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RCRA PERMIT PART B NUMBER HW50289 RCRA FACILITY INVESTIGATION PRELIMINARY REMEDIAL ACTION PLANS NAS FORT WORTH TX

9/9/1994

ARMY CORP OF ENGINEERS

File: 17G
A.F.

NAVAL AIR STATION
FORT WORTH JRB
CARSWELL FIELD
TEXAS

ADMINISTRATIVE RECORD
COVER SHEET

AR File Number 85

CARSWELL AIR FORCE BASE, TEXAS

RCRA Permit, Part B, Number HW50289

PRELIMINARY REMEDIAL ACTION PLANS

SWMU NO. 16, SWMU NO. 22
SWMU NO. 23, SWMU NO. 24
SWMU NO. 32, SWMU NO. 35
SWMU NO. 36, SWMU NO. 61
SWMU NO. 63

9 September 1991

Prepared By
U.S. Army Corps Of Engineers
Fort Worth District

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1. PURPOSE

This preliminary remedial action plan is prepared in response to the RCRA Permit, Part B, Number HW50289, issued to Carswell Air Force Base (AFB) by the Texas Water Commission (TWC), dated 7 February 1991. The plan includes history, investigations, findings and recommendations for the following Solid Waste Management Units (SWMU's):

SWMU 16, Bldg 1060, Waste Accumulation Area.

SWMU 22, Landfill 4.

SWMU 23, Landfill 5.

SWMU 24, Waste Burial Area.

SWMU 32, Bldg 1410, Waste Accumulation Area.

SWMU 35, Oil/Water Separation System.

SWMU 36, Bldg 1191, Waste Accumulation Area.

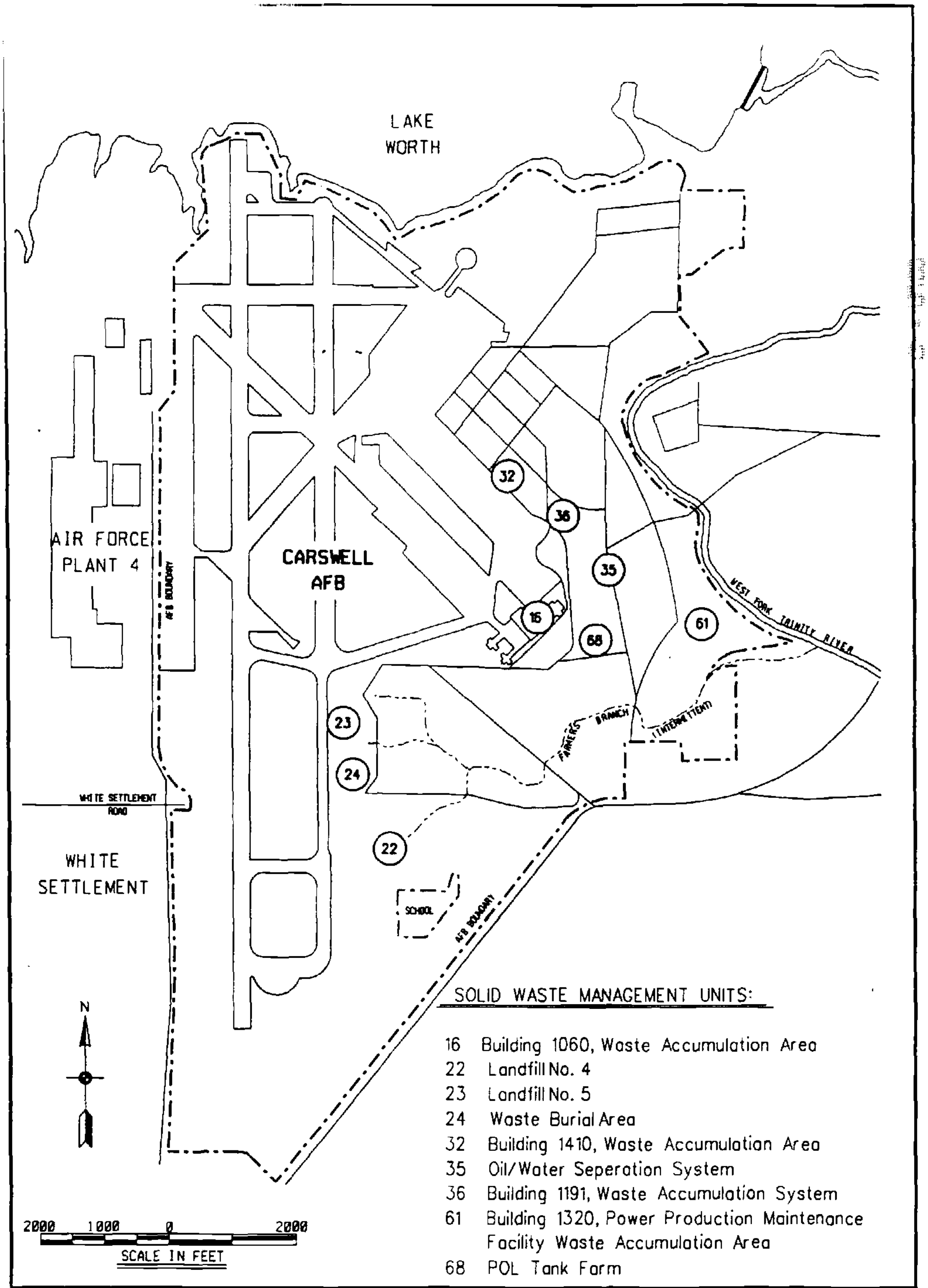
SWMU 61, Bldg 1320, Power Production Maintenance Facility, Waste Accumulation Area.

SWMU 68, POL Tank Farm.

2. BACKGROUND

Carswell Air Force Base (AFB) was established in 1942 and located six miles west of downtown Fort Worth, in Tarrant County, Texas. The base operates the Weapons Storage Area (WSA) located five miles west of the base on White Settlement Road.

Wastes have been generated and disposed of at Carswell AFB since the beginning of industrial operation in 1942. Major industrial operations include maintenance of jet engines, aerospace ground equipment, fuel systems, weapon systems and pneudraulic systems; maintenance of general and special purpose vehicles; aircraft corrosion control; and non-destructive inspection



CARSWELL AIR FORCE BASE, TEXAS
SOLID WASTE MANAGEMENT UNIT LOCATIONS
FIGURE 1

activities. The generated wastes are primarily oils, lubricants, recoverable fuels, spent solvents and cleaners.

The Installation Restoration Program (IRP) at Carswell AFB has progressed through Phases I and II. Phase I Records Search was completed in February 1984 by CH2M Hill, Inc., Phase II Confirmation/Quantification, Stage 1 was completed in October 1986 by Radian Corporation and Phase II Confirmation/ Quantification, Stage 2, Draft was dated in October 1988 by Radian Corporation. The individual plans refer to testing done during these investigations.

For SWMU No. 24, Waste Burial Area, a separate RCRA facility investigation/remediation plan for the removal of buried drums and an underground storage tank was submitted an 7 May 1991 and approved by the Texas Water Commission.

The information contained in the individual preliminary remedial action plans was obtained from these past studies:

1. Installation Restoration Program Records Search For Carswell Air Force Base, February 1984, CH2M Hill.

2. Installation Restoration Program, Stage 2, Carswell Air Force Base, October 1988, Radian Corporation.

3. Installation Restoration Program, Stage 2, Site Characterization Report For The Flightline Area, November 1990, Radian Corporation.

4. Installation Restoration Program, Stage 2 Remedial Investigation For The Flightline Area, February 1991, Radian Corporation.

5. Installation Restoration Program, Feasibility Study, Flightline Area, Draft, May 1991, Radian Corporation.

6. Installation Restoration Program, Remedial Investigation, East Area, Draft, April 1991, Radian Corporation.

7. Installation Restoration Program, Feasibility Study, East Area, May 1991, Radian Corporation.

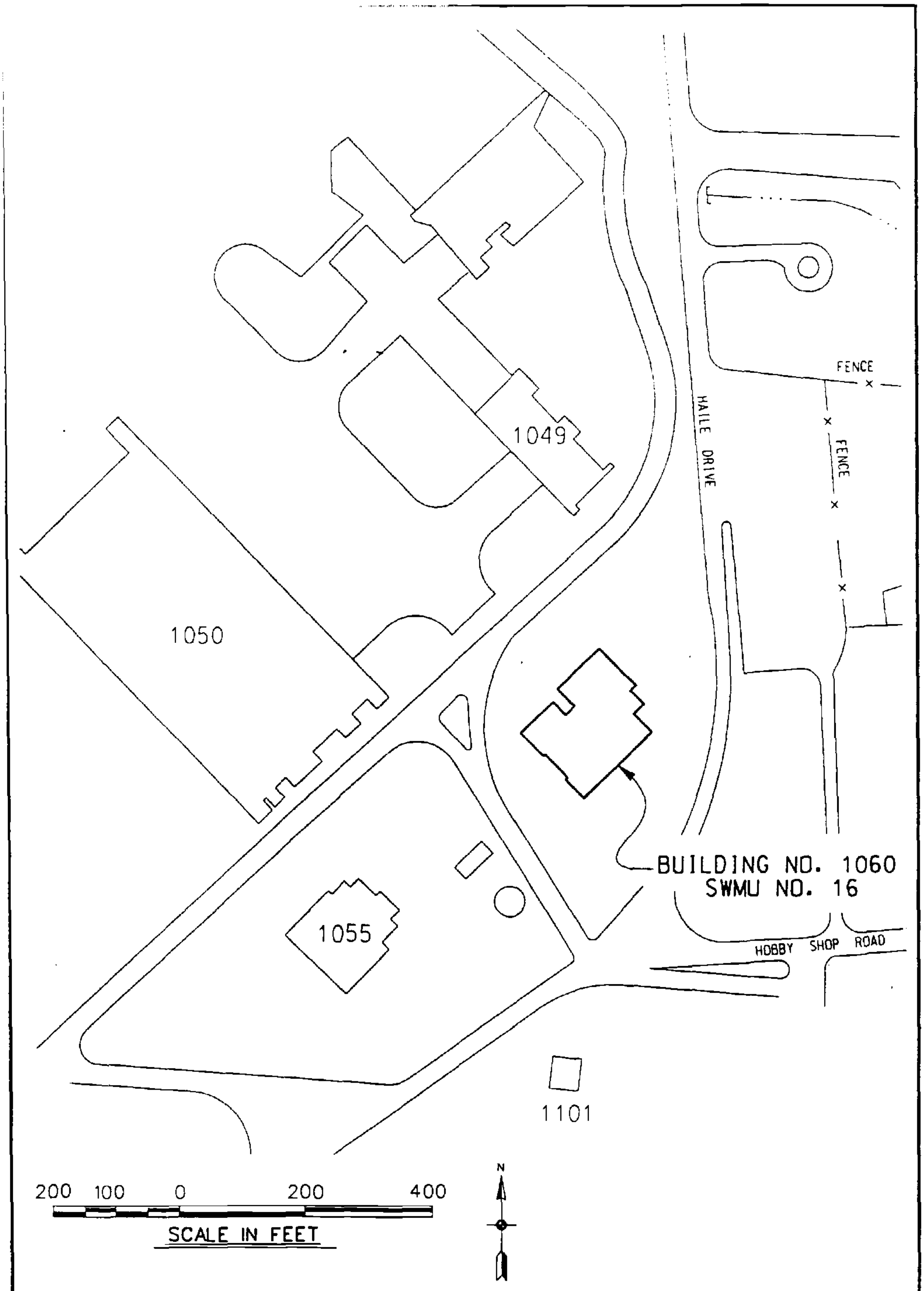
SWMU No. 16, Bldg. 1060, Waste Accumulation Area

Bldg 1060 is a Corrosion Control Shop for the Field Maintenance Squadron. The shop operations include paint stripping, cleaning and painting of small aircraft parts. The waste accumulation area is a container storage area for waste generated from shop operations. Waste is stored in 55-gallon drums on wooden pallets in a fenced-off area of the asphalt parking lot. The fenced off area is approximately 20 feet wide by 40 feet long. The unit is not covered. Waste is transported by truck from this unit to the Central Waste Holding Area (SWMU No. 53). The fenced storage area was recently replaced by a curbed, covered accumulation point in the same vicinity.

The unit manages paint lacquer, MEK with polyurethane paint, paint stripper, PD-680, plastic beads contaminated with paint, the filters from the paint booth, and rags containing paint and MEK. The unit manages approximately from 495 to 660 gallon per year of paint stripper and PD-680.

At the time of the visual site inspection in February 1989, a dark stain on the soil was observed at the corner of the unit. The stain extended to a shallow storm water drainage feature approximately 20 feet from the unit. Staining was also observed near the edge of the drums.

Samples will be taken in and around the area of the old stain to determine if any soil contamination exists. Samples will be analyzed for total petroleum hydrocarbons, purgeable halocarbons, and purgeable aromatic hydrocarbons. If any contamination is found, the affected soil will be removed, properly disposed of, and replaced; clearance samples will also be taken. There is no documented history of releases to groundwater, therefore, groundwater will not be sampled unless soil sample results indicate possible groundwater contamination.



SITE PLAN
SWMU NO. 16, BUILDING NO. 1060
FIGURE 2

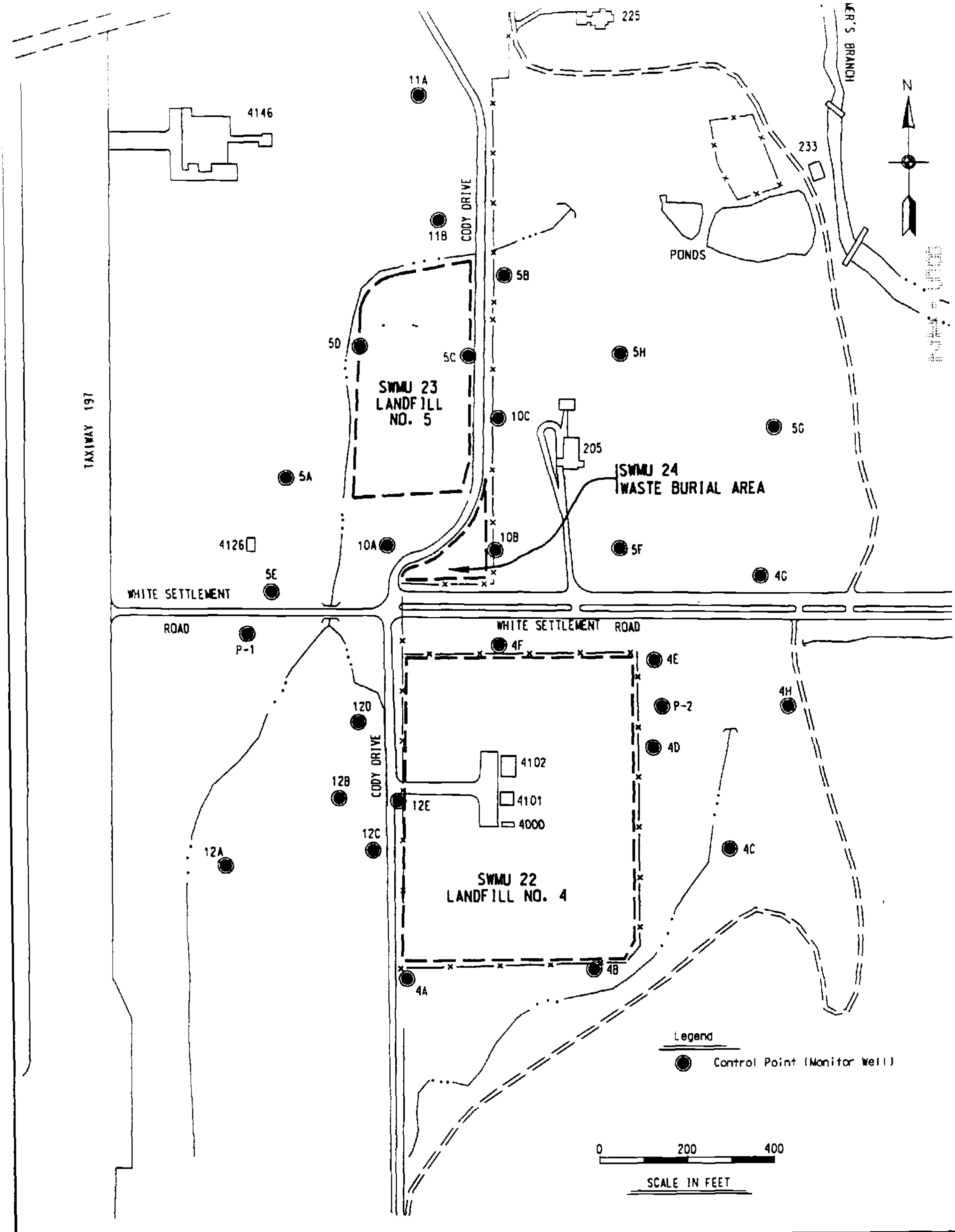
SWMU No. 22, Landfill 4.

SWMU No. 22 consists of ten acres of land located east of the runway and is currently the location of the radar site. The site was operated as the main landfill from approximately 1956 to 1975. At least six large pits, approximately twelve feet deep were filled with refuse which was burned and buried. Various materials suspected of being hazardous were reportedly disposed at this site, including drums of waste liquids, partially full paint cans and cadmium batteries. Written records indicate that waste paints, thinners, and strippers; oil containing absorbent materials; PD-680 (safety cleaning solvent) and oils may have been routinely disposed of at this site.

Eight monitoring wells were installed at the site. Upper deposits consist of clayey silt with variable amounts of fine sand and gravel underlain by sand and gravel deposits and vary in thickness from 17 feet to 39.5 feet. Bedrock, shale and limestone of the Goodland Formation was encountered at the base of the upper zone deposits at all locations with the exception of one boring. Ground water occurs in the upper zone materials underlying the site at depths ranging from approximately 13 feet to 28 feet.

Split-spoon samples were collected and visually examined for evidence of contamination and samples were selected for analysis of moisture content, metals, oil and grease, volatile and semivolatile organic compounds. Heavy metals were detected at the normal ranges, with the exception of silver (1.9 mg/Kg) in two holes. No oil and grease were detected. Toluene was detected in low levels (less than 8.8 ug/Kg) in the soil samples in two holes. Several phthalate compounds were detected in the soil samples at the site, however, the occurrences of these compounds were found to be invalid as the same compounds coincided with phthalates found in reagent blanks.

Ground water was sampled for chemical analysis twice in 1988. Samples



SITE PLAN
SWMU NO. 22, LANDFILL NO. 4
SWMU NO. 23, LANDFILL NO. 5
SWMU NO. 24, WASTE BURIAL AREA
FIGURE 3

were analyzed for water quality indicators, heavy metals, purgeable halocarbons, purgeable aromatics, and extractable priority pollutants. The total dissolved solids ranged from 430 mg/L to 920 mg/L, with the highest value in the first round of sampling. Sulfate concentrations increased in every well, except one, from the first to the second sampling round. MCLs were exceeded in Round 1 for lead, chromium, barium and cadmium. Round 2 results indicated that arsenic, lead, chromium and barium concentrations surpassed MCLs. Iron and manganese exceeded MCLGs during both sampling rounds. Purgeable halocarbons were detected in every upper zone monitor well at the site. TCE was the principal halocarbon, with values ranging from not detected to 4,200 ug/L. The only other compound surpassing MCLs for purgeable halocarbons was vinyl chloride, detected in both rounds at only one well. Toluene was detected in low levels (majority less than 10 ug/L, but up to 27 ug/L) from five wells. Benzene was found exceeding MCLs in Round 1 at one well, however, it was not detected in the second sampling round.

Results of Stage 2 field laboratory tests indicate that there is a TCE plume in the upper zone ground water in the area of SWMU No's 22, 23 and 24. Additional upper zone wells are recommended to determine the extent of TCE both upgradient and downgradient of the existing wells. Surface water sampling is recommended to determine the water quality of Farmers Branch and the ponds near Building 233. The preliminary evaluation of possible remedial alternatives indicated that ground water extraction and treatment would be recommended, however, in order to properly evaluate such an option, additional data on the aquifer characteristics are needed. Therefore, one or two aquifer tests, each consisting of a pumping well and three or more observation wells, are recommended to provide the data ultimately needed. SWMU No's 22, 23, and 24 appear to be best treated as combined sites in dealing with the problem of TCE in the ground water.

The most favorable remedial alternative to use is to place an impermeable multi-media cap over the area to prevent infiltration. In addition, a soil/bentonite slurry wall would be constructed around each of the areas to prevent waste migration. The system would be complimented with wells, pumps, pipe network and air stripping. A detailed description of alternative (2A) is included in the Feasibility Study for the Flightline Area done by Radian Corporation Draft Report May 1991, IRP Stage 2 found at Appendix A.

SWMU No. 23, Landfill 5.

SWMU No. 23 is located northwest of Landfill 4 and was constructed adjacent to a small tributary of Farmers Branch. The landfill was operated between 1963 and 1975 and was constructed by building a clay berm adjacent to the creek and then filling the area behind the berm up to its existing level. This site received all types of flightline wastes and refuse, and was regularly burned prior to covering.

Eight monitoring wells were installed at the site. The thickness of the upper zone ranges from 8 feet to at least 40 feet. The surficial clay and silt deposits are generally 5 to 10 feet thick and the sand and gravel deposits are 10 to 30 feet thick. The grain size of the sand and gravel generally increased with depth. Bedrock, shale and limestone of the Goodland Formation was encountered at the base of the upper zone deposits at all locations with the exception of two borings which were not deep enough to encounter bedrock. Ground water occurs in the upper zone materials underlying the site at depths ranging from less than 2 feet to 27 feet.

Split-spoon samples were collected in five of the borings and visually examined for evidence on contamination and samples were selected for analysis of moisture content, metals, oil and grease, volatile and semivolatile organic compounds. Heavy metals were detected at the normal ranges, with the exception of silver (1.8 mg/Kg) in two holes and arsenic (13 mg/Kg) in one hole. Oil and grease were only detected in one hole with a value of 15.0 mg/Kg. TCE was only revealed at one boring with a value of 22 ug/Kg. Soil samples contained toluene (up to 31 ug/Kg) in five of the seven samples analyzed. Several phthalate compounds and acetone were detected in the soil samples at the site. These compounds varied in concentrations of 100 to 800 ug/Kg.

Ground water was sampled for chemical analysis twice in 1988. Samples were analyzed for water quality indicators, heavy metals, purgeable halocarbons, purgeable aromatics, and extractable priority pollutants. The total dissolved solids (TDS) ranged from 380 mg/L to 770 mg/L. Except for two wells, there was a noticeable increase in TDS values between the two sampling events. Nitrate and sulfate concentrations increased in every well also. MCLs were exceeded in Round 1 for arsenic, lead and chromium. Round 2 results indicated that arsenic, lead, chromium and barium concentrations surpassed MCLs. Iron and manganese exceeded MCLGs during both sampling rounds. Purgeable halocarbons were detected in every monitor well at the site. The principal ground water contaminant is trichloroethylene (TCE). TCE was detected in every sample from the monitor wells, except one. The TCE concentration ranged from 52 to 3,800 ug/L. 1,1,1-trichloroethane was detected (67 ug/L) in the first round at one well. Other purgeable halocarbons detected above MCL values included vinyl chloride and trans-1,2-dichloroethene. The only detected purgeable aromatic was benzene, which was detected only in the first round and at one well. Water samples were analyzed for extractable priority pollutants and bis(2-ethylhexyl) phthalate was detected in low levels (5.2 ug/L).

SWMU No. 23, as discussed previously with SWMU No. 22, appears to be best treated as a combined site with SWMU No's 22 and 24 in dealing with the problem of TCE in the ground water.

The most favorable remedial alternative to use is to place an impermeable multi-media cap over the area to prevent infiltration. In addition, a soil/bentonite slurry wall would be constructed around each of the areas to prevent waste migration. The system would be complimented with wells, pumps, pipe network and air stripping. A detailed description of alternative (2A) is included in the Feasibility Study for the Flightline Area done by Radian Corporation Draft Report May 1991, IRP Stage 2 found at

Appendix A.

SWMU No. 24, Waste Burial Site.

SWMU No. 24 is located adjacent to and north of White Settlement Road, where the road dead-ends at the taxiway. The site was used for burial of wastes during the 1960s. Various types of hazardous materials, including drums of cleaning solvents, leaded sludge, and possibly ordnance materials were reported disposed of at this site. Fort Worth District, Corps of Engineers has given notice to precede to the Contractor as of August of 91.

Three boreholes were drilled and three upper zone monitor wells were installed at the site. The upper zone materials consist of surficial deposits of clayey silt with variable amounts of fine sand and gravel, underlain by sand and gravel deposits. The thickness of the upper zone ranges from 31 feet to 39 feet. The surficial clay and silt deposits are 7 to 14 feet thick and the sand and gravel deposits are 19 to greater than 27 feet thick. Shale and limestone of the Goodland Formation underlie the upper zone materials and occurs at a maximum of greater than 39 feet west of the site and at its shallowest depth of 31 feet northwest of the site. Ground water occurs in the upper zone materials at a depth ranging from 20 feet to 30 feet.

Split-spoon samples were collected and analyzed for heavy metals, oil and grease, petroleum hydrocarbons, volatile organic compounds, semivolatile organic compounds, pesticides, and PCBs. No heavy metals were detected above the normal ranges. There was no detection of oil and grease or petroleum hydrocarbons. TCE was detected in one sample, however, this finding was not confirmed with a duplicate sample. Toluene was estimated in low levels (5.3 ug/Kg and 2.0 ug/Kg) in two samples. Various phthalate compounds were detected in the soil samples ranging up to 390 ug/Kg. Pesticides or PCBs were not detected in any soil samples at this site.

Ground water samples were sampled for chemical analysis in two rounds of sampling. Samples were analyzed for water quality indicators, heavy metals, oil and grease, petroleum hydrocarbons, phenols, purgeable halocarbons, purgeable aromatics, organochlorine pesticides and herbicides. Total dissolved solids concentrations were fairly uniform through the two sampling rounds, ranging from 510 to 670 mg/L. Water samples were found to exceed MCLs for chromium at one well during both rounds of sampling. Chromium also exceeded MCLs at a second well during the first round and at a third well during the second round of sampling. Iron and manganese exceeded MCLGs at the three wells during both sampling rounds. Ground water analyses detected oil and grease in all three monitor wells in Round 1. Values ranged from 0.3 mg/L to 1 mg/L. However in Round 2, oil and grease were not detected at any of the wells. Petroleum hydrocarbons were detected (0.40 and 0.60 mg/L) in the first round, however, no petroleum hydrocarbons were detected in the second round. Phenols were detected in the first round and confirmed by a second column analysis. Concentrations of 2,4-dinitrophenol, 2-chlorophenol, and 2-methyl,-4,6-dinitrophenol were detected in the first round, but not the second round of sampling. Trichloroethylene (TCE) was detected in concentrations greater than the MCL in all ground water sampled at the site. Values ranged from 1,900 ug/L to 11,000 ug/L. Chloroethene was detected at 850 ug/L in one well in the first round, but was not detected in the second round. Purgeable aromatics pesticides nor herbicides were not detected in the ground water at the site.

A geophysical survey was conducted by Ecology and Environment, Inc., in February 1991 to determine/confirm the presence of buried drums at the site. The survey confirmed the location of approximately 9 drums located near the surface. A sample of one of the drums indicated the contents of the drums to be TCE. An RCRA Facility Investigation/Remediation plan for the removal of buried drums and a suspected underground storage tank was submitted to TWC on 7 May 1991 and approved.

SWMU No. 24, as discussed previously with SWMU No's 22 and 23, appears to best treated as a combined site with SWMU No's 22 and 23 in dealing with the problem of TCE in the groundwater.

The most favorable remedial alternative to use is to place an impermeable multi-media cap over the area to prevent infiltration. In addition, a soil/bentonite slurry wall would be constructed around each of the areas to prevent waste migration. The system would be complimented with wells, pumps, pipe network and air stripping. A detailed description of alternative (2A) is included in the Feasibility Study for the Flightline Area done by Radian Corporation Draft Report May 1991, IRP Stage 2 found at Appendix A.

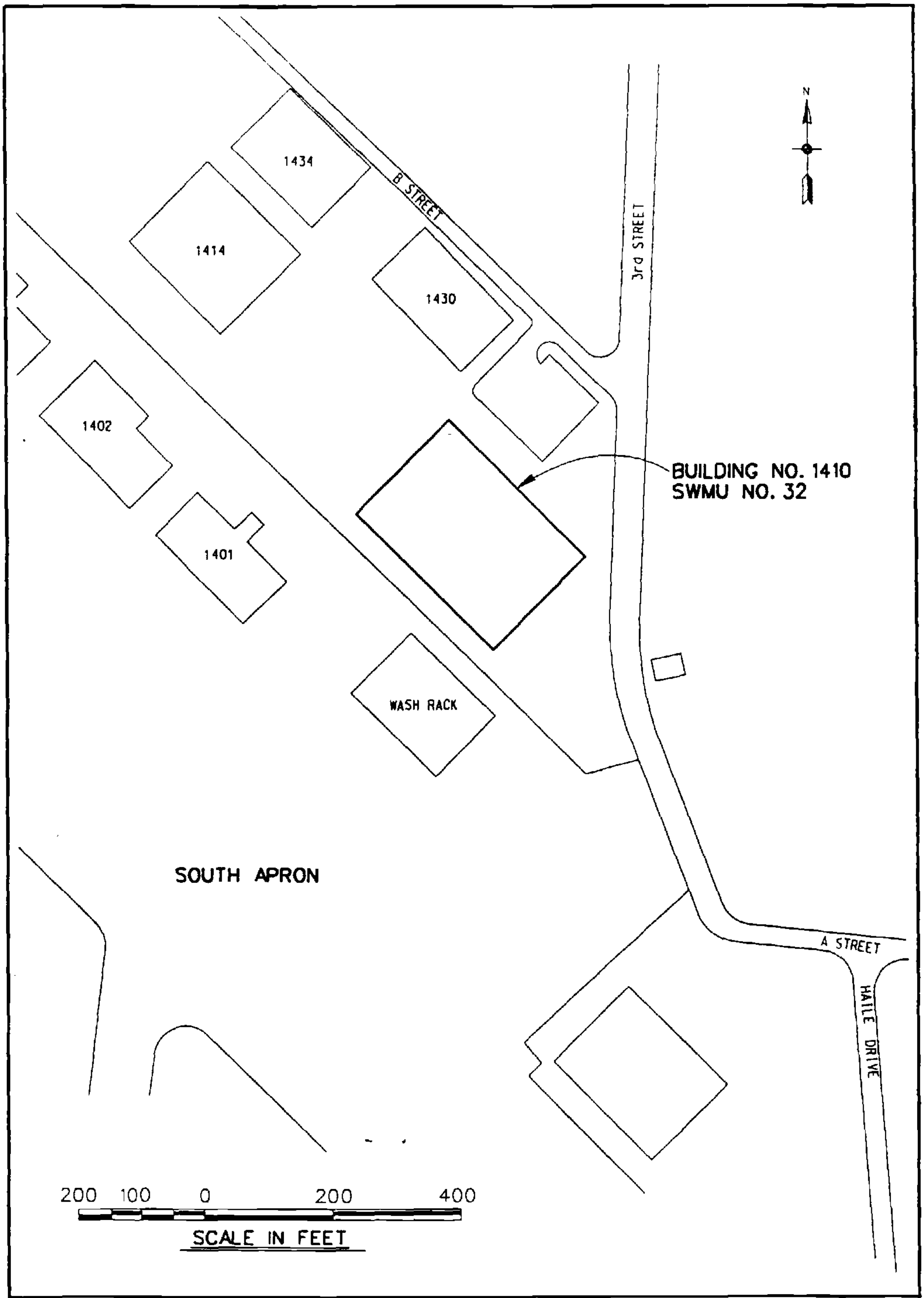
SWMU No. 32, Bldg 1410, Waste Accumulation Area

Building 1410 Waste Accumulation Area is an outdoor, uncovered, concrete-based container storage area. The unit manages wastes generated by the Engine Shop and Wheel and Tire Shop inside Building 1410. The waste from the Engine Shop is managed in drums on wooden pallets occupying one half of the site, while the waste from the Wheel and Tire Shop is transferred to drums occupying the other half of the site. In addition to the 55-gallon drums, the unit also consists of a 500-gallon tank. A contaminant retaining wall consisting of sandbags stacked two high is located along the perimeter of the unit. The unit is located approximately 25 yards from a storm drainage ditch. Some of the drums have open bungholes, others are secured by metal plates and locked. Wastes from this unit are disposed of by contractor removal through DRMO. A new curbed, covered accumulation point was recently constructed at this site and now houses all hazardous waste and hazardous material.

The unit manages 7808 engine oil drained from jet engines, carbon and fingerprint removers, PD-680 (Type II), waste JP-4 fuel, and a solvent manufactured by Rochester Midland designated SE 377E. The carbon and fingerprint removers are degreasers. The unit manages approximately 600 gallons of 7808 engine oil per year, 200 gallons of carbon and fingerprint remover per year, 550 gallons of PD-680 Type II per year, and 300 gallons of waste JP-4 per year.

There is no documented history of releases for this unit, but during the visual site inspection conducted in February 1989, the concrete within, and to some extent outside the sand bags, was stained with oily material that had either leaked from a drum or been spilled at this unit.

Soil samples will be taken to accurately define the area and depth of contamination that requires clean-up. Samples will be analyzed for Total



SITE PLAN

SWMU NO. 32, BUILDING NO. 1410

FIGURE 4

Petroleum Hydrocarbons, BTEX, and TCLP for lead and chromium. Upon completion of the sampling, the contaminated soil will be remove, properly disposed of and replaced; clearance samples will also be taken. There is no documented history of releases to ground water; therefore, groundwater will not be sampled unless soil sample results indicate possible groundwater contamination.

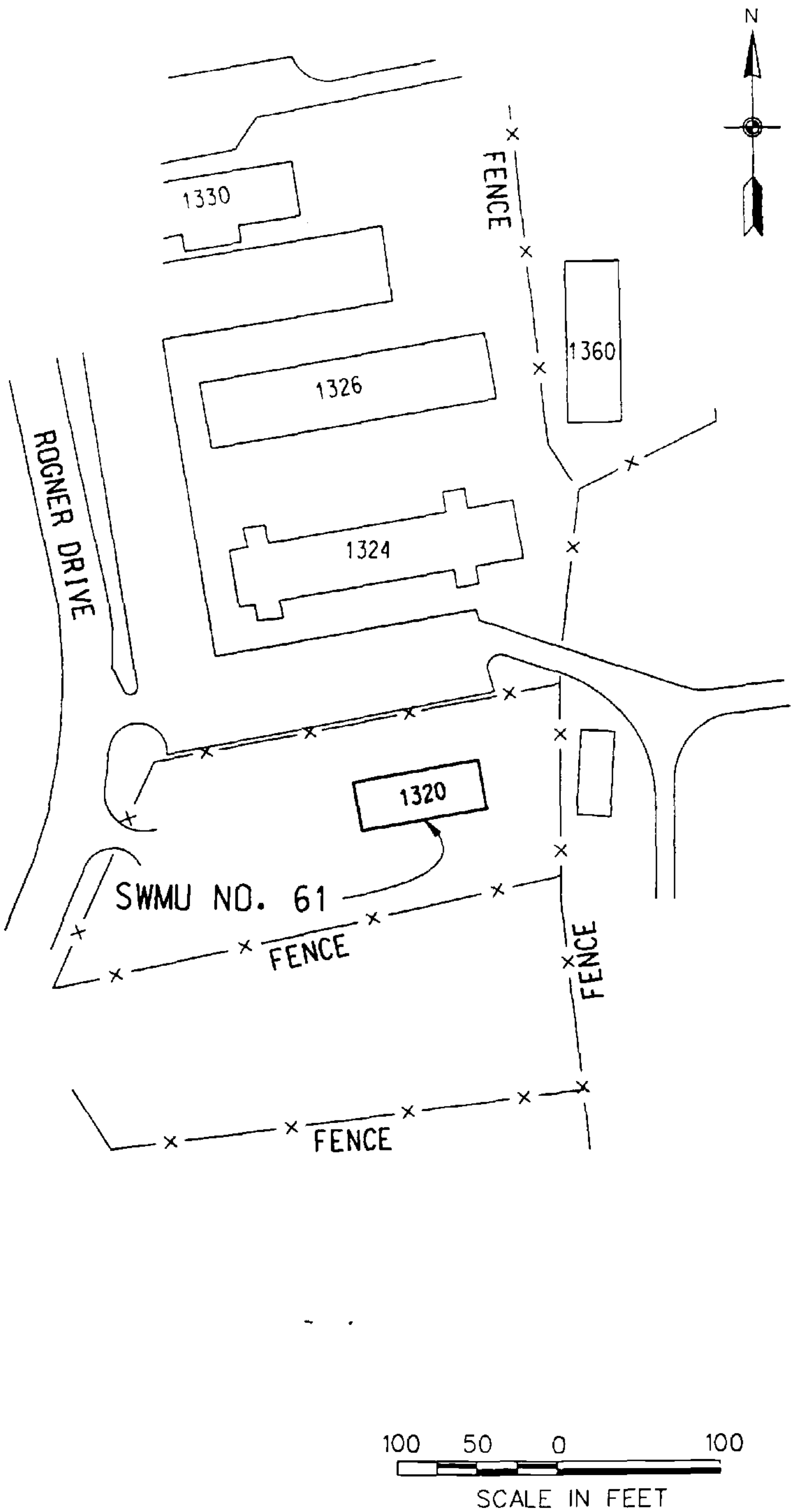
SWMU No. 35, Oil/Water Separation System

This unit consists of a main trench floor drain, underground conduits, and an oil/water separator outside Building 1194, Vehicle Refueling Shop. Floor rinsed washes down the drain through the conduits to the Oil/Water Separator. There, the oil is skimmed from the wastewater and the wastewater is pumped out onto the parking lot surface. The parking lot slopes towards the surrounding bare ground where a storm water sewer catches runoff from the area. The floor in the building is paved with concrete and slopes toward the drain. The trench is approximately 1 foot deep, 18 inches wide and 30 feet long. Reportedly, the underground conduits are also constructed of concrete. The oil/water separator is a below-ground concrete box located beneath an asphalted area. It is comprised of two main units, one for separation, and another for holding the skimmed oil. A pressure gauge sticking out of the ground indicates the oil level in the oil holding tank, and thus, the need for pumping it out. The separation unit has a capacity of 2,000 gallons. The construction details of the unit were not documented.

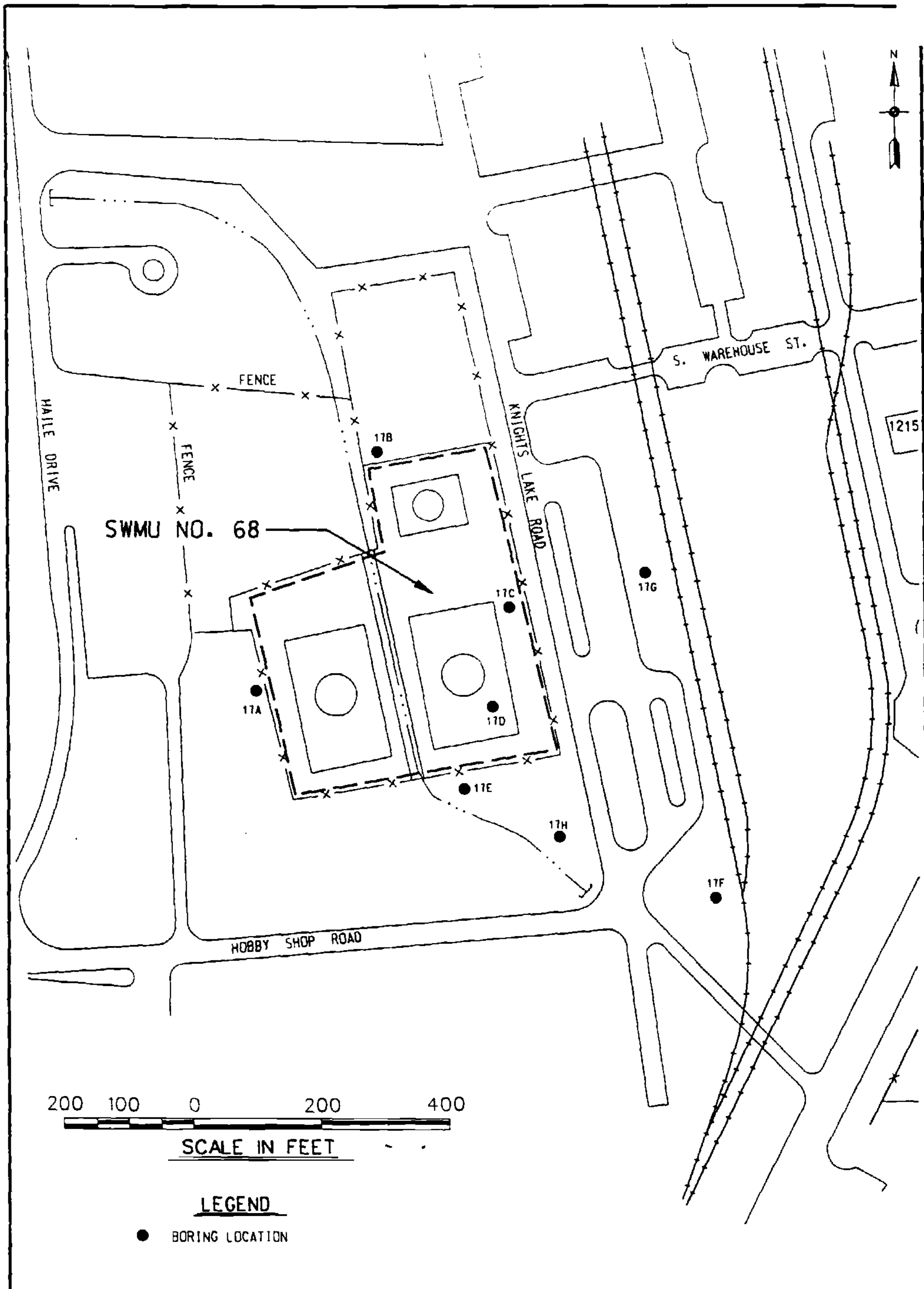
The unit manages floor washing which consist of wastewater contaminated with fuel, PD-680, anti-freeze, and transmission fluid, as well as waste oil.

There is no documented history of releases for this unit. Separated wastewater is reportedly released onto the parking lot surface. At the time of the visual site inspection conducted in February 1989, the soil in the area's runoff pathway appeared stained with oil.

Soil samples will be taken to accurately define the area and depth of contamination around the storm sewer drain. Upon completion of the sampling, the contaminated soil will be removed, properly disposed of and replaced; clearance samples will also be taken. Samples will be analyzed for Total Petroleum Hydrocarbons, TCLP for lead, and BTEX. The process for pumping out



SITE PLAN
SWMU NO. 61, BUILDING NO. 1320
FIGURE 6



SITE PLAN
SWMU NO. 68, POL TANK FARM
FIGURE 7

that two soil vapor plumes exist at the site. The largest plume encompasses an area approximately 100 feet wide and 300 feet long in the vicinity of Tanks 1156 and 1157. The smaller plume envelops a circular area with a diameter of approximately 125 feet located east of the site and adjacent to Building 1213.

Soil samples from the five monitor wells were collected during drilling and analyzed for petroleum hydrocarbons, volatile organic compounds, and lead. The soil at the site was analyzed for lead concentration and all samples were well within normal ranges of heavy metal concentrations. The presence of petroleum hydrocarbons was confirmed at three borings with values ranging from 240 mg/Kg to 8900 mg/Kg. Soil analysis found low levels of benzene at two wells and toluene at three wells. Methylene chloride was detected at four wells.

Samples of ground water were collected from the five wells and analyzed for water quality indicators, heavy metals, petroleum hydrocarbons, purgeable halocarbons, purgeable aromatics, and extractable priority pollutants. The total dissolved solids (TDS) at the site ranged from 450 mg/L to 980 mg/L. With the exception of TDS, none of the water quality indicators exceeded recommended limits. Several heavy metals detected in ground water at the site exceeded federal guidelines. Arsenic, lead, barium, cadmium, and chromium exceeded MCLs at all five wells sampled. Concentrations of these metals were 0.13 ug/mL for arsenic, 0.56 ug/mL for lead, 2.2 ug/mL for barium, 0.031 ug/mL for cadmium and 0.56 ug/mL for chromium. MCLGs were exceeded by iron and manganese during both sampling events at all five wells. Selenium was detected at all five wells during the ICP metal screen but was not verified with additional testing. Sodium was the only metal concentration that increased at each well between sampling events. Petroleum hydrocarbons were encountered in the vicinity of the POL Tank Farm in water samples taken from four wells in Round 1 and three wells in Round 2. Water collected from one well in Round 2 contained 0.20 ug/L of trichloroethylene and vinyl chloride was detected in both rounds in another well. Although the values are below MCLs, they are above the MCLGs for these contaminants. MCLs for benzene were exceeded in the first sampling rounds at two wells. Benzene, however, was not detected at either of these locations in the second sampling round. Other detections of purgeable aromatics during the second round included ethylbenzene, toluene and m- and p-xylenes. Analyses of extractable priority pollutants were only performed on water from one well. The compounds found were at low levels and appeared to be decreasing slightly in concentration between sampling rounds.

The soil chemistry data reviewed indicated that petroleum hydrocarbons are the principal contaminant. The pattern of contamination in soil resembles the occurrence of ground water contaminants. Drilling in the unsaturated portion of the upper zone deposits generally did not yield materials with visible contamination, suggesting localized sources of contamination and migration of contamination in the ground water.

Four additional wells are recommended to complete the definition of the extent of contamination at the site and in addition to the new wells, continue to monitor the existing wells. All monitor wells at the site should be sampled and the ground water analyzed for purgeable aromatic compounds, petroleum hydrocarbons, metals and general water quality parameters.

The most favorable remedial alternative to use is construct an groundwater extraction well, air strip the contaminants and to pump the treated water back into the groundwater. A detailed description of alternative 4A is included in the Feasibility Study for the Flightline Area done by Radian Corporation Draft Report May 1991, IRP Stage 2 (Appendix B, page 3.5).

APPENDIX A

Installation Restoration Program, Stage 2, Feasibility Study Report For The Flightline Area, Draft Report - May 1991 Radian Corporation

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FEASIBILITY STUDY FOR THE FLIGHTLINE AREA

DRAFT REPORT
FOR
CARSWELL AIR FORCE BASE, TEXAS

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

MAY 1991

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USAF CONTRACT NO. F33615-87-D-4023, DELIVERY ORDER NO. 0004, MODIFICATION 0005
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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:

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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: [signature] for
Nelson H. Lund, P.E.
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,

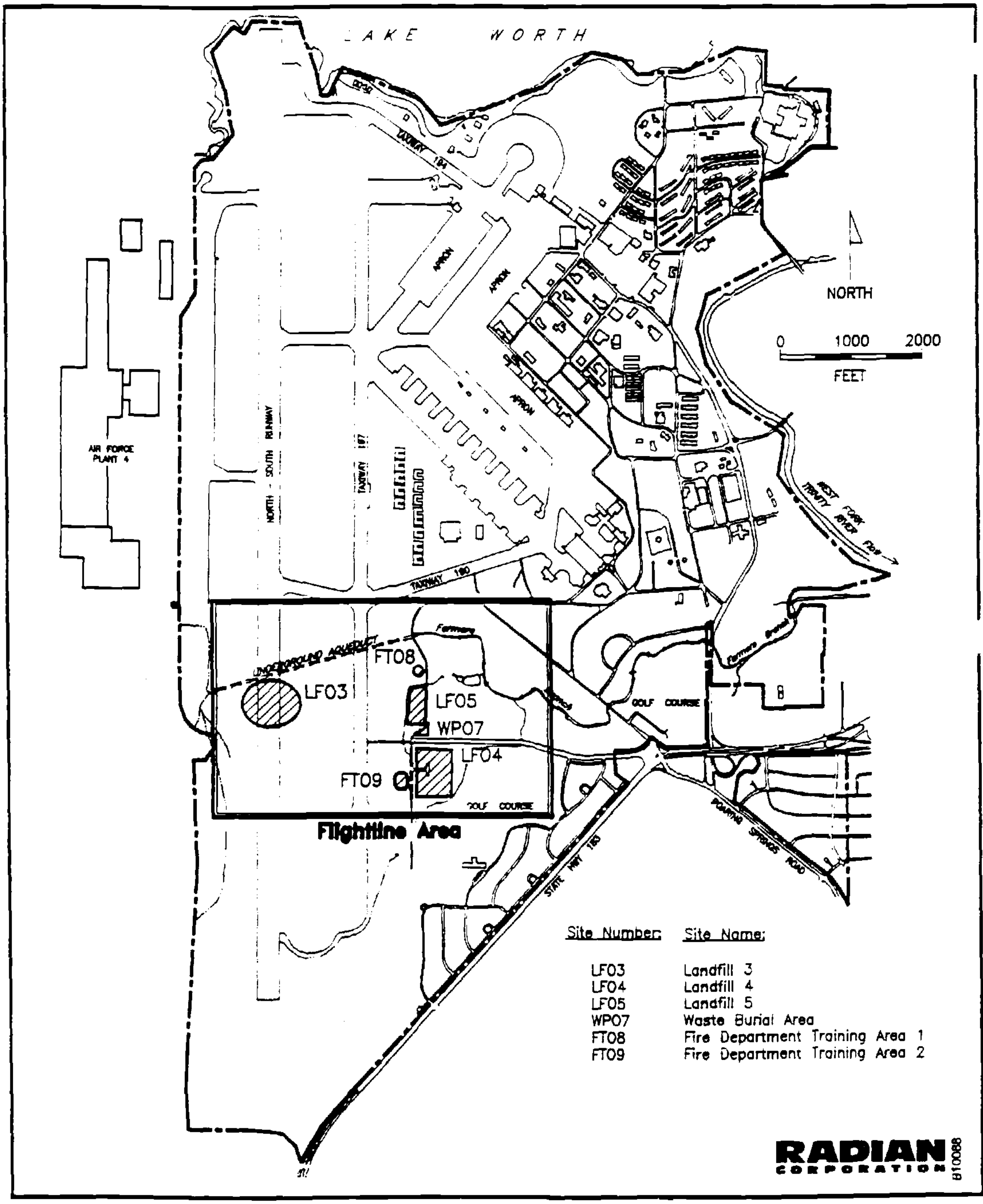


Figure ES-1. Location of Flightline Area IRP Sites, Carswell AFB, Texas and are underlain by the low permeability limestones and shales of the Cretaceous Goodland and Walnut Formations which form a basal aquiclude. Ground water in the Upper Zone Aquifer is encountered at depths ranging from approximately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

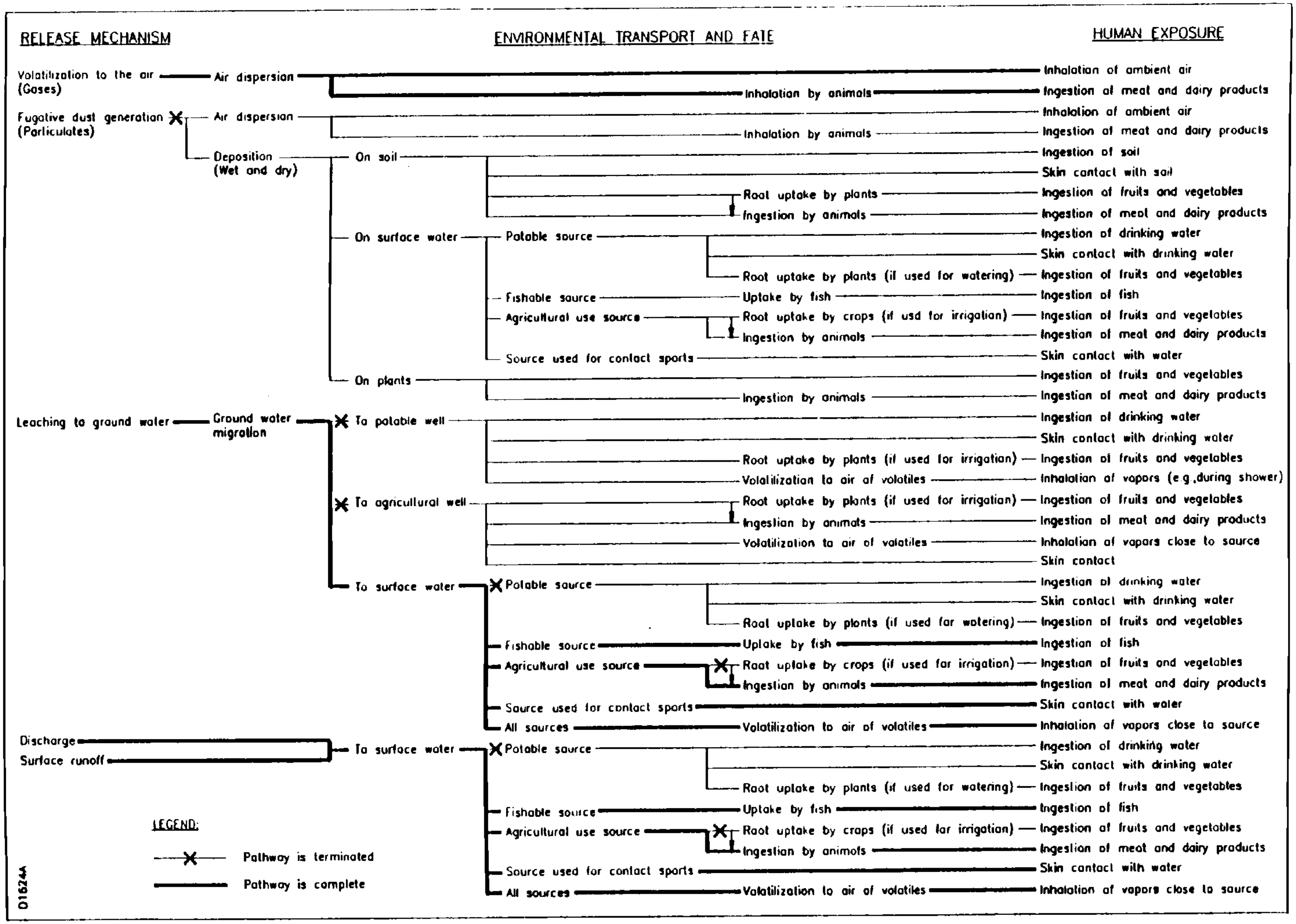


Figure ES-2. Potential Exposure Pathways for Contaminants Released from the Carswell AFB Flightline Area and by estimating incremental individual cancer risks for maximum exposed on- and off-site individuals, respectively. Human health risks were determined to be insignificant. Minimal risk (from the 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

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.

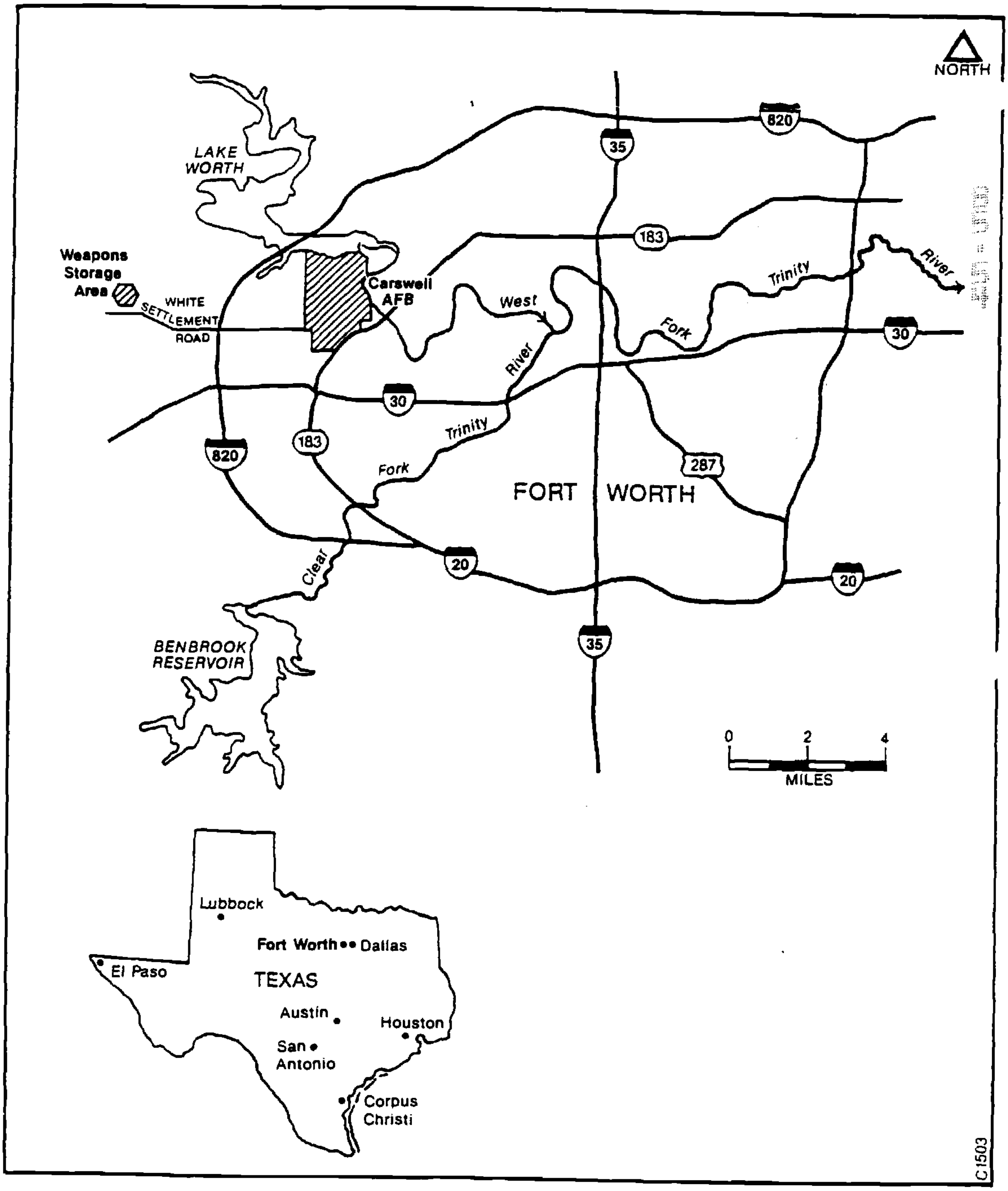


Figure 1-1. Regional Setting of Carswell AFB, Texas

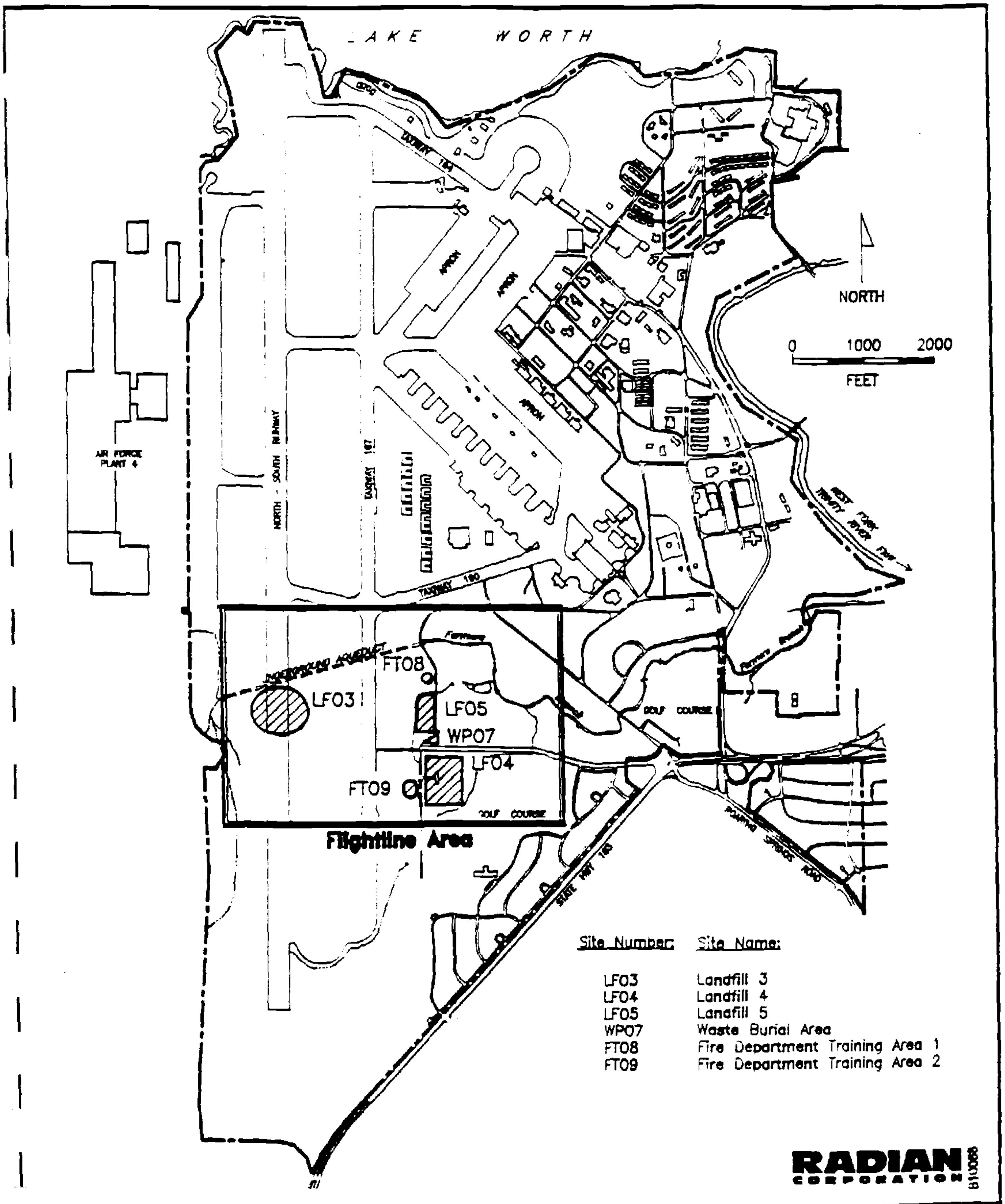


Figure 1-2. Locations of Flightline Area IRP Sites, Carswell AFB, Texas

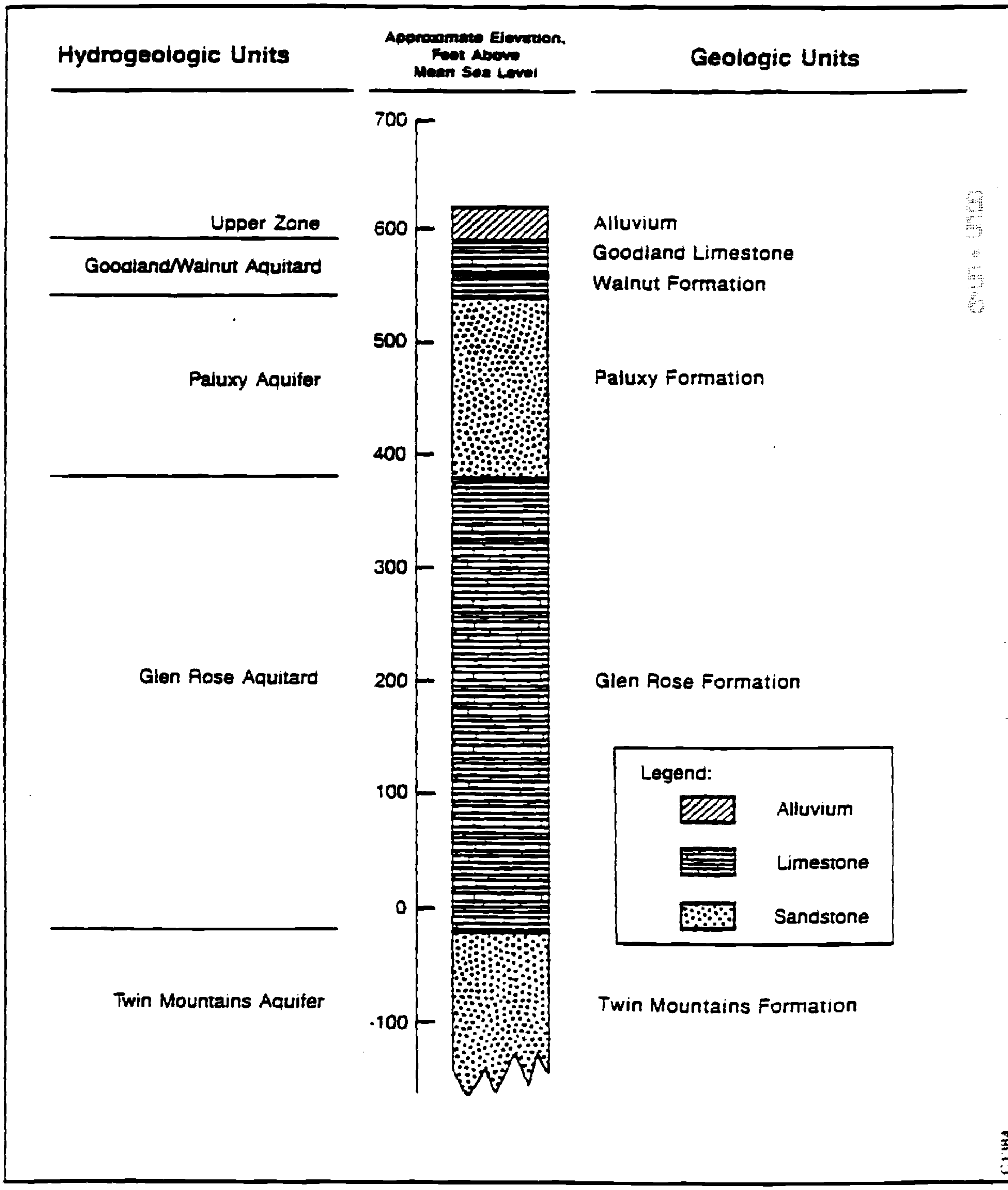


Figure 1-3. Generalized Hydrogeologic Units, Carswell AFB, Texas (Radian, 1989)

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

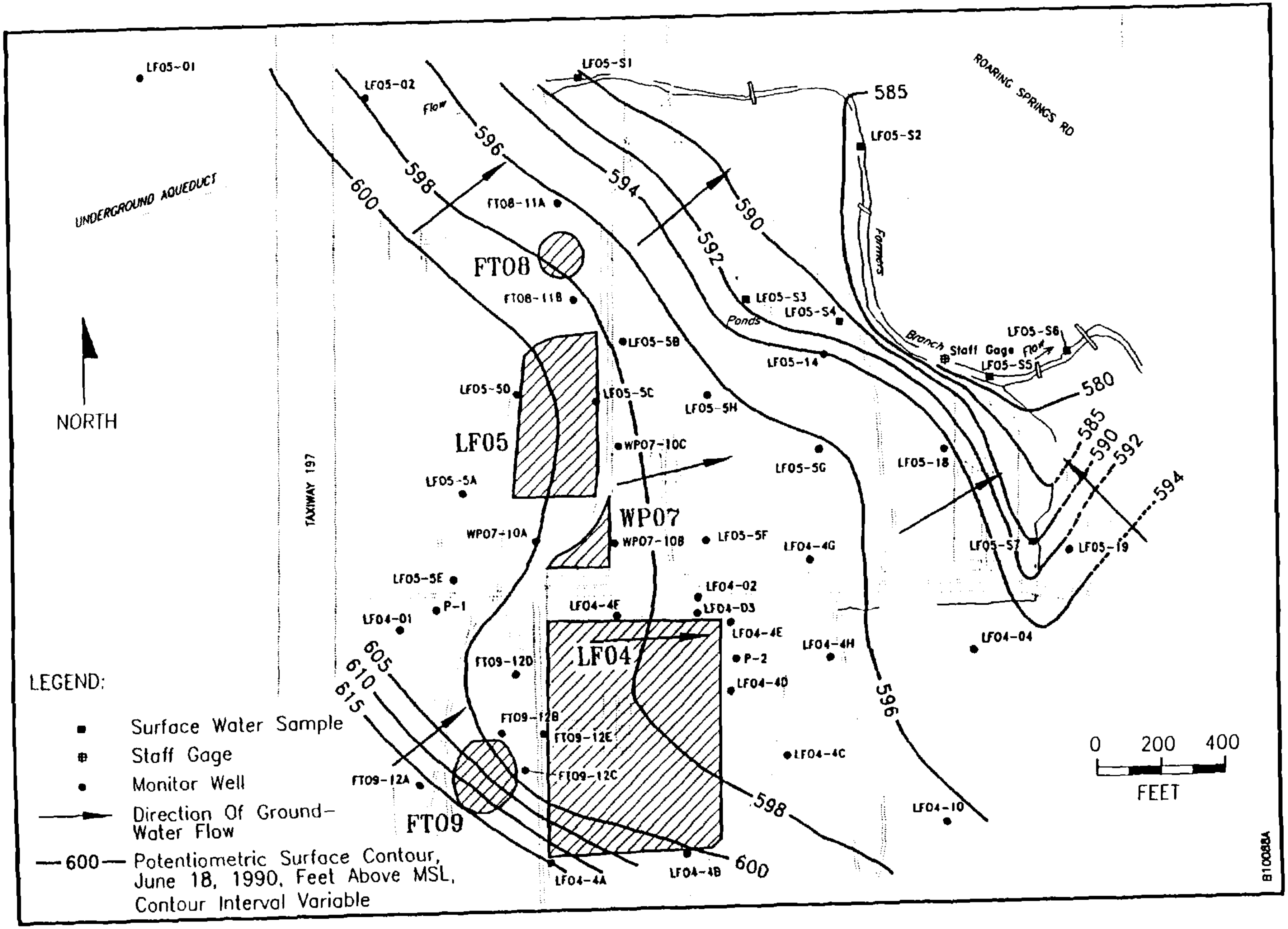


Figure 1-4. Potentiometric Surface Map of Upper Zone Aquifer, Flightline Area, Carswell AFB, Texas

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.

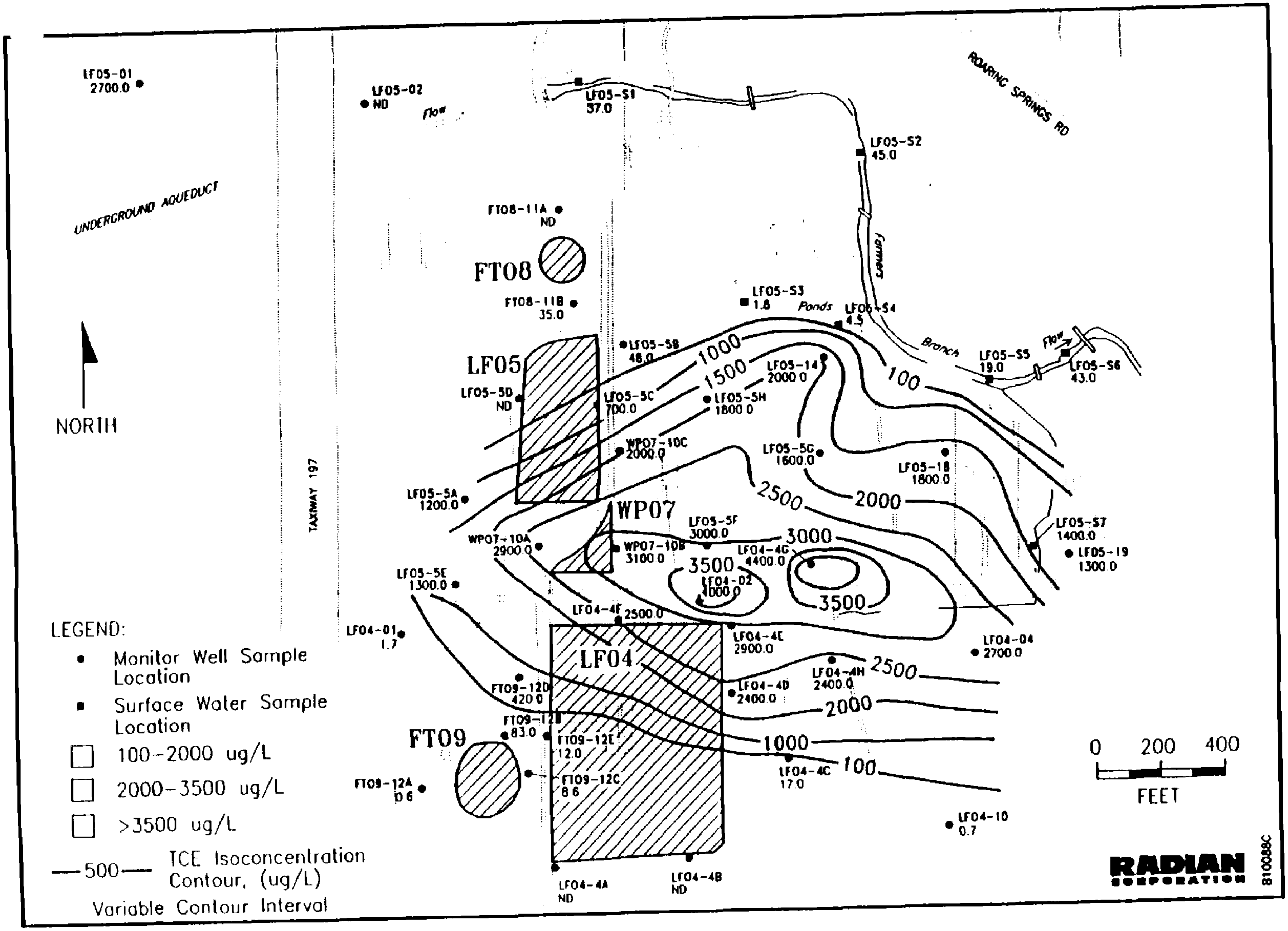


Figure 1-5. TCE Isoconcentration Contour Map, Flightline Area, Carswell AFB, Texas
(Based on Spring, 1990 Water Sampling)
Note: Figure will be colored in Final Report

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

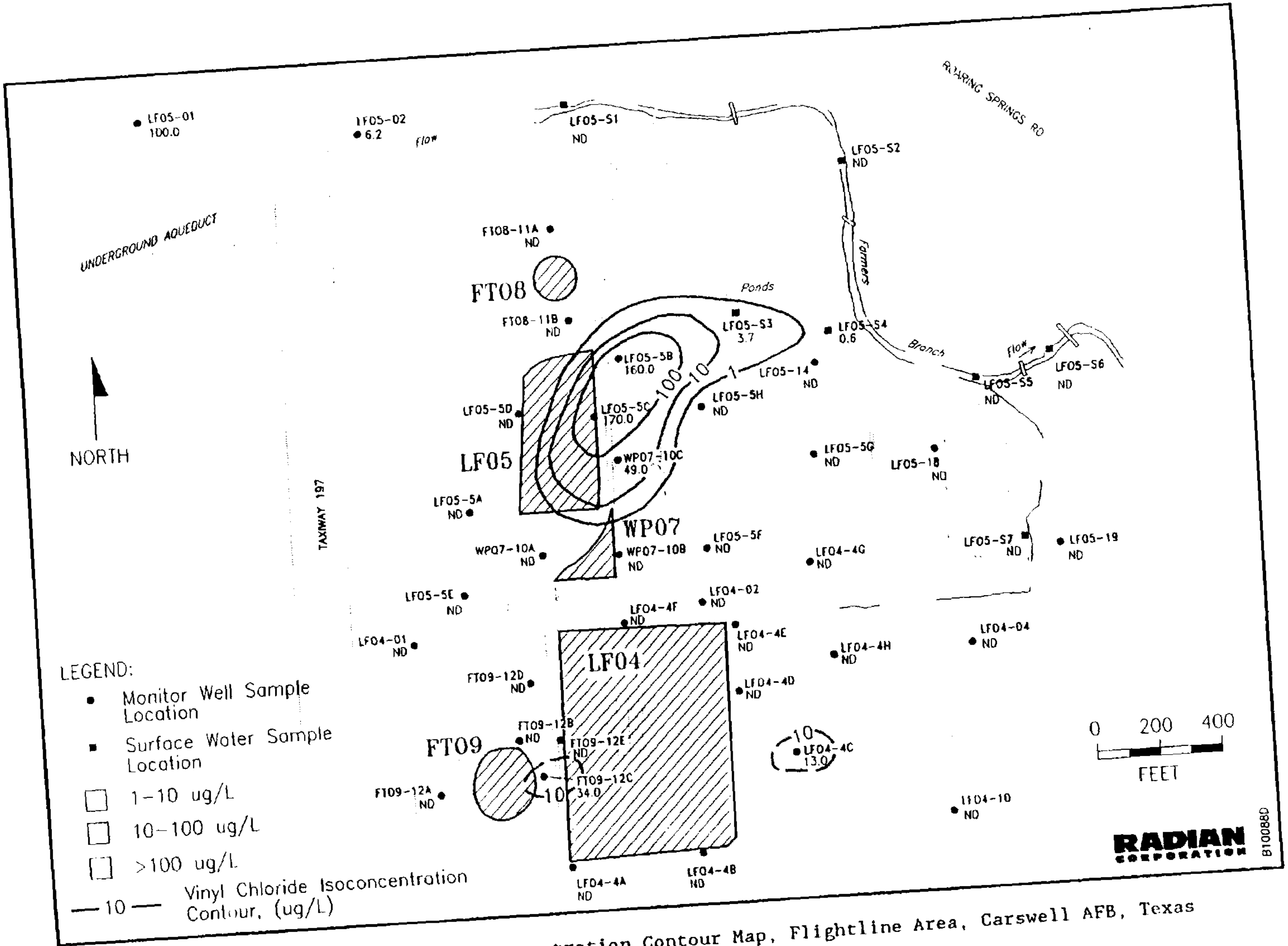


Figure 1-6. Vinyl Chloride Isoconcentration Contour Map, Flightline Area, Carswell AFB, Texas
(Based on Spring, 1990 Water Sampling)
Note: Figure will be colored in Final Report

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.

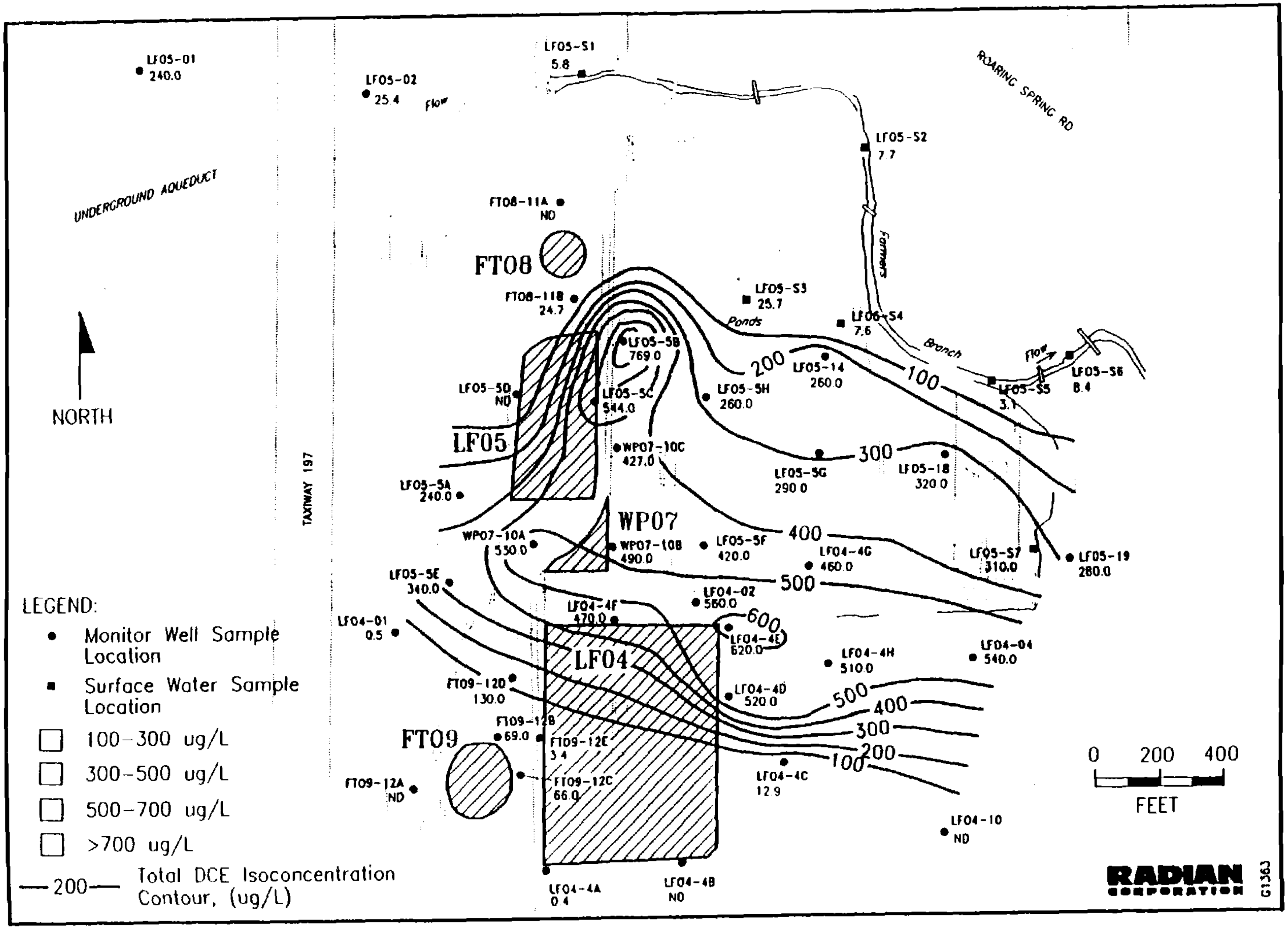


Figure 1-7. Total 1,2-Dichloroethene Isoconcentration Contour Map, Flightline Area, Carswell AFB, Texas (Based on Spring, 1990 Water Sampling)
Note: Figure will be colored in Final Report

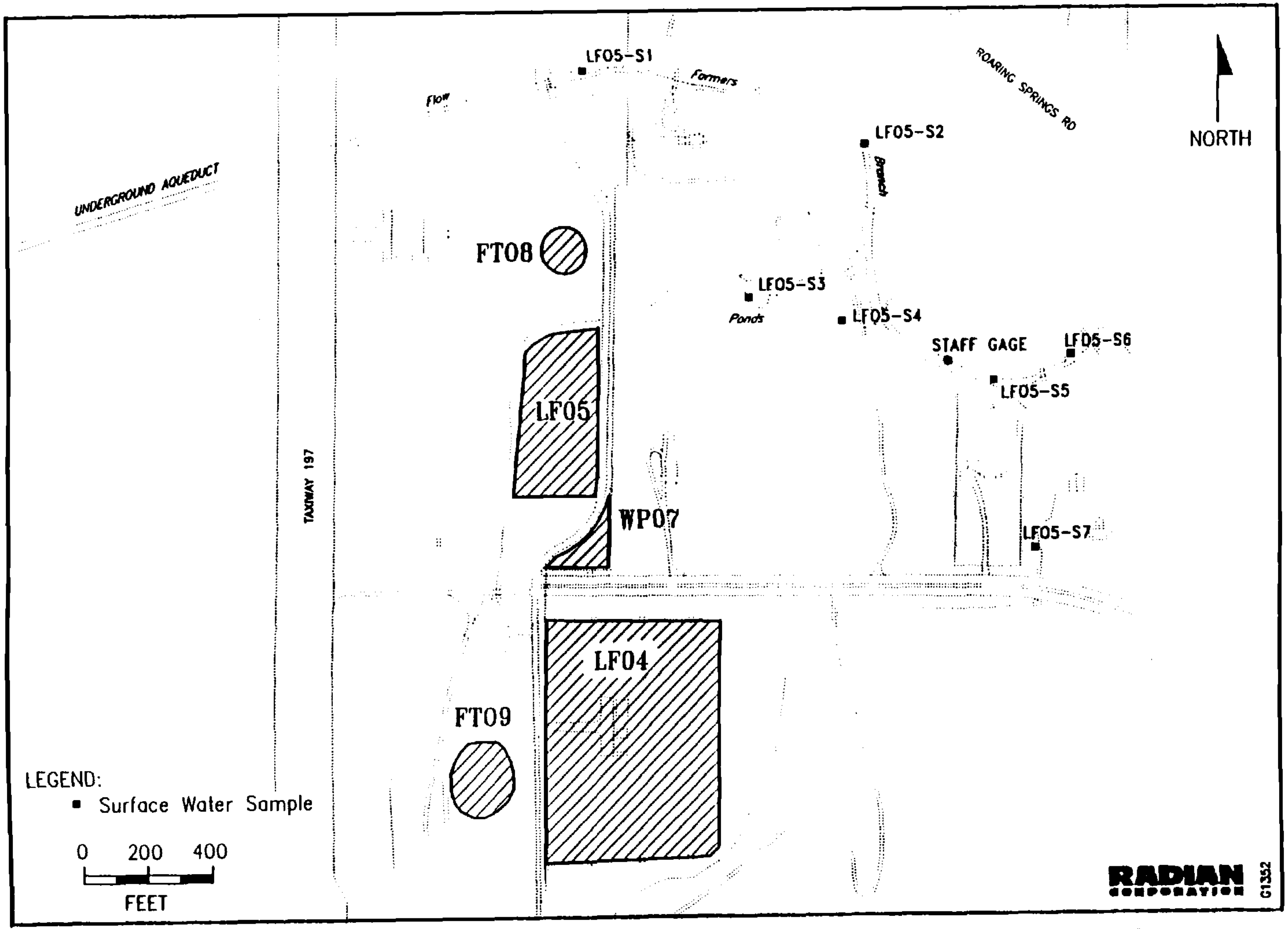


Figure 1-8. Location of Surface Water Sampli Points, Flightline Area, Carswell AFB, Texas
(Apri 1990)

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)	D.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).

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.

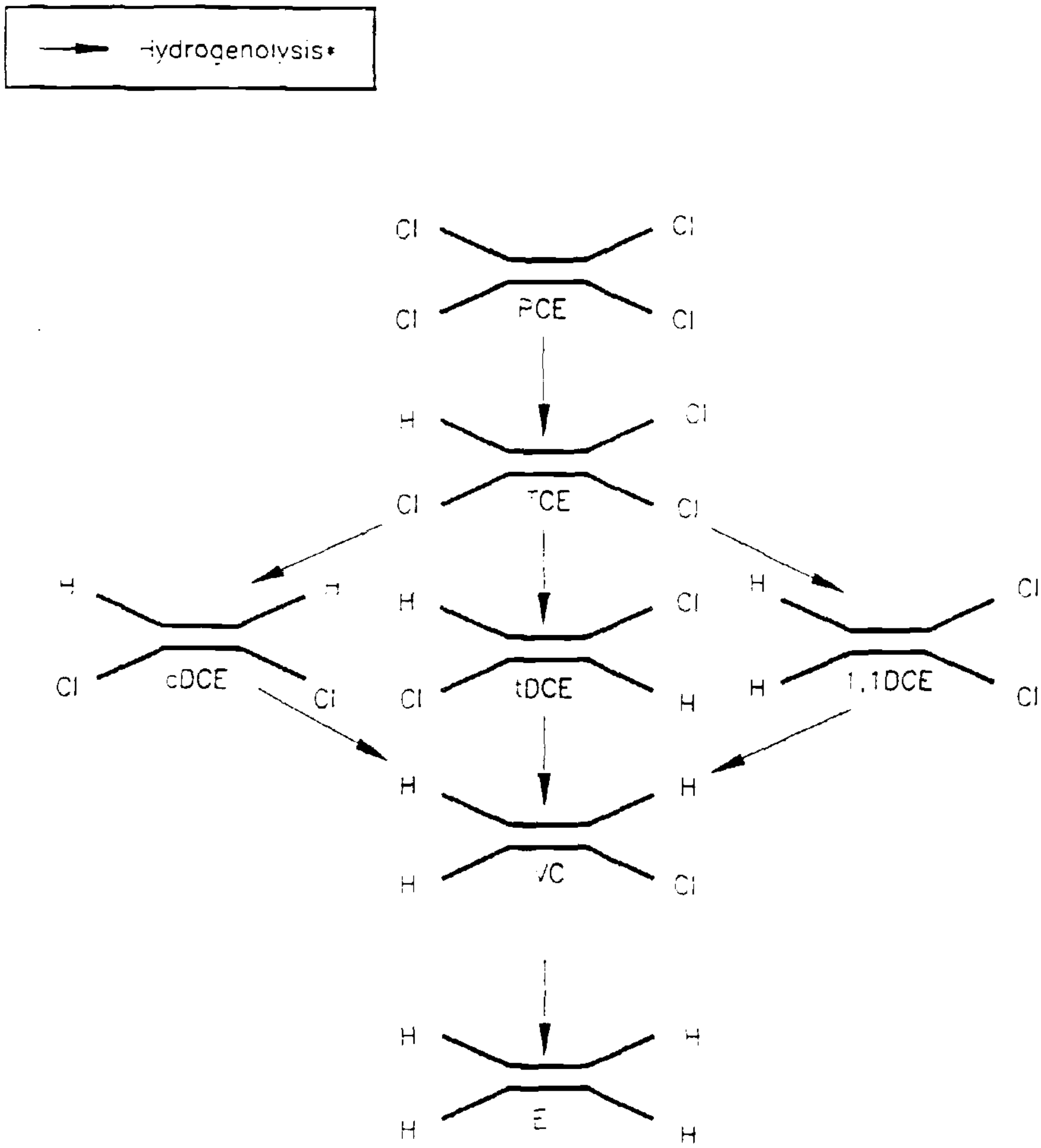
Diffusion and dispersion are chemical and mechanical processes whereby a contaminant tends to spread from the expected direction of transport in ground water. Both of these processes contribute to dilution of contaminants within the body of the plume, and to enlargement of the plume. Thus, they influence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



PCE – tetrachloroethene
TCE – trichloroethene
cDCE – cis-1,2-dichloroethene
tDCE – trans-1,2-dichloroethene
1,1DCE – 1,1-dichloroethene
VC – vinyl chloride
E – ethene

* A reduction reaction in which a carbon-halogen bond is broken and hydrogen replaces the halogen substituent.

Source: Vogel, Criddle and McCarty, 1987

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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: $\tilde{v}$ = 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

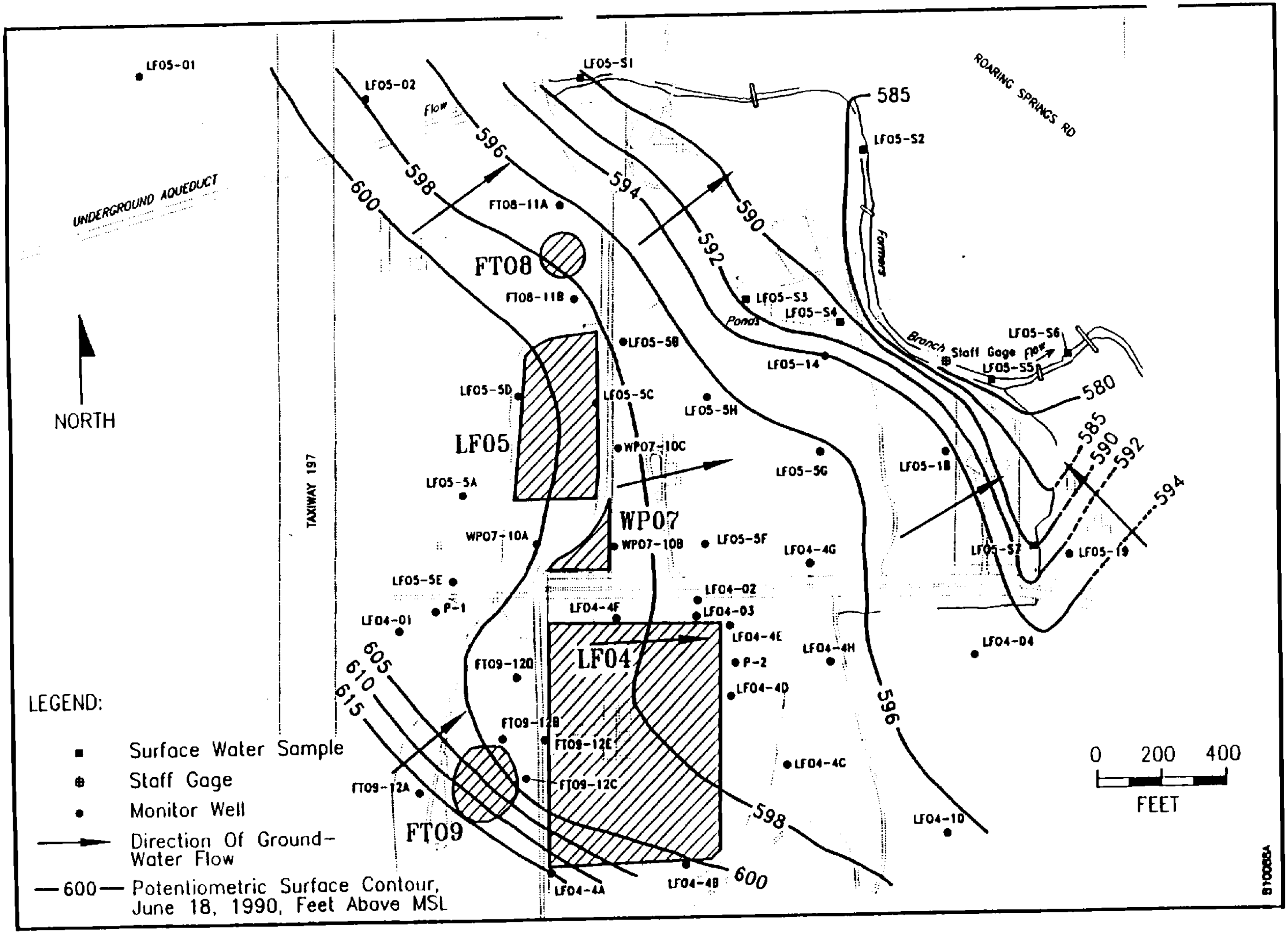

Figure 1-10. Upper Zone Aquifer Potentiometric Surface Map (June 1990), Flightline Area, Carswell AFB, Texas

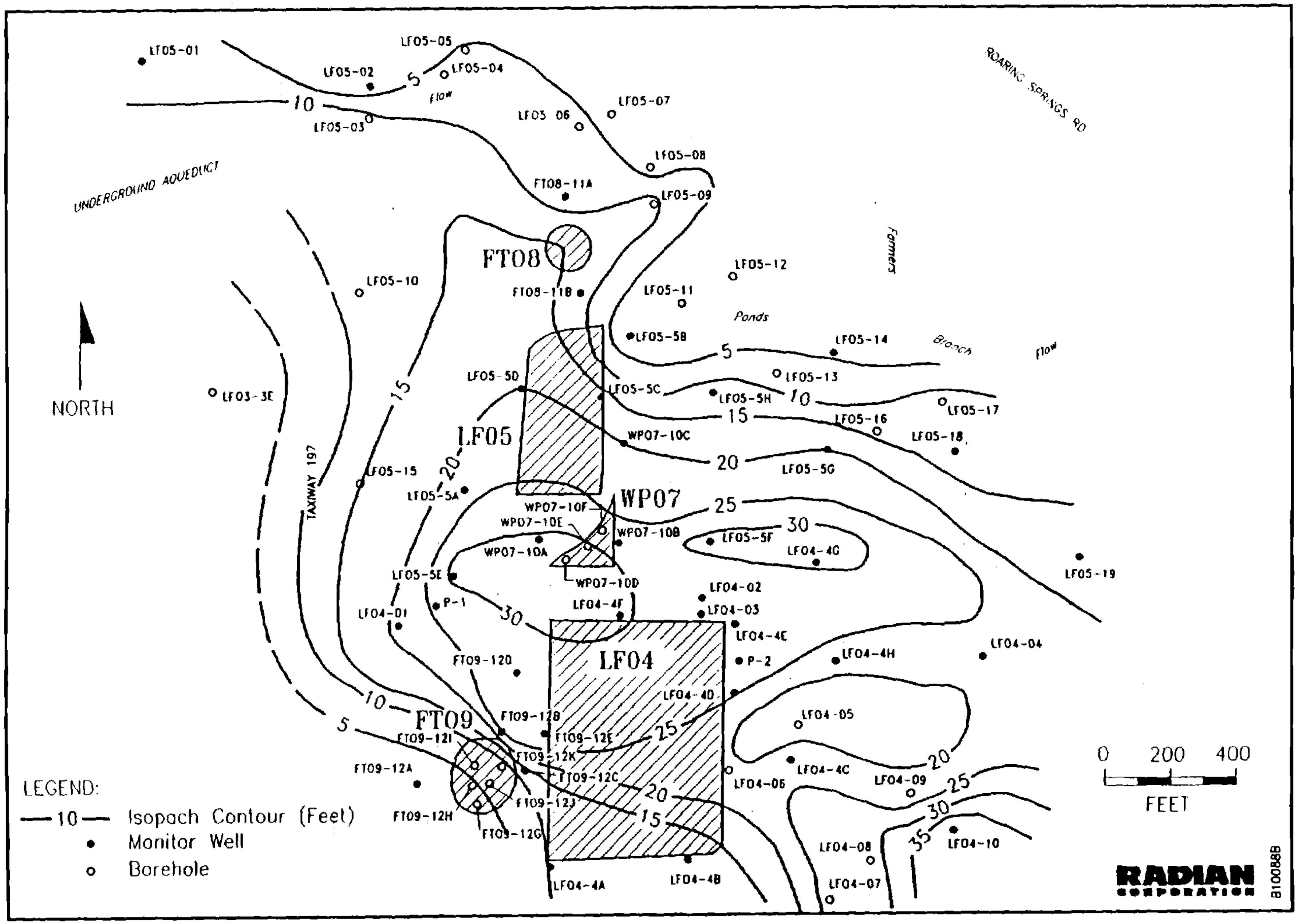

Figure 1-11. Sand and Gravel Isopach Map, Flightline Area Carswell AFB Texas

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 $\mu g/L$ 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 $\mu g/L$, 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

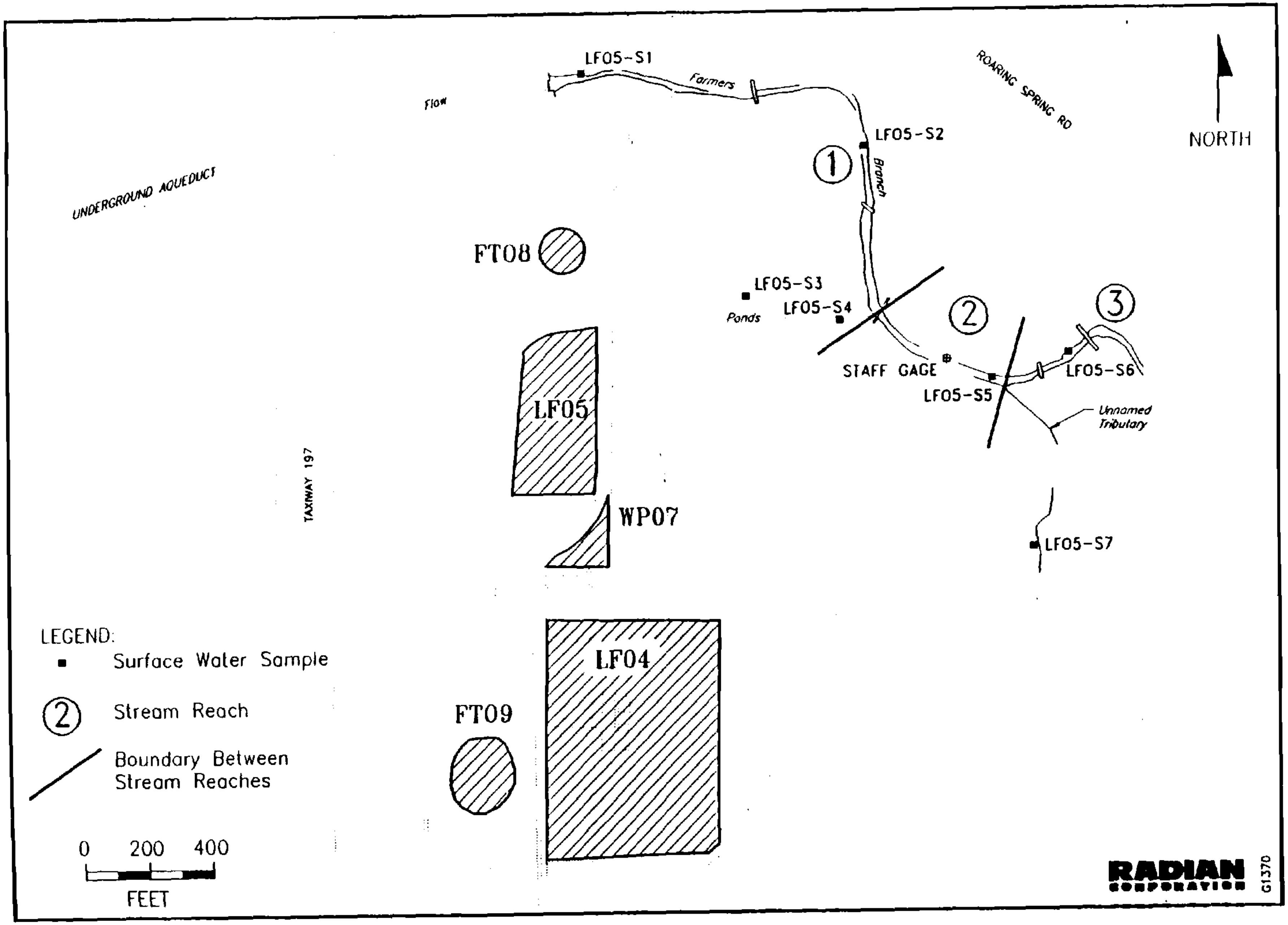

Figure 1-12. Surface Water Sampling Points and Three Divided Reaches of Farmers Branch, Flightline Area, Carswell AFB, Texas

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 evapo-transpiration 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.

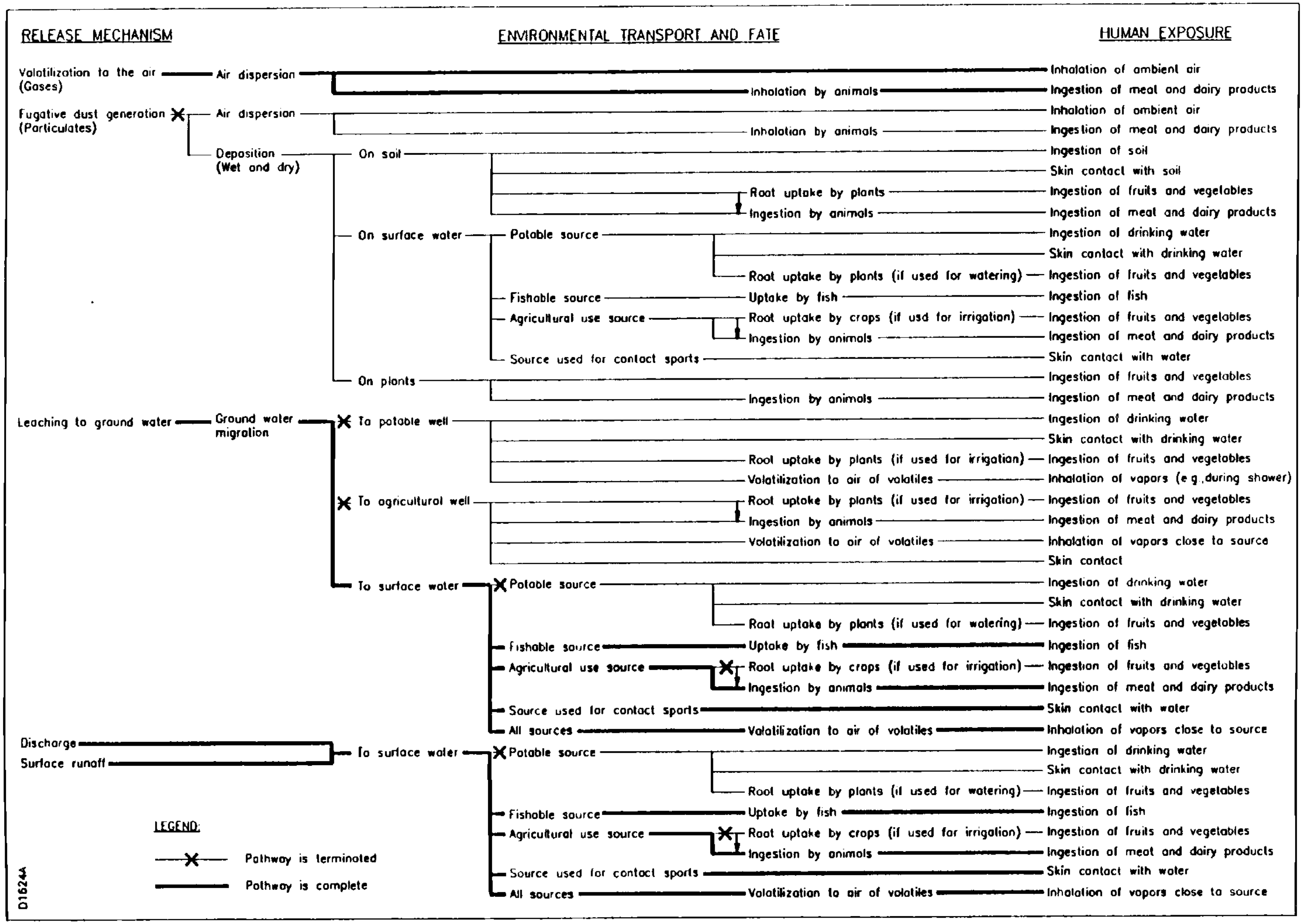

Figure 1-13. Potential Exposure Pathways for Contaminants Released from the Carswell AFB Flightline Area

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 EPA

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.

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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		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

Environmental Media	Remedial Action Objectives
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).

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

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.

*Rer⁻ial technologies or process options eliminated from further conside· ion (see Section 2.3).

(Co· ·ued)

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 whith 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.

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)

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)

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 groundwater.
		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.

*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.

*k dial technologies or process options eliminated from further consi tion (see Section 2.3).

(C nued)

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.

In-Situ Treatment--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).

Physical Treatment--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.

Chemical Treatment--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.

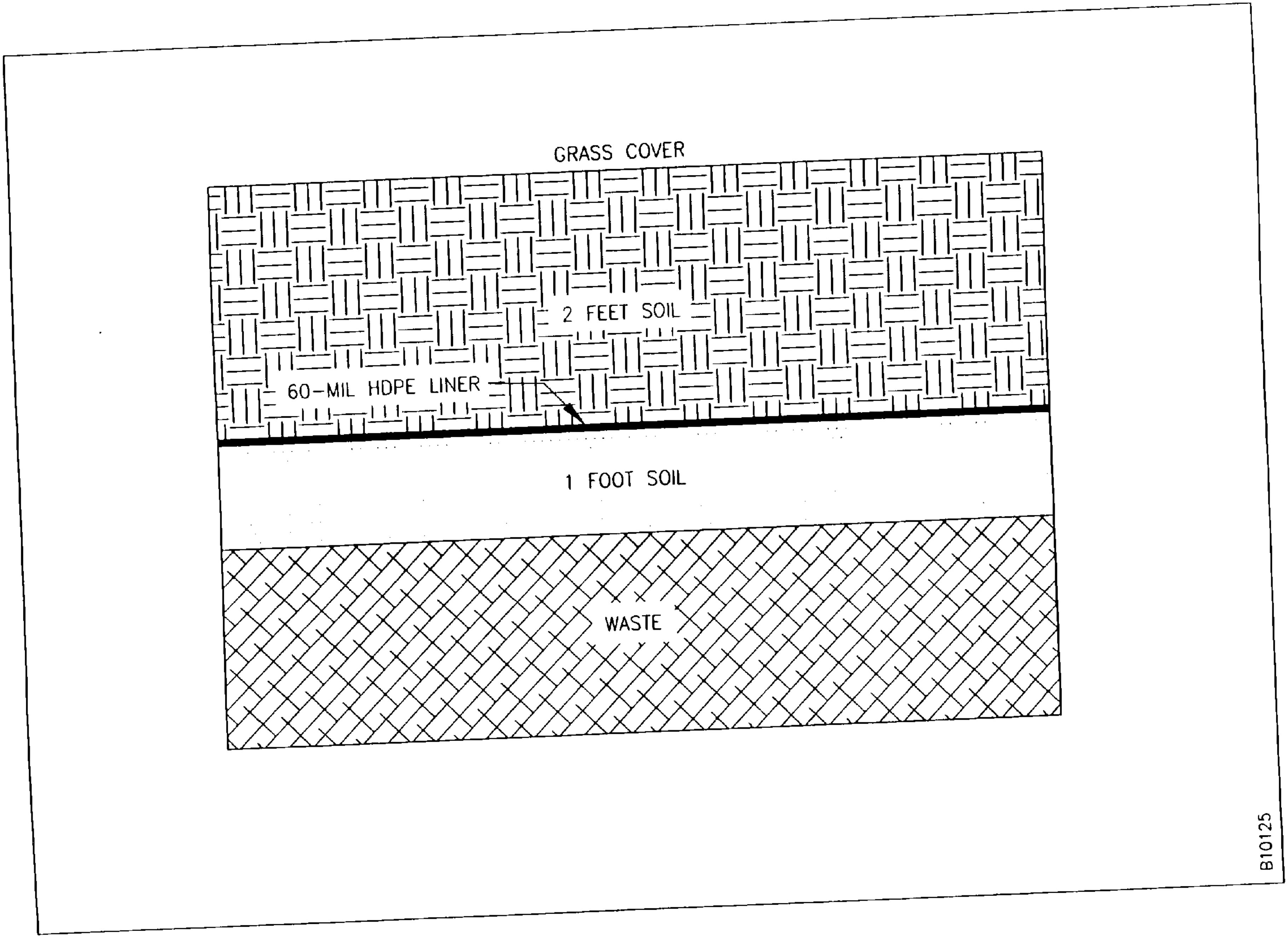

Figure 2-1. Multi-Media Cap Design

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.

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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*
Waste Containment												
Cap Existing Landfills	NA	■	■	■	■					■	■	
Slurry Wall Placed Around Perimeter of Landfill	NA	■	■					■	■			
Ground-Water Extraction Wells Placed on Perimeter of Landfill	NA			■	■	■	■					
Ground Water												
Monitoring	NA	■	■	■	■	■	■	■	■	■	■	■
Extraction Well System	NA	■	■	■	■	■	■	■	■	■	■	■
On-Site Air Stripping	NA	■	■	■	■	■	■	■	■	■	■	
Disposal												
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

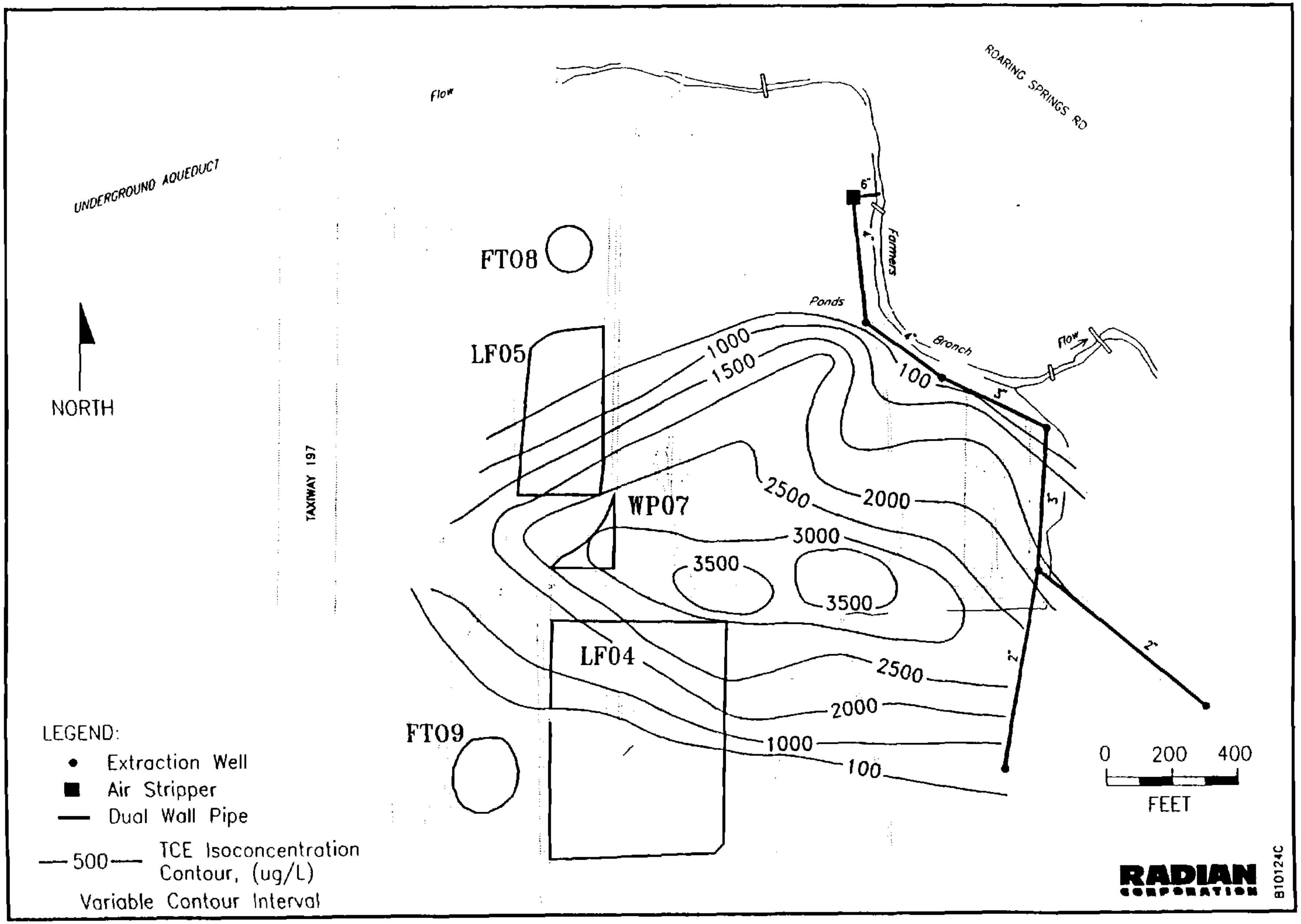

Figure 3-1. Ground-Water Extraction System Lo‿ ‿ed Adjacent to Farmers Branch Creek (Option 1)

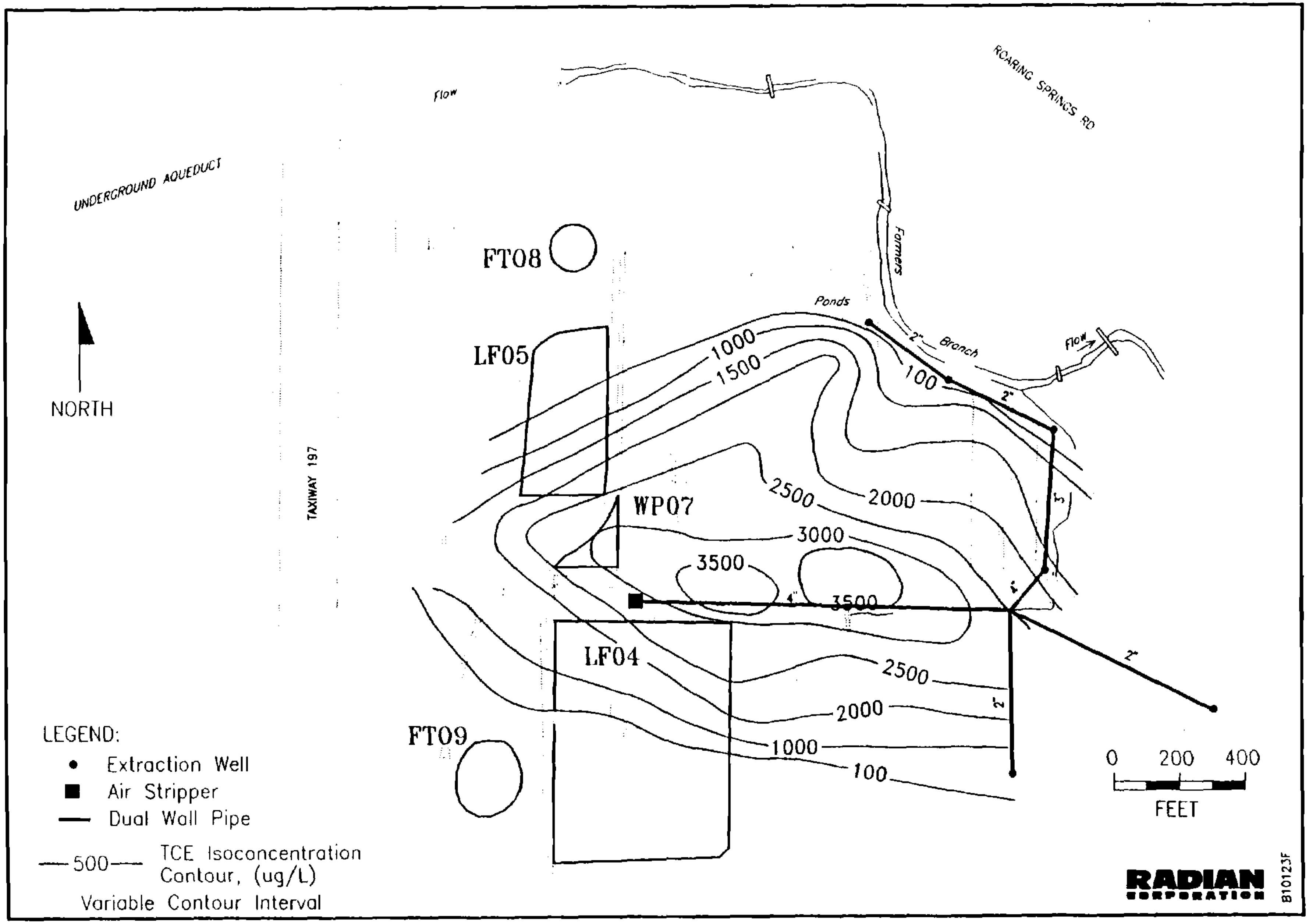

Figure 3-2. Ground-Water Extraction System Located Between Sites LF04 and LF05 (Option 2)

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.

<u>On-Site Air Stripping Treatment System (ASTS)</u>

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 apor 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 ficiency, and the column diameter is designed from flooding correlations

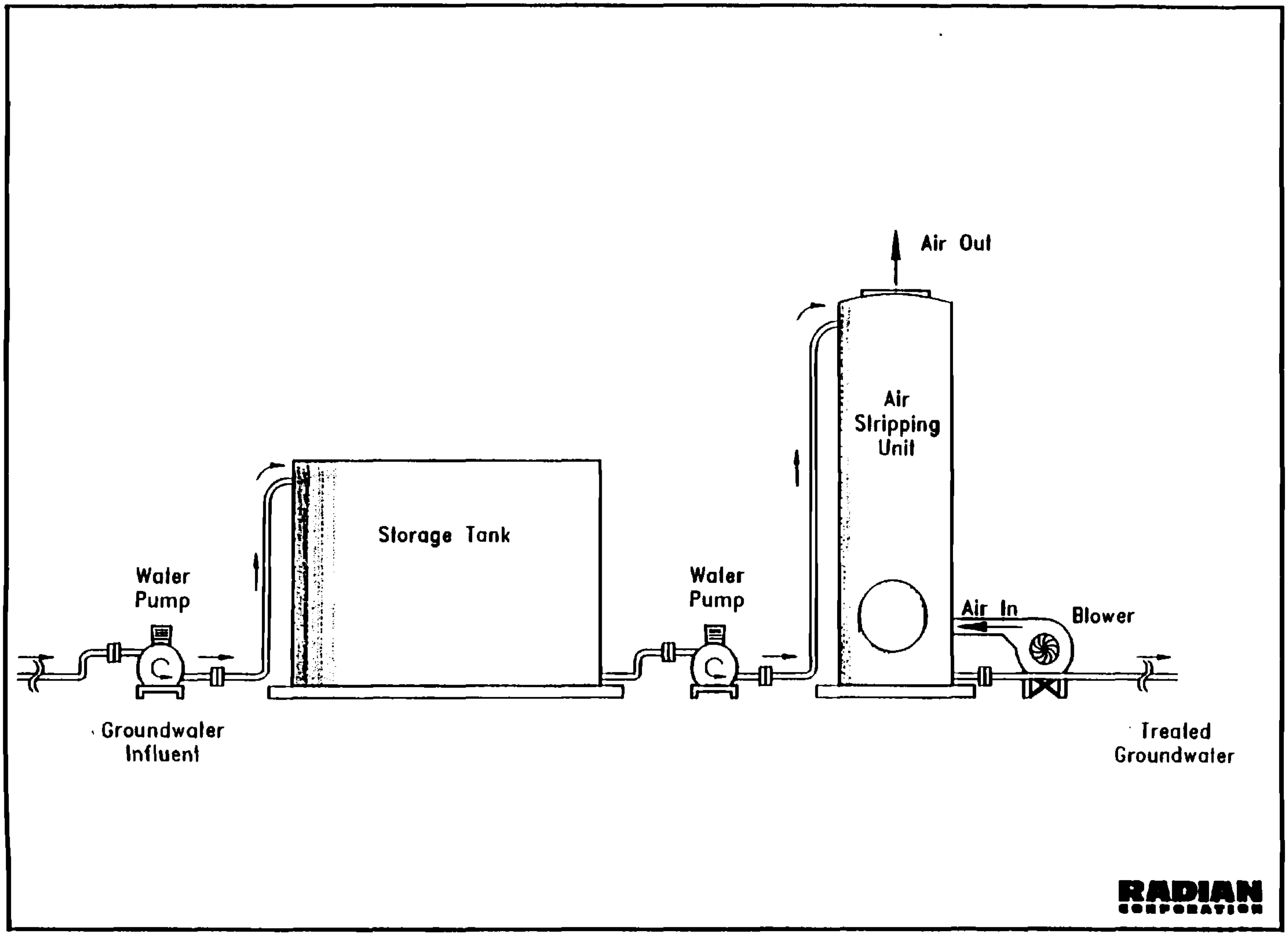

Figure 3-3. Schematic of Proposed Air Stripper Treatment Unit

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

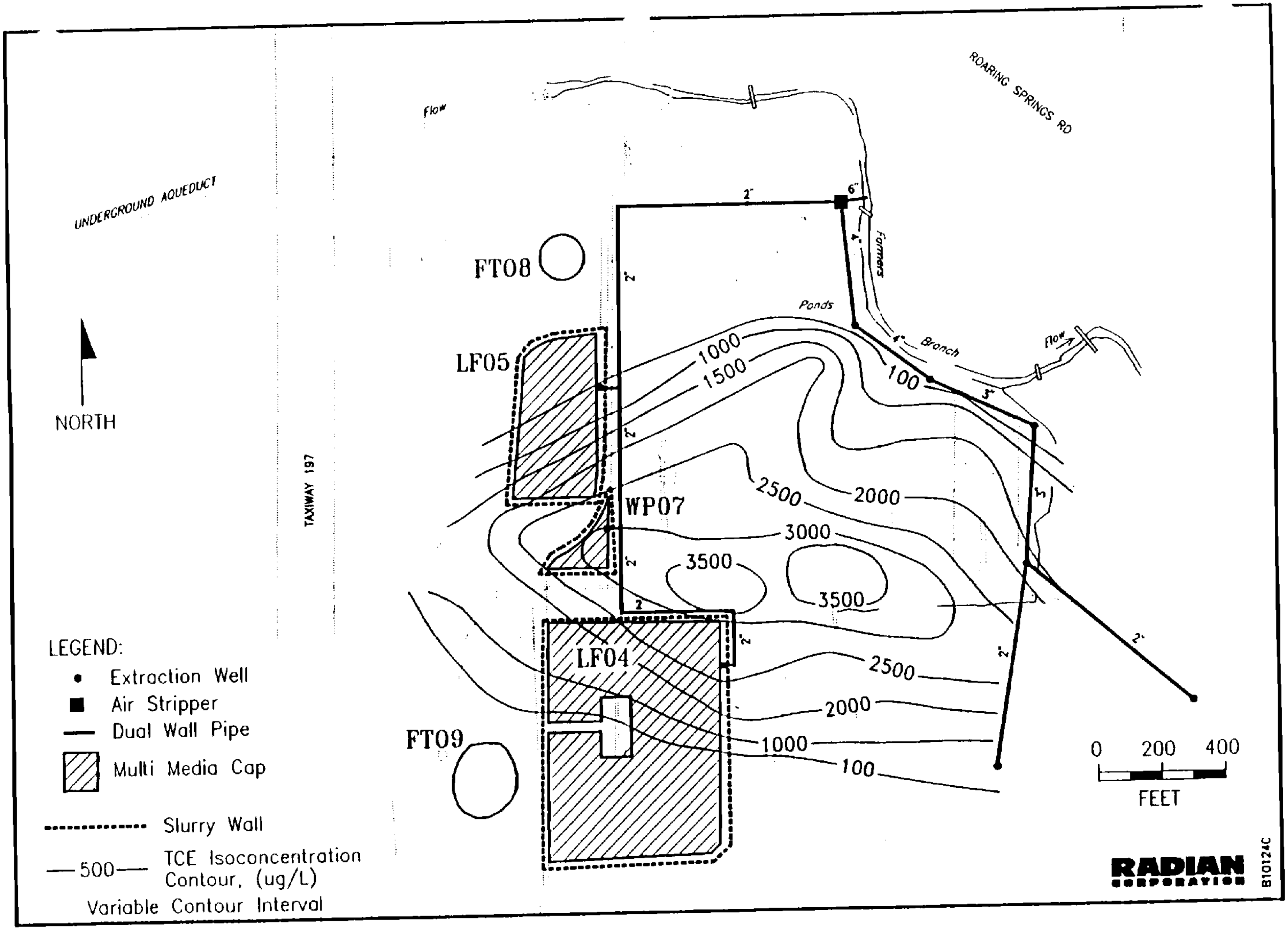

Figure 3-4. Alternative 2A

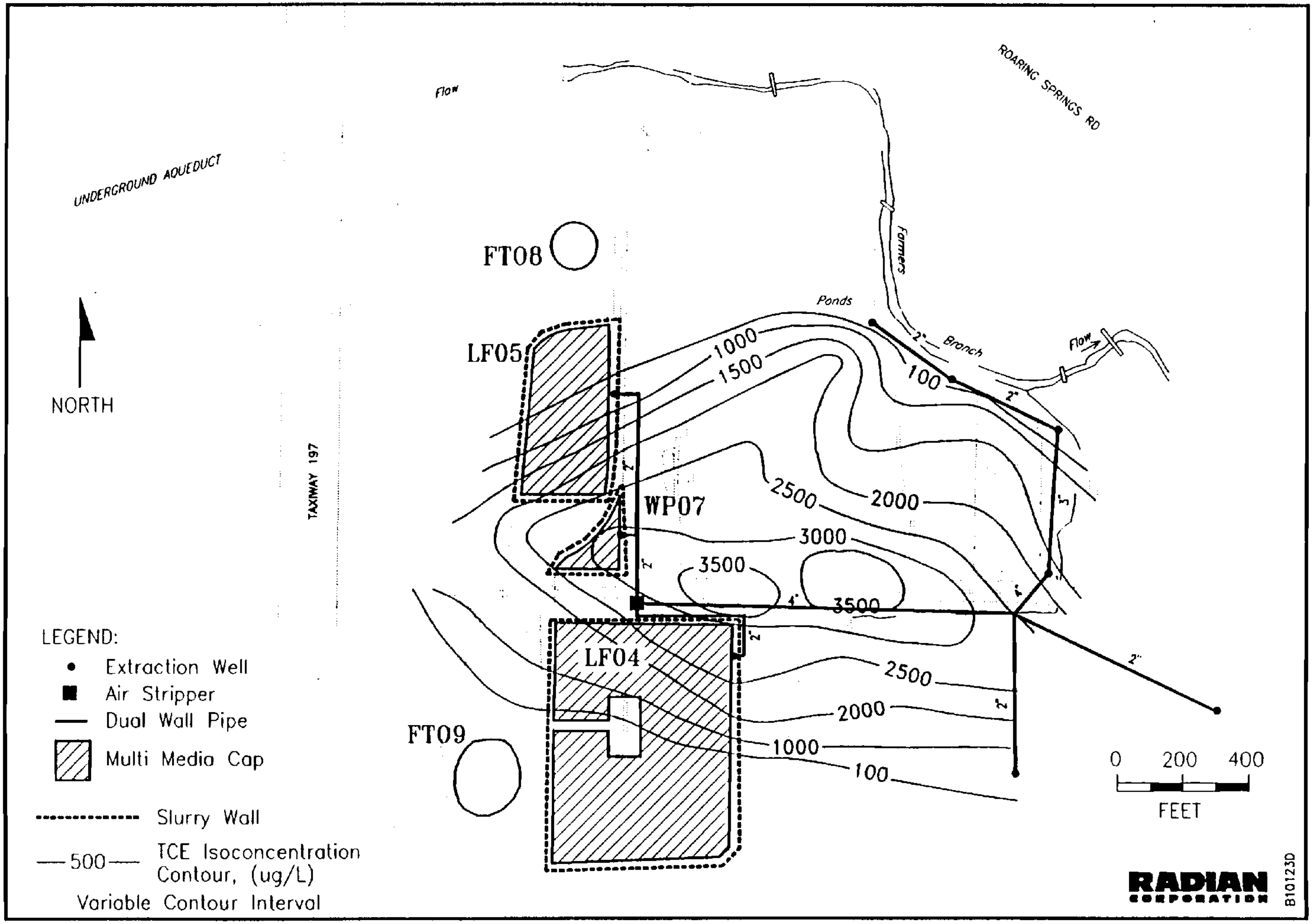

Figure 3-5. Alternative 2B

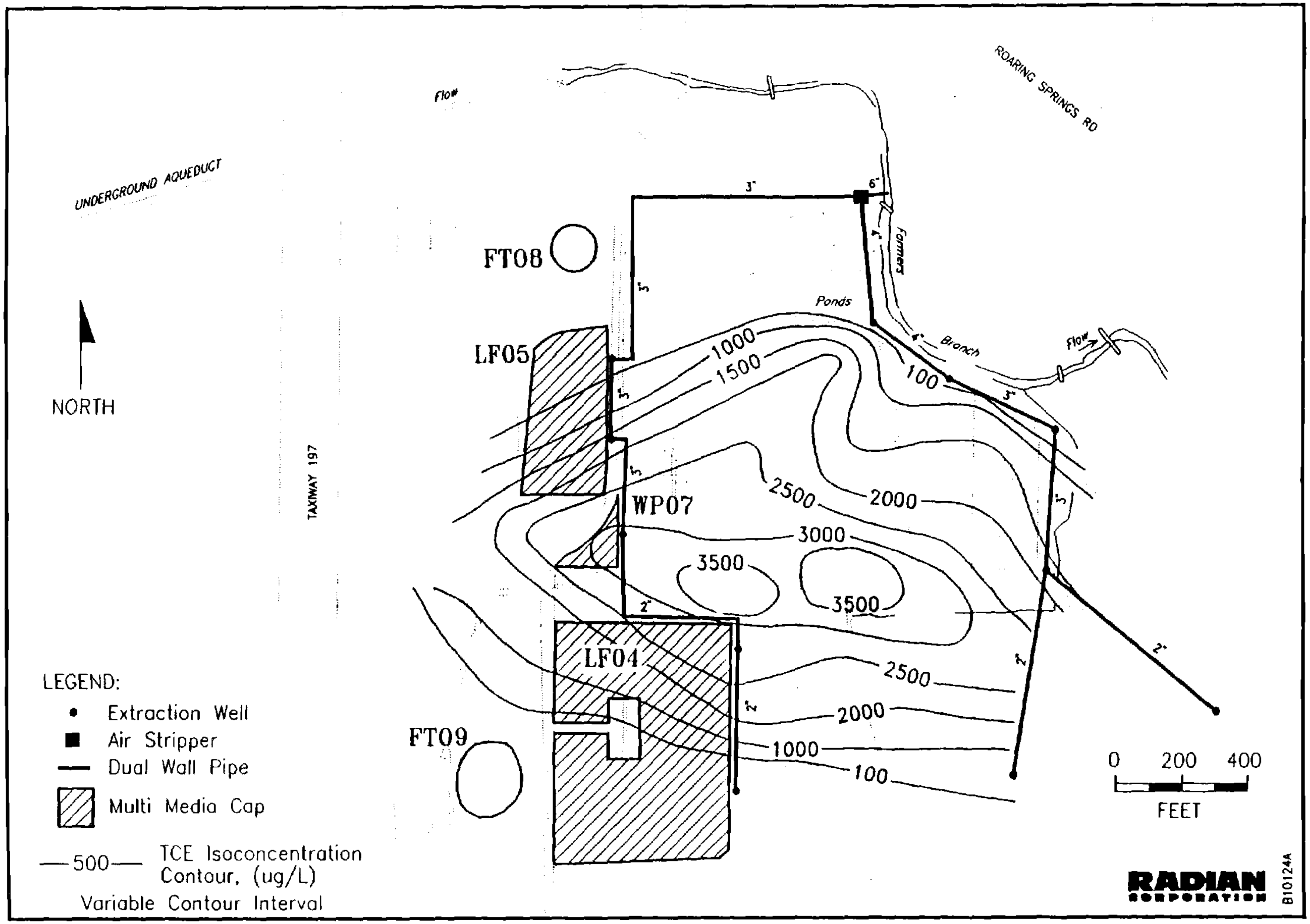

Figure 3-6. Alternative 3A

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.

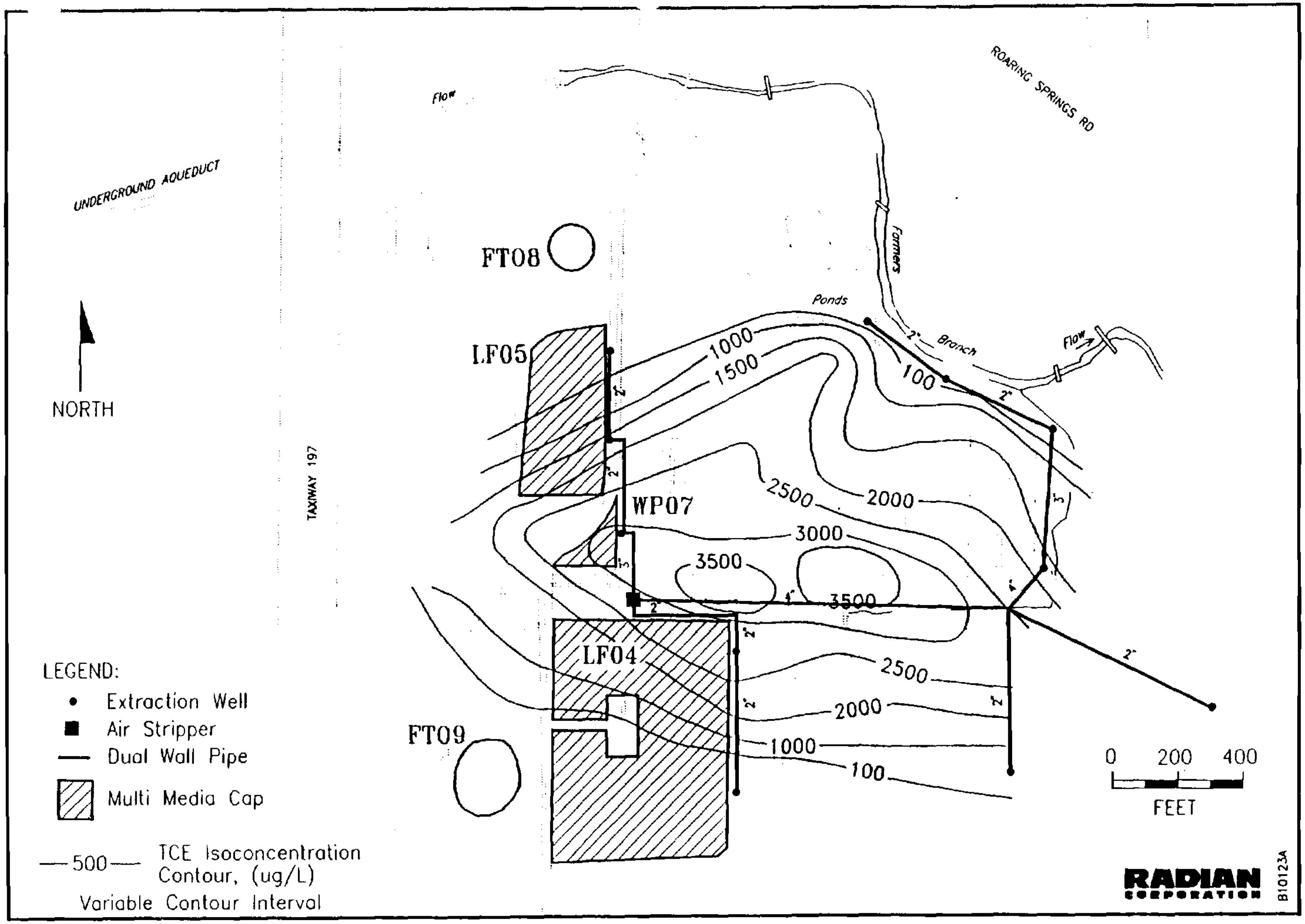

Figure 3-7. Alternative 3B

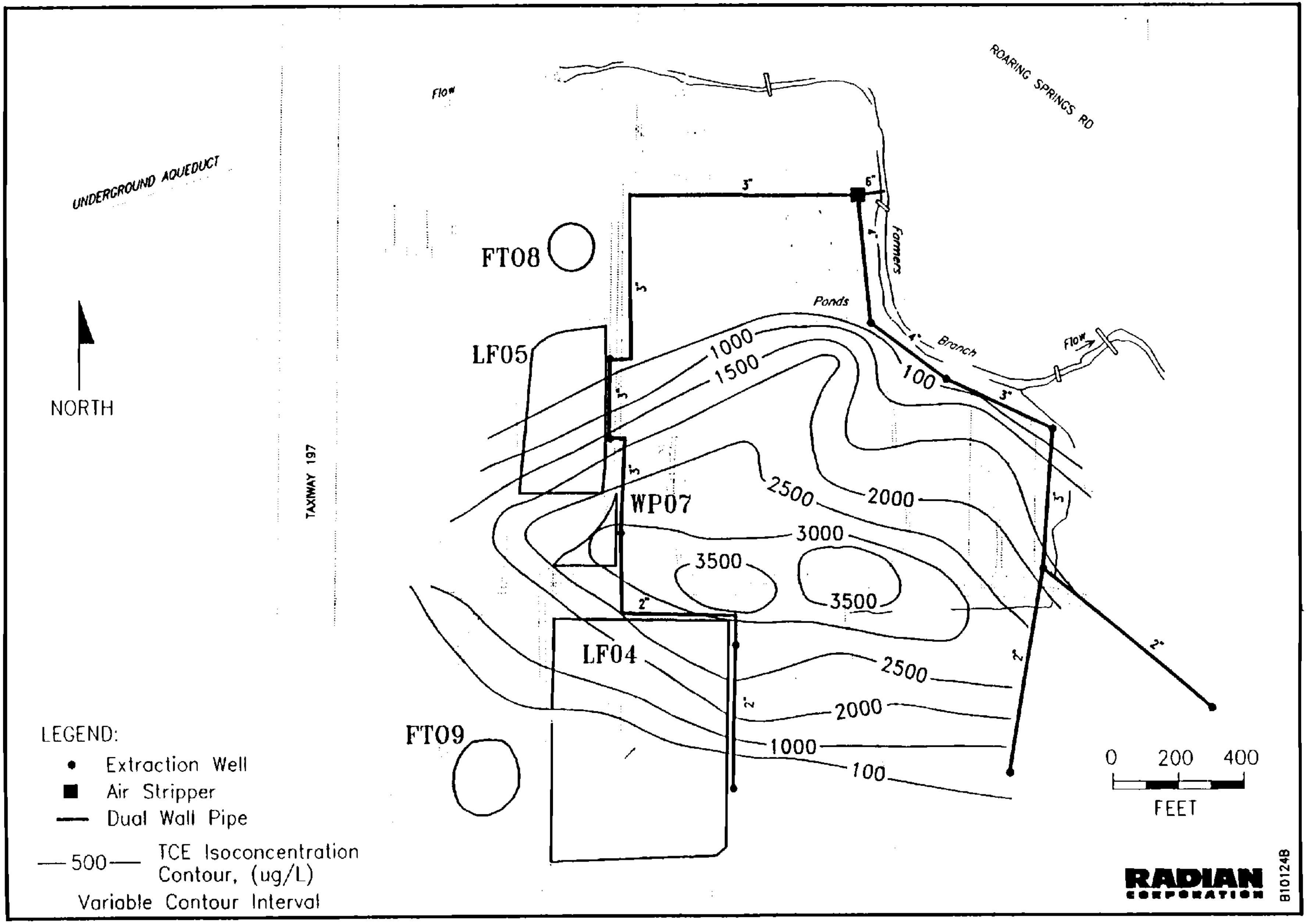

Figure 3-8. lternative 4A

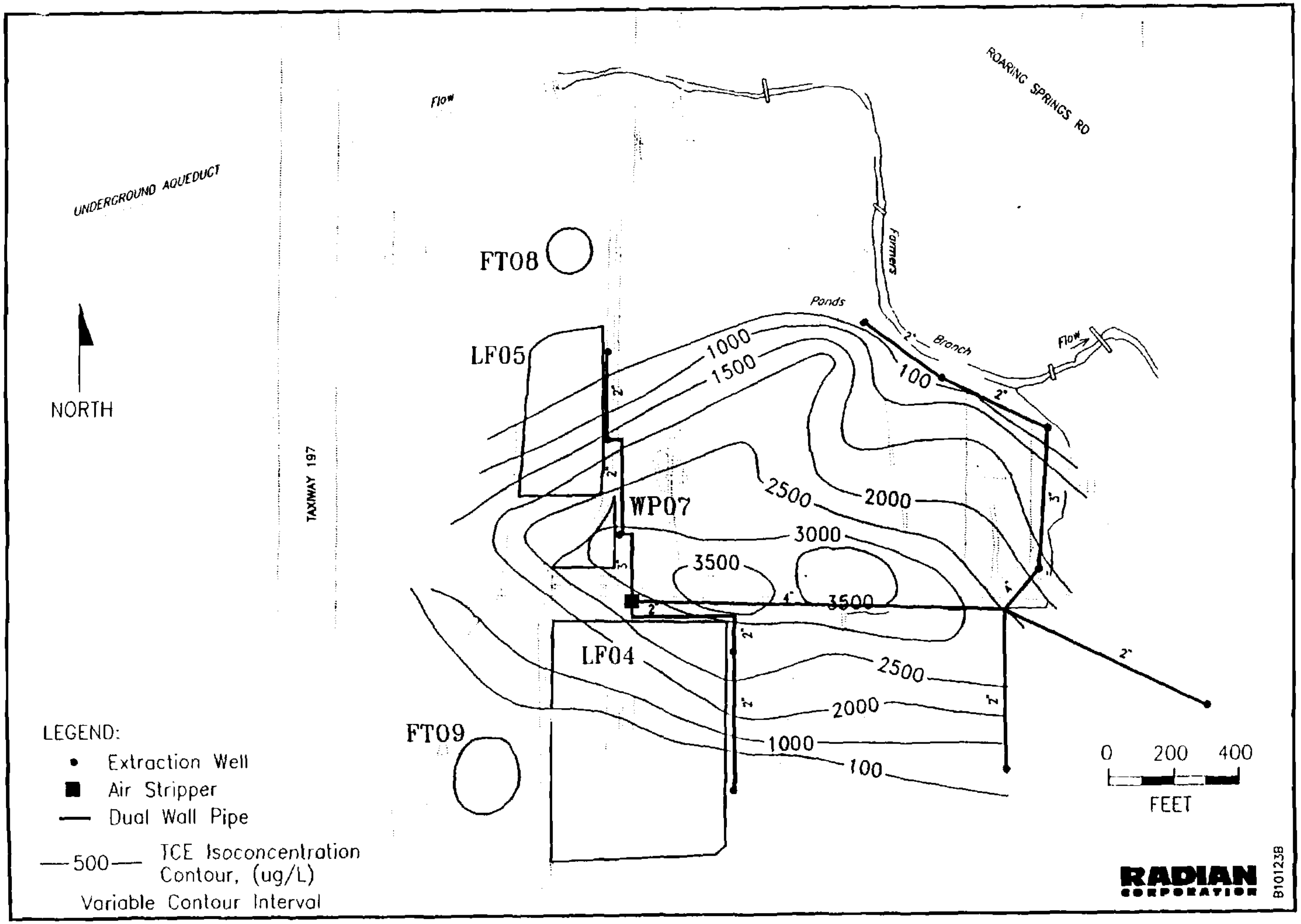

Figure 3-9. Alternative 4B

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.

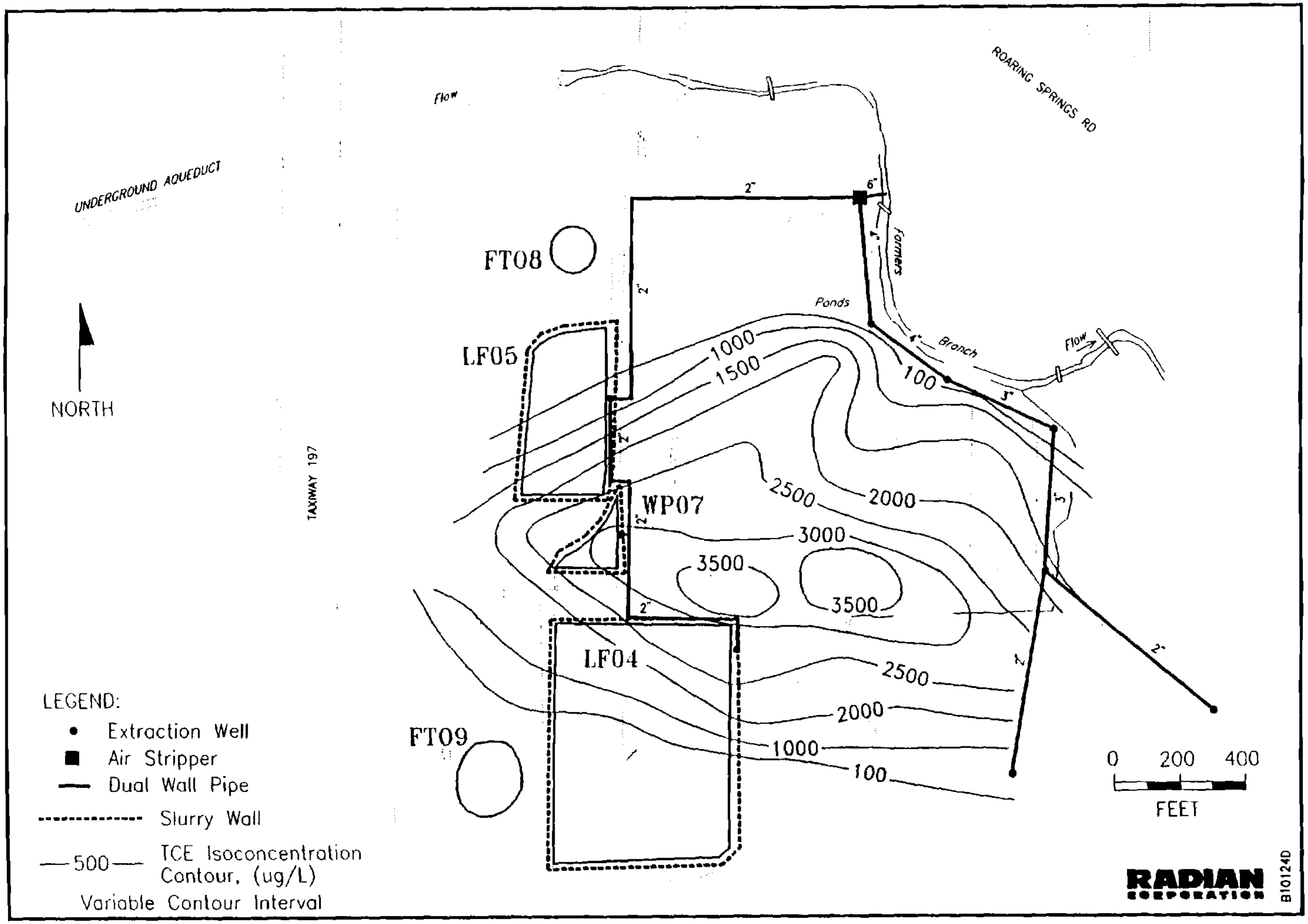

Figure 3-10. Alternative 5A

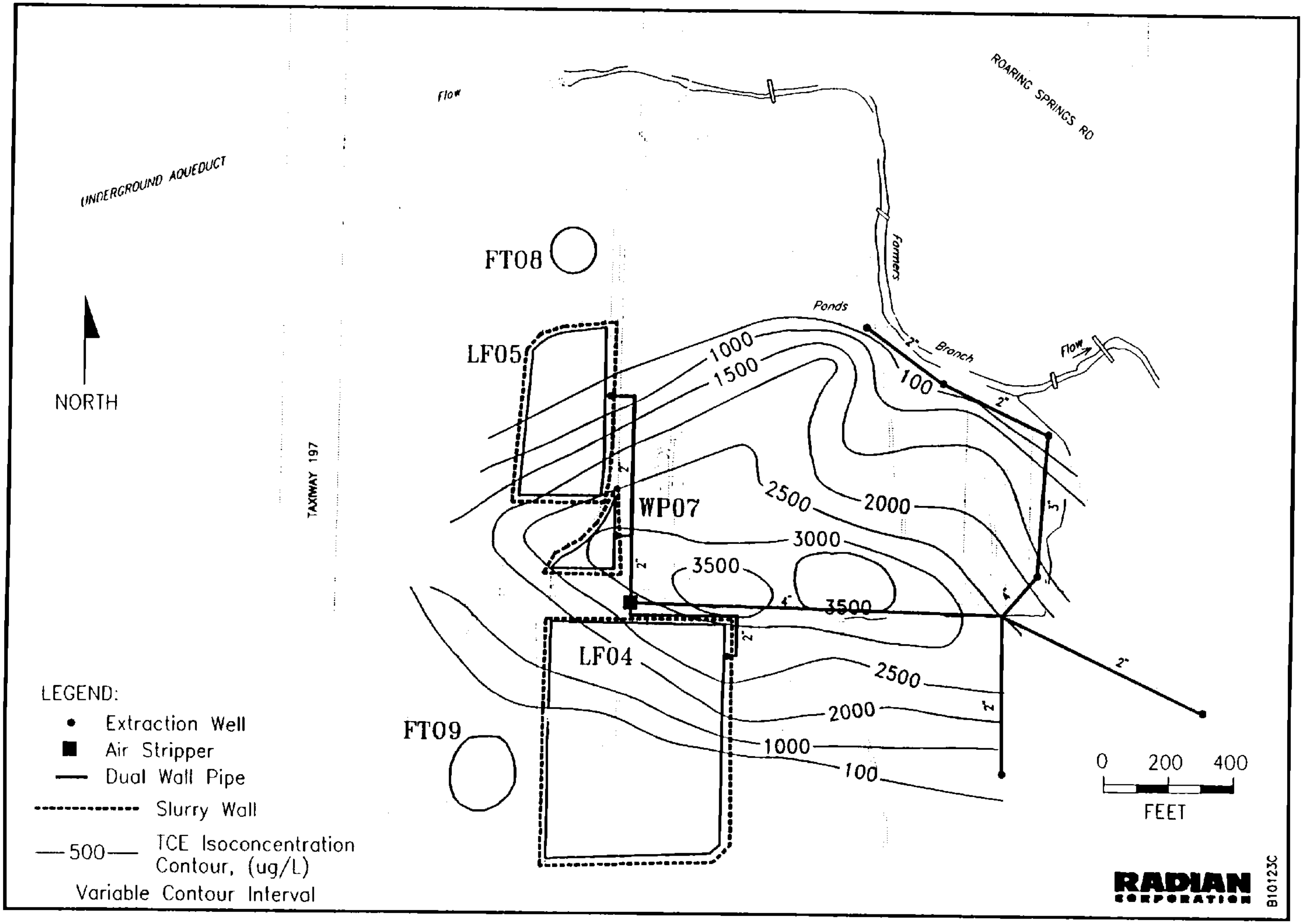

Figure 3-11. .lternative 5B

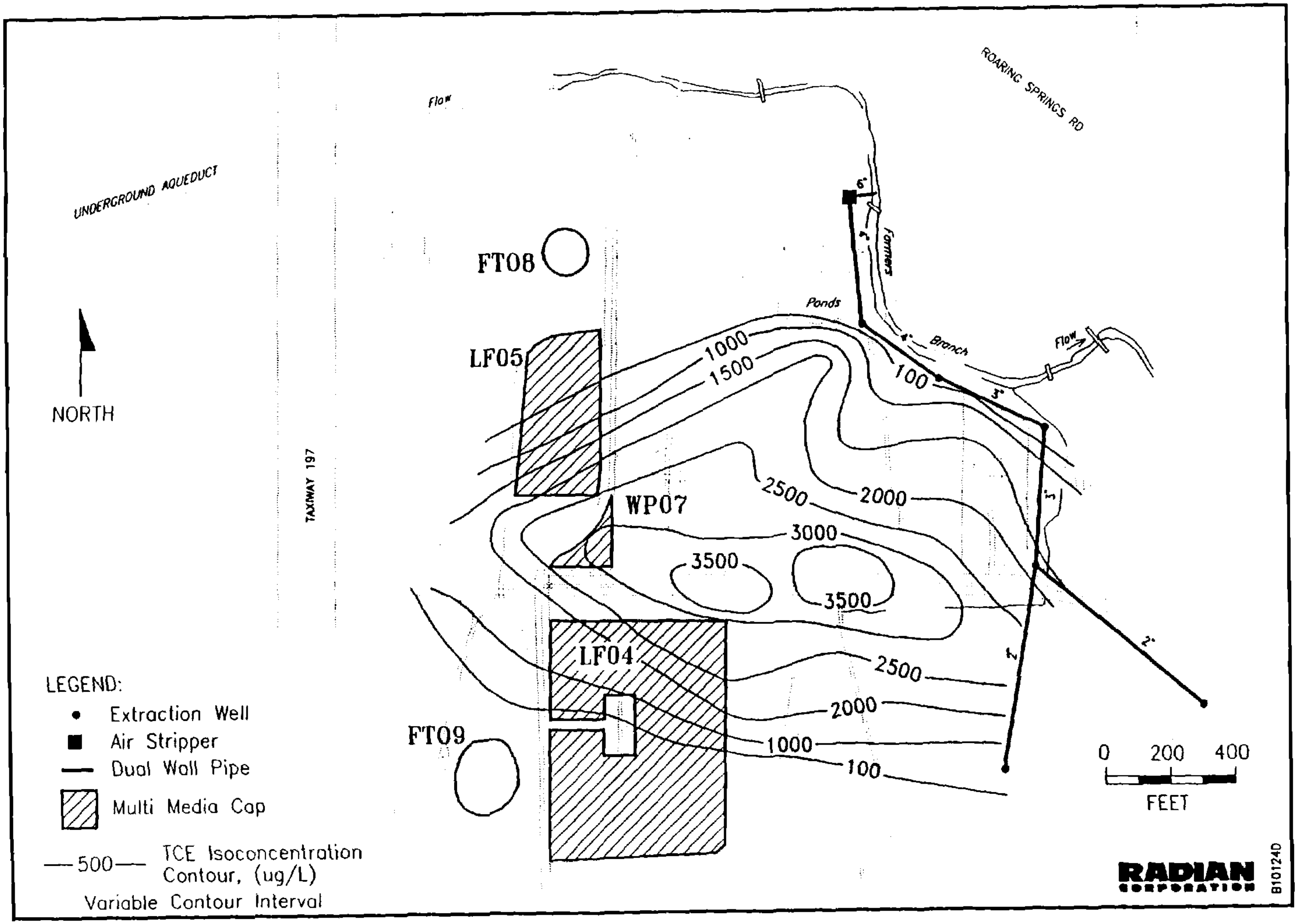

Figure 3-12. Alternative 6A

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.

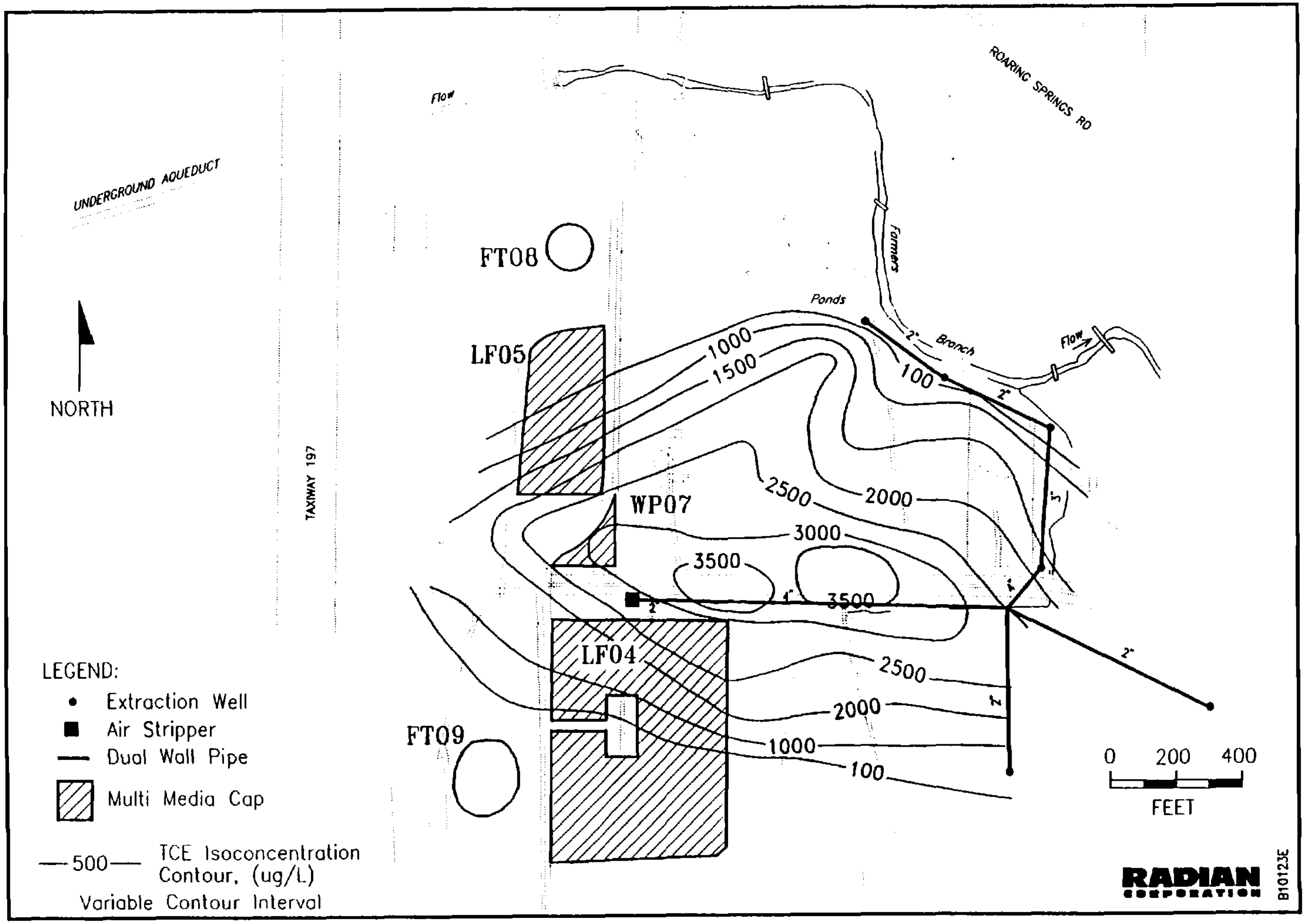

Figure 3-13. Alternative 6B

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.

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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

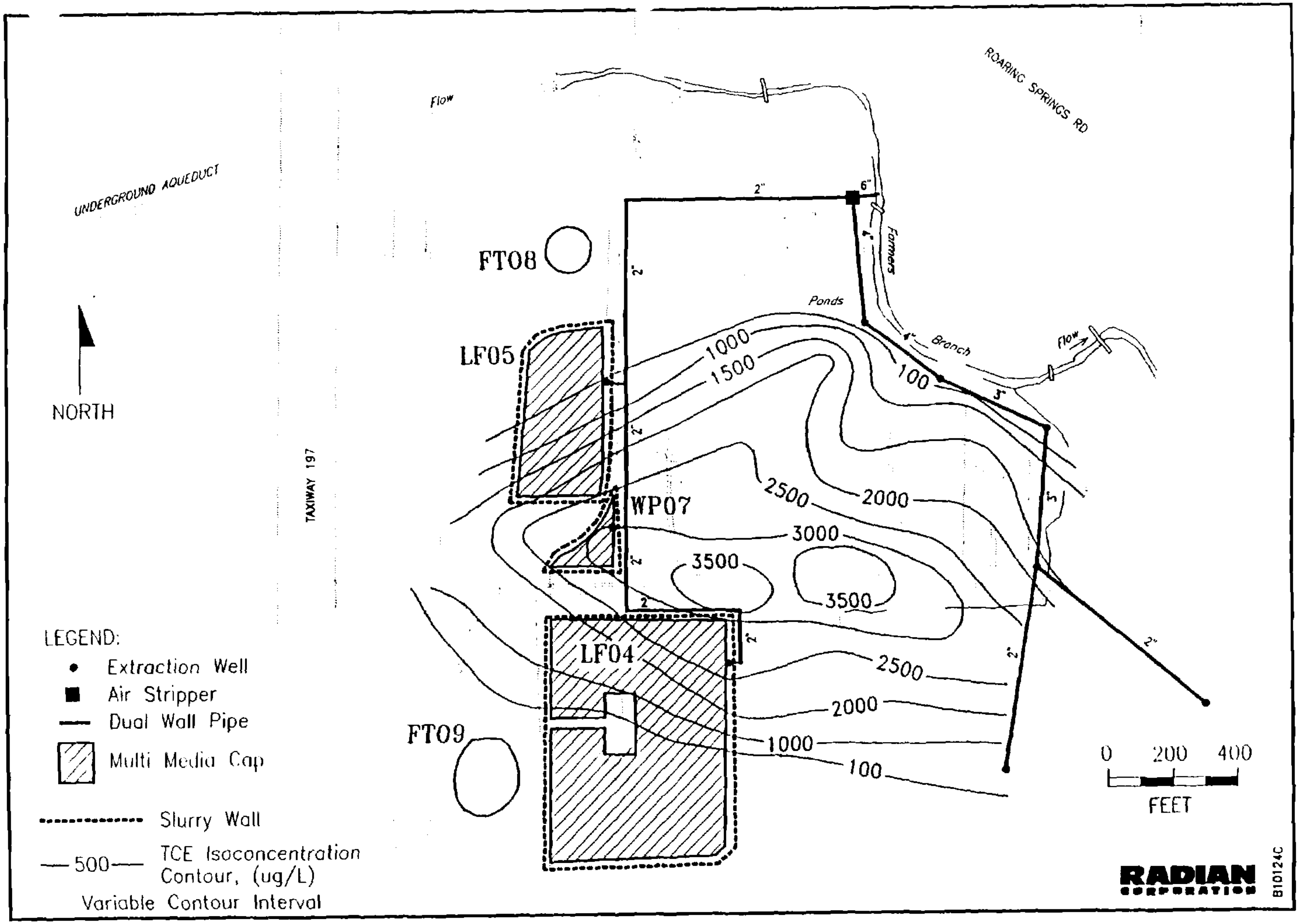

Figure 4-1. Alternative 2A

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.

-ıdditional data generated by the pump tests will be used in a computer uıation to model aquifer response to the ground-water extraction system. s will ensure that the extraction well system is properly designed to ture all Upper Zone ground-water contamination.

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

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

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

Alternative 2B - Description and Criteria Assessment

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

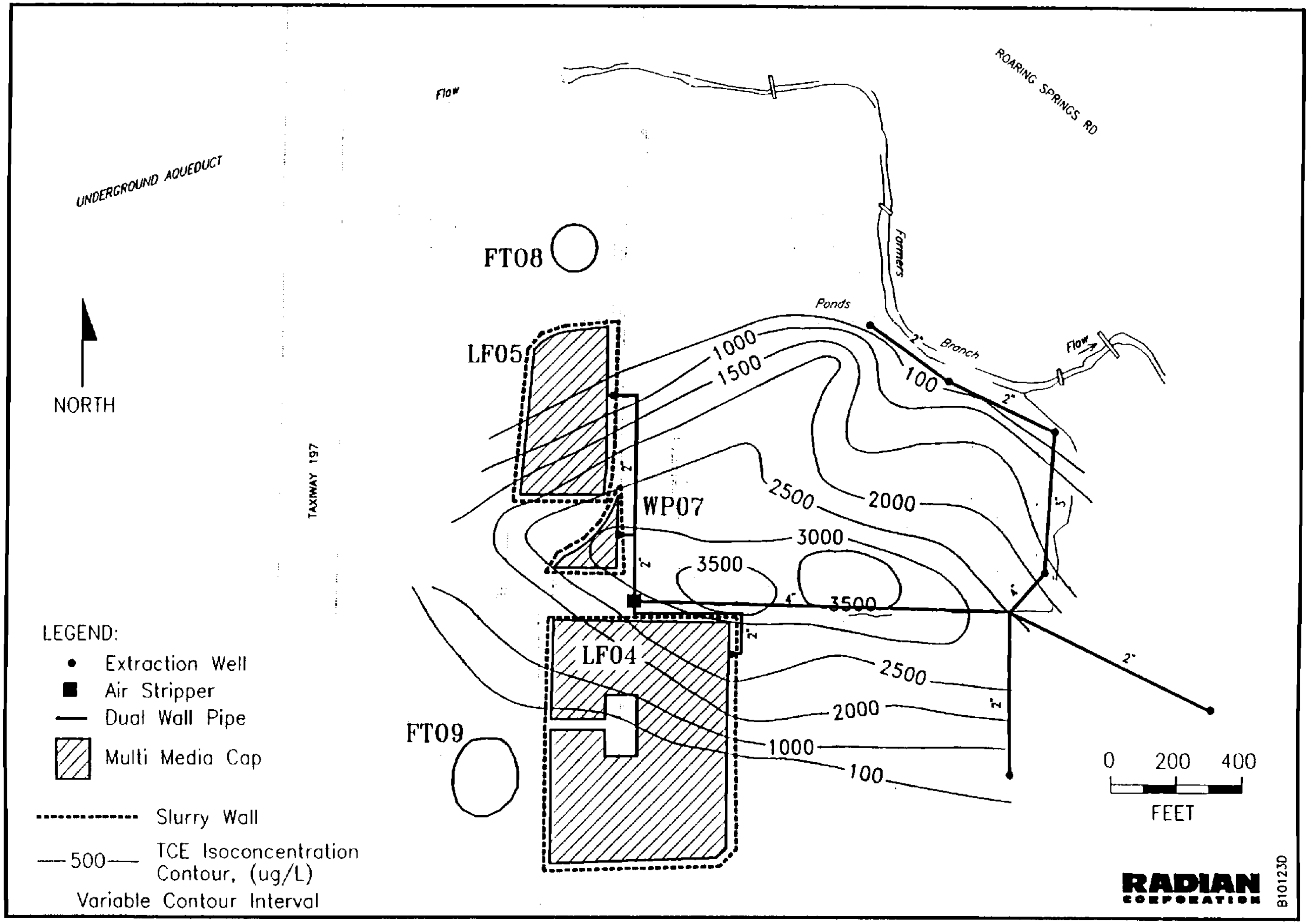

Figure 4-2. Alternative 2B

r--ated effluent to be discharged into the POTW sewer line and/or to be used)r base golf course irrigation.

The criteria assessment for this alternative is the same as Alter- ıtive 2A except for the discharge criteria. Because the treated effluent is .scharged into the City of Fort Worth POTW, the discharge requirements will :obably be less stringent for this alternative than for discharge into ırmers Branch. The 30-year present worth cost of this alternative is :timated to be $7,366,000, with a projected $5,533,000 for capital expen- .tures. The annual operating and maintenance cost for the first 10 years of eration is estimated to be $67,000. For the 20 years following, the annual eration and maintenance cost will be reduced to an estimated $52,000. A tailed cost estimate for each component of this alternative is listed in pendix A, Table A-2. The economical benefits of using a portion of the eated ground water to irrigate the base golf course are not included in the st estimates.

! Alternative 3A

5.1 Alternative 3A - Description

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

ı.2 Alternative 3A - Criteria Assessment

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

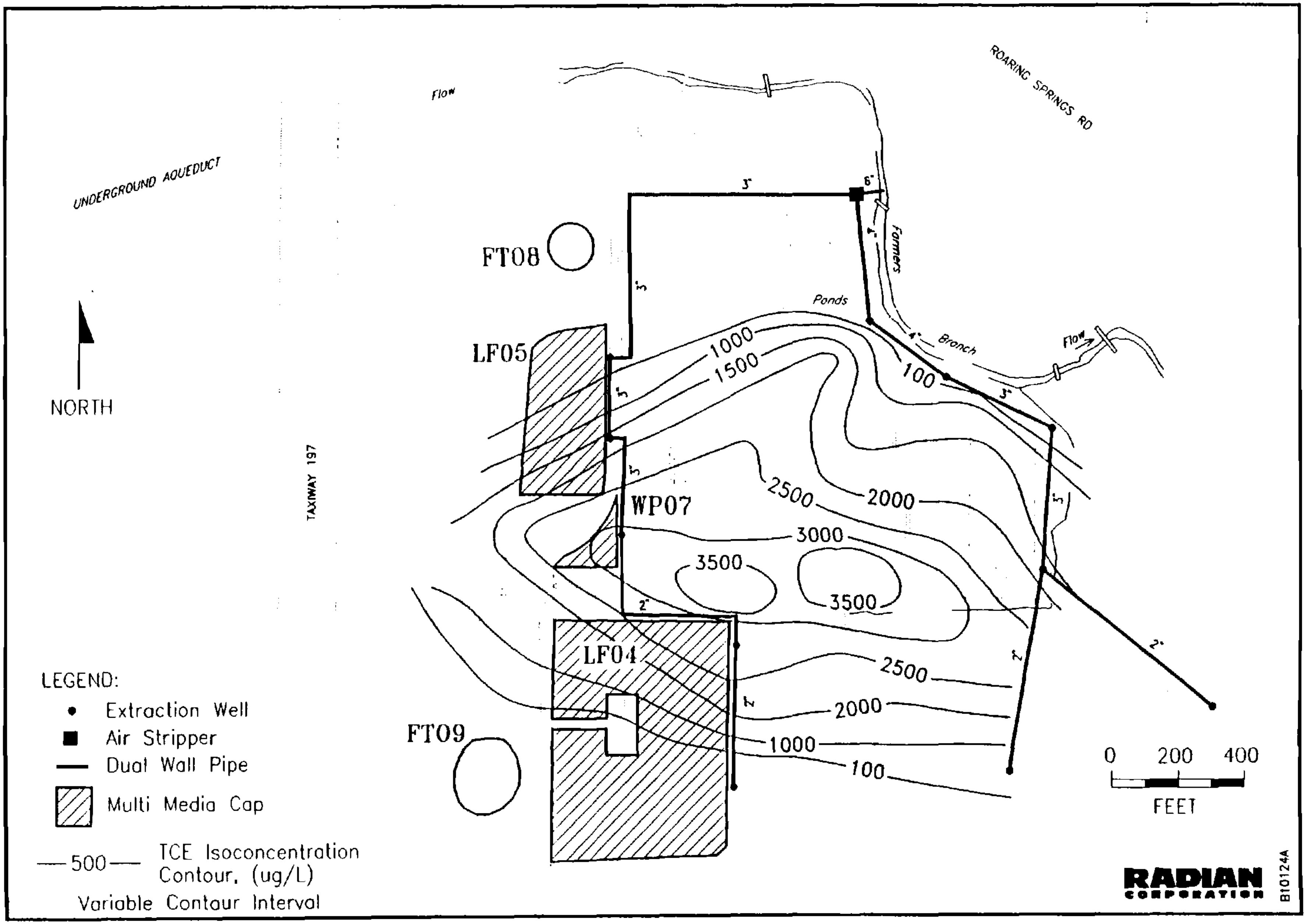

Figure 4-3. Alternative 3A

r placed on the downgradient side of the three waste disposal areas to reate a hydraulic barrier that will prevent future contaminant migration in round water from the three landfills. This hydraulic barrier is judged to be s effective as the slurry wall in Alternative 2A. In addition to capturing ontaminants migrating from the disposal areas, it will also capture any conamination that is migrating into the Flightline Area from upgradient, offite sources (i.e., AF Plant 4). If, as expected, a significant component of pper Zone ground-water contamination in the Flightline Area has its source on F Plant 4, the three additional pumping wells included in this alternative rovide additional pumping capacity to contain and remove the contaminant lume. However, in contrast to the slurry wall which is permanent, the ydraulic 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 perating and maintenance cost for the first 10 years of operation is esimated to be $71,000 and for the following 20 years, the annual operation and ε tenance cost will be reduced to an estimated $56,000. A detailed cost stimate for each component of this alternative is listed in Appendix A, Table -3. The economical benefits of using a portion of the treated ground water o irrigate the base golf course are not included in the cost estimates.

.6 Alternative 3B - Description and Criteria Assessment

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

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

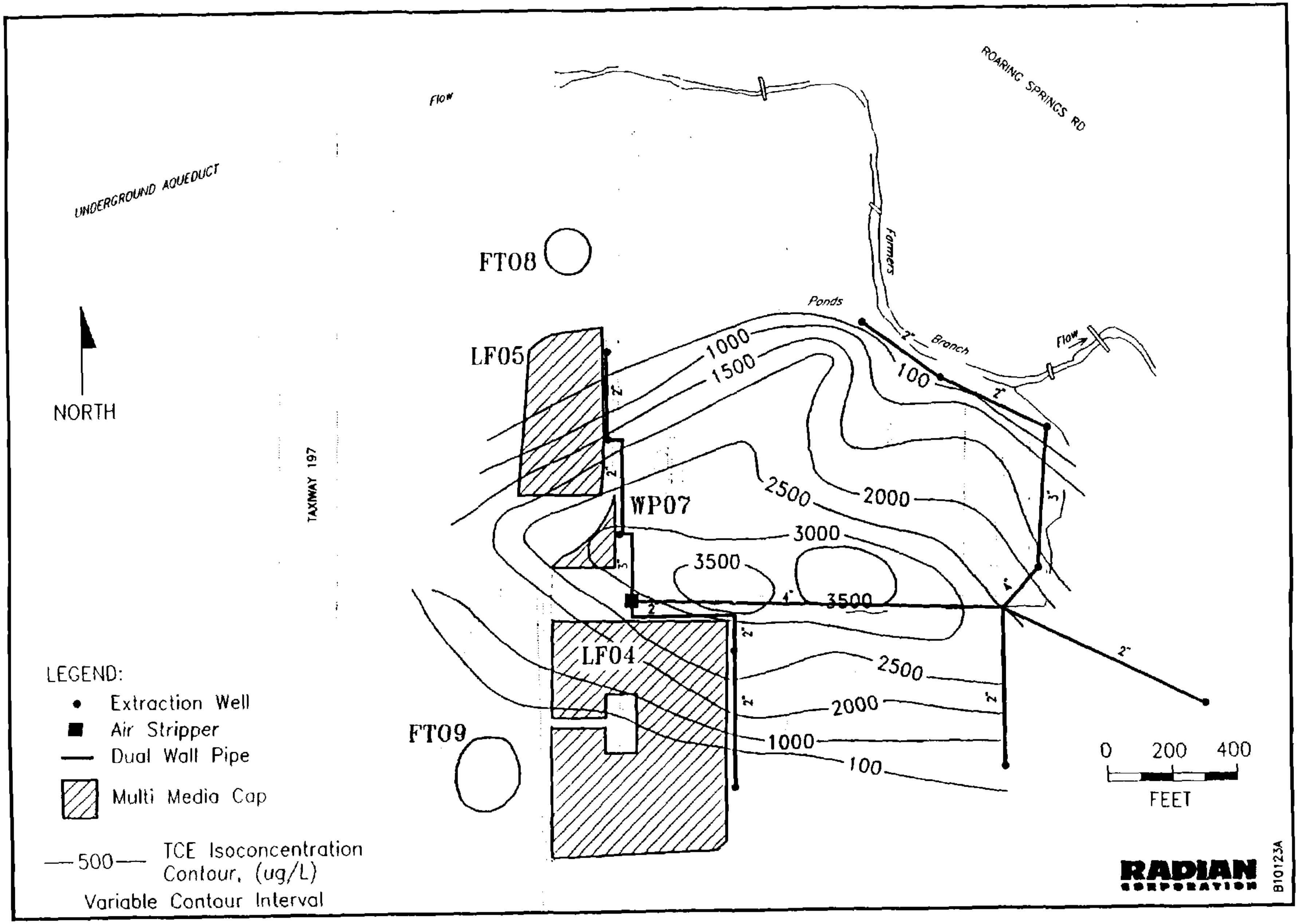

Figure 4-4. lternative 3B

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, round-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 apture the increased hydraulic loading.

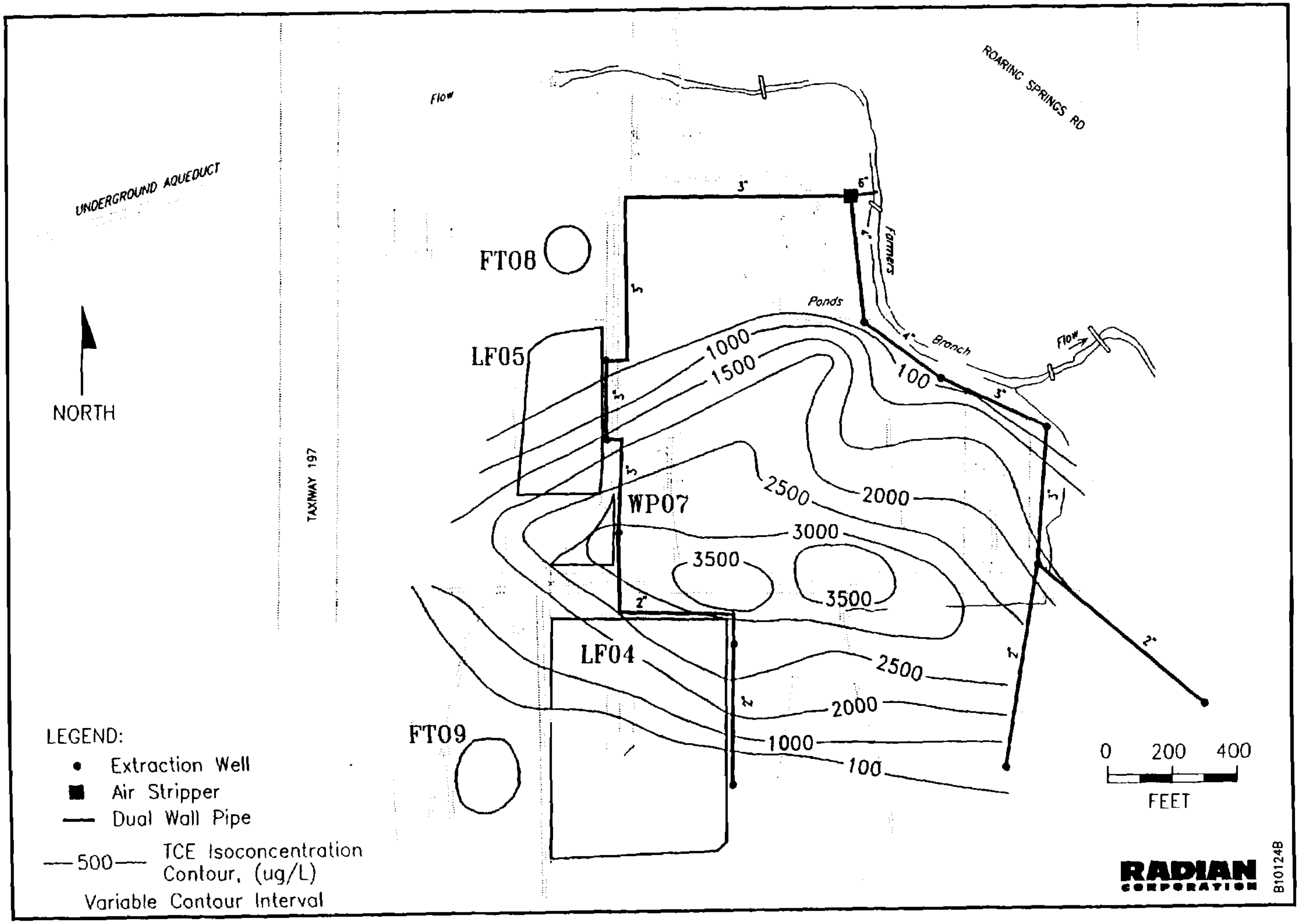

Figure 4-5 Alternative 4A

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.

.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

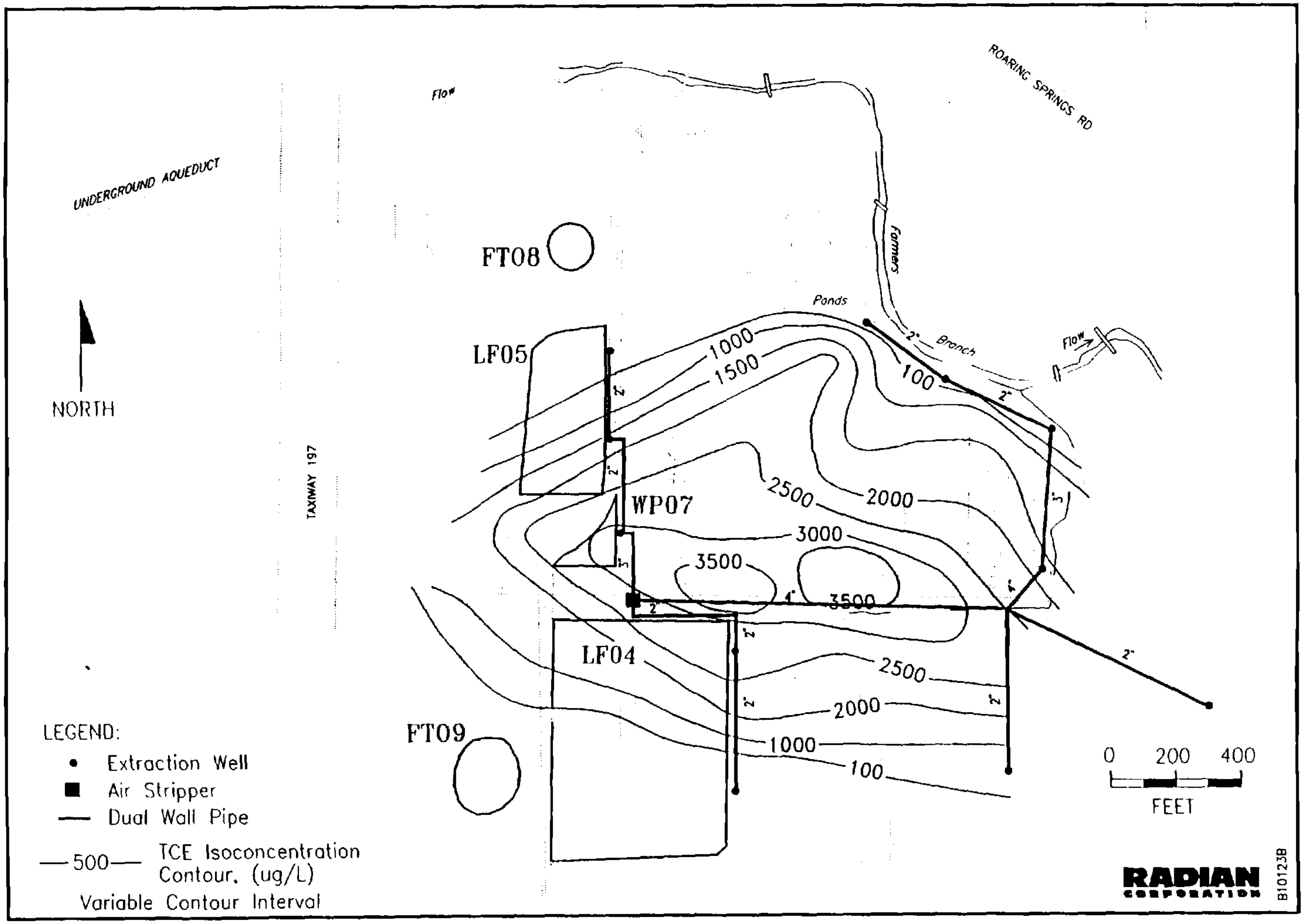

Figure 4-6 Alternative 4B

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.

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.

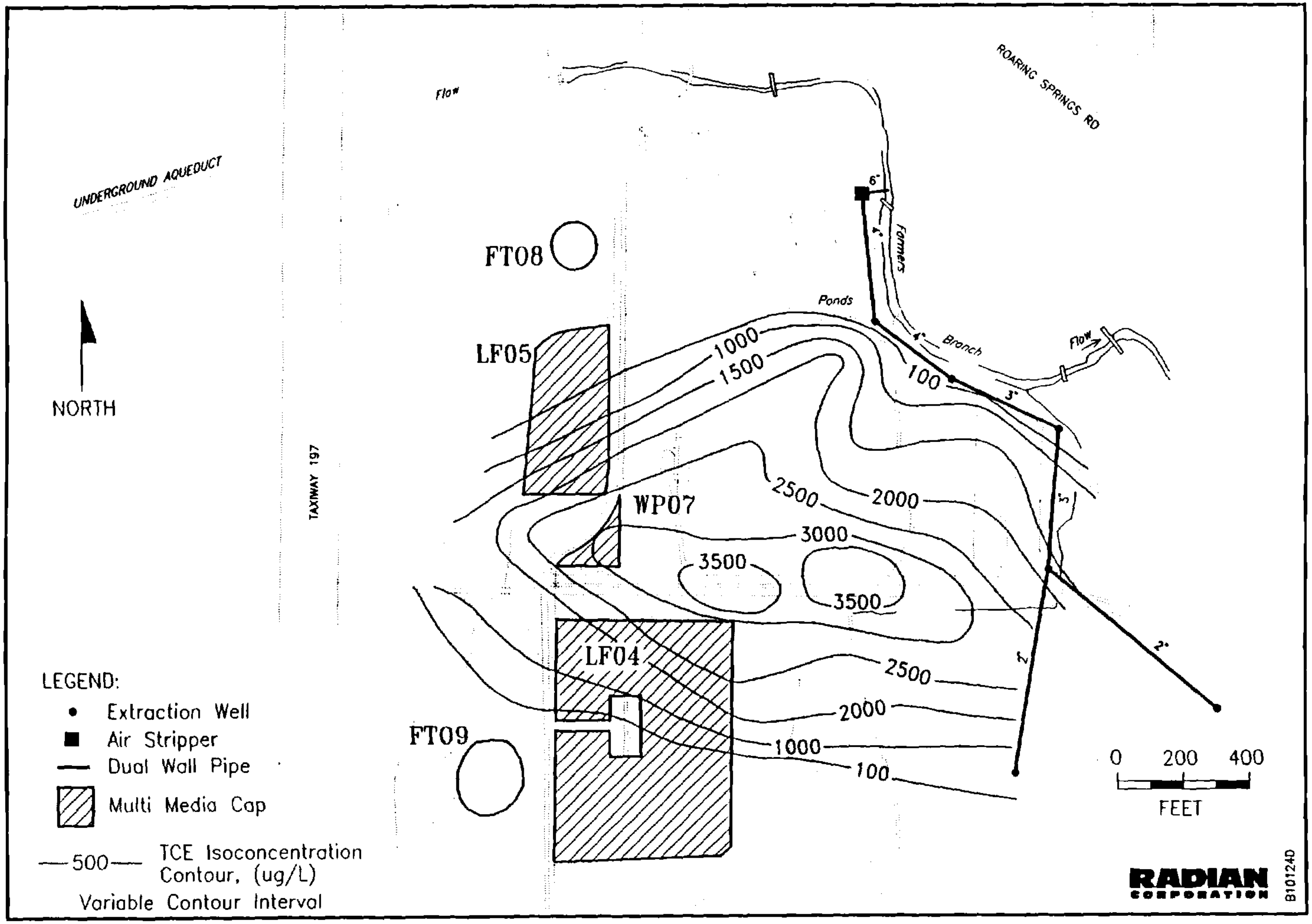

Figure 7. Alternative 5A

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.

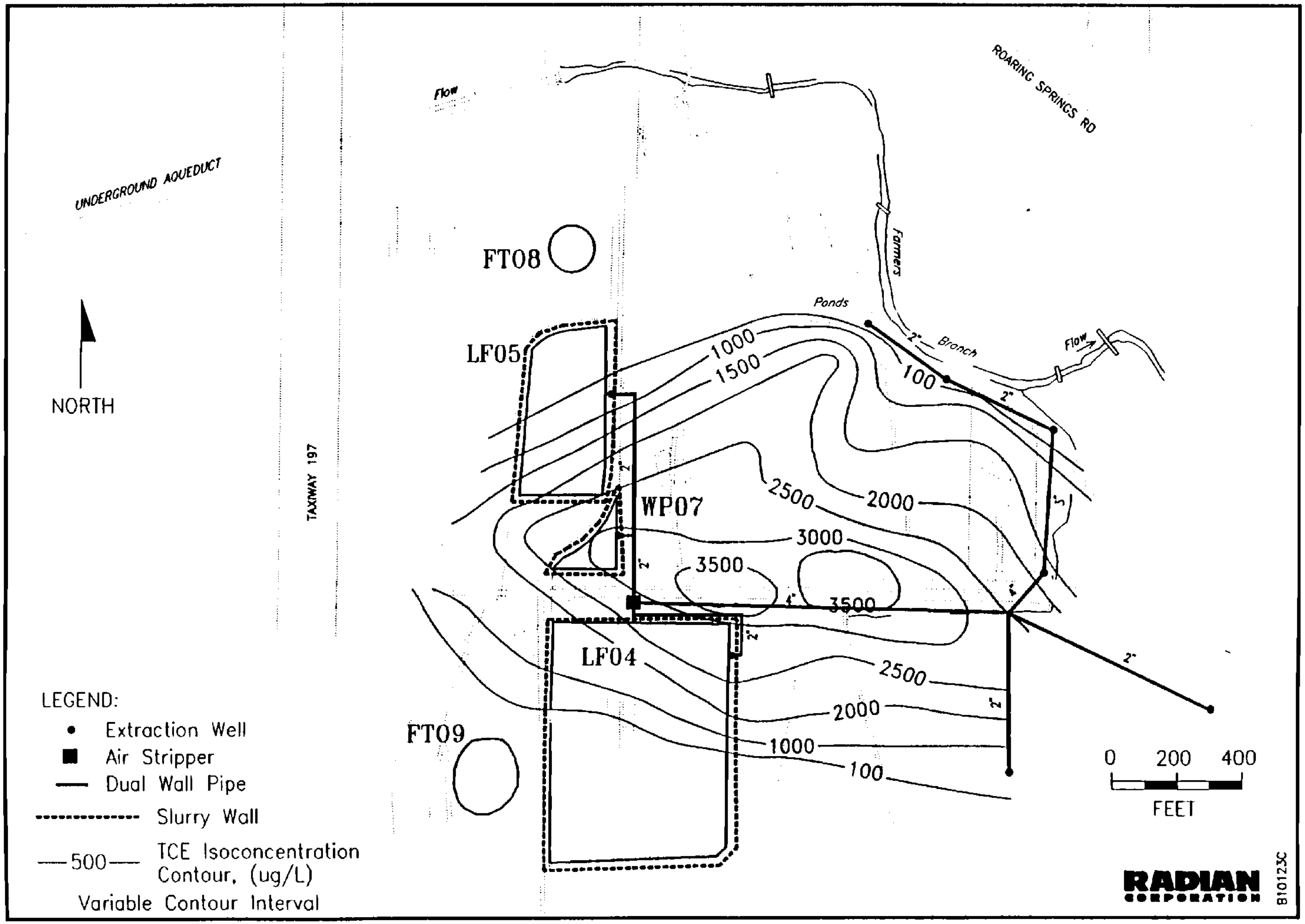

Figure 4-8. ternative 5B

ˈ1 Comparative Analysis

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

11.1 Matrix Approach

Up to this point, each alternative has been individually evaluated th 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 .teria were expanded to provide a more detailed comparison of the alter- :ives. Table 4-2 presents a comparison of the initial evaluation criteria ›ove) with the expanded evaluation criteria that are included in the matrix ›roach. For example, the initial criterion for evaluating the long-term :ectiveness of the remedial alternative was expanded to include off-site ›acts, need for further study, and products generated from the alternative. xplanation 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	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															
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 resent 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

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APPENDIX A

Cost Estimates

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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				
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 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

)PERATION AND MAINTENANCE 'OSTS	Total Cost/Year	
	0-10 Years	10-30 Years
round-Water Monitoring System		
emi-Annual Sampling and ıalysis 15 Wells (0-10 years) @ $1000/well 10 Wells (10-30) years	30,000	20,000
'ound-Water Withdrawal 'stems 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
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				
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 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)

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

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
				129,310
Subtotal				
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	Total Cost/Year 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
Subtotal				81,605
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
				129,310
Subtotal				
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
Subtotal				81,605
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)

TABLE A-7. (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	10,000	5,000
Power		
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

APPENDIX B

Installation Restoration Program, Stage 2, Feasibility Study Report For The East Area, Draft Report - May 1991 Radian Corporation

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FEASIBILITY STUDY
FOR THE EAST AREA

DRAFT REPORT
FOR
CARSWELL AIR FORCE BASE, TEXAS

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

MAY 1991

PREPARED BY

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USAF CONTRACT NO. F33615-87-D-4023, DELIVERY ORDER NO. 0004, MODIFICATION 0005
CONTRACTOR CONTRACT NO. 227-005-04, DCN 91-227-005-04-14

IRP TECHNICAL OPERATIONS BRANCH (HSD/YAQE)
KARL RATZLAFF
TECHNICAL PROJECT MANAGER

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BROOKS AIR FORCE BASE, TEXAS 78235-5501

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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
Lawrence N. French	Project Director/Delivery Order Manager (1987-88)
Debra L. Richmann	Project Director (1990)
Guy J. Childs	Supervising Geologist (1987-1988)
Stephen E. Fain	Supervising Geologist (1990)
Scott B. Blount	Supervising Geologist (1990)
Sandra A. Smith	Risk Assessment Task Leader
Kathleen A. Alsup	Remedial Alternatives Task Leader
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 — Senior Technical Reviewers
James H. Clary
James L. Machin
Leo M. Dielmann

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: WLBoutte for
Nelson H. Lund, P.E.
Contract Manager

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EXECUTIVE SUMMARY

Four sites at Carswell Air Force Base, Texas, are the subject of a feasibility study (FS) performed by Radian Corporation for the Human Systems Division at Brooks Air Force Base, Texas.

Those four sites, which were identified in the East Area of Carswell AFB under USAF Installation Restoration Program (IRP), are the following (refer to Figure ES-1):

- Site LF01--Landfill 1;
- Site SD13--Unnamed Stream and Abandoned Gasoline Station;
- Site ST14--POL Tank Farm; and
- Site BSS--Base Service Station.

The FS relied on data obtained during the 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. Guidance published by the U.S. Environmental Protection Agency in response to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) was used to perform the FS.

Benzene, lead, and arsenic were the principal contaminants detected in ground water and surface water samples collected from the East Area sites in 1990. Low concentrations of some additional metals and volatile organic compounds were also detected. Soil sampling and analysis was not required by the scope of work for the 1990 effort, but limited data generated in previous IRP efforts provided inconclusive evidence of soil contamination potentially requiring remediation at Sites ST14 and BSS.

Three remedial action objectives were identified for the FS:

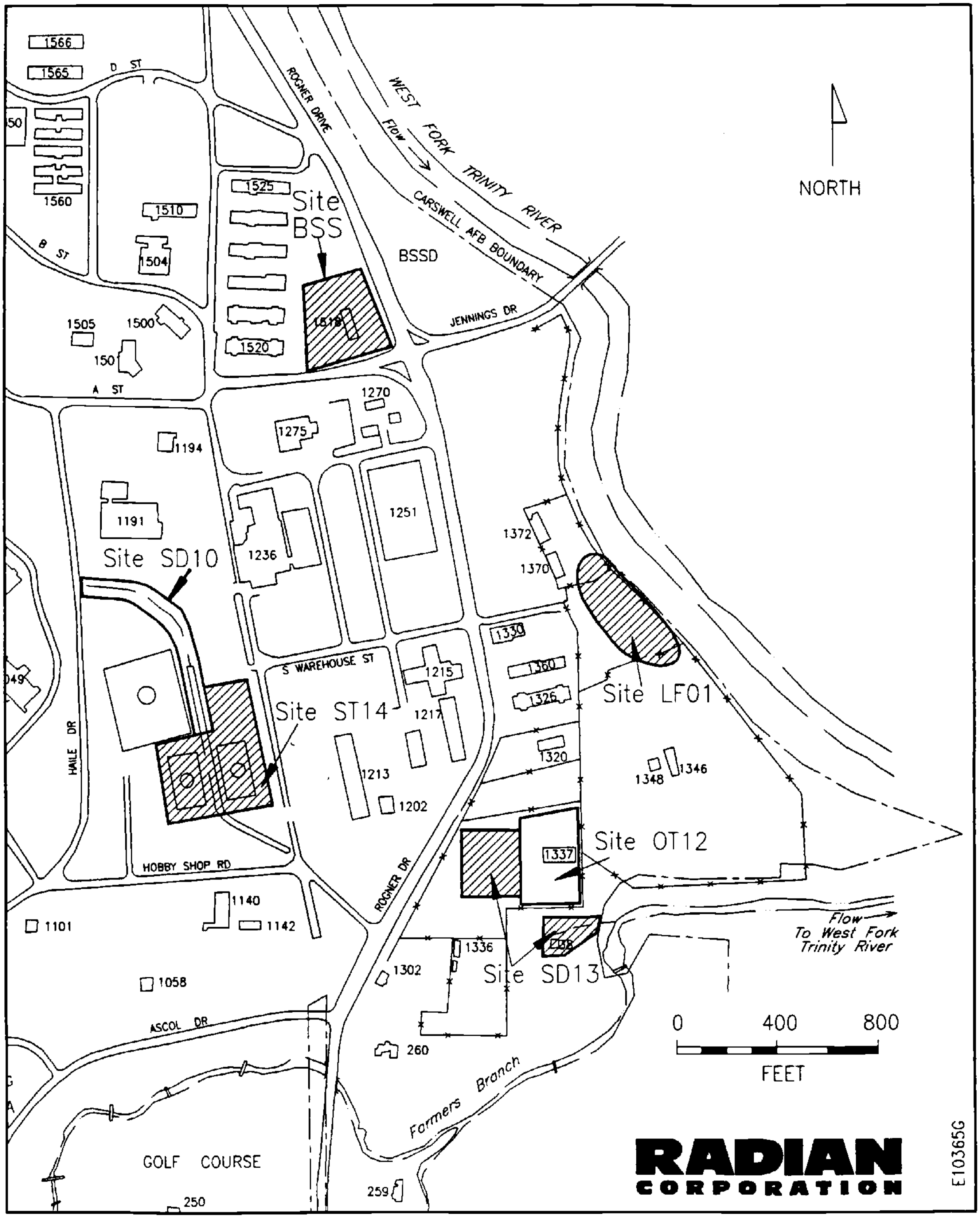

Figure ES-1. Location of East Area IRP Sites, Carswell AFB, Texas
Note: Only cross-hatched sites are included in the FS

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

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

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

These general objectives were developed in detail during the FS.

Potential media-specific response actions, technologies, and process options available for remedying the contamination in the East Area first were identified and then were screened. The screening process eliminated technologies that were inappropriate or that did not meet the criteria of (1) demonstrated performance and effectiveness, (2) constructability and implementability, and (3) cost. Refer to Table ES-1 for a summary of technologies that remained after the screening process. For each site, the potentially applicable technologies were combined into preliminary media-specific remedial alternatives that were developed and screened against the broad criteria of effectiveness, implementability and cost. For Sites LF01 and SD13, the no-action alternative was identified as the only appropriate action. Nine ground-water remedial alternatives (including the no-action alternative) were developed for each of Sites ST14 and BSS. The components of these alternatives are shown in Tables ES-2 and ES-3, respectively. Five preliminary alternatives, potentially applicable to contaminated soil remediation, if required, at Sites ST14 and BSS were also developed (see Table ES-4 for components of each alternative).

TABLE ES-1. SUMMARY OF REMEDIAL ACTION OPTIONS FOR THE EAST AREA IRP SITES

	Site			
	LF01	SD13	ST14	BSS
No Action	■	■	■	■
<u>Institutional</u>				
Long-Term Monitoring	■	■	■	■
<u>Containment</u>				
Hydraulic Barrier (see ground-water extraction)			■	■
<u>Ground-Water Extraction</u>				
Extraction Well Fields			■	■
Interceptor Trenches			■	■
<u>Ground-Water Pretreatment</u>				
Oil/Water Separator			■	
<u>Primary Ground-Water Treatment</u>				
Air Stripping			■	■
In-Situ Biological Treatment			■	■
<u>Treated Ground-Water Discharge</u>				
Discharge to POTW			■	■
Discharge to Stream			■	■
Aquifer Recharge			■	■
<u>Soil Treatment</u>				
Soil Vapor Extraction			■	■
In-Situ Biological Treatment			■	■
Excavation/Soil Piles		■	■	■
<u>Secondary Treatment</u>				
Carbon Adsorption			■	■
Fume Incineration			■	■
<u>Treated Soil Disposal</u>				
On Site		■		■

TABLE ES-2. PRELIMINARY GROUND-WATER REMEDIAL ALTERNATIVES[a] FOR SITE ST14--POL TANK FARM

Technology	Alternatives								
	1	2A	2B	2C	3	4A	4B	4C	5
Monitoring	•	•	•	•	•	•	•	•	•
Interceptor Trenches	NA	•	•	•	•				
Extraction Wells	NA					•	•	•	•
Oil/Water Separator	NA	•	•	•	•	•	•	•	•
Air Stripping	NA	•	•	•		•	•	•	
In-Situ Bio-Treatment	NA				•				•
Treated Ground-Water Reinjection	NA	•			•	•			•
Ground-Water Disposal to POTW	NA		•				•		
Ground-Water Discharge to Stream	NA			•				•	

NA - No Action

[a] Preliminary remedial alternatives do not include secondary ground-water treatment (i.e., fume incineration or carbon adsorption for stripped contaminants).

TABLE ES-3. PRELIMINARY GROUND-WATER REMEDIAL ALTERNATIVES[a] FOR SITE BSS--BASE SERVICE STATION

Technology	Alternatives								
	1	2A	2B	2C	3	4A	4B	4C	5
Monitoring	•	•	•	•	•	•	•	•	•
Interceptor Trenches	NA	•	•	•	•				
Extraction Wells						•	•	•	•
Air Stripping	NA	•	•	•		•	•	•	
In-Situ Bio-Treatment	NA				•				•
Treated Ground-Water Reinjection	NA	•			•	•			•
Ground-Water Disposal to POTW	NA		•				•		
Ground-Water Discharge to Stream	NA			•				•	

NA = No Action

[a] Preliminary remedial alternatives do not include secondary ground-water treatment.

TABLE ES-4. PRELIMINARY SOIL REMEDIAL ALTERNATIVES[a] FOR SITE ST14--POL TANK FARM AND SITE BSS--BASE SERVICE STATION

	Alternatives				
Technology	1	2A	2B	3	4
Confirmation Sampling	•	•	•	•	•
Excavation	NA			•	
In-Situ Bio-Treatment	NA				•
Soil Vapor Extraction	NA	•	•		
Extraction Trenches	NA	•			
Extraction Wells	NA		•		
Soil Piles	NA			•	
On-Site Treated Soil Disposal	NA			•	

NA = No Action

[a] If required, pending results of additional soil sampling and analysis--preliminary remedial alternatives do not include secondary treatment.

As a result of the alternatives screening, for Sites LF01 and SD13 only the no-action alternative was retained for detailed evaluation. For Site ST14, the no-action alternative (Alternative 1), two air stripping alternatives (Alternatives 4A and 4B) and one in-situ biological treatment alternative (Alternative 5) were retained for detailed evaluation. For Site BSS, the no-action alternative (Alternative 1), two air stripping alternatives (Alternatives 2A and 2B) and one in-situ biological treatment alternative (Alternative 3) were retained for detailed evaluation. Because of data limitations, the preliminary soil remedial alternatives cannot undergo detailed analysis until additional data become available.

The detailed analysis of ground-water alternatives was then performed for the four East Area sites, using the evaluation criteria established by CERCLA:

- Overall protection of human health and the environment;
- Compliance with applicable or 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 two remaining CERCLA criteria, state and community acceptance, will be evaluated in the Record of Decision.)

The FS concluded with a comparative (matrix) evaluation of alternatives for Sites ST14 and BSS. The most cost-effective alternative for Site ST14 was determined to be Alternative 5. The most cost-effective alternative for Site BSS was determined to be Alternative 3. The no-action alternative is the appropriate action for Sites LF01 and SD13.

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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 East Area of Carswell AFB, Texas. Six former waste disposal/release sites within the East 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 East Area IRP sites are:

- Site LF01--Landfill 1;
- Site SD10--Flightline Drainage Ditch;
- Site OT12--Entomology Dry Well;
- Site SD13--Unnamed Stream and Abandoned Gasoline Station;
- Site ST14--POL Tank Farm; and
- Site BSS--Base Service Station.

Data obtained in the earlier IRP investigations were sufficient to prepare a decision document (Radian, 1990a) identifying the recommended remedial alternative and a detailed remedial design and specifications for Site SD10; and for Carswell AFB personnel to complete final site characterization activities (soil sampling and analysis) to confirm the absence of contamination prior to planned construction at Site OT12. These sites are therefore not included in this FS. A second decision document (Radian, 1990b), outlining the preliminary basis for recommendation of an appropriate remedial alternative for Site BSS, was also prepared. An additional round of groundwater samples was collected from existing Site BSS monitor wells and analyzed in the 1990 effort. The results generally support the remedial alternative presented in the decision document (Radian, 1990b), but because no additional soil sampling was included in the SOW received by Radian for the additional effort, the need for and potential magnitude of a soils remedial action remains unresolved. Sites LF01, SD13, and ST14 are the remaining East Area sites addressed by this FS. Because the contaminants detected at Sites SD13 and ST14 are similar in nature, and because they are probably at least partially related to a common source in the POL Tank Farm (Site ST14), the remedial technologies and alternatives identified for the POL Tank Farm will also affect Site SD13. As in the case of Site BSS, no additional soil sampling at Site ST14 was authorized in the 1990 effort. Therefore, the need for and potential magnitude of any soils remedial action in the POL Tank Farm requires resolution prior to detailed design of a remedial alternative.

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 and Feasibility Studies Under CERCLA (Interim Final) (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 Upper Zone ground-water contamination in the East Area.

Background information pertaining to the general hydrogeologic setting of Carswell AFB and to site-specific conditions in the East Area, summarized from the RI report (Radian, 1991), is provided in Section 1.2. Section 2 presents the results of the identification and screening of technologies applicable to contamination in the East Area. Remedial action objectives (RAOs) and remedial technologies are presented in Sections 2.1 and 2.2, respectively. Section 2.3 provides a list of the technologies remaining after screening and provides more detailed descriptions of these technologies as they could be implemented at one or more of the East Area sites.

Section 3 describes the basis for developing media-specific alternatives (Section 3-1) and the results of the alternatives screening evaluation (Section 3.2). Because insufficient data are available to perform a detailed evaluation of soils remedial alternatives, preliminary soils alternatives are developed and screened on a qualitative basis only. This approach is consistent with CERCLA guidance. Section 4 presents the detailed evaluation of ground-water remedial alternatives for Sites LF01, SD13, ST14, and BSS. The CERCLA evaluation criteria and methodology are described in Section 4.1. Feasible alternatives for remediation of ground water remaining after the initial screening are developed by site and are evaluated individually against the CERCLA evaluation criteria (Sections 4.2 through 4.5). Section 4.6 discusses possibilities for and benefits of coordinating remedial actions at multiple sites. The alternatives are evaluated on a comparative basis in Section 4.7.

1.2 Background Information

Most of the background information contained in this section is based on the most recent data from the East 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 (Figure 1-1). 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 1-2 shows the location of the East 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. During a previous IRP effort, two monitor wells installed in the

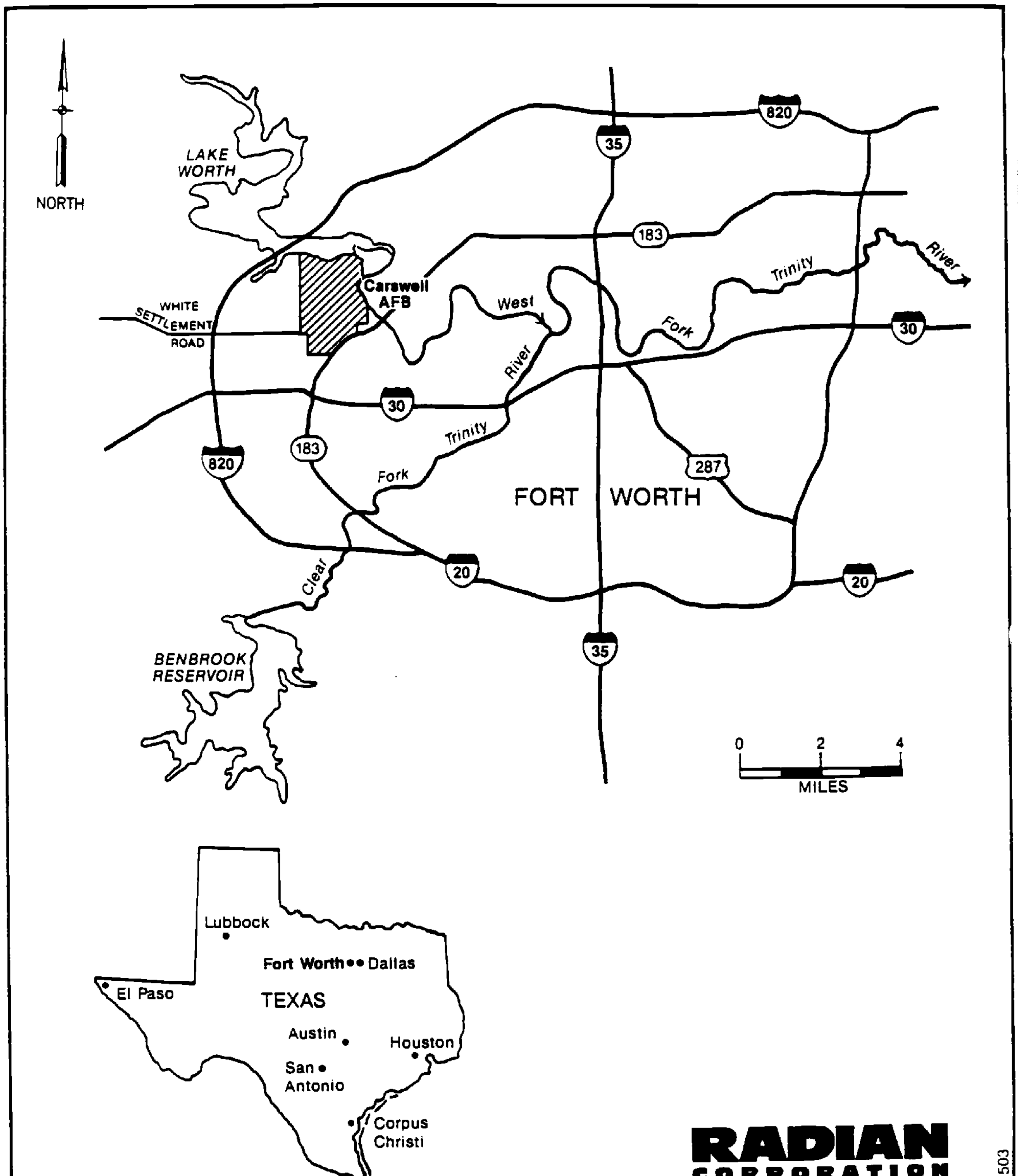

Figure 1-1. Regional Setting of Carswell AFB, Texas

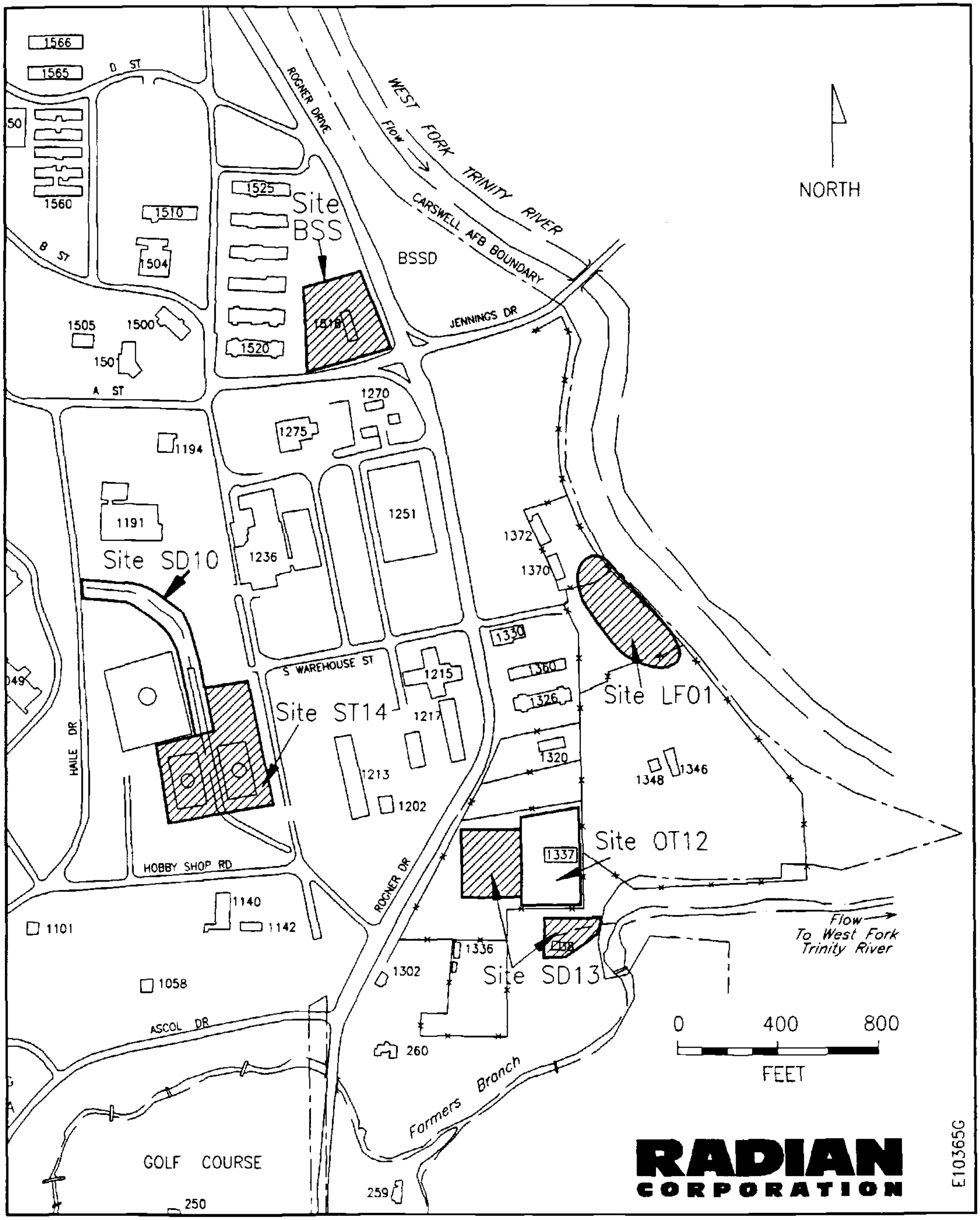

Figure 1-2. Location of East Area IRP Sites, Carswell AFB, Texas (Note: Only cross-hatched sites are included in the FS)

Paluxy Aquifer in the Flightline Area of the base and sampled in 1988 provided no evidence of deeper ground-water contamination (Radian, 1989). Figure 1-3 shows the general depth of occurrence and thickness of each of the major hydrogeologic units expected in the East 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.

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 range 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 East Area Description

The East Area is located on land that gently slopes eastward to the West Fork of the Trinity River and southward to Farmers Branch. Elevations range from 595 feet MSL west of the POL Tank Farm (Site ST14) to 560 feet MSL on the flood plain above the West Fork of the Trinity River and Farmers Branch.

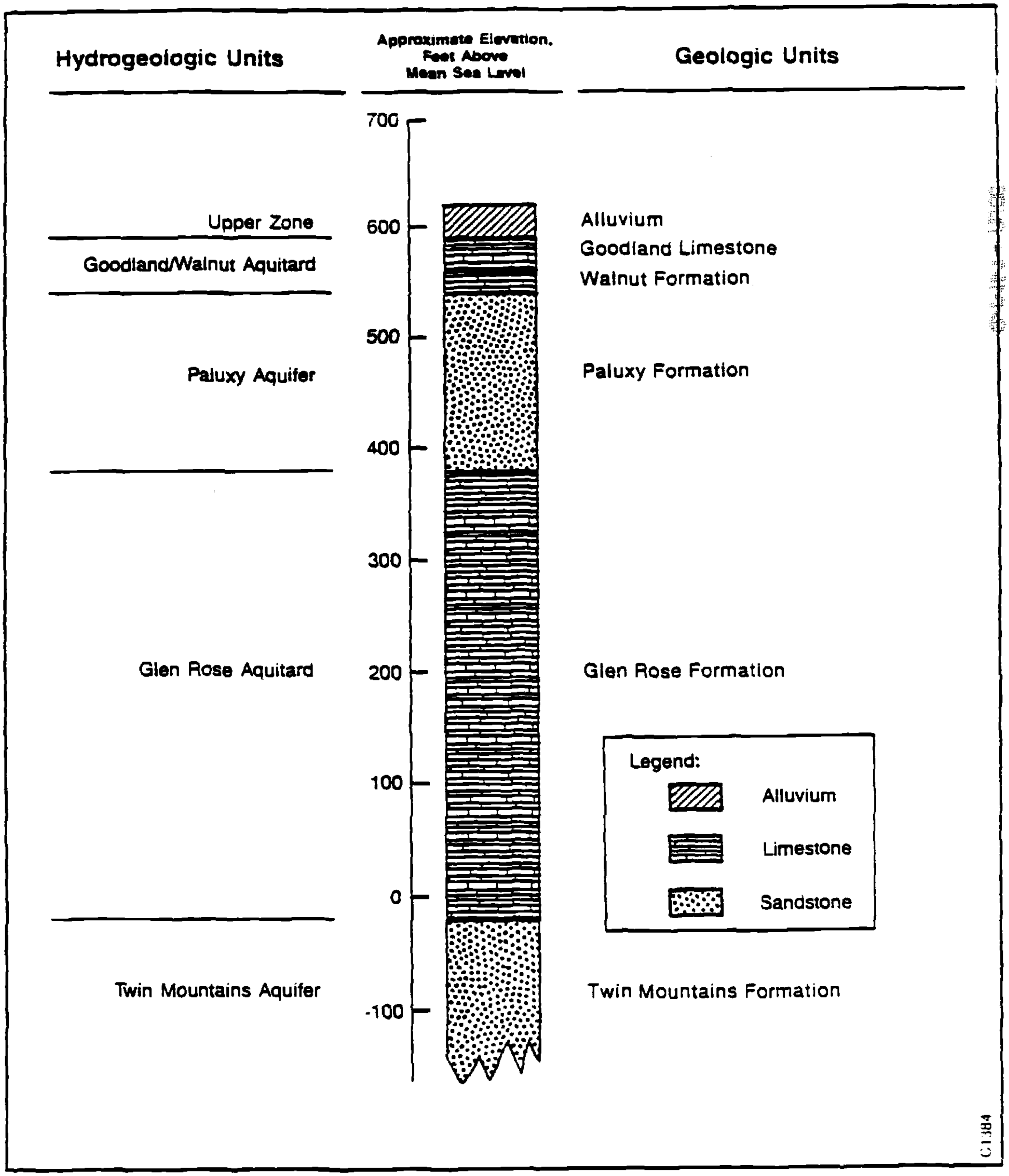

Figure 1-3. Generalized Hydrogeologic Units, Carswell AFB, Texas (Radian, 1989)

The Soil Conservation Service (SCS) has identified three soil associations in the East Area of Carswell AFB (USDA, 1981). The clayey soils of the Sanger-Purves-Slidell association occur in the western portion of the East Area at Site ST14. Approaching the Trinity River, the Bastsil-Silawa loamy soils are prevalent in the nearly level to sloping stream terrace sections found at Sites SD13 and Site BSS, while the Frio-Trinity association of clayey soil occurs in the nearly level flood plain environment in the easternmost portion of Site LF01. The reported permeabilities of the surficial soils range from $<4.2 \times 10^{-5}$ to 3×10^{-3} cm/sec (USDA, 1981).

The main surface water bodies in the East Area are the West Fork of the Trinity River, Farmers Branch, and Unnamed Stream at Site SD13 (Figure 1-2). Surface drainage at Sites LF01 and BSS is toward the Trinity River, with drainage at Sites ST14 and SD13 being mainly toward Farmers Branch.

Water in Unnamed Stream emerges from an oil/water separator. Water enters the separator from a french drain which was installed to intercept fuel spills and/or leaks from the POL Tank Farm (Site ST14). Unnamed Stream is a perennial stream feeding into Farmers Branch.

The Upper Zone alluvial deposits in the East Area generally consists of 5 to 15 feet of gray to black clay and clayey silt overlying, 2 to 10 feet of fine-grained sand, and up to 5 feet of gravel. The underlying Goodland Formation is usually encountered between 7 and 20 feet below ground level (bgl), although it occurred deeper in some wells. In general, across the East Area the depth to the Goodland decreases as the West Fork of the Trinity River is approached. However, within 400 feet of the river, the trend reverses and the depth to bedrock may exceed 20 feet. The Goodland in the East Area is dry and occurs as gray, hard limestone and as blue-gray, mottled shale. No monitor wells were drilled in the East Area that penetrated through the Goodland and Walnut Formations into the Paluxy Aquifer.

The depth to Upper Zone ground water in the East Area ranges from about 6 to 13.5 feet bgl. A potentiometric surface map for the Upper Zone of the East Area, based on a synoptic water level survey performed on 18 June

1990, is presented in Figure 1-4. The ground-water surface generally slopes from west to east, indicating ground-water flow toward the West Fork of the Trinity River or Farmers Branch. The direction of ground-water flow in the Upper Zone is apparently controlled principally by the elevation of the upper surface of the Goodland Limestone. Hydraulic conductivities of the Upper Zone materials, based on slug tests in six East Area monitor wells, range from about 1.2 x 10^{-2} cm/sec to 1 x 10^{-5} cm/sec (Radian, 1989).

1.2.2 Site History

The physical features and historical uses of each of the four East Area IRP sites included in this FS are summarized below. The descriptions of these sites and the wastes reportedly disposed of or released from each are taken mainly from the Phase I Records Search (CH2M Hill, 1984).

Site LF01--Landfill 1

Landfill 1 is reportedly the original base landfill and was operated during the 1940s. The site is located adjacent to the West Fork of the Trinity River levee at the current location of the Defense Reutilization and Marketing Office (DRMO) storage yard. Due to its age, no records were found concerning past waste disposal practices. However, analytical data obtained in the IRP studies performed to date suggest solvent- and metal-bearing wastes may have been disposed of in this landfill.

Site SD13--Unnamed Stream and Abandoned Gasoline Station

Site SD13 consists of two areas: a paved lot near an abandoned gasoline station located west of the former Entomology Dry Well (Site OT12) and Unnamed Stream itself. Unnamed Stream is a small tributary of Farmers Branch that emerges from an underground oil/water separator (Facility 38). The stream and the separator are located south of the communications building (No. 1337) and immediately south of the fenced civil engineering storage yard. The oil/water separator is connected to a french drain system which was

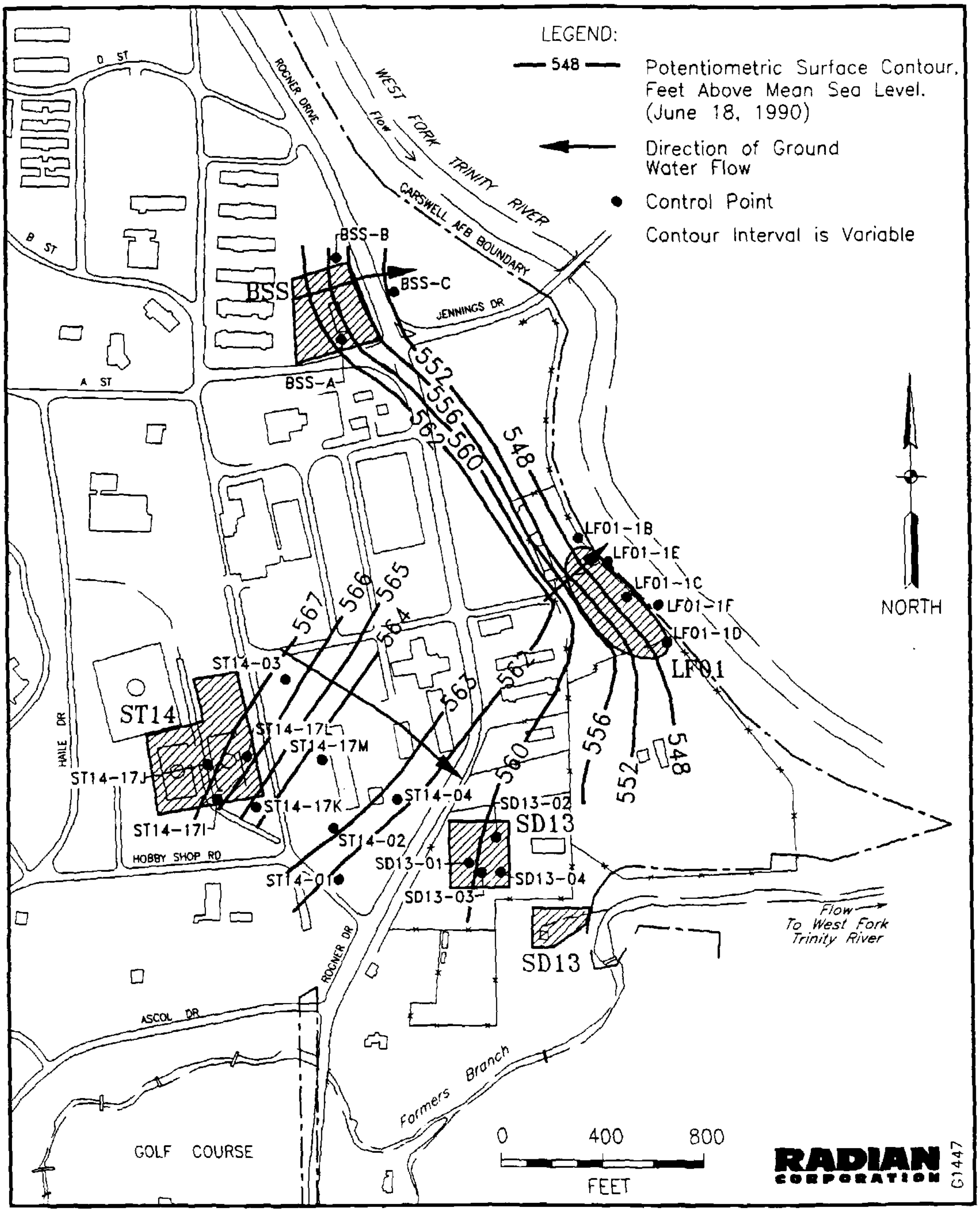

Figure 1-4. Potentiometric Surface Map of the Upper Zone, East Area, Carswell AFB, Texas

reportedly built in 1965 to intercept hydrocarbon products leaking from the POL Tank Farm into sewer pipes. The location of the french drain has been approximated, but is not documented in available base records. Unnamed Stream is perennial, receiving flow from ground water entering the french drain and discharging from the separator.

Site ST14--POL Tank Farm

The POL Tank Farm is located along Knights Lake Road, near the Carswell AFB main gate. The site is occupied by two above-ground fuel storage tanks. Three additional tanks were formerly located at this site, but have been dismantled. During the early 1960s, fuel was discovered in the ground at this area and downgradient of the site. A french drain system was installed in the downgradient area to collect the released fuel. The french drain discharged through the oil/water separator at Site SD13 (Section 1.2.2). At that time, the leaking underground pipes were reportedly located and replaced. No other fuel releases were reported after 1965, but the french drain system continues to collect residual hydrocarbon constituents which are discharged through the oil/water separator. As previously noted, the exact location of the french drain is unknown.

Site BSS--Base Service Station

The Base Service Station is located on the northwest corner of Rogner Drive and Jennings Drive. Gasoline is stored in four 10,000-gallon, fiberglass reinforced plastic underground tanks located north of the pump islands. Surface drainage from Site BSS flows to culverts adjacent to Rogner Drive. The Base Service Station has been in operation for less than 20 years. It was constructed to replace the abandoned service station located at Site SD13. The main contaminants identified at Site BSS are petroleum fuel and fuel derivatives.

1.2.3 Nature and Extent of Contamination

The Carswell AFB IRP Phase II Stage 1 report (Radian, 1986) identified volatile organic compounds and metals at several sites in the East Area. Additional work was performed during Stage 2 (1987-88) to define the concentration distribution and extent of detected contaminants and to investigate other sites (e.g., Site BSS) with the potential for subsurface contamination. The four sites included in this report had additional work performed in 1990.

Ground-water and surface water samples collected during the 1990 field program were analyzed for various volatile organic compounds and metals species. Metals analyses were performed on both unfiltered and filtered samples to evaluate concentrations of total and dissolved metals, respectively. In previous IRP investigations conducted by Radian, only total metals analyses were required. Total metals analyses yield results that are not representative of the dissolved concentrations of metals in water and therefore, can lead to erroneous conclusions regarding water quality.

Concentrations of both volatile organic compounds and inorganic constituents in ground-water and surface water samples collected in 1990 were generally lower than concentrations of the same analytes determined in previous IRP studies. This trend may be the result of natural attenuation of these constituents in the ground-water or surface water systems. However, it should be noted that the weeks immediately preceding the spring 1990 sampling event were characterized by abnormally high precipitation (and flooding). It is possible that temporarily increased infiltration and recharge may have resulted in some dilution of contaminant concentrations.

Since the wastes and historically detected contaminants vary from site to site, not all samples were analyzed for the same suite of chemical constituents. Therefore, the nature (and extent) of contaminants is most conveniently discussed on a site-specific basis. The Informal Technical Information Report (ITIR) for the current effort includes complete analytical summary tables, QA/QC data, sample cross-reference tables, and chain-ofcustody documentation (Radian, 1990c). A detailed discussion of QA/QC results is included in the East Area RI report (Radian, 1991).

1.2.3.1 Site LF01--Landfill 1

Collection and analysis of soil samples was not required in the 1990 IRP effort. Samples were collected from two boreholes drilled on site in the previous Stage 2 site investigation (1988), but no evidence of volatile organic or inorganic soil contamination was suggested by the analytical results. However, oil and grease concentrations up to 50 milligrams per kilogram (mg/kg) were detected in some soil samples.

In pre-1990 IRP investigations, ground-water constituents detected at Site LF01 were metals, and to a lesser extent, volatile organic compounds. In Stage 1, both metals and volatile organic compounds were identified at the site at concentrations below MCLs. All volatile organic compounds identified were near instrument detection limit concentrations.

As previously noted, all metals analyses performed in investigations prior to 1990 were for total metals. In the Stage 2 investigation, selenium, arsenic, barium, cadmium, chromium, and lead each were detected above their MCL in one or more unfiltered samples. All of the metals were detected in downgradient monitor wells LF01-1E and LF01-1F (Figure 1-5). Only chromium and cadmium were detected in other wells.

Based on these data, no metal contaminant plume could be identified due to the limited number of wells and the varying distribution of metals detected. Nevertheless, because the metals identified in Stage 2 were generally found in higher concentrations in the downgradient wells (LF01-1E and LF01-1F) relative to background concentrations, the source of the metals was interpreted to be Landfill 1. No metals were detected above their respective MCLs in any (filtered or unfiltered) ground-water samples collected in 1990. Therefore, the previous basis for suggesting Upper Zone metals contamination was not reproducible and is unsupported by the most recent data.

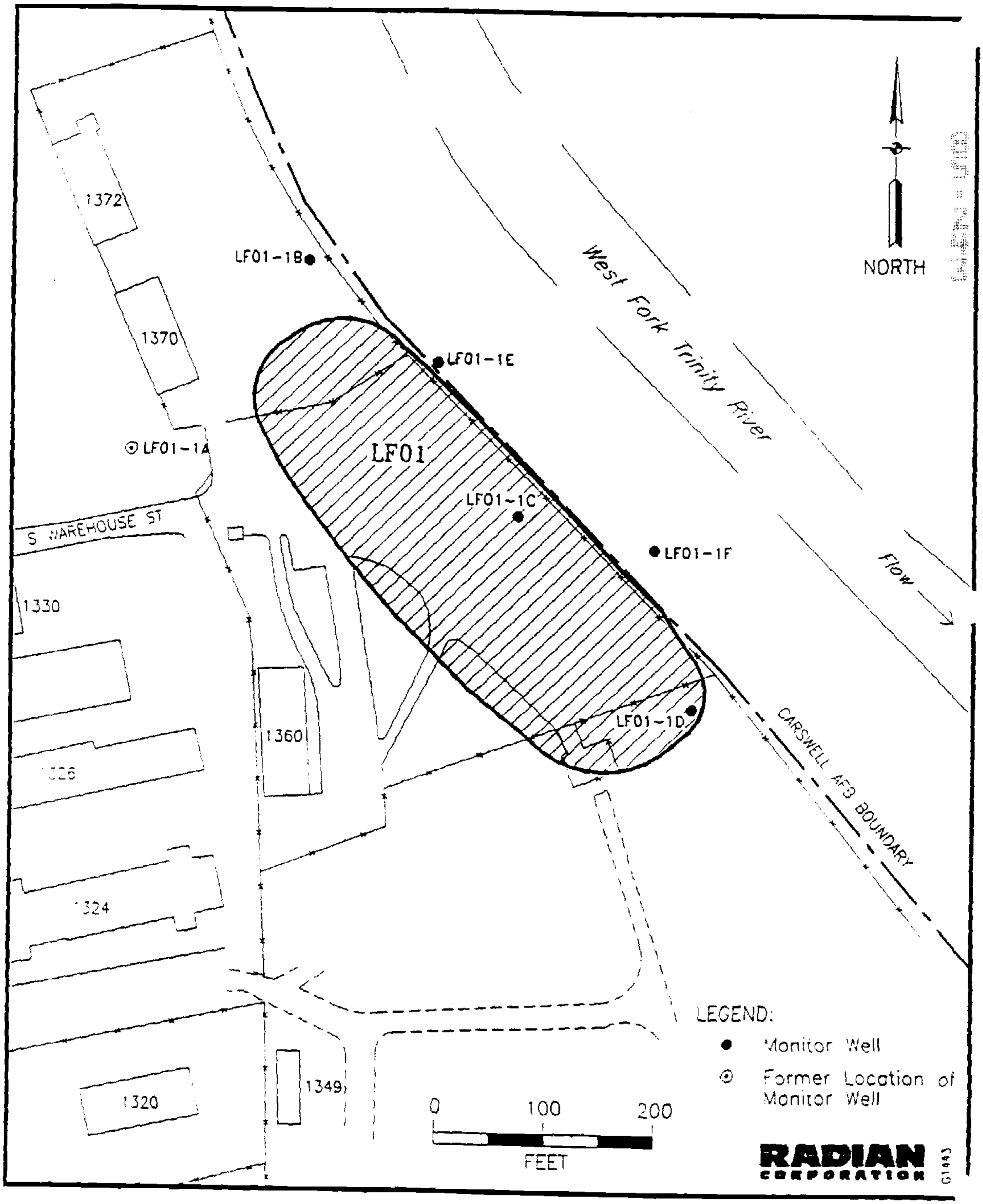

Figure 1-5. Location of Wells Sampled at Site LF01, East Area, Carswell AFB, Texas

Volatile organic compounds were detected in both rounds of ground-water samples collected during Stage 2. Trichloroethene (TCE) and vinyl chloride were detected in several wells at levels below their MCLs. No definable volatile organic contaminant plume was identified beneath Site LF01, because the distribution of detected compounds was sporadic, and the detected concentrations were very low. Similar results were obtained in 1990. Vinyl chloride; cis-1,2-DCE; and chlorobenzene were detected, but only vinyl chloride was detected in more than one well. All concentrations were below MCLs and were at or less than five times their respective detection limits. Such low concentrations have a high degree of uncertainty associated with them.

1.2.3.2 Site SD13--Unnamed Stream and Abandoned Gasoline Station

IRP activities conducted at Site SD13 in 1985 revealed high levels of organic compounds in grab samples of ground water collected from three soil borings. These constituents were suspected to be from petroleum releases associated with the abandoned gasoline station at the site. However, in 1990, when monitor wells were installed at the site and sampled, the volatile organic compound results did not confirm this hypothesis. No volatile organic compounds or metals were detected above MCLs in ground-water samples from Site SD13.

No volatile organic compounds were detected above MCLs in the surface water samples from Site SD13. The analytical results for inorganic constituents and field observations suggest that metals in Unnamed Stream are preferentially adsorbed to sediments rather than remaining dissolved in the surface water (Radian, 1989; 1991). Total concentrations of arsenic, lead, and selenium were detected above MCLs in at least one surface water sample, but only selenium was reported above the MCL in any dissolved metals analysis. This result was subsequently determined to be a reporting error; the actual concentration was below detection. Locations of monitor wells and surface water sampling points at Site SD13 are shown in Figure 1-6.

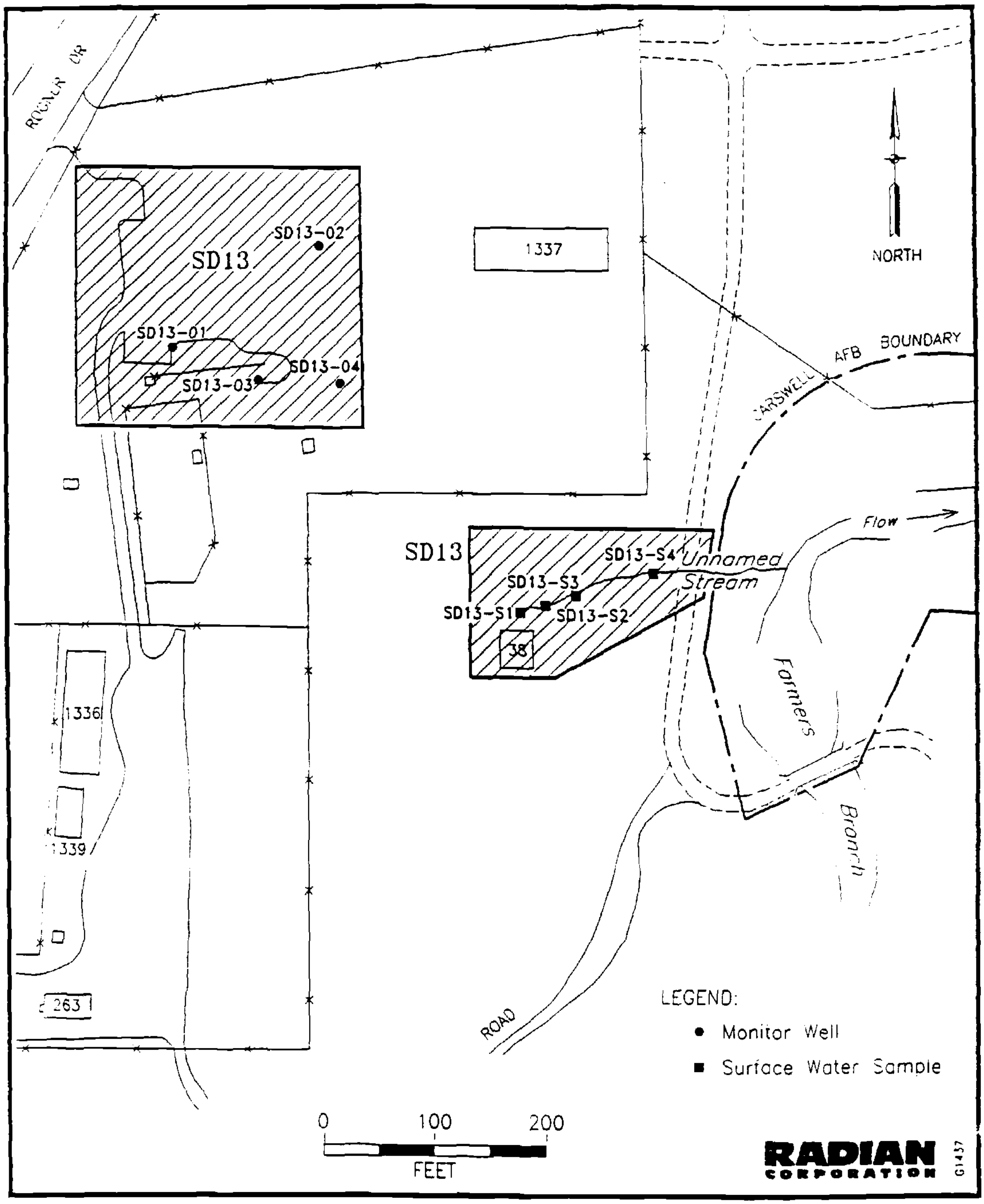

Figure 1-6. Location of Monitor Wells and Surface Water Samples, Site SD13, East Area, Carswell AFB, Texas

1.2.3.3 Site ST14--POL Tank Farm

Benzene, ethylbenzene, chlorobenzene, toluene, and total xylenes were detected in the ground water at Site ST14. Of these, ethylbenzene was the most common. However, benzene was the only volatile organic compound detected at a concentration which exceeded its MCL. Figure 1-7 depicts the probable extent of benzene contamination at Site ST14, interpreted from the 1990 analytical data and the distribution of soil gas determined in an earlier survey (Radian, 1989). Two separate plumes of benzene are suggested. These plumes are roughly coincident with the two plumes interpreted earlier (Radian, 1989). The ground-water sample from monitor well ST14-17M, located at the center of the benzene plume beneath the fuel loading facility, had the highest concentration of benzene, and the only concentration in excess of the MCL. More than 2 feet of free-phase hydrocarbon was floating on the water in monitor well ST14-17M at the time of the 1990 sampling. The highest concentrations of chlorobenzene, toluene, and total xylenes were also detected in this well.

Chromium was detected above its MCL in only one well at Site ST14, and this concentration was measured in the total metals analysis. Lead was detected above MCLs in three monitor well samples at Site ST14, but only one analysis was for dissolved metals. The single dissolved lead concentration above the MCL was analyzed by atomic absorption (AA) and is considered suspect because it was higher than the corresponding total lead concentration. Lead was not detected in either the filtered or unfiltered samples from the same well that were analyzed by inductively coupled plasma emission spectroscopy (ICPES).

1.2.3.4 Site BSS--Base Service Station

Figure 1-8 shows the locations of the three monitor wells at site BSS sampled most recently in 1990. Both volatile organic compounds and metals were identified at Site BSS. In the previous Stage 2 investigation (Radian, 1989), volatile organic compounds were detected primarily in ground-water samples from monitor well BSS-B. In samples collected during the spring 1990

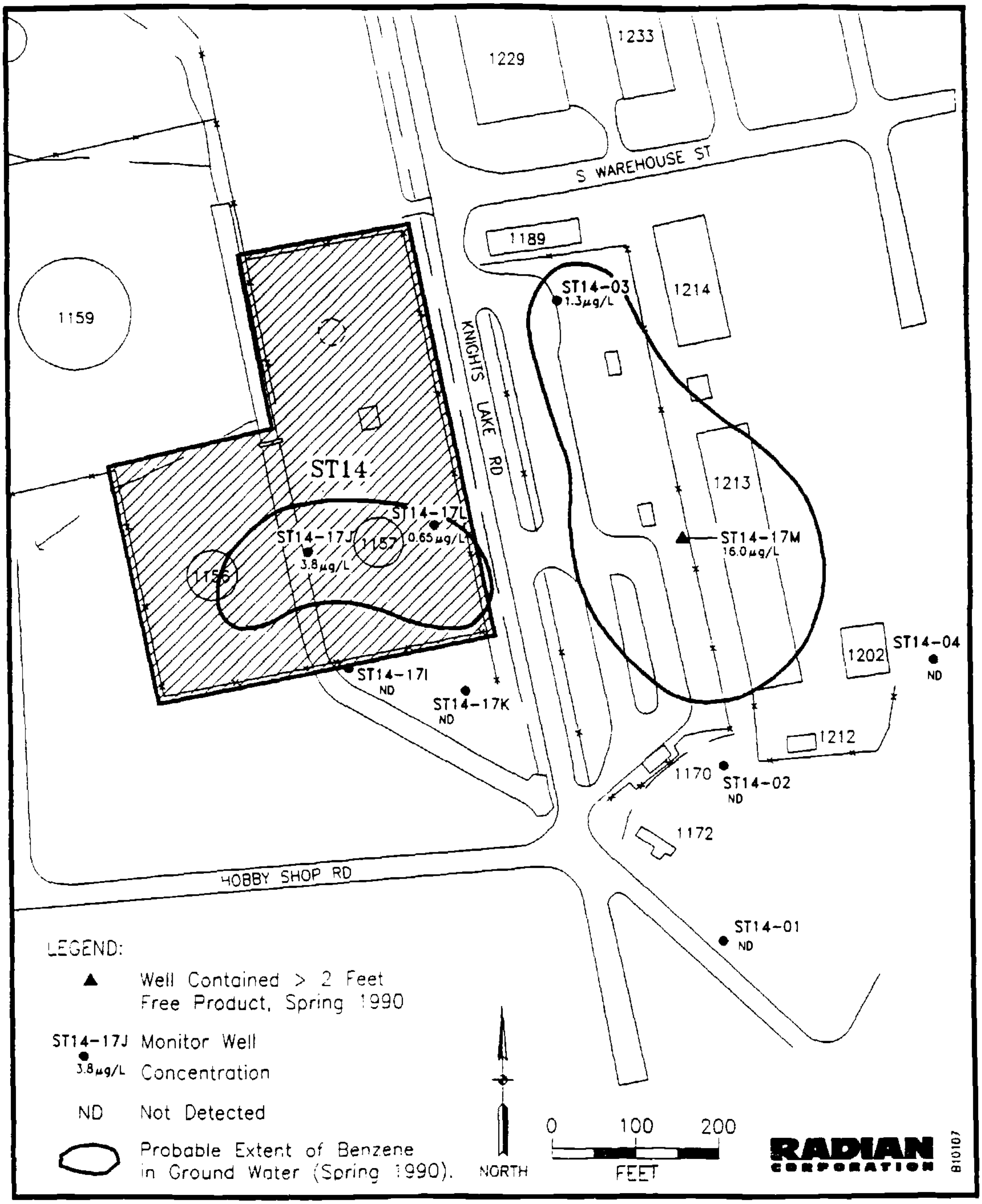

Figure 1-7. Probable Extent of Benzene Contamination (Spring 1990), Site ST14, East Area, Carswell AFB, Texas

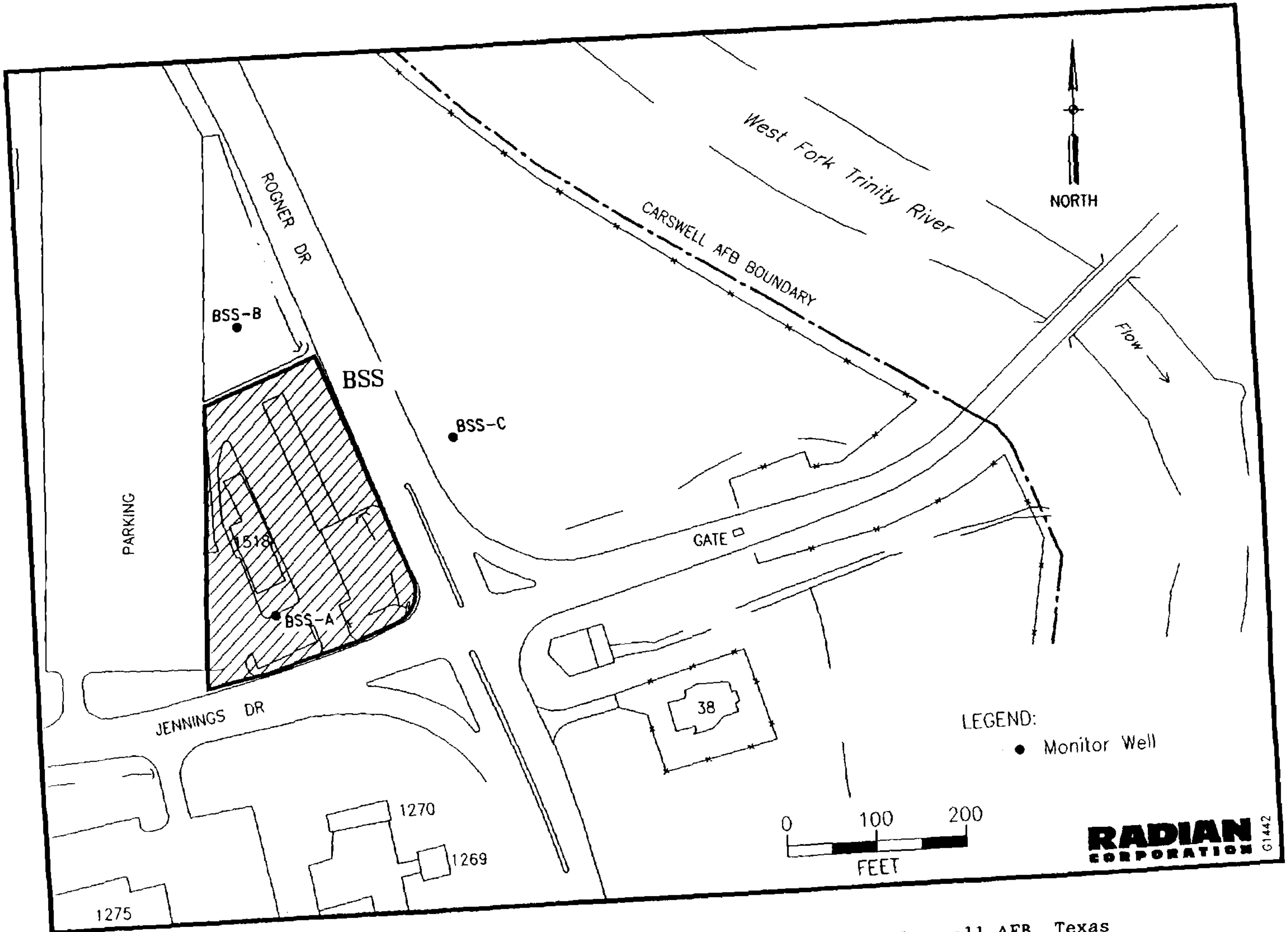

Figure 1-8. Location of Monitor Wells, Site BSS, East Area, Carswell AFB, Texas

sampling event, volatile organic compounds were detected only in this well. The 1990 analytical results confirm the localized nature of the volatile organic contamination and support the interpretation that past leakage from the underground storage tank(s) adjacent to monitor well BSS-B is the main source of the observed contamination.

In the 1990 sampling event, cadmium was detected above the MCL in monitor well BSS-C in the total metals analysis. Cadmium was not detected in any other well, or in the filtered sample (dissolved metals fraction) from the same well. Therefore, there is insufficient evidence to conclude there is ground-water contamination by cadmium (or by any other metals) at the site.

1.2.4 Contaminant Fate and Transport

Ground-water and surface water sampling and analysis conducted in the East Area in 1990 revealed volatile organic contamination at levels above MCLs in Upper Zone ground water at two sites (Site ST14 and Site BSS). No confirmed contaminants were detected above MCLs in the surface water in Unnamed Stream (Site SD13). The fate and transport mechanisms for the main detected analytes are discussed in the following sections.

1.2.4.1 Fate of Main Analytes Detected in the East Area

Benzene and lead were the principal ground-water constituents occurring in excess of MCLs in the East Area sites. Total concentrations of arsenic and lead were identified above MCLs in the surface water at Site SD13. In general these constituents exhibit the following characteristics relative to fate in ground-water and/or surface water systems:

- Benzene is relatively soluble in water, and is relatively inactive chemically. Volatilization is the principal means of removal of benzene from ground water. It also biodegrades slowly in ground water.

- Lead may be removed from the ground water up to 100 percent by the formation of organic complexes and other compounds with high affinities to adsorb onto soil grains and/or low solubility coefficients. As such, lead will tend to accumulate in soils near sources. Lead in surface water may also be removed through bioaccumulation.

- Arsenic has a high chemical activity, and cycles through the surface water system by sorption and desorption from soil grains and the formation of various compounds and complexes. Due to this high activity, little arsenic is removed from the surface water by these processes. However, arsenic may be removed from surface water by bioaccumulation.

1.2.4.2 Contaminant Transport Pathways

Following is a site-by-site discussion of the various contaminants found in the East Area and the transport mechanisms through the ground-water and surface water systems.

Site LF01--Landfill 1

Recent ground-water sampling results show very low levels of vinyl chloride and cis-1,2-dichloroethene (1,2-DCE) in wells LF01-1C and LF01-1F. Ground-water samples collected in 1988 contained very low levels of trichloroethene (TCE) and vinyl chloride.

Since there is no historical record indicating the use of cis-1,2-dichloroethene or vinyl chloride at Carswell AFB, the small quantities of these compounds in ground water are likely to be the result of the chemical and biological breakdown of TCE, which was detected in the 1988 study. Although several metals were detected in the ground water at total concentrations exceeding MCLs during the 1988 investigation (Radian, 1989), there were no metals (dissolved or total) detected above MCLs in the 1990 sampling.

The low levels of volatile organic contaminants in the Upper Zone ground water would be expected to move downgradient to the east, toward the West Fork of the Trinity River. Shallow ground-water flow near the river probably will be discharged at the surface as broadly diffuse seepage, much of which will be consumed by evapotranspiration. There is no visual evidence of seepage at the land surface between Site LF01 and the river. Shallow ground-water flow is not expected to be downward, to deeper aquifers (because of the Goodland/Walnut aquitard beneath the Upper Zone), or laterally beyond the river. Any contaminants which reach the river by ground-water migration would move downstream with the surface water flow. Any VOCs present in the surface water will be subject to volatilization to the air. Since the detected concentrations of volatile organic compounds in ground water are already low (in most cases at levels less than five times their detection limits), it is unlikely that these compounds would be detectable following their introduction into the West Fork of the Trinity River.

Site SD13--Unnamed Stream and Abandoned Gasoline Station

Any contaminants in the ground water would be expected to move hydraulically downgradient, eventually entering either Unnamed Stream or Farmers Branch, and finally discharging into the West Fork of the Trinity River. Any VOCs discharged into the surface water would be subject to volatilization to the air. No metals were detected above MCLs in the shallow ground water at Site SD13.

No volatile organic compounds were detected above MCLs in Unnamed Stream. The results of the laboratory analysis for inorganic constituents and field observations suggest that some metals in Unnamed Stream are preferentially adsorbed to sediments rather than dissolved in the surface water. This mode of transport (i.e., adsorbed to sediment) would result in slower migration of contaminants downstream than for the dissolved phase, and would be slower than the actual surface water flow rate. As evidenced by the lower dissolved and total concentrations of arsenic and lead in the downstream water samples, the metals apparently tend to adsorb to the stream bed sediments near their source. Both metals also have a tendency to bioaccumulate. The presence of iron oxides, identified as coating on sediments in Unnamed Stream in the Phase II Stage 1 investigation, suggests that precipitation of metals is active in the stream sediments. The removal of metals such as lead and arsenic is enhanced by this process, as these metals commonly co-precipitate with or are adsorbed onto hydrous iron oxide compounds. Both lead and arsenic are, relatively speaking, nonvolatile and will tend to remain adsorbed to the sediments in Unnamed Stream. As long as there is a source of these metals, the sediments in the upper reaches of the stream will continue to act as a "sink" for them.

Site ST14--POL Tank Farm

The average Upper Zone ground-water flow velocity at the POL Tank Farm is approximately 0.3 feet per day, and Upper Zone ground-water flow is toward the southeast, or Farmers Branch. Therefore, the hydrocarbon contamination observed in the shallow ground water at Site ST14 is expected to migrate with the shallow ground water toward Farmers Branch. Volatilization and degradation of the hydrocarbon constituents from the ground water will tend to decrease the concentration of hydrocarbon constituents as they move downgradient, assuming there are no additional sources. Increased volatilization of the hydrocarbon constituents in Farmers Branch surface water would be expected due to increased surface area and turbulence in the stream.

Alternatively, hydrocarbon constituents from the POL Tank Farm could be intercepted by the existing french drain system and flow through the oil/water separator, ultimately entering Farmers Branch by Unnamed Stream. Volatilization of the constituents would be expected throughout this pathway.

The low dissolved lead concentrations in the shallow ground water, the nonvolatile nature of the metal, and the affinity of the metal to adsorb onto sediments suggest the overall distribution of lead at the site will not change significantly in the future.

Site BSS--Base Service Station

Migration of volatile organic compounds in the Upper Zone ground water will generally be toward the West Fork of the Trinity River, in the direction of ground-water flow. However, the permeable water-bearing sands observed at monitor well BSS-B are not present in the lithologic log for borehole BSS-D, located downgradient, or east, of Site BSS. Therefore, ground-water flow velocities are probably lower east of monitor well BSS-B, but contaminants could still potentially migrate toward the river in the lower permeability materials.

The principal fate of the volatile organic compounds detected in the ground water at well BSS-B would be volatilization to the atmosphere. This could occur as the ground water moves toward the West Fork of the Trinity River or upon entering the river. Insufficient downgradient well control precludes determination of the maximum contaminant extent. Metals contamination is not a concern at Site BSS.

1.2.5 Baseline Risk Assessment

The results of the baseline risk assessments for the four East Area IRP sites included in the 1990 study are summarized below. More complete descriptions of the risk assessment process are provided in the IRP Stage 2 RI/FS report (Radian, 1989) and in the East Area RI report (Radian, 1991).

Using both the 1988 and 1990 sampling results for soil, ground water, and surface water in the East Area, lists of indicator chemicals were developed for each site. The indicator chemicals were selected according to the method described in the U.S. EPA Health Evaluation Manual (EPA, 1986a) and are shown in Tables 1-1 through 1-4.

Although some of the indicator chemicals, particularly the metals and the semivolatile compounds, probably are not representative of site conditions (because of leaching from suspended sediment as a result of sample acidification and/or laboratory contamination, respectively), they were

TABLE 1-1. INDICATOR CHEMICALS FOR SITE LF01--LANDFILL 1

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

TABLE 1-2. INDICATOR CHEMICALS FOR SITE SD13--UNNAMED STREAM AND ABANDONED GASOLINE STATION

Metals	Semivolatile Organic Compounds	Volatile Organic Compounds (VOCs)
Antimony	None	Benzene
Arsenic		Tetrachloroethene
Barium		Toluene
Beryllium		
Cadmium		
Chromium		
Lead		
Nickel		
Selenium		
Silver		

TABLE 1-3. INDICATOR CHEMICALS FOR SITE SD14--POL TANK FARM

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

TABLE 1-4. INDICATOR CHEMICALS FOR SITE BSS--BASE SERVICE STATION

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

included in the risk assessment process to ensure a conservative evaluation of possible health risks.

Possible mechanisms of contaminant release from the East Area sites include: 1) volatilization to the air, 2) leachate to ground water, 3) direct release to surface water, and 4) contaminated ground-water discharge to surface water. Figures 1-9 and 1-10 illustrate the potential pathways for human exposure for each of the East Area sites. Based on the potential pathways identified, potential human and wildlife receptors for exposure to contaminants migrating from the East Area sites were identified.

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 East Area site VOC indicator chemical emissions are all lower than the conservative Texas Air Control Board (TACB) Effects Screening Levels (ESLs). For Sites LF01, SD13, ST14, and BSS respectively, the estimated emissions of the individual VOC indicator chemicals are lower by: 7 to 9, 3 to 6, 3 to 9, and 4 to 10 orders of magnitude. Potential ingestion exposures included consuming meat and dairy products or fish exposed to contaminants; however, neither of these potential pathways was found to represent a significant threat of human exposure. The likelihood of dermal exposure to contaminants in Farmers Branch and the West Fork of the Trinity River was so remote that it did not merit quantification.

The threat to human health posed by each 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 that the threat of noncarcinogenic health effects of inhalation

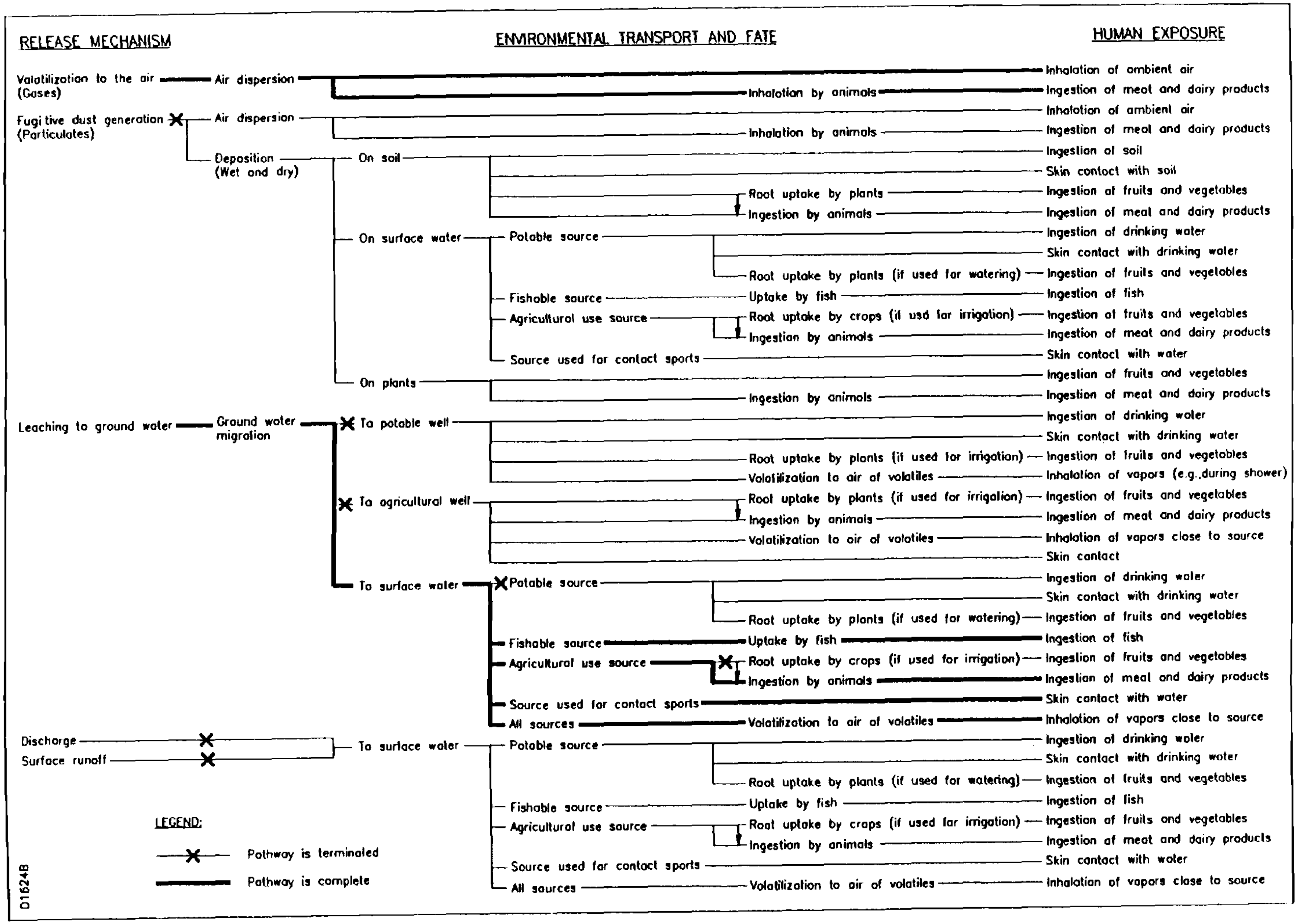

Figure 1-9. Potential Pathways to Human Exposure from Landfill 1, the POL Tank Farm, and the Base Service Station

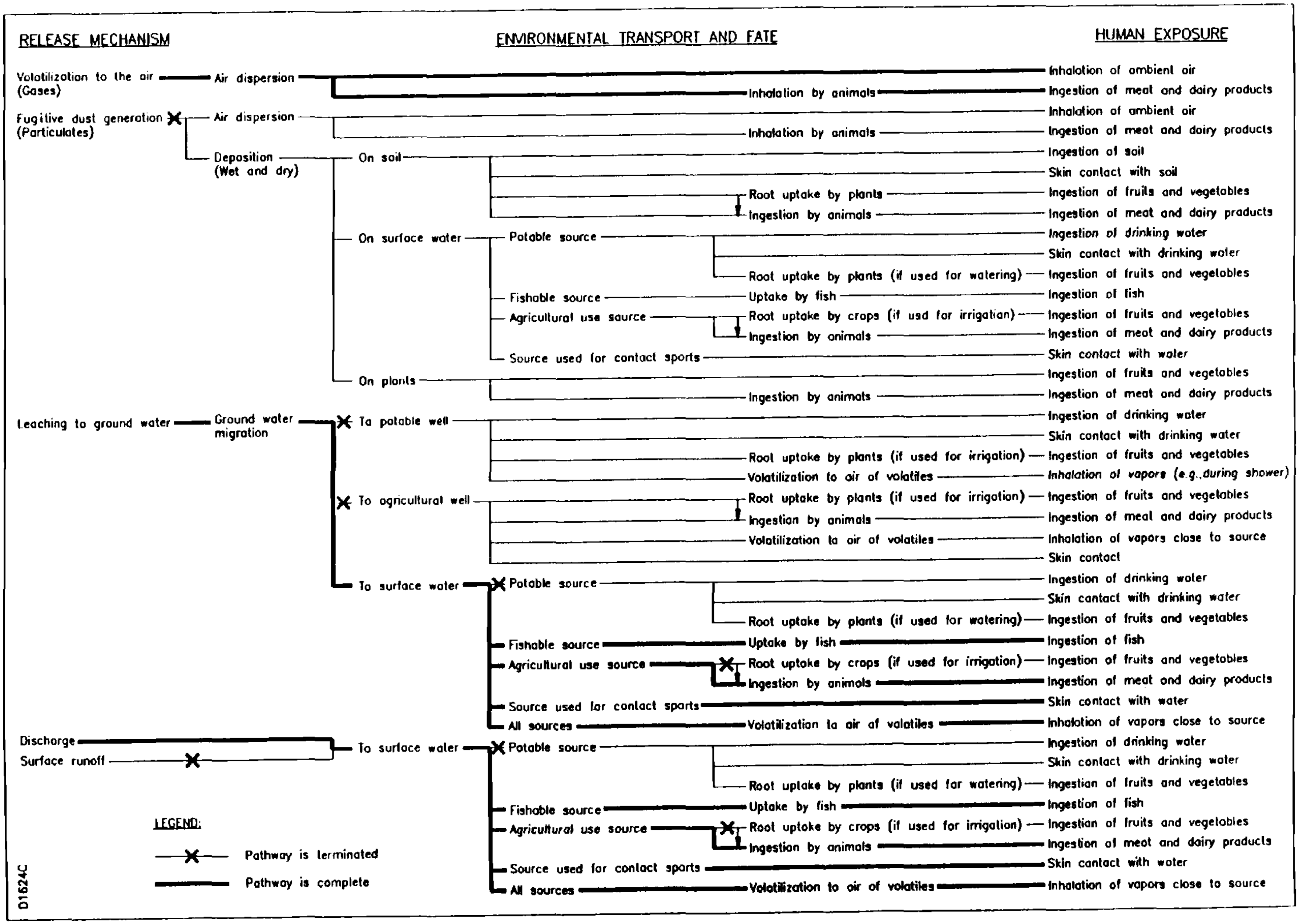

Figure 1-10. Potential Pathways to Human Exposure from Site SD13

exposure to contaminants from all East Area sites is not significant. For Sites LF01 and SD13, the expected maximum concentrations of all contaminants was at least six orders of magnitude below their RFDs. Similarly, for Sites ST14 and BSS, the concentrations were at least five orders of magnitude lower. For each site, incremental individual cancer risks were estimated for maximum exposed individuals at locations both on site and off site. The highest calculated risks were all dismissed as inconsequential, ranging from 5.7 in 100 million (Site ST14) to 9 in 10 billion (Site LF01). Ingestion and dermal risks were considered minimal and were not quantified.

Some risk exists for terrestrial wildlife that use Farmers Branch, Unnamed Stream, or the West Fork of the Trinity River as a source of drinking water and for aquatic organisms in these surface water bodies. However, all such risks were concluded to be minimal.

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 environmental media at Carswell AFB. A variety of publications were reviewed both to identify and to screen remedial action technologies potentially appropriate to Carswell AFB IRP sites. General publications that are particularly appropriate to Carswell AFB are Evaluating Cost-Effectiveness of Remedial Actions at Uncontrolled Hazardous Waste Sites (Radian, 1983), 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. Technologies that remained after the screening are discussed in Section 2.3 as they relate to actual site conditions.

2.1 Remedial Action Objectives

The FS was performed to develop feasible remedial alternatives to mitigate environmental contamination associated with East Area IRP Sites LF01, SD13, ST14, and BSS. Volatile organic compounds, primarily benzene, associated with fuel spills and/or leaks are the main contaminants detected in the Upper Zone ground water, surface water, and soils in the East Area.

The remedial action objectives for this FS are:

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

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

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

To identify and evaluate remedial alternatives, contaminated environmental media were identified based on the IRP RI results (Radian, 1989; 1991). These media are wastes 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 medium based upon the following standards or criteria:

- 70-year cancer risk;
- Maximum contaminant levels (MCLs) for organics (40 CFR 141.12 and 141.61) and inorganics (40 CFR 141.11 and 141.62) established by the national interim primary drinking water standards;
- Final MCLs for organics and inorganics (Federal Register, Vol. 56, No. 20, 30 January 1991); and
- Maximum BTEX (benzene, toluene, ethylbenzene, and xylene) and TPH (total petroleum hydrocarbon) levels for soil and ground water (TWC, 1990).

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 East Area sites. As discussed in the RI report (Radian, 1991), metals are included as indicator chemicals on the basis of total detected concentrations in water samples. However, the dissolved metals concentrations detected in the 1990 sampling event do not suggest a metals contamination problem.

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

Environmental Medium	Remedial Action Objectives
WASTES AND CONTAMINATED SOIL	FOR HUMAN HEALTH: Prevent soil or waste ingestion or direct contact that would contribute to an excess cancer risk equal to or greater than 10^{-6} (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 carcinogens [TCE, 1,2-DCE, tetrachloroethylene, vinyl chloride, methylene chloride, benzene, chloroform, and bis(2-ethylhexyl)-phthalate] at locations where these substances would contribute to excess inhalation cancer risk levels equal to or greater than 10^{-6} so that risk levels are lower than 10^{-6}. FOR ENVIRONMENTAL PROTECTION: 1) Prevent soil contaiminant migration 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)

TABLE 2-1. (Continued)

<table>
<tr><th>Environmental Medium</th><th>Remedial Action Objectives</th></tr>
<tr><td>UPPER ZONE GROUND WATER</td><td>FOR HUMAN HEALTH: Prevent ingestion of ground water that would contribute to an excess cancer risk equal to or greater than 10^{-6}.

FOR ENVIRONMENTAL PROTECTION: Remove contaminants from the ground water to levels below the following concentrations:

<u>Inorganics</u>
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

<u>Organics</u>
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</td></tr>
<tr><td>SURFACE WATER</td><td>FOR HUMAN HEALTH: Prevent surface water ingestion or skin contact that would contribute to an excess cancer risk equal to or greater than 10^{-6}. Prevent fish consumption that would contribute to an excess cancer risk equal to or greater than 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).</td></tr>
</table>

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

2.2 Screening of Technologies

Available literature was reviewed to identify potential response actions, technologies, and process options applicable to each contaminated environmental medium in the East Area. These remedial technologies are discussed in Section 2.2.1 (wastes and contaminated soil), Section 2.2.2 (ground water), and Section 2.2.3 (surface water).

The applicability of each technology 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 results are shown in Tables 2-2 through 2-4. Technologies which are not appropriate for conditions at the East Area sites, or which do not meet the criteria of demonstrated performance and effectiveness, constructability and implementability, and cost are indicated with an asterisk. 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, are not compatible with the characteristics of the East Area sites, or are too costly in comparison to other feasible technologies.

2.2.1 Wastes and Contaminated Soil

Very limited analytical data from the 1988 (Radian, 1989) effort indicated soil contamination from fuel spills and/or leaks at Sites ST14 and BSS. However, because no additional samples were collected during the 1990 effort, it is unclear what the areal extent and volumes of contaminated soil at these sites are, or if in fact the contamination currently persists in concentrations that exceed RAOs for soils. The baseline risk assessments for these and the other East Area sites, which included evaluation of the 1988 soils data, concluded that none of the sites pose a significant human health risk. Additional soil sampling and analysis will be required to determine if the areas of historically documented soil contamination require remediation.

Table 2-2 presents response actions, technologies, and process options potentially applicable to wastes and contaminated soil in the East Area, along with a brief description of each and comments on the screening. Potentially applicable response actions are no action, institutional actions, containment, removal, treatment, and disposal.

No-Action Response--The "no-action" response 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 implemented in the East 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 or diversion/collection of run-on. Capping waste bodies and/or contaminated soil source areas ("hot spots") reduces surface exposure and prevents 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/release sites would be an effective technology. However, except for Site LF01 (Landfill 1), the potential contaminant source areas are not sufficiently well-defined at the surface to consider capping. Similarly, surface diversion/collection systems are not applicable. Site LF01 (Landfill 1) is already paved over, and furthermore, the 1990 analytical results for ground water do not indicate ongoing releases of organic or inorganic constituents at levels of concern (i.e., above MCLs). Therefore, surface containment technologies were eliminated from further consideration.

Subsurface control involves controlling or re-directing ground-water flow, as well as preventing migration of contaminants in the soil, so as to contain the contaminants within a specific area. Used alone, physical subsurface barriers do not promote any reduction in toxicity or existing concentrations of contaminants and may hinder biodegradation and volatilization of organic contaminants. If soil contamination is eliminated

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.	Not applicable so long as base is federally owned/controlled.
Containment	Surface Controls	Capping*	Compacted clay, synthetic membrane, or both placed over contaminated area to prevent surface water infiltration or to aid in other remedial actions (e.g., soil vapor extraction).	Potentially applicable to minimize waste/leachate generation from well defined sources. Minimize exposure to waste/leachate.
		Grading*	Land surface reshaped to manage run-off, to 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.	Does not remove or cause destruction of contaminants and may hinder natural processes. Satisfies no-migration objective, but not good for long-term remedy unless used in conjunction with other technology.

*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
Containment (Cont.)	Subsurface Barriers (Cont.)	Slurry Walls*	Trench filled with bentonite mixture or other material surrounding contaminated area.	Does not remove or cause destruction of contaminants and may hinder natural processes. Satisfies no-migration objective, but not good for long-term remedy unless used in conjunction with other technology.
Removal	Excavation	Hydraulic Dredging*	Slurried 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. However, generally not feasible for contaminated soil under structures, roads, or near subsurface pipelines (or utilities).
Treatment	In Situ	Soil Flushing*	Extractant solution injected or sprayed on contaminated area to mobilize sorbed contaminants, then contaminants pumped to surface for treatment.	Potentially applicable. More expensive than other equally (or more) effective technologies in this category (e.g., soil vapor extraction).
		Bio-treatment	Soil flushed with oxygenated water and nutrients to stimulate soil bacteria.	Potentially applicable.
		Soil Vapor Extraction	Vapors extracted from soil using vacuum wells; vapors are treated with activated carbon or by incineration-catalytic conversion.	Potentially 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.	Potentially applicable. More expensive than other equally (or more) effective technologies in this category (e.g., soil vapor extraction).
		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 of obsidian or very strong glass.	Applicable to sites with radioactive or very highly toxic waste contamination. Very expensive, hard to implement around existing structures and within project's time frame.

(Continued)

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

†This remedial technology requires excavation of the contaminated soil. Excavation is generally not feasible if soil contamination exists under structures, roads, or near subsurface pipelines (or ut'lities).

TABLE 2-2. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (Cont.)	Physical Treatment	Soil Shredding*†	Shredder with high speed cleated belts aerates, mixes, and pulverizes soil through a violent churning action. Essentially, air strips VOCs from soil.	Potentially applicable. More expensive than other equally (or more) effective technologies (e.g., soil piles).
	Biological Treatment	Landfarming*†	Waste applied to soil surface and tilled to degrade or immobilize contaminants. Chemicals, nutrients, and absorbents may aid in process.	Potentially applicable. More expensive than other equally (or more) effective technologies (e.g., soil piles).
		Soil Piles†	Soil excavated and placed in a pile. Drain pipes are placed across pile and volatilization and biodegradation of the petroleum products are enhanced.	Potentially applicable.
	Chemical Treatment	Soil Washing*†	Contaminants extracted from excavated soil by mixing soil with extractant. The contaminated solution is then treated.	Potentially applicable. Very expensive compared to other equally (or more) effective technologies (e.g., soil piles).
		Solidification/ Stabilization*†	Addition to excavated soil of large amounts of a siliceous material combined with a settling agent such as lime resulting in a dewatered, stabilized, solidified waste product.	Potentially applicable. More expensive than other equally (or more) effective technologies (e.g., soil piles).
		Asphalt Incorporation*†	Soil extracted and added to asphalt as an asphalt ingredient.	Potentially applicable but still in research stage.
	Thermal Destruction	Electric Reactor*†	Electrically heated fluid wall reactor pyrolyzes organics and inorganics from solid, liquid, or gas.	Potentially applicable. Very expensive compared to other equally effective technologies (e.g., soil piles).
		Rotary Kiln Incinerator*†	Waste thermally destroyed by mixing with oxygen and fuel in a rotating vessel.	Potentially applicable. Very expensive compared to other equally effective technologies (e.g., soil piles).

(Continued)

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

†This remedial technology requires excavation of the contaminated soil. Excavation is generally not feasible if soil contamination exists under structures, roads, or near subsurface pipelines (or utilities).

TABLE 2-2. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (Cont.)	Thermal Destruction (Cont.)	Infrared Incineration Systems*†	Solids, sludges, and contaminated soils destroyed by infrared energy provided by silicon carbide resistance heating elements.	Potentially applicable. Very expensive compared to other equally effective technologies (e.g., soil piles).
		Fluidized Bed Incineration*†	Wastes incinerated in a turbulent bed of inert granular material to improve transfer of heat to waste streams.	Potentially applicable. Very expensive process compared to other equally effective technologies (e.g., soil piles).
Disposal	Disposal	Landfill*†	Land disposal of contaminated soils or waste in a RCRA-permitted facility.	Not applicable without treatment. Land ban restrictions.
		On-Site Disposal†	Various potential applications for use as clean fill.	Potentially applicable.

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

†This remedial technology requires excavation of the contaminated soil. Excavation is generally not feasible if soil contamination exists under structures, roads, or near subsurface pipelines (or utilities).

by treatment, there is no need for subsurface controls. Therefore, all four subsurface containment options--liners, sheet piles, grouting, and slurry walls--were eliminated from further evaluation.

Removal--Removal of contaminated soil/waste would be accomplished by excavation using conventional techniques. At a site such as Site ST14 (POL Tank Farm), where there are numerous surface and subsurface structures, excavation may not be feasible unless the areas of soil contamination are very localized. Excavation is required in conjunction with implementation of some other remedial options (e.g., ground-water interceptor trenches), and could be applicable to local areas of contamination suspected to be present at Site BSS (Base Service Station). Any contaminated soils that are removed could require treatment prior to disposal.

Treatment--Soil leaching, solidification/stabilization, and vitrification were eliminated from consideration as in-situ treatment options because they are too difficult to implement or are more expensive than other, equally effective (or more-effective) treatments, such as biological treatment and soil vapor extraction. In-situ biological degradation and soil vapor extraction are cost-effective technologies for remediation of organic contamination in soils and were selected for further evaluation.

Treatment technologies that require removal of contaminated soil/wastes are generally more costly and potentially more difficult to implement than in-situ technologies. Soil washing (chemical extraction), asphalt incorporation, solidification/stabilization, landfarming, and soil shredding were eliminated from further consideration because they are more expensive than soil piles, an equally effective (or more-effective) treatment technology. The soil piles method uses biological degradation and volatilization to treat organic and volatile organic contamination in soils. Soil piles were chosen for further evaluation.

Disposal--Off-site disposal of untreated soil/waste in a landfill potentially presents regulatory problems that may be difficult (or impossible) to resolve. At this time, landfills in the Fort Worth area are not accepting untreated petroleum-contaminated soil. Once treated, off-site disposal of excavated soil/waste is feasible, but was eliminated because on-site disposal of treated material would be more easily implemented and cost-effective.

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 are no action, institutional actions, containment, extraction/recovery, treatment, and discharge.

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

Institutional Actions--Two institutional actions were considered: 1) restriction of access to Upper Zone ground water and 2) using monitor wells to monitor Upper Zone ground-water quality. Since proven technologies are available for treating the ground-water contaminants detected in Upper Zone ground water on the East Area of the base, restricting aquifer use is not appropriate and was eliminated. Ground-water monitoring, in conjunction with the no-action alternative, is applicable at sites where current concentrations of indicator chemicals are below the RAOs (i.e., Sites SD13 and LF01). Ground-water monitoring is also an applicable technology when used to evaluate the effectiveness of additional remedial technologies.

Ground-Water Containment--The discussion of containment technologies for wastes and contaminated soil also applies to ground water. Additional hydraulic barriers (pumping or injection wells, or passive collection using subsurface drains/interceptor trenches) could be used both to control contaminated ground-water migration and to extract ground-water (see below).

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. Also applicable when baseline risk is negligible.
Institutional Actions	Access Restriction	Deed Restriction*	Deed to property restricts use of wells in the area of influence.	Considered only if remediation is not possible. Very hard to enforce. Not applicable.
	Monitoring	Ground-Water Wells	Contaminated area monitored by system of upgradient and downgradient wells.	May be used alone or 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. However, does not remove or cause destruction of contaminants and may hinder natural processes.
		Asphalt*	Asphalt sprayed over source areas of ground-water contamination.	Potentially applicable to prevent infiltration. However, does not remove or cause destruction of contaminants and may hinder natural processes.
		Concrete*	Concrete slab installed over source areas of ground-water contamination.	Potentially applicable to prevent infiltration. However, does not remove or cause destruction of contaminants and may hinder natural processes.
		Multi-Media Cap*	Clay and synthetic membrane covered by soil over source areas of ground-water contamination.	Potentially applicable to prevent infiltration. However, does not remove or cause destruction of contaminants and may hinder natural processes.

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

(Continued)

TABLE 2-3. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Containment (Continued)	Subsurface Barriers Vertical	Slurry Wall*	Trench around areas of contamination is filled with a soil (or cement) and bentonite slurry.	Does not remove or cause destruction of contaminants and may hinder natural processes. Satisfies no-migration objective, but not good for long-term remedy unless used in conjunction with other technology.
		Grout Curtain*	Pressure injection of grout in a regular pattern of drilled holes below contaminated area.	Does not remove or cause destruction of contaminants and may hinder natural processes. Satisfies no-migration objective, but not good for long-term remedy unless used in conjunction with other technology.
		Vibrating Beam*	Vibrating force to advance beams into the ground with the injection of slurry as beam is withdrawn.	Does not remove or cause destruction of contaminants and may hinder natural processes. Satisfies no-migration objective, but not good for long-term remedy unless used in conjunction with other technology.
		Sheet Piles*	Interconnected steel sheets forced into the ground surrounding contaminated areas.	Unreliable because the interlocks connecting the sheets are not sealed.
		Hydraulic Barriers	Series of extraction wells (or trenches) and injection wells to create a hydraulic barrier to off-site migration of contaminants.	Potentially applicable.
		Liners*	Synthetic or clay liner placed beneath wastes to contain leachate.	Not feasible. Waste already in place.
Extraction	Collection Systems	Ground-Water Extraction Wells (Hydraulic Barrier)	Series of pumping wells to extract contaminated ground water.	Potentially applicable, used in conjunction with ground-water treatment processes.
		Interceptor Trench	Buried conduit conveys and collects leachate by gravity flow.	Potentially applicable, used in conjunction with ground-water treatment process.

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

(Continued)

TABLE 2-3. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment	In-Situ Treatment	Aerobic Biological	Bacteria and nutrients added to contaminated ground water to enhance degradation process.	Potentially applicable. Aquifer matrix and ground water probably have enough carbon source to aid in sustaining growth.
		Anaerobic Biological*	A reducing agent and nutrients added to contaminated ground water in a no-oxygen environment to enhance the degradation of low-molecular-weight halogenated organics.	Not applicable. Difficult to create anerobic conditions in the Upper Zone Aquifer.
		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.	Potentially applicable but very expensive due to treatment or excavation of spent materials.
		Chemical Reaction*	System of injection wells to inject oxidizer such as hydrogen peroxide to degrade contaminants.	Potentially applicable but biological treatment may be more effective. Potential for remnant oxidizer to be left in subsurface.
	Physical Treatment	Oil/Water Separation	Bulk separation of immiscible materials.	Potentially applicable as a pretreatment step, immiscible fluids in ground water.
		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. Possibly could be used as a pretreatment step.
		Air Stripping	Mass transfer where volatile contaminants in ground water are transferred to air.	Potentially applicable.
		Steam Stripping*	Continuous fractional distillation of volatile compounds from ground water in a packed or tray tower using clean steam.	Potentially applicable. More expensive than other equally effective treatment (e.g., air stripping).
		Carbon Adsorption	Contaminated ground water flows through a series of packed bed reactors containing activated carbon or used as vapor treatment with air stripping.	Potentially applicable but very expensive as a primary treatment due to operating and maintenance (O&M) costs. Air stripping is less expensive and as effective.

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

(Continued)

TABLE 2-3. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (Continued)	Biological Treatment	Activated Sludge*	Contaminated water aerated in basin where a suspended active microbial population degrades organics. The water is then clarified.	Ground water may not have sufficient carbon source to sustain biological growth.
		Fixed Film*	Contact of contaminated water with microbes attached to some medium for waste degradation (e.g., rotating biological contactor).	Ground water may not have sufficient carbon source to sustain biological growth.
		Anaerobic Lagoon*	Large, deep basin where high organic loadings promote thermophilic anaerobic digestion of organics.	Not applicable for organics in East Area.
	Chemical Treatment	Ion Exchange/Resin Adsorption*	Toxic metal ions removed from water by exchanging with an ion attached to the solid resin material.	Little evidence of metals contamination in East Area.
		Oxidation/Reduction*	Contaminated water reacted with either an oxidizer or reducer to lower or raise the oxidation state.	Not typically used for VOC-contaminated waters.
		Reverse Osmosis*	Solvent forced by high pressure through a membrane that is permeable to the solvent molecules, but not the solute.	Little evidence of metals contamination in East Area. Organics may dissolve membrane.
		Precipitation/ Flocculation/ Sedimentation*	Chemicals added to contaminated water to precipitate metals from the water, agglomerate the precipitate, and allow the precipitate to settle.	Little evidence of metals contamination in East Area.
	Thermal Destruction	Electric Reactors*	Waste combusted in a horizontally rotating cylinder designed for uniform heat transfer.	More applicable for concentrated waste streams; very expensive.
		Rotary Kiln*	Waste injected into hot agitated bed of sand where combustion occurs.	More applicable for concentrated waste streams; very expensive.
		Fluidized Bed*	Electrically heated fluid wall reactor that pyrolyzes organics and inorganics.	More applicable for concentrated waste streams; very expensive.
		Fume Incineration-Catalytic Conversion	Vapor wastes thermally treated and catalyzed. Generally used in conjunction with air stripping.	May be used in secondary treatment.
Discharge	On Site/Off Site	Local Stream	Extracted water discharged to a local stream.	Potentially applicable but requires prior treatment.

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

(Continued)

TABLE 2-3. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Discharge (Continued)	On Site/Off Site (Continued)	Aquifer Recharge	Extracted water reinjected or allowed to percolate into aquifer using injection wells or sprinkling system.	Potentially applicable, but requires prior treatment.
		Deep Well Injection*	Extracted water discharged to deep well injection system.	Not applicable due to regulatory problems.
		POTW	Extracted water discharged to local POTW for treatment.	May require treatment before discharging to POTW, otherwise may not be accepted.

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

Ground-Water Extraction--Two ground-water extraction technologies were considered: extraction well fields and interceptor trenches. Interceptor trenches are potentially applicable because of the shallow depth of the Upper Zone ground water throughout much of the East Area. Ground-water extraction wells are also a feasible technology, especially in those areas where greater ground-water depth makes subsurface drain systems less cost-effective and/or difficult to implement. In addition, properly designed and constructed ground-water extraction technologies would also create a hydraulic barrier that would restrict the further migration of contaminated ground water.

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

Three in-situ treatments were eliminated from further consideration: anaerobic biological treatment, adsorption bed treatment, and chemical reaction. These treatments were either inappropriate or too difficult to implement (anaerobic biological treatment and chemical reaction); or too costly (adsorption bed treatment) when compared to other equally effective technologies. Aerobic biological treatment, which uses bacteria and nutrients to enhance biodegradation, is potentially applicable for remediation of ground water contaminated with hydrocarbon constituents.

Several physical treatment options were considered for treating contaminated ground water extracted from the East Area. The two pretreatment processes were granular media filtration and oil/water separation. The three treatment processes were air stripping, steam stripping, and carbon adsorption.

Oil/water separation is the only pretreatment option considered potentially applicable (or necessary) for remediation of ground-water contamination in the East Area. Free-phase hydrocarbon was observed in one well at Site ST14 (POL Tank Farm) during the 1990 sampling event. While the data suggest a limited occurrence of free-phase contaminant, oil/water separation may be required before ground-water treatment. Suspended solids are not expected to be a problem, so granular media filtration was eliminated from further evaluation.

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 if no secondary treatment of off-gas is required. A cost comparison of air and steam stripping units showed that the capital costs of the two technologies are comparable. In the absence of secondary treatment requirements for the air stripper, the operating costs of steam stripping are greater than those of air stripping. However, if secondary treatment, such as carbon, is required, the operation and maintenance costs of air stripping approach those of steam stripping. Steam stripping was eliminated from further consideration for the following reasons:

- Possibly higher operating and maintenance costs than air stripping for the same level of treatment; and

- Use of a more complicated process, requiring a higher level of expertise for operation than air stripping.

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 contaminants that are non-volatile. However, the operating and maintenance (O&M) costs of carbon absorption units are much greater than those of 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 adsorption was eliminated from further consideration as a primary treatment option. However, carbon adsorption will be considered for a secondary treatment option (e.g., as a vapor phase treatment for air stripping).

Biological Treatment--Three biological treatment technologies were screened: activated sludge, fixed film, and anaerobic lagoon.

Two of these processes (activated sludge and fixed film) are performed under aerobic conditions. In general, the hydrocarbon constituents found in the East Area can be effectively degraded by these processes. However, the extracted contaminated ground water may not have a sufficient carbon source to sustain growth of the microorganisms. Degrading the ground-water contaminants in anaerobic lagoons is inefficient, requiring long retention times. Therefore, biological treatment processes, other than in-situ bio-treatment (see page 2-18 for description) were eliminated from further consideration.

Chemical Treatment--Four chemical treatment technologies were evaluated: ion exchange/resin adsorption, oxidation/reduction, reverse osmosis, and precipitation/flocculation/sedimentation. All are effective in treating ground water contaminated with metals; however, all but oxidation/reduction are ineffective for treating organic compounds. Since there is little evidence to suggest a metals contamination problem at the East Area sites, the chemical treatment options were eliminated from further consideration.

Certain oxidation/reduction processes have been developed to treat organics (e.g., ultraviolet radiation/peroxidation). The oxidation reduction processes can be quite effective in destroying organic contaminants in ground water, but color, turbidity, and naturally occurring organics (such as humic and fulvic acids) can reduce the effectiveness of the process. Oxidation/reduction processes are typically used when less expensive or rigorous processes are not effective. Since air stripping is equally effective for the contaminants present in the East Area and usually less costly, oxidation/reduction processes were eliminated from further consideration.

Thermal Destruction--Thermal destruction processes such as 1) electric reactors, 2) rotary kiln, and 3) fluidized bed incineration 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. Fume incineration (catalytic conversion) could be used as a secondary treatment with other remedial techniques such as air stripping. Considering the typical ground-water contaminant concentrations in the Upper Zone ground water, fume incineration was the only thermal destruction technology retained for further consideration.

Discharge of Ground Water--Options for discharging untreated ground water to a local stream, by aquifer recharge, or by deep well injection were evaluated and rejected because they do not meet regulatory requirements. Discharge of untreated effluent to the local publicly owned treatment works (POTW) is unlikely to be allowed under the local ordinances and was also eliminated. However, once the water is treated, all of these become 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 were also presented as ground-water treatment technologies and were discussed in Section 2.2.2. The only surface water body within the East Area that was sampled during the IRP is Unnamed Stream. As previously described, the source of Unnamed Stream is ground water discharging from an oil-water separator/french drain system that collects ground water from Site ST14 (POL Tank Farm) upgradient of the stream. Although benzene was detected above the MCL at a maximum concentration of 120 $\mu g/L$ in a first-round sample collected in 1988, no benzene was detected in any of the second-round surface water samples (Radian, 1989). Furthermore, no volatile organic compounds or verified concentrations of dissolved metals exceeded MCLs in any samples collected from Unnamed Stream in 1990. Therefore, the only applicable technology listed in Table 2-4 is continued monitoring of surface water (or ground water at points of discharge to surface water).

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 (other than monitoring).	Consideration required for base case. Also applicable when baseline rate is negligible.
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.	Not needed, little evidence of surface water contamination.
		Grading*	Land surface reshaped to manage run-off control.	Not needed, little evidence of surface water contamination.
		Revegetation*	Capped and/or graded surface is stabilized with vegetation.	Not needed, little evidence of surface water contamination.
	Run-on/Run-off Diversion	Channels and* Waterways	Excavated ditches, usually wide and shallow, that intercept run-off from contaminated areas.	Not needed, little evidence of surface water contamination.
		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 of or along perimeter of contaminated area to divert run-on.	Not needed, little evidence of surface water contamination.
	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.	Not needed, little evidence of surface water contamination.
Treatment	In Situ Treatment	Aerobic Biological*	Hydrogen peroxide and nutrients added to contaminated water to enhance degradation process.	Not needed, little evidence of surface water contamination.

*Remedial technologies or process options eliminated from further consideration.

(Continued)

TABLE 2-4. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (Cont.)	In Situ Treatment (Cont.)	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.	Not needed, little evidence of surface water contamination.
		Steam Stripping*	Continuous fractional distillation of volatile compounds from surface water in a packed or tray tower using clean steam.	Not needed, little evidence of surface water contamination.
		Carbon Adsorption*	Contaminated surface water flows through a series of packed bed reactors containing activated carbon.	Not needed, little evidence of surface water contamination.
	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 needed, little evidence of surface water contamination.
		Fixed Film*	Contact of contaminated water with microbes attached to some medium for waste degradation (e.g., rotating biological contactor).	Not needed, little evidence of surface water contamination.
		Anaerobic Lagoon*	Large, deep basin where high organic loadings and an impervious surface grease layer promote thermophilic anaerobic digestion of organics.	Not needed, little evidence of surface water contamination.
	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. Little evidence of metals contamination.
		Oxidation/Reduction*	Contaminated water reacted with either an oxidizer or reducer to lower or raise the oxidation state.	Not needed, little evidence of surface water contamination.
		Reverse Osmosis*	Solvent forced by high pressure through a membrane that is permeable to the solvent molecules, but not the solute.	Not needed, little evidence of surface water contamination.
		Precipitation/Flocculation/Sedimentation*	Chemicals added to contaminated water to precipitate metals from the water, agglomerate the precipitate, and allow the precipitates to settle.	Not needed, little evidence of metals contamination.
	Thermal Destruction*	Electric Reactors*	Electrically heated fluid wall reactor that pyrolyzes organics and inorganics.	Not needed, little evidence of organic contamination.

*Remedial technologies or process options eliminated from further consideration.

(Continued)

TABLE 2-4. (Continued)

Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (Cont.)	Thermal Destruction*	Rotary Kiln*	Waste combusted in a horizontally rotating cylinder designed for uniform heat transfer.	Not needed, little evidence of organic contamination.
		Fluidized Bed*	Waste injected into hot agitated bed of sand where combustion occurs.	Not needed, little evidence of organic contamination.

*Remedial technologies or process options eliminated from further consideration.

2.3 Selection of Remedial Technologies

Categories of remedial technologies that are potentially applicable to documented contamination in the East Area IRP are: institutional actions, containment, soil and ground-water removal (extraction), soil and ground-water treatment, and soil and ground-water disposal. The remedial technologies remaining after screening for Sites LF01, SD13, ST14 and BSS are listed in Table 2-5. To provide the information necessary for developing and screening alternatives in Section 3.0, a detailed description of each of the remaining technologies and how they could be implemented at the site(s) is given in the following sections.

2.3.1 Long-Term Monitoring

Long-term monitoring of ground-water quality (and surface water quality at Site SD13--Unnamed Stream) is a key element of all remedial alternatives. Upper Zone monitor wells already in place at each of the East Area sites may be sampled on a regular, pre-determined schedule and analyzed for waste-specific indicator chemicals. Additional monitor wells may be required on a site-specific basis to supplement the existing networks to fully evaluate the effectiveness of the selected remediation actions.

2.3.2 Ground-Water Extraction Wells

Pumping wells can be used to control migration of contaminated ground water in the Upper Zone (i.e., serve as a hydraulic barrier) as well as to extract ground water for treatment. Extraction wells are generally more cost-effective than passive extraction systems in hydrogeologic settings where the saturated zone is comparatively thicker and deeper, and where above- and below-ground structures may restrict the location of extraction systems requiring excavation.

TABLE 2-5. SUMMARY OF REMEDIAL ACTION OPTIONS FOR THE EAST AREA IRP SITES

	Site			
	LF01	SD13	ST14	BSS
No Action	■	■	■	■
<u>Institutional</u>				
Long-Term Monitoring	■	■	■	■
<u>Containment</u>				
Hydraulic Barrier (see ground-water extraction)			■	■
<u>Ground-Water Extraction</u>				
Extraction Well Fields			■	■
Interceptor Trenches			■	■
<u>Ground-Water Pretreatment</u>				
Oil/Water Separator			■	
<u>Primary Ground-Water Treatment</u>				
Air Stripping			■	■
In-Situ Biological Treatment			■	■
<u>Treated Ground-Water Discharge</u>				
Discharge to POTW			■	■
Discharge to Stream			■	■
Aquifer Recharge			■	■
<u>Soil Treatment</u>				
Soil Vapor Extraction			■	■
In-Situ Biological Treatment			■	■
Excavation/Soil Piles		■	■	■
<u>Secondary Treatment</u>				
Carbon Adsorption			■	■
Fume Incineration			■	■
<u>Treated Soil Disposal</u>				
On Site		■		■

2.3.3 Interceptor Trenches

Interceptor trenches constitute a passive ground-water extraction technology that can also act as a hydraulic barrier to control ground-water flow (and contaminant migration). Construction of interceptor trenches requires excavation (of potentially contaminated material), installation of piping and a pumping system, and backfilling. This technology is most cost-effective in settings where ground water occurs at shallow depth, and where the saturated zone is relatively thin and underlain by a low permeability confining zone. Interceptor trenches can be used in geologic materials where relatively low permeability limits the effectiveness of pumping wells.

2.3.4 Air Stripping Treatment System

The air stripping process is designed to remove volatile organic contaminants. Once extracted from the aquifer, ground water is pumped to storage tanks at a treatment pad through a pipeline. In one possible design, the ground water is then contacted with countercurrent or cross-current air in a packed tower. Other types of air stripping equipment use stacked trays or spray aeration chambers. Figure 2-1 is a schematic of the overall process. In addition to a stripping tower or chamber and water storage tanks, the system includes liquid-circulating pumps and an air blower.

Air-stripping equipment consists of simple gas-liquid contacting devices consisting of a shell containing packing material or trays, and a liquid-distributing device designed to effectively irrigate the packing (trays). The contaminated ground water enters the top of the column and flows by gravity counter-current to the air. As the water passes down through the column, it becomes progressively less contaminated. The volatile organic compound (VOC)-laden air is discharged at the top of the column. 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. Because multiple VOCs, each with a somewhat different equilibrium constant, are present in the Upper Zone

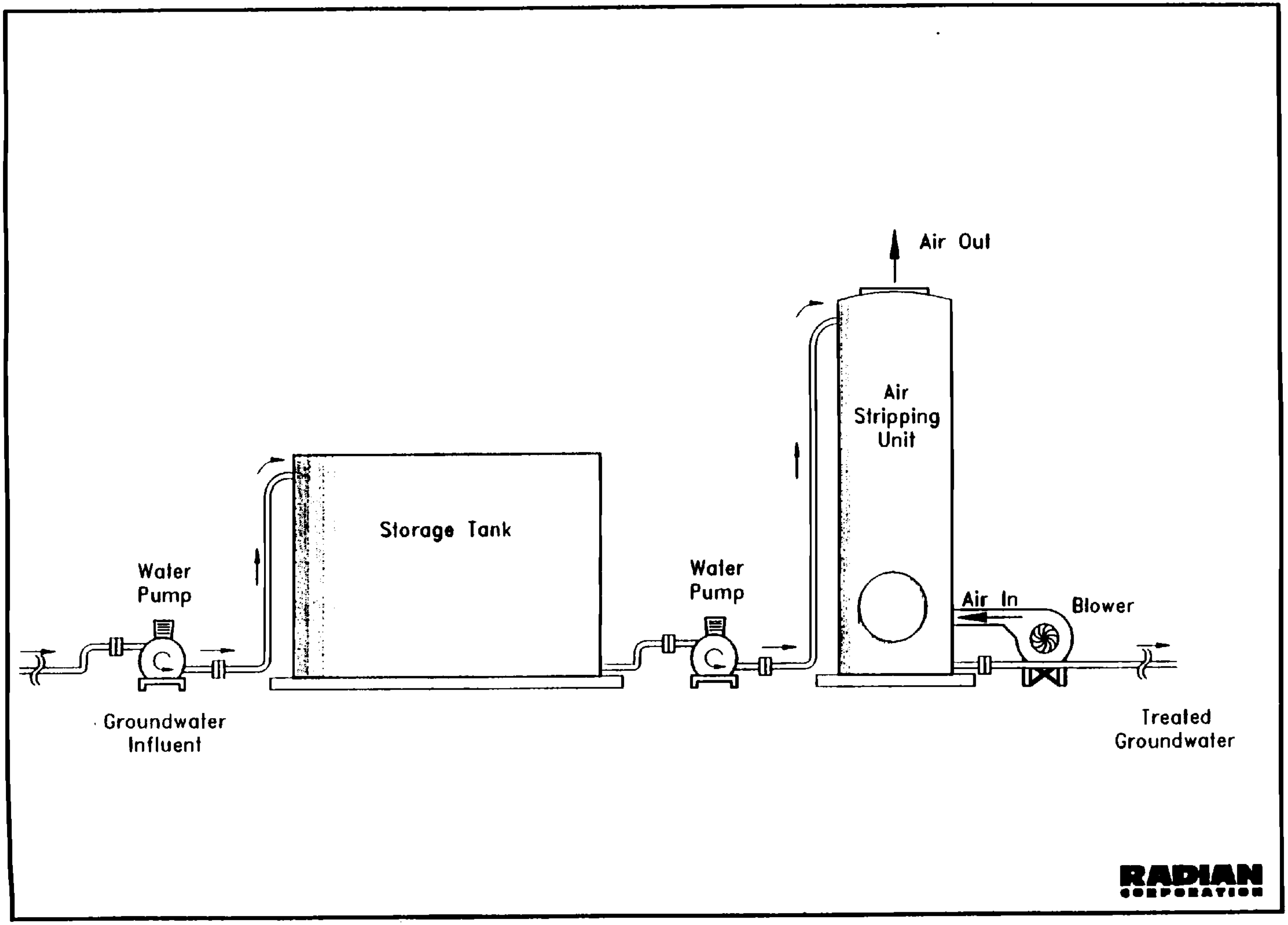

Figure 2-1. Schematic of Air S′ `pping Treatment System

ground water beneath the East Area, the final design of the air stripper will be determined by the total amount of VOCs requiring removal.

2.3.5 In-Situ Biological Treatment

Biodegradation occurs by microbial activity naturally present in ground water and soils. In-situ biological degradation involves the stimulation of this process in order to break down certain organic compounds such as petroleum hydrocarbons. Microorganisms use organic compounds which contain only carbon, hydrogen, and oxygen for nourishment. Certain cyanobacteria, yeasts, and molds have been shown to aerobically oxidize petroleum hydrocarbons. The microorganisms feed on the organic compounds found in the ground water and the aquifer matrix and require oxygen and water in order to survive.

While the biological treatment of ground water occurs in-situ, the water is initially pumped to the surface. A mixing tank is used to add nutrients (such as nitrogen, phosphorus, and trace elements) and oxygen sources (such as hydrogen peroxide) in order to optimize microbial activity. The ground water is then returned to the aquifer either by an infiltration gallery or by injection wells (see Figure 2-2). Treatment of contaminated soil may also be achieved by percolating water mixed with nutrients and an oxygen source through the affected soil. Factors influencing biodegradation include:

- Levels of contamination;
- Dissolved oxygen levels;
- Oxidation reduction potential;
- Temperature;
- Water and soil pH;
- Aquifer and soil permeability;
- Natural microbial community; and
- Nutrient availability.

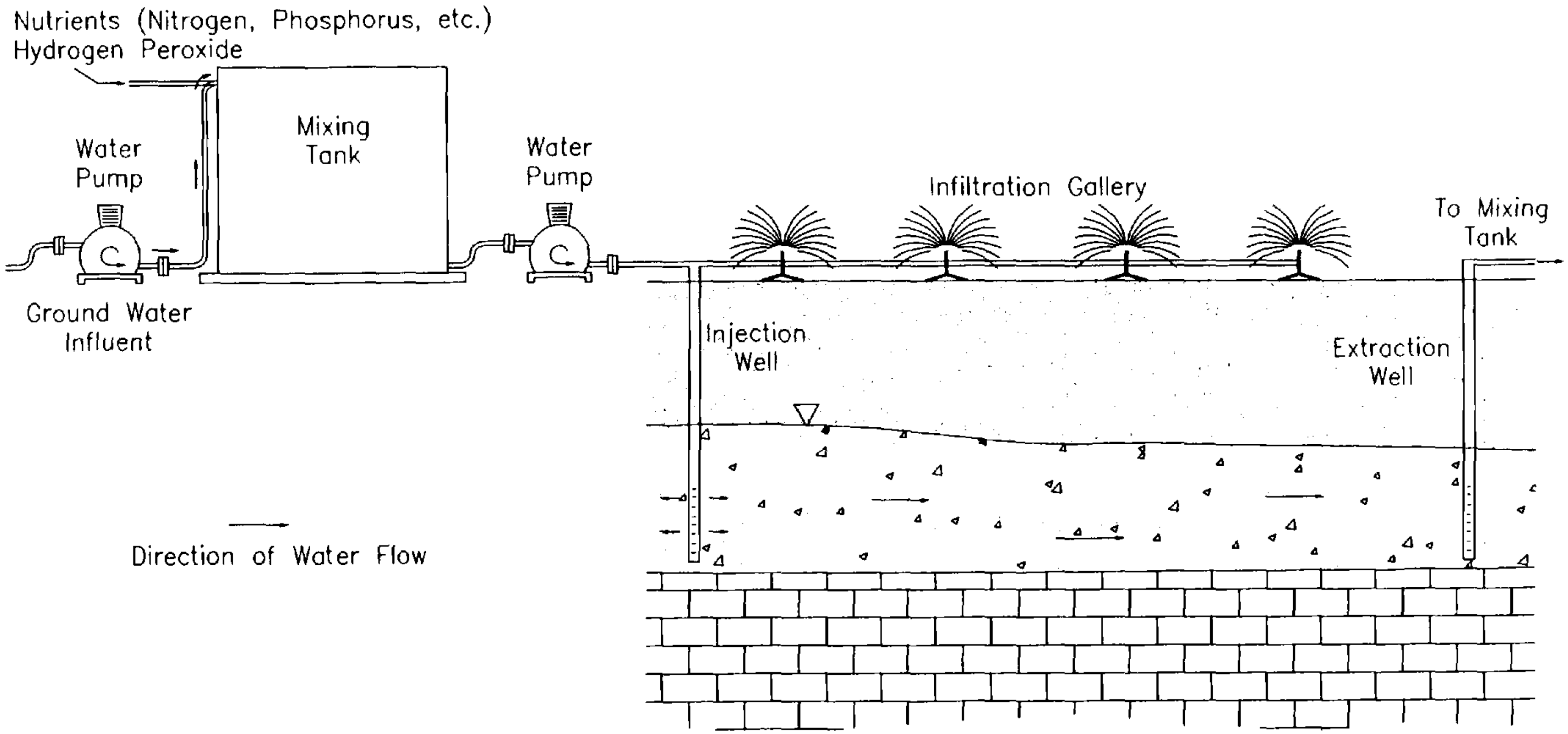

Figure 2-2. Schematic of In-Situ Biol‹ .cal Treatment System

Few of the listed data have been collected for the sites in the East Area. Prior to design, the collection of these data on a site-specific basis would be necessary.

2.3.6 Soil Vapor Extraction

To treat petroleum hydrocarbon contamination with soil vapor extraction, a blower is used to induce a vacuum in the soil through a series of trenches or wells (Figure 2-3). The petroleum hydrocarbon compounds then volatilize and are transported to the surface. As with air stripping, the off-gas may require treatment to acceptable air limits. To aid in inducing the vacuum the treated area could be covered with a synthetic membrane.

Factors influencing soil vapor extraction are:

- Soil moisture content;
- Soil porosity and permeability;
- Clay content of soil;
- Organic/mineral content of soil;
- Temperature;
- Wind and barometric pressure;
- Evaporation; and
- Precipitation.

Prior to design, the collection and evaluation of these data would be necessary on a site-specific basis.

Increases in soil moisture content, clay content, organic/mineral content, and precipitation decrease volatilization and increase treatment time. Increases in soil porosity, soil permeability, temperature, wind, barometric pressure, and evaporation increase volatilization.

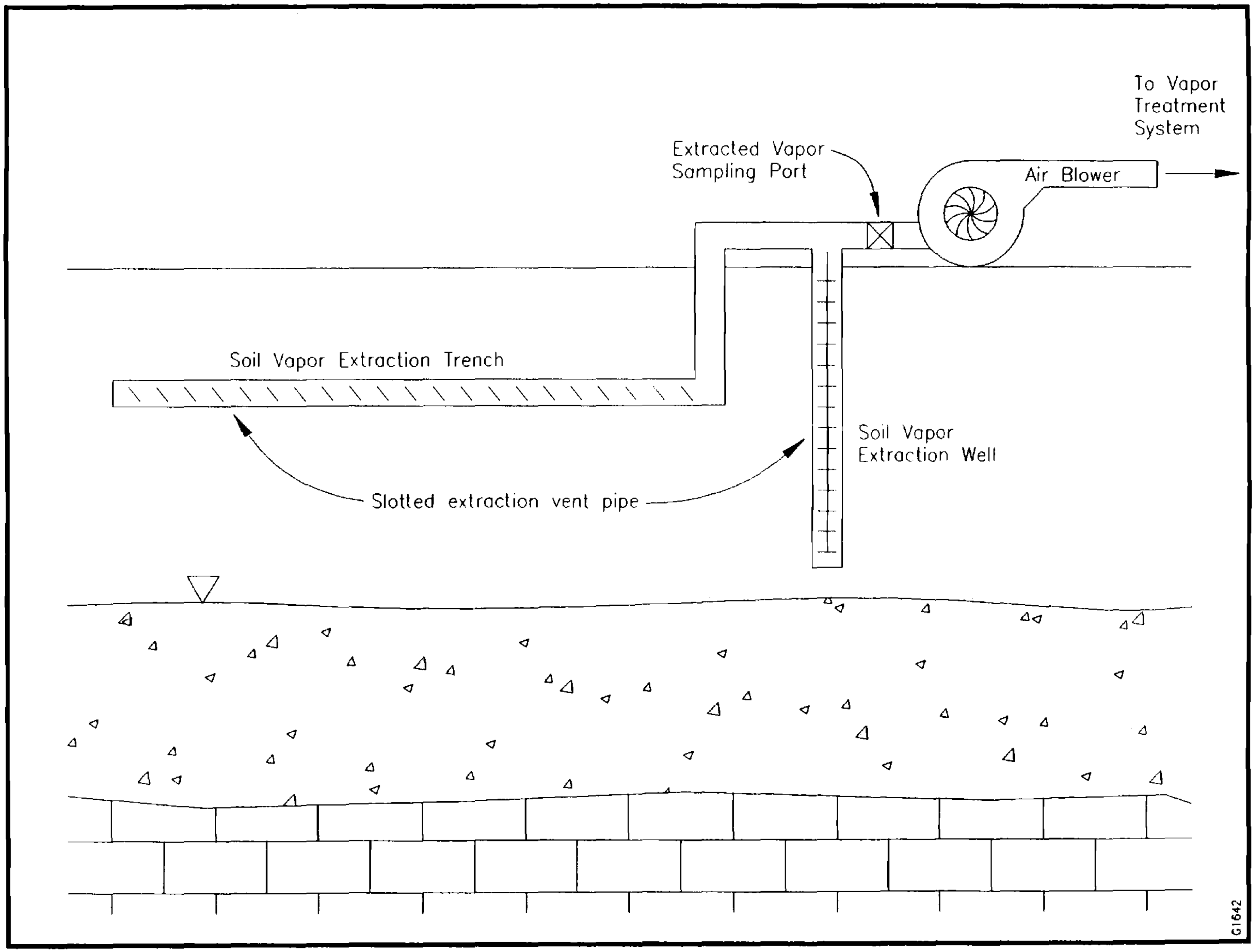

Figure 2-3. Schematic of Soil Vapor Extraction System

2.3.7 Soil Piles

In this technology, the contaminated soil is excavated and placed in a pile at a remote location for treatment. The soil pile is constructed such that volatilization and biodegradation are enhanced in the soil. The pile is built by placing a plastic liner on the ground on which 1 to 2 feet of contaminated soil is placed. Drain pipes are then laid across the pile and more soil is added. The next pipe layer is placed cross-wise to the first. This is continued until the desired number of lifts are reached. Fertilizer may be added between lifts to promote biodegradation. The pile is covered with black plastic to control run-off, and by absorbing heat, increases the volatilization and biodegradation rates. Volatile gases are collected by pipes and discharged. To enhance treatment, air can be drawn through pipes by a blower.

2.3.8 Secondary Treatment Systems

Air stripping is the only primary treatment option considered which may require secondary treatment. If the air/vapor emissions from the stripping tower exceed state standards, a secondary treatment will be required.

Regulatory Requirements

Two exemptions (68 and 118) from the Texas Air Control Board (TACB) Standard Exemption List (August 11, 1989) define the criteria for requiring emission control devices for air stripping, soil vapor extraction, or soil piles. Exemption 68 allows steam, air, or inert gas stripping provided that the total emissions or air contaminants, excluding nitrogen, do not exceed 5 pounds per hour (lb/hr). Furthermore, the exemption allows combustion of stripped vapors as long as the total emissions of contaminants (excluding nitrogen, carbon dioxide, air, oxygen, and water vapor) do not exceed 5 lb/hr. Exemption 68 requires soil stripping operations to be at least 1,000 feet from any residence, structure, or recreational area not occupied or used solely by the operator or owner of the property on which the operations are conducted.

Compounds not specifically listed in the exemption may be stripped as long as they meet the requirements of Standard Exemption 118 paragraphs (b), (c), and (d).

Exemption 118 presents air emission screening levels for benzene. As a component of the final design process, the performance of air dispersion modeling will be needed to verify that the treatment locations proposed in this study are acceptable relative to the screening level. Exemption 118(b) further restricts the placement of the air or soil stripping treatment system. The exemption states that "emission points associated with the facilities or changes shall be located at least 100 feet from any off-plant receptor."

To prevent emissions of air contaminants from exceeding the 5 lb/hr allowed by Standard Exemption 68, the maximum VOC concentration in the ground water at Carswell AFB that could be treated without air emission control devices (assuming a 100% stripping efficiency) would be 990 g/L at a ground-water flow rate of 10 gpm. For soil treatment, the maximum VOC concentration and vapor extraction rate cannot be determined until additional soil sampling and analysis is performed.

The two potential sites for the treatment pad(s) at Carswell AFB were selected to comply with the requirements of Standard Exemptions 68 and 118. No other special considerations or construction requirements are necessary for air stripping, soil vapor extraction, or soil piles.

Secondary Treatment Options

Two types of secondary treatments considered for the air/vapor stream are granular activated carbon (GAC) adsorption and fume incineration-catalytic conversion.

Activated carbon treatment removes organic substances from the air/vapor stream by adsorption onto the large internal surface area of specially prepared carbon. When the adsorptive capacity of activated carbon is exhausted, the activated carbon is then removed and is either thermally regenerated or disposed of as a hazardous waste.

Fume incineration-catalytic conversion converts the VOC contaminants to carbon dioxide and water vapor. The gas stream is pulled off the air-stripping unit or vacuum extraction blower and is passed through a burner. The burner pre-heats or combusts the gases to catalyzing temperature. The heated gases then pass over the catalyst where an exothermic reaction breaking down the hydrocarbons takes place. The gas stream is then discharged to the atmosphere.

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3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

Remedial actions for the East Area of Carswell AFB should reduce the concentrations of volatile organic contaminants in the Upper Zone ground water and soils to meet the established remedial action objectives (RAOs) and criteria. Remedial action alternatives that achieve RAOs for the four East Area sites were developed using the technologies identified in Section 2.

The screening conducted (see Section 2) identified applicable technologies for remedial actions in the East Area. The technologies are generally media-specific, so a complete remedial action could consist of several technologies. Some technologies are applicable only in the support of other, "primary" technologies. Good examples of "secondary" technologies, or those that support a primary technology, are oil/water separation pretreatment, carbon or fume incineration treatment for off-gases, and effluent disposal options. Secondary technologies may be common to all alternatives or specific to a few. Primary technologies are technologies upon which a remedial action alternative may be based. Typically, primary technologies are treatment technologies (e.g., air stripping and in-situ bio-treatment). Remedial action alternatives are then developed by combining applicable primary technologies with applicable secondary technologies for each medium.

For the East Area, remedial action alternatives were developed for each affected medium at each of the four sites. As stated in Section 1, the need for and potential magnitude of soils remedial action is unresolved. Therefore, the remedial action alternatives for soils have not been combined with the remedial action alternatives for ground water and surface water. Remedial action alternatives developed for the four East Area sites are described in Section 3.1. The opportunities for combining or coordinating soils remedial actions with other media-specific and site-specific remedial actions is discussed in Section 4.6.

Once developed, each of the remedial actions were evaluated against the short- and long-term aspects of three broad criteria: effectiveness, implementability, and cost. The evaluations were used as a screening tool to eliminate inappropriate remedial action alternatives and to identify alternatives for a more detailed evaluation. Evaluations for each of the alternatives are given in Section 3.2. A summary of the remedial action alternatives remaining after screening is given in Section 3.3.

3.1 Development of Alternatives

Sections 3.1.1 through 3.1.4 discuss alternatives for the four sites.

3.1.1 Site LF01--Landfill 1

Alternative 1, the no-action alternative, is the only alternative applicable to current Upper Zone ground-water conditions at Site LF01 [i.e., no contaminants detected above MCLs in the latest (1990) sampling round]. No records exist concerning the type of waste disposed of at or near the landfill. While the Stage 1, Stage 2, and the most recent investigations have detected evidence of solvent- and metal-bearing wastes, the constituent concentrations in the ground water do not exceed the criteria established for satisfaction of the remedial action objectives (RAOs). The combined effects of the proximity of the landfill to the West Fork of the Trinity River, the permeability of the upper hydraulic zone, and the length of time the waste has been buried could have resulted in the migration of a significant portion of the waste constituents from the landfill. The data also suggest that some natural degradation of the waste has occurred, as evidenced by the presence of cis-1,2 dichloroethene and vinyl chloride, which were not historically used on base, but are transformation products of tetrachloroethene and TCE. Any attempts to contain or otherwise isolate the waste source may hinder natural attenuation processes.

The baseline risk assessment for the site indicated that the total hazard index for non-carcinogenic effects was significantly lower than the level of concern established by EPA, and that the individual cancer risk for the maximum on-site and off-site exposed individual was 10^{-10}. Furthermore, assuming that the river is the only practical pathway for terrestrial organisms to be exposed to any contaminants released from the landfill, then the risk to terrestrial wildlife that use the river as a drinking water source and to aquatic organisms in the river is interpreted to be minimal. Attempts to pump and treat ground water from Site LF01 would increase the risk of exposure by bringing contaminated water to the surface. Treatment of ground water extracted from Site LF01 would remove minimal amounts of contaminants. Poor treatment efficiencies for such low concentrations in ground water would be expected. Because there are no apparent risks to human health or the environment from the site, and because pumping and treating ground water would achieve minimal reductions in contaminant mass, the no-action alternative is the only feasible alternative for Site LF01.

The no-action alternative for Site LF01 would include long-term monitoring of contaminant concentrations in the ground water. Since there are no records of the nature of wastes formerly disposed of in Landfill 1, samples should be analyzed for aromatic and chlorinated volatile organics and dissolved metals on a quarterly basis; and semivolatile organics, pesticides, herbicides, and PCBs on an annual basis. Evidence of increased migration, such as significantly or consistently higher contaminant concentrations, or significant changes in the occurrence of contaminants, would justify the initiation of further evaluation.

3.1.2 Site SD13--Abandoned Gasoline Station and Unnamed Stream

As in the case of Site LF01, Alternative 1, the no-action alternative, is the only alternative applicable to current Upper Zone ground water and surface water conditions at Site SD13 [i.e., no dissolved metals or volatile organic compound concentrations above MCLs in the latest (1990) sampling round]. The source of contaminants detected above MCLs in the past in Unnamed Stream is interpreted to be fuel releases from Site ST14 (POL Tank Farm) which were channeled to the stream through a french drain system and an oil/water separator. Alternatives to address contamination from Site ST14 are described in Section 3.1.3. Although low levels of volatile organic compounds were detected in ground-water samples collected in 1990 from monitor wells installed around the abandoned gasoline station, no concentrations were above the remedial action objectives (RAOs). Furthermore, based upon contaminant concentrations, the source does not appear to be the abandoned station, and may be located at the POL Tank Farm. Surface water samples collected in 1990 also satisfied the RAOs.

The baseline risk assessment for Site SD13 indicated that the total hazard index for non-carcinogenic effects was significantly lower than the level of concern established by EPA, and that the individual cancer risk for inhalation of ambient concentrations of volatile organic contaminants did not exceed 1.4 in 10^{-8}. The exposure pathways and risks to terrestrial wildlife are similar to those presented by Site LF01. Attempts to pump and treat contaminated ground water would increase the risk of exposure to the extracted ground water and to treatment by-products. As they would at Site LF01, treatment processes would be expected to remove only minimal concentrations (and indirectly minimal masses) of contaminants from the ground water, because of the difficulty in extracting them from the formation and the low treatment efficiencies expected for such low influent concentrations. Because Site SD13 presents minimal, if any, risks to human health and the environment, and because pumping and treating ground water would achieve insignificant reductions in contaminant mass, the no-action alternative is the only feasible alternative for Site SD13.

The no-action alternative for Site SD13 would include long-term monitoring of contaminant concentrations in the ground water and surface water in Unnamed Stream. Based on the ground-water and surface water constituents detected historically, existing monitor wells and established surface water sampling points on Unnamed Stream should be sampled quarterly and analyzed for volatile aromatic compounds and dissolved metals. Evidence of increased migration such as significantly or consistently higher contaminant concentrations, or significant changes in the occurrence of the contaminant plume, would justify the initiation of further evaluation.

3.1.3 Site ST14--POL Tank Farm

Because of the limitations of the soils analytical data for Site ST14 (previously discussed), media-specific remedial alternatives for this site were developed and screened separately. Section 3.1.3.1 describes preliminary remedial alternatives for ground water at Site ST14, and Section 3.1.3.2 discusses potentially applicable preliminary remedial alternatives for contaminated soils.

3.1.3.1 Preliminary Ground-Water Alternatives

Nine remedial alternatives (including the no-action alternative) were developed to address Upper Zone ground-water contamination at Site ST14. The component technologies of each of these alternatives are identified and numbered in Table 3-1. Except for the no-action alternative, two secondary technologies are common to all alternatives: oil/water separation prior to primary ground-water treatment, and long-term ground-water monitoring.

Oil/water separation is included as a pre-treatment technology because more than 2 feet of immiscible hydrocarbon was present in one of the site monitor wells sampled in 1990. Pre-treatment of the hydrocarbon/water mixture will separate the hydrocarbon from the ground water, thus increasing the treatment efficiency, decreasing the operating and maintenance requirements, and removing a large mass of concentrated contaminants using a relatively simple process. The separated hydrocarbon phase will be temporarily stored on-site (less than 90 days) and will be periodically shipped off-site for recycling, if possible, or for disposal.

Long-term monitoring at Site ST14 will make use of the existing monitoring well network plus additional wells. The Upper Zone monitor well network currently in place at Site ST14 consists of nine wells. It is anticipated that all existing wells, and up to five additional wells, installed beyond the downgradient limits of the existing plumes of

TABLE 3-1. PRELIMINARY GROUND-WATER REMEDIAL ALTERNATIVES[a] FOR SITE ST14--POL TANK FARM

Technology	Alternatives								
	1	2A	2B	2C	3	4A	4B	4C	5
Monitoring	•	•	•	•	•	•	•	•	•
Interceptor Trenches	NA	•	•	•	•				
Extraction Wells	NA					•	•	•	•
Oil/Water Separator	NA	•	•	•	•	•	•	•	•
Air Stripping	NA	•	•	•		•	•	•	
In-Situ Bio-Treatment	NA				•				•
Treated Ground-Water Reinjection	NA	•			•	•			•
Ground-Water Disposal to POTW	NA		•				•		
Ground-Water Discharge to Stream	NA			•				•	

NA - No Action

[a] Preliminary remedial alternatives do not include secondary ground-water treatment (i.e., fume incineration or carbon adsorption for stripped contaminants).

contamination and the ground-water extraction system, will be required to monitor the effectiveness of the selected ground-water remedial alternative. These wells will be sampled and analyzed for volatile aromatic compounds, total petroleum hydrocarbons, and dissolved metals on a quarterly basis for the duration of site remediation.

Each preliminary alternative developed for Site ST14 is described below.

Alternative 1--Alternative 1, the no-action alternative, provides a baseline for comparison of other alternatives that involve implementation of remedial actions. The no-action alternative consists solely of the previously described long-term monitoring of Upper Zone ground water in the vicinity of Site ST14. If an imminent risk becomes apparent from the monitoring data, further action would then be undertaken.

Alternative 2 (A, B, C)--The three variations of Alternative 2 (2A, 2B, and 2C) differ only in the treated ground-water disposal option. The primary remedial technology utilized in Alternative 2 is air stripping. The secondary remedial technologies that support air stripping are ground-water extraction/interceptor trenches and effluent disposal. The contaminant plume in the ground water would be intercepted by two extraction/interceptor trenches, the approximate locations of which are shown in Figures 3-1 through 3-3. Placement of the trenches is based on passive interception of the interpreted benzene plumes shown in the figures. The extraction/interceptor trenches should also serve as a hydraulic barrier for downgradient containment of the existing ground-water plumes. The ground water extracted from the trenches would be pumped to an air stripper where volatile organic contaminants would be removed. At the hydrocarbon constituent concentrations expected in ground water, it is assumed the air stripper can be operated at a rate that does not require secondary treatment of emissions (i.e., fume incineration and/or activated carbon). The treated ground water would then be disposed of in one of three ways, described below.

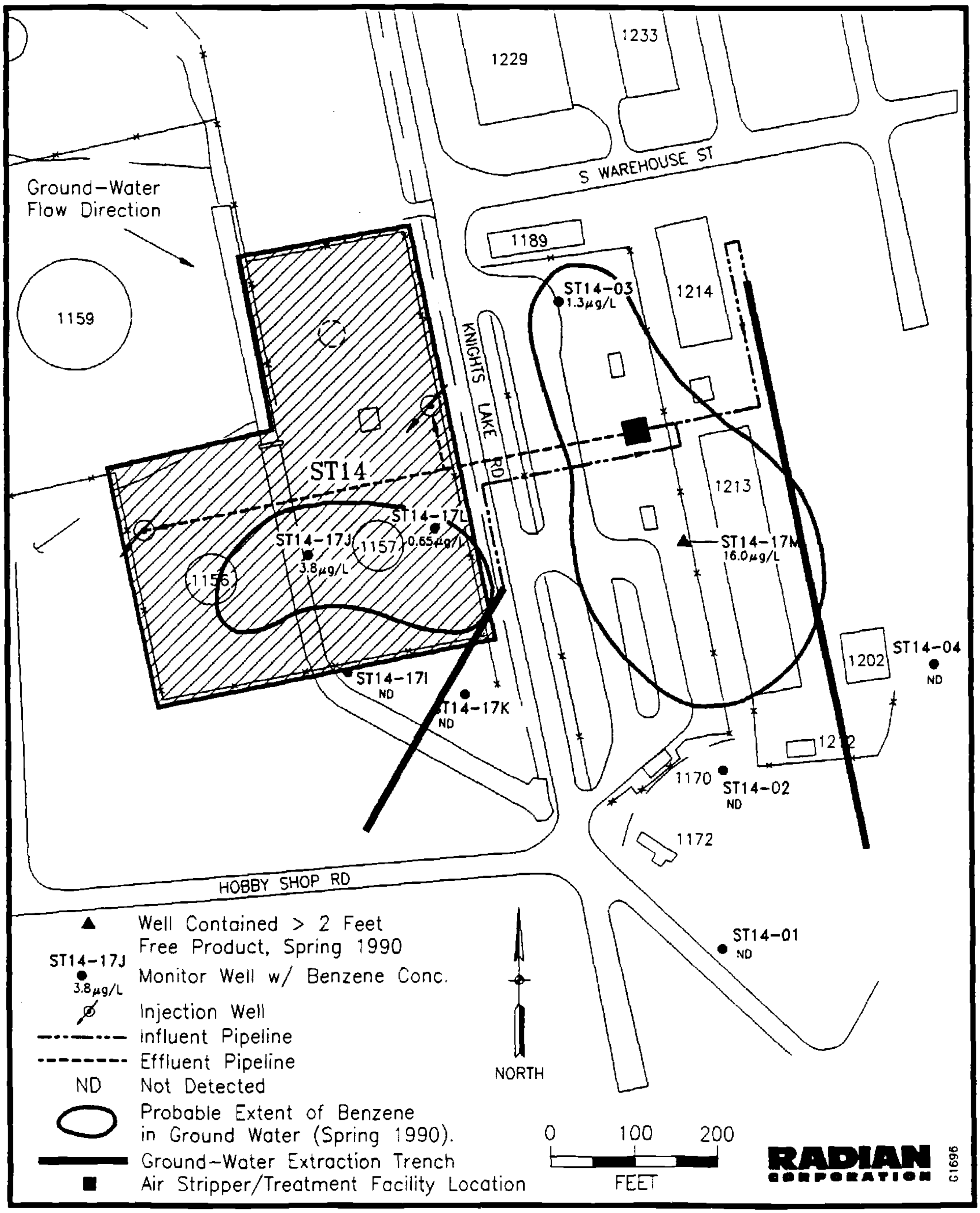

Figure 3-1. Basic Remedial Action Components of Alternative 2A, Site ST14, East Area, Carswell AFB, Texas

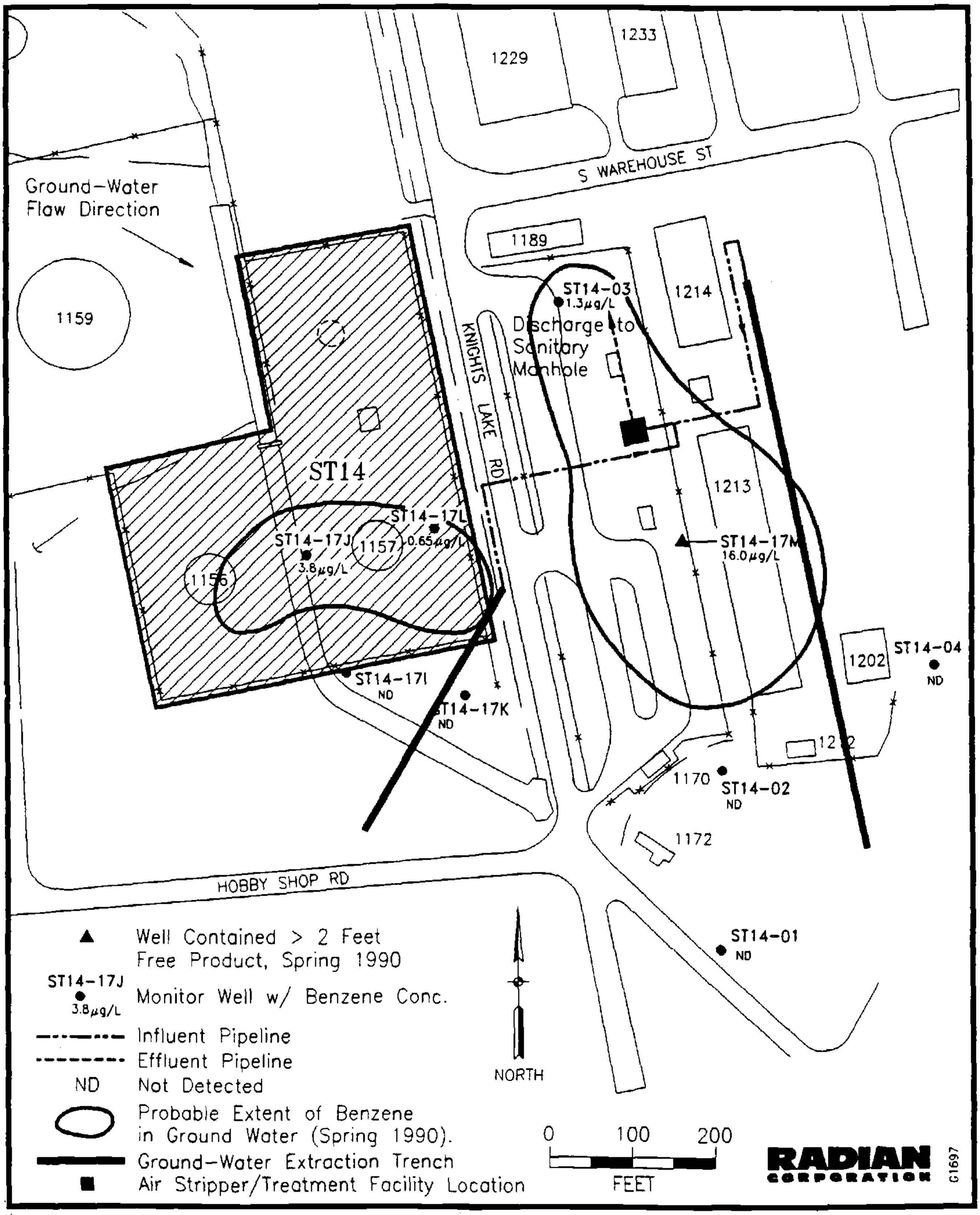

Figure 3-2. **Basic Remedial Action Components of Alternative 2B, Site ST14, East Area, Carswell AFB, Texas**

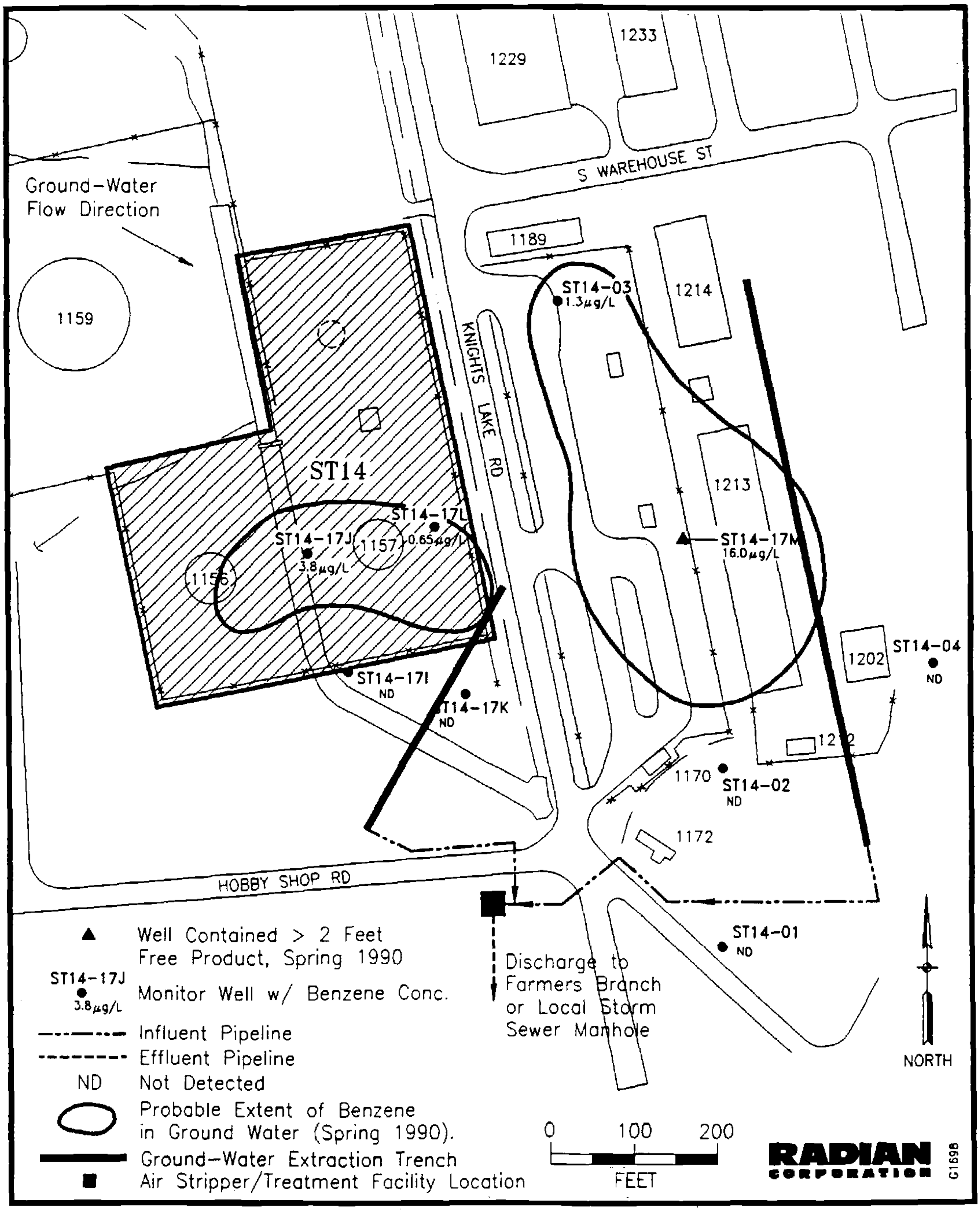

Figure 3-3. Basic Remedial Action Components of Alternative 2C, Site ST14, East Area, Carswell AFB, Texas

The three variations of Alternative 2 (2A, 2B, and 2C) differ only in the method of disposal for treated effluent. In Alternative 2A, treated ground water is re-injected into the upper hydrogeologic zone. Re-injection would be accomplished through the use of infiltration galleries or extraction wells located upgradient of the contaminant plume. Re-injection of the treated effluent would promote additional ground-water flow through the contaminated portion of the Upper Zone Aquifer, thus potentially enhancing remediation. The components for Alternative 2A are shown conceptually in Figure 3-1. In Alternative 2B, treated effluent is discharged to a sanitary sewer in the vicinity and ultimately re-treated at the local POTW. Discharge to the sanitary sewer with additional treatment at the POTW provides a contingency for treatment even in the event of an upset condition at the air stripper. The components for Alternative 2B are shown conceptually in Figure 3-2.

In Alternative 2C, the treated effluent is discharged to the base storm sewer or nearby drainage ditch, which ultimately flows into Farmers Branch and the West Fork of the Trinity River. During upset conditions at the air stripper, on- and off-base personnel, as well as wildlife, could potentially be exposed to contaminated ground water or to volatilized constituents. The components for Alternative 2C are shown conceptually in Figure 3-3.

In all three variations of Alternative 2, construction of the ground-water extraction/interceptor trenches potentially involves excavation of contaminated soils. It should be noted that treatment of any contaminated soils generated in implementation of Alternative 2 will be required for all three variations. Because of the lack of data regarding contaminated soils in the vicinity of Site ST14, disposal and/or treatment options for contaminated soils will be deferred until appropriate data have been collected. Contaminated soils generated during the ground-water remediation will be temporarily stored (less than 90 days) on-site until a suitable alternative has been selected for all of the contaminated soils at Site ST14.

Alternative 3--Alternative 3 differs from Alternative 2 in that it includes in-situ biological treatment instead of air stripping as the primary ground-water treatment technology. As discussed in Section 2.3.5, the in-situ biological treatment technology involves extraction of ground water, mixing ground water with specialized bacteria and nutrients, and re-injecting the water into the Upper Zone. This technology thereby precludes the other two treated effluent disposal options (discharge to POTW or stream). The major components of Alternative 3 are shown in Figure 3-4.

Construction of the ground-water extraction/interceptor trenches for Alternative 3 may involve excavation of potentially contaminated soils. Treatment of any contaminated soils generated from the remedial action will be required. However, because of the lack of data regarding contaminated soils in the vicinity of Site ST14, disposal and/or treatment options for contaminated soils will be deferred until appropriate data have been collected. Soils generated during the ground-water remediation will be temporarily stored (less than 90 days) on-site until a suitable alternative has been selected for all of the contaminated soils at Site ST14.

Alternative 4 (A, B, C)--Alternative 4 utilizes the same primary remedial technology, air stripping, as Alternative 2. The difference between Alternatives 2 and 4 is the secondary technology used to extract/intercept contaminated ground water. An extraction well is used instead of an extraction/interceptor trench to create the hydraulic barrier (cone of depression) and for recovery of contaminated ground water for treatment. Figures 3-5 through 3-7 illustrate the basic components of Alternative 4.

The discharge rate for the extraction well for Site ST14 is estimated to be between 10 and 20 gpm. The proposed well location was chosen to capture all existing ground-water contamination. Although the interpreted plumes shown in Figure 1-6 are based on benzene concentrations detected in 1990, the well location was selected to capture any related hydrocarbon constituents. Calculations assumed steady state flow conditions, a

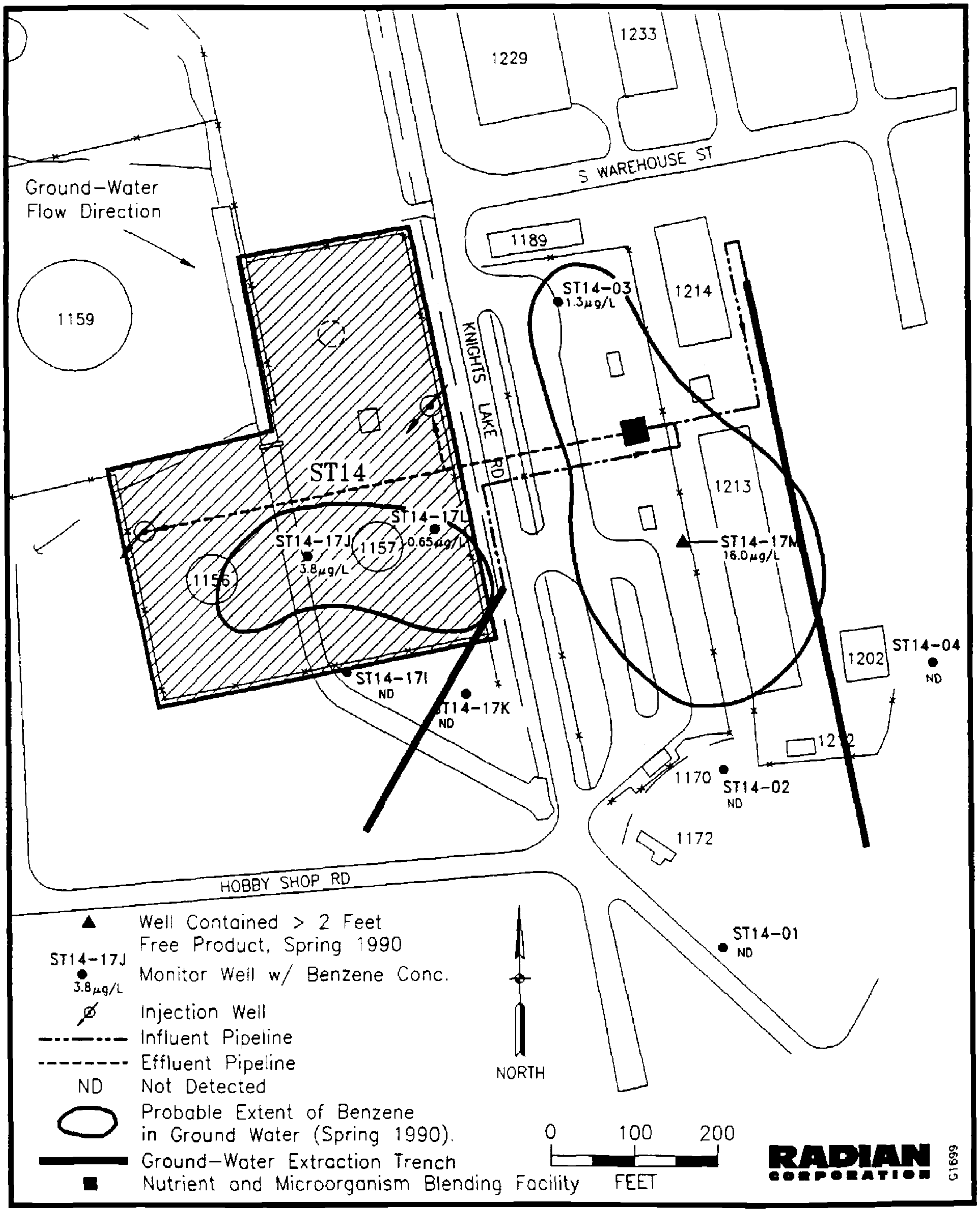

Figure 3-4. Basic Remedial Action Components of Alternative 3, Site ST14, East Area, Carswell AFB, Texas

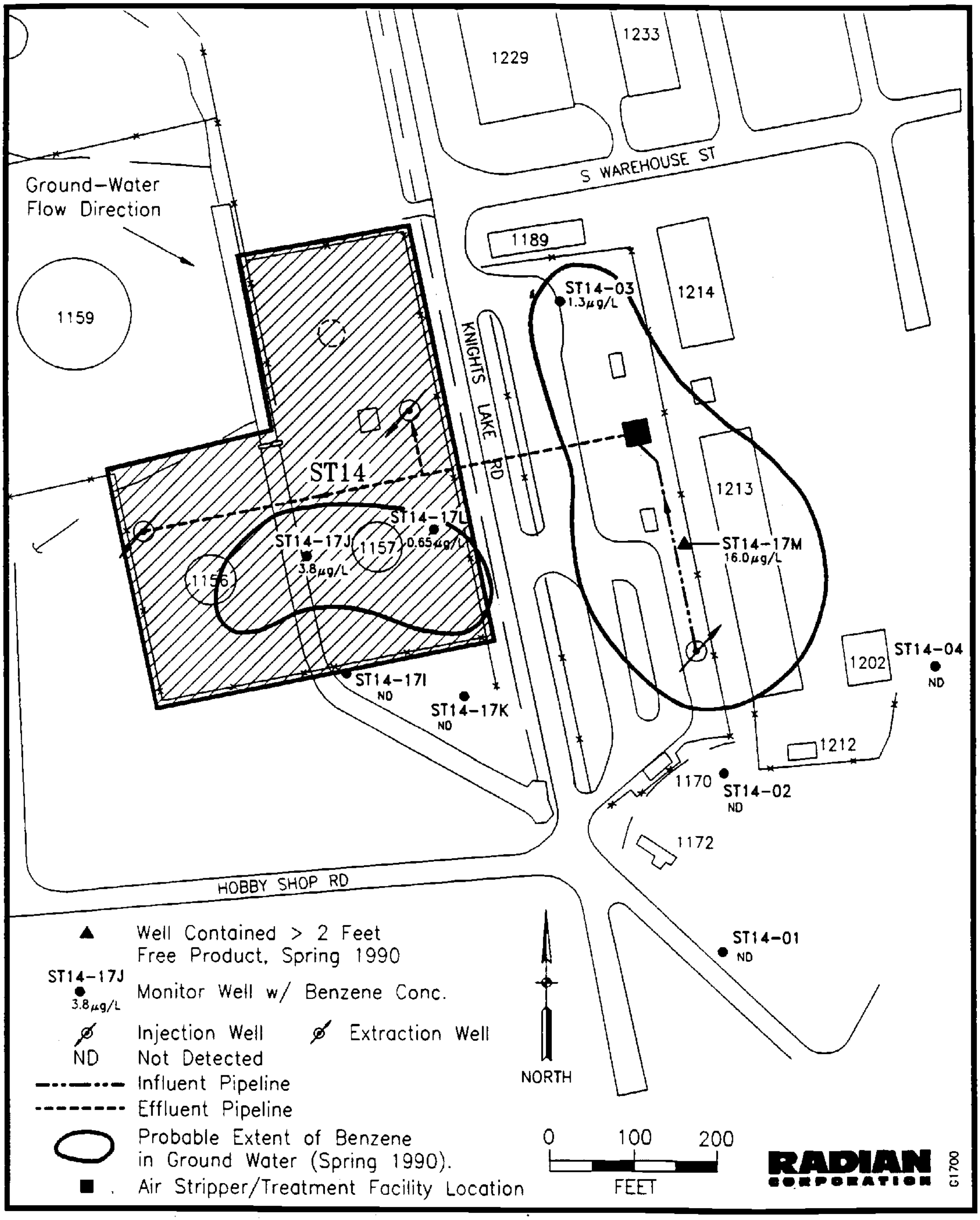

Figure 3-5. Basic Remedial Action Components for Alternative 4A, Site ST14, East Area, Carswell AFB, Texas

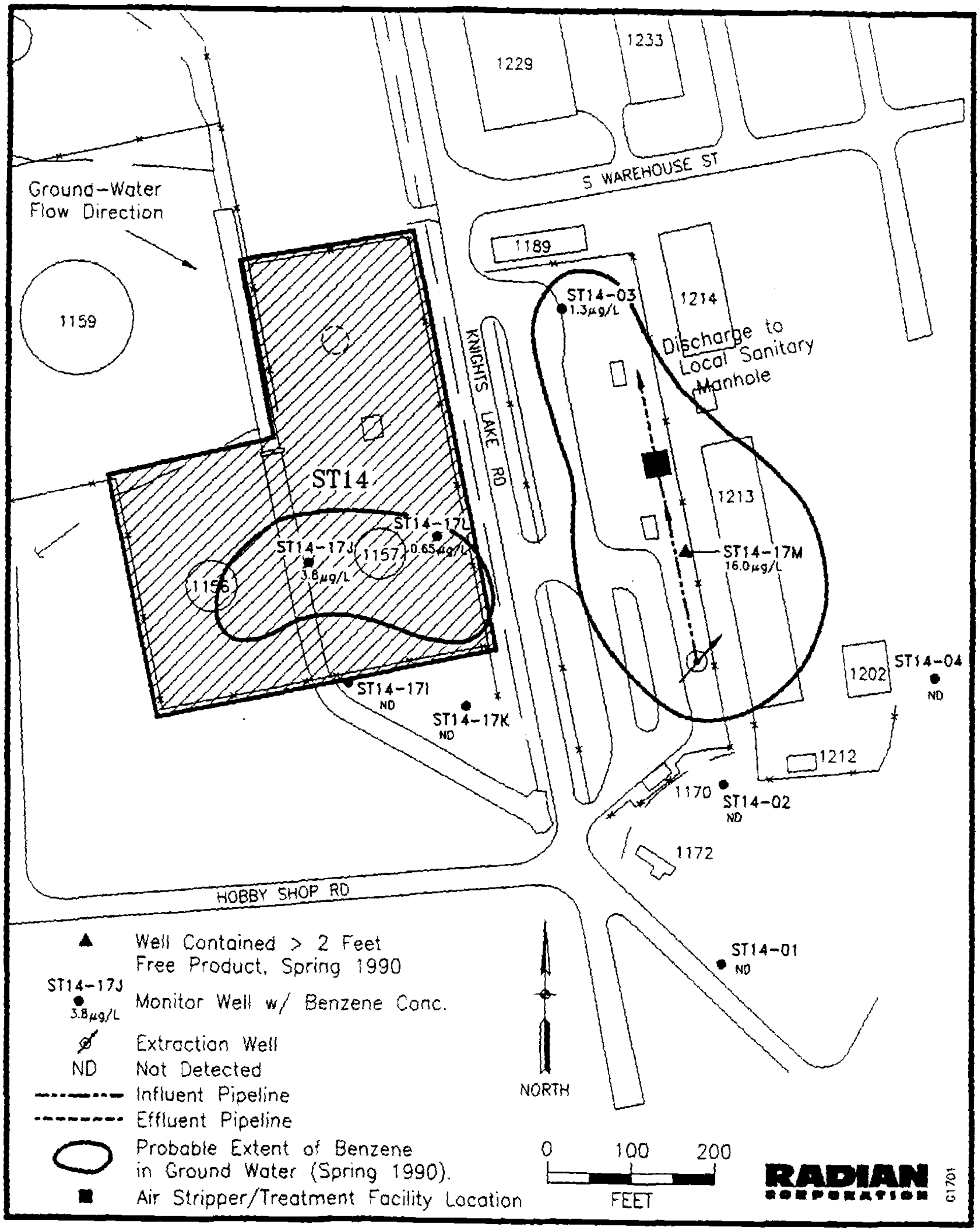

Figure 3-6. Basic Remedial Action Components for Alternative 4B, Site ST14, East Area, Carswell AFB, Texas

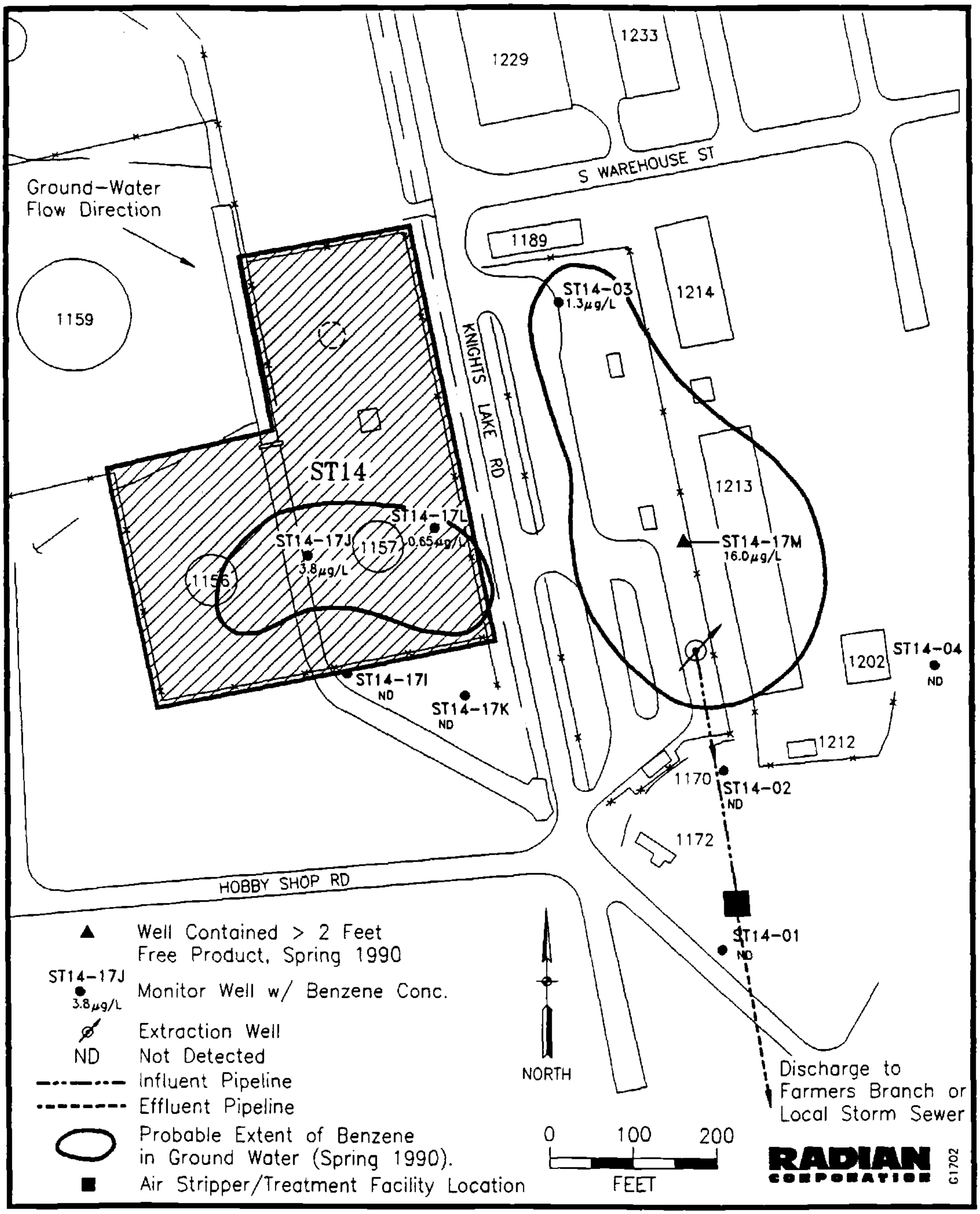

Figure 3-7. Basic Remedial Action Components for Alternative 4C, Site ST14, East Area, Carswell AFB, Texas

homogenous, isotropic, infinite aquifer, and a fully penetrating extraction well. The aquifer properties were estimated by using the data from the East Area RI report (Radian 1991). The regional flow gradient was assumed to be 0.01 to the southeast and the saturated hydraulic conductivity was assumed to be 0.3 ft/day. The saturated thickness was estimated to be 8 feet. The proposed ground-water extraction well location and estimated extraction rates are preliminary estimates based on limited information on aquifer hydraulic properties. They would require field verification to support detailed design prior to remedial action implementation, if selected.

Alternative 5--Alternative 5 is the same as Alternative 3, except that an extraction well is substituted for the interceptor trenches. As a consequence, no excavation (and potentially no soil treatment) is required in this alternative. The basic components for Alternative 5 are shown in Figure 3-8.

3.1.3.2 Preliminary Soil Alternatives--Site ST14

Four remedial alternatives (including the no-action alternative) were developed to address soil contamination potentially present at Site ST14. The component technologies of each alternative are identified in Table 3-2.

As previously noted, the only soils data for this site are from 1988. At that time, the evidence of soils contamination consisted primarily of detectable levels of total petroleum hydrocarbons (TPH) in three boreholes located in two separate areas of the site. Therefore, soil sampling to confirm the current existence of contamination at levels requiring remedial action, and the extent of soil contamination, if present, is a common element of all four alternatives. Each remedial alternative is described briefly below.

Alternative 1--Alternative 1, the no-action alternative, is similar to the no-action alternative described previously for ground water. The only

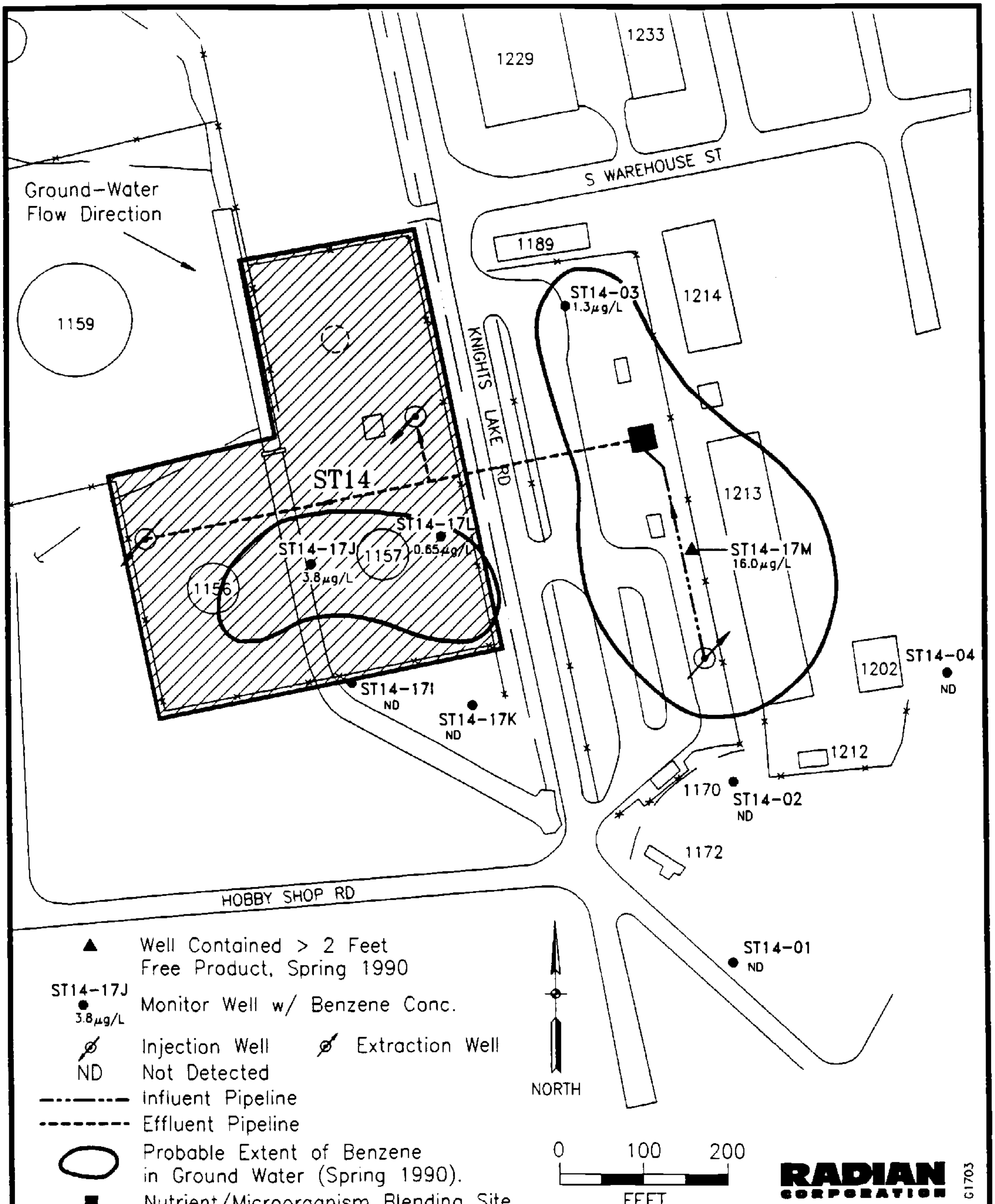

Figure 3-8. Basic Remedial Action Components of Alternative 5, East Area, Carswell AFB, Texas

TABLE 3-2. PRELIMINARY SOIL REMEDIAL ALTERNATIVES[a] FOR SITE ST14--POL TANK FARM

Technology	Alternatives				
	1	2A	2B	3	4
Confirmation Sampling	•	•	•	•	•
Excavation	NA			•	
In-Situ Bio-Treatment	NA				•
Soil Vapor Extraction	NA	•	•		
Extraction Trenches	NA	•			
Extraction Wells	NA		•		
Soil Piles	NA			•	
On-Site Treated Soil Disposal	NA			•	

NA = No Action

[a] If required, pending results of additional soil sampling and analysis--preliminary remedial alternatives do not include secondary treatment.

difference is that instead of long-term quarterly monitoring, a single round of soil and soil gas samples would be collected. Soil samples would be analyzed for TPH and BTEX to determine if previously detected (i.e., 1988) hydrocarbon constituents are currently present in concentrations that exceed RAOs, or constitute an unacceptable level of risk.

Alternative 2--Alternative 2 uses soil vapor extraction as the primary technology for remediation of contaminated soils. Soil vapors are removed using vapor extraction wells. Two variations of Alternative 2 were developed based on different methods of extraction. In Alternative 2A, extraction trenches are used to intercept soil gas, while in Alternative 2B soil gas is extracted using vapor extraction wells. If necessary, secondary vapor treatment (fume incineration or carbon adsorption) could be added to the system to meet air emission standards.

Alternative 3--In Alternative 3, contaminated soils will be excavated and treated in soil piles. Confirmation sampling and analysis are included to ensure that all contaminated soils are removed (laterally and vertically) and are treated to attain ARARs. Treated soils will be disposed of or used as clean fill at the base.

Alternative 4--In Alternative 4, soils are treated in-situ by introducing nutrient-enriched water to enhance biological degradation of hydrocarbon constituents. The in-situ biological treatment process for soils could be used in conjunction with in-situ biological treatment of the ground water. Sampling and analysis would be necessary to define the areas requiring treatment, as well as to confirm the effectiveness and completeness of the treatment process.

3.1.4 Site BSS--Base Service Station

As in the case of Site ST14, the limited soils data available for Site BSS require the development and screening of remedial alternatives on a media-specific basis.

3.1.4.1 Preliminary Ground-Water Alternatives

Nine remedial alternatives (including the no-action alternative) were developed to address Upper Zone ground-water contamination at Site BSS. The component technologies of each of these alternatives are identified in Table 3-3. These alternatives correspond to the alternatives identified by the same numbers for Site ST14, except that none of the alternatives for Site BSS include oil/water separation. No immiscible hydrocarbon lens has ever been observed in any of the Site BSS wells during IRP activities. Refer to the descriptions of the ground-water alternatives presented in Section 3.1.3.

The only technology common to all alternatives for Site BSS is long-term ground-water monitoring. Long-term monitoring at Site BSS will make use of the existing monitoring well network and additional monitor wells. The Upper Zone monitoring well network currently in place at Site BSS consists of three wells. It is expected that three or four additional monitor wells will be required downgradient of existing contamination to evaluate the effectiveness of the selected remedial alternative. Monitor wells should be sampled and analyzed for volatile aromatic compounds, TPH, and dissolved metals on a quarterly basis for the duration of the remedial action. However, because of the thin saturated zone and local variability in the occurrence of Upper Zone ground water at this site, it is possible that some wells may be dry during any given sampling event, especially after ground-water control technologies are in place.

As described in Section 3.1.3, Alternatives 2 through 5 are various combinations of ground-water treatment and disposal technologies and either extraction wells or interceptor trenches for ground-water recovery and hydraulic control. Figures 3-9 through 3-16 illustrate the fundamental components of Alternatives 2 through 5.

TABLE 3-3. PRELIMINARY GROUND-WATER REMEDIAL ALTERNATIVES[a] FOR SITE BSS--BASE SERVICE STATION

Technology	Alternatives								
	1	2A	2B	2C	3	4A	4B	4C	5
Monitoring	•	•	•	•	•	•	•	•	•
Interceptor Trenches	NA	•	•	•	•				
Extraction Wells						•	•	•	•
Air Stripping	NA	•	•	•		•	•	•	
In-Situ Bio-Treatment	NA				•				•
Treated Ground-Water Reinjection	NA	•			•	•			•
Ground-Water Disposal to POTW	NA		•				•		
Ground-Water Discharge to Stream	NA			•				•	

NA - No Action

[a] Preliminary remedial alternatives do not include secondary ground-water treatment.

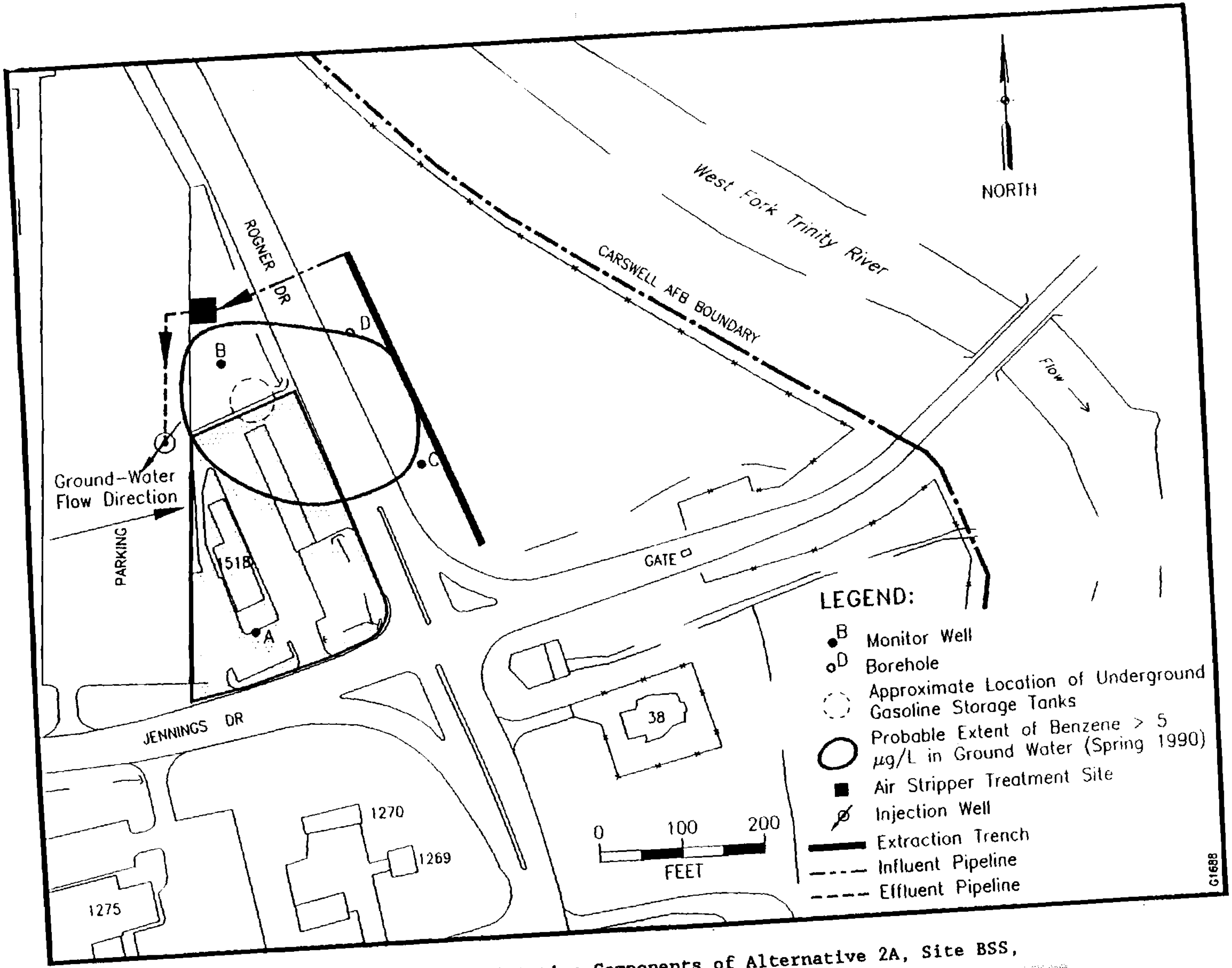

Figure 3-9. Basic Remedial Action Components of Alternative 2A, Site BSS, East Area, Carswell AFB, Texas

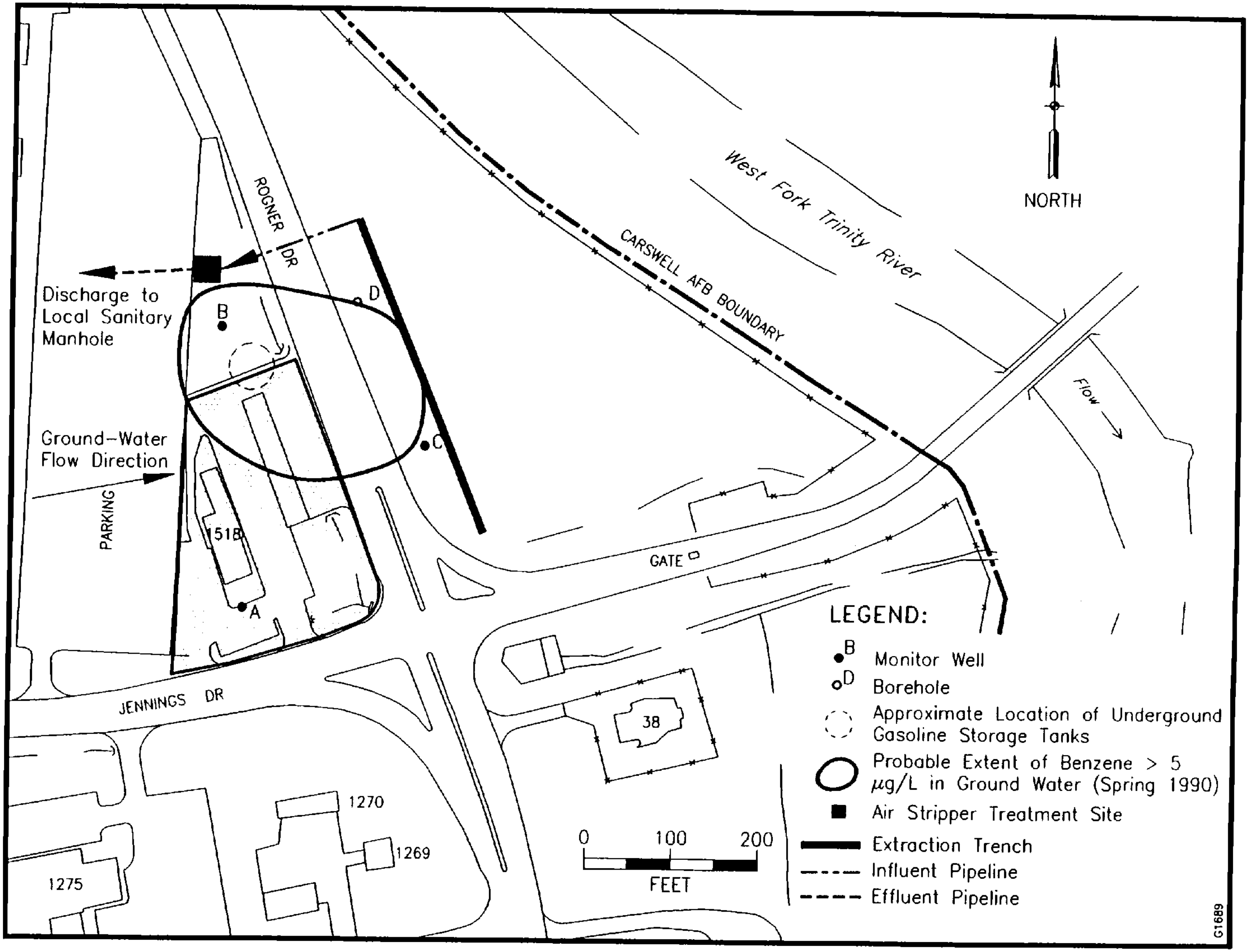

Figure 3-10. **Basic Remedial Action Components of Alternative 2B, Site BSS, East Area, Carswell AFB, ‹as**

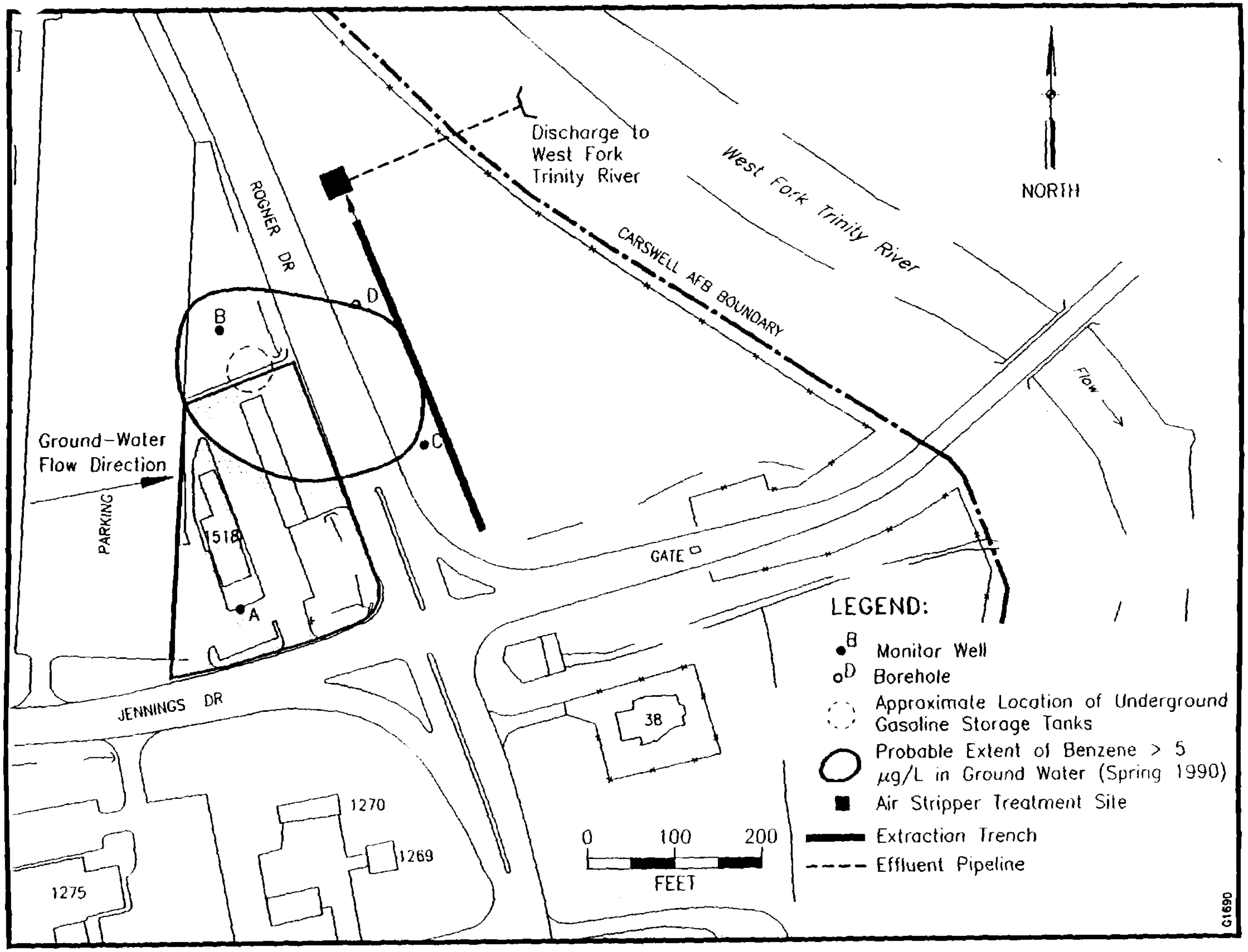

Figure 3-11. Basic Remedial Action Components of Alternative 2C, Site BSS, East Area, Carswell AFB, Texas

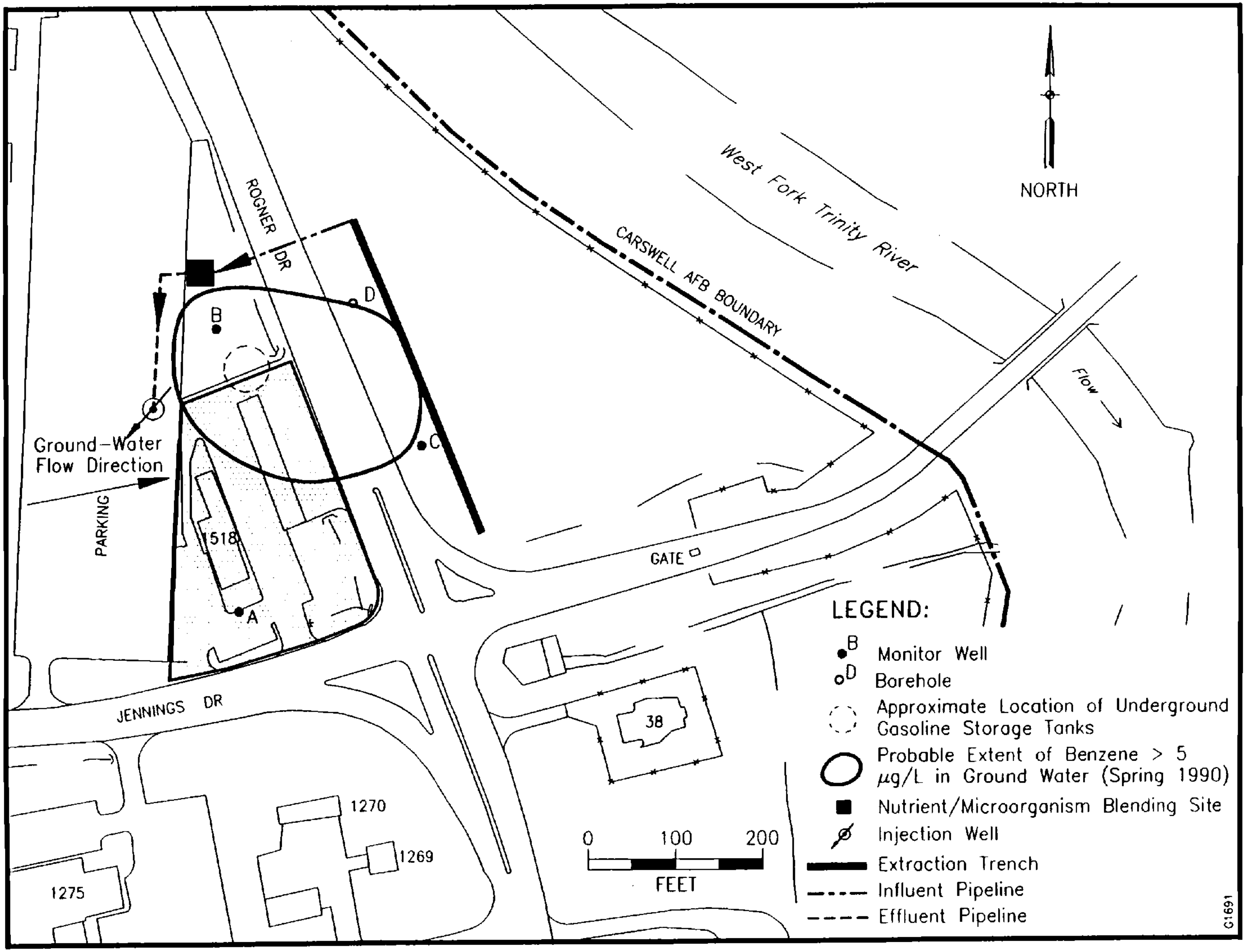

Figure 3-12. Basic Remedial Action Components of Alternative 3, Site BSS, East Area, Carswell AFB, Texas

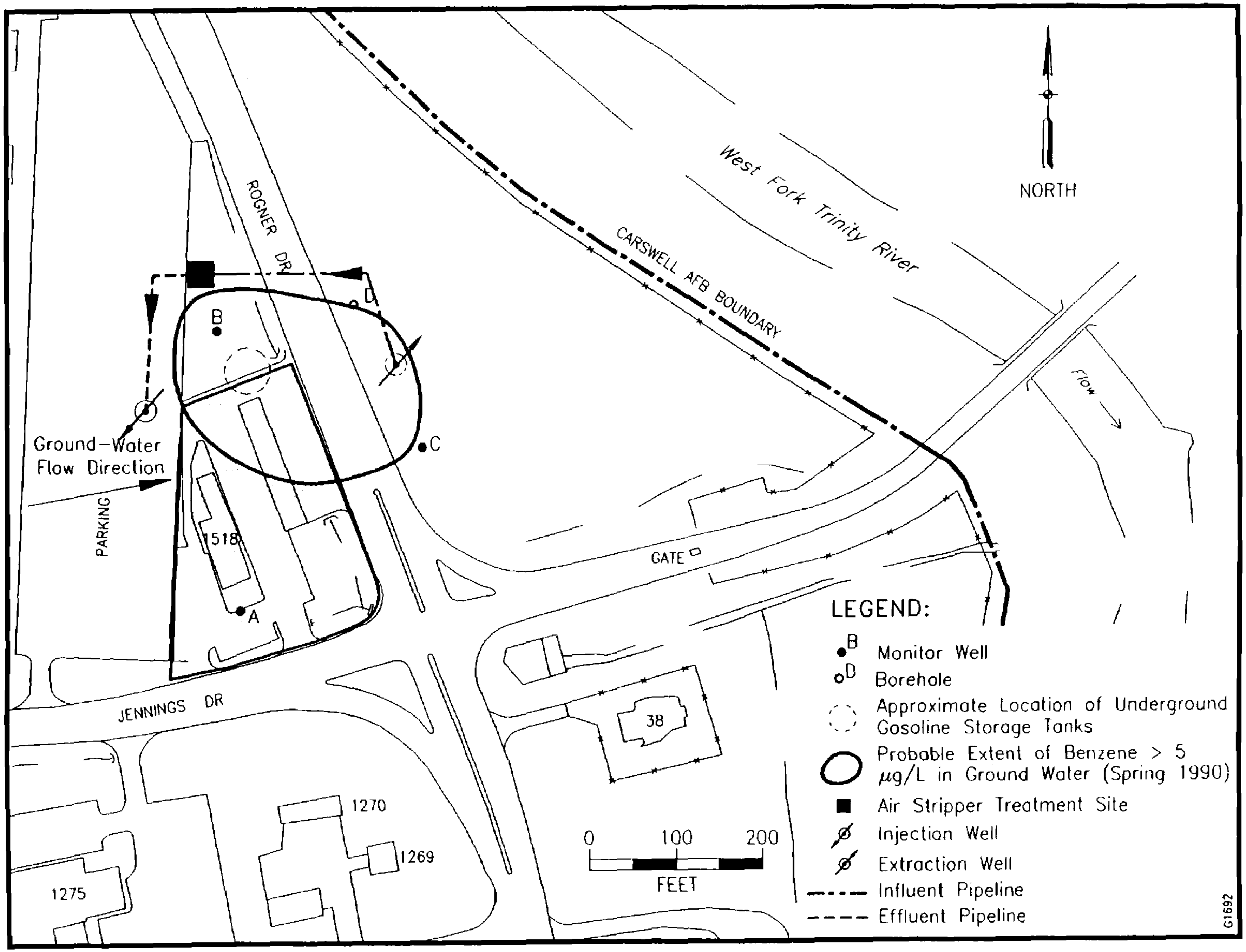

Figure 3-13. Basic Remedial Action Components of Alternative 4A, Site BSS, East Area, Carswell AFB, Texas

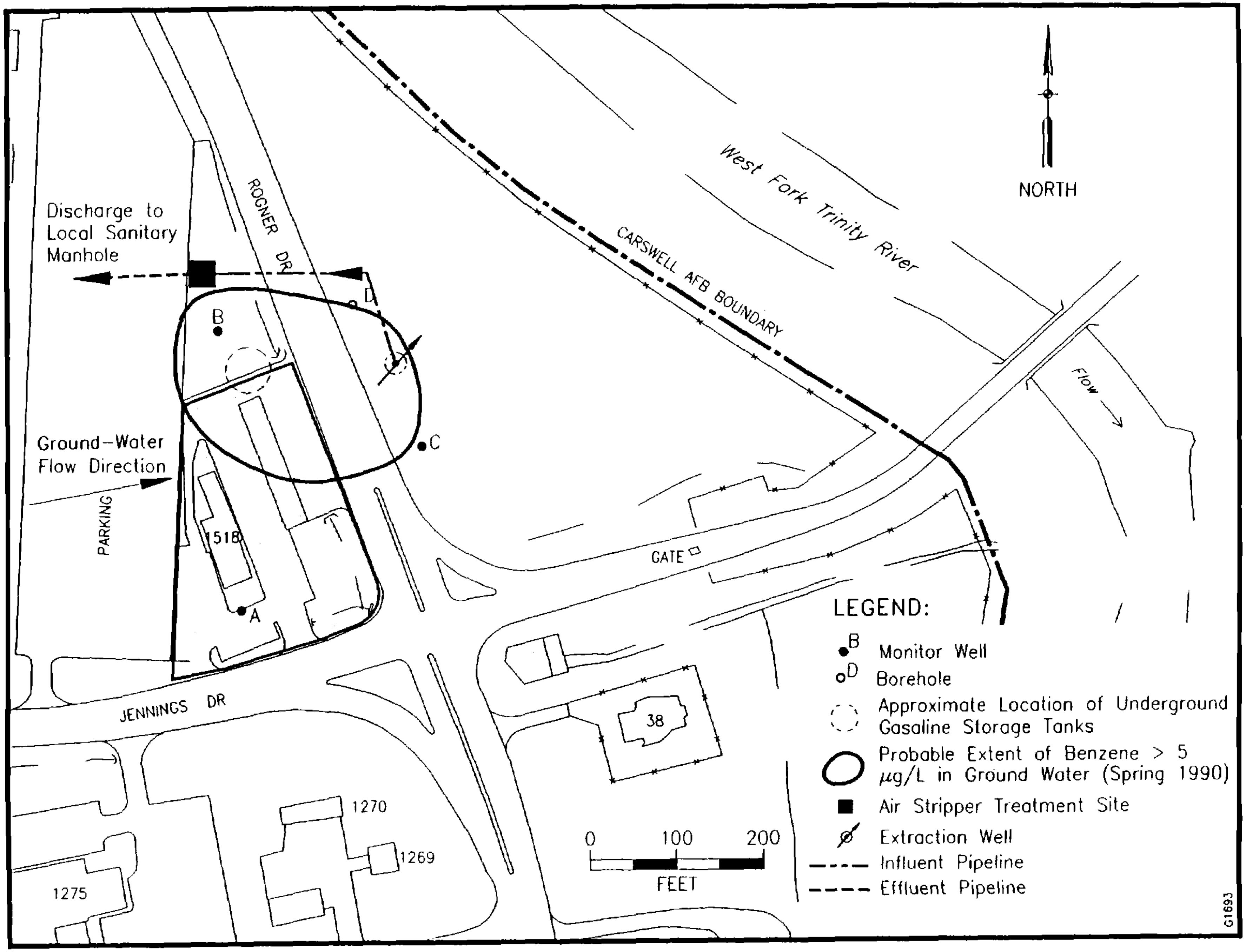

Figure 3-14. Basic Remedial Action Compc nts of Alternative 4B, Site BSS, East Area. Carswell AFB, Tex-s

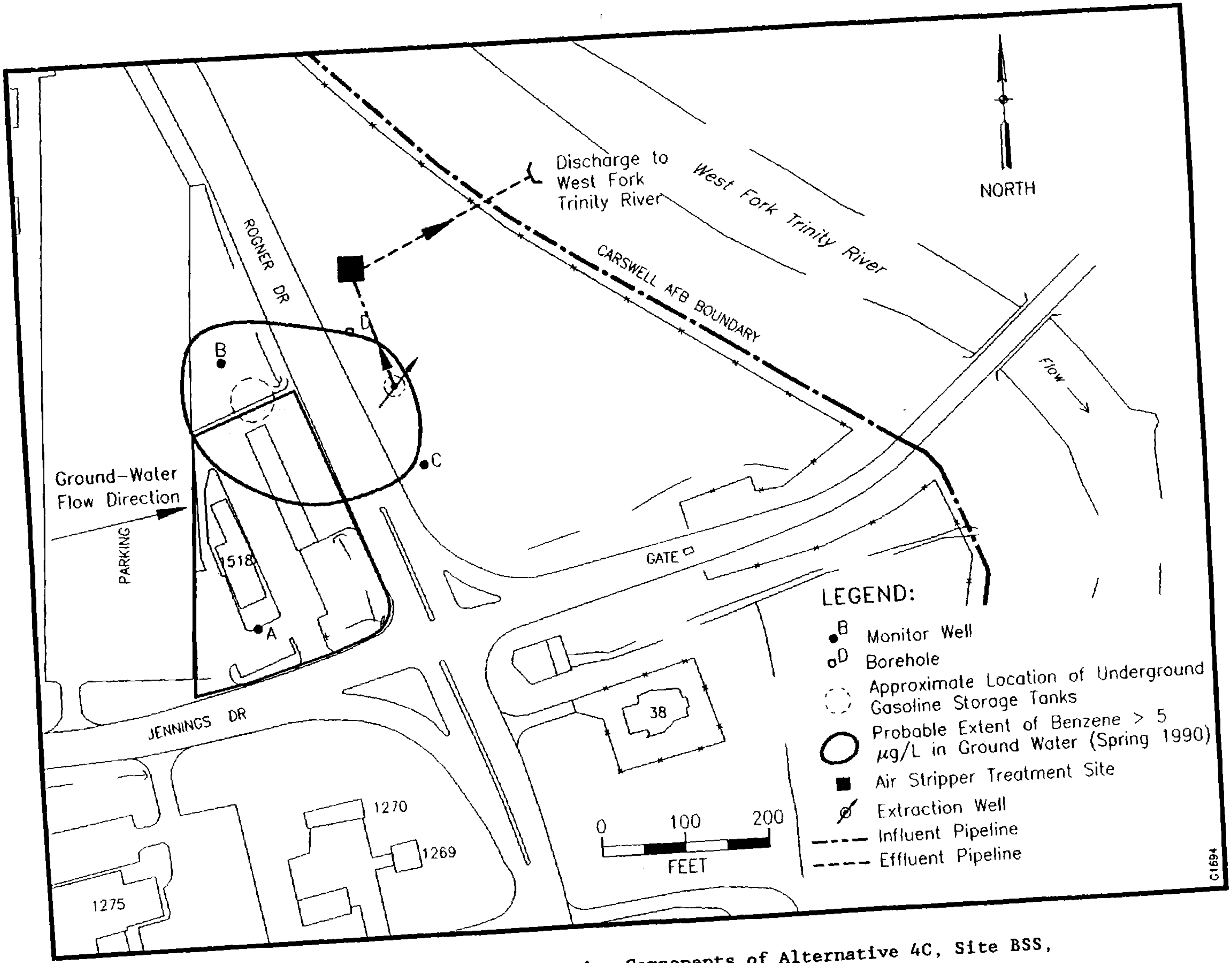

Figure 3-15. Basic Remedial Action Components of Alternative 4C, Site BSS, East Area, Carswell AFB, Texas

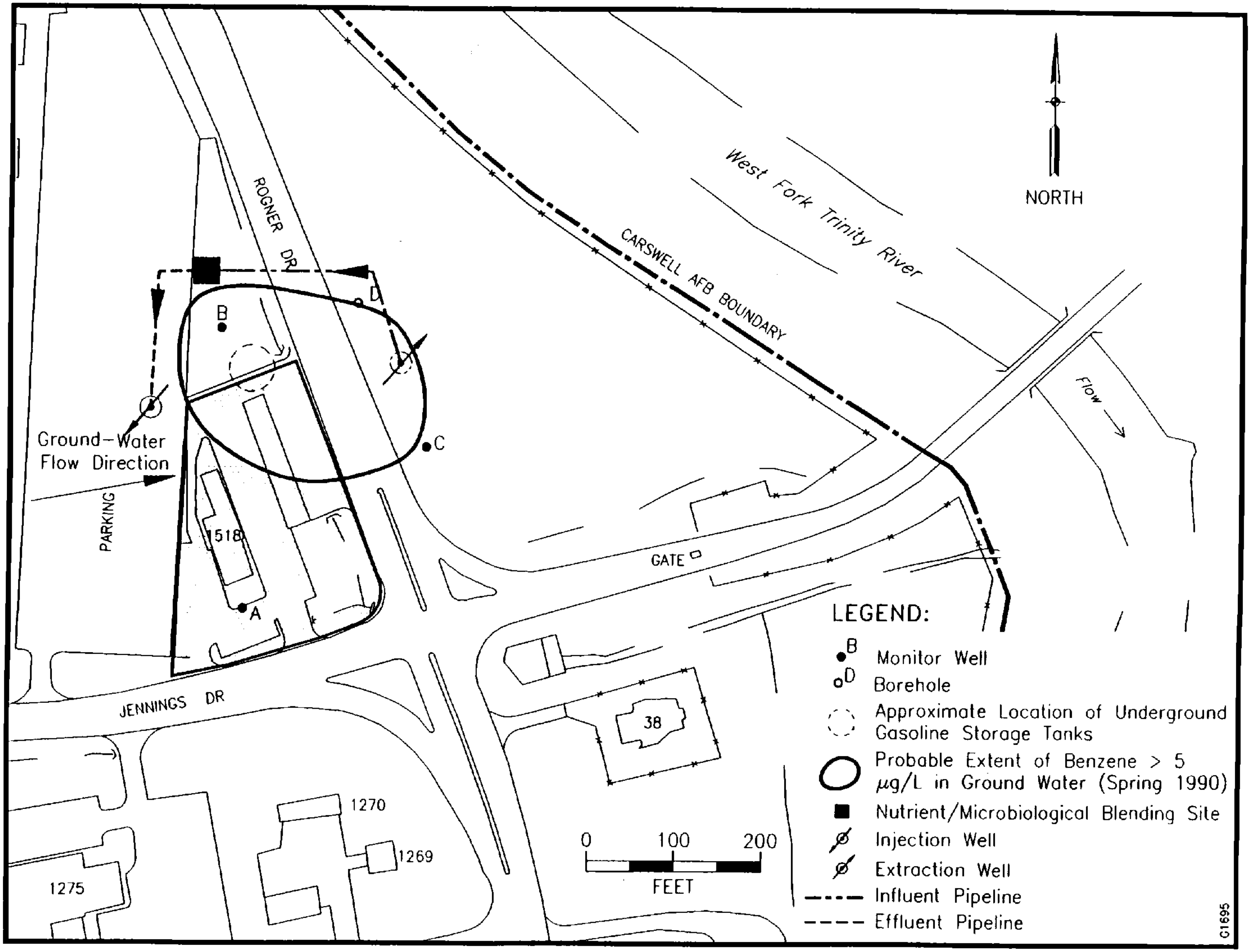

Figure 3-16. Basic Remedial Action mponents of Alternative 5, Site BSS, East Area. Carswell AF.. Texas

3.1.4.2 Preliminary Soil Alternatives

The same four remedial alternatives (including the no-action alternative) developed to address soil contamination potentially present at Site ST14 are applicable to Site BSS. They are listed in Table 3-4.

3.2 Screening of Preliminary Alternatives

The CERCLA guidance (EPA, 1988) describes a method of screening alternatives to reduce the number 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 and operation and a measure 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 be eliminated only if its cost is at least one order of magnitude greater than that of the other options.

3.2.1 Site LF01--Landfill 1

The no-action alternative allows continued potential for leachate generation and migration of contaminants because buried wastes remain in place and no mechanisms for reduction of their toxicity, mobility, or volume are instituted. As stated in Section 3.1.1, the ground water at Site LF01 currently meets or exceeds the remedial action objectives. The no-action alternative does include long-term monitoring to detect any changes (degradation) in ground-water quality. The network of Upper Zone monitor

TABLE 3-4. PRELIMINARY SOIL REMEDIAL ALTERNATIVES[a]
FOR SITE BSS--BASE SERVICE STATION

Technology	Alternatives 1	2A	2B	3	4
Confirmation Sampling	•	•	•	•	•
Excavation	NA			•	
In-Situ Bio-Treatment	NA				•
Soil Vapor Extraction	NA	•	•		
Extraction Trenches	NA	•			
Extraction Wells	NA		•		
Soil Piles	NA			•	
On-Site Treated Soil Disposal	NA			•	

NA = No Action

[a] If required, pending results of additional soil sampling and analysis--preliminary remedial alternatives do not include secondary treatment.

wells existing at the site is considered sufficient for long-term use, so implementation of Alternative 1 should not present any difficulties. The cost of the no-action alternative for Site LF01 would be minimal (essentially the cost for sampling, analysis, and monitor well maintenance).

3.2.2 Site SD13--Abandoned Gasoline Station and Unnamed Stream

The no-action alternative at Site SD13 allows continued potential for migration of contaminants and provides no mechanisms for reduction of their toxicity, mobility, or volume. As stated in Section 3.1.2, the ground water and surface water at Site SD13 currently meets the RAOs. The no-action alternative does include long-term monitoring to detect any changes (degradation) in ground-water or surface water quality. The network of Upper Zone monitor wells existing at the site is considered sufficient for long-term use, so implementation of this alternative should not present any difficulties. The cost of Alternative 1 for Site SD13 would be minimal (essentially the cost for sampling, analysis, and monitor well maintenance).

3.2.3 Site ST14--POL Tank Farm

Ground water and soil are discussed in Sections 3.2.3.1 and 3.2.3.2, respectively.

3.2.3.1 Preliminary Ground-Water Alternatives

Alternatives 1 through 5 and the results of their screening are discussed in this section.

Alternative 1--Because no remedial technologies (except for long-term ground-water monitoring) are implemented, this alternative allows continued potential for release and migration of contaminants in ground water, and degradation of the Upper Zone ground-water quality. The no-action alternative provides no mechanisms for reduction in toxicity, mobility, or volume of wastes or waste constituents in ground water through treatment. It fails to meet any of the RAOs, including MCLs. This alternative also provides no reduction in toxicity, mobility, or volume of waste or waste constituents in Upper Zone ground water. The no-action alternative for Site ST14 should not present any implementation problems. The cost of Alternative 1 is negligible in comparison to the other alternatives.

Alternatives 2 and 3--Alternatives 2 and 3 include interceptor trenches to collect contaminated ground water and to act as a hydraulic barrier to further plume migration and oil/water separation for pretreatment. Alternatives 2A, 2B, and 2C utilize air stripping to treat contaminated ground water. Alternative 3 utilizes in-situ biological treatment to treat the contaminated ground water. Both alternatives should effectively mitigate the ground-water contamination at Site ST14, and should result in a reduction of the mobility and volume of contamination.

For Alternatives 2A, 2B, and 2C, the use of an air stripper to treat contaminated ground water transfers the contaminants to the air. As stated in Section 2, the mass of contaminants transferred on a daily basis is not expected to exceed TACB standards, but if they do, secondary treatment would be implemented to treat the contaminants. For Alternatives 2A and 2B, process upsets should not result in increased exposure to contaminants. For Alternative 2C, a process upset could result in a release of contaminated ground water to Farmers Branch (or another receiving water body). It is expected that any release would be discovered and corrected rapidly. Considering the dilution and volatilization expected to occur in the receiving stream, increased exposure to contaminants should be minimal.

For Alternative 3, the use of in-situ biological treatment should result in in-place destruction of contaminants. Therefore, the toxicity would be reduced or eliminated.

Installation of an interceptor trench at this site presents some implementability concerns. The Upper Zone Aquifer at Site ST14 has an average saturated thickness of approximately 8 feet. The depth to the base of the aquifer in the area of proposed ground-water extraction is about 18 feet below ground level. In addition, there are many buried pipelines and conduits in this area. Therefore, it would be difficult to install an interceptor trench at this location.

Some additional difficulties may be involved in implementing Alternative 3. Regulatory acceptance of the in-situ biological treatment system would be necessary prior to implementation. Treatability studies may be required to demonstrate the effectiveness and timeliness of treatment, before the regulatory agencies would approve the alternative.

For Alternative 2C, additional implementability concerns could result from NPDES permitting requirements for discharge into Farmers Branch (or another receiving stream). Permitting could require six months to one year. The permit would have to be issued prior to implementation of the alternative. Public perception and acceptance could delay the permit longer or even result in denial of the permit.

Alternative 2B may also require a permit to discharge into the sanitary sewer. However, this permit would be issued under the POTW's sewer use ordinance. Preliminary conversations with the City of Fort Worth indicated that the expected volume and quality of the treated ground water from the air stripper should not present a problem to the treatment plant and should meet the sewer use ordinance requirements.

The cost of constructing the extraction/interceptor trenches will be greater than that of constructing an extraction well with the same capability. However, because other costs for Alternatives 2 and 3 should be in the same order of magnitude as Alternatives 4 and 5, the total costs should be comparable to Alternatives 4 and 5.

Alternative 4--Alternatives 4A, 4B, and 4C all include an extraction well for plume containment and ground-water extraction; oil/water separation for pretreatment; and air stripping as the primary treatment technology. All of these are proven technologies that can be implemented with minimal disruption of base activities. The effectiveness of Alternatives 4A, 4B, and 4C is identical to Alternatives 2A, 2B, and 2C, because, with the exception of the extraction method, the same technologies are used.

The use of an extraction well for Alternative 4 should be easily implemented at Site ST14. Unlike extraction trenches, the extraction well (and re-injection wells in Alternative 4A) can be placed to avoid existing structures and utilities. Other implementation concerns for Alternatives 4A, 4B, and 4C are identical to those described for Alternatives 2A, 2B, and 2C.

The costs for Alternative 4 are within the same order-of-magnitude range as the other alternatives, even though the extraction well should cost less to install than the extraction trenches in Alternative 2. Therefore, Alternative 4 poses no concerns relative to the cost criterion.

<u>Alternative 5</u>--Alternative 5 includes proven technologies for ground-water containment, extraction, and pretreatment that are all readily implementable considering site-specific conditions. While in-situ biological treatment has become more commonplace in recent years, it still has not gained the widespread acceptance of other, more-established treatment methods. The effectiveness of the alternative should be the same as that described for Alternative 3. The use of an extraction well for Alternative 5 eliminates the implementability concerns associated with extraction trenches used in Alternative 3. However, the other implementability concerns stated for Alternative 3 also apply to Alternative 5. The costs for Alternative 5 are in the same order-of-magnitude range as the other alternatives. Therefore, Alternative 5 poses no concerns related to the cost criterion.

<u>Results of Ground-Water Alternatives Screening</u>--Alternatives 2A, 2B, 2C, and 3 were eliminated from further consideration because they could be implemented only with great difficulty and large scale disruption of Base operations near Site ST14. Alternative 4C was eliminated from further consideration because of potential problems with public acceptance and permitting. While Alternative 5 may pose some regulatory acceptance problems, it was retained for further evaluation to provide a basis for comparison to the air stripping alternative.

3.2.3.2 Preliminary Soil Alternatives

Available soils analytical data are insufficient to support screening of preliminary soil remedial alternatives. To apply the screening criteria of effectiveness, implementability, and cost, the volumes, locations and extent, depth, and concentrations of hydrocarbon contaminants in soil, if any, must be documented. On a qualitative basis, Alternative 3, which includes excavation of contaminated soils, is probably more difficult to implement than the other alternatives (because of potential interference with surface and subsurface structures), unless contaminated soils are restricted to shallow depths and are volumetrically small. The cost to implement Alternative 1 (no action) is negligible compared to the other three, which are expected to be in the same order-of-magnitude range. As in the case of ground-water alternatives, the no-action alternative is ineffective, providing no reduction in the toxicity, mobility, or volume of contaminants. Alternatives 2, 3, and 4 consist of technologies that are proven to be effective for the contaminants of concern.

3.2.4 Site BSS--Base Service Station

Ground water and soil are discussed in Sections 3.2.4.1 and 3.2.4.2, respectively.

3.2.4.1 Preliminary Ground-Water Alternatives

Alternatives 1 through 5 and the results of their screening are discussed in this section.

Alternative 1--Because no remedial technologies (except for long-term ground-water monitoring) are implemented, this alternative allows continued potential for release and migration of contaminants in ground water, and degradation of the Upper Zone ground-water quality. The no-action alternative provides no mechanisms for reduction in toxicity, mobility, or volume of wastes or waste constituents in ground water through treatment. It fails to meet any of the RAOs, including MCLs. This alternative also provides no reduction in toxicity, mobility, or volume of waste or waste constituents in Upper Zone ground water. The no-action alternative for Site BSS should not present any implementation problems. The cost of Alternative 1 is negligible in comparison to the other alternatives.

Alternatives 2 and 3--Alternatives 2 and 3 include interceptor trenches to collect contaminated ground water and to act as a hydraulic barrier to further plume migration. Alternatives 2A, 2B, and 2C utilize air stripping to treat contaminated ground water. Alternative 3 utilizes in-situ biological treatment to treat the contaminated ground water. Both alternatives should effectively mitigate the ground-water contamination at Site BSS, and should result in a reduction of the mobility and volume of contamination.

For Alternatives 2A, 2B, and 2C, the use of an air stripper to treat contaminated ground water transfers the contaminants to the air. As stated in Section 2, the mass of contaminants transferred on a daily basis is not expected to exceed TACB standards, but if they do, secondary treatment would be implemented to treat the contaminants. For Alternatives 2A and 2B, process upsets should not result in increased exposure to contaminants. For Alternative 2C, a process upset could result in a release of contaminated ground water to the West Fork of the Trinity River (or another receiving water body). It is expected that any release would be discovered and corrected quickly. Considering the dilution and volatilization expected to occur in the receiving stream, any increased exposure to contaminants should be minimal.

For Alternative 3, the use of in-situ biological treatment should result in in-place destruction of contaminants. Therefore, the toxicity of the contaminant plume would be reduced or eliminated.

Installation of the interceptor trench for Alternatives 2 and 3 to collect contaminated ground water and to act as a hydraulic barrier to further plume migration should be easily implemented. Very few structures or utilities are located at or around Site BSS. Due to the generally thin (approximately 2 feet) saturated thickness, and shallow depth to the base of the Upper Zone (generally 10 feet or less), interceptor trenches would be very effective. Other implementation issues for Alternatives 2 and 3 are described in the following paragraphs.

Regulatory acceptance of the in-situ biological treatment system used in Alternative 3 would be necessary prior to implementation. Treatability studies may be required to demonstrate the effectiveness and timeliness of treatment, before the regulatory agencies would approve the alternative.

For Alternative 2C, additional implementability concerns could result from NPDES permitting requirements for discharge into the West Fork of the Trinity River (or another receiving stream). Permitting could require six months to one year. The permit would have to be issued prior to implementation of the alternative. Public perception and acceptance could delay the permit longer or even result in denial of the permit.

Alternative 2B may also require a permit to discharge into the sanitary sewer. However, this permit would be issued under the POTW's sewer use ordinance. Preliminary conversations with City of Fort Worth personnel have indicated that the expected volume and quality of the treated ground water from the air stripper should not present a problem to the treatment plant and should meet the sewer use ordinance requirements.

The cost criterion does not pose a problem for Alternatives 2 or 3. The cost of constructing the extraction/interceptor trenches will be greater than that of constructing an extraction well with the same capability. However, because other costs for Alternatives 2 and 3 should be in the same order of magnitude as Alternatives 4 and 5, the total costs should be comparable to Alternatives 4 and 5.

<u>Alternatives 4 and 5</u>--Alternatives 4 and 5 include an extraction well for plume containment and ground-water withdrawal, with either air stripping (Alternatives 4A, 4B, and 4C) or in-situ biological treatment (Alternative 5) as the primary treatment option. All of the component

technologies are implementable and are in an acceptable range of costs. However, sustained withdrawal of contaminated ground water at even a low pumping rate may not be feasible due to the small volume and variable occurrence of Upper Zone ground water at this site. Therefore, Alternatives 4 and 5 may not be effective because extraction wells are not suited to the site-specific hydrogeologic conditions at Site BSS. Other effectiveness and implementability issues for Alternatives 4 and 5 are similar to those discussed for Alternatives 2 and 3. The costs for Alternatives 4 and 5 are in the same order of magnitude as Alternatives 2 and 3, so the cost criterion does not present a problem.

Results of Ground-Water Alternative Screening--Alternatives 4A, 4B, 4C, and 5 were eliminated from further evaluation because they are incompatible with the site-specific hydrogeologic conditions and, therefore, do not meet the effectiveness criterion. Alternative 2C was eliminated from further consideration because of potential problems with public acceptance and permitting. While Alternative 3 may pose some regulatory acceptance problems, it was retained for further evaluation to provide a basis for comparison to the air stripping alternative.

3.2.4.2 Preliminary Soil Alternatives

Available soils analytical data for Site BSS are also insufficient to support screening of preliminary soil remedial alternatives. To apply the screening criteria of effectiveness, implementability, and cost, the volumes, locations and extent, depth, and concentrations of hydrocarbon contaminants in soil, if any, must be documented. On a qualitative basis, Alternatives 2 and 3, which include excavation, are probably more difficult to implement than Alternative 4 (because of potential disruption of service station operations during excavation for soil removal or vapor extraction trench construction), unless contaminated soils are restricted to shallow depths and are volumetrically small. The cost to implement Alternative 1 (no action) is negligible compared to the other three, which are expected to be in the same order-of-magnitude range. As in the case of ground-water alternatives, the no-action alternative is ineffective, providing no reduction in the toxicity, mobility, or volume of contaminants. Alternatives 2, 3, and 4 consist of technologies that are proven to be effective for the contaminants of concern.

3.3 Summary of Preliminary Alternative Development and Screening

For Sites LF01 (Landfill 1) and SD13 (Unnamed Stream and Abandoned Gasoline Service Station), only the no-action alternative was retained for detailed evaluation.

For Site ST14 (POL Tank Farm), the no-action alternative (Alternative 1), two air stripping alternatives (Alternatives 4A and 4B), and one in-situ biological treatment alternative (Alternative 5) were retained for detailed evaluation.

For Site BSS (Base Service Station), the no-action alternative (Alternative 1), two air stripping alternatives (Alternatives 2A and 2B) and one in-situ biological treatment alternative (Alternative 3) were retained for detailed evaluation.

As previously explained, preliminary soil remedial alternatives cannot undergo detailed analysis until additional data become available.

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4.0 DETAILED ANALYSIS OF ALTERNATIVES

The detailed analysis of alternatives is limited (on the basis of currently available soils data) to further development and evaluation of ground-water alternatives for the four East Area IRP sites. The detailed analysis consists of: further definition of alternatives, if necessary; individual analysis of alternatives against the CERCLA evaluation criteria (identified below); and comparative analysis of the alternatives against the evaluation criteria. The evaluation criteria for the detailed analysis of alternatives are:

- Overall protection of human health and the environment;
- Compliance with applicable or 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.

State and community acceptance criteria will be addressed in the Record of Decision (ROD) when comments on the RI/FS reports and proposed plan have been received.

Section 4.1 provides a description of the detailed evaluation criteria and the method of analysis. Sections 4.2 through 4.5 present the detailed analysis of ground-water alternatives for Sites LF01, SD13, ST14, and BSS, respectively. Section 4.6 identifies and describes potential opportunities for coordination of remedial activities at multiple sites, and Section 4.7 summarizes the comparative analysis of alternatives based on cost-effectiveness.

4.1 Description of Evaluation Criteria and Analysis Method

Descriptions of the evaluation criteria are provided below.

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

The ability of each alternative to comply with all ARARs (as defined by the RAOs), or the need to justify a waiver if some ARARs cannot be achieved, is evaluated for each alternative using this criterion.

The long-term effectiveness and permanence of each alternative is evaluated with respect to the magnitude of the residual risk, and to 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 reduction of contaminant toxicity, mobility, or volume would be achieved focuses on the anticipated performance of the treatment technologies used in each alternative. 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 each alternative 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 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 cost estimates are based on a variety of information: quotes from suppliers in the area of the site, generic unit costs, vendor information, conventional cost estimating guides, design manuals, and experience. The feasibility study-level cost estimates shown have been prepared to help guide the evaluation and implementation of the project. 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 variables. A significant uncertainty that will affect the cost is the actual volume of contaminated ground water. Such uncertainties, however, would affect the costs of all the alternatives.

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

Annual operating and maintenance (O&M) costs, which include operating 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 is based on a 30-year period of performance and a five-percent discount rate.

4.2 Detailed Evaluation of the No-Action Alternative for Site LF01

The following subsections describe the alternative and discuss each of the CERCLA evaluation criteria.

4.2.1 Description of the Alternative

Except for long-term monitoring, no remedial activities would be implemented at Site LF01 with the no-action alternative. Long-term monitoring of Site LF01 will involve sampling the five existing monitor wells at the site. No new monitor wells are required for Site LF01. Since there are no records of the nature of wastes formerly disposed of in Landfill 1, samples should be analyzed for aromatic and chlorinated volatile organics and dissolved metals on a quarterly basis; and semivolatile organics, pesticides, herbicides, and PCBs on an annual basis. Evidence of increased migration, such as significantly or consistently higher contaminant concentrations, or significant changes in the occurrence of the contaminants, would justify the initiation of further evaluation.

4.2.2 Protection of Human Health and the Environment

The no-action alternative does not reduce the risk to human health or the environment resulting from contamination at Site LF01. Recent data indicate that ground water at the site is in compliance with the remedial action objective criteria, and that the risk presented by site contamination is insignificant (10^{-10}). Ground-water flow at Site LF01 is currently towards the West Fork of the Trinity River. If the detected contaminants reach the river, the concentrations will be further reduced by the effects of dilution and volatilization. Therefore, the risk to human health or the environment would be the same or lower than that determined in the baseline risk assessment.

4.2.3 Compliance with ARARs

While the no-action alternative provides no mechanisms for ground-water cleanup, ground-water contaminant concentrations determined in 1990 were lower than the applicable RAOs (i.e., MCLs and 70-year cancer risk criterion).

4.2.4 Long-Term Effectiveness and Permanence

Because no remedial activity is implemented for the no-action alternative, the residual risk remains the same as the baseline risk. Natural attenuation should result in some long-term reduction in risks. Contamination is left on site and long-term monitoring and other institutional controls may be necessary in perpetuity.

4.2.5 Reduction in Toxicity, Mobility, or Volume

No reduction in the toxicity, mobility, or volume of contamination occurs from implementation of the no-action alternative. It neither inhibits nor prevents continued leachate generation and migration of contaminants, nor does it prevent further degradation of Upper Zone ground-water quality. However, the 1990 data suggest that the waste mass has either degenerated or stabilized so that leachate production and contaminant migration are minimal. The detected contaminant concentrations are near detection levels, and are less than MCLs. Long-term monitoring of the ground water at Site LF01 will allow initiation of remedial actions if significant changes in contaminant concentrations are detected.

4.2.6 Short-Term Effectiveness

The baseline risk assessment for Site LF01 indicates that the risks to human health and the environment are insignificant. Implementation of the no-action alternative will not increase these risks. Numerical remedial action objectives are satisfied at this time. However, cleanup of residual contaminants to background levels will occur only by natural attenuation.

4.2.7 Implementability

Implementation of the no-action alternative should present no problems.

4.2.8 Cost

The present worth cost estimate for the no-action alternative for Site LF01 is approximately $384,300. Capital costs for the no-action alternative are negligible, because no action is required. The annual O&M cost estimate is approximately $25,000.

4.3 Detailed Evaluation of the No-Action Alternative for Site SD13

The following subsections describe the alternative and discuss each of the CERCLA evaluation criteria.

4.3.1 Description of the Alternative

Except for long-term monitoring, no remedial activities would be implemented at Site SD13 with the no-action alternative. Long-term monitoring of Site SD13 will involve sampling the four existing monitor wells and established surface water sampling points on Unnamed Stream. No new monitor wells or surface water sampling points are considered necessary to adequately monitor Site SD13. Based on the ground-water and surface water constituents detected historically, existing monitor wells and established surface water sampling points on Unnamed Stream should be sampled and analyzed quarterly for volatile aromatic compounds and dissolved metals. Evidence of increased migration, such as significantly or consistently higher contaminant concentrations, or significant changes in the occurrence of the contaminants, would justify the initiation of further evaluation.

4.3.2 Protection of Human Health and the Environment

The no-action alternative does not reduce the risk to human health or the environment resulting from contamination at Site SD13. Recent data indicate that ground water at the site is in compliance with the RAOs, and that the risk presented by site contamination is insignificant (10^{-8}). Ground-water flow at Site SD13 is currently toward Unnamed Stream and the West Fork of the Trinity River. Even if the detected contaminants reach the stream or the river, the concentrations will be further reduced by the effects of dilution and volatilization. Therefore, the risk to human health or the environment would be the same or lower than that determined in the baseline risk assessment.

4.3.3 Compliance with ARARs

While the no-action alternative provides no mechanisms for ground-water cleanup, ground-water contaminant concentrations determined in 1990 were lower than the applicable RAOs (i.e., MCLs and 70-year cancer risk criterion).

4.3.4 Long-Term Effectiveness and Permanence

Because no remedial activity is implemented for the no-action alternative, the residual risk remains the same as the baseline risk. Natural attenuation should result in some long-term reduction in risks. Contamination is left on site and long-term monitoring and other institutional controls may be necessary in perpetuity.

4.3.5 Reduction in Toxicity, Mobility, or Volume

No reduction in the toxicity, mobility, or volume of contamination occurs from implementation of the no-action alternative. It neither inhibits nor prevents continued migration of contaminants, nor does it prevent further degradation of Upper Zone ground-water or surface water quality. The contaminant concentrations detected in 1990 are near detection levels and are less than MCLs. Long-term monitoring of the ground water and surface water at Site SD13 will allow initiation of remedial actions if significant changes in contaminant concentrations are detected.

4.3.6 Short-Term Effectiveness

The baseline risk assessment for Site SD13 indicates that the risks to human health and the environment are insignificant. Implementation of the no-action alternative will not increase these risks. Numerical remedial action objectives are satisfied at this time. However, cleanup of detected contaminants to background levels will occur only by natural attenuation.

4.3.7 Implementability

Implementation of the no-action alternative for Site SD13 should present no problems.

4.3.8 Cost

The present worth cost estimate for the no-action alternative for Site SD13 is approximately $387,400. Capital costs for the no-action alternative are negligible, because no action is required. The annual O&M cost estimate is approximately $25,200.

4.4 Detailed Evaluation of Alternatives for Site ST14

Alternatives 1, 4A, 4B, and 5 are evaluated in the following subsections

4.4.1 Alternative 1--No Action

The following subsections describe the alternative and discuss each of the CERCLA evaluation criteria.

4.4.1.1 Description of the Alternative

Except for long-term monitoring, no remedial activities would be implemented at Site ST14 with the no-action alternative. Long-term monitoring at Site ST14 will make use of the existing Upper Zone monitoring well network and additional wells. The existing monitoring well network consists of nine wells. It is anticipated that all existing wells, and up to five additional wells installed beyond the downgradient limits of the existing contaminant plumes and the location of the ground-water extraction system, will be required to monitor the effectiveness of the selected ground-water remedial alternative. These wells will be sampled and analyzed for volatile aromatic compounds, total petroleum hydrocarbons, and dissolved metals on a quarterly basis for the duration of site remediation. Evidence of increased migration, such as significantly or consistently higher contaminant concentrations, or significant changes in the occurrence of the contaminants, would justify the initiation of further evaluation.

4.4.1.2 Protection of Human Health and the Environment

The no-action alternative does not reduce the risk to human health or the environment resulting from contamination at Site ST14. Ground-water contamination currently exceeds the requirements for satisfying the remedial action objectives. The baseline risk assessment for the site determined that the noncarcinogenic health effects originating from the site were insignificant compared to the standards set by EPA. Carcinogenic health effects associated with the site were approximately 10^{-8} based on inhalation exposure. The risk assessment concluded that the ingestion and dermal exposure pathways were insignificant. Ground-water flow at Site ST14 is currently toward Unnamed Stream and the West Fork of the Trinity River. If contaminants reach the stream or the river, the concentrations will be further reduced by the effects of dilution and volatilization. Therefore, the risk to human health or the environment would be the same or lower than that determined in the baseline risk assessment.

4.4.1.3 Compliance with ARARs

The no-action alternative does not meet the RAOs established for the site. Immiscible hydrocarbon contamination observed at the site in 1990 has the potential to migrate and contaminate previously uncontaminated areas. Some contaminant concentrations in the ground water at Site ST14 were in excess of MCLs in 1990.

4.4.1.4 Long-Term Effectiveness and Permanence

Because no remedial activity is implemented for the no-action alternative, the residual risk remains the same as the baseline risk. Natural attenuation could result in some long-term reduction in risks. However, natural attenuation with the waste mass in place would occur over a long period of time, so long-term reduction in risk due to natural attenuation should be insignificant. Long-term monitoring will identify changes in contaminant concentrations and the extent of the contaminant plume. Further remedial action may become necessary if these changes appear to present additional risks or hazards not apparent at this time. Because contamination is left on site, long-term monitoring and other institutional controls may be necessary in perpetuity.

4.4.1.5 Reduction in Toxicity, Mobility, or Volume

No reduction in the toxicity, mobility, or volume of contamination occurs from implementation of the no-action alternative. It neither inhibits nor prevents continued migration of contaminants, nor does it prevent further degradation of Upper Zone ground-water quality. Long-term monitoring of the ground water at Site ST14 will allow initiation of remedial actions if significant changes in contaminant concentrations or extent are detected.

4.4.1.6 Short-Term Effectiveness

The baseline risk assessment for Site ST14 indicates that the risks to human health and the environment are insignificant. Implementation of the no-action alternative will not increase these risks. Remediation of the contaminant plume to meet the criteria used to measure successful achievement of remedial action objectives can occur only by natural attenuation and only after a long period of time.

4.4.1.7 Implementability

Implementation of the no-action alternative for Site ST14 involves the design and execution of a long-term monitoring program and the installation of five monitor wells, neither of which activities should present problems. The primary obstacle to implementation of the no-action alternative will be securing approval from regulatory agencies and gaining public acceptance. The alternative calls for leaving a potentially significant volume of untreated free-phase hydrocarbon, as well as a large volume of contaminated ground-water, untreated and uncontained. Regulatory acceptance will be difficult unless other options are technically infeasible for Site ST14.

4.4.1.8 Cost

The present worth cost estimate for the no-action alternative for Site ST14 is approximately $844,200. Estimated capital costs for the no-action alternative include the costs of installing five additional ground-water monitor wells and are approximately $26,400. The annual O&M cost estimate is approximately $53,200.

4.4.2 Alternative 4A--Air Stripping and Re-injection

The following subsections describe the alternative and discuss each of the CERCLA evaluation criteria.

4.4.2.1 Description of the Alternative

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

- Long-term ground-water monitoring as described in Alternative 1, Section 4.4.1.1;
- One ground-water extraction well tentatively located near the southwest corner of Building 1213;
- An oil/water separator located at the air stripping treatment site near the northwest corner of Building 1213;
- An air stripping tower and required ancillary equipment located at the air stripping treatment site near the northwest corner of Building 1213;
- Approximately 250 feet of 2-inch/4-inch dual-wall containment pipe for conveyance of contaminated ground water;
- Approximately 670 feet of 2-inch, Schedule 80 PVC pipe for conveyance of treated ground water; and
- Two ground-water injection wells located within the limits of Site ST14 as shown on Figure 4-1.

The treated effluent will be re-injected into the Upper Zone upgradient of the two contaminant plumes present at Site ST14.

4.4.2.2 Protection of Human Health and the Environment

Alternative 4A should reduce the risk to human health and the environment resulting from ground-water contamination at Site ST14. This

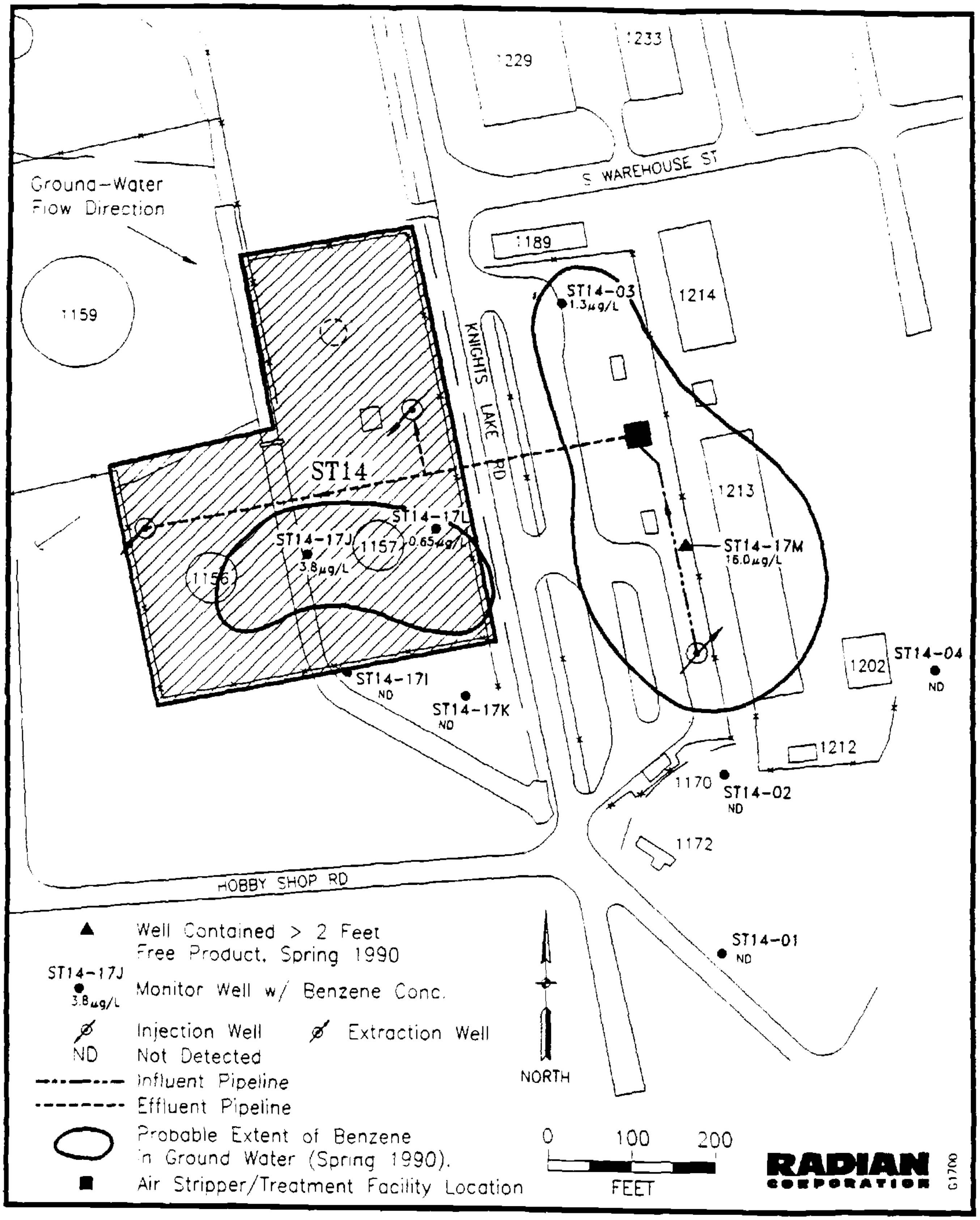

Figure 4-1. Remedial Alternative 4A, Site ST14, East Area, Carswell AFB, Texas

alternative will extract contaminated ground water and immiscible hydrocarbon from the Upper Zone. The immiscible hydrocarbon will be removed in the oil/water separator and either recycled or destroyed off site. The air stripper will remove soluble hydrocarbons and other volatile organic compounds from the ground water prior to re-injecting it into the aquifer. Re-injection should result in increased flushing of the Upper Zone and thus potentially decreased remediation time. Migration of contaminated ground water to other portions of the Upper Zone, as well as to nearby Unnamed Stream or Farmers Branch, should be minimized and possibly prevented by Alternative 4A. The only potential risk of exposure to site contaminants could be from the contaminant-laden air stripper off-gas. The mass of contaminants released from the air stripper will be limited to 5 lb/day. If the emissions rate exceeds that, secondary treatment, such as fume incineration or activated carbon adsorption, will be implemented. Therefore, the risk of exposure to contaminants from the air stripper should be minimal.

4.4.2.3 Compliance with ARARs

Alternative 4A should achieve all remedial action objectives established for the site. The immiscible hydrocarbons will be removed and disposed of off site. Contaminant concentrations in site ground water will be reduced below MCLs. Therefore, further contamination of ground water and contaminant migration to other portions of the Upper Zone or to other media should be minimized. Measures to prevent and contain spills originating from pipelines conveying contaminated ground water, treatment equipment, and by-product storage will all be incorporated into the design and implementation of the alternative.

4.4.2.4 Long-Term Effectiveness and Permanence

Once Alternative 4A has been implemented, residual risks from contamination at Site ST14 should be less than the baseline risk. The majority of contaminants in the ground water will be removed, and the remaining concentrations of contaminants (less than MCLs, as required) will be further reduced by natural attenuation. Unless a previously unidentified contaminant source exists, the residual risks should be acceptable and the remedy should be considered permanent. The alternative relies on ground water to flush contaminants from Upper Zone materials. Therefore, insoluble compounds which may be strongly adsorbed onto soils will not be removed. Long-term monitoring of the ground water after remediation will identify changes in contaminant concentrations and will identify significant changes in contaminant distribution which might indicate new contaminant sources or leaching of remnant contamination. Additional remedial measures could be determined and evaluated at that time.

4.4.2.5 Reduction in Toxicity, Mobility, or Volume

By hydraulically containing and removing contamination from the Upper Zone at Site ST14, Alternative 4A should reduce the mobility and volume of contamination. The oil/water separator and the air stripper should remove contaminants from the ground water, but they will not reduce the toxicity of the contaminants. Immiscible hydrocarbon from the oil/water separator will be recycled or destroyed, thus reducing the toxicity for that portion of the contaminants. Soluble contaminants in the ground water should be transferred out of solution into the air phase in the air stripper. Airborne contaminants would be significantly diluted or, if necessary, will be treated using fume incineration or activated carbon adsorption. Therefore, toxicity is effectively reduced.

4.4.2.6 Short-Term Effectiveness

The baseline risk assessment for Site ST14 indicates that the risks to human health and the environment are insignificant. Remedial activities conducted for Alternative 4A should not result in any increase in risk to on- or off-base personnel. Drill cuttings may temporarily introduce the risk of exposure for on-site personnel and for contaminant migration. However, if drill cuttings are handled, stored, and disposed of correctly, the temporary increase in risk should be insignificant. RAOs should be achieved within 1 to 5 years after implementation of the alternative.

4.4.2.7 Implementability

Alternative 4A makes use of proven, reliable technologies for remediation of Site ST14, and no outstanding impediments to implementation should occur. Some minor disruptions of base traffic may occur while the effluent line is constructed under Knights Lake Road. However, these disruptions should be minimized if boring and jacking rather than open cut techniques are used to construct the crossing. No permitting or regulatory approval problems are anticipated for Alternative 4A.

4.4.2.8 Cost

The present worth cost estimate for Alternative 4A for Site ST14 is approximately $1,307,000. The estimated capital cost for Alternative 4A is approximately $510,600. The annual O&M cost estimate is approximately $94,300.

4.4.3 Alternative 4B--Air Stripping and Discharge to the Sanitary Sewer

The following subsections describe the alternative and discuss each of the CERCLA evaluation criteria.

4.4.3.1 Description of the Alternative

Alternative 4B (see Figure 4-2) includes most of the components of Alternative 4A. However, rather than re-injecting the treated ground water, it will be discharged to a nearby sanitary sewer. The differences between Alternative 4A and 4B are as follows:

- No ground-water injection wells will be used in Alternative 4B;

- A new "drop" manhole will be constructed on a nearby 8-inch sanitary sewer line; and

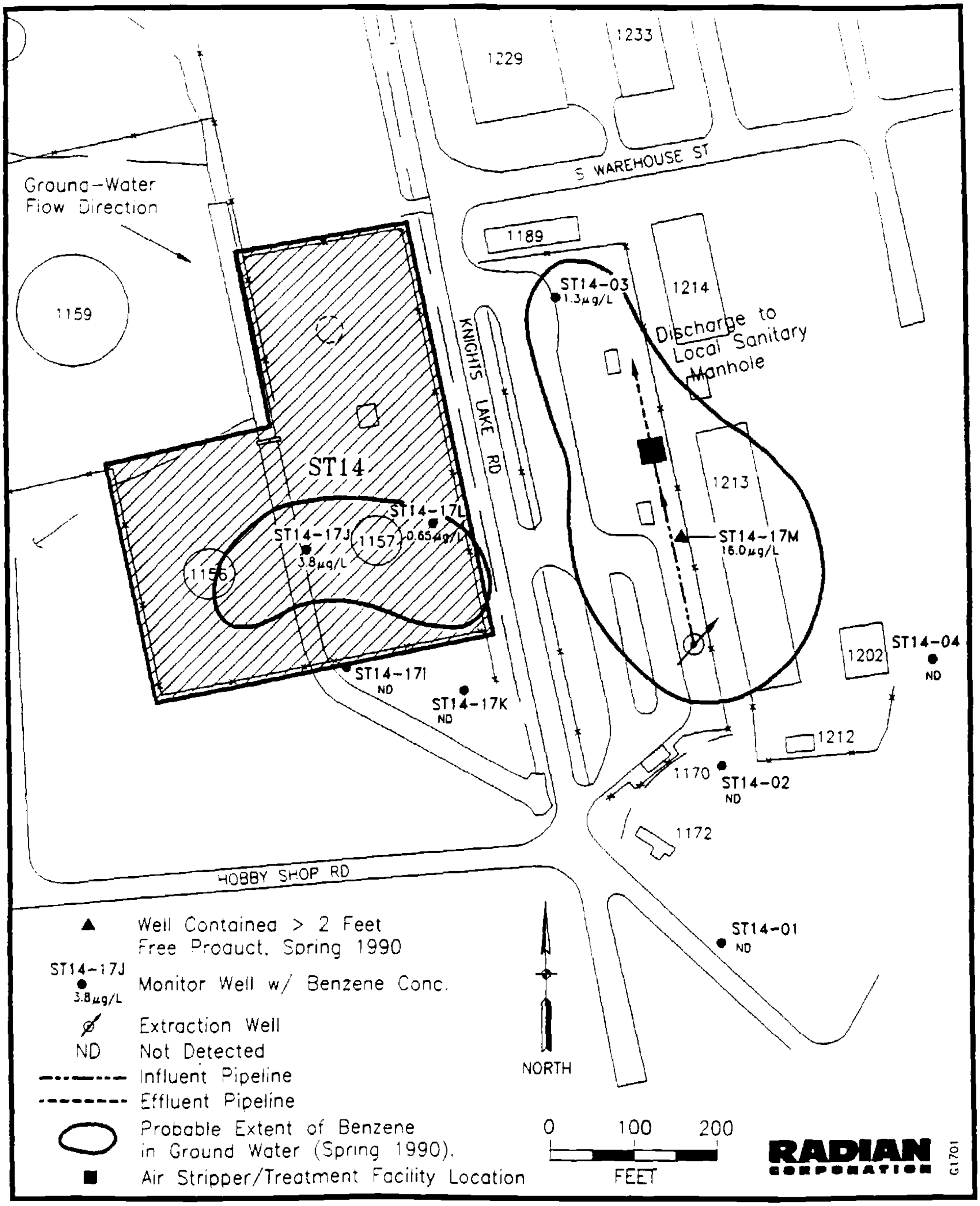

Figure 4-2. Alternative 4B, Site ST14, East Area, Carswell AFB, Texas

- Approximately 250 feet of 4-inch, Schedule 80 PVC pipe will be used for conveying treated effluent to the sanitary manhole (in lieu of the 670 feet of 2-inch PVC pipe used in Alternative 4A).

The remaining components will be the same as those for Alternative 4A.

4.4.3.2 Protection of Human Health and the Environment

The evaluation of Alternative 4B for this criterion is the same as for Alternative 4A, with the following additional concerns, caused by the fact that in Alternative 4B, treated ground water would be discharged to a nearby sanitary sewer. During a process upset, contaminated ground water could be discharged to the sanitary sewer and some volatilization of contaminants could occur. With dilution in the ambient air, the risk of exposure to contaminants should be minimal. Also under an upset condition, contaminated ground water could leak from the sanitary sewer and contaminate other water-bearing and non-water-bearing zones. Again, the dilution and volatilization factor in the sewer should be sufficient to minimize any additional risk.

4.4.3.3 Compliance with ARARs

The evaluation of Alternative 4B for this criterion should be the same as that for Alternative 4A. However, Alternative 4B must also meet the pretreatment requirements of the City of Fort Worth's sanitary sewer use ordinance. Preliminary conversations with City of Fort Worth personnel indicate that the air stripping process provides adequate removal of volatile organic contaminants to achieve the limits established by the City.

4.4.3.4 Long-Term Effectiveness and Permanence

The evaluation of Alternative 4B for this criterion should be the same as that for Alternative 4A, with the following exception: if at any time the City of Fort Worth changes its sewer use ordinance or limits the incoming flow to the POTW, an alternate disposal method for the treated effluent may be required. Presumably, adequate notice would be given to allow evaluation of other discharge options and to prevent disruption of operations.

4.4.3.5 Reduction in Toxicity, Mobility, or Volume

The evaluation of Alternative 4B for this criterion should be the same as that for Alternative 4A. However, during upset conditions the potential exists for contaminant discharge to the sanitary sewer. Such discharges could result in the migration of contaminants through leaking sewer pipes and in the exposure of City workers to volatilized contaminants.

4.4.3.6 Short-Term Effectiveness

The evaluation of Alternative 4B for this criterion is the same as that for Alternative 4A.

4.4.3.7 Implementability

The evaluation of Alternative 4B for this criterion should be the same as that for Alterative 4A, with the following exception: implementation of Alternative 4B may require a permit to discharge into the sanitary sewer. This permit would be issued under the POTW's sewer use ordinance. Preliminary conversations with City of Fort Worth personnel have indicated that the volume and quality of the treated ground water from the air stripper should not present a problem to the treatment plant and should meet the sewer use ordinance requirements.

4.4.3.8 Cost

The present worth cost estimate for Alternative 4B for Site ST14 is approximately $1,880,600. The estimated capital cost for Alternative 4B is approximately $469,000. The annual O&M cost estimate is approximately $91,900.

4.4.4 Alternative 5--In-Situ Biological Treatment

The following subsections describe the alternative and discuss each of the CERCLA evaluation criteria.

4.4.4.1 Description of the Alternative

Alternative 5 (see Figure 4-3) uses many of the components of Alternative 4A. However, Alternative 5 involves the use of in-situ biological degradation rather than air stripping to treat the contaminated ground water. Changes in components between Alternatives 4A and 5 are as follows:

- A nutrient and microorganism blending facility will be substituted for the air stripping tower; and

- 670 feet of 2-inch/4-inch dual-wall containment pipe will be used (in lieu of the 670 feet of 2-inch, Schedule 80 PVC pipe used in Alternative 4A).

In Alternative 5, treatment of contaminated ground water will occur in the Upper Zone. Therefore, the piping from the blending facility to the injection wells will be conveying contaminated ground water. Dual containment piping is necessary to minimize contaminant migration resulting from pipe breaks or leaks.

4.4.4.2 Protection of Human Health and the Environment

Alternative 5A should reduce the risk to human health and the environment resulting from ground-water contamination at Site ST14. This alternative will extract contaminated ground water and immiscible hydrocarbon from the Upper Zone. The immiscible hydrocarbon will be removed in the oil/water separator and either recycled or destroyed off site. The remaining ground water contaminated with dissolved organic contaminants will be blended

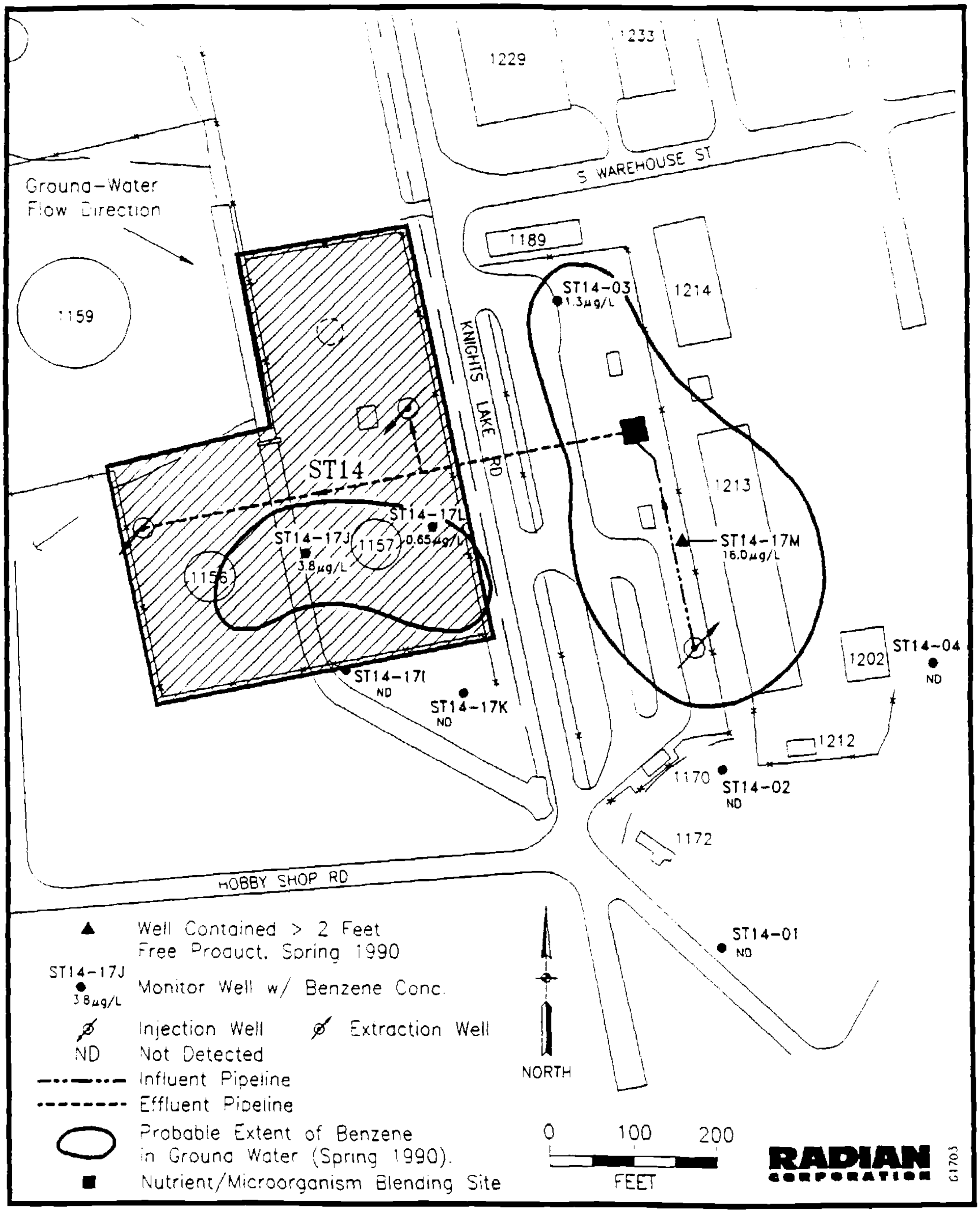

Figure 4-3. Alternative 5, Site ST14, East Area, Carswell AFB, Texas

with nutrients and microorganisms and re-injected into the Upper Zone. The microorganisms will utilize the carbon from the contaminants as an energy source, converting it to carbon dioxide and water. Contaminants adsorbed onto soil particles in the saturated portions of the Upper Zone may also be degraded. As a result of the extraction and re-injection, the Upper Zone should experience increased flushing and thus potentially reduced remediation time. Migration of contaminated ground water to other portions of the Upper Zone, as well as to Unnamed Stream or Farmers Branch, should be minimized and possibly prevented by Alternative 5. Potential spills from the blending facility, the oil/water separator, and influent and effluent pipelines will be minimized through the use of appropriate containment designs.

4.4.4.3 Compliance with ARARs

Alternative 5 should achieve all remedial action objectives established for the site. Immiscible hydrocarbon and dissolved contaminants in the Upper Zone will be biologically oxidized in situ to concentrations below MCLs. Further contamination of ground water and contaminant migration to other portions of the Upper Zone or to other media should be minimized, if not prevented. Measures to contain spills originating from pipelines conveying contaminated ground water, blending equipment, and by-product storage will all be incorporated into the design and implementation of the alternative, thus minimizing inadvertent migration of contaminants from treatment equipment.

4.4.4.4 Long-Term Effectiveness and Permanence

The evaluation of Alternative 5 for this criterion should be the same as that for Alternative 4A. However, the expected simultaneous biological treatment of the ground water and the aquifer materials should virtually eliminate residual contamination in the Upper Zone.

4.4.4.5 Reduction in Toxicity, Mobility, or Volume

The evaluation of Alternative 5 for this criterion is essentially the same as that for Alternative 4A. Alternative 5 provides an additional benefit by biologically destroying the contaminants of concern, thus reducing the toxicity.

4.4.4.6 Short-Term Effectiveness

The evaluation of Alternative 5 for this criterion is essentially the same as that for Alternative 4A, with one exception. Alternative 5 may require additional time to achieve the RAOs. The length of time that the biological treatment requires to achieve the RAOs will depend on the microorganism population and on physical conditions in the Upper Zone.

4.4.4.7 Implementability

Alternative 5 makes use of several proven, reliable technologies in support of a somewhat new and innovative approach to biological treatment. Physically, the implementation of Alternative 5 depends on the Upper Zone being sufficiently homogeneous and isotropic such that microorganisms and nutrients injected into it will contact all of the contamination. The permeability and porosity of the soil must be adequate to allow for the growth of microorganisms without impeding flow. The in-situ biological process has been used in recent years to clean up a number of sites. However, regulatory acceptance of the in-situ biological treatment system would be necessary prior to implementation. Treatability studies may be required to demonstrate the effectiveness and timeliness of treatment before the regulatory agencies approve the alternative.

4.4.4.8 Cost

The present worth cost estimate for Alternative 5 for Site ST14 is approximately $1,933,000. The estimated capital cost for Alternative 5 is approximately $391,900. The annual O&M cost estimate is approximately $100,300.

4.5 Detailed Evaluation of Alternatives for Site BSS

Alternatives 1, 2A, 2B, and 3 are evaluated in the following subsections.

4.5.1 Alternative 1--No Action

The following subsections describe the alternative and discuss each of the CERCLA evaluation criteria.

4.5.1.1 Description of the Alternative

Except for long-term monitoring, no remedial activities would be implemented at Site BSS with the no-action alternative. Long-term monitoring at Site BSS will make use of the existing Upper Zone monitoring well network and additional wells. The existing monitoring well network consists of three wells. It is expected that three or four additional monitor wells will be required downgradient of existing contamination to evaluate the effectiveness of the selected remedial alternative. Monitor wells should be sampled and analyzed for volatile aromatic compounds, total petroleum hydrocarbons, and dissolved metals on a quarterly basis for the duration of the remedial action. However, because of the thin saturated zone and local variability in the occurrence of Upper Zone ground water at this site, it is possible that some wells may be dry during any given sampling event, especially once ground-water control technologies are in place. Evidence of increased migration, such as significantly or consistently higher contaminant concentrations, or significant changes in the occurrence of the contaminants, would justify the initiation of further evaluation.

4.5.1.2 Protection of Human Health and the Environment

The no-action alternative does not reduce the risk to human health or the environment resulting from contamination at Site BSS. Ground-water contamination currently exceeds the requirements for satisfying the remedial action objectives. The baseline risk assessment for the site determined that the noncarcinogenic health effects originating from the site were insignificant compared to the standards set by EPA. Carcinogenic health effects associated with the site were approximately 10^{-9} based on inhalation exposure. The risk assessment concluded that the ingestion and dermal exposure pathways were insignificant. Ground-water flow at Site BSS is currently toward the West Fork of the Trinity River. If contaminants reach the river, the concentrations will be further reduced by the effects of dilution and volatilization. Therefore, the risk to human health or the environment would be the same or lower than that determined in the baseline risk assessment.

4.5.1.3 Compliance with ARARs

The no-action alternative does not meet the RAOs established for the site. Some contaminant concentrations in ground water at Site BSS were in excess of MCLs in 1990.

4.5.1.4 Long-Term Effectiveness and Permanence

Because no remedial activity is implemented for the no-action alternative, the residual risk remains the same as the baseline risk. Natural attenuation could result in some long-term reduction in risks. However, natural attenuation would occur over a long period of time, so long-term reduction in risk should be insignificant. Long-term monitoring will identify changes in contaminant concentrations and the extent of the contaminant plume. Further remedial action may become necessary if these changes appear to present additional risks or hazards not currently apparent. Because contamination is left on site, long-term monitoring and other institutional controls may be necessary in perpetuity.

4.5.1.5 Reduction in Toxicity, Mobility, or Volume

No reduction in the toxicity, mobility, or volume of contamination occurs from implementation of the no-action alternative. It neither inhibits nor prevents continued migration of contaminants, nor does it further prevent degradation of Upper Zone ground-water quality. Long-term monitoring of the ground water at Site BSS will allow initiation of remedial actions if significant changes in contaminant concentrations or extent are detected.

4.5.1.6 Short-Term Effectiveness

The baseline risk assessment for Site BSS indicates that the risks to human health and the environment are insignificant. Implementation of the no-action alternative will not increase these risks. Remediation of the contaminant plume to meet the criteria used to measure successful achievement of remedial action objectives can occur only by natural attenuation and only after a long period of time.

4.5.1.7 Implementability

Implementation of the no-action alternative for Site BSS involves the design and execution of a long-term monitoring program and the installation of four ground-water monitoring wells, neither of which activities should present problems. The primary obstacle to implementation of the no-action alternative will be securing approval from regulatory agencies and gaining public acceptance. The alternative calls for leaving an unknown volume of untreated hydrocarbon residue, as well as contaminated ground water, untreated and uncontained. Regulatory acceptance will be difficult unless other options are technically infeasible for Site BSS.

4.5.1.8 Cost

The present worth cost estimate for the no-action alternative for Site BSS is approximately $430,000. The estimated capital cost for the no-action alternative including the cost of four additional ground-water monitor wells is approximately $21,100. The annual O&M cost estimate is approximately $26,600.

4.5.2 Alternative 2A--Air Stripping and Re-injection

The following subsections describe the alternative and discuss each of the CERCLA evaluation criteria.

4.5.2.1 Description of the Alternative

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

- Long-term ground-water monitoring as described in Alternative 1, Section 4.5.1.1;
- Approximately 300 feet of ground-water extraction trench located approximately 60 feet east of and parallel to Rogner Drive;
- An air stripping tower and required ancillary equipment located at the air stripping treatment site in the northern portion of Site BSS;
- Approximately 200 feet of 2-inch/4-inch dual-wall containment pipe for conveyance of contaminated ground water;
- Approximately 200 feet of 2-inch, Schedule 80 PVC pipe for conveyance of treated ground water; and
- One ground-water injection well located in the northwest corner of the Site BSS.

The treated effluent will be re-injected into the Upper Zone upgradient of the contaminant plumes present at Site BSS.

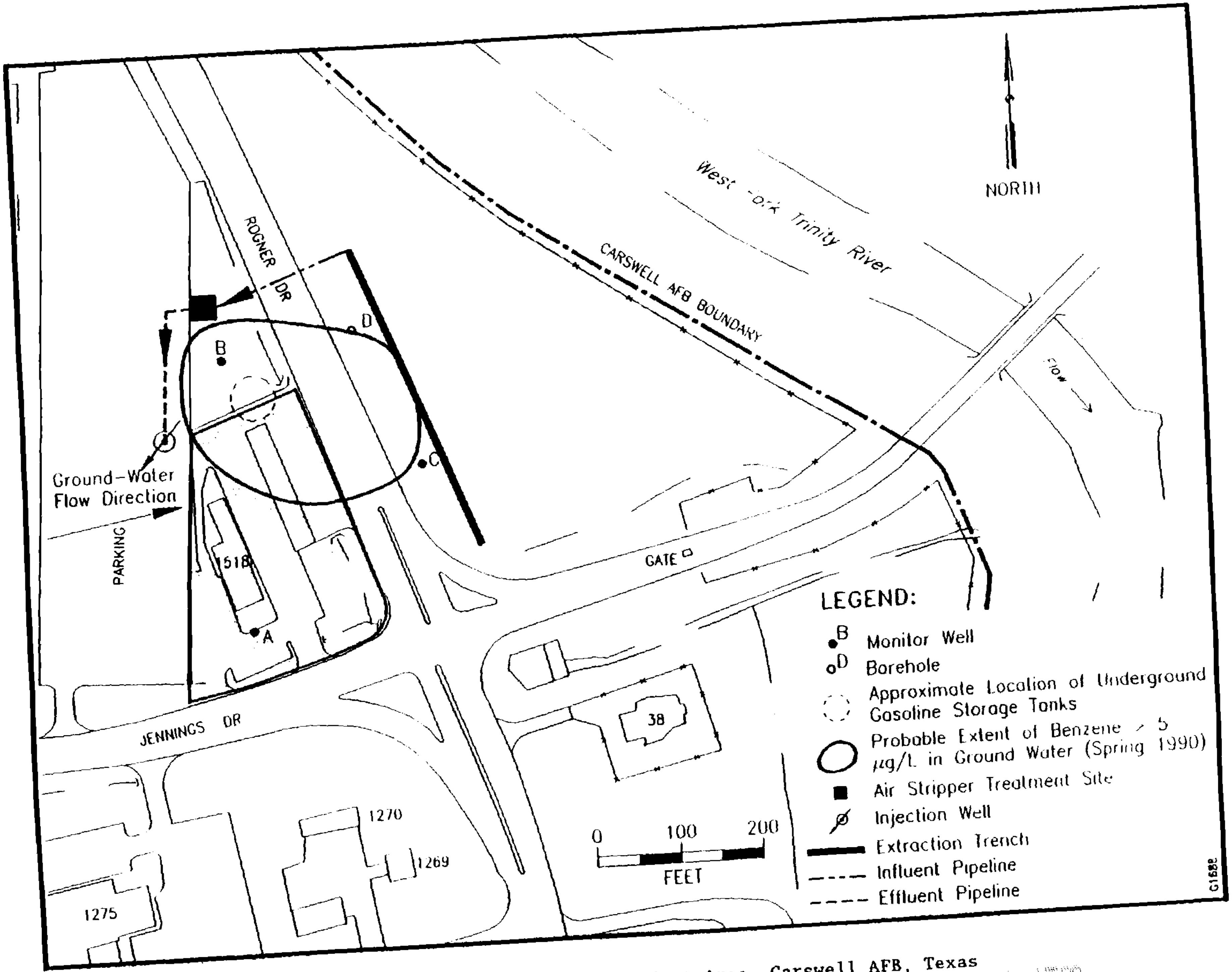

Figure 4-4. Alternative 2A, Site BSS East Area, Carswell AFB, Texas

4.5.2.2 Protection of Human Health and the Environment

Alternative 2A should reduce the risk to human health and the environment resulting from ground-water contamination at Site BSS. The alternative will extract contaminated ground water from the Upper Zone. The air stripper will remove soluble hydrocarbons and other volatile organic compounds from the ground water prior to re-injecting it into the aquifer. Re-injection should result in increased flushing of the Upper Zone and thus potentially decreased remediation time. Migration of contaminated ground water to other portions of the Upper Zone, as well as to the nearby West Fork of the Trinity River, should be minimized and possibly prevented by Alternative 2A. The only potential risk of exposure to site contaminants could be from the contaminant-laden air stripper off-gas. The mass of contaminants released from the air stripper will be limited to 5 lb/day, beyond which secondary treatment, such as fume incineration or activated carbon adsorption, will be implemented. Therefore, the risk of exposure to contaminants from the air stripper should be minimal.

4.5.2.3 Compliance with ARARs

Alternative 2A should achieve all remedial action objectives established for the site. Contaminant concentrations in site ground water should be reduced below MCLs. Therefore, further contamination of groundwater and contaminant migration to other portions of the Upper Zone or to other media should be minimized. Measures to prevent and contain spills originating from pipelines conveying contaminated ground water, treatment equipment, and by-product storage will all be incorporated into the design and implementation of the alternative.

4.5.2.4 Long-Term Effectiveness and Permanence

Once Alternative 2A has been implemented, residual risks from contamination at Site BSS should be less than the baseline risk. The majority of contaminants in the ground water will be removed, and the remaining concentrations of contaminants (less than MCLs, as required) will be further reduced by natural attenuation. Unless a previously unidentified contaminant source exists, the residual risks should be acceptable and the remedy should be considered permanent. The alternative relies on ground water to flush contaminants from Upper Zone materials. Therefore, insoluble compounds which may be strongly adsorbed onto soils will not be removed. Long-term monitoring of the ground water after remediation will identify changes in contaminant concentrations and will identify significant changes in contaminant distribution which might indicate new contaminant sources or leaching of remnant contamination. Additional remedial measures could be determined and evaluated at that time.

4.5.2.5 Reduction in Toxicity, Mobility, or Volume

By hydraulically containing and removing contamination from the Upper Zone at Site BSS, Alternative 2A should reduce the mobility and volume of contamination. The air stripper should remove contaminants from the ground water, but it will not reduce the toxicity of the contaminants. No by-products are expected from the remedial action. Soluble contaminants in the ground water should be transferred out of solution into the air phase in the air stripper. Airborne contaminants would be significantly diluted or, if necessary, will be treated using fume incineration or activated carbon adsorption. Therefore, toxicity is effectively reduced.

4.5.2.6 Short-Term Effectiveness

The baseline risk assessment for Site BSS indicates that the risks to human health and the environment are insignificant. Remedial activities conducted for Alternative 2A should not result in any increase in risk to on- or off-base personnel. Soil excavated during construction of the trench may temporarily introduce the risk of exposure for on-site personnel and for contaminant migration. However, if soil is handled, stored, and disposed of correctly, the temporary increase in risk from the soil should be insignificant. Remedial action objectives should be achieved relatively quickly (1 to 5 years) once implementation of the alternative has begun.

4.5.2.7 Implementability

Alternative 2A makes use of proven, reliable technologies for remediation of Site BSS, and no outstanding impediments to implementation should occur. The extraction trenches should operate well under the conditions at Site BSS. Passive extraction procedures such as trenches are optimum for the variable occurrence and small volume of contaminated ground water found at Site BSS. Some minor disruptions of base traffic may occur while the effluent line is constructed under Rogner Drive. However, these disruptions should be minimized if boring and jacking rather than open cut techniques are used to construct the crossing. No permitting or regulatory approval problems are anticipated for Alternative 2A.

4.5.2.8 Cost

The present worth cost estimate for Alternative 2A for Site BSS is approximately $1,570,400. The estimated capital cost for Alternative 2A is approximately $528,900. The annual O&M cost estimate is approximately $67,800.

4.5.3 Alternative 2B--Air Stripping and Discharge to the Sanitary Sewer

The following subsections describe the alternative and discuss each of the CERCLA evaluation criteria.

4.5.3.1 Description of the Alternative

Alternative 2B (see Figure 4-5) includes most of the components of Alternative 2A. However, rather than re-injecting the treated ground water, it will be discharged to a nearby sanitary sewer. The differences between Alternative 2A and 2B are as follows:

- No ground-water injection wells will be used in Alternative 2B;

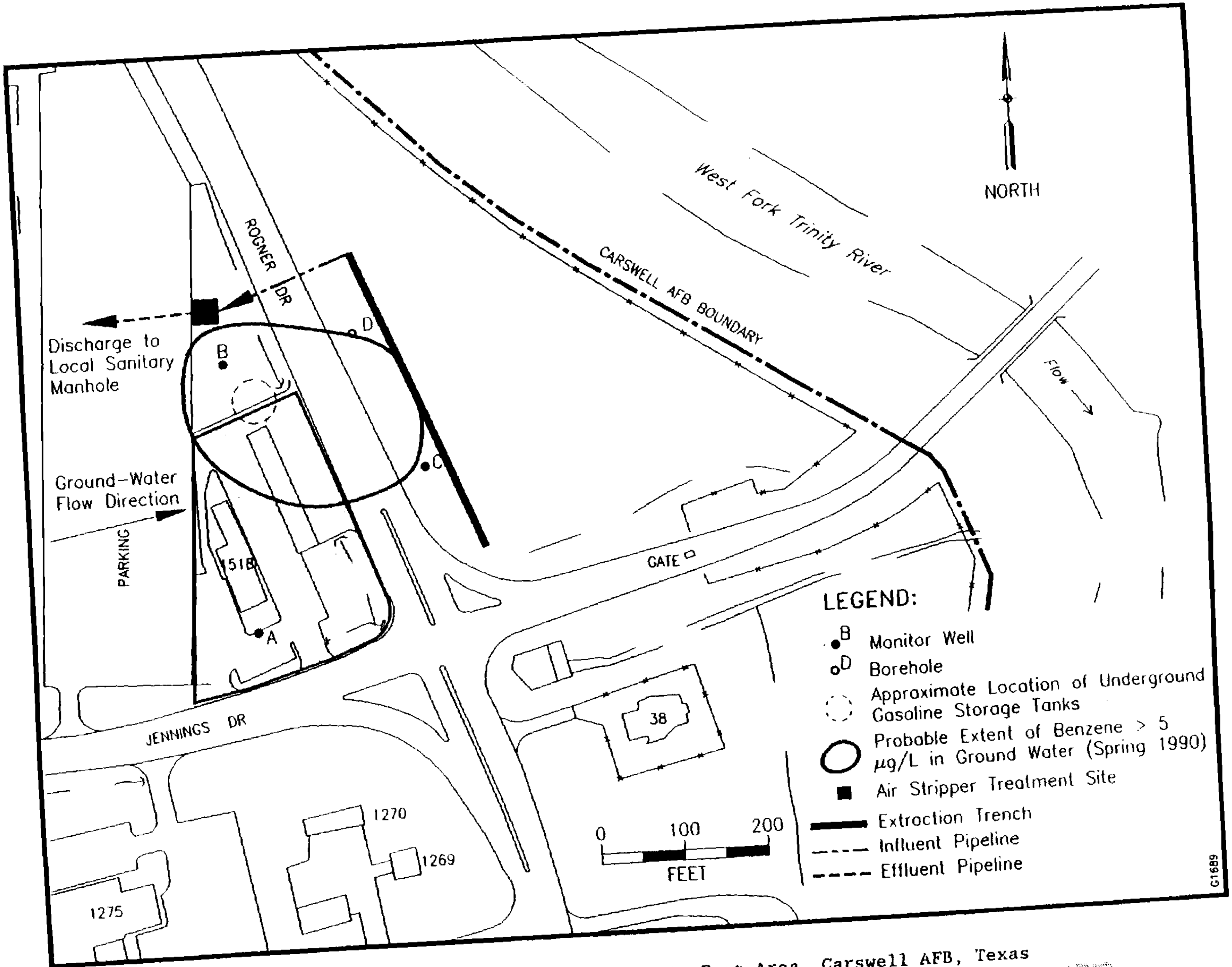

Figure 4-5. Alternative 2B, Site BSS, East Area, Carswell AFB, Texas

- A new "drop" manhole will be constructed on a nearby 8-inch sanitary sewer line; and

- Approximately 200 feet of 4-inch, Schedule 80 PVC pipe will be used to convey treated effluent to the sanitary manhole (in lieu of the 200 feet of 2-inch PVC pipe used in Alternative 2A).

The remaining components will be the same as those for Alternative 2A.

4.5.3.2 Protection of Human Health and the Environment

The evaluation of Alternative 2B for this criterion is the same as for Alternative 2A, with the following additional concerns, caused by the fact that in Alternative 2B, treated ground water would be discharged to a nearby sanitary sewer. During a process upset, contaminated ground water could be discharged to the sanitary sewer, and some volatilization of contaminants could occur. With dilution in the ambient air, the risk of exposure to contaminants should be minimal. Also under an upset condition, contaminated ground water could leak from the sanitary sewer and contaminate other water-bearing and non-water-bearing zones. Again, the dilution and volatilization factor in the sewer should be sufficient to minimize any additional risk.

4.5.3.3 Compliance with ARARs

The evaluation of Alternative 2B for this criterion should be the same as that for Alternative 2A. However, Alternative 2B must also meet the pretreatment requirements of the City of Fort Worth's sanitary sewer use ordinance. Preliminary conversations with City of Fort Worth personnel indicate that the air stripping process provides adequate removal of volatile organic contaminants to achieve the limits established by the City.

4.5.3.4 Long-Term Effectiveness and Permanence

The evaluation of Alternative 2B for this criterion should be the same as that for Alternative 2A, with the following exception: if at any time the City of Fort Worth changes its sewer use ordinance or limits the incoming flow to the POTW, an alternate disposal method for the treated effluent may be required. Presumably, notification of the changes by the City would be adequate to evaluate other discharge options, make a selection, and avoid disruption of operations.

4.5.3.5 Reduction in Toxicity, Mobility, or Volume

The evaluation of Alternative 2B for this criterion should be the same as that for Alternative 2A. However, during upset conditions the potential exists for contaminant discharge to the sanitary sewer. Such discharges could result in the migration of contaminants through leaking sewer pipes and in the exposure of City workers to volatilized contaminants.

4.5.3.6 Short-Term Effectiveness

The evaluation of Alternative 2B for this criterion is the same as that for Alternative 2A.

4.5.3.7 Implementability

The evaluation of Alternative 2B for this criterion should be the same as that for Alterative 2A, with the following exception: implementation of Alternative 2B may require a permit to discharge into the sanitary sewer. This permit would be issued under the POTW's sewer use ordinance. Preliminary conversations with City of Fort Worth personnel have indicated that the volume and quality of the treated ground water from the air stripper should not present a problem to the treatment plant and should meet the sewer use ordinance requirements.

4.5.3.8 Cost

The present worth cost estimate for Alternative 2B for Site BSS is approximately $1,523,400. The estimated capital cost for Alternative 2B is approximately $516,000. The annual O&M cost estimate is approximately $65,500.

4.5.4 Alternative 3--In-Situ Biological Treatment

The following subsections describe the alternative and discuss each of the CERCLA evaluation criteria.

4.5.4.1 Description of the Alternative

Alternative 3 (see Figure 4-6) uses many of the components of Alternative 2A. However, Alternative 3 involves the use of in-situ biological degradation rather than air stripping to treat the contaminated ground water. Changes in components between Alternative 2A and 3 are as follows:

- A nutrient and microorganism blending facility will be substituted for the air stripping tower; and

- 200 feet of 2-inch/4-inch dual-wall containment pipe will be used (in lieu of the 200 feet of 2-inch, Schedule 80 PVC pipe used in Alternative 2A).

In Alternative 3, treatment of contaminated ground water will occur in the Upper Zone. Therefore, the piping from the blending facility to the injection wells will be conveying contaminated ground water. Dual containment piping is necessary to minimize contaminant migration resulting from pipe breaks or leaks.

amount of residual contamination in the Upper Zone. Leaching of remnant contamination after remediation is complete is therefore minimized or prevented.

4.5.4.5 Reduction in Toxicity, Mobility, or Volume

The evaluation of Alternative 3 for this criterion is essentially the same as that for Alternative 2A. Alternative 3 provides an additional benefit by biologically destroying the contaminants of concern, thus reducing the toxicity.

4.5.4.6 Short-Term Effectiveness

The evaluation of Alternative 3 for this criterion is essentially the same as that for Alternative 2A, with one exception. Alternative 3 may require additional time to achieve the RAOs. The length of time that the biological treatment requires to achieve the RAOs will depend on the microorganism population and on physical conditions in the Upper Zone.

4.5.4.7 Implementability

Alternative 3 makes use of several proven, reliable technologies in support of a somewhat new and innovative approach to biological treatment. Physically, the implementation of Alternative 3 depends on the Upper Zone being sufficiently homogeneous and isotropic such that microorganisms and nutrients injected into it will contact with all of the contamination. The permeability and porosity of the soil must be adequate to allow for the growth of microorganisms without impeding flow. The in-situ biological process has been used in recent years to clean up a number of sites. However, regulatory acceptance of the in-situ biological treatment system would be necessary prior to implementation. Treatability studies may be required to demonstrate the effectiveness and timeliness of treatment before the regulatory agencies approve the alternative.

the Upper Zone (generally 10 feet or less), interceptor trenches would be very effective. Other implementation issues for Alternatives 2 and 3 are described in the following paragraphs.

Regulatory acceptance of the in-situ biological treatment system used in Alternative 3 would be necessary prior to implementation. Treatability studies may be required to demonstrate the effectiveness and timeliness of treatment, before the regulatory agencies would approve the alternative.

For Alternative 2C, additional implementability concerns could result from NPDES permitting requirements for discharge into the West Fork of the Trinity River (or another receiving stream). Permitting could require six months to one year. The permit would have to be issued prior to implementation of the alternative. Public perception and acceptance could delay the permit longer or even result in denial of the permit.

Alternative 2B may also require a permit to discharge into the sanitary sewer. However, this permit would be issued under the POTW's sewer use ordinance. Preliminary conversations with City of Fort Worth personnel have indicated that the expected volume and quality of the treated ground water from the air stripper should not present a problem to the treatment plant and should meet the sewer use ordinance requirements.

The cost criterion does not pose a problem for Alternatives 2 or 3. The cost of constructing the extraction/interceptor trenches will be greater than that of constructing an extraction well with the same capability. However, because other costs for Alternatives 2 and 3 should be in the same order of magnitude as Alternatives 4 and 5, the total costs should be comparable to Alternatives 4 and 5.

Alternatives 4 and 5--Alternatives 4 and 5 include an extraction well for plume containment and ground-water withdrawal, with either air stripping (Alternatives 4A, 4B, and 4C) or in-situ biological treatment (Alternative 5) as the primary treatment option. All of the component technologies are implementable and are in an acceptable range of costs. However, sustained withdrawal of contaminated ground water at even a low pumping rate may not be feasible due to the small volume and variable occurrence of Upper Zone ground water at this site. Therefore, Alternatives 4 and 5 may not be effective because extraction wells are not suited to the site-specific hydrogeologic conditions at Site BSS. Other effectiveness and implementability issues for Alternatives 4 and 5 are similar to those discussed for Alternatives 2 and 3. The costs for Alternatives 4 and 5 are in the same order of magnitude as Alternatives 2 and 3, so the cost criterion does not present a problem.

Results of Ground-Water Alternative Screening--Alternatives 4A, 4B, 4C, and 5 were eliminated from further evaluation because they are incompatible with the site-specific hydrogeologic conditions and, therefore, do not meet the effectiveness criterion. Alternative 2C was eliminated from further consideration because of potential problems with public acceptance and permitting. While Alternative 3 may pose some regulatory acceptance problems, it was retained for further evaluation to provide a basis for comparison to the air stripping alternative.

3.2.4.2 Preliminary Soil Alternatives

Available soils analytical data for Site BSS are also insufficient to support screening of preliminary soil remedial alternatives. To apply the screening criteria of effectiveness, implementability, and cost, the volumes, locations and extent, depth, and concentrations of hydrocarbon contaminants in soil, if any, must be documented. On a qualitative basis, Alternatives 2 and 3, which include excavation, are probably more difficult to implement than Alternative 4 (because of potential disruption of service station operations during excavation for soil removal or vapor extraction trench construction), unless contaminated soils are restricted to shallow depths and are volumetrically small. The cost to implement Alternative 1 (no action) is negligible compared to the other three, which are expected to be in the same order-of-magnitude range. As in the case of ground-water alternatives, the no-action alternative is ineffective, providing no reduction in the toxicity, sites. Alternative 2, and to a lesser extent Alternative 3, offers this advantage. The disadvantages that apply to the combined soils alternatives are the same as those that apply to the combined ground-water alternatives.

4.6.3 Combined Soil and Ground-Water Alternatives

The interactions of ground water and soil responses to certain remedial alternatives are significant at Sites BSS and ST14. Therefore, opportunities for combining complementary remedial actions for each medium exist at both sites individually and together.

The ground-water and soil treatment technologies which provide complementary remediation due to media interactions, and which therefore can be combined as remedial alternatives, are:

- Air stripping of ground-water and soil vapor extraction;
- In-situ biological treatment of ground water and soil; and
- Air stripping of ground-water and soil pile treatment.

Soil vapor extraction depends on the porosity of the subsurface to remove the VOC contaminants. If a treatment is chosen that may decrease soil porosity, such as injection of nutrient-rich water for biological treatment, it would reduce the effectiveness of the soil vapor extraction. In-situ biological treatment of the ground water and soil complement each other. The microorganisms and nutrients allowed to infiltrate into the soil will percolate down to the water table and augment the ground-water bio-treatment. Treatment of contaminant-laden soil vapors from the soil piles can easily be treated along with contaminant-laden air stripper off-gases. All three complementary remedial actions would avoid duplication or unnecessary diversity of treatment facilities for the remedial alternatives, (e.g., two secondary treatment facilities, one for air-stripping off-gas and the other for soil vapors, or two biological mixing facilities, one for ground water and the other for soils). As mentioned previously, the need for the secondary treatment for air stripping and soil gas is dependent on the quantity of emissions and on state guidelines.

The obvious advantage of coordinating media-specific alternatives is cost. By combining treatment facilities, a reduction in the capital cost for one (combined) facility versus two (uncombined) facilities should be realized. In addition to capital cost, another potential benefit of combining treatment facilities is that the O&M cost for one (combined) facility should be marginally smaller than the cost for two smaller (uncombined) facilities. Treatment efficiencies, and thus power and materials, should be higher with a larger facility. The labor needed to staff and maintain one (combined) facility should be less than that for two (uncombined) facilities.

For coordinating combined-media remedial alternatives, there are the same opportunities as those that exist for coordinating media-specific remedial alternatives at Sites ST14 and BSS. The advantages and disadvantages for the coordinated combined-media alternatives are also the same.

4.7 Comparative Evaluation of Remedial Alternatives

A matrix evaluation was conducted on the remedial alternatives discussed in the preceding sections. The matrix approach allows a comparative analysis of the alternatives using both their ability to satisfy established criteria and present worth cost. The matrix evaluation was performed using information presented in Sections 4.4 and 4.5 of this report.

4.7.1 Matrix Approach

Up to this point, each alternative has been descriptively evaluated with respect to the following criteria:

- 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, a scoring system was established for the above criteria, and scores for each criteria were determined for each alternative. Table 4-1 lists the scoring basis for each of the evaluation criteria parameters (except for cost).

Tables 4-2 and 4-3 are blank evaluation matrix tables showing the four alternatives for each site, evaluation parameters, weighting factors, cost measures, the effectiveness total column, and the effectiveness-to-cost quotient column. The capital, operating 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 six of the seven criteria are developed for each alternative. These scores are multiplied by a weighting factor (top row on Tables 4-2 and 4-3) and summed to determine the effectiveness total. The alternative having the greatest quotient of the effectiveness total divided by the present worth cost total is considered to be the most cost-effective alternative. The quotient value is presented in the right hand column of the matrix.

The results of the comparative analysis using the matrix approach are presented in Tables 4-4 and 4-5. From Table 4-4, the most cost-effective alternative (excluding the no-action alternative) for Site ST14 is Alternative 5. From Table 4-5, the most cost-effective alternative for Site BSS is Alternative 3. As previously documented, the only feasible action for Sites LF01 and SD13 is no action, other than long-term monitoring. Therefore, the matrix evaluation is not applicable to these sites.

TABLE 4-1. CRITERIA SCORES FOR DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

Criterion	Scoring Basis
Overall Protection of Human Health/-Environment	3 - Will greatly reduce risk 2 - Will reduce risks 1 - Will not reduce risks
Compliance with ARARs	3 - Will meet or exceed ARARs 2 - Will meet ARARs 1 - Will not meet ARARs
Long-Term Effectiveness/Permanence	3 - Very little residual contamination after remediation 2 - Some residual contamination after remediation 1 - Contamination unchanged by remediation
Reduction in Toxicity, Mobility, or Volume	3 - Reduction of all three 2 - Reduction in mobility and volume, but not toxicity 1 - No reduction in mobility, volume, or toxicity
Short-Term Effectiveness	3 - Very few additional risks to on- and off-site personnel during remediation; remedial action objectives achieved within 2-5 years 2 - Some minor additional risks; remedial action objectives met within 10 years 1 - Major risks during implementation; remedial action objectives met within 20 to 30 years
Implementability	3 - No impediments 2 - Some impediments, but easily overcome 1 - Some impediments overcome with difficulty

TABLE 4-2. REMEDIAL ALTERNATIVES COMPARATIVE EVALUATION MATRIX, SITE ST14, EAST AREA, CARSWELL AFB, TEXAS

Alternative	Capital Cost ($ M)	O&M Cost ($ M)	NPW ($ M)	Protect. Human Hlth. & Env.	Compliance w/ARARs	Long-Term Effect.	Reduct. of Tox., Mob. & Vol.	Short-Term Effect.	Implement.	Effect. Total	Effect. Quotient
Weighting Factor	1	1	1	3	2	3	3	1	2		
1 No Action											
4A Air Stripping and Re-injection											
4B Air Stripping and Discharge to San. Sew.					--Intentionally Left Blank--						
5 In-situ Biological Treatment											

M = 1,000,000 (e.g., $2M = $2,000,000)

TABLE 4-3. REMEDIAL ALTERNATIVES COMPARATIVE EVALUATION MATRIX, SITE BSS, EAST AREA, CARSWELL AFB, TEXAS

Alternative	Capital Cost ($ M)	O&M Cost ($ M)	NPW ($ M)	Protect. Human Hlth. & Env.	Compliance w/ARARs	Long-Term Effect.	Reduct. of Tox., Mob. & Vol.	Short-Term Effect.	Implement.	Effect. Total	Effect. Quotient
Weighting Factor	1	1	1	3	2	3	3	1	2		
1 No Action	--Intentionally Left Blank--										
2A Air Stripping and Re-injection											
2B Air Stripping and Discharge to San. Sew.											
3 In-situ Biological Treatment											

M = 1,000,000 (e.g., $2M = $2,000,000)

TABLE 4-4. REMEDIAL ALTERNATIVES COMPARATIVE EVALUATION MATRIX, SITE ST14, EAST AREA, CARSWELL AFB, TEXAS

Alternative	Capital Cost ($ M)	O&M Cost ($ M)	NPW ($ M)	Protect. Human Hlth. & Env.	Compliance w/ARARs	Long-Term Effect.	Reduct. of Tox., Mob. & Vol.	Short-Term Effect.	Implement.	Effect. Total	Effect. Quotient
Weighting Factor	1	1	1	3	2	3	3	1	2		
1 No Action	0.0264	0.053	0.8442	1	1	1	1	2	1	15	18
4A Air Stripping and Re-injection	0.5106	0.0943	1.3070	2	3	2	2	3	3	33	25
4B Air Stripping and Discharge to San. Sew.	0.4690	0.0918	1.8806	2	3	2	2	3	2	31	16
5 In-situ Biological Treatment	0.3919	0.1002	1.9330	3	3	2	3	2	2	36	19

M = 1,000,000 (e.g., $2M = $2,000,000)

TABLE 4-5. REMEDIAL ALTERNATIVES COMPARATIVE EVALUATION MATRIX, SITE BSS, EAST AREA, CARSWELL AFB, TEXAS

Alternative	Capital Cost ($ M)	O&M Cost ($ M)	NPW ($ M)	Protect. Human Hlth. & Env.	Compliance w/ARARs	Long-Term Effect.	Reduct. of Tox., Mob. & Vol.	Short-Term Effect.	Implement.	Effect. Total	Effect. Quotient
Weighting Factor	1	1	1	3	2	3	3	1	2		
1 No Action	0.0211	0.0266	0.4300	1	1	1	1	2	1	15	35
2A Air Stripping and Re-injection	0.5288	0.0678	1.5704	2	3	2	2	3	3	33	21
2B Air Stripping and Discharge to San. Sew.	0.5160	0.0655	1.5233	2	3	2	2	3	2	31	20
3 In-situ Biological Treatment	0.3592	0.0671	1.3904	3	3	2	3	2	2	36	26

M = 1,000,000 (e.g., $2M = $2,000,000)

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GLOSSARY

1,2-DCE	cis-1,2-dichloroethene
AFB	air force base
Ag	silver
ARAR	applicable or relevant and appropriate requirement
As	arsenic
Ba	barium
bgl	below ground level
BTEX	benzene, toluene, ethylbenzene, and xylene(s)
Cd	cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cfm	cubic feet (or foot) per minute
Cr	chromium
DRMO	Defense Reutilization and Marketing Office
EPA	U.S. Environmental Protection Agency
ESLs	Effects Screening Levels [used by the Texas Air Control Board]
ft/day	feet (or foot) per day
g/L	gram(s) per liter
gpm	gallon(s) per minute
IRP	Installation Restoration Program
lb/day	pound(s) per day
lb/hr	pound(s) per hour
MCL	maximum contaminant level (established under the Safe Drinking Water Act)
mg/L	milligram(s) per liter

GLOSSARY (con't)

NPDES	National Pollutant Discharge Elimination System
O&M	operating and maintenance
Pb	lead
POTW	publicly owned treatment works
RAO	remedial action objective
ROD	Record of Decision
Se	selenium
TACB	Texas Air Control Board
TCE	trichloroethene
TPH	total petroleum hydrocarbon(s)
TWC	Texas Water Commission
VOC	volatile organic compound
μg/L	microgram(s) per liter

APPENDIX A

Cost Estimates

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Cost estimates for each of the alternatives are presented in Tables A-1 and A-8. The cost estimates encompass both capital costs and operating and maintenance costs. In addition, a present worth analysis was performed. In conducting the present worth analysis, the following assumptions were made: as recommended by CERCLA guidance, a discount rate of 5 percent was used. A 30 year period of performance was used to calculate the present worth of annual O&M costs. The present value costs for each remedial alternative assume that all design, permitting, and construction occurs within the first year of remediation. Pumps and equipment will require replacement every 10 years. Construction costs are for labor and material costs only. A 1.4 multiplier was used to estimate contractor overhead and profit. The accuracy of these "study estimate" costs is expected to be within 50 percent. The costs presented were developed from Means Site Work Cost Data, 1990, 95th Annual Edition, and from vendor quotes.

TABLE A-1
COST ESTIMATE FOR ALTERNATIVE 1 (No-Action) SITE LF01

OPERATION AND MAINTENANCE COSTS

	Total Cost ($) / Year 0-30 Years
Ground-Water Monitoring System	
Semi-Annual Sampling and Analysis 5 Wells @ $5000/well	25,000

Total Annual Operation and Maintenance Cost	25,000

NET PRESENT VALUE

Present Value of Operation and Maintenance Cost	384,311
	===========
TOTAL PRESENT VALUE	384,311

TABLE A-2

COST ESTIMATE FOR ALTERNATIVE 1 (No-Action) SITE SD13

OPERATION AND MAINTENANCE COSTS

	Total Cost ($) / Year 0-30 Years
Ground-Water Monitoring System	
Semi-Annual Sampling and Analysis 4 Wells @ $3600/well	14,400
4 Surface Water Stations @ $2,700/Point	10,800
Total Annual Operation and Maintenance Cost	25,200

NET PRESENT VALUE

Present Value of Operation and Maintenance Cost	387,386
TOTAL PRESENT VALUE	387,386

TABLE A-3

COST ESTIMATE FOR ALTERNATIVE 1 (No-Action) SITE ST14

Capital Costs	Units	Qty	Unit Price ($)	Total Cost ($)
Additional Mon Wells	Ea	5	2,000	10,000
Additional Well SUBTOTAL				10,000
Multiplier				1.4
TOTAL				14,000
CONSTRUCTION SUBTOTAL				14,000

Percentage of Total Cost

	Percentages	
Bid Contignencies	15	2,100
Scope Contingencies	25	3,500
Construction Total		19,600
Permitting and Legal	5	980
Bonding and Insurance	3	588
Service During Construction	4	784
Miscellaneous Lab Testing	5	980
Total Implementation Cost		22,932
Engineering Design	15	3,440
Total Capital Cost		26,372

OPERATION AND MAINTENANCE COSTS

	Total Cost ($) / Year 0-30 Years
Ground-Water Monitoring System	
Semi-Annual Sampling and Analysis 14 Wells @ $3800/well	53,200

Total Annual Operation and Maintenance Cost	53,200

NET PRESENT VALUE

Capital Cost	26,372
Present Value of Operation and Maintenance Cost	817,814
	==========
TOTAL PRESENT VALUE	844,186

TABLE A-4

COST ESTIMATE FOR ALTERNATIVE 4A SITE ST14

Capital Costs	Units	Qty	Unit Price ($)	Total Cost ($)
Ground Water Withdrawal System				
Extraction Well	Ea	1	2,000	2,000
Well Pump	Ea	1	2,500	2,500
Plastic Dual Wall Pipe and fittings	LF	250	32.00	8,000
Excavation Backfill (1' wide, 3' deep)	LF	250	2.45	613
Withdrawal System SUBTOTAL				13,113
Multiplier				1.4
TOTAL				18,358
Ground-water treatment system				
Oil Water Separator	Ea	1	38,000	38,000
Air Stripping Tower	Ea	1	50,000	50,000
Liquid Circ. Pump	Ea	1	3,550	3,550
Gas Blower	Ea	1	20,000	20,000
Storage Tank	Ea	1	7,500	7,500
Controls & Plumbing	Ea	1	20,000	20,000
Containament Pad	Ea	1	10,000	10,000
Sched 80 PVC - 2" pipe and fittings	LF	670	4.40	2,948
Excavation Backfill (1' wide, 3' deep)	LF	670	2.45	1,642
Boring for 2" pipe (100' minimum)	LF	100	12.14	1,214
Jacking Pit Prep	Ea	1	8,000	8,000
Ground-water treatment System SUBTOTAL				162,854
Multiplier				1.4
TOTAL				227,995

Treated Water Injection System				
Injection Wells	Ea	2	2,000	4,000
Injection Pumps	Ea	2	3,500	7,000
Injection System SUBTOTAL				11,000
Multiplier				1.4
TOTAL				15,400
Additional Mon Wells	Ea	5	2,000	10,000
Additional Well SUBTOTAL				10,000
Multiplier				1.4
TOTAL				14,000
CONSTRUCTION SUBTOTAL				275,752

Percentage of Total Cost

	Percentages	
Bid Contignencies	15	41,363
Scope Contingencies	25	68,938
Construction Total		386,053
Permitting and Legal	3	11,582
Bonding and Insurance	3	11,582
Service During Construction	4	15,442
Miscellaneous Lab Testing	5	19,303
Total Implementation Cost		443,961
Engineering Design	15	66,594
Total Capital Cost		510,556

OPERATION AND MAINTENANCE COSTS

	Total Cost($) / Year 0-30 Years
Ground-Water Monitoring System	
Quarterly Sampling and Analysis 14 Wells @ $3800/well	53,200
Ground Water Withdrawal System Power (@ .06/Kwh)	
1 Extraction well, 1.5Hp, 100% on-line	550
Labor @ $25/hr, 200hr/yr	5,000
1 Injection Well, 5Hp, 100% on-line	2,000
Air Stripping Treatment System	
Sampling and Analysis of Effluent	10,000
1 Blower(5Hp) & 1 Pump(5Hp) 100% on-line	3,900
Maintenance ($35/hr, 500 hr)	17,500
Annualized Equipment Replacment Cost	
1 Well Pump @ $2500	161
2 Injection Pumps @ $3500/pump	451
1 Circulation Pump @ $ 3550	229
1 Gas Blower @ $20,000	1,289
Total Annual Operation and Maintenance Cost	94,280

NET PRESENT VALUE	
Capital Cost	510,556
Present Value of Operation and Maintenance Cost	1,449,316
TOTAL PRESENT VALUE	1,307,034

TABLE A-5

COST ESTIMATE FOR ALTERNATIVE 4B SITE ST14

Capital Costs	Units	Qty	Unit Price ($)	Total Cost ($)
Ground Water Withdrawal System				
Extraction Well	Ea	1	2,000	2,000
Well Pump	Ea	1	2,500	2,500
Plastic Dual Wall Pipe and fittings	LF	250	32.00	8,000
Excavation Backfill (1' wide, 3' deep)	LF	250	2.45	613
Withdrawal System SUBTOTAL				13,113
Multiplier				1.4
TOTAL				18,358
Ground-water treatment system				
Oil Water Separator	Ea	1	38,000	38,000
Air Stripping Tower	Ea	1	50,000	50,000
Liquid Circ. Pump	Ea	1	3,550	3,550
Gas Blower	Ea	1	20,000	20,000
Storage Tank	Ea	1	7,500	7,500
Controls & Plumbing	Ea	1	20,000	20,000
Containment Pad	Ea	1	10,000	10,000
Excavation Backfill (1' wide, 3' deep)	LF	670	2.45	1,642
Ground-water treatment System SUBTOTAL				150,692
Multiplier				1.4
TOTAL				210,968
Treated Water Transport System				
Manhole to Existing 8" Sewer Line	Ea	1	1,620	1,620
Sched 80 PVC - 4" pipe and fittings	LF	250	7.15	1,788

Excavation Backfill (1' wide, 3' deep)	LF	250	2.45	613
Treated Water Transport System SUBTOTAL				4,020
Multiplier				1.4
TOTAL				5,628
Additonal Mon. Well	Ea	5	2,000	10,000
Additional Well SUBTOTAL				10,000
Multiplier				1.4
TOTAL				14,000
CONSTRUCTION SUBTOTAL				248,954

Percentage of Total Cost

	Percentages	
Bid Contignencies	15	37,343
Scope Contingencies	25	62,238
Construction Total		348,535
Permitting and Legal	5	17,427
Bonding and Insurance	3	10,456
Service During Construction	4	13,941
Miscellaneous Lab Testing	5	17,427
Total Implementation Cost		407,786
Engineering Design	15	61,168
Total Capital Cost		468,954

OPERATION AND MAINTENANCE COSTS

	Total Cost ($)/Year 0-30 Years
Ground-Water Monitoring System	
Quarterly Sampling and Analysis 14 Wells @ $3800/well	53,200
Ground Water Withdrawal System Power (@ .06/Kwh)	
1 Extraction well, 1.5Hp, 100% on-line	550
Labor @ $25/hr, 200hr/yr	5,000
Air Stripping Treatment System	
Sampling and Analysis of Effluent	10,000
1 Blower(5Hp) & 1 Pump(5Hp) 100% on-line	3,900
Maintenance ($35/hr, 500 hr)	17,500
Annualized Equipment Replacment Cost	
1 Well Pump @ $2500	161
1 Circulation Pump @ $ 3550	229
1 Gas Blower @ $20,000	1,289
Total Annual Operation and Maintenance Cost	91,829

NET PRESENT VALUE

Capital Cost	468,954
Present Value of Operation and Maintenance Cost	1,411,636
TOTAL PRESENT VALUE	1,880,590

TABLE A-6

COST ESTIMATE FOR ALTERNATIVE 5 SITE ST14

Capital Costs	Units	Qty	Unit Price ($)	Total Cost ($)
Ground Water Withdrawal System				
Extraction Well	Ea	1	2,000	2,000
Well Pump	Ea	1	2,500	2,500
Plastic Dual Wall Pipe and fittings	LF	250	32.00	8,000
Excavation Backfill (1' wide, 3' deep)	LF	250	2.45	613
Boring for 2" pipe (100' minimum)	LF	100	12.14	1,214
Jacking Pit Prep	Ea	1	8,000	8,000
Withdrawal System SUBTOTAL				22,327
Multiplier				1.4
TOTAL				31,257
Ground-water treatment system				
Oil Water Separator	Ea	1	38,000	38,000
Microorganism Blending Facility				
Storage Tank	Ea	1	7,500	7,500
Blending Tank	Ea	1	3,000	3,000
Mixer	Ea	1	4,900	4,900
Booster	Ea	1	2,500	2,500
Chemical Feed System	Ea	1	4,600	4,600
Containment Pad	Ea	1	10,000	10,000
Plastic Dual Wall Pipe and fittings	LF	670	32.00	21,440
Excavation Backfill (1' wide, 3' deep)	LF	670	2.45	1,642
Ground-water treatment System SUBTOTAL				93,582
Multiplier				1.4
TOTAL				131,014

Blended Water Injection System

Injection Wells	Ea	2	2,000	4,000
Injection Pumps	Ea	2	3,500	7,000
Injection System SUBTOTAL				11,000
Multiplier				1.4
TOTAL				15,400
Additional Mon Wells	Ea	5	2,000	10,000
Additional Well SUBTOTAL				10,000
Multiplier				1.4
TOTAL				14,000
CONSTRUCTION SUBTOTAL				191,671

Percentage of Total Cost

	Percentages	
Bid Contignencies	15	28,751
Scope Contingencies	25	47,918
Construction Total		268,340
Permitting and Legal	5	13,417
Bonding and Insurance	3	8,050
Service During Construction	4	10,734
Treatability and Misc. Testing	15	40,251
Total Implementation Cost		340,791
Engineering Design	15	51,119
Total Capital Cost		391,910

OPERATION AND MAINTENANCE COSTS

	Total Cost ($)/Year 0-30 Years
Ground-Water Monitoring System	
Quarterly Sampling and Analysis 14 Wells @ $3800/well	53,200
Ground Water Withdrawal System Power (@ .06/Kwh)	
1 Extraction well, 1.5Hp, 100% on-line	550
Labor @ $25/hr, 200hr/yr	5,000
1 Injection Well, 5Hp, 100% on-line	2,000
Microorganism Blending Facility	
Sampling and Analysis of Effluent	10,000
Process Pumps (5Hp),100% on-line	1,950
Mixer (3Hp), 100% on-line	1,200
Chemical Feed (1Hp), 100% on-line	400
Maintenance ($35/hr, 700 hr)	24,500
Annualized Equipment Replacment Cost	
1 Well Pump @ $2500	161
2 Injection Pumps @ $3500/pump	451
1 Booster Pump @ $ 3550	229
1 Mixer @ $4900	316
1 Chemical Feed System @ $4600	296
Total Annual Operation and Maintenance Cost	100,253

NET PRESENT VALUE	
Capital Cost	391,910
Present Value of Operation and Maintenance Cost	1,541,140
	===========
TOTAL PRESENT VALUE	1,933,050

TABLE A-7

COST ESTIMATE FOR ALTERNATE 1 (No-Action) SITE BSS

Capital Costs	Units	Qty	Unit Price ($)	Total Cost ($)
Additional Mon Wells	Ea	4	2,000	8,000
Additional Well SUBTOTAL				8,000
Multiplier				1.4
TOTAL				11,200
CONSTRUCTION SUBTOTAL				11,200

Percentage of Total Cost

	Percentages	
Bid Contignencies	15	1,680
Scope Contingencies	25	2,800
Construction Total		15,680
Permitting and Legal	5	784
Bonding and Insurance	3	470
Service During Construction	4	627
Miscellaneous Lab Testing	5	784
Total Implementation Cost		18,346
Engineering Design	15	2,752
Total Capital Cost		21,097

OPERATION AND MAINTENANCE COSTS

	Total Cost ($) / Year 0-30 Years
Ground-Water Monitoring System	
Semi-Annual Sampling and Analysis 7 Wells @ $3800/well	26,600
Total Annual Operation and Maintenance Cost	26,600

NET PRESENT VALUE

Capital Cost	21,097
Present Value of Operation and Maintenance Cost	408,907
	==========
TOTAL PRESENT VALUE	430,005

TABLE A-8

COST ESTIMATE FOR ALTERNATIVE 2A SITE BSS

Capital Costs	Units	Qty	Unit Price ($)	Total Cost ($)
Ground Water Withdrawal System				
Ground-Water Extraction Trench (3'wide, 10'deep)	100 LF	3	18,000	54,000
Well Pump	Ea	1	2,500	2,500
Plastic Dual Wall Pipe and fittings	LF	200	32.00	6,400
Excavation Backfill (1' wide, 3' deep)	LF	200	2.45	490
Boring for 2" pipe (100' minimum)	LF	100	12.14	1,214
Jacking Pit Prep	Ea	1	8,000	8,000
Withdrawal System SUBTOTAL				72,604
Multiplier				1.4
TOTAL				101,646
Ground-water treatment system				
Air Stripping Tower	Ea	1	50,000	50,000
Liquid Circ. Pump	Ea	1	3,550	3,550
Gas Blower	Ea	1	20,000	20,000
Storage Tank	Ea	1	7,500	7,500
Controls & Plumbing	Ea	1	20,000	20,000
Containment Pad	Ea	1	10,000	10,000
Sched 80 PVC - 2" pipe and fittings	LF	200	4.40	880
Excavation Backfill (1' wide, 3' deep)	LF	200	2.45	490
Ground-water treatment System SUBTOTAL				112,420
Multiplier				1.4
TOTAL				157,388

Treated Water Injection System				
Injection Wells	Ea	2	2,000	4,000
Injection Pumps	Ea	2	3,500	7,000
Injection System SUBTOTAL				11,000
Multiplier				1.4
TOTAL				15400
Additional Mon Wells	Ea	4	2,000	8000
Additional Well SUBTOTAL				8000
Multiplier				1.4
TOTAL				11,200
CONSTRUCTION SUBTOTAL				285,634

Percentage of Total Cost

	Percentages	
Bid Contignencies	15	42,845
Scope Contingencies	25	71,408
Construction Total		399,887
Permitting and Legal	3	11,997
Bonding and Insurance	3	11,997
Service During Construction	4	15,995
Miscellaneous Lab Testing	5	19,994*
Total Implementation Cost		459,870
Engineering Design	15	68,981
Total Capital Cost		528,851

OPERATION AND MAINTENANCE COSTS

	Total Cost ($)/Year 0-30 Years
Ground-Water Monitoring System	
Quarterly Sampling and Analysis 7 Wells @ $3800/well	26,600
Ground Water Withdrawal System Power (@ .06/Kwh)	
1 Sump Pump, 3.0Hp, 70% on-line	850
Labor @ $25/hr, 200hr/yr	5,000
1 Injection Well, 5Hp, 100% on-line	2,000
Air Stripping Treatment System	
Sampling and Analysis of Effluent	10,000
1 Blower(5Hp) & 1 Pump(5Hp) 100% on-line	3,900
Maintenance ($35/hr, 500 hr)	17,500
Annualized Equipment Replacment Cost	
1 Sump Pump @ $2500	161
1 Injection Pumps @ $3500	226
1 Circulation Pump @ $ 3550	229
1 Gas Blower @ $20,000	1,289
Total Annual Operation and Maintenance Cost	67,754

NET PRESENT VALUE

Capital Cost	528,851
Present Value of Operation and Maintenance Cost	1,041,553
TOTAL PRESENT VALUE	1,570,403

TABLE A-9

COST ESTIMATE FOR ALTERNATIVE 2B SITE BSS

Capital Costs	Units	Qty	Unit Price ($)	Total Cost ($)
Ground Water Withdrawal System				
Ground-Water Extraction Trench (3'wide, 10'deep)	100 LF	3	18,000	54,000
Well Pump	Ea	1	2,500	2,500
Plastic Dual Wall Pipe and fittings	LF	200	32	6,400
Excavation Backfill (1' wide, 3' deep)	LF	200	2.45	490
Boring for 2" pipe (100' minimum)	LF	100	12.14	1,214
Jacking Pit Prep	Ea	1	8,000	8,000
Withdrawal System SUBTOTAL				72,604
Multiplier				1.4
TOTAL				101,646
Ground-water treatment system				
Air Stripping Tower	Ea	1	50,000	50,000
Liquid Circ. Pump	Ea	1	3,550	3,550
Gas Blower	Ea	1	20,000	20,000
Storage Tank	Ea	1	7,500	7,500
Controls & Plumbing	Ea	1	20,000	20,000
Containment pad	Ea	1	10000	10,000
Excavation Backfill (1' wide, 3' deep)	LF	200	2.45	490
Ground-water treatment System SUBTOTAL				111,540
Multiplier				1.4
TOTAL				156,156
Treated Groundwater Transport				
Manhole to Existing 8" Sewer Line	Ea	1	1,620	1,620

Sched 80 PVC - 4" pipe and fittings	LF	200	7.15	1,430
Excavation Backfill (1' wide, 3' deep)	LF	200	2.45	490

Treated Water Transport System SUBTOTAL				3,540
Multiplier				1.4

TOTAL				4,956
Additional Mon Wells	Ea	4	2,000	8,000

Additional Well SUBTOTAL				8,000
Multiplier				1.4

TOTAL				11,200
CONSTRUCTION SUBTOTAL				273,958

Percentage of Total Cost

	Percentages	
Bid Contingencies	15	41,094
Scope Contingencies	25	68,489

Construction Total		383,541
Permitting and Legal	5	19,177
Bonding and Insurance	3	11,506
Service During Construction	4	15,342
Miscellaneous Lab Testing	5	19,177

Total Implementation Cost		448,743
Engineering Design	15	67,311

Total Capital Cost		516,054

OPERATION AND MAINTENANCE COSTS

	Total Cost ($) / Year 0-30 Years
Ground-Water Monitoring System	
Semi-Annual Sampling and Analysis 7 Wells @ $3800/well	26,600
Ground Water Withdrawal System Power (@ .06/Kwh)	
1 Sump Pump, 3.0Hp, 70% on-line	850
Labor @ $25/hr, 200hr/yr	5,000
Air Stripping Treatment System	
Sampling and Analysis of Effluent	10,000
1 Blower(5Hp) and 1 Pump(5Hp100% on-line	3,900
Maintenance ($35/hr, 500 hr)	17,500
Annualized Equipment Replacment Cost	
1 Sump Pump @ $2500	161
1 Circulation Pump @ $ 3550	229
1 Gas Blower @ $20,000	1,289
Total Annual Operation and Maintenance Cost	65,529

NET PRESENT VALUE

Capital Cost	516,054
Present Value of Operation and Maintenance Cost	1,007,340
TOTAL PRESENT VALUE	1,523,394

TABLE A-10

COST ESTIMATE FOR ALTERNATIVE 3 SITE BSS

Capital Costs	Units	Qty	Unit Price ($)	Total Cost ($)
Ground Water Withdrawal System				
Ground-Water Extraction Trench (3'wide, 10'deep)	100 LF	3	18,000	54,000
Well Pump	Ea	1	2,500	2,500
Plastic Dual Wall Pipe and fittings	LF	200	32.00	6,400
Excavation Backfill (1-foot wide, 3-foot deep)	LF	200	2.45	490
Withdrawal System SUBTOTAL				63,390
Multiplier				1.4
TOTAL				88,746
Ground-water treatment system				
Microorganism Blending Facility				
Storage Tank	Ea	1	7,500	7,500
Blending Tank	Ea	1	3,000	3,000
Mixer	Ea	1	4,900	4,900
Booster	Ea	1	2,500	2,500
Chemical Feed System	Ea	1	4,600	4,600
Containment Pad	Ea	1	10,000	10,000
Plastic Dual Wall Pipe and fittings	LF	200	32.00	6,400
Excavation Backfill (1' wide, 3' deep)	LF	200	2.45	490
Boring for 2" pipe (100' minimum)	LF	100	12.14	1,214
Jacking Pit Prep	Ea	1	8,000	8,000
Ground-water treatment System SUBTOTAL				48,604
Multiplier				1.4
TOTAL				68,046

Blended Water Injection System				
Injection Wells	Ea	1	2,000	2,000
Injection Pumps	Ea	1	3,500	3,500
Injection System SUBTOTAL				5,500
Multiplier				1.4
TOTAL				7,700
Additional Mon Wells	Ea	4	2,000	8,000
Additional Well SUBTOTAL				8,000
Multiplier				1.4
TOTAL				11,200
CONSTRUCTION SUBTOTAL				175,692

Percentage of Total Cost

	Percentages	
Bid Contignencies	15	26,354
Scope Contingencies	25	43,923
Construction Total		245,968
Permitting and Legal	5	12,298
Bonding and Insurance	3	7,379
Service During Construction	4	9,839
Treatability and Misc. Testing	15	36,895
Total Implementation Cost		312,380
Engineering Design	15	46,857
Total Capital Cost		359,237

OPERATION AND MAINTENANCE COSTS

	Total Cost ($) / Year 0-30 Years
Ground-Water Monitoring System	
Semi-Annual Sampling and Analysis 7 Wells @ $3800/well	26,600
Ground Water Withdrawal System Power (@ .06/Kwh)	
1 Sump Pump, 3.0Hp, 70% on-line	850
Labor @ $25/hr, 200hr/yr	5,000
1 Injection Well, 5Hp, 100% on-line	2,000
Air Stripping Treatment System	
Sampling and Analysis of Effluent	10,000
1 Blower(5Hp) & 1 Pump(5Hp) 100% on-line	3,900
Maintenance ($35/hr, 500 hr)	17,500
Annualized Equipment Replacment Cost	
1 Well Pump @ $2500	161
1 Injection Pumps @ $3500	226
1 Booster Pump @ $ 3550	229
1 Mixer @ $4900	316
1 Chemical Feed System @ $4600	296
Total Annual Operation and Maintenance Cost	67,078

NET PRESENT VALUE

Capital Cost	359,237
Present Value of Operation and Maintenance Cost	1,031,150
TOTAL PRESENT VALUE	1,390,386

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ADMINISTRATIVE RECORD

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