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NAVAL AIR STATION
FORT WORTH JRB
CARSWELL FIELD
TEXAS

ADMINISTRATIVE RECORD
COVER SHEET

AR File Number 74

RCN: 227-005-04
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INSTALLATION RESTORATION PROGRAM (IRP)

STAGE 2

CARSWELL AFB, TEXAS

RADIAN CORPORATION
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DRAFT REPORT - MAY 1991

FEASIBILITY STUDY REPORT FOR THE FLIGHTLINE AREA

PREPARED FOR

HEADQUARTERS STRATEGIC AIR COMMAND
(HQ SAC/DE)
OFFUTT AIR FORCE BASE, NEBRASKA 68113-5001

UNITED STATES AIR FORCE
HUMAN SYSTEMS DIVISION (AFSC)
IRP PROGRAM OFFICE (HSD/YAQ)
BROOKS AIR FORCE BASE, TEXAS 78235-5501

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FEASIBILITY STUDY
FOR THE FLIGHTLINE AREA

DRAFT REPORT
FOR
CARSWELL AIR FORCE BASE, TEXAS

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USAF CONTRACT NO. F33615-87-D-4023, DELIVERY ORDER NO. 0004, MODIFICATION 0005
CONTRACTOR CONTRACT NO. 227-005-04, DCN 91-227-005-04-26

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PREFACE

Radian Corporation is the contractor for the Installation Restoration Program (IRP) Phase II, Stage 2 investigation at Carswell AFB, Texas. The work was performed under USAF Contract No. F33615-87-D-4023, Delivery Order 0004, in two separate efforts; the first in 1987-88, and the second in 1990.

A hydrogeological investigation was conducted at several landfills, fire department training areas, and fuels handling areas to further assess and define the extent of contamination confirmed in the Stage 1 investigation at Carswell AFB. Soil gas surveys were conducted in 1988 at two locations to determine the extent of petroleum hydrocarbon vapors. Ground-water monitor wells were installed in alluvial materials to further define the limits of ground-water contamination. Soil samples were collected during drilling operations and with hand augers at selected sites and analyzed for a broad range of parameters in the initial Stage 2 effort. Water samples collected from the wells and several surface water bodies were analyzed for a wide spectrum of total metals, inorganic compounds, and organic compounds. Dissolved metals concentrations were analyzed only in the samples collected in 1990. A pumping test of the Upper Zone Aquifer was also performed in the Flightline Area in 1990. A baseline risk assessment, incorporating all analytical data, was performed, and remedial action alternatives were identified and evaluated for the Flightline Area and four sites in the East Area of the base (Sites LF01, SD13, ST14, and BSS) in the Feasibility Study.

Key Radian project personnel were:

Nelson H. Lund	IRP Contract Manager
William L. Boettner	IRP Program Manager
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Stephen E. Fain	Supervising Geologist (1990)
Scott B. Blount	Supervising Geologist (1990)
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Jeffery P. Young	Flightline Area FS Task Leader
Gary S. Shaw	East Area FS Task Leader
Gary L. Patton	Database Management and QA/QC Task Leader

Greg A. Hamer James H. Clary James L. Machin Leo M. Dielmann	Senior Technical Reviewers

Radian would like to acknowledge the cooperation of the Carswell AFB Civil Engineering Staff. In particular, Radian acknowledges the assistance of Mr. Frank Grey, Mr. Raj Sheth, and Sgt. Stanley Reinhartz.

The work reported herein was accomplished between December 1987 and July 1990. Mr. Karl W. Ratzlaff, IRP Technical Operations Branch, Human Services Division (AFSC) IRP Program Office (HSD/YAQ), was the Technical Project Manager.

Approved: ______________ for

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Contract Manager

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EXECUTIVE SUMMARY

Radian performed a Feasibility Study (FS) for remediation of environmental contamination present in the Flightline Area of Carswell AFB, Texas. The data used to support the FS were obtained during the Installation Restoration Program (IRP) Remedial Investigation (RI), various stages of which were performed by Radian between 1988 and 1991; and from the earlier IRP Phase I (CH2M Hill, 1984) and Phase II Stage 1 (Radian, 1986) efforts. The Flightline Area IRP sites addressed by this FS are:

- Site LF04 - Landfill 4;
- Site LF05 - Landfill 5; and
- Site WP07 - Waste Burial Area.

Site FT09, Fire Department Training Area 2, is not included in this FS because the detailed engineering design and specifications for remediation of this site are currently in preparation. The locations of these, and other IRP Flightline Area sites that are addressed in separate project reports and documents, are shown in Figure ES-1.

Affected environmental media in the Flightline Area include soil, ground water and surface water which are contaminated with volatile organic compounds, mainly associated with waste chlorinated solvents. The FS focused primarily on ground-water and surface water contamination, because soil contamination in the unsaturated zone is generally localized around the waste disposal areas.

Based on the available data, ground-water contamination appears to be limited to the shallowest water-bearing zone, known as the Upper Zone Aquifer. In the Flightline Area, as well as across Carswell AFB and in the adjoining area of Air Force (AF) Plant 4, the Upper Zone consists of unconsolidated Quaternary and Recent alluvial deposits (sand, gravel, silt and clay) that contain ground water under unconfined conditions. The Upper Zone deposits in the Flightline Area vary from approximately 5 to 49 feet thick,

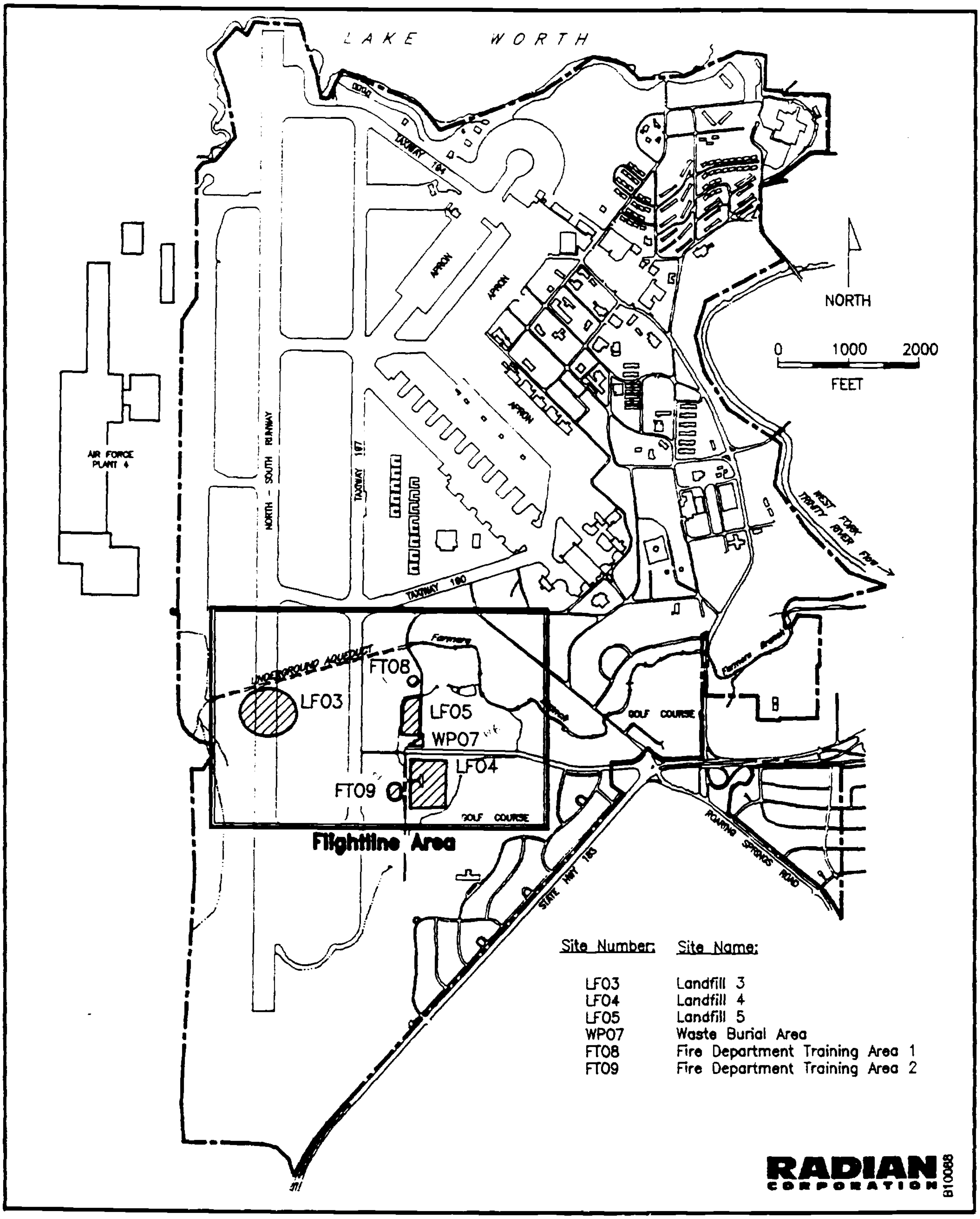

Figure ES-1. Location of Flightline Area IRP Sites, Carswell AFB, Texas and are underlain by the low permeability limestones and shales of the Cretaceous Goodland and Walnut Formations which form a basal aquiclude. Ground water in the Upper Zone Aquifer is encountered at depths ranging from approximately 4 to 30 feet below ground level (bgl).

The main surface water bodies located in the Flightline Area are Farmers Branch, an unnamed tributary that flows into Farmers Branch, and two small ponds on the base golf course. Farmers Branch eventually discharges to the Trinity River, which is located along the eastern boundary of Carswell AFB. The Upper Zone ground water and surface water bodies in the Flightline Area are hydraulically interconnected, with ground water discharging to surface water.

Trichloroethene (TCE), vinyl chloride, tetrachloroethene (PCE), and the cis- and trans- isomers of 1,2-dichloroethene (1,2-DCE) are the main contaminants detected in the ground water and surface water in the Flightline Area. Based on the concentrations and distribution of these compounds in ground water, most recently determined in the 1990 sampling and analysis program, the three former waste disposal areas (Sites LF04, LF05 and WP07) appear to be sources for some of the ground-water contaminants detected downgradient of the sites. However, all of these compounds were also detected in samples from monitor wells located hydraulically upgradient of all Carswell AFB IRP sites in the Flightline Area, indicating that additional off-base sources must also be contributing to the existing Upper Zone ground-water contamination. The occurrence of volatile organic contaminants in the Upper Zone ground water on the AF Plant 4 property, upgradient of the Flightline Area, is documented (Hargis and Associates, 1989). The source(s) of the contamination on AF Plant 4 have thus far not been fully defined. However, it is likely that they are also the source(s) for the contamination detected in the upgradient Flightline Area wells, and are contributing some component to the contaminant plumes that exist downgradient of the Flightline Area IRP sites.

The FS was performed in accordance with procedures described in U.S. EPA Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (1988). The main components of the FS are:

- Identification and screening of remedial technologies;
- Development and screening of remedial alternatives; and
- Detailed individual and comparative evaluation of feasible remedial alternatives against the evaluation criteria defined in the EPA guidance document.

As explained previously, because as yet incompletely defined upgradient sources are apparently continuing to contribute to the ground-water contamination in the Flightline Area, the FS focused on identification of remedial technologies and alternatives capable of eliminating future releases of waste or waste constituents from the Flightline Area IRP sites; and prevention of further migration of contaminants from the Flightline Area in ground water and surface water. Additional detailed information on the nature, distribution and magnitude of the upgradient contaminant source(s) is required before a remedial action for ultimate mitigation of the existing ground-water contamination can be designed.

Data from the RI were used to perform a baseline risk assessment for the Flightline Area. Nineteen indicator chemicals were selected using a conservative approach, according to the method described in the U.S. EPA Health Evaluation Manual (1986). Potential mechanisms for contaminant release were evaluated; volatilization to air, leachate generation and migration to ground water, and contaminated ground-water discharge to surface water were determined to be the most important in the Flightline Area. Applicable contaminant fate and transport mechanisms, and potential exposure pathways and receptors were identified and are illustrated diagrammatically in Figure ES-2. The threat to human health was evaluated on the basis of noncarcinogenic and carcinogenic risks, by comparing predicted annual average contaminant concentrations with Inhalation Reference Doses (RFDs) for chronic exposure;

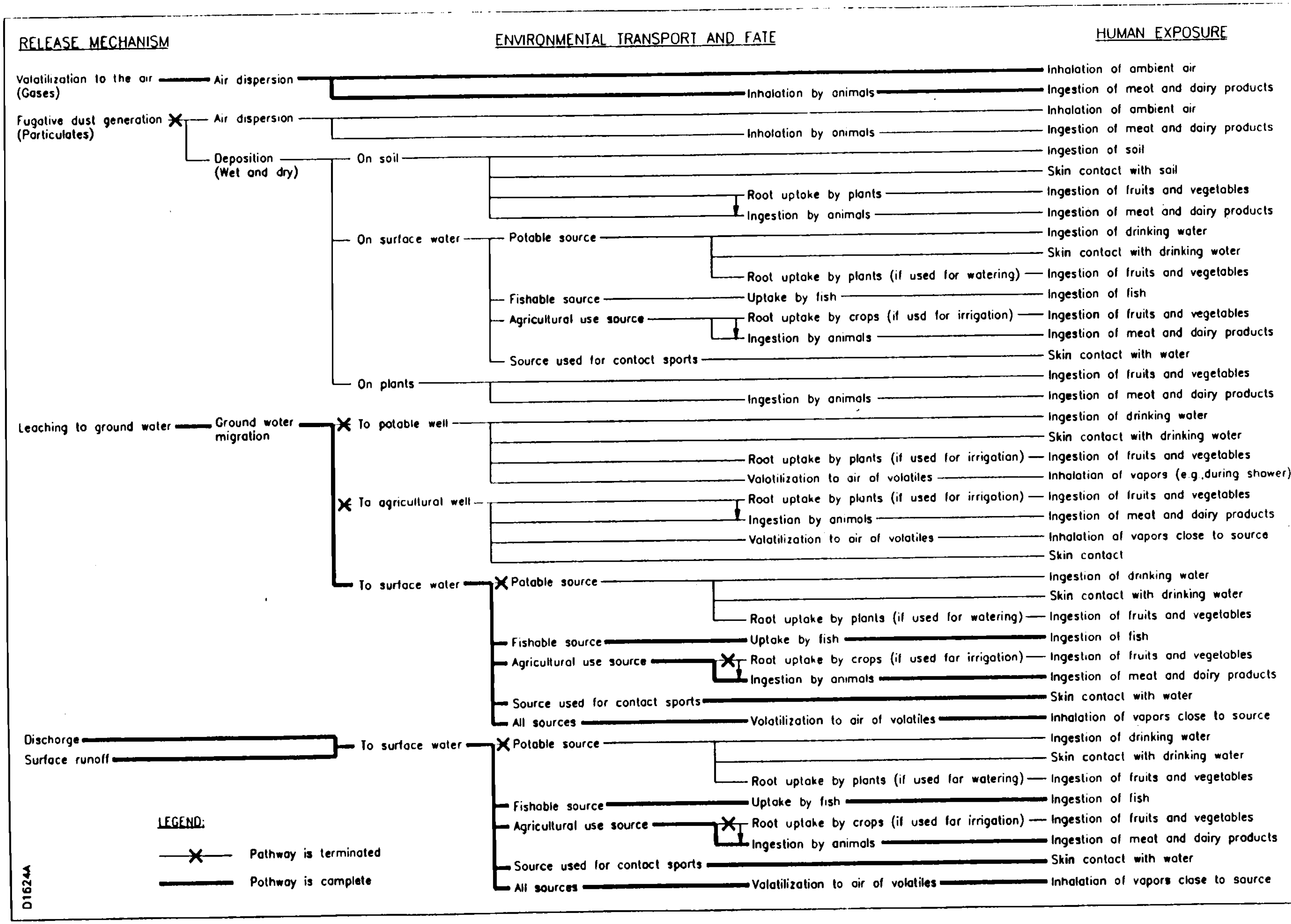

Figure ES-2. Potential Exposure Pathways for Contaminants Released from the Carswell AFB Flightline Area and by estimating incremental individual cancer risks for maximum exposed on- and off-site individuals, respectively. Human health risks were determined to be insignificant. Minimal risk (from the three Flightline sites) was determined to exist to wildlife that use the Flightline Area surface water for drinking, and to aquatic organisms that live in these water bodies. The evaluation was based on comparison of surface water concentrations of detected indicator chemicals with U.S. EPA Quality Criteria for Water (1986).

Remedial Action Objectives (RAOs) were developed for the FS and include:

- Reduce or eliminate potential future impacts to human health and the environment;
- Reduce or eliminate the potential for future contaminant migration in ground water; and
- Reduce or eliminate the potential for continuing mobilization of contaminants from soils or residual wastes.

Achievement of RAOs was assessed against the following standards and criteria:

- 70-year cancer risk potential;
- National Interim Primary Drinking Water Standard Maximum Contaminant Levels (MCLs) for organic compounds (40 CFR 141.12 and 141.61) and metals (40 CFR 141.11 and 141.62); and
- Final MCLs for organics and inorganics (Federal Register, Vol. 56, No. 20, January 30, 1991).

Generic response actions, technologies and process options applicable to wastes and contaminated soil, ground water, and surface water were identified and screened for compatibility with site-specific environmental conditions in the Flightline Area. Technologies determined to be inapplicable to the contaminants of concern, unproven, or incompatible with the hydrogeologic setting were eliminated from further consideration. Remedial technologies that remained after the screening are applicable to waste containment, ground-water treatment, and ground-water disposal and include:

- Impermeable multi-media ;
- Slurry walls;
- Hydraulic barriers;
- Ground-water extraction wells;
- Ground-monitoring;
- Air stripping;
- Effluent discharge to Farmers Branch;
- Effluent use for seasonal golf course irrigation; and
- Effluent discharge to the local publicly-owned treatment works (POTW).

Eleven remedial alternatives were developed from various combinations of these technologies and are presented, along with the No Action Alternative, in Table ES-1. Remedial technologies common to each of Alternatives 2 through 5 are ground-water monitoring, extraction wells, on-site air stripping, and use of the ground-water effluent for seasonal golf course irrigation in combination with one of the other disposal options.

Each of the alternatives was screened against the broad evaluation criteria of effectiveness, implementability and cost. As a result of the screening, Alternatives 6A, 6B and 7 were eliminated from further

TABLE ES-1. PRELIMINARY REMEDIAL ACTION ALTERNATIVES

	Alternatives											
	1	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7*
<u>Waste Containment</u>												
Cap Existing Landfills	NA	■	■	■	■					■	■	
Slurry Wall Placed Around Perimeter of Landfill	NA	■	■					■	■			
Ground-Water Extraction Wells Placed on Perimeter of Landfill	NA			■	■	■	■					
<u>Ground Water</u>												
Monitoring	NA	■	■	■	■	■	■	■	■	■	■	■
Extraction Well System	NA	■	■	■	■	■	■	■	■	■	■	■
On-Site Air Stripping	NA	■	■	■	■	■	■	■	■	■	■	
<u>Disposal</u>												
Discharge Treated Effluent into Farmers Branch Creek	NA	■		■		■		■		■		
Discharge Treated Effluent into POTW	NA		■		■		■		■		■	
Seasonal Irrigation of Base Golf Course	NA	■	■	■	■	■	■	■	■	■	■	■

NA = No Action

*Alternative 7 utilizes any of the waste containment options listed in Alternatives 2, 3, 4, 5, or 6.

consideration because they failed to meet the effectiveness and implementability criteria.

The nine remaining alternatives were assessed individually against seven broad CERCLA evaluation criteria of:

- Overall protection human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility or volume;
- Short-term effectiveness;
- Implementability; and
- Cost.

Alternatives were also evaluated relative to each other, based on expanded versions of these criteria. Table ES-2, the remedial alternatives comparative evaluation matrix summarizes the results of the FS and identifies Alternative 4B as the most cost-effective remedial alternative.

TABLE ES-2. RESULTS OF REMEDIAL ALTERNATIVES COMPARATIVE EVALUATION

Primary Alternatives	Capital ($ M)	O&M ($ M)	NPV ($ M)	Technology Status	Compliance with ARARs	Constructability	Off-Site Impacts	Need for Further Study	Impacts to Base Operation	Products Generated	Reliability	Regulatory Acceptance	Permitting Requirements	Effectiveness Total	Effectiveness Total/Cost Total
Weighting Factors	1	1	1	4	4	4	3	2	3	3	3	5	5		
2A: Cap/-Slurry Wall/-Treatment/Farmers Branch	5.546	1.833	7.380	3	3	1	2	2	1	2	3	2	1	71	9.8
2B: Cap/-Slurry Wall/-Treatment/POTW	5.329	1.833	7.366	3	3	1	2	2	1	2	3	3	2	81	11.0
3A: Cap/GW Ex/Treatment/Farmers Branch	4.427	1.941	6.368	4	3	2	2	2	2	3	3	2	1	85	13.6
3B: Cap/GW Ex/Treatment/POTW	4.424	1.941	6.365	4	3	2	2	2	2	3	3	3	2	95	15.2
4A: GW Ex/Treatment/Farmers Branch	0.850	1.941	2.791	4	2	3	3	2	3	3	2	2	1	88	32.5
4B: GW Ex/Treatment/POTW	0.847	1.941	2.788	4	2	3	3	2	3	3	2	3	2	98	36.1
5A: Slurry Wall/Treatment/Farmers Branch	1.970	1.833	3.803	3	3	1	2	2	1	2	3	2	1	71	18.7
5B: Slurry Wall/Treatment/POTW	1.956	1.833	3.789	3	3	1	2	2	1	2	3	3	2	81	21.4

O&M = Annual Operation and Maintenance Cost

NPV = Net Present Value

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1.0 INTRODUCTION

In partial fulfillment of the requirements of the Scope of Work (SOW) for Delivery Order 04, Modification 05 of Contract No. F33615-87-D-4023 with the U.S. Air Force, Radian Corporation (Radian) performed a Feasibility Study (FS) for remediation of environmental contamination present in the Flightline Area of Carswell AFB, Texas. Six former waste disposal sites within the Flightline Area have been studied and characterized with respect to the nature and extent of contamination, if any, associated with each under the Air Force Installation Restoration Program (IRP). The Flightline Area IRP sites are:

- Site LF03 - Landfill 3;
- Site LF04 - Landfill 4;
- Site LF05 - Landfill 5;
- Site WP07 - Waste Burial Area 10;
- Site FT08 - Fire Department Training Area 1; and
- Site FT09 - Fire Department Training Area 2.

Investigations performed to date at Sites LF03 and FT08 have provided no evidence that these sites have released any hazardous waste or waste constituents in quantities that could endanger human health or the environment. No Further Action Decision Documents (NFADDs) were prepared for each of these sites (Radian, 1990a,b). Documented contamination associated with Site FT09 is also addressed in a separate Decision Document (Radian, 1990c) in which the recommended Remedial Action (RA) is described. Detailed Plans and Specifications for the RA are currently in preparation. The remaining sites (LF04, LF05, and WP07) each received similar types of wastes which are consistent with contaminants detected in the shallow ground water, surface water and soils in the Flightline Area. Remedial alternatives to address Flightline Area contamination from these sources, as well as to control future migration of contaminants from additional unidentified upgradient, off-base sources, were developed and evaluated.

1.1 Purpose and Organization of Report

The purpose of this report is to document the procedures and findings of the FS, which was performed in accordance with the U.S. EPA Guidance for Conducting Remedial Investigations (RI) and Feasibility Studies (FS) Under CERCLA (EPA, 1988). Activities performed in the FS and documented in this report include:

- Identification and screening of remedial technologies;
- Development and screening of remedial alternatives; and
- Detailed evaluation of alternatives for remediation of documented environmental contamination in the Flightline Area.

Background information, pertaining to the general hydrogeologic setting of Carswell AFB and to site-specific conditions in the Flightline Area, summarized from the RI report (Radian, 1991a), are provided in Section 1.2. Section 2 presents the results of the identification and screening of technologies applicable to contamination in the Flightline Area. Remedial Action Objectives (RAO) and General Response Actions (GRA) are presented in Sections 2.2 and 2.3, respectively. Section 2.4 provides a summary of the identification and screening of technology types and process options. Section 3 describes the basis for developing media-specific alternatives (Section 3-1) and the results of the alternatives screening evaluation. Section 4 is the detailed evaluation of remedial alternatives for the Flightline Area. Feasible alternatives, remaining after the initial screening, are evaluated individually against the nine CERCLA evaluation criteria (Section 4.2) and relative to each other, based on trade-offs of advantages/disadvantages for expanded versions of each of the criteria (Section 4.3).

1.2 Background Information

Most of the background information contained in this section is based on the most recent and comprehensive data from the Flightline Area

(Radian, 1991), combined with information summarized from earlier IRP reports (CH2M Hill, 1984; Radian, 1986, 1989).

Carswell AFB is located six miles west of Fort Worth in Tarrant County, Texas. The base is bordered by Lake Worth to the north, the West Fork of the Trinity River and the community of Westworth to the east and southeast, and Air Force Plant 4 (AF Plant 4) to the west (Figure 1-1). Figure 1-2 shows the location of the Flightline Area IRP sites.

Five major hydrogeologic units exist beneath Carswell AFB. From shallowest to deepest they are: 1) an Upper Zone of unconfined ground water occurring within the alluvial terrace deposits associated with the Trinity River; 2) an aquitard of predominantly dry limestone of the Goodland and Walnut Formations; 3) an aquifer in the Paluxy Sand; 4) an aquitard of relatively impermeable limestone in the Glen Rose Formation; and 5) a major aquifer in the sandstone of the Twin Mountains Formation. The Upper Zone was the only unit studied in this most recent Stage 2 site characterization (1990) effort. Previous IRP reports determined that contaminated ground water was only present in the Upper Zone formation. Figure 1-3 shows the general depth of occurrence and thickness of each of the major hydrogeologic units expected in the Flightline Area. The following subsections present the hydrogeologic characteristics of the Upper Zone formation and the Goodland/Walnut Aquitard that lies beneath it.

The Upper Zone ground water occurs within the alluvial deposits at Carswell AFB. Low permeability is typical of this alluvium, however, there are zones of greater permeability corresponding to sands and gravels of former channel deposits. Recharge to the water-bearing deposits is local, from rainfall and infiltration from stream channels and drainage ditches. The direction of ground-water flow is generally controlled by the bedrock topography of the Walnut Formation, and to a lesser extent by land surface topography.

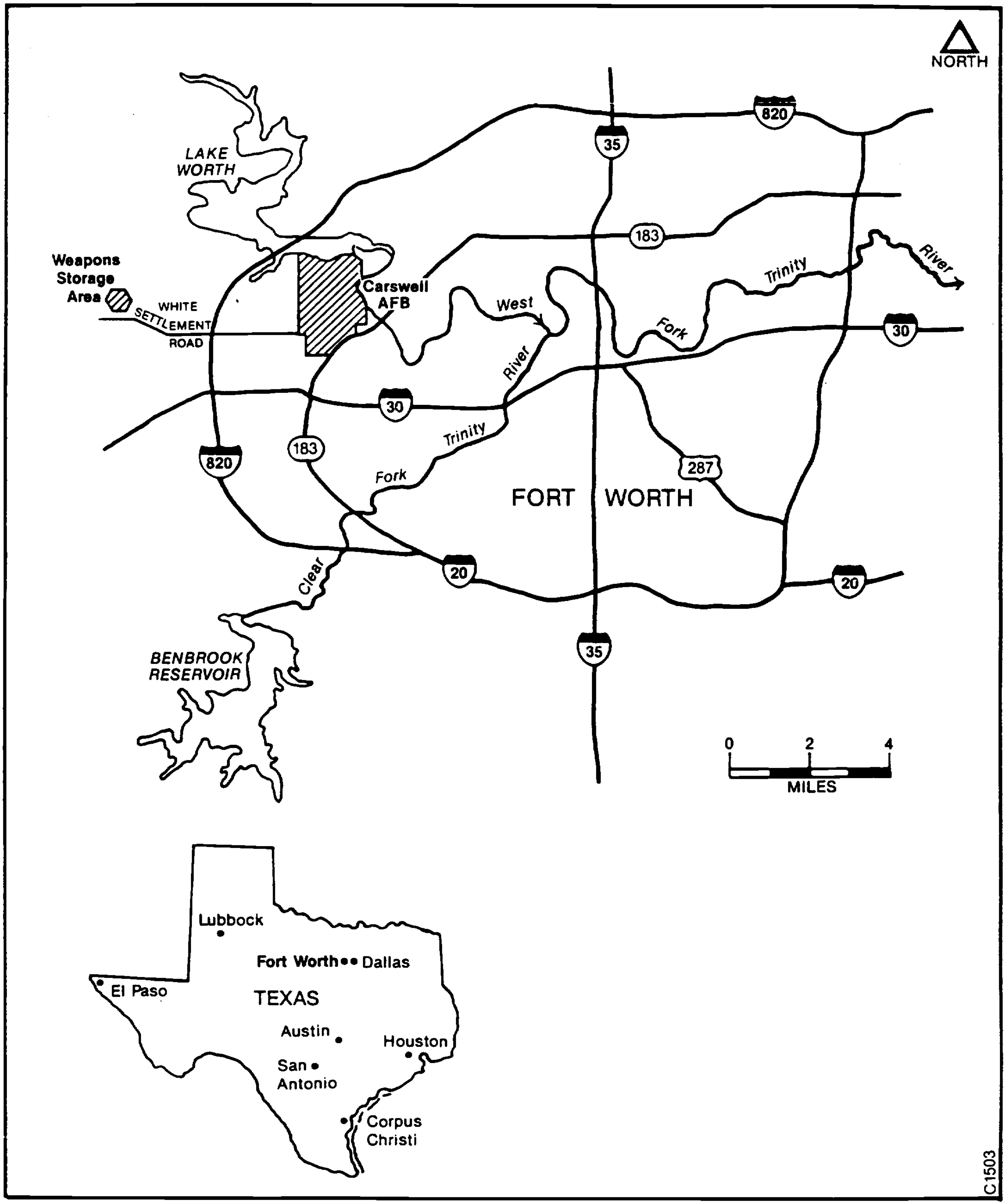

Figure 1-1. Regional Setting of Carswell AFB, Texas

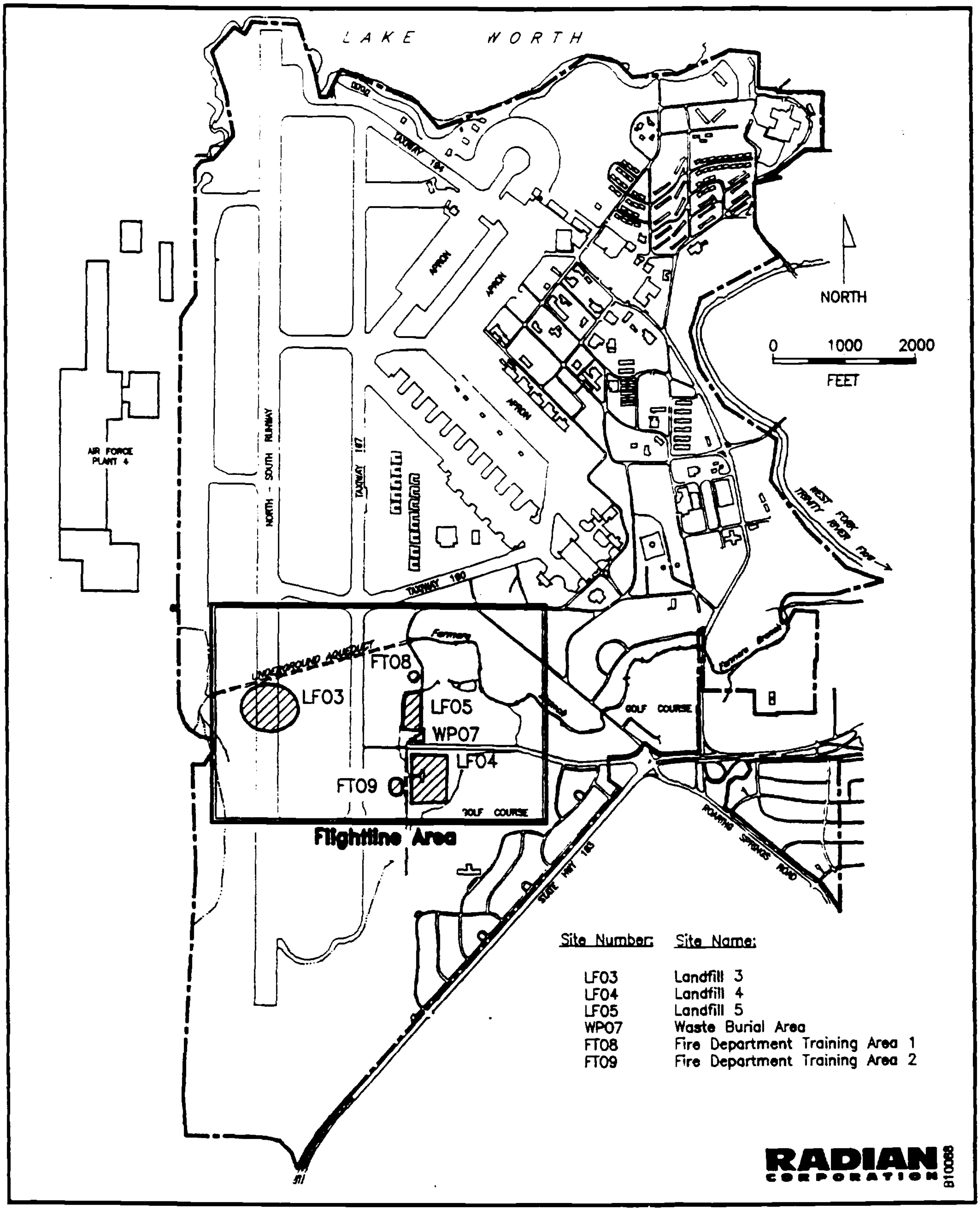

Figure 1-2. Locations of Flightline Area IRP Sites, Carswell AFB, Texas

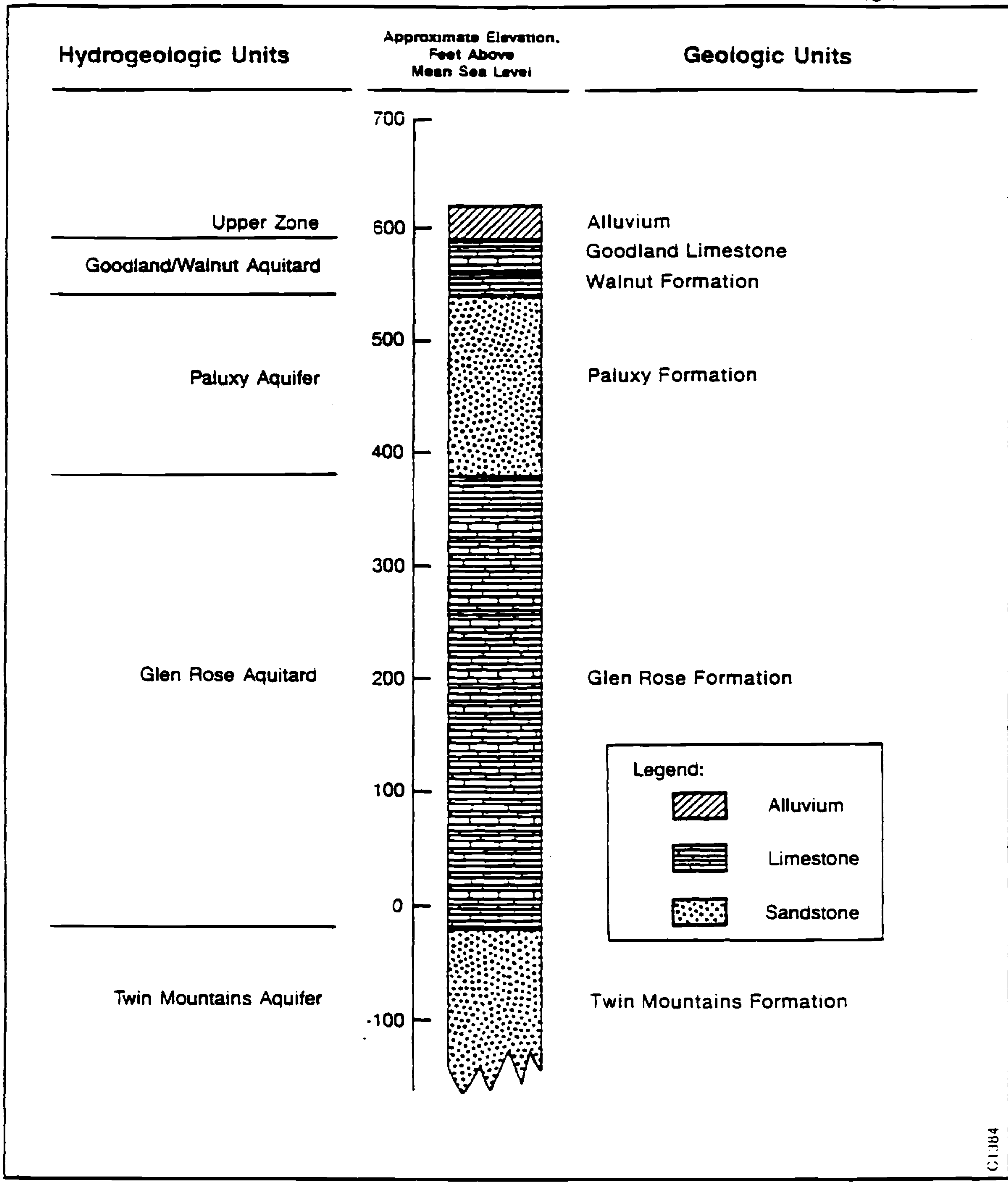

Figure 1-3. Generalized Hydrogeologic Units, Carswell AFB, Texas (Radian, 1989)

The Upper Zone ground water is separated from deeper aquifers by the low permeability limestones and shales of the Goodland Limestone and Walnut Formation. The aquitard is composed of moist clay and shale layers interbedded with dry limestone beds. The thickness of the Goodland/Walnut aquitard is approximately 30-40 feet beneath the Flightline Area at Carswell AFB. This thickness estimate is based on two monitor wells drilled through the aquitard and completed in the Paluxy Aquifer during the initial Stage 2 study (Radian, 1989). No corresponding information is available for the East Area where all subsurface borings were terminated at or above the top of bedrock.

1.2.1 Flightline Area Description

The land surface in the Flightline Area ranges from essentially a level surface near the main north-south runway to gently rolling land near tributaries of Farmers Branch at the golf course. Elevations in the area range from approximately 625 feet above mean sea level (MSL) at Landfill 3 (Site LF03) to 580 feet MSL at the northern end of Landfill 5 (Site LF05) and at Fire Department Training Area 1 (Site FT08).

All of the Flightline Area IRP sites included in the FS are underlain by soils of the Sanger-Purvis-Slidell soil association (USDA, 1981). This association typically consists of clay loam, clay over bedrock, and silty clay. The soil thickness is variable, ranging from about 8 to 80 inches, and permeabilities generally vary from less than 4.2 x 10E-5 cm/sec to 3 x 10E-4 cm/sec.

The main surface water bodies in the Flightline Area are Farmers Branch, an unnamed tributary that flows into Farmers Branch, and two ponds on the base golf course. Surface drainage in the Flightline Area is generally to the north and east, toward Farmers Branch. Farmers Branch eventually discharges to the Trinity River, located on the eastern boundary of Carswell AFB.

Quaternary alluvium, deposited by the Trinity River, is found at the surface throughout the Flightline Area site. The alluvium consists of floodplain and fluviatile terrace deposits of gravel, sand, silt, and clay overlying the eroded surface of the Goodland Limestone.

Drilling in the Flightline Area indicates that the alluvial deposits (and fill) range from just over 5 feet to about 49 feet thick. The irregular thickness of the alluvium is due to depositional events, stream channeling, and erosion. In general, silt and clay with variable amounts of sand and gravel occur at the land surface down to depths of 5 to 10 feet. Underlying the silt and clay is a sand and gravel unit that normally increases in grain size with increasing depth. These strata appear to be relatively continuous across the area although coarse gravel deposits occur in limited areas generally east of the Fire Department Training Areas 1 (Site FT08) and 2 (Site FT09). The sand deposits are fine-grained to coarse-grained, tan to rust in color, and composed predominantly of quartz. Gravel is mostly limestone and shell fragments ranging in size from fine gravel to cobbles.

Thick sand and gravel sequences, indicative of channel deposits, occur east of Taxiway 197 and roughly paralleling White Settlement Road. Sand and gravel thicknesses greater than 20 feet occur in an approximately 800 foot wide area, with White Settlement Road serving as the approximate median to the pattern.

Underlying the alluvium are the Cretaceous Goodland and Walnut Formations. Both formations consist of interbedded, fossiliferous, hard limestone and calcareous shale. The bedrock is fractured and there is considerable jointing and flaking. These strata are generally dry, although small amounts of water are occasionally present in the shale and clay units.

The thickness of the Goodland/Walnut Formations, as observed during the drilling of Paluxy wells P-1 and P-2 (Figure 1-3), is approximately 30-40 feet beneath the Flightline Area. However, because the top of the Goodland/Walnut Formations is an erosional surface, the thickness in specific areas is probably quite variable. It has been reported that the Quaternary alluvium and the Cretaceous Paluxy Formation are in direct contact where the Goodland/Walnut Formations were completely eroded away at the eastern boundary of AF Plant 4 (Hargis and Associates, 1985).

Underlying the Goodland and Walnut Formations is the Cretaceous Paluxy Formation, often referred to as the Paluxy Sand. The Paluxy Formation is the deepest unit penetrated in the Flightline Area during the IRP efforts. In the two Paluxy monitor wells P-1 and P-2, drilling penetrated the upper sand member and was terminated in an underlying shale unit. The upper sand member ranged from 30 to 35 feet in thickness and consisted of varying amounts of sand, sandstone, clay, and shale. The shale unit separating the Upper and Lower Paluxy Sands was encountered at approximately 105 feet below land surface in both monitor wells.

Figure 1-4 is a potentiometric surface map of Upper Zone ground water in the Flightline Area. It includes surface water elevations measured at six locations on Farmers Branch. Upper Zone ground water in the Flightline Area generally flows in a northeastward direction, toward Farmers Branch where ground-water discharges to the stream.

1.2.2 Site History

The physical features and past waste disposal practices for the three Flightline Area IRP sites addressed in the FS are described in the following text. Historical information concerning these sites is taken mainly from the IRP Phase I report (CH2M Hill, 1984).

Site LF04 - Landfill 4

Landfill 4 includes approximately 10 acres of land located east of the south end of Taxiway 197. It was the main landfill during much of the history of Carswell AFB. While in active use, at least six large pits, approximately 12 feet deep, were filled with refuse which was burned and

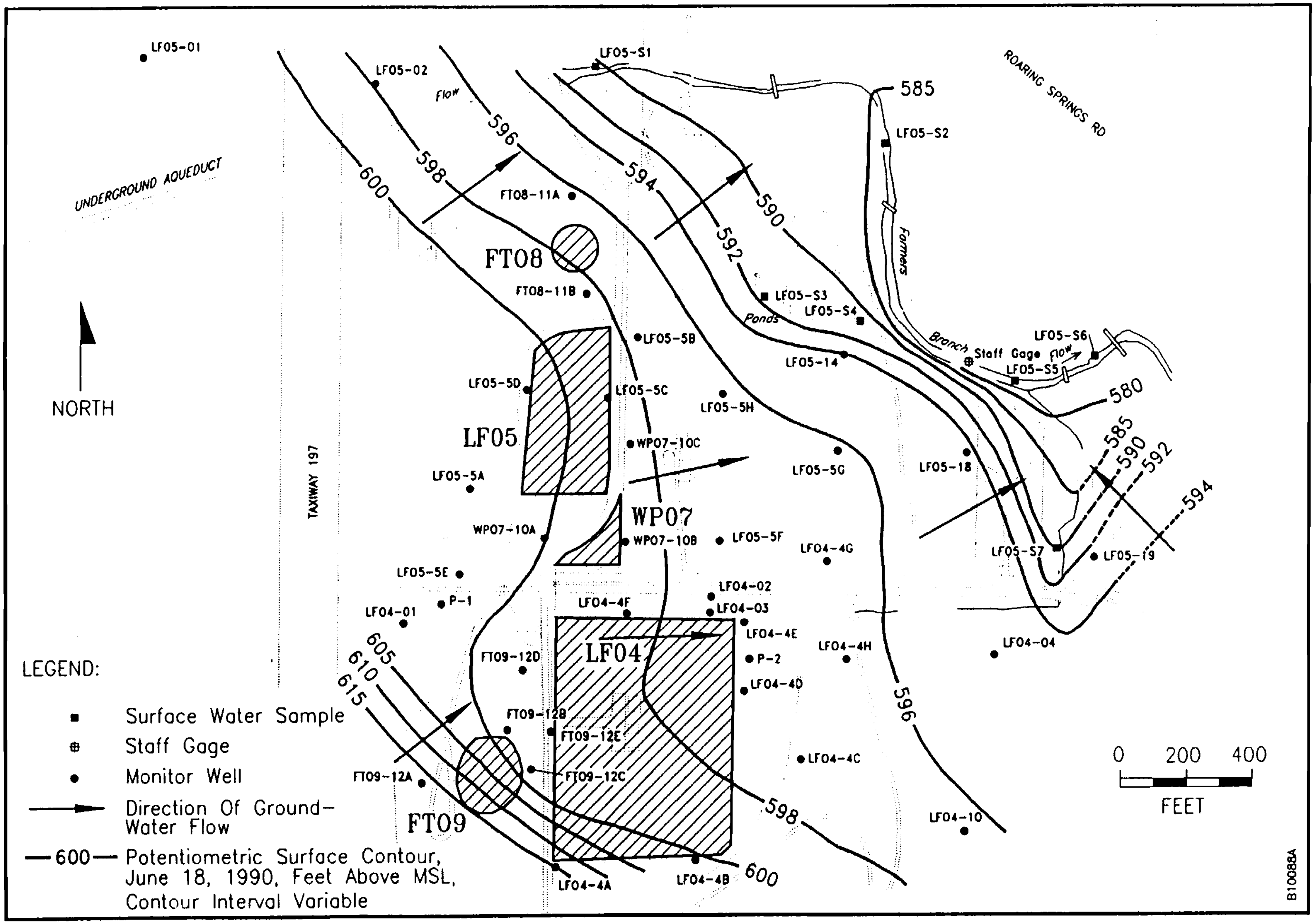

Figure 1-4. Potentiometric Surface Map of Upper Zone Aquifer, Flightline Area, Carswell AFB, Texas

buried. Various potentially hazardous wastes were reported disposed of at this site, including drums of waste liquids, partially full paint cans, and cadmium batteries.

Site LF05 - Landfill 5

Landfill 5 is located northwest of Landfill 4, adjacent to a small tributary to Farmers Branch. The landfill was constructed by building a clay berm along the creek and filling the area behind the berm up to the existing level. The landfill received all types of flightline wastes and refuse. Flightline wastes typically include such substances as oils, thinners, strippers, and paints. Waste materials in the landfill were burned regularly and buried.

Site WP07 - Waste Burial Area

Site WP07 is located adjacent to and north of White Settlement Road where it comes to a dead end at the taxiway. The area was used for burial of wastes during the 1960s. Various types of hazardous wastes, including drums of cleaning solvents, leaded sludge, and possibly ordnance were reportedly disposed of at this site.

1.2.3 Nature and Extent of Contamination

Environmental sampling and analysis performed during the IRP has documented the presence of soil, ground-water and surface water contamination in the Flightline Area of Carswell AFB. The extent of soil contamination in the unsaturated zone is generally limited to small areas immediately surrounding and/or directly underlying the waste disposal sites. Therefore, the focus of the following discussions is on Upper Zone ground-water and surface water contamination.

1.2.3.1 Ground-Water Contamination

Contamination detected in the ground water beneath the Flightline Area is apparently limited to the Upper Zone Aquifer. The low permeability, underlying bedrock (Goodland and Walnut Formations) is not water-bearing and acts as a basal confining layer to the Upper Zone Aquifer. No contaminants were detected in ground-water samples collected in 1988 from two Flightline Area monitor wells completed in the deeper Paluxy Aquifer. Based on the limited available data, the vertical extent of contamination in this area appears to be the bedrock surface.

Trichloroethene (TCE) is the main ground-water contaminant detected in the Flightline Area. The only other volatile organic compound detected in excess of the Maximum Contaminant Level (MCL) was vinyl chloride. Two compounds, tetrachloroethene and cis-1,2-dichloroethene, were detected in concentrations exceeding MCLs.

Four metals exceeded their MCLs in the most recent (1990) round of sampling and analysis. However, all of these, as well as previously reported metals results, reflect total metals concentrations in unfiltered samples. Total chromium was detected above the MCL in samples from three monitor wells. Total lead, arsenic and mercury were detected at levels above their respective MCL in one well each. Analyses for total metals may yield results that are not representative of true ground-water quality. Fine suspended material in the unfiltered sample can break down as a result of sample preservation (acidification), releasing additional metal ions into the water sample. Dissolved metals analyses, performed on filtered water samples, tend to yield results more representative of in-situ ground-water quality. On the basis of what are considered the most representative available data from the 1990 sampling event, there is no evidence of a metals contamination problem in the Upper Zone ground water beneath the Flightline Area.

Table 1-1 summarizes the volatile organic compounds detected in ground-water samples collected from the Flightline Area in 1990. TCE exceeded

TABLE 1-1. SUMMARY OF VOLATILE ORGANIC COMPOUNDS DETECTED IN UPPER ZONE GROUND-WATER SAMPLES FROM THE FLIGHTLINE AREA, CARSWELL AFB, TEXAS (SPRING 1990)

Analytical Parameter	EPA Standards or Proposed Standards* (µg/L)	Range of Detection Limits	Range of Concentrations of Constituents Detected	Total Number of Samples: Analyses for Constituent (No. of Wells)	Total Number of Samples: With Constituent Detected and Second Column Confirmation (No. of Wells)	Total Number of Samples: Exceeding EPA MCL/PMCL (No. of Wells)
Purgeable Halocarbons (601) µg/L						
1,1,1-Trichloroethane	200 (M)	0.2-50	0.37-0.70	74 (35 + 2 dup)	3 (3)	0
1,1,2,2-Tetrachloroethane		0.15-38	ND	74 (35)	0	0
1,1,2-Trichloroethane		0.2-50	ND	74 (35)	0	0
1,1-Dichloroethane		0.5-120	1.1	74 (35)	1 (1)	0
1,1-Dichlorethene	7 (M)	0.2-50	1.3-1.5	74 (35)	2 (2)	0
1,2-Dichlorobenzene		0.5-120	ND	74 (35)	0	0
1,2-Dichloroethane	5 (M)	0.1-25	ND	74 (35)	0	0
1,2-Dichloropropane	5 (M)	0.1-25	ND	74 (35)	0	0
1,3-Dichlorobenzene		0.32-80	ND	74 (35)	0	0
1,4-Dichlorobenzene	75 (M)	0.24-60	9.6	74 (35)	1 (1)	0
2-Chloroethylvinyl ether		0.5-130	ND	74 (35)	0	0
Bromodichloromethane		0.1-25	ND	74 (35)	0	0
Bromoform		0.5-130	ND	74 (35)	0	0
Bromomethane		1.2-300	ND	74 (35)	0	0
Carbon tetrachloride	5 (M)	0.12-30	ND	74 (35)	0	0
Chlorobenzene		0.25-63	2.3	74 (35)	1 (1)	0
Chloroethane		0.52-130	1.8	74 (35)	1 (1)	0
Chloroform		0.1-25	ND	74 (35)	0	0
Chloromethane		0.3-75	ND	74 (35)	0	0
Dibromochloromethane		0.2-50	ND	74 (35)	0	0
Methylene chloride		0.4-100	64-90	74 (35)	2 (2)	0
Tetrachloroethene	5 (P)	0.1-25	0.55-30	74 (35)	6 (6)	3 (3)
Trichloroethene	5 (M)	0.2-50	0.56-4400	74 (35)	32 (3)	29 (27)
Trichlorofluoromethane		0.2-50	ND	74 (35)	0	0
Vinyl chloride	2 (M)	0.2-50	6.2-170	74 (35)	8 (7)	8 (7)
cis-1,2-Dichloroethene	70 (P)	0.2-50	0.37-730	74 (35)	32 (30)	23 (22)
cis-1,3-Dichloropropene		0.2-50	ND	74 (35)	0	0
trans-1,2-Dichloroethene	100 (P)	0.2-50	0.72-44	74 (35)	6 (6)	0
trans-1,3-Dichloropropene		0.34-85	ND	74 (35)	0	0

*EPA standards are designated: M - Maximum Contaminant Level (MCL) and P - Proposed Maximum Contaminant Level (PMCL).

the MCL in 27 of the 35 wells sampled. Vinyl chloride exceeded the MCL in seven wells. Tetrachloroethene (PCE) was detected in samples from six wells, and exceeded the MCL in three of them. The MCL for cis-1,2-dichloroethene was also exceeded in samples from 23 monitor wells. This compound was detected in samples from all but five wells in the Flightline Area. Trans-1,2-dichloroethene, another isomer of dichloroethene, was also detected widely in the Flightline Area, but generally in lower concentrations than the cis-isomer, and in no concentrations above the MCL.

Figure 1-5 is an isoconcentration contour map of the TCE plume as it was detected in the Flightline Area in 1990. The center of the plume appears to be bimodal and is located hydraulically downgradient of Landfill 4. The TCE concentrations were detected at maximum levels in monitor wells LF04-4G and LF04-02 (4400 and 4000 μg/L, respectively). Insofar as it is defined, the TCE plume underlies approximately 50 acres of base property, with most of the plume existing beneath the base golf course. The areal extent of the plume is reasonably well defined, except for the eastern (upgradient) and western limits. The plume appears to intersect Farmers Branch in the northeastern part of the Flightline Area.

Available data indicate multiple sources of the TCE (and other volatile organic compounds) detected in the Upper Zone ground water in the Flightline Area. The disposal methods and types of wastes disposed of in Landfills 4 and 5 (Sites LF04 and LF05) and in Waste Burial Area 10 (Site WP07) are consistent with the nature and distribution of contaminants detected in downgradient wells. However, TCE has also been detected repeatedly in samples from monitor wells located hydraulically upgradient of all of these sites, suggesting one or more additional sources. Air Force Plant 4 (AF Plant 4) is the principal candidate source of the upgradient contamination, and is probably also contributing some portion of the contaminants detected in the downgradient wells. However, the available data do not permit quantitative determination of the contributions from specific sources.

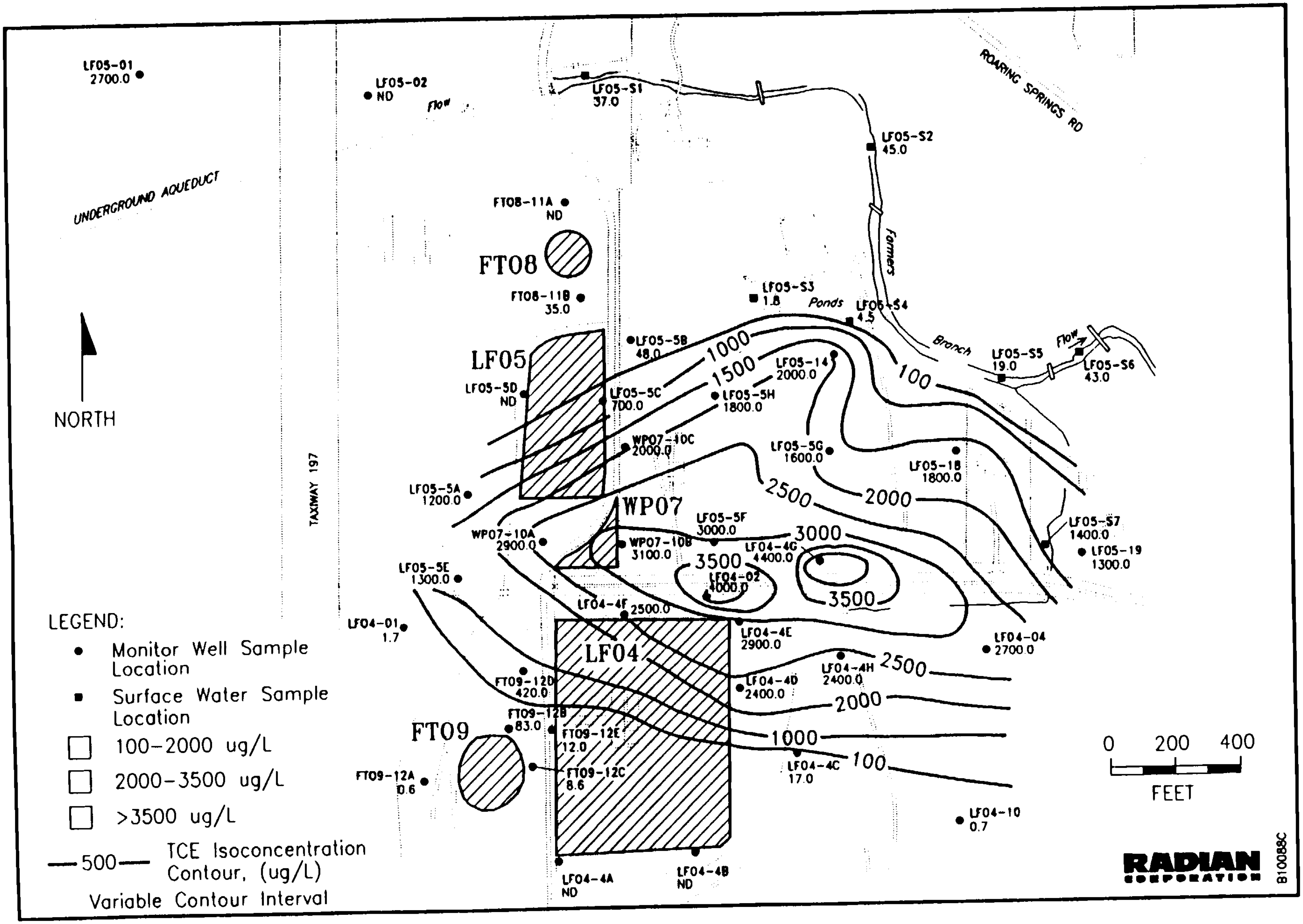

Figure 1-5. TCE Isoconcentration Contour Map, Flightline Area, Carswell AFB, Texas
(Based on Spring, 1990 Water Sampling)
Note: Figure will be colored in Final Report

Vinyl chloride is the only other volatile organic compound detected above a currently established MCL in ground-water samples from the Flightline Area. In the 1990 sampling effort, vinyl chloride exceeded the MCL in samples from seven monitor wells. Figure 1-6 is an isoconcentration contour map of vinyl chloride in Upper Zone ground water. Unlike the relatively continuous plume of TCE beneath the Flightline Area, vinyl chloride occurrences are present in four general areas. The main area is located immediately downgradient of Landfill 5 (Site LF05), and the maximum vinyl chloride concentration (170 μg/L) was detected in the sample from monitor well LF05-5C, near the center of the area. The areal limits of this plume are well defined by the surrounding monitor wells in which no vinyl chloride was detected, and Landfill 5 is considered the main source of the contamination.

Vinyl chloride was also detected in samples from single wells located immediately downgradient of Sites FT09 and LF04, respectively; and in two wells located upgradient of all Flightline IRP sites. The presence of vinyl chloride in the upgradient wells suggests that AF Plant 4 may be the source, similar to the case with TCE. However, because vinyl chloride is an intermediate transformation product of TCE, it is unclear what portion, if any of the vinyl chloride detected in the Flightline Area is of primary origin.

Detectable concentrations of PCE were confirmed in samples from only six Flightline Area monitor wells in 1990, and exceeded the MCL in three of these. Considering the limited occurrence of PCE and because TCE is a transformation product of PCE, it is suggested that either the amount of PCE originally disposed of was much smaller than that of TCE, or the detected PCE is residual primary PCE, with most already transformed to daughter products.

Samples from 30 Flightline Area monitor wells collected in 1990 contained detectable concentrations of cis-1,2-dichloroethene (cis-1,2-DCE), ranging from less than 1 to 730 μg/L. Detectable concentrations of trans-1,2-dichloroethene (trans-1,2-DCE) were confirmed in six wells, with

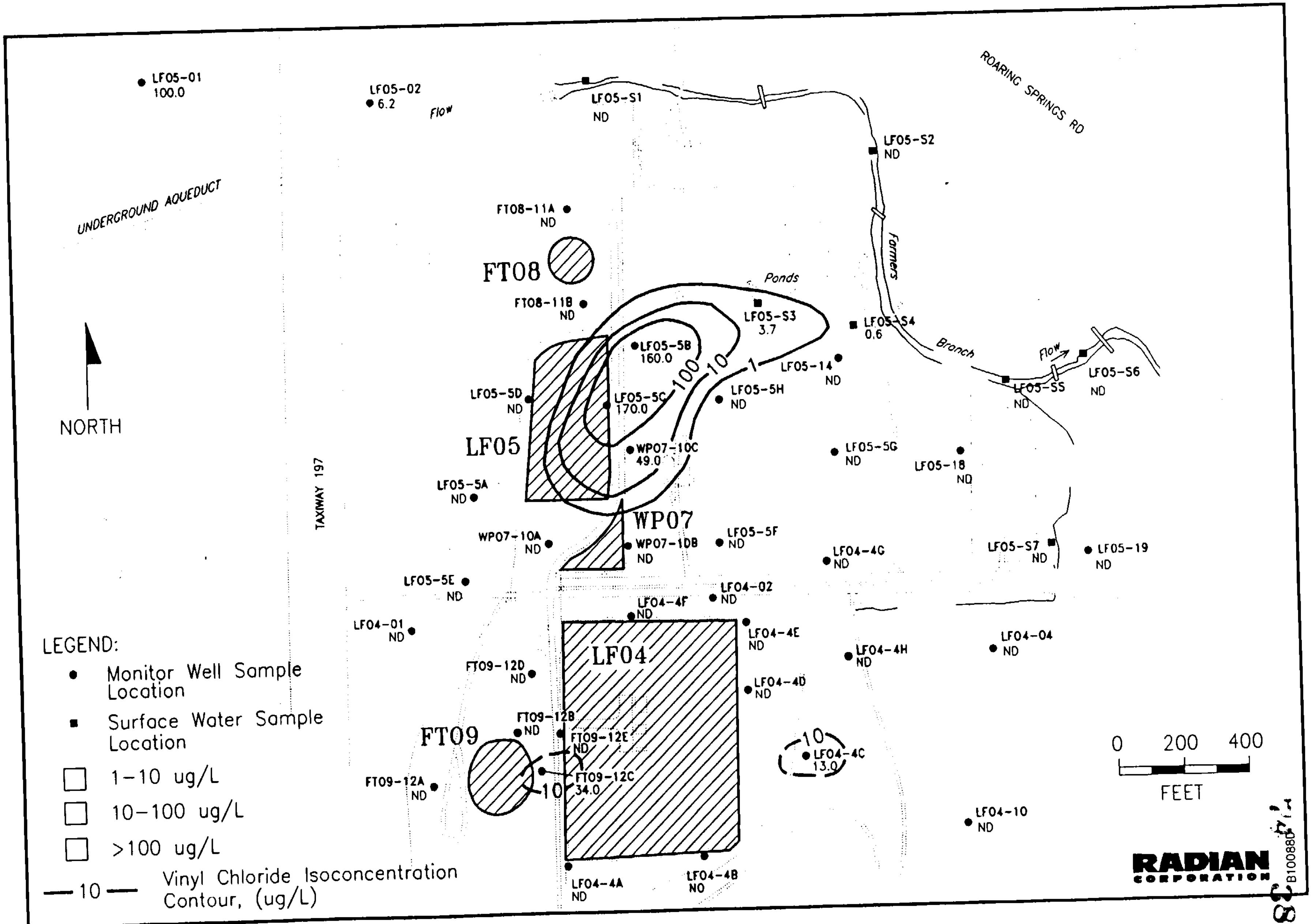

Figure 1-6. Vinyl Chloride Isoconcentration Contour Map, Flightline Area, Carswell AFB, Texas
(Based on Spring, 1990 Water Sampling)
Note: Figure will be colored in Final Report

concentrations ranging from less than 1 to 44 μg/L. Trans-1,2-DCE was detected only in samples that also contained cis-1,2-DCE.

Figure 1-7 is an isoconcentration contour map for total 1,2-DCE (sum of cis- and trans- isomers) in Upper Zone ground water. The configuration of the plume is similar to that interpreted for TCE; however the two highest concentration areas are located downgradient of Landfills 4 and 5, respectively. Like the TCE plume, the western (upgradient) and eastern limits of the plume are not defined, but the repeated detection of 1,2-DCE in wells upgradient of all Flightline Area IRP sites suggests one or more additional sources, including AF Plant 4.

Several other volatile halocarbon compounds were detected in the Upper Zone ground water from the Flightline Area. In the 1990 sampling effort, 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, 1,4-dichlorobenzene, chlorobenzene, chloroethane, and methylene chloride were detected in at least one sample. None of these compounds, however, were detected in concentrations above MCLs.

1.2.3.2 Surface Water Contamination

Seven surface water samples were collected from the locations indicated on Figure 1-8 during the 1990 field program. Four of the samples were collected from Farmers Branch, one was from a tributary to Farmers Branch, and one was collected from each of two ponds on the base golf course. The locations on Farmers Branch were previously sampled in the earlier Stage 2 study. A staff gauge was also installed in Farmers Branch at the location indicated on the figure. Surface water sampling points were selected to characterize the nature and extent of contamination, and to determine the relationship, if any, between surface water and ground-water contamination.

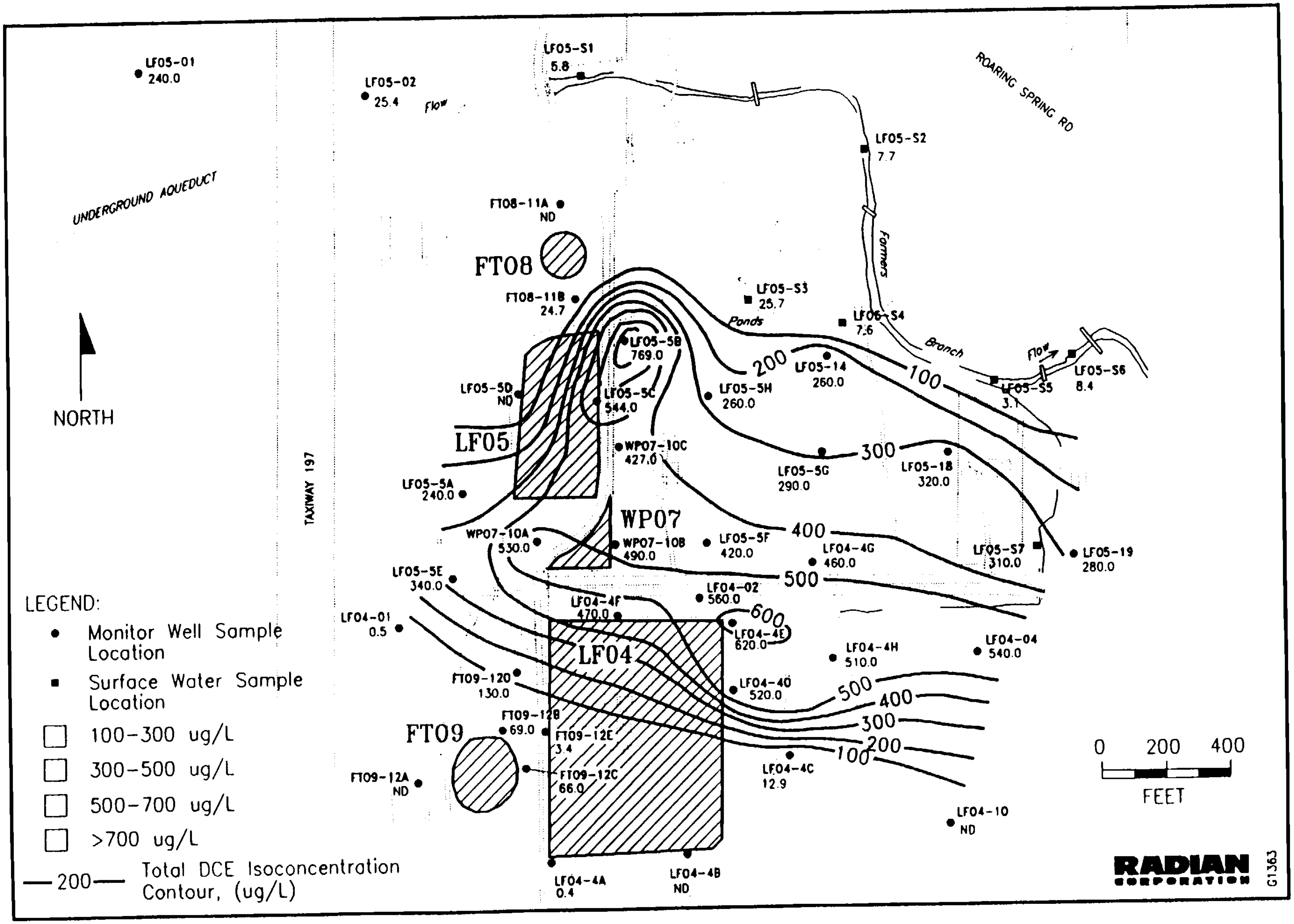

Figure 1-7. Total 1,2-Dichloroethene Isoconcentration Contour Map, Flightline Area, Carswell AFB, Texas (Based on Spring, 1990 Water Sampling)
Note: Figure will be colored in Final Report

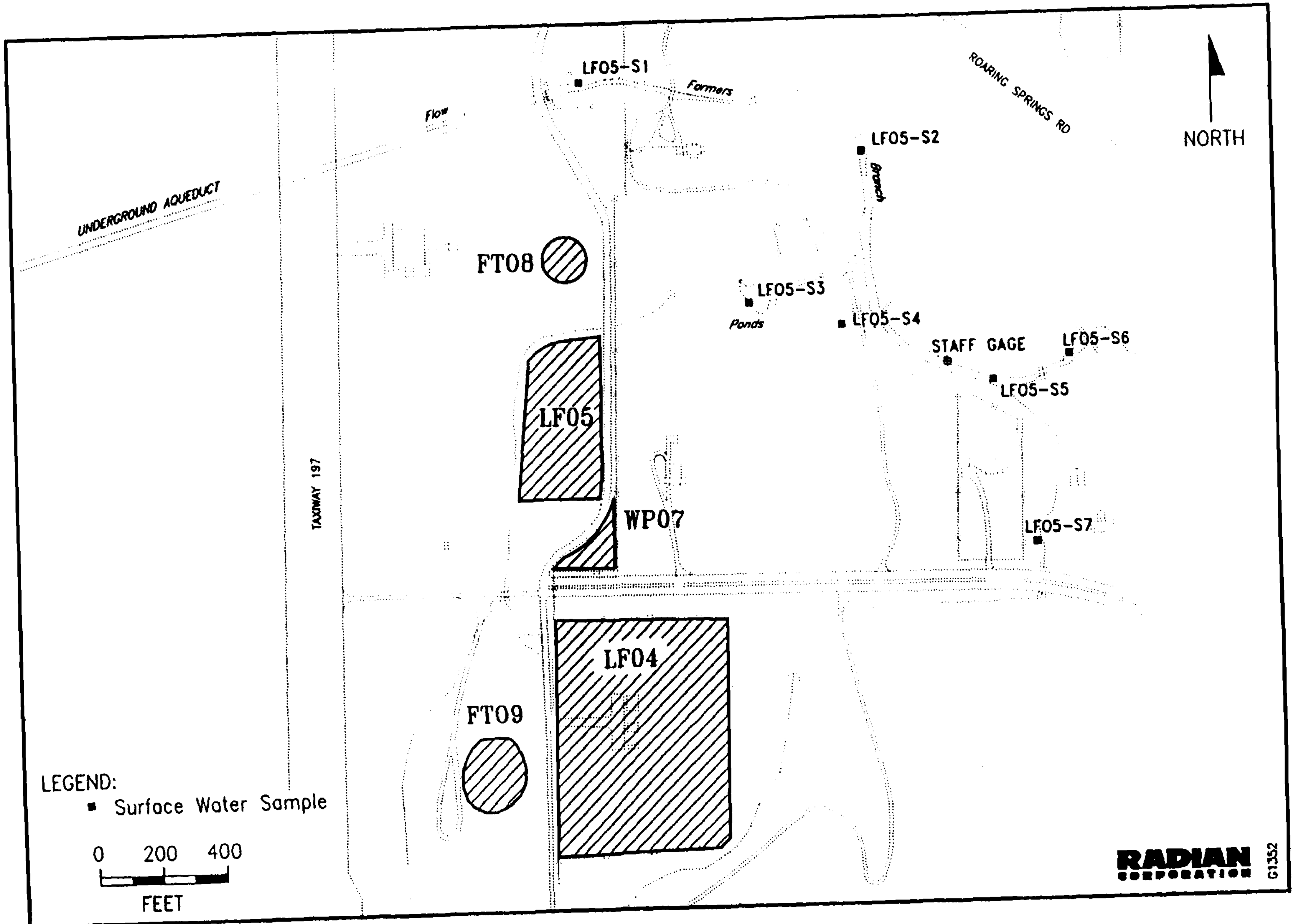

Figure 1-8. Location of Surface Water Sampling Points, Flightline Area, Carswell AFB, Texas (Spring, 1990)

No metals were detected at concentrations above MCLs in any of the surface water samples collected in 1990. As was the case with ground water, metals analyses performed on previously collected samples were all for total, rather than dissolved concentrations. Therefore, the limited available data do not suggest a metals contamination problem in surface water of the Flightline Area.

Table 1-2 summarizes the 1990 analytical results for volatile organic compounds in surface water samples. TCE was detected in all samples and exceeded the MCL at five locations. Detected concentrations ranged from 1.8 to 1400 μg/L. The highest concentration, measured at LF05-S7, is very close to the ground-water concentrations in the surrounding area, suggesting direct hydraulic communication. Lower concentrations of TCE detected at upstream sampling locations are probably related to one or more upgradient, off-base sources, probably located at AF Plant 4. The composition of the surface water sample collected at LF05-S1 strongly supports this interpretation, since this sampling point is at the location where the underground aqueduct comes to the surface after carrying the flow in Farmers Branch beneath the runway area. At the point of emergence, surface water has yet to be potentially influenced by any of the IRP sites in the Flightline Area, since it has been transported in an underground concrete conduit from the vicinity of AF Plant 4.

Vinyl chloride was the only other volatile organic compound detected above the MCL. It was detected in the samples from the two golf course ponds and exceeded the MCL in one (LF05-S3).

The other volatile organic compounds detected in one or more surface water samples were the two isomers of 1,2-DCE. As in the case of Upper Zone ground water, cis-1,2-DCE was more pervasive than the trans-isomer, and it was detected at significantly higher concentrations. Concentrations of cis-1,2-DCE ranged from approximately 3 to 310 μg/L, while trans-1,2-DCE concentrations were all less than 1 μg/L.

TABLE 1-2. SUMMARY OF VOLATILE ORGANIC COMPOUNDS DETECTED IN SURFACE WATER SAMPLES FROM THE FLIGHTLINE AREA, CARSWELL AFB, TEXAS (SPRING 1990)

Analytical Parameter	EPA Standards* (µg/L)	Range of Detection Limits	Range of Concentrations of Constituents Detected	Total Number of Samples: Analyses for Constituent (No. of Locations)	Total Number of Samples: With Constituent Detected and Second Column Confirmation (No. of Locations)	Total Number of Samples: Exceeding EPA Standard (No. of Locations)
Purgeable Halocarbons (601) µg/L						
1,1,1-Trichloroethane	200 (M)	0.20-10.0	ND	8 (7)	0	0
1,1,2,2-Tetrachloroethane		0.15-7.5	ND	8 (7)	0	0
1,1,2-Trichloroethane		0.20-10.0	ND	8 (7)	0	0
1,1-Dichloroethane		0.50-25.0	ND	8 (7)	0	0
1,1-Dichlorethene	7 (M)	0.20-10.0	ND	8 (7)	0	0
1,2-Dichlorobenzene		0.50-25.0	ND	8 (7)	0	0
1,2-Dichloroethane	5 (M)	0.10-5.0	ND	8 (7)	0	0
1,2-Dichloropropane	5 (M)	0.10-5.0	ND	8 (7)	0	0
1,3-Dichlorobenzene		0.32-16.0	ND	8 (7)	0	0
1,4-Dichlorobenzene	75 (M)	0.24-12.0	ND	8 (7)	0	0
2-Chloroethylvinyl ether		0.50-25.0	ND	8 (7)	0	0
Bromodichloromethane		0.10-5.0	ND	8 (7)	0	0
Bromoform		0.50-25.0	ND	8 (7)	0	0
Bromomethane		1.2-59.0	ND	8 (7)	0	0
Carbon tetrachloride	5 (M)	0.12-6.0	ND	8 (7)	0	0
Chlorobenzene		0.25-13.0	ND	8 (7)	0	0
Chloroethane		0.52-26.0	ND	8 (7)	0	0
Chloroform		0.10-5.0	ND	8 (7)	0	0
Chloromethane		0.30-15.0	ND	8 (7)	0	0
Dibromochloromethane		0.20-10.0	ND	8 (7)	0	0
Methylene chloride		0.40-20.0	ND	8 (7)	0	0
Tetrachloroethene	5 (P)	0.10-5.0	ND	8 (7)	0	0
Trichloroethene	5 (M)	0.20-10.0	1.8-1400	8 (7)	8 (7)	6 (5)
Trichlorofluoromethane		0.20-10.0	ND	8 (7)	0	0
Vinyl chloride	2 (M)	0.20-10.0	0.56-3.7	8 (7)	2 (2)	1 (1)
cis-1,2-Dichloroethene	70 (P)	0.20-10.0	3.1-310.0	8 (7)	8 (7)	1 (1)
cis-1,3-Dichloropropene		0.20-10.0	ND	8 (7)	0	0
trans-1,2-Dichloroethene	100 (P)	0.20-10.0	0.46-0.66	8 (7)	2 (2)	0
trans-1,3-Dichloropropene		0.34-17.0	ND	8 (7)	0	0

*EPA standards are designated: M - Maximum Contaminant Level (MCL) and P - Proposed Maximum Contaminant Level (PMCL).

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The maximum downstream extent of surface water contamination in Farmers Branch has not been determined, as the sample collected from the farthest downstream sampling point contained 8.4 μg/L total 1,2-DCE and 43 μg/L TCE (above the MCL). Also, as previously indicated, the sample collected upstream of all Flightline Area IRP sites contained detectable concentrations of volatile organic compounds. Therefore, the upstream extent of surface water contamination is also undefined, but clearly off-base sources are contributing to surface water contamination present in the Flightline Area.

1.2.4 Contaminant Fate and Transport

The fate and transport of contaminants in the Flightline Area and the potential for off-site and off-base migration are dependent on physical hydrogeological conditions, ground-water/surface water interconnection, and the physicochemical nature and concentrations of the detected species. Volatile organic compounds, detected in the Upper Zone ground water and surface water in the Flightline Area, are the only hazardous waste constituents identified in concentrations that exceed enforceable health-based regulatory criteria (i.e., MCLs).

1.2.4.1 Contaminant Fate

The fate or persistence of the volatile organic compounds detected in the Flightline Area is controlled by processes such as: convection; adsorption and desorption on solid matrices; diffusion and dispersion; chemical and biological degradation; and volatilization. Additionally, the nature of the contributing source(s), with respect to initial concentration and availability of contaminants, affects both fate and transport.

Diffusion and dispersion are chemical and mechanical processes whereby a contaminant tends to spread from the expected direction of transport in ground water. Both of these processes contribute to dilution of contaminants within the body of the plume, and to enlargement of the plume. Thus, they influence contaminant persistence and apparent retardation during transport.

Compounds that are readily adsorbed onto soil or sediment matrices, but are not readily desorbed are relatively immobile in aqueous systems. TCE, the main contaminant in the Flightline Area, tends to have equal affinity for adsorbtion and desorbtion, so it is relatively mobile in water.

Concentrations of TCE and other volatile organic compounds may decrease through the process of volatilization from soils or aqueous media. In ground-water systems, resorption following volatilization may also occur if a compound has both a high adsorption and desorption capacity, and if the water table tends to fluctuate. It will tend to volatilize and adsorb onto particles in the unsaturated zone, then be resorbed into ground water when the water table rises. Compounds such as 1,2-DCE and vinyl chloride, with low sorption coefficients, are more likely to be permanently removed from ground-water through volatilization than TCE which is volatile and sorptive. However, since the Upper Zone water table in the Flightline Area has not fluctuated significantly since 1985 when water level surveys began, the net affect of volatilization is probably permanent, ongoing loss of all volatile organic compounds from ground water.

Chemical and biological degradation of the organic compounds in the Upper Zone ground water are important factors influencing their fate in the Flightline Area. Tetrachloroethene (PCE), trichloroethene (TCE), cis- and trans-1,2-dichloroethene and vinyl chloride are all related by the chemical process of hydrogenolysis. From this reaction, PCE is broken down into a series of daughter products, ultimately yielding carbon dioxide and water. This process is very common in nature, and may be biologically driven, as a form of biodegradation.

Figure 1-9 summarizes the three chemical and biological transformation pathways for the four principal organic contaminants in the Flightline Area. It is noteworthy that the half-lives for these pathways vary from tens of days to two to three years, and the pathway to cis-1,2-DCE is generally favored. Since TCE and PCE formerly were both widely used industrial solvents, some portion of the detected TCE is probably primary. It is doubtful that the sole source of TCE detected in the Flightline Area is

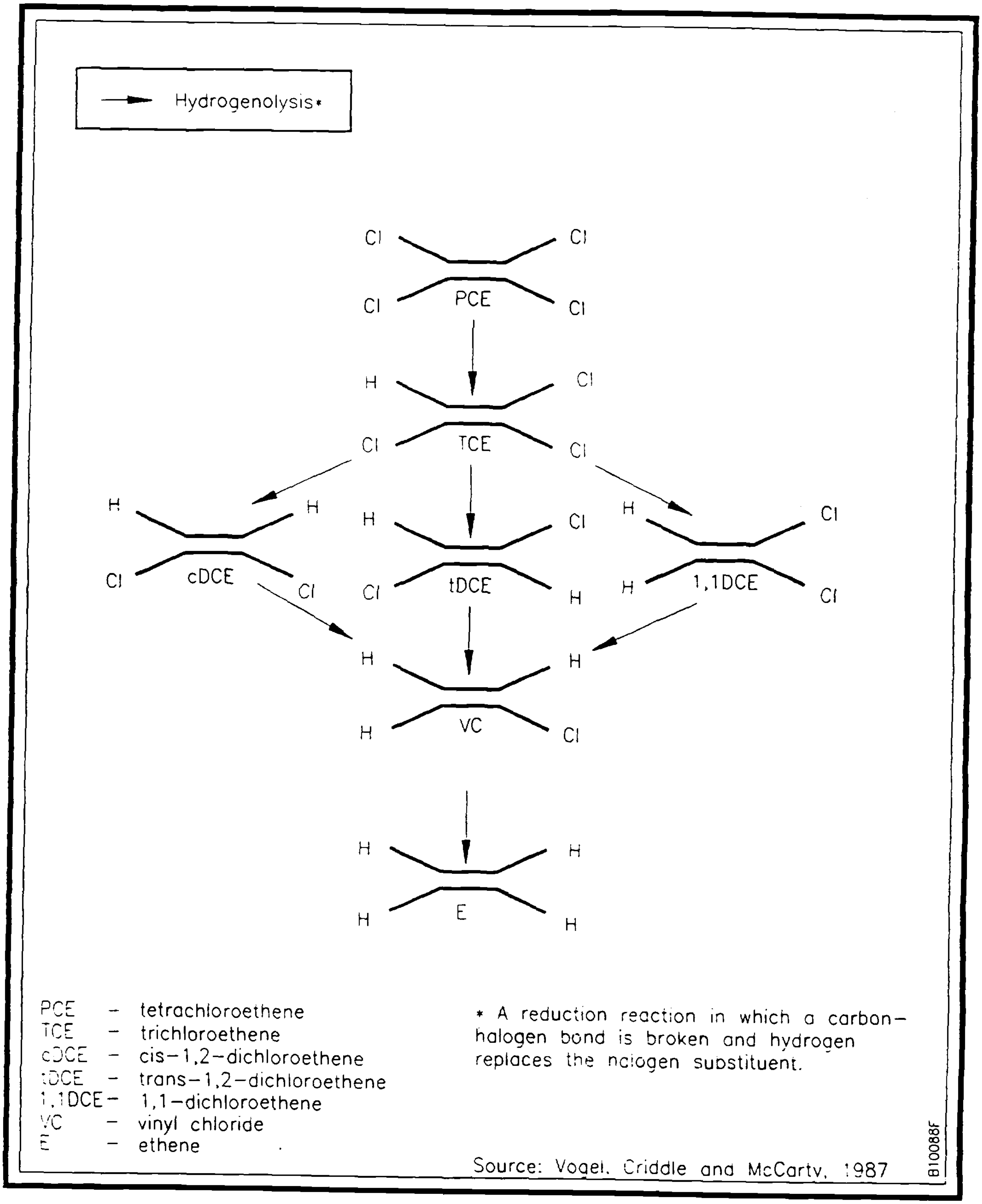

Figure 1-9. Potential Degradation Products and Reaction Mechanisms for Reduction of Chlorinated Ethanes and Ethylenes

from the breakdown of PCE. However, based on the limited amount of PCE detected, either a significant portion of the original concentration of this solvent has broken down into TCE or related daughter products, or the original volume of PCE was much lower than TCE.

Reportedly, 1,2-DCE and vinyl chloride are not known to have ever been used at the base. It is therefore reasonable that the presence of 1,2-DCE and vinyl chloride are the result of the chemical and biological breakdown of TCE. By comparing the zones of highest concentrations in these three plumes, some interpretations are suggested regarding the timing and duration of releases of contaminants.

The locations and concentration distributions of contaminants within the plumes suggests an earlier introduction of TCE from Site LF05 into shallow ground water, with significant degradation to 1,2-DCE and vinyl chloride having occurred, and a later release from Site LF04, where time has allowed only degradation to 1,2-DCE to occur. Furthermore, the overall release of contaminants from Site LF04 may have decreased somewhat with time, as concentrations of TCE immediately downgradient from Site LF04 have decreased since the previous sampling in April 1988.

The fact that cis-1,2-DCE is favored in the chemical breakdown of TCE supports the hypothesis that all of the 1,2-DCE present in the Flightline Area results from TCE degradation. As stated earlier, cis-1,2-DCE is present in concentrations far exceeding trans-1,2-DCE, and the compound was detected in five times as many wells. This would be expected if the two compounds are daughter products of TCE, as the breakdown pathways of TCE to trans-1,2-DCE or 1,1-DCE are considered minor. However, all of the interpretations offered in this section are speculative. Review of the historical ground-water chemical data from the Flightline Area indicates considerable variability in concentrations of volatile organic compounds over short periods (i.e., between monthly sampling rounds). These fluctuations are unlikely to be related to contaminant degradation patterns. Whether they are driven by environmental factors, such as precipitation; episodic (pulsed) releases of additional contaminants; sampling or analytical variability; or combinations of these and other factors is unknown.

1.2.4.2 Contaminant Transport

Ground water and surface water in the Flightline Area are in hydraulic communication, based on results of synoptic water level measurements, and supported by similar analytical results in both media. Also, it is clear that the tributary to Farmers Branch represents a zone of ground-water discharge which ultimately contributes contaminated surface water to Farmers Branch. To simplify the following presentation, contaminant migration is addressed separately in terms of ground-water and surface water systems.

Transport in Ground Water

In comparing the distribution of volatile organic compounds detected in 1990 to that determined on the basis of earlier data (Radian, 1989), it appears the Upper Zone ground-water plume may have migrated up to several hundred feet in the intervening two years. Recognizing the potential uncertainties associated with sampling and analytical results, the data indicate the highest ground-water TCE concentrations occurred at monitor well WP07-10B in 1988, but were detected between monitor wells LF04-4G and LF04-02 in 1990.

Data generated from Upper Zone Aquifer pump testing performed in June 1990, and synoptic water-level data suggest the average ground-water velocity in the Upper Zone is approximately 9 feet per day, based on a hydraulic conductivity of 785 feet/day and a hydraulic gradient of 0.0035. Since the hydraulic conductivity derived from aquifer testing falls in the typical range for clean sands and gravels (Freeze and Cherry, 1979), a porosity of 30% was assumed. The estimate for the average ground-water flow velocity is derived from a simplification of Darcy's Law:

$$\bar{v} = \frac{Ki}{\emptyset}$$

where: $\bar{v}$ = average ground-water flow velocity

k = hydraulic conductivity of Upper Zone Aquifer (average 2.8×10^{-1} cm/sec or 785 feet/day),

i = hydraulic gradient (0.0035) in the Upper Zone; and

Ø = estimated porosity of the Upper Zone deposits (0.30).

Based on this calculation, the TCE plume is migrating approximately one order of magnitude slower than ground-water flow. This is consistent with physical, chemical and biological factors which affect the TCE mobility in ground water.

The main contaminant plume appears to be migrating in a direction which is generally consistent with the direction of ground-water flow. Figure 1-10 is a potentiometric surface map generated from the June 1990 water level survey, with the Upper Zone ground-water flow directions indicated. The dominant direction of migration closely parallels the thickest accumulations of sand and gravel (paleochannel deposits) in the Flightline Area (Figure 1-11). A comparison of the sand and gravel isopach map with the 1990 TCE plume map (Figure 1-5) clearly indicates that plume migration is preferentially influenced by the locations of the relatively porous and permeable basal sands and gravels.

The direction of plume migration appears to be roughly parallel to White Settlement Road. The maximum extent of the plume in that direction is unknown, as samples from the two most easterly monitoring wells, LF04-04 and LF05-19 had detected levels of 2700 and 1300 μg/L TCE, respectively, in the Spring 1990 sampling event. However, given historical observations and at the estimated rate of contaminant transport, the apex of the contaminant plume is not expected to reach the vicinity of LF04-04 and LF05-19 for several years.

It is along this vector of migration that the plume most directly intersects the unnamed tributary to Farmers Branch. Both TCE and 1,2-DCE were detected in high concentrations in surface water sample LF05-S7 collected from the small tributary. At this location, contaminated ground water appears to

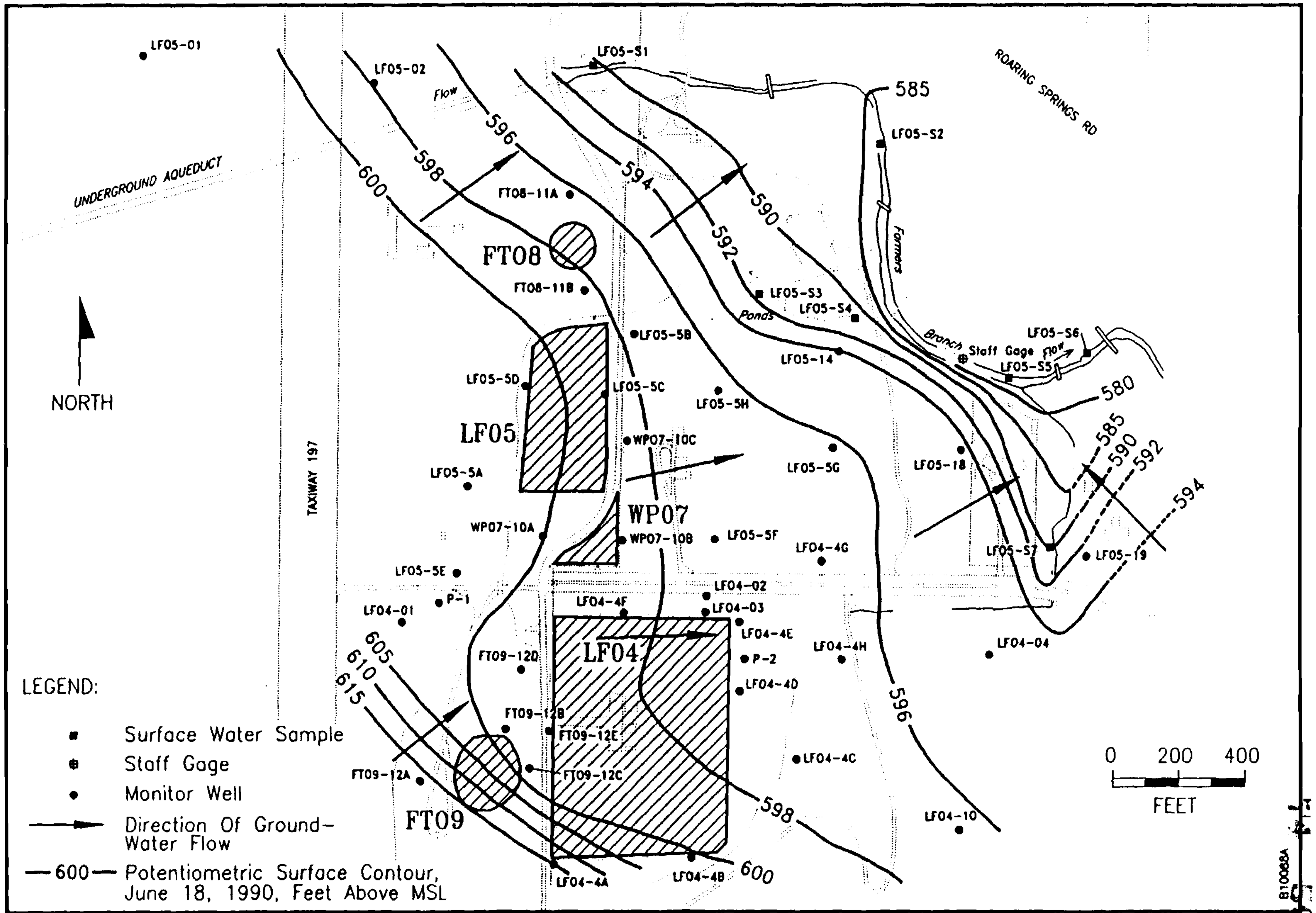

Figure 1-10. Upper Zone Aquifer Potentiometric Surface Map (June 1990), Flightline Area, Carswell AFB, Texas

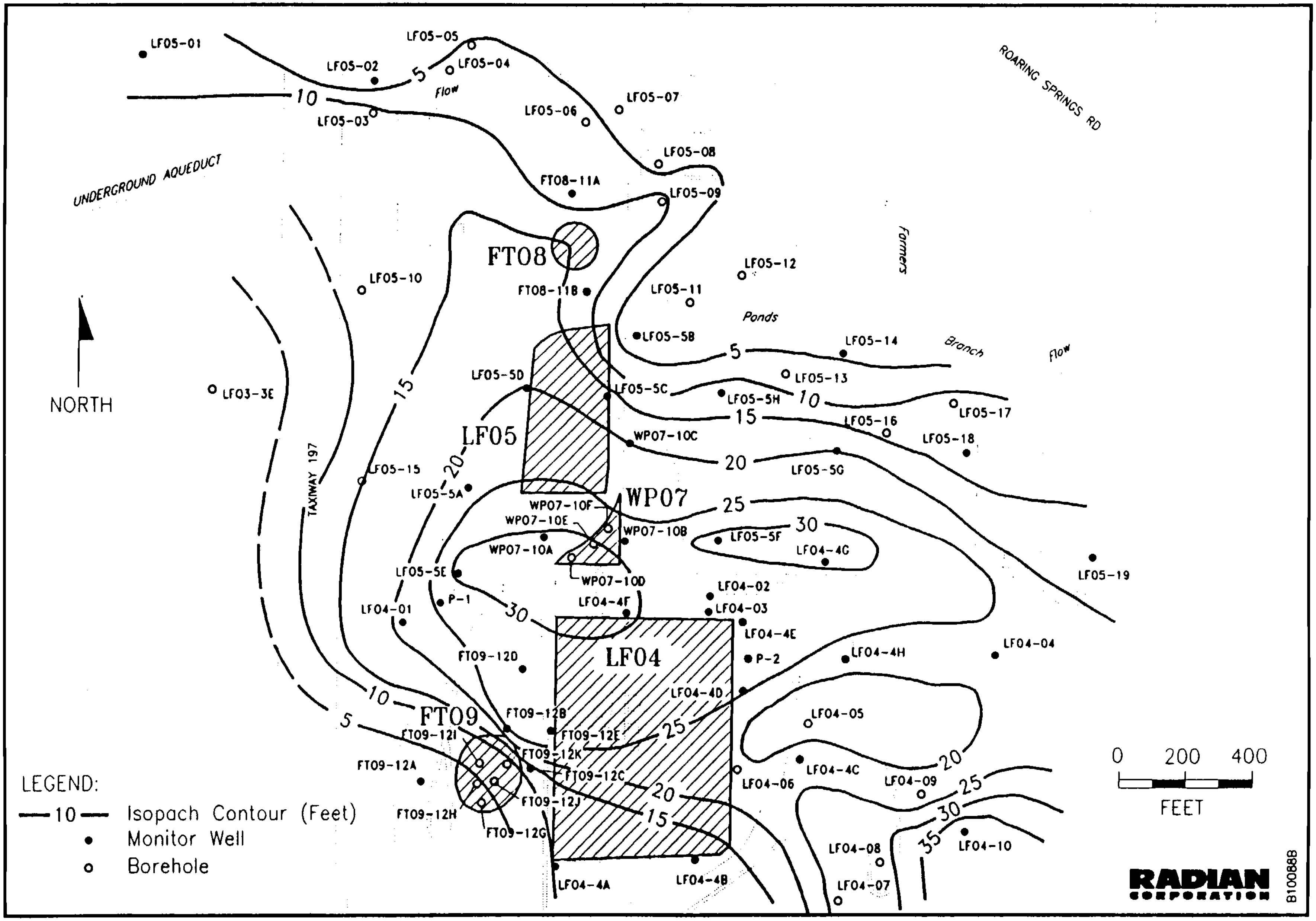

Figure 1-11. Sand and Gravel Isopach Map, Flightline Area, Carswell AFB, Texas

discharge directly into the tributary, which in turn flows into Farmers Branch. Because upstream flow in this small tributary intermittently disappears into the subsurface (from the southeast corner of Site LF04 to just upstream of LF05-S7), it is likely that the water reflects almost entirely ground-water discharge. However, the tributary is not a ground-water flow boundary, i.e., all ground-water contamination in the vicinity of the small tributary is neither captured nor diverted as surface water flow. Elevated concentrations of TCE and 1,2-DCE were detected in wells located hydraulically downgradient of the tributary, especially on the south side of White Settlement Road, where TCE was detected at 2700 μg/L in monitor well LF04-04.

The more northerly component of the TCE plume migration, which parallels the direction of ground-water flow, is toward Farmers Branch. Farmers Branch was sampled at four locations in 1990. While the dominant ground-water flow is in the direction of Farmers Branch, migration of the main contaminant plume deviates somewhat from that direction. TCE concentrations of 1.8 and 4.5 μg/L, found in surface water samples collected in two small ponds located immediately north of monitor well LF04-14, appear to approximate the northerly extent of the ground-water TCE plume. Continued migration to the east of these ponds would intersect Farmers Branch. Since no samples have been collected on the opposite (northern) side of Farmers Branch, it is uncertain whether the ground water on that side of the stream is contaminated, or if Farmers Branch is a ground-water flow boundary. Contamination in Farmers Branch and the tributary to Farmers Branch is discussed in Section 1.2.4.3 below.

TCE has not been encountered as a dense non-aqueous phase liquid (DNAPL) in any monitor wells installed in the Flightline Area. However, if DNAPL did exist, it would tend to sink due to its higher specific gravity relative to water. All new Flightline Area monitor wells, installed in 1990, were drilled and completed at the top of the Goodland/Walnut Formation, which is the aquitard beneath the Upper Zone and considered to represent the maximum depth of contamination. If DNAPL was present, it would have most likely been detected in these wells.

1.2.4.3 Transport in Surface Water

The distribution of surface water contamination in the Flightline Area is directly linked to the configuration and migration of the ground-water plume, and is influenced by variations in the discharge rate and flow velocity of the two principal surface water bodies in the area. Farmers Branch, which ultimately flows off-site, had variable concentrations of TCE and 1,2-DCE based on the sample location. In addition, Farmers Branch is fed by the small tributary draining the southern portion of the study area, from which the most highly contaminated surface water samples were collected. For this discussion, Farmers Branch is divided into three reaches, each with a different contaminant input and potential for contaminant migration.

Figure 1-12 shows the location of the surface water sampling sites and identifies the three divided reaches of Farmers Branch. The first reach of Farmers Branch includes the upstream portion from the end of the concrete underground aqueduct to the waterfall adjacent to the golf course ponds. This section of Farmers Branch is not influenced by the main TCE plume, as the golf course ponds are located approximately at the northern edge of the plume. TCE was detected, however, in the two samples collected in this reach. The TCE in these samples is believed to be from an upgradient source, not associated with the Flightline Area IRP sites, as previously discussed in this report. While the concentrations of TCE detected in this portion of Farmers Branch are significantly above the MCL, it is probable that contamination detected in this reach does not contribute greatly to the downstream concentrations of TCE. A large percentage of all volatile organic contaminants (including TCE and 1,2-DCE) are probably stripped from the stream by natural aeration and volatilization as the stream crosses the waterfall which separates the first reach from the second reach.

The second reach of Farmers Branch includes that portion which is downstream of the waterfall and upstream of the intersection of Farmers Branch and the small tributary. The main TCE plume appears to intersect the stream

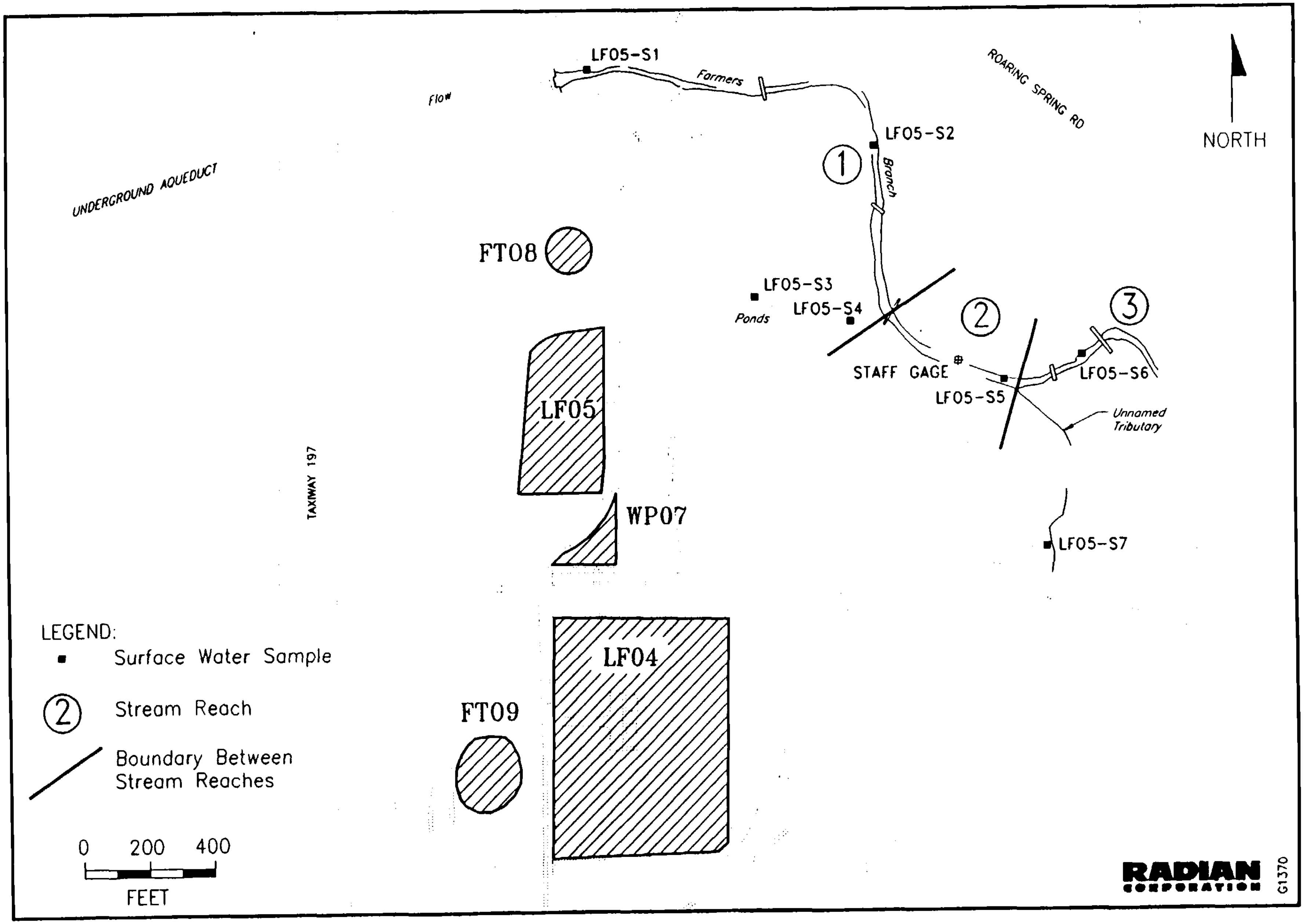

Figure 1-12. Surface Water Sampling Points and Three Divided Reaches of Farmers Branch, Flightline Area, Carswell AFB, Texas

in this stream, and both TCE and 1,2-DCE were detected in sample LF05-S5. However, even with continued migration of the main TCE plume in the direction of Farmers Branch, the concentrations detected in this segment of the stream are not expected to increase significantly, and hence are not expected to be a major contributor to downstream contamination. The reason for this is the Upper Zone Aquifer crops out in a broad cutbank of Farmers Branch along the length of this reach, so the ground water is not in direct communication with the stream. Instead, Upper Zone ground-water surfaces in a series of seeps along the cutbank, and flows down the rock into a series of pools which are located on limestone bedrock of the Goodland/Walnut Formation. As in the case of the upper reach, this allows for significant volatilization and evapotranspiration to occur, and consequently results in reduction of the volatile organic contaminants in the water before mixing with surface water in Farmers Branch can occur. It is likely that only minor amounts of contaminants from both reaches migrate downstream to the third reach.

TCE and 1,2-DCE in the ground water (on the order of 1300 μg/L and 280 μg/L, respectively) are discharging as surface water in the vicinity of surface water sample location LF05-S7. This water, in turn, discharges directly into Farmers Branch in the third reach, and constitutes the principal pathway for migration of contaminants beyond the Flightline Area, and potentially off-base. Since the tributary to Farmers Branch is characterized by water quality equivalent to a direct discharge of the main TCE plume, the discharge of the tributary and also Farmers Branch were calculated to determine the effects of dilution as the two bodies intersect. This was done using the simple relationship:

$$Q = vA$$

where: Q = discharge
v = velocity
A = cross-sectional area

Applying this equation to values obtained in the field, the slow moving tributary had a calculated discharge rate of approximately 0.2 cubic feet per second (cfs) or about 129,000 gallons per day (gpd). In contrast, at the time of field measurement, the discharge of Farmers Branch was approximately 6.0 cfs, or about 3,900,000 gpd. This translates into a dilution factor of about 30, suggesting that contaminant concentrations in Farmers Branch would be thirty times lower than those occurring in the tributary. Surface water sampling results confirmed this, as the TCE concentrations between samples LF05-S7 and LF05-S6 (1400 μg/L and 43 μg/L) appear diluted by a factor of 33, and 1,2-DCE concentrations between the same two locations (310 μg/L at LF05-S7 and 8.4 μg/L at LF05-S6) appear diluted by a factor of 37.

As the ground-water plume continues migrating to the east, the concentrations of organic contaminants detected in the small tributary, and in Farmers Branch, may increase proportionately. However, plume degradation by physical, chemical and biological factors may off-set some of the anticipated increase with the net result that transport of contaminants off-site is expected to remain fairly constant over the next few years. Currently, TCE migration off-site in Farmers Branch is estimated at 45 μg/L and 1,2-DCE migration off-site is estimated at 8.4 μg/L. There are no data available to estimate the concentration of these contaminants in reaches of Farmers Branch beyond the Flightline Area. However, the natural factors described in Section 1.2.4.1, principally volatilization will reduce the organic contaminant content of Farmers Branch before its ultimate discharge into the Trinity River.

1.2.5 Baseline Risk Assessment

The results of the baseline risk assessment for the Flightline Area are summarized below. More complete descriptions of the risk assessment process are provided in the IRP Stage 2 RI/FS report (Radian, 1989) and the RI report (Radian, 1991).

Using both the 1988 and 1990 sampling results for soil, ground water, and surface water in the Flightline Area, 19 indicator chemicals were selected from the approximately 80 chemicals known to be present at the site.

The indicator chemicals were selected according to the method described in the U.S. EPA Health Evaluation Manual (1986a) and include:

Metals	Semivolatile Organic Compounds	Volatile Organic Compounds (VOCs)
Antimony	Bis(2-ethylhexyl)-phthalate	Benzene
Arsenic		Chloroform
Barium		1,2-Dichloroethane
Beryllium		Methylene chloride
Cadmium		Tetrachloroethene
Chromium		Toluene
Lead		Trichloroethene
Nickel		Vinyl chloride
Selenium		
Silver		

Although several of the indicator chemicals, particularly the metals and the semivolatile compounds, are probably not representative of site conditions but may reflect cross-contamination, they were included in the risk assessment process to ensure a conservative evaluation of possible health risks.

Possible mechanisms of contaminant release from the Flightline Area sites include: 1) volatilization to the air, 2) fugitive dust generation, 3) leachate to ground water, 4) surface runoff, 5) direct release to surface water, and 6) contaminated ground-water discharge to surface water. Of these, volatilization to the air, leachate to ground water, and contaminated ground water discharging to surface water appear to be the most viable in the Flightline Area. Figure 1-13 illustrates the potential pathways for human exposure. All of the pathways initially involve contaminants volatilizing to the air or leaching to the ground water. Based on the potential pathways identified, potential human and wildlife receptors for exposure to contaminants migrating from the Flightline Area were identified.

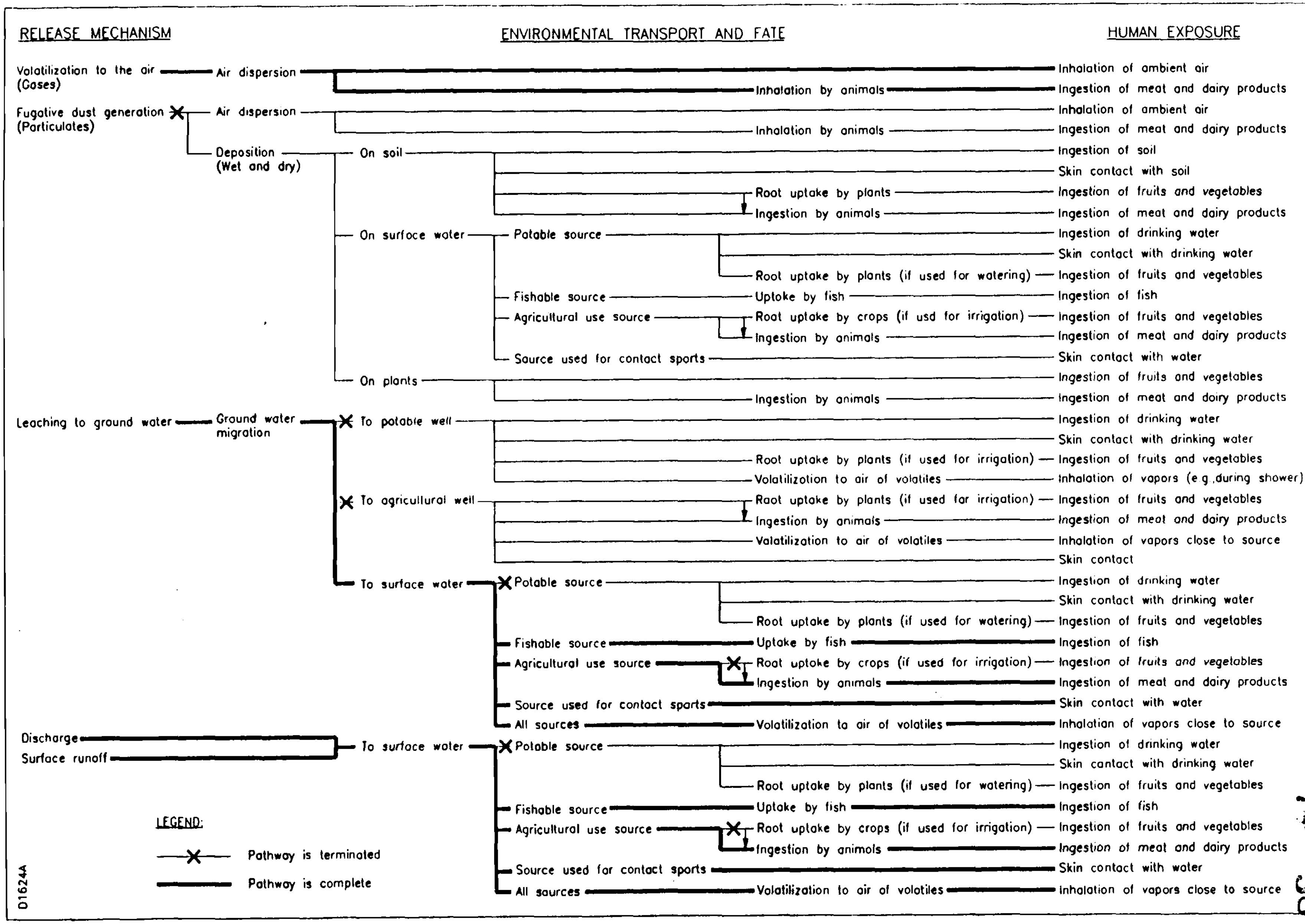

Figure 1-13. Potential Exposure Pathways for Contaminants Released from the Carswell AFB Flightline Area

Potentially significant contaminant transport and fate mechanisms were identified and include: 1) air dispersion, 2) ground-water migration, 3) discharge to the surface, 4) transport in surface water, and 5) subsequent uptake by plants and animals.

Three types of exposures - inhalation, ingestion, and dermal contact were quantified in the risk assessment. The maximum predicted annual average concentrations resulting from estimated Flightline Area VOC indicator chemical emissions are lower than the conservative TACB Effects Screening Levels (ESLs) by four to eight orders of magnitude. Potential ingestion exposures included consuming meat and dairy products or fish exposed to contaminants, however, neither of these potential pathways were found to represent a significant threat of human exposure. Dermal exposure to contaminants in Lake Worth and the Trinity River was found to be at most insignificant. Skin contact with water in Farmers Branch, which is not amenable to swimming or other contact activities other than wading, could contribute to dermal exposure, but the low likelihood of such a pathway being complete did not merit quantification.

The threat to human health posed by the site was evaluated in terms of noncarcinogenic and carcinogenic risks. The noncarcinogenic evaluation involved comparing maximum predicted annual average concentrations at various locations, both on-site and off-site, with inhalation Reference Doses (RFDs) for chronic (long-term) exposure. The results of this comparison indicate the threat of noncarcinogenic health effects of inhalation exposure to contaminants from the Flightline Area is not significant. Seven of the eight VOC indicator chemicals detected in the Flightline Area are potential carcinogens. Incremental individual cancer risks were estimated for maximum exposed individuals at locations both on- and off-site. The highest calculated risk of one in 10 million was dismissed as inconsequential. Ingestion and dermal risks were considered minimal and were not quantified.

When considering the threat to wildlife and aquatic organisms from the contaminants migrating from the Flightline Area, the levels of contaminants found in the site surface water bodies were compared to the <u>EPA</u>

Quality Criteria for Water (1986b). Some risk exists for terrestrial wildlife that use Farmers Branch, the small tributary, or the golf course ponds as a source of drinking water; and for aquatic organisms in these surface water bodies. Lead was detected in a concentration exceeding the chronic criterion for fresh water aquatic life in the westernmost golf course pond. However the detected concentration is questionable as it was reported in the dissolved metals analyses; the total lead concentration from the same sample location was less than the dissolved concentration and less than the chronic effects criterion. Silver was detected at three locations in concentrations above its chronic criterion value, with all three measurements from the total metals analysis. All dissolved concentrations were below the detection limit, but the detection limit for the analytical method (10 μg/L) was above the chronic effects criterion. Therefore it is not possible to determine if any dissolved silver concentrations exceeded the criterion.

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Radian conducted a literature search to identify potential response actions, technologies, and process options available for remedying the contaminated media at Carswell AFB. A variety of publications and references were reviewed to both identify and screen possible remedial action technologies appropriate to Carswell AFB IRP sites. These references are listed in the bibliography. General references that are particularly appropriate to Carswell AFB are Evaluating Cost-Effectiveness of Remedial Actions at Uncontrolled Hazardous Waste Sites (Radian, 1983), U.S. EPA Handbook: Remedial Action at Waste Disposal Sites (Revised) (EPA, 1986c), and Treatment Technology Briefs, Alternatives to Hazardous Waste Landfills, (EPA, 1986d). Section 2.1 defines the remedial action objectives (RAOs) of this FS. The screening of technologies is presented in Section 2.2.

2.1 Remedial Action Objectives

The FS was performed to develop feasible remedial alternatives to mitigate environmental contamination directly associated with the Flightline Area IRP sites listed in Section 1.0, and to capture the Upper Zone groundwater contamination related to one or more of these sites, and to additional upgradient source(s). Volatile organic compounds are the main contaminants and have been documented in the Upper Zone ground water, surface water, and soils in the Flightline Area. At present, the existing contamination does not constitute a significant threat to human health, based on the baseline risk assessment results.

The remedial action objectives for this FS are:

1) Reduce or eliminate potential future impacts to human health and the environment;

2) Reduce or eliminate the potential for future contaminant migration in the ground water; and

3) Reduce or eliminate the potential for continuing mobilization of metals and/or organic contaminants in near-surface soil (Upper Zone deposits) or residual wastes as leachate.

To identify and evaluate alternative remedial actions, contaminated environmental media were identified based on the IRP RI results. These media include waste material and contaminated soil, Upper Zone ground water, and surface water. Specific remedial action objectives identified for each of the media are presented in Table 2-1. Remedial action objectives were developed for each media based upon the following standards or criteria:

- 70-year cancer risk potential;
- National interim primary drinking water standards maximum contaminant levels (MCLs) for organics (40 CFR 141.12 and 141.61) and inorganics (40 CFR 141.11 and 141.62); and
- Final MCLs for organics and inorganics (Federal Register, Vol. 56, No. 20, January 30, 1991).

Table 2-1 does not list all contaminants that have regulatory criteria or standards. Instead the table lists those contaminants that were identified as indicator chemicals in the baseline risk assessment for the Carswell AFB Flightline Area. As discussed in the RI report (Radian, 1991), metals are included as indicator chemicals based on total detected concentrations in water samples. However, the dissolved metals concentrations detected in the 1990 sampling event do not suggest a metals contamination problem.

2.2 Technologies

A literature search was performed to develop a list of potential response actions, technologies, and process options applicable to each contaminated environmental media in the Flightline Area. These remedial technologies are discussed in Section 2.2.1 (waste and soil), Section 2.2.2 (ground water), and Section 2.2.3 (surface water).

TABLE 2-1. REMEDIAL ACTION OBJECTIVES FOR FLIGHTLINE AREA IRP SITES, CARSWELL AFB, TEXAS

Environmental Media	Remedial Action Objectives
WASTE AND CONTAMINATED SOIL	FOR HUMAN HEALTH: Prevent ingestion or direct contact with soil or waste at sites which contributes to greater than or equal to 10^{-6} excess cancer risk (or a potential risk characterized as greater than negligible) from the following carcinogens: TCE, benzene, bis(2-ethylhexyl)phthalate, arsenic, cadmium, and methylene chloride. Reduce inhalation of potential carcinogens [TCE, 1,2-DCE, tetrachloroethylene, vinyl chloride, methylene chloride, benzene, chloroform, and bis(2-ethylhexyl)phthalate] at locations which contribute to excess inhalation cancer risk levels of greater than or equal to 10^{-6} so that risk levels are lower than 10^{-6}. FOR ENVIRONMENTAL PROTECTION: Prevent migration of contaminants from soil that would result in ground-water contamination in excess of the following concentrations for each specific contaminant:

Inorganics		Organics	
Arsenic	0.05 mg/L	TCE	5 µg/L
Barium	1.0 (2.0) mg/L	Vinyl Chloride	2 µg/L
Cadmium	0.01 (0.005) mg/L	Benzene	5 µg/L
Chromium	0.05 (0.1) mg/L	cis-1,2-DCE	(100) µg/L
Lead	0.05 mg/L	trans-1,2-DCE	(70) µg/L
Selenium	0.01 (0.05) mg/L	Tetrachloroethene	8 µg/L
Silver	0.05 mg/L	Toluene	2,000 µg/L

(Continued)

( ) = Final MCL as of 30 January 1991, not effective until 30 July 1992.

TABLE 2-1. (Continued)

Environmental Media	Remedial Action Objectives
GROUND WATER	FOR HUMAN HEALTH: Prevent ingestion of ground water that contributes to an excess cancer risk of greater than or equal to 10^{-6}. FOR ENVIRONMENTAL PROTECTION: Remove contaminants from the ground water to levels below the following concentrations: **Inorganics**: Arsenic 0.05 mg/L; Barium 1.0 (2.0) mg/L; Cadmium 0.01 (0.005) mg/L; Chromium 0.05 (0.1) mg/L; Lead 0.05 mg/L; Selenium 0.01 (0.05) mg/L; Silver 0.05 mg/L **Organics**: Vinyl Chloride 2 µg/L; Benzene 5 µg/L; cis-1,2-DCE (100) µg/L; trans-1,2-DCE (70) µg/L; TCE 5 µg/L; Tetrachloroethene 8 µg/L; Toluene 2,000 µg/L
SURFACE WATER	FOR HUMAN HEALTH: Prevent ingestion of or skin contact with surface water that contributes to an excess cancer risk of greater than or equal to 10^{-6}. Prevent ingestion of fish from surface water that contributes to an excess cancer risk of greater than or equal to 10^{-6}. FOR ENVIRONMENTAL PROTECTION: Prevent future discharge of contaminated ground water to surface water. If treated ground-water effluent is discharged to Farmers Branch, it must meet the environmental protection criteria for ground water (above).

Inorganics		Organics	
Arsenic	0.05 mg/L	Vinyl Chloride	2 µg/L
Barium	1.0 (2.0) mg/L	Benzene	5 µg/L
Cadmium	0.01 (0.005) mg/L	cis-1,2-DCE	(100) µg/L
Chromium	0.05 (0.1) mg/L	trans-1,2-DCE	(70) µg/L
Lead	0.05 mg/L	TCE	5 µg/L
Selenium	0.01 (0.05) mg/L	Tetrachloroethene	8 µg/L
Silver	0.05 mg/L	Toluene	2,000 µg/L

( ) = Final MCL as of 30 January 1991, not effective until 30 July 1992.

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The applicability of each process option is dependent on the physical and chemical characteristics of the contaminants, the aquifer properties of the Upper Zone, and/or the physical and chemical characteristics of the soil matrix. The preliminary screening shown in Tables 2-2 through 2-4 identifies technologies which are not appropriate for the Flightline Area remediation efforts. These technologies are eliminated from further consideration because they are not applicable to the contaminants of concern, are unproven in actual field studies at this time, or are not compatible with the characteristics of the Flightline Area sites.

2.2.1 Waste Material and Contaminated Soil

Table 2-2 presents response actions, technologies, and process options potentially applicable to wastes and contaminated soil in the Flightline Area, along with a brief description of each and comments on the screening. Potentially applicable response actions include: institutional actions, containment, removal, treatment, disposal, and vapor control.

No Response Action--The "no response" action is included as a baseline consideration. No action is taken in this option, and all wastes and contaminated soil are left in place.

Institutional Actions--Institutional actions are already instituted in the Flightline Area. Guards and security fences restrict access to the area. This action does not reduce the amount of contamination.

Containment--Containment actions involve both surface and subsurface control measures. Surface control consists of capping the waste and contaminated soil areas to reduce surface exposure and prevent surface water infiltration and potential leachate generation. Caps may consist of compacted clay, a synthetic liner, or both. Caps placed over the former waste disposal sites (LF04, LF05, and WP07) would prevent surface water infiltration, subsequently reducing the migration of contaminants from the landfills.

TABLE 2-2. IDENTIFICATION AND SCREENING OF TECHNOLOGIES FOR WASTE MATERIAL AND CONTAMINATED SOIL

Response Action	Remedial Technology	Process Options	Description	Screening Comments
No Action	None	Not Applicable	No Action.	Consideration required as base case.
Institutional Actions	Access Restriction	Fencing	Fence with locked gates placed around contaminated area.	Potentially applicable when used with other options.
		Deed Restriction	Deed to property restricts use of contaminated area.	Potentially applicable when used with other options.
Containment	Surface Controls	Capping	Compacted clay, synthetic membrane, or both placed over contaminated area to prevent surface water infiltration.	Potentially applicable to minimize exposure of waste/leachate generation.
		Grading	Land surface reshaped to manage run-off, prevent ponding, and to control erosion.	Potentially applicable when used with other options.
		Revegetation	Surface of graded and capped area stabilized with shallow-rooted vegetation to reduce erosion.	May be used in conjunction with grading and capping.
		Diversion/Collection	Contaminated area surrounded with dikes, ditches, or other to prevent run-on.	Potentially applicable when used with other options.
	Immobilization*	Microencapsulation*	Waste physically sealed within an organic binder or resin.	In research stage.
	Subsurface Barriers	Liners*	Synthetic or clay liner placed beneath contaminated area.	Not applicable because waste is already in place.
		Sheet Piles*	Interconnected steel sheets forced into the ground surrounding contaminated area.	Unreliable because the interlocks connecting the sheets are not sealed.
		Grouting*	Grout pressure injected in a regular pattern of drilled holes.	Potentially applicable for the Upper Zone.
		Slurry Walls	Trench filled with bentonite mixture or other material surrounding contaminated area.	Potentially applicable for the Upper Zone.
Removal	Excavation	Hydraulic Dredging*	Slurry from materials removed by pumping.	Not applicable.
		Mechanical Excavation	Contaminated materials removed with conventional construction equipment such as backhoes, drag lines, front-end loaders, shovels, etc.	Potentially applicable for removal of "hot spot" areas.
Treatment	In Situ	Soil Flushing*	Extractant solution injected or sprayed on contaminated area to mobilize sorbed contaminants, then contaminants pumped to surface for treatment.	Not applicable.

*Remedial technologies or process options eliminated from further consideration (see Section 2.3).

(Continued)

TABLE 2-2. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (Cont.)	In Situ (Cont.)	Biotreatment*	Soil flushed with oxygenated water and nutrients to stimulate soil bacteria.	Not applicable.
		Enzymatic Degradation*	Purified enzyme extracts catalyze the degradation of carbohydrates and proteins.	Not applicable.
		Vacuum Extraction*	Vapors extracted from soil using vacuum wells, vapors are treated with activated carbon or by burning.	Not applicable.
		Solidification/* Stabilization	Soils mixed in a closed system to depth of 30 feet with either dry or fluid treatment chemicals to produce a solidified end product.	Not applicable.
	On Site/Off Site	Soil Washing*	Contaminants extracted from excavated soil by mixing soil with extractant. The contaminated solution is then treated.	Not applicable.
		Sludge Dewatering*	Liquid removed from sludge waste by vacuum filter, filter press, belt filter, or centrifuge.	Not applicable.
		Vitrification*	Large electrodes inserted into silicate type soils and connected to graphite on the soil surface with high current electricity passing through both. Heat causes melting downward through soil. Some organics volatilize, others along with inorganics are trapped in the melt as it cools and becomes a form or obsidian or very strong glass.	Applicable to sites with radioactive or very highly toxic waste contamination. Very expensive, hard to implement around existing structures, time frame.
		Solidification/ Stabilization*	Addition of large amounts of a siliceous material combined with a settling agent such as lime resulting in a dewatered, stabilized, solidified waste product.	Not applicable.
		Landfarming*	Waste applied to soil surface and tilled to degrade or immobilize contaminants. Chemicals, nutrients, and absorbents may aid in process.	Not applicable.
		Soil Shredding*	Shredder with high speed cleated belts aerate, mix, and pulverize soil through a violent churning action. Essentially, air strips VOCs from soil.	Not applicable.
	Thermal Destruction	Electric Reactor*	Electrically heated fluid wall reactor pyrolyzes organics and inorganics from solid, liquid, or gas.	Not applicable.

*Remedial technologies or process options eliminated from further consideration (see Section 2.3).

(Continued)

TABLE 2-2. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (Cont.)	Thermal Destruction (Cont.)	Rotary Kiln Incinerator*	Waste thermally destroyed by mixing with oxygen and fuel in a rotating vessel.	Not applicable.
		Infrared Incineration Systems*	Solids, sludges, and contaminated soils destroyed by infrared energy provided by silicon carbide resistance heating elements.	Not applicable.
		Fluidized Bed Incineration*	Wastes incinerated in a turbulent bed of inert granular material to improve transfer of heat to waste streams.	Not applicable.
		Circulating Bed Combuster*	Similar to fluidized bed, but operates at higher velocities and with finer sorbents.	Not applicable.
		Advanced Electrical Reactor*	Wastes pyrolytically destroyed by infrared radiation.	Not applicable.
		Pyrolysis Process*	Waste thermally degraded to a volatile gas which can be used as a fuel source, and residual solid comprised of fixed carbon and ash.	Not applicable.
Disposal	Disposal	Landfill	Land disposal of contaminated soils or waste in a RCRA permitted facility.	Not applicable without treatment. Land ban restrictions.

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TABLE 2-3. IDENTIFICATION AND SCREENING OF TECHNOLOGIES FOR GROUND WATER

Response Action	Remedial Technology	Process Options	Description	Screening Comments
No Action	None	Not Applicable	No action.	Consideration required for base case.
Institutional Actions	Access Restriction	Deed Restriction*	Deed to property restricts use of wells in the area of influence.	Only considered if remediation is not possible. Very hard to enforce.
	Monitoring	Ground-Water Wells	Contaminated area monitored by system of upgradient and downgradient wells.	May be used in conjunction with remedial actions to evaluate the effectiveness of remedial actions or the extent of contamination/ground-water movement.
Containment	Capping	Clay and Soil	Compacted clay covered with soil over source areas of ground-water contamination.	Potentially applicable to prevent infiltration.
		Asphalt	Asphalt sprayed over source areas of ground-water contamination.	Potentially applicable to prevent infiltration.
		Concrete	Concrete slab installed over source areas of ground-water contamination.	Potentially applicable to prevent infiltration.
		Multi-Media Cap	Clay and synthetic membrane covered by soil over source areas of ground-water contamination.	Potentially applicable to prevent infiltration.
	Subsurface Barriers Vertical	Slurry Wall	Trench around areas of contamination is filled with a soil (or cement) bentonite slurry.	Potentially applicable to contain leachate.
		Grout Curtain	Pressure injection of grout in a regular pattern of drilled holes below contaminated area.	Potentially applicable to contain leachate.
		Vibrating Beam	Vibrating force to advance beams into the ground with the injection of slurry as beam is withdrawn.	Potentially applicable to contain leachate.
		Sheet Piles	Interconnected steel sheets forced into the ground surrounding contaminated areas.	Potentially applicable to contain leachate.
		Hydraulic Barriers	See "Extraction" below.	

*Remedial technology or process option eliminated from further consideration.

(Continued)

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TABLE 2-3. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Containment (Continued)	Subsurface Barriers Vertical (Continued)	Liners*	Synthetic or clay liner placed beneath wastes to contain leachate.	Not feasible. Waste already in place.
Extraction	Collection Systems	Ground-Water Production Wells (Hydraulic Barrier)	Series of pumping (and injection) wells to extract contaminated ground water.	Potentially applicable, used in conjunction with treatment process.
		Subsurface Drains*	Buried conduit conveys and collects leachate by gravity flow.	Not feasible. Too deep.
Treatment	In-Situ Treatment	Neutralization*	Injection of dilute acids or bases to adjust pH. Normally serves as pretreatment.	Not applicable. Ground-water pH is normal.
		Aerobic Biological*	Bacteria and nutrients added to contaminated ground water to enhance degradation process.	Not applicable for inorganics or low-molecular-weight halogenated organic compounds.
		Anaerobic Biological*	A reducing agent and nutrients added to contaminated ground water to enhance the degradation of low-molecular-weight halogenated organics such as TCE.	Potentially applicable for treatment of TCE, but still in research stage. Long treatment time and produces undesirable by-products.
		Adsorption or Permeable Bed*	Excavated trenches placed perpendicular to ground-water flow and filled with an appropriate material (e.g., activated carbon) to treat the plume as it flows through.	Not feasible. Too deep. In addition, must also treat or excavate spent materials.
	In-Situ Treatment (Continued)	Chemical Reaction*	System of injection wells to inject oxidizer such as hydrogen peroxide to degrade contaminants.	Because of the low permeability zones in the aquifer, it is doubtful that complete contact between the treatment fluid and the contaminants can be achieved.

*Remedial technology or process option eliminated from further consideration.

(Continued)

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TABLE 2-3. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (Continued)	Physical Treatment	Gravity Separation	Bulk separation of immiscible materials.	Not needed, little, if any, immiscible fluids in ground-water.
		Air Stripping	Mass transfer where volatile contaminants in ground water are transferred to air.	Potentially applicable for organics.
		Steam Stripping	Continuous fractional distillation of volatile compounds from ground water in a packed or tray tower using clean steam.	Potentially applicable for organics.
		Carbon Adsorption	Contaminated ground water flows through a series of packed bed reactors containing activated carbon.	Potentially applicable, very common for chlorinated hydrocarbon removal.
		Granular Media Filtration*	Pretreatment process to remove solids or colloidal material from liquids by passing ground water through a bed of granular material (sand).	Does not reduce toxicity, and Upper Zone ground water does not have high TDS/TSS. Could be used as a polishing step.
		Centrifugation	Based on density, fluid mixtures mechanically separated.	Potentially applicable as pretreatment for organics.
		Evaporation*	Liquids concentrated and volume reduced by separating liquid from dissolved or suspended particles.	Not applicable.
		Dissolved Air* Flotation	Highly pressurized air forms bubbles that remove suspended solids.	Not applicable. No TDS/TSS problem.
	Biological Treatment	Activated Sludge*	Contaminated water aerated in basin where a suspended active microbial population degrades organics. The water is then clarified.	Not applicable for TCE concentrations found in Flightline Area because of toxicity problems.
		Pure Oxygen Activated Sludge*	Same as activated sludge, but uses oxygen or oxygen enriched air instead of air to increase transfer of oxygen.	Toxicity problems. Not applicable for TCE concentrations found in Flightline Area.

*Remedial technology or process option eliminated from further consideration.

(Continued)

TABLE 2-3. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (Continued)	Biological Treatment (Continued)	Contact Stabilization*	Modification of the activated sludge process involves two-stage aeration. Short first stage relies on adsorption of organics on mixed liquor; second stage involves aerobic treatment of adsorbed material.	Toxicity problems. Not applicable for TCE concentrations found in Flightline Area.
		Extended Aeration*	Same as activated sludge, but relies on longer detention times and higher microbe population.	Extended retention times, not applicable for TCE concentrations found in Flightline Area.
		Fixed Film*	Contact of contaminated water with microbes attached to some inert medium (rock) for waste degradation.	Toxicity problems. Not applicable for TCE concentrations found in Flightline Area.
		Fluidized Bed Reactor*	Fixed-film reactor where the microbe support media (sand, activated carbon) is fluidized and thereby provides a vast surface area for biological growth and waste degradation.	Toxicity problems. Not applicable for TCE concentrations found in Flightline Area.
		Rotating Biological Contactor*	Contaminated water is contacted with microbial mass attached to a series of rotating discs.	Toxicity problems. Not applicable for TCE concentrations found in Flightline Area.
		Anaerobic Lagoon*	Large, deep basin where high organic loadings promote thermophilic anaerobic digestion of organics.	Extended retention times. Not applicable for organics in Flightline Area.
	Chemical Treatment	Ion Exchange/-Resin Adsorption	Toxic metal ions removed from water by exchanging with an ion attached to the solid resin material.	Potentially applicable as a secondary treatment for metals, but only after organic removal. Little evidence of metals contamination in Flightline Area.
		Oxidation/Reduction*	Contaminated water reacted with either an oxidizer or reducer to lower or raise the oxidation state.	Not typically feasible for use with saturation-level VOC-contaminated waters.
		Photolysis Oxidation	Contaminated ground water subjected to ultraviolet radiation in conjunction with a strong oxidant to destroy organo-metal complexes.	Potentially applicable.

*Remedial technology or process option eliminated from further consideration.

(Continued)

TABLE 2-3. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (Continued)	Chemical Treatment (Continued)	Critical Fluid Extraction*	A self-contained solvent extraction system that uses liquified gases as the extracting solvent. Separation of gas and extracted organics is accomplished by reducing pressure.	Potentially applicable, however, new unproven technology.
		Neutralization*	pH of ground water adjusted by addition of acid or base.	Not applicable. Upper Zone ground-water pH is normal.
		Reverse Osmosis	Solvent forced by high pressure through a membrane that is permeable to the solvent molecules, but not the solute.	Potentially applicable as a secondary treatment for metals, but only after organic removal. Little evidence of metals contamination in Flightline Area.
		Precipitation/ Flocculation/ Sedimentation	Chemicals added to contaminated water to precipitate metals from the water, agglomerate the precipitate, and allow the precipitate to settle.	Potentially applicable as a secondary treatment for metals, if required.
	Thermal Destruction	Electric Reactors*	Waste combusted in a horizontally rotating cylinder designed for uniform heat transfer.	More applicable for concentrated waste streams.
		Rotary Kiln*	Waste injected into hot agitated bed of sand where combustion occurs.	More applicable for concentrated waste streams.
		Fluidized Bed*	Electrically heated fluid wall reactor that pyrolyzes organics and inorganics.	More applicable for concentrated waste streams.
		Liquid or Vapor* Injection Incineration	Liquid wastes introduced into combustion chambers through atomizing nozzles.	More applicable for concentrated waste streams. May be used in secondary treatment.
		Circulating Bed Combuster*	Same as fluidized bed, but operates at higher velocities and with finer sorbents.	More applicable for concentrated waste streams.
		Supercritical Water*	Uses high pressure to convert organic wastes into superheated steam, innocuous gases, and salts.	More applicable for concentrated waste streams.
Discharge	On Site/Off-Site	Local Stream	Extracted water discharged to a local stream.	Potentially applicable but requires prior treatment.
		Aquifer Recharge	Extracted water reinjected or allowed to percolate into aquifer using injection wells or sprinkling system.	Potentially applicable, but requires prior treatment; regulatory approval.

*Remedial technology or process option eliminated from further consideration.

(Continued)

TABLE 2-3. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Discharge (Continued)	On Site/Off-Site (Continued)	Deep Well Injection*	Extracted water discharged to deep well injection system.	Not applicable.
		POTW	Extracted water discharged to local POTW for treatment.	Will require treatment at POTW, may not be accepted.

*Remedial technology or process option eliminated from further consideration.

TABLE 2-4. IDENTIFICATION AND SCREENING OF TECHNOLOGIES FOR SURFACE WATER

Response Action	Remedial Technology	Process Options	Description	Screening Comments
No Action	None	Not Applicable	No Action.	Consideration required for base case.
Institutional Actions	Access Restriction	Fencing*	Fence with locked gates installed around contaminated area.	Cannot control flow of surface water.
		Deed Restrictions*	Deed to property restricts use of contaminated area.	Not applicable.
	Monitoring	Monitoring Stations	System of monitoring stations to collect samples of surface water for analysis.	Use to monitor effectiveness of remedial actions.
Collection/Diversion	Surface Controls	Capping	Compacted clay, synthetic membrane (or both), concrete, or asphalt placed over contaminated area to prevent run-off contamination.	Potentially applicable if sites will be permanently closed.
		Grading	Land surface reshaped to manage run-off control.	Potentially applicable.
		Revegetation	Capped and/or graded surface is stabilized with vegetation.	Potentially applicable.
	Run-on/Run-off Diversion	Channels and Waterways	Excavated ditches, usually wide and shallow that intercept run-off from contaminated areas.	Potentially applicable.
		Terraces and Benches'	Embankments along steep slopes to intercept and divert flow by reducing slope length.	No site is located on steep slopes.
		Dikes and Berms	Temporary structures constructed immediately upslope from or along perimeter of contaminated area to divert run-on.	Potentially applicable.
	Run-off Collection	Chutes and Downpipes*	Structures used to carry run-off from one level to another level without erosive damage.	No site is located on steep slopes.
		Seepage Basins and Ditches	Collection areas for diverted run-on or run-off surface water.	Can only manage non-contaminated water.
Treatment	In Situ Treatment	Neutralization*	Use of dilute acids or bases to adjust pH. Normally serves as pretreatment.	Not applicable because surface-water pH is normal.
		Aerobic Biological*	Hydrogen peroxide and nutrients added to contaminated water to enhance degradation process.	Not applicable for inorganics or low molecular weight halogenated organic compounds.

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*Remedial technologies or process options eliminated from further consideration (see Section 2.3).

(Continued)

TABLE 2-4. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (Cont.)	In Situ Treatment (Cont.)	Anaerobic Biological*	A reducing agent and nutrients added to contaminated water to enhance degradation of low molecular weight halogenated organics such as PCE and TCE.	Potentially applicable for treatment of TCE, but still in research stage.
		Adsorption*	Excavated trenches placed perpendicular to surface water flow and filled with an appropriate material to treat the plume as it flows through.	Not applicable.
	Physical Treatment	Air Stripping	Mass transfer where volatile contaminants in water are transferred to air.	Potentially applicable for organics.
		Steam Stripping	Continuous fractional distillation of volatile compounds from surface water in a packed or tray tower using clean steam.	Potentially applicable for organics.
		Carbon Adsorption	Contaminated surface water flows through a series of packed bed reactors containing activated carbon.	Potentially applicable; very common for chlorinated hydrocarbon removal.
		Granular Media Filtration*	Pretreatment process to remove solids or colloidal material from liquids by passing surface water through a bed of granular material (sand).	Does not reduce toxicity, and surface water does not have a TDS/TSS problem. Could use as a polishing step.
		Centrifugation*	Fluid mixtures mechanically separated based on density.	Not applicable.
		Evaporation*	Liquids concentrated and volume reduced by separating liquid from dissolved or suspended particles.	Not applicable.
		Dissolved Air Flotation	Highly pressurized air forms bubbles that remove suspended solids.	Not applicable because there is no TDS/TSS problem in surface water.
	Biological Treatment	Activated Sludge*	Contaminated water aerated with air in basin where a suspended active microbial population degrades organics. The water is then clarified.	Not applicable for TCE because of toxicity problems.
		Anaerobic Lagoon*	Large, deep basin where high organic loadings and an impervious surface grease layer promote thermophilic anaerobic digestion of organics.	Not applicable.
	Chemical Treatment	Ion Exchange/Resin Adsorption	Toxic metal ions removed from water by exchanging with an ion attached to the solid resin material.	Not applicable for organic removal. Little evidence of metals contamination.

*Remedial technologies or process options eliminated from further consideration (see Section 2.3).

(Continued)

TABLE 2-4. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
		Oxidation/Reduction*	Contaminated water reacted with either an oxidizer or reducer to lower or raise the oxidation state.	Not applicable.
		Critical Fluid Extraction*	A self contained solvent extraction system that uses liquified gases as the extracting solvent, separation of gas and extracted organics is accomplished by reducing pressure.	Not applicable.
		Neutralization*	pH of surface water adjusted by addition of acid or base.	Not applicable. Surface water pH is normal.
		Reverse Osmosis	Solvent forced by high pressure through a membrane that is permeable to the solvent molecules, but not the solute.	Potentially applicable. Organics could dissolve membrane.
		Precipitation/Flocculation/Sedimentation*	Chemicals added to contaminated water to precipitate metals from the water, agglomerate the precipitate, and allow the precipitates to settle.	Not used for TCE removal. Could be used for metals removal, if needed.
Treatment (Cont.)	Thermal Destruction*	Electric Reactors*	Electrically heated fluid wall reactor that pyrolyzes organics and inorganics.	More applicable for concentrated waste streams.
		Rotary Kiln*	Waste combusted in a horizontally rotating cylinder designed for uniform heat transfer.	More applicable for concentrated waste streams.
		Fluidized Bed*	Waste injected into hot agitated bed of sand where combustion occurs.	More applicable for concentrated waste streams.
		Circulating Bed Combuster*	Same as fluidized bed, but operates at higher velocities and with finer sorbents.	More applicable for concentrated waste streams.
		Supercritical Water*	Utilizes high pressure to convert organic wastes into superheated steam, innocuous gases, and salts.	More applicable for concentrated waste streams.

Subsurface controls involve controlling or re-directing ground-water flow, as well as the preventing migration of contaminants in the soil, so as to contain the contaminants within a specific area. Of the four options considered--sheet piles, slurry walls, hydraulic barriers, and grouting--creating a hydraulic barrier would be the most effective because waste constituents appear to have already migrated from the landfills. Slurry walls around the landfill are also potentially applicable, especially if concentrations of waste constituents in the ground-water are observed to increase during remedial action implementation.

Removal--Removal of wastes would be accomplished by excavating the waste material and contaminated soil in each disposal area (LF04, LF05, and WP07). Reportedly each of the three IRP sites potentially contains wastes such as drums of liquid waste, paint cans, batteries and oils (CH2M-Hill, 1984). Due to the land ban restrictions, disposal of the excavated waste in an off-site landfill would require some degree of treatment for each waste before disposal. In addition, the most recent analytical results suggest that the waste constituent concentrations migrating from each of the sites in Upper Zone ground water is decreasing. For these reasons, the removal option is technically and economically infeasible.

Treatment--Treatment of the wastes stored in each of the disposal sites would be difficult because the exact contents are not known. Each site contains mixed wastes, therefore, a complex treatment system would have to be designed. For these reasons all treatment options were eliminated from further consideration.

Disposal--All disposal options were eliminated from further consideration because waste removal was considered to be technically and economically infeasible.

2.2.2 Ground Water

Table 2-3 presents response actions, technologies, and process options for ground water. The response actions applicable to control contaminants in ground water include institutional actions, containment, extraction/recovery, treatment, vapor control, and discharge.

No Response Action--The "no response" action is included as a baseline consideration. No action is taken in this option, and the ground water is left in place, untreated and uncontained.

Institutional Actions--Two institutional action alternatives were considered: 1) restriction of access to Upper Zone ground water and 2) using monitoring wells to monitor Upper Zone ground-water quality. Since proven technologies are available for treating the ground-water contaminants found in the Flightline Area, restricting aquifer use is not appropriate. As a sole response alternative, ground-water monitoring is not sufficient. This action will be used in conjunction with other remedial technologies to evaluate their effectiveness.

Ground-Water Containment-- The discussion of containment for wastes and contaminated soil also applies to ground water and will not be repeated here (see Section 2.2.1).

Ground-Water Extraction--Two ground-water collection systems were considered: subsurface drains and collection well fields. Subsurface drains were eliminated from further consideration because the depth of the Upper Zone ground water makes the technology uneconomical and very difficult to implement. A collection well field is the recommended technology for extracting the ground water. In addition, designing the well field correctly will create hydraulic barriers that will restrict the further migration of contaminated ground water.

Ground-Water Treatment--Five remedial technology categories were considered for ground-water treatment: in-situ, physical, biological, chemical, and thermal.

<u>In-Situ Treatment</u>--In-situ treatment was eliminated from further consideration when the four processes considered--neutralization, aerobic and anaerobic biological treatment, and adsorption bed treatment--proved to be inappropriate (neutralization), ineffective (biological treatment), or infeasible (adsorption bed treatment).

<u>Physical Treatment</u>--Several physical treatment options were considered for treating contaminated ground water extracted from the Flightline Area. The five pretreatment processes were centrifugation, dissolved air flotation, evaporation, granular media filtration, and density separation. The three treatment processes were air stripping, steam stripping, and carbon adsorption.

None of the pretreatment options are considered applicable to ground-water contamination in the Flightline Area. Free phase DNAPL in association with the extracted ground water is not expected. Also, dissolved and suspended solids are not expected to be a problem.

Air and steam stripping are both considered potential primary treatment options for removing volatile organic compounds (the main contaminants) from the ground water. Air stripping is the preferred choice of the two, since it is less expensive to operate and maintain. A cost comparison of air and steam stripping units showed that, while the capital costs of the two technologies are comparable, the operating costs of steam stripping are greater than those of air stripping. Because of the cost difference and because both methods are expected to achieve similar removal efficiencies for the expected contaminant loadings, steam stripping was eliminated from further consideration.

Carbon adsorption is also a viable technology for primary and secondary treatment. This technology is used primarily to remove organic compounds from waste streams. Activated carbon can also remove other pollutants that are non-volatile. However, the installation and operating costs of carbon absorption units are much greater than those for air stripping because of the significant cost in handling, transporting, and disposing of spent carbon, which is a hazardous waste. Because of the cost difference, and because both methods are expected to achieve similar removal efficiencies for the expected contaminant loadings, carbon absorption was eliminated from further consideration.

Eight biological treatment technologies were screened: activated sludge, pure oxygen activated sludge, contact stabilization, extended aeration, fixed film, fluidized bed reactor, rotating biological contactor, and anaerobic lagoon.

All of these processes, except the anaerobic lagoon, are either designed specifically for, or can be conducted under, aerobic conditions. In general, halogenated organic compounds (e.g., TCE) cannot be effectively degraded by these processes because the chemicals are very toxic to the microbes. Anaerobic processes are more successful in breaking down halogenated compounds; however, these processes require long retention times. Therefore, biological treatment processes were eliminated from further consideration.

<u>Chemical Treatment</u>--Six chemical treatment technologies were evaluated: neutralization, ion exchange/resin adsorption, photolysis oxidation, critical fluid extraction (supercritical extraction), reverse osmosis, oxidation/reduction, and precipitation/flocculation/sedimentation. As previously mentioned, neutralization was eliminated as unnecessary due to the natural pH of the ground water. Ion exchange/resin adsorption, oxidation/reduction, precipitation/flocculation/sedimentation, and reverse osmosis are effective in treating ground water contaminated with metals, but these processes have not been developed to treat organic compounds. Since there is little evidence to suggest a metals contamination problem, they were also eliminated from further consideration.

The remaining two processes, photolysis oxidation and critical fluid extraction, are mainly used to treat organic contamination. Photolysis oxidation uses ultraviolet (UV) radiation in the presence of a strong oxidant to destroy organic-metal complexes. This process has become commercially available in the last few years and could potentially be used to treat the TCE ground-water contamination in the Flightline Area. However, the cost of photolysis oxidation treatment is much higher than air stripping (a proven technology). Therefore, this treatment was eliminated from further consideration.

Critical fluid extraction uses a solvent (e.g., carbon dioxide) in a supercritical state to dissolve volatile organic compounds. This technology has not been developed sufficiently (e.g., low flow restrictions apply to this process) for considering it a viable option to use in the Flightline Area.

Thermal Destruction--Thermal destruction processes such as 1) electric reactors, 2) rotary kiln, 3) fluidized bed incineration, 4) circulating bed combustor, 5) liquid injection incineration, and 6) supercritical water treatment could be used to destroy contaminants in ground water. However, these processes are not usually feasible for liquid streams unless high concentrations of organic compounds reduce or eliminate the need for supplemental fuel. Considering the typical ground-water contaminant concentrations in the Upper Zone ground water, thermal destruction was eliminated as a primary treatment technology.

Discharge of Untreated Ground Water--Options for discharging untreated ground water to the local publicly owned waste water treatment plant (POTW) via the sewer lines or by deep well injection were evaluated and rejected because they were either too costly (off-base disposal facility) or prohibited (POTW or deep-well injection). However, once the water is treated, it can be disposed of by discharging into sewer lines to the POTW, by discharging to Farmers Branch, or by using it for golf course irrigation. All of these are feasible options that will be considered in developing remedial alternatives.

2.2.3 Surface Water

Table 2-4 presents response actions, technologies, and process options that apply to surface water. All of the treatment technologies for surface water are also presented as ground-water treatment technologies and are discussed in Section 2.2.2. The main surface water bodies in the Flightline Area, Farmers Branch Creek, its unnamed tributary, and the two ponds located on the golf course, are contaminated and are hydraulically connected to the Upper Zone Aquifer. Therefore, the only applicable process options listed in Table 2-4 are continued monitoring and construction of a barrier to prevent contaminated ground water from discharging to the surface water. The barrier could consist of a slurry wall and pumping well(s), or a series of pumping wells that would control contaminant migration.

2.3 Selection of Remedial Technologies

Categories of remedial technology that are applicable to the Flightline Area are waste containment, ground-water treatment, and ground-water disposal. Selected technologies will be developed in the following sections as part of remedial alternatives that comply with the remedial action objectives listed in Section 2.1. The selected waste containment technologies are:

- Impermeable Multi-Media Cap;
- Slurry Wall; and
- Hydraulic Barrier.

Ground-water extraction wells, ground-water monitoring, and air stripping are the selected technologies for ground-water treatment. If needed, vapor phase, activated carbon adsorption can be used to treat the waste gases of the air stripping process to prevent the release of organic compounds to the atmosphere. However, the Texas Air Control Board (TACB) exemptions on emissions from the air stripping operations associated with ground water treatment make the necessity of these processes unlikely. Air stripping is a proven technology and very economical if air emissions do not require treatment.

The three selected technologies for disposal of treated ground-water include:

- Discharge into Farmers Branch;
- Seasonal golf course irrigation; and
- Discharge into the local POTW.

Each of the selected waste containment and ground-water treatment technologies is described further in the following paragraphs. The various disposal options (and combinations) are included in the remedial alternatives developed and screened in Section 3.

2.3.1 Multi-Media Cap

An impermeable cap over each disposal area could be used to inhibit infiltration of rainwater during a storm event. During a storm event, some portion of the rainwater will infiltrate each site and potentially mobilize contaminants into the ground water. An impermeable cap will significantly reduce the amount of precipitation percolating through the wastes, thus reducing the driving force for contaminant migration. Caps have been shown to decrease migration from landfills by up to 80%. A typical multi-media cap design is illustrated in Figure 2-1. The cap consists of a vegetative top layer, a 60-mil HDPE liner, and a 12-inch layer of low-permeability soil bedding. Caps would be placed over the total waste disposal and contaminated soil areas of Sites LF05 and WP07. However, a cap would have to be constructed around the radar station located on Site LF04.

2.3.2 Slurry Wall

Slurry walls could be constructed around the perimeters of Sites LF04, WP07, and LF05 to provide a vertical barrier that would prevent future contaminant migration. A slurry wall composed of a soil/bentonite mixture can provide low permeability vertical barriers (on the order of 10E-7 cm/sec). In this case, the slurry walls would extend downward from the ground surface to the top of the Goodland/Walnut aquiclude (approximately 25 feet bgl). This option also includes a ground-water pumping well located within each waste disposal area to prevent the accumulation of ground water inside the slurry wall.

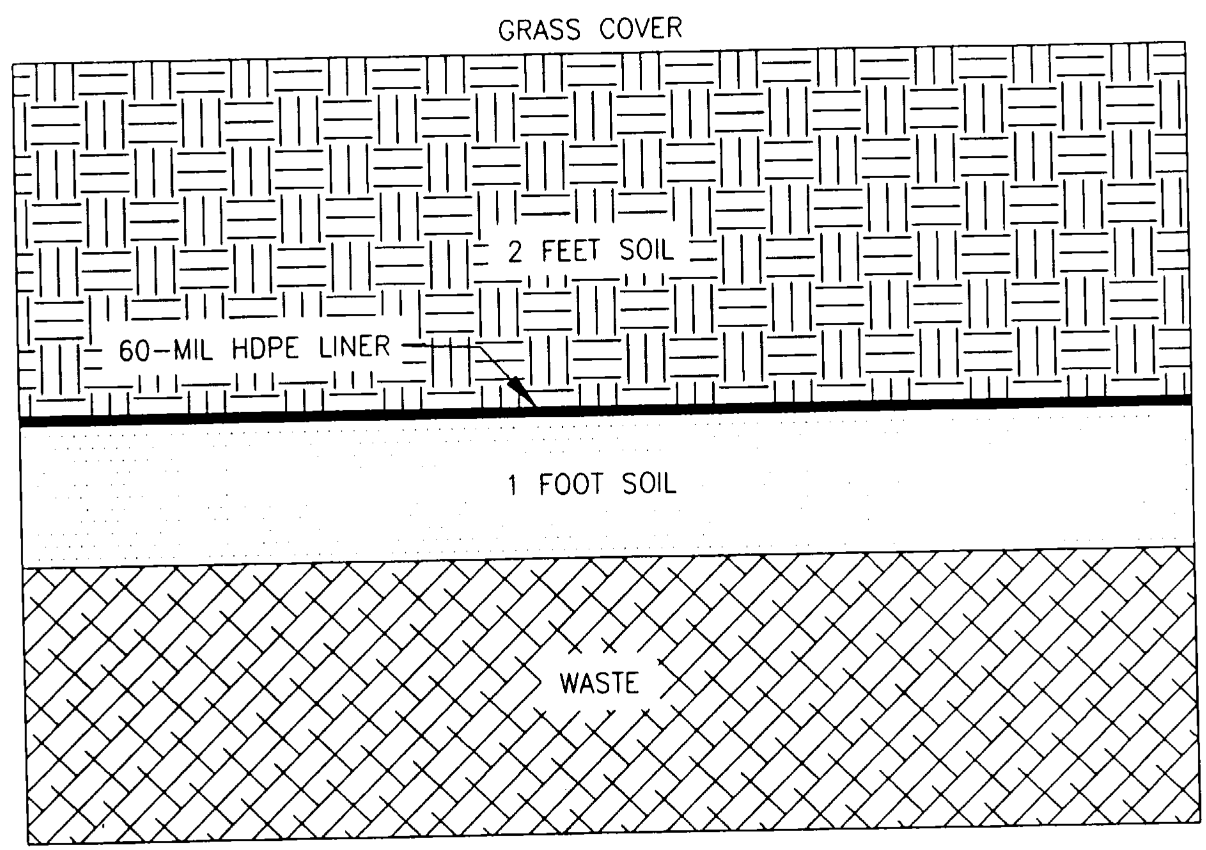

Figure 2-1. Multi-Media Cap Design

Slurry walls are constructed by excavating a narrow trench, 24- to 30-inches wide. The use of a soil/bentonite slurry allows for the trench to be excavated without the use of lateral supports in the trench. As the trench is dug, the slurry is pumped into the trench and its level is maintained near the top of the trench. As the water content of the soil/bentonite backfill comes to equilibrium with the surrounding soil, the strength of the slurry wall becomes approximately equal to the strength of the surrounding soil.

2.3.3 Ground-Water Extraction Wells as a Hydraulic Barrier

This option involves installation of ground-water extraction wells on the downgradient sides of Sites LF04, LF05, and WP07 to control and remove contaminated ground water. The extracted ground water would be transported to the treatment or disposal area. The wells would be designed to capture any contamination that might be generated by and migrating from the three landfills. The objective of this option is to eliminate ongoing contaminant migration from the three waste disposal areas and is considered separately from the ground-water withdrawal system that will capture the downgradient contaminant plumes.

2.3.4 Ground-Water Monitoring

A ground-water monitoring program is required to track the migration of the various contaminant plumes and to evaluate the effectiveness of the overall remedial action. Numerous Upper Zone monitor wells already exist in the Flightline Area, however, some additional wells will be required downgradient of the maximum plume extent and beyond the limit of influence of the ground-water withdrawal system to ensure that the contaminant plumes are contained.

2.3.5 Ground-Water Extraction System

A ground-water extraction system consisting of a pumping well network could be designed to be capable of capturing contaminated Upper Zone ground-water and preventing further migration of the existing volatile organic contaminant plumes. The pumping wells would also act as a hydraulic barrier, preventing contaminated ground-water discharge into Farmers Branch or its tributary. The piping system from the ground-water extraction wells to the treatment system would consist of double containment pipe with a leak detection system.

2.3.6 Air Stripping Treatment System

The air stripping treatment system (ASTS) consists of the air stripping unit, storage tank, a liquid pump, and a blower. The air stripping unit contains a packing material to disperse the ground water as it flows down (by gravity) through the unit. Air is forced into the unit by the blower and as the contaminated ground water comes in contact with the air, the contaminants volatilize and are discharged into the atmosphere.

3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

3.1 Development of Alternatives

The primary objectives of the remedial action for the Flightline Area of Carswell AFB is to reduce the concentrations of volatile organic contaminants in the ground water to meet the interim primary drinking water MCLs, and to prevent future migration of contaminants from IRP Sites LF04, LF05, and WP07. The technologies that remained after preliminary screenings (Section 2.0) were combined into remedial alternatives. The remedial alternatives are various combinations of feasible waste containment, ground-water treatment, and treated ground-water effluent disposal technologies. The candidate remedial alternatives all include components from each of the three technology categories. The 12 identified remedial alternatives (including the No Action Alternative) are listed in Table 3-1.

The following subsections contain descriptions of the seven remedial alternatives listed Table 3-1. These alternatives were screened for their feasibility for remediation of contamination in the Flightline Area.

3.1.1 Alternative 1

Alternative 1, the No Action Alternative, provides a baseline for comparing the other alternatives because no remedial activities are implemented. This alternative allows continued generation of leachate, migration of contaminants in ground water, and further degradation of the Upper Zone ground-water quality in (and potentially beyond) the Flightline Area. The No Action Alternative also provides no mechanisms for reduction in toxicity, mobility, or volume of contaminated ground water through treatment.

TABLE 3-1. PRELIMINARY REMEDIAL ACTION ALTERNATIVES

	Alternatives											
	1	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7*
<u>Waste Containment</u>												
Cap Existing Landfills	NA	■	■	■	■					■	■	
Slurry Wall Placed Around Perimeter of Landfill	NA	■	■					■	■			
Ground-Water Extraction Wells Placed on Perimeter of Landfill	NA			■	■	■	■					
<u>Ground Water</u>												
Monitoring	NA	■	■	■	■	■	■	■	■	■	■	■
Extraction Well System	NA	■	■	■	■	■	■	■	■	■	■	■
On-Site Air Stripping	NA	■	■	■	■	■	■	■	■	■	■	
<u>Disposal</u>												
Discharge Treated Effluent into Farmers Branch Creek	NA	■		■		■		■		■		
Discharge Treated Effluent into POTW	NA		■		■		■		■		■	
Seasonal Irrigation of Base Golf Course	NA	■	■	■	■	■	■	■	■	■	■	■

NA - No Action

*Alternative 7 utilizes any of the waste containment options listed in Alternatives 2, 3, 4, 5, or 6.

3.1.2 Description of the Common Components of Alternatives 2-5

Alternatives 2-5 have the following technology components in common:

- Ground-water monitoring;
- Ground-water extraction with pumping wells;
- On-site air stripping; and
- Disposal of treated ground-water effluent.

Each of these alternatives is described in detail in the following subsections. In subsequent discussions, they are referenced by number, and any differences or uncertainties concerning their planned implementation are identified.

Ground-Water Monitoring

A ground-water monitoring program is required to assess the migration of the various contaminant plumes and the effectiveness of the ground-water withdrawal system. Approximately 15 of the monitor wells located in the Flightline Area will be sampled semi-annually. Field QA/QC procedures will involve taking duplicate samples (one duplicate for every 10 samples collected). Additional field QA/QC procedures will include collecting trip and equipment blanks. Samples from each monitor well will be analyzed for volatile organic compounds. Installation of three to five additional ground-water monitor wells, beyond the downgradient limits of the existing plume and the locations of the ground-water extraction wells, is also required to verify that the extraction system is capturing the contaminant plume.

Ground-Water Extraction System

Preliminary designs of two ground-water extraction systems to capture and remove the volatile organic contaminant plumes are shown in Figures 3-1 and 3-2. The two main components of the extraction systems are pumping wells and dual wall containment piping. The layout of the dual wall

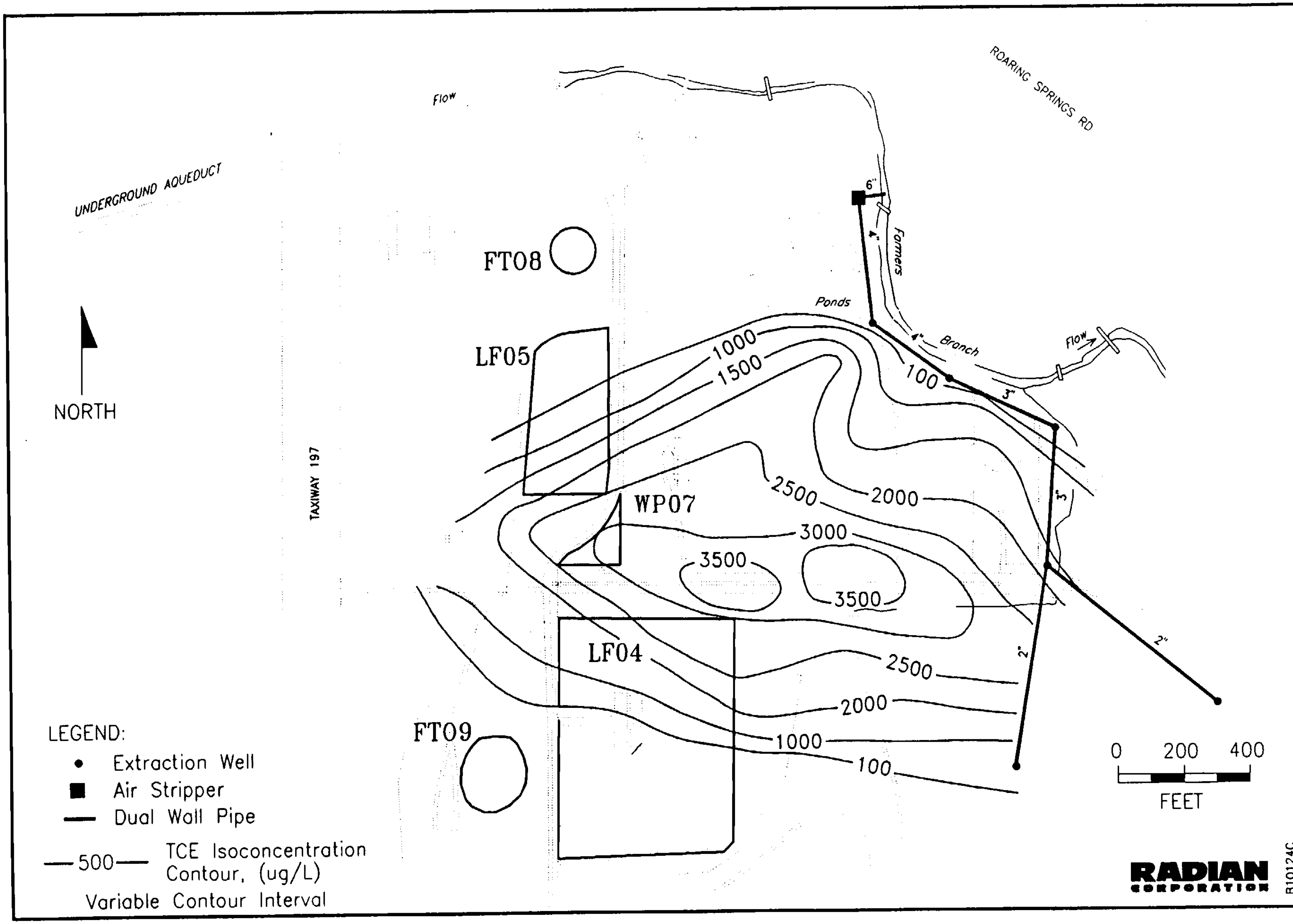

Figure 3-1. Ground-Water Extraction System Located Adjacent to Farmers Branch Creek (Option 1)

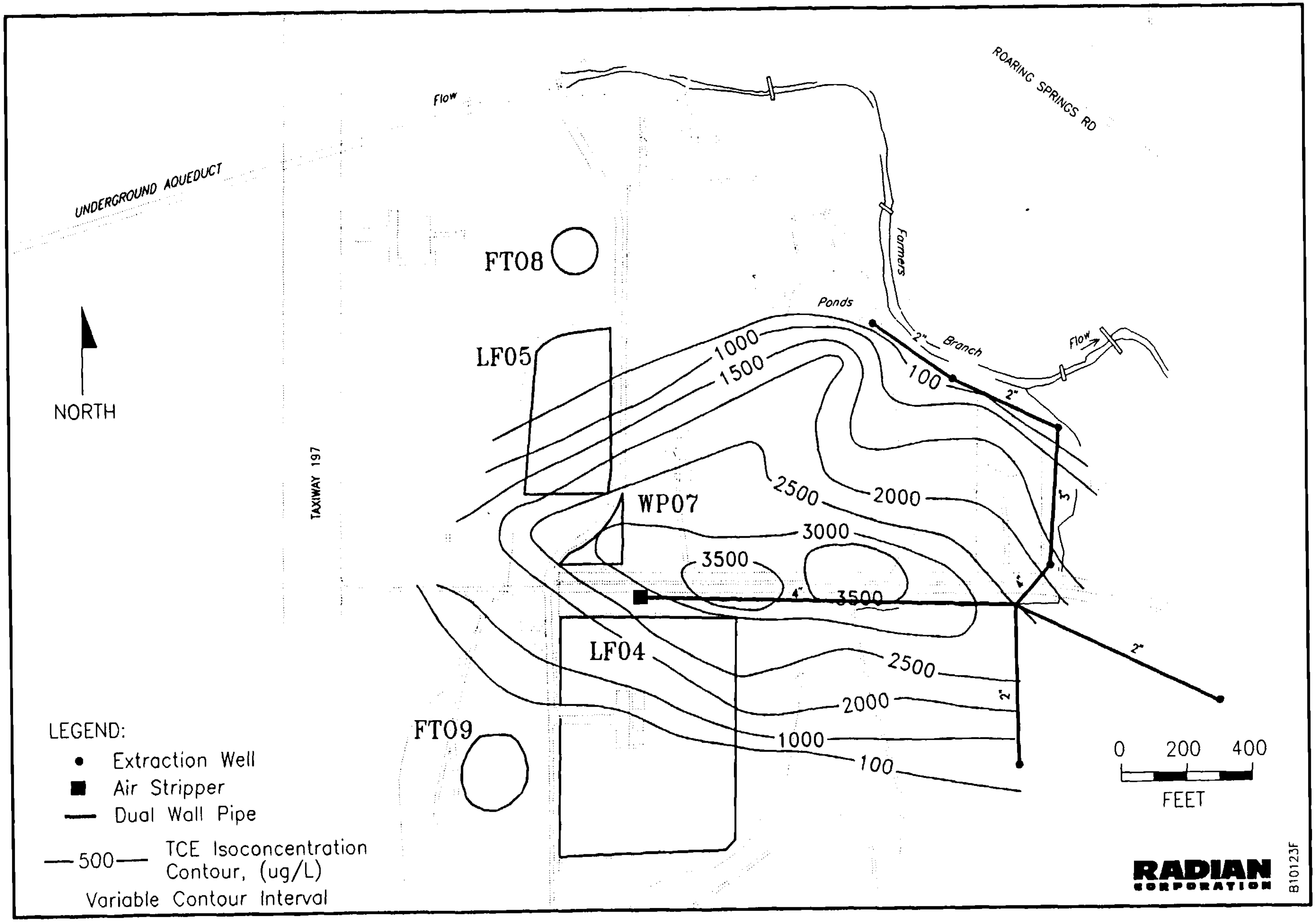

Figure 3-2. Ground-Water Extraction System Located Between Sites LF04 and LF05 (Option 2)

containment piping system depends upon the location of the air stripper treatment system. One option is to route the contaminated water to a treatment system located adjacent to Farmers Branch (Figure 3-1). The treated effluent would then be discharged into Farmers Branch via a PVC pipeline. The other option is to transport the contaminated water to a treatment unit located between sites LF04 and LF05 (Figure 3-2). The treated ground water would then be discharged to the City of Fort Worth POTW through an 18- to 24-inch municipal sewer line that is present at this location. The dual containment pipe consists of one pipe within another. For example, a 2-inch carrier pipe would be contained within a 4-inch containment pipe.

The ground-water extraction well locations are also shown on Figures 3-1 and 3-2. The pumping rates for each of the six wells ranges from 30- to 50-gpm. The combined discharge of the pumps was estimated at 250 gpm. The well locations and discharge rates were chosen to capture the entire known areas of contamination. Although only the TCE plume is shown on the figures, the extraction well locations were chosen to also capture the related 1,2 DCE and vinyl chloride plumes.

Calculations assumed steady state flow conditions, a homogenous, isotropic, infinite aquifer, and fully penetrating wells. The aquifer properties were estimated by using the data from the pump test performed in the Flightline Area in June 1990. The regional flow gradient was assumed to be 0.0035 to the east or northeast. Saturated hydraulic conductivity was assumed to be 784 ft/day (average value from the pump test performed in June 1990). The saturated thickness was estimated to be between 13- and 15-feet. The proposed well locations and discharge rates represent preliminary estimates based on limited information on aquifer hydraulic properties. They will require field verification, and possible design modification during the initial stage of remedial action implementation.

On-Site Air Stripping Treatment System (ASTS)

The air stripping process proposed for treatment of ground water in the Flightline Area is designed to remove volatile organic contaminants. Once extracted from the aquifer, the ground water is pumped to the storage tanks at the treatment pad via a buried, dual containment pipeline. The ground water is then contacted with countercurrent air in a packed tower. Figure 3-3 is a schematic of the overall process. In addition to a stripping tower filled with packing material and water storage tanks, the system includes liquid-circulating pumps and an air blower.

The vertical packed tower is a simple gas-liquid contacting device consisting of a cylindrical shell containing a support plate for the packing material, and a liquid-distributing device designed to effectively irrigate the packing. The contaminated ground water enters the top of the column and flows by gravity countercurrent to the air. As the water passes down through the column, it comes into contact with air that contains progressively fewer volatile organic contaminants.

The dissolved organic compounds are stripped from the ground water because these compounds tend to volatilize into the gas phase until their vapor and liquid concentrations reach thermodynamic equilibrium. For dilute aqueous mixtures of volatile organic compounds (VOCs), the equilibrium distribution of a pollutant between the gas and water phases can be described adequately by Henry's Law:

$$p = Hc$$

where: p = partial pressure of a VOC in the gas phase, atm;
H = Henry's Law constant, atm-m^3/gmole; and
c = concentration of the VOC in the aqueous phase, gmole/m^3.

The Henry's Law constant for each VOC determines its volatility and ease of stripping. Therefore, a major parameter affecting an air stripper's performance is the Henry's law constant for each VOC. In addition, the liquid loading rate and the gas-to-liquid ratio affect the mass transfer process and is also important parameters affecting the performance of an air stripper. The height of a packed tower is designed for a certain desired VOC removal efficiency, and the column diameter is designed from flooding correlations

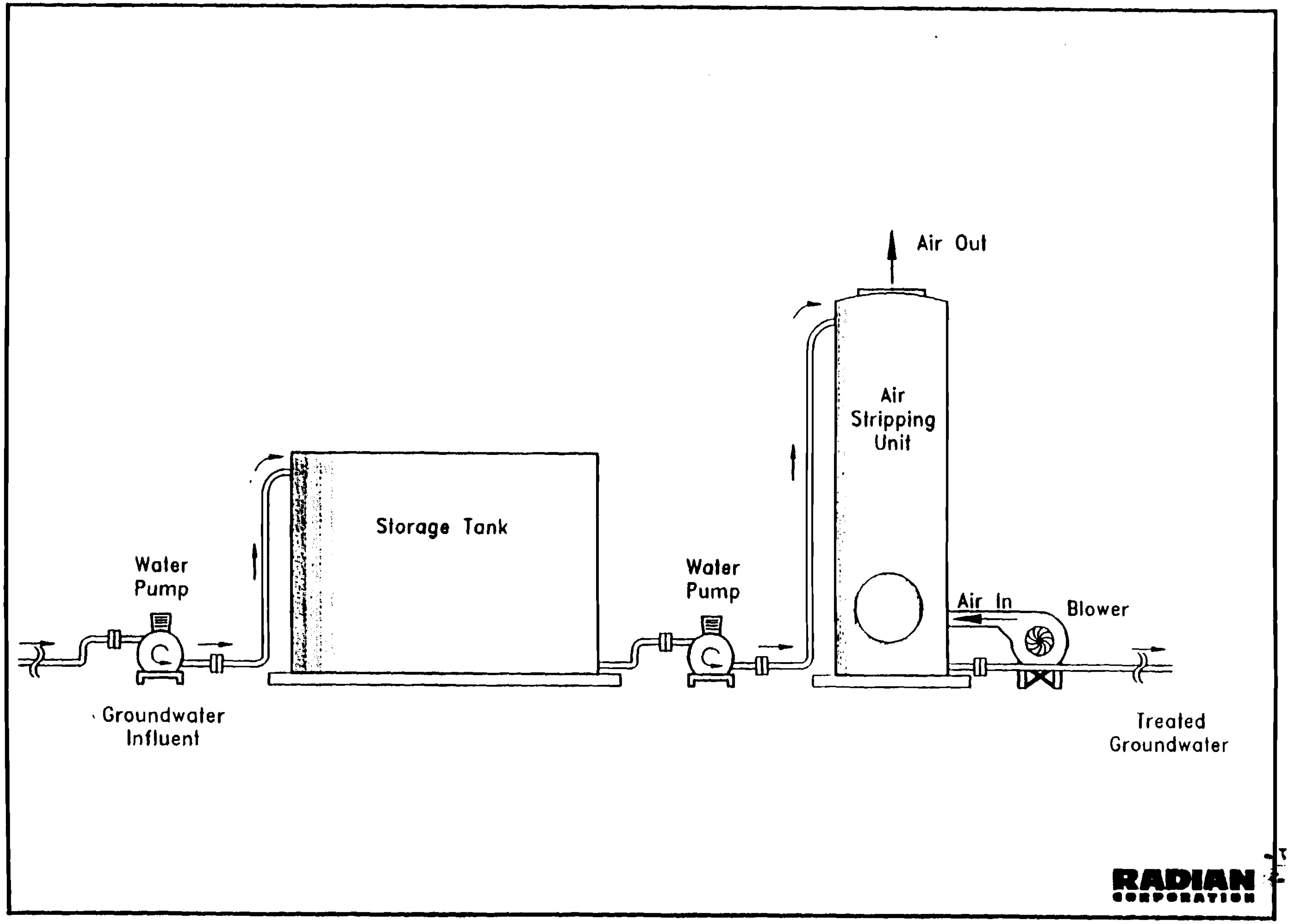

Figure 3-3. Schematic of Proposed Air Stripper Treatment Unit

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to provide a desired pressure drop. Because several VOCs are present in the Upper Zone ground water beneath the Flightline Area, the final design of the air stripper will be determined by the total amount of VOCs removed.

Disposal of Treated Effluent

Three methods for disposing of effluent from the air stripper treatment unit were selected for evaluation: 1) discharge into Farmers Branch, 2) discharge into the City of Fort Worth's POTW, and 3) seasonal irrigation of the base golf course. Each method is described in the following subsections.

Discharge Into Farmers Branch--If treated effluent is discharged into Farmers Branch, a NPDES permit would be required. To comply with the permit, the ground water would need to be treated to remove VOCs to concentrations below the MCLs listed in Table 2-1.

Discharge to POTW--Treated effluent from the air stripping treatment system could be discharged into a nearby sanitary sewer that ultimately discharges to the POTW. An 18- to 24-inch pipe is located just north of Site LF04. During the pump test, with permission from the City of Fort Worth, contaminated ground water produced during the test was discharged into this line through a manhole. The sanitary sewer discharges into the Village Creek Wastewater Treatment Plant located in Fort Worth. The discharge requirements for the POTW discharge option would be less stringent than the NPDES permit requirements needed for discharge to Farmers Branch. However, the Village Creek Treatment Plant's specific requirements would have to be negotiated before implementation of this option.

Seasonal Irrigation of the Golf Course--A portion of the treated effluent could be used to irrigate the base golf course. Since the demand for irrigation is seasonal, this option could only be used to supplement the primary disposal options discussed above. Both proposed treatment locations are close to the golf course, so effluent transportation costs would be minimal.

3.1.3 Alternative 2

Alternative 2A

The primary components of Alternative 2A are shown in Figure 3-4. They consist of placing an impermeable multi-media cap over Sites LF04 (except for the area taken up by the radar station), WP07, and LF05 to prevent infiltration. In addition, a soil/bentonite slurry wall will be constructed around each of the three areas to prevent waste migration. One pumping well will be installed within each of the three slurry walls to prevent the possible accumulation of ground water. Any extracted water will be transported through a 2-inch/4-inch dual wall containment pipe to the ASTS located northwest of the waste sites, adjacent to Farmers Branch. The volatile organic contaminant plumes that have migrated downgradient of the sites will be captured and pumped to the ASTS by the six ground-water extraction wells shown on Figure 3-4. The treated effluent will be discharged into Farmers Branch. However, a portion of the treated ground water may be used to irrigate the base golf course, as needed.

Alternative 2B

Alternative 2B (Figure 3-5) includes the same components as Alternative 2A except the ASTS is located just north of Site LF04 allowing the treated effluent to be discharged into the POTW sewer line and/or to irrigate the base golf course seasonally.

3.1.4 Alternative 3

Alternative 3A

The components of this alternative are shown in Figure 3-6. They are the same as those in Alternative 2A, except ground-water extraction wells are used instead of slurry walls to prevent continued contaminant migration

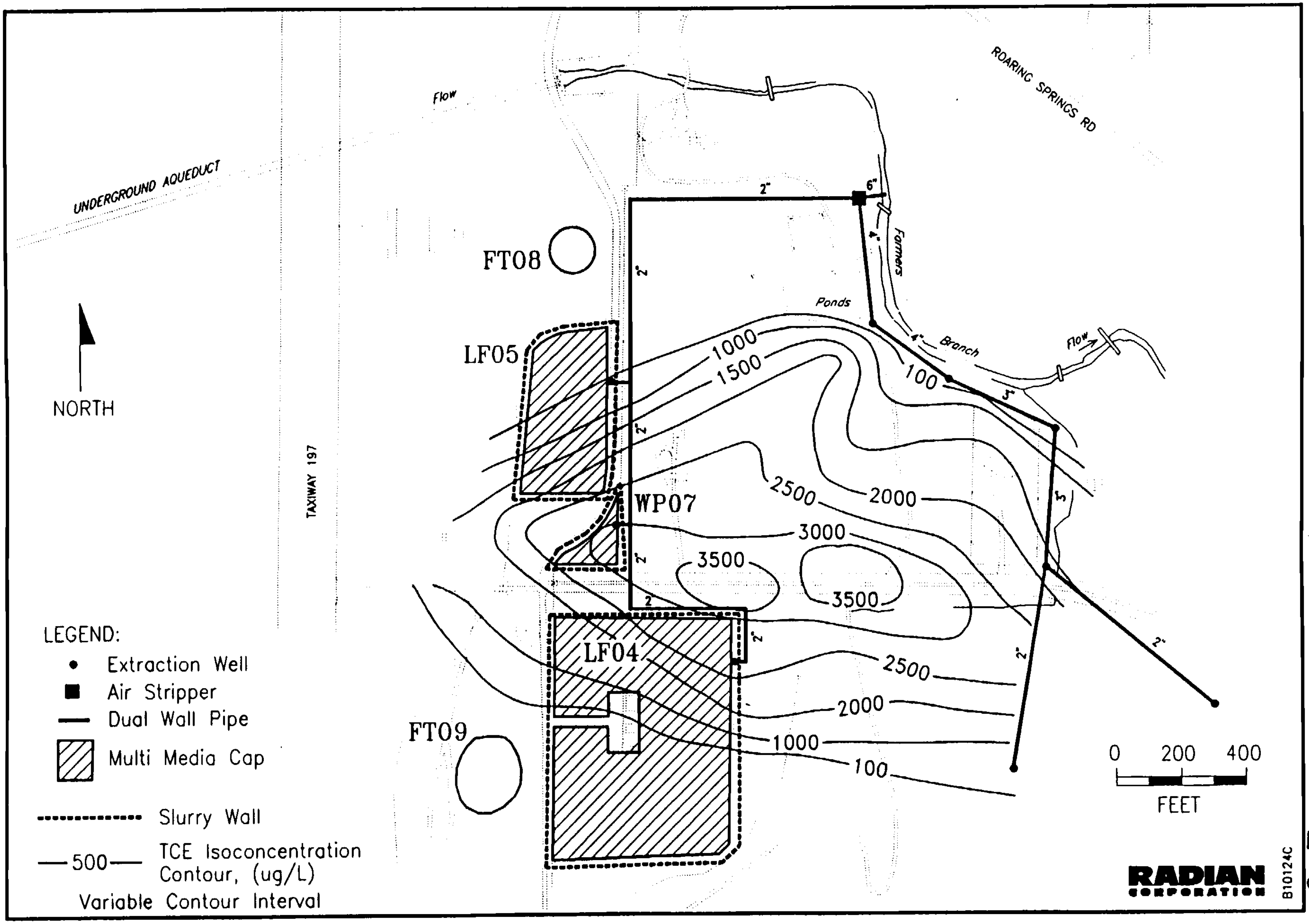

Figure 3-4. Alternative 2A

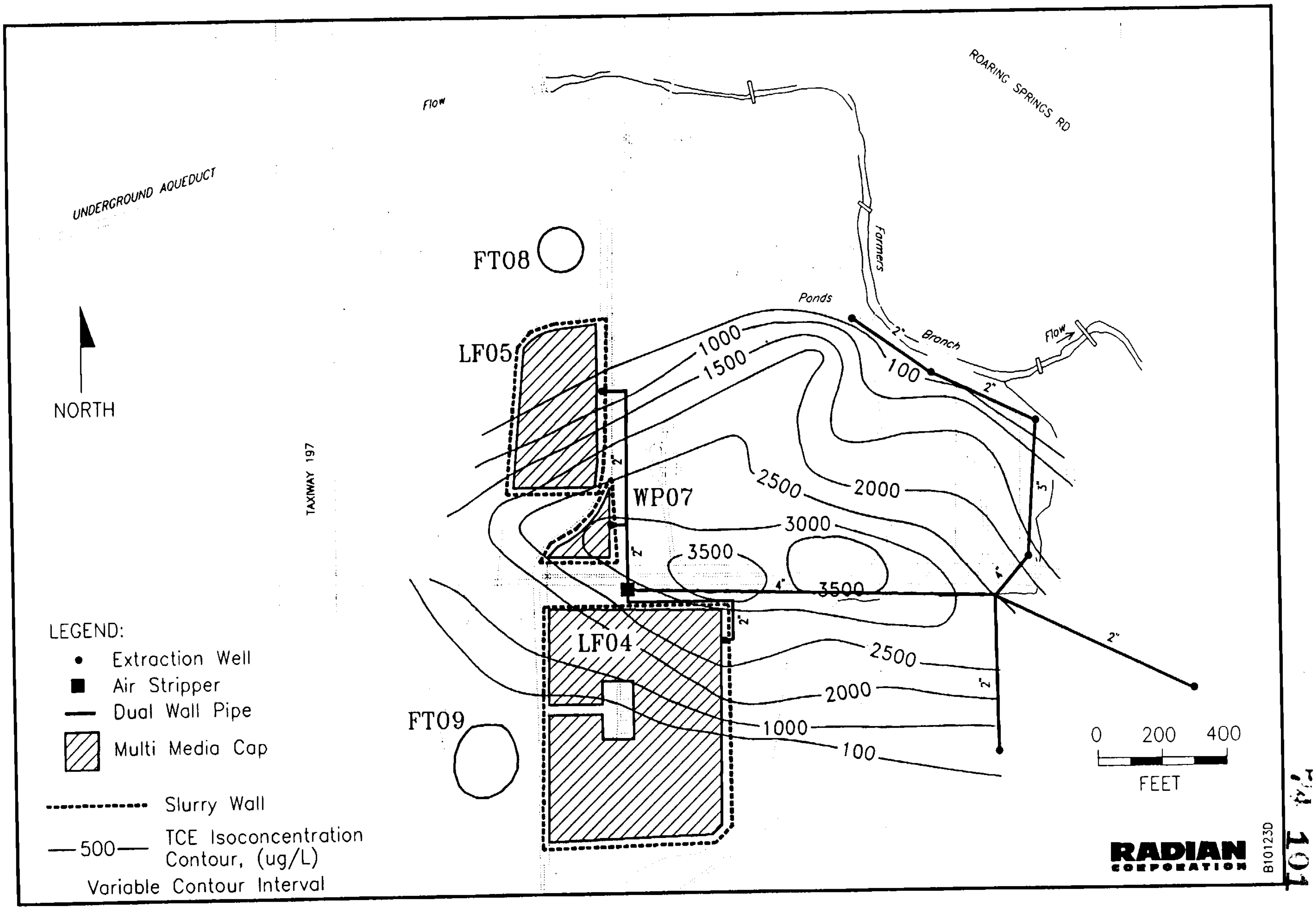

Figure 3-5. Alternative 2B

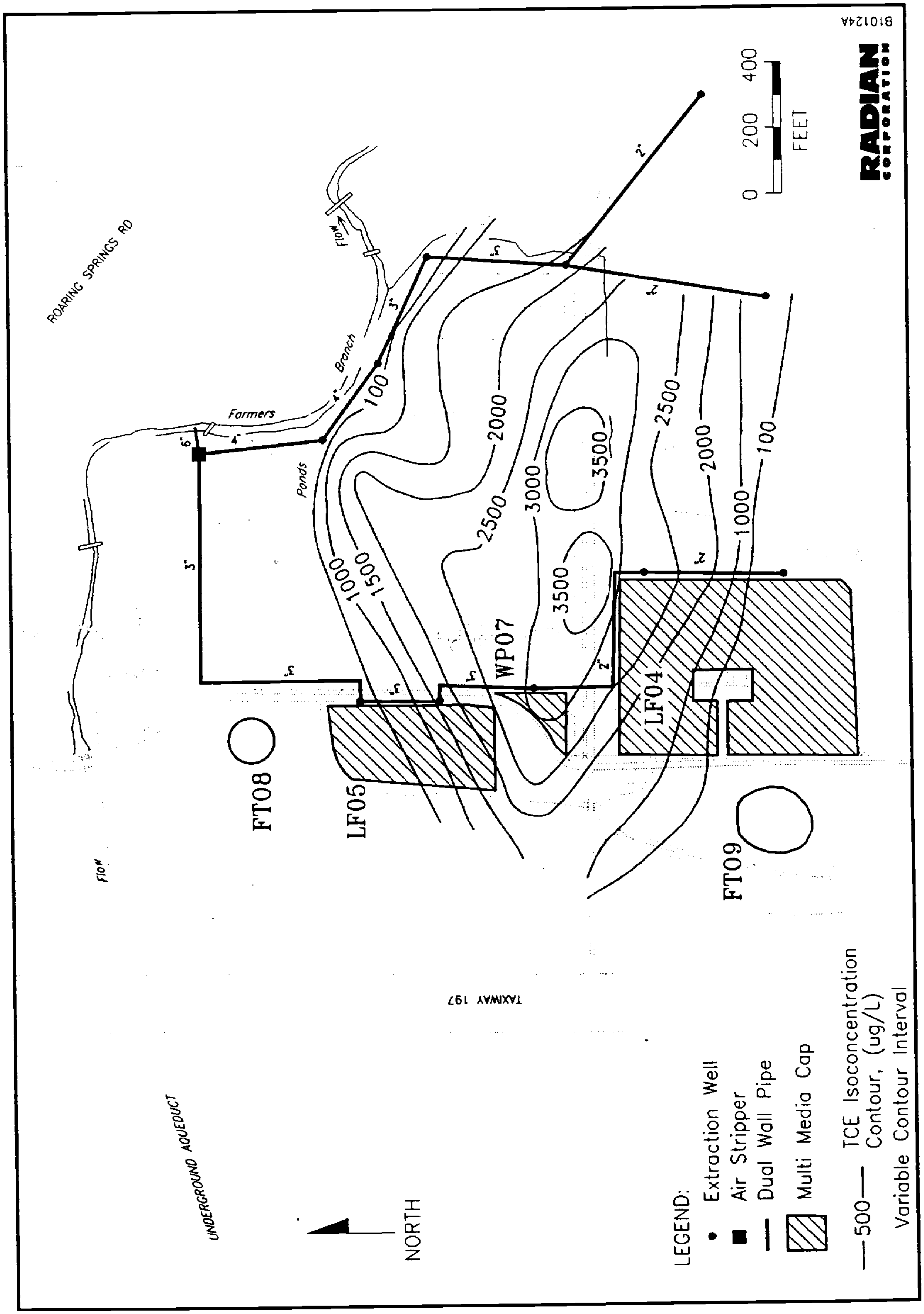

Figure 3-6. Alternative 3A

from the three waste disposal areas. Ground-water extraction wells are placed on the downgradient side of each waste disposal area and are designed to capture any contaminants migrating from the three sites in Upper Zone ground water. The extracted ground water will be transported to the ASTS for treatment before it is discharged into Farmers Branch and/or used to irrigate the base golf course, as needed.

Alternative 3B

Alternative 3B (Figure 3-7) includes the same components as Alternative 3A, except the ASTS is located just north of Site LF04 allowing the treated effluent to be discharged into the POTW sewer line and/or used to irrigate the base golf course.

3.1.5 Alternative 4

Alternative 4A

The components of Alternative 4A are shown in Figure 3-8. This alternative is similar to Alternative 3A except no impermeable caps over Sites LF04, WP07, and LF05 are included. This design allows stormwater to "flush" contaminants present in the three waste disposal areas into the ground water. Ground-water extraction wells will be installed on the downgradient side of each of the three areas and will be designed to capture contaminated ground water. The extracted ground water will be transported to the ASTS for treatment before it is discharged into Farmers Branch and/or used to irrigate the base golf course, seasonally.

Alternative 4B

Alternative 4B (Figure 3-9) contains the same components as Alternative 4A except the ASTS is located just north of Site LF04 allowing the treated effluent to be discharged into the POTW sewer line and/or used to irrigate the base golf course.

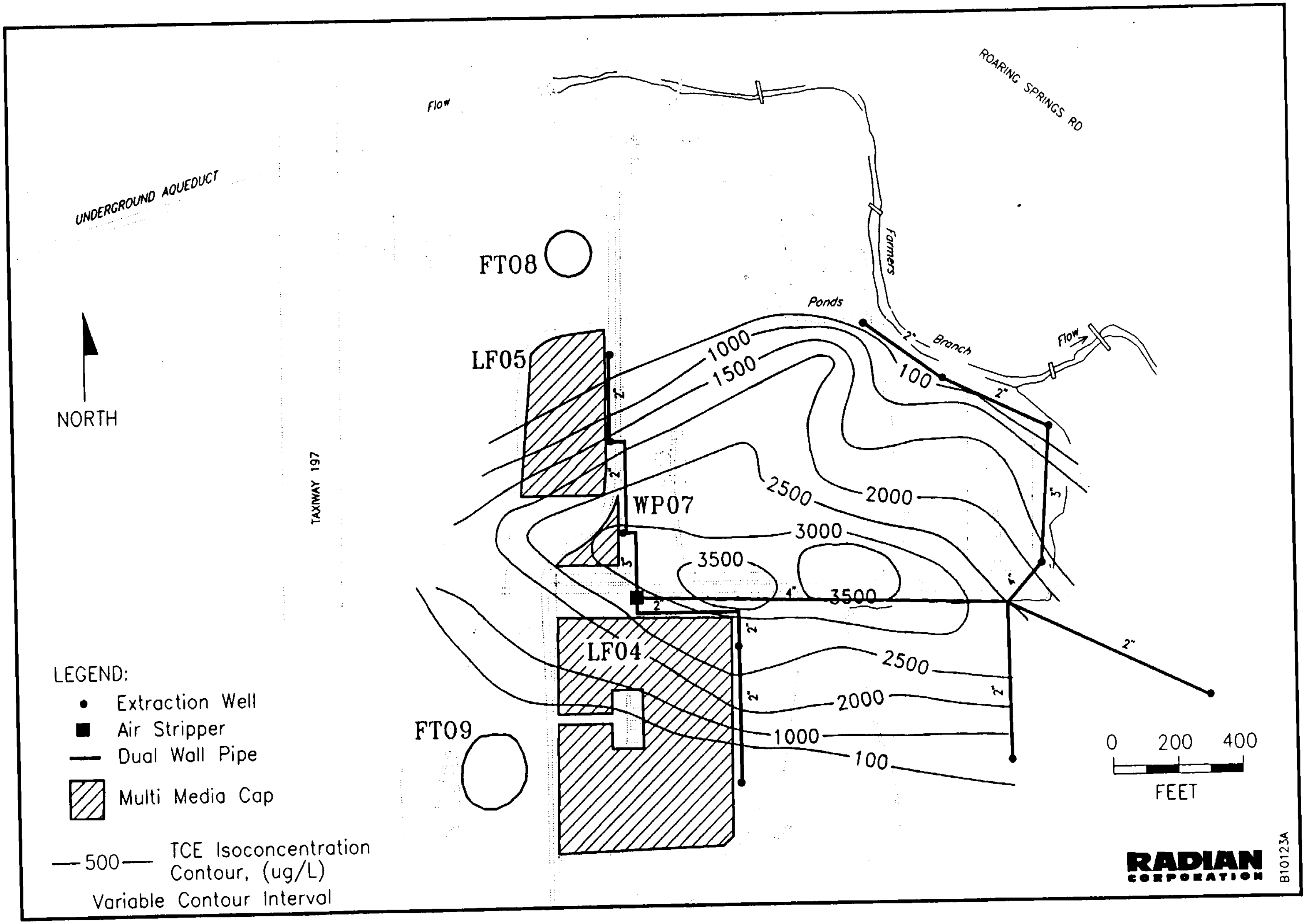

Figure 3-7. Alternative 3B

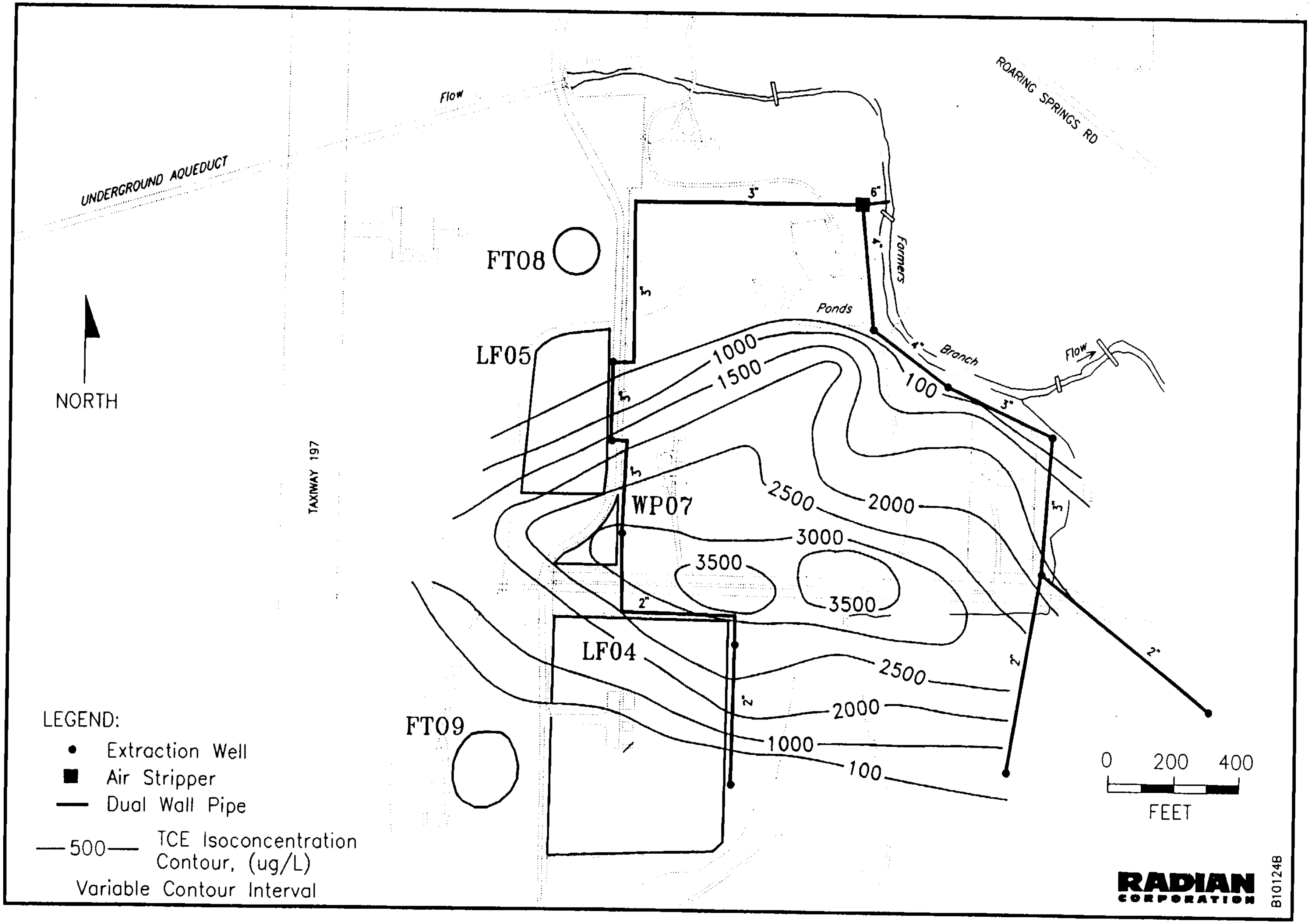

Figure 3-8. Alternative 4A

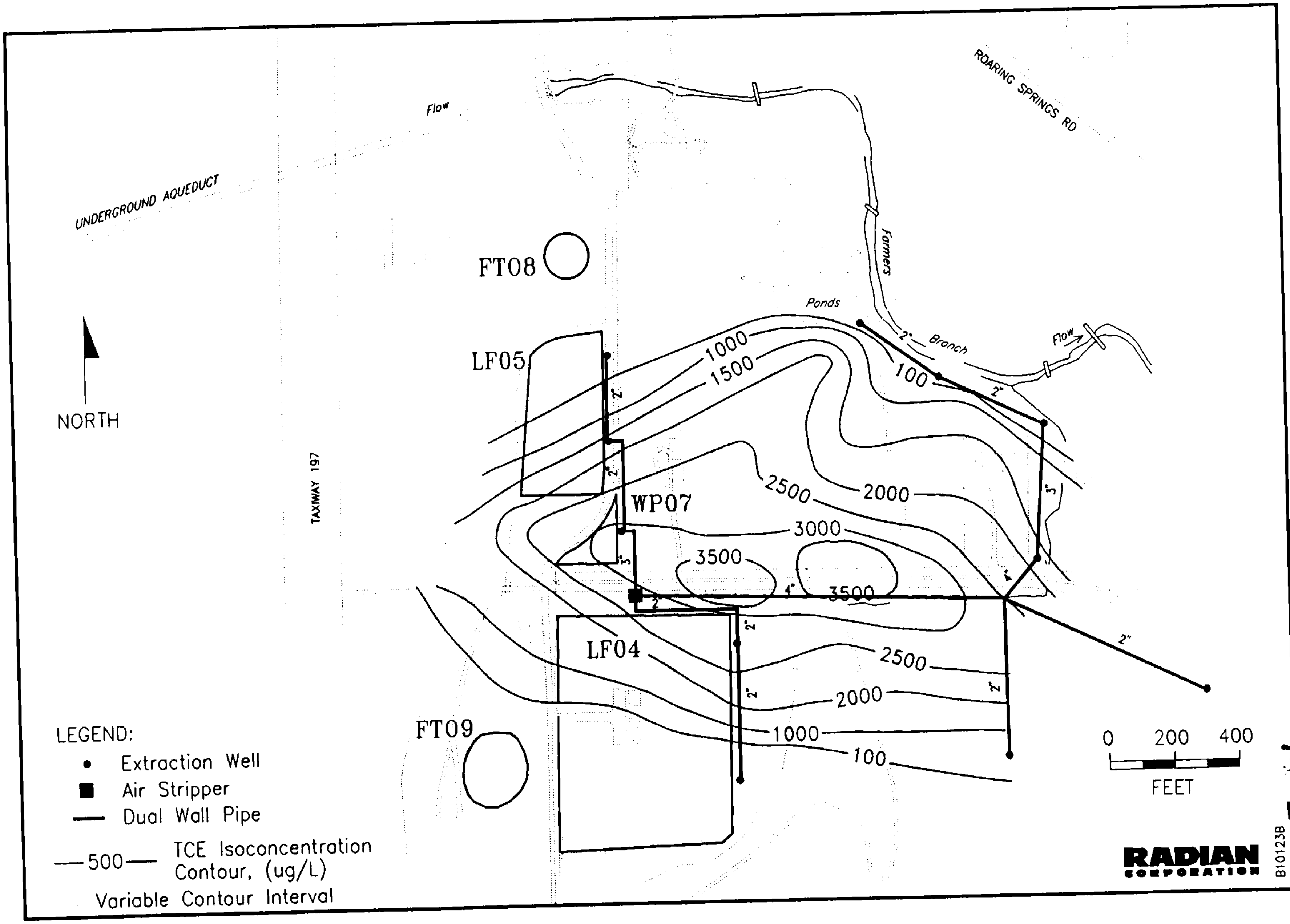

Figure 3-9. Alternative 4B

3.1.6 Alternative 5

Alternative 5A

Alternative 5A (Figure 3-10) is similar to Alternative 4A, except this alternative utilizes a soil/bentonite slurry wall to prevent further migration of contaminants from Sites LF04, WP07, and LF05. One ground-water extraction well is located within the slurry wall around each of the three waste disposal areas. The extraction wells will prevent the accumulation of infiltration and/or ground water within the slurry wall boundaries. The extracted water will be transported to the ASTS for treatment before discharge to Farmers Branch and/or use to irrigate the base golf course.

Alternative 5B

Alternative 5B (Figure 3-11) contains the same components as Alternative 5A except the ASTS is located just north of LF04 allowing for the treated effluent to be discharged into the POTW sewer line and/or used to irrigate the base golf course.

3.1.7 Alternative 6

Alternative 6A

Alternative 6A is shown in Figure 3-12. This alternative utilizes a multi-media cap to prevent further release of contaminants from Sites LF04, WP07, and LF05. This alternative effectively eliminates infiltration and the "flushing" of contaminants into ground water. Extracted ground water from the downgradient extraction system will be transported to the ASTS for treatment before discharge to Farmers Branch and/or use to irrigate the base golf course.

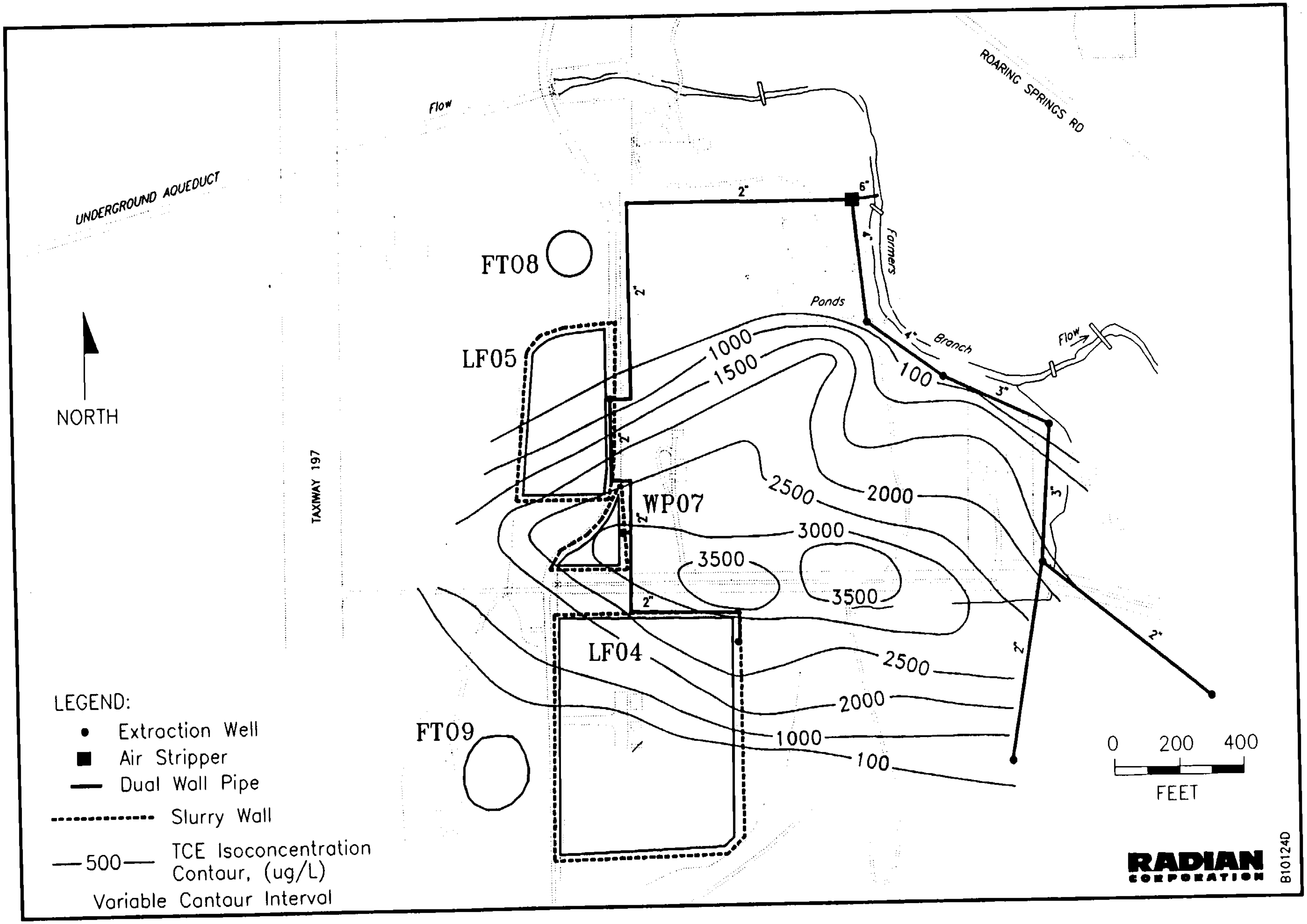

Figure 3-10. Alternative 5A

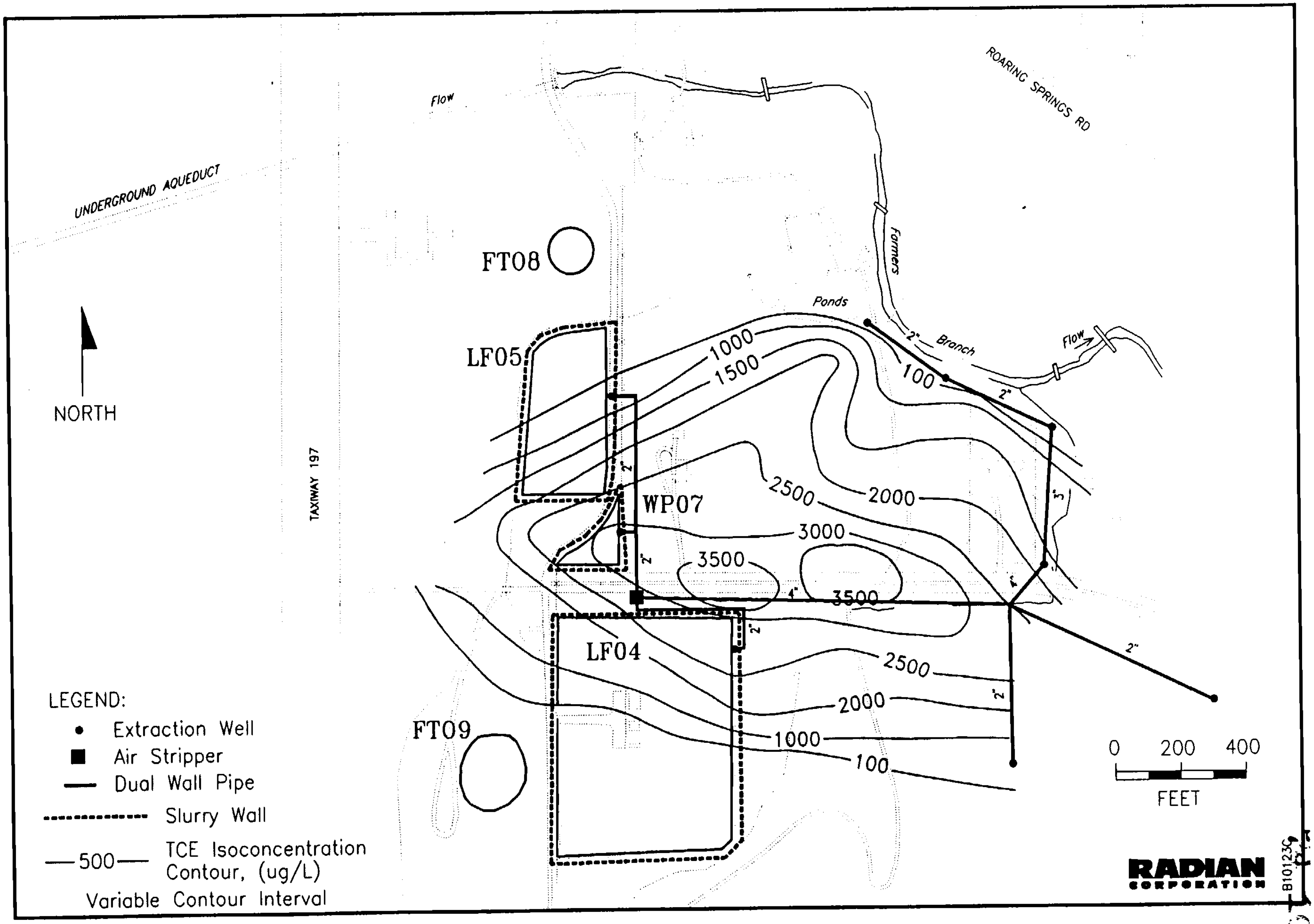

Figure 3-11. Alternative 5B

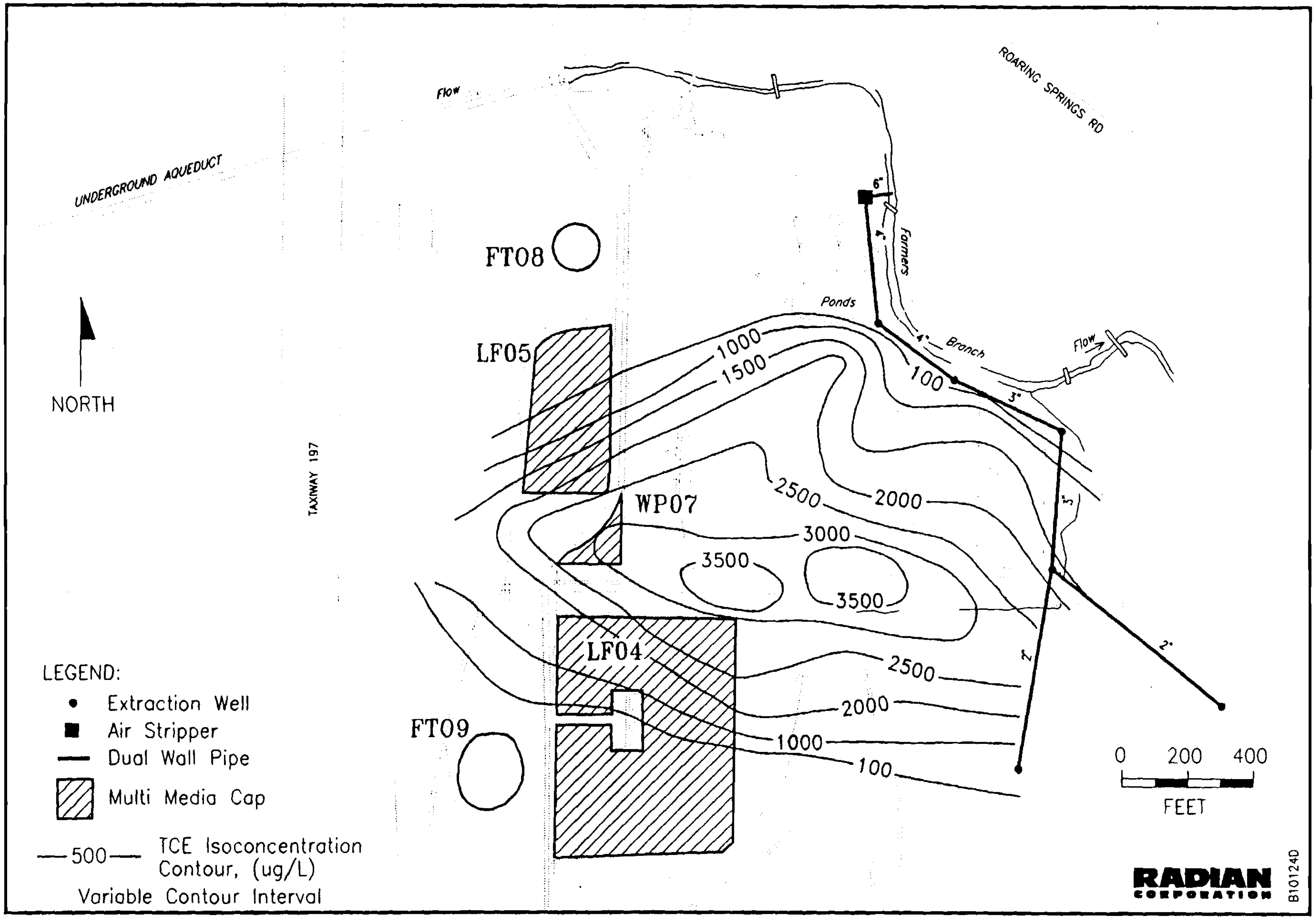

Figure 3-12. Alternative 6A

Alternative 6B

Alternative 6B (Figure 3-13) contains the same components as Alternative 6A except the ASTS is located just north of LF04 allowing the treated effluent to be discharged into the POTW sewer line and/or used to irrigate the base golf course.

3.1.8 Alternative 7

Alternative 7 could include the other components of any of alternatives 2B, 3B, 4B, 5B, or 6B. This alternative, instead of treating the contaminated ground water the extracted water would be discharged directly into the POTW sewer line. The contaminated ground water would be blended with other municipal wastewater before it arrives for treatment at the Village Creek Wastewater Treatment Plant.

3.2 Screening of Alternatives

The purpose of screening the alternatives is to reduce the number of alternatives that will undergo a more thorough and extensive evaluation during the detailed analysis phase of the FS (see Section 4). The alternatives are evaluated against the short- and long-term aspects of three broad criteria: effectiveness, implementability, and cost. Effectiveness is a measure of the degree to which the remedial action protects human health and the environment. Specifically, it is a measure of how well the treatment reduces toxicity, mobility, and volume. Implementability is a measure of the relative ease of installation, operation, and of the time required to reach a given level of improvement. Federal, state, and local regulatory requirements relevant to the remedial action alternatives are also considered when evaluating the implementability of an alternative. The cost of each alternative is used for comparative purposes. During this phase, the cost of each alternative is compared on an order-of-magnitude basis. For example, an alternative will only be eliminated if its cost is one order-of-magnitude or more higher than the other options.

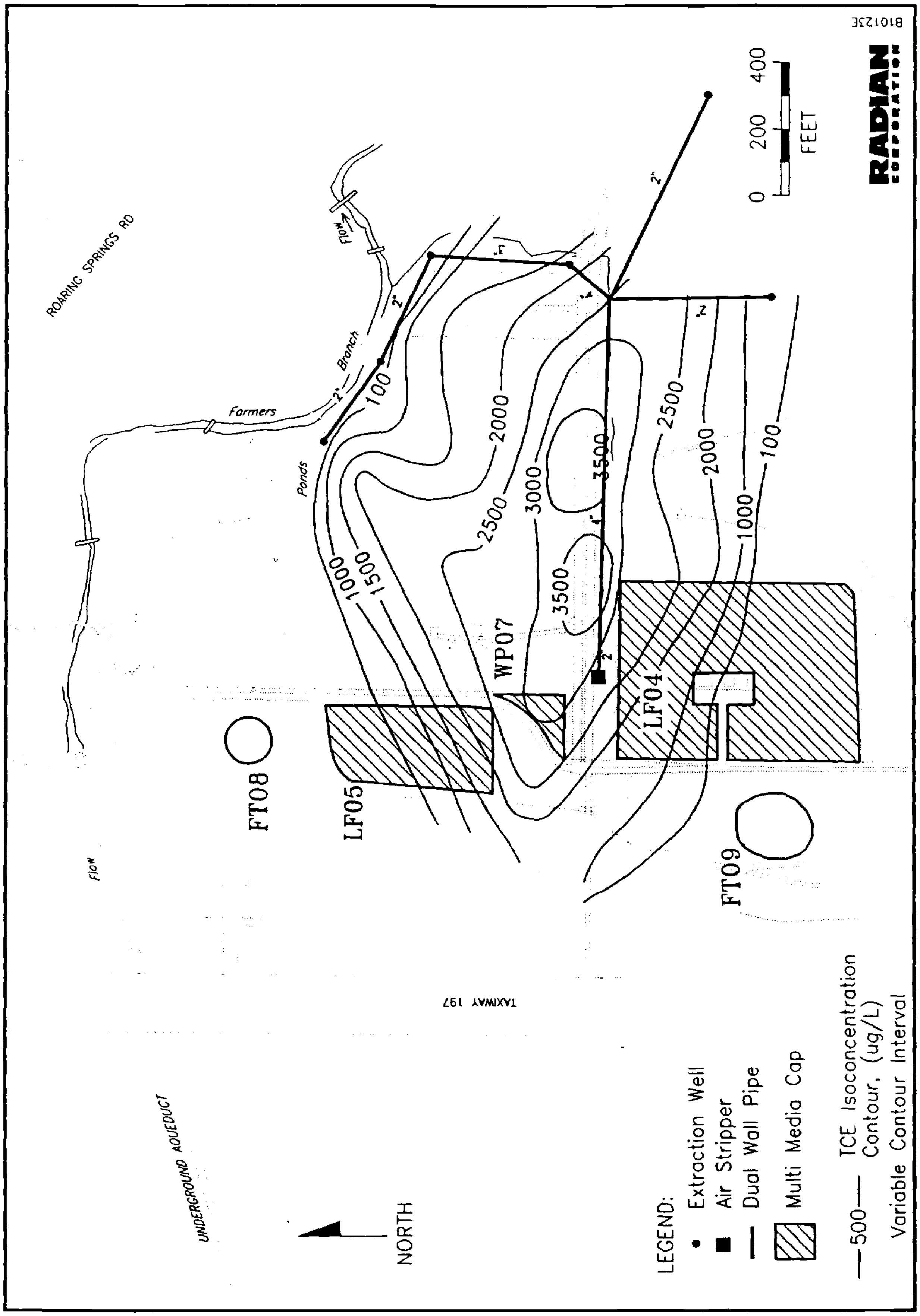

Figure 3-13. Alternative 6B

3.2.1 Effectiveness

Alternative 1

The No Action Alternative allows the continued migration of contaminants and further degradation of Upper Zone ground-water quality. It fails to meet any ARARs, including interim primary drinking water MCLs. This alternative also provides no reduction in toxicity, mobility, or volume of documented contaminants ground-water, surface water and soil in the Flightline Area.

Alternatives 2-6

Alternatives 2-6 include several common components including pumping wells for ground-water extraction, monitor well networks, and treatment by air stripping. The extraction system is designed prevent further migration of the plume and to remediate existing ground-water contamination by withdrawing and treating the contaminated ground water that exists downgradient of Sites LF04, WP07, and LF05. The system can be operated and monitored so that any threats human health or the environment are minimized. Also, the ASTS will effectively reduce the level of volatile organic contaminants in the extracted ground water to concentrations below MCLs before disposal.

The differences between Alternatives 2-6 consist of 1) the technologies used to contain the waste material and 2) the treated effluent disposal method. Discharging the effluent from the ASTS into Farmers Branch or the POTW are both effective options, along with using a portion of the effluent to irrigate the base golf course.

Alternatives 2-6 vary in their level of effectiveness in containing wastes present in Sites LF04, WP07, and LF05. Alternatives 2A/2B and 3A/3B are the most effective options because they utilize both vertical and horizontal barriers to prevent contaminant migration. The impermeable cap will reduce infiltration and the slurry wall (Alternatives 2A/2B) or the ground-water extraction wells (Alternatives 3A/3B) will prevent any leachate from further migration in ground water. Alternatives 4A/4B and 5A/5B only provide a vertical barrier. These alternatives will reduce the amount of contaminant release into the ground water. However, there will be some flow through the waste bodies because no cap is included to prevent infiltration. This additional hydraulic loading may reduce the effectiveness of the vertical barriers. In contrast to Alternatives 4A/4B and 5A/5B, Alternatives 6A/6B only include a multi-media cap to prevent infiltration. While caps have been shown to reduce the amount of contaminant migration by as much as 80 percent, some contaminant mobilization from the waste is possible.

Alternative 7

The main difference between this alternative and Alternatives 2-6 is that the contaminated ground water is not treated before disposal into the POTW. Because the untreated ground water is discharged directly into the POTW, the only reduction in toxicity comes from the dilution of the contaminated ground water with the municipal wastewater. The effectiveness of this option is limited because no ground-water treatment takes place before disposal. Municipal sewer lines are prone to leak, thus contaminants could be reintroduced into the ground along the discharge pipe. In addition, in sufficient concentrations, TCE is toxic to many of the treatment unit processes employed by the Village Creek Treatment Plant.

3.2.2 Implementability

Alternative 1

There are no implementability concerns for the No Action Alternative.

Alternative 2-6

Problems associated with the implementability of Alternatives 2-6 are minimal. There would be some disruption of base activities during the construction of the cap and slurry walls over and around Sites LF04, WP07, and

LF05 (Alternatives 2A/2B, 3A/3B, 5A/5B, and 6A/6B). All ground-water monitoring and pumping wells can be installed with minimal disruption to base activities. However, each of these alternatives consist of some construction activities in secured areas.

Each of these remedial alternatives can be implemented with existing technologies and reliably operated to meet performance requirements, with the exception of Alternatives 6A/6B. Alternatives 6A/6B do not meet performance requirements because they do not provide an effective means by which to control possible leaching of contamination into the ground water. While a cap reduces infiltration, some continuing leachate generation and migration is possible.

Alternative 7

Alternative 7 can be easily implemented and is technically feasible. However, because the ground water is not treated, there are regulatory problems involved with the discharge of contaminated water into the POTW. The sewer lines are not dual contained so the possibility of reintroducing contaminants into the ground exists. Also, before this option could be implemented, approval from the Village Creek Treatment Plant would have to be granted.

3.2.3 Costs

Alternative 1

The cost of the No Action Alternative is negligible.

Alternatives 2-7

At this point, none of these alternatives were eliminated on the basis of cost. None of the 12 alternatives were judged to be an order-of-magnitude higher or lower in cost than the others. The preliminary net present value cost estimates ranged between 2- and 10-million dollars (including operation and maintenance costs). Obviously, Alternatives 2A/2B would be the most expensive because both a cap and a slurry wall are used. Alternative 7 would be the least expensive because the ASTS option is eliminated. Cost estimates were developed for each alternative and are presented in the detailed analysis (Section 4.0)

3.2.4 Results of Alternative Screening

Alternatives 6A, 6B and 7 were eliminated from further evaluation because these alternatives do not adequately meet the effectiveness and implementability criteria listed above.

4.0 DETAILED ANALYSIS OF SELECTED REMEDIAL TECHNOLOGIES

The purpose of this section is to discuss the results of the individual and comparative analyses of the final selected alternatives. Each alternative is described, then how the alternative performs with respect to each of the following criteria is discussed:

- Overall protection of human health and the environment;
- Compliance with Applicable and Relevant and Appropriate Requirements (ARARs);
- Long-term effectiveness and permanence;
- The reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost.

The State Acceptance and Community Acceptance Criteria will be addressed in the ROD once comments on the RI/FS reports and proposed plan have been received. Section 4.1 discusses the criteria upon which the detailed analysis is based. Sections 4.2 through 4.11 assess each remedial alternative by the criteria. In Section 4.12 the remedial alternatives are evaluated relative to each other against expanded versions of these criteria.

4.1 Summary Analysis of Alternatives

The nine remedial alternatives selected for detailed evaluation are listed in Table 4-1. The No Action Alternative must be considered because it

TABLE 4-1. FINAL REMEDIAL ACTION ALTERNATIVES

	Alternatives								
	1	2A	2B	3A	3B	4A	4B	5A	5B
<u>Waste Containment</u>									
Cap Existing Landfills	NA	■	■	■	■				
Slurry Wall Placed Around Perimeter of Landfill	NA	■	■					■	■
Ground-Water Extraction Wells Placed on Perimeter of Landfill	NA			■	■	■	■		
<u>Ground Water</u>									
Monitoring	NA	■	■	■	■	■	■	■	■
Extraction Well System	NA	■	■	■	■	■	■	■	■
On-Site Air Stripping	NA	■	■	■	■	■	■	■	■
<u>Disposal</u>									
Discharge Treated Effluent into Farmers Branch Creek	NA	■		■		■		■	
Discharge Treated Effluent into POTW	NA		■		■		■		■
Seasonal Irrigation of Base Golf Course	NA	■	■	■	■	■	■	■	■

NA = No Action

provides a baseline against which the other alternatives can be compared. The remaining alternatives have several components in common: ground-water monitoring, ground-water extraction wells, and air stripping. These alternatives differ in how the waste remaining in Sites LF04, WP07, and LF05 will be contained, and how the treated ground water will be disposed.

The evaluation of each alternative with respect to the overall protection of human health and the environment focuses on how the alternative can reduce the risk from potential exposure pathways by implementing treatment, engineering, or institutional controls. This evaluation also examines whether the alternatives pose any unacceptable short-term or cross-media effects.

The major federal and state requirements that are relevant and appropriate to each alternative are identified. The ability of each alternative to meet all ARARs, or the need to justify a waiver if some ARARs cannot be achieved, is noted for each.

The long-term effectiveness and permanence of each alternative is evaluated with respect to the magnitude of the residual risk, and the adequacy and reliability of the controls used to manage the remaining untreated ground water and treatment residuals over the long term. Alternatives that afford the highest degree of long-term effectiveness and permanence are those that leave little or no contamination remaining at the site, so long-term maintenance and monitoring are unnecessary. Thus, reliance on institutional controls is minimized.

The discussion of how contaminant toxicity, mobility, or volume will be reduced focuses on the anticipated performance of the treatment technologies. This evaluation relates to the statutory preference for selecting a remedial action that can reduce the toxicity, mobility, or volume of hazardous substances. Other important treatment characteristics are the irreversibility of the treatment process, the type and quantity of residuals resulting from any treatment process, and the amount of waste treated or destroyed.

The evaluation of the short-term effectiveness of the alternatives focuses on the protection of military personnel, workers, and the community during the remedial action, the environmental impacts of implementing the action, and the time required to reach cleanup goals.

The analysis of the implementability of each alternative emphasizes the technical and administrative feasibility of implementing the alternatives, as well as the availability of necessary goods and services. Implementability includes such characteristics as: the ability to construct and operate components of the alternatives; the ability to obtain services, equipment, and specialists; the ability to monitor the performance and the effectiveness of the technologies; and the ability to obtain necessary approval from other agencies.

The cost estimates presented in this report are order-of-magnitude level estimates meant to be used for comparative purposes only. These costs are based on a variety of information, including quotes from suppliers in the area of the site, generic unit costs, vendor information, conventional cost estimating guides, design manuals, and previous experience. The feasibility study level cost estimates shown have been prepared to help guide the project evaluation and implementation. The actual costs of the project will depend on the true labor and material costs, actual site conditions, competitive market conditions, final project scope, the implementation schedule, and other variable factors. A significant uncertainty that will affect the cost is the actual volume of contaminated ground water. Such variables, however, would affect the costs of all the alternatives.

Capital costs include those expenditures required to implement the remedial action. Both direct and indirect costs are considered in the development of capital cost estimates. Direct costs include construction costs or expenditures for the equipment, labor, and materials needed to implement a remedial action. Indirect costs include those associated with engineering, permitting (as required), construction management, and other services necessary to carry out the remedial action.

Annual O&M costs, which include operation labor, maintenance materials and labor, energy, and purchased services, have also been estimated. The estimates include those O&M costs that may be incurred even after the initial remedial activity is complete. Determination of the present worth costs are based on a 30-year period of performance, and a five percent discount rate.

4.2 Alternative 1

4.2.1 Alternative 1 - Description

No remedial activities would be implemented with the No Action Alternative; therefore, the long-term human health and environmental risks for the site would be essentially the same as those identified in the baseline risk assessment.

4.2.2 Alternative 1 - Criteria Assessment

The No Action Alternative does not reduce the risk to human health or the environment. It does not inhibit or prevent continued leachate generation and migration of the contaminant plume, nor further degradation of Upper Zone ground-water quality. This alternative fails to meet any ARARs. Because no controls for exposure and no long term management measures are incorporated, all current and potential future risks remain under this alternative. The No Action Alternative has no provisions for reducing the toxicity, mobility, or volume of the contaminated ground water through treatment.

No additional risks would be posed to the base personnel, the community, the workers, or the environment if this alternative were implemented. No implementability concerns are posed in the No Action Alternative.

The present worth cost and capital cost of Alternative 1 are negligible since no action is required.

4.3 Alternative 2A

4.3.1 Alternative 2A - Description

The components of Alternative 2A are illustrated in Figure 4-1. They consist of:

- An impermeable multi media cap over waste disposal areas LF04 (except for the area taken up by the radar station), WP07, and LF05;
- A soil/bentonite slurry wall around each of the three sites;
- One pumping well within each of the three slurry walls;
- Six Upper Zone ground-water extraction wells;
- A 2-inch/4-inch dual wall containment pipe for conveyance of extracted ground water; and
- An Air Stripping Treatment System (ASTS).

The treated effluent will be discharged to Farmers Branch. However, a portion of the treated ground water may be used to irrigate the base golf course, as needed.

4.3.2 Alternative 2A - Criteria Assessment

This alternative will protect both human health and the environment. The cap and slurry wall will effectively contain residual landfill wastes and waste constituents. The ground-water extraction system will prevent further downgradient migration of the volatile organic contaminant plumes by creating a capture zone. The extraction system will also be

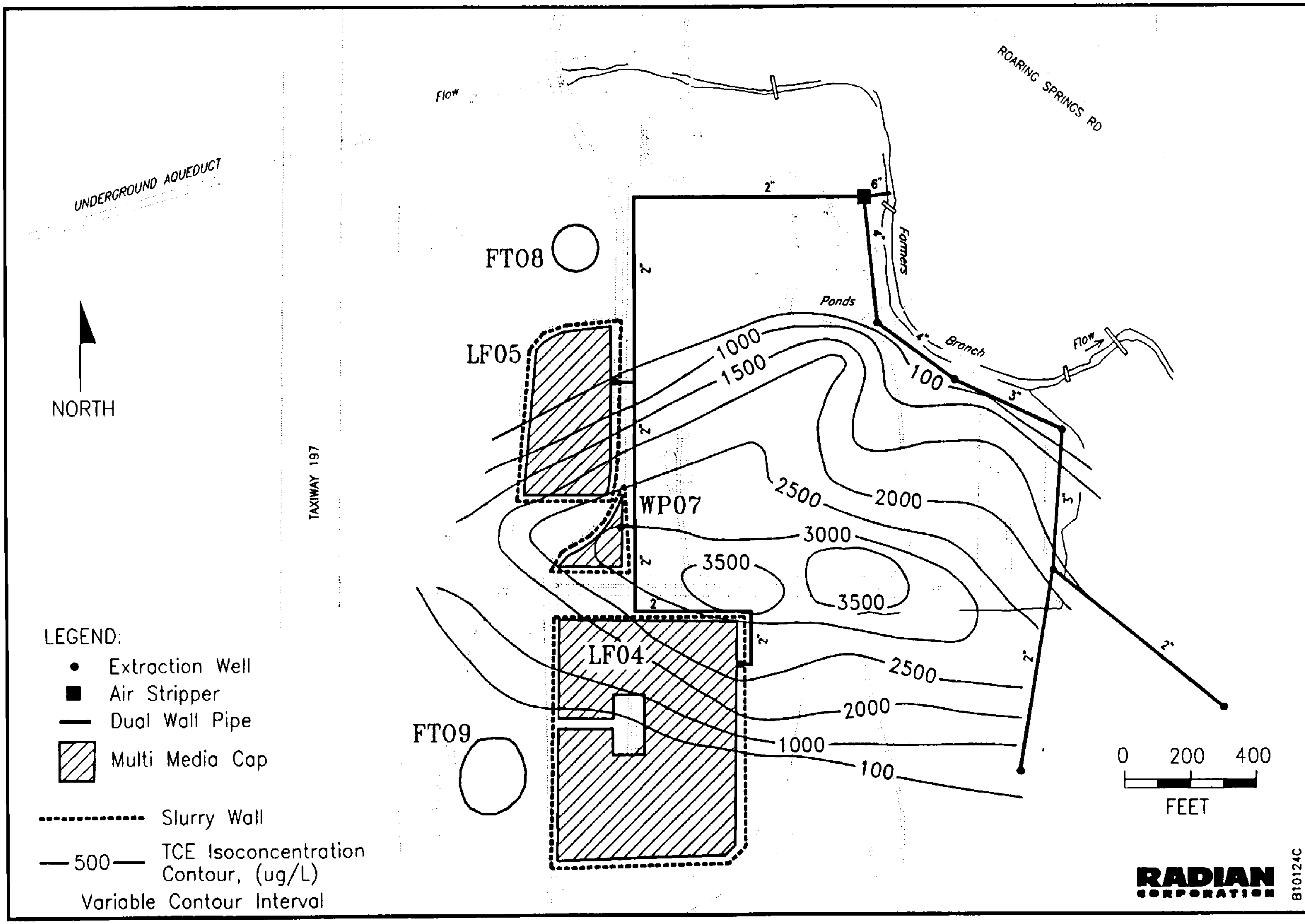

Figure 4-1. Alternative 2A

designed to control ground-water flow so as to prevent contaminated ground water from flowing into Farmers Branch or its tributary, thus effectively eliminating the surface water pathway for potential off-base migration of contaminants in concentrations of concern.

This alternative will meet the MCLs for TCE and the other organic contaminants identified in the Upper Zone ground water. However, because Sites LF04, WP07, and LF05 are not the only source of contamination, the long term effectiveness of this alternative can not be determined at this time. The cap and slurry wall will provide permanent, long term barriers that will significantly reduce or prevent further contaminant migration from the waste disposal sites. The extraction well system will capture the plume and extracted water will be treated to remove contaminants to RAO levels prior to discharge. However, since the source(s) and magnitude of the ground-water contamination upgradient from the Flightline Area IRP sites is not known, the required duration of system operation to achieve acceptable levels can not be determined. To determine the system's long-term effectiveness and to reduce the uncertainty concerning achievement of cleanup goals, the ground-water extraction and treatment systems will be monitored under a long-term program. Necessary modifications to the system will be implemented as required, based on the monitoring results.

This alternative will reduce the toxicity and mobility of TCE and the other contaminants present in the three waste disposal areas and Upper Zone ground water in the Flightline Area. Therefore, little or no potential exists for the extracted contaminants to be reintroduced to the environment.

This alternative involves the use of proven technologies. The multi media cap and the soil/bentonite slurry wall require construction materials that are readily available. The construction of both the cap and the slurry wall will require the presence of heavy machinery in the Flightline Area during construction activities. This may cause some disruption of base activities. The installation of the ground-water extraction wells will require no special techniques, materials, permits, or labor. However, additional pump tests to better define the aquifer properties are recommended.

The additional data generated by the pump tests will be used in a computer simulation to model aquifer response to the ground-water extraction system. This will ensure that the extraction well system is properly designed to capture all Upper Zone ground-water contamination.

Operation of the ground-water extraction system will require frequent monitoring of the Upper Zone ground-water quality to assess the effectiveness of this remedial system, and it will be necessary to control operating parameters to improve the systems effectiveness. Engineering judgement will be required during operation to determine the operating parameters for this alternative, such as pumping rates of the extraction wells, and the air flow rate in the air stripper. The components of the extraction system can be expanded, if additional contamination is discovered.

The air stripper will reduce the contaminant level to below the MCL for each organic contaminant present in the ground water. A NPDES permit will be required so that the treated effluent can be discharged into Farmers Branch. Strict compliance with the NPDES permit is required or a fine may be administered. No permits are required if a portion of the treated water is used to irrigate the base golf course.

The 30-year present worth cost of Alternative 2A is estimated to be $7,380,000, with a projected $5,547,00 for capital expenditures. The annual operating and maintenance cost for the first 10 years of operation is estimated to be $67,000. For the following 20 years, the annual operation and maintenance cost will be reduced to an estimated $52,000. A detailed cost estimate for each component of this alternative is listed in Appendix A, Table A-1. The economical benefits of using a portion of the treated ground water to irrigate the base golf course are not included in the cost estimates.

4.4 Alternative 2B - Description and Criteria Assessment

Alternative 2B (Figure 4-2) includes the same components as Alternative 2A except the ASTS is located just north of Site LF04 allowing the

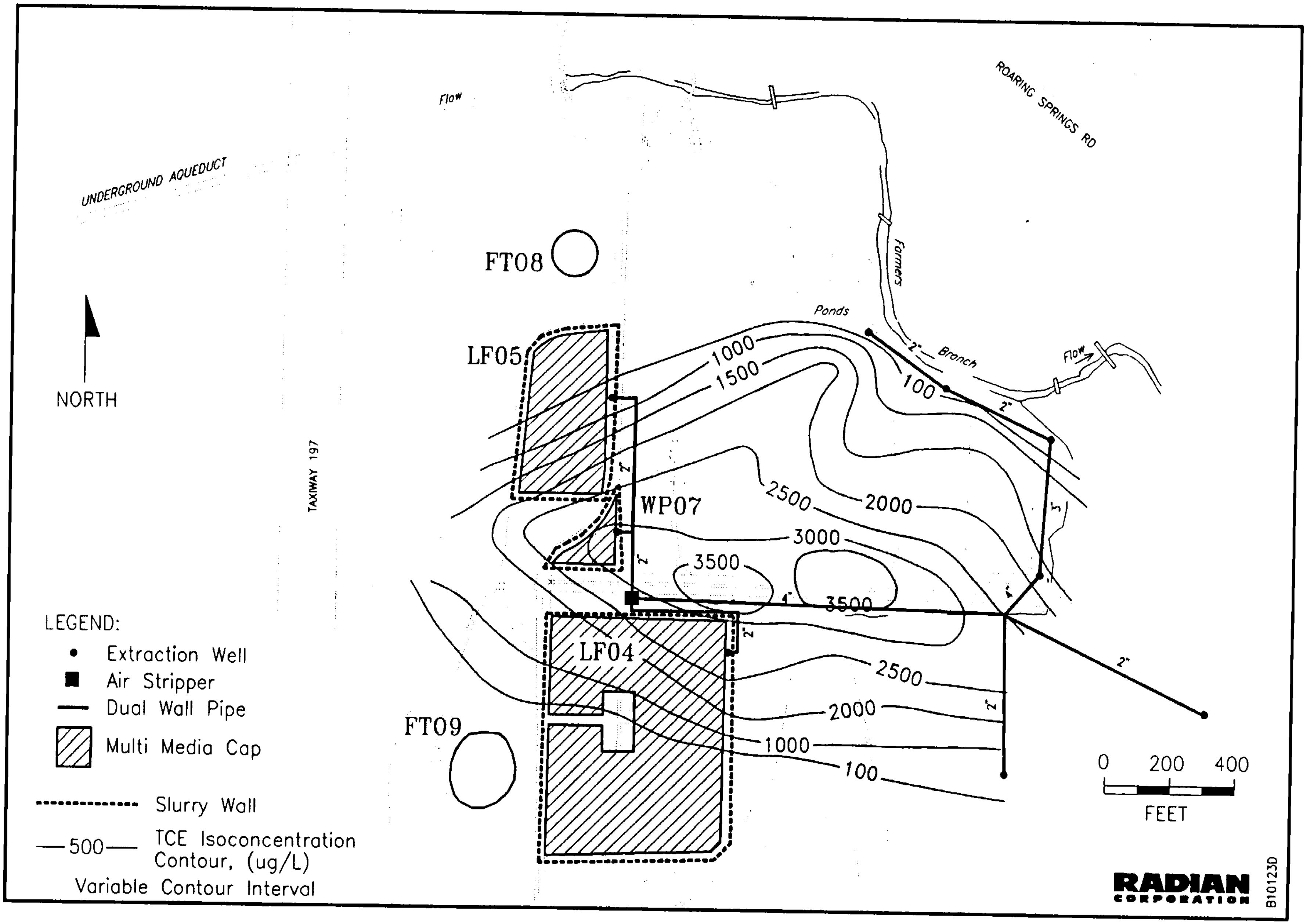

Figure 4-2. Alternative 2B

treated effluent to be discharged into the POTW sewer line and/or to be used for base golf course irrigation.

The criteria assessment for this alternative is the same as Alternative 2A except for the discharge criteria. Because the treated effluent is discharged into the City of Fort Worth POTW, the discharge requirements will probably be less stringent for this alternative than for discharge into Farmers Branch. The 30-year present worth cost of this alternative is estimated to be $7,366,000, with a projected $5,533,000 for capital expenditures. The annual operating and maintenance cost for the first 10 years of operation is estimated to be $67,000. For the 20 years following, the annual operation and maintenance cost will be reduced to an estimated $52,000. A detailed cost estimate for each component of this alternative is listed in Appendix A, Table A-2. The economical benefits of using a portion of the treated ground water to irrigate the base golf course are not included in the cost estimates.

4.5 Alternative 3A

4.5.1 Alternative 3A - Description

The components of this alternative are shown in Figure 4-3. They are the same as Alternative 2A except ground-water extraction wells are used instead of slurry walls to prevent contaminant migration from the three waste disposal areas. Ground-water extraction wells are placed on the downgradient side of each waste disposal area and are designed to capture any contaminants migrating from the three sites in the Upper Zone ground water. The extracted ground water will be transported to the ASTS for treatment before it is discharged into Farmers Branch and/or is used to irrigate the base golf course.

4.5.2 Alternative 3A - Criteria Assessment

The criteria assessment for this alternative is very similar to that of Alternative 2A. In this alternative, ground-water extraction wells

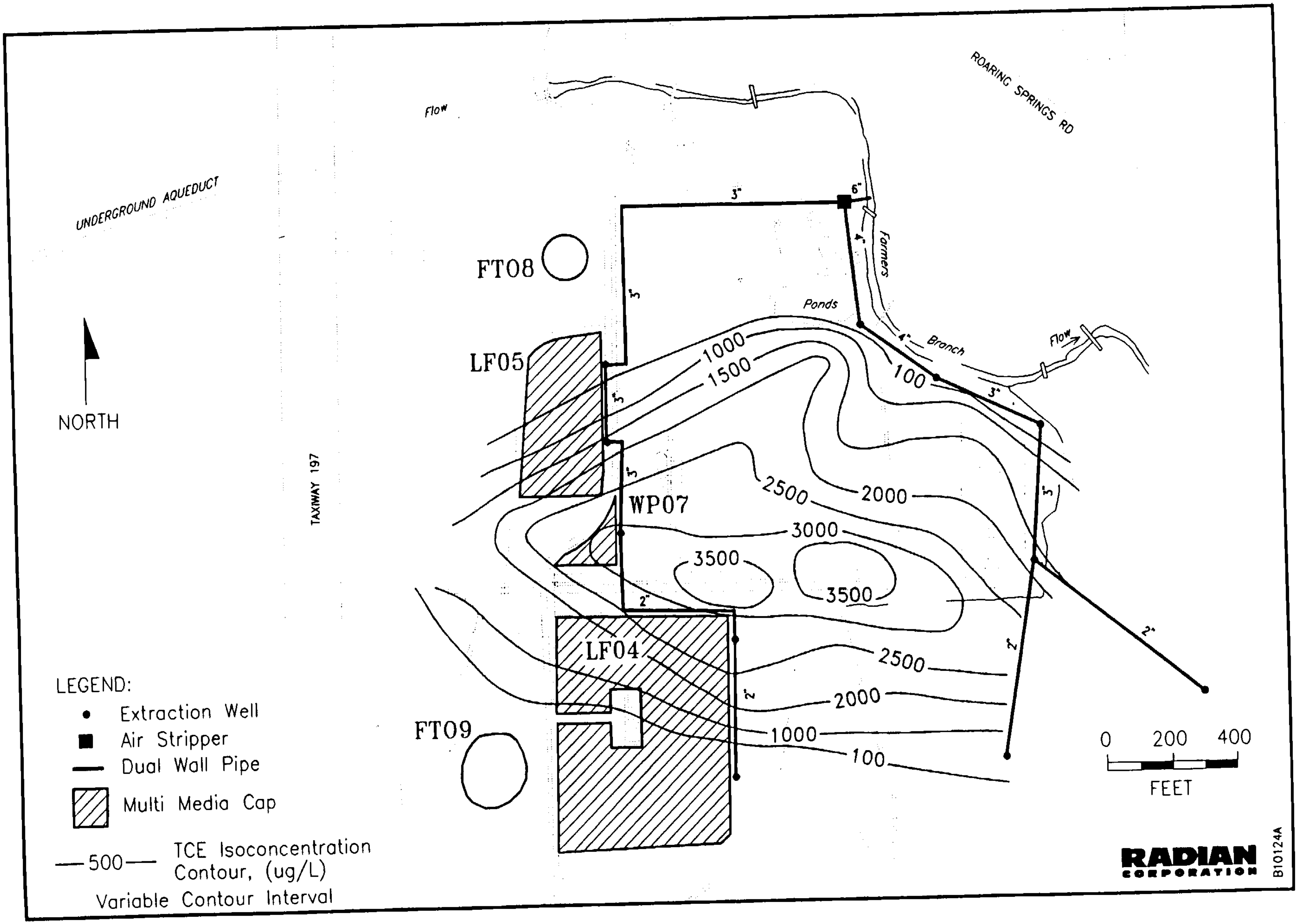

Figure 4-3. Alternative 3A

are placed on the downgradient side of the three waste disposal areas to create a hydraulic barrier that will prevent future contaminant migration in ground water from the three landfills. This hydraulic barrier is judged to be as effective as the slurry wall in Alternative 2A. In addition to capturing contaminants migrating from the disposal areas, it will also capture any contamination that is migrating into the Flightline Area from upgradient, off-site sources (i.e., AF Plant 4). If, as expected, a significant component of Upper Zone ground-water contamination in the Flightline Area has its source on AF Plant 4, the three additional pumping wells included in this alternative provide additional pumping capacity to contain and remove the contaminant plume. However, in contrast to the slurry wall which is permanent, the hydraulic barrier is only effective while the wells are pumping.

The 30-year present worth cost of Alternative 3A is estimated to be $6,368,000 with a projected $4,427,000 for capital expenditures. The annual operating and maintenance cost for the first 10 years of operation is estimated to be $71,000 and for the following 20 years, the annual operation and maintenance cost will be reduced to an estimated $56,000. A detailed cost estimate for each component of this alternative is listed in Appendix A, Table A-3. The economical benefits of using a portion of the treated ground water to irrigate the base golf course are not included in the cost estimates.

4.6 Alternative 3B - Description and Criteria Assessment

Alternative 3B (Figure 4-4) contains the same components as Alternative 3A except the ASTS is located just north of Site LF04, allowing the treated effluent to be discharged into the POTW sewer line and/or to be used to irrigate the base golf course.

The criteria assessment for this alternative is the same as for Alternative 3A except for the discharge criteria. Because the treated effluent is discharged into the City of Fort Worth POTW, the discharge requirements will probably be less stringent for this alternative than for discharging into Farmers Branch. The 30-year present worth cost of this

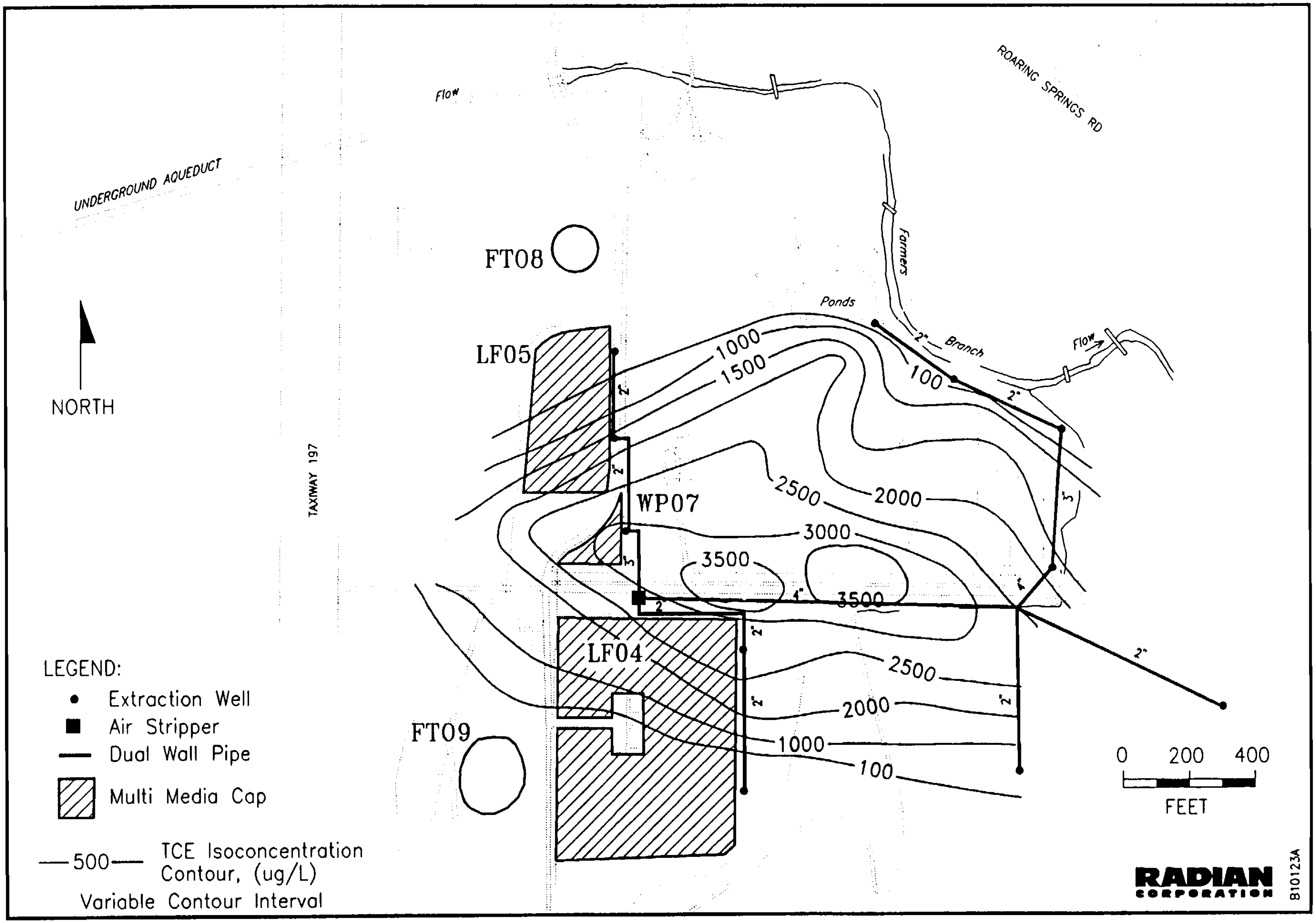

Figure 4-4. Alternative 3B

alternative is estimated to be $6,365,000, with a projected $4,424,000 for capital expenditures. The annual operating and maintenance cost for the first 10 years of operation is estimated to be $71,000. For the next 20 years, the annual operation and maintenance cost will be reduced to an estimated $56,000. A detailed cost estimate for each component of this alternative is listed in Appendix A, Table A-4. The economical benefits of using a portion of the treated ground water to irrigate the base golf course are not included in the cost estimates.

4.7 Alternative 4A

4.7.1 Alternative 4A - Description

The components of Alternative 4A are shown in Figure 4-5. This alternative is similar to Alternative 3A except there are no impermeable caps placed over Sites LF04, WP07, and LF05, thus allowing stormwater to "flush" contaminants from the waste disposal bodies into the ground water. However, ground-water extraction wells, placed on the downgradient side of each of the three areas will be designed to capture any contaminants released from the wastes into ground water. The extracted ground water will be transported to the ASTS for treatment before it is discharged into Farmers Branch and/or is used to irrigate the base golf course.

4.7.2 Alternative 4A - Criteria Assessment

This alternative contains many of the same components as Alternative 3A; therefore, the criteria assessment for this alternative is very similar to that for Alternative 3A. However, the protection of human health and the environment afforded by Alternative 4A is somewhat less than by Alternative 3A because no caps are included. Conversely, infiltration through the three waste disposal areas could potentially enhance mobilization of waste constituents into the ground water, thereby potentially reducing the time to achieve clean-up levels. The ground-water extraction wells placed on the perimeter of Sites LF04, WP07, and LF05 would be designed to remove and capture the increased hydraulic loading.

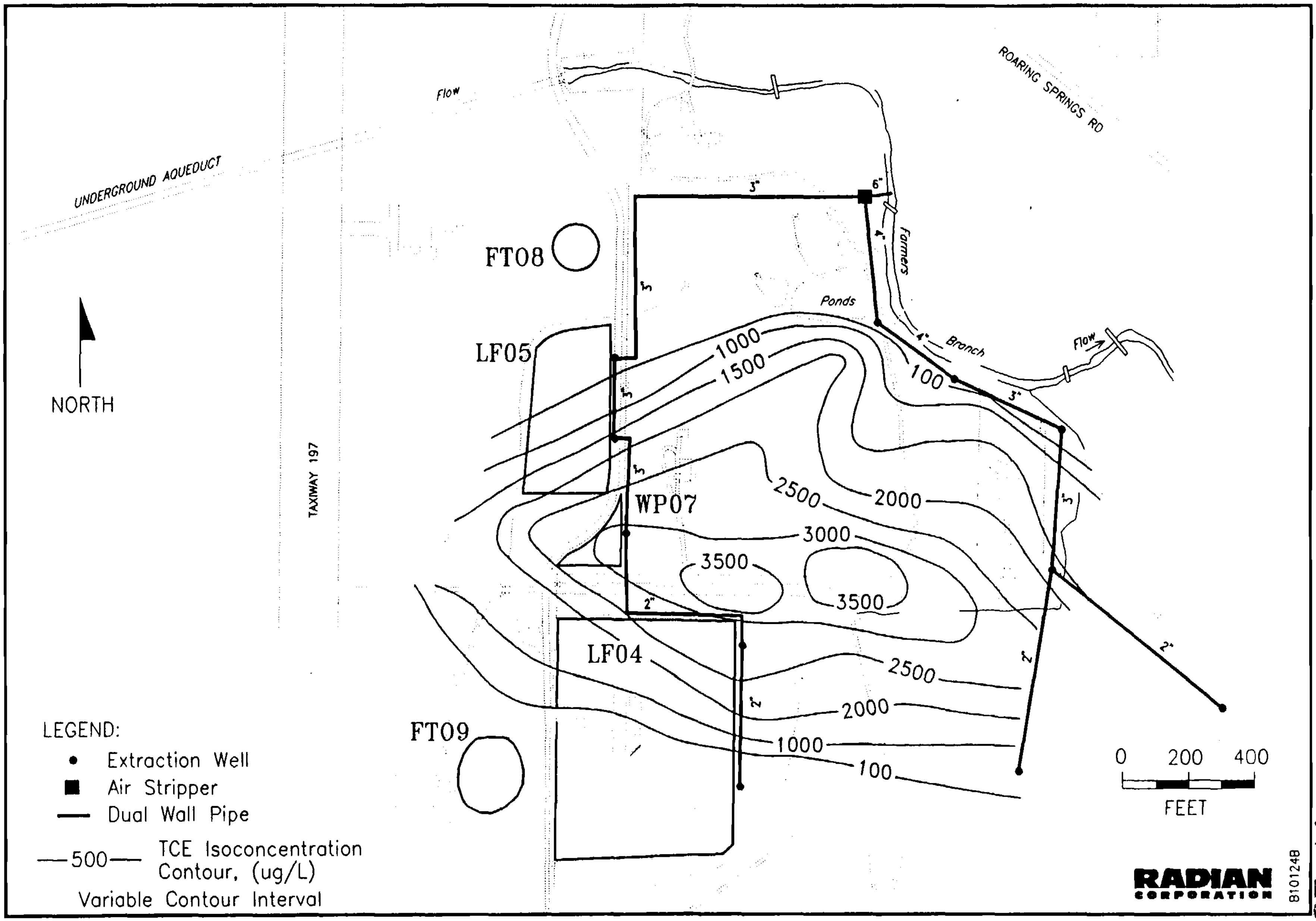

Figure 4-5. Alternative 4A

74 123

This alternative would require much less construction time and would cause minimal disruption to base activities in the Flightline Area. As with the other alternatives, additional pump tests and computer modeling of the extraction system are recommended to ensure the designed extraction system meets the remedial action objectives.

The cost of this alternative is substantially less than the other alternatives. The 30-year present worth cost of Alternative 4A is estimated to be $2,791,000 with a projected $850,000 for capital expenditures. The annual operating and maintenance cost for the first 10 years of operation is estimated to be $71,000 and for the 20 years thereafter, the annual operation and maintenance cost will be reduced to an estimated $56,000. A detailed cost estimate for each component of this alternative is listed in Appendix A, Table A-5. The economical benefits of using a portion of the treated ground water to irrigate the base golf course are not included in the cost estimates.

4.8 Alternative 4B - Description and Criteria Assessment

Alternative 4B (Figure 4-6) contains the same components as Alternative 4A except the ASTS is located just north of Site LF04 allowing the treated effluent to be discharged into the POTW sewer line and/or to be used to irrigate the base golf course.

The criteria assessment for this alternative is the same as Alternative 4A except for the discharge criteria. Because the treated effluent is discharged into the City of Fort Worth POTW, the discharge requirements will probably be less stringent for this alternative than for discharge to Farmers Branch. The 30-year present worth cost of this alternative is estimated to be $2,788,000, with a projected $847,000 for capital expenditures. The annual operating and maintenance cost for the first 10 years of operation is estimated to be $71,000 and for the following 20 years, the annual operation and maintenance cost will be reduced to an estimated $56,000. A detailed cost

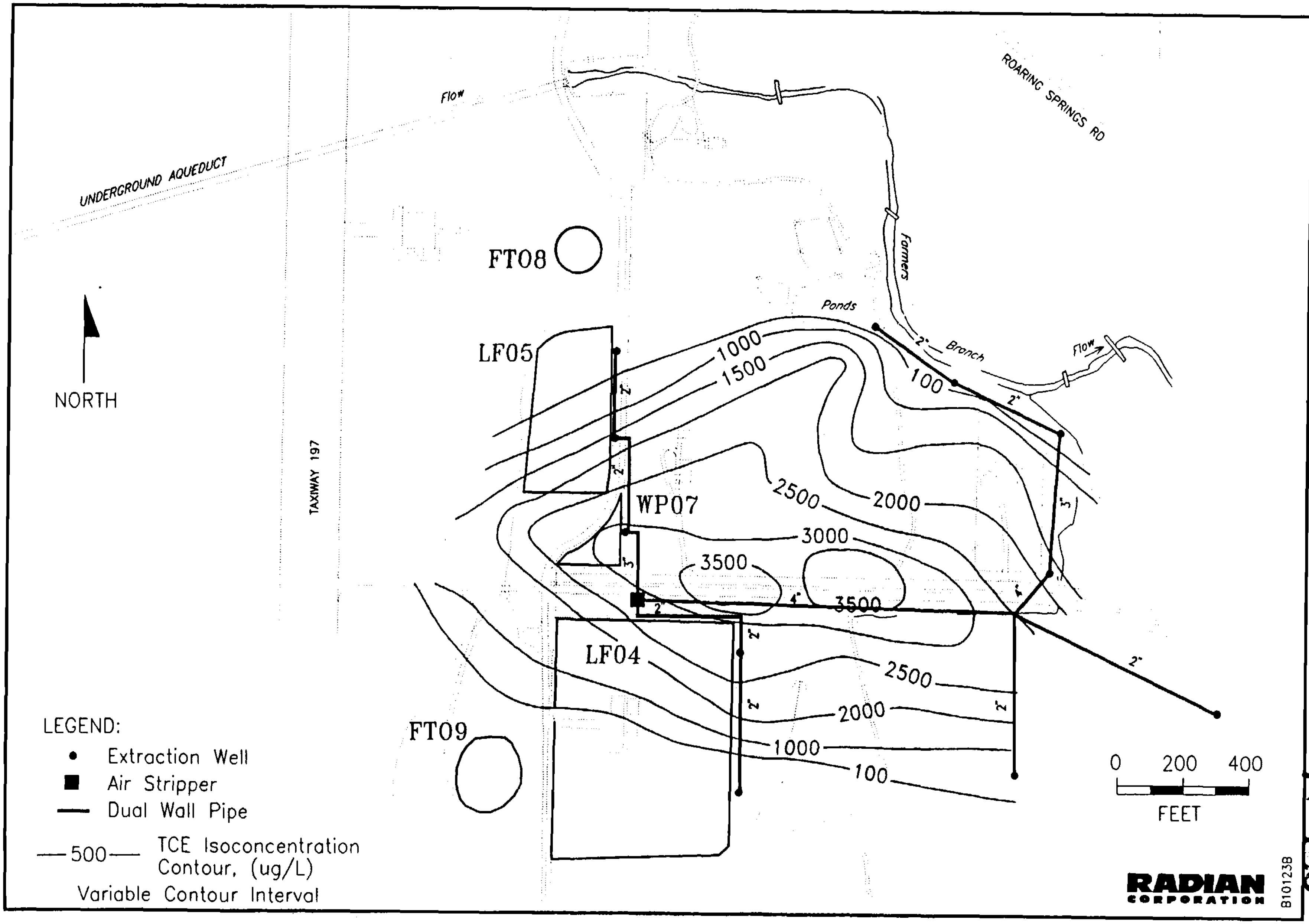

Figure 4-6. Alternative 4B

estimate for each component of this alternative is listed in Appendix A, Table A-6. The economical benefits of using a portion of the treated ground water to irrigate the base golf course are not included in the cost estimates.

4.9 Alternative 5

4.9.1 Alternative 5A - Description

Alternative 5A (Figure 4-7) is similar to Alternative 4A except this alternative utilizes a soil/bentonite slurry wall to prevent future migration of contaminants from Sites LF04, WP07, and LF05. One ground-water extraction well is located within the slurry wall at each of the three waste disposal areas. The extraction wells will prevent the accumulation of water within the slurry wall boundaries. The extracted water will be transported to the ASTS for treatment before it is discharged into Farmers Branch and/or is used to irrigate the base golf course.

4.9.2 Alternative 5A - Criteria Assessment

The criteria assessment for this alternative is very similar to the criteria assessment for Alternative 5A. The only difference between the two alternatives is no impermeable caps are included in Alternative 5A. This should decrease the construction time to approximately two to four months; however, there would still be a significant amount of disruption of base activities in the Flightline Area.

The slurry wall will effectively isolate the three waste disposal areas and prevent ground-water contaminant escape from the disposal site. The extraction well placed inside each of the slurry walls is an integral part in this alternative because of the increased infiltration that will result without the installation of impermeable caps.

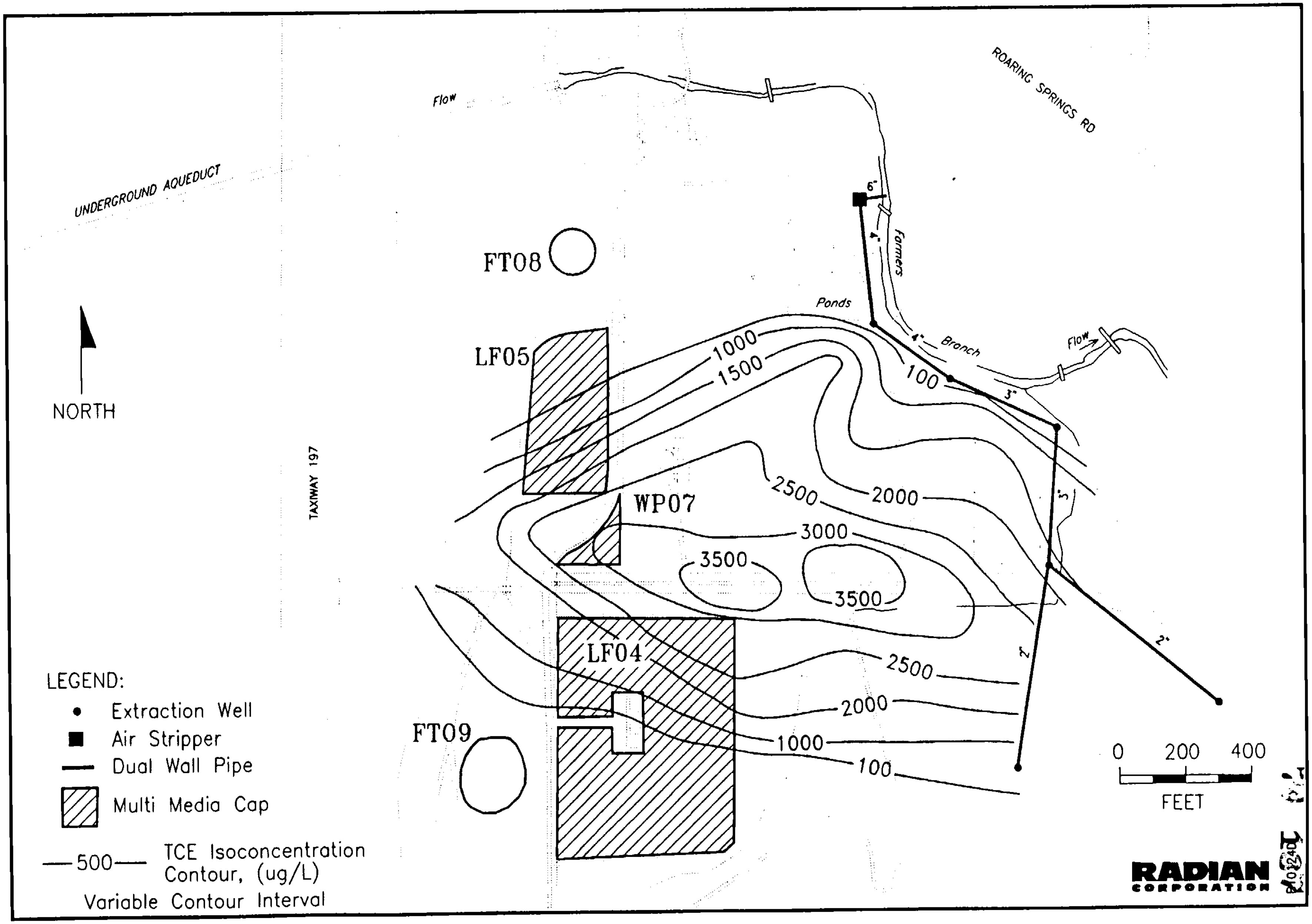

Figure 4-7. Alternative 5A

The 30-year present worth cost of Alternative 5A is estimated to be $3,803,000, with a projected $1,970,000 for capital expenditures. The annual operating and maintenance cost for the first 10 years of operation is estimated to be $67,000 and for the 20 years after that, the annual operation and maintenance cost will be reduced to an estimated $52,000. A detailed cost estimate for each component of this alternative is listed in Appendix A, Table A-7. The economical benefits of using a portion of the treated ground water to irrigate the base golf course are not included in the cost estimates.

4.10 Alternative 5B - Description and Criteria Assessment

Alternative 5B (Figure 4-8) contains the same components as Alternative 5A except the ASTS is located just north of Site LF04 allowing the treated effluent to be discharged into the POTW sewer line and/or used to irrigate the base golf course.

The criteria assessment for this alternative is the same as Alternative 5A except for the discharge criteria. Because the treated effluent is discharged into the City of Fort Worth POTW, the discharge requirements will probably be less stringent for this alternative than for discharge into Farmers Branch. The 30-year present worth cost of this alternative is estimated to be $3,789,000, with a projected $1,956,000 for capital expenditures. The annual operating and maintenance cost for the first 10 years of operation is estimated to be $67,000 and for the next 20 years will be reduced to an estimated $52,000 annually. A detailed cost estimate for each component of this alternative is listed in Appendix A, Table A-8. The economical benefits of using a portion of the treated ground water to irrigate the base golf course are not included in the cost estimates.

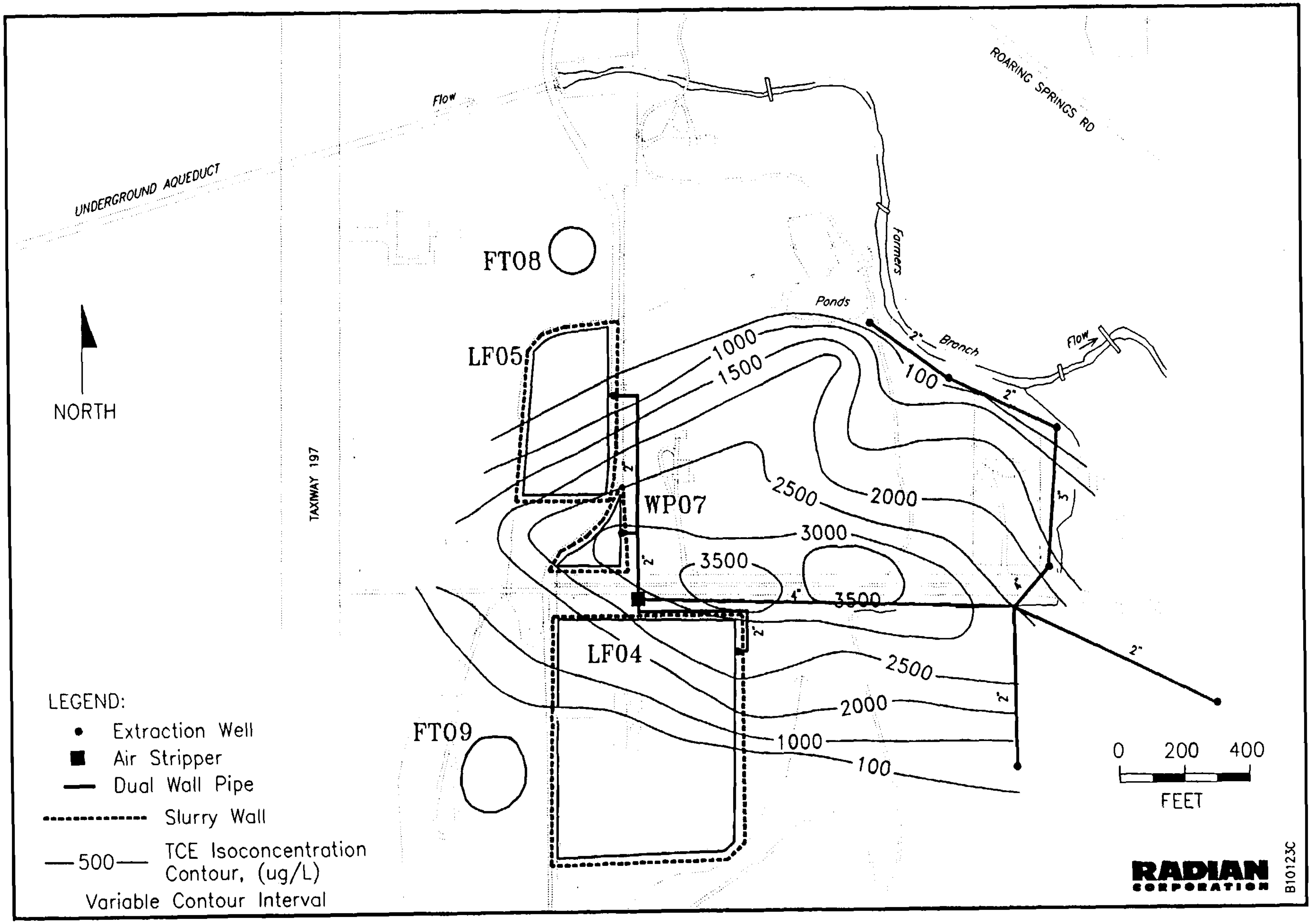

Figure 4-8. Alternative 5B

4.11 Comparative Analysis

A matrix evaluation was conducted on the remedial alternatives discussed in the preceding sections. The matrix approach provides information about each alternative in relation to a set of expanded evaluation criteria. Evaluations were performed using information presented in this report and engineering experience.

4.11.1 Matrix Approach

Up to this point, each alternative has been individually evaluated with respect to the criteria listed below:

- Overall protection of human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost.

For the comparative analysis or matrix evaluation, the above criteria were expanded to provide a more detailed comparison of the alternatives. Table 4-2 presents a comparison of the initial evaluation criteria (above) with the expanded evaluation criteria that are included in the matrix approach. For example, the initial criterion for evaluating the long-term effectiveness of the remedial alternative was expanded to include off-site impacts, need for further study, and products generated from the alternative. An explanation of each evaluation parameter follows.

TABLE 4-2. COMPARISON OF INITIAL AND EXPANDED EVALUATION CRITERIA

Initial Criteria	Expanded Evaluation Criteria
Overall protection of human health and the environment.	Technology status, reliability, regulatory and public acceptance.
Compliance with ARARs.	Compliance with ARARs.
Long-term effectiveness and permanence.	Off-site impacts, need for further study, products generated.
The reduction of toxicity, mobility, or volume through treatment.	Products generated.
Short-term effectiveness.	Constructability, reliability, off-site impacts.
Implementability.	Constructability, impacts to base operations, regulatory and public acceptance, permitting requirements.
Cost.	Cost.

Technology Status

Each technology that is part of a remedial alternative was evaluated according to how well it protects both human health and the environment and its reliability. 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 and tested at sites with similar conditions. A technology was considered experimental if it had only been demonstrated in the lab as a bench-scale unit, 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 surface water discharge. Alternatives will be evaluated for their ability to be protective of public/human health, welfare, and the environment in this evaluation.

Constructability

The constructability criterion evaluates the ease with which an alternative can be constructed and operated. Physical access to construction areas, availability of materials, and availability of appropriate human resources are evaluated.

Off-Site 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 pump test data, pilot-scale testing, and computer modeling are needed before the action can be implemented.

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. To a large extent, acceptance will be based on the actual and perceived capability of the alternative to provide protection of human health and the environment.

Permitting Requirements

The number, type, and anticipated difficulty in acquiring permits for each removal action alternative is evaluated by this criterion.

Costs

Capital, annual operation and maintenance, and present worth costs were determined for each alternative. Detailed cost estimates are listed in Appendix A. Cost estimates were developed to within 50 percent of the actual costs, but do not necessarily represent a budgetary estimate for construction.

Table 4-3 is a blank evaluation matrix table showing the eight alternatives (the No Action Alternative is not included), evaluation parameters, weighing factors, cost measures, the effectiveness total column, and the effectiveness to cost quotient column. The capital, operation and maintenance, and net present value costs for each alternative discussed earlier in the report are summarized in the table under the appropriate column headings. Using the matrix approach, evaluation scores for the eleven criteria are developed for each alternative. Table 4-4 lists the scoring basis for each of the evaluation criteria parameters. These scores are multiplied by a weighing factor (top row on Table 4-3) and summed to determine the effectiveness total. 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 the effectiveness "total score" divided by the

TABLE 4-3. REMEDIAL ALTERNATIVES COMPARATIVE EVALUATION MATRIX

Primary Alternatives	Cap-ital ($ M)	O&M ($ M)	NPV ($ M)	Tech-nology Status	Compli-ance with ARARs	Con-struct-ability	Off-Site Impacts	Need for Further Study	Impacts to Base Opera-tion	Products Gener-ated	Relia-bility	Regula-tory Accep-tance	Permit-ting Re-quire-ments	Effec-tive-ness Total	Effec-tive-ness Total/ Cost Total
Weighting Factors															
2A: Cap/-Slurry Wall/-Treatment/ Farmers Branch															
2B: Cap/-Slurry Wall/-Treatment/POTW															
3A: Cap/GW Ex/Treatment/ Farmers Branch															
3B: Cap/GW Ex/Treatment/ POTW															
4A: GW Ex/ Treatment/ Farmers Branch															
4B: GW Ex/ Treatment/ POTW															
5A: Slurry Wall/ Treatment/ Farmers Branch															
5B: Slurry Wall/ Treatment/ POTW															

O&M = Annual Operation and Maintenance Cost

NPV = Net Present Value

TABLE 4-4. CARSWELL AFB FLIGHTLINE AREA REMEDIAL ALTERNATIVES 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. Constructability	3 - No impediments
	2 - Some impediments
	1 - Severe impediments
4. Off-Site 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. Impacts to Carswell AFB 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

(Continued)

TABLE 4-4. (Continued)

Parameter	Scoring Basis
7. Products Generated	3 = No residuals are produced requiring treatment and/or off-site disposal
	2 = One to two residuals are produced requiring minimal treatment and/or off-site disposal
	1 = More than two residuals are produced requiring treatment and/or off-site disposal
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 = Discharge permits to sanitary sewer system and renegotiation of fee ordinances required.
	1 = NPDES permit required for perpetual high volume discharges to Farmers Branch Creek

NPDES = National Pollution Discharge Elimination System 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.

The results of the comparative analysis using the matrix approach are presented in Table 4-5. Using this approach, Alternative 4B is shown to be the most cost effective.

TABLE 4-5. RESULTS OF REMEDIAL ALTERNATIVES COMPARATIVE EVALUATION

Primary Alternatives	Capital ($ M)	O&M ($ M)	NPV ($ M)	Technology Status	Compliance with ARARs	Constructability	Off-Site Impacts	Need for Further Study	Impacts to Base Operation	Products Generated	Reliability	Regulatory Acceptance	Permitting Requirements	Effectiveness Total	Effectiveness Total/Cost Total
Weighting Factors	1	1	1	4	4	4	3	2	3	3	3	5	5		
2A: Cap/-Slurry Wall/-Treatment/Farmers Branch	5.546	1.833	7.380	3	3	1	2	2	1	2	3	2	1	71	9.8
2B: Cap/-Slurry Wall/-Treatment/POTW	5.329	1.833	7.366	3	3	1	2	2	1	2	3	3	2	81	11.0
3A: Cap/GW Ex/Treatment/Farmers Branch	4.427	1.941	6.368	4	3	2	2	2	2	3	3	2	1	85	13.6
3B: Cap/GW Ex/Treatment/POTW	4.424	1.941	6.365	4	3	2	2	2	2	3	3	3	2	95	15.2
4A: GW Ex/Treatment/Farmers Branch	0.850	1.941	2.791	4	2	3	3	2	3	3	2	2	1	88	32.5
4B: GW Ex/Treatment/POTW	0.847	1.941	2.788	4	2	3	3	2	3	3	2	3	2	98	36.1
5A: Slurry Wall/Treatment/Farmers Branch	1.970	1.833	3.803	3	3	1	2	2	1	2	3	2	1	71	18.7
5B: Slurry Wall/Treatment/POTW	1.956	1.833	3.789	3	3	1	2	2	1	2	3	3	2	81	21.4

O&M = Annual Operation and Maintenance Cost

NPV = Net Present Value

BIBLIOGRAPHY

CH2M Hill. "Installation Restoration Program Records Search for Carswell Air Force Base, Texas" prepared for: Strategic Air Command, Deputy Chief of Staff, Engineering and Services, Offutt Air Force Base, Nebraska 68113, Contract No. F08637-80-G0010-5009, February 1984.

Federal Register, Vol. 52, No. 130, July 8, 1987.

Federal Register, Vol. 56, No. 20, January 30, 1991

Freeze, R.A. and J.A. Cherry. Groundwater, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1979.

Hargis & Associates, Inc. "Preliminary Results of Recent Drilling and Sampling Activities, U.S. Air Force Plant No. 4, Fort Worth, Texas," letter report to General Dynamics Corporation, April 12, 1985.

Hargis & Associates, Inc. "Summary of Interim Remedial Investigations, January 1987 to April 1989, U.S. Air Force Plant 4, Fort Worth, Texas, April 1989.

Means Site Work Cost Data, 95th Annual Edition, 1990.

Oak Ridge National Laboratory. "Users Manual for the Defense Priority Model," prepared for U.S. Air Force OEHL, Brooks AFB, Texas, August, 1987.

Radian Corporation. Evaluating Cost-Effectiveness of Remedial Actions at Uncontrolled Hazardous Waste Sites, EPA Solid and Hazardous Waste Research Division, Municipal Environmental Research Laboratory, Cincinnati, OH, 1983.

Radian Corporation. "Installation Restoration Program for Carswell Air Force Base, Texas: Phase II - Confirmation/Quantification Stage 1," prepared for Strategic Air Command, Command Surgeons Office (HQSAC/SGPB), Offutt Air Force Base, Nebraska 68113, Contract No. F33615-84-D-4402, October 1986.

BIBLIOGRAPHY (Continued)

Radian Corporation. "Installation Restoration Program for Carswell Air Force Base, Texas: RI/FS Stage 2," Prepared for Headquarters Strategic Air Command (HQ SAC/DE), Offutt Air Force Base, Nebraska, 68113-5001, 1989.

Radian Corporation. Decision Summary, Technical Document to Support No Further Action, U.S. Air Force Installation Restoration Program, Site 3, Landfill 3, Carswell AFB, Texas, 1990a.

Radian Corporation. Decision Summary, Technical Document to Support No Further Action, U.S. Air Force Installation Restoration Program, Site 11, Fire Department Training Area, Carswell AFB, Texas, 1990b.

Radian Corporation. U.S. Air Force Installation Restoration Program Remedial Investigation/Feasibility Study, Site 12, Carswell AFB, Texas Decision Paper, April 1990c.

Radian Corporation. Draft Installation Restoration Program (IRP) Stage 2 Remedial Investigation for the Flightline Area, 1991.

Title 40 Code of Federal Regulations, Part 141 - National Primary Drinking Water Regulations, 1989.

U.S. EPA. Superfund Public Health Evaluation Manual. Office of Emergency and Remedial Response, EPA/540/1-86/060, Washington, D. C., 1986a.

U.S. EPA. "Quality Criteria for Water." EPA 440/5-86-001, May 1, 1986b.

U.S. EPA. Handbook Remedial Action at Waste Disposal Sites (Revised), Office of Emergency and Remedial Response, EPA/625/6-85/006, Washington, D. C., 1986c.

U.S. EPA. Treatment Technology Briefs, Alternatives to Hazardous Waste Landfills, Hazardous Waste Engineering Research Laboratory, EPA/600/8-86/017, Cincinnati, OH, 1986d.

BIBLIOGRAPHY (Continued)

U.S. EPA. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Office of Emergency and Remedial Response, EPA/540/G-89/004, Washington, D. C., 1988.

U.S.D.A. Soil Survey for Tarrant County, Texas, June, 1981.

COST ESTIMATES

Cost estimates for each of the eight alternatives are presented in Tables A-1 through A-8. The cost estimates include both capital and operation and maintenance costs. In addition, a present worth analysis was performed. In conducting the present worth analysis, assumptions were made regarding the discount rate and the period of performance. The Superfund program recommends that a discount rate of 5 percent be assumed along with a 30 year period of performance. The accuracy of these "study estimate" costs is expected to within 50 percent. The costs presented in Tables A-1 through A-8 were developed from Means Site Work Cost Data, 1990; 95th Annual Edition and vendor quotes.

TABLE A-1. COST ESTIMATE FOR ALTERNATIVE 2A

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Multi Media Cap				
LF04	SF	350,000	2.74	959,000
WP07	SF	20,000	2.74	54,800
LF05	SF	125,000	2.74	342,500
Subtotal				1,356,300
Multiplier				1.4
Cap Total				1,898,820
Cut-Off-Wall				
LFO4	LF	2,400	100	240,000
WP07	LF	650	100	65,000
LF05	LF	1,500	100	150,000
Ground-Water Extraction Wells Placed Inside Cut-Off-Wall				
Extraction Wells	EA	3	2,000	6,000
Well Pumps	EA	3	2,500	7,500
Plastic Dual Wall Pipe	LF	2,475	32	79,200
2-in/4-in Diameters	LF	2,475	2.45	6,064
Excavation Backfill (1-foot wide, 3-foot deep)	LF	2,540	2.45	6,223
Cut-Off-Wall Subtotal				553,764
Multiplier				1.40
Total				775,269
Ground-Water Withdrawal System				
Extraction Wells	EA	6	2,000	12,000
Well Pumps	EA	6	2,500	15,000
Plastic Dual Wall Pipe				
2 in/4-inch Diameters	LF	1,205	32	38,560
3 in/4-inch Diameters	LF	755	35	26,425
4 in/6-inch Diameters	LF	580	37	21,460
PVC Discharge Pipe to Sewer (6-inch)	LF	100	10	970
Excavation Backfill	LF	2,540	2.45	6,223
(1-foot wide, 3-foot deep)	LF			
1 Booster Pump	EA	1	2,500	2,500
Subtotal				123,138
Multiplier				1.40
Total				172,393
Air Stripping Treatment System (ASTM)				

(Continued)

TABLE A-1 (Continued)

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Air Stripper System Including Stripper Vessel with Packing and Liquid				
Pump and Gas Blower	EA	1	50,000	50,000
Storage Tank	EA	1	20,000	20,000
Subtotal				70,000
Multiplier				1.40
Total				98,000
Construction Subtotal				2,944,482
	Percentage of Total Cost			
Bid Contingencies	15.00%			441,672
Scope Contingencies	25.00%			736,121
Construction Total				4,112,275
Permitting and Legal	5.00%			206,114
Bonding and Insurance	3.00%			123,668
Service During Construction	4.00%			164,891
Miscellaneous Lab Testing	5.00%			206,114
Total Implementation Cost				4,823,062
Engineering Design	15.00%			723,454
Total Capital Cost				5,546,522

OPERATION AND MAINTENANCE COSTS	Total Cost/Year	
	0-10 Years	10-30 Years
Ground-Water Monitoring System		
Semi-Annual Sampling and Analysis 15 Wells (0-10 years) @ $1000/well 10 Wells (10-30) years	30,000	20,000
Ground-Water Withdrawal Systems Power (@.06/Kwh)		
6 Pumping Wells	3,330	3,330
3 Pumping Wells (inside slurry wall, pump 25% of the time)	500	500
Labor		
$25/hr, 200 hr/yr	5,000	5,000
Air Stripping Treatment System		
Maintenance ($35/hr, 500 hr)	17,500	17,500

(Continued)

TABLE A-1 (Continued)

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Sampling and Analysis of Effluent Power			10,000	10,000
1 Blower and 1 Pump			800	800
Total Annual Operating and Maintenance Cost			67,130	52,130
NET PRESENT VALUE				
Capital Cost			5,546,522	
Present Value of Operating and Maintenance Cost			1,833,319	
Total Cost			7,380,000	

*SF = square feet

LF = linear feet

EA = each

TABLE A-2. COST ESTIMATE FOR ALTERNATIVE 2B

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Multi Media Cap				
LF04	SF	350,000	2.74	959,000
WP07	SF	20,000	2.74	54,800
LF05	SF	125,000	2.74	342,500
Subtotal				1,356,300
Multiplier				1.4
Cap Total				1,898,820
Cut-Off-Wall				
LFO4	LF	2,400	100	240,000
WP07	LF	650	100	65,000
LF05	LF	1,500	100	150,000
Ground-Water Extraction Wells Placed Inside Cut-Off-Wall				
Extraction Wells	EA	3	2,000	6,000
Well Pumps	EA	3	2,500	7,500
Plastic Dual Wall Pipe	LF	980	32	31,360
2-in/4-in Diameters	LF	980	2.45	2,401
Excavation Backfill (1-foot wide, 3-foot deep)	LF	3,835	2.45	9,396
Cut-Off-Wall Subtotal				502,261
Multiplier				1.40
Total				703,165
Ground-Water Withdrawal System				
Extraction Wells	EA	6	2,000	12,000
Well Pumps	EA	6	2,500	15,000
Plastic Dual Wall Pipe				
2 in/4-inch Diameters	LF	1,860	32	59,520
3 in/4-inch Diameters	LF	445	35	15,575
4 in/6-inch Diameters	LF	1,430	37	52,910
PVC Discharge Pipe to Sewer (6-inch)	LF	100	10	970
Excavation Backfill (1-foot wide, 3-foot deep)	LF	3,835	2.45	9,396
1 New Manhole	EA	1	1,620	1,620
1 Booster Pump	EA	1	2,500	2,500
Subtotal				169,491
Multiplier				1.40
Total				237,287

(Continued)

TABLE A-2 (Continued)

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Air Stripping Treatment System (ASTM)				
Air Stripper System Including Stripper Vessel with Packing and Liquid				
Pump and Gas Blower	EA	1	50,000	50,000
Storage Tank	EA	1	20,000	20,000
Subtotal				70,000
Multiplier				1.40
Total				98,000
Construction Subtotal				2,937,272
	Percentage of Total Cost			
Bid Contingencies	15.00%			440,591
Scope Contingencies	25.00%			734,381
Construction Total				4,112,181
Permitting and Legal	5.00%			205,609
Bonding and Insurance	3.00%			123,365
Service During Construction	4.00%			164,487
Miscellaneous Lab Testing	5.00%			205,609
Total Implementation Cost				4,811,252
Engineering Design	15.00%			721,688
Total Capital Cost				5,532,940

OPERATION AND MAINTENANCE COSTS	Total Cost/Year	
	0-10 Years	10-30 Years
Ground-Water Monitoring System		
Semi-Annual Sampling and Analysis 15 Wells (0-10 years) @ $1000/well 10 Wells (10-30) years	30,000	20,000
Ground-Water Withdrawal Systems Power (@.06/Kwh)		
6 Pumping Wells	3,330	3,330
3 Pumping Wells (inside slurry wall, Pump 25% of the time)	500	500
Labor		
$25/hr, 200 hr/yr	5,000	5,000

(Continued)

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TABLE A-2 (Continued)

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Air Stripping Treatment System				
Maintenance ($35/hr, 500 hr)			17,500	17,500
Sampling and Analysis of Effluent Power			10,000	5,000
1 Blower and 1 Pump			800	800
Total Annual Operating and Maintenance Cost			67,130	52,130
NET PRESENT VALUE				
Capital Cost			532,940	
Present Value of Operating and Maintenance Cost			1,833,319	
Total Cost			7,366,000	

*SF = square feet

LF = linear feet

EA = each

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TABLE A-3. COST ESTIMATE FOR ALTERNATIVE 3A

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Multi Media Cap				
LF04	SF	350,000	2.74	959,000
WP04	SF	20,000	2.74	54,800
LF05	SF	125,000	2.74	342,500
Subtotal				1,356,300
Multiplier				1.4
Cap Total				1,898,820
Ground-Water Extraction Wells Placed on Perimeter of Landfill				
Extraction Wells	EA	5	2,000	10,000
Well Pumps	EA	5	2,500	12,500
Plastic Dual Wall Pipe				
2-in/4-in Diameters	LF	1,160	32	37,120
3-in/4-in Diameters	LF	1,785	35	62,475
Excavation Backfill (1-foot wide, 3-foor deep)	LF	2,945	2.45	7,215
Subtotal				129,310
Multiplier				1.40
Total				181,034
Ground-Water Withdrawal System				
Extraction Wells	EA	6	2,000	12,000
Well Pumps	EA	6	2,500	15,000
Plastic Dual Wall Pipe				
2 in/4-inch Diameters	LF	1,205	32	38,580
3 in/4-inch Diameters	LF	755	35	26,425
4 in/6-inch Diameters	LF	580	37	21,460
PVC Discharge Pipe to Sewer (6-inch)	LF	100	10	970
Excavation Backfill	LF	2,540	2.45	6,223
(1-foot wide, 3-foot deep)	LF			
1 Booster Pump	EA	1	2,500	2,500
Subtotal				123,138
Multiplier				1.40
Total				172,393
Air Stripping Treatment System (ASTM)				
Air Stripper System Including Stripper Vessel with Packing and Liquid				

(Continued)

TABLE A-3. (Continued)

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Pump and Gas Blower	EA	1	50,000	50,000
Storage Tank	EA	1	20,000	20,000
Subtotal				70,000
Multiplier				1.40
Total				98,000
Construction Subtotal				2,340,146
	Percentage of Total Cost			
Bid Contingencies	15.00%			352,537
Scope Contingencies	25.00%			587,562
Construction Total				3,290,347
Permitting and Legal	5.00%			164,517
Bonding and Insurance	3.00%			98,710
Service During Construction	4.00%			131,614
Miscellaneous Lab Testing	5.00%			164,517
Total Implementation Cost				3,849,705
Engineering Design	15.00%			577,456
Total Capital Cost				4,427,161

OPERATION AND MAINTENANCE COSTS

	Total Cost/Year	
	0-10 Years	10-30 Years
Ground-Water Monitoring System		
Semi-Annual Sampling and Analysis 15 Wells (0-10 years) @ $1000/well 10 Wells (10-30) years	30,000	20,000
Ground-Water Withdrawal Systems Power (@.06/Kwh)		
6 Pumping Wells	3,330	3,330
5 Pumping Wells	2,750	2,750
Labor		
$25/hr, 200 hr/yr	6,250	6,250
Air Stripping Treatment System		
Maintenance ($35/hr, 500 hr)	17,500	17,500
Sampling and Analysis of Effluent Power	10,000	5,000
1 Blower and 1 Pump	800	800
Total Annual Operating and Maintenance Cost	70,630	55,630

(Continued)

TABLE A-3. (Continued)

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
NET PRESENT VALUE				
Capital Cost			4,427,161	
Present Value of Operating and Maintenance Cost			1,940,926	
Total Cost			6,368,087	

*SF = square feet

LF = linear feet

EA = each

TABLE A-4. COST ESTIMATE FOR ALTERNATIVE 3B

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Multi Media Cap				
LF04	SF	350,000	2.74	959,000
WP04	SF	20,000	2.74	54,800
LF05	SF	125,000	2.74	342,500
Subtotal				1,356,300
Multiplier				1.4
Cap Total				1,898,820
Groundwater Extraction Wells Placed on perimeter of landfill				
Extraction Wells	EA	5	2,000	10,000
Well Pumps	EA	5	2,500	12,500
Plastic Dual Wall Pipe				
2-in/4-in Diameters	LF	1,520	32	48,640
3-in/4-in Diameters	LF	180	35	6,300
Excavation Backfill (1-foot wide, 3-foor deep)	LF	1,700	2.45	4,165
				81,605
Subtotal				
Multiplier				1.40
Total				114,247
Groundwater Withdrawal System				
Extraction Wells	EA	6	2,000	12,000
Well Pumps	EA	6	2,500	15,000
Plastic Dual Wall Pipe				
2 in/4-inch Diameters	LF	1,860	32	59,520
3 in/4-inch Diameters	LF	445	35	15,575
4 in/6-inch Diameters	LF	1,430	37	52,910
PVC Discharge Pipe to Sewer (6-inch)	LF	100	10	970
Excavation Backfill	LF	3,835	2.45	9,396
(1-foot wide, 3-foot deep)	LF			
1 New Manhole	EA	1	1,620	1,620
1 Booster Pump	EA	1	2,500	2,500
Subtotal				169,491
Multiplier				1.40
Total				237,287

(Continued)

TABLE A-4. (Continued)

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Air Stripping Treatment System (ASTM)				
Air Stripper System Including Stripper Vessel with Packing and Liquid				
Pump and Gas Blower	EA	1	50,000	50,000
Storage Tank	EA	1	20,000	20,000
Subtotal				70,000
Multiplier				1.40
Total				98,000
Construction Subtotal				2,342,523
	Percentage of Total Cost			
Bid Contingencies	15.00%			352,253
Scope Contingencies	25.00%			587,089
Construction Total				3,287,696
Permitting and Legal	5.00%			164,385
Bonding and Insurance	3.00%			98,631
Service During Construction	4.00%			131,508
Miscellaneous Lab Testing	5.00%			164,385
Total Implementation Cost				3,846,604
Engineering Design	15.00%			576,991
Total Capital Cost				4,423,595

OPERATION AND MAINTENANCE COSTS	Total Cost/Year	
	0-10 Years	10-30 Years
Groundwater Monitoring System		
Semi-Annual Sampling and Analysis 15 Wells (0-10 years)@$1000/well 10 Wells (10-30) years	30,000	20,000
Groundwater Withdrawal Systems Power (@.06/Kwh)		
6 Pumping Wells	3,330	3,330
5 Pumping Wells	2,750	2,750
Labor		
$25/hr, 200 hr/yr	6,250	6,250
Air Stripping Treatment System		
Maintenance ($35/hr, 500 hr)	17,500	17,500

(Continued)

TABLE A-4. (Continued)

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Sampling and Analysis of Effluent Power			10,000	5,000
1 Blower and 1 Pump			800	800
Total Annual Operating and Maintenance Cost			67,430	52,430
NET PRESENT VALUE				
Capital Cost			4,423,595	
Present Value of Operating and Maintenance Cost			1,940,926	
Total Cost			6,365,000	

*SF = square feet

LF = linear feet

EA = each

TABLE A-5. COST ESTIMATE FOR ALTERNATIVE 4A

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Ground-Water Extraction Wells Placed on perimeter of landfill				
Extraction Wells	EA	5	2,000	10,000
Well Pumps	EA	5	2,500	12,500
Plastic Dual Wall Pipe .				
2-in/4-in Diameters	LF	1,160	32	37,120
3-in/4-in Diameters	LF	1,785	35	62,475
Excavation Backfill (1-foot wide, 3-foor deep)	LF	2,945	2.45	7,215
Subtotal				129,310
Multiplier				1.40
Total				181,034
Ground-Water Withdrawal System				
Extraction Wells	EA	6	2,000	12,000
Well Pumps	EA	6	2,500	15,000
Plastic Dual Wall Pipe				
2 in/4-inch Diameters	LF	1,205	32	38,560
3 in/4-inch Diameters	LF	775	35	26,425
4 in/6-inch Diameters	LF	580	37	21,460
PVC Discharge Pipe to Sewer (6-inch)	LF	100	10	970
Excavation Backfill	LF	2,450	2.45	6,223
(1-foot wide, 3-foot deep)	LF			
1 Booster Pump	EA	1	2,500	2,500
Subtotal				123,138
Multiplier				1.40
Total				172,393
Air Stripping Treatment System (ASTM)				
Air Stripper System Including Stripper Vessel with Packing and Liquid				
Pump and Gas Blower	EA	1	50,000	50,000
Storage Tank	EA	1	20,000	20,000
Subtotal				70,000
Multiplier				1.40
Total				98,000
Construction Subtotal				451,428

(Continued)

TABLE A-5. (Continued)

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
	Percentage of Total Cost			
Bid Contingencies	15.00%			67,714
Scope Contingencies	25.00%			112,857
Construction Total				631,999
Permitting and Legal	5.00%			31,600
Bonding and Insurance	3.00%			18,960
Service During Construction	4.00%			25,280
Miscellaneous Lab Testing	5.00%			31,600
Total Implementation Cost				739,438
Engineering Design	15.00%			110,916
Total Capital Cost				850,354

OPERATION AND MAINTENANCE COSTS	Total Cost/Year	
	0-10 Years	10-30 Years
Ground-Water Monitoring System		
Semi-Annual Sampling and Analysis 15 Wells (0-10 years)@$1000/well 10 Wells (10-30) years	30,000	20,000
Ground-Water Withdrawal Systems Power (@.06/Kwh)		
6 Pumping Wells	3,330	3,330
5 Pumping Wells	2,750	2,750
Labor		
$25/hr, 250 hr/yr	6,250	6,250
Air Stripping Treatment System		
Maintenance ($35/hr, 500 hr)	17,500	17,500
Sampling and Analysis of Effluent Power	10,000	5,000
1 Blower and 1 Pump	800	800
Total Annual Operating and Maintenance Cost	70,630	55,630
NET PRESENT VALUE		
Capital Cost	850,354	
Present Value of Operating and Maintenance Cost	1,940,926	
Total Cost	2,791,280	

*SF = square feet
LF = linear feet
EA = each

TABLE A-6. COST ESTIMATE FOR ALTERNATIVE 4B

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Groundwater Extraction Wells Placed on Perimeter of Landfill				
Extraction Wells	EA	5	2,000	10,000
Well Pumps	EA	5	2,500	12,500
Plastic Dual Wall Pipe				
2-in/4-in Diameters	LF	1,520	32	48,640
3-in/4-in Diameters	LF	180	35	6,300
Excavation Backfill (1-foot wide, 3-foor deep)	LF	1,700	2.45	4,165
				81,605
Subtotal				
Multiplier				1.40
Total				114,247
Ground-Water Withdrawal System				
Extraction Wells	EA	6	2,000	12,000
Well Pumps	EA	6	2,500	15,000
Plastic Dual Wall Pipe				
2 in/4-inch Diameters	LF	1,860	32	59,520
3 in/4-inch Diameters	LF	445	35	15,575
4 in/6-inch Diameters	LF	1,430	37	52,910
PVC Discharge Pipe to Sewer (6-inch)	LF	100	10	970
Excavation Backfill	LF	3,835	2.45	9,396
(1-foot wide, 3-foot deep)	LF			
1 New Manhole	EA	1	1,620	1,620
1 Booster Pump	EA	1	2,500	2,500
Subtotal				169,491
Multiplier				1.40
Total				237,287
Air Stripping Treatment System (ASTM)				
Air Stripper System Including Stripper Vessel with Packing and Liquid				
Pump and Gas Blower	EA	1	50,000	50,000
Storage Tank	EA	1	20,000	20,000
Subtotal				70,000
Multiplier				1.40
Total				98,000
Construction Subtotal				449,534

(Continued)

TABLE A-6. (Continued)

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
	Percentage of Total Cost			
Bid Contingencies	15.00%			67,430
Scope Contingencies	25.00%			112,384
Construction Total				629,348
Permitting and Legal	5.00%			31,467
Bonding and Insurance	3.00%			18,880
Service During Construction	4.00%			25,174
Miscellaneous Lab Testing	5.00%			31,467
Total Implementation Cost				736,337
Engineering Design	15.00%			110,451
Total Capital Cost				846,787
OPERATION AND MAINTENANCE COSTS				
			Total Cost/Year	
			0-10 Years	10-30 Years
Groundwater Monitoring System				
Semi-Annual Sampling and Analysis 15 Wells (0-10 years)@$1000/well 10 Wells (10-30) years			30,000	20,000
Groundwater Withdrawal Systems Power (@.06/Kwh)				
6 Pumping Wells			3,330	3,330
5 Pumping Wells			2,750	2,750
Labor				
$25/hr, 200 hr/yr			6,250	6,250
Air Stripping Treatment System				
Maintenance ($35/hr, 500 hr)			17,500	17,500
Sampling and Analysis of Effluent Power			10,000	5,000
1 Blower and 1 Pump			800	800
Total Annual Operating and Maintenance Cost			70,630	55,630
NET PRESENT VALUE				
Capital Cost			846,787	
Present Value of Operating and Maintenance Cost			1,940,926	
Total Cost			2,787,713	

*SF = square feet

LF = linear feet

EA = each

TABLE A-7. COST ESTIMATE FOR ALTERNATIVE 5A

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Cut-Off-Wall				
LF04	LF	2,400	100	240,000
WP07	LF	650	100	65,000
LF05	LF	1,500	100	150,000
Ground-Water Extraction Wells Placed on perimeter of landfill				
Extraction Wells	EA	3	2,000	6,000
Well Pumps	EA	3	2,500	7,500
Plastic Dual Wall Pipe (2-in/4-in Diameters)	LF	2,475	32	79,200
Excavation Backfill	LF	2,475	2.45	6,064
Cut-Off-Wall Subtotal				553,764
Multiplier				1.40
Total				775,269
Ground-Water Withdrawal System				
Extraction Wells	EA	6	2,000	12,000
Well Pumps	EA	6	2,500	15,000
Plastic Dual Wall Pipe				
2 in/4-inch Diameters	LF	1,205	32	38,560
3 in/4-inch Diameters	LF	755	35	26,425
4 in/6-inch Diameters	LF	580	37	21,460
PVC Discharge Pipe to Sewer (6-inch)	LF	100	10	970
Excavation Backfill	LF	2,540	2.45	6,223
(1-foot wide, 3-foot deep)	LF			
1 Booster Pump	EA	1	2,500	2,500
Subtotal				123,138
Multiplier				1.40
Total				172,393
Air Stripping Treatment System (ASTM)				
Air Stripper System Including Stripper Vessel with Packing and Liquid				
Pump and Gas Blower	EA	1	50,000	50,000
Storage Tank	EA	1	20,000	20,000
Subtotal				70,000
Multiplier				1.40
Total				98,000
Construction Subtotal				1,045,662

(Continued)

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
	Percentage of Total Cost			
Bid Contingencies	15.00%			156,849
Scope Contingencies	25.00%			261,416
Construction Total				1,463,927
Permitting and Legal	5.00%			73,169
Bonding and Insurance	3.00%			43,918
Service During Construction	4.00%			58,557
Miscellaneous Lab Testing	5.00%			73,196
Total Implementation Cost				1,712,795
Engineering Design	15.00%			256,919
Total Capital Cost				1,969,714

OPERATION AND MAINTENANCE COSTS	Total Cost/Year	
	0-10 Years	10-30 Years
Ground-Water Monitoring System		
Semi-Annual Sampling and Analysis 15 Wells (0-10 years) @$1000/well 10 Wells (10-30) years	30,000	20,000
Ground-Water Withdrawal Systems Power (@.06/Kwh)		
6 Pumping Wells	3,330	3,330
5 Pumping Wells	500	500
Labor		
$25/hr, 200 hr/yr	5,000	5,000
Air Stripping Treatment System		
Maintenance ($35/hr, 500 hr)	17,500	17,500
Sampling and Analysis of Effluent Power	10,000	5,000
1 Blower and 1 Pump	800	800
Total Annual Operating and Maintenance Cost	67,130	52,130
NET PRESENT VALUE		
Capital Cost	1,969,714	
Present Value of Operating and Maintenance Cost	1,833,319	
Total Cost	3,803,033	

*SF = square feet
LF = linear feet
EA = each

TABLE A-8. COST ESTIMATE FOR ALTERNATIVE 5B

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Cut-Off-Wall				
LF04	LF	2,400	100	240,000
WP07	LF	650	100	65,000
LF05	LF	1,500	100	150,000
Ground-Water Extraction Wells Placed on perimeter of landfill				
Extraction Wells	EA	3	2,000	6,000
Well Pumps	EA	3	2,500	7,500
Plastic Dual Wall Pipe (2-in/4-in Diameters)	LF	980	32	31,360
Excavation Backfill	LF	980	2.45	2,401
Cut-Off-Wall Subtotal				502,261
Multiplier				1.40
Total				703,165
Ground-Water Withdrawal System				
Extraction Wells	EA	6	2,000	12,000
Well Pumps	EA	6	2,500	15,000
Plastic Dual Wall Pipe				
2 in/4-inch Diameters	LF	1,860	32	59,520
3 in/4-inch Diameters	LF	445	35	15,575
4 in/6-inch Diameters	LF	1,430	37	52,910
PVC Discharge Pipe to Sewer (6-inch)	LF	100	10	970
Excavation Backfill	LF	3,835	2.45	9,396
(1-foot wide, 3-foot deep)	LF			
1 New Manhole	EA	1	1,620	1,620
1 Booster Pump	EA	1	2,500	2,500
Subtotal				169,491
Multiplier				1.40
Total				237,287
Air Stripping Treatment System (ASTM)				
Air Stripper System Including Stripper Vessel with Packing and Liquid				
Pump and Gas Blower	EA	1	50,000	50,000
Storage Tank	EA	1	20,000	20,000
Subtotal				70,000
Multiplier				1.40
Total				**98,000**

TABLE A-8. (Continued)

Capital Costs	Units*	Quantity	Unit Price ($)	Total Cost ($)
Construction Subtotal				1,038,452
	Percentage of Total Cost			
Bid Contingencies	15.00%			155,768
Scope Contingencies	25.00%			259,613
Construction Total				1,453,833
Permitting and Legal	5.00%			72,692
Bonding and Insurance	3.00%			43,615
Service During Construction	4.00%			58,153
Miscellaneous Lab Testing	5.00%			72,692
Total Implementation Cost				1,700,985
Engineering Design	15.00%			255,148
Total Capital Cost				1,956,133

OPERATION AND MAINTENANCE COSTS

	Total Cost/Year	
	0-10 Years	10-30 Years
Ground-Water Monitoring System		
Semi-Annual Sampling and Analysis 15 Wells (0-10 years)@$1000/well 10 Wells (10-30) years	30,000	20,000
Ground-Water Withdrawal Systems Power (@.06/Kwh)		
6 Pumping Wells	3,330	3,330
5 Pumping Wells	500	500
Labor		
$25/hr, 200 hr/yr	5,000	5,000
Air Stripping Treatment System		
Maintenance ($35/hr, 500 hr)	17,500	17,500
Sampling and Analysis of Effluent Power	10,000	5,000
1 Blower and 1 Pump	800	800
Total Annual Operating and Maintenance Cost	67,130	52,130
NET PRESENT VALUE		
Capital Cost	1,956,133	
Present Value of Operating and Maintenance Cost	1,833,319	
Total Cost	3,789,451	

*SF = square feet

LF = linear feet

EA = each

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