139.4	164.4	2.46	2.91	2.90	3.42
40	1.18	1.72	137	162	139.9	164.9	2.83	3.33	3.33	3.92
45	1.34	2.07	137	162	140.4	165.4	3.19	3.76	3.75	4.42
50	1.51	2.47	137	162	141.0	166.0	3.56	4.19	4.19	4.93
55	1.69	2.90	137	162	141.6	166.6	3.93	4.63	4.63	5.44
60	1.88	3.36	137	162	142.2	167.2	4.31	5.07	5.07	5.96
65	2.08	3.87	137	162	143.0	168.0	4.69	5.52	5.52	6.49
70	2.30	4.41	137	162	143.7	168.7	5.08	5.96	5.98	7.02
75	2.52	4.99	137	162	144.5	169.5	5.47	6.42	16.44	7.55
80	2.76	5.60	137	162	145.4	170.4	5.87	6.88	6.91	8.10
85	3.00	6.25	137	162	146.3	171.3	6.28	7.35	7.39	8.65
90	3.26	6.94	137	162	147.2	172.2	6.69	7.83	7.87	9.21
95	3.53	7.66	137	162	148.2	173.2	7.11	8.31	8.37	9.78
100	3.81	8.43	137	162	149.2	174.2	7.54	8.80	8.87	10.35
105	4.10	9.23	137	162	150.3	175.3	7.97	9.30	9.38	10.94
110	4.40	10.06	137	162	151.5	176.5	8.42	9.81	9.90	11.54
115	4.71	10.93	137	162	152.7	177.7	8.87	10.32	10.43	12.14
120	5.04	11.84	137	162	153.9	178.9	9.33	10.84	10.97	12.76
125	5.37	12.79	137	162	155.2	180.2	9.80	11.38	11.53	13.38
130	5.72	13.77	137	162	156.5	181.5	10.28	11.92	12.09	14.02
135	6.08	14.79	137	162	157.9	182.9	10.77	12.47	12.67	14.67
140	6.44	15.85	137	162	159.3	184.3	11.26	13.03	13.25	15.33

future. The piping, fittings and valves of the A and B Zone extraction wells are sized to handle flows of up to 45 gpm (at 4.6 ft/s) without developing excessive pipe friction losses. Similarly, the piping, fittings and valves of the C Zone extraction well are sized to handle flows of up to 140 gpm (at 4 ft/s). To accommodate these flow requirements, 2-inch lines for Wells A and B and a 4-inch line for Well C were selected to transport the groundwater from the pump inlet up to the wellhead. A 4-inch header line was selected to transport the groundwater from each wellhead to the groundwater holding tank. This 4-inch line can transport up to 235 gpm (at 6 ft/s) without developing excessive friction head losses.

C3.2 Groundwater Holding Tank

The groundwater holding tank will be used as a reservoir for the GWTP pipeline booster pump and for contingency holding purposes. The holding tank will be equipped with a vapor tight top and with a granulated activated carbon adsorption unit for treatment of displaced vapor phase organics forced from the tank by a rising liquid level. For purposes of this discussion, the tank design will include a secondary containment liner and a leak detection system. The specifications of the holding tank are contained in Table C3-1. The proposed tank design was based on conservative engineering practices and not on any legal requirements.

The holding tank will have a 38,500 gallon capacity which will be sufficient to provide a 4 hour storage volume, assuming an extraction rate of 155 gpm from the wells. The reservoir volume required for a minimum cycle time of 20 minutes for the booster pump is 7,500 gallons. Because the pump reservoir volume requirement is much smaller than 38,500 gallons, the final sizing of the holding tank will depend on the contingency holding volume the GWTP personnel would require in the event of a plant upset, or in case of excessive flows to the sanitary sewer (see Section C2.3).

C3.3 Booster Pumps

A centrifugal booster pump will be used to pump the groundwater at a rate of 155 gpm from the groundwater holding tank to the GWTP. An identical centrifugal pump will be placed in parallel with the primary booster pump to serve as a backup pump. The head calculations for the booster pumps are shown in Table C3-4 and the resulting pump specifications are summarized in Table C3-1.

TABLE C3-4. BOOSTER PUMP: HEAD LOSS CALCULATIONS

Pump ID: SEGMENT A*		Pump ID: SEGMENT B**		Pump ID: SEGMENT C***	
Length of Line (ft):	3640.00	Length of Line (ft):	1360.00	Length of Line C (ft):	1445.00
Friction Factor:	0.0150	Friction Factor:	0.0150	Length of Line C′ (ft):	100.00
Pipe Diameter (ft):	0.50	Pipe Diameter (ft):	0.50	Friction Factor:	0.0150
				Pipe C Diameter (ft):	0.50
				Pipe C′ Diameter (ft):	0.83

Fitting	HL Coeff	Number	Total K
Discharge Pipe			
45 Bend	0.35	15.00	5.25
90 Bend	0.75	4.00	3.00
Check Valve	2.00	1.00	2.00
Tee	1.00	1.00	1.00
Gate Valve	0.17	1.00	0.17
Entrance	1.00	1.00	1.00
Flow Meter	60.00	1.00	60.00
TOTAL:			72.42

Fitting Losses

Fitting	HL Coeff	Number	Total K
45 Bend	0.35	10.00	3.50
90 Bend	0.75	0.00	0.00
Check Valve	2.00	1.00	2.00
Tee	1.00	1.00	1.00
Gate Valve	0.17	0.00	0.00
Entrance	1.00	0.00	0.00
Flow Meter	60.00	0.00	0.00
TOTAL:			6.50

Fitting Losses

Fitting	HL Coeff	Number	Total K
45 Bend	0.35	1.00	0.35
90 Bend	0.75	9.00	6.75
Check Valve	2.00	0.00	0.00
Tee	1.00	0.00	0.00
Gate Valve	0.17	1.00	0.17
Enlargement	0.41	1.00	0.41
Exit	1.00	1.00	1.00
TOTAL:			8.68

* SEGMENT A = Pipeline Segment from OU B groundwater holding tank to the OU C pipeline connection point.
** SEGMENT B = Pipeline Segment from the OU C pipeline connection point to the OU D connection point.
*** SEGMENT C = Pipeline Segment from the OU D pipeline connection point to the GWTP influent holding tank.

(Continued)

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TABLE C3-4. (Continued)

Booster Pump Flow (gpm)	Segment A Vlcy (ft/s)	Vlcy Head Loss* (ft)	Total Frct Loss** (ft)	Min Stat Loss*** (ft)	Max Stat Loss*** (ft)	Min Total Loss**** (ft)	Max Total Loss**** (ft)	Min BHP	Max BHP	Min Elec. Input (HP)	Max Elec. Input (HP)
20.00	0.23	0.00	9.57	-11.00	6.00	-1.43	15.57	-0.01	0.16	-0.02	0.19
40.00	0.45	0.00	11.72	-11.00	6.00	0.72	17.72	0.01	0.36	0.02	0.42
60.00	0.68	0.01	14.32	-11.00	6.00	3.32	20.32	0.10	0.62	0.12	0.72
80.00	0.91	0.01	17.37	-11.00	6.00	6.37	23.37	0.26	0.94	0.30	1.11
100.00	1.13	0.02	20.88	-11.00	6.00	9.88	26.88	0.50	1.36	0.59	1.60
120.00	1.36	0.03	24.83	-11.00	6.00	13.83	30.83	0.84	1.87	0.99	2.20
140.00	1.59	0.04	29.24	-11.00	6.00	18.24	35.24	1.29	2.49	1.52	2.93
155.00	1.76	0.05	32.85	-11.00	6.00	21.85	38.85	1.71	3.04	2.01	3.58
175.00	1.99	0.06	38.05	-11.00	6.00	27.05	44.05	2.39	3.89	2.81	4.58
200.00	2.27	0.08	45.19	-11.00	6.00	34.19	51.19	3.45	5.17	4.06	6.08
220.00	2.50	0.10	51.41	-11.00	6.00	40.41	57.41	4.49	6.38	5.28	7.50
260.00	2.95	0.14	65.21	-11.00	6.00	54.21	71.21	7.12	9.35	8.37	11.00
280.00	3.18	0.16	72.78	-11.00	6.00	61.78	78.78	8.74	11.14	10.28	13.11
300.00	3.40	0.18	80.81	-11.00	6.00	69.81	86.81	10.58	13.15	12.44	15.47

* VLCY HEAD LOSS (ft) = $V^2/2g$

** TOTAL FRCT LOSS (ft) = Pipe and fitting friction loss (Segment A)
+ Pipe and fitting friction loss (Segment B)
+ Pipe and fitting friction loss (Segment C)

$$= (V_a^2/2g)\left[fL_a/D_a + \sum_i K_{i,a}\right] + V_b^2\left[fl_b/D_b + \sum_i K_{i,b}\right]$$

$$+ (V_c^2/2g)\left[fL_c/D_c + \Sigma K_{i,c}\right]$$

where V_a = velocity through pipe segment A = $\frac{\text{Volumentric Flow Rate}}{\text{X-Sectional Area}}$

f = pipe friction factor
K = fitting friction loss factor
L = pipe length (ft)
D = pipe diameter (ft)
g = 32.2 (ft/s^2)

*** MIN STAT LOSS = H (GWTP Holding Tank)
- H (OUB Holding Tank)
MAX STAT LOSS = H (GWTP Holding Tank)
- H (OUB Pipeline)
where H = height above ground surface (ft)

**** TOTAL LOSS = Total Head Loss = VLCY HEAD LOSS + TOTAL FRCT LOSS + STATIC LOSS

C3.4 Proposed Pipeline to the OU C Extraction Pipeline

Figure C2-5 shows the proposed route for the new pipeline that will transport groundwater from the holding tank to the GWTP via the existing pipelinesystem in OU C. This route is preliminary, in that an underground utility survey must be completed to determine the optimal pipeline route. The new pipeline will consist of a 6-inch diameter fibercast pipe that connects the groundwater holding tank to the 6-inch OU C extraction pipeline. A 6-inch line through OU B was selected to provide sufficient hydraulic capacity to transport the groundwater to the GWTP from the northern TCE/1,2-DCE plume extraction wells and to provide extra capacity to handle flows from any future extraction wells that may be constructed in OU B. The 6-inch line in OU B can carry up to 375 gpm (at 6 ft/s) additional flow. However, the existing flow in the OU C/OU D pipeline may limit this excess capacity to 100 gpm.

To pass beneath on-base railroad tracks and roads, and to allow easy access to facilities along Kilzer Avenue, approximately 40 percent of the pipeline will be underground (see Figure C2-5). The aboveground portions of pipe will consist of 6-inch diameter single wall pipe that is supported on 15-foot centers approximately 1 to 1.5 feet above the ground. The underground pipe will consist of a 6-inch carrier fibercast pipe within an 8-inch containment pipe. For purposes of this design, the underground double-containment pipe have been equipped with liquid sensors and alarm instrumentation in the event of leaks from the inner to the outer pipeline casing. The final design may be different.

Two possible design options have been identified for the underground portion of the pipeline: placement in a utility trench or direct burial. A third possible design is to have the entire pipeline route be located above ground. In the first design, the double containment pipe would be contained in a 3 foot wide by 4 foot deep concrete utility trench that would be constructed along Kilzer Avenue. One advantage of the utility trench design is that McClellan AFB could use the utility trench to house other utility lines that may need to be run across that portion of OU B. Another advantage of the utility trench is that it could be constructed with removable covers to allow easy access to the utility lines (including the groundwater pipeline). The major disadvantage of the utility trench option is the cost (see Section C6.0).

The second design option is to bury the double containment pipeline directly, without constructing a utility trench. This option is less expensive than the first option yet still allows access to base facilities. The double containment pipeline design

was developed using conservative engineering practices and not based on any legal requirement. The final selected design may be different. The third design option of all aboveground pipe is less expensive than either the first or second options. However, the third design option has the disadvantage of limiting access to existing or planned facilities west of Kilzer Avenue. The costs for all three options are detailed in Section C6.0.

C4.0 GROUNDWATER EXTRACTION/CONVEYANCE TO THE SANITARY SEWER

In this interim action, the groundwater will be pumped directly from the three extraction wells to the on-base sanitary sewer line. The proposed aboveground pipeline route to the sanitary sewer line is shown in Figure C2-6. No groundwater holding tank or booster pumps will be necessary in this design. Each of the major components of the groundwater extraction/sanitary sewer conveyance system design are discussed in the sections below.

C4.1 Extraction Wells

The extraction wells will be constructed as described in Section C3.0 above. The total dynamic head that each well pump must overcome to transport water from the well to the sanitary sewer line. For a given pumping rate, the total dynamic head required to pump the groundwater from the pump inlet to the sanitary sewer line (for the interim action) is less than the total dynamic head required to pump the groundwater from the pump inlet 22 feet above the ground surface to the holding tank inlet (for the long term GWTP piping option). Therefore, each well pump will be selected based on the total head calculated to transport the groundwater from the pump inlet to the groundwater holding tank (see Table C3-4). In this way, the same well pumps can be used to pump groundwater from the wells to the sanitary sewer in the interim action and to pump groundwater from the wells to the holding tank in the long term GWTP piping action.

C4.2 Pipeline to the Sanitary Sewer Line

The pipeline to the sanitary sewer line will consist of 4-inch, single-wall, aboveground pipe; the proposed pipeline route is shown in Figure C2-6. A 4-inch line was selected because it has sufficient hydraulic capacity to handle flow from the extraction wells up to 235 gpm (at 6 ft/s). The pipe will be supported on 15-foot centers, 1 to 1.5 feet above the ground. Aboveground piping was selected because the pipeline to the sanitary sewer is only a temporary connection and because it is more cost effective to run the pipe aboveground for the short term. Also, the length of the proposed pipeline route is relatively short (i.e. 210 feet) and temporary aboveground piping along "AF" street will not hinder access to any existing facilities.

C4.3 Connection to the Existing Sanitary Sewer Line

The groundwater pipeline will connect to the segment of the existing on-base sanitary sewer line located approximately 19 feet east of Extraction Well A (see Figure C2-6). This segment of the 6-inch diameter sanitary sewer line (i.e. between "AF" street and maintenance hole 44) is currently not in use and has sufficient capacity to accept the groundwater from the extraction wells. A new maintenance hole will be constructed at the tie-in point where the groundwater pipeline will connect to the sanitary line.

C5.0 COST ESTIMATES

Cost estimates were developed for both of the following alternatives:

- An extraction well system with a temporary pipeline connection to the sanitary sewer system; and
- An extraction well system with a permanent pipeline connection to the GWTP.

For the sanitary sewer discharge option, two cost estimates were developed based on a range of sanitary sewer connection fees expected to be imposed by the County of Sacramento Department of Public Works. For the GWTP discharge option, cost estimates were developed for three different piping design options. The detailed cost estimates for each of the sanitary sewer and GWTP discharge options are shown in Tables C5-1 through C5-4. The cost to construct the three extraction wells and the three monitoring wells (one for each hydrogeologic zone) are common to all the discharge options and are presented separately in Table C5-5. Table C5-6 presents the O&M costs for each option. The following sections describe each discharge option and discuss the relative costs for each. Table C5-7 summarizes the relative costs for all the discharge options.

C5.1 Sanitary Sewer Discharge

The majority of the capital cost for the sanitary sewer discharge option is expected to be due to the sanitary sewer connection fee. However, the County of Sacramento, Department of Public Works has not yet determined the connection fees to charge facilities that discharge contaminated groundwater into the sanitary sewer. For this reason, two capital cost estimates were developed for the sanitary sewer discharge option based on an estimated range of sanitary sewer connection fees.

The first cost estimate is shown in Table C5-1. In this cost estimate, the $660,000 sanitary sewer connection fee estimate is based on the fees McClellan AFB paid to purchase a permanent connection to the sanitary sewer for their Industrial Wastewater Treatment Plant effluent. The second cost estimate is also shown in Table C5-1. This $240,000 cost estimate was based on the fees recently charged to a company in Sacramento to purchase a temporary connection to the sanitary sewer for discharge of

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TABLE C5-1. SANITARY SEWER DISCHARGE COST ESTIMATES

Construction Item	Units[1]	Quantity	Unit Price	Total Cost
1. New Manhole[2]				
Concrete in place	ea	1	1,025	1,025
Slab top (4' manhole)	ea	1	206	206
Frame and cover	ea	1	197	197
2. Single Wall Above Ground Pipe[3]	ft	210	12.7	2,667
3. Fittings				
4" tee[2]	ea	3	48	144
4" 90 degree ell[2]	ea	9	39	351
Miscellaneous fittings (retrofit to direct flow west)	ls			500
4. Retrofit MH 44A[2] (to handle forced flow)	ls			2,000
5. Potential Sewer Connection Fees				
"Permanent" connection fees				660,000
"Temporary" connection fees				243,000

(Continued)

[1] ea = each
ft = foot
ls = lump sum

[2] Source: Means Site Work Cost Data, 1990; 9th Annual Edition.

[3] Source: Vendor quote.

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TABLE C5-1. (Continued)

"PERMANENT" CONNECTION FEES

Total Direct Costs:	$ 667,090
Sacramento Cost Index (10%):	66,709
Contingency (5%):	33,355
SUBTOTAL:	767,154
General Contractor O&P (25%):	191,788
CONSTRUCTION SUBTOTAL:	958,942
Engineering Design Cost (10%):	95,894
Bonding and Insurance (10%):	95,894
Construction Management (7%):	67,126
GRAND TOTAL:	$1,121,962

"TEMPORARY" CONNECTION FEES

Total Direct Costs:	$ 250,090
Sacramento Cost Index (10%):	25,009
Contingency (5%):	12,505
SUBTOTAL:	287,604
General Contractor O&P (25%):	71,901
CONSTRUCTION SUBTOTAL:	359,504
Engineering Design Cost (10%):	35,950
Bonding and Insurance (10%):	35,950
Construction Management (7%):	25,165
GRAND TOTAL:	$ 420,620

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TABLE C5-2. GWTP PIPELINE COST ESTIMATE (UTILITY TRENCH DESIGN OPTION)

Construction Item	Units [1]	Quantity	Unit Price	Total Cost
1. Pipeline Trench Sitework				
A. Earthwork				
1. Conc Trench Excav [2]	CY	847	2.89	2,448
2. Jacking Pits	EA	6	10,000	60,000
3. Horizontal Boring [2] (24-inch casing)	LF	300	254	76,200
B. Backfill	CY	283	0.44	125
1. Conc Trench Excav [2]				
C. Compaction				
1. Conc Trench Excav [2]	CY	283	1.92	543
2. Borrow Material [2]	CY	283	5.4	1,528
3. Borrow Material-Haul [2]	CY	283	4.88	1,381
2. Pipeline Trench Concrete				
A. Formwork				
1. Conc Trench: [2]				
Inside Form	SFCA	11,430	4.61	52,692
Outside Form	SFCA	10,160	1.99	20,218
B. Reinforcing Steel [2]				
1. Trench	TONS	29	805	23,345
C. Concrete in Place [2]	CY	236	186.8	44,085
3. Trench Covers [2]	SF	3,810	23.72	90,373
Add for 5/8" thick plate	SF	3,810	8	30,480
4. Soil Disposal				
A. Transportation and Disposal	TON	1,128	200	225,600
5. Pipe				
A. Double Contained-6" [3]	LF	1,570	36.75	57,698
1. Fittings/Joints [3]	LS			19,700
2. Fabrication [3]	HRS	68	50	3,400
3. Installation Labor [2]	LF	1,570	9.25	14,523
4. Pipe Supports	EA	105	95	9,975
5. Valves	EA	2	500	1,000

(Continued)

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TABLE C5-2. (Continued)

Construction Item	Units [1]	Quantity	Unit Price	Total Cost
5. (Continued)				
B. Single Wall-6" [3]	LF	2,680	12.7	34,036
1. Fittings/Joints [3]	LS			6,000
2. Fabrication [3]	HRS	116	50	5,800
3. Installation Labor [2]	LF	2,680	9.25	24,790
4. Aboveground Pipe Supports	EA	179	125	22,375
5. Valves	EA	2	500	1,000
6. Holding Tank (4-hour storage capacity) [3]	LS	1	7,800	7,800
1. Secondary Cont/Leak Detection [3]	LS	1	3,700	3,700
2. Conical Tank Roof [3]	LS	1	1,124	1,124
3. Tank Pad [2]	SF	263	4.36	1,147
4. Tank Installation [2,3]	LS			5,800
5. GAC Vent Unit	LS	1		800
7. Pumps				
1. Booster Pumps [3]	EA	2	1,800	3,600
TOTAL DIRECT COSTS:				$853,285
Sacramento Cost Index (10%):				85,329
Contingency (5%):				42,664
SUBTOTAL:				981,278
General Contractor O&P (25%):				245,320
SUBTOTAL:				1,226,598
Engineering & Design (10%):				122,660
Bonding & Insurance (10%):				122,660
Construction Management (7%):				85,862
GRAND TOTAL COST ESTIMATE:				$1,312,459

[1] CY = cubic yard; LF = linear foot; LS = lump sum; SF = square foot; SFCA = square foot contact area.

[2] Source: Means Site Work Cost Data, 1990; 95h Annual Edition.

[3] Source: Vendor quotes.

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TABLE C5-3. GWTP PIPELINE COST ESTIMATE (DIRECT BURIAL DESIGN OPTION)

Construction Item	Units[1]	Quantity	Unit Price	Total Cost
1. Sitework				
A. Earthwork				
1. Trenching (incl. Excav, Backfill, Compaction)[2]	LF	1,270	6.52	8,280
2. Jacking Pits	EA	6	10,000	60,000
3. Horizontal Boring[2] (24-Inch Casing)	LF	300	254	76,200
2. Pipe Bedding[2]	LF	1,270	0.57	724
3. Soil Disposal				
A. Transportation and Disposal (Assume 10% Spoil)	TON	47	200	9,400
4. Pipe				
A. Double Contained-6"[3]	LF	1,570	36.75	57,698
1. Fittings/Joints[3]	LS			19,700
2. Fabrication[3]	HRS	68	50	3,400
3. Installation Labor[2]	LF	1,570	9.25	14,523
4. Valves	EA	2	500	1,000
B. Single Wall - 6"[3]	LF	2,680	12.7	34,036
1. Fittings/Joints[3]	LS			6,000
2. Fabrication[3]	HRS	116	50	5,800
3. Installation Labor[2]	LF	2,680	9.25	24,790
4. Abv Grnd Pipe Supports	EA	179	125	22,375
5. Valves	EA	2	500	1,000
5. Holding Tank (4 Hr Storage Capacity)[3]	LS	1	7,800	7,800
1. Secondary Cont/Leak Detection[3]	LS	1	3,700	3,700
2. Conical Tank Roof	LS	1	1,124	1,124
3. Tank Pad[2,3]	SF	263	4.36	1,147
4. Tank Installation[3]	LS			5,800
5. GAC Adsorption Unit	EA	1	800	800

(Continued)

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TABLE C5-3. (Continued)

Construction Item	Units[1]	Quantity	Unit Price	Total Cost
6. Pumps				
1. Booster Pump[3]	EA	2	1,800	3,600
TOTAL DIRECT COSTS:				368,896
Sacramento Cost Index (10%):				36,890
Contingency (5%):				18,445
SUBTOTAL:				424,230
General Contractor Overhead and Profit (25%):				106,058
SUBTOTAL				530,288
Engineering & Design (10%):				53,029
Bonding & Insurance (10%):				53,029
Construction Management (7%):				37,120
GRAND TOTAL:				$567,408

1 EA = Each
LF = Linear Foot
HRS = Hours
LS = Lump Sum
SF = Square Feet

2 Source: Means Site Work Cost Data, 1990; 9th Annual Edition.

3 Source: Vendor Quote.

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TABLE C5-4. GWTP PIPELINE COST ESTIMATE (ABOVE GROUND PIPE DESIGN OPTION)

Construction Item	Units[1]	Quantity	Unit Price	Total Cost
1. Sitework				
A. Earthwork				
1. Jacking Pits	EA	6	10,000	60,000
2. Horizontal Boring[2] (24-Inch Casing)	LF	300	254	76,200
2. Soil Disposal				
A. Transportation and Disposal	TON	29	300	8,700
3. Pipe				
A. Single Wall-6"[3]	LF	3,950	12.7	50,165
1. Fittings/Joints[3]	LS			3,100
2. Fabrication[3]	HRS	229	50	11,450
3. Installation Labor[2]	LF	3,950	9.25	36,538
4. Abv Grnd Pipe Supports	EA	264	125	33,000
5. Valves	EA	6	500	3,000
4. Holding Tank (4 Hr Storage Capacity)[3]	LS	1	7,800	7,800
1. Secondary Cont/Leak Detection[3]	LS	1	3,700	3,700
2. Conical Tank Roof[3]	LS	1	1,124	1,124
3. Tank Pad[2,3]	SF	263	4.36	1,147
4. Tank Installation[3]	LS			5,800
5. Carbon Canister	LS	1	800	800
5. Pumps				
1. Booster Pump[3]	EA	2	1,800	3,600
TOTAL DIRECT COSTS:				306,123

(Continued)

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TABLE C5-4. (Continued)

Sacramento Cost Index (10%):	30,612
Contingency (5%):	15,306
SUBTOTAL:	352,042
General Contractor Overhead and Profit (25%):	88,010
SUBTOTAL	440,052
Engineering & Design (10%):	44,005
Bonding & Insurance (10%):	44,005
Construction Management (7%):	30,804
GRAND TOTAL:	$558,866

1 EA = Each
LF = Linear Foot
HRS = Hours
LS = Lump Sum
SF = Square Feet

2 Source: Means Site Work Cost Data, 1990; 9th Annual Edition.

3 Source: Vendor Quote.

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TABLE C5-5. EXTRACTION WELL SYSTEM COST ESTIMATES

Construction Item	Units[1]	Quantity	Unit Price	Total Cost
1. Extraction Well Costs				
A. Extraction Well Vaults				
1. Formwork[2]				
Inside	SFCA	132	4.61	609
Outside	SFCA	114	1.99	227
2. Concrete in place[2]	CY	2	186.8	374
			638	1,914
3. Vault covers[2]	EA	3		
B. Extraction Well Material/Construction[3]				
1. EW A-1	LS			14,500
2. EW B-1	LS			19,000
3. EW C-1	LS			28,500
C. Monitoring Well Material/Construction[3]				
4. MW A	LS			12,300
5. MW B	LS			16,300
6. MW C	LS			25,000
D. Cuttings Disposal[3]	Ton	35.8	340	12,172
2. Well Pump Costs				
A. Well Pump A-1	EA	1	1000	1,000
B. Well Pump B-1	EA	1	500	500
C. Well Pump C-1	EA	1	1800	1,800
D. Control Panels	EA	3	580	1,740
E. Flow Regulators (1.5")	EA	2	57.9	116
F. Flow Regulators (2.5")	EA	1	109	109
G. Pump Discharge (2")	FT	270	1.9	513
H. Pump Discharge (4")	FT	140	5.7	798
Direct Cost Total:				137,471
Sacramento Cost Index (10%)				13,747

(Continued)

TABLE C5-5. (Continued)

Construction Item	Units[1]	Quantity	Unit Price	Total Cost
Contingency (5%)				6,874
Subtotal				158,091
General Contractor O&P (25%)				39,523
Subtotal				$197,614
Engineering and Design (10%)				19761
Bonding and In surance (10%)				19761
Construction Management (7%)				13833
GRAND TOTAL				$211,447

[1] SFCA = Square foot contact area. LS = Lump sum. FT = Foot. CY = Cubic yard. EA = Each.
[2] Means Site Work Cost Data, 1990. 9th Annual edition.
[3] Vendor quote.

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TABLE C5-6. OPERATION AND MAINTENANCE COSTS

Item			Estimated O&M Cost (Cost/Yr)
1.	Extraction Well/ Monitoring Well System		
	A. Repairs [1]		2,800
	B. Utility Requirements [2]		4,400
	C. Monitoring Well Sampling & Analysis [3]		8,960
		TOTAL:	16,160
2.	Sanitary Sewer Discharge		
	A. Repairs [4]		5,850
	B. Sewer Use Charges [5]		30,000
		TOTAL:	35,850
3.	GWTP Discharge		
	A. Repairs [4]		5,850
	B. Utility Requirements		
	1. Booster Pump [2]		1,000
	2. GWTP [6]		4,500
		TOTAL:	11,350

1. Assumes one extraction well pump replacement per year and $1,000 for miscellaneous well maintenance tasks.

2. Assumes $.05/KW-h.

3. Assumes quarterly sampling of the three monitoring wells. Analytical costs based on analyzing each sample by EPA Methods 6010, 8010, and 8020.

4. Assumes 6 pipeline repairs per year ($4,100 per year) and $1,800 per year for replacement fittings/materials.

5. Based on Sacramento Regional County Sanitation District Sewer Rate Ordinances; Ordinance No. SRSD-0029.

6. Assumes that additional flow from the northern plume extraction wells will increase the GWTP utility costs by 5%.

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TABLE C5-7: SUMMARY OF COST ESTIMATES

Item		Estimated Construction Cost*
1.	Extraction Well/ Monitoring Well System	$ 197,600
2.	Sanitary Sewer Discharge	
	"Temporary" Connection Fee	420,600
	"Permanent" Connection Fee	1,122,000
3.	GWTP Discharge	
	Utility Trench Option	1,312,500
	Direct Pipe Burial Option	567,400
	Above Ground Pipe Option	559,000

* Includes direct and indirect capital costs, construction management costs, bonding and insurance costs, and engineering and design costs.

contaminated groundwater. As can be seen from Table C5-1, the potential sanitary sewer connection fees charged to McClellan AFB will have a direct impact on the cost of the sanitary sewer discharge option. The estimated O&M cost for the sanitary sewer discharge option is shown in Table C5-6. Monthly sanitary sewer use fees charged by the County of Sacramento Department of Public Works constitute approximately 80% of the estimated O&M costs. The remainder of the estimated O&M cost is due to expected pipeline and fitting repairs.

C5.2 Groundwater Treatment Plant Discharge

Cost estimates were developed for the extraction well/GWTP pipeline alternative based on three different piping design options. In the first piping design alternative, the portion of the pipeline route along Kilzer Avenue (see Figure C2-5) consists of double containment pipe placed in a concrete utility trench; the remainder of the pipeline route consists of single-wall pipe constructed aboveground. The concrete utility trench would have removable steel covers and is assumed to be approximately 3 feet wide and 4 feet deep to accommodate both the groundwater pipeline and other utilities. As can be seen in the cost estimate contained in Table C5-2, approximately 75 percent of the direct capital costs associated with this option are due to the construction of the utility trench and disposal of the soil removed from the trench.

In the second piping design alternative, the portion of the pipeline route along Kilzer Avenue is placed underground by direct burial. In this option, the underground pipe consists of double containment pipe, and the aboveground pipe consists of single containment pipe. The direct capital cost estimate for this option (see Tables C5-3 and C5-7) is approximately 40 percent that of the utility trench option. However, this option does not have the added benefit of allowing other base utilities to be installed along the same pipeline route.

In the third piping design alternative, the entire pipeline route except for street and railroad crossings is constructed aboveground with single-wall pipe. The major advantage of this option is that it is the least expensive of the three options evaluated (see Tables C5-4 and C5-7). However, this option may not be feasible because aboveground piping along Kilzer Avenue may hinder access to existing and planned facilities west of the pipeline route.

The estimated O&M cost for the GWTP discharge option is presented in Table C5-6. Approximately 50% of the estimated O&M cost is due to the utility costs for the booster pump and for the GWTP operations. The remainder of the estimated O&M cost is due to expected pipeline and fitting repairs.

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APPENDIX D

ANALYTICAL DATA

TABLE 1-1. SUMMARY OF FIELD SAMPLE ANALYTICAL RESULTS,
OPERABLE UNIT B EE/CA, GROUNDWATER,
SEPTEMBER 1989 TO MARCH 1990, McCLELLAN AIR FORCE BASE

			WELL NUMBER							
			MW-155		MW-156		MW-157		MW-157	
Field Sample ID			WELL-16A		WELL-16B		WELL-29A		WELL-AB29A	
Date Sampled			14-Sep-89		14-Sep-89		21-Sep-89		21-Sep-89	
Sampled By			RAD		RAD		RAD		RAD	
Lab			RAS		RAS		RAS		RAS	
Field Analysis			Normal Sample		Normal Sample		Normal Sample		Ambient Blank	
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8010 (ug/L)										
1,1,1,2-Tetrachloroethane	NE		ND	(1)	ND	(1)	ND	(50)	ND	(0.2)
1,1,1-Trichloroethane	200	MCL	ND	(1)	ND	(1)	ND	(50)	ND	(0.2)
1,1,2,2-Tetrachloroethane	1	MCL	ND	(1)	ND	(1)	ND	(50)	ND	(0.2)
1,1,2-Trichloroethane	32	MCL	ND	(1)	ND	(1)	ND	(50)	ND	(0.2)
1,1-Dichloroethane	NE		ND	(0.5)	ND	(0.5)	ND	(25)	ND	(0.1)
1,1-Dichloroethene	6	MCL	ND	(0.5)	ND	(0.5)	ND	(25)	ND	(0.1)
1,2,3-Trichloropropane	NE		NA		NA		NA		NA	
1,2-Dichlorobenzene	NE		ND	(1)	ND	(1)	ND	(50)	ND	(0.2)
1,2-Dichloroethane	0.5	MCL	ND	(0.5)	ND	(0.5)	ND	(25)	ND	(0.1)
1,2-Dichloropropane	5	PMCL	ND	(0.5)	ND	(0.5)	ND	(25)	ND	(0.1)
1,3-Dichlorobenzene	130	MCL	ND	(2.5)	ND	(2.5)	ND	(130)	ND	(0.5)
1,4-Dichlorobenzene	5	MCL	ND	(1)	ND	(1)	ND	(50)	ND	(0.2)
1-Chlorohexane	NE		ND	(10)	ND	(10)	ND	(500)	ND	(2)
2-Chloroethylvinylether	NE		ND	(10)	ND	(10)	ND	(500)	ND	(2)
Benzyl Chloride	NE		ND	(50)	ND	(50)	ND	(2500)	ND	(10)
Bromobenzene	NE		ND	(10)	ND	(10)	ND	(500)	ND	(2)
Bromodichloromethane	100	PMCL	ND	(0.5)	ND	(0.5)	ND	(25)	ND	(0.1)
Bromoform	100	PMCL	ND	(10)	ND	(10)	ND	(500)	ND	(2)
Bromomethane	NE		ND	(5)	ND	(5)	ND	(250)	ND	(1)
Carbon Tetrachloride	0.5	MCL	ND	(1)	ND	(1)	ND	(50)	ND	(0.2)
Chlorobenzene	30	AL	ND	(1)	ND	(1)	ND	(50)	ND	(0.2)
Chloroethane	NE		ND	(2.5)	ND	(2.5)	ND	(130)	ND	(0.5)
Chloroform	100	PMCL	ND	(0.5)	ND	(0.5)	ND	(25)	ND	(0.1)
Chloromethane	NE		ND	(2.5)	ND	(2.5)	ND	(130)	ND	(0.5)
Dibromochloromethane	100	PMCL	ND	(1)	ND	(1)	ND	(50)	ND	(0.2)
Dibromomethane	NE		ND	(10)	ND	(10)	ND	(500)	ND	(2)
Methylene Chloride	NE		ND	(2)	ND	(2)	ND	(100)	ND	(0.4)
Tetrachloroethene	5	MCL	ND	(0.5)	ND	(0.5)	390. C	(25)	ND	(0.1)
Total 1,2-Dichloroethene	16	AL	ND	(0.5)	47. C	(0.5)	ND	(25)	ND	(0.1)
Total Chlorotoluene	NE		ND	(50)	ND	(50)	ND	(2500)	ND	(10)

(Continued.)

TABLE 1-1. (Continued.)

			WELL NUMBER							
			MW-155		MW-156		MW-157		MW-157	
Field Sample ID			WELL-16A		WELL-16B		WELL-29A		WELL-AB29A	
Date Sampled			14-Sep-89		14-Sep-89		21-Sep-89		21-Sep-89	
Sampled By			RAD		RAD		RAD		RAD	
Lab			RAS		RAS		RAS		RAS	
Field Analysis			Normal Sample		Normal Sample		Normal Sample		Ambient Blank	
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8010 (ug/L)										
Trans-1,3-Dichloropropene	NE		ND	(2)	ND	(2)	ND	(100)	ND	(0.4)
Trichloroethene	5	MCL	48. C	(1)	78. C	(1)	4800. C	(50)	ND	(0.2)
Trichlorofluoromethane	150	AL	ND	(0.5)	ND	(0.5)	ND	(25)	ND	(0.1)
Trichloropropane	NE		ND	(10)	ND	(10)	ND	(500)	ND	(2)
Vinyl Chloride	0.5	MCL	ND	(1)	ND	(1)	ND	(50)	ND	(0.2)
bis(2-Chloroisopropyl)Ether	NE		ND	(50)	ND	(50)	ND	(2500)	ND	(10)
cis-1,3-Dichloropropene	NE		ND	(2)	ND	(2)	ND	(100)	ND	(0.4)

TABLE 1-1. (Continued.)

			WELL NUMBER							
			MW-157		MW-158		MW-158		MW-159	
Field Sample ID			WELL-EB29A		WELL-29-A-2		EB-1		MW-159	
Date Sampled			21-Sep-89		05-Oct-89		05-Oct-89		28-Dec-89	
Sampled By			RAD		RAD		RAD		RAD	
Lab			RAS		RAS		RAS		RAS	
Field Analysis			Equipment Blank		Normal Sample		Equipment Blank		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8010 (ug/L)										
1,1,1,2-Tetrachloroethane	NE		ND	(0.2)	ND	(20)	ND	(0.2)	ND	(50)
1,1,1-Trichloroethane	200	MCL	ND	(0.2)	ND	(20)	ND	(0.2)	ND	(2)
1,1,2,2-Tetrachloroethane	1	MCL	ND	(0.2)	ND	(20)	ND	(0.2)	ND	(1.5)
1,1,2-Trichloroethane	32	MCL	ND	(0.2)	ND	(20)	ND	(0.2)	ND	(2)
1,1-Dichloroethane	NE		ND	(0.1)	ND	(10)	ND	(0.1)	ND	(5)
1,1-Dichloroethene	6	MCL	ND	(0.1)	ND	(10)	ND	(0.1)	ND	(2)
1,2,3-Trichloropropane	NE		NA		NA		NA		ND	(50)
1,2-Dichlorobenzene	NE		ND	(0.2)	ND	(20)	ND	(0.2)	ND	(5)
1,2-Dichloroethane	0.5	MCL	ND	(0.1)	ND	(10)	ND	(0.1)	ND	(1)
1,2-Dichloropropane	5	PMCL	ND	(0.1)	ND	(10)	ND	(0.1)	ND	(1)
1,3-Dichlorobenzene	130	MCL	ND	(0.5)	ND	(50)	ND	(0.5)	ND	(3.2)
1,4-Dichlorobenzene	5	MCL	ND	(0.2)	ND	(20)	ND	(0.2)	ND	(2.4)
1-Chlorohexane	NE		ND	(2)	ND	(200)	ND	(2)	ND	(50)
2-Chloroethylvinylether	NE		ND	(2)	ND	(200)	ND	(2)	ND	(5)
Benzyl Chloride	NE		ND	(10)	ND	(1000)	ND	(10)	ND	(100)
Bromobenzene	NE		ND	(2)	ND	(200)	ND	(2)	ND	(50)
Bromodichloromethane	100	PMCL	ND	(0.1)	ND	(10)	ND	(0.1)	ND	(1)
Bromoform	100	PMCL	ND	(2)	ND	(200)	ND	(2)	ND	(5)
Bromomethane	NE		ND	(1)	ND	(100)	ND	(1)	ND	(12)
Carbon Tetrachloride	0.5	MCL	ND	(0.2)	ND	(20)	ND	(0.2)	ND	(1.2)
Chlorobenzene	30	AL	ND	(0.2)	ND	(20)	ND	(0.2)	ND	(2.5)
Chloroethane	NE		ND	(0.5)	ND	(50)	ND	(0.5)	ND	(5.2)
Chloroform	100	PMCL	ND	(0.1)	ND	(10)	ND	(0.1)	3.9 C	(1)
Chloromethane	NE		ND	(0.5)	ND	(50)	ND	(0.5)	ND	(3)
Dibromochloromethane	100	PMCL	ND	(0.2)	ND	(20)	ND	(0.2)	ND	(2)
Dibromomethane	NE		ND	(2)	ND	(200)	ND	(2)	ND	(50)
Methylene Chloride	NE		ND	(0.4)	ND	(40)	2.0 C	(0.4)	ND	(4)
Tetrachloroethene	5	MCL	ND	(0.1)	80. C	(10)	ND	(0.1)	1.3 C	(1)
Total 1,2-Dichloroethene	16	AL	ND	(0.1)	28. C	(10)	ND	(0.1)	45. C	(2)
Total Chlorotoluene	NE		ND	(10)	ND	(1000)	ND	(10)	ND	(250)
Trans-1,3-Dichloropropene	NE		ND	(0.4)	ND	(40)	ND	(0.4)	ND	(3.4)

(Continued.)

TABLE 1-1. (Continued.)

			WELL NUMBER					
			MW-157		MW-158		MW-158	MW-159
Field Sample ID			WELL-EB29A		WELL-29-A-2		EB-1	MW-159
Date Sampled			21-Sep-89		05-Oct-89		05-Oct-89	28-Dec-89
Sampled By			RAD		RAD		RAD	RAD
Lab			RAS		RAS		RAS	RAS
Field Analysis			Equipment Blank		Normal Sample		Equipment Blank	Normal Sample
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8010 (ug/L)										
Trichloroethene	5	MCL	ND	(0.2)	1000. C	(20)	0.64 C	(0.2)	85. C	(2)
Trichlorofluoromethane	150	AL	ND	(0.1)	ND	(10)	ND	(0.1)	ND	(2)
Trichloropropane	NE		ND	(2)	ND	(200)	ND	(2)	NA	
Vinyl Chloride	0.5	MCL	ND	(0.2)	ND	(20)	ND	(0.2)	ND	(2)
bis(2-Chloroisopropyl)Ether	NE		ND	(10)	ND	(1000)	ND	(10)	ND	(100)
cis-1,3-Dichloropropene	NE		ND	(0.4)	ND	(40)	ND	(0.4)	ND	(2)

TABLE 1-1. (Continued.)

			WELL NUMBER							
			MW-1053		MW-1054		MW-1055		MW-1055	
Field Sample ID			WELL-27A		WELL-26A		26B		AB-1	
Date Sampled			15-Sep-89		03-Oct-89		06-Oct-89		06-Oct-89	
Sampled By			RAD		RAD		RAD		RAD	
Lab			RAS		RAS		RAS		RAS	
Field Analysis			Normal Sample		Normal Sample		Normal Sample		Ambient Blank	
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8010 (ug/L)										
1,1,1,2-Tetrachloroethane	NE		ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
1,1,1-Trichloroethane	200	MCL	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
1,1,2,2-Tetrachloroethane	1	MCL	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
1,1,2-Trichloroethane	32	MCL	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
1,1-Dichloroethane	NE		ND	(0.1)	ND	(0.1)	ND	(0.1)	ND	(0.1)
1,1-Dichloroethene	6	MCL	ND	(0.1)	ND	(0.1)	ND	(0.1)	ND	(0.1)
1,2,3-Trichloropropane	NE		NA		NA		NA		NA	
1,2-Dichlorobenzene	NE		ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
1,2-Dichloroethane	0.5	MCL	ND	(0.1)	ND	(0.1)	ND	(0.1)	ND	(0.1)
1,2-Dichloropropane	5	PMCL	ND	(0.1)	ND	(0.1)	ND	(0.1)	ND	(0.1)
1,3-Dichlorobenzene	130	MCL	ND	(0.5)	ND	(0.5)	ND	(0.5)	ND	(0.5)
1,4-Dichlorobenzene	5	MCL	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
1-Chlorohexane	NE		ND	(2)	ND	(2)	ND	(2)	ND	(2)
2-Chloroethylvinylether	NE		ND	(2)	ND	(2)	ND	(2)	ND	(2)
Benzyl Chloride	NE		ND	(10)	ND	(10)	ND	(10)	ND	(10)
Bromobenzene	NE		ND	(2)	ND	(2)	ND	(2)	ND	(2)
Bromodichloromethane	100	PMCL	ND	(0.1)	ND	(0.1)	ND	(0.1)	ND	(0.1)
Bromoform	100	PMCL	ND	(2)	ND	(2)	ND	(2)	ND	(2)
Bromomethane	NE		ND	(1)	ND	(1)	ND	(1)	ND	(1)
Carbon Tetrachloride	0.5	MCL	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
Chlorobenzene	30	AL	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
Chloroethane	NE		ND	(0.5)	ND	(0.5)	ND	(0.5)	ND	(0.5)
Chloroform	100	PMCL	ND	(0.1)	0.19 C	(0.1)	ND	(0.1)	ND	(0.1)
Chloromethane	NE		ND	(0.5)	ND	(0.5)	ND	(0.5)	ND	(0.5)
Dibromochloromethane	100	PMCL	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
Dibromomethane	NE		ND	(2)	ND	(2)	ND	(2)	ND	(2)
Methylene Chloride	NE		ND	(0.4)	ND	(0.4)	ND	(0.4)	0.45 U	(0.4)
Tetrachloroethene	5	MCL	ND	(0.1)	0.17 C	(0.1)	ND	(0.1)	ND	(0.1)
Total 1,2-Dichloroethene	16	AL	ND	(0.1)	0.20 C	(0.1)	ND	(0.1)	ND	(0.1)
Total Chlorotoluene	NE		ND	(10)	ND	(10)	ND	(10)	ND	(10)
Trans-1,3-Dichloropropene	NE		ND	(0.4)	ND	(0.4)	ND	(0.4)	ND	(0.4)

(Continued.)

TABLE 1-1. (Continued.)

			WELL NUMBER							
			MW-1053		MW-1054		MW-1055		MW-1055	
Field Sample ID			WELL-27A		WELL-26A		26B		AB-1	
Date Sampled			15-Sep-89		03-Oct-89		06-Oct-89		06-Oct-89	
Sampled By			RAD		RAD		RAD		RAD	
Lab			RAS		RAS		RAS		RAS	
Field Analysis			Normal Sample		Normal Sample		Normal Sample		Ambient Blank	
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8010 (ug/L)										
Trichloroethene	5	MCL	ND	(0.2)	1.1 C	(0.2)	ND	(0.2)	ND	(0.2)
Trichlorofluoromethane	150	AL	ND	(0.1)	ND	(0.1)	ND	(0.1)	ND	(0.1)
Trichloropropane	NE		ND	(2)	ND	(2)	ND	(2)	ND	(2)
Vinyl Chloride	0.5	MCL	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
bis(2-Chloroisopropyl)Ether	NE		ND	(10)	ND	(10)	ND	(10)	ND	(10)
cis-1,3-Dichloropropene	NE		ND	(0.4)	ND	(0.4)	ND	(0.4)	ND	(0.4)

TABLE 1-1. (Continued.)

			WELL NUMBER							
			MW-1056		MW-1056		MW-1057		Trip Blank	
Field Sample ID			MW-1056		MW-1056A		WELL-26D		TB-1	
Date Sampled			27-Dec-89		27-Dec-89		27-Sep-89		27-Sep-89	
Sampled By			RAD		RAD		RAD		RAD	
Lab			RAS		RAS		RAS		RAS	
Field Analysis			Normal Sample		Field Duplicate		Normal Sample		Trip Blank	
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8010 (ug/L)										
1,1,1,2-Tetrachloroethane	NE		ND	(5)	ND	(5)	ND	(0.2)	ND	(0.2)
1,1,1-Trichloroethane	200	MCL	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
1,1,2,2-Tetrachloroethane	1	MCL	ND	(0.15)	ND	(0.15)	ND	(0.2)	ND	(0.2)
1,1,2-Trichloroethane	32	MCL	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
1,1-Dichloroethane	NE		ND	(0.5)	ND	(0.5)	ND	(0.1)	ND	(0.1)
1,1-Dichloroethene	6	MCL	ND	(0.2)	ND	(0.2)	ND	(0.1)	ND	(0.1)
1,2,3-Trichloropropane	NE		ND	(5)	ND	(5)	NA		NA	
1,2-Dichlorobenzene	NE		ND	(0.5)	ND	(0.5)	ND	(0.2)	ND	(0.2)
1,2-Dichloroethane	0.5	MCL	ND	(0.1)	ND	(0.1)	ND	(0.1)	ND	(0.1)
1,2-Dichloropropane	5	PMCL	ND	(0.1)	ND	(0.1)	ND	(0.1)	ND	(0.1)
1,3-Dichlorobenzene	130	MCL	ND	(0.32)	ND	(0.32)	ND	(0.5)	ND	(0.5)
1,4-Dichlorobenzene	5	MCL	ND	(0.24)	ND	(0.24)	ND	(0.2)	ND	(0.2)
2-Chlorohexane	NE		ND	(5)	ND	(5)	ND	(2)	ND	(2)
2-Chloroethylvinylether	NE		ND	(0.5)	ND	(0.5)	ND	(2)	ND	(2)
Benzyl Chloride	NE		ND	(10)	ND	(10)	ND	(10)	ND	(10)
Bromobenzene	NE		ND	(5)	ND	(5)	ND	(2)	ND	(2)
Bromodichloromethane	100	PMCL	ND	(0.1)	ND	(0.1)	ND	(0.1)	ND	(0.1)
Bromoform	100	PMCL	ND	(0.5)	ND	(0.5)	ND	(2)	ND	(2)
Bromomethane	NE		ND	(1.2)	ND	(1.2)	ND	(1)	ND	(1)
Carbon Tetrachloride	0.5	MCL	ND	(0.12)	ND	(0.12)	ND	(0.2)	ND	(0.2)
Chlorobenzene	30	AL	ND	(0.25)	ND	(0.25)	ND	(0.2)	ND	(0.2)
Chloroethane	NE		ND	(0.52)	ND	(0.52)	ND	(0.5)	ND	(0.5)
Chloroform	100	PMCL	ND	(0.1)	ND	(0.1)	ND	(0.1)	ND	(0.1)
Chloromethane	NE		ND	(0.3)	ND	(0.3)	ND	(0.5)	ND	(0.5)
Dibromochloromethane	100	PMCL	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
Dibromomethane	NE		ND	(5)	ND	(5)	ND	(2)	ND	(2)
Methylene Chloride	NE		1.5 C	(0.4)	0.94 C	(0.4)	0.41 C	(0.4)	ND	(0.4)
Tetrachloroethene	5	MCL	ND	(0.1)	ND	(0.1)	ND	(0.1)	ND	(0.1)
Total 1,2-Dichloroethene	16	AL	1.4 C	(0.2)	2.0 C	(0.2)	ND	(0.1)	ND	(0.1)
Total Chlorotoluene	NE		ND	(25)	ND	(25)	ND	(10)	ND	(10)
Trans-1,3-Dichloropropene	NE		ND	(0.34)	ND	(0.34)	ND	(0.4)	ND	(0.4)

(Continued.)

TABLE 1-1. (Continued.)

			WELL NUMBER							
			MW-1056		MW-1056		MW-1057		Trip Blank	
Field Sample ID			MW-1056		MW-1056A		WELL-26D		TB-1	
Date Sampled			27-Dec-89		27-Dec-89		27-Sep-89		27-Sep-89	
Sampled By			RAD		RAD		RAD		RAD	
Lab			RAS		RAS		RAS		RAS	
Field Analysis			Normal Sample		Field Duplicate		Normal Sample		Trip Blank	
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8010 (ug/L)										
Trichloroethene	5	MCL	4.6 C	(0.2)	4.4 C	(0.2)	ND	(0.2)	ND	(0.2)
Trichlorofluoromethane	150	AL	ND	(0.2)	ND	(0.2)	ND	(0.1)	ND	(0.1)
Trichloropropane	NE		NA		NA		ND	(2)	ND	(2)
Vinyl Chloride	0.5	MCL	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
bis(2-Chloroisopropyl)Ether	NE		ND	(10)	ND	(10)	ND	(10)	ND	(10)
cis-1,3-Dichloropropene	NE		ND	(0.2)	ND	(0.2)	ND	(0.4)	ND	(0.4)

TABLE 1-1. (Continued.)

		WELL NUMBER			
		MW-155	MW-156	MW-158	MW-158
Field Sample ID		WELL-16A	WELL-16B	WELL-29-A-2	29-A-2/D
Date Sampled		14-Sep-89	14-Sep-89	05-Oct-89	05-Oct-89
Sampled By		RAD	RAD	RAD	RAD
Lab		RAS	RAS	RAS	RAS
Field Analysis		Normal Sample	Normal Sample	Normal Sample	Field Duplicate
Analytes	Maximum Contaminant Level Or Action Level	Result / Detection Limit	Result / Detection Limit	Result / Detection Limit	Result / Detection Limit
8020 (ug/L)					
1,2-Dichlorobenzene	NE	ND (0.2)	ND (0.2)	ND (50)	ND (20)
1,3-Dichlorobenzene	130 MCL	ND (0.4)	ND (0.4)	ND (100)	ND (40)
1,4-Dichlorobenzene	5 MCL	ND (0.2)	ND (0.2)	ND (50)	ND (20)
Benzene	1 MCL	ND (0.1)	ND (0.1)	ND (25)	ND (10)
Chlorobenzene	30 AL	ND (0.1)	ND (0.1)	ND (25)	ND (10)
Ethylbenzene	680 MCL	ND (0.1)	ND (0.1)	ND (25)	ND (10)
Toluene	NE	ND (0.3)	ND (0.3)	ND (75)	ND (30)
Total Xylenes	1750 MCL	ND (0.2)	ND (0.2)	ND (50)	ND (20)

TABLE 1-1. (Continued.)

			WELL NUMBER							
			MW-159		MW-1053		MW-1056		Trip Blank	
Field Sample ID			MW-159		WELL-27A		MW-1056		TB-1A	
Date Sampled			28-Dec-89		15-Sep-89		27-Dec-89		05-Oct-89	
Sampled By			RAD		RAD		RAD		RAD	
Lab			RAS		RAS		RAS		RAS	
Field Analysis			Normal Sample		Normal Sample		Normal Sample		Trip Blank	
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8020 (ug/L)										
1,2-Dichlorobenzene	NE		ND	(4)	ND	(0.2)	ND	(0.4)	ND	(0.2)
1,3-Dichlorobenzene	130	MCL	ND	(4)	ND	(0.4)	ND	(0.4)	ND	(0.4)
1,4-Dichlorobenzene	5	MCL	ND	(3)	ND	(0.2)	ND	(0.3)	ND	(0.2)
Benzene	1	MCL	ND	(2)	ND	(0.1)	ND	(0.2)	ND	(0.1)
Chlorobenzene	30	AL	ND	(2)	ND	(0.1)	ND	(0.2)	ND	(0.1)
Ethylbenzene	680	MCL	ND	(2)	ND	(0.1)	ND	(0.2)	ND	(0.1)
Toluene	NE		ND	(2)	ND	(0.3)	ND	(0.2)	ND	(0.3)
Total Xylenes	1750	MCL	ND	(2)	ND	(0.2)	ND	(0.2)	ND	(0.2)

TABLE 1-1. (Continued.)

		WELL NUMBER							
		MW-155		MW-156		MW-1054		MW-1055	
Field Sample ID		WELL-16A		WELL-16B		WELL-26A		26B	
Date Sampled		14-Sep-89		14-Sep-89		03-Oct-89		06-Oct-89	
Sampled By		RAD		RAD		RAD		RAD	
Lab		RAS		RAS		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8040 (ug/L)									
2,4,6-Trichlorophenol	NE	ND	(0.6)	ND	(0.6)	ND	(0.6)	ND	(0.6)
2,4-Dichlorophenol	NE	ND	(0.5)	ND	(0.5)	ND	(0.5)	ND	(0.5)
2,4-Dimethylphenol	NE	ND	(0.3)	ND	(0.3)	ND	(0.3)	ND	(0.3)
2,4-Dinitrophenol	NE	ND	(13)	ND	(13)	ND	(13)	ND	(13)
2-Chlorophenol	NE	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)
2-Nitrophenol	NE	ND	(2)	ND	(2)	ND	(2)	ND	(2)
4,6-Dinitro-2-Methylphenol	NE	ND	(16)	ND	(16)	ND	(16)	ND	(16)
4-Chloro-3-Methylphenol	NE	ND	(0.4)	ND	(0.4)	ND	(0.4)	ND	(0.4)
4-Nitrophenol	NE	ND	(2.5)	ND	(2.5)	ND	(2.5)	ND	(2.5)
Pentachlorophenol	NE	ND	(7.5)	ND	(7.5)	ND	(7.5)	ND	(7.5)
Phenol	NE	ND	(0.2)	ND	(0.2)	ND	(0.2)	ND	(0.2)

TABLE 1-1. (Continued.)

	WELL NUMBER		
	MW-1055		
Field Sample ID	26B-D		
Date Sampled	06-Oct-89		
Sampled By	RAD		
Lab	RAS		
Field Analysis	Field Duplicate		
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit
8040 (ug/L)			
2,4,6-Trichlorophenol	NE	ND	(0.6)
2,4-Dichlorophenol	NE	ND	(0.5)
2,4-Dimethylphenol	NE	ND	(0.3)
2,4-Dinitrophenol	NE	ND	(13)
2-Chlorophenol	NE	ND	(0.2)
2-Nitrophenol	NE	ND	(2)
4,6-Dinitro-2-Methylphenol	NE	ND	(16)
4-Chloro-3-Methylphenol	NE	ND	(0.4)
4-Nitrophenol	NE	ND	(2.5)
Pentachlorophenol	NE	ND	(7.5)
Phenol	NE	ND	(0.2)

TABLE 1-1. (Continued.)

	WELL NUMBER MW-157
Field Sample ID	MW-157
Date Sampled	19-Mar-90
Sampled By	RAD
Lab	RAS
Field Analysis	Normal Sample

Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit
8240 (ug/L)				
1,1,1,2-Tetrachloroethane	NE		ND	(160)
1,1,1-Trichloroethane	200	MCL	ND	(150)
1,1,2,2-Tetrachloroethane	1	MCL	ND	(200)
1,1,2-Trichloroethane	32	MCL	ND	(200)
1,1-Dichloroethane	NE		ND	(190)
1,1-Dichloroethene	6	MCL	ND	(110)
1,2,3-Trichloropropane	NE		ND	(160)
1,2-Dibromo-3-Chloropropane	NE		ND	(280)
1,2-Dibromoethane	0.02	MCL	ND	(190)
1,2-Dichloroethane	0.5	MCL	ND	(110)
1,2-Dichloropropane	5	PMCL	ND	(200)
1,4-Dichloro-2-butene (total)	NE		ND	(200)
2-Butanone	NE		ND	(10)
2-Hexanone	NE		ND	(10)
4-Methyl-2-Pentanone	NE		ND	(10)
Acetone	NE		ND	(10)
Acetonitrile	NE		ND	(260)
Acrolein	NE		ND	(3000)
Acrylonitrile	NE		ND	(3200)
Benzene	1	MCL	ND	(180)
Bromodichloromethane	100	PMCL	ND	(140)
Bromoform	100	PMCL	ND	(190)
Bromomethane	NE		ND	(200)
Carbon Disulfide	NE		ND	(200)
Carbon Tetrachloride	0.5	MCL	ND	(110)
Chlorobenzene	30	AL	ND	(200)
Chloroethane	NE		ND	(200)
Chloroform	100	PMCL	ND	(100)
Chloromethane	NE		ND	(200)
Dibromochloromethane	100	PMCL	ND	(120)

(Continued.)

RADIAN CORPORATION

TABLE 1-1. (Continued.)

	WELL NUMBER
	MW-157
Field Sample ID	MW-157
Date Sampled	19-Mar-90
Sampled By	RAD
Lab	RAS
Field Analysis	Normal Sample

Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit
8240 (ug/L)				
Dibromomethane	NE		ND	(200)
Dichlorodifluoromethane	NE		ND	(160)
Ethyl Methacrylate	NE		ND	(680)
Ethylbenzene	680	MCL	ND	(200)
Iodomethane	NE		ND	(230)
Methyl Methacrylate	NE		ND	(1100)
Methylene Chloride	NE		ND	(200)
Propanenitrile	NE		ND	(1700)
Styrene	NE		ND	(200)
Tetrachloroethene	5	MCL	1100.	(160)
Toluene	NE		ND	(200)
Total Xylenes	1750	MCL	ND	(200)
Trans-1,3-Dichloropropene	NE		ND	(200)
Trichloroethene	5	MCL	7700.	(100)
Trichlorofluoromethane	150	AL	ND	(200)
Vinyl Acetate	NE		ND	(280)
Vinyl Chloride	0.5	MCL	ND	(200)
cis-1,3-Dichloropropene	NE		ND	(200)
trans-1,2-Dichloroethene	NE		ND	(200)

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TABLE 1-1. (Continued.)

			WELL NUMBER							
			MW-155		MW-155		MW-155		MW-1053	
Field Sample ID			WELL-16A		EE/CA-16A		EB-16A		WELL-27A	
Date Sampled			10-Oct-89		10-Oct-89		10-Oct-89		15-Sep-89	
Sampled By			RAD		RAD		RAD		RAD	
Lab			RAS		RAS		RAS		RAS	
Field Analysis			Normal Sample		Field Duplicate		Equipment Blank		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8270 (ug/L)										
1,2,4,5-Tetrachlorobenzene	NE		ND	(1.5)	ND	(1.5)	ND	(1.5)	ND	(1.5)
1,2,4-Trichlorobenzene	NE		ND	(1.9)	ND	(1.9)	ND	(1.9)	ND	(1.9)
1,2-Dichlorobenzene	NE		ND	(1.9)	ND	(1.9)	ND	(1.9)	ND	(1.9)
1,3-Dichlorobenzene	130	MCL	ND	(1.9)	ND	(1.9)	ND	(1.9)	ND	(1.9)
1,3-Dinitrobenzene	NE		ND	(2.6)	ND	(2.6)	ND	(2.6)	ND	(2.6)
1,4-Dichlorobenzene	5	MCL	ND	(4.4)	ND	(4.4)	ND	(4.4)	ND	(4.4)
1,4-Naphthoquinone	NE		ND	(1.2)	ND	(1.2)	ND	(1.2)	ND	(1.2)
1-Chloronaphthalene	NE		ND	(2.1)	ND	(2.1)	ND	(2.1)	ND	(2.1)
1-Methylnaphthalene	NE		ND	(3.9)	ND	(3.9)	ND	(3.9)	ND	(3.9)
1-Naphthylamine	NE		ND	(5.7)	ND	(5.7)	ND	(5.7)	ND	(5.7)
2,3,4,6-Tetrachlorophenol	NE		ND	(6.8)	ND	(6.8)	ND	(6.8)	ND	(6.8)
2,4,5-Trichlorophenol	NE		ND	(10)	ND	(10)	ND	(10)	ND	(10)
2,4,6-Trichlorophenol	NE		ND	(2.7)	ND	(2.7)	ND	(2.7)	ND	(2.7)
2,4-Dichlorophenol	NE		ND	(2.7)	ND	(2.7)	ND	(2.7)	ND	(2.7)
2,4-Dimethylphenol	NE		ND	(2.7)	ND	(2.7)	ND	(2.7)	ND	(2.7)
2,4-Dinitrophenol	NE		ND	(42)	ND	(42)	ND	(42)	ND	(42)
2,4-Dinitrotoluene	NE		ND	(5.7)	ND	(5.7)	ND	(5.7)	ND	(5.7)
2,6-Dichlorophenol	NE		ND	(6.8)	ND	(6.8)	ND	(6.8)	ND	(6.8)
2,6-Dinitrotoluene	NE		ND	(1.9)	ND	(1.9)	ND	(1.9)	ND	(1.9)
2-Acetylaminofluorene	NE		ND	(6.4)	ND	(6.4)	ND	(6.4)	ND	(6.4)
2-Chloronaphthalene	NE		ND	(1.9)	ND	(1.9)	ND	(1.9)	ND	(1.9)
2-Chlorophenol	NE		ND	(3.3)	ND	(3.3)	ND	(3.3)	ND	(3.3)
2-Methylnaphthalene	NE		ND	(10)	ND	(10)	ND	(10)	ND	(10)
2-Methylphenol	NE		ND	(10)	ND	(10)	ND	(10)	ND	(10)
2-Naphthylamine	NE		ND	(13)	ND	(13)	ND	(13)	ND	(13)
2-Nitroaniline	NE		ND	(50)	ND	(50)	ND	(50)	ND	(50)
2-Nitrophenol	NE		ND	(3.6)	ND	(3.6)	ND	(3.6)	ND	(3.6)
2-Picoline	NE		ND	(2.4)	ND	(2.4)	ND	(2.4)	ND	(2.4)
3,3'-Dichlorobenzidine	NE		ND	(17)	ND	(17)	ND	(17)	ND	(17)
3,3'-Dimethylbenzidine	NE		ND	(8.2)	ND	(8.2)	ND	(8.2)	ND	(8.2)
3-Methylcholanthrene	NE		ND	(3.5)	ND	(3.5)	ND	(3.5)	ND	(3.5)

(Continued.)

TABLE 1-1. (Continued.)

		WELL NUMBER			
		MW-155	MW-155	MW-155	MW-1053
Field Sample ID		WELL-16A	EE/CA-16A	EB-16A	WELL-27A
Date Sampled		10-Oct-89	10-Oct-89	10-Oct-89	15-Sep-89
Sampled By		RAD	RAD	RAD	RAD
Lab		RAS	RAS	RAS	RAS
Field Analysis		Normal Sample	Field Duplicate	Equipment Blank	Normal Sample
Analytes	Maximum Contaminant Level Or Action Level	Result / Detection Limit	Result / Detection Limit	Result / Detection Limit	Result / Detection Limit
8270 (ug/L)					
3-Methylphenol	NE	ND (13)	ND (13)	ND (13)	ND (13)
3-Nitroaniline	NE	ND (50)	ND (50)	ND (50)	ND (50)
4,6-Dinitro-2-Methylphenol	NE	ND (24)	ND (24)	ND (24)	ND (24)
4-Aminobiphenyl	NE	ND (3)	ND (3)	ND (3)	ND (3)
4-Bromophenyl-Phenylether	NE	ND (1.9)	ND (1.9)	ND (1.9)	ND (1.9)
4-Chloro-3-Methylphenol	NE	ND (3)	ND (3)	ND (3)	ND (3)
4-Chloroaniline	NE	ND (10)	ND (10)	ND (10)	ND (10)
4-Chlorophenyl-Phenylether	NE	ND (4.2)	ND (4.2)	ND (4.2)	ND (4.2)
4-Methylphenol	NE	ND (10)	ND (10)	ND (10)	ND (10)
4-Nitroaniline	NE	ND (50)	ND (50)	ND (50)	ND (50)
4-Nitrophenol	NE	ND (2.4)	ND (2.4)	ND (2.4)	ND (2.4)
5-Nitro-o-toluidine	NE	ND (2.6)	ND (2.6)	ND (2.6)	ND (2.6)
7,12-Dimethylbenz(a)anthracene	NE	ND (1.4)	ND (1.4)	ND (1.4)	ND (1.4)
Acenaphthene	NE	ND (1.9)	ND (1.9)	ND (1.9)	ND (1.9)
Acenaphthylene	NE	ND (3.5)	ND (3.5)	ND (3.5)	ND (3.5)
Acetophenone	NE	ND (2.8)	ND (2.8)	ND (2.8)	ND (2.8)
Aniline	NE	ND (10)	ND (10)	ND (10)	ND (10)
Anthracene	0.7 AL	ND (1.9)	ND (1.9)	ND (1.9)	ND (1.9)
Benzidine	NE	ND (44)	ND (44)	ND (44)	ND (44)
Benzo(a)anthracene	NE	ND (7.8)	ND (7.8)	ND (7.8)	ND (7.8)
Benzo(a)pyrene	NE	ND (2.5)	ND (2.5)	ND (2.5)	ND (2.5)
Benzo(b)fluoranthene	NE	ND (4.8)	ND (4.8)	ND (4.8)	ND (4.8)
Benzo(g,h,i)perylene	NE	ND (4.1)	ND (4.1)	ND (4.1)	ND (4.1)
Benzo(k)fluoranthene	NE	ND (2.5)	ND (2.5)	ND (2.5)	ND (2.5)
Benzoic acid	NE	ND (50)	ND (50)	ND (50)	ND (50)
Benzyl Alcohol	NE	ND (10)	ND (10)	ND (10)	ND (10)
Benzyl Chloride	NE	ND (2.6)	ND (2.6)	ND (2.6)	ND (2.6)
Butylbenzylphthalate	NE	ND (2.5)	ND (2.5)	ND (2.5)	ND (2.5)
Chlorobenzilate	NE	ND (4.1)	ND (4.1)	ND (4.1)	ND (4.1)
Chrysene	NE	ND (2.5)	ND (2.5)	ND (2.5)	ND (2.5)
Dibenz(a,h)anthracene	NE	ND (2.5)	ND (2.5)	ND (2.5)	ND (2.5)

(Continued.)

TABLE 1-1. (Continued.)

		WELL NUMBER							
		MW-155		MW-155		MW-155		MW-1053	
Field Sample ID		WELL-16A		EE/CA-16A		EB-16A		WELL-27A	
Date Sampled		10-Oct-89		10-Oct-89		10-Oct-89		15-Sep-89	
Sampled By		RAD		RAD		RAD		RAD	
Lab		RAS		RAS		RAS		RAS	
Field Analysis		Normal Sample		Field Duplicate		Equipment Blank		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8270 (ug/L)									
Dibenz(a,j)acridine	NE	ND	(2.2)	ND	(2.2)	ND	(2.2)	ND	(2.2)
Dibenzofuran	NE	ND	(10)	ND	(10)	ND	(10)	ND	(10)
Diethylphthalate	NE	ND	(1.9)	ND	(1.9)	ND	(1.9)	ND	(1.9)
Dimethyl Phthalate	NE	ND	(1.6)	ND	(1.6)	ND	(1.6)	ND	(1.6)
Diphenylamine	NE	ND	(2)	ND	(2)	ND	(2)	ND	(2)
Ethylmethanesulfonate	NE	ND	(3.4)	ND	(3.4)	ND	(3.4)	ND	(3.4)
Fluoranthene	NE	ND	(2.2)	ND	(2.2)	ND	(2.2)	ND	(2.2)
Fluorene	NE	ND	(1.9)	ND	(1.9)	ND	(1.9)	ND	(1.9)
Hexachlorobenzene	NE	ND	(1.9)	ND	(1.9)	ND	(1.9)	ND	(1.9)
Hexachlorobutadiene	NE	ND	(0.9)	ND	(0.9)	ND	(0.9)	ND	(0.9)
Hexachlorocyclopentadiene	NE	ND	(6)	ND	(6)	ND	(6)	ND	(6)
Hexachloroethane	NE	ND	(1.6)	ND	(1.6)	ND	(1.6)	ND	(1.6)
Hexachloropropene	NE	ND	(5.7)	ND	(5.7)	ND	(5.7)	ND	(5.7)
Indene	NE	ND	(4.3)	ND	(4.3)	ND	(4.3)	ND	(4.3)
Indeno(1,2,3-cd)pyrene	NE	ND	(3.7)	ND	(3.7)	ND	(3.7)	ND	(3.7)
Isophorone	NE	ND	(2.2)	ND	(2.2)	ND	(2.2)	ND	(2.2)
Isosafrole	NE	ND	(1.5)	ND	(1.5)	ND	(1.5)	ND	(1.5)
Methapyrilene	NE	ND	(12)	ND	(12)	ND	(12)	ND	(12)
Methylmethanesulfonate	NE	ND	(4.9)	ND	(4.9)	ND	(4.9)	ND	(4.9)
N-Nitroso-di-n-butylamine	NE	ND	(3.1)	ND	(3.1)	ND	(3.1)	ND	(3.1)
N-nitroso-di-n-propylamine	NE	ND	(10)	ND	(10)	ND	(10)	ND	(10)
N-nitrosodimethylamine	NE	ND	(10)	ND	(10)	ND	(10)	ND	(10)
N-nitrosodiphenylamine	NE	ND	(1.9)	ND	(1.9)	ND	(1.9)	ND	(1.9)
N-nitrosopiperidine	NE	ND	(2.9)	ND	(2.9)	ND	(2.9)	ND	(2.9)
Naphthalene	NE	ND	(1.6)	ND	(1.6)	ND	(1.6)	ND	(1.6)
Nitrobenzene	NE	ND	(1.9)	ND	(1.9)	ND	(1.9)	ND	(1.9)
P-dimethylamino-azobenzene	NE	ND	(3.4)	ND	(3.4)	ND	(3.4)	ND	(3.4)
Pentachlorobenzene	NE	ND	(1.5)	ND	(1.5)	ND	(1.5)	ND	(1.5)
Pentachloroethane	NE	ND	(1.9)	ND	(1.9)	ND	(1.9)	ND	(1.9)
Pentachloronitrobenzene	NE	ND	(2.6)	ND	(2.6)	ND	(2.6)	ND	(2.6)
Pentachlorophenol	NE	ND	(3.6)	ND	(3.6)	ND	(3.6)	ND	(3.6)

(Continued.)

TABLE 1-1. (Continued.)

		WELL NUMBER							
		MW-155		MW-155		MW-155		MW-1053	
Field Sample ID		WELL-16A		EE/CA-16A		EB-16A		WELL-27A	
Date Sampled		10-Oct-89		10-Oct-89		10-Oct-89		15-Sep-89	
Sampled By		RAD		RAD		RAD		RAD	
Lab		RAS		RAS		RAS		RAS	
Field Analysis		Normal Sample		Field Duplicate		Equipment Blank		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
8270 (ug/L)									
Phenanthrene	NE	ND	(5.4)	ND	(5.4)	ND	(5.4)	ND	(5.4)
Phenol	NE	ND	(1.5)	ND	(1.5)	ND	(1.5)	ND	(1.5)
Pronamide	NE	ND	(1.8)	ND	(1.8)	ND	(1.8)	ND	(1.8)
Pyrene	NE	ND	(1.9)	ND	(1.9)	ND	(1.9)	ND	(1.9)
Pyridine	NE	9.2	(2.4)	ND	(2.4)	ND	(2.4)	ND	(2.4)
Quinoline	NE	ND	(3.1)	ND	(3.1)	ND	(3.1)	ND	(3.1)
Safrole	NE	ND	(2.5)	ND	(2.5)	ND	(2.5)	ND	(2.5)
a,a-Dimethylphenethylamine	NE	ND	(7.5)	ND	(7.5)	ND	(7.5)	ND	(7.5)
bis(2-Chloroethoxy)Methane	NE	ND	(5.3)	ND	(5.3)	ND	(5.3)	ND	(5.3)
bis(2-Chloroethyl)Ether	NE	ND	(5.7)	ND	(5.7)	ND	(5.7)	ND	(5.7)
bis(2-Chloroisopropyl)Ether	NE	ND	(5.7)	ND	(5.7)	ND	(5.7)	ND	(5.7)
bis(2-Ethylhexyl)Phthalate	NE	ND	(2.5)	ND	(2.5)	ND	(2.5)	3.9	(2.5)
di-n-Butylphthalate	NE	ND	(2.5)	ND	(2.5)	ND	(2.5)	ND	(2.5)
di-n-Octyl Phthalate	NE	ND	(2.5)	ND	(2.5)	ND	(2.5)	ND	(2.5)
n-Nitrosodiethylamine	NE	ND	(2.7)	ND	(2.7)	ND	(2.7)	ND	(2.7)
n-Nitrosomethylethylamine	NE	ND	(3.5)	ND	(3.5)	ND	(3.5)	ND	(3.5)
n-Nitrosomorpholine	NE	ND	(3.4)	ND	(3.4)	ND	(3.4)	ND	(3.4)
n-Nitrosopyrrolidine	NE	ND	(4.2)	ND	(4.2)	ND	(4.2)	ND	(4.2)
o-Toluidine	NE	ND	(2.5)	ND	(2.5)	ND	(2.5)	ND	(2.5)
p-Acetophenetidine	NE	ND	(2.1)	ND	(2.1)	ND	(2.1)	ND	(2.1)

TABLE 1-1. (Continued.)

			WELL NUMBER					
			MW-155 Total		MW-155 Dissolved		MW-156 Total	MW-156 Dissolved
Field Sample ID			WELL-16A		WELL-16A		WELL-16B	WELL-16B
Date Sampled			14-Sep-89		14-Sep-89		14-Sep-89	14-Sep-89
Sampled By			RAD		RAD		RAD	RAD
Lab			RAS		RAS		RAS	RAS
Field Analysis			Normal Sample		Normal Sample		Normal Sample	Normal Sample
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
6010 (mg/L)										
Aluminum	1	MCL	0.95	(0.045)	0.15	(0.045)	0.58	(0.045)	0.16	(0.045)
Antimony	NE		ND	(0.034)	ND	(0.034)	ND	(0.034)	ND	(0.034)
Arsenic	0.05	MCL	ND	(0.053)	ND	(0.053)	ND	(0.053)	ND	(0.053)
Barium	1	MCL	0.030	(0.002)	0.020	(0.002)	0.049	(0.002)	0.043	(0.002)
Beryllium	NE		ND	(0.001)	ND	(0.001)	ND	(0.001)	ND	(0.001)
Boron	NE		0.29 B	(0.006)	0.28 B	(0.006)	0.41 B	(0.006)	0.28 B	(0.006)
Cadmium	0.01	MCL	0.011	(0.004)	ND	(0.004)	ND	(0.004)	ND	(0.004)
Calcium	NE		20. B	(0.01)	20. B	(0.01)	28. B	(0.01)	27. B	(0.01)
Chromium	0.05	MCL	0.012	(0.007)	ND	(0.007)	0.014	(0.007)	0.011	(0.007)
Cobalt	NE		ND	(0.007)	ND	(0.007)	0.0090	(0.007)	ND	(0.007)
Copper	NE		0.26	(0.006)	0.17	(0.006)	0.14	(0.006)	0.11	(0.006)
Iron	NE		4.0	(0.007)	0.12	(0.007)	0.73	(0.007)	0.39	(0.007)
Lead	0.05	MCL	ND	(0.042)	ND	(0.042)	ND	(0.042)	ND	(0.042)
Magnesium	NE		13.	(0.03)	13.	(0.03)	20.	(0.03)	20.	(0.03)
Manganese	NE		0.062	(0.002)	0.035	(0.002)	0.031	(0.002)	0.021	(0.002)
Molybdenum	NE		ND	(0.008)	ND	(0.008)	ND	(0.008)	ND	(0.008)
Nickel	NE		ND	(0.015)	ND	(0.015)	ND	(0.015)	ND	(0.015)
Potassium	NE		ND	(3)	ND	(3)	ND	(3)	ND	(3)
Selenium	0.01	MCL	ND	(0.075)	ND	(0.075)	ND	(0.075)	ND	(0.075)
Silicon	NE		40.	(0.058)	38.	(0.058)	42.	(0.058)	42.	(0.058)
Silver	0.05	MCL	ND	(0.007)	ND	(0.007)	ND	(0.007)	ND	(0.007)
Sodium	NE		24.	(0.029)	24.	(0.029)	23.	(0.029)	23.	(0.029)
Thallium <	NE		ND	(0.051)	ND	(0.051)	ND	(0.051)	ND	(0.051)
Vanadium	NE		0.026	(0.008)	0.020	(0.008)	0.025	(0.008)	0.025	(0.008)
Zinc	NE		0.12	(0.002)	0.068 S	(0.002)	0.046	(0.002)	0.035	(0.002)

TABLE 1-1. (Continued.)

			WELL NUMBER							
			MW-157		MW-158 Total		MW-158 Dissolved		MW-158 Total	
Field Sample ID			MW-157		WELL-29-A-2		WELL-29-A-2		EB-1	
Date Sampled			19-Mar-90		05-Oct-89		05-Oct-89		05-Oct-89	
Sampled By			RAD		RAD		RAD		RAD	
Lab			RAS		RAS		RAS		RAS	
Field Analysis			Normal Sample		Normal Sample		Normal Sample		Equipment Blank	
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
6010 (mg/L)										
Aluminum	1	MCL	0.21	(0.045)	6.7	(0.045)	0.21	(0.045)	0.16	(0.045)
Antimony	NE		ND	(0.034)	ND	(0.034)	ND	(0.034)	ND	(0.034)
Arsenic	0.05	MCL	ND	(0.053)	ND	(0.053)	ND	(0.053)	ND	(0.053)
Barium	1	MCL	0.033	(0.002)	0.094	(0.002)	0.031	(0.002)	0.0060	(0.002)
Beryllium	NE		ND	(0.001)	ND	(0.001)	ND	(0.001)	ND	(0.001)
Boron	NE		NA	(0.006)	0.26	(0.006)	0.30	(0.006)	0.28	(0.006)
Cadmium	0.01	MCL	ND	(0.004)	ND	(0.004)	ND	(0.004)	ND	(0.004)
Calcium	NE		18.	(0.01)	23.	(0.01)	18.	(0.01)	0.16	(0.01)
Chromium	0.05	MCL	0.015	(0.007)	0.018	(0.007)	ND	(0.007)	ND	(0.007)
Cobalt	NE		ND	(0.007)	ND	(0.007)	ND	(0.007)	ND	(0.007)
Copper	NE		0.032	(0.006)	0.012	(0.006)	ND	(0.006)	ND	(0.006)
Iron	NE		0.33	(0.007)	8.6	(0.007)	0.12	(0.007)	0.080	(0.007)
Lead	0.05	MCL	ND	(0.042)	ND	(0.042)	ND	(0.042)	ND	(0.042)
Magnesium	NE		12.	(0.03)	16.	(0.03)	13.	(0.03)	ND	(0.03)
Manganese	NE		0.062	(0.002)	0.23	(0.002)	0.046	(0.002)	ND	(0.002)
Molybdenum	NE		ND	(0.008)	ND	(0.008)	ND	(0.008)	ND	(0.008)
Nickel	NE		0.040	(0.015)	0.032	(0.015)	ND	(0.015)	ND	(0.015)
Potassium	NE		ND	(3)	ND	(3)	ND	(3)	ND	(3)
Selenium	0.01	MCL	ND	(0.075)	ND	(0.075)	ND	(0.075)	ND	(0.075)
Silicon	NE		NA	(0.058)	52.	(0.058)	39.	(0.058)	0.60	(0.058)
Silver	0.05	MCL	ND	(0.007)	ND	(0.007)	ND	(0.007)	ND	(0.007)
Sodium	NE		18.	(0.029)	27.	(0.029)	26.	(0.029)	0.72	(0.029)
Thallium	NE		ND	(0.051)	ND	(0.051)	ND	(0.051)	ND	(0.051)
Vanadium	NE		0.026	(0.008)	0.046	(0.008)	0.022	(0.008)	ND	(0.008)
Zinc	NE		0.18	(0.002)	0.085	(0.002)	0.014	(0.002)	ND	(0.002)

TABLE 1-1. (Continued.)

		WELL NUMBER			
		MW-158 Dissolved	MW-1054 Total	MW-1054 Dissolved	MW-1055 Total
Field Sample ID		EB-1	WELL-26A	WELL-26A	26B
Date Sampled		05-Oct-89	06-Oct-89	06-Oct-89	06-Oct-89
Sampled By		RAD	RAD	RAD	RAD
Lab		RAS	RAS	RAS	RAS
Field Analysis		Equipment Blank	Normal Sample	Normal Sample	Normal Sample
Analytes	Maximum Contaminant Level Or Action Level	Result / Detection Limit	Result / Detection Limit	Result / Detection Limit	Result / Detection Limit
6010 (mg/L)					
Aluminum	1 MCL	0.13 (0.045)	7.3 (0.045)	0.18 (0.045)	20. (0.045)
Antimony	NE	ND (0.034)	ND (0.034)	ND (0.034)	ND (0.034)
Arsenic	0.05 MCL	ND (0.053)	ND (0.053)	ND (0.053)	ND (0.053)
Barium	1 MCL	0.0050 (0.002)	0.096 (0.002)	0.030 (0.002)	0.18 (0.002)
Beryllium	NE	ND (0.001)	ND (0.001)	ND (0.001)	0.0010 (0.001)
Boron	NE	0.23 (0.006)	0.27 (0.006)	0.30 (0.006)	0.28 (0.006)
Cadmium	0.01 MCL	ND (0.004)	ND (0.004)	ND (0.004)	ND (0.004)
Calcium	NE	0.21 (0.01)	30. (0.01)	23. (0.01)	40. (0.01)
Chromium	0.05 MCL	ND (0.007)	0.030 (0.007)	0.010 (0.007)	0.054 (0.007)
Cobalt	NE	ND (0.007)	0.0080 (0.007)	ND (0.007)	0.016 (0.007)
Copper	NE	ND (0.006)	ND (0.006)	ND (0.006)	ND (0.006)
Iron	NE	0.013 (0.007)	12. (0.007)	ND (0.007)	28. (0.007)
Lead	0.05 MCL	ND (0.042)	ND (0.042)	ND (0.042)	ND (0.042)
Magnesium	NE	ND (0.03)	19. (0.03)	14. (0.03)	17. (0.03)
Manganese	NE	ND (0.002)	0.20 (0.002)	0.014 (0.002)	0.44 (0.002)
Molybdenum	NE	ND (0.008)	ND (0.008)	ND (0.008)	ND (0.008)
Nickel	NE	ND (0.015)	0.036 (0.015)	ND (0.015)	0.030 (0.015)
Potassium	NE	ND (3)	ND (3)	ND (3)	6.4 B (3)
Selenium	0.01 MCL	ND (0.075)	ND (0.075)	ND (0.075)	ND (0.075)
Silicon	NE	0.44 (0.058)	52. (0.058)	35. (0.058)	63. (0.058)
Silver	0.05 MCL	ND (0.007)	ND (0.007)	ND (0.007)	ND (0.007)
Sodium	NE	0.70 (0.029)	23. B (0.029)	21. B (0.029)	41. B (0.029)
Thallium	NE	ND (0.051)	ND (0.051)	ND (0.051)	ND (0.051)
Vanadium	NE	ND (0.008)	0.052 (0.008)	0.022 (0.008)	0.078 (0.008)
Zinc	NE	ND (0.002)	0.16 (0.002)	0.012 (0.002)	2.5 (0.002)

TABLE 1-1. (Continued.)

		WELL NUMBER		
		MW-1055 Total	MW-1055 Dissolved	MW-1055 Dissolved
Field Sample ID		26B-D	26B	26B-D
Date Sampled		06-Oct-89	06-Oct-89	06-Oct-89
Sampled By		RAD	RAD	RAD
Lab		RAS	RAS	RAS
Field Analysis		Field Duplicate	Normal Sample	Field Duplicate
Analytes	Maximum Contaminant Level Or Action Level	Result / Detection Limit	Result / Detection Limit	Result / Detection Limit
6010 (mg/L)				
Aluminum	1 MCL	17. (0.045)	0.27 (0.045)	0.31 (0.045)
Antimony	NE	ND (0.034)	ND (0.034)	ND (0.034)
Arsenic	0.05 MCL	ND (0.053)	ND (0.053)	ND (0.053)
Barium	1 MCL	0.17 (0.002)	0.019 (0.002)	0.019 (0.002)
Beryllium	NE	ND (0.001)	ND (0.001)	ND (0.001)
Boron	NE	0.31 (0.006)	0.35 (0.006)	0.29 (0.006)
Cadmium	0.01 MCL	ND (0.004)	ND (0.004)	ND (0.004)
Calcium	NE	38. (0.01)	19. (0.01)	19. (0.01)
Chromium	0.05 MCL	0.047 (0.007)	0.0070 (0.007)	ND (0.007)
Cobalt	NE	0.013 (0.007)	ND (0.007)	ND (0.007)
Copper	NE	ND (0.006)	ND (0.006)	ND (0.006)
Iron	NE	25. (0.007)	0.12 (0.007)	0.28 (0.007)
Lead	0.05 MCL	ND (0.042)	ND (0.042)	ND (0.042)
Magnesium	NE	16. (0.03)	9.6 (0.03)	9.6 (0.03)
Manganese	NE	0.39 (0.002)	0.0060 (0.002)	0.0090 (0.002)
Molybdenum	NE	ND (0.008)	ND (0.008)	0.0080 (0.008)
Nickel	NE	0.040 (0.015)	ND (0.015)	ND (0.015)
Potassium	NE	6.1 B (3)	4.3 B (3)	4.7 B (3)
Selenium	0.01 MCL	ND (0.075)	ND (0.075)	ND (0.075)
Silicon	NE	62. (0.058)	30. (0.058)	30. (0.058)
Silver	0.05 MCL	ND (0.007)	ND (0.007)	ND (0.007)
Sodium	NE	42. B (0.029)	39. B (0.029)	38. B (0.029)
Thallium	NE	ND (0.051)	ND (0.051)	ND (0.051)
Vanadium	NE	0.071 (0.008)	0.022 (0.008)	0.024 (0.008)
Zinc	NE	2.2 (0.002)	0.020 (0.002)	0.036 (0.002)

TABLE 1-1. (Continued.)

			WELL NUMBER							
			MW-155		MW-156		MW-157		MW-158	
Field Sample ID			WELL-16A		WELL-16B		WELL-29A		WELL-29-A-2	
Date Sampled			14-Sep-89		14-Sep-89		21-Sep-89		05-Oct-89	
Sampled By			RAD		RAD		RAD		RAD	
Lab			RAS		RAS		RAS		RAS	
Field Analysis			Normal Sample		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
7196 (mg/L)										
Chromium, Hexavalent	50	PMCL	ND	(0.02)	ND	(0.02)	ND	(0.02)	0.020	(0.02)

TABLE 1-1. (Continued.)

			WELL NUMBER					
			MW-158		MW-1054		MW-1055	MW-1055
Field Sample ID			29-A-2/D		WELL-26A		26B	EB-2
Date Sampled			05-Oct-89		03-Oct-89		06-Oct-89	06-Oct-89
Sampled By			RAD		RAD		RAD	RAD
Lab			RAS		RAS		RAS	RAS
Field Analysis			Field Duplicate		Normal Sample		Normal Sample	Equipment Blank
Analytes	Maximum Contaminant Level Or Action Level		Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
7196 (ug/L)										
Chromium, Hexavalent	50	PMCL	ND	(0.02)	ND	(0.02)	ND	(0.02)	ND	(0.02)

TABLE 1-1. (Continued.)

		WELL NUMBER					
		MW-155		MW-156		MW-157	
Field Sample ID		WELL-16A		WELL-16B		WELL-29A	
Date Sampled		14-Sep-89		14-Sep-89		21-Sep-89	
Sampled By		RAD		RAD		RAD	
Lab		RAS		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
A403 (mg/L)							
Bicarbonate	NE	98.	(10)	130.	(10)	93.	(10)
Carbonate	NE	ND	(10)	ND	(10)	ND	(10)

TABLE 1-1. (Continued.)

		WELL NUMBER							
		MW-155		MW-156		MW-1049		MW-1050	
Field Sample ID		WELL-16A		WELL-16B		MW-1049		MW-1050	
Date Sampled		14-Sep-89		14-Sep-89		07-Nov-89		08-Nov-89	
Sampled By		RAD		RAD		RAD		RAD	
Lab		RAS		RAS		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
E130.2 (mg/L)									
Hardness, as CaCO3	NE	NA		NA		100.	(10)	88.	(10)
Total Hardness	NE	94.	(10)	130.	(10)	NA		NA	

TABLE 1-1. (Continued.)

		WELL NUMBER							
		MW-155		MW-156		MW-157		MW-1049	
Field Sample ID		WELL-16A		WELL-16B		WELL-29A		MW-1049	
Date Sampled		14-Sep-89		14-Sep-89		21-Sep-89		07-Nov-89	
Sampled By		RAD		RAD		RAD		RAD	
Lab		RAS		RAS		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
E160.1 (mg/L)									
Total Dissolved Solids	NE	230.	(10)	280.	(10)	240.	(10)	250.	(10)

TABLE 1-1. (Continued.)

		WELL NUMBER	
		MW-1050	
Field Sample ID		MW-1050	
Date Sampled		08-Nov-89	
Sampled By		RAD	
Lab		RAS	
Field Analysis		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit
E160.1 (mg/L)			
Total Dissolved Solids	NE	200.	(10)

TABLE 1-1. (Continued.)

		WELL NUMBER							
		MW-155		MW-156		MW-157		MW-1049	
Field Sample ID		WELL-16A		WELL-16B		WELL-29A		MW-1049	
Date Sampled		14-Sep-89		14-Sep-89		21-Sep-89		07-Nov-89	
Sampled By		RAD		RAD		RAD		RAD	
Lab		RAS		RAS		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
E160.2 (mg/L)									
Total Suspended Solids	NE	39.	(10)	29.	(10)	310.	(10)	22.	(10)

TABLE 1-1. (Continued.)

	WELL NUMBER
	MW-1050
Field Sample ID	MW-1050
Date Sampled	08-Nov-89
Sampled By	RAD
Lab	RAS
Field Analysis	Normal Sample

Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit
E160.2 (mg/L)			
Total Suspended Solids	NE	ND	(10)

TABLE 1-1. (Continued.)

		WELL NUMBER							
		MW-155		MW-156		MW-157		MW-159	
Field Sample ID		WELL-16A		WELL-16B		WELL-29A		MW-159	
Date Sampled		14-Sep-89		14-Sep-89		21-Sep-89		28-Dec-89	
Sampled By		RAD		RAD		RAD		RAD	
Lab		RAS		RAS		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
E215.1 (mg/L)									
Calcium	ME	18.	(1)	25.	(1)	18.	(1)	15.	(0.1)

TABLE 1-1. (Continued.)

		WELL NUMBER			
		MW-1049		MW-1050	
Field Sample ID		MW-1049		MW-1050	
Date Sampled		07-Nov-89		08-Nov-89	
Sampled By		RAD		RAD	
Lab		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit
E215.1 (mg/L)					
Calcium	NE	19.	(0.1)	15.	(0.1)

TABLE 1-1. (Continued.)

	WELL NUMBER			
	MW-155	MW-156	MW-157	MW-159
Field Sample ID	WELL-16A	WELL-16B	WELL-29A	MW-159
Date Sampled	14-Sep-89	14-Sep-89	21-Sep-89	28-Dec-89
Sampled By	RAD	RAD	RAD	RAD
Lab	RAS	RAS	RAS	RAS
Field Analysis	Normal Sample	Normal Sample	Normal Sample	Normal Sample

Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
E242.1 (mg/L)									
Magnesium	NE	12.	(a)	18.	(a)	15.	(5.1)	11.	(0.1)

TABLE 1-1. (Continued.)

		WELL NUMBER			
		MW-1049		MW-1050	
Field Sample ID		MW-1049		MW-1050	
Date Sampled		07-Nov-89		08-Nov-89	
Sampled By		RAD		RAD	
Lab		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit
E242.1 (mg/L)					
Magnesium	NE	14.	(0.1)	12.	(0.1)

TABLE 1-1. (Continued.)

		WELL NUMBER							
		MW-155		MW-156		MW-157		MW-159	
Field Sample ID		WELL-16A		WELL-16B		WELL-29A		MW-159	
Date Sampled		14-Sep-89		14-Sep-89		21-Sep-89		28-Dec-89	
Sampled By		RAD		RAD		RAD		RAD	
Lab		RAS		RAS		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
E258.1 (mg/L)									
Potassium	NE	2.4	(a)	2.6	(a)	3.8	(0.5)	1.4	(0.1)

TABLE 1-1. (Continued.)

		WELL NUMBER			
		MW-1049		MW-1050	
Field Sample ID		MW-1049		MW-1050	
Date Sampled		07-Nov-89		08-Nov-89	
Sampled By		RAD		RAD	
Lab		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit
E258.1 (mg/L)					
Potassium	NE	2.5	(0.1)	2.7	(0.1)

TABLE 1-1. (Continued.)

		WELL NUMBER							
		MW-155		MW-156		MW-157		MW-159	
Field Sample ID		WELL-16A		WELL-16B		WELL-29A		MW-159	
Date Sampled		14-Sep-89		14-Sep-89		21-Sep-89		28-Dec-89	
Sampled By		RAD		RAD		RAD		RAD	
Lab		RAS		RAS		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
E273.1 (mg/L)									
Sodium	NE	20.	(a)	20.	(a)	40.	(5.1)	17.	(0.1)

TABLE 1-1. (Continued.)

		WELL NUMBER			
		MW-1049		MW-1050	
Field Sample ID		MW-1049		MW-1050	
Date Sampled		07-Nov-89		08-Nov-89	
Sampled By		RAD		RAD	
Lab		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit
E?73.1 (mg/L)					
Sodium	NE	16.	(0.1)	28.	(0.1)

TABLE 1-1. (Continued.)

	WELL NUMBER			
	MW-155	MW-156	MW-157	MW-159
Field Sample ID	WELL-16A	WELL-16B	WELL-29A	MW-159
Date Sampled	14-Sep-89	14-Sep-89	21-Sep-89	28-Dec-89
Sampled By	RAD	RAD	RAD	RAD
Lab	RAS	RAS	RAS	RAS
Field Analysis	Normal Sample	Normal Sample	Normal Sample	Normal Sample

Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
E300.0 (mg/L)									
Chloride	NE	23.	(0.1)	22.	(0.02)	22.	(0.1)	18.	(0.1)
Fluoride	NE	ND	(0.5)	ND	(0.5)	ND	(0.1)	0.22	(0.1)
Orthophosphate	NE	0.21	(0.01)	0.24	(0.01)	0.24	(0.01)	ND	(0.1)
Sulfate	NE	9.4	(0.05)	5.9	(0.05)	NA		NA	

TABLE 1-1. (Continued.)

		WELL NUMBER			
		MW-1049		MW-1050	
Field Sample ID		MW-1049		MW-1050	
Date Sampled		07-Nov-89		08-Nov-89	
Sampled By		RAD		RAD	
Lab		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit
E300.0 (mg/L)					
Chloride	NE	20.	(0.04)	19.	(0.04)
Fluoride	NE	ND	(0.1)	ND	(0.1)
Orthophosphate	NE	ND	(0.1)	ND	(0.1)
Sulfate	NE	NA		NA	

TABLE 1-1. (Continued.)

		WELL NUMBER			
		MW-1049		MW-1050	
Field Sample ID		MW-1049		MW-1050	
Date Sampled		07-Nov-89		08-Nov-89	
Sampled By		RAD		RAD	
Lab		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit
E310.1 (mg/L)					
Bicarbonate	NE	110.	(1)	98.	(1)
Carbonate	NE	NA	(1)	NA	(1)
Hydroxide	NE	NA	(1)	NA	(1)

TABLE 1-1. (Continued.)

		WELL NUMBER							
		MW-155		MW-156		MW-157		MW-1049	
Field Sample ID		WELL-16A		WELL-16B		WELL-29A		MW-1049	
Date Sampled		14-Sep-89		14-Sep-89		21-Sep-89		07-Nov-89	
Sampled By		RAD		RAD		RAD		RAD	
Lab		RAS		RAS		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
E350.1 (mg/L)									
Ammonia	NE	0.08	(0.02)	0.10	(0.02)	0.51	(a)	ND	(0.01)

TABLE 1-1. (Continued.)

	WELL NUMBER
	MW-1050
Field Sample ID	MW-1050
Date Sampled	08-Nov-89
Sampled By	RAD
Lab	RAS
Field Analysis	Normal Sample

Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit
E350.1 (mg/L)			
Ammonia	NE	ND	(0.01)

TABLE 1-1. (Continued.)

		WELL NUMBER							
		MW-155		MW-156		MW-157		MW-1049	
Field Sample ID		WELL-16A		WELL-16B		WELL-29A		MW-1049	
Date Sampled		14-Sep-89		14-Sep-89		21-Sep-89		07-Nov-89	
Sampled By		RAD		RAD		RAD		RAD	
Lab		RAS		RAS		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
E353.2 (mg/L)									
Nitrate-Nitrite	NE	1.4	(0.04)	1.0	(0.02)	2.5	(0.1)	4.1 B	(0.04)

TABLE 1-1. (Continued.)

	WELL NUMBER		
	MW-1050		
Field Sample ID	MW-1050		
Date Sampled	08-Nov-89		
Sampled By	RAD		
Lab	RAS		
Field Analysis	Normal Sample		
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit
E353.2 (mg/L)			
Nitrate-Nitrite	NE	1.7 B	(0.04)

TABLE 1-1. (Continued.)

		WELL NUMBER			
		MW-155		MW-156	
Field Sample ID		WELL-16A		WELL-16B	
Date Sampled		14-Sep-89		14-Sep-89	
Sampled By		RAD		RAD	
Lab		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit
E365.2 (mg/L)					
Total Phosphate	ME	0.14	(0.02)	0.10	(0.02)

TABLE 1-1. (Continued.)

		WELL NUMBER					
		MW-157		MW-1049		MW-1050	
Field Sample ID		WELL-29A		MW-1049		MW-1050	
Date Sampled		21-Sep-89		07-Nov-89		08-Nov-89	
Sampled By		RAD		RAD		RAD	
Lab		RAS		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
E375.4 (mg/L)							
Sulfate	NE	ND	(5)	4.0	(1)	5.8	(1)

TABLE 1-1. (Continued.)

		WELL NUMBER							
		MW-155		MW-156		MW-157		MW-1049	
Field Sample ID		WELL-16A		WELL-16B		WELL-29A		MW-1049	
Date Sampled		14-Sep-89		14-Sep-89		21-Sep-89		07-Nov-89	
Sampled By		RAD		RAD		RAD		RAD	
Lab		RAS		RAS		RAS		RAS	
Field Analysis		Normal Sample		Normal Sample		Normal Sample		Normal Sample	
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
E377.1 (mg/L)									
Sulfite	NE	ND	(2)	ND	(2)	ND	(2)	ND	(2)

TABLE 1-1. (Continued.)

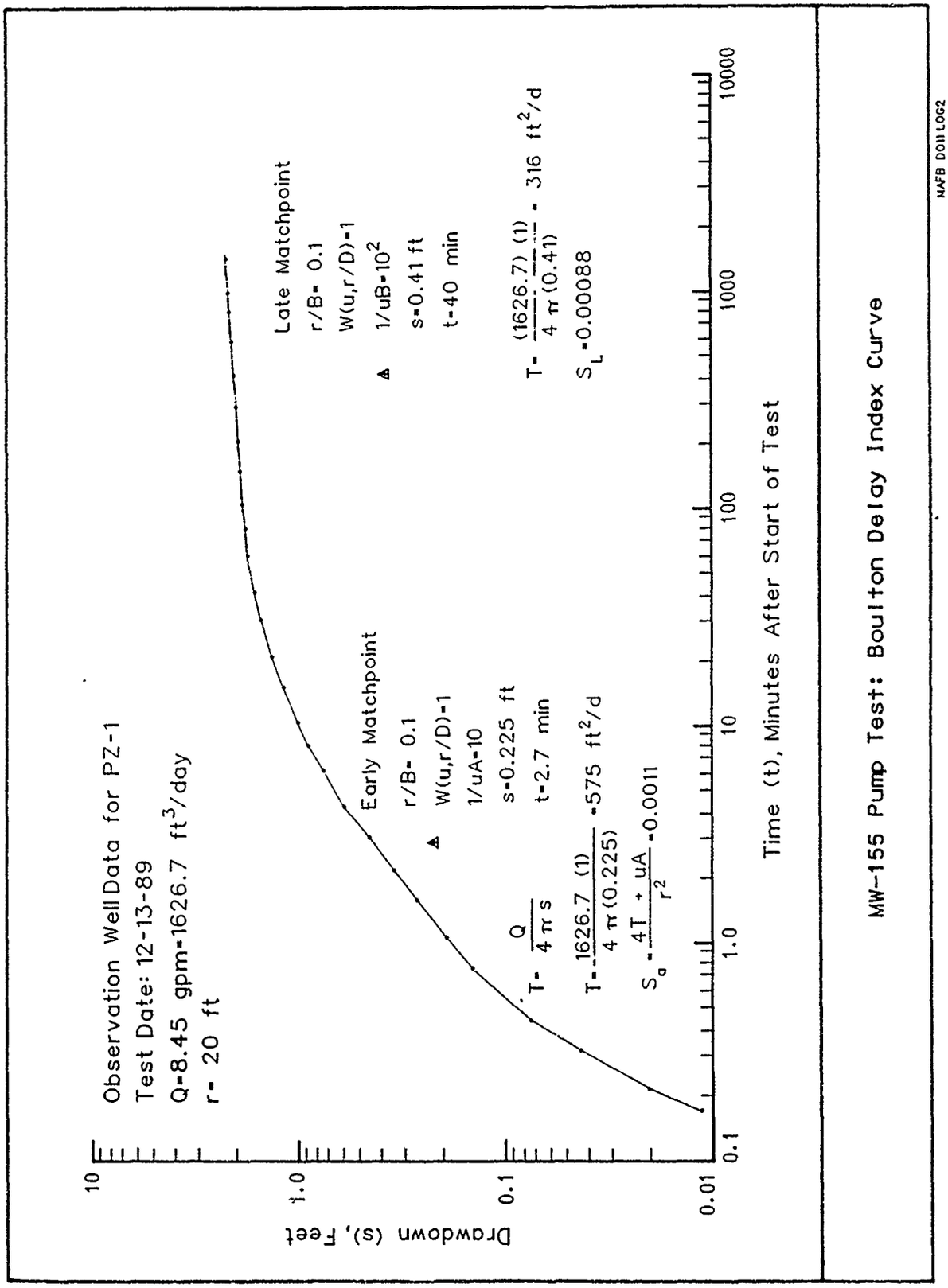
	WELL NUMBER
	MW-1050
Field Sample ID	MW-1050
Date Sampled	08-Nov-89
Sampled By	RAD
Lab	RAS
Field Analysis	Normal Sample

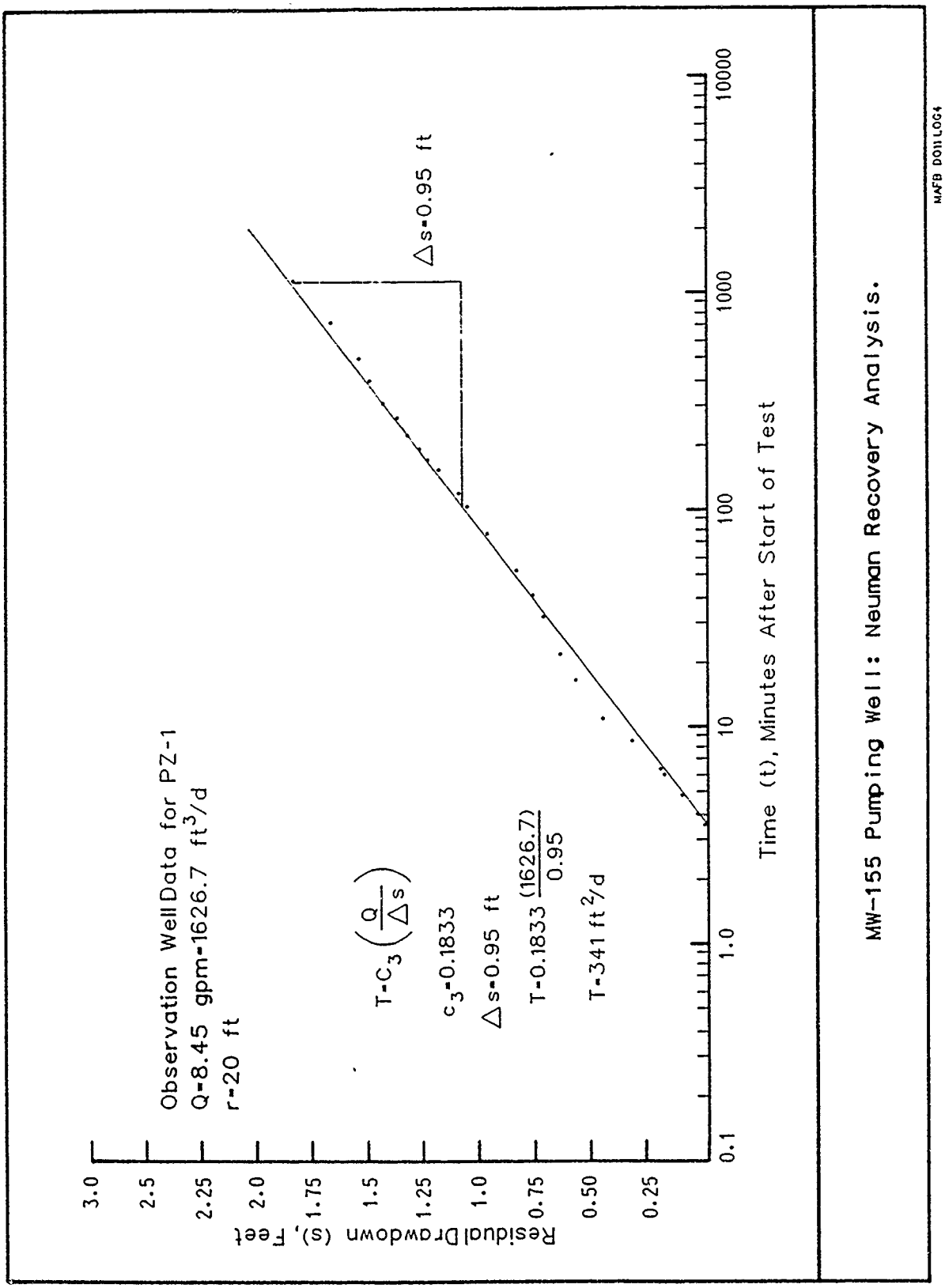
Analytes	Maximum Contaminant Level Or Action Level	Result	Detection Limit
E377.1 (mg/L)			
Sulfite	NE	ND	(2)

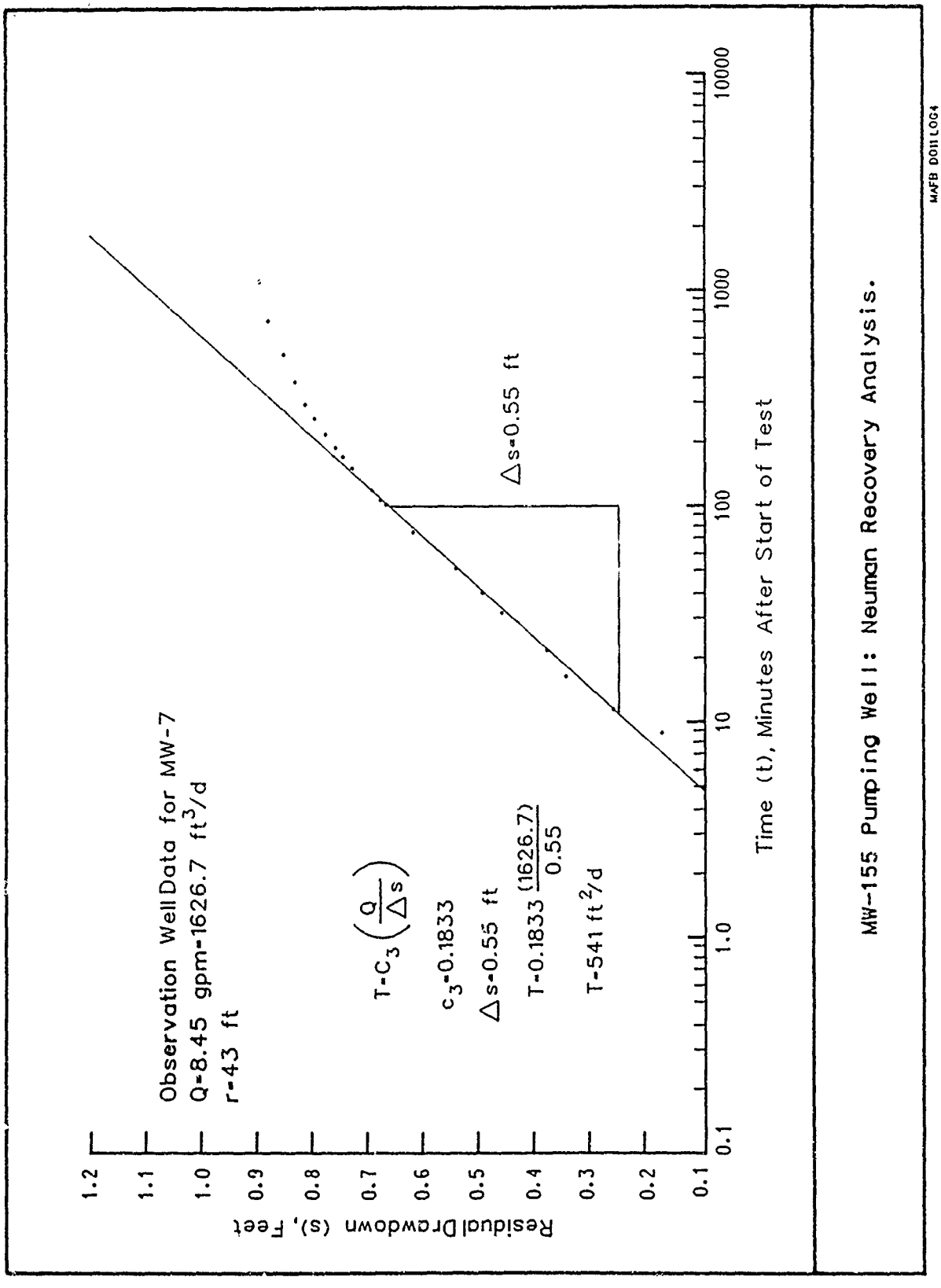
() = Value in parenthesis is detection limit
C = Confirmed on second column
MW = Monitoring well
NE = Threshold value not established
RAS = Radian Analytical Services
U = Unconfirmed, second column not requested

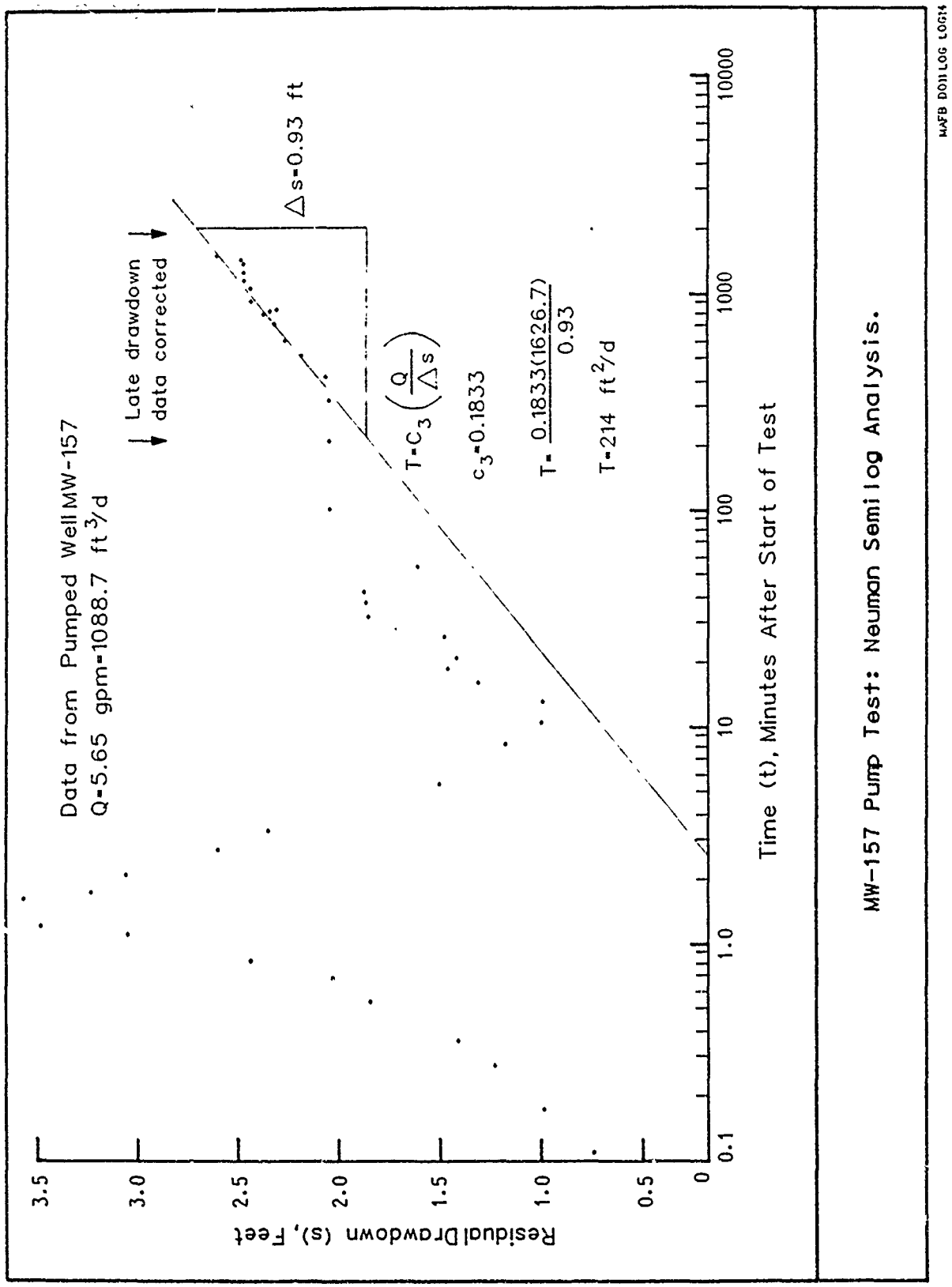
AL = DHS action level
FD = Field duplicate
NA = Not analyzed
PMCL = US. EPA primary maximum contaminant level
S = Determined by method of standard addition

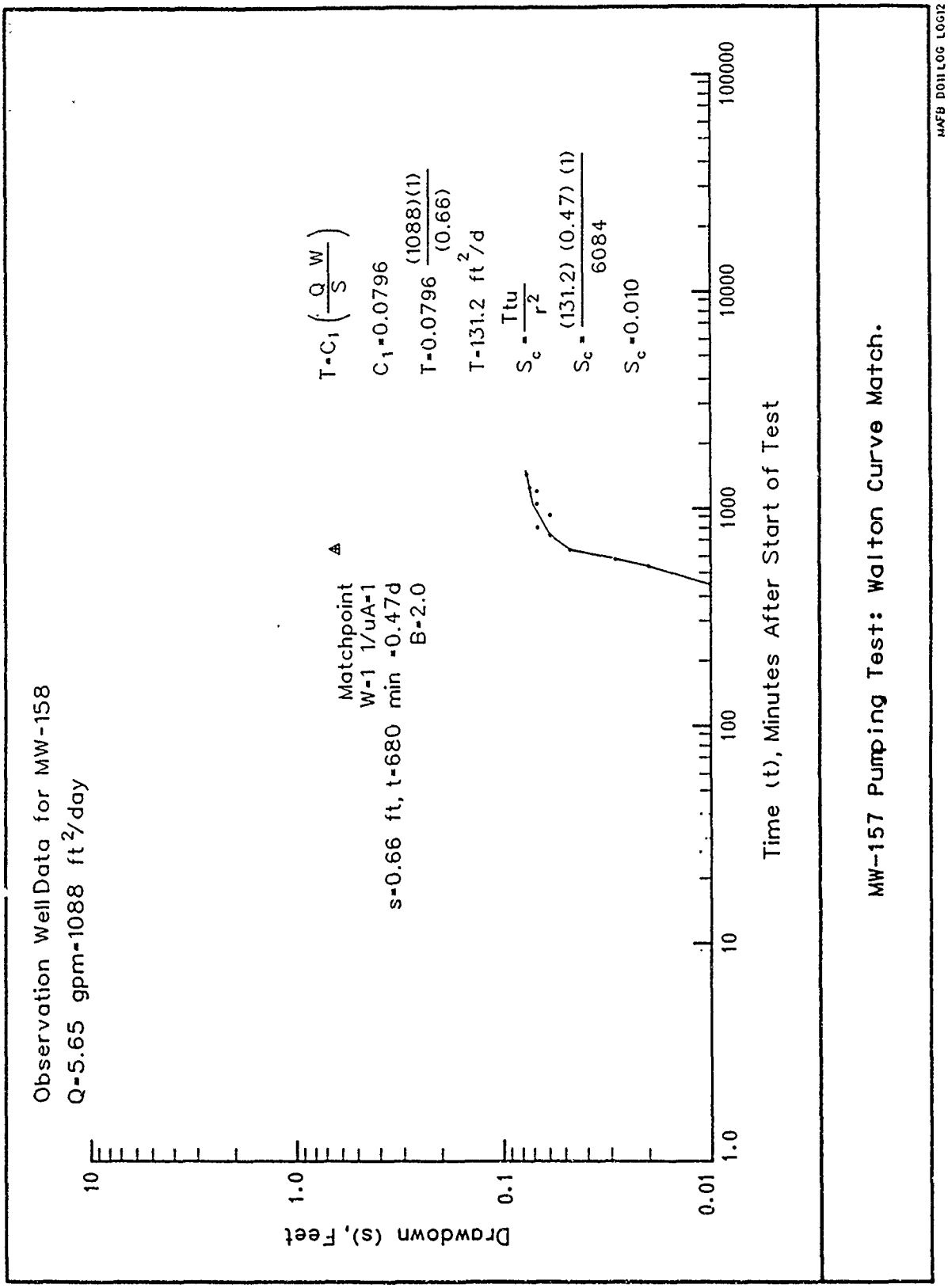
B = Detected in blank, result not corrected
MCL = DHS maximum contaminant level
ND = Not detected at specified detection limit
RAD = Radian Corporation, Sacramento
TB = Trip blank

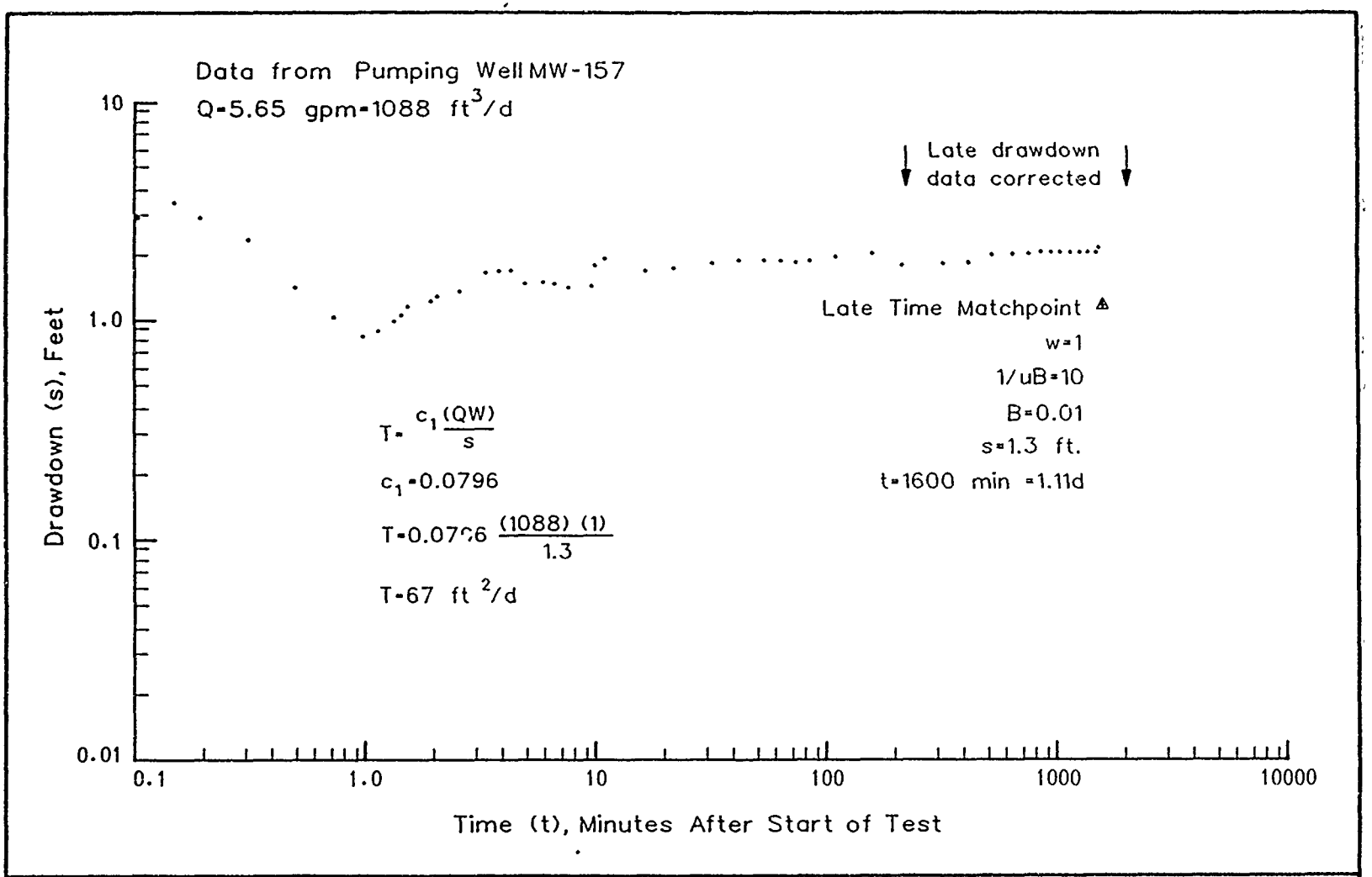

Observation Well Data for PZ-1
Test Date: 12-13-89
Q=8.45 gpm=1626.7 ft³/day
r= 20 ft
Late Matchpoint
r/B= 0.1
W(u,r/D)=1
1/uB=10⁻²
s=0.41 ft
t=40 min
T= (1626.7) (1) / 4 π (0.41) = 316 ft²/d
S_L=0.00088
Early Matchpoint
r/B= 0.1
W(u,r/D)=1
1/uA=10
s=0.225 ft
t=2.7 min
T= Q / 4 π s
T= 1626.7 (1) / 4 π (0.225) =575 ft²/d
S_a = 4T + uA / r² =0.0011
Drawdown (s), Feet
10
1.0
0.1
0.01
0.1
1.0
10
100
1000
10000
Time (t), Minutes After Start of Test
MW-155 Pump Test: Boulton Delay Index Curve
WAFB DOI LOG2


Observation Well Data for PZ-1
Q-8.45 gpm-1626.7 ft³/d
r-20 ft
T-C3 (Q/Δs)
c3-0.1833
Δs-0.95 ft
T-0.1833 (1626.7)/0.95
T-341 ft²/d
Δs-0.95 ft
Residual Drawdown (s), Feet
3.0
2.5
2.25
2.0
1.75
1.5
1.25
1.0
0.75
0.50
0.25
0.1
1.0
10
100
1000
10000
Time (t), Minutes After Start of Test
MW-155 Pumping Well: Neuman Recovery Analysis.
MAFB D011LOG4


MW-155 Pumping Well: Neuman Recovery Analysis.
Residual Drawdown (s), Feet
Time (t), Minutes After Start of Test
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.1
1.0
10
100
1000
10000
Observation Well Data for MW-7
Q=8.45 gpm=1626.7 ft³/d
r=43 ft
T=C3 (Q/Δs)
C3=0.1833
Δs=0.55 ft
T=0.1833 (1626.7)/0.55
T=541 ft²/d
Δs=0.55 ft
MAFB D011 LOG4

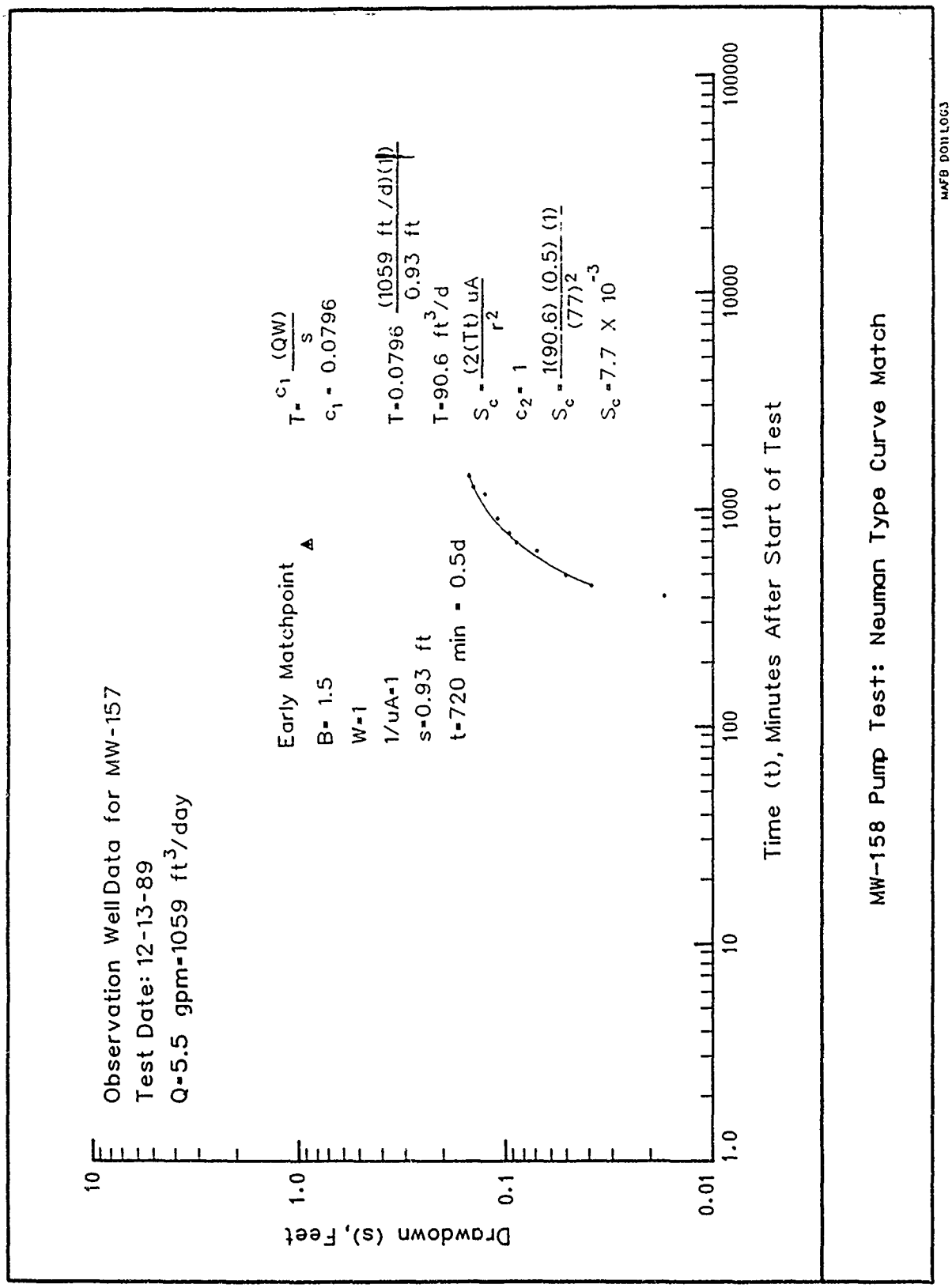

Data from Pumped Well MW-157
Q=5.65 gpm=1088.7 ft³/d
Late drawdown
data corrected
Δs=0.93 ft
T=C3 (Q/Δs)
C3=0.1833
T= 0.1833(1626.7)/0.93
T=214 ft²/d
Residual Drawdown (s), Feet
Time (t), Minutes After Start of Test
MW-157 Pump Test: Neuman Semilog Analysis.
MAFB D011 LOG LOG14

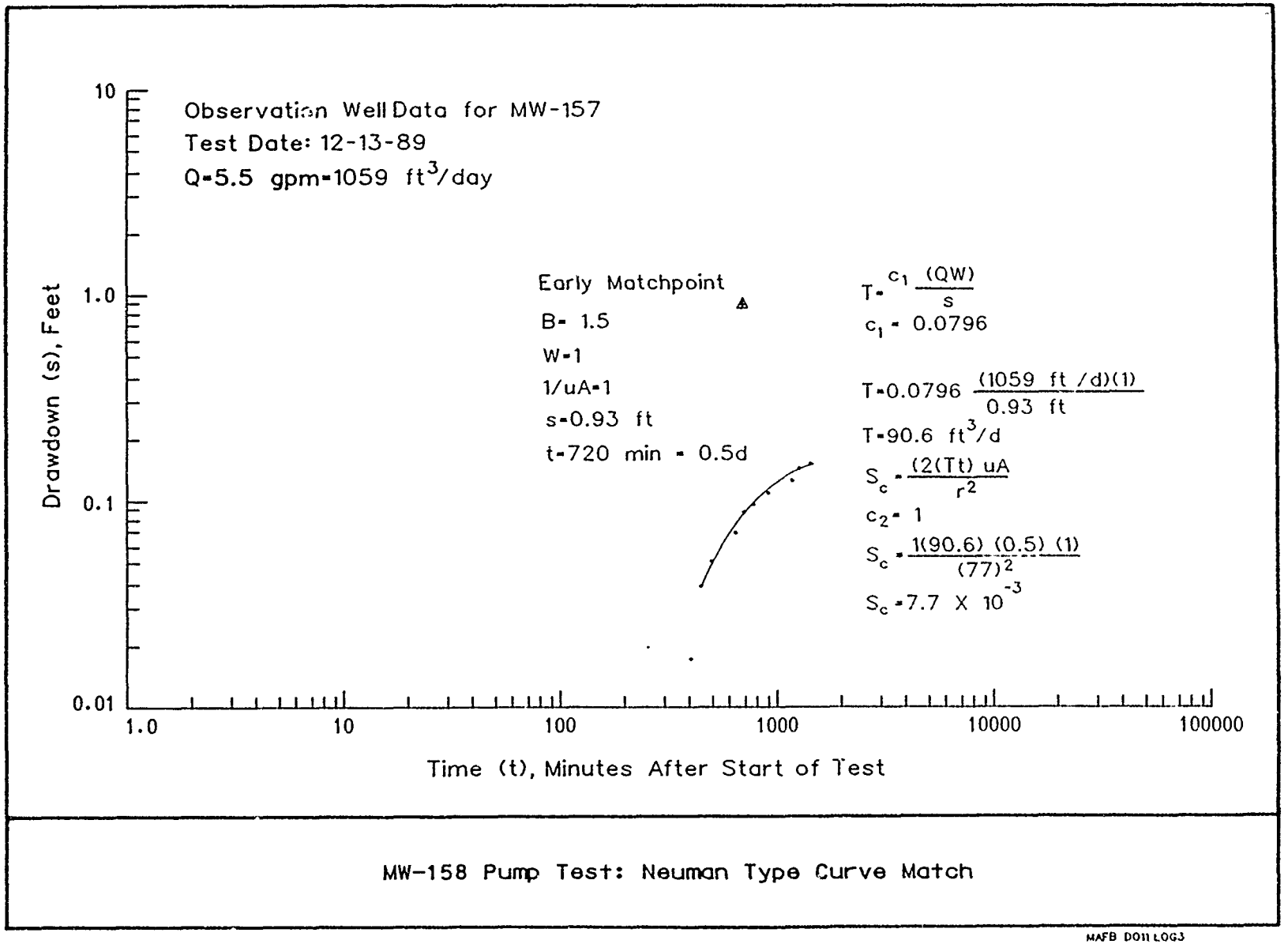

Observation Well Data for MW-158
Q-5.65 gpm-1088 ft²/day
Matchpoint
W-1 1/uA-1
s-0.66 ft, t-680 min -0.47d
B-2.0
T-C1 (Q W / S)
C1-0.0796
T-0.0796 (1088)(1) / (0.66)
T-131.2 ft²/d
Sc - Ttu / r²
Sc - (131.2) (0.47) (1) / 6084
Sc -0.010
Drawdown (s), Feet
10
1.0
0.1
0.01
1.0
10
100
1000
10000
100000
Time (t), Minutes After Start of Test
MW-157 Pumping Test: Walton Curve Match.
MAFB DOILOG LOG12



MW-157 Pumping Well: Neuman Curve Match.

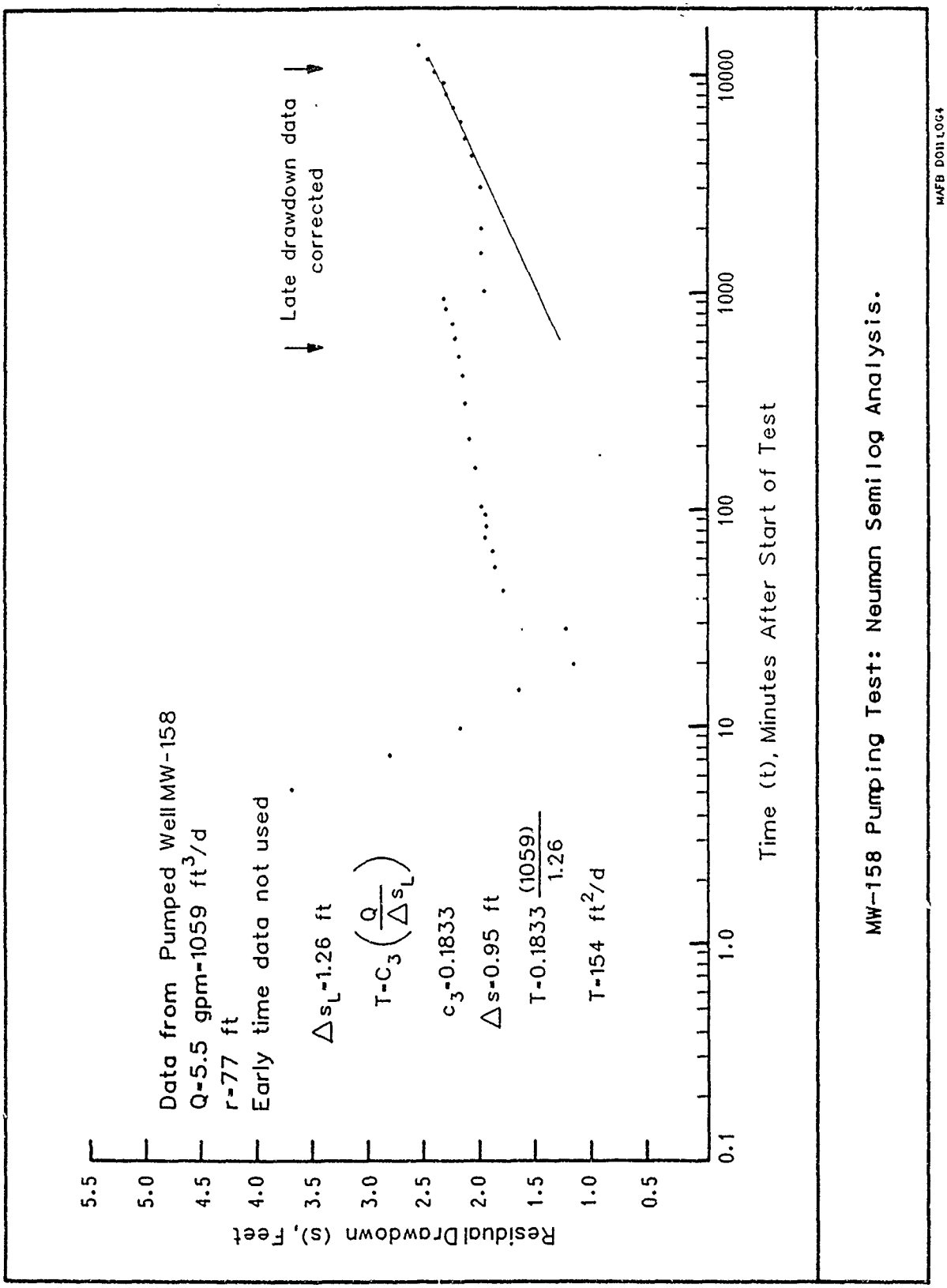
MAFB D011 LOG LOG13

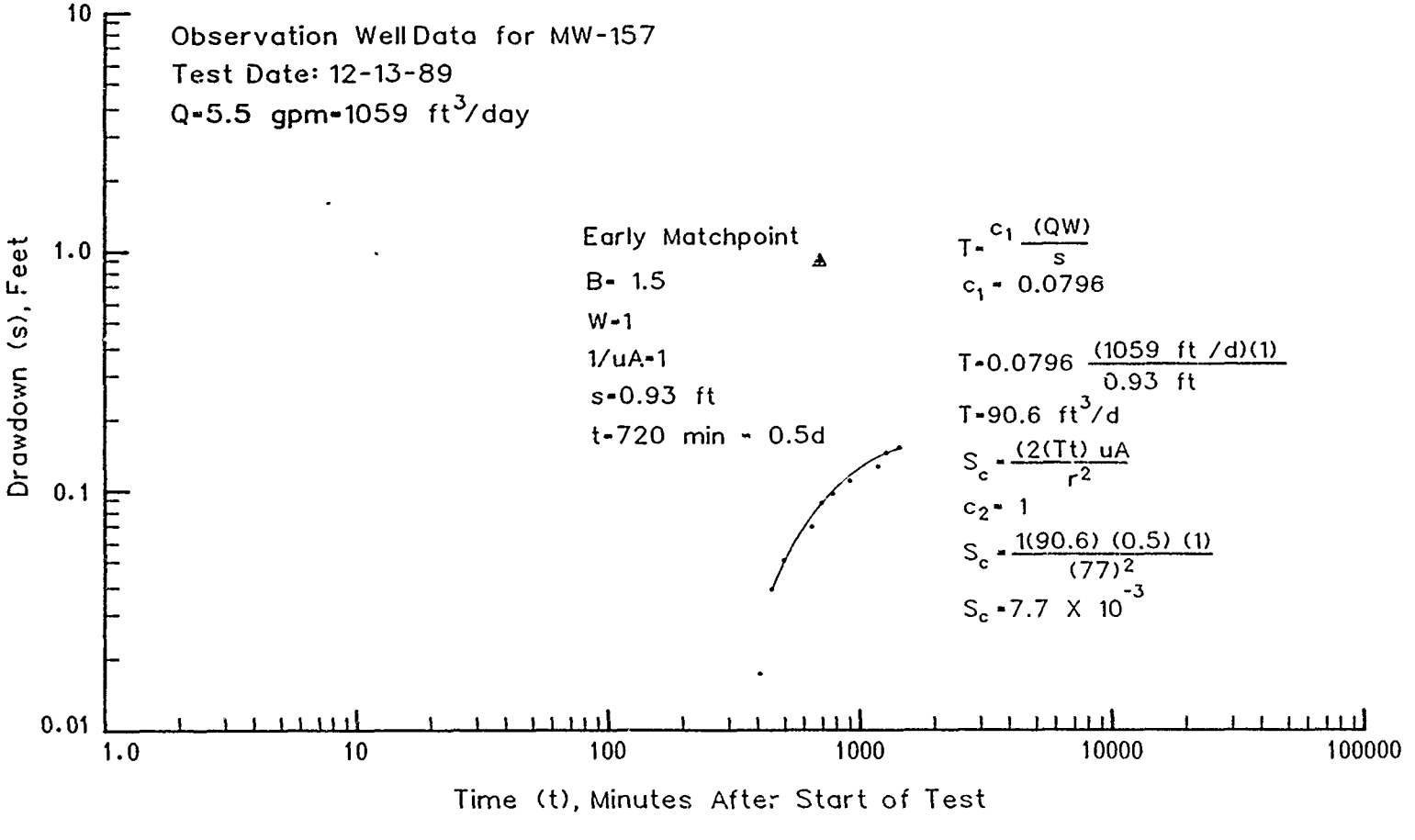

Observation Well Data for MW-157
Test Date: 12-13-89
Q-5.5 gpm-1059 ft³/day
Early Matchpoint
B- 1.5
W-1
1/uA-1
s-0.93 ft
t-720 min - 0.5d
T=c1 (QW)/s
c1 - 0.0796
T-0.0796 (1059 ft/d)(1)/0.93 ft
T-90.6 ft³/d
Sc=(2(Tt) uA)/r²
c2- 1
Sc=1(90.6)(0.5)(1)/(77)²
Sc-7.7 X 10⁻³
Drawdown (s), Feet
10
1.0
0.1
0.01
1.0
10
100
1000
10000
100000
Time (t), Minutes After Start of Test
MW-158 Pump Test: Neuman Type Curve Match
MAFB DOI LOG3



MW-158 Pump Test: Neuman Type Curve Match

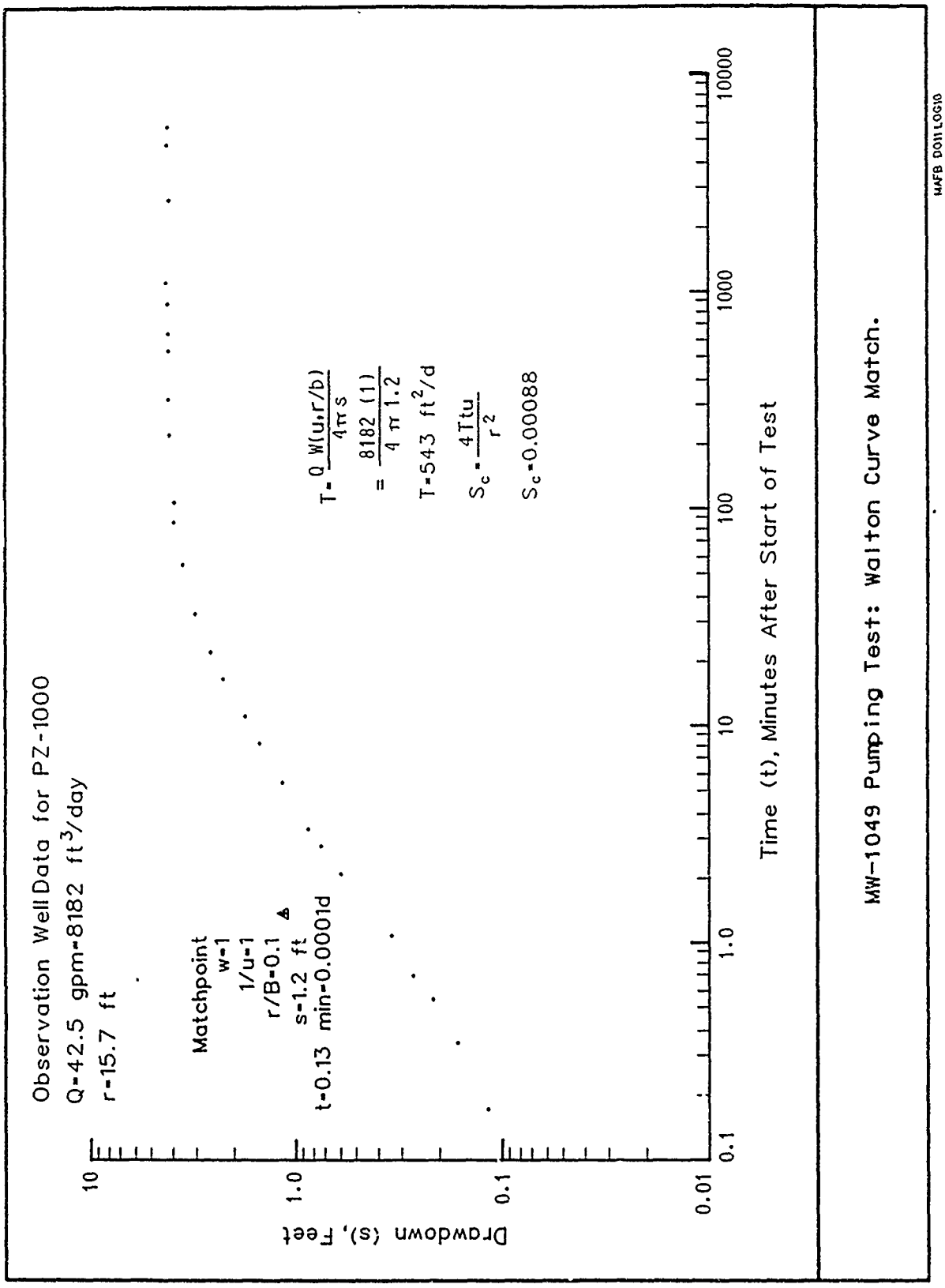
MAFB D011 LOG3

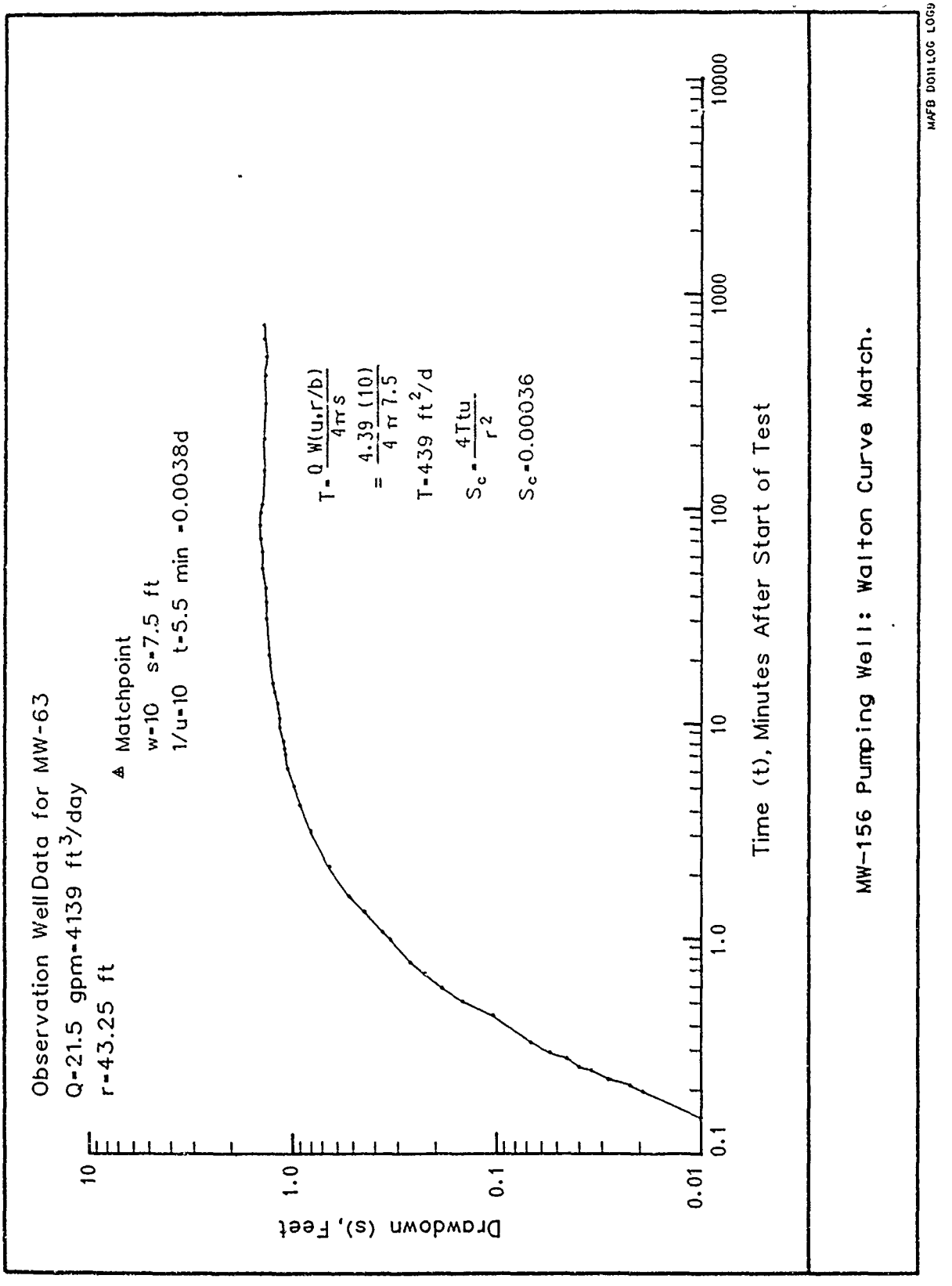

Residual Drawdown (s), Feet
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
1.0
10
100
1000
10000
Time (t), Minutes After Start of Test
Late drawdown data corrected
Data from Pumped Well MW-158
Q-5.5 gpm-1059 ft³/d
r-77 ft
Early time data not used
Δs_L-1.26 ft
$T = C_3\left(\frac{Q}{\Delta s_L}\right)$
c_3-0.1833
Δs-0.95 ft
$T = 0.1833\ \frac{(1059)}{1.26}$
T-154 ft²/d
MW-158 Pumping Test: Neuman Semi log Analysis.
MAFB DOIILOG4

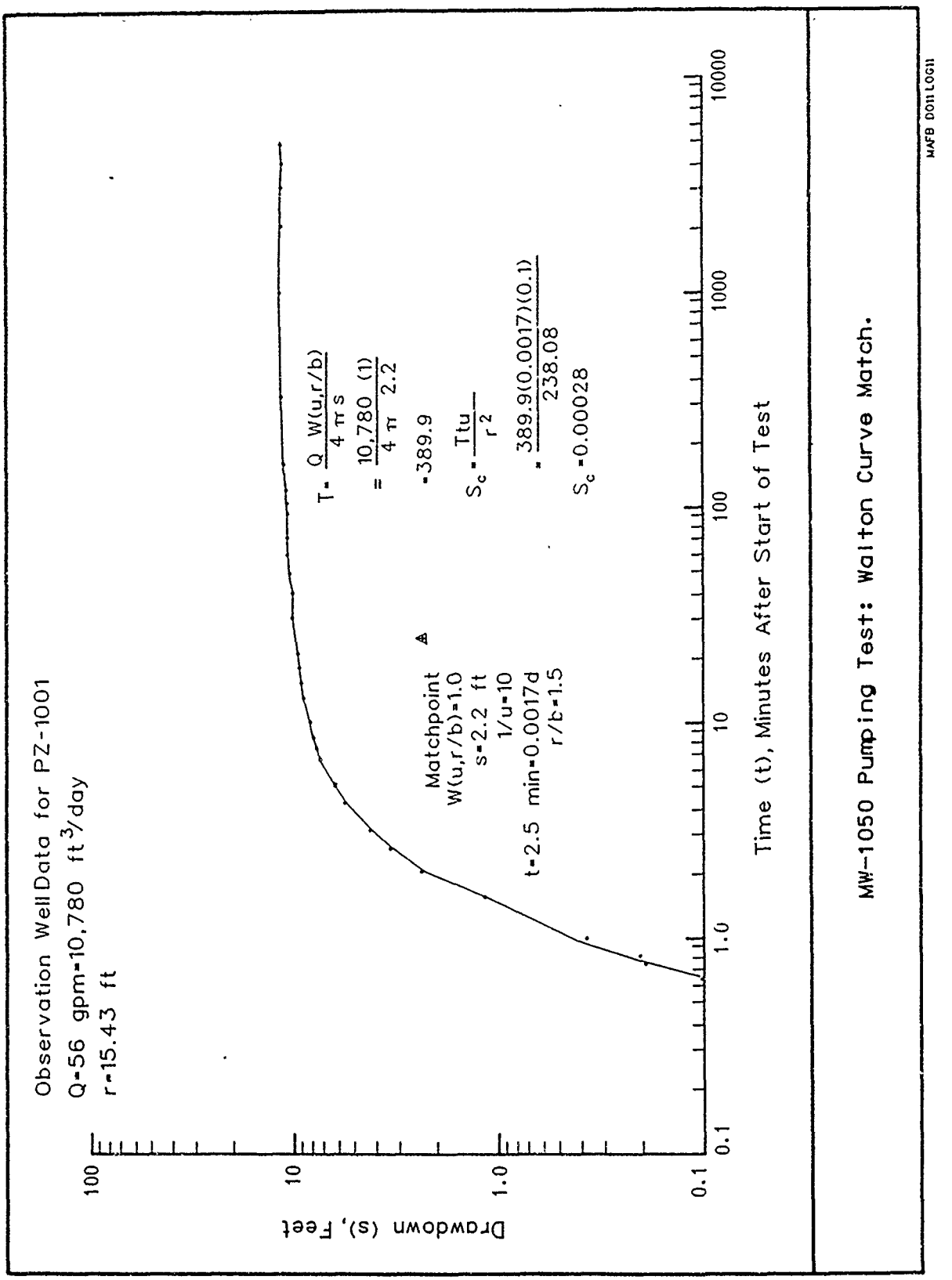


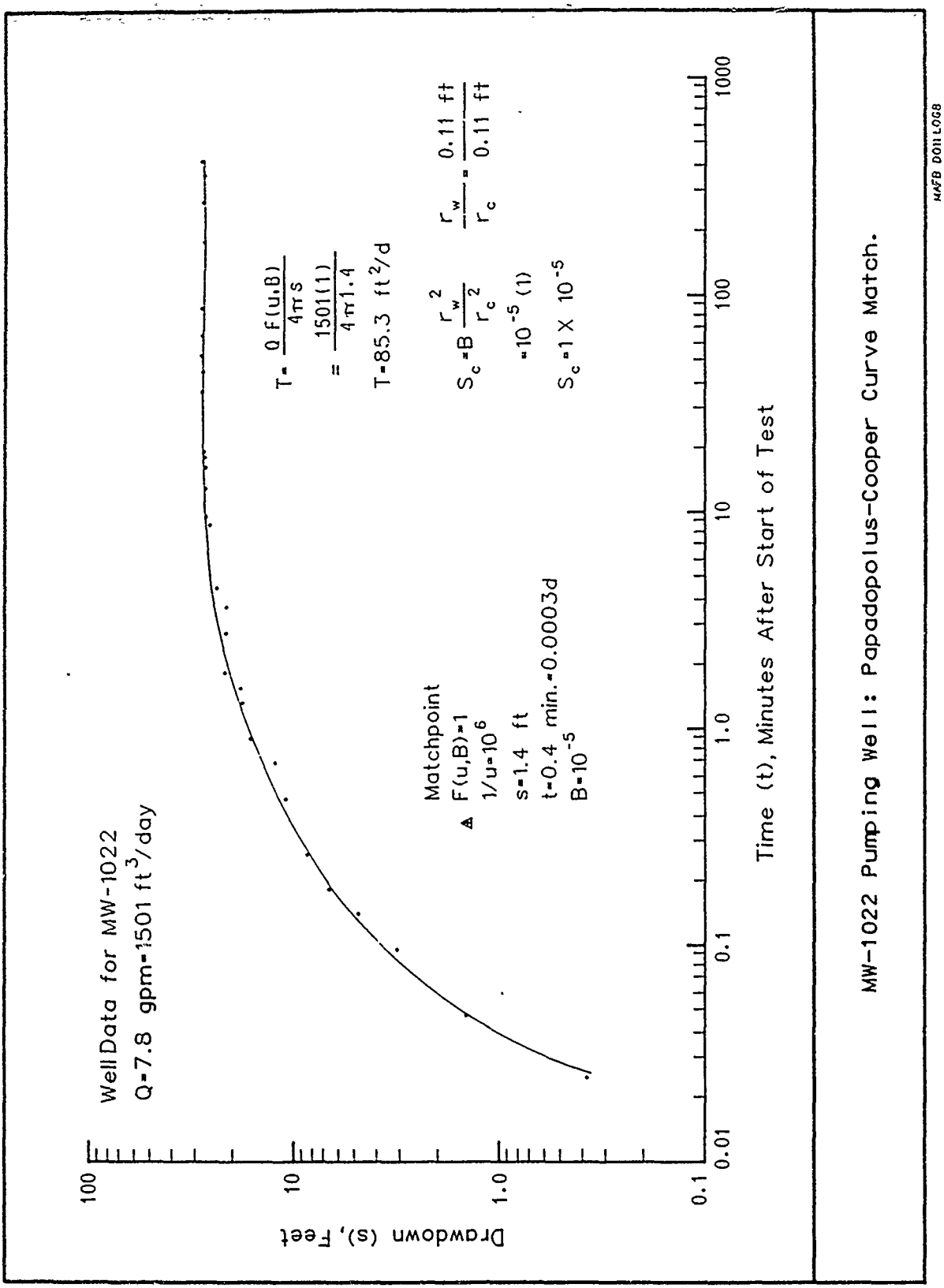
MW-158 Pump Test: Neuman Type Curve Match

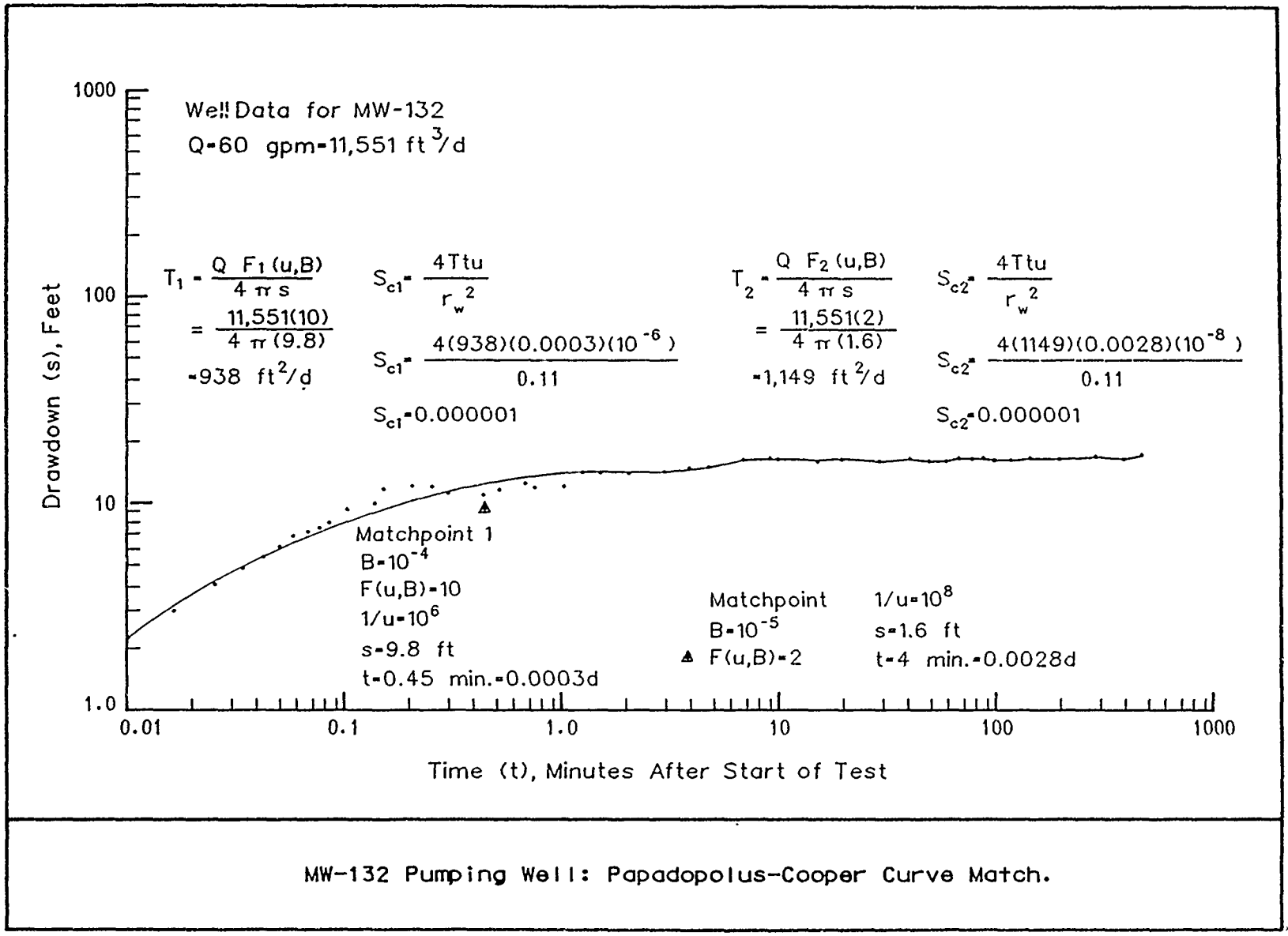
MAFB D011 LOG3


Observation Well Data for PZ-1000
Q=42.5 gpm=8182 ft³/day
r=15.7 ft
Matchpoint
w=1
1/u=1
r/B=0.1
s=1.2 ft
t=0.13 min=0.0001d
T = Q W(u,r/b) / 4πs
= 8182 (1) / 4 π 1.2
T=543 ft²/d
Sc = 4Ttu / r²
Sc=0.00088
Drawdown (s), Feet
10
1.0
0.1
0.01
0.1
1.0
10
100
1000
10000
Time (t), Minutes After Start of Test
MW-1049 Pumping Test: Walton Curve Match.
MAFB D011L0G10


Observation Well Data for MW-63
Q-21.5 gpm-4139 ft³/day
r-43.25 ft
Matchpoint
w-10 s-7.5 ft
1/u-10 t-5.5 min -0.0038d
T- Q W(u,r/b) / 4πs
= 4.39 (10) / 4 π 7.5
T-439 ft²/d
Sc- 4Ttu / r²
Sc-0.00036
Drawdown (s), Feet
10
1.0
0.1
0.01
0.1
1.0
10
100
1000
10000
Time (t), Minutes After Start of Test
MW-156 Pumping Well: Walton Curve Match.
MAFB DOI LOG LOG9

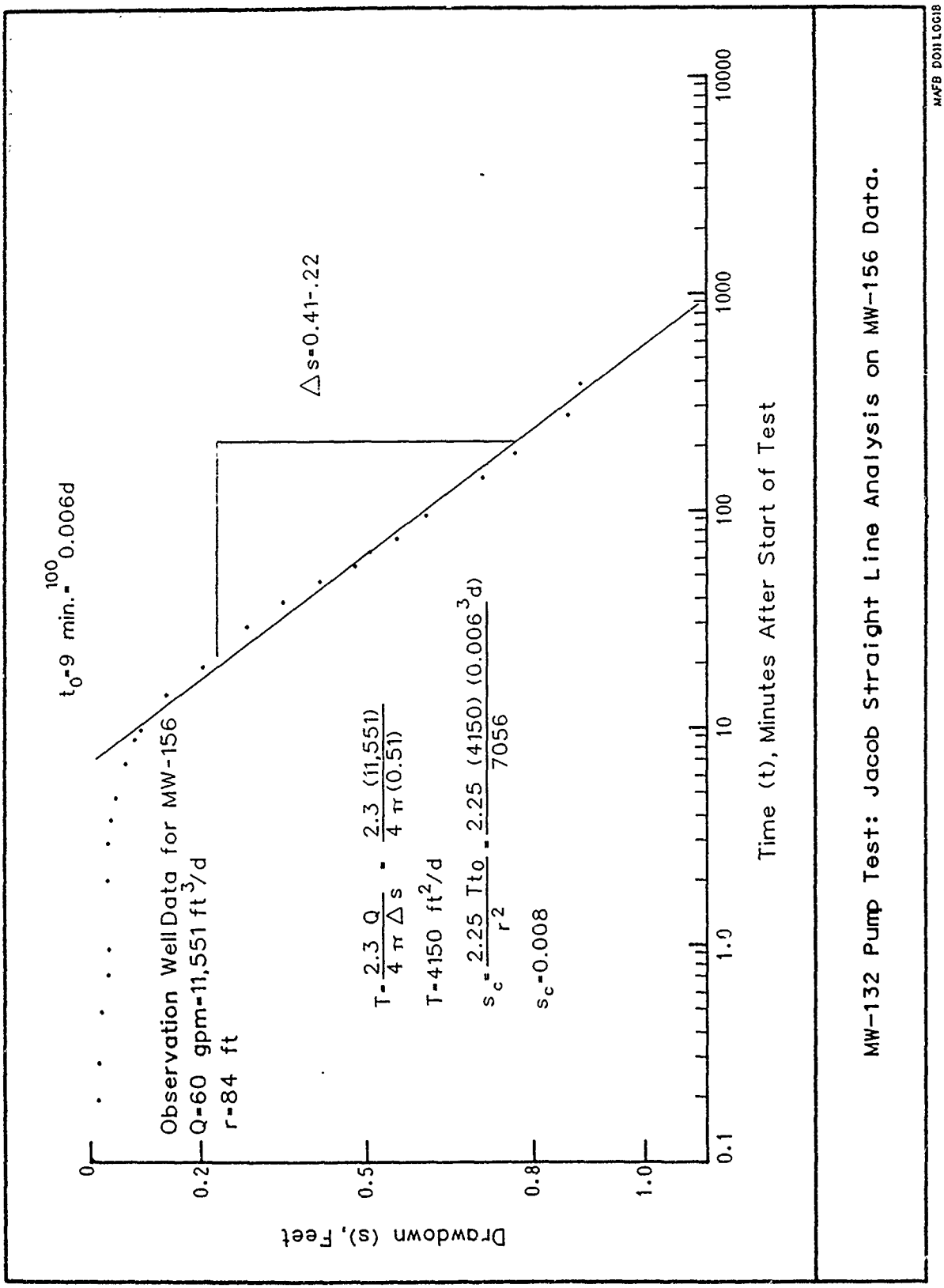

Observation Well Data for PZ-1001
Q=56 gpm=10,780 ft³/day
r=15.43 ft
Drawdown (s), Feet
100
10
1.0
0.1
0.1
1.0
10
100
1000
10000
Time (t), Minutes After Start of Test
T= Q W(u,r/b) / 4πs
= 10,780 (1) / 4π 2.2
=389.9
Sc = Ttu / r²
= 389.9(0.0017)(0.1) / 238.08
Sc =0.00028
Matchpoint
W(u,r/b)=1.0
s=2.2 ft
1/u=10
t=2.5 min=0.0017d
r/b=1.5
MW-1050 Pumping Test: Walton Curve Match.
MAFB DOH LOGII

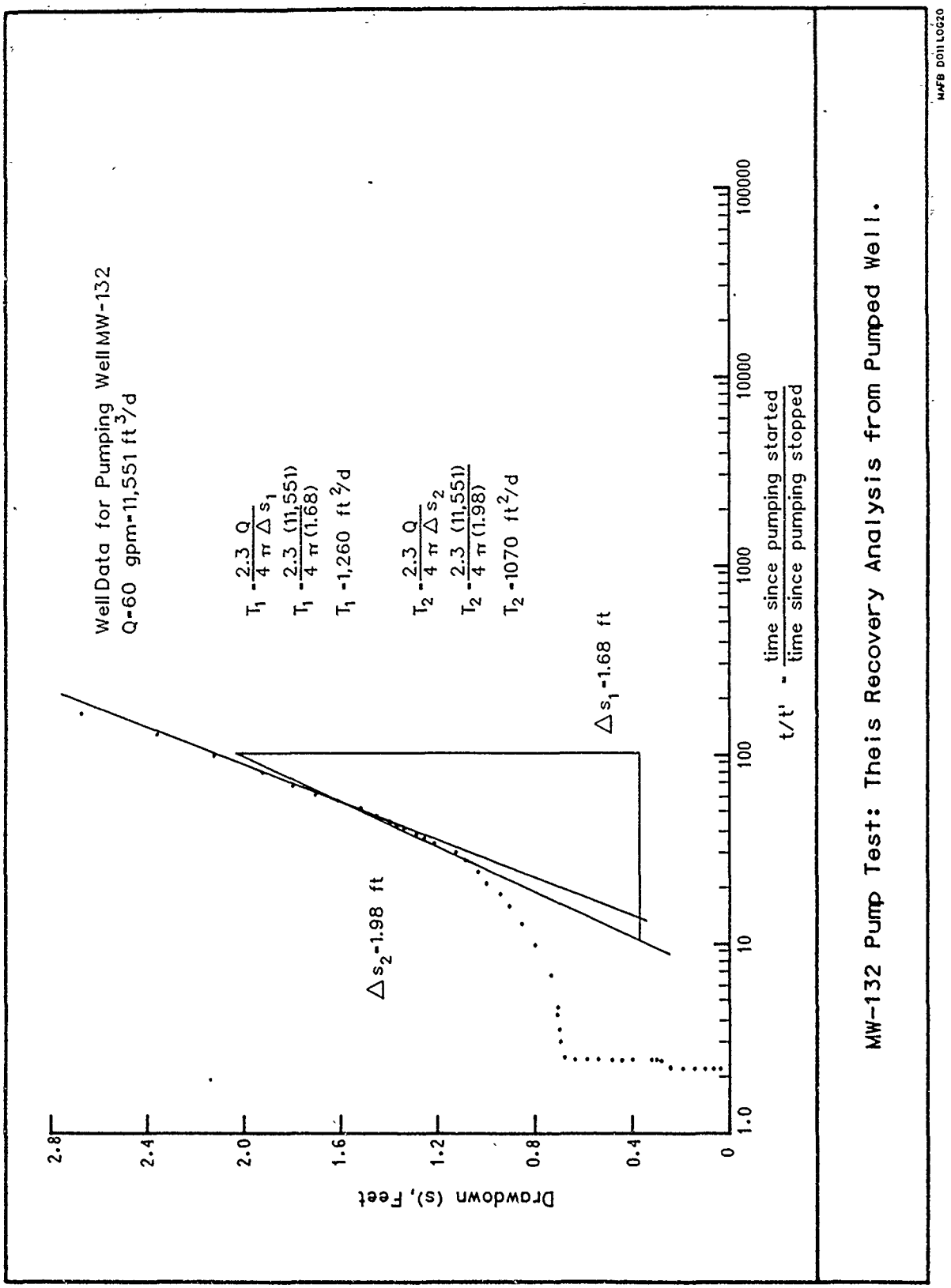

Well Data for MW-1022
Q=7.8 gpm=1501 ft³/day
Matchpoint
F(u,B)=1
1/u=10⁶
s=1.4 ft
t=0.4 min.=0.0003d
B=10⁻⁵
T = Q F(u,B) / 4πs
= 1501(1) / 4π1.4
T=85.3 ft²/d
Sc=B r_w² / r_c²
=10⁻⁵ (1)
Sc=1 X 10⁻⁵
r_w / r_c = 0.11 ft / 0.11 ft
Drawdown (s), Feet
100
10
1.0
0.1
0.01
0.1
1.0
10
100
1000
Time (t), Minutes After Start of Test
MW-1022 Pumping Well: Papadopolus-Cooper Curve Match.
MAFB D011LOGB

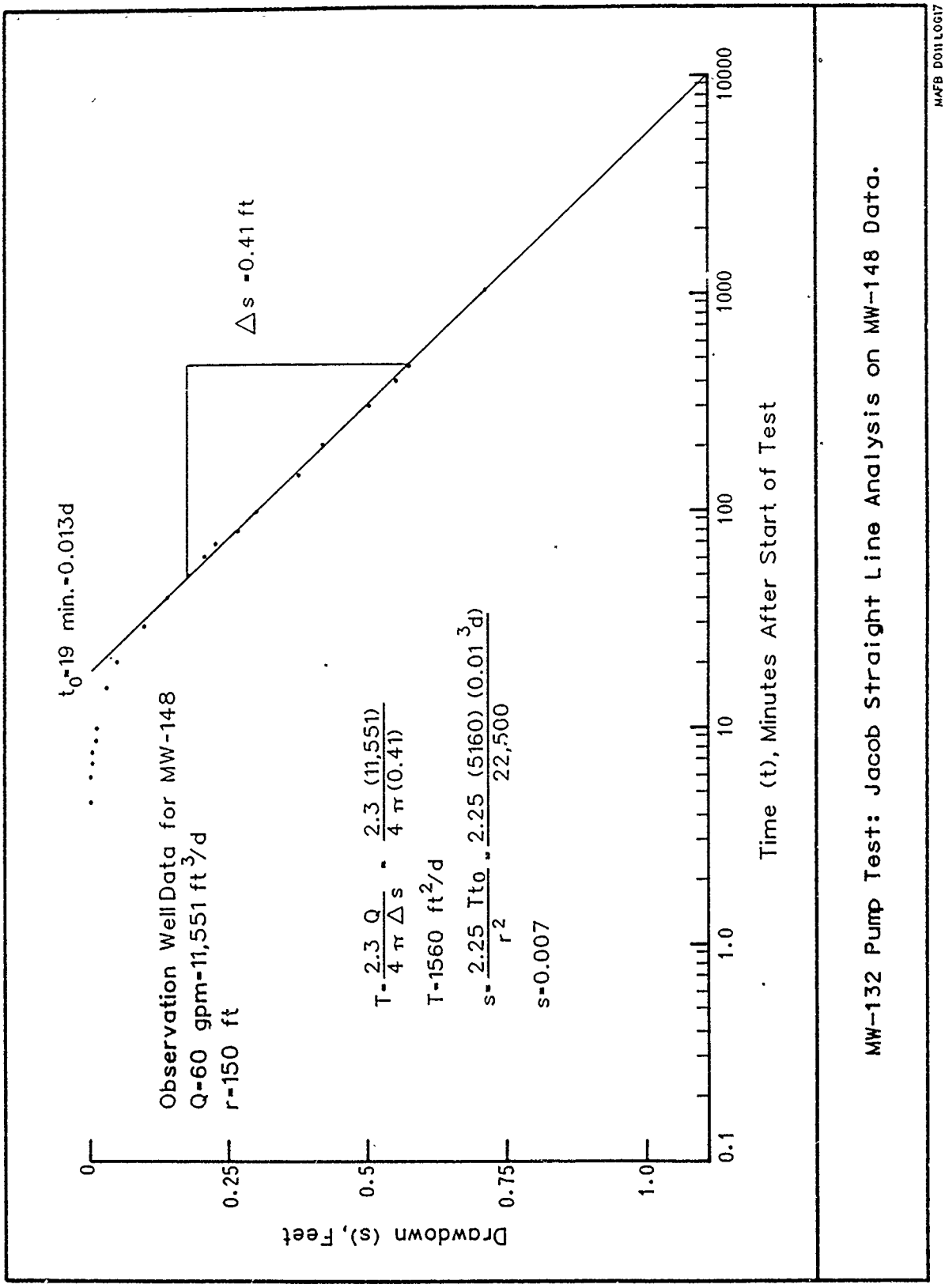


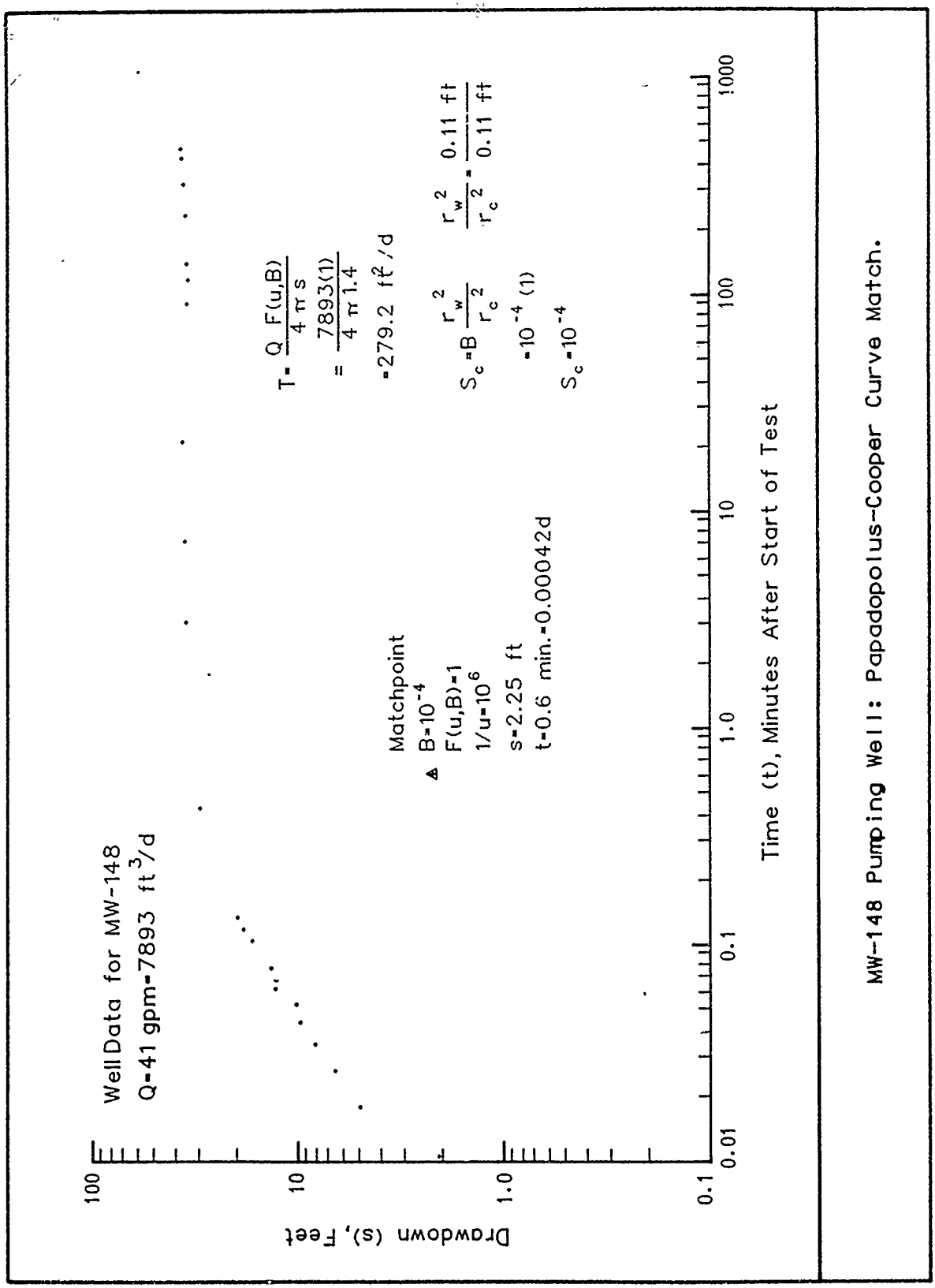
MW-132 Pumping Well: Papadopolus-Cooper Curve Match.

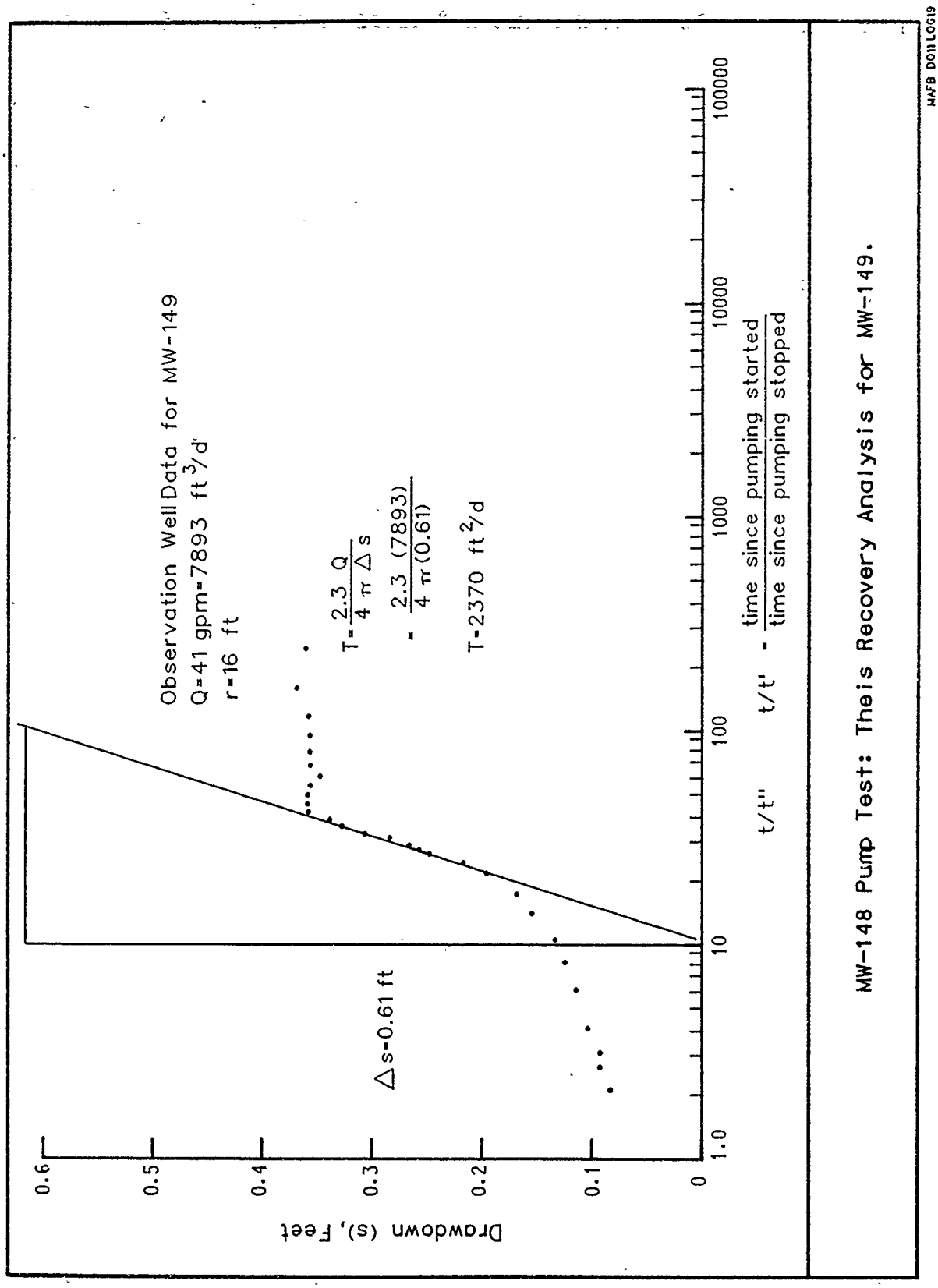
MAFB D011 LOG LOG16


Drawdown (s), Feet
0
0.2
0.5
0.8
1.0
0.1
1.0
10
100
1000
10000
Time (t), Minutes After Start of Test
Observation Well Data for MW-156
Q=60 gpm=11,551 ft³/d
r=84 ft
t₀=9 min.=100 0.006d
Δs=0.41-.22
T=2.3 Q/4 π Δs = 2.3 (11,551)/4 π (0.51)
T=4150 ft²/d
s_c=2.25 Tto/r² = 2.25 (4150) (0.006³d)/7056
s_c=0.008
MW-132 Pump Test: Jacob Straight Line Analysis on MW-156 Data.
MAFB D011LOG1B

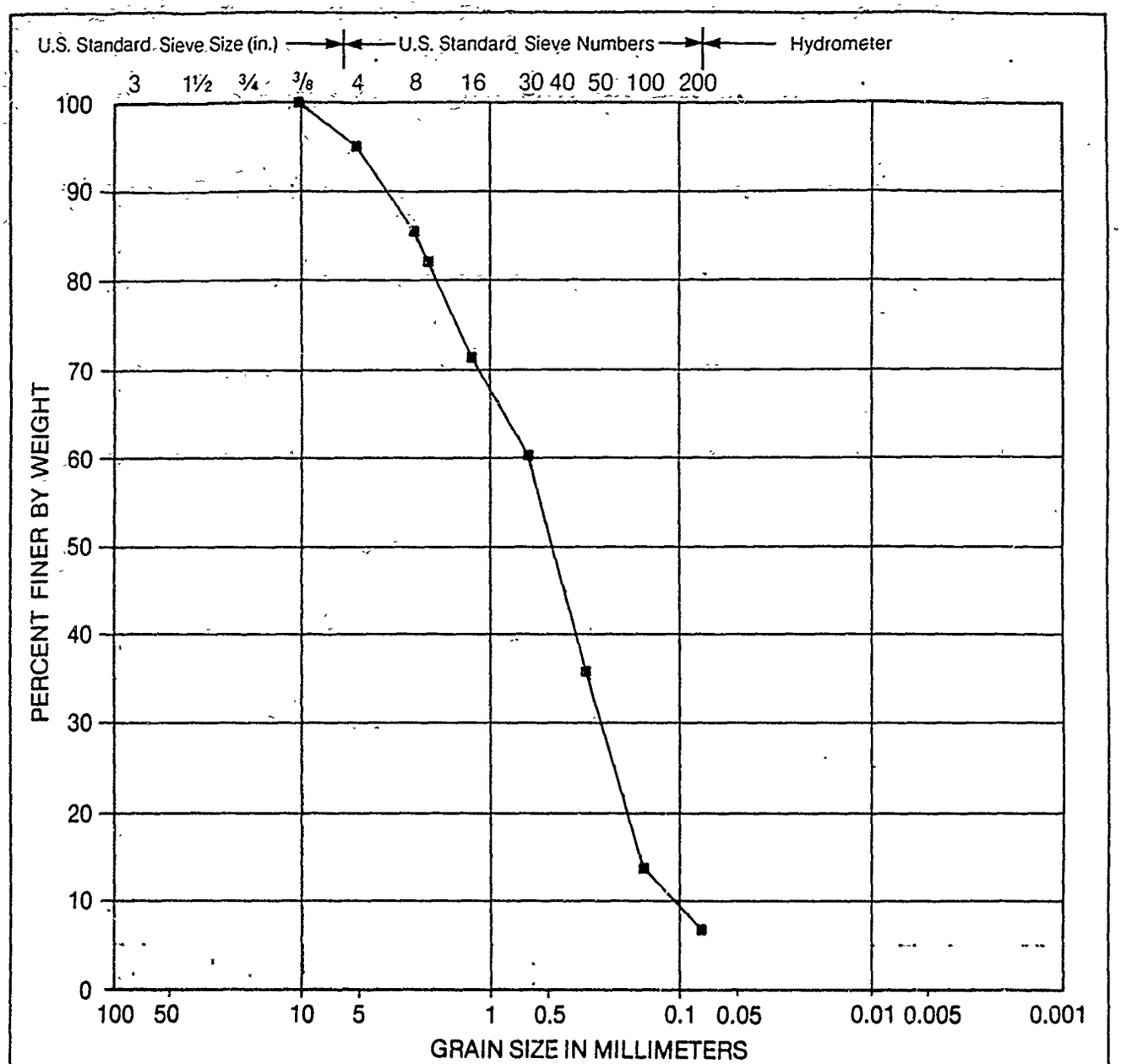

Well Data for Pumping Well MW-132
Q-60 gpm-11,551 ft³/d
$T_1 = \frac{2.3\ Q}{4\pi\Delta s_1}$
$T_1 = \frac{2.3\ (11,551)}{4\pi(1.68)}$
T_1 -1,260 ft²/d
$T_2 = \frac{2.3\ Q}{4\pi\Delta s_2}$
$T_2 = \frac{2.3\ (11,551)}{4\pi(1.98)}$
T_2 -1070 ft²/d
Δs_1-1.68 ft
Δs_2-1.98 ft
Drawdown (s), Feet
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
1.0
10
100
1000
10000
100000
t/t' = time since pumping started / time since pumping stopped
MW-132 Pump Test: Theis Recovery Analysis from Pumped Well.
WAFB D011L0620


MW-132 Pump Test: Jacob Straight Line Analysis on MW-148 Data.
Drawdown (s), Feet
Time (t), Minutes After Start of Test
0
0.25
0.5
0.75
1.0
0.1
1.0
10
100
1000
10000
t_o=19 min.=0.013d
Δs =0.41 ft
Observation Well Data for MW-148
Q=60 gpm=11,551 ft³/d
r=150 ft
$T=\frac{2.3\ Q}{4\pi\Delta s}=\frac{2.3\ (11,551)}{4\pi(0.41)}$
T=1560 ft²/d
$s=\frac{2.25\ Tt_o}{r^2}=\frac{2.25\ (5160)\ (0.01^3 d)}{22,500}$
s=0.007
MAFB D011LOG17


Well Data for MW-148
Q=41 gpm=7893 ft³/d
Matchpoint
B=10⁻⁴
F(u,B)=1
1/u=10⁶
s=2.25 ft
t=0.6 min.=0.00042d
T = Q F(u,B) / 4πs
= 7893(1) / 4π1.4
=279.2 ft²/d
Sc = B rw² / rc²
=10⁻⁴ (1)
=10⁻⁴
Sc = rw² / rc² = 0.11 ft / 0.11 ft
Drawdown (s), Feet
100
10
1.0
0.1
0.01
0.1
1.0
10
100
1000
Time (t), Minutes After Start of Test
MW-148 Pumping Well: Papadopolus-Cooper Curve Match.
MAFB 0011.LOG.LOG15


Observation Well Data for MW-149
Q=41 gpm=7893 ft³/d
r=16 ft
T=2.3 Q / 4 π Δs
= 2.3 (7893) / 4 π(0.61)
T=2370 ft²/d
Δs=0.61 ft
t/t' = time since pumping started / time since pumping stopped
t/t'
Drawdown (s), Feet
0
0.1
0.2
0.3
0.4
0.5
0.6
1.0
10
100
1000
10000
100000
MW-148 Pump Test: Theis Recovery Analysis for MW-149.
MAFB D011LOG19

RADIAN CORPORATION



COBBLES	GRAVEL: COARSE	GRAVEL: FINE	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT OR CLAY

Symbol	Sample Source	Classification
■	11A ● 100.0 FT Boring MW 11A	BROWN SAND W/SILT (SW-SM)

HLA **Harding Lawson Associates**
Engineers, Geologists & Geophysicists

Particle Size Analysis

PLATE

D-70

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	17474.002.02	TJD	05-23-1990		

RADIAN
CORPORATION

Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project Name: RADIAN CORPORATION
Project Number: 17474.002.02
Test Date: 05-23-1990
Location: 11A
@ %100.0

Total Sample Weight (g): 26.4

Percent Passing No. 10 Sieve : 0.0

Representative Sample Weight (g): ----

PI Results (used in determining fines classification)

Liquid Limit: ---
Plasticity Index: ---

Soil Composition (%):

Gravel : 4.9
Sand : 87.5
Fines : 7.6

Particle Diameter (mm):

@ 60% Passing : 0.5897
@ 30% Passing : 0.2454
@ 10% Passing : 0.0960

Coefficient of Uniformity: 6.15E 0

Coefficient of Curvature: 1.06E 0

Soil Classification: BROWN SAND W/SILT (SW-SM*)

Frost Classification: --

Data Entry By: REW

File #: 497

RADIAN CORPORATION

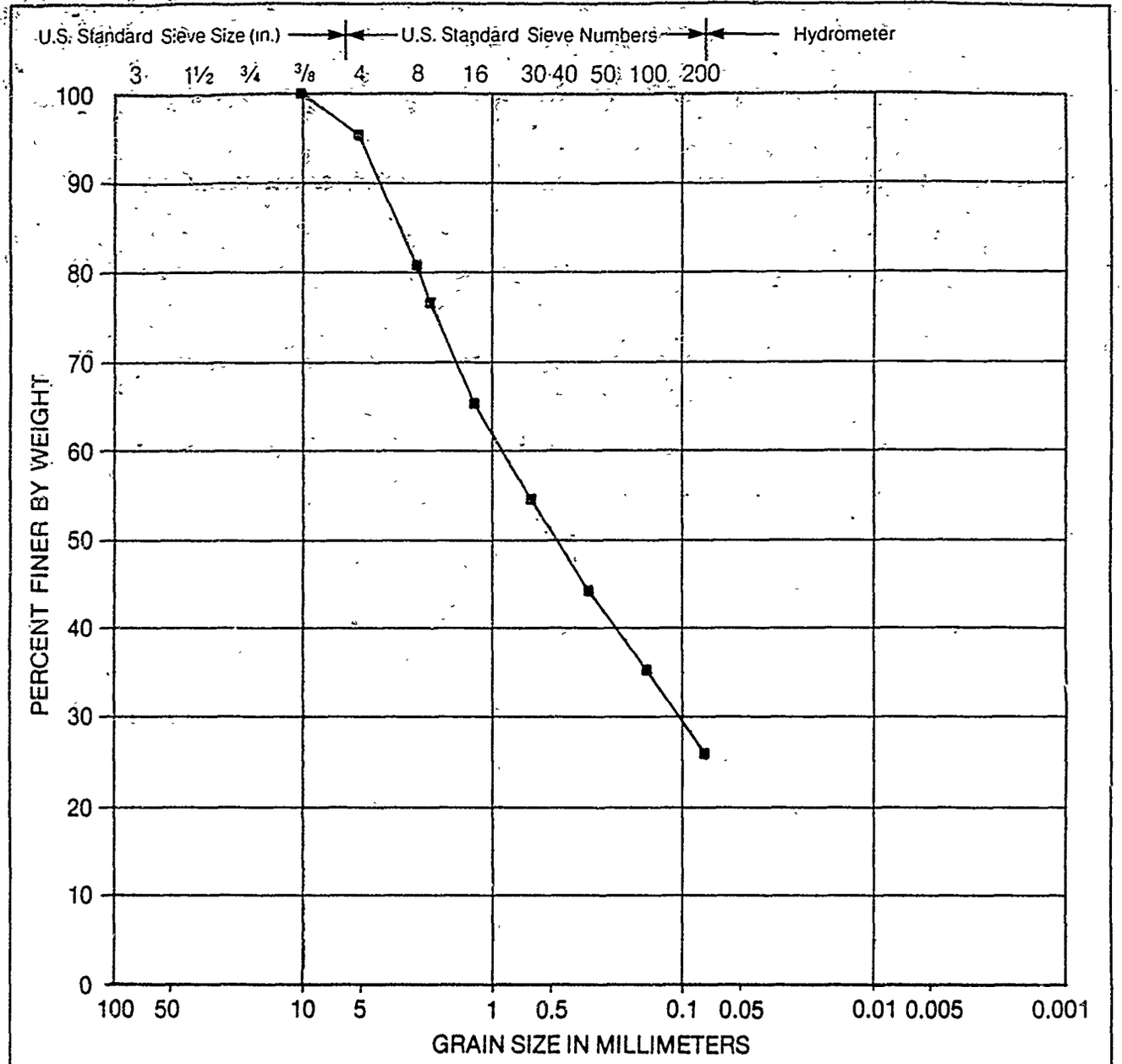
Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project : RADIAN CORPORATION ID : 17474.002.02 Test Date : 05-23-1990

Data Entry By : REW Location : 11A @ 100.0 Data File : TEST0497

Sieve Name	Sieve Size (mm)	Cum. Weight Retained (g)	Percent of Total Weight Passing
3.000 in	75.000	0.0	100.0
1.500 in	37.500	0.0	100.0
3/4 in	19.000	0.0	100.0
3/8 in	9.500	0.0	100.0
No. 4	4.750	1.3	95.1
No. 8	2.360	3.8	85.6
No. 10	2.000	4.7	82.2
No. 16	1.180	7.5	71.6
No. 30	0.600	10.4	60.6
No. 50	0.300	16.8	36.4
No. 100	0.150	22.6	14.4
No. 200	0.075	24.4	7.6

RADIAN CORPORATION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Sample Source	Classification
■	11A @ 111.0 FT Boring MW 11A	BROWN SILTY SAND (SM)

HLA **Harding Lawson Associates**
Engineers, Geologists & Geophysicists

Particle Size Analysis

PLATE

D-73

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	17474.002.02	TJD	05-23-1990		

RADIAN
CORPORATION

Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project Name: RADIAN CORPORATION
Project Number: 17474.002.02

Test Date: 05-23-1990
Location: 11A @ %111.0

Total Sample Weight (g): 21.5

Percent Passing No. 10 Sieve : 0.0

Representative Sample Weight (g): ----

PI Results (used in determining fines classification)

Liquid Limit: ---

Plasticity Index: ---

Soil Composition (%):

Gravel : 4.7
Sand : 68.8
Fines : 26.5

Particle Diameter (mm):

@ 60% Passing : 0.8291
@ 30% Passing : 0.0973
@ 10% Passing : 0.0219

Coefficient of Uniformity: 3.78E 1

Coefficient of Curvature: 5.21E-1

Soil Classification: BROWN SILTY SAND (SM*)

Frost Classification: --

Data Entry By: REW

File #: 498

RADIAN CORPORATION

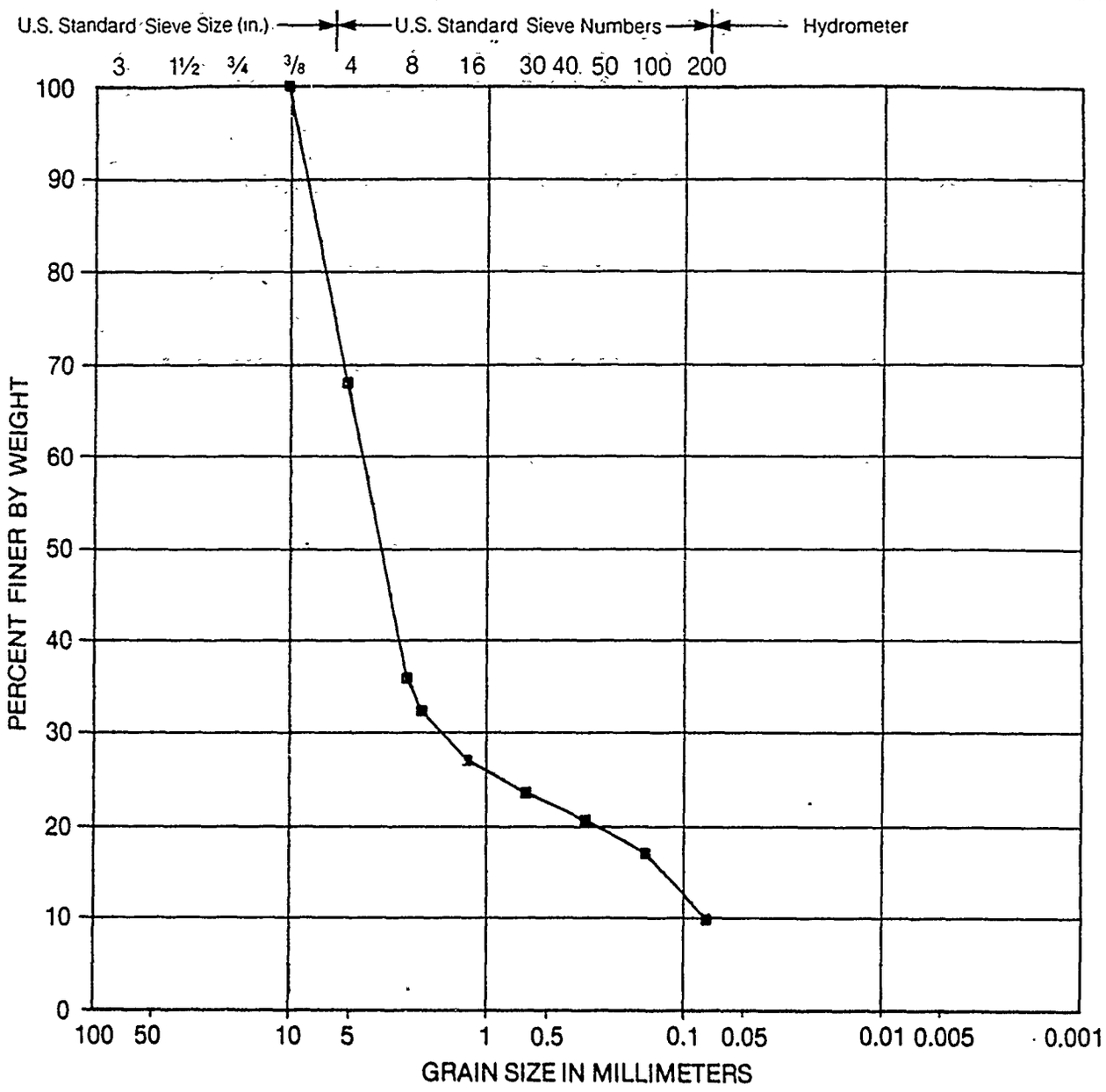
Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project : RADIAN CORPORATION ID : 17474.002.02 Test Date : 05-23-1990

Data Entry By : REW Location : 11A @ 111.0 Data File : TEST0498

Sieve Name	Sieve Size (mm)	Cum. Weight Retained (g)	Percent of Total Weight Passing
3.000 in	75.000	0.0	100.0
1.500 in	37.500	0.0	100.0
3/4 in	19.000	0.0	100.0
3/8 in	9.500	0.0	100.0
No. 4	4.750	1.0	95.3
No. 8	2.360	4.1	80.9
No. 10	2.000	5.0	76.7
No. 16	1.180	7.4	65.6
No. 30	0.600	9.7	54.9
No. 50	0.300	11.9	44.7
No. 100	0.150	13.8	35.8
No. 200	0.075	15.8	26.5

RADIAN CORPORATION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Sample Source	Classification
■	11A @ 121.0 FT Boring MW 11A	BROWN SAND W/SILT AND GRAVEL (SP-SM)

Harding Lawson Associates
Engineers, Geologists & Geophysicists

Particle Size Analysis

PLATE

D-76

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	17474.002.02	TJD	05-23-1990		

RADIAN CORPORATION

Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project Name: RADIAN CORPORATION
Project Number: 17474.002.02

Test Date: 05-23-1990
Location: 11A @ %121.0

Total Sample Weight (g): 17.0

Percent Passing No. 10 Sieve : 0.0

Representative Sample Weight (g): ----

PI Results (used in determining fines classification)

Liquid Limit: --- Plasticity Index: ---

Soil Composition (%):		Particle Diameter (mm):	
Gravel :	31.8	@ 60% Passing :	3.9622
Sand :	57.6	@ 30% Passing :	1.4919
Fines :	10.6	@ 10% Passing :	0.0708

Coefficient of Uniformity: 5.60E 1

Coefficient of Curvature: 7.93E 0

Soil Classification: BROWN SAND W/SILT AND GRAVEL (SP-SM*)

Frost Classification: --

Data Entry By: REW File #: 499

RADIAN CORPORATION

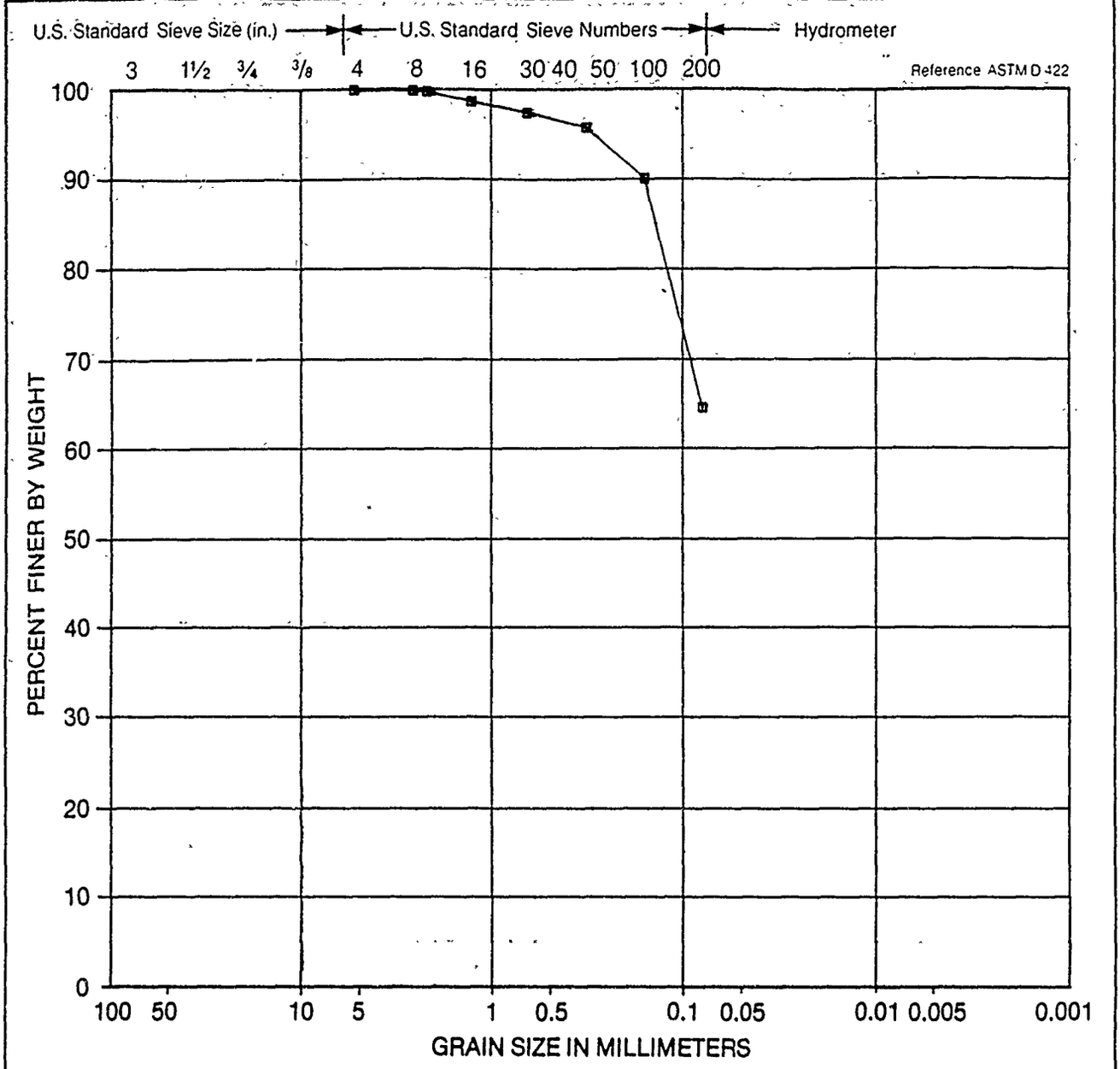
Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project : RADIAN CORPORATION ID : 17474.002.02 Test Date : 05-23-1990

Data Entry By : REW Location : 11A @ 121.0 Data File : TEST0499

Sieve Name	Sieve Size (mm)	Cum. Weight Retained (g)	Percent of Total Weight Passing
3.000 in	75.000	0.0	100.0
1.500 in	37.500	0.0	100.0
3/4 in	19.000	0.0	100.0
3/8 in	9.500	0.0	100.0
No. 4	4.750	5.4	68.2
No. 8	2.360	10.8	36.5
No. 10	2.000	11.4	32.9
No. 16	1.180	12.3	27.6
No. 30	0.600	12.9	24.1
No. 50	0.300	13.4	21.2
No. 100	0.150	14.0	17.6
No. 200	0.075	15.2	10.6

RADIAN CORPORATION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Sample Source	Classification
■	29A-2 @ 0.0 FT Boring MW158	BROWN SANDY SILT (ML)

Harding Lawson Associates
Engineers, Geologists & Geophysicists

Particle Size Analysis

PLATE

D-79

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	17474.002.02	DA	01-16-1990		

RADIAN
CORPORATION

Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project Name: RADIAN CORP.
Project Number: 17474,002.02

Test Date: 01-16-1990
Location: 29A-2 @ 0.0

Total Sample Weight (g): 264.2

Percent Passing No. 10 Sieve : 0.0

Representative Sample Weight (g): ----

PI Results (used in determining fines classification)

Liquid Limit: --- Plasticity Index: ---

Soil Composition (%):

Gravel : 0.0
Sand : 35.1
Fines : 64.9

Particle Diameter (mm):

@ 60% Passing : ---
@ 30% Passing : ---
@ 10% Passing : ---

Coefficient of Uniformity: ----

Coefficient of Curvature: ----

Soil Classification: BROWN SANDY SILT (ML*)

Frost Classification: --

Data Entry By: PSA

File #: 576

RADIAN CORPORATION

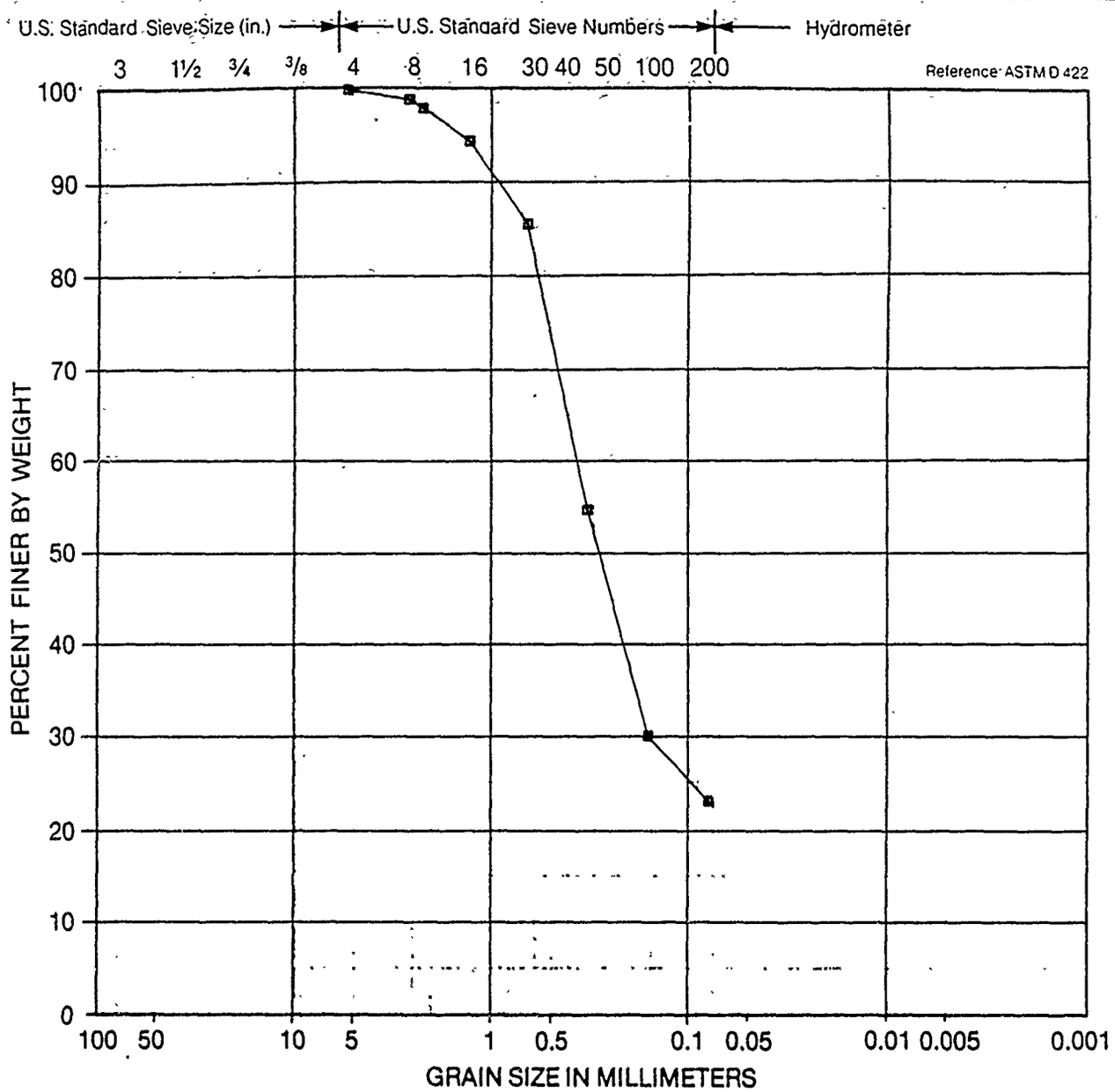
Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project : RADIAN CORP. ID : 17474,002.02 Test Date : 01-16-1990

Data Entry By : PSA Location : 29A-2 @ 0.0 Data File : TEST0576

Sieve Name	Sieve Size (mm)	Cum. Weight Retained (g)	Percent of Total Weight Passing
3.000 in	75.000	0.0	100.0
1.500 in	37.500	0.0	100.0
3/4 in	19.000	0.0	100.0
3/8 in	9.500	0.0	100.0
No. 4	4.750	0.0	100.0
No. 8	2.360	0.1	100.0
No. 10	2.000	0.5	99.8
No. 16	1.180	3.2	98.8
No. 30	0.600	6.5	97.5
No. 50	0.300	11.0	95.8
No. 100	0.150	26.0	90.2
No. 200	0.075	92.7	64.9

RADIAN CORPORATION



COBBLES	GRAVEL: COARSE	GRAVEL: FINE	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT OR CLAY
	GRAVEL		SAND			

Symbol	Sample Source	Classification
■	16A-P @ 0.0 FT Boring PZ 1	BROWN CLAYEY SAND (SC)

HLA **Harding Lawson Associates**
Engineers, Geologists & Geophysicists

Particle Size Analysis

PLATE

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	17474.002.02	TJD	01-16-1990		

RADIAN
CORPORATION

Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project Name: RADIAN CORP.
Project Number: 17474,002.02

Test Date: 01-16-1990
Location: 16A-P @ 0.0

Total Sample Weight (g): 212.4

Percent Passing No. 10 Sieve : 0.0

Representative Sample Weight (g): ----

PI Results (used in determining fines classification)

Liquid Limit: --- Plasticity Index: ---

Soil Composition (%):

Gravel : 0.0
Sand : 76.2
Fines : 23.8

Particle Diameter (mm):

@ 60% Passing : 0.3343
@ 30% Passing : 0.1381
@ 10% Passing : 0.0191

Coefficient of Uniformity: 1.75E 1

Coefficient of Curvature: 2.98E 0

Soil Classification: BROWN CLAYEY SAND (SC*)

Frost Classification: --

Data Entry By: PSA File #: 577

RADIAN CORPORATION

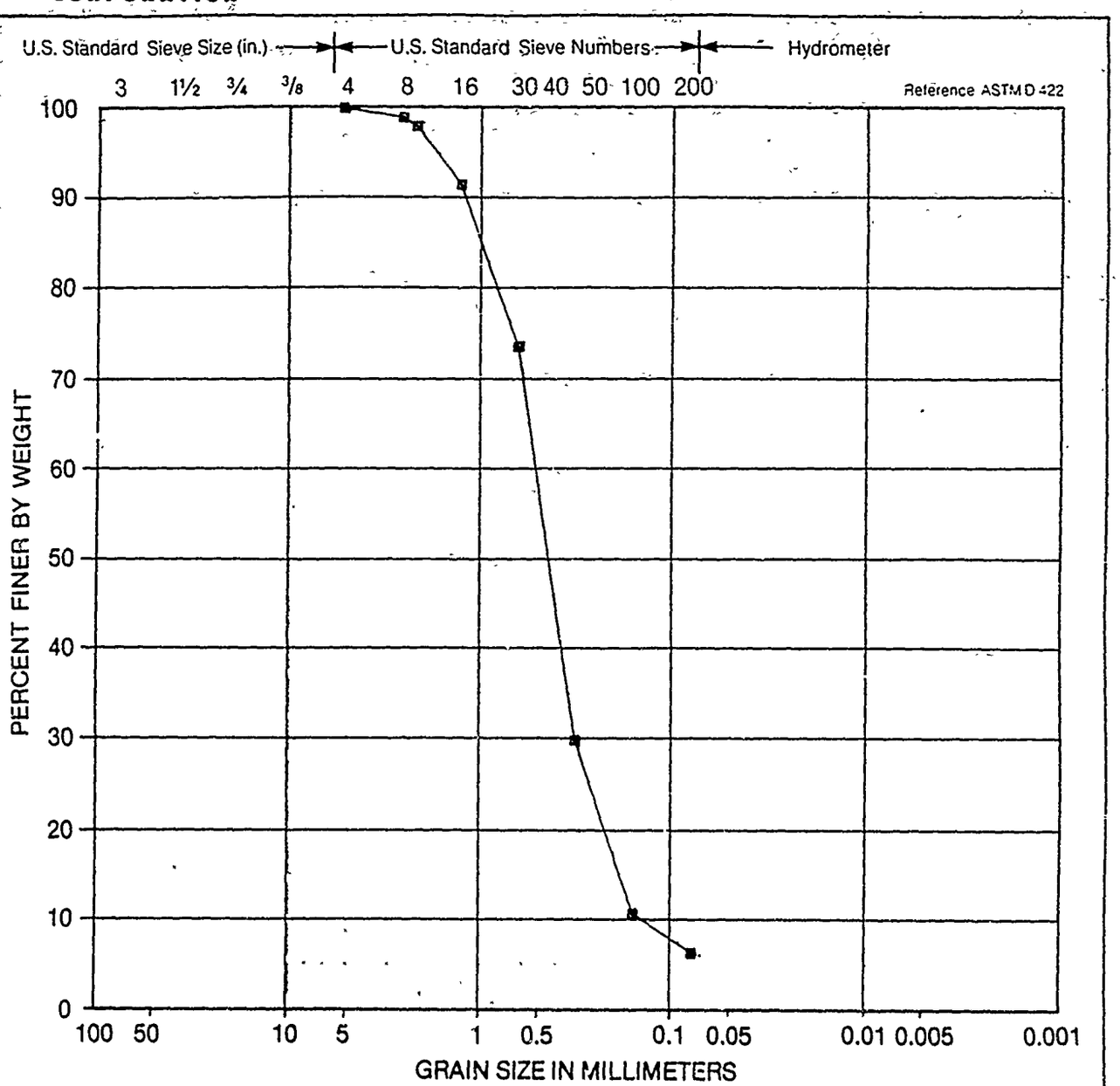
Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project : RADIAN CORP. ID : 17474,002.02 Test Date : 01-16-1990

Data Entry By : PSA Location : 16A-P @ 0.0 Data File : TEST0577

Sieve Name	Sieve Size (mm)	Cum. Weight Retained (g)	Percent of Total Weight Passing
3.000 in	75.000	0.0	100.0
1.500 in	37.500	0.0	100.0
3/4 in	19.000	0.0	100.0
3/8 in	9.500	0.0	100.0
No. 4	4.750	0.0	100.0
No. 8	2.360	2.2	99.0
No. 10	2.000	4.1	98.1
No. 16	1.180	11.6	94.5
No. 30	0.600	30.2	85.8
No. 50	0.300	95.1	55.2
No. 100	0.150	146.9	30.8
No. 200	0.075	161.8	23.8

RADIAN CORPORATION



COBBLES	GRAVEL: COARSE	GRAVEL: FINE	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT OR CLAY
	GRAVEL		SAND			

Symbol	Sample Source	Classification
■	12A-P @ 0.0 FT Boring PZ 1000	BROWN SAND W/SILT (SP-SM)

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Engineers, Geologists & Geophysicists

Particle Size Analysis

PLATE

D-85

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	17474.002.02	TJD	01-16-1990		

RADIAN
CORPORATION

Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project Name: RADIAN CORP.
Project Number: 17474,002.02

Test Date: 01-16-1990
Location: 12A-P @ 0.0

Total Sample Weight (g): 185.9

Percent Passing No. 10 Sieve : 0.0

Representative Sample Weight (g): ----

PI Results (used in determining fines classification)

Liquid Limit: --- Plasticity Index: ---

Soil Composition (%):

Gravel : 0.0
Sand : 92.8
Fines : 7.2

Particle Diameter (mm):

@ 60% Passing : 0.4808
@ 30% Passing : 0.2946
@ 10% Passing : 0.1176

Coefficient of Uniformity: 4.09E 0

Coefficient of Curvature: 1.53E 0

Soil Classification: BROWN SAND W/SILT (SP-SM*)

Frost Classification: --

Data Entry By: PSA File #: 578

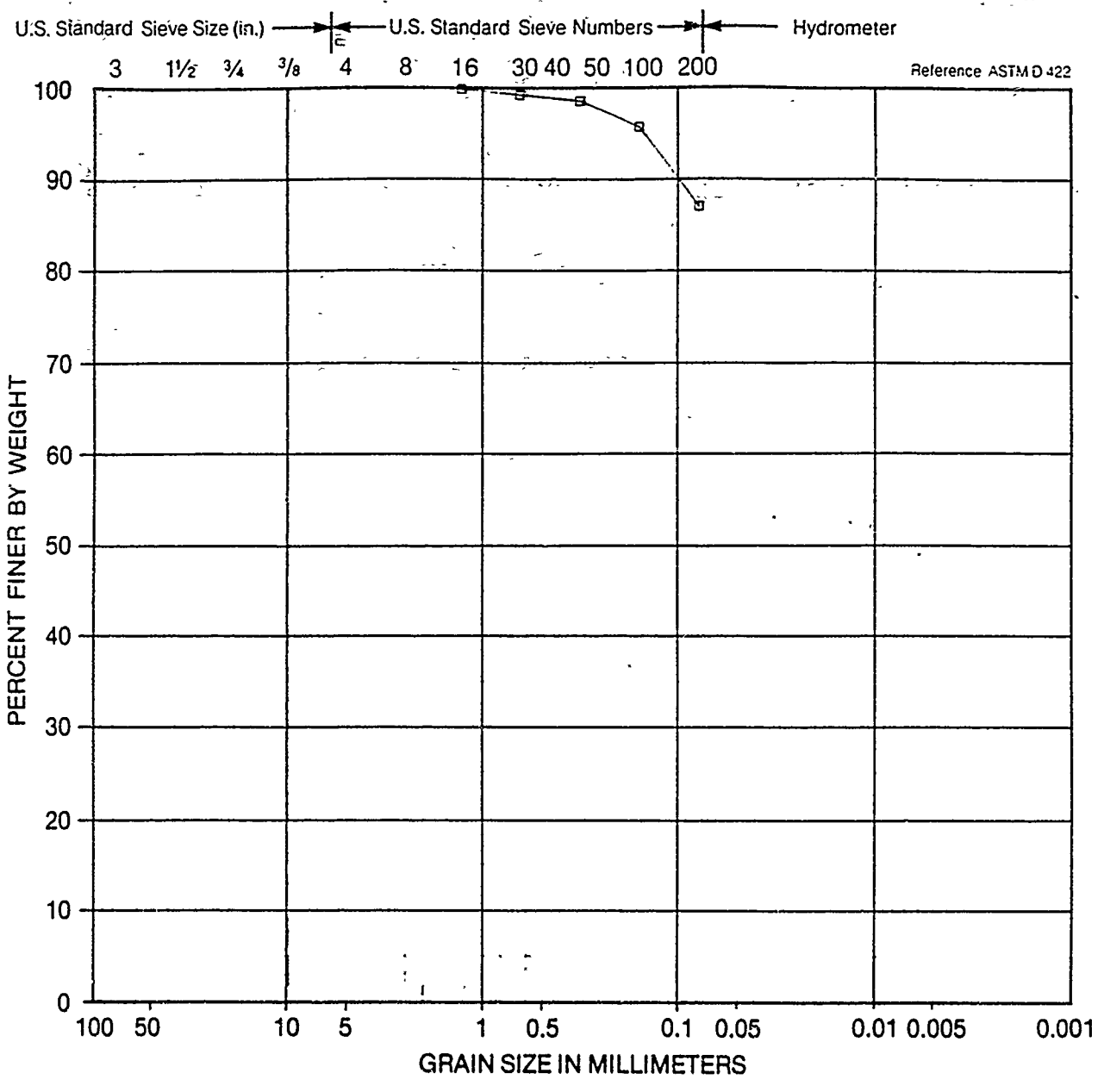
Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project : RADIAN CORP. ID : 17474,002.02 Test Date : 01-16-1990

Data Entry By : PSA Location : 12A-P @ 0.0 Data File : TEST0578

Sieve Name	Sieve Size (mm)	Cum. Weight Retained (g)	Percent of Total Weight Passing
3.000 in	75.000	0.0	100.0
1.500 in	37.500	0.0	100.0
3/4 in	19.000	0.0	100.0
3/8 in	9.500	0.0	100.0
No. 4	4.750	0.0	100.0
No. 8	2.360	1.9	99.0
No. 10	2.000	3.7	98.0
No. 16	1.180	15.7	91.6
No. 30	0.600	48.6	73.9
No. 50	0.300	129.2	30.5
No. 100	0.150	164.5	11.5
No. 200	0.075	172.5	7.2

RADIAN CORPORATION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Sample Source	Classification
□	16B-P @ 0.0 FT Boring PZ 2	BROWN SILT (ML)

HLA **Harding Lawson Associates**
Engineers, Geologists & Geophysicists

Particle Size Analysis

PLATE

D-88

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	17474.008.08	TJD	01-18-1990		

RADIAN CORPORATION

Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project Name: RADIAN CORP.
Project Number: 17474,002.02

Test Date: 01-18-1990
Location: 16B-P @ 0.0

Total Sample Weight (g): 173.8

Percent Passing No. 10 Sieve : 0.0

Representative Sample Weight (g): ----

PI Results (used in determining fines classification)

Liquid Limit: ---

Plasticity Index: ---

Soil Composition (%):

Gravel : 0.0

Sand : 12.8

Fines : 87.2

Particle Diameter (mm):

@ 60% Passing : ---

@ 30% Passing : ---

@ 10% Passing : ---

Coefficient of Uniformity: ----

Coefficient of Curvature: ----

Soil Classification: BROWN SILT (ML*)

Frost Classification: --

Data Entry By: PSA

File #: 598

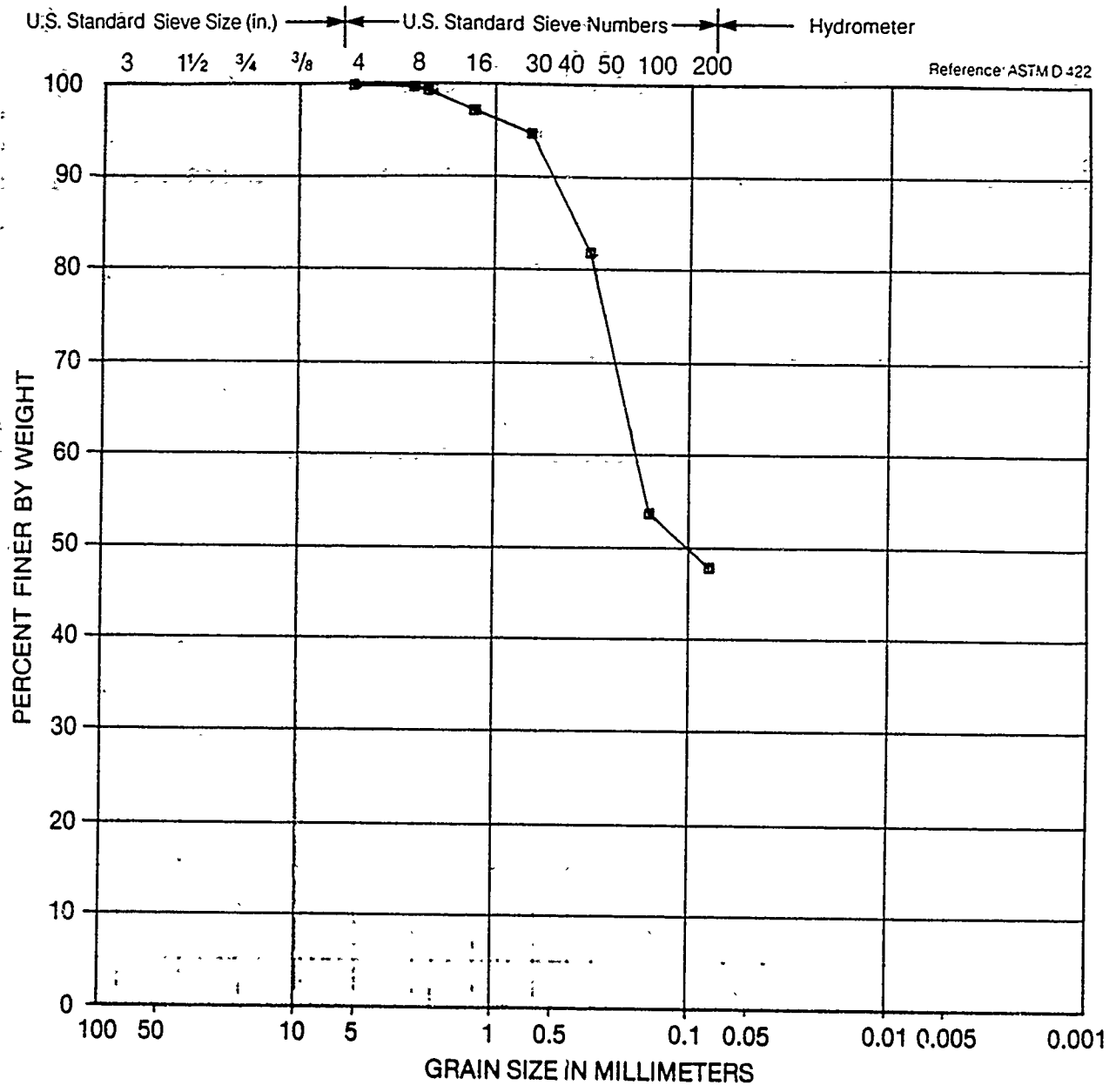
Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project : RADIAN CORP. ID : 17474,002.02 Test Date : 01-18-1990

Data Entry By : PSA Location : 16B-P @ 0.0 Data File : TEST0598

Sieve Name	Sieve Size (mm)	Cum. Weight Retained (g)	Percent of Total Weight Passing
3.000 in	75.000	0.0	100.0
1.500 in	37.500	0.0	100.0
3/4 in	19.000	0.0	100.0
3/8 in	9.500	0.0	100.0
No. 4	4.750	0.0	100.0
No. 8	2.360	0.0	100.0
No. 10	2.000	0.0	100.0
No. 16	1.180	0.0	100.0
No. 30	0.600	1.1	99.4
No. 50	0.300	2.3	98.7
No. 100	0.150	7.2	95.9
No. 200	0.075	22.3	87.2

RADIAN CORPORATION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Sample Source	Classification
■	12B-P @ 0.0 FT Boring PZ 1001	BROWN CLAYEY SAND (SC)

HLA **Harding Lawson Associates**
Engineers, Geologists & Geophysicists

Particle Size Analysis

PLATE

D-91

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	17474.002.02	TJB	01-16-1990		

RADIAN CORPORATION

Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project Name: RADIAN CORP.
Project Number: 17474,002.02

Test Date: 01-16-1990
Location: 12B-P @ 0.0

Total Sample Weight (g): 188.2

Percent Passing No. 10 Sieve : 0.0

Representative Sample Weight (g): ----

PI Results (used in determining fines classification)

Liquid Limit: --- Plasticity Index: ---

Soil Composition (%):

Gravel : 0.0
Sand : 51.6
Fines : 48.4

Particle Diameter (mm):

@ 60% Passing : 0.1735
@ 30% Passing : ---
@ 10% Passing : ---

Coefficient of Uniformity: ----

Coefficient of Curvature: ----

Soil Classification: BROWN CLAYEY SAND (SC*)

Frost Classification: --

Data Entry By: PSA File #: 575

Particle Size Analysis
Sieve Method
HLA Laboratory Analysis Routines Ver 3.0

Project : RADIAN CORP. ID : 17474,002.02 Test Date : 01-16-1990

Data Entry By : PSA Location : 12B-P @ 0.0 Data File : TEST0575

Sieve Name	Sieve Size (mm)	Cum. Weight Retained (g)	Percent of Total Weight Passing
3.000 in	75.000	0.0	100.0
1.500 in	37.500	0.0	100.0
3/4 in	19.000	0.0	100.0
3/8 in	9.500	0.0	100.0
No. 4	4.750	0.0	100.0
No. 8	2.360	0.4	99.8
No. 10	2.000	1.1	99.4
No. 16	1.180	5.1	97.3
No. 30	0.600	9.8	94.8
No. 50	0.300	33.8	82.0
No. 100	0.150	86.3	54.1
No. 200	0.075	97.2	48.4