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REMEDIAL INVESTIGATION AND PRELIMINARY ASSESSMENT SITE INSPECTION
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RUST GEOTECH

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**NAVAL AIR STATION
FORT WORTH JRB
CARSWELL FIELD
TEXAS**

**ADMINISTRATIVE RECORD
COVER SHEET**

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Air Force Plant 4

Remedial Investigation and Preliminary Assessment/ Site Inspection Report

Volume I

September 1995

Prepared for
U.S. Department of the Air Force
Headquarters Aeronautical Systems Center
Wright-Patterson Air Force Base, Ohio



Submitted by Rust Geotech under
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Air Force Plant 4

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Under DOE Contract No. DE-AC04-86ID12584 with the
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Grand Junction Projects Office
Grand Junction, Colorado

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List of Acronyms

ASC	Aeronautical Systems Center
ASD	Aeronautical Systems Division
atm	atmospheres
ATSDR	Agency for Toxic Substances and Disease Registry
BTEX	benzene, toluene, ethylbenzene, and xylene
CAFB	Carswell Air Force Base
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
cm/hr	centimeters per hour
cm/sec	centimeters per second
COCs	chemicals of concern
CoPCs	contaminants of potential concern
Corps	Army Corps of Engineers
CRDL	Contract Required Detection Limit
CWM	Chemical Waste Management
DCA	dichloroethane
DCE	dichloroethene
DCP	dichloropropane
DDD	p,p'-dichlorodiphenyldichloroethane
DDE	p,p'-dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DNAPL	dense nonaqueous phase liquid
DOE	U.S. Department of Energy
DOE-GJPO	U.S. Department of Energy Grand Junction Projects Office
DOT	U.S. Department of Transportation
DYCP	Die Yard Chemical Pits
Eh	oxygen and oxidation-reduction potential
EN	essential nutrients
EP	extraction procedure
EPA	Environmental Protection Agency
f_{oc}	organic carbon content
FDTA-2	Fire Department Training Area No. 2
FDTA-5	Fire Department Training Area No. 5
FDTA-6	Fire Department Training Area No. 6
FEMA	Federal Emergency Management Agency
FFA	Federal Facility Agreement
FFSA	Former Fuel Storage Area
FS	Feasibility Study
FSA-1	Fuel Saturation Area No. 1
FSA-2	Fuel Saturation Area No. 2
FSA-3	Fuel Saturation Area No. 3

FSA	Fuel Saturation Area
ft	feet
ft/day	feet per day
ft/d	feet per day
ft ² /day	square feet per day
gc/ms	gas chromatography/mass spectrometry
GD	General Dynamics
Geotech	Chem-Nuclear Geotech, Inc.
H	Henry's Law constant
HARM	Hazard Assessment Rating Methodology
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient
i.d.	inside diameter
ICP	inductively coupled plasma
ICRP	International Commission on Radiation Protection
IDL	instrument detection limit
ILCR	incremental lifetime cancer risks
in	inches
IRP	Installation Restoration Program
JETS	Jet Engine Test Stand
K	hydraulic conductivity
kg	kilogram
K_h	horizontal hydraulic conductivity
K_{oc}	organic carbon/water partition coefficient
K_{ow}	octanol/water partition coefficient
K_z	vertical hydraulic conductivity
LNAPLs	light nonaqueous phase liquids
LOAEL	lowest observed adverse effect level
$\log K_{oc}$	logarithm of K_{oc}
$\log K_{ow}$	logarithm of K_{ow}
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/kg/d	milligrams per kilogram per day
mgd	million gallons per day
mm	millimeter
mol/L	moles per liter
mol/m ³	moles per cubic meter
MSCL	Mississippi State Chemical Laboratory
MSL	mean sea level
NAPL	nonaqueous phase liquid
NARF	Nuclear Aerospace Research Facility
ng/L	nanograms per liter
NIST	National Institute of Standards and Technology

NOAEL	no observed adverse effect level
NTUs	nephelometric turbidity units
o.d.	outside diameter
PA/SI	Preliminary Assessment/Site Inspection
PAHs	polynuclear aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
pCi/g	pico Curies per gram
PID	photoionization detector
Plant 4	Air Force Plant No. 4
ppm	parts per million
PPMTL	priority-pollutant metals
PQL	practical quantitation limit
QA/QC	quality assurance/quality control
RoPCs	receptors of potential concern
RI/FS	Remedial Investigation/Feasibility Study
RME	reasonable maximum exposure
RSD	relative standard deviation
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
semi-VOCs	semivolatile organic compounds
slug tests	single-well aquifer tests
SMCL	secondary maximum contaminant level
SQL	sample quantitation limit
SWMUs	Solid Waste Management Units
TAL	Target Analyte List
TCA	trichloroethane
TCE	trichloroethene
TCL	Target Compound List
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TIC	tentatively identified compounds
TNRCC	Texas Natural Resource Conservation Commission
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TRC	Technical Review Committee
TWC	Texas Water Commission
UCL	upper confidence limit
USAF	United States Air Force
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UST	underground storage tank
V_c	average contaminant velocity
VOCs	volatile organic compounds

WWCB	Waste Water Collection Basin
°C	degrees Celsius
°F	degrees Fahrenheit
ρ_b	bulk density
$\mu\text{g/g}$	micrograms per gram
$\mu\text{g/m}^3$	micrograms per cubic meter
$\mu\text{g/kg}$	micrograms per kilogram
$\mu\text{g/L}$	micrograms per liter

Executive Summary

Environmental contamination was identified at U.S. Air Force Plant No. 4 (Plant 4) through site investigations conducted by the U.S. Air Force (USAF) during the 1980s. As a result, Plant 4 was placed on the U.S. Environmental Protection Agency's (EPA) National Priorities List in August 1990. Pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), the USAF, EPA Region VI, and the Texas Natural Resources Conservation Commission (TNRCC) formerly known as Texas Water Commission (TWC) entered into a Federal Facility Agreement (FFA) in November 1990, to address environmental impacts from past practices at Plant 4. Rust Geotech (Geotech), formerly known as Chem-Nuclear Geotech, Inc., operating contractor for the U.S. Department of Energy Grand Junction Projects Office (DOE-GJPO), through a Memorandum of Agreement between the U.S. Air Force and the U.S. Department of Energy (DOE), prepared a Preliminary Assessment/Site Inspection (PA/SI) and Remedial Investigation/Feasibility Study (RI/FS) Work Plan that was approved in October 1990.

This report summarizes the RI/PA/SI activities undertaken in accordance with the Work Plan (UNC Geotech 1990) and presents RI/PA/SI results. The purpose of the PA/SI activities was to delineate possible contaminant source areas beneath the Assembly Building/Parts Plant and investigate the locations of previously removed underground storage tanks. The purpose of the RI activities was to characterize the nature and extent of contamination at Plant 4 and to assess the potential risk to human health and the environment associated with the contamination. The results of the RI and the risk assessment provide the basis for an assessment of appropriate remedial actions that will be presented in a Feasibility Study (FS) report.

Plant 4 is an aircraft manufacturing facility located in Tarrant County, Texas, 7 miles northwest of the city of Fort Worth. The plant is bounded by Lake Worth on the north, Carswell Air Force Base (CAFB) on the east, the community of White Settlement on the south and west, and the city of Fort Worth on the west. The facility occupies 602 acres and employs approximately 19,200 people. The facility has been in operation since 1942 and currently produces F-16 aircraft, radar units, and various aircraft and missile components.

Historically, the manufacturing processes at Plant 4 have generated an estimated 5,500 to 6,000 tons of waste oils, fuels, solvents, paint residues, and spent process chemicals per year. These wastes were disposed on site by burial in landfills, burning, or discharge into pits or the sanitary sewer system. A waste treatment plant was constructed in the early 1970s to treat the process chemical solutions, rinse waters and other waste waters, and solvents. Some wastes, such as paint residues and process cyanide solutions, were later disposed off site by a contractor, while waste oils and fuels continued to be disposed in

on-site landfills or burned during fire training exercises. In the late 1970s, the burning of fuels for fire training exercises was phased out and all waste oils and recoverable solvents have since been disposed off-site by a contractor. Currently, through waste minimization techniques, the off-site disposal of wastes is less than 2,500 tons per year.

A search of historical records performed by CH2M Hill, Inc., in 1984 identified 20 hazardous spill and waste disposal sites at Plant 4. Subsequent investigations identified 11 additional sites (Table ES-1). Based on previous investigations, seven of these 31 sites require no further action, and decision documents have been generated. One additional site also falls into this category but the documentation has not been prepared. The 23 remaining sites include industrial processing areas, fuel storage areas, landfills, known chemical and fuel spills, chemical disposal pits, fire training areas, an interim remedial action location, and the Assembly Building/Parts Plant (Figure ES-1). On Figure ES-1, underground storage tanks (USTs) No. 19 and No. 24B and the French Drain are shown but are not listed as separate sites. The French Drain is located between Landfills No. 1 and No. 3. All RI/FS geographical information is shown in Plate 1. Although previous studies had identified contaminants at each of the sites, the extent and nature of the contamination had not been fully assessed. Remedial actions were implemented at some sites, but no investigations were previously performed to assess the success of these actions. It was also recognized that additional information was needed to assess potential pathways of contaminant migration from the identified sites.

Data collection requirements for characterizing Plant 4 are identified in the Work Plan (UNC Geotech 1990). Site characterization activities were implemented in three phases. Phase I included a review of the existing data and preparation of planning documents. During Phase II, soil-gas surveys were conducted to provide initial screening of sites and to guide subsequent surface and subsurface investigations. Phase III included drilling soil borings; installing monitoring wells; and collecting soil, water, stream sediment, lake sediment, air, and ecological samples for chemical analyses. The standard suite of analyses included target compound list volatile and semivolatile organic compounds, priority pollutant metals, total petroleum hydrocarbons, and oil and grease. Other characterization activities included geologic and lithologic mapping, bedrock coring, groundwater elevation measurements, and aquifer testing.

Existing data were reviewed during Phase I and used to prepare planning documents in support of PA/SI and RI/FS activities at Plant 4. The planning documents prepared by Geotech included the *Work Plan*, *Sampling and Analysis Plan*, *Quality Assurance Project Plan*, and *Health and Safety Plan*. These documents were reviewed by the Aeronautical Systems Center (ASC), EPA Region VI, and TWC and approved in October 1990.

Phase II soil-gas investigations were conducted in 1990 around the perimeter of the Assembly Building/Parts Plant and Fuel Saturation Areas No. 1, No. 2, and No. 3. Two analytical techniques were used to analyze soil-gas samples: gas chromatography/mass spectrometry (gc/ms) and specific indicator detectors.

Table ES-1 Air Force Plant 4 Investigation Sites

Title
Landfill No. 1 (Site LF01)
Landfill No. 2 (Site LF02)*
Landfill No. 3 (Site LF03)
Landfill No. 4 (Site LF04)
Fire Department Training Area No. 2 (Site FT05)
Fire Department Training Area No. 3 (Site FT06)*
Fire Department Training Area No. 4 (Site FT07)*
Fire Department Training Area No. 5 (Site FT08)
Fire Department Training Area No. 6 (Site FT09)
Chrome Pit No. 1 (Site DP10)*
Chrome Pit No. 2 (Site DP11)*
Chrome Pit No. 3 (Site DP12)
Die Yard Chemical Pits (Site DP13)
Fuel Saturation Area No. 1 (Site SS14)
Fuel Saturation Area No. 2 (Site SS15)
Fuel Saturation Area No. 3 (Site SS16)
Former Fuel Storage Area (Site SS17)
Solvent Lines (Site SS18)*
Nuclear Aerospace Research Facility (Site OT19)*
Waste Water Collection Basins (Site WP20)
West Compass Rose (Site OT21)*
East Parking Lot/Flightline (Site OT22)
French Drain (Site OT23)
Jet Engine Test Stand (Site OT24)
Underground Storage Tank No. 19 (Site ST25)
Underground Storage Tank No. 20 (Site ST26)
Underground Storage Tank No. 24A (Site ST27)
Underground Storage Tank No. 24B (Site ST28)
Underground Storage Tank No. 25A (Site ST29)
Underground Storage Tank No. 30 (Site ST30)
Assembly Building/Parts Plant Perimeter

* Site is in process for no further action documentation. See Appendix K for current documentation.

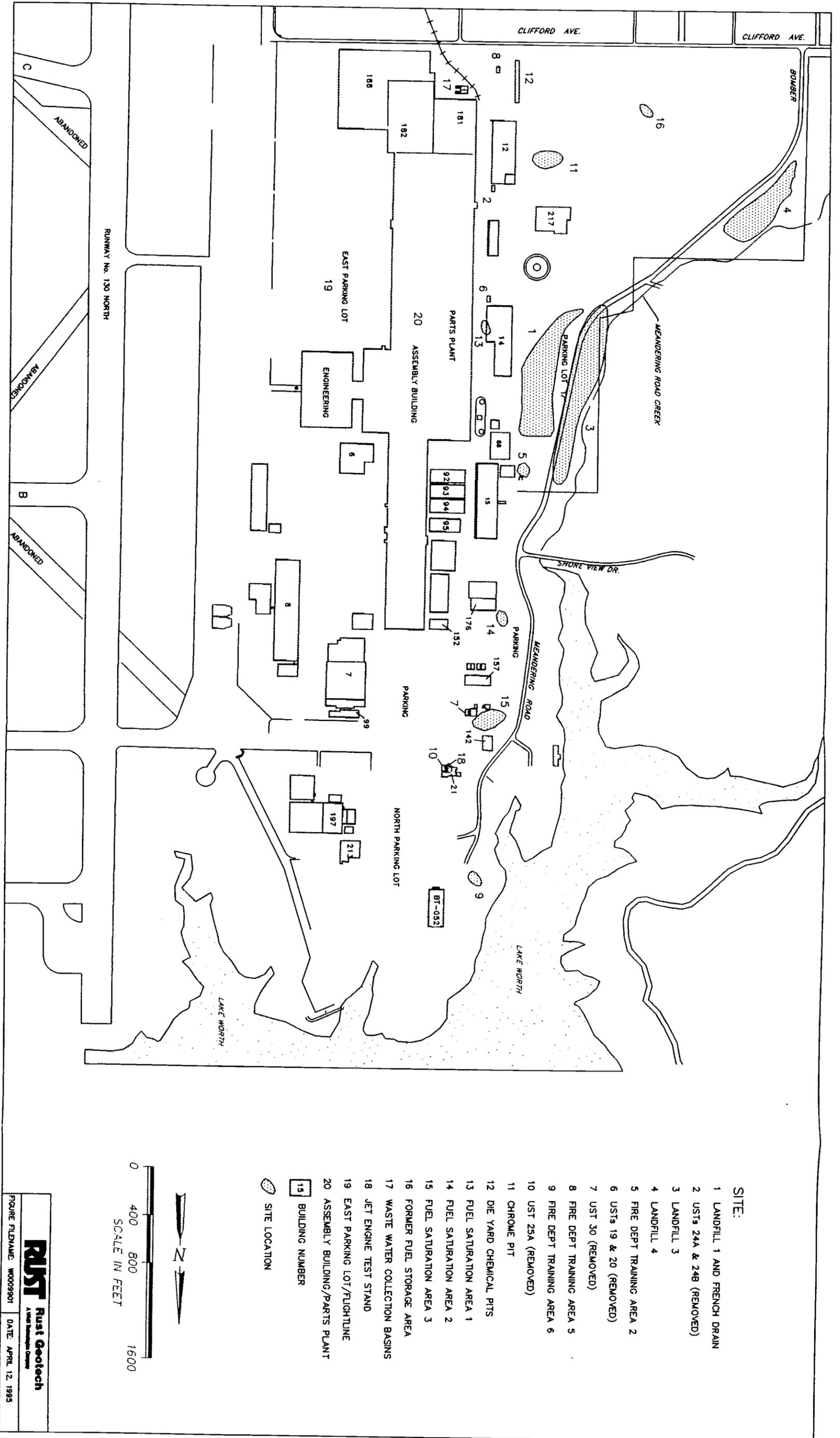


Figure ES-1. RI/FS Investigation Sites.

Phase III field activities began in early February 1991 and continued through mid-May 1992. Data collected during this time period were combined with quarterly monitoring results obtained between February 1990 and March 1991 to assess the nature and extent of contamination at Plant 4. A total of 168 soil borings were drilled and 43 monitoring wells were installed. Thirty-eight monitoring wells were installed in the alluvial aquifer (also referred to as the upper-zone flow system) and 5 wells were installed in the Paluxy Formation. Four off-site locations were sampled to assess if contaminants originating at Plant 4 were migrating across the facility boundary.

Approximately 2,500 soil samples were collected for chemical analysis from the RI soil borings. Locations for the soil borings and wells were selected to meet the technical data requirements for each site investigation and have a minimal effect on facility operations.

The RI monitoring wells and five existing wells were sampled in two rounds during September and October 1991. Analytical results of the two sampling rounds were evaluated and compared for redundancy of data. On the basis of these evaluations, a third sampling round was deemed unnecessary. Groundwater elevations were measured at 199 Plant 4 monitoring wells that were accessible during the September 1991 sampling round. Continuous water-level recorders were placed in five monitoring wells in September 1991 and were downloaded in November 1991 and January, June, and December 1992 at which time they were removed from the wells. Single-well aquifer tests (slug tests) were conducted at 32 Plant 4 monitoring wells. Wells that recovered quickly were typically tested two or three times to evaluate reproducibility of the results.

Surface-water samples were collected from 11 locations along Meandering Road Creek (directly west of and adjacent to Plant 4) during the RI. Data from these locations were combined with analytical results obtained for samples collected prior to the RI from an additional six creek locations and one seep location to assess the nature and extent of surface-water contamination in the vicinity of Plant 4. Stream-sediment samples were also collected during the RI at seven surface-water sampling locations along the creek.

Surface-water samples were also collected from nine locations on Lake Worth. Except for two samples, all samples were collected along the Lake Worth shoreline corresponding to the northern boundary of Plant 4. One background sample location was selected west of Plant 4 and north of the community of White Settlement. Lake sediment samples were collected from 22 locations in Lake Worth: three from each of six surface-water inlets and four from intermediate locations. Sediment samples were also collected from the background location west of Plant 4. In addition to the standard suite of analytes, selected samples were analyzed for polynuclear aromatic hydrocarbons, polychlorinated biphenyls, and organochlorines (pesticides).

One surface-water sample was collected in October 1991 from Farmers Branch, a small tributary of the West Fork of the Trinity River that originates south of Plant 4. This sample was obtained at the outfall of the aqueduct that conveys water under the runway at CAFB.

Tissue samples from mosquito fish netted from five locations along Lake Worth and in Meandering Road Creek were analyzed for polynuclear aromatic hydrocarbons, polychlorinated biphenyls, organochlorines, and metals. One sampling location selected as a background site was located on Live Oak Creek approximately 3 miles west of the facility. The tissue sampling effort was conducted with the assistance of U.S. Fish and Wildlife Service personnel.

Toxicity tests were conducted on surface-water samples collected from three locations in creeks upgradient of Lake Worth to assess the effects of the water on living organisms. Two sampling sites were located on Meandering Road Creek (one upgradient of the Plant 4 facility and one downgradient of several waste disposal sites). The third sampling site was located on Live Oak Creek and represents background lake conditions.

Air samples were collected from two locations: one at Plant 4 and the other approximately 0.75 mile west of the facility. Sampling was conducted during a 14-week period beginning in mid-February 1992. Samples were collected every 6 days and analyzed for both volatile organic compounds (VOCs) and particulates.

Data collected during the RI were used, in part, to assess hydrogeologic conditions at Plant 4. The hydrogeologic system at Plant 4 consists of three primary components: (1) the upper-zone flow system, (2) the Walnut Formation aquitard, and (3) the Paluxy Aquifer. The upper-zone flow system is the uppermost groundwater unit at Plant 4 and is characterized by water-table conditions, hydraulic conductivities ranging from 10^{-6} to 10^{-1} centimeters per second (cm/sec), and a major groundwater divide extending north to south beneath the Assembly Building/Parts Plant. The upper-zone flow system is underlain by the shale and limestone of the Goodland Limestone and the Walnut Formation. Recharge to the upper zone occurs as infiltration of precipitation and leakage from water supply lines, sewer lines, and fire prevention water lines. Discharge from the upper zone occurs as seepage to Meandering Road Creek for groundwater flowing to the west and as baseflow to the West Fork of the Trinity River and Farmers Branch for groundwater flowing to the east.

Discharge from the upper zone to the Paluxy Aquifer occurs in the vicinity of the "window area" beneath the East Parking Lot. The window area is located in the vicinity of monitoring wells HM-86 and P-15US. The term "window area" refers to an area where the Goodland Limestone is absent and the Walnut Formation is thin (and may be absent) because of past deep erosion of the bedrock caused by former channels of West Fork of the Trinity River. Elsewhere in the Plant 4 area, the aquitard formed by the Goodland Limestone and Walnut Formation is relatively thick, commonly 30 feet or

greater. The hydraulic conductivity of the Walnut Formation ranges from 10^{-11} to 10^{-9} cm/sec based on the results of triaxial-cell tests conducted on core samples.

The Paluxy Aquifer underlies the Walnut Formation and is composed of sandstone with interbedded siltstone, claystone, and shale. This aquifer, which is approximately 160 feet thick, is a major source of municipal water for the community of White Settlement and elsewhere in Tarrant County. The Paluxy Aquifer is recharged by precipitation on the formation outcrop to the west, infiltration of water from Lake Worth and Eagle Mountain Lake, and leakage from the upper zone in the vicinity of the window area. Leakage into the Paluxy Aquifer may also occur in the lower reaches of Meandering Road Creek. Discharge from the Paluxy Aquifer occurs as withdrawals from pumping wells and base flow into the western portions of Lake Worth and Eagle Mountain Lake.

Because the Paluxy Aquifer is a significant source of municipal water supplies, the contaminant migration pathways associated with this system are of the greatest concern. A hydraulic head map based on water-level data obtained from field measurements, published reports, and mathematical groundwater flow simulations shows that the regional groundwater flow direction in the Paluxy Aquifer is oriented in an easterly direction. In the vicinity of Plant 4, local groundwater flow directions range from southeasterly to southwesterly. These local flow directions are the result of recharge from Lake Worth and pumping from municipal supply wells located south and west of the facility. Local groundwater flow directions suggest that White Settlement supply wells WS-2, WS-H3, and WS-12 are the nearest potential receptors for contamination in the Paluxy Aquifer in the vicinity of Plant 4.

Site characterization performed at Plant 4 indicates that groundwater contamination consists of VOCs, some semivolatile organic compounds (semi-VOCs), and inorganic compounds. The most prevalent VOC is trichloroethene (TCE) and to a lesser extent 1,1,1-trichloroethane (TCA). Also common in the groundwater are the environmental degradation byproducts of these compounds including *cis*- and *trans*-1,2-dichloroethene (DCE), 1,1-DCE, and vinyl chloride. Other organic solvent compounds such as methylene chloride; acetone; and the fuel-related compounds benzene, toluene, ethylbenzene, and xylene were also detected in various concentrations. Semivolatile organic compounds detected in the groundwater have included 1,2 dichlorobenzene; 1,4-dichlorobenzene; naphthalene; 2-methylnaphthalene; and 2,4-dimethylphenol.

The highest concentrations of groundwater contamination occur near source areas. TCE concentrations approaching saturation were detected in the groundwater samples from wells in the south central part of Plant 4, where numerous potential sources exist, and near Fire Department Training Area No. 2 (FDTA-2). The highest concentrations of TCE are present in the upper-zone groundwater flow system. Plumes of decreasing concentrations of TCE, TCA, and their degradation products extend along the groundwater flow direction in the upper zone. The East Parking Lot Plume originates at the south-central and west-central parts of Plant 4 and extends in an easterly direction to

beyond the property line, onto CAFB. Potential sources for the East Parking Lot Plume include Chrome Pits No. 1, No. 2, and No. 3; the Die Yard Chemical Pits (DYCP); Fire Department Training Area No. 5 (FDTA-5); and degreaser tanks T-534 and T-544 located within Building 181 at the eastern part of the Fuel Saturation Area No. 1 (FSA-1); and dense nonaqueous phase liquid (DNAPL) from FDTA-2. The extent and shape of the plume is controlled by the presence of a buried paleochannel that cuts through the Goodland Limestone and into the Walnut Formation. The West Plume originates near Landfill No. 1 and the west part of FSA-1, and extends in a westerly direction toward Meandering Road Creek. The FDTA-2 source area is located within, and contributes dissolved-phase contamination to, the West Plume. Adjacent to the Jet Engine Test Stand (JETS), the North Plume contains VOCs in excess of MCLs.

Contamination is introduced into the Paluxy Formation primarily through vertical leakage from the upper-zone flow system in the vicinity of the East Parking Lot window area. Samples from monitoring wells completed in the upper portion of the Paluxy Formation in the vicinity of the window area contain relatively high concentrations (up to 2,100 $\mu\text{g/L}$) of TCE. Estimates of the volumetric flux into the Paluxy Formation range from one to several hundred cubic feet per day. Assuming the TCE concentration in leaking groundwater is 20,000 micrograms per liter (typical of upper zone wells in the window area), an estimate of the mass flux is 0.00025 to 0.025 ounces per day. Because the uppermost Paluxy Formation is variably saturated within the Plant 4 area, vertical migration of contamination to the fully saturated portions of the Paluxy Formation is a function of the unsaturated hydraulic conductivity. Little contamination has migrated to the fully saturated portions of the Paluxy Formation because the unsaturated hydraulic conductivity is relatively low.

Chromium is the most prevalent inorganic priority pollutant detected above the maximum contaminant level (MCL) in samples from upper-zone groundwater. Limited detections of six other priority pollutants in upper-zone groundwater (antimony, arsenic, cadmium, lead, nickel, and thallium) slightly exceed their respective MCLs. Aluminum, manganese, and iron frequently exceed secondary drinking water standards.

Aluminum was detected above the secondary MCL in a groundwater sample collected from the Paluxy Formation monitoring well P-08US located in the window area of the East Parking Lot Plume. Elevated aluminum values in this area are potentially the result of vertical leakage from the upper-zone system. Evidence supporting this position is provided by several nearby monitoring wells completed in the upper-zone system that exhibit elevated aluminum concentrations.

Surface-water contamination in the vicinity of Plant 4 is primarily associated with Meandering Road Creek. The highest contamination identified in the creek results from elevated concentrations of VOCs. The primary VOCs of concern included TCE, *cis*-1,2-DCE, 1,2-DCE, and vinyl chloride. Discharge of contaminated upper-zone groundwater into the creek is the most likely source for VOC contamination. Lower

concentrations of other contaminants, including one semi-VOC (4-methylphenol), total petroleum hydrocarbons (TPH), and oil and grease, were reported as isolated occurrences in the creek during the RI. In addition to upper-zone groundwater, other potential sources for this contamination are surface-water runoff and storm-sewer discharge.

The only target analyte reported in surface-water samples collected from Lake Worth was carbon disulfide. Carbon disulfide was detected in samples obtained at three locations along the northern boundary of Plant 4. The magnitude of the concentrations reported and the distribution of sampling sites suggest that sources for the contamination are probably not related but located near the points of sample collection.

One surface-water sample was collected from Farmers Branch at the outfall of the aqueduct that conveys water under the runway at CAFB. Analytical results for this sample indicated that no VOCs and only low concentrations of metals were present in Farmers Branch at this location.

TCE is the most prevalent VOC in soils. Widespread occurrence of this compound, at relatively low concentrations, is associated with saturated soils under the south end of the Assembly Building, the East Parking Lot area, and at least as far as Runway Number 130 North. Relatively low concentrations of TCE were detected in vadose-zone soils from the DYCP, FDTA-2, and Landfill No. 4. Relatively high concentrations of TCE occur in vadose-zone soil samples only at two sites: Chrome Pit No. 3 and Landfill No. 3. Other VOCs detected less frequently but at relatively high concentrations in soils include toluene, 2-butanone, methylene chloride, and 1-2 DCE. Some or all of these compounds were detected at Landfills No. 1 and No. 3, the former USTs No. 19 and No. 20, and the DYCP.

TPH contamination was detected in soil samples obtained from the JETS, FSA-1, and FSA-3, reflecting JP-4 leaks in underground fuel lines. Semi-VOCs, typically associated with petroleum products, are characteristic of the contamination at these sites. Another group of semi-VOCs that were detected are those typically associated with asphalt. The highest concentrations of these semi-VOC contaminants were detected at Landfills No. 1 and No. 4.

Inorganic soil contamination is characterized by the presence of antimony, cadmium, chromium, copper, lead, nickel, silver, and zinc at concentrations greater than the upper range in natural background. Elevated concentrations of these constituents appear to be limited to Landfills No. 1, No. 3, and No. 4, and the FDTA-2.

Minimal soil contamination was detected at FSA-2 and FDTA-6, and no soil contamination was detected at the Waste Water Collection Basin (WWCB) and Former Fuel Storage Area. Additionally, the WWCBs were examined in June, 1991, when they

were drained and cleaned due to a TCE release. No evidence of cracks were noted in the concrete; however, the liner was missing over much of the WWCB's surface area.

The results of the ambient-air monitoring program conducted at Plant 4 indicated that plant activities are contributing measurable quantities of four VOCs to the air when compared with the respective off-site concentrations measured. Maximum on-site concentrations of dichlorodifluoromethane; Freon 113; 1,1,1-trichloroethane; and trichloroethene ranged from 4 to 14 times greater than the maximum off-site concentrations. Additionally, results of the program indicated that activities at Plant 4 do not contribute measurable quantities of particulates to the air.

A baseline risk assessment was conducted to assess the potential risks associated with possible exposure to contaminants from Plant 4. The objectives of a baseline risk assessment are to (1) evaluate the need for action, (2) provide a basis for assessing levels of chemicals that can remain on site and still be adequately protective of public health, and (3) provide a basis for comparing various remedial alternatives. The major components of a baseline risk assessment are data collection and evaluation, exposure assessment, toxicity assessment, and risk characterization. The risk assessment conducted for Plant 4 was based on the EPA's *Human Health Evaluation Manual*.

A total of 37 chemicals of potential concern were identified in the samples collected at Plant 4. These chemicals were found most frequently in soils and less frequently in groundwater, air, and surface water. The selection of chemicals of potential concern was based primarily on their frequency of detection (excluding Class A carcinogens) and by comparing their concentrations with background concentrations. Table ES-2 lists the chemicals of potential concern for this risk assessment.

Table ES-2 Chemicals of Potential Concern

● Arsenic	● 1,2-Dichlorobenzene	● Methylphenol
● Barium	● 1,4-Dichlorobenzene	● Naphthalene
● Benzene	● 1,1-Dichloroethane	● Nickel
● Benzo(a)anthracene	● 1,1-Dichloroethene	● Phenanthrene
● Benzo(a)pyrene	● 2,4-Dimethylphenol	● Pyrene
● Benzo(b)fluoranthene	● Ethylbenzene	● Toluene
● Benzo(k)fluoranthene	● Fluoranthene	● 1,1,1-Trichloroethane
● Cadmium	● Freon 113	● Trichloroethene
● Chromium	● Lead	● 1,2,4-Trimethylbenzene
● Chrysene	● Mercury	● 1,3,5-Trimethylbenzene
● <i>cis</i> -1,2-Dichloroethene	● Methylene Chloride	● Vinyl Chloride
● Copper	● 2-methylnaphthalene	● Zinc

The risk assessment examined both current and future exposure pathways. An exposure pathway is considered to be complete if there is a contaminant release to the environment, an environmental transport mechanism, a point of exposure by a receptor,

and a route of exposure. Complete current exposure pathways include dermal contact with contaminated surface water by residents, ingestion and dermal contact with contaminated soil by Plant 4 personnel, and inhalation of contaminated air by Plant 4 personnel. The complete future exposure pathways are: ingestion of groundwater from White Settlement production wells by future residents, inhalation of and dermal contact with organic compounds in groundwater by future residents during showering, and ingestion and dermal contact with contaminated soil by future Plant 4 personnel.

Exposure point concentrations for contaminants in soil and air were based on concentrations measured on site. Future groundwater concentrations were estimated using a conservative analytical groundwater transport model. A cross-media transfer equation was used to calculate concentrations of volatile chemicals in the air during and after showering and a simple dilution model was used to derive exposure point concentrations in surface water.

The most significant carcinogenic risks for the exposure scenarios examined in this risk assessment range from 1×10^{-4} to 1×10^{-3} . This occurred from the future ingestion of groundwater from White Settlement production wells and the future inhalation of volatile compounds during showering with groundwater from White Settlement production wells. TCE is the only chemical that contributes to this risk. Benzo(a)pyrene is the main contributor of risk to current and future land use.

For noncarcinogens, the Hazard Index is 0.5 for current land use and 1.1 for future land use indicating acceptable risk for current land use but unacceptable risk for future land use. This increase in future land use risk is due to ingestion of groundwater.

The Plant 4 ecological risk assessment focused on the relatively natural areas near Meandering Road Creek and Lake Worth. In addition, the risk assessment addressed the aquatic community in Farmers Branch Creek.

Contaminants detected in Landfill Nos. 3 and 4 soils, Meandering Road Creek and Lake Worth surface water, and Meandering Road Creek and Lake Worth sediments were screened to form medium-specific lists of contaminants of potential concern (CoPCs).

Ecological receptors of potential concern (RoPCs) for Plant 4 included the largemouth bass (*Micropterus salmoides*), the red-tailed hawk (*Buteo jamaicensis*), the red fox (*Vulpes fulva*), the raccoon (*Procyon lotor*), terrestrial prey species (i.e. small mammals), and aquatic prey species (i.e. benthic macroinvertebrates and small fish).

Ecological risk was characterized using a weight-of-evidence approach in which food web model data, direct toxicity data, and toxicity test data were considered. In the food web models and direct toxicity assessments, ecological risk was quantified by calculating hazard quotients (HQs) such that HQ equals the measured dose or concentration divided

by an ecotoxicological benchmark value. A hazard quotient that exceeds 1.0 indicates potential ecological risk.

The results of the toxicity tests were inconclusive, so they were not used to quantify risk.

Hazard quotients exceeded 1.0 for mice exposed to soil, for largemouth bass exposed to sediment, and for aquatic organisms exposed to sediments. Hazard quotients did not exceed 1.0 for the red-tailed hawk, the red fox, or the raccoon.

To address ecological risk in Farmers Branch Creek, maximum concentrations of the CoPCs detected in Farmers Branch Creek were compared to concentrations at which the hazard quotient equalled 1.0 in the Meandering Road Creek model. Based on this comparison, no hazard quotients would exceed 1.0 for fish in Farmers Branch Creek. Therefore, it is unlikely that fish in Farmers Branch Creek are at risk from Plant 4 contaminants.

The remedial action objectives for Plant 4 were developed to address the requirements of CERCLA as amended by SARA and are designed to decrease the potential risks to human health and the environment from exposures to contaminants. The primary objective, according to the Baseline Risk Assessment, is to reduce future exposure to groundwater from White Settlement production wells that are contaminated by organic compounds. Two secondary objectives are to reduce contaminant levels in the alluvial groundwater and the Paluxy Aquifer and to remove groundwater contamination sources.

1.0 Introduction

1.1 Purpose and Scope

This RI/PA/SI Report was prepared for the ASC of U.S. Air Force Systems Command, Plant 4, located in Fort Worth, Texas. This report summarizes the results of the RI/PA/SI performed by Rust Geotech, formerly known as Chem-Nuclear Geotech, Inc., operating contractor for DOE-GJPO. This report provides data and information necessary to determine the most appropriate method of cleanup for 31 Installation Restoration Program (IRP) sites at Plant 4.

Geotech conducted the RI/PA/SI under a Memorandum of Agreement between the USAF and DOE following placement of Plant 4 on the National Priorities List in August 1990. The RI/PA/SI was performed in accordance with CERCLA and SARA, the primary pieces of legislation governing remedial action at past hazardous waste disposal sites.

This report includes (1) a description of all field investigation activities and resulting data on the nature and extent of contamination, (2) evaluations of contaminant fate and transport, (3) a baseline risk assessment, and (4) conclusions. A second report currently in progress, the FS, will provide a detailed analysis of remedial action alternatives for cleanup of the Plant 4 sites.

The RI/FS process is designed to ensure that hazardous and/or toxic waste sites are identified, characterized, and remedial actions implemented in a timely and cost-effective manner. The ultimate objective of the RI/FS process is to evaluate and determine the remedial actions that, when implemented, will provide adequate public health and environmental protection.

Past waste disposal or spill sites at Plant 4 investigated under the IRP and/or subsequent RI/PA/SI studies are shown in Plates 1 and 2. Sites included landfills, fire department training areas, chemical disposal pits, areas of past fuel and chemical spills, and leaking underground storage tank areas.

Following an extensive review of data generated during previous investigations, a PA/SI and RI/FS Work Plan was developed and approved by the EPA and the TNRCC. The objectives of the plan were to (1) determine the lateral and vertical extent of contamination at each site; (2) identify the "pathways" or mechanisms through which contamination might affect humans or the natural environment; (3) assess the risk or harm to health, safety, public welfare, and the environment from the current conditions at Plant 4; (4) develop, screen, and evaluate a range of alternatives to reduce or eliminate the possible effects of contamination on humans or the natural environment at

Plant 4; (5) assess the human and environmental impacts of the remedial action alternatives for each site; and (6) prepare "No Further Action" decision documents for those sites where the data indicate that the site does not pose a threat to humans or the natural environment. The plan was approved in August 1990 and field data collection was performed during 1990 and 1991.

1.2 Site Background

1.2.1 Site Description

1.2.1.1 Location

The Plant 4 facility is located in Tarrant County, Texas, 7 miles northwest of the city of Fort Worth (see Figure 1.2.1-1). Plant 4 is bounded on the north by Lake Worth, on the east by CAFB, on the west by the city of Fort Worth, and on the south and west by the city of White Settlement.

1.2.1.2 Industrial Setting

Plant 4 occupies 602 acres and employs approximately 19,200 people in various positions pertaining to aircraft manufacturing and associated processes. The current work force is down from the 1989 maximum of approximately 31,500 employees.

Naval Air Station Fort Worth, formerly known as Carswell Air Force Base (CAFB) and hereafter referred to as CAFB in this report, lies directly adjacent to Plant 4 on the east. CAFB occupies about 2,800 acres and is currently on the base realignment and closure list. When the base was active it employed approximately 1,200 military personnel and 300 civilians.

1.2.1.3 Environmental Setting

Plant 4 and the surrounding areas to the south and east are highly urbanized and, consequently, do not contain natural vegetation for wildlife. Approximately 70 percent of the Plant 4 surface area is covered by buildings, concrete, or asphalt. The remaining 30 percent of the surface area is primarily grass-covered soils located on the radar range, Landfills No. 3 and No. 4, along Meandering Road Creek, and along the shores of Lake Worth. The area to the west-northwest of Plant 4 contains primarily residential lots with an abundance of natural vegetation. Lake Worth, located north of Plant 4, provides recreational boating, fishing, and water skiing. The lake also provides municipal water to the city of Fort Worth and is a recharge source to the underlying Paluxy Aquifer that provides municipal water to the city of White Settlement.

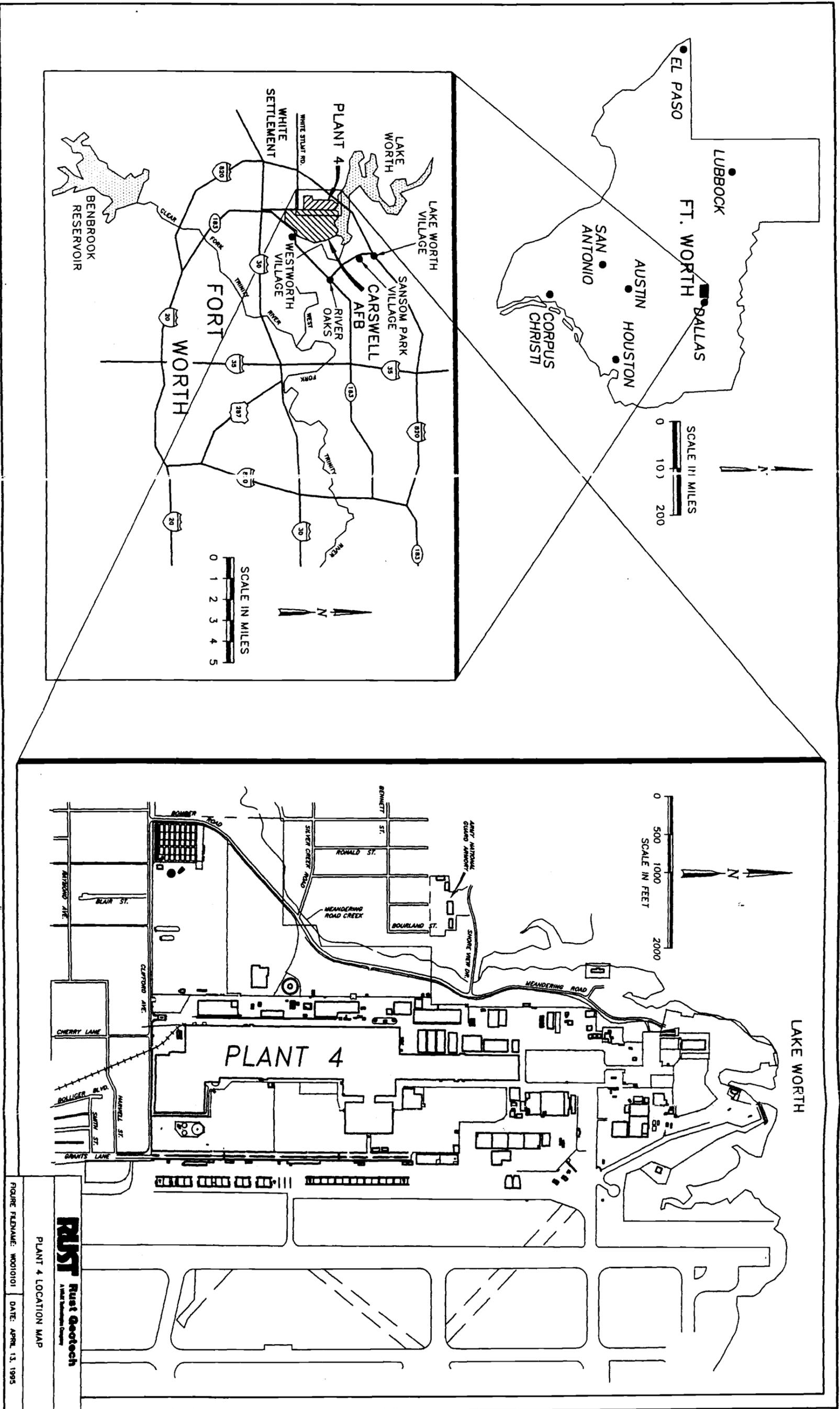


Figure 1.2.1-1. Plant 4 Location Map.

RUST Rust Geotech
 A Rust Technology Company

PLANT 4 LOCATION MAP

FIGURE FILENAME: W0010101 DATE: APRIL 13, 1995

1.2.2 Site History

Plant 4 became operational in 1942 when Consolidated Aircraft began manufacturing the B-24 bomber for national defense during World War II. In 1953, General Dynamics (GD) took over operation of the manufacturing facility. Since 1953, Plant 4 has produced B-36, B-58, and F-111 aircraft, and currently produces F-16 aircraft. In addition to F-16 aircraft, Plant 4 produces spare parts, radar units, and missile components. On March 1, 1993, Lockheed, Fort Worth Company, took over operations of Plant 4 as a successor to GD.

Manufacturing operations at Plant 4 have resulted in the generation of various hazardous wastes that include waste oils, fuels, spent solvents, paint residues, and spent process chemicals. Throughout most of the plant's history, waste oil, solvents, and fuels were disposed at on-site landfills or were burned during fire training exercises. Chemical wastes were initially discharged to the sanitary sewer system and treated by the city of Fort Worth's treatment system. In the 1970s, chemical process wastes were treated on site at a newly constructed chemical waste treatment system prior to being discharged to the sanitary sewer system. Currently, waste oils and solvents are disposed by a contractor, and burning of these wastes has been discontinued. Chemical wastes continue to be treated on site.

1.2.3 Previous Investigations

Potential contamination at Plant 4 was first noted by a private citizen in September 1982. GD was notified and took immediate action. The source of the observed contamination was thought to be leachate from a landfill. In October 1982, GD began construction of French Drain Number 1 to prevent migration of contaminated groundwater toward Meandering Road Creek and divert the flow of surface water from the outfall where the contamination was first noted.

In November 1982, ASC (formerly Aeronautical Systems Division [ASD]), through GD, retained Hargis & Montgomery, Inc., to investigate the potential for groundwater contamination at Plant 4. Hargis & Montgomery and later Hargis + Associates, Inc., drilled approximately 260 soil borings, of which approximately 160 were constructed as monitoring wells. Results of these investigations are contained within several reports (Hargis & Montgomery 1983; Hargis + Associates 1985a-c, 1987a-b, 1988a-b).

The IRP for Plant 4 was initiated in March 1984 when CH2M Hill, Inc., conducted a Phase I Records Search (CH2M Hill 1984). CH2M Hill ranked 20 identified disposal sites in August 1984 according to the USAF Hazard Assessment Rating Methodology (HARM).

The Army Corps of Engineers (Corps) was retained in June 1985 to further delineate groundwater conditions along the southern base boundary and the East Parking Lot area of Plant 4. The Corps drilled 28 soil borings and constructed six monitoring wells (U.S. Army Corps of Engineers 1986).

Radian Corporation (Radian) was retained in September 1985 to perform the Phase II, Stage I, Confirmation/Quantification of the IRP. Radian drilled 26 soil borings and constructed 14 groundwater monitoring wells. Additional work included a confirmation sampling round of all existing monitoring wells. A summary report of field investigations performed during the IRP Phase II, Stage 1, Confirmation/Quantification studies was prepared (Radian Corporation 1987).

In December 1985, Intellus Corporation was contracted to conduct an IRP Phase IV Remedial Action Plan for 10 potential disposal sites and a Phase IV-A Remedial Action Plan and Phase IV-B Design and Construction for Fuel Saturation Areas Numbers 1 and 3. In support of these tasks, Intellus Corporation drilled 36 soil borings and constructed 24 groundwater monitoring wells (Intellus Corporation 1986a-b and 1987).

A Technical Review Committee (TRC) for Plant 4 was established in 1983. The TRC consists of representatives from the EPA Region VI; the TWC; the city of Fort Worth; the city of White Settlement; the USAF; the Corps; and Lockheed. Periodic TRC meetings have been held since 1983 to keep the local authorities and the community informed of Remedial Investigations at Plant 4.

1.3 Report Organization

This report summarizes the results of Preliminary Assessment/Site Inspection and Remedial Investigation studies performed by the DOE-GJPO at Plant 4 and incorporates the results of previous IRP investigations, where appropriate, to provide a basis for remedial decisions under the CERCLA of 1980. This report generally follows the format suggested in the EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, October 1988.

2.0 Field Investigations

2.1 General Investigation Methods

The investigation for the PA/SI and RI/FS was based on the findings and recommendations of previous investigations conducted by Hargis & Montgomery, Hargis + Associates, the Corps, Intellus Corporation, and Radian Corporation. A work plan (UNC Geotech 1990) was prepared that detailed the recommendations and decision rationale for conducting fieldwork, performing a risk assessment, developing potential remedial responses, and determining data quality objectives. A *Final Sampling and Analysis Plan*, a *Final Health and Safety Plan*, and a *Final Quality Assurance Plan* were also prepared for Plant 4 in August 1990 to provide guidance for the field investigation. Table 2.1-1 presents a summary of previous environmental investigations at Plant 4. Plate 3 presents locations of soil borings and monitoring wells established during previous investigations.

The sections that follow describe field investigation activities for areas at Plant 4 known or suspected to contain hazardous contamination that required additional information on the type and extent of contaminants. Figure 2.1-1 shows the investigated sites. Plate 1 shows all sites which include:

- Landfill No. 1 (Site LF01)
- Landfill No. 2 (Site LF02)*
- Landfill No. 3 (Site LF03)
- Landfill No. 4 (Site LF04)
- Fire Department Training Area No. 2 (Site FT05)
- Fire Department Training Area No. 3 (Site FT06)*
- Fire Department Training Area No. 4 (Site FT07)*
- Fire Department Training Area No. 5 (Site FT08)
- Fire Department Training Area No. 6 (Site FT09)
- Chrome Pit No. 1 (Site DP10)*
- Chrome Pit No. 2 (Site DP11)*
- Chrome Pit No. 3 (Site DP12)
- Die Yard Chemical Pits (Site DP13)
- Fuel Saturation Area No. 1 (Site SS14)
- Fuel Saturation Area No. 2 (Site SS15)
- Fuel Saturation Area No. 3 (Site SS16)
- Former Fuel Storage Site (Site SS17)
- Solvent Lines (Site SS18)*
- Nuclear Aerospace Research Facility (Site OT19)*
- Waste Water Collection Basins (Site WP20)
- West Compass Rose (Site OT21)*

- East Parking Lot/Flightline (Site OT22)
- French Drain (Site OT23)
- Jet Engine Test Stand (Site OT24)
- Underground Storage Tank No. 19 (Site ST25)
- Underground Storage Tank No. 20 (Site ST26)
- Underground Storage Tank No. 24A (Site ST27)
- Underground Storage Tank No. 24B (Site ST28)
- Underground Storage Tank No. 25A (Site ST29)
- Underground Storage Tank No. 30 (Site ST30)
- Assembly Building/Parts Plant Perimeter

* Site is in process for no further action documentation. See Appendix N for current documentation.

Additional figures and tables are included that show the sampling locations, sample numbers, and analyses performed. Sections describing general methods, sample handling, data, and document management precede discussions of specific sampling sites.

Results of the field investigation were used in the evaluation of (1) the presence or absence and relative concentrations of contaminants at the waste sites, (2) the vertical and lateral extent of contamination, and (3) the potential pathways for the migration of contaminants within the environment. Results of prior investigations were used to aid in the evaluation of current site conditions if the data were acceptable. When prior data were used, the data source was specified in the Section 4 site evaluation.

2.1.1 Soil-Gas Survey

Soil-gas surveys were conducted at four sites: the Assembly Building/Parts Plant and the three Fuel Saturation Areas (FSAs). Samples were collected from a nominal depth of 4 feet using hollow, stainless steel drive rods and drive points. Soil-gas measurements were made initially using a calibrated Photovac TIP II photoionization detector to determine the presence of VOCs. A sorbent tube was attached to the drive rod and a low-volume sampling pump was used to pull a measured volume of soil gas through the sorbent tube. Sorbent tubes were analyzed by the Geotech laboratory by thermal desorption into a GC/MS. Colorimetric indicator detectors were used to measure TPH at the FSAs. Colorimetric detectors were also used at selected locations to detect possible VOCs such as benzene or vinyl chloride. Sorbent tubes were also used at each FSA to collect representative samples for laboratory VOC analysis.

Each location selected for soil-gas sampling was checked against Plant 4 underground utility maps, approved by GD Facility Engineering personnel, and then verified by Geotech utility locators with instruments. Locations were selected on the basis of meeting the data quality objectives while having a minimal impact on daily plant operations.

Table 2.1-1 Prior Investigations at Plant 4

Prior Investigation	Die Yard Chemical Pits
Phase I Investigation, Drilling and Construction of Upper Zone Test Holes and Monitoring Wells, Hargis & Montgomery, January 31, 1983	Test Holes TH-1 through TH-8
Phase I Investigation of Subsurface Conditions at Plant 4, Hargis & Montgomery, February 3, 1983	Monitoring Wells HM-3a, HM-3b, HM-4a, HM-4b, Test Hole TH-3
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Monitoring Wells HM-12, HM-24, HM-25, HM-28
Ten-Site Field Investigation, Plant 4, Intellus Corporation, November 1986	Soil Borings FB-9, FB-10 Monitoring Well F-221
Construction Site Assessment for the Die Yard Zone, Intellus Corporation, January 1987	
Prior Investigation	FSA-1
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Monitoring Wells HM-53, HM-55, Paluxy Wells P-6U, P-6M
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	Soil Boring SB-4
Draft Remedial Action Plan and Conceptual Documents for Fuel Saturation Areas Nos. 1 and 3, Intellus Corporation, July 1986	Monitoring Wells F-203, F-204, F-206, F-207, F-211
Prior Investigation	FSA-2
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Monitoring Well HM-80
Ten-Site Investigation Plant 4, Intellus Corporation, November 1986	FB-4, Soil Boring inside fence near HM-80, Monitoring Well F-212
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	Soil Borings SB-1, SB-2, SB-3
Prior Investigation	FSA-3
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Monitoring Well HM-78
Draft Remedial Action Plan and Conceptual Documents for Fuel Saturation Areas Nos. 1 and 3, Intellus Corporation, July 1986	Monitoring Wells F-200, F-201, F-202, F-208, F-210, F-222, F-223 (not documented)
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	
Evaluation of Condenser Water Pipeline and Remedial Measures, Fuel Saturation Area No. 3, Hargis + Associates, July 15, 1988	Temporary Monitoring Wells FSA 3-1 to FSA 3-12 (FSA 3-5 and FSA 3-9 were soil borings)
Summary of Interim Remedial Investigations, January 1987 to April 1989, Plant 4, Hargis + Associates, July 19, 1989	
Analysis of USTs at Plant 4, Forth Worth, TX, Vol III, Hargis + Associates, June 2, 1989	UST 25A, UST 30
Final Draft Work Plan RI/FS Plant 4, Hargis Volume II, Appendices C-I, January 31, 1989	F-222 and F-223 discussed
Prior Investigation	FDTA-2
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 15, 1985	HM-51, HM-66
Ten-Site Field Investigation, Plant 4, Intellus Corporation, November 1986	Install F-213; Test Boring FB-7
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	Terrain Conductivity Survey

Table 2.1-1 (continued) Prior Investigations at Plant 4

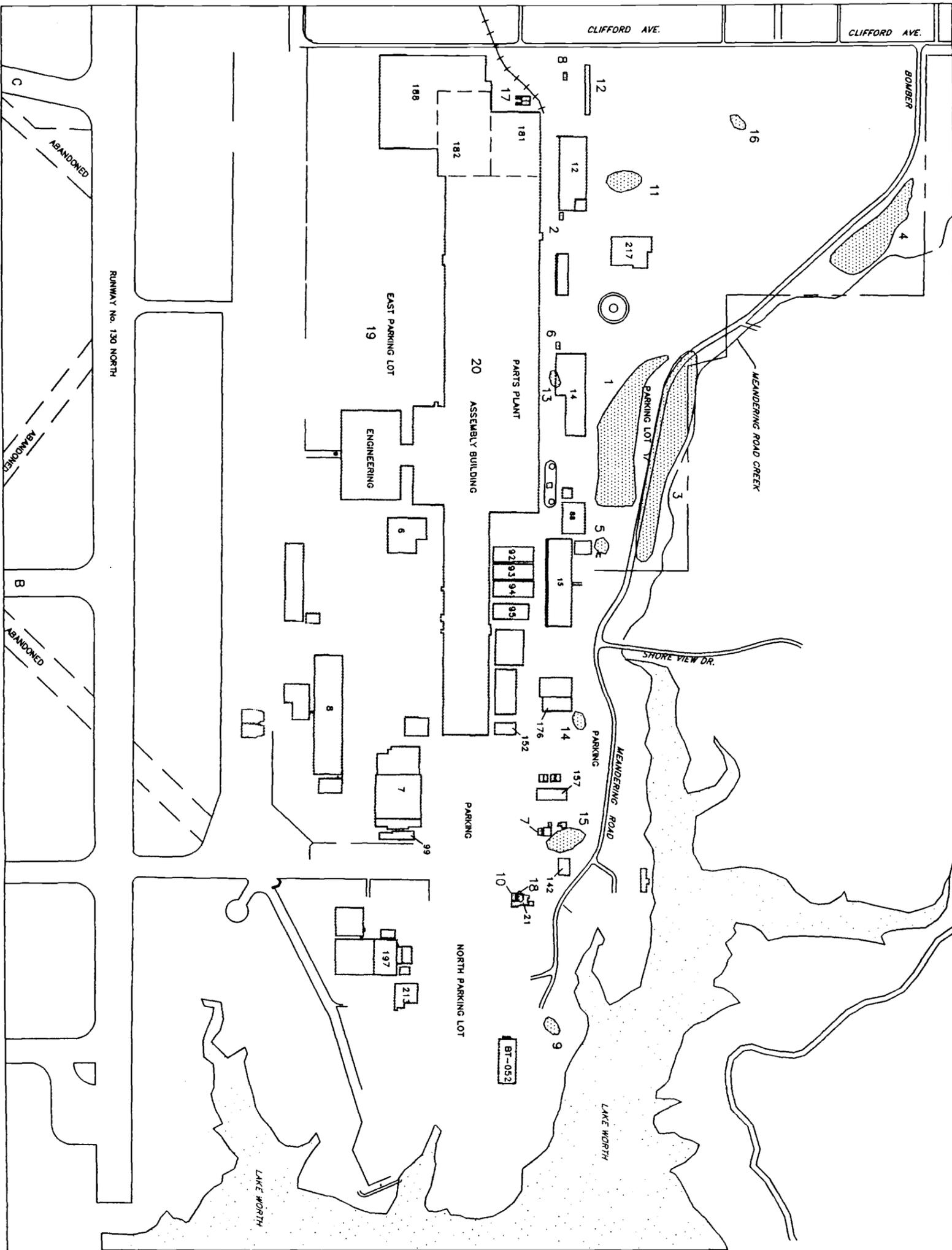
Prior Investigation	FDTA-5
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Monitoring Well HM-25 (Also with DYCP)
Construction Site Assessment for the Die Yard Zone, Intellus Corporation, January 1987	
Ten-Site Field Investigation, Plant 4, Intellus Corporation, November 1986	Install F-221
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	Soil Borings SB-5
Prior Investigation	FDTA-6
Phase I Investigation of Subsurface Contamination at Plant 4, Hargis & Montgomery, February 3, 1983	Test Hole 26, Paluxy Well P-3
Ten-Site Field Investigation, Plant 4, Intellus Corporation, November 1986	Test Borings FB-1, FB-2, FB-3
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	Hand Auger 6 Test Holes, HA-1 to HA-6
Prior Investigation	Chrome Pit No. 3
Phase I Investigation of Subsurface Contamination at Plant 4, Hargis & Montgomery, February 3, 1983	Monitoring Well HM-1
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Monitoring Wells HM-15, HM-16, HM-17, HM-30; Paluxy Well P-2
Ten-Site Field Investigation, Plant 4, Intellus Corporation, November 1986	Soil Boring FB-8, Monitoring Well F-222
Collection and Analysis of Soil Samples, Versar, Inc., January 20, 1990	11 Soil Borings, X-1 through X-11
Prior Investigation	Former Fuel Storage Area
Phase I Investigation, Drilling and Construction of Test Holes and Monitoring Wells, Hargis & Montgomery, January 31, 1983	Test Hole TH-9
Phase I Investigation of Subsurface Contamination at Plant 4, Hargis & Montgomery, February 3, 1983	Monitoring Well HM-8
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	Monitoring Well HM-100
Prior Investigation	Jet Engine Test Stand
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Monitoring Well HM-81
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	Monitoring Wells HM-105, HM-107, HM-108; Soil Borings SB-9, SB-10
Prior Investigation	Landfill No. 1
Assess Subsurface Conditions, General Dynamics Corporation, November 1982, No Report	Test Holes GDC-1 and GDC-3 through GDC-11
Phase I Investigation, Drilling, and Construction of Test Holes and Monitoring Wells, Hargis & Montgomery, January 31, 1983	Test Holes TH-10 and TH-20 through TH-25
Phase I Investigation of Subsurface Contamination at Plant 4, Hargis & Montgomery, February 3, 1983	Monitoring Wells HM-6, HM-7, HM-10
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Drainpipe-1982; French Drain 1-November 1982; French Drain 2-August 1983; Monitoring Wells HM-18, HM-19, HM-49, HM-50, HM-62; Paluxy Wells P-4, P-7U, P-7M
Ten-Site Field Investigation, Plant 4, Intellus Corporation, November 1986	2 Monitoring Wells - September 1986; F-216, F-127

Table 2.1-1 (continued) Prior Investigations at Plant 4

IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	1 Paluxy Well, Creek Sampling, 5 locations
Prior Investigation	Landfill No. 2
Phase I Investigation of Subsurface Contamination at Plant 4, Hargis & Montgomery, February 3, 1983	Monitoring Well IIM-2
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Monitoring Wells HM-42, HM-43, HM-46
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	Paluxy Well P-21U Geophysical Survey - Conductivity
Prior Investigation	Landfill No. 3
Assess Subsurface Conditions, General Dynamics Corporation, November 1982, No Report	Test Holes GDC-2, GDC-12, GDC-13
Phase I Investigation, Drilling and Construction of Test Holes and Monitoring Wells, Hargis & Montgomery, January 31, 1983	Test Holes TH-11 through TH-19 (suspected Burn Pit)
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Monitoring Wells HM-21, HM-26, HM-27, HM-34, HM-35, HM-36, HM-37, HM-38, HM-39; Paluxy Well P-10U, P-10M
Ten-Site Field Investigation, Plant 4, Intellus Corporation, November 1986	2 Test Holes, FB-11, 12; 1 Monitoring Well, F-214
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	1 Paluxy Well P-22U; Geophysical Survey - Conductivity
Summary of Interim Remedial Investigations, January 1987 to April 1989, Hargis + Associates, July 19, 1989	3 Paluxy Wells P-22M, P-24U & P-24M
Prior Investigation	Landfill No. 4
Phase I Investigation of Subsurface Contamination at Plant 4, Hargis & Montgomery, February 3, 1983	2 Monitoring Wells, HM-5, HM-9
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	Paluxy Well P-20M, Monitoring Well HM-101
Prior Investigation	East Parking Lot
Drilling of Miscellaneous Test Holes, Foundation Tests, etc., Prior to Hargis Phase I (See Hargis Phase I, Appendix III)	Foundation Test Borings SL-4 through SL-26 and SL-41 through SL-47 for Engineering Building; SL-38, SL-39, SL-40 for Building 189
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Monitoring Well HM-67, HM-68, HM-82
Investigation of Groundwater Pollution at Plant 4, U.S. Army Corps of Engineers, October 1986	28 Soil Borings in East Parking Lot
Summary of Interim Remedial Investigations, January 1987 to April 1989 Plant 4, Hargis + Associates, July 19, 1989	Soil Borings RSB-1 to RSB-15; Monitoring Wells HM-87 to HM-97 (October 1987); Soil Gas Survey, Seismic Survey; Soil Borings RSB-16 to RSB-33; Monitoring Wells HM-98, HM-99, HM-110 to HM-113, March 1988; Soil Borings RSB-34 to RSB-66 (December 1988); Monitoring Wells HM-114 to HM-127 (Jan./Feb. 1989); Paluxy Well P-8US, P-8UN (July 1987), P-11US, P-13US (Aug. 1987), P-15US, P-15U, P-16US, P-17US (Aug. 1987), P-18US, P-19US (March 1988)

Table 2.1-1 (continued) Prior Investigations at Plant 4

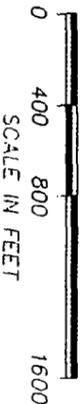
Prior Investigation	Waste Water Collection Basins
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Monitoring Well HM-47
Ten-Site Field Investigation, Plant 4, Intellus Corporation, November 1986	Soil Borings FB-5, FB-6 (CP-2)
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	Monitoring Well HM-104
Prior Investigation	Assembly Building/Parts Plant
Drilling of Miscellaneous Test Holes, Foundation Tests, etc., Prior to Hargis Phase I (See Hargis Phase I, Appendix III)	Foundation Tests 1942 to 1952; Austin Co. AC-1, AC-4, AC-5, AC-6, AC-12, AC-14, AC-15, AC-16, AC-17; Foundation Tests 1964 to 1967; Southwest Labs SL-27 to SL-37 - Materials Storage Building
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	Monitoring Wells HM-31, HM-47, HM-48; HM-52, HM-55, HM-56, HM-57, HM-58, HM-59, HM-64, HM-69, HM-70; Paluxy Monitoring Wells P-5U, P-5M, P-6U, P-6M, P-9U, P-9M; Paluxy Wells P-12U, P-12M
Ten-Site Field Investigation, Plant 4, Intellus Corporation, November 1986	2 Soil Borings FB-5, FB-6; 2 Monitoring Wells F-218, F-219
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	2 Monitoring Wells, HM-103, HM-104
Summary of Interim Remedial Investigations, January 1987 to April 1989 Plant 4, Hargis + Associates, July 1989	6 New Paluxy Completions, Paluxy Wells P-5UN, P-9UN, P-US, P-9US, P-12US, P-U, P-9U, P-12U; Abandoned P-12UN
Prior Investigation	UST (Removed)
Analysis of USTs at Plant 4, Forth Worth, TX, Vol III, Hargis + Associates, June 2, 1989	Description of Tank Status
Prior Investigation	Background Activities
Phase I Investigation of Subsurface Contamination at Plant 4, Hargis & Montgomery, February 3, 1983	EPA Wells 1, 2, 3, 4, May 31 to June 2, 1983, Hargis, 1983b
Phase II Investigation of Subsurface Contamination at Plant 4, Hargis + Associates, September 25, 1985	
IRP Phase II Confirmation/Quantification Stage I, Radian Corporation, December 1987	Paluxy Well P-23U
Prior Investigation	Other Areas
Results of Soil and Groundwater Assessment for the Proposed Systems Development Laboratory and Anechoic Chamber Buildings, Hargis + Associates, Inc., December 16, 1985	3 Monitoring Wells, HM-83, HM-84, HM-85 (near West Compass Rose); 24 Soil Borings, SB-1 through SB-24
Environmental Assessment, Advanced Materials Development Laboratory Site, Hargis + Associates, Inc., October 20, 1989	7 Soil Borings (southwest of Landfill No. 2)



SITE:

- 1 LANDFILL 1 AND FRENCH DRAIN
- 2 UTS 24A & 24B (REMOVED)
- 3 LANDFILL 3
- 4 LANDFILL 4
- 5 FIRE DEPT TRAINING AREA 2
- 6 UTS 19 & 20 (REMOVED)
- 7 UST 30 (REMOVED)
- 8 FIRE DEPT TRAINING AREA 5
- 9 FIRE DEPT TRAINING AREA 6
- 10 UST 25A (REMOVED)
- 11 CHROME PIT
- 12 DIE YARD CHEMICAL PITS
- 13 FUEL SATURATION AREA 1
- 14 FUEL SATURATION AREA 2
- 15 FUEL SATURATION AREA 3
- 16 FORMER FUEL STORAGE AREA
- 17 WASTE WATER COLLECTION BASINS
- 18 JET ENGINE TEST STAND
- 19 EAST PARKING LOT/FLIGHTLINE
- 20 ASSEMBLY BUILDING/PARTS PLANT
- 15 BUILDING NUMBER

● SITE LOCATION



RUST Rust Geotech
A Hunt Technologies Company

FIGURE FILENAME: W0007301 DATE: APRIL 12, 1995

Figure 2.1-1. RI/FS Investigation Sites.

2.1.2 Surface Soil Sampling

Prior to sampling, the immediate area to be sampled was cleaned of debris and litter. A barrel auger (hand operated) was used to penetrate surface and near-surface soil to the desired depth to obtain a sample for analysis. Samples were generally collected from 0 to 2 feet. The sampling equipment consisted of a stainless steel auger bit attached to a stainless steel rod and a "T" handle. The auger bit was used to bore a hole to the desired depth and withdrawn. The barrel portion of the auger bit held the soil cuttings and eliminated contact with the sidewall of the borehole, which minimized the potential for contaminating the sample with soil from other sections of the borehole.

As the sample barrel was lifted from the borehole, the sample was scanned with a photoionization detector (PID) to screen for VOCs. Where radioactive materials were expected to be encountered, the sample was scanned with a beta-gamma Geiger-Mueller detector and an alpha scintillometer. These measurements aided in decision-making concerning sample packaging, handling, shipping, and personnel-protection requirements.

Using a stainless steel spoon, the sample material was removed from the auger barrel, placed in a stainless steel tray, and thoroughly mixed prior to bottling. Sample material to be analyzed for VOCs was bottled immediately upon removal from the auger barrel to avoid loss of the VOCs. Following sample collection, the sampling equipment was cleaned by decontamination procedures described in Section 2.1.9.

2.1.3 Lake and Creek Sediment Sampling

Sediment samples were collected to a depth of 2 feet at locations in Lake Worth, Meandering Road Creek, and one background location. A pontoon boat was used to collect sediment samples from the bed of Lake Worth. Sediment sampling depths were limited to approximately 17 feet, which allowed samples to be collected from all locations. Sampling locations were agreed upon by the EPA, the U.S. Fish and Wildlife Service (USFWS), and Geotech.

Sediment samples were collected using a stainless steel hand corer equipped with an eggshell core catcher. A grab sample was collected from each 1-foot interval to a depth of 2 feet and immediately bottled for VOC analysis. The remainder of the sample material from each 1-foot interval was composited for other analyses. Composite samples were collected from within a 3-foot by 3-foot area, as several hand cores were necessary to collect the required volume for all analyses.

The hand corer was pressed into the sediment in a smooth continuous motion, twisted, and then removed from the water. The nosepiece was removed and the sample placed into a stainless steel tray. The sample was transferred into pre-labeled sample containers with stainless steel spoons and preserved as required. Equipment was decontaminated before collecting each sample as discussed in Section 2.1.9.

Samples collected near the Nuclear Aerospace Research Facility (NARF) were field scanned for radioactivity with alpha, beta, and gamma detection equipment to determine any personnel protection or transportation requirements. Samples were then sent out for laboratory analysis.

2.1.4 Lake and Stream Water Sampling

The container immersion method was used to obtain grab samples from Lake Worth and Meandering Road Creek. Temperature, pH, and electrical conductivity were measured at the time of sampling. Field personnel wore disposable gloves and submerged the sample containers below the water surface. If the water was flowing, the bottle was pointed upstream until it was filled to the desired volume. The container was lifted from the water, capped, rinsed with distilled or deionized water, and wiped with a lint-free tissue. Three water samples were collected from a pool in Meandering Road Creek at SW-5 from separate depths: near the surface, mid-level, and about 1 inch from the bottom. The samples were labeled, preserved as required, and analyzed. A disposable bailer was used to collect depth-specific samples. Caution was used to avoid disturbing the bailer during this task. A bottom-emptying device was used to decant the samples.

Seep samples were collected along the Meandering Road Creek drainage between previous seep sampling locations and at any additional seeps present along the drainage at the time of sampling. When required, preservatives were added to the sample bottle. The sample bottle was tilted and the sample poured slowly into the sample container along the side of the bottle.

2.1.5 Drilling and Subsurface Soil Sampling

2.1.5.1 Locating Utilities

At each location where sampling required ground penetration, the site was investigated for underground utilities. Utility maps provided by GD Facility Engineering diagramed the utilities for each sampling area. The utility survey also indicated past activity at each location by labels on piping, conduits, etc.

2.1.5.2 Drilling in Unconsolidated Alluvium

Truck-mounted hollow-stem auger rigs were employed at Plant 4 to conduct the subsurface soil sampling in conjunction with the drilling of groundwater monitoring wells. With the truck-mounted auger rig centered over the sample location, a 140-pound hammer dropped through a distance of 30 inches, or an equivalent hydraulic driver, was used to drive a 3-inch-diameter (o.d.) by 24-inch-long stainless steel split-barrel sampler into the surface material to the desired sample depth. Following retrieval of the surface sample, the hollow-stem augers, with close-fitting center bits, were used to advance the borehole to the next sampling depth.

After reaching the desired depth, the center bit was withdrawn and the split-barrel sampler inserted. The sampler was then driven for 2 feet or until no further penetration was achieved after 50 blows for each 6 inches of penetration.

Drill cuttings and water removed during the drilling process were placed in drums, sealed, and transported to a designated waste storage area for later disposal. Drums were labeled and a drum log was maintained to track the drums.

2.1.5.3 Drilling in Consolidated Rock

Drilling through consolidated rock was conducted to (1) install DNAPL traps, (2) obtain core from the Paluxy Formation, and (3) install monitoring wells in the Paluxy Formation. To install DNAPL traps in alluvial monitoring wells, hollow-stem augers were drilled approximately 2 feet into the Walnut Formation, creating a sump. A section of the well screen was placed into the bedrock to permit the detection of DNAPLs.

The five wells installed in the Paluxy Formation during this investigation were cored from near the top of the Walnut Formation to the bottom of the well. Hollow-stem augers were used to advance the borehole to the top of the Walnut Formation. A rotary bit was used to cut a 12-inch-diameter hole about 5 feet into the Walnut Formation, into which steel casing, extending to the surface, was set and cemented. A small coring rig was used to core the hole to total depth. After coring was completed, the core hole was reamed to permit installation of the monitoring well. A small amount of bentonite drilling mud was required to complete the coring and reaming activities because of the soft siltstones, mudstones, and sandstones encountered in the Paluxy Formation. These holes were flushed with potable water to remove the bentonite prior to installation of the monitoring well. No other drilling additives were used. Selected sections of core were analyzed for vertical hydraulic conductivity, total organic carbon content, organic partition coefficient, and distribution coefficient. All core was described on lithology logs (see Appendix B-2) as it was removed from the borehole and placed in core boxes that were stored at Plant 4.

2.1.5.4 Sampling Unconsolidated Alluvium

Sampling of unconsolidated alluvium was performed by split-barrel sampling. A split-barrel sampler was driven the length of the barrel (2 feet), or until no further penetration was possible. The sampler was carefully removed from the borehole and separated from the drive-rod assembly. The sampler was laid flat on a plastic sheet, and the head and drive shoe were removed. Half of the split-barrel was removed, exposing the sample. The uppermost portion of the sample (slough) was discarded. The sampled interval was screened with a PID while in the split-barrel sampler. Samples to be analyzed for VOCs were removed immediately from the exposed sample. If elevated VOC levels were detected with the PID, that portion of the sample was collected for VOC analysis. The remaining sample material was placed in a stainless steel pan and

was thoroughly mixed prior to bottling. If a discrete section of the core had evidence of visible contamination, the section was sampled without mixing the entire sample volume.

Following each sample collection, the split-barrel was cleaned to avoid cross-contamination of the samples, as specified in Section 2.1.9. Equipment blanks were collected to verify decontamination or to account for possible interferences.

2.1.5.5 Core Sampling in Bedrock

In the five Paluxy monitoring wells (P-27 through P-31), the core was retrieved from the Walnut and Paluxy Formations. After a 12¼-inch-diameter borehole had been drilled approximately 5 feet into the Walnut Formation, casing was set and cemented in the hole. A schematic of construction of a Paluxy Formation monitoring well is presented in Figure 2.1.5-1. The cement was allowed to set for several days and a Mobile Drill Model 53 core rig was then used to core the remainder of the hole. Coring was accomplished using a 10-foot long double tube, swivel-type core barrel that retrieved NX-size (1⅞-inch diameter) core from a 4¼-inch-diameter hole.

Core runs were typically for the entire 10-foot length of the core barrel; however, when core recovery from previous runs was poor (less than 50 percent recovery), core runs of approximately 5 feet were conducted in an attempt to increase core recovery. Immediately after the core was removed from the hole, it was described in the borehole log in terms of rock type, nature and type of cementation, number of fractures present, porosity, bedding characteristics, color, and mineral composition. The core was separated into 2-foot lengths and placed in cardboard core boxes that contained 10 feet of core (in five 2-foot lengths). Each core box was labeled with the hole (well) number and the depth interval contained in each box. The insides of the core boxes were labeled with the beginning and ending depths of each 2-foot core segment. Lost intervals were noted in the borehole log and in the core box by placing 2-inch by 2-inch wooden blocks, labeled with the lost interval depths, at the location of the missing core intervals.

Coring was conducted until the total depth of the hole was reached. During coring, bentonite was occasionally added to water as a thickener to bring up coarse material and clean out the borehole. Core recovery was usually poor in sections of the Paluxy Formation where flowing sands were encountered in saturated, poorly consolidated sandstones. After total depth was reached and coring was completed, the borehole was reamed out to a diameter of 6 to 7⅝ inches in preparation for well completion.

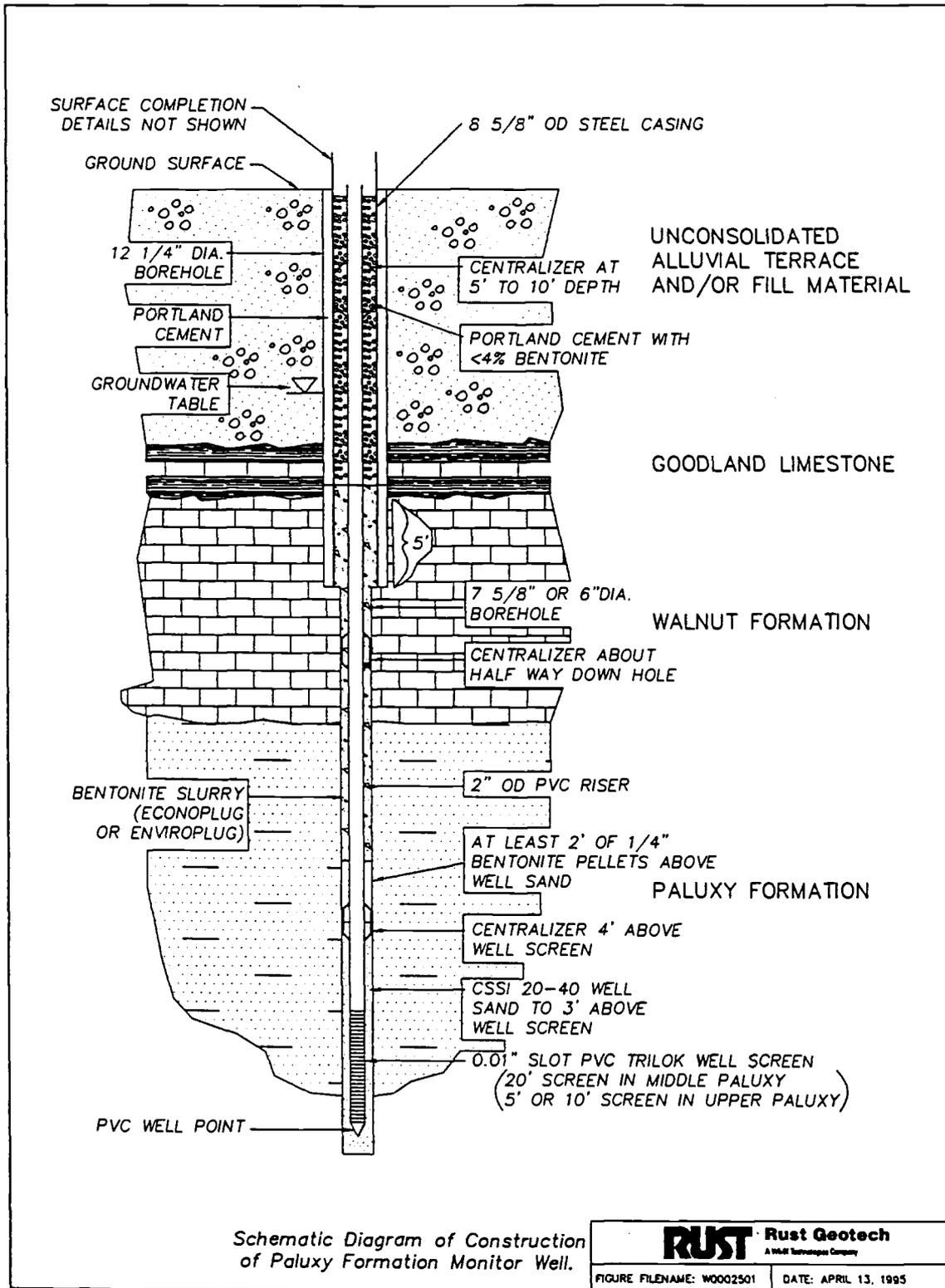


Figure 2.1.5-1 Schematic Diagram of Paluxy Monitoring Well Construction

2.1.6 Monitoring Well Installation

2.1.6.1 Alluvial Monitoring Wells

Alluvial monitoring wells were drilled using truck-mounted drill rigs with hollow-stem augers. After completion of soil sampling through the hollow-stem augers, the borehole was augered to the required depth. As the well completion materials were installed, the auger flights were slowly removed to prevent cave-in. At several sites it was necessary to maintain a head of potable water on the casing to prevent fine sands from flowing into the augers.

Monitoring wells were typically completed using 2-inch inside diameter (i.d.) polyvinyl chloride (PVC) screen with 0.01-inch slot size and 2-inch i.d. flush-joint threaded casing (see Figure 2.1.6-1). At sites where fuels or solvents were known to exist, stainless steel riser pipe was used to prevent possible degradation of the PVC material. The annular area around the screen extending 2 feet above the screened area was packed with well sand. A bentonite pellet seal at least 3 feet thick was then placed above the sand pack. The remainder of the annular space around the casing was grouted to the surface with a grout mixture of cement and powdered bentonite. The bentonite content of the cement grout did not exceed 5 percent by total volume. In a variance from the *Work Plan*, many of the monitoring wells installed early in the investigation were grouted with a high-solids bentonite grout. Geotech personnel believed bentonite grout was preferable to cement/bentonite grout for the Plant 4 area. Appendix B-1 (Volume III) includes a listing of monitoring wells indicating the type of grout used for each completion.

The screen was installed to detect the contaminants of interest at each site. Wells installed for the collection of light nonaqueous phase liquids (LNAPLs) were screened such that the screen length would allow for seasonal fluctuations in the water table or drawdown from potential pumping operations in other areas. Nearby monitoring wells were checked to determine current water levels at each location. Historical water levels were also investigated prior to setting a LNAPL screen to determine water level fluctuations.

Monitoring wells designed to collect soluble organic compounds were installed such that the screen was located within the central portion of the aquifer or within a layer of interest. Monitoring wells designed for the collection of DNAPLs were screened such that the bottom of the screened interval extended into the underlying confining layer on which the DNAPLs were expected to pool. A sump was drilled at least 2 feet into the Walnut Formation to allow the detection of DNAPLs. As specified above, all monitoring wells were completed with a sand pack, bentonite seal, and grout. A locking cover and concrete pad were also installed at the surface, and steel posts were installed where necessary to protect the well. The posts were painted to allow visibility in high-traffic areas. Monitoring well completion diagrams are provided in Appendix B-1, (Volume III).

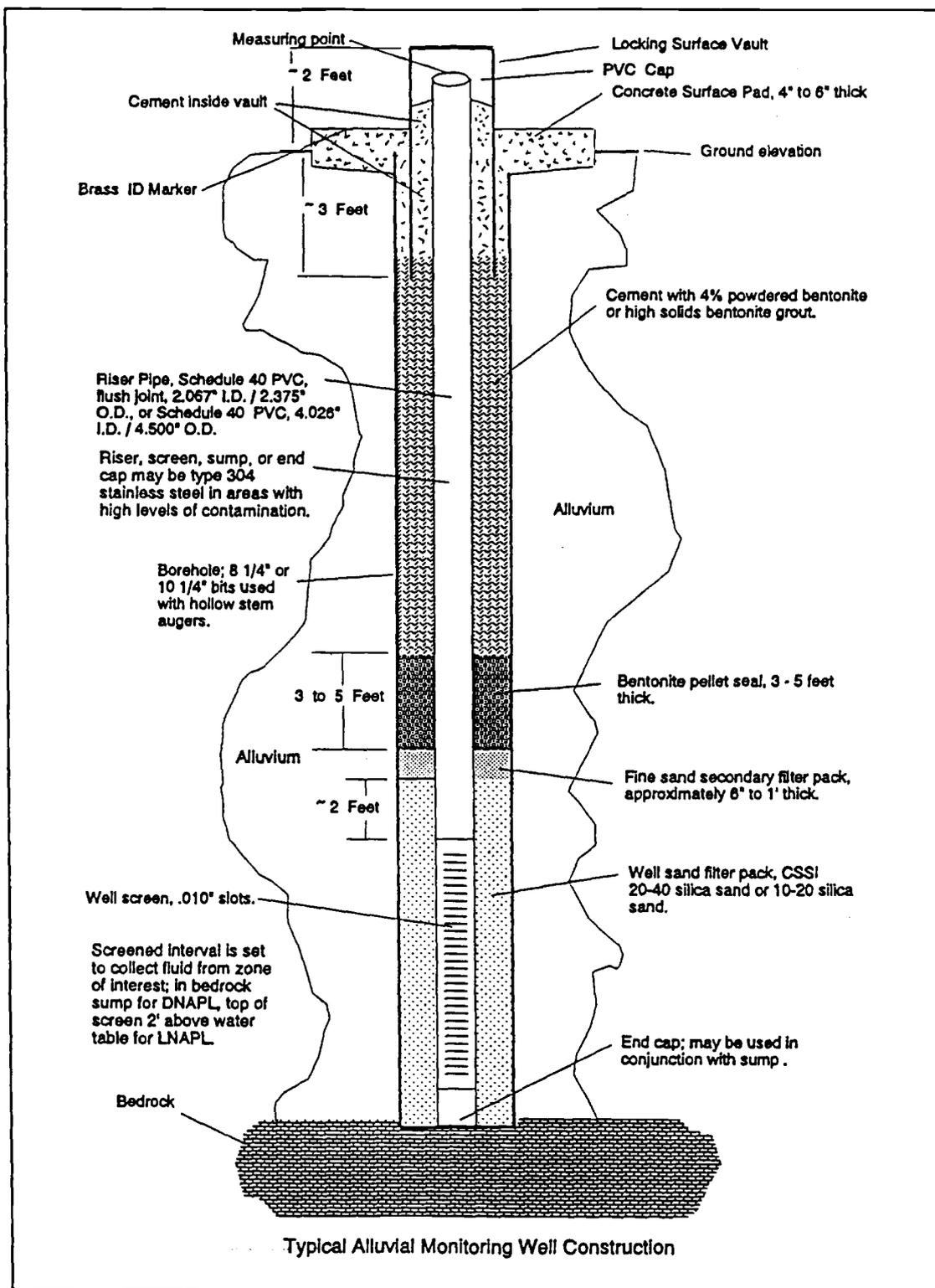


Figure 2.1.6-1 Typical Monitoring Well Installation

Drill cuttings and water removed during the drilling process were scanned with a PID. The cuttings and water were drummed or otherwise containerized for later disposal.

2.1.6.2 Paluxy Formation Monitoring Wells

Five monitoring wells were installed to test the Paluxy Formation water quality and hydrologic characteristics (see Figure 2.1.5-1). Two wells were installed into the middle portion of the Paluxy Aquifer, outside the Plant 4 boundaries on the city of White Settlement right-of-way. Three monitoring wells were installed into the upper portion of the Paluxy Aquifer at locations within the Plant 4 boundaries. All Paluxy Formation monitoring well locations were situated with approval of EPA personnel.

All Paluxy Formation wells were installed in the same manner. Hollow-stem augers were used to drill to the top of the Walnut Formation. Either a hollow-stem bit or a rotary bit was used to drill an approximate 12-inch-diameter borehole about 5 feet into the Walnut Formation. An 8-inch-diameter steel casing was cemented in the borehole, and sections were welded together to bring the steel casing to the surface. This casing prevented contaminated water in the alluvial aquifer from penetrating into the Paluxy Aquifer. After allowing at least 3 days for the cement to set and seat the casing, the cement was drilled out and coring commenced (see Table 2.1.6-1).

Table 2.1.6-1 Geotech Paluxy Formation Monitoring Wells

Monitoring Well	Location
P-27U	West of Building 14
P-28U	North Parking Lot
P-29M	City of White Settlement, Bourland St.
P-30M	City of White Settlement, Clifford Ave.
P-31U	FDTA-5 Area (dry well)

All Paluxy Formation monitoring wells were cored through the Walnut and Paluxy Formations to total depth. After coring was completed, the boreholes were reamed out with either a 6-inch or 7⁵/₈-inch-diameter drill bit to allow well installation to continue. Bentonite drilling mud used during coring and reaming of the boreholes was washed from the boreholes and stored in drums. Wells were installed using 2-inch-diameter threaded PVC pipe and 0.01-inch screen. Well sand was placed using a tremie pipe until the sand was 2 to 3 feet above the top of the well screen.

Bentonite pellets were placed on top of the sand pack to a minimum thickness of 3 feet. High-solids bentonite grout was tremied into place using a side discharging tremie pipe that forced any fluid in the well to the surface. This fluid was stored in drums for later disposal. Bentonite grout was pumped into the borehole as required to bring the top of the grout to about 6 feet from the surface. At the surface, either a flush mount or an above-ground vault was installed. All monitoring wells were equipped with padlocks.

2.1.6.3 Monitoring Well Development

Following well installation and a minimum of 1 week to allow for the grout to set, the wells were developed using a vented surge-block technique. Surging, followed by pumping with a submersible pump, hand pump, or bailing with disposable bailers, was performed until the measured parameters (temperature, electrical conductivity, and pH) were stable over three bore volumes. Borehole volume was calculated using the following relationships.

Borehole Volume = Casing Volume + Filter Pack Volume

Casing Volume (gallons) = $(r_1/12)^2 \times \pi \times (h_1 - h_2) \times 7.48$

Filter Pack Volume (gallons) = $[(r_2/12)^2 - (r_1/12)^2] \times \pi \times (h_1 - h_2) \times 7.48 \times 0.30$

Where:

- r_1 = radius of well casing (inches)
- r_2 = radius of well bore (inches)
- π = 3.1416
- h_1 = depth of well (feet) from top of casing
- h_2 = depth to water (feet) from top of well casing
- 0.30 = estimated porosity of filter pack
- 7.48 = gallons per cubic foot

A minimum of 10 bore volumes of fluid was removed from each monitoring well unless the well was repeatedly pumped dry. Wells in areas with limited amounts of water were developed until parameters were stable while trying to remove 10 bore volumes of fluid.

The *Final Sampling and Analysis Plan* for Plant 4 stated well development would continue until discharge water was free from sand and the turbidity was less than 5 nephelometric turbidity units (NTUs). The 5-NTU standard was found to be impractical due to the amount of silt in the alluvium and the low amount of water available for development. Parameter stability was achieved on almost all of the monitoring wells, but the 5-NTU standard was not met on any well.

2.1.7 Groundwater Sampling

Groundwater was sampled from selected existing and all newly installed monitoring wells. Electrical conductivity, temperature, and pH were measured at the time of sampling. Dissolved oxygen and oxidation-reduction potential (Eh) were also measured at 20 percent of the locations.

All monitoring wells were purged before sampling for a minimum of three bore volumes or until the well was purged dry. This ensured that a representative sample of the aquifer was collected. If the well was purged dry, sample containers were filled as soon as the well recovered enough to provide sufficient volume. Many of these wells failed to recover completely before sampling. The pH, temperature, and electrical conductivity of the discharge water were monitored during purging with a flow-through cell apparatus. For wells that did not produce enough water to allow the use of a flow-through cell, a clean polyethylene sample container was used to collect water for parameter monitoring. Samples were collected after the pH, electrical conductivity, and temperature stabilized to ± 0.25 pH, ± 50 $\mu\text{mhos/cm}$, and ± 0.5 $^{\circ}\text{C}$, respectively, for at least one-half of a bore volume. Purge water was contained in barrels and stored for later disposal.

Probes were immersed into the flow-through cell soon after purging began to monitor the pH, temperature, and electrical conductivity. The pH meter was calibrated with standard solutions of 4.00, 7.00, and 10.00 pH prior to taking the measurements. Buffer ranges were selected to bracket the expected pH of the borehole fluid. All measurements were adjusted for temperature.

Electrical conductivity was measured using a conductivity meter that was calibration checked before sampling with 1000 μmhos calibration solution. Temperature, pH, and electrical conductivity measurements were recorded at regular intervals throughout the time of purging. Dissolved oxygen readings were not collected at wells that were frequently purged dry.

Newly constructed wells were purged with a peristaltic suction-lift type pump, a submersible pump designed for 2-inch wells, a submersible bladder pump (stainless steel with a Teflon[®] bladder), or a high density polyethylene disposable bailer. These methods were also used to collect the inorganic samples. VOC samples were collected using disposable bailers.

Samples requiring filtration were filtered through a 0.45-micron cellulose/acetate or membrane filter in conjunction with a flow-through filtration system. The filtration system consisted of a filter holder with the filter sandwiched between Teflon[®] support screens. Disposable-cartridge filters were also used during this investigation.

Sample bottles were filled by allowing the pump or bailer discharge to flow gently down the side of the bottle with minimal entry turbulence. The sample was capped and stored

at 4 °C. For samples requiring preservation (such as HNO₃ for metals or HCL for VOCs to pH less than 2 for metals), the proper amount of preservative was added and the bottle capped. Samples collected for organics were bottled with no bubbles and cooled to 4 °C.

2.1.8 Water-Level Measurements

Electronic interface probes were used to measure depths to the top of any free product layer (both LNAPL and DNAPL) and to the top of water in monitoring wells by detecting differences in conductivity between layers. The depths to fluid level were determined using the casing top as the measuring point. In the absence of a defined measuring point, measurements were made from the north side of the casing. The groundwater levels in all new wells were measured prior to purging and sampling. Water-level measurements were used to calculate purge volumes and to estimate groundwater flow directions and velocities. Wells with LNAPL present were not used to create piezometric maps as the presence of LNAPL may depress the local water table. At several existing monitoring wells, an electric sounder was used to measure water levels because access ports or dedicated pumps at these wells did not allow the use of an interface probe. These existing wells had no history of nonaqueous phase liquids or high levels of contamination (see Appendix D, Geotech Water-Level Measurements).

2.1.9 Decontamination Methods

2.1.9.1 Soil Sampling Equipment

All soil sampling equipment was thoroughly decontaminated before use. A decontamination area was established with a plastic ground cover, stainless steel wash pans, and appropriate cleaning supplies at each sampling site as required. All visible contamination was removed with a steel brush and/or paper towels. Equipment was washed with scrub brushes and soapy water (Isoclean® or equivalent), rinsed with clean potable water, rinsed with laboratory-grade methanol, then rinsed with distilled water, and allowed to air dry. After drying, equipment was wrapped in clean polyethylene sheeting until use. All waste methanol and water was contained and stored in drums pending disposal.

2.1.9.2 Drilling Equipment

Drill rigs, augers, rods, hand tools, and accessory equipment were inspected daily for fluids or substances that could contaminate sample material or boreholes. All leaks were required to be diapered and immediately repaired. All drilling equipment was cleaned with a high pressure hot-water wash prior to entry on the site. Equipment was again cleaned with hot water between borings. After hot-water cleaning, all down-hole equipment was rinsed with methanol, rinsed with distilled water, and allowed to air dry prior to re-use. For the cleaning of drilling equipment, a decontamination pad was constructed using plastic sheeting spread over concrete with a slope leading to a sump.

The decontamination pad was designed to ensure that the decontamination fluids were impounded or containerized for later disposal, which will be based on identification of contaminants through sampling and analysis of waste materials.

2.1.9.3 Groundwater Sampling Equipment

All measurement and sampling equipment contacting groundwater was wiped with clean rags or paper towels as the equipment was removed from the well. Outer surface areas were cleaned by the method described in Section 2.1.9.1.

Sampling equipment that was contaminated internally, such as pumps and tubing, was cleaned by circulating decontamination solutions through the system. This was accomplished by pumping soapy water, clean potable water, and distilled water through the tubing system. Exterior surfaces were cleaned with a soap wash, potable water rinse, methanol rinse and a final distilled water rinse. Discharge water and solvents were stored in steel drums.

2.1.10 Sample Handling, Packaging, and Shipping

All sample containers were pre-cleaned and obtained from an EPA-approved supplier for Superfund sites (e.g., I-Chem). Containers were individually inspected for integrity and cleanliness prior to use. Suspect containers were discarded.

Sample bottles for liquid inorganic analyses were filled to approximately 90 percent of capacity to allow for expansion of the contents. The 40-milliliter vials for volatile organic analysis were filled with no headspace or bubbles. Sample bottles for other organic analyses were filled with minimum headspace.

Sample preservation was performed immediately upon collection. Ice chests were used to cool samples during field sampling, packaging, and shipping. Samples were stored in a refrigerator if they were not shipped the day of collection. This refrigerator was kept in a locked room and custody sealed to ensure sample security.

Those samples that had low levels of contaminants were handled, packaged, and shipped as environmental samples. Those samples containing high concentrations of contaminants based on field screening methods were handled, packaged, and shipped according to the regulations issued by the United States Department of Transportation (DOT), 49 CFR Parts 171 through 178, and EPA sampling, packaging, and shipping methods (40 CFR 260). Table 2.1.10-1 shows the type of containers and holding times for the different analyses.

All samples were packaged and shipped in a manner that protected the integrity of the sample and minimized any detrimental effects from possible leakage. Packaging and shipping included placing sample containers in zip-lock plastic bags, placing samples in

Table 2.1.10-1 Sample Containers, Preservation, Holding Times, and Analytical Methods

Analytical Parameter	Matrix	Container Type/Size*	Preservation	Holding Time	Analytical Method
TCL Volatile Organics	Water	Glass With Teflon™ Septa/40 mL	No Residual Chlorine; Conc. HCl to pH <2; Cool to 4°C	14 Days	EPA 8240 or 8260 of SW-846 (3rd Ed.) or EPA 624 of 40 CFR 136 or EPA 524.2
TCL Volatile Organics	Soil	Glass With Teflon™ Lined Cap/125 mL	Cool to 4°C	14 Days	EPA 8240 or 8260 of SW-846 (3rd Ed.) or EPA 624 of 40 CFR 136
TCL Semivolatile Organics	Water	Glass with Teflon™ Lined Cap/4 to 6 L	No Residual Chlorine; Cool to 4°C	Extr. 7 Days; Anal. 40 Days	EPA 8270 of SW-846 (3rd Ed.) or EPA 625 of 40 CFR 136
TCL Semivolatile Organics	Soil	Glass with Teflon™ Lined Cap/250 mL	Cool to 4°C	14 Days	EPA 8270 of SW-846 (3rd Ed.) or EPA 625 of 40 CFR 136
Dissolved Priority Pollutant Metals (Sb,As,Be,Cd,Cr,Cu,Pb,Ni,Se)	Water	HDPE/500-mL Amber Bottle	Filter Through 0.45 Micron; HNO ₃ to pH <2	6 Months	Analyzed by Geotech Methods As-2*, As-5*, or As-6†
Total Priority Pollutant Metals (Sb,As,Be,Cd,Cr,Cu,Pb,Ni,Se,Ag,Tl,Zn)	Water	HDPE/500-mL Amber Bottle	HNO ₃ to pH <2	6 Months	Digest by EPA 3005,3010,3020 of SW-846 (3rd Ed.) Anal. by Geotech Methods As-2*, As-5*, or As-6†
Total Priority Pollutant Metals	Soil	HDPE WM/250-mL	None	6 Months	Digest by Geotech Method L-9 Anal. by Geotech Method As-2*, As-5*, or As-6†
Radioisotope Analysis	Soil	HDPE WM/500-mL	None	Unlimited	Geotech Method As-6† for total-U, Method C-10 for Th-230, and Gamma Spectroscopy for Ra-226, Co-60, and Cs-137
Inorganics (F,Cl,SO ₄ ,PO ₄ , CrO ₄)	Water	HDPE/500-mL	Filter Through 0.45 Micron; Cool to 4°C	28 Days	Geotech Method D-3‡
Inorganics (NO ₃ ,NO ₂) (from same sample bottle as F,Cl, SO ₄ ,PO ₄)	Water	HDPE/500-mL	Filter Through 0.45 Micron; Cool to 4°C	48 Hours	Geotech Method D-3‡
Inorganics (CN)	Water	HDPE/500-mL	NaOH to pH > 12; Cool to 4°C	14 Days	EPA Method 335.2
Inorganics (Na,Mg,Fe, K,Ca)	Water	HDPE/500-mL	HNO ₃ to pH <2	6 Months	EPA Method 6010
Inorganics (Si)	Water	HDPE/125-mL	Cool to 4°C	28 Days	EPA Method 6010
TCLP Metals	Soil	HDPE WM/250-mL	None	6 Months	Extract by Geotech Method L-20*; Digest ext. by EPA 3010, 3020 of SW-846, (3rd Ed.), Anal. by Geotech Method As-2*, As-5*, or As-6†
TCLP (VOCs and semi-VOCs)	Soil	Glass with Teflon™ Lined Cap/1 L	Cool to 4°C	14 Days	Extract by EPA Method 1311, then 8240/8260 (VOCs) or 8270 (semi-VOCs)
Total Petroleum Hydrocarbons	Water	Glass with Teflon™ Lined Cap/1 L	Cool to 4°C; Add 5 mL/L HCl	Not Specified	Analyzed by Geotech Method CC-1†
Total Petroleum Hydrocarbons	Soil	Glass with Teflon™ Lined Cap/125 mL	Cool to 4°C	Not Specified	Analyzed by Geotech Method CC-1†
Oil and Grease	Water	Glass with Teflon™ Lined Cap/1 L	Cool to 4°C; Add 5 mL/L HCl	Not Specified	Analyzed by EPA Method 413.2
Oil and Grease	Soil	Glass with Teflon™ Lined Cap/125 mL	Cool to 4°C	Not Specified	Geotech Method K-7
Waterborne Petroleum Oil	Water	Glass with Teflon™ Lined Cap/1 L	Cool to 4°C if held longer than 14 days	Not Specified	Analyzed by ASTM Method D 3328-78

*Sample volumes may vary according to laboratory requirements.
 †Geotech methods are described in the following: Analytical Chemistry Laboratory Administrative Plan and Quality Control Methods, Analytical Chemistry Laboratory Handbook of Analytical and Sample Preparation Methods, and Analytical Chemistry Laboratory Gamma-Ray Spectroscopy Systems Operation and Methods Manual.
 ‡Geotech Method As-2, SOP for EPA Method 7000 series; As-5, SOP for EPA Method 6010
 †Geotech Method As-6 (CP/MAS, SOP for EPA Method 6020
 †Geotech Method L-20, SOP for EPA Method 1311
 †Geotech Method CC-1, SOP for EPA Method 418.1
 †Geotech Method D-3, SOP for EPA Method 300.0

foam socks or equivalent packing material, and packing samples in vermiculite. Shipping coolers were lined with plastic trash bags with the drain plugs sealed to prevent leakage. Shipping containers were properly labeled according to DOT guidelines. Samples identified as hazardous were shipped on a Hazardous Materials Manifest signed by a DOT certified shipper.

Each shipment of samples was accompanied by a signed Chain of Sample Custody form that specified the analyses required for each sample and any unique handling requirements based on information obtained in the field. Laboratories were routinely notified of sample shipments prior to arrival. Chain of Sample Custody forms are shown in Appendix M.

2.1.11 Field Quality Assurance and Quality Control

2.1.11.1 Introduction

This section describes the quality assurance and quality control measures that were instituted for the field sampling and analysis phase of the PA/SI and RI/FS processes at Plant 4. The objective was to provide systematic control of all phases of the processes, which included proper sampling design, sampling procedures, accuracy, precision, comparability, and completeness.

2.1.11.2 Sample Identity

To maintain evidence of authenticity, the samples collected for Plant 4 were identified by a label attached to the sample container that included the company name, sample interval, unique identification number, date, time, and sampler's name. In addition, a copy of the sample label with the same information was kept in the evidentiary files for the project.

2.1.11.3 Sample Custody

To maintain the integrity of the samples, it was necessary to demonstrate that the samples were kept under custody from the time they were collected to the time they were analyzed. Chain of Sample Custody forms were used to list all sample possession transfers and show that the sample was in constant custody between collection and analysis.

The sample shipping containers had custody seals placed over the container openings to ensure that the integrity of the samples was not compromised during shipment. The receiving laboratory examined the seals on arrival and documented that the seals were intact. Upon opening of the containers, the condition of the sample containers was also noted (i.e., broken bottles, leaking bottles, broken seal around the lid). No discrepancies were noted by the laboratories.

2.1.11.4 Transportation and Shipment of Samples

All shipments were made in compliance with DOT regulations governing shipment of hazardous materials and substances. A copy of the regulations in 49 CFR 171-179 was available to field personnel responsible for marking, labeling, packaging, documenting, and shipping hazardous material, substances, and waste. In addition to meeting all DOT requirements, special care was taken to ensure the integrity of the sample through proper packaging and shipping (see Section 2.1.10).

To determine the proper identification of a hazardous sample, field personnel reviewed field measurement data and the logbooks for relevant information concerning the sample material in each container. This information included such things as radioactivity levels, presence of organic vapors, pH, or any other information useful in classifying the samples for shipment. If a sample was known or suspected to contain a specific hazardous material, the sampler noted the presence of the material on the sample label. This information was necessary for the receiving laboratory to determine proper handling of the sample prior to analysis and to prepare laboratory equipment for analysis.

2.1.11.5 Document Control

The preparation, issuance, and revision of documents that specify quality requirements, or prescribe activities affecting quality, were controlled to ensure that the correct documents were being used and enforced during the sampling and analysis phase of the RI/FS process. The following describes the various documents that were controlled:

- **Field Logbooks:** Field personnel used bound logbooks with consecutively numbered pages for each major field task performed (i.e., soil sampling, groundwater sampling, monitoring well drilling). The field logbooks were used to record the daily activities of the field team, record any field measurements taken, sketch maps of measurement and sample locations, and note observations that indicated the quality of the data. Each page was signed and dated by the person making the entries on that page and also signed and dated by a second person who reviewed the entries for accuracy and clarity. Each logbook was signed out to the individual responsible for completion of the logbook.
- **Daily Drilling Log:** A log was maintained of each day's drilling activities and contained records of footage drilled, materials used, problems encountered, and general observations. The log identified each boring by a specific identification number and location and contained the names of drilling personnel and their employer(s). The Geotech drilling supervisor reviewed these logs daily for completeness and accuracy.
- **Well Completion Log:** A well completion log was prepared for each new well that included the well identification number, well location, installation description,

completion diagram, and a lithologic log. The well completion log was signed and dated by the person entering the information and was checked by another person for accuracy and clarity. Well logs are presented in Appendix B-2.

- **Lithologic Log:** A lithologic log was completed for each monitoring-well boring and soil boring. The log includes the sampling location, hole number, sample number, sampling depth interval, soil descriptions, PID readings, and comments, if any. The log was signed and dated by the person recording the information and was checked for accuracy and clarity by a second person. Lithologic logs of soil borings are presented in Appendix A-2.
- **Groundwater Sample Collection Forms:** Groundwater sample collection forms were completed during each well sampling. This form is a comprehensive form used to document water quality field measurements taken at the time of sampling and purging. Information recorded includes pump type, purge volumes and rates, and type of sample bottles, preservatives, and filters used. Sample collection forms are presented in Appendix C.
- **Chain-of-Custody Forms:** A copy of each chain-of-custody form was retained in a file for the project records for traceability in case of sample loss or delays during shipment. This file was maintained in the field until completion of fieldwork and then became part of the permanent project file. Copies received by the laboratory were included in the laboratory data packages.
- **Evidentiary File:** All pertinent information gathered in the course of fieldwork (e.g., permits obtained for access, drilling, or excavation, correspondence relating to the project, completed forms, completed logbooks, software programs, training records, accident reports, and other records and files) are maintained in the permanent project file.

2.1.11.6 Laboratory Quality Control

Internal Quality Control Checks: For subcontracted analyses, internal quality control was performed according to EPA SW-846 (Third Edition). The laboratories selected had a thorough internal quality assurance/quality control (QA/QC) system that met or exceeded the requirements set forth in EPA SW-846 (Third Edition), including the following minimum requirements:

- Each instrument was initially calibrated and the calibration was verified with a calibration standard specified for each instrument. The calibration standard was either an EPA Quality Control Solution or a National Institute of Standards and Technology (NIST) traceable control solution. Calibration verification during an analysis run was performed after every 10 samples.

- A preparation blank was prepared and analyzed to check for contamination caused by reagent preparation for each analytical run.
- A matrix spike sample was prepared and analyzed at a rate of 1 per group of 10 samples of a similar matrix.
- At least 1 duplicate sample analysis was performed on each group of 10 samples of similar matrix.
- For analyses by GC/MS, surrogate spike analyses were performed on all samples.
- An interference check sample was analyzed for each analytical run to verify interelement and background correction factors on a regular basis for analysis performed using an Inductively Coupled Plasma (ICP) Procedure.

For Geotech laboratory analyses, the internal quality control was as specified in EPA SW-846 (Third Edition) and as follows:

- Dissolved Metals (waters)

A portion of 1 sample for every 10 samples or 1 one sample per batch, whichever was greater, was spiked with a known amount of each analyte and analyzed to check for matrix interferences. Spike recoveries were between 90 and 110 percent.

One sample for every 10 samples or 1 sample per batch, whichever was greater, was analyzed in duplicate.

One check sample containing known amounts of each element was analyzed for every 10 samples or every batch, whichever was greater.

- Metals (total metals—waters)

A portion of 1 digested sample for every 10 samples or 1 sample per batch, whichever was greater, was spiked with a known amount of each analyte and analyzed for matrix interferences. Spike recovery was between 90 and 110 percent.

- Metals (total metals—soils)

One sample for every 10 or 1 sample per batch, whichever was greater, was digested and analyzed in duplicate.

Certified reference materials were included at a frequency of 1 for every 10 samples or 1 per batch, whichever was greater.

A blank was carried through the digestion procedures with every batch.

- Metals (extraction procedure [EP] toxicity—soil extracts)

The extract from each sample was spiked for each analyte. Standard addition was performed if the spike recovery was outside the range of 85 to 115 percent.

One extracted sample for every 10 or 1 sample per batch, whichever was greater, was analyzed in duplicate.

- Anions and Total Dissolved Solids (TDS) (waters)

One sample for every 10 or 1 sample per batch, whichever was greater, was analyzed in duplicate.

One check sample containing known amounts of each analyte was analyzed for every 10 samples or every batch, whichever was greater.

A portion of 1 sample (except for TDS) for every 10 or 1 sample per batch, whichever was greater, was spiked with known amounts of each analyte. Spike recoveries must be between 90 and 110 percent.

- Volatile Compounds

One sample for every 10 or 1 sample per batch, whichever was greater, was analyzed in duplicate.

One check sample containing known amounts of each analyte was analyzed for every 10 samples or every batch, whichever was greater.

A portion of 1 sample for every 10 or 1 sample per batch, whichever was greater, was spiked with known amounts of each analyte.

- Duplicates

Duplicate samples for both water and soil were collected and submitted blind to the laboratory at a rate of 10 percent.

- Trip Blanks

Seven water trip blanks were submitted to the contracted laboratories for analysis of VOCs.

- **Equipment Blanks**

Water equipment blanks were collected at a rate of one per day for the purpose of evaluating equipment contamination in the field. The equipment blanks were analyzed for the same constituents as the water samples.

Table 2.1.11-1 presents the reporting limits for laboratory analysis of samples. For volatile and semivolatile organic compounds, the listed limits are the Practical Quantitation Limits (PQLs), as listed in the appropriate EPA Methods of SW-846 (Third Edition). Other limits are method detection limits.

2.2 Assembly Building/Parts Plant

2.2.1 Introduction

The main objective of the PA/SI investigation of the Assembly Building/Parts Plant was to identify potential source areas for contamination present in groundwater downgradient of the buildings. Soil-gas screening of the entire perimeter of the building provided both upgradient and downgradient information on the nature of potential contamination. Specific areas of potential contamination were further investigated to help define the contaminant source.

Most investigations to date have concentrated on defining the extent of the contaminant plumes, and, as a result, the source of contamination has not been determined. Thirty-four monitoring wells, both alluvial and Paluxy, were installed along the perimeter of the Assembly Building/Parts Plant during previous investigations. Soil test holes for foundation design provided soil types and depth to the underlying Walnut Formation.

The most widespread contaminant east of the building is TCE. Spills of TCE have occurred within the chemical process building adjacent to the Parts Plant. Trenches, sumps, floor drains, buried pipelines, and abandoned pipelines are present throughout the manufacturing facility. These are all potential source areas or transport routes for contamination resulting from spills and leaks.

2.2.2 Current Investigations

A soil-gas survey was conducted around the entire perimeter of the building with 54 sampling locations spaced approximately every 200 feet. Sampling began in June 1990 and was completed in October 1990. Sample locations were selected to meet the 200-foot criteria and were placed in areas free of underground utilities.

Samples were collected from a nominal depth of 4 feet using a Geoprobe® sampling system with a hollow, stainless steel drive rod and expendable drive points. Soil-gas measurements were made initially using a calibrated photoionization detector

Table 2.1.11-1 Reporting Limits for Laboratory Analyses

Analytical Parameter	Analytical Method	CRQL ¹	
		Groundwater ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Volatile Organics (Target Compound List)	EPA Method 8240 (SW-846, Third Edition)		
Acetone		10	10
Benzene		5	5
Bromodichloromethane		5	5
Bromoform		5	5
Bromomethane		10	10
2-Butanone		10	10
Carbon disulfide		5	5
Carbon tetrachloride		5	5
Chlorobenzene		5	5
Chlorodibromomethane		5	5
Chloroethane		10	10
2-Chloroethyl vinyl ether		10	10
Chloroform		5	5
Chloromethane		10	10
1,1-Dichloroethane		5	5
1,1-Dichloroethene		5	5
<i>trans</i> -1,2-Dichloroethene		5	5
1,2-Dichloropropane		5	5
<i>cis</i> -1,3-Dichloropropene		5	5
<i>trans</i> -1,3-Dichloropropene		5	5
Ethyl benzene		5	5
2-Hexanone		50	50
Methylene chloride		5	5
4-Methyl-2-pentanone		50	50
Styrene		5	5
1,1,2,2-Tetrachloroethane		5	5
Tetrachloroethene		--	--
Toluene		5	5
1,1,1-Trichloroethane		5	5
1,1,2-Trichloroethane		5	5
Trichloroethene		5	5
Vinyl acetate		50	50
Vinyl chloride		10	10
Xylene		5	5

1) Contract Required Quantitation Limit

Table 2.1.11-1 (continued) Reporting Limits for Laboratory Analyses

Analytical Parameter	Analytical Method	CRQL ¹	
		Groundwater ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Semivolatile Organics (Target Compound List)	EPA Method 8270 (SW-846, Third Edition)		
Acenaphthene		10	660
Acenaphthylene		10	660
Anthracene		10	660
Benzoic acid		50	3,300
Benzo(a)anthracene		10	660
Benzo(b)fluoranthene		10	660
Benzo(k)fluoranthene		10	660
Benzo(g,h,i)perylene		10	660
Benzo(a)pyrene		10	660
Benzyl alcohol		20	1,300
Bis(2-chloroethoxy)methane		10	660
Bis(2-chloroethyl)ether		10	660
Bis(2-chloroisopropyl)ether		10	660
Bis(2-ethylhexyl)phthalate		10	660
4-Bromophenyl phenyl ether		10	660
Butyl benzyl phthalate		10	660
4-Chloroaniline		20	1,300
2-Chloronaphthalene		10	660
4-Chloro-3-methylphenol		20	1,300
2-Chlorophenol		10	660
4-Chlorophenyl phenyl ether		10	660
Chrysene		10	660
Dibenz(a,h)anthracene		10	660
Dibenzofuran		10	660
Di-n-butylphthalate		10	660
1,2-Dichlorobenzene		10	660
1,3-Dichlorobenzene		10	660
1,4-Dichlorobenzene		10	660
3,3'-Dichlorobenzidine		20	1,300
2,4-Dichlorophenol		10	660
Diethylphthalate		10	660
2,4-Dimethylphenol		10	660
Dimethylphthalate		10	660
4,6-Dinitro-2-methylphenol		50	3,300

1) Contract Required Quantitation Limit

Table 2.1.11-1 (continued) Reporting Limits for Laboratory Analyses

Analytical Parameter	Analytical Method	CRQL ¹	
		Groundwater ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Semivolatile Organics (Target Compound List)	EPA Method 8270 (SW-846, Third Edition)		
2,4-Dinitrophenol		50	5,330
2,4-Dinitrotoluene		10	660
2,6-Dinitrotoluene		10	660
Di-n-octylphthalate		10	660
Fluoranthene		10	660
Fluorene		10	660
Hexachlorobenzene		10	660
Hexachlorobutadiene		10	660
Hexachlorocyclopentadiene		10	660
Hexachloroethane		--	--
Indeno(1,2,3-cd)pyrene		10	660
Isophorone		10	660
2-Methylnaphthalene		10	660
2-Methylphenol		10	660
4-Methylphenol		10	660
Naphthalene		10	660
2-Nitroaniline		50	3,300
3-Nitroaniline		50	3,300
4-Nitroaniline		50	3,300
Nitrobenzene		10	660
2-Nitrophenol		10	660
4-Nitrophenol		50	3,300
N-Nitroso-di-n-pyrolamine		--	--
N-Nitrosodiphenlamine		10	660
Pentachlorophenol		50	3,300
Phenanthrene		10	660
Phenol		10	660
Pyrene		--	--
1,2,4-Trichlorobenzene		10	660
2,4,5-Trichlorophenol		10	660
2,4,6-Trichlorophenol	10	660	
Total Petroleum Hydrocarbons (TPH)	EPA Method 418.1	0.10	10 mg/kg
Oil and Grease	EPA Method 413.2	0.20	5 mg/kg

1) Contract Required Quantitation Limit

Table 2.1.11-1 (continued) Reporting Limits for Laboratory Analyses

Analytical Parameter	Analytical Method	CRDL ¹	
		Groundwater (µg/L)	Soil (mg/kg)
Prior			
Antimony	EPA Method 6010	60	12
Arsenic	EPA Method 7000 Series	10	2
Beryllium	EPA Method 6010	5	1
Cadmium	EPA Method 6010	5	1
Chromium	EPA Method 6010	10	2
Copper	EPA Method 6010	25	5
Lead	EPA Method 7000 Series	5	1
Nickel	EPA Method 6010	40	8
Selenium	EPA Method 7000 Series	5	1
Silver	EPA Method 6010	10	2
Thallium	EPA Method 7000 Series	10	2
Zinc	EPA Method 6010	20	4
Other Inorganics			
Cyanide	EPA Method 335.2	0.02 mg/L	4
Lake Worth sediment samples analyzed using U.S. Dept. Interior/Fish and Wildlife Service analytical methods ² for specified metals.			Sediments mg/kg
Aluminum	EPA Method 7000 Series		10
Cadmium	EPA Method 7000 Series		0.20
Chromium	EPA Method 7000 Series		1.0
Nickel	EPA Method 7000 Series		5.0
Lead	EPA Method 7000 Series		5.0

1) Contract Required Detection Limit

2) Analysis to have been by FWS-9-OAS-91-111 (USFWS) or EPA CLP methods, whichever was more stringent.

(Photovac TIP II). A low-volume vacuum pump was attached to the rods and a sorbent tube was used to collect a sample for laboratory VOC analysis.

Based on the soil-gas survey, perimeter locations containing elevated VOCs were further investigated by drilling 22 soil borings (see Table 2.2.2-1) and collecting soil samples. The borings were drilled from the surface to the top of the water table or bedrock. Samples were collected in 5-foot intervals with samples for VOC analysis being grab samples and the remaining samples being a composite of each 5-foot interval. Compositing soil samples were analyzed for semi-VOCs, petroleum hydrocarbons, and metals.

Table 2.2.2-1 Soil Borings—Assembly Building/Parts Plant Perimeter

SB-34	SB-48
SB-35	SB-49
SB-36	SB-52
SB-37	SB-53
SB-38	SB-54
SB-39	SB-55
SB-42	SB-56
SB-43	SB-109
SB-44	SB-110
SB-46	SB-112
SB-47	SB-116

Based on the soil-gas and soil boring survey results, three soil boring/monitoring well locations (see Table 2.2.2-2) were identified to be drilled inside the Assembly Building/Parts Plant to help define the location and extent of soil and water contamination beneath the buildings. The borings were completed as monitoring wells to provide groundwater flow and quality data beneath the facility. These wells were flush-mounted in low traffic areas. Groundwater samples were collected monthly for two sampling rounds. Samples were analyzed for VOCs, semi-VOCs, petroleum hydrocarbons, and metals.

**Table 2.2.2-2 Assembly Building/Parts Plant Interior
Soil Borings/Monitoring Wells**

SB-152	(Monitoring Well W-158)
SB-153	(Monitoring Well W-159)
SB-154	(Monitoring Well W-160)

2.3 Former Underground Storage Tank Sites

2.3.1 Site Description

Fourteen USTs were removed at Plant 4 prior to December 22, 1988, which was the effective date of Federal Subtitle I regulations. Twelve of the tanks contained petroleum products and two contained hazardous substances (Hargis + Associates 1989). Following removal of the tanks, soil samples collected from the excavations indicated that six of the tank locations had contaminants in soils.

At the six contaminated locations, Tank Nos. 19, 20, 24A, 24B, 25A, and 30 contained 2-butanone, xylene, gasoline, gasoline, JP-4, and JP-4, respectively. Analytical results of the soil samples from the tank excavations generally indicated that the contaminants in the soil corresponded to the former contents of the tanks. There were, however, several compounds present that were not reported as being stored in the tanks. Contaminants found in soils associated with each underground storage tank are as follows:

- Tank 19 -- 2-butanone
- Tank 20 -- 2-butanone, ethylbenzene, xylene
- Tank 24A -- 1,1,1-trichloroethane, *trans*-1,2-dichloroethene, ethylbenzene, methylene chloride, tetrachloroethene, toluene, trichloroethene, and xylene
- Tank 24B -- 1,1,1-trichloroethane, tetrachloroethene, methylene chloride, and toluene
- Tank 25A -- benzene, toluene, ethylbenzene, xylene
- Tank 30 -- benzene, toluene, ethylbenzene, xylene

Figure 2.3.1-1 shows the location of Tank Nos. 19 and 20; Figure 2.3.1-2 shows the location of Tanks 24A and B; and Figure 2.3.1-3 shows the location of Tanks 25A and 30. No further remedial action was performed after the tanks were removed. The excavations were backfilled and paved.

Previous sampling at the former tank locations was insufficient to determine the potential levels and extent of contamination associated with leaks and spills from the tanks. These tank areas were evaluated as potential source areas for groundwater contamination of the upper zone. Although preliminary sampling has shown that contamination exists at the six locations, no attempt was made to characterize the extent of contamination prior to backfilling, grading, and paving. These sites may have been a significant source of contamination to the soils and groundwater over the years.

2.3.2 Field Investigations

2.3.2.1 Soil Sampling and Lithologic Logging

Soil borings were drilled around the perimeter of each of the six former underground storage tank locations where contamination was reported to be present (see Table 2.3.2-1). Borings were drilled from the surface to the top of the water table. In addition, one boring was drilled in the approximate center of the formerly excavated area to determine if any contamination remained below the depth of the tanks. At two tank sites where the tanks were adjacent to buildings (Tanks 25A and 30), the number of borings was reduced as borings could not be completed inside the structures. At UST (removed) sites 19 - 20 and 24A - 24B, in a variance to the *Final Sampling and Analysis Plan (SAP)*, the number of borings was reduced as the tanks at each site were only

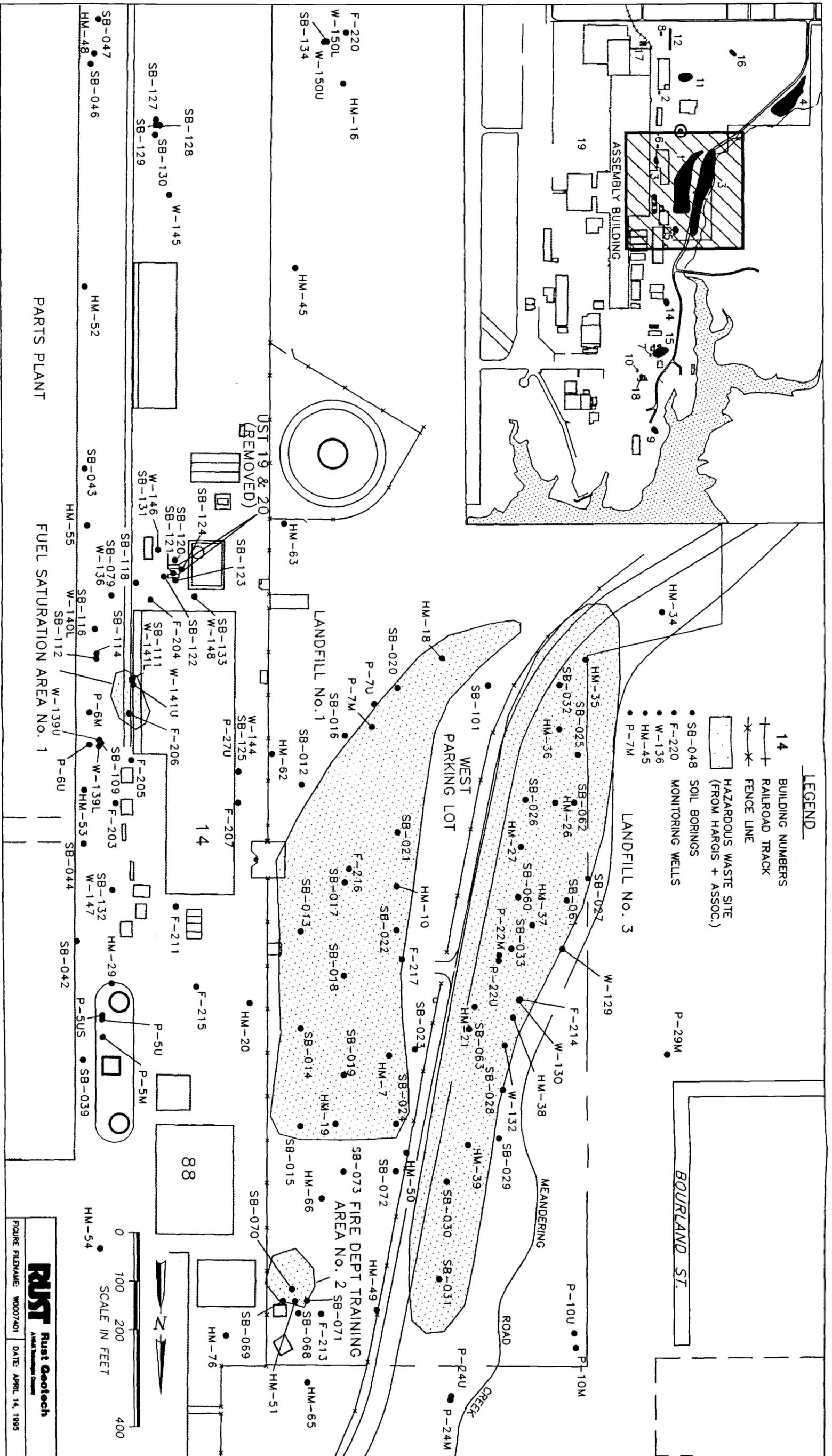


Figure 2.3.1-1. RI/FS Investigation Sites in the West Central Area.

RUST Rust Geotech
ANALYTICAL SERVICES COMPANY
 FIGURE FILENAME: W0007401 DATE: APRIL 14, 1995

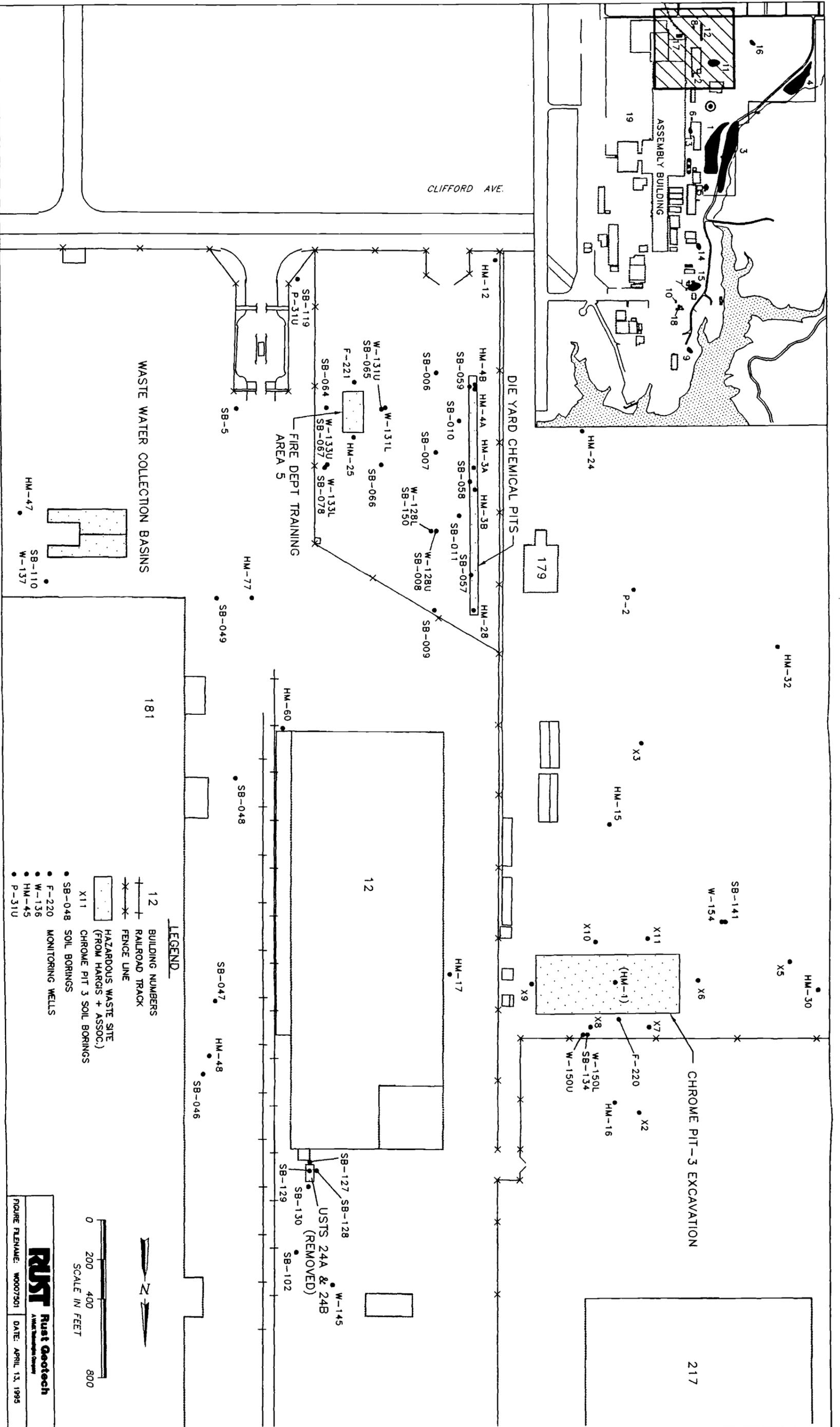


Figure 2.3.1-2. RI/FS Investigation Sites in the South Central Area

Table 2.3.2-1 UST Soil Borings

UST 19 and 20	SB-120, SB-121, SB-122, SB-123, SB-124
UST 24A and 24B	SB-127, SB-128, SB-129, SB-130
UST 25A	SB-041, SB-099, SB-100, SB-106
UST 30	SB-080, SB-081, SB-082, SB-083

3 to 5 feet apart. One soil boring was placed between the tanks' former locations, instead of drilling three borings 2 feet apart. If contamination exceeding established thresholds was encountered, additional borings were to be drilled approximately 50 feet outward from the contaminated boring to help define the extent of contamination. At the UST 24A and 24B location, in a variance from the *SAP*, additional borings were not completed because contaminant levels were low and borings 50 feet away would have been too distant to detect contamination. A boring planned for the east side of the UST 24A and 24B site could not be drilled as utility lines and physical barriers prohibited access. At UST 25A, located immediately adjacent to Building 21, (the Jet Engine Test Stand), the proximity of the building did not allow two planned borings to be completed on the north and west sides of the former tank. Four borings were completed in the area covered by the former tank site to determine the extent of contamination.

Soil samples at all locations were collected from 5-foot intervals. Samples for VOC analysis were grab samples and the remaining samples were composites of the entire 5-foot interval. Composite soil samples were analyzed for semi-VOCs and petroleum hydrocarbons. Ten percent of the composite samples were also analyzed for metals. Lithology logs were completed while soil borings were drilled to determine the depth of excavation and to note any visible contamination.

2.3.2.2 Groundwater Sampling

Where contamination extended to the water table at the former tank sites, samples were taken from existing monitoring wells to determine groundwater quality (see Table 2.3.2-2). If no wells existed in the area of the former tanks, monitoring wells were installed to compare groundwater quality upgradient and downgradient of the site.

Results of the groundwater sampling can be used to determine if the former tank sites are source areas for groundwater contamination. Groundwater samples were analyzed for VOCs, semi-VOCs, and petroleum hydrocarbons.

Table 2.3.2-2 Monitoring Wells at Former UST Sites

W-134	Tank 25A	Upgradient
W-146	Tanks 19 and 20	Upgradient
W-148	Tanks 19 and 20	Downgradient
W-145	Tanks 24A and 24B	Downgradient

2.3.2.3 Water-Level Measurements

Water- or fluid-level measurements were made on existing nearby monitoring wells to determine depth to the water table. Interface probes capable of detecting thin DNAPL or LNAPL layers were used for fluid-level measurements.

2.4 Landfill No. 1

2.4.1 Site Description

From 1942 to approximately 1966, several types of hazardous and nonhazardous wastes were disposed in Landfill No. 1, which is located west of Facilities Building 14. This site, which encompasses about 6 acres, is presently the site of the West Parking Lot (see Figure 2.3.1-1).

The majority of the waste disposed at Landfill No. 1 consisted of general refuse, rubble, plaster, lumber, and fill dirt. Potentially hazardous wastes were also disposed in the landfill. These included drums of unspecified liquid wastes, solvents, thinners, and paint wastes from tank trucks, all of which were dumped in shallow pits. Oils and fuels were also dumped in pits and subsequently burned. Aerial photographs show that at least five separate pits were located within the landfill. Sludge from these pits was periodically dredged out and deposited in the landfill area. Other suspected wastes include mercury and magnesium wastes, chromate sludges, and cyanide.

The landfill was closed in 1966, and the area was graded and paved for vehicle parking. Prior to the grading and paving, two 6-inch-diameter perforated pipes were laid on bedrock just east of Meandering Road. These were intended to channel leachate from the landfill to a storm sewer outfall. When contaminants were identified in water samples collected from a storm drain in 1982, the original perforated pipes were rerouted to a collection basin and French Drain No. 1 was constructed.

In 1983, a portion of the landfill was excavated and the material was moved to an approved hazardous waste disposal facility as an interim remedial action. Within the excavation, a French Drain was constructed to intercept contaminated groundwater (French Drain No. 2). The excavation was then backfilled and the site repaved. Groundwater was collected from French Drains Nos. 1 and 2 and processed through a water treatment system at Plant 4.

On the basis of data from previous studies, the following contaminants have been reported to occur at Landfill No. 1 in concentrations that exceed Federal Maximum Contamination Limits (MCLs).

- Acenaphthene
- Arsenic
- Benzene
- Cadmium
- Chromium
- Ethylbenzene
- Fluoranthene
- Lead
- Tetrachloroethene
- Toluene
- 1,1,1-Trichloroethane
- Trichloroethene (TCE)
- Vinyl chloride

As evidenced by the above list of contaminants, Landfill No. 1 still contains oil and grease, waste solvents, and processed chemical wastes. The interim remedial actions have eliminated only a portion of the potential source in this area for these contaminants. A large portion of the landfill was characterized for types and relative concentrations of buried contaminants.

2.4.2 Field Investigations

Previous investigations consisted of 22 test holes, 12 monitoring wells, and the French Drain excavations. Table 2.1-1 lists reports prepared from the previous investigations.

During this investigation, 16 soil borings were drilled in and near Landfill No. 1 to further delineate the areal extent, depth, and types of contamination (see Table 2.4.2-1). Boreholes were drilled on a grid designed to cover the previously identified extent of Landfill No. 1. The grid was extended when contamination was detected in boreholes outside the previously identified area. Soil samples were composited from 5-foot intervals collected from the surface to the water table. Composite samples were analyzed for semi-VOCs, oil and grease, and metals. A grab sample was collected for VOC analysis from within the 5-foot interval where PID readings or visual examination indicated possible contamination.

Table 2.4.2-1 Landfill No. 1 Soil Borings

SB-12	SB-20
SB-13	SB-21
SB-14	SB-22
SB-15	SB-23
SB-16	SB-24
SB-17	SB-72
SB-18	SB-73
SB-19	SB-101

2.5 Landfill No. 3

2.5.1 Site Description

Landfill No. 3 encompasses approximately 3 acres west of Landfill No. 1, adjacent to Meandering Road Creek (see Figure 2.3.1-1). The landfill was used from 1942 to 1945 for the disposal of a variety of wastes including hazardous liquid wastes consisting of mixed oils and solvents. Some of these wastes were burned in at least one small pit within the landfill. From 1945 to 1966, the landfill was inactive. Fill dirt and rubble were used to fill and grade Landfill No. 3 from 1966 to 1967.

Results of soil sampling from soil borings and groundwater sampling from monitoring wells show that the soils contain anomalous concentrations of VOCs and petroleum hydrocarbons. Results also indicate the groundwater is contaminated with cyanide, metals, VOCs, semi-VOCs, fuel hydrocarbons, and oil and grease. Two monitoring wells in the landfill once contained a large amount of fuel-related floating product and solvent-related free product.

The major contaminants appear to be confined to a relatively small area within the landfill. Aerial photographs indicate the area of concern was at one time an open drainage channel extending from Bomber Road west to Meandering Road Creek. This channel contains a storm sewer that runs roughly east-west. The channel has been filled and leveled, covering the storm sewer. The following contaminants were found in Landfill No. 3 in concentrations that exceed Federal MCLs:

- Acenaphthene
- Arsenic
- Chromium
- 1,2-Dichlorobenzene
- 1,4-Dichlorobenzene
- Fluorene
- Lead
- Methylene chloride
- Naphthalene
- Phenanthrene
- Tetrachloroethene
- Toluene
- *trans*-1,2-Dichloroethene
- Trichloroethene
- Vinyl chloride

2.5.2 Field Investigations

Results of soil sampling and groundwater sampling during previous investigations indicate that both media are contaminated with fuel and solvents. In two monitoring wells at the site, F-214 and HM-38, solvent-related products were detected. Table 2.1-1 lists reports prepared from the previous investigations.

The main objectives of the current investigation at Landfill No. 3 were to (1) define the lateral extent of contamination and delineate the extent of contaminants in concentrations exceeding Federal MCLs, (2) determine the location(s) and concentration of contaminants discharging from the upper zone into the Meandering Road Creek, and (3) characterize the hydrologic flow system at Landfill No. 3.

Previous investigations had roughly defined the extent of contamination. However, additional soil borings were necessary to better define the lateral extent of contamination. Previous investigations also did not adequately define the flow characteristics of the groundwater at Landfill No. 3. This flow information was necessary to determine contaminant fate and transport as well as risk to human health and the environment. More information was obtained on the concentration of contaminants being discharged to and received by the Meandering Road Creek drainage; this information was necessary for the risk assessment and evaluation of remedial action alternatives.

2.5.2.1 Soil Sampling and Lithologic Logging

A sampling grid was established on 100-foot centers across Landfill No. 3. Sixteen soil borings (see Table 2.5.2-1) were drilled and sampled at grid points to define the lateral and vertical extent of contamination. The borings were drilled from the surface to the top of the Walnut Formation. Composite soil samples were collected for each 2-foot interval to the top of the water table. The composite samples were analyzed for semi-VOCs, oil and grease, and metals. Samples collected for VOCs were not composites but were grab samples from each 2-foot interval.

Table 2.5.2-1 Landfill No. 3 Soil Borings/Monitoring Wells

SB-25	SB-33
SB-26	SB-60
SB-27	SB-61
SB-28	SB-62
SB-29	SB-63
SB-30	W-129 (also a temporary monitoring well)
SB-31	W-130 (also a temporary monitoring well)
SB-32	W-132 (also a temporary monitoring well)

Three soil borings were selected for the installation of temporary monitoring wells for water-level measurements and two rounds of groundwater sampling. The groundwater was analyzed for VOCs, semi-VOCs, TPH, and metals. Data from the temporary wells provided groundwater flow and water-quality data to be used in contaminant transport modeling. Temporary monitoring wells were constructed the same as other monitoring wells except a 4-inch concrete pad was not constructed around the well vault. The temporary monitoring wells will remain in place following the remedial investigation.

2.5.2.2 Groundwater Sampling

To determine if contaminants from upper-zone discharge are migrating to the Paluxy Aquifer, one monitoring well (P-29M) was installed within the middle portion of the Paluxy Aquifer west of Landfill No. 3. A groundwater sample was collected after well completion and development, and again one month later. Each sample was analyzed for VOCs, semi-VOCs, TPH, and metals.

2.5.2.3 Nonaqueous Phase Liquids (NAPL) Sampling

LNAPL had previously been identified in monitoring wells F-214 and HM-38; LNAPL were found during the Geotech investigation in HM-38 in Landfill No. 3. DNAPL were detected in F-214 and W-130. A VOC sample collected from F-214 identified the DNAPL as mainly TCE and toluene.

2.5.2.4 Groundwater Seep Sampling

Groundwater from four seeps, SW-8 through SW-11, downgradient of the landfill along Meandering Road Creek, was sampled to estimate the amount and relative concentrations of contaminants discharging from the upper zone into the Meandering Road Creek drainage. Seep samples were analyzed for VOCs, semi-VOCs, TPH, and metals. Figure 2.5.2-1 shows the location of the seep sampling locations.

2.5.2.5 Creek Channel Soil and Sediment Sampling

Channel soil and sediment sampling was conducted across the Meandering Road Creek drainage (Figure 2.5.2-2) to determine contaminant distribution from a possible point of upper-zone discharge to the present stream channel. Seven samples were collected from the creek bank and edge of the landfill, west of monitoring well F-214, to a location 10 feet from the creek. This sampling location area was selected because F-214 is contaminated and is near an existing drainage channel that has been backfilled to level the landfill. This location also provided a worst-case example of soil contamination on the edge of the landfill. Samples were collected from the surface to a depth of 2 feet. Soil and sediment samples were analyzed for VOCs, semi-VOCs, oil and grease, and metals.

2.5.2.6 Single-Well Aquifer Testing

Aquifer tests were performed on two monitoring wells, HM-27 and P-29M, that were properly completed and not previously tested, to determine hydraulic conductivity and groundwater flow velocity of the upper zone at Landfill No. 3. The aquifer tests were performed using the slug withdrawal method. Wells with free product or minor amounts of water were not suitable for testing.

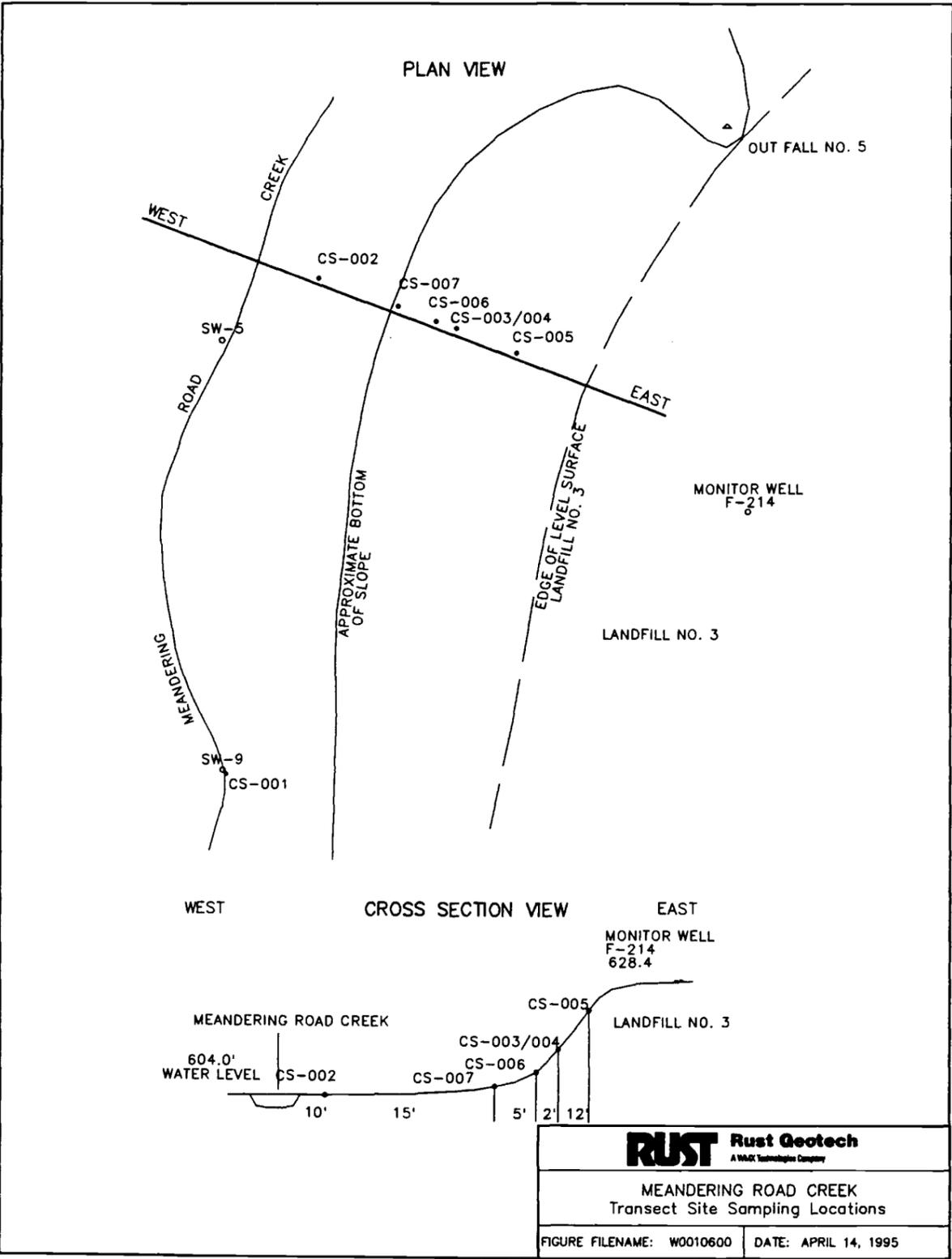


Figure 2.5.2-2. Meandering Road Creek Transect Site Sampling Locations.

2.5.2.7 Water- and NAPL- Level Measurements

Prior to sampling from new and existing monitoring wells, measurements were made using an interface probe to determine the presence or absence of free-floating product. The interface probe was then used to detect any DNAPL present and to measure depth to bottom of the well to determine silt accumulation.

2.6 Landfill No. 4

2.6.1 Site Description

Landfill No. 4 is located near the southwest boundary of the Plant 4 facility (see Figure 2.6.1-1). This landfill occupies approximately 2 acres of land west of Meandering Road. Landfill No. 4 utilized a low area adjacent to Meandering Road Creek for the disposal of construction rubble from 1956 to the early 1980s. Evidence (Radian 1987) suggests that other types of wastes may have been disposed from 1966 until approximately 1973. These wastes are thought to have included small quantities of hazardous wastes such as solvents, oils, fuels, and thinners.

VOCs and other organic compounds were reported during interviews (CH2M Hill 1984) but were not confirmed in subsequent field investigations. On the basis of IRP Phase II investigations, a "No Further Action" remedial action alternative was recommended.

Soil samples, however, were not previously collected at this site. Based on a review of aerial photographs of the landfill when it was still in use, it appears that materials other than construction rubble were deposited in the landfill. Because the landfill is located on the Meandering Road Creek flood plain, a potential exists for migration of contaminants into the surface waters of Meandering Road Creek.

2.6.2 Field Investigations

Although this site was recommended for "No Further Action," there was not sufficient data to support this decision. The decision was based solely on groundwater monitoring data from two monitoring wells, with one (HM-5) being in the upper (upgradient) portion of the landfill and the other (HM-9) being downgradient of the landfill (see Plate 1). The objective of the sampling at Landfill No. 4 was to evaluate whether leachate was flowing from the landfill into the adjacent soils on the flood plain of Meandering Road Creek.

Five soil borings (see Table 2.6.2-1) were evenly spaced on top and along the length of Landfill No. 4 to collect representative soil samples (see Figure 2.6.1-1). Soil borings were drilled to bedrock with samples collected at 2-foot intervals (i.e., 2 to 4, 4 to 6,

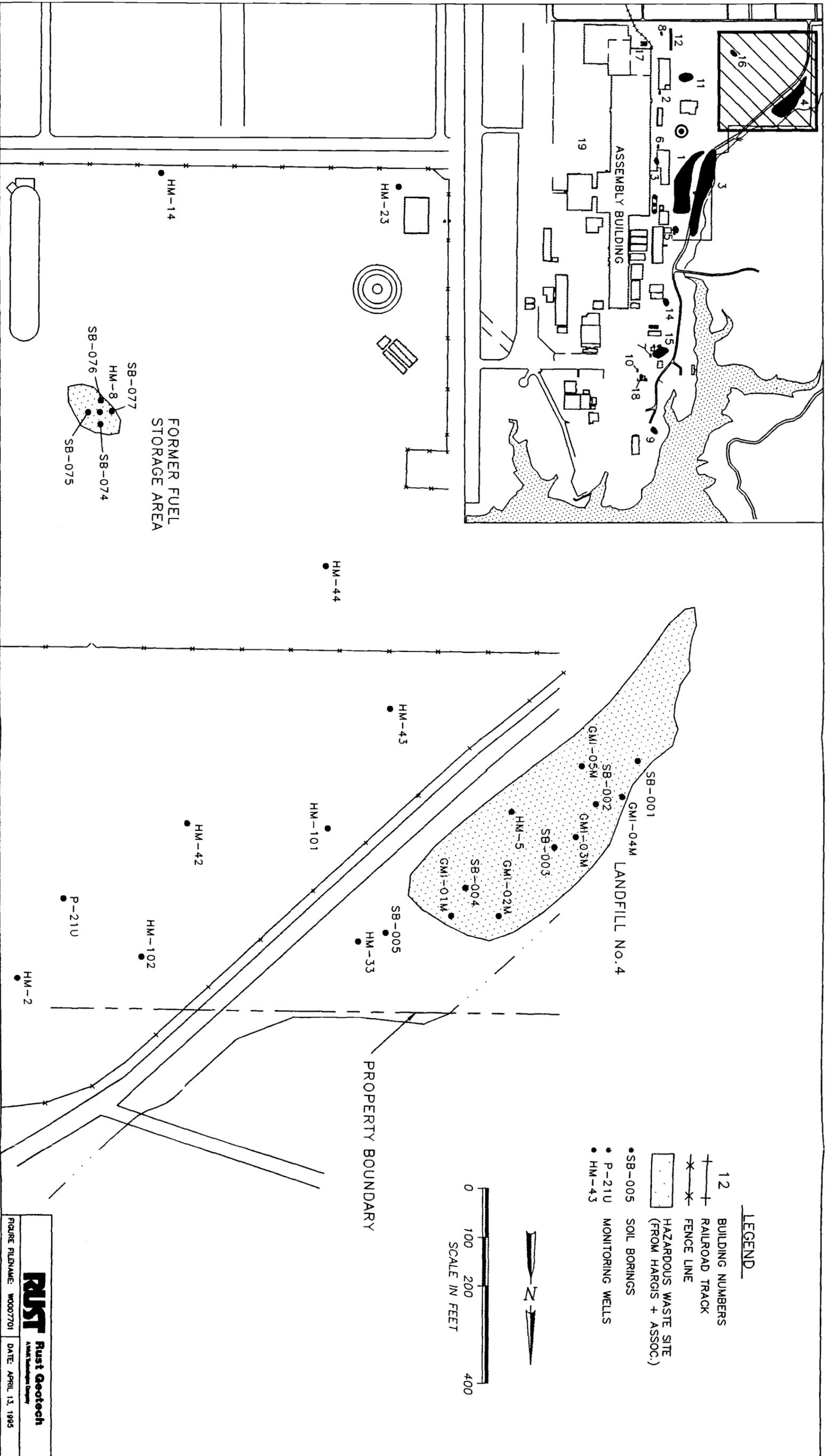


Figure 2.6.1-1. RI/FS Investigation Sites in the Southwest Area.

RUST	
<small>ANALYTICAL SERVICES COMPANY</small>	
FIGURE FILENAME: W0007701	DATE: APRIL 13, 1995
Rust Geotech	

Table 2.6.2-1 Landfill No. 4 Soil Borings/Monitor Wells

SB-001	SB-003	SB-005	GMI-01M	GMI-04M
SB-002	SB-004		GMI-02M	GMI-05M
			GMI-03M	

6 to 8, and 8 to 10 feet below the surface). With the exception of the samples for VOCs, each 2-foot interval was composited and analyzed for semi-VOCs, oil and grease, and metals. Samples for VOC analysis were grab samples from each 2-foot interval and were collected immediately upon opening the split barrel. Lithologic logs were completed while drilling to determine depths of fill and to observe any visible contamination.

Geo-Marine, Inc., drilled five two-inch monitor wells (see Table 2.6.2-1) in July 1994, along the top of Landfill No. 4 for collection of soil and groundwater samples. Figure 2.6.1-1 shows the location of these monitor wells.

The wells were drilled to bedrock with soil samples collected at approximately 5-foot intervals. Only one well, GMI-05M, contained enough water to be developed. All samples were analyzed for VOCs, semi-VOCs, oil and grease, total petroleum hydrocarbons, and metals. Soil logs were completed for each well to determine depths of fill and to observe any visible contamination.

2.7 Fire Department Training Area No. 2 (FDTA-2)

2.7.1 Site Description

FDTA-2 was a 50-foot-diameter earthen ring located north of Landfill No. 1 in the west parking lot (see Figure 2.3.1-1). This location was used for fire training exercises from 1955 to 1956. Exercises were held twice a year with approximately 250 gallons of waste oils and fuels used for each exercise. It is suspected that disposal of oils and fuels and uncontrolled burns may have been more frequent (CH2M Hill 1984). This site has been graded and paved to provide parking.

Both soil and groundwater analyses indicate that fuel-related contamination is present at FDTA-2. Groundwater collected from the center of FDTA-2 was found to contain contaminants that indicate the presence of solvent-related free product. Contaminants at FDTA-2 with levels exceeding Federal standards are TCE, dichloroethene (DCE), and toluene.

2.7.2 Field Investigations

Previous investigations did not define the lateral and vertical extent of contamination. Also, the hydraulic parameters of the upper zone in the area of FDTA-2 were not adequately defined.

Four soil borings (see Table 2.7.2-1) were drilled surrounding monitoring well HM-51, which is located near the approximate center of FDTA-2. The borings were located 25 feet north, south, east, and west of the existing well. In a variance from the *Final Sampling and Analysis Plan*, four additional soil borings that were to have been drilled to aid in the determination of the full extent of contamination were not completed. Based on field screening of sample material from the four boreholes, elevated levels of contaminants were not detected. Because contamination in the vadose zone associated with a fire training area would be localized and would tend to migrate downward to the water table, the four extra borings were not drilled. Water samples from four downgradient monitor wells (F-213, HM-49, HM-65, and HM-66) also did not indicate elevated levels of contaminants associated with a fire training area.

Table 2.7.2-1 FDTA-2 Soil Borings

SB-68	SB-70
SB-69	SB-71

Soil samples were collected from the borings to determine the vertical extent of contamination and to provide preliminary information on the horizontal extent of contamination. The soil samples were collected from the surface to the top of the water table in 2-foot intervals. Lithology logs were prepared to describe visual contamination and examine depths of previous excavations. Grab samples for VOC analysis were collected from each interval, and the remaining material was composited and analyzed for semi-VOCs, petroleum hydrocarbons, and metals. If present, groundwater was bailed from each borehole and analyzed. The boreholes were left standing for several hours (and in at least one case overnight), to allow water to accumulate, but there was insufficient water to analyze.

2.8 Fire Department Training Area No. 5 (FDTA-5)

2.8.1 Site Description

FDTA-5, located south of Facilities Building No. 12 (see Figure 2.3.1-2), consisted of a shallow pit about 35-feet wide by 45-feet long that received waste fuels, oils, and unspecified chemicals that were burned for fire extinguisher training exercises during the mid-1960s.

Previous analytical results of soil samples collected from two soil borings (see Table 2.1-1) within the pit area indicate that the shallow soils did not contain anomalous concentrations of contaminants. Groundwater samples, however, contained anomalous concentrations of VOCs, semi-VOCs, and fuel hydrocarbons. Fuel-related product was observed in a monitoring well in the vicinity of FDTA-5. Arsenic was also detected in monitoring wells at FDTA-5 in concentrations exceeding drinking water standards.

2.8.2 Field Investigations

Although previous investigations indicated the soils at FDTA-5 were not contaminated, additional soil sample data was needed to confirm these initial findings. If the soils are not contaminated, the groundwater contamination found in the FDTA-5 area may be related to a different upgradient source of contamination. Additional groundwater data were needed from upgradient and downgradient monitoring wells to determine if FDTA-5 is a source area for groundwater contamination. Aquifer testing was needed to characterize the hydraulic parameters of the upper zone in the FDTA-5 area to allow modeling of groundwater flow and contaminant transport.

2.8.2.1 Soil Sampling and Lithologic Logging

Five soil borings (see Table 2.8.2-1) were drilled at FDTA-5 to help define the lateral extent of soil contamination. The soil borings were located 50 feet northeast, northwest, southeast, and southwest of monitoring well HM-25, which is located near the reported center of the training area. The borings were drilled to the top of the water table, and soil samples were collected in 5-foot intervals. Samples for VOC analysis were grab samples taken from each 5-foot interval. The remaining samples were composite samples representing the entire 5-foot interval. Composite samples were analyzed for semi-VOCs, oil and grease, and metals.

2.8.2.2 Groundwater Sampling

The northeast and southwest soil borings were extended to the top of the Walnut Formation using the same method (hollow-stem auger drilling) used to reach the top of the water table. These two borings, completed as monitoring wells, were constructed to enable sampling of discrete intervals for DNAPLs. Another monitoring well was

Table 2.8.2-1 FDTA-5 Soil Borings/Monitoring Wells

SB-64	
SB-65	Converted to W-131U
SB-66	
SB-67	Converted to W-133U
SB-78	Converted to W-133L

installed adjacent to each of these wells in order to detect LNAPLs and soluble organic compounds. The samples were analyzed for VOCs, semi-VOCs, and metals. The LNAPL well at W-133U, completed in the Goodland Formation, was dry and could not be sampled for groundwater. The southwestern wells (W-131L and W-131U) were used to determine if upgradient sources were contributing to contamination found in monitoring well HM-25. The northeast well (W-133L) was used to assess the contribution of FDTA-5 to downgradient groundwater contamination.

2.8.2.3 Water-Level Measurements and NAPL Sampling

All fluid level measurements were made using an interface probe capable of detecting thin layers having different conductivities. No NAPL layers were detected during the Geotech investigation in FDTA-5. Water levels in existing nearby wells were checked to determine current water levels at the time of well installation.

2.8.2.4 Single-Well Aquifer Testing

Aquifer tests were performed on the new monitoring wells, W-131U and W-133L, to determine flow directions and hydraulic parameters in the upper zone at FDTA-5. Aquifer tests were completed using the slug-withdrawal method.

2.9 Fire Department Training Area No. 6 (FDTA-6)

2.9.1 Site Description

FDTA-6 was the primary training area at Plant 4. It was located on the northwestern side of Plant 4 adjacent to Meandering Road and Lake Worth (see Figure 2.3.1-3). FDTA-6 consisted of a 50-foot-diameter gravel-lined ring that was approximately 2-feet deep and surrounded by an earthen berm (Hargis & Montgomery 1983). The training area was used from the late 1950s to 1980 for periodic training exercises that used approximately 250 gallons of waste fuels and oils per exercise. Before 1970, training exercises were conducted twice a year; after 1970, exercises were conducted monthly (Radian 1987). The IRP Phase I investigation (CH2M Hill 1984) indicated that unknown quantities of fuels and oils were likely deposited in FDTA-6 between training

exercises. Analytical results from previous investigations indicated that the soils at FDTA-6 are contaminated with VOCs, semi-VOCs, fuel hydrocarbons, and oil and grease. No groundwater samples were collected in the immediate area of FDTA-6 because no upper-zone groundwater exists in the area. Bedrock in the FDTA-6 area is approximately 3 feet below the surface.

During the Geotech investigation, it was noted that the area of FDTA-6 was used as a temporary storage area for fill dirt. This fill material was piled over an area covering part of the former FDTA-6 site and the area directly to the south. This material was removed by May 1991.

2.9.2 Field Investigations

Interim remedial action was performed at FDTA-6 in 1982 and 1983 when oil and fuel contaminated soils were removed and hauled to an approved hazardous waste landfill. Although most of the contamination may have been removed, there were insufficient data to verify contamination no longer exists at FDTA-6.

Analytical results of previous investigations indicated that the soils around FDTA-6 are contaminated with VOCs, semi-VOCs, fuel hydrocarbons, and oil and grease. The following list of contaminants were identified at FDTA-6:

- Bis(2-ethylhexyl)phthalate
- Di-n-butyl phthalate
- Diethyl phthalate
- Fuel-related hydrocarbons
- Naphthalene
- Oil and grease
- Phenanthrene
- Trichloroethane

2.9.2.1 Soil Sampling and Lithologic Logging

To confirm that FDTA-6 does not pose a threat to human health or the environment, additional information was obtained to define the overall extent of contamination.

On the basis of a review of information concerning the interim remedial action, four soil borings (see Table 2.9.2-1) were drilled around the perimeter of the excavated portion of FDTA-6 (see Figure 2.3.1-3). Walnut Formation limestones were encountered at depths of 2 to 4 feet below the surface in all FDTA-6 borings. The borings were drilled to the top of the Walnut Formation and a single soil sample was collected; VOCs were collected immediately from grab samples and the remaining sample material was composited over the entire length of the boring. The composite samples were analyzed

for semi-VOCs, oil and grease, and metals. In addition, a single boring was drilled in the approximate center of the excavated portion of FDTA-6, to determine if contamination exists below the excavated zone. This boring was sampled and analyzed using the same protocol specified for the other borings at FDTA-6.

Table 2.9.2-1 FDTA-6 Soil Borings

SB-094	SB-097
SB-095	SB-098
SB-096	

If present, groundwater was sampled to determine groundwater quality; however, no groundwater was encountered at this site.

2.10 Chrome Pit No. 3

2.10.1 Site Description

From 1957 to 1973, Chrome Pit No. 3, located on the Radar Range west of Facilities Building No. 12 (see Figure 2.3.1-2), was used for the disposal of chromate sludge, barium-chromate sludge, dilute metal solutions, and drums of unidentified liquids from 1957 to 1973. The pit measured 66-feet wide by 165-feet long by 22-feet deep.

As an interim remedial action during December 1983 and January 1984, approximately 8,900 cubic yards of contaminated soil were excavated and removed from Chrome Pit No. 3. Analytical results of samples collected during the excavation indicate that the greatest concentrations of contaminants were removed. However, some contaminants may have remained in the soils and groundwater adjacent to the excavated portion of the pit.

Analytical results from soil and groundwater samples previously collected in or near Chrome Pit No. 3 indicate that the following contaminants were present in concentrations exceeding Federal standards:

- Bis(2-ethylhexyl)phthalate
- Chromium
- Cyanide
- Diethyl phthalate
- Trichloroethene

2.10.2 Field Investigations

Although remedial action was performed at Chrome Pit No. 3, the number of samples collected within the excavated area was insufficient to determine if the site no longer poses a threat to human health or the environment.

Additional sampling of the shallow subsurface was conducted in December 1989 when 11 soil borings were drilled and sampled adjacent to the Chrome Pit No. 3 excavated area (Versar Inc. 1990). The results from this sampling are combined with the results of the 1991 RI/FS investigation to make a final remedial action alternative decision.

The December 1989 soil sampling was concentrated around the perimeter of the former excavation and an area to be occupied by a proposed chemical waste treatment process building. Borings were drilled to a nominal depth of 10 feet with samples collected over 2-foot intervals. Samples for VOC analysis were grab samples whereas the remainder of the samples represented composites of each 2-foot interval. The samples were analyzed for VOCs, semi-VOCs, and metals (including hexavalent chromium). Analytical results for the 1989 samples indicated that no contaminants above background concentrations were present in Chrome Pit No. 3 soils. Geotech collected one additional soil sample from SB-134 at a depth of 26 to 29 feet and analyzed the sample for VOCs, semi-VOCs, metals, and cyanide.

2.10.2.1 Groundwater Sampling

Previous investigations included installation of several monitoring wells in and near Chrome Pit No. 3; Geotech installed three monitoring wells (see Table 2.10.2-1). Monitoring well HM-1 was destroyed when the interim action occurred. However, because contamination was previously identified in groundwater in Chrome Pit No. 3, one upgradient and one downgradient monitoring well were installed to help determine the source of groundwater contaminants in the Chrome Pit No. 3 area. The monitoring wells were completed to allow sampling of discrete intervals for LNAPLs, DNAPLs, and soluble organic compounds. Monitoring well W-150U was drilled approximately five feet from W-150L.

Table 2.10.2-1 New Chrome Pit No. 3 Monitoring Wells

W-150U	(Dry)
W-150L	(SB-134)
W-154	(SB-141)

Groundwater samples were collected in September and October 1991 and analyzed for VOCs, semi-VOCs, and metals. Groundwater samples also were collected from existing wells HM-14, HM-16, HM-24, and HM-30, and analyzed to verify previously detected contaminants.

2.10.2.2 Single-Well Aquifer Testing

Aquifer tests were performed on existing well HM-17. The new monitoring wells did not contain sufficient water to allow a valid aquifer test. Aquifer tests were conducted using the slug withdrawal method.

2.10.2.3 Water-Level Measurements

Water levels were measured at various times during the Geotech investigation (see Appendix D). No LNAPLs or DNAPLs were detected in the Chrome Pit No. 3 area during the Geotech investigation.

2.11 Die Yard Chemical Pits (DYCP)

2.11.1 Site Description

The DYCP site is located east of the Radar Range and south of Facilities Building No. 12 (see Figure 2.3.1-2). Three pits with approximate dimensions of 20-feet wide by 90-feet long and 10-feet deep were constructed in 1956 and were used for the disposal of chromate sludges, metal solutions, and other chemical wastes. In 1962, the site was graded and the entire area was paved for parking (Lot No. 9). On the basis of the IRP Phase I investigation, it is suspected that contaminated soils from the pits may have been spread around the area during the grading activities. The area encompassing the original pits was excavated, and 1,100 cubic yards of contaminated soil were removed and transported to an approved hazardous waste landfill for disposal (CH2M Hill 1984). Confirmation sampling was not conducted to verify that the area was adequately remediated.

2.11.2 Field Investigations

Sampling and analysis of the soils in the entire DYCP area were performed to determine if contaminants exceeding background concentrations are present and if they are present, their lateral and vertical extent. Results of previous investigations indicate that contaminants were still present following the interim remedial action of the pits.

On the basis of previous investigations, the following contaminants in concentrations exceeding Federal standards are present in the DYCP:

- Methylene chloride
- Trichloroethene
- Toluene

2.11.2.1 Soil Sampling and Lithologic Logging

Nine soil borings (see Table 2.11.2-1) were drilled in the area of the excavated pits to determine the lateral and vertical extent of contamination. No soil borings were drilled on the west side of the former pits because of extensive underground utilities in the area. The borings were drilled to the top of the water table and soil samples were collected from 5-foot intervals beginning at the surface. Samples for VOC analysis were grab samples collected immediately upon opening the split-barrel sampler; the remaining samples were collected as composites from each 5-foot interval. The composite samples were analyzed for metals, cyanide, and semi-VOCs. The soil borings in the central portion of the excavated pits were sampled from the 15 to 20 and 20 to 25 foot intervals only.

Table 2.11.2-1 DYCP Soil Borings/Monitoring Wells

SB-006	SB-057
SB-007	SB-058
SB-008 (W-128U)	SB-059
SB-009	SB-150 (W-128L)
SB-010	

2.11.2.2 Groundwater Sampling

Upper-zone monitoring wells HM-3A, HM-3B, HM-4A, and HM-4B were installed within the former pits site and were destroyed when the pits were excavated. There are also four existing monitoring wells around the former pits site: HM-12, HM-24, HM-25, and HM-28. However, groundwater contamination was not adequately characterized during previous investigations and the hydrologic flow system at the site also was not characterized. Additional monitoring wells were needed to assist in determining whether groundwater contamination in the DYCP area could be attributed to the former pits or whether it resulted from other upgradient sources.

During the RI field investigations, one of the soil borings (SB-150) on the east side of the DYCP was completed as an upper-zone monitoring well (W-128L) to evaluate the groundwater quality immediately downgradient of the former pits. The monitoring well was completed to allow sampling of discrete intervals for DNAPLs and soluble organic compounds. Monitoring well W-128U (dry) was installed to detect any LNAPL layer present. A groundwater sample also was collected from existing well HM-24, which is located upgradient of the site. Samples were analyzed for VOCs, semi-VOCs, metals, and cyanide.

2.11.2.3 NAPL Sampling

Interface probe measurements did not indicate any LNAPL or DNAPL layers in W-128L during the Geotech investigation. Lithologic logging of soil samples did not indicate the presence of separate liquid phase layers in the DYCP area.

2.11.2.4 Single-Well Aquifer Testing

Slug withdrawal tests were performed on well W-128L to determine hydraulic parameters of the upper zone. Nearby wells HM-12, HM-28, HM-17, W-131U, and W-133L also were tested to determine hydraulic conductivity in this area.

2.12 Fuel Saturation Area No. 1 (FSA-1)

2.12.1 Site Description

FSA-1 is located just west of the Parts Plant and east of Facilities Building No. 14 (see Figure 2.3.1-1). The ground at this location reportedly became saturated by leaking fuel lines from the mid-1970s to the early 1980s. The saturated area is immediately north of a former UST site where three fuel tanks (containing JP-5 and gasoline) and a fuel pumping station were removed prior to 1988. A 4-inch JP-4 pipeline also passed through the FSA-1 area with several bends at this location. This pipeline was abandoned and filled with concrete.

Analytical results from soil samples collected from one soil boring at the site indicated that the soils are contaminated with fuel-related hydrocarbons. Groundwater collected from monitoring wells in the FSA-1 area also contained anomalous concentrations of VOCs, semi-VOCs, fuel-related hydrocarbons, and metals. Four existing monitoring wells have fuel-related floating product. Table 2.1-1 lists reports from the previous investigations.

Contaminants previously identified at the FSA-1 site with concentrations exceeding Federal standards are as follows:

- Benzene
- Ethylbenzene
- Toluene
- Trichloroethene
- Chromium

2.12.2 Field Investigations

2.12.2.1 Soil-Gas Sampling

Before the soil sampling/monitoring well installation phase of the Geotech investigation began, a soil-gas survey was conducted in the FSA-1 area to better define the overall lateral extent of fuel-related contamination. A sampling grid was marked to cover the previously defined area of contamination. Sample points were placed every 10 feet and soil-gas samples were collected from a depth of 4 feet at the sample locations. A hollow steel rod was used to measure VOCs in the soil gas using a PID and TPH colorimetric indicator tubes. Several locations also were sampled with an activated charcoal adsorption tube for laboratory analysis of VOCs. The grid was extended when the previously defined extent of contamination was found to be too small (see Section 4.3.11). The extent of contamination defined by the soil-gas sampling was used to determine placement of the soil sampling boreholes.

2.12.2.2 Soil Sampling and Lithologic Logging

The extent of contamination as defined by the soil-gas survey was extended beyond the previously defined area. Nine soil borings were drilled and sampled in FSA-1 (see Table 2.12.2-1). The borings were drilled to the top of the water table and soil samples collected from 5-foot intervals. The samples to be analyzed for VOCs were grab samples whereas the remaining samples were taken from composites of each 5-foot interval. The composite samples were analyzed for semi-VOCs, TPH, and metals.

Table 2.12.2-1 FSA-1 Soil Borings/Monitoring Wells

SB-044	SB-114
SB-079 (W-136)	SB-116
SB-109 (W-139L)	SB-118
SB-111 (W-141L)	SB-132 (W-147)
SB-112 (W-140L)	

2.12.2.3 Groundwater Sampling

Five of the nine soil borings were completed as upper-zone groundwater monitoring wells. The wells were completed in a way that allows sampling of discrete intervals for LNAPLs, DNAPLs, and soluble organic compounds. Both W-139 (U & L) and W-141 (U & L) were completed with two wells drilled at each location: one for DNAPL and soluble analytes, and one for LNAPL sampling. Because wells with floating product may be added to a treatment system installation of 4-inch-diameter wells was required. Remaining wells were installed as single-completion wells. Samples were obtained from wells once a month for two months to determine groundwater quality (September and October, 1991). One sample containing floating product from FSA-1 was analyzed to determine the type of product and the probable source. Groundwater was analyzed for VOCs, semi-VOCs, and fuel hydrocarbons.

2.12.2.4 NAPL Sampling

Floating product was identified in monitoring well W-139U. One sample of floating product from W-139U was analyzed to determine what type of product was present and the possible source of the contamination. The analytical results were compared to the analysis of pure product samples of JP-4, JP-5, unleaded gasoline, fuel oil, and diesel fuel. The chromatogram of the W-139U product is closest to weathered JP-4 fuel.

2.12.2.5 Single-Well Aquifer Testing

Slug withdrawal tests were performed on all new monitoring wells. The results were compared with aquifer test data from existing wells to define the hydraulic parameters of the upper zone at the FSA-1 area.

2.12.2.6 Water- and NAPL-Level Measurements

Water-level measurements were taken prior to sampling from all wells in the FSA-1 area for determination of groundwater flow directions and flow velocity. All fluid-level measurements were made using an interface probe capable of detecting thin layers having different conductivities. Floating product was detected in monitoring well W-139U (see Appendix D).

2.13 Fuel Saturation Area No. 2 (FSA-2)

2.13.1 Site Description

FSA-2, located northwest of Facilities Building No. 176 (see Figure 2.3.1-3), is a site that reportedly was saturated in the 1970s and early 1980s by fuels leaking from a buried fuel pipeline.

From five soil borings that were drilled and sampled during previous investigations (see Table 2.1-1), only one shallow soil sample was reported to contain anomalous concentrations of VOCs and fuel hydrocarbons, none exceeding current Federal standards. Samples from one of two groundwater monitoring wells in the FSA-2 area also contained only trace amounts of fuel hydrocarbons.

2.13.2 Field Investigations

Although soil and groundwater contamination at FSA-2 does not appear to be extensive, additional information was needed to determine the lateral and vertical extent of contamination. Field investigations consisted of soil-gas surveys followed by drilling of five soil borings and installation of one monitoring well.

2.13.2.1 Soil-Gas Sampling

A soil-gas survey was conducted as a screening tool over the FSA-2 area. The survey was conducted using a 20-foot grid spacing, with the grid set up over the previously identified extent of contamination. Soil-gas measurements were made at selected grid points depending on the levels of contamination detected. Very little soil-gas contamination was detected in the FSA-2 area. A Geoprobe® sampling unit was used to drive steel rods to a depth of 4 feet where possible. An air sampling pump was used to purge the sampling rod and associated tubing to ensure soil gas was collected from the appropriate zone. A PID was calibrated and used to measure VOCs. In addition, Draeger colorimetric indicator tubes were used at each location to detect TPH. At 10 percent of the locations, a sorbent tube was used to collect a sample for laboratory VOC analysis.

2.13.2.2 Soil Sampling and Lithologic Logging

Results of the soil-gas survey were used to guide the placement of soil borings. An EPA representative reviewed previous data collected at FSA-2, evaluated results of the soil-gas investigation, and, in agreement with Geotech, selected five soil boring locations in the FSA-2 area (see Table 2.13.2-1). Three locations (SB-103, -104, and -105) were at grid points where soil-gas measurements indicated anomalous concentrations of contamination. One of these three locations (SB-103) was converted into monitoring well W-135. Two more soil borings (SB-138 and -144) were drilled to the west of the FSA-2 area in the parking lot west of the security fence. Soil borings were drilled from the surface to the top of the bedrock, and samples were collected in 3-foot intervals. Samples for VOC analysis were grab samples from each 3-foot interval. The remaining samples were composites of each interval and were analyzed for semi-VOCs and TPH. An additional monitoring well that was to have been placed downgradient of FSA-2 was not completed due to the shallow bedrock (Walnut Formation at 4.5 feet) and lack of groundwater downgradient of the site.

Table 2.13.2-1 FSA-2 Soil Borings/Monitoring Wells

SB-103 (W-135)	SB-138
SB-104	SB-144
SB-105	

2.13.2.3 Groundwater Sampling

Groundwater samples from W-135 were analyzed for VOCs, semi-VOCs, TPH, and total metals.

2.13.2.4 Single-Well Aquifer Testing

Aquifer testing was performed to characterize the hydraulic parameters of the upper zone for use in groundwater and contaminant transport modeling. Monitoring well W-135 produced water very slowly and was not suitable for aquifer testing. Instead, monitoring well F-212 was tested for hydraulic conductivity using the slug withdrawal method.

2.13.2.5 Water- and NAPL-Level Measurements

Fluid-level measurements made with an interface probe indicated that no LNAPL or DNAPL layers were present in the FSA-2 area.

2.14 Fuel Saturation Area No. 3 (FSA-3)

2.14.1 Site Description

FSA-3, located immediately east of Meandering Road between Facilities Building Nos. 157 and 142 (see Figure 2.3.1-3), is contaminated from buried fuel pipelines that leaked during the 1970s and early 1980s. The FSA-3 area also has numerous underground utilities and several UST sites.

Fuel-related floating product has been observed in 7 of 13 monitoring wells in the area. Analytical results of groundwater samples show that the groundwater at FSA-3 contains anomalous concentrations of VOCs, semi-VOCs, and fuel hydrocarbons.

Contaminants previously found in FSA-3 at concentrations that exceed Federal standards are:

- Benzene
- Chlorobenzene
- Ethylbenzene
- Naphthalene
- Toluene
- Trichloroethene

2.14.2 Field Investigations

Data from twenty monitoring wells obtained during previous investigations have provided information throughout FSA-3 (see Table 2.1-1). However, additional soil sample data were required around the perimeter of FSA-3 to better define the lateral and vertical extent of contamination. In a variance from the *Final Sampling and Analysis Plan*, three additional monitoring wells that were to have been installed at FSA-3 were not completed because prior investigations provided sufficient data to define the extent of contamination. Shallow bedrock to the west and northwest limited the investigation but allowed definition of the extent of contamination. Previous investigations by Hargis + Associates provided sufficient information to define the extent on the north side of the site. The Geotech investigation concentrated on the south and east sides of FSA-3.

2.14.2.1 Soil-Gas Sampling

A soil-gas survey was conducted as a screening tool in the FSA-3 area to help define the lateral extent of soil contamination. A sampling grid was established over the extent of contamination as mapped by prior investigations. When contamination was found to extend past the grid, selected points were investigated to define the extent of contamination. Numerous underground utilities and storage of structural steel in the areas investigated restricted the locations available for surveying.

Soil-gas samples were collected from a depth of 4 feet through a hollow steel rod drilled with a Geoprobe® sampling unit. Measurements were made with a calibrated PID at each location. A Draeger® colorimetric indicator tube also was used to sample for TPH at each location. At 10 percent of the locations a sorbent tube was used to collect a sample for laboratory VOC analysis.

2.14.2.2 Soil Sampling and Lithologic Logging

On the basis of previous data and the approximate extent of contamination outlined by the soil-gas survey, 18 soil borings (see Table 2.14.2-1) were drilled at locations in the FSA-3 area to help define the lateral and vertical extent of contamination. Soil samples were collected at 3-foot intervals from the surface to the top of the water table. The

samples collected for VOC analysis were grab samples from each 3-foot interval. The remaining samples were composites of each interval. Composite samples were analyzed for semi-VOCs and TPH. One sample from SB-149 was analyzed for toxicity characteristic leaching procedure (TCLP) characteristics to determine the leachability of contaminants for various remedial action technologies.

Table 2.14.2-1 FSA-3 Soil Borings

SB-084	SB-093
SB-085 (W-134)	SB-102
SB-086	SB-107
SB-087	SB-108
SB-088	SB-113 (W-143)
SB-089	SB-115
SB-090	SB-117
SB-091	SB-148
SB-092	SB-149

2.14.2.3 Groundwater Sampling

Water quality data was also needed to help define the extent of contamination. This included installation and sampling of new wells in addition to selected sampling of existing wells.

Four additional monitoring wells were to be installed: two to the east and two to the west of FSA-3. Where possible, soil borings were completed as monitoring wells. Shallow bedrock west of FSA-3 prevented installation of any new monitoring wells on that side. Two new wells were installed on the east side of FSA-3: W-143, in the North Parking Lot, and W-134 which also provides information for the Jet Engine Test Stand site. Well W-143 was planned as an upgradient well outside the FSA-3 area, but minor amounts of contamination (fuel odor, elevated PID readings) at SB-102 (the original planned site for W-143) forced relocation of the well to the east. Records showed a 1942 underground aviation gas line just east of SB-102.

Groundwater samples were collected from the new wells following completion and development. Samples were analyzed for VOCs, semi-VOCs, and fuel hydrocarbons.

2.14.2.4 Single-Well Aquifer Testing

Hydraulic parameters of the upper zone at FSA-3 were required for groundwater and contaminant transport modeling. Aquifer tests were conducted on one new (W-143) and two existing (F-208 and HM-105) monitoring wells. All aquifer tests were performed using the slug withdrawal method. These data were used to determine the hydraulic parameters of the upper zone at FSA-3. Well W-134 did not produce enough water to permit an accurate aquifer test.

2.14.2.5 Water- and NAPL-Level Measurements

Water-level measurements were made to help determine flow directions at FSA-3. Measurements were taken prior to each round of sampling from new monitoring wells and from existing wells. Hydrologic data will be used in groundwater and contaminant transport modeling. All fluid-level measurements were made with an interface-type fluid-level meter.

2.15 Former Fuel Storage Area (FFSA)

2.15.1 Site Description

A 100,000-gallon above-ground aviation fuel storage tank, located near the center of the Radar Range and used from the early 1940s to 1962, was suspected to have leaked. The tank was removed from the site and relocated in 1962. This site has been identified as the FFSA (see Figure 2.6.1-1).

Sampling of soils and groundwater at the site in 1982 indicated that both media were contaminated by semi-VOCs and oil and grease. In addition, anomalous concentrations of nickel were present in a monitoring well located south of the area (HM-14). Subsequent sampling during IRP Phase II investigations indicated that no significant contamination is present at the site and a recommendation for a "No Further Action" remedial action alternative was made.

2.15.2 Field Investigations

One test hole, TH-9, and monitoring well HM-8, were drilled in December 1982 at the previous site of the fuel tank (see Table 2.1-1). In January 1986, monitoring well HM-100 was installed downgradient of the Former Fuel Storage Area (FFSA). Although the site was recommended for "No Further Action," additional soil and groundwater sampling was needed to confirm previous results and to provide additional data on the extent of any contamination at the site.

2.15.2.1 Soil Sampling and Lithologic Logging

Four soil borings (see Table 2.15.2-1) were drilled 25 feet north, south, east, and west of monitoring well HM-8 (see Figure 2.6.1-1) where contamination was previously detected to determine the lateral and vertical extent of contamination. Two borings were drilled from the surface to the top of the water table (SB-074 and -075) with samples collected at 5-foot intervals. In a variance from the *Final Sampling and Analysis Plan*, the two other borings were only drilled to a depth of 16 and 20 feet. During the field investigation, a decision was made by the project hydrologist not to drill SB-076 and -077 to the water table based on two reasons: (1) visual contamination (oil stained soil) at the FFSA was only observed to a depth of 3 feet and (2) based on the groundwater flow direction, contaminants would flow toward the two deeper borings. At least two additional 5-foot composite samples were collected below the deepest level of contamination in each of the shallow borings.

Samples for VOC analysis were grab samples from each 5-foot interval. Other samples were composited over each 5-foot interval. Composite samples were analyzed for fuel hydrocarbons and oil and grease.

Table 2.15.2-1 FFSA Soil Borings

SB-074	SB-076
SB-075	SB-077

2.15.2.2 Groundwater Sampling

An additional groundwater sample was collected from monitoring well HM-14 and analyzed for nickel to confirm results of previous sampling. Prior to sampling for nickel, a submersible pump and associated piping were removed from well HM-14. The removed pump and piping were in good condition.

2.16 Jet Engine Test Stand (JETS)

2.16.1 Site Description

The JETS site, located northeast of Facilities Building No. 142 and east of Meandering Road (see Figure 2.3.1-3), was identified by Radian (1987) during the IRP Phase II investigations as a site containing fuel-related contamination in soils and groundwater. The site is located north of a fuels test area and an area of known fuel contamination (FSA-3).

There appear to be several possible sources for contamination at the JETS. Facilities Building No. 21, the JETS constructed a sump in 1975 to collect water for cooling, noise suppression, and building cleanup. The water is pumped to an industrial waste line. Adjacent to the site and Building No. 21 were two underground tanks once used for fuel storage. Immediately north of the JETS is an active underground JP-4 tank. Both the sump and the removed tanks were suspected sources of contaminants. Soil samples collected from five borings in the vicinity of the JETS contained anomalous concentrations of fuel hydrocarbons and oil and grease. Groundwater samples collected from four monitoring wells in the vicinity of the JETS indicated that two of the wells contained fuel-related hydrocarbons.

Contaminants previously identified in samples from the JETS site that have concentrations in excess of Federal standards are:

- Oil and grease
- TPH

2.16.2 Field Investigations

Although the site was formerly recommended for "No Further Action," previous data indicate that contaminants are present at the site. Three monitoring wells were installed near the JETS in August 1986 (Radian 1987): HM-105, HM-107, and HM-108. Two soil borings also were drilled in August 1986 by Radian: SB-9 and SB-10. Boring SB-9, which was drilled 6 feet south of two underground tanks (UST 25A - removed), encountered liquid hydrocarbons. Additional soil borings and soil samples were needed to better define the extent of contamination. During the RI, seven soil borings (see Table 2.16.2-1) were drilled in the JETS area. Four of these were drilled to investigate the former underground tanks (UST Site 25A) next to Building 21. One soil boring, SB-085, was converted to monitoring well W-134.

Table 2.16.2-1 JETS Soil Borings/Monitoring Wells

SB-041	UST-25A
SB-085	(W-134)
SB-099	UST-25A
SB-100	UST-25A
SB-106	UST-25A
SB-107	
SB-108	

2.16.2.1 Soil Sampling and Lithologic Logging

Three soil borings (SB-085, -107, and -108) were drilled and sampled around the perimeter of the JETS. In a variance from the *Final Sampling and Analysis Plan*, one boring to the north of the JETS was not drilled. The area immediately north of the JETS has many underground utilities prohibiting subsurface investigations and when clear of the utilities, the borehole would be located very close to SB-10 (Radian) or HM-81. Data from SB-10 and HM-81 were used to delineate the extent of contamination on the north side of the JETS.

Borings were sampled in 5-foot intervals from the surface to the top of the water table. A grab sample for VOC analysis was taken from each interval. The remaining sample was a composite of each 5-foot interval. Composite soil samples were analyzed for semi-VOCs, petroleum hydrocarbons, and oil and grease.

2.16.2.2 Groundwater Sampling

Groundwater quality data were collected from existing wells located downgradient of the site, a new monitoring well was installed upgradient of the site, and groundwater samples were collected to determine if the site is contributing contaminants to the hydrologic system. Temporary wells located downgradient of the JETS (see Figure 2.3.1-3) were sampled to determine if the JETS area is contributing contaminants to the groundwater. Groundwater samples were analyzed for VOCs, semi-VOCs, and petroleum hydrocarbons. One monitoring well (W-134) was installed east of the JETS area to determine upgradient groundwater quality.

2.16.2.3 Single-Well Aquifer Testing

To determine the hydraulic parameters of the upper zone in the JETS area, aquifer testing using the slug withdrawal method was performed on existing wells F-208 and HM-105. The new monitoring well, W-134, did not produce enough water to allow an accurate aquifer test.

2.16.2.4 Water-Level Measurements

Water-level measurements were taken from existing wells and the new well prior to sampling to better define the groundwater flow direction at the site. Measurement data were used for groundwater flow and contaminant transport modeling. All measurements were made with an interface probe. No NAPL layers were detected in the JETS area.

2.17 Waste Water Collection Basins (WWCB)

2.17.1 Site Description

The WWCB, located south of the Process Building (Facilities Building No. 181), consist of two plastic-lined concrete waste basins, each with an approximate capacity of 85,000 gallons, designed to collect and settle suspended solids from plant waste water (see Figure 2.3.1-2). IRP Phase I investigations determined that several spills from vapor degreasers in the Process Building (primarily TCE) have flowed to the basins via floor drains. Other chemical spills may have entered the basins via the floor drains. The integrity of the liner coating the concrete basins had not been evaluated for several years. It was suspected that a crack in the basin floor or wall may have allowed contaminants to leak to the surrounding soils.

Analytical results for groundwater samples previously collected from one monitoring well (HM-47) southeast of the WWCB, indicate that the groundwater is contaminated with VOCs and heavy metals. It is uncertain whether the VOCs in the groundwater at this location can be attributed to the WWCB. The presence of TCE in the groundwater indicates that the source is related to the Process Building (vapor degreaser spills). A sanitary sewer line runs on an east-west line under the site and a storm drain, which runs northwest-southeast, is located approximately 75 feet south of the WWCB. Other upgradient sources, such as Chrome Pit No. 2 and the DYCP, may be the source of heavy metals found in groundwater samples. Several organic compounds were present in samples from the downgradient well including *trans*-1,2-dichloroethene, TCE, and chlorobenzene.

2.17.2 Field Investigations

Solvent and other chemical spills may have entered the WWCB and, through leakage, entered soils and groundwater. Groundwater downgradient of the WWCB was shown to contain TCE, which is used extensively in the Process Building. To evaluate whether the basins were a source of TCE and other contaminants, additional subsurface soil sampling and upper-zone groundwater sampling was performed both upgradient and downgradient of the basins. Aquifer tests and water-level measurements also were performed to characterize the hydrologic flow conditions in the area of the WWCB.

The initial objective of data collection in the WWCB area was to determine if the WWCB are a source of contamination or if the source exists upgradient of the WWCB. In addition, a visual inspection of the integrity of the WWCB walls and floors was made to determine if significant leakage may be occurring from the WWCB.

2.17.2.1 Soil Sampling and Lithologic Logging

One soil boring (SB-110) was drilled immediately north and east of the WWCB. The boring was drilled to the top of the water table and soil samples were collected from 5-foot intervals. The samples for VOC analysis were grab samples from each 5-foot interval; the remaining samples were composites of each interval. The composite samples were analyzed for semi-VOCs and metals.

2.17.2.2 Groundwater Sampling

The soil boring was deepened following soil sampling and completed as an upper-zone monitoring well (W-137). Groundwater samples were analyzed for VOCs, semi-VOCs, and metals. Results of groundwater sampling of the new monitoring well were compared with results from upgradient wells (HM-77, F-221, W-133L) and with well HM-47 (downgradient) to determine if the WWCB are contributing to existing groundwater contamination to the east.

2.17.2.3 Single-Well Aquifer Testing

Slug withdrawal tests were not conducted in the WWCB area. Aquifer tests were performed in the nearby DYCP area and on three new wells installed inside the Assembly Building/Parts Plant.

2.17.2.4 Water-Level Measurements

Water-level measurements were taken prior to each sampling to determine groundwater flow directions at the site. All measurements were made with an interface probe. No NAPL layers were detected in the WWCB area.

2.17.2.5 Inspection of the WWCB

General Dynamics discovered a TCE leak from a tank in the Process Building in June 1991. TCE had leaked from a tank through the drain system into the WWCB. Fluid from the WWCB was drained into portable tanks for treatment, and the WWCB were cleaned of sludges contaminated with TCE. The empty WWCB walls, floors, and liners were visually examined on June 15-16, 1991. The concrete appeared in good shape with no visible cracks. The plastic liner was missing over large areas of the floor and was cracked at places on the walls. The trench system on the outside of the building leading to the WWCB also was examined and several sections were observed to be open to the soil.

2.18 East Parking Lot/Flightline

2.18.1 Site Description

The East Parking Lot/Flightline area (see Plate 1) is located east of the Assembly Building/Parts Plant. Previously installed monitoring wells in the East Parking Lot area were found to contain high concentrations of DCE, TCE, and chromium during IRP Phase II Stage 1 investigations. Hargis + Associates (1985a), the Corps (1986), and Intellus (1986b) further investigated the area by drilling and installing monitoring wells in the contaminated upper zone, and conducting aquifer testing and groundwater sampling.

2.18.2 Field Activities

The Assembly Building/Parts Plant perimeter survey (see Section 2.2) was conducted to determine potential source areas for contamination found in the East Parking Lot/Flightline area. A large amount of information exists for the area, but the maximum extent (downgradient) of contamination has not been defined. The objective of the East Parking Lot/Flightline area sampling was to define the overall extent of contamination.

Previous investigations have determined that the Walnut Formation either thins out or is eroded completely in places under the East Parking Lot. Contamination from the alluvial deposits is suspected to pass through the Walnut Formation into the upper portion of the Paluxy Aquifer in an area known as the "window area." The window area is located in the East Parking Lot near Grants Lane in the general area of monitoring well HM-82. Extensive prior investigations have resulted in 31 monitoring wells in the East Parking Lot. Previous investigators have drilled 30 monitoring wells and numerous soil borings in the Flightline area (see Table 2.1-1). CAFB also has many monitoring wells and soil borings to the east of Plant 4.

2.18.2.1 Soil Sampling and Lithologic Logging

Locations for additional groundwater monitoring wells (upper zone) and soil borings in the East Parking Lot/Flightline area were identified and sited with the concurrence of EPA Region VI. Ten soil borings (see Table 2.18.2-1) were drilled in the East Parking Lot/Flightline area. Six of these borings were converted into monitoring wells.

2.18.2.2 Groundwater Sampling

Well installations in the Flightline area were coordinated with GD Flightline Operations personnel. Well location, drilling permits, and site access for one monitoring well (W-153) east of the main runway were coordinated with CAFB Airfield Management and Civil Engineering personnel. Monitoring wells were completed to allow sampling of LNAPLs, DNAPLs, and soluble organic compounds. Samples collected from each new monitoring well were analyzed for VOCs, metals, and TPH for two sampling rounds.

Table 2.18.2-1 East Parking Lot/Flightline Soil Borings/Monitoring Wells

SB-135 (W-149)	SB-143 (W-153)
SB-136	SB-145
SB-137 (W-151)	SB-146 (W-155)
SB-139	SB-147 (W-156)
SB-142 (W-152)	SB-155

2.18.2.3 Single-Well Aquifer Testing

Aquifer tests for hydraulic conductivity were conducted on three new monitoring wells in the East Parking Lot/Flightline area. Two new wells were not tested due to low water yield, and well W-153 was not tested because of access restrictions at the time of testing. All aquifer tests were performed using the slug withdrawal method.

2.18.2.4 Water-Level Measurements

All water-level measurements were made using an interface type water-level recorder. No NAPL layers were detected during the investigation in the East Parking Lot/Flightline area.

2.19 Site-Wide Investigations

2.19.1 Background Sampling

2.19.1.1 Background Sampling of Soils

Insufficient prior background data for soils in the Plant 4 area precluded comparisons of anomalous concentrations of specific contaminants in Plant 4 soil samples with background levels. Soil samples were collected from two locations near Plant 4 to determine background concentrations of specific analytes. Inorganic analytes also were compared to a data set of soil samples from the western United States (Shacklette and Boerngen 1984).

The two background locations were selected on the basis of similar lithology as Plant 4 and because they were in areas with no prior industrial activity. Soil and soil-gas samples collected at each location were analyzed, and the results were used for comparing analyte concentrations found at Plant 4 with background concentrations.

Plant 4 background soil samples were taken from two locations near Plant 4 (see Plate 2). One location was south of Clifford Avenue, adjacent to well W-157, on property currently owned by Lockheed. The second background location was west of Meandering Road Creek, adjacent to well P-29M, on city of White Settlement property.

At each background location a soil boring was drilled to a depth of 2 feet using a hand-operated stainless steel barrel auger. Two samples were collected at each location: one from the surface to a depth of 1 foot and a second from 1 to 2 feet. Each 1-foot interval was composited after a grab sample was collected for VOC analysis. The composited sample was analyzed for semi-VOCs, metals, and oil and grease.

2.19.1.2 Background Sampling of the Paluxy Aquifer

During the RI, two monitoring wells were installed off site in the middle portion of the Paluxy Aquifer (P-29M and P-30M). Data from these wells were used to provide background data for water quality in the Paluxy Aquifer.

2.19.1.3 Background Sampling of the Upper-Zone Aquifer

Water samples designated as background for the upper-zone aquifer were not collected during the RI.

2.19.1.4 Background Sampling of Soil Gas

Two soil-gas samples were collected adjacent to off-site monitoring wells W-157 and P-29M. Samples were collected from a depth of 4 feet and sent to the laboratory for VOC analysis.

2.19.1.5 Background Sampling of Lake Worth

One background sample was collected from Lake Worth (see Location 1, Figure 2.19.1-1) at the west end of a small embayment approximately 0.5 mile west of the Lockheed Lake Worth pumping station. Surface water and two lake sediment samples were collected at this location.

Sediment samples were collected from the lake bottom to 2 feet in depth. Upon retrieval, the samples were split into 1-foot sections for analysis. Grab samples for VOC analysis were taken directly from the sampler, and the remaining material was composited from several samples for radioisotope, TPH, oil and grease, and priority-pollutant metals analysis.

One water sample was collected using the container immersion technique. The lake water was measured for pH, temperature, and conductivity when samples were collected. Samples were analyzed for VOCs, priority-pollutant metals, TPH, oil and grease, polychlorinated biphenyls (PCBs), and pesticides.

2.19.1.6 Background Sampling of Meandering Road Creek

Background water samples of Meandering Road Creek were taken upgradient of Landfill No. 4 at location SW-2 (see Figure 2.5.2-1). Samples were originally planned to have been collected further from the site, but the creek is normally dry above this point. When the creek does have water flowing it is usually a flood event that would not yield a representative sample. Samples were analyzed for semi-VOCs, oil and grease, VOCs, TPH, and priority-pollutant metals.

2.19.1.7 Background Samples for Biomonitoring

One background biomonitoring location was selected in agreement with EPA and USFWS personnel. The background biomonitoring site (Location 28) was located off Silver Creek Road, about 5 miles from Plant 4, near a small park on Live Oak Creek (see Figure 2.19.1-2). Water was collected on three separate occasions during one 7-day period and transported to Trac Laboratory in Denton, Texas, for testing.

2.19.1.8 Background Samples for Tissue Sampling

Two locations were selected for the collection of background tissue samples in agreement with EPA and USFWS. One location was at the Lake Worth background sampling site (see Location 1, Figure 2.19.1-1), and the other was at the Live Oak Creek site (see Location 28, Figure 2.19.1-2). The only tissue samples collected were from mosquito fish, in agreement with the USFWS personnel. Fish sampling was done using nets from the shore and from a pontoon boat. Sample containers were weighed before and after filling. Samples were frozen and shipped on dry ice and analyzed for polynuclear aromatic hydrocarbons (PAHs), PCBs, and pesticides.

2.19.1.9 Background Samples for Air Monitoring

One background air monitoring site was set up adjacent to White Settlement municipal well WS-6T, approximately 0.75 mile west of Plant 4 (see Figure 2.19.1-3 in Section 2.19.6 and Plate 2). The air monitoring equipment was placed inside a locked security fence in a residential neighborhood. Samples were collected concurrently with the samples collected on site and were analyzed for VOCs and select metals.

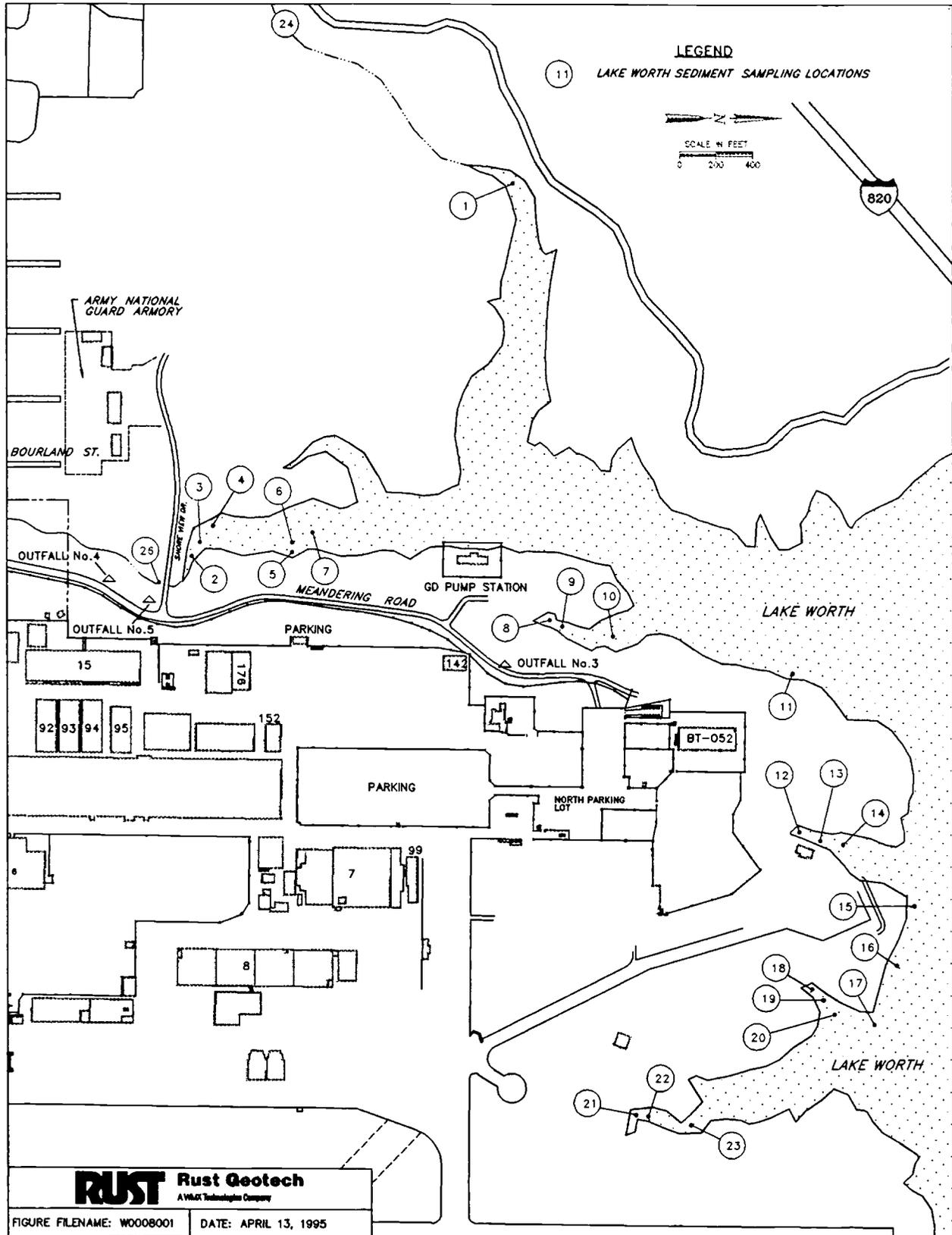


Figure 2.19.1-1. Lake Worth Water and Sediment Sampling Locations.

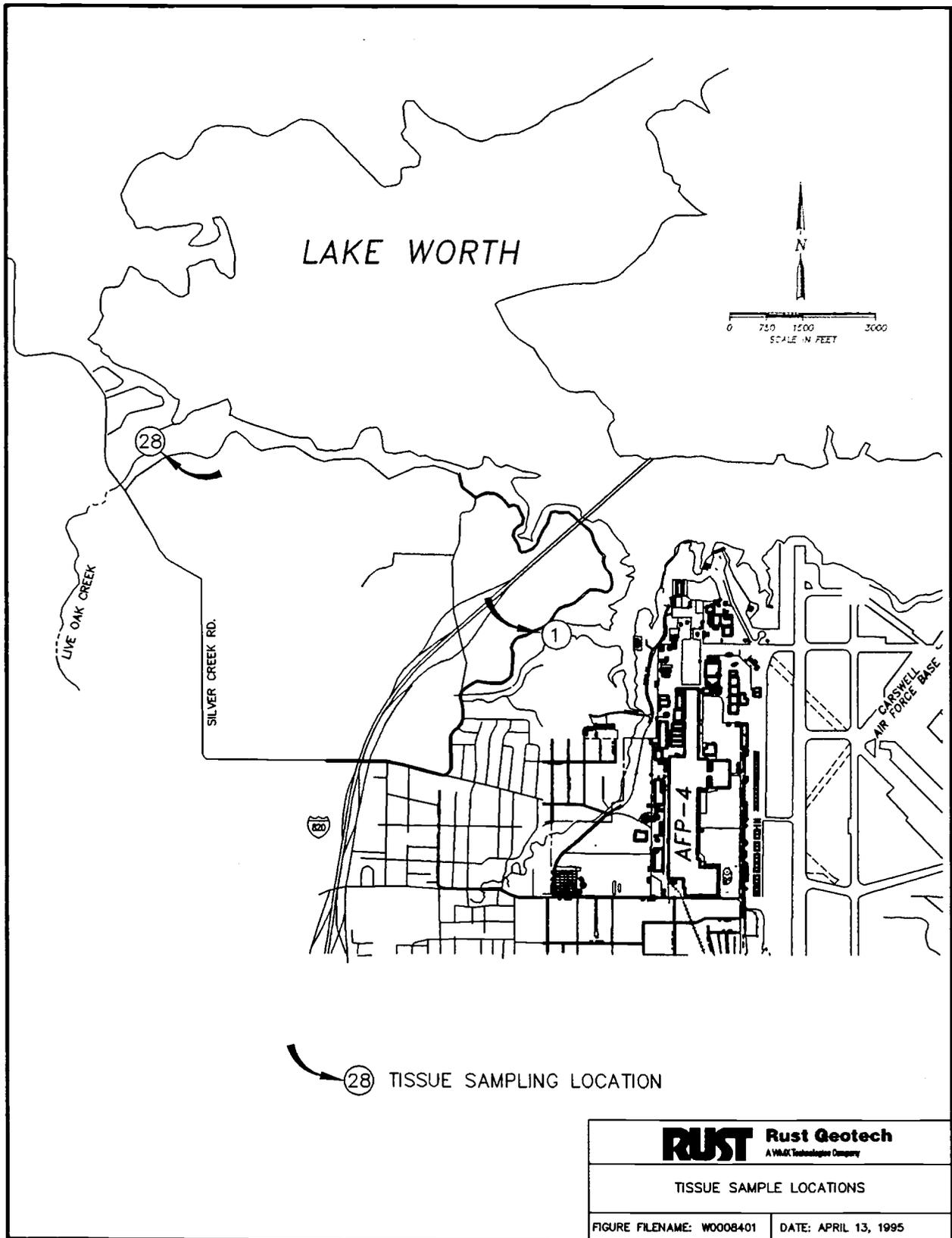


Figure 2.19.1-2. Background Biomonitoring/Tissue Sample Locations

2.19.2 Upper-Zone Hydrogeologic Characterization

Previous studies have shown that upper-zone groundwater was contaminated as the result of past waste-handling activities. Because the distribution and movement of contaminants in upper-zone groundwater have not been completely defined, additional hydrogeologic characterization was performed for this flow system. This characterization included:

- Lithologic logging of upper-zone soil borings and monitoring wells
- Water-level of new and existing upper-zone wells
- Continuous water-level monitoring of selected upper-zone wells
- Single-well aquifer testing (slug-testing for hydraulic conductivity)

2.19.2.1 Lithologic Logging

Lithologic logging was conducted for 152 soil borings and eight monitoring-well borings. Twenty-nine of the soil borings were completed as monitoring wells, providing a total of 37 new upper-zone groundwater monitoring wells installed during the RI.

Lithologic logging was performed by collecting continuous split-barrel samples through a hollow-stem auger as the borings were drilled. Split-barrel samples were collected using a 3-inch o.d. by 24-inch-long stainless steel split-barrel sampler driven by a 140-pound drop hammer. Each sample was collected by driving the sampler the full 24 inches, or until penetration was less than 6 inches per 50 hammer blows.

After retrieving the sampler from the boring, it was opened and placed on the logging table for inspection by the site geologist. Lithologic information was then recorded on a lithologic log. Information contained in the lithologic description included:

- Typical name (sand, gravel, clay, etc.)
- Munsell color
- Percentage sand and gravel
- Sorting (poor to well)
- Grain angularity
- Induration or plasticity
- Moisture content (moist to saturated)

At some locations, paired monitoring wells were installed in separate borings to monitor upper and lower portions of the upper-zone groundwater system. At these locations, split-barrel sampling was conducted only for that portion of the second boring which extended below the bottom of the first boring. However, lithologic logs were prepared for both wells at every paired-well location.

Each lithologic log was inspected and verified by a second geologist or hydrogeologist after being completed by the site geologist. Lithologic logs for upper-zone soil borings and monitoring wells are presented in Appendix A-2.

Lithologic data were used in conjunction with slug test results to define local variations in hydraulic conductivity and porosity. This local-scale variability was then incorporated into the analysis of groundwater flow and contaminant transport.

2.19.2.2 Water-Level Monitoring

Synoptic water-level measurements were made at all accessible upper-zone monitoring wells during April 1990, March 1991, and September 1991. Water levels in monitoring wells installed during the RI were included in the September 1991 measurement episode only.

At each well, an interface probe was used to measure the depth to water below the top of the inner well casing. The interface probe allowed field technicians to distinguish between water and nonaqueous phase liquids (NAPLs) that may have been floating on the top or pooled at the bottom of the water column. The probe was lowered into the well until the reel unit began emitting an audible signal. A beeping signal indicated the presence of a NAPL, and a steady signal indicated the presence of water. When floating NAPLs were detected, the depth measurement was recorded as a "depth-to-floater." The probe was then lowered further until the steady tone was heard and this depth was recorded as the depth to water. The difference between the two measurements was the thickness of the hydrocarbon product column in the well. When pooled NAPLs were detected below the water column, the depth measurement was recorded as "depth-to-sinker." Wells containing NAPLs are discussed in Section 4.5.1.

Wells that had submersible pumps suspended from steel pump-hanger plates could not be measured with an interface probe because the diameter of the probe exceeded the diameter of the access hole. These wells were measured using a conventional electric water-level probe.

Synoptic water-level measurements were made to provide hydraulic head data as a function of space for both the upper-zone flow system and the Paluxy Aquifer. This data was then used to prepare water table or hydraulic head maps that were used to assess the direction and velocity of groundwater flow in the upper zone and the Paluxy Aquifer. Water-level measurements for nested wells were also used to evaluate vertical flow components within the upper zone and the Paluxy Aquifer. In the window area, where the upper zone is hydraulically connected to the Paluxy Aquifer, vertical gradients were used to evaluate the magnitude of recharge from the upper zone to the Paluxy Aquifer.

The synoptic water-level measurements are presented in Appendix D and discussed in Section 3.8.

2.19.2.3 Continuous Water-Level Monitoring

Continuous water-level monitoring was conducted at two upper-zone monitoring wells: HM-86 and W-143. Continuous water-level monitoring also was conducted at the adjacent P-14US and P-28U wells. Data collection began on September 10, 1991. The objective of the monitoring was to identify seasonal variations in hydraulic head, evaluate the impact of external stresses, assess aquifer parameters and characteristics, and determine the degree of vertical communication between the upper zone and the Paluxy Aquifer (particularly in the vicinity of the window area).

Data was collected using electronic pressure transducers and data loggers. In-Situ, Inc., data loggers were programmed to receive data from In-Situ and Keller-PSI, Inc., pressure transducers. The transducers were connected to shielded and vented cables and lowered into the wells to a position approximately 2 feet above the bottom of each well. The depth of placement was measured during installation as was the depth to water in the well. These two measurements defined the height of the water column above the transducer. The transducer cable was then connected to the data logger and the elevation head at the transducer was checked electronically. If this value did not agree with the value calculated from the manual measurements, the logger and transducer were reprogrammed and rechecked for agreement. If elevation heads from manual and electronic measurements repeatedly differed by more than ± 0.01 foot, the transducer, the logger, or both were replaced.

Once proper transducer and logger operation had been verified, the logger was programmed to record depth-to-water measurements on the hour. The logger was then started and placed in a locked well vault designed to prevent unauthorized access to the well and recording equipment. The data recorded in the loggers was then transferred to a personal computer at 3- to 5-month intervals. The continuous water-level monitoring terminated on November 2, 1992, although the data from this last interval have not yet been collected from the data loggers.

The results of the continuous water-level monitoring are discussed in Section 3.8.

2.19.2.4 Single-Well Aquifer Testing

To determine the hydraulic conductivity of the upper-zone clays, sands, and gravels, single-well aquifer tests (slug tests) were conducted on 29 upper-zone monitoring wells. These included all suitable wells installed during the RI and several wells installed during previous investigations. Wells were considered suitable for slug testing if they contained a water column that was at least 7-feet high and were screened in a single hydrogeologic unit. A well with a screen or filter pack extending through a portion of

the Walnut Formation and a portion of the alluvium was considered unsuitable for slug testing because each unit has different hydraulic characteristics. These different characteristics cannot be distinguished from the results of a single slug test on one well.

The slug withdrawal method was used for all upper-zone slug tests. Data were recorded using an electronic pressure transducer connected to a high-speed data logger. The transducer was lowered into the well to a position 1 foot above the bottom of the well. The transducer cable was then securely fixed to the above-ground portion of the well casing and connected to the data logger. A clean 10-foot-long PVC bailer was then lowered into the well until it was fully submerged or until the bottom of the bailer reached the position of the transducer. A 1.67-inch o.d. bailer was used in 2-inch monitoring wells, and a 3.5-inch o.d. bailer was used in 4-inch monitoring wells. The elevation head measured by the transducer and displayed by the logger was observed until the water level in the well had declined to its equilibrium level. The data logger was then started and the full bailer was quickly removed from the well and emptied into a small storage tank. Bailed water was later transferred to drums containing monitoring-well purge water.

During the recovery of the water level in the well, data were recorded at variable rates beginning with five measurements per second for the first 2 seconds and progressing to one measurement every 10 minutes after an elapsed time of 100 minutes. This logging rate deviates from that proposed in the *Work Plan* (UNC Geotech 1990) because In-Situ, Inc. data loggers were used instead of a less reliable model. The logging rates that were used are suitable for slug testing applications. Data recording continued until the water-level recovery was 95 percent complete. Repeat slug tests were conducted on all wells except those that required more than 10 hours to achieve 95 percent recovery.

The results of the slug testing are presented and discussed in Section 3.8.

2.19.2.5 Vertical Hydraulic Conductivity Testing

To allow calculation of vertical flow rates in the Walnut and Paluxy Formations, vertical hydraulic conductivity testing was performed on core samples collected from P-27U, P-28U, and P-30M. Three core samples were obtained from each of these borings for analysis.

Vertical hydraulic conductivity was determined using the procedure described in ASTM D 5084-90, "Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter." Cores were collected using an "NX-size" (1.945-inch diameter) core barrel. Core samples were trimmed to a length of approximately 2 inches before testing. Test results included the saturated vertical hydraulic conductivity and the effective porosity. Vertical hydraulic conductivity results are presented and discussed in Section 3.8.

2.19.2.6 Total Organic Carbon Analysis

To determine the potential for adsorption of organic contaminants in groundwater moving through the Walnut and Paluxy Formations, the total organic carbon (TOC) content was measured for 10 samples taken from these two formations. Three samples were analyzed from P-27U and P-28U and four samples were analyzed from P-30M.

TOC content was measured using the sediment adaptation of the procedure described in ASTM D 4129-88. Samples were crushed and ground prior to analysis. Results included the percentage of total carbon (including carbonate), the percentage of carbon in the form of carbonate, and the percentage of total organic carbon. Results are presented and discussed in Section 3.8.

2.19.3 Paluxy Aquifer System Characterization

Because the Paluxy Aquifer system is an important water supply in the Fort Worth metropolitan area, its hydraulic, water-quality, and contaminant transport characteristics were thoroughly investigated.

Groundwater quality data were collected to provide information on site-wide water quality of the Paluxy Aquifer system. This information was used to assess the impacts of individual contamination sites on the overall water quality of the Paluxy Aquifer system downgradient of Plant 4.

2.19.3.1 Lithologic Logging and Coring

Subsurface coring and monitoring well installations were completed for five additional Paluxy Aquifer monitoring wells (see Table 2.19.3-1) in areas where data were lacking (see Plate 1). Boreholes were cored continuously from the top of the Walnut Formation until the borehole was completed in the desired portion of the Paluxy Formation. Core sections were logged and stored in core boxes for archival purposes. Selected sections of the core were submitted to an engineering laboratory for analysis to determine vertical hydraulic conductivity, TOC content, and organic partition and distribution coefficients. Hydraulic parameter data were used for contaminant transport modeling for Plant 4 and adjacent properties. After coring was complete, the boreholes were reamed out to allow well installation. Groundwater samples were collected from the new wells and analyzed for VOCs, semi-VOCs, and metals.

Table 2.19.3-1 Paluxy Monitoring Wells

P-27U	P-30M
P-28U	P-31U (Dry)
P-29M	

2.19.3.2 Water-Level Monitoring

Synoptic water-level measurements were made at all accessible Paluxy Formation monitoring wells during April 1990, March 1991, and September 1991. Water levels in monitoring wells installed during the RI were included in the September 1991 measurement episode only.

At each well, an interface probe was used to measure the depth to water below the top of the inner well casing. The interface probe allowed field technicians to distinguish between water and hydrocarbon liquids that may have been floating on the top of the water column. The probe was lowered into the well until the reel unit began emitting an audible signal. A beeping signal indicated the presence of a hydrocarbon liquid, and a steady signal indicated the presence of water. When hydrocarbon liquids were detected, the depth measurement was recorded as a "depth-to-floater." The probe was then lowered further until the steady tone was heard, and this depth was recorded as the depth to water. The difference between the two measurements was the thickness of the hydrocarbon product column in the well.

Wells that had submersible pumps suspended from steel pump-hanger plates could not be measured with an interface probe because the diameter of the probe exceeded the diameter of the access hole. These wells were measured using a conventional electric water-level probe.

Synoptic water-level measurements were made to provide hydraulic head data as a function of space for both the upper-zone flow system and the Paluxy Aquifer. These data then were used to prepare water-table or hydraulic head maps that were used to assess the direction and velocity of groundwater flow in the upper zone and the Paluxy Aquifer. Water-level measurements for nested wells also were used to evaluate vertical flow components within the upper zone and the Paluxy Aquifer. In the window area, where the upper zone is hydraulically connected to the Paluxy Formation, vertical gradients also were used to evaluate the magnitude of recharge from the upper zone to the Paluxy Aquifer.

The synoptic water-level measurements are presented in Appendix D and discussed in Section 3.8.

2.19.3.3 Continuous Water-Level Monitoring

Continuous water-level monitoring was conducted at three Paluxy Formation monitoring wells: P-28U, P-11U, and P-14US. Data collection began on September 10, 1991. The objective of the monitoring was to identify seasonal variations in hydraulic head, evaluate the impact of external stresses, assess aquifer parameters and characteristics, and determine the degree of vertical communication between the upper zone and the Paluxy Formation (particularly in the vicinity of the window area).

Data were collected using electronic pressure transducers and data loggers. In-Situ, Inc., data loggers were programmed to receive data from In-Situ and Keller-PSI, Inc., pressure transducers. The transducers were connected to shielded and vented cables and lowered into the wells to a position approximately 2 feet above the bottom of each well. The depth of placement was measured during installation as was the depth to water in the well. These two measurements defined the height of the water column above the transducer. The transducer cable was then connected to the data logger and the elevation head at the transducer was checked electronically. If this value did not agree with the value calculated from the manual measurements, the logger and transducer were reprogrammed and rechecked for agreement. If elevation heads from manual and electronic measurements repeatedly differed by more than ± 0.01 foot, the transducer, the logger, or both were replaced.

Once proper transducer and logger operation was verified, the logger was programmed to record depth-to-water measurements on the hour. The logger was then started and placed in a locked well vault designed to prevent unauthorized access to the well and recording equipment. The data recorded in the loggers were transferred to a personal computer at 3- to 5-month intervals. The continuous water-level monitoring terminated on November 2, 1992, although the data from this last interval have not yet been collected from the data loggers.

The results of the continuous water-level monitoring are discussed in Section 3.8.

2.19.3.4 Single-Well Aquifer Testing

To determine the hydraulic conductivity of the Paluxy Formation, single-well aquifer tests (slug tests) were conducted on four Paluxy Formation monitoring wells. These included all suitable wells installed during the RI and several wells installed during previous investigations. Wells were considered suitable for slug testing if they contained a water column that was at least 7-feet high.

The slug withdrawal method was used for all Paluxy Formation slug tests. Data were recorded using an electronic pressure transducer connected to a high-speed data logger. The transducer was lowered into the well until the transducer was 20 feet below the water level or until it was within 1 foot of the bottom of the well. The transducer cable was then securely fixed to the above-ground portion of the well casing and connected to the data logger. A clean 10-foot-long PVC bailer was lowered into the well until it was fully submerged or until the bottom of the bailer reached the position of the transducer. A 1.67-inch o.d. bailer was used in Paluxy Formation wells. The elevation head measured by the transducer and displayed by the logger was observed until the water level in the well had declined to its equilibrium level. The data logger was then started and the full bailer was quickly removed from the well and emptied into a small storage tank. Bailed water was later transferred to drums containing monitoring-well purge water.

During the recovery of the water level in the well, data were recorded at variable rates beginning with five measurements per second for the first 2 seconds and progressing to one measurement every 10 minutes after an elapsed time of 100 minutes. Data recording continued until the water-level recovery was 95 percent complete. Repeat slug tests were conducted on all wells except those that required more than 10 hours to achieve 95 percent recovery.

The results of the slug testing are presented and discussed in Section 3.8.

2.19.3.5 Vertical Hydraulic Conductivity Testing

To allow calculation of vertical flow rates in the Walnut and Paluxy Formations, vertical hydraulic conductivity testing was performed on core samples collected from P-27U, P-28U, and P-30M. Three core samples were obtained from each of these borings for analysis.

Vertical hydraulic conductivity was determined using the procedure described in ASTM D 5084-90, "Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter." Cores were collected using an "NX-size" (1.945-inch diameter) core barrel. Core samples were trimmed to a length of approximately 2 inches before testing. Test results included the saturated vertical hydraulic conductivity and the effective porosity. Vertical hydraulic conductivity results are presented and discussed in Section 3.8.

2.19.3.6 Total Organic Carbon Analysis

To determine the potential for adsorption of organic contaminants in groundwater moving through the Walnut and Paluxy formations, the TOC content was measured for 10 samples taken from these two formations. Three samples were analyzed from P-27U and P-28U and four samples were analyzed from P-30M.

TOC content was measured using the sediment adaptation of the procedure described in ASTM D 4129-88. Samples were crushed and ground prior to analysis. Results included the percentage of total carbon (including carbonate), the percentage of carbon in the form of carbonate, and the percentage of total organic carbon. Results are presented and discussed in Section 3.8.

2.19.4 Lake Worth Investigations

Contaminants from Plant 4 may be entering Lake Worth via surface water drainage and upper-zone groundwater discharge. Because Lake Worth is used as a source of public water supply and is also a source of recharge to the Paluxy Aquifer, additional data were needed to evaluate the potential risk to human health and the environment from contaminants in surface water and sediment of Lake Worth.

2.19.4.1 Water Sampling

Water samples were collected from eight locations (Lake Worth Sampling Locations 1, 2, 5, 8, 11, 12, 18, and 21 [see Figure 2.5.2-1]) to obtain surface water quality data from Lake Worth adjacent to Plant 4. The data were used to determine if contaminants are present in the waters of Lake Worth, the likely source of the contaminants, and potential receptors and risk associated with those contaminants. One background sample was collected from Lake Worth approximately 0.5 mile west of the Lockheed Lake Worth pump station to determine if changes in water quality occur as a result of activities at Plant 4. One water sample was collected at Lake Worth Sampling Location 24 (Plate 2) which is located on the unnamed creek with drainage to the Lake Worth background site (Location 1). Samples were grab samples using the container immersion method. Water samples were analyzed for VOCs, semi-VOCs, TPH, oil and grease, and dissolved metals. Temperature, pH, and electrical conductivity were measured at each sampling location at the time of sampling.

2.19.4.2 Sediment Sampling

Sediment samples were collected from areas where contamination was most likely to be found, such as areas where surface drainage discharges into Lake Worth, (Figure 2.19.1-1) to determine if past contaminant spills or releases have reached Lake Worth. The data from the sediments were used to assess potential risk associated with contaminated sediments.

Six coves of Lake Worth that have drainage originating at Plant 4 were sampled, with three sediment samples collected from each cove. Lake sampling locations were established by lining up with landmarks on shore. One sample was taken 10 feet from the shoreline, and two more samples were taken evenly spaced toward the middle of the cove or arm of the lake. The maximum beginning sampling depth was 17 feet. Samples were collected to a depth of 22 inches into the sediments (the length of the sampler) and split into two 11-inch samples for analysis. Samples for VOC analysis were bottled immediately. The sampler was returned to the lake bottom several times to gather sufficient material for a composite sample. A total of 25 sediment sampling locations were sampled in Lake Worth. The type of analysis performed was dependent on the sampling location (see Table 2.19.4-1), with some sites having special analysis. Seven samples were analyzed for VOCs, semi-VOCs, oil and grease, TPH, and metals. VOC samples were bottled immediately from the sample barrel, and the remainder of the material was composited for other analyses. Samples collected from the drainage near the Nuclear Aerospace Research Facility (NARF) area were also analyzed for radioisotopes. A field scan was performed for alpha, beta, and gamma radiation on all samples collected from sediments near the former NARF site, with no radiation levels above background detected. Twenty-one samples were analyzed for polynuclear aromatic hydrocarbons (PAHs) and three were analyzed for PCBs and pesticides.

Table 2.19.4-1 Summary of Lake Worth Sediment Samples

LOCATION	TYPE OF ANALYSIS											
1	BKG	VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs	PCBs/Pesticide	RAD	Grain	Moisture	TOC
2		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs	PCBs/Pesticide		Grain	Moisture	TOC
3									Metals (2)			
4							PAHs		Metals (2)	Grain	Moisture	TOC
5		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs			Grain	Moisture	TOC
6							PAHs		Metals (2)	Grain	Moisture	TOC
7							PAHs		Metals (2)	Grain	Moisture	TOC
8		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs			Grain	Moisture	TOC
9							PAHs		Metals (2)	Grain	Moisture	TOC
10							PAHs		Metals (2)	Grain	Moisture	TOC
11		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs			Grain	Moisture	TOC
12		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs			Grain	Moisture	TOC
13							PAHs		Metals (2)	Grain	Moisture	TOC
14							PAHs		Metals (2)	Grain	Moisture	TOC
15										Grain	Moisture	TOC
16										Grain	Moisture	TOC
17										Grain	Moisture	TOC
18		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs			Grain	Moisture	TOC
19							PAHs			Grain	Moisture	TOC
20							PAHs			Grain	Moisture	TOC
21		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs			Grain	Moisture	TOC
22							PAHs		Metals (2)	Grain	Moisture	TOC
23							PAHs		Metals (2)	Grain	Moisture	TOC
24							PAHs	PCBs/Pesticide		Grain	Moisture	TOC
25	Tissue sampling only, also sampled as SW-5											
26							PAHs		Metals (2)	Grain	Moisture	TOC
27	Biototoxicity Sampling											
28	Tissue sampling only											

Notes:
 Metals (1) - Priority-Pollutant Metals as in Sampling Plan
 Metals (2) - Metals analysis for aluminum, cadmium, chromium, lead, and nickel.
 O&G - Oil and Grease
 PAHs - Polynuclear Aromatic Hydrocarbons
 RAD - Radioisotope Analysis
 Semi-VOCs - Semivolatile Organic Compounds
 Grain - Grain Size Analysis
 TOC - Total Organic Content
 Moisture - % Moisture

A background sediment sample was collected at a location 0.5 mile west of the Lockheed Lake Worth pumping station and was analyzed for all analytes except selected metals (Al, Cd, Cr, Ni, and Pb).

Two types of metals analysis were run on selected samples. Aluminum, cadmium, chromium, nickel, and lead were selected for analysis using procedures specified by the USFWS, to aid in their evaluation of the inorganic data. Analysis was to be by the more stringent of either FWS-9-OAS-91-111 (USFWS) or the EPA Method 7000 Series. The selected metals were analyzed by a USFWS contract laboratory using the EPA Method 7000 Series. These metals are used in aircraft production, are constituents in fuels, or were identified as chemicals of concern in the risk assessment. This group of selected metals was analyzed in addition to the Priority-Pollutant Metals (PPMTL).

2.19.5 Meandering Road Creek Investigations

Upper-zone groundwater is known to discharge from Plant 4 along the Meandering Road Creek drainage by way of seeps. Much of the upper-zone groundwater upgradient of the seeps is contaminated with fuels, solvents, oil and grease, and metals. A potential exists for contamination of surface waters and sediments as a result of upper-zone discharge into Meandering Road Creek. It is also suspected that the creek is providing recharge to the Paluxy Aquifer. A potential exists for contaminant migration into the Paluxy Aquifer, which supplies domestic water to surrounding communities.

The objective of the Meandering Road Creek study was to determine the extent of surface water contamination originating from Plant 4. Upstream surface water and sediment samples were needed to determine potential contamination to the surface water pathway from upstream sources before the creek enters the Plant 4 facility boundary. Sample analyses along the facility boundary were needed to better define the source areas for contamination entering Meandering Road Creek from Plant 4. Additional seeps required identification and sampling to characterize upper-zone discharge.

2.19.5.1 Water Sampling

Existing surface-water sampling locations that had been sampled by Hargis + Associates on a routine basis were not resampled. New locations (SW-1 through SW-8) were established both upstream and between previously established sampling locations to better define the distribution of contaminants (see Figure 2.5.2-1). Sampling station SW-5 in the Meandering Road Creek west of monitoring well F-214 was selected because an emulsion was observed in the water at the bottom of a pool cut into the creek bed. A sample was collected and analyzed for chemical content. These samples were collected using the container immersion method and analyzed for VOCs, semi-VOCs, metals, TPH, and oil and grease. Water-quality parameters (pH, electrical conductivity, temperature) were monitored in the field at the time of sampling.

2.19.5.2 Sediment Sampling

Sediment samples were collected at seven new creek sampling locations (SW-01 through SW-07) and analyzed for VOCs, semi-VOCs, metals, TPH, and oil and grease. Lake Worth Sampling Location 26, in Meandering Road Creek, upstream from Lake Worth, was sampled for PAHs, selected metals, total organic content, grain size, and moisture to provide additional data requested by the USFWS.

2.19.5.3 Seep Sampling

Water samples were collected at all seeps evident along the Meandering Road Creek drainage to determine potential source areas for contaminant migration to the creek. Sample data were used to study contaminant fate and transport after discharge from the seeps in the area of Landfill No. 3 (SW-05, -08, and -09) to the stream bed. Additional seeps (SW-10 and -11) were identified and sampled near Outfall No. 3 (near the JETS).

2.19.6 Air Quality Monitoring

The potential contamination of the air pathway as the result of past and current activities at Plant 4 was not adequately addressed by previous IRP investigations. Several areas are known to contain soils and groundwater contaminated with VOCs that have the potential for entering the air pathway through volatilization. Other areas, such as the fire department training areas, may contain surface contaminants that are available to the air pathway through windblown particles. Consequently, data were collected to evaluate the potential risk to human health and the environment from contaminants released to the air.

Two air-quality monitoring stations were established at Plant 4 (see Figure 2.19.1-3). The first station, located approximately 0.75 mile west of the facility within the security fence at White Settlement municipal well WS-6T, approximately 50 feet from the street, was established as an offsite ambient air-quality monitoring station. This site was chosen because it is located within a residential neighborhood with no significant industrial influence to the ambient air quality. The second station, located on the Plant 4 facility approximately 300 feet north of Building 176, was established as an onsite air-quality monitoring station. This site was chosen because it was predominantly downwind of the facility and several IRP sites during the period in which the samples were collected.

In addition to the data collected from the two air-quality monitoring stations, wind data (speed and direction) were obtained from the meteorological station at CAFB.

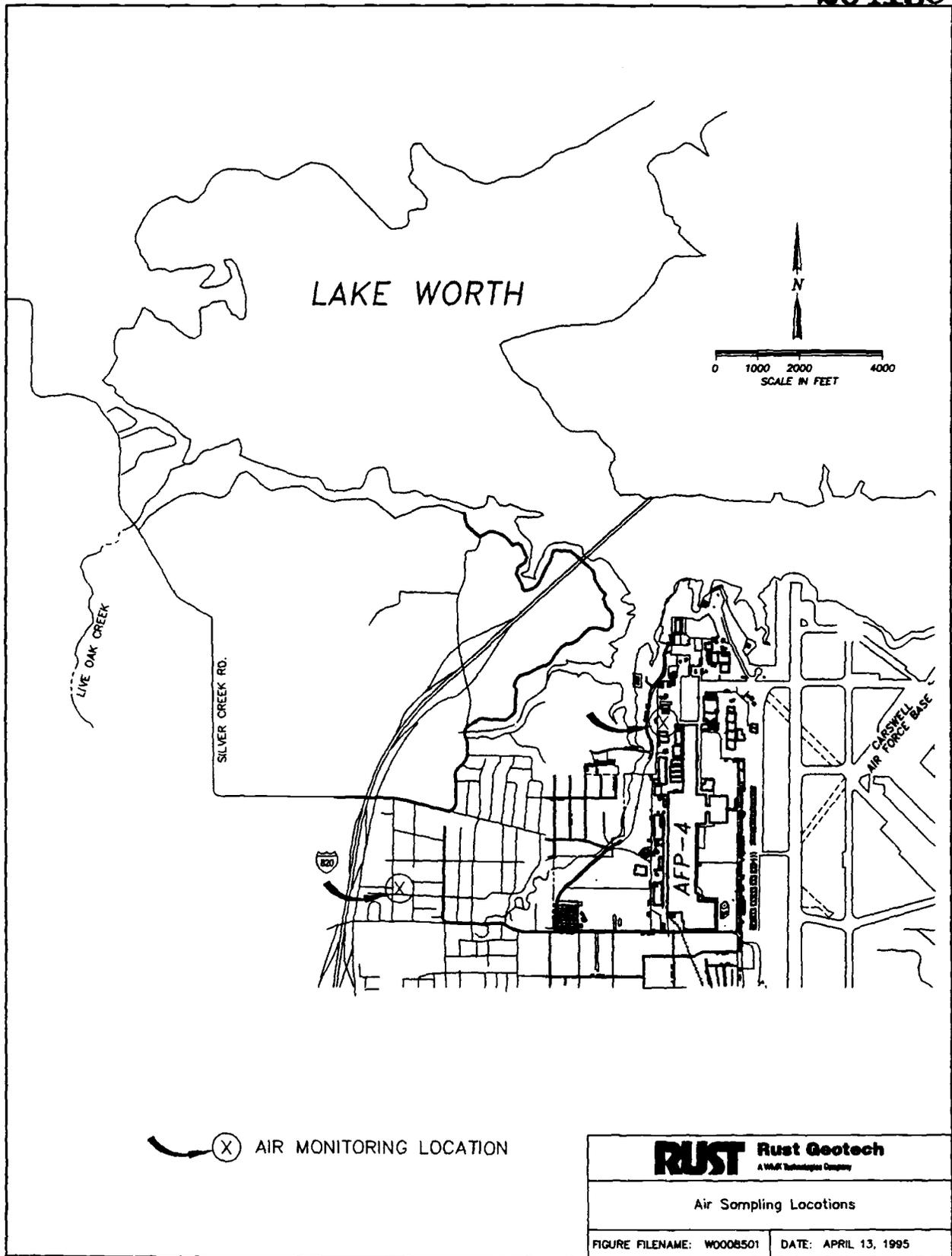


Figure 2.19.1-3. Air Sampling Locations.

2.19.6.1 Volatile Organic Compound Sampling

Each monitoring station was equipped to collect samples for VOC analysis (see Figure 2.19.1-4). The sampling equipment was positioned and operated in accordance with EPA 40 CFR Part 50 (*Sample Siting Criteria*) and EPA Compendium Method TO-14. A sample set (one sample from each station) was collected every 6 days coincident with the State of Texas Ambient Air Monitoring Division's sampling schedule. Fifteen sample sets were collected and analyzed for target compound list VOCs. Each sample set was collected over a continuous 24-hour period using SUMMA® passivated stainless steel canisters. All VOC samples were analyzed in accordance with EPA Compendium Method TO-14.

2.19.6.2 High Volume Particulate Sampling

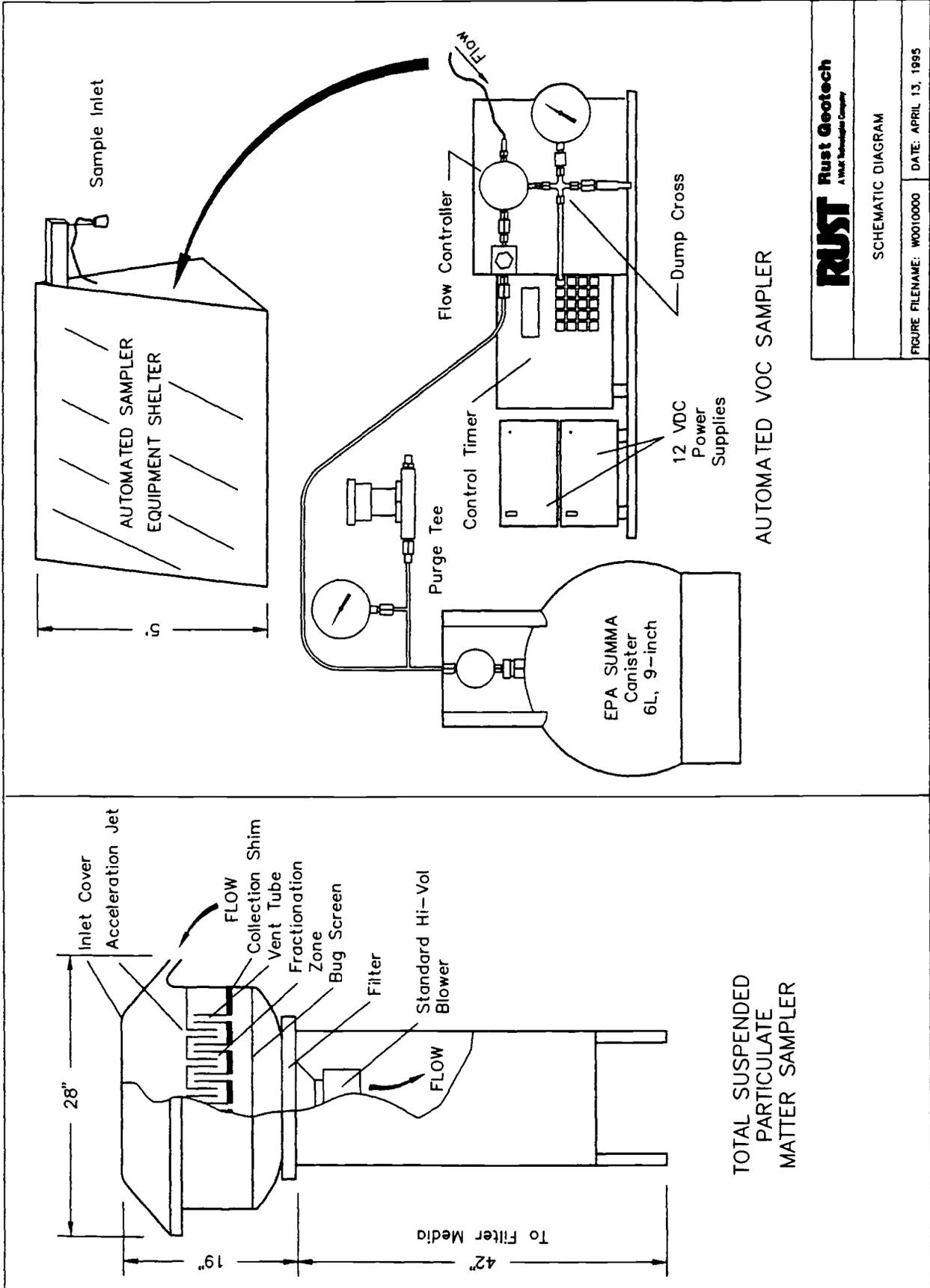
Each monitoring station was equipped with a high-volume air particulate sampler (see Figure 2.19.1-4). The sampling equipment was positioned and operated in accordance with EPA 40 CFR Part 50 (*Sample Siting Criteria*) and EPA 40 CFR Part 41, Appendix B (*Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere [High-Volume Method]*). A sample set (one sample from each station) was collected every 6 days coincident with the State of Texas Ambient Air Monitoring Division's sampling schedule. Fifteen sample sets were collected and analyzed for selected metals. Each sample set was collected over a 5-day period using Whatman EPM-2000 ultrahigh purity glass-fiber filters. Blank filters accompanied the samples from the first two sampling events. All samples, including the blank filters, were analyzed for cadmium, chromium, lead, and zinc by graphite furnace atomic absorption.

2.19.6.3 Wind Speed and Wind Direction Data

Wind data (speed and direction) were obtained from the meteorological station at CAFB for each day during the period in which air-quality monitoring was performed at Plant 4 (January 1, 1992, through May 19, 1992). Typically, these and several other meteorological parameters (sea level pressure, temperature, and dew point) are monitored and recorded at 5 minutes before each hour, with additional information recorded when necessary to document significant changes in the monitored parameters. Appendix I-2 contains a summary of the meteorological data obtained from CAFB.

2.19.7 Ecological Characterization

Biological and ecological studies were conducted to allow toxicity impacts on the environment to be evaluated. Three studies were undertaken: a cataloging of the flora and fauna compiled from the literature, bioassay toxicity sampling and testing, and tissue sampling and analysis. The main focus of the flora and fauna cataloging was the identification of threatened and endangered species. The purpose of bioassay toxicity



RUST
A WAT Technology Company

SCHEMATIC DIAGRAM

FIGURE FILENAME: W0010000 DATE: APRIL 13, 1995

Figure 2.19.1-4. Schematic Diagram of Air Sampling Equipment.

testing and tissue analysis was to provide data for defining contaminant locations and quantifying contaminant concentrations in representative water and fish samples.

2.19.7.1 Flora and Fauna Catalog

Discussions of the plants and animals indigenous to the High Prairie and to the drainage of the West Fork of the Trinity River (west of Elm Fork)—the two habitat zones of north-central Texas relevant to the study area—are found in Peter and McGregor (1988) and Prikryl (1990). Information more specific to the study area is provided by De Vore (1990), who conducted an archaeological reconnaissance of the CAFB adjacent to Plant 4, and by IT Corp. (1992), who conducted the risk assessment for this RI.

The High Prairie of western Tarrant County is dominated by mixed grasses, primarily bluestem, grama, buffalo, and introduced species. Trees are few but include, in order of descending frequency, hackberry, elm, post oak, walnut, mesquite, cottonwood, and gum bumelia (Peter and McGregor 1988).

Within the drainage of the West Fork of the Trinity River are two major communities: the flood plain forest and bottomland prairies. A variety of trees occurs along the river's course and its tributaries—primarily post oak, elm, Spanish oak, hackberry, and ash. Incidental species include locust, blackjack oak, red oak, sycamore, bur oak, mesquite, cottonwood, willow, gum bumelia, mulberry, red haw, and pecan (Peter and McGregor 1988). The bottom prairies, which are open areas within the flood plain forest, "...appear to have been areas subject to seasonal overflow where surface water was retained" (Peter and McGregor 1988). Vegetation is dominated by grasses—originally, little bluestem, big bluestem, and Indiangrass—but now primarily introduced species (e.g., crabgrass and Bermuda) (IT Corp. 1992).

Mammals, reptiles, amphibians, birds, fish, and invertebrates inhabit the region encompassing the two habitat zones discussed above (De Vore 1990). Mammals commonly seen include white tail deer, gray fox, red fox, coyote, raccoon, striped skunk, opossum, cottontail, jackrabbit, armadillo, fox squirrel, and various rodents. Birds likely in the region include wild turkey, mourning dove, pileated woodpecker, little blue heron, great blue heron, black-crowned night heron, American egret, cattle egret, migratory waterfowl, and various hawks, owls, and buzzards. Sunfish, catfish, shad, drum, minnows, and shellfish are among the aquatic resources present locally.

In the immediate Plant 4 area, the Texas Parks and Wildlife Department reports no special species or natural communities. In the overall Lake Worth area, the Department has identified one sensitive species, the Texas garter snake, and several managed areas. The Texas garter snake has been given the Federal status of "Category 2," which includes organisms that could be threatened or endangered but about which the USFWS requires more field data for a definitive determination. Two bird rookeries occur on Lake Worth: the Silver Creek Rookery, 2.7 miles northwest of Plant 4, on the western shore of

the lake and the Fort Worth Nature Center Rookery, located 3.8 miles north of Plant 4 on the shore of the northern segment of Lake Worth. At each, the Great Blue Heron is the dominant species. Also on the north shore of Lake Worth is the 3500 acre Fort Worth Nature Center and Refuge, which is affiliated with the Fort Worth Nature Center Rookery.

2.19.7.2 Bioassay Toxicity Testing

Bioassay toxicity testing is the process of exposing selected fish and invertebrates to water samples collected from specific locations and observing the toxic effects of the samples on these organisms. The results of the analysis can indicate where toxicants are present in a geographical area and can provide a general overview as to the severity of toxicity.

Bioassay toxicity testing was conducted in an attempt to determine whether water contamination is originating from Plant 4 or areas upstream of Plant 4. Three locations (locations noted are indicated as Lake Worth Sampling Locations on Plates 1 and 2 and Figure 2.19.1-2) were chosen for sample collection: an upstream site (Location 27), a site adjacent to Plant 4 (Location 25), and a background site (Location 28). Locations 25 and 27 are along Meandering Road Creek; Location 28 is approximately 2 miles west of Plant 4 on Live Oak Creek. Location 28 was chosen by the USFWS. (See Figure 2.19.1-2 and Plate 1 for locations.)

Three water samples were collected at each location. These samples were collected intermittently over a period of 5 days and submitted on the day of collection to TRAC Laboratories, Inc., of Denton, Texas, for analysis. TRAC Laboratories investigated the stream samples' chronic toxicity to water flea and fathead minnow, which were cultured at TRAC Laboratories.

The water flea and the fathead minnow were exposed to undiluted samples from Locations 25, 27, and 28 and to samples diluted by 50 percent from Location 25. These organisms also were exposed to a water sample prepared by TRAC Laboratories to represent the control sample. Testing and control sample preparation were conducted according to the requirements of EPA/600/4-89/001 (TRAC Laboratories, Inc. 1991).

Organisms were exposed to a sample for approximately 24 hours and then analyzed for toxic effects. To characterize toxic effect, TRAC laboratories calculated the survival rate for both water flea and fathead minnow, the mean neonate production per female in water flea, and the mean final dry weight of fathead minnows. Statistical comparisons (one-tailed) between the control and collected sample exposures were made with the TOXSTAT 3.0 statistical package (TRAC Laboratories, Inc. 1991).

2.19.7.3 Tissue Sampling and Analysis

Tissue sampling and analysis can contribute to the ecological characterization of a site by providing evidence for the presence or absence of contamination in the food chain. Additionally, a comparison of contaminant levels in tissue samples collected at different locations around a site may aid in pinpointing the origins of those contaminants.

Five locations around Plant 4 were chosen for tissue sampling (see Plate 1 and Figure 2.19.1-2; locations are indicated on plates as Lake Worth Sampling Locations). Location 1, a background location, was in an arm of Lake Worth approximately 0.5 mile west of the Plant 4 pump station. Location 2 was in Lake Worth at the mouth of Meandering Road Creek. Location 25 was in Meandering Road Creek approximately 0.25 mile from Lake Worth. Location 26 was in Meandering Road Creek approximately 200 feet from Lake Worth. Location 28, a background location selected by the USFWS, was in Live Oak Creek approximately 2.5 miles west-northwest of Plant 4.

Collected for tissue analysis was the mosquito fish, a species considered ideal for tissue analysis because it is abundant in the Lake Worth area, is highly tolerant of chemical contaminants, and stores contaminants in its fatty tissues. Mosquito fish were collected at the five locations with seines, placed in appropriate sample containers, and frozen (as described in *Analytical Methods for U.S. EPA Priority Pollutants and Pesticides in Tissues from Estuarine and Marine Organisms*, EPA 1986) for 15-21 days, until the samples could be submitted to the Mississippi State Chemical Laboratory (MSCL) for whole-tissue analysis.

Ten fish samples were sent to the MSCL, where the samples were composited into five samples for analysis. Constituents of interest were agreed upon by USFWS and EPA representatives in advance of sample collection. These constituents included organochlorines/PCBs, PAHs, and certain metals (Al, Cd, Cr, Ni, and Pb). Methods used for the analysis of chlorinated hydrocarbons/PCBs and PAHs were those listed in the MSCL's contract with the USFWS. Methods used for the analysis of metals were those described in the U.S. EPA's *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846*. Method 3010 was used for fish tissue digestion.

2.19.8 Leachability Testing

TCLP leachability tests of contaminated soils were conducted to determine the extent to which these soils are contributing to the contamination of groundwater. Selected soil samples (see Table 2.19.8-1) from each different type of hazardous waste site at Plant 4 (e.g., FSAs, FDTAs, landfills, chrome pits) were analyzed for leachability by TCLP.

Table 2.19.8-1 TCLP Sample Locations

SB-006	DYCP
SB-018	LF-1
SB-033	LF-3
SB-067	FDTA-5
SB-122	UST-19
SB-149	FSA-3

2.19.9 Common Ions

Approximately 20 percent of the groundwater samples were analyzed for common ions for use in geochemical characterization and modeling of the aquifer systems present at Plant 4 (see Table 2.19.9-1). These data are useful in determining sources of groundwater recharge and groundwater flow paths. They may also be useful when evaluating remedial action alternatives and the possible effect of common ion constituents on the technology being evaluated.

Table 2.19.9-1 Monitoring Wells Sampled for Common Ions

P-29M	W-144
W-131U	W-149
W-137	W-153
W-143	

2.19.10 Archaeological Survey

A Class I cultural resources inventory for the study area and immediately adjacent lands was conducted to determine the archaeological and historical resources that were known in the project area, the current impacts and the potential impacts from remedial action, and the types of cultural resources that could be found in undisturbed areas. The inventory consisted of a literature search and a files/database search. The literature search was conducted through the libraries of Texas Christian University, Southern Methodist University, and the Archaeology Research Program at the Institute for the Study of Earth and Man. The files/database search was conducted by the Texas Archaeological Research Laboratory of the Balcones Research Center at the University of Texas at Austin.

Plant 4 is located in the High Prairie within the drainage of the West Fork of the Trinity River at an elevation of 500 to 600 feet above mean sea level. Erosional valleys dissect the expanse of nearly level plains, cutting through to limestone bedrock. Grasslands predominate while trees are dispersed and include post oak, elm, hackberry, mesquite, cottonwood, gum bumelia, and walnut (Peter and McGregor 1988). Wildlife inhabitants include mammals, reptiles, amphibians, birds, fish, and invertebrates. De Vore (1990) reports the following as being present in the region: deer, gray and red fox, raccoon, opossum, cottontail rabbit, squirrel, wild turkey, mourning dove, pileated woodpecker, migratory waterfowl, American egret, little blue heron, black-crowned night heron, cattle egret, and aquatic species—sunfish, catfish, shad, drum, minnows, and limited shellfish.

Little of the original terrain remains within the boundary of Plant 4. Significant alteration of the landscape has resulted from the construction of numerous buildings, extensive paving, and the installation of storm drains and sewage lines. The construction of Lake Worth in the 1910s modified the West Fork channel and inundated the river's flood plain and the benches that once defined the river's course along the northern edge of Plant 4 (De Vore 1990). Lands abutting Plant 4 on the east, south, and west likewise have undergone substantial disturbance.

Compared with the amount of archaeological work that has been conducted in the Elm Fork drainage of the upper Trinity River and the lower Trinity River drainage, very little has been done in the West Fork watershed (Lynott 1977). Therefore, Peter and McGregor (1988) base the following scheme of temporal division of the Prehistoric period in the upper Trinity River drainage on work of previous researchers in the region and in the State of Texas in general:

Paleo-Indian	ca. 11,000 B.C. - 6000 B.C.
Archaic	6000 B.C. - A.D. 700
Late Prehistoric	A.D. 700 - A.D. 1600
Protohistoric	A.D. 1600 - A.D. 1800

Paleo-Indian occupation of the upper Trinity River drainage is evidenced primarily by surface finds of diagnostic lanceolate projectile points and by points from "subsurface contexts where they were found mixed stratigraphically with later materials" (ibid.). Point styles represented in this area include Clovis, Folsom, Plainview, Hell Gap, Meserve, Angostura, Scottsbluff, and others. Although early reports concluded that such finds indicated a Paleo-Indian lifeway that was based on big-game hunting, Prikryl (1990) claims that evidence for this belief is lacking in most areas of North America, including north-central Texas, and that a generalized hunting-and-gathering economy was more likely. Paleo-Indian sites of the upper Trinity River drainage are generally associated with the second river terrace (Sciscenti 1972).

The Archaic period in the upper Trinity River drainage is not well known. Few controlled excavations have been conducted; consequently, there is "a lack of information concerning the types of features and spatial patterning that would allow conclusions about the nature of Archaic period occupations" (Peter and McGregor 1988). Under Crook and Harris' original definition (published in the early 1950s), the Archaic period Trinity aspect was divided into early (Carrollton focus) and late (Elam focus) periods. The former was associated with the Carrollton and Trinity dart points types, various steep-bitted gouges, scrapers, and spokeshaves, the Waco sinker, the Carrollton ax, and the use of nonlocal lithic material. Diagnostic of the latter period were the Ellis, Yarbrough, and Elam projectile points and an increased use of locally available quartzite. Prikryl (1990) assigns essentially the same bracketing dates to the Archaic period in North-Central Texas but divides the Archaic into the Early, Middle, and Late periods, and notes the relative abundance of sites and materials associated with the Late Archaic. Generally, Archaic sites in the upper Trinity River drainage were associated with the first river terrace (Sciscenti 1972).

The initial appearance of ceramics and arrow points marks the Late Prehistoric period in the upper Trinity drainage. Most investigated sites of this period occurred in the East Fork and middle Trinity drainages and were assigned to the Wylie focus. Associated with these sites are permanent or semi-permanent villages evincing house structures, hearths, trash pits, and burials (Peter and McGregor 1988). Lynott (1977) suggests early and late phases of the Late Prehistoric period in the upper Trinity drainage, which are distinguished by sand- and grog-tempered ceramics and shell-tempered ceramics, respectively. Arrow points tentatively considered indicative of the early phase are the Alba and Scallorn types, those of the late phase are the Perdiz and various unstemmed, triangular forms (Peter and McGregor 1988).

The Protohistoric period is not well documented in the upper Trinity River drainage. Peter and McGregor (1988) report that there has been no excavation of a Protohistoric site in this drainage and that characterization of the native peoples of this time period is not yet possible.

Archaeological evidence and documentation of the historic Indian occupation of the upper Trinity River basin is sparse, but it is probable that the Wichita traveled and lived here. Other groups associated with the area include the Kichai, the Yojuane (Sciscenti 1972), the Caddo, the Kickapoo, and Shawnee (Journey and others 1988). Additionally, Lynott (1977) suggests that a series of hunting and gathering bands united in this area as the Tonkawa tribe to fend off the Wichita and Comanche.

Foreign settlement of other areas of Texas was well underway by the 1800s, but it did not extend as far north as the upper Trinity River basin (Sciscenti 1972). Not until the 1840s did actual settlement of this area begin, but it happened quickly. By 1855, the

frontier period was over in north-central Texas (Jurney and others 1988). Bird's Fort, operating by 1840, and Camp Worth, established in 1849, were among the earliest settlements in the basin (Sciscenti 1972).

A search of maps and related files at the Texas Archaeological Research Laboratory revealed no previously recorded cultural resources within the boundary of Plant 4 (Spock 1991). The nearest recorded resources were reported by Steven L. De Vore (1990) during a reconnaissance survey of high probability areas on the CAFB and consisted of two historic trash dumps/scatters, one historic building foundation footing, one historic bridge, and one prehistoric isolated lithic find of unknown cultural affiliation.

The paucity of cultural resources at and near Plant 4 is no doubt largely attributable to the intense ground disturbance that has occurred as a result of the area's development. Although cultural resources are unlikely to be located within the Plant 4 boundaries, previously undisturbed areas (particularly drainage courses, knolls, and rockshelters) should be subjected to a Class III survey (100 percent pedestrian), and cultural materials evaluated for their significance, prior to ground disturbance in those areas. Potential finds include projectile points, beads, hearths, ceramic shards, structures, foundations, and tools.

3.0 Physical Characteristics of the Study Area

3.1 Physiography

Plant 4 is located within the Western Cross Timbers Section and the Grand Prairie Section of the Central Lowlands Physiography Province. Most of Plant 4 is within the Grand Prairie Section, which is typically a broad, gently sloping terrace of sedimentary rock mantled by a thin layer of light brown to black loamy soil. The Grand Prairie Section is typically grass-covered with isolated stands of upland timber.

The northwest corner of Plant 4 lies within the Western Cross Timbers Section, which is characterized by rolling to hilly topography that is dissected into steep hills and deep ravines. The Western Cross Timbers Section is typified by sandy soils supporting a heavy growth of post oak and blackjack oak.

Topography at Plant 4 is generally flat except for areas adjacent to Meandering Road Creek and Lake Worth. Elevations at the site range from 590 feet above mean sea level along the shore of Lake Worth to approximately 670 feet above mean sea level at the southwest corner of the site.

3.2 Cultural Geography

3.2.1 Land Use

Plant 4 is located in a highly urbanized area because of its close proximity to the city of Fort Worth (see Figure 1.2.1-1). Plant 4 is directly bounded on the west by the city of Fort Worth and on the west and south by the city of White Settlement. The portion of Fort Worth adjacent to Plant 4 contains residential and commercial properties. The city of White Settlement includes residential, commercial, and light industrial properties. The area is accessed by two major interstate highways, I-80 from the north and south, and I-30 from the east and west. Plant 4 is accessed directly from I-30 by State Highway 341.

3.2.2 Demography

The population of Tarrant County (Fort Worth metropolitan area) is approximately 1,170,000; 447,600 of which live in the city of Fort Worth. Numerous smaller communities (suburbs) make up the balance of the population. The communities of White Settlement, Lake Worth Village, Westworth Village, River Oaks, and Sansom Park Village lie within a 3-mile radius of Plant 4 and have the following populations based on a 1990 census: White Settlement—15,472; Lake Worth Village—4,591; Westworth Village—2,350; River Oaks—6,580; and Sansom Park Village—3,928.

Residential housing is immediately adjacent to Plant 4 on the south and west sides. Six schools are within a 2-mile radius of Plant 4, the closest school is 0.5 mile south of the facility. Lockheed, the operating contractor at Plant 4, is the largest employer in the Fort Worth metropolitan area with a work force of 19,200 people, followed by Bell Helicopter (8,000) and the city of Fort Worth (6,000).

3.3 Air Quality

Ambient air quality for Tarrant County and the Fort Worth metropolitan area is monitored routinely at several locations by the Texas Air Control Board (TACB) and local agencies. The parameters monitored include total particulates (PM₁₀), carbon monoxide (CO), sulfur dioxide (SO₂), ozone, nitrogen dioxide (NO₂), and lead. According to information received from the TACB (see Table 3.3-1), the 1991 attainment status for Tarrant County was as follows. The status for PM₁₀ was "Unclassified" because not enough data had been collected for classification. The maximum levels recorded for PM₁₀ ranged from 53 to 101 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) (Federal standard is 150 $\mu\text{g}/\text{m}^3$), and the annual averages ranged from 20.1 to 25.1 $\mu\text{g}/\text{m}^3$ (Federal standard is 50 $\mu\text{g}/\text{m}^3$). The status for ozone was "Nonattainment," and the 1-hour maximum levels ranged from 0.15 to 0.17 parts per million (ppm) (Federal standard is 0.12 ppm). The status for CO, SO₂, and NO₂ was "Attainment," with levels recorded well below the Federal standards. The status for lead was "Not Designated" because the data had not yet been evaluated. Quarterly averages for lead levels were 0.02 $\mu\text{g}/\text{m}^3$ (Federal standard is 1.5 $\mu\text{g}/\text{m}^3$).

3.4 Meteorology

Plant 4 is located at approximately 32 degrees north latitude and 97 degrees west longitude in north-central Texas. The climate at the site is typified by hot summers and cool, dry winters.

Area meteorological data were obtained from the meteorological station at CAFB. These data were used to summarize historical data collected between 1942 and 1990 (see Table 3.4-1) and to assess recent data collected hourly from April 1, 1991, through March 31, 1992 (see Figures 3.4-1 through 3.4-3). Each of these data sets is discussed separately below.

3.4.1 Summary of Historical Data

As shown in Table 3.4-1, the mean annual temperature in the vicinity of Plant 4 is 66 degrees Fahrenheit (°F). Mean monthly temperatures range from 45 °F in January to 86 °F in July. Extreme low and high temperatures have been reported at 0 and 110 °F, respectively. Typically, the cooler months include December through February when average daily maximum temperatures range from 55 to 60 °F, and average daily

Table 3.3-1 Air Quality of the Fort Worth Area

FEDERAL STANDARDS	MONITORING SITE						
	Tarrant County	CAMS-13 (Northwest) Mescham Field	CAMS-18 (Downtown) 100 N. Pecan	CAMS-17 (TC-Keller) City of Keller	Worth Heights (Elem. School) 618 E. Butler	City FAA Site (Center Point) 13800 FAA Rd.	Geddes 5933 Geddes
TOTAL PARTICULATE (PM 10) Status Minimum (ug/m ³) Maximum (ug/m ³) Annual Average (ug/m ³)	Unclassified				7 73 25.1	6 53 20.1	6 101 23.3
OZONE Status 1 Hr. Maximum (ppm)	Nonattainment	0.15		0.17			
CARBON MONOXIDE (CO) Status 2nd Highest Hr. (ppm) 2nd Highest 8 Hr. (ppm)	Attainment	6.3 3.3	6.8 4.5				
SULFUR DIOXIDE (SO2) Status 2nd Highest 3 Hr. (ppm) 2nd Highest 24 Hr. (ppm) Annual Average (ppm)	Attainment	0.01 0.00 0.001					
NITROGEN DIOXIDE (NO2) Status Annual Average (ppm)	Attainment	0.014					
LEAD Status 1st Quarter Mean (ug/m ³) 2nd Quarter Mean (ug/m ³) 3rd Quarter Mean (ug/m ³) 4th Quarter Mean (ug/m ³) Yearly Average (ug/m ³) Yearly Maximum (ug/m ³)	Not Designated		0.02 0.02 0.02 0.02 0.06		0.02 0.02 0.02 0.02 0.06		
ug/m ³ - micrograms per cubic meter ppm - parts per million							

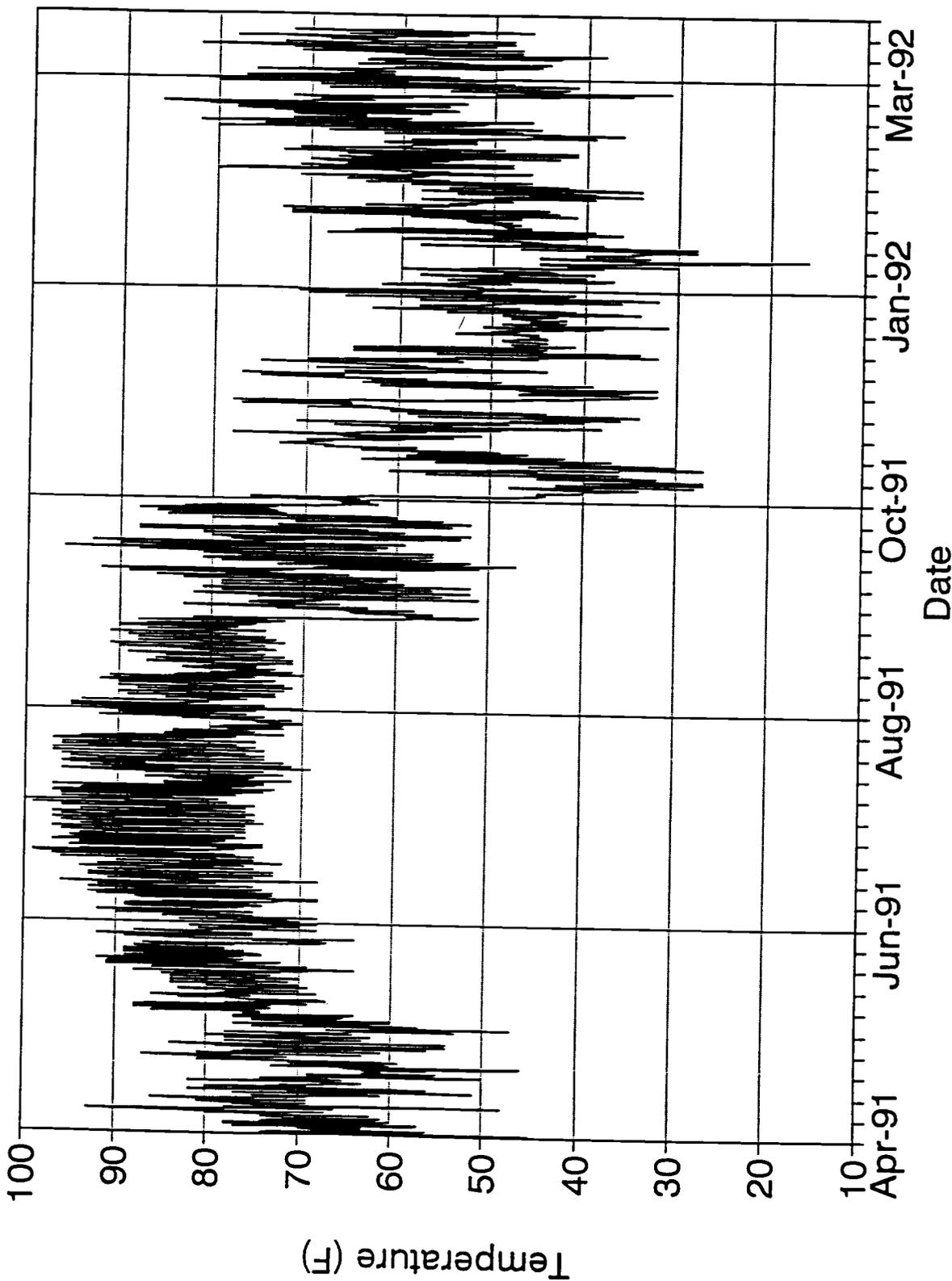


Figure 3.4-1. Distribution of Hourly Temperature Measurements for the Period April 1991 through March 1992.

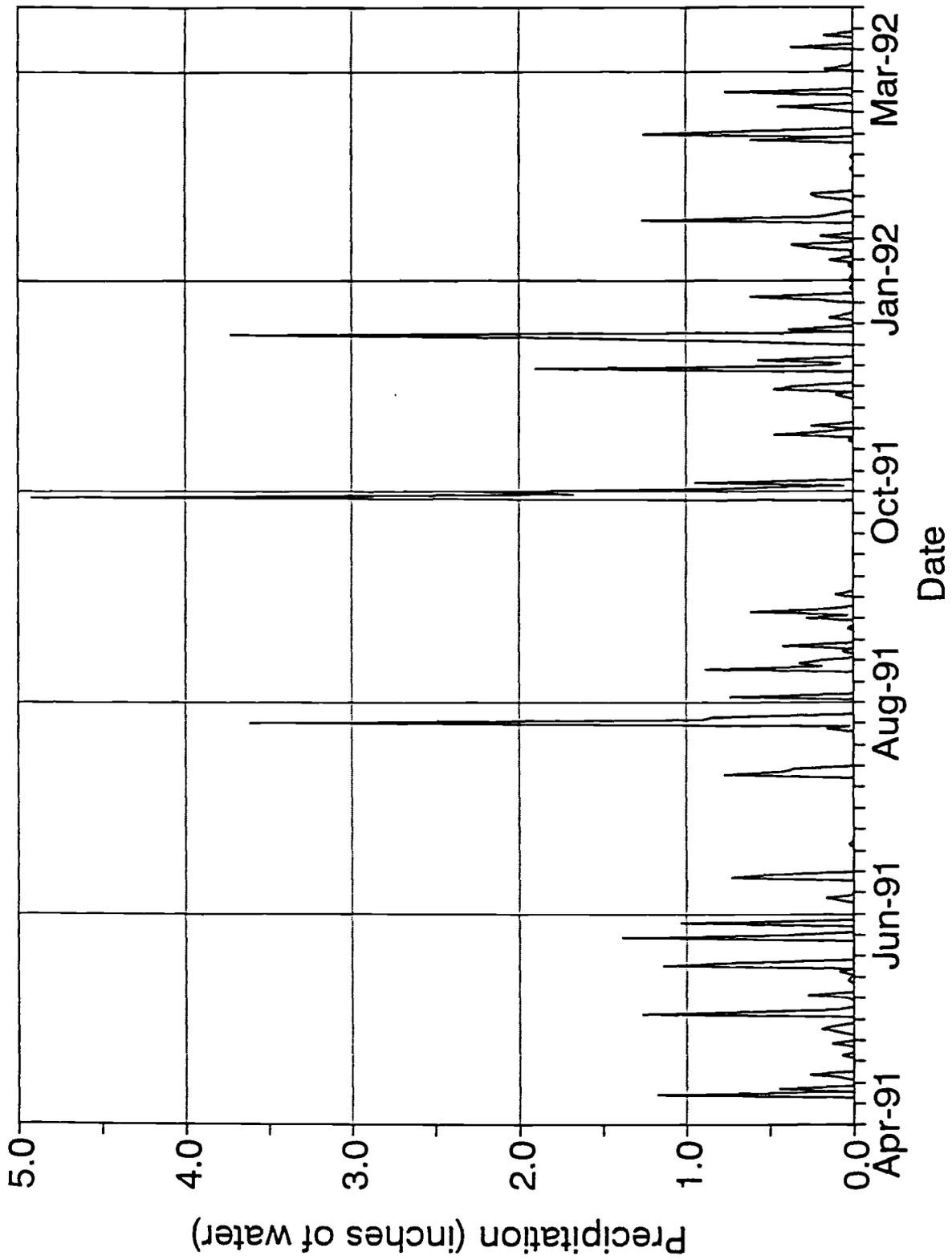


Figure 3.4-2. Distribution of Daily Total Precipitation Measurements for the Period April 1991 through March 1992.

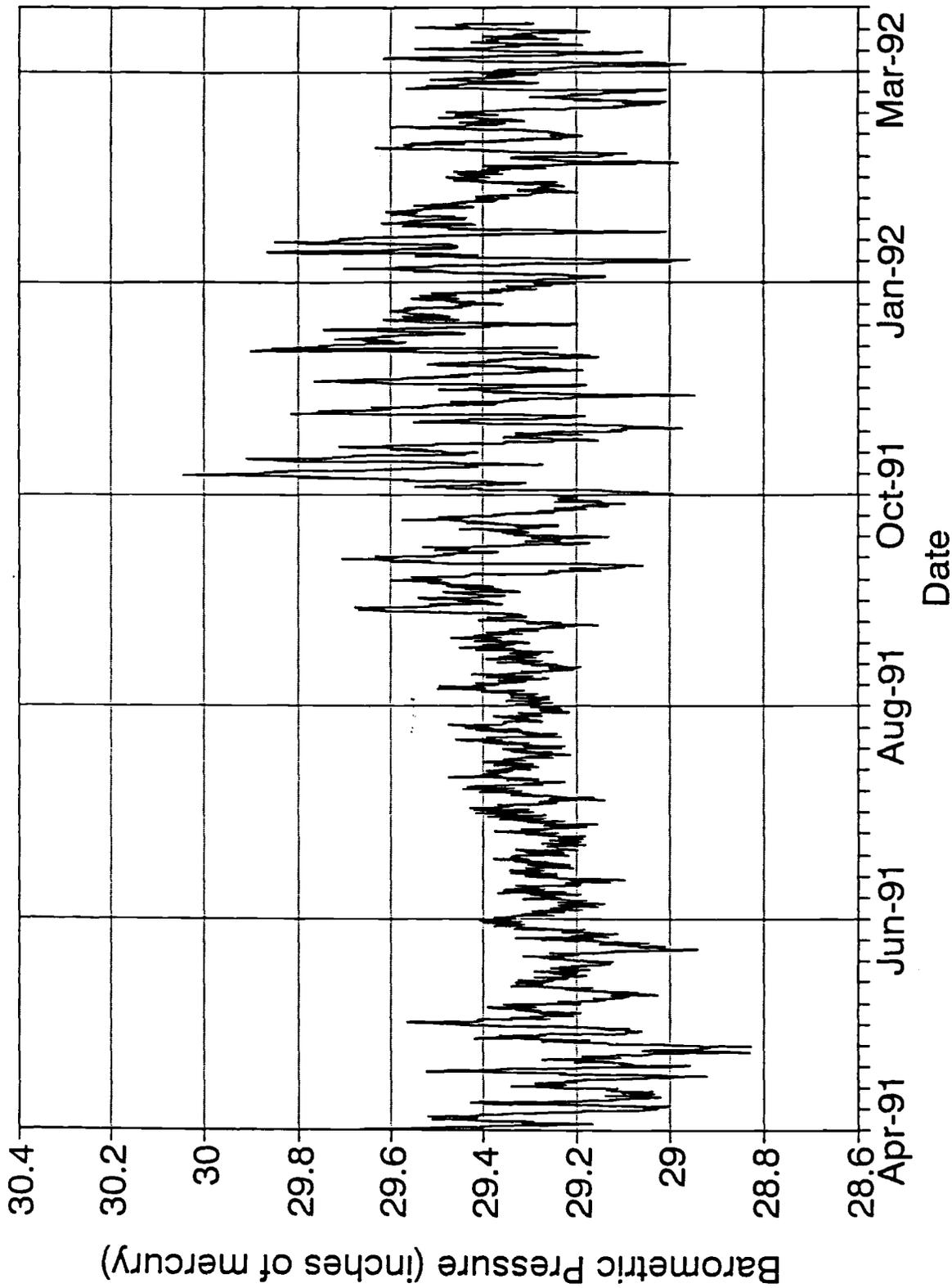


Figure 3.4-3. Distribution of Hourly Barometric Pressure Measurements for the Period April 1991 through March 1992.

Table 3.4-1 Summary of Meteorological Data Collected from 1942 to 1990

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual	Years of Record
Avg. Temperature (°F)	45	50	57	57	74	82	86	85	78	68	56	48	66	46
Daily Max.	55	60	67	76	83	94	96	95	90	78	66	59	77	46
Daily Min.	35	39	46	56	64	72	76	75	68	57	46	38	56	46
Highest Recorded	88	88	95	99	101	110	109	110	107	105	89	91	110	46
Lowest Recorded	2	5	11	31	42	55	61	60	43	33	17	0	0	46
Avg. Precipitation (Inches)	1.8	1.8	2.3	3.8	4.4	2.9	2.4	1.9	3.6	3.2	1.7	1.8	31.6	46
Monthly Max.	5.9	8.4	6.5	14.2	15.2	11.3	9	6	9.6	10.7	7.4	6.7	15.2	44
Monthly Min.	<0.05	0.1	<0.05	0.2	0.6	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	44
24-Hour Max.	2.8	3	3.4	3.3	5.7	3.5	5.9	3.1	4	3.2	2.8	2.9	5.9	44
No. Thunderstorms	1	2	4	6	8	6	5	5	4	3	1	1	46	46
Avg. Snowfall (Inches)	1	1	<0.05	0	0	0	0	0	0	0	<0.05	<0.05	2	43
24-Hour Max.	5	8	7	0	0	0	0	0	0	0	4	3	8	41
Monthly Max.	8	12	7	0	0	0	0	0	0	0	4	3	12	41
Avg. Wind Direction	N	N	S	S	S	S	S	S	S	S	S	N	S	10
Speed (Knots)	7	8	8	8	7	7	6	6	6	6	7	7	7	10
Cloud Cover (%)	60	60	60	50	60	60	40	40	50	50	60	60	50	10
Rel. Humidity (%) ^a	63	66	63	62	70	66	57	57	63	63	64	62	63	10

a - calculated as an average of the morning and afternoon readings

Source: Carswell Air Force Base, Texas, Meteorological Station, 1942-1990

minimum temperatures range from 35 to 39 °F. The warmer months include June through August when average daily maximum temperatures range from 94 to 96 °F, and average minimum temperatures range from 72 to 76 °F.

Mean annual precipitation is 31.6 inches, with some precipitation occurring every month. Average monthly precipitation amounts are highest from April through May, ranging from 3.8 to 4.4 inches, and from September through October, ranging from 3.2 to 3.6 inches. Average monthly precipitation amounts are lowest from November through February, ranging from 1.7 to 1.8 inches, and during August when the monthly average is 1.9 inches. Thunderstorms may be expected every month; however, thunderstorms occur most frequently during spring and summer.

Precipitation typically consists of a mixture of rain and snow during the late fall and winter months. Snowfall amounts are generally greatest in January and February, when average snowfalls of 1 inch may be expected. Although average snowfall amounts are typically low, snowfall amounts of up to 12 inches in 1 month have been recorded.

During most of the year, the predominant wind direction is from the south. During the winter months (i.e., December through February) the predominant wind direction is from the north. Constant winds with an average speed of 7 knots are typical year round.

The average cloud cover in the area is 50 percent. Average relative humidity values range from 57 percent in July and August to 70 percent in May. Average relative humidity is 63 percent.

3.4.2 Recent Data

Figure 3.4-1 presents the temperature variations from April 1, 1991, to March 31, 1992. The highest maximum temperatures were reported in July and August, with maximum values ranging from about 90 to 100 °F. The lowest minimum temperatures occurred between November and March, with minimum values ranging from about 25 to 45 °F. The lowest temperature reported during the period was approximately 15 °F in early February.

The magnitude of daily temperature fluctuations was generally lowest from late May to late September. During this period, maximum and minimum daily temperatures were relatively constant, and the average magnitude of fluctuations between extremes was about 20 °F. The magnitude of maximum and minimum temperature values, as well as fluctuations between extremes, were much more variable during the rest of the year. The greatest daily fluctuations between extremes were reported in November, when fluctuations of up to 60 °F were observed.

Figure 3.4-2 shows the precipitation amounts reported from April 1, 1991, to March 31, 1992. As shown, some precipitation was reported each month. Storm events producing the greatest amounts of precipitation occurred in August (approximately 3.5 inches), November (approximately 4.5 inches), and December (approximately 3.5 inches). Except for these extremes, precipitation amounts generally ranged from less than 0.5 inch to about 1.5 inches. Storm events that produced measurable amounts of precipitation were reported most frequently during April, May, September, and December. The driest months during the period included July, October, and February.

Figure 3.4-3 shows the barometric pressure measurements reported from April 1, 1991, to March 31, 1992. Barometric pressures ranged from a low of about 28.80 inches of mercury in late April to a high of about 30.05 inches in November. Barometric pressures remained relatively constant during the summer months, ranging from 29.10 to 29.50 inches. Barometric pressures were most variable during the winter months, ranging from lows of 28.95 inches to highs of up to 30.05 inches.

3.5 Ecology

Because of the urban environment surrounding Plant 4, there are few natural terrestrial and aquatic communities in the area. However, Lake Worth and several small inlets along its boundary, and Meandering Road Creek, do support a limited complex of terrestrial and aquatic communities. The terrestrial community generally occupies a narrow strip of upland between the Plant 4 facilities and the creek and the lake; the aquatic communities include those of the creek, the inlets, and the lake (IT Corp. 1992).

The terrestrial ecosystem is characterized by upland sites where vegetation is dominated by native and introduced grasses (e.g., *Andropogon*, *Digitaria*, and *Cynodon*), and occasional oaks (*Quercus* spp.). Mice, gophers, squirrels, rabbits, granivorous and insectivorous birds, lizards, snakes, skunks, and higher predators such as hawks, owls, and foxes are expected to inhabit this community. Actual sightings in this community included foxes, rats, squirrels, and fire ants.

A well-developed, wooded riparian corridor approximately 50 to 100 feet wide occurs at the interface of the terrestrial community and the aquatic community of Meandering Road Creek. Here, oaks (*Quercus* spp.), hackberries (*Celtis* spp.), Osage-orange (*Maclura pomifera*), and wild roses (*Rosa* spp.) dominate the vegetative growth. Wildlife expected in the riparian community are amphibians, arboreal mammals, insectivorous birds, and animals that forage or prey near water, such as skunks, raccoons, and snakes. Actual wildlife sightings included gulls, ducks, cranes, passerine birds, snakes, turtles, and insects. Raccoon tracks were also observed in this area. The riparian community diminishes as the creek approaches Lake Worth; along the outer reaches of the creek's inlet and along the lake itself, there is an almost direct interface between the upland and lake communities, as the shoreline drops steeply into the water. Cattails, rushes, and other forms of wetland vegetation are absent from the lake shore.

Meandering Road Creek is an ephemeral stream fed mainly by stormwater runoff with some baseflow contributed by groundwater discharge (seeps) along the east side of the draw. High rainfall events periodically scour the streambed and help control the development of the aquatic community. Living components of the stream community include fish, macroinvertebrates, zooplankton, algae, and microbes. No submergent or emergent macrophytes were detected in the stream at the time of field sampling. The presence of small fish in pools indicated an active trophic system that is probably based both on detrital decay from the riparian and upland systems and on algal productivity.

The Meandering Road Creek inlet provides an interface between the stream and lake systems; four smaller inlets provide more direct interfaces between the terrestrial and lake systems. On occasion, inlet water quality may be significantly affected by direct contributions from adjacent terrestrial systems (and by flow from the creek, in the case of the Meandering Road Creek inlet), but in terms of community structure, the inlets are expected to be similar to Lake Worth. Biota of the inlet community include fish, turtles, macroinvertebrates, zooplankton, macrophytes, algae, and microbes.

Constructed in the early 1900s, Lake Worth is a steep-sided, relatively shallow (less than 30-feet deep) reservoir on the West Fork of the Trinity River. It is used for recreation and fishing, and as a domestic water supply. All trophic levels are expected in the aquatic food web of the lake, including predatory vertebrates (fish, turtles), macroinvertebrates, zooplankton, macrophytes, algae, and microbes. The transition between the inlet and lake systems is not well defined, and the extent of mixing has not been studied. However, it is expected that lake currents and mixing rates result in a gradient of ecological conditions from the main body of Lake Worth to the upper reaches of the inlets (IT Corp. 1992).

3.6 Surface Water Hydrology

The primary surface waters in the vicinity of Plant 4 include Lake Worth, Meandering Road Creek, and Farmers Branch and West Fork of the Trinity River (see Plate 2). Lake Worth extends along the northern boundary of the site. Meandering Road Creek borders the western site boundary and flows north to Lake Worth. Farmers Branch flows eastward near the southern boundary of the site and discharges into the West Fork of the Trinity River. The West Fork of the Trinity River flows southeastward from the Lake Worth dam and spillway. Each of the primary surface water features is described in further detail in the following sections.

3.6.1 Lake Worth

The Lake Worth reservoir was constructed in 1914 by the city of Fort Worth as a municipal water supply (U.S. Geological Survey [USGS] 1989). The reservoir was created by damming the West Fork of the Trinity River northeast of Plant 4. In addition to municipal water supply, the reservoir is also used for irrigation and recreation.

The reservoir was constructed with a dam elevation of 606.3 feet above mean sea level. According to Tarrant County Water Control and Improvement District Number One daily gauge records, the dam spillway was originally constructed at an elevation of 594.3 feet above mean sea level; however, the elevation of the dam spillway was modified and lowered to 594 feet above mean sea level in 1980. At full capacity, the reservoir averages 6 feet in depth, with a maximum depth of 28 feet, and covers approximately 3,560 acres with 37,066 acre-feet of storage. The spillway has a maximum discharge capacity of 55,000 cubic feet per second. The drainage area associated with Lake Worth covers approximately 2,064 square miles (USGS 1989).

Historically, silt accumulation was recognized as a problem in Lake Worth. The silting problem was significantly reduced in 1934 following completion of two upstream reservoirs: Bridgeport and Eagle Mountain. Because the reservoir was never dredged, large silt accumulations may exist. Through adsorption, these accumulations would significantly impact the fate of chemical constituents present in the lake.

The Tarrant County Water Control and Improvement District Number One maintains reservoir records that include information on precipitation, stage heights, diversion quantities, and flood gauging, from 1920 to the present. Review of records from water years 1940 to 1991 indicate that releases over the spillway may occur at any time of the year. During the 1940s, the reservoir had a constant net release; from approximately 1948 to present, the average annual stage height has typically been below the spillway. Estimated average annual storage values for the period ranged from 23,746 acre-feet in 1956 to 38,664 acre-feet in 1942.

3.6.2 Meandering Road Creek

Meandering Road Creek borders Plant 4 to the west and flows north to Lake Worth. Meandering Road Creek is an intermittent stream receiving the majority of its flow from surface water runoff discharged into the creek via storm drains and culverts. Several seeps were identified along the east bank of the creek during field reconnaissance. The presence of these seeps indicates that Meandering Road Creek also receives some baseflow from groundwater.

3.6.3 Farmers Branch

Farmers Branch originates in White Settlement and flows south of Plant 4 in an easterly direction to the West Fork of the Trinity River. Like Meandering Road Creek, Farmers Branch is an intermittent stream that receives most of its flow from surface water runoff discharged into the creek via storm drains and culverts. Comparison of water-table elevations in the vicinity of Farmers Branch with a topographic profile of the stream indicates that Farmers Branch may receive some recharge from groundwater.

3.6.4 West Fork of the Trinity River

Near Plant 4, the West Fork of the Trinity River flows in a southeasterly direction from the Lake Worth dam and spillway. Flow in the West Fork of the Trinity River is largely controlled by releases from Lake Worth. However, some flow is attributed to surface water runoff that reaches the stream via tributaries. Water table elevations near the stream (see Figure II-26) suggest that the West Fork of the Trinity River may receive recharge from the upper-zone groundwater system.

3.6.5 Evaluation of Flood Potential

In 1982, the Federal Emergency Management Agency (FEMA) requested a flood insurance study to investigate the existence and severity of flood hazards in the unincorporated areas of Tarrant County, including the area in the vicinity of Lake Worth. This study physically delineated theoretical flood events, such as the 100- and 500-year flood. Results of the study estimated that stage heights for the 100-year flood will be 599.9 feet and approximately 602.7 feet for the 500-year flood (FEMA 1987). These values equate to stage heights over the spillway of 5.9 feet and 8.7 feet, respectively. According to reservoir records obtained from the Tarrant County Water Control and Improvement District Number One, the historical stage height nearest to the projected events was 4.17 feet over the spillway, recorded on May 25, 1957.

Delineations of the projected extent of the 100- and 500-year flood plains in the vicinity of Plant 4 are shown in Figure II-11. These delineations are consistent with the estimated Lake Worth stage heights presented in the 1987 FEMA study. Areas where the extent of the 100- and 500-year flood events closely correspond are designated as the combined 100- and 500-year flood event in Figure II-11. As shown, neither the 100- nor 500-year flood event will directly impact Plant 4. Therefore, flooding is not considered a likely mechanism for transport of chemicals from the site. In addition, protection against flooding may not be a design consideration during implementation of any future on-site remedial actions.

Meandering Road Creek, located west of the Plant 4 boundary, is impacted by the 100-year flood. One-hundred-year flood waters are estimated to extend approximately 900 feet upstream from the mouth of Meandering Road Creek. Therefore, any chemicals present in sediment and surface soil within this area could potentially be transported to the Lake Worth system through submersion and erosion. Any future remedial actions within the projected extent of the 100-year flood event will require design consideration for protection against flooding.

The remaining primary surface waters in the area, Farmers Branch and the West Fork of the Trinity River, are both impacted by the projected extent of the 100- and 500-year flood events. Both the 100- and 500-year flood events are estimated to extend

approximately 1,600 feet upstream from the mouth of Farmers Branch. The extent of flooding along the West Fork of the Trinity River would be most pronounced in the area immediately below the Lake Worth dam. Any chemicals present in sediment and surface soil within the projected extent of flooding along these surface waters could potentially be transported downstream along the West Fork of the Trinity River.

3.7 Geology

3.7.1 Regional Geologic and Structural Setting

The bedrock geology of west-central Tarrant County is characterized by sedimentary rocks of the Early Cretaceous period underlain by undifferentiated rocks of the Paleozoic era. Unconsolidated thin alluvial deposits of the Quaternary period cover bedrock in and near major stream and river valleys.

The sedimentary rocks in the site area were deposited in a stable structural setting on the Texas craton. Figure 3.7.1-1 shows the structural features and their proximity to the site in Tarrant County. Those features include the Mexia-Talco fault system about 80 miles to the east, the front of the Ouachita overthrust about 30 miles to the east, and the south end of the axis of the Fort Worth basin, located directly under the site, in which sediments accumulated during most of the Paleozoic era.

In the latter part of the Paleozoic era, during the Permian period, the site area was uplifted and the extensive erosion that occurred through the Jurassic period produced a flat surface upon which early Cretaceous period marine sediments (Comanchean Series) were deposited along an oscillating shoreline. The marine sediments are preserved as a southeast-thickening wedge of rocks extending from the site area into the East Texas basin (see Figure 3.7.1-1). From the Late Cretaceous period through the Tertiary period, the sea withdrew toward the gulf, and, except for minor periods of subsidence, the land surface was eroded and modified by streams. During the Quaternary period, the streams deposited alluvial sediments. The older sediments are represented by terrace deposits above the alluvial-filled valleys of present streams.

Table 3.7.1-1 lists the regional stratigraphic units of interest in the vicinity of Plant 4. These units are described in the following section in descending order, from youngest to oldest.

Unconsolidated alluvial sediments and fill material overlie Cretaceous period rocks and consist of Holocene epoch fill material and flood plain deposits and Pleistocene epoch terrace deposits. The fill material on and adjacent to the Plant 4 site was emplaced since the 1940s and consists of general refuse and construction debris (i.e., lumber, asphalt, metal, concrete, glass, and plastic) mixed with gravel, sand, silt, and clay. The flood plain deposits consist of alluvium (i.e., gravel, sand, silt, silty clay, and organic material) that fill present stream and river valleys. The Pleistocene epoch terrace

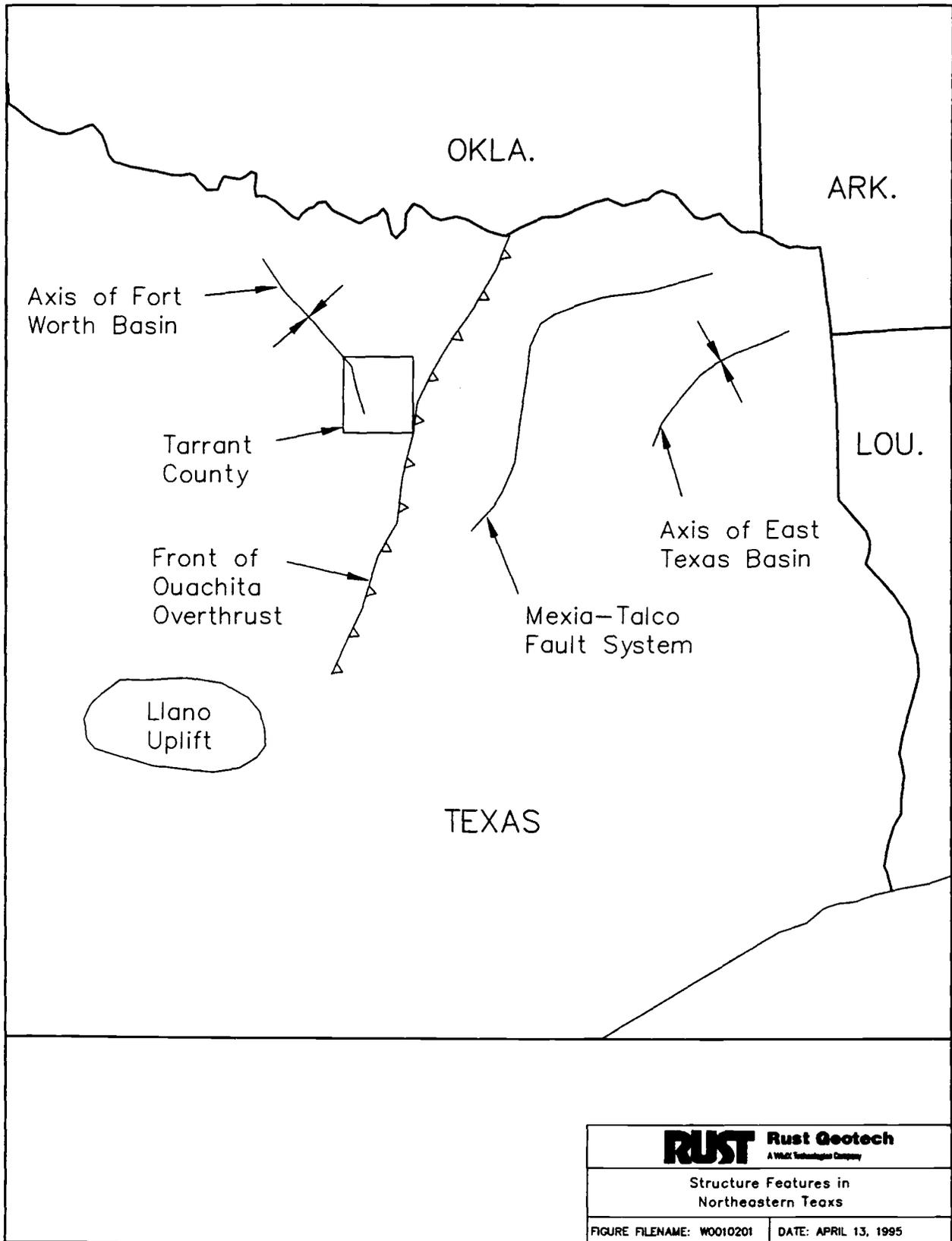


Figure 3.7.1-1. Structural Features in Northeastern Texas (modified from Nordstrom, 1982).

Table 3.7.1-1 Stratigraphic Units of Interest in the Vicinity of Plant 4

Era	System	Series	Group	Stratigraphic Units
Cenozoic	Quaternary	Holocene		Fill Material Alluvium
		Pleistocene		Fluvial Terrace Deposits
	Tertiary			
Mesozoic	Cretaceous	Gulf		
		Comanche	Washita	Duck Creek Limestone Kiamichi Formation
			Fredericksburg	Goodland Limestone Walnut Formation
			Trinity	Paluxy Formation Glen Rose Formation Twin Mountains Formation
Paleozoic			Paleozoic Rocks Undifferentiated	

deposits occur above the present stream valleys and consist of gravel, sand, and silt that represent older flood plain deposits.

Lower Cretaceous period rocks consist of the Washita, Fredericksburg, and Trinity Groups (see Table 3.7.1-1), all of which dip gently toward the east-southeast at approximately 0.4 degrees or 37 feet per mile (Leggat 1957). Rocks of the Washita Group occur south and east of Plant 4; the two lowermost formations in the group, Duck Creek Limestone and Kiamichi Formation, form the hilltops and hillsides, respectively, about 1 mile east and south of the plant. The Duck Creek Limestone consists of gray, aphanitic, fossiliferous limestone that is 30- to 100-feet thick (McGowen and others 1988). The slope-forming Kiamichi Formation is from 20- to 50-feet thick and consists of alternating brown clay and gray, aphanitic, fossiliferous limestone beds (McGowen and others 1988).

Rocks of the Fredericksburg Group, which consist of Goodland Limestone and the conformably underlying Walnut Formation, crop out in Plant 4 or underlie most of the site. The Goodland Limestone forms low, rounded hills and buttes, and upland surfaces

capped by terrace material and is usually well-exposed on steep, west-facing escarpments. The Goodland Limestone comprises white, chalky, fossiliferous, thinly to massively bedded, resistant limestone, and gray to yellow-brown silty marl. The formation is extensively jointed and ranges from 0- to 130-feet thick in Tarrant County (Leggat 1957). West of the Plant 4 area, the Walnut Formation forms resistant ridges of indurated fossiliferous limestone and shell coquinite. Included in the formation, which is an average of 30 feet thick, are interbedded brown sandy clay, thinly bedded fossiliferous clay, fissile shale, and iron-stained earthy limestone (Leggat 1957).

Rocks of the Trinity Group, which consist of the Paluxy, Glen Rose, and Twin Mountains Formations, crop out west of Plant 4 and underlie the site. The Paluxy Formation, disconformably separated from the overlying Walnut Formation, forms the bed of Lake Worth and consists of sandstone and siltstone interbedded with sandy to silty, calcareous, waxy clay and shale (Nordstrom 1982). The sandstone, composed of fine- to coarse-grained white quartz, is well-sorted, poorly consolidated, and cross-bedded. Iron and pyrite nodules occur in the sandstone, and lignite is locally present. The thickness of the Paluxy Formation in Tarrant County ranges from 140 to 190 feet (Leggat 1957). Conformably underlying the Paluxy Formation is the Glen Rose Formation that consists of sandstone, clay, sandy clay, limestone, and anhydrite. In the Lake Worth area, the Glen Rose Formation is approximately 250 feet thick. The Twin Mountains Formation (formerly the Travis Peak Formation) is overlain conformably by the Glen Rose Formation. The Twin Mountains Formation grades upward from a basal conglomerate of chert and quartz to a fine- to coarse-grained sandstone interbedded with shale and clay (Leggat 1957). The thickness of the Twin Mountains Formation is approximately 250 feet below Lake Worth with increasing thickness to the east.

Undifferentiated Paleozoic-era rocks are overlain unconformably by the Twin Mountains Formation. The Paleozoic-era rocks are 6,000 to 7,000 feet thick and consist of well-indurated shales, sandstones, and limestones.

3.7.2 Site Geology

Figure 3.7.2-1 shows the surface geology of an approximate 16-square-mile area that surrounds and includes the Plant 4 site. The geologic map presented in the figure is part of the larger geologic map of central Tarrant County, published at 1:24,000 scale on an aerial photograph base map by the Fort Worth Geological Society (Rogers and others 1972). Several spot field checks were performed to verify the accuracy of the mapped geologic contacts. Minor modifications were made to the existing map to add a thin strip of Paluxy Formation outcrop along the shore of Lake Worth northwest of Plant 4 and a narrow band of Paluxy Formation outcrop along Meandering Road Creek just south of Lake Worth.

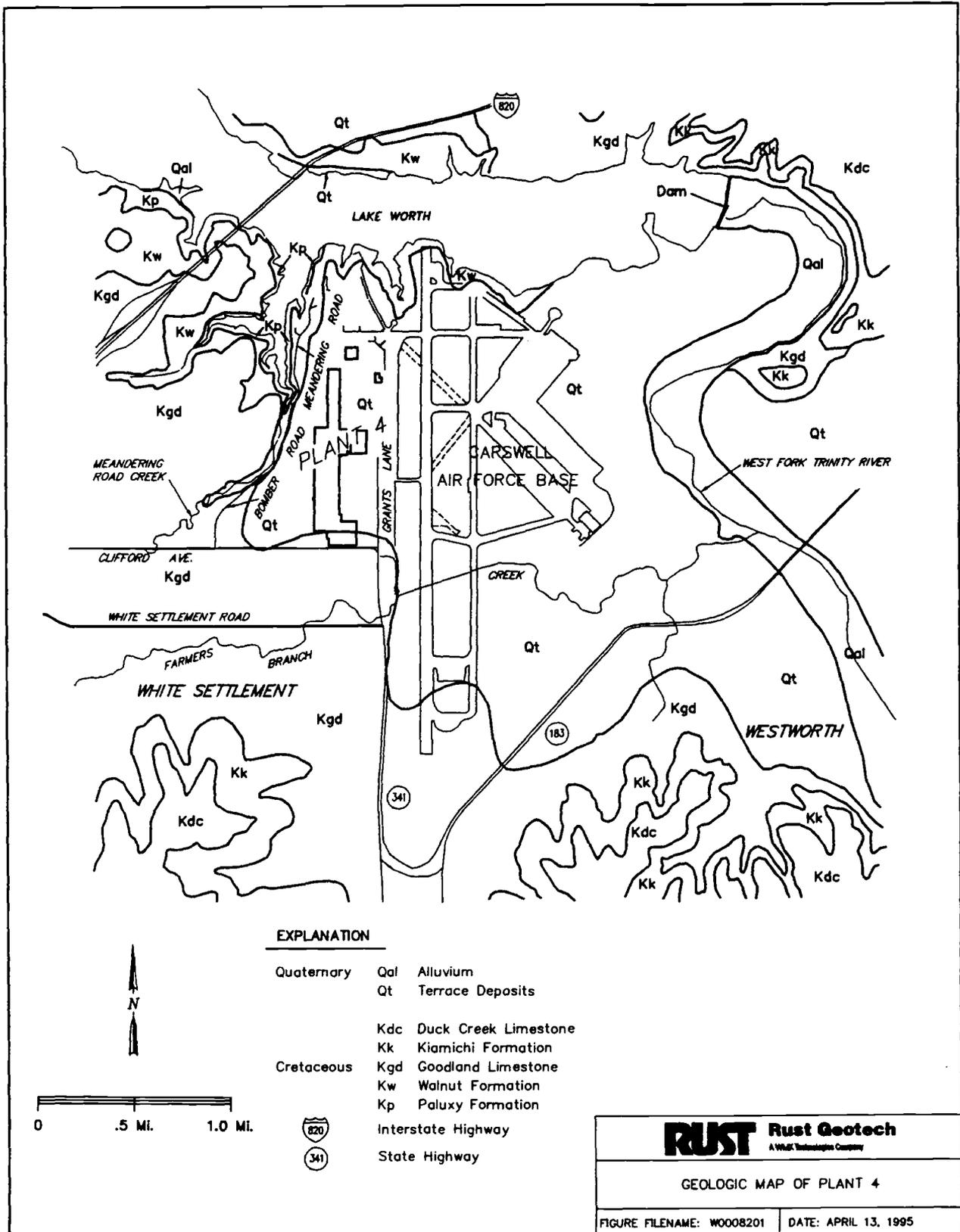


Figure 3.7.2-1. Geologic Map of the Air Force Plant 4 Area.

Geologic units that are of concern at the site were penetrated by monitoring wells and soil borings; these units include, in descending order, fill material, alluvium, terrace deposits, Goodland Limestone, Walnut Formation, and Paluxy Formation. The following sections describe the physical characteristics and thickness of each of these units around the site.

3.7.2.1 Fill Material, Alluvium, and Terrace Deposits

Quaternary period alluvium that occurs downstream from the Lake Worth dam in the present flood plain of the West Fork of the Trinity River, east of Plant 4 and CAFB, is mainly of the Holocene or Recent epoch (see Figure 3.7.2-1). Older alluvial deposits and the terrace deposits of mainly the Pleistocene epoch cover most of the nearly flat surface that tilts gently to the east. Plant 4 and CAFB occupy most of this flat surface, which continues eastward to the flood plain of the West Fork of the Trinity River and includes part of Westworth Village.

Fill material is included in the area mapped as terrace deposits in both Plant 4 and CAFB. The fill occurs in abandoned landfills, waste pits, excavated areas, and where the land surface was graded or altered for construction of buildings, parking lots, and other paved areas such as runways (Hargis + Associates 1989b). The fill material generally comprises unconsolidated mixtures of clay, silt, sand, and gravel but may also contain general refuse, chemical sludge, and construction debris (i.e., lumber, asphalt, metal, concrete, glass, and plastic). Fill material is particularly common along the west side of Plant 4 in Landfill Nos. 1 through 4 where the fill may be up to 20 feet thick. In these landfills, fill material replaced terrace deposits that were removed or fill was dumped on the slope at the edge of the terrace. In some places, fill material extends down to bedrock.

The unconsolidated terrace alluvial material is poorly to moderately sorted and is composed of heterogeneous interbedded clay, silt, sand, and gravel. Individual beds are not laterally continuous. Most of the clastic material (which ranges up to cobble size) in these sediments consists of limestone and fossil shell fragments; sand grains composed of quartz are a minor constituent.

Terrace deposits and/or fill material are present over most of the area of Plant 4 and CAFB. Fill and terrace material are not present along some of the west edge of Plant 4 where the Walnut Formation crops out and in parts of the south end of Plant 4 where the Goodland Limestone crops out (see Figure 3.7.2-1). The thickness of the terrace/fill varies considerably around Plant 4. The thickest accumulations are up to about 50 feet in the area of the Radar Range and up to nearly 60 feet in the east part of the East Parking Lot. These thickness variations indicate the presence of valleys and hills on the bedrock surface. The valleys have been eroded mainly into the Goodland Limestone and the Walnut Formation.

The general configuration of the bedrock surface upon which the terrace alluvial material was deposited may be inferred from the computer-contoured map that shows the elevation of the top of competent bedrock (see Figure 3.7.2-2), which corresponds to the base of the upper zone. The thickness of weathered bedrock above the competent bedrock ranges from zero to as much as 10 feet. Figure 3.7.2-2 shows the positions of three troughs or channels where the thickest accumulations of terrace material are located. The first channel is located beneath the southern end of the Assembly Building and extends to the northeast, beneath the East Parking Lot, and then southeast beneath the flightline (Runway No. 130 North). In the vicinity of the Flightline area, the channel apparently splits with the main link extending to the southeast. A cross section presented in the Interim Remedial Investigation Report (Hargis + Associates 1989a) and the cross sections in Figures II-1, II-2, and II-8 show that this channel cut down nearly through the entire thickness of the Walnut Formation. The second channel extends north from the FFSA to Landfill No. 2. These two troughs are likely the expression of meander bends that mark the former position of the West Fork of the Trinity River. A third trough is subtle and extends east and southeast from FDTA-2 toward the Assembly Building.

Coarse sand and gravel deposits occur immediately above bedrock in several areas on Plant 4 and CAFB. The greatest thickness of these coarse deposits is in the troughs where the gravels were deposited as channel lag on the scoured bedrock surface. The trough near the FFSA contains basal sand and gravel at least 20-feet thick. Basal sand and gravel in the trough in the East Parking Lot area reaches a thickness of at least 15 feet (Hargis + Associates 1989a). Basal sand and gravel in the southeastward extension of this trough under the runways at CAFB range up to at least 35-feet thick. Sand and gravel greater than 20-feet thick at CAFB occurs in an 800-foot wide area that trends eastward approximately in line with White Settlement Road. These deposits probably coincide with the location of a former channel of what is now Farmers Branch Creek (Radian Corporation 1990).

3.7.2.2 Goodland Limestone

Rocks of the lower Cretaceous period Goodland Limestone (the upper member of the Fredericksburg Group) crop out in only a few small areas in the south and southwest parts of Plant 4 and CAFB (see Figure 3.7.2-1). The Goodland Limestone is present in the subsurface at Plant 4 and CAFB, except where erosion has removed it in the northwest part of Plant 4, the north part of CAFB, and in deeply eroded meander bends cut by former courses of the West Fork of the Trinity River beneath both Plant 4 and CAFB.

The top of the formation is highly weathered in places because it was exposed for a long period prior to deposition of overlying Quaternary period alluvial deposits. The thickness of the formation on the site is variable, depending on the amount of erosion that has occurred. The thickest Goodland Limestone encountered in the site area (just

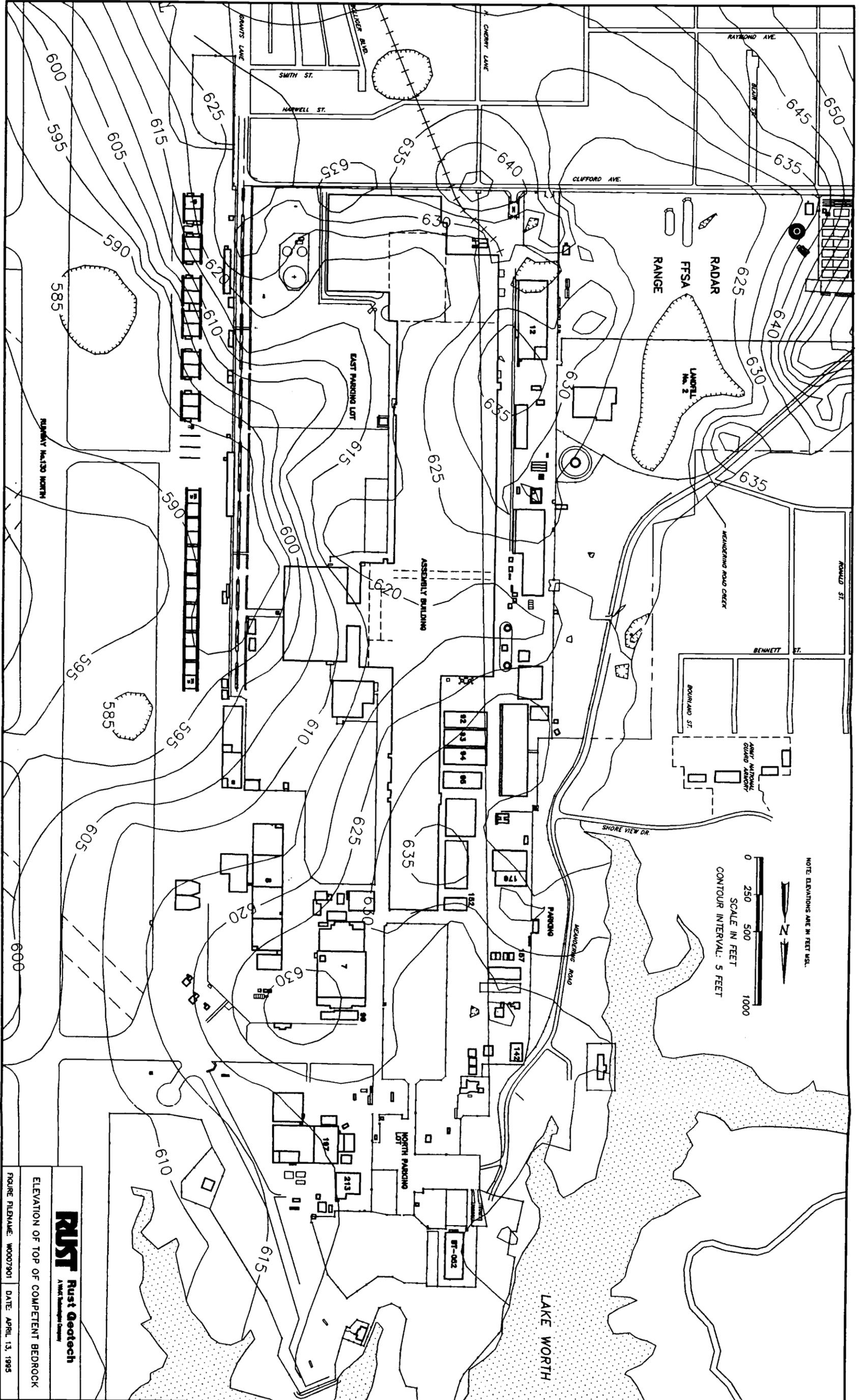


Figure 3.7.2-2. Elevation of Top of Competent Bedrock.

RUST Geotech
 A Hunt Building Company

ELEVATION OF TOP OF COMPETENT BEDROCK

FIGURE FILENAME: W0007901 DATE: APRIL 13, 1995

west of Plant 4 at well EPA-4) is 47 feet. For wells within Plant 4, the maximum thickness of Goodland is 20 to 25 feet, as shown in cross sections in the Interim Remedial Investigation Report (Hargis + Associates 1989a).

The Goodland Limestone consists of chalky white, fossiliferous, dense, thinly to massively bedded limestone interbedded with gray to yellow-brown stiff clay and marl. The formation forms prominent white escarpments along streams, an example of which is the outcrop near well EPA-4 on the steep slope just east of Meandering Road Creek. Extensive jointing is exposed in this outcrop; however, core samples from the Goodland Limestone indicate that joints are rare in unweathered limestone. No subsurface faults are known to occur in the Goodland Limestone in the vicinity of Plant 4 (Hargis + Associates 1989b).

3.7.2.3 Walnut Formation

The Lower Cretaceous period Walnut Formation (the lower member of the Fredericksburg Group) underlies most of Plant 4 and CAFB. The formation crops out in the low cliffs along the Lake Worth shore north and northwest of Plant 4 and along Meandering Road Creek west of Plant 4 (see Figure 3.7.2-1).

Where erosional channels have not been cut into the top of the Walnut Formation, the thickness of the formation at Plant 4 is fairly constant and varies between 25 and 35 feet. The maximum reported thickness of the Walnut Formation in the Plant 4 area (at well P-1 between Clifford Avenue and the Assembly Building) is 46 feet (Hargis + Associates 1989b). A reinterpretation of the thickness of the Walnut Formation from the lithologic log from well P-1 places the thickness of the Walnut Formation at about 30 feet, which is similar to the Walnut Formation thickness at nearby well P-26.

The configuration of the top of the Walnut Formation at Plant 4 was shown previously (Hargis + Associates 1989b, Figure 5). Except for the deep channel cut into the Walnut Formation in the East Parking Lot, the top of the Walnut Formation shows few abrupt changes in elevation. A reinterpretation of the sharp rise or knob in the top of the Walnut Formation south of Building 12 (Hargis + Associates 1989b, Figure 5) shows the feature is unsubstantiated because the wells (HM-3A, HM-4A, and F-221) on the feature did not penetrate deep enough to contact the Walnut Formation.

The three cross sections in the Interim Remedial Investigation Report (Hargis + Associates 1989a, Figures 6, 7, and 8) and the cross sections in Figures II-1 through II-10 show the thickness of the Walnut Formation throughout Plant 4. Water levels shown on the Volume II cross-sections (Figures II-1 through II-10) are based on September 1991 or the most recent September/October water-level measurements. The cross section through the south edge of Plant 4 by Hargis + Associates (1989a, Figure 8) does not show the thick knob of Walnut Formation shown in the earlier Hargis + Associates report (1989b, Figure 5); therefore, the Walnut Formation thickness in this

part of the site is characterized as fairly constant. The north-oriented cross section in the report by Hargis + Associates (1989a, Figure 6) and Figures II-1, II-2, and II-8 show the abrupt decrease in thickness of the Walnut Formation in the East Parking Lot area where the former river channel cut through most of the Walnut Formation. It is possible that the former channel has cut entirely through the Walnut Formation and into the underlying Paluxy Formation in the East Parking Lot area; however, no lithologic data from wells and soil borings confirm this.

The northwest-oriented cross section in the report by Hargis + Associates (1989a, Figure 7) suggests that in the northwest end of the section, Meandering Road Creek has cut through the entire thickness of the Walnut Formation. Determination of the base of the Walnut Formation from lithologic logs for wells located both east (wells P-22 and P-24) and west (wells P-10 and P-29) of lower Meandering Road Creek indicates that contact with the underlying Paluxy Formation is at an elevation of 600 feet. This suggests that the lower section of Meandering Road Creek has cut through the entire thickness of the Walnut Formation for a distance of about 1,000 feet before it empties into Lake Worth, which is normally at an elevation of 593 to 594 feet. However, a field inspection along the lowermost reach of Meandering Road Creek did not identify the basal contact of the Walnut Formation and the underlying Paluxy Formation in the creek bed because of thick cover and absence of outcrops.

The Walnut Formation, also referred to as Walnut "Shell" (Rogers and others 1972) and Walnut Clay (McGowen and others 1988), is mainly a shell agglomerate or coquinite that contains abundant *Gryphaea marcoui* and *Exogyra texana* (Leggat 1957). The coquinite often has a matrix of calcareous shale and clay. Interbeds of calcareous shale and clay also occur. Black, fissile shale was encountered in several boreholes from the upper part of the formation just above the coquinite. Dense sandy limestone, silty shale, and minor pyrite also occur in the lower part of the formation.

A disconformity separates the base of the Walnut Formation from the top of the Paluxy Formation. No faults or prominent fractures are known to occur in the Walnut Formation.

3.7.2.4 Paluxy Formation

The Paluxy Formation, commonly called the Paluxy Sand, is the upper member of the Lower Cretaceous period Trinity Group. The Paluxy Formation underlies all of Plant 4, and its uppermost part crops out along the Lake Worth shoreline just northwest of Plant 4.

The thickness of the Paluxy Formation ranges from 133 to 175 feet in the Plant 4 area (Hargis + Associates 1989b). The formation predominantly consists of several thick sandstone layers (cumulatively, about 120-feet thick in this area) separated by thin, discontinuous shale and claystone layers. The lower part of the Paluxy Formation is

generally coarser grained than the upper part. The top of the underlying Glen Rose Formation is defined as the first occurrence of a limestone unit.

In the Plant 4 area, the Paluxy Formation was deposited as a strandplain facies, which consists largely of sandstone (Caughey 1977). This intercalated sandstone and shale sequence was deposited as a shifting complex of near-shore (littoral) environments on the western margin of the East Texas embayment.

Sandstones in the Paluxy Formation are porous, fine- to very fine-grained, and composed of moderately to well sorted, subangular to subrounded, white quartz sand. The sandstones are poorly cemented (friable) to slightly indurated with sparry calcite cement (Caughey 1977). Traces of pyrite, iron oxides (limonite concretions), and glauconite occur in the sandstone, and these can be locally abundant. Thinner sandstone beds tend to be the most diverse and contain pyrite nodules, traces of lignite, silicified wood, and carbonized plant fragments. The sandstones commonly exhibit low-angle cross-bedding. This cross-bedding was observed in core from the Paluxy Formation and in outcrop along the Lake Worth shoreline northwest of Plant 4 where horizontal fossiliferous limestone beds of the Walnut Formation truncate cross-bedded yellow-brown sandstone of the upper Paluxy Formation.

Bedding in the gray to green-gray or olive green shales (mudrocks) and silty claystones of the Paluxy Formation may be horizontally laminated, massive, or burrowed (churned or bioturbated). The mudstones commonly contain carbonized plant fragments and thin beds of lignite.

The thicknesses of individual sandstone and shaley units in the Paluxy Formation vary across the site. In the upper part of the Paluxy Formation, differences in the individual sandy and clayey units can be subtle (i.e., silty claystone compared to very fine-grained sandstone) and facies changes occur across the site (claystone may grade into very fine-grained sandstone).

Previous reports divided the Paluxy Formation at Plant 4 into upper, middle, and lower Paluxy units (Hargis + Associates 1989a, 1989b). This division was characterized as three distinct, continuous sandstone units separated by continuous beds of shale, claystone, and siltstone. Additionally, a distinct sand unit, termed the Upper Sand, was reported in the uppermost portion of the Paluxy Formation. The upper Paluxy Formation was reported to contain finer-grained sediments than the middle and lower Paluxy Formation.

Core descriptions from five boreholes drilled into the Paluxy Formation by Geotech from May to July 1991 did not substantiate the division of the Paluxy Formation described above by Hargis + Associates (1989a, 1989b), which was derived largely from drill cuttings from numerous boreholes. Because core recovery was only fair in the Paluxy Formation (many zones of very fine-grained, friable, water saturated sandstone were not

recovered), geophysical logs of boreholes were evaluated to help determine if continuous clayey or shaley lithologic units separate the sandstone of the Paluxy Formation across the site. It was recognized by the Corps (1986) during their installations of Paluxy Formation monitoring wells that lithologic logs of the Paluxy Formation made from drill cuttings did not agree with the geophysical logs of the same sections of rock. Given the soft, friable character of the Paluxy Formation and its fine-grained nature, drill cuttings were often not representative of the lithology being drilled; therefore, greater reliance can be placed on the geophysical logs to provide information on subtle lithologic changes.

Geophysical logs available for the following 11 boreholes were evaluated in a cursory nature to determine the presence of continuous clayey or shaley intervals within the Paluxy Formation: P-5U, P-9U, P-10U, P-12U, P-13M, P-15U, P-21U, P-22U, P-24EB, P-25EB, and P-26EB. The geophysical logs for the 11 boreholes are presented in Appendix L. All 11 boreholes have gamma-ray logs. In addition, resistivity and spontaneous potential logs were run in three of the boreholes, and a resistivity log was run in one of the boreholes. Only three of the geophysically-logged boreholes (P-24EB, P-25EB, and P-26EB) penetrated the entire thickness of the Paluxy Formation. One borehole (P-13U) penetrated all the way through the upper and middle portions of the Paluxy Formation. The remaining seven logged boreholes penetrated 50 feet or less into the upper portion of the Paluxy Formation.

The three deep boreholes that penetrated the entire thickness of the Paluxy Formation and were logged using borehole geophysics do not provide sufficient coverage to allow a detailed site-wide correlation of individual sandy and shaley units reported in the borehole logs.

The most extensive unit that can be mapped within the Paluxy Formation on the basis of the geophysical logs and the five Geotech core logs is a shale or silty shale bed about 3- to 5-feet thick that occurs just below a fine-grained sandstone bed 5 feet in thickness at the top of the Paluxy Formation. This correlation could only be made along the south edge of the Plant 4 site in boreholes P-12U, P-13U, and P-26EB (from east to west), and this relationship was verified by description of core from boreholes P-30M and P-31U in the same area. The correlation of this shale unit northward across the site in boreholes P-25EB and P-26EB is tenuous, however. At borehole P-25EB, the uppermost shale is approximately 20 feet below the top of the Paluxy Formation, and at borehole P-26EB, the first shaley unit is approximately 40 feet below the top of the formation.

Other minor shaley or silty shale units in the Paluxy Formation can be recognized in the geophysical logs, but these units do not support correlation across the site. Subtle and frequent facies changes in the fine-grained sediments of the Paluxy Formation are the principal reasons that individual shaley or clayey units in the Paluxy Formation are traceable for only hundreds of feet rather than across the site.

3.8 Hydrogeology

The hydrogeologic system of interest at Plant 4 includes three main units: an upper-zone groundwater system; an aquitard system composed of competent bedrock of the Goodland Limestone and Walnut Formation; and the Paluxy Aquifer, which is a source of municipal water supply for the city of White Settlement. The hydrogeology of the upper-zone groundwater system and the underlying aquitard formations are discussed in Sections 3.8.1 and 3.8.2, respectively. Hydrogeology of the Paluxy Aquifer is discussed in Section 3.8.3.

3.8.1 Upper-Zone Groundwater

Upper-zone groundwater at Plant 4 occurs in unconsolidated Quaternary Period deposits and weathered Goodland Limestone, both of which overlie competent bedrock. Lithology of the upper-zone groundwater system consists primarily of silt and clay material, with silty sand and gravel deposits often present in paleochannels incised into bedrock.

The upper-zone groundwater system is underlain by competent Goodland Limestone and Walnut Formation. The Goodland Limestone is an assemblage of interbedded siltstone, claystone and limestone. The Walnut Formation consists of highly indurated limestone and shell agglomerate. These two formations form an aquitard that restricts the flow of groundwater between the upper-zone flow system and the underlying Paluxy Formation. In many areas the Goodland Limestone is located at or very near the land surface. Upper-zone groundwater is essentially absent in these areas. Elsewhere the Goodland Limestone and Walnut Formation are incised by paleochannels filled with alluvium. The Goodland Limestone is often entirely absent in these areas. Locally, such as beneath the East Parking Lot, the Walnut Formation has been eroded almost completely by a paleochannel, creating a potential for groundwater flow into the Paluxy Formation.

Detailed lithologic descriptions of the unconsolidated Quaternary Period deposit and cross sections through the upper-zone are presented in Section 3.7.

3.8.1.1 Upper-Zone Groundwater: Recharge and Discharge

Natural recharge to the upper-zone flow system occurs through direct infiltration of precipitation and runoff. Extensive paved areas and buildings restrict the natural infiltration of precipitation over much of Plant 4. However, precipitation does infiltrate through several large grassy areas that include portions of the flight-line area, the radar range, and Landfills No. 2, 3, and 4.

Additional recharge also occurs as leakage from water-supply lines, fire-fighting pipe systems, cooling-water systems, sanitary sewers, and storm sewers. Preliminary data from General Dynamics for the period January 1, 1991, through December 31, 1991, can be

used to estimate losses from the combined water-supply, sanitary sewer, storm sewer and outfall (Nos. 1 and 4) systems. Data obtained from General Dynamics (General Dynamics Facility Management 1992) indicate that General Dynamics purchased 934.7 million gallons of water from the City of Fort Worth in 1991. After use, this water was then discharged to the sanitary sewer and Outfalls No. 1 and 4. City water was also used to keep the fire-fighting system pressurized.

For 1991, Plant 4 records indicate a storm-sewer discharge of 677.6 million gallons, an Outfall No. 1 discharge of 127 million gallons, and an Outfall No. 4 discharge of 14.6 million gallons. The difference between inflow and outflow is 115.5 million gallons for 1991. This is equivalent to a leakage-induced recharge rate of 316,000 gallons per day (gpd). This value is considered to be a conservative estimate of the leakage rate because past employment and water usage have been greater than in 1991. Additionally, limited data available from earlier years suggests that losses in the past may have been greater due to temporary line breaks and/or perforations (General Dynamics Facility Management 1992).

Some losses are also expected from the cooling water system. This system consists of a 1-mile long, 48-inch-diameter pipeline supplied with water from Lake Worth. This system delivers water under pressure to the main cooling tower and then returns it under open-channel flow conditions to the lake. The system operates at flow rates that vary between 6 and 40 million gallons per day (mgd) (General Dynamics Facility Management 1992). However, this system is not continuously monitored and leakage rates cannot be estimated.

A recharge rate of approximately 316,000 gpd over the main plant area represents a moderate flux into the upper-zone flow system. As such, losses from the pipe systems have some influence over the direction and rate of groundwater flow and contaminant transport and contribute to the dilution of subsurface contamination.

Specifically, this localized recharge to upper-zone groundwater contributes, in part, to the high hydraulic heads measured beneath Plant 4. Figure II-24, a map of water-table elevations in the upper zone, shows two groundwater mounds in the vicinity of the main building. One mound is located at the southern portion of the Assembly Building/Parts Plant, and the second is located near the northern portion of the Assembly Building/Parts Plant. As shown in Figure II-25, a map of the base of the upper-zone flow system, locally high areas of competent bedrock underlie the groundwater mounds. This indicates that the bedrock topography also contributes to the high water-table elevations found beneath the plant.

If the leakage from the pipe systems was reduced, water-table elevations beneath the plant would decline. This would lead to smaller hydraulic gradients, lower groundwater velocities, and lower dilution ratios for subsurface contamination. Flow directions might also change, although such changes would likely be minor as the directions of

groundwater flow are strongly influenced by the topography of the competent bedrock. Given that the volume of water lost from the Plant 4 water-distribution system is typical of conventional potable water-supply systems, it is unlikely that significant reductions in the loss rate are possible, as long as the plant is in operation. Complete elimination of potable water losses would require the excavation and replacement of tens of thousands of feet of pipe that currently underlie the main building—together with a myriad of other utilities. Nonetheless, the result of leakage reductions (and complete leakage elimination) is being examined, in terms of flow directions and gradients, via the groundwater flow model.

Discharge from the upper-zone flow system occurs primarily as seeps to Meandering Road Creek, baseflow to Farmers Branch, and discharge to the West Fork of the Trinity River. Locations of these discharge sites are shown on the regional water-table map (Figure II-26). Discharge from the upper-zone groundwater also occurs as vertical leakage into the Paluxy Aquifer. Most of the vertical leakage occurs in areas such as the axes of paleochannels where considerable portions of the Goodland Limestone and Walnut Formations are absent. Results of previous investigations indicate that one such area exists beneath the East Parking Lot. This location has been referred to as the "window area" (Figure 3.8.1-1). The relative quantities of water discharging from the upper-zone flow system at various discharge locations are unknown.

3.8.1.2 Upper-Zone Groundwater: Hydraulics

The upper-zone flow system is bounded by the water table and the contact between unconsolidated deposits/weathered bedrock and competent bedrock. The difference in elevation between the water table and competent bedrock defines the saturated thickness. The elevation of the water table was measured at 179 upper-zone monitoring wells at Plant 4 in September, 1991. One complete set of measurements was taken in September 1991. A local-scale water-table contour map, constructed from these measurements is presented in Figure II-24. Additionally a regional-scale water-table contour map (Figure II-26) was constructed on the basis of upper-zone water-level measurements at Plant 4, CAFB, and surface-water elevations in the West Fork of the Trinity River.

Both Figures II-24 and II-26 show that the upper-zone flow system contains groundwater mounds at the northern and southern parts of the Assembly Building/Parts Plant. These mounds are likely a result of groundwater recharge from leaking water pipelines. As shown on Figures II-24 and II-26, groundwater flow directions diverge from the mounds.

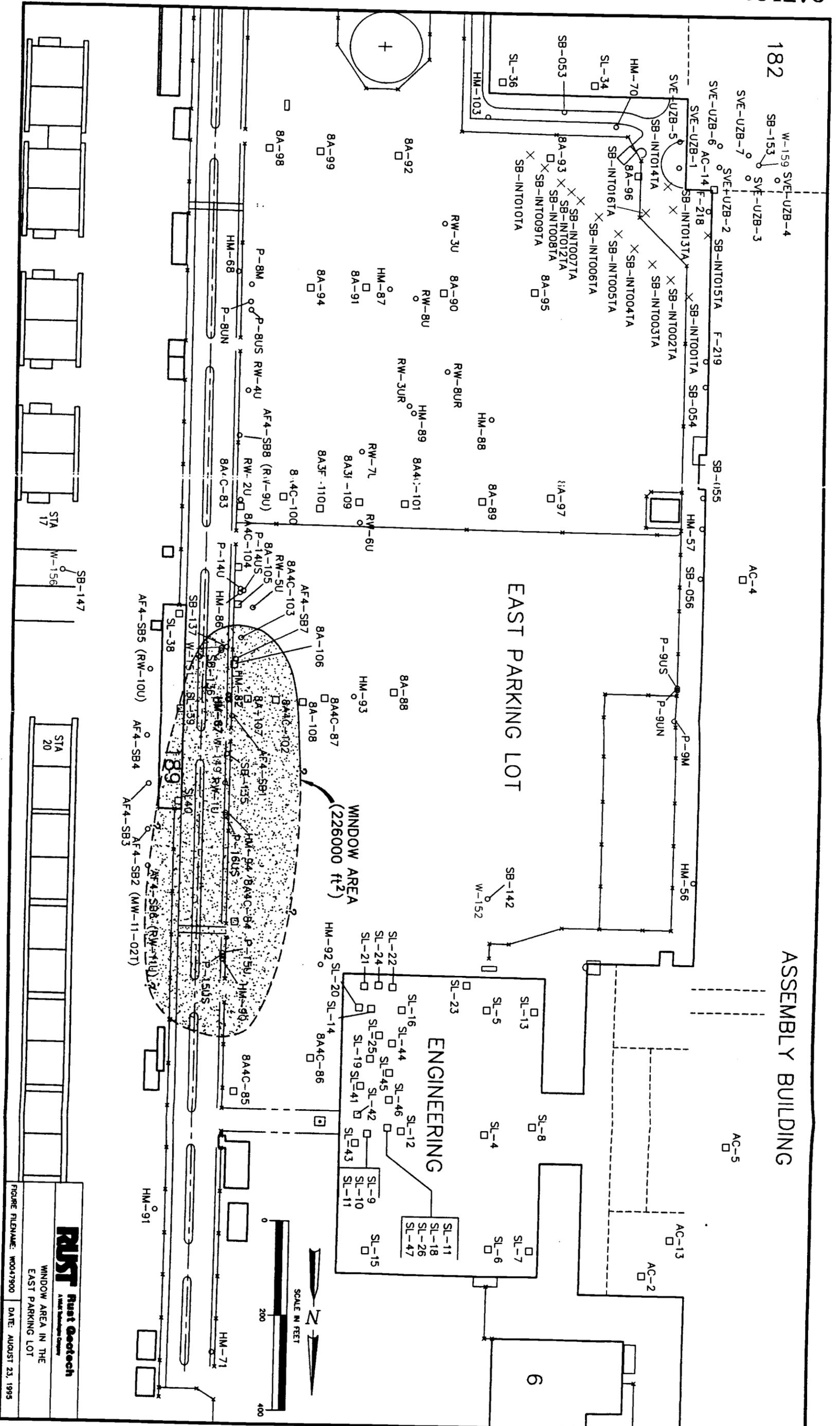


Figure 3.8.1-1. Location of Window Area in the East Parking Lot.

RUST Rust Geotech
 A Rust Technologies Company
 WINDOW AREA IN THE
 EAST PARKING LOT
 FIGURE FILENAME: W0047900 DATE: AUGUST 23, 1995

Groundwater flows in three primary directions in the vicinity of Plant 4. The dominant flow direction is towards the east, originating at the south central part of Plant 4. Secondary flow directions include the westerly flow direction originating at the west central part of the Assembly Building/Parts Plant, and the northerly flow direction originating at the northern part of the Assembly Building/Parts Plant. Approximate hydraulic gradients (defined as the change in head along the flow path) in these three flow domains range from 0.005 to 0.01 in the easterly flow direction, 0.004 to 0.2 in the westerly flow direction, and 0.01 to 0.03 in the northerly flow direction.

The area beneath and just west of the Assembly Building is characterized by relatively flat hydraulic gradients. To show additional detail in this area, bedrock and water table contour maps plotted at 2-foot contours are provided in Figures 3.8.1-2 and 3.8.1-3 respectively. These figures show that both the water-table and bedrock topography form a saddle in the vicinity of Building 14, with groundwater flow directed east and west of this saddle.

The base of the upper-zone flow system at Plant 4 is defined as the top of competent bedrock. Records of drillholes installed at Plant 4 were used to obtain elevations of the top of competent bedrock material. Figure II-25 is a contour map which illustrates the top of competent bedrock at Plant 4. Paleochannels trending northeast across the East Parking Lot, southeast across the flight lines at CAFB, and north from the northern end of the Assembly Building/Parts Plant are evident in Figure II-25. Saturated thicknesses in the upper-zone flow system are generally greatest along the axes of these paleochannels.

Basal gravel is frequently present at the contact between competent bedrock and the upper zone. Basal gravel attains maximum thickness in the East Parking Lot area along the course of the main northeast trending paleochannel. Lithologic logs compiled by previous investigators (Hargis + Associates 1989) indicate that monitoring well HM-089, located within the paleochannel, contains 16 feet of basal gravel deposits. Basal gravel thicknesses are significantly less outside the paleochannel.

Slug tests were performed on 25 monitoring wells to obtain estimates of hydraulic conductivity in the upper zone. Some of the wells included in the slug testing program have screens that extend into weathered portions of the Goodland Limestone. It was considered appropriate to test these wells (such as W-128L, W-133L, and W-157) because the upper-zone flow system has been defined to include unconsolidated alluvium and weathered portions of the Goodland Limestone. Results of the slug tests are suitable for characterizing the hydraulic conductivity of a small cylinder of porous media that surrounds the well screen. The results of slug tests are representative of smaller volumes of porous media than are the results of conventional pumping tests. The tests were performed according to the procedures identified in the RI Work Plan. The only exception was that a different recording schedule was used to accommodate the In Situ data loggers. Slug test analyses were based on the method of Bouwer and Rice (1976),

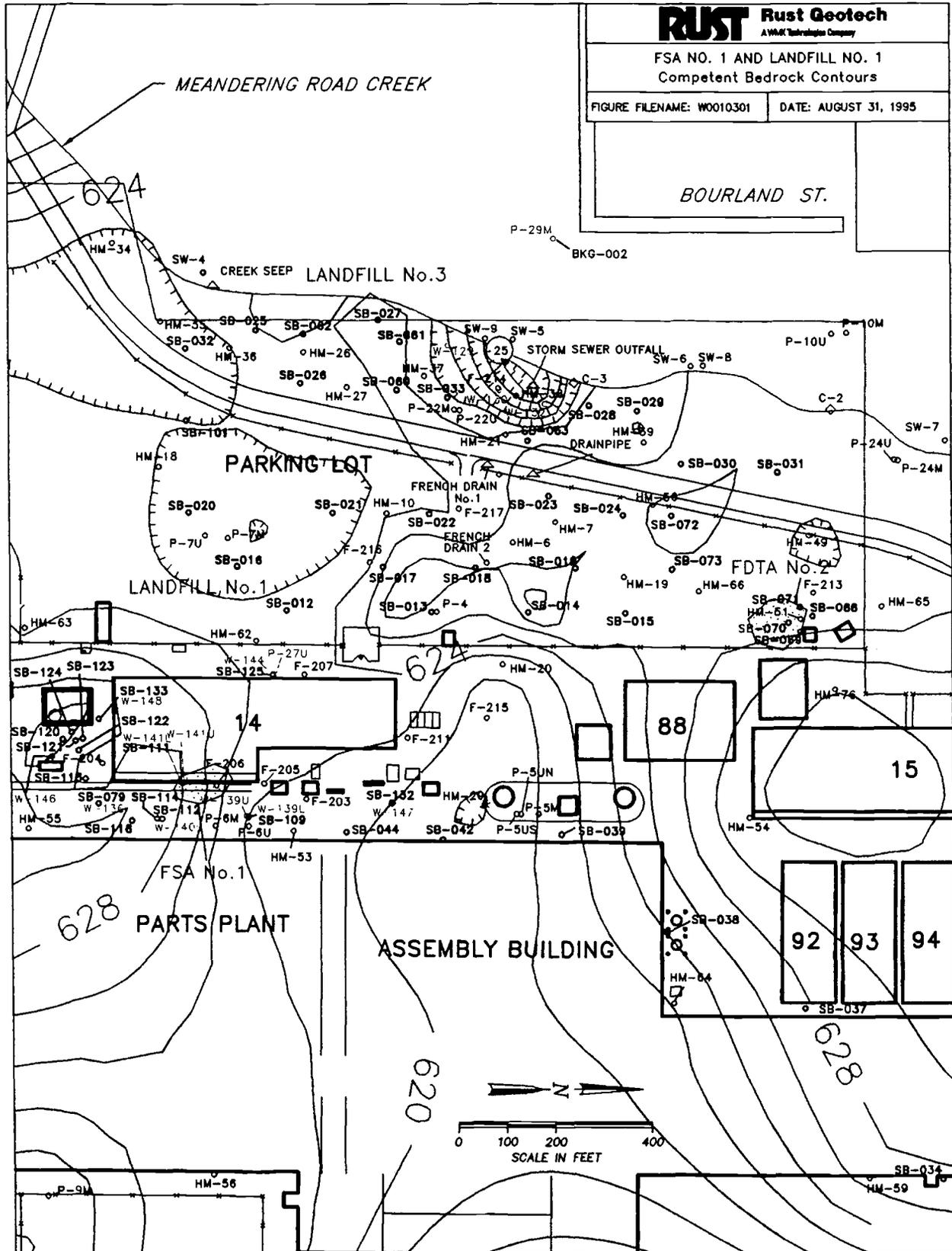


Figure 3.8.1-2. Enlarged View Showing Elevation Contours for Competent Bedrock in FSA No. 1 and Landfill No. 1 Areas.

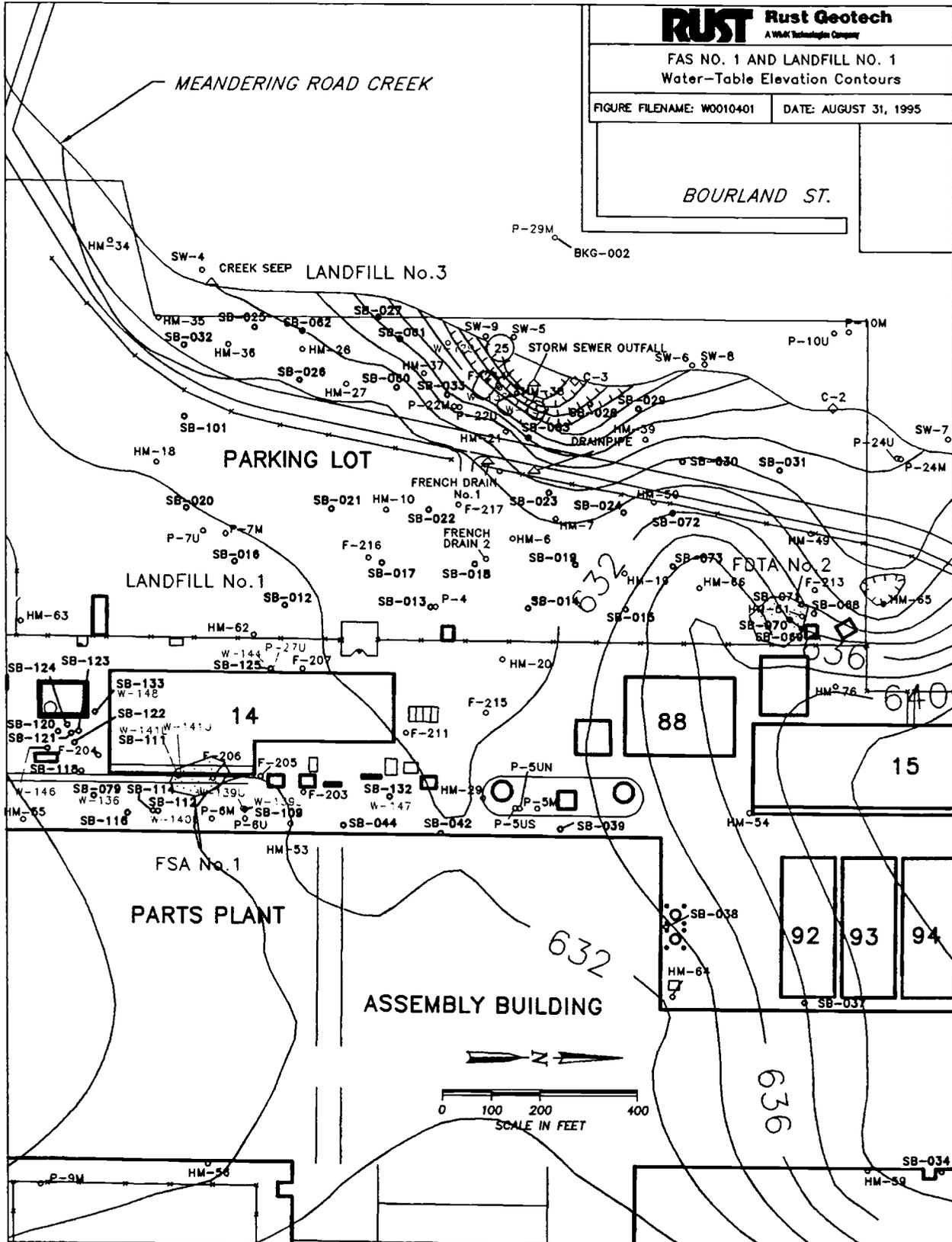


Figure 3.8.1-3. Enlarged View Showing Water-Table Elevation Contours in FSA No. 1 and Landfill No. 1 Areas.

and Bouwer (1989). The calculations associated with the slug test analysis are presented in Appendix O. Hydraulic conductivities obtained from the slug testing in the easterly flowing groundwater area are presented in Table 3.8.1-1. Estimated hydraulic conductivity values in the easterly flowing groundwater zone ranged from 1.97×10^{-2} cm/s in monitoring well W-159 to 9.76×10^{-6} cm/s in monitoring well W-157. The mean of the logarithms of the hydraulic conductivities in the easterly flowing groundwater system is 4.52×10^{-4} cm/s based on a sampled population of thirteen monitoring wells. No distinct difference between hydraulic conductivity estimated for wells located within paleochannels and wells placed outside paleochannel margins was indicated on the basis of slug test results.

Table 3.8.1-1 Slug Test Results in Easterly Flowing Upper-Zone Groundwater

Well Number(Test Number)	Hydraulic Conductivity (cm/sec)
W-128L	1.05×10^{-3}
W-131U(1)	1.01×10^{-2}
W-131U(2)	1.13×10^{-2}
W-133L(1)	1.83×10^{-3}
W-133L(2)	1.77×10^{-3}
W-149(1)	1.18×10^{-4}
W-149(2)	1.22×10^{-4}
W-151(1)	2.34×10^{-3}
W-151(2)	2.21×10^{-3}
W-153(1)	3.58×10^{-3}
W-153(2)	3.39×10^{-3}
W-156	1.85×10^{-3}
W-157	9.76×10^{-6}
W-158(1)	3.18×10^{-3}
W-158(2)	2.94×10^{-3}
W-159(1)	1.57×10^{-2}
W-159(2)	1.97×10^{-2}
W-160(1)	5.62×10^{-3}
W-160(2)	5.81×10^{-3}
HM-12(1)	5.52×10^{-3}
HM-12(2)	3.56×10^{-3}
HM-28(1)	6.90×10^{-3}
HM-28(2)	6.69×10^{-3}

Estimated hydraulic conductivity values for the westerly flowing groundwater system are presented in Table 3.8.1-2. The maximum hydraulic conductivity value in the westerly flowing groundwater area was estimated to be 1.13×10^{-1} cm/s at monitoring well W-144; the minimum value was estimated to be 7.73×10^{-5} cm/s at monitoring well W-141U. The mean of the logarithms of the estimated hydraulic conductivity values is 2.39×10^{-3} cm/s based on a sampled population of eight monitoring wells.

Table 3.8.1-2 Slug Test Results In the Westerly Flowing Upper-Zone Groundwater

Well Number(Test Number)	Hydraulic Conductivity (cm/sec)
W-136(1)	6.69×10^{-3}
W-136(2)	6.25×10^{-3}
W-140(1)	1.05×10^{-2}
W-140(2)	9.84×10^{-3}
W-140(3)	1.17×10^{-2}
W-141U	7.73×10^{-5}
W-144	1.13×10^{-1}
W-147(1)	4.03×10^{-4}
W-147(2)	2.13×10^{-4}
F-216(1)	2.06×10^{-3}
F-216(2)	2.12×10^{-3}
F-217(1)	2.32×10^{-3}
F-217(2)	2.42×10^{-3}
F-217(3)	2.45×10^{-3}
HM-27(1)	1.08×10^{-3}
HM-27(2)	1.17×10^{-3}

Estimated hydraulic conductivities for the northerly flowing groundwater area are presented in Table 3.8.1-3. The maximum hydraulic conductivity value in the northerly flowing groundwater area was estimated to be 3.00×10^{-2} cm/s at monitoring well W-143; the minimum value was estimated to be 3.75×10^{-6} cm/s at monitoring well F-212. The mean of the logarithms of the estimated hydraulic conductivity values is 5.31×10^{-4} cm/s based on a population of four monitoring wells.

Table 3.8.1-3 Slug Test Results for Northerly Flowing Upper-Zone Groundwater

Well Number(Test Number)	Hydraulic Conductivity (cm/sec)
W-143(1)	3.00×10^2
W-143(2)	2.76×10^2
F-208(1)	2.69×10^4
F-208(2)	2.54×10^4
F-212	3.75×10^4
HM-105(1)	2.84×10^3
HM-105(2)	2.93×10^3
HM-105(3)	2.70×10^3

Although the number of slug tests in the different flow areas varied, the resulting estimates of hydraulic conductivity indicate that there is extreme variability in the hydraulic conductivity across the site. A mean of the logarithms of the hydraulic conductivity parameter provides an average that is skewed in the direction of lower hydraulic conductivities relative to the arithmetic mean. Given that research has shown that the hydraulic conductivity parameter is often log-normally distributed, the logarithmic approach to estimating average hydraulic conductivity is justified (Domenico and Schwartz 1990, pp. 66 - 67). Note that an average computed on the basis of the logarithms of individual conductivity values is identical to the geometric mean of the raw conductivity values (Equation 3.20, Domenico and Schwartz 1990).

Published values of hydraulic conductivities for silty sand range from 1.0×10^{-5} to 1.0×10^{-1} cm/s, and porosity values for silts and clays range from 0.20 to 0.33 (dimensionless) (deMarsily 1986, p. 36). Together with hydraulic gradient values presented earlier, the two parameters of hydraulic conductivity and porosity may be used to estimate the average linear velocity of upper-zone groundwater. The average linear velocity is defined as

$$\bar{v} = \frac{v}{n} = \frac{K}{n} \frac{dh}{dl} \quad \text{Equation 3-1}$$

where:

- v = Darcy flux, or specific discharge ($L^3/L^2 T$)
- n = porosity (dimensionless)
- K = hydraulic conductivity (L/T)
- dh/dl = hydraulic gradient

A matrix in which Equation 3-1 is solved for each of the flow directions in the upper zone is presented in Table 3.8.1-4.

Except for the westerly flowing maximum value, estimated minimum and maximum average linear velocity values are relatively consistent throughout Plant 4. The maximum hydraulic gradient calculated in the westerly area was in the vicinity of Landfill No. 3. The hydraulic gradients may be steep in this area due to the head loss associated with the groundwater flowing across the low hydraulic conductivity bedrock ridge that parallels Meandering Road Creek. There were no hydraulic conductivity values obtained in this area during the RI.

Table 3.8.1-4 Estimated Minimum and Maximum Values of Average Linear Velocity in Upper-Zone Groundwater

Flow System	Mean-of-Logs Hydraulic Conductivity (cm/s)	Assumed Porosity (dimensionless)	Hydraulic Gradient (dimensionless)	Darcy Flux (cm/s)	Average Linear Velocity (cm/s)
Easterly Flow (minimum)	1.15×10^{-3}	0.20-0.30	0.005	5.75×10^{-6}	1.92×10^{-5} - 2.88×10^{-5} (0.05-0.08 ft/d)
Easterly Flow (maximum)	1.15×10^{-3}	0.20-0.30	0.01	1.15×10^{-5}	3.83×10^{-5} - 5.75×10^{-5} (0.11-0.17 ft/d)
Westerly Flow (minimum)	2.39×10^{-3}	0.20-0.30	0.004	9.56×10^{-6}	3.19×10^{-5} - 4.79×10^{-5} (0.09-0.14 ft/d)
Westerly Flow (maximum)	2.39×10^{-3}	0.20-0.30	0.2	4.78×10^{-4}	1.59×10^{-3} - 2.39×10^{-3} (4.51-6.77 ft/d)
Northerly Flow (minimum)	5.31×10^{-4}	0.20-0.30	0.01	5.31×10^{-6}	1.77×10^{-5} - 2.66×10^{-5} (0.05-0.08 ft/d)
Northerly Flow (maximum)	5.31×10^{-4}	0.20-0.30	0.03	1.59×10^{-5}	5.31×10^{-5} - 7.97×10^{-5} (0.15-0.23 ft/d)

3.8.2 Goodland Limestone and Walnut Formation Aquitard

The Goodland Limestone is an assemblage of interbedded siltstone, claystone, and limestone while the Walnut Formation consists of highly indurated limestone and shell agglomerate. These two formations form an aquitard that restricts the vertical flow of groundwater between the upper-zone flow system and the Paluxy Aquifer. The entire section of Walnut Formation and at least a portion of the Goodland Limestone are present within most of the Plant 4 area. In the vicinity of Plant 4, the maximum thickness of the aquitard is approximately 30 feet. However, the aquitard is thin, and in

some cases nearly absent, in areas where paleochannels have incised into the Goodland Limestone and Walnut Formation. As previously discussed, the window area in which the aquitard is almost absent is located beneath the East Parking Lot. Probable weathering of the remaining veneer of Walnut Formation in this area creates a potential groundwater flow into the Paluxy Formation.

Most of the characterization activities performed during the RI focused on the Walnut Formation because the Walnut Formation comprises most of the aquitard in the vicinity of Plant 4. Vertical hydraulic conductivity of competent Walnut Formation was measured on several drilling core samples collected during the RI. Table 3.8.2-1 presents the results of the vertical hydraulic conductivity measurements. The logarithmic mean of the measured hydraulic conductivity values is 7.0×10^{-10} cm/s, based on a sampling of 6 cores.

**Table 3.8.2-1 Results of Vertical Permeability Testing
in the Competent Walnut Formation Aquitard**

Sample Location	Depth of Sample	Effective Porosity (percent)	Hydraulic Conductivity (cm/s)
P-27	47'2" to 47'6"	8.6	4.2×10^9
P-27	56'4" to 57'0"	8.2	5.2×10^{-10}
P-28	37'2" to 37'6"	7.2	1.2×10^9
P-28	50'2" to 50' 6"	6.4	7.3×10^{-11}
P-30	38'0" to 38'6"	12	8.5×10^9
P-30	52'10" to 53'4"	2.3	7.1×10^{-11}

In addition to the hydraulic conductivities discussed above, hydrographs for paired upper-zone and Paluxy Formation monitoring wells also indicate that there is relatively little flow from the upper-zone to the Paluxy Formation. Hydrographs for HM-86 and P-14US (located in the East Parking Lot window area), and W-143 and P-28U (located in the North Parking Lot) are shown in Figures 3.8.2-1 and 3.8.2-2, respectively. Figure 3.8.2-1 shows two significant step-like changes in the water level in HM-86. These changes are not present in the P-14US hydrograph, indicating poor hydraulic communication. The Walnut Formation at this location is six feet thick. In Figure 3.8.2-2, W-143 shows two smaller increases in the upper zone water-level. Again, these trends are not present in the hydrograph for the Paluxy Formation well, P-28U.

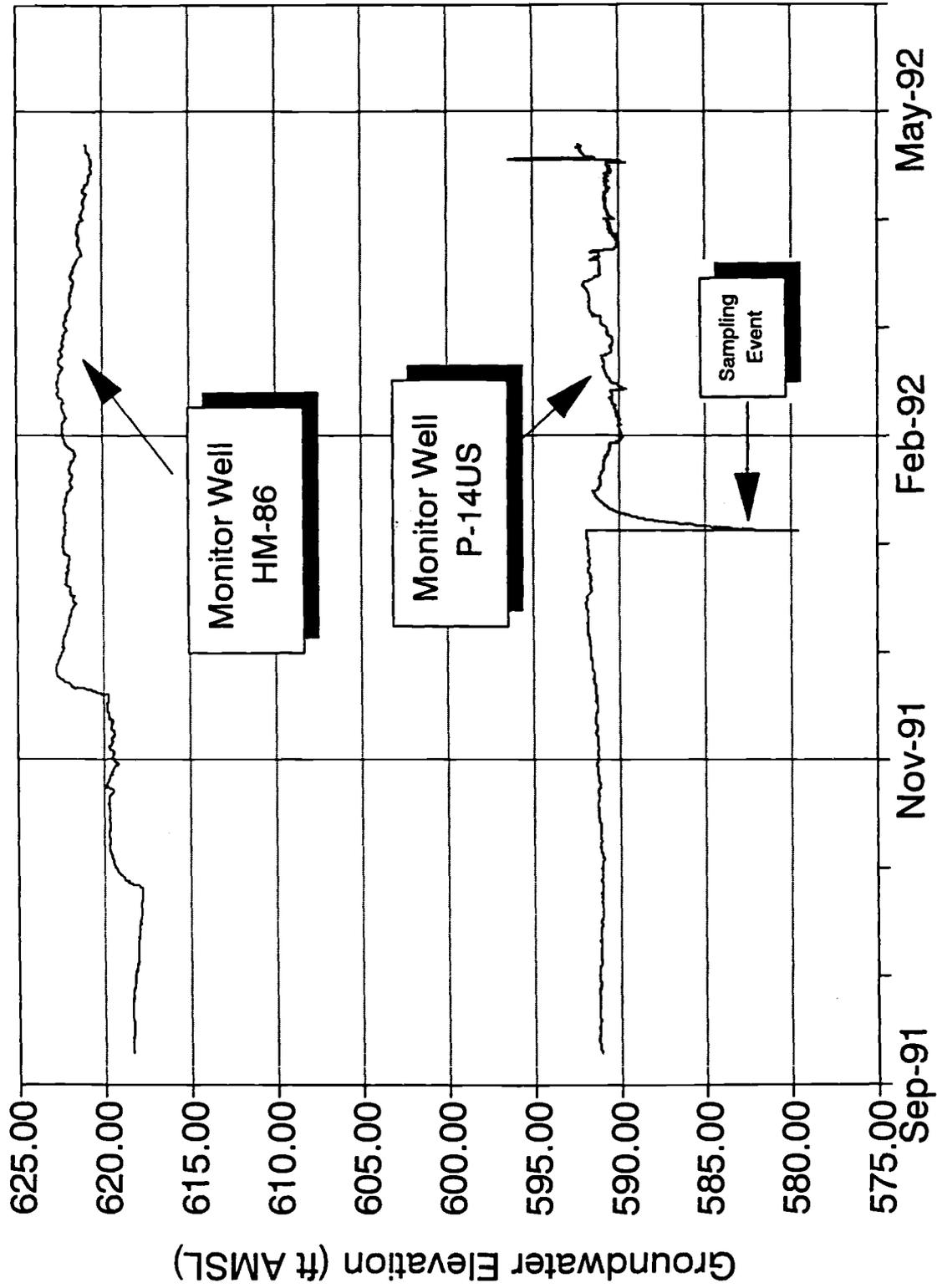


Figure 3.8.2-1. Groundwater Elevations for the Period 10 September 1991 through 19 May 1992 for Monitoring Wells HM-86 and P-14US.

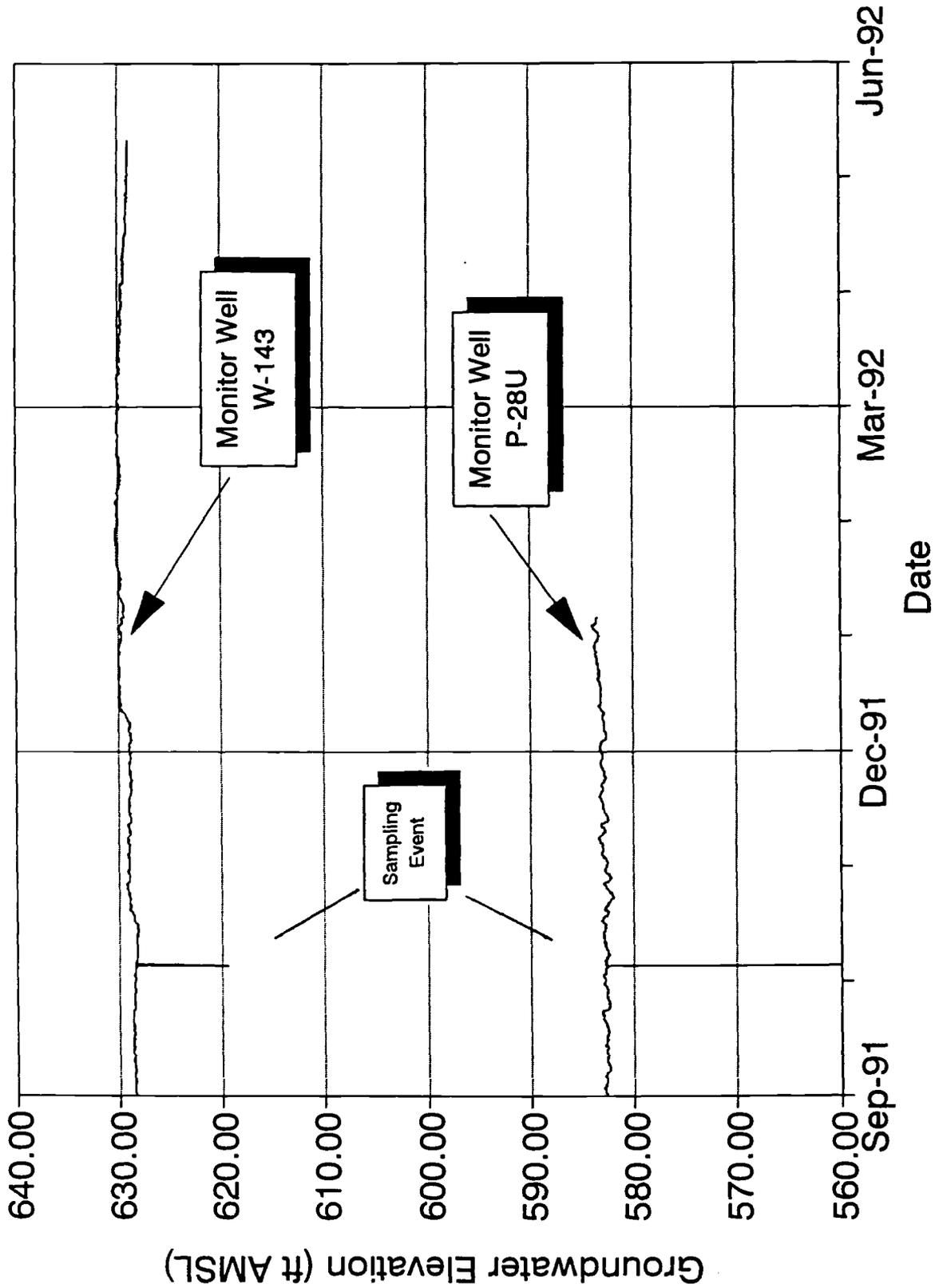


Figure 3.8.2-2. Groundwater Elevations for the Period 12 September 1991 through 19 June 1992 for Monitoring Wells W-143 and P-28U

The large differences in hydraulic head at these two pairs of wells (approximately 28 feet at HM-86/P-14US and 46 feet at W-143/P-28U) also indicate large vertical head losses, which are consistent with the presence of a low-conductivity aquitard.

At locations in the paleochannel beneath the East Parking Lot where the Walnut Formation is a minimum, the effectiveness of this aquitard is diminished and vertical flux rates will be higher. The vertical Darcy velocity and average linear velocity can be estimated using Equation 3-1 with the hydraulic gradient defined at locations of paired upper-zone and Paluxy Formation wells. Paired wells in the paleochannel-window area include P-14US/HM-86, P-15US/HM-90, and P-16US/HM-94.

Because vertical flow from the upper-zone into the Paluxy Formation is a case of flow perpendicular to layering, K in Equation 3-1 must be replaced with K_z , the equivalent vertical hydraulic conductivity (Freeze and Cherry 1979, p. 33). The expression for the equivalent vertical hydraulic conductivity is:

$$K_z = \frac{d}{\sum_{i=1}^n \frac{d_i}{K_i}} \quad \text{Equation 3-2}$$

where K_z = equivalent vertical hydraulic conductivity
 d = combined thickness of heterogeneous units
 d_i = individual thickness of strata i
 K_i = hydraulic conductivity of strata i

It is important to note that the definition of the d_i and d should be consistent with the definition of ΔL that is used in calculating the hydraulic gradient that will be used with K_z to estimate the Darcy velocity. This relationship is discussed in Appendix Q, Hydrologic Calculations, Notes, and Drawings.

When Equation 3-2 is used to calculate the equivalent vertical hydraulic conductivity for an interval that includes strata with very low hydraulic conductivities, d_i/K_i values for high permeability strata have a negligible contribution and are commonly ignored (see Appendix Q, Hydrologic Calculations, Notes, and Drawings).

The equivalent vertical hydraulic conductivities for the three window area well pairs are presented in Table 3.8.2-2. These equivalent vertical conductivities are then used to estimate the vertical Darcy flux and average linear vertical velocity through the Walnut Formation in the vicinity of the window area. The results are presented in Table 3.8.2-3. The complete details for these calculations are presented in Appendix Q.

Table 3.8.2-2 Estimated Equivalent Vertical Hydraulic Conductivity for Flow Through Walnut Formation

Sample Location	K_i Walnut (cm/sec)	d_i Walnut (ft)	K_i Paluxy (cm/sec)	d_i Paluxy (ft)	d (ft)	K_e (cm/s)
HM-86 and P-14US	7.0×10^{-8}	6.6	2×10^{-8}	4.75	26	7.84×10^{-8} (2.22×10^{-4} ft/d)
HM-90 and P-15US	7.0×10^{-8}	2.0	2×10^{-8}	2.5	18.0	1.17×10^{-7} (3.32×10^{-4} ft/d)
HM-94 and P-16US	7.0×10^{-8}	2.25	2×10^{-8}	3.5	19.35	9.34×10^{-8} (2.65×10^{-4} ft/d)

Table 3.8.2-3 Vertical Average Linear Velocity and Darcy Flux Through the Walnut Formation in the Window Area

Sample Location	K_e (ft/d)	Porosity (dimensionless)	Hydraulic Gradient (dimensionless)	Vertical Darcy Flux (ft/d)	Vertical Average Linear Velocity (ft/d)
HM-86 and P-14US	2.22×10^{-4}	0.074	1.08	2.39×10^{-4}	3.23×10^{-3}
HM-90 and P-15US	3.32×10^{-4}	0.074	1.16	3.86×10^{-4}	5.22×10^{-3}
HM-94 and P-16US	2.65×10^{-4}	0.074	0.32	8.57×10^{-5}	1.16×10^{-3}

In these calculations, measured K_i values were not available for the Walnut Formation in the window area. Because the Walnut Formation is thin and likely weathered in this area, K_i was assumed to be two orders of magnitude greater than the logarithmic mean K for the competent Walnut Formation, or 7×10^{-8} cm/s (see Table 3.8.2-1). For the Paluxy Formation, K_i was set equal to 2×10^{-8} cm/s, which is the logarithmic mean of the vertical hydraulic conductivities measured for Paluxy Formation core samples (see Table 3.8.3-5).

The porosity used to calculate the average linear velocity through the Walnut Formation was 7.4 percent. This is the arithmetic average of porosity values reported for Walnut Formation core samples (see Appendix P, Vertical Hydraulic Conductivity Analysis of Walnut Formation and Paluxy Formation Core Samples via Triaxial Cell Testing).

The estimated vertical flow velocity through the Walnut Formation suggests that as long as the Walnut Formation is present, the downward flow of groundwater is very limited. The primary control impeding the downward flow of groundwater is the low vertical hydraulic conductivity of the competent Walnut Formation. The distribution of contamination in the Paluxy Formation over most of Plant 4 confirms that there is very little flux of upper-zone groundwater flowing through the aquitard.

However, in the window area, the Paluxy Formation is significantly contaminated with TCE and its degradation products (Section 4.5.3). This suggests that although a remnant of the Walnut Formation may be present, it is significantly weathered. It also suggests that the degree of weathering has increased the hydraulic conductivity to the point where the aquitard is leaking appreciably in the window area. The volume of leakage through the Walnut Formation is discussed in Section 3.8.3.1.

3.8.3 The Paluxy Aquifer

The Paluxy Aquifer is an unconfined to semi-confined sandstone aquifer that underlies the Walnut Formation aquitard. The bottom of the Paluxy Aquifer is defined as the first occurrence of limestone beneath the Paluxy Formation. Limestone is the dominant component of the Glen Rose Formation which underlies the Paluxy Formation.

In Tarrant and Dallas Counties, the Paluxy Aquifer is widely used as a source of water for domestic, municipal, and industrial water supplies. Development of the Paluxy Aquifer began in the early 1900s, with total production in the Tarrant and Dallas County areas reaching a peak in the late 1960s (Nordstrom 1982). The decline in production since the late 1960s resulted from large declines in hydraulic head caused by heavy pumping in eastern Tarrant County and central Dallas County. The declining water levels led to the abandonment of inefficient wells (Nordstrom 1982), which were then replaced by the development of other sources, such as the Twin Mountains Aquifer. In the immediate vicinity of Plant 4, seven municipal water supply wells obtain water from the Paluxy Aquifer. These wells are owned by the city of White Settlement and are shown on Plate 2. Although complete historical production records are not available for these wells, pumpage has been relatively constant in recent years (Mike Ostrosky, city of White Settlement, telecon 1992). Average daily production rates for each of the White Settlement municipal wells are shown in Table 3.8.3-1.

**Table 3.8.3-1 Average Daily Production for White Settlement
Municipal Supply Wells Completed in the Paluxy Aquifer
(Data Provided by City of White Settlement, October 1989)**

Well Number	Average Daily Production (Gallons Per Day)	Depth of Screened Interval (Feet)	Total Depth (Feet)
WS-1	73,000	Not Available	254
WS-2	56,000	Not Available	200
WS-3	75,100	180-200	201
WS-H3	65,900	212-242	282
WS-5A	82,600	175-305	305
WS-8	68,900	175-286	286
WS-12	62,000	Not Available	195

As noted in Section 3.7, the Paluxy Aquifer has been characterized in previous site reports as a stratified aquifer consisting of three distinct flow systems separated by continuous aquitards composed of siltstone, claystone, and/or shale. Of the four references that address the hydrogeology of the Tarrant County area (Leggat 1957, Peckham and others 1963, Caughey 1977, Nordstrom 1982) only Leggat (1957) raises the possibility of stratified-flow characteristics within the Paluxy Aquifer. Leggat (1957) notes that the Paluxy Aquifer may be divided into upper and lower sand members and that the sand beds do not maintain constant thickness or lithology over long distances. However, specific data are not provided in support of this hypothesis.

A review of lithologic logs from previous reports (largely based on drill cuttings) and lithologic logs based on continuously-cored holes installed during the RI/FS field investigation indicates that sandstone is the most prevalent rock within the Paluxy Formation; however, the formation also contains abundant low-permeability zones comprised of interbedded shale, siltstone, and claystone. These interbedded units range in thickness from less than 1 foot to more than 10 feet. For example, in the lithologic log for well P-11M (U.S. Army Corps of Engineers 1986), the interval extending from 71 to 153 feet below ground level (bgl) was logged as "sand/sandstone" and was noted to contain 9 individual "shaley zones" that ranged in thickness from 0.7 feet to 4.8 feet. The 4.8-foot shaley zone was found at 104 to 109.8 feet bgl. Thicknesses of the other shaley zones identified in the lithologic logs did not exceed 3 feet. Variable-thickness shale and siltstone/claystone layers separated by sandstone intervals are further documented in the lithologic logs for other wells, such as P-12M and P-13M (U.S. Army Corps of

Engineers 1986) and P-27U through P-31U (see Appendix B-1). Cross-sections prepared by previous investigators and containing many of these wells have commonly displayed these variable-thickness shale and siltstone layers as thick, continuous sequences (up to 20 feet) of low-permeability rock. However, as noted above, lithologic logs for individual boreholes do not support this interpretation.

Hydrogeologic cross-sections through the Paluxy Aquifer are presented in Figures II-1 through II-10. Water-levels shown on the cross-sections are based on September, 1991 or the most recent September/October data. The location of each of the cross-sections is depicted in Plate 4. The site-scale hydrostratigraphic characteristics of the Paluxy Aquifer are shown in the three-dimensional fence-diagram presented on Plate 5. Due to the scale of the fence diagram, individual lithologic units less than 5 feet thick are not shown. Sequences within the Paluxy Formation that include shale and siltstone/claystone interbeds with thicknesses less than five feet are illustrated as "interbedded sandstone."

As shown by cross-sections 1 through 10 (Figures II-1 through II-10), and as described in Section 3.7, individual shale and siltstone/claystone units are frequently encountered throughout the vertical extent of the Paluxy Aquifer. There appears to be a greater tendency to encounter low-permeability shale and siltstone/claystone layers in the upper portions of the Paluxy Aquifer than in the lower portions of the aquifer. In most instances, individual shale and siltstone/claystone units cannot be correlated over large distances because of the variable distribution of the units and the uncertainty associated with the lithologic logs prepared on the basis of drill cuttings.

On the basis of these observations, the Paluxy Aquifer is regarded as a single unconfined to semi-confined flow system consisting of a largely sandstone matrix with abundant layers of interbedded shale, siltstone, and claystone. This interpretation of the Paluxy-Aquifer and the evaluation of Plant 4 lithologic logs prepared for the Paluxy Formation are further discussed in Chem-Nuclear Geotech (1992), "A Modification in the Former Conceptual Model of the Paluxy Aquifer Flow System."

3.8.3.1 Paluxy Aquifer Recharge and Discharge

Recharge to the Paluxy Aquifer occurs largely as infiltration of precipitation falling on the outcrop in Wise, Parker, Hood, and Tarrant Counties. Recharge also occurs as infiltration from Lake Worth and Eagle Mountain Lake, both of which lie at least partially within the boundary of the outcrop. Additional minor amounts of recharge also occur as infiltration from streams that cross the outcrop. In the immediate vicinity of Plant 4, it is evident that small amounts of recharge are also derived from leakage of upper-zone groundwater through the window area (where the Walnut Formation has been severely eroded) and leakage of surface water through the lower reaches of Meandering Road Creek. In both of these areas, most if not all of the Walnut Formation has been eroded reducing the capacity of this aquitard to impede the vertically downward flow of upper-zone groundwater and surface water.

Evidence of recharge entering the Paluxy Formation in these areas is provided by the hydraulic head data from "US," "U," and "M" series wells located within these potential recharge areas. In the window area, the uppermost wells in the Paluxy Formation are those with a "US" designation. The "U" designation indicates those wells completed in the next lower portion of the Paluxy Aquifer. As shown in Appendix D-1, the fence diagram (Plate 5), and Figures II-1, II-2, and II-8, "US" wells located in the vicinity of the window area (P-8, P-9, P-14, and P-15) have water levels several feet higher than the paired "U" wells at these locations. This indicates that downward flow occurs within the Paluxy Aquifer at these locations. This downward flow most likely originates as recharge transmitted through the eroded portion of the Walnut Formation. This same characteristic is observed in the "U" and "M" wells at P-10 and P-24. These two well pairs are located in the vicinity of lower Meandering Road Creek, where erosion has also removed much of the Walnut Formation bedrock.

Using the Darcy flux calculation from Section 3.8.2, it is possible to estimate the vertical flux rate through the Walnut Formation in the window area. The volumetric flux is given by $Q = V \cdot A$, where V is the Darcy flux through the Walnut Formation given in Section 3.8.2, and A is the area through which flow occurs. As noted in the lithologic log for monitoring well HM-94 (Hargis + Associates 1985a), the Walnut Formation is 1.5-foot thick at this location. Similar thicknesses are reported for the Walnut Formation at nearby wells P-15 and P-16 (located approximately 250 feet apart). Assuming that flow occurs mainly through the area shown by the shaded oval in Figure 3.8.1-1, (area $A = 226,000 \text{ ft}^2$) where the Walnut Formation is approximately 1.5 to 2.5 feet thick, an upper limit on the estimate of recharge flux into the Paluxy Aquifer would be:

$$(2.4 \times 10^{-4} \text{ ft/d}) \times 226,000 \text{ ft}^2 = 54 \text{ ft}^3/\text{day}$$

This calculation is based on the average of the Darcy flux rates at P-15 and P-16 (Table 3.8.2-3) and the assumption that the Walnut Formation is weathered in the window area. If the Walnut Formation limestone found in the window area remains indurated and competent, the recharge flux through the thinnest portion of the formation could be as low as $0.5 \text{ ft}^3/\text{d}$. Smaller fluxes can be expected elsewhere in the East Parking Lot paleochannel where Walnut Formation thickness exceed the 1.5 to 2.5 feet observed in the Window area.

Further understanding of the window area vertical flux will be obtained during calibration of the site-scale flow model. During this phase, vertical flux parameters will be adjusted in order to match calibration targets in the window area. Numerical simulations will then provide improved estimates of the vertical flux in the window area.

Although no direct measurements of infiltration derived from precipitation have been made or reported in the literature, a qualitative estimate can be developed by considering several factors. Nordstrom (1982) notes that average annual precipitation on

the Paluxy Formation outcrop is 31 inches. However, only a small fraction of the 31 inches becomes recharge, as most is lost to runoff and evapotranspiration. Leggat (1957) reports that annual runoff accounts for 2.5 to 4 inches per year, and evapotranspiration during the growing season accounts for another 67 percent of annual precipitation, or 21 inches. This leaves between 6 and 7.5 inches available for recharge and evapotranspiration during spring, fall, and winter. Assuming off-season evapotranspiration consumes 2 to 5 inches of this remainder, maximum recharge rates are likely to be in the range of 1 to 5 inches per year. Based on a simple mass balance calculation for the Trinity-group aquifer system, Nordstrom estimated that effective recharge was approximately 5 percent of precipitation, or 1.5 inches per year. Recharge estimates of 1 to 5 inches per year are supported by preliminary results of a numerical simulation of the Paluxy Aquifer flow system. This model encompasses western Tarrant County and Eastern Parker County (Figure II-30) and is based on an assumed recharge rate of 2 inches per year over the outcrop.

Discharge from the Paluxy Aquifer is largely due to pumping from numerous water-supply wells throughout Tarrant, Dallas, and surrounding counties. It is likely that some discharge also occurs as groundwater evapotranspiration from the outcrop area and baseflow to streams, Lake Worth, and Eagle Mountain Lake.

Maximum production from Paluxy Aquifer wells was 13,000 acre-ft per year in both 1963 and 1969 (Nordstrom 1982). Production for 1976, the last year for which data are published, was 9,600 acre-feet.

3.8.3.2 Paluxy Aquifer: Hydraulics

Regional literature classifies the Paluxy Aquifer as an unconfined flow system in the Tarrant County area. As shown in the cross-sections presented in Figures II-1 through II-10, the high frequency of interbedded shale and siltstone/claystone units can be expected to cause the aquifer to behave in a semi-confined manner in the immediate vicinity of Plant 4.

Maps of Paluxy Aquifer water-level elevations in the Parker and Tarrant County areas surrounding Plant 4 are shown in Figure II-28 for the year 1955, Figure II-29 for the year 1989, and Figure II-31 for the year 1976. These maps show that the regional flow direction in the Paluxy Formation has been and remains nearly due east. The maps for 1955 and 1976 were reproduced from Nordstrom (1982). The map for 1989 was reproduced from an unpublished map on file with the Texas Water Commission. Comparison of Figures II-28 and II-31 show that hydraulic heads have remained relatively constant in the eastern portion of Parker County. This is indicative of near-steady state flow conditions in the portion of the Paluxy Aquifer that lies west of the Tarrant-Parker county line.

In central Tarrant County, near the eastern edge of Figures II-28 and II-31, water-table elevations declined between 1955 and 1976 by nearly 100 feet in some areas. This large drawdown was due mainly to a large cone of depression created by heavy pumping in the vicinity of the cities of Euless (in eastern Tarrant County) and Dallas (in central Dallas County). This cone of depression is easily recognized in Figure 31 of Leggat (1982).

Comparison of the contours shown in the 1976 and 1989 maps suggests that water-table elevations increased over this 13 year period. However, this apparent increase is an artifact of the relatively small number of data points used to prepare the 1989 map. Comparison of individual data points common to both maps indicates that elevations have remained relatively constant or declined only slightly within the area encompassed by Figure II-29. Leggat (1982) speculated that water levels would increase following the decline in production from the Paluxy Aquifer in the late 1960s. The data have not confirmed this prediction, but water levels have remained relatively constant over much of the area of interest (Figures II-29 and II-31). This observation is consistent with Plant 4 water-level data that includes three sets of continuous water-level monitoring data (Figures 3.8.2-1, 3.8.2-2, and 3.8.3-1), and multiple sets of synoptic water-level measurement data (Appendix D-1). The hydrographs for the Paluxy wells in these figures show only small random fluctuations (on the order of one to two feet) and very small periodic fluctuations (on the order of hundredths to tenths of a foot). The periodic fluctuations are caused by diurnal changes in atmospheric pressure and gravitational deformation of the porous media.

Maps of depth-specific hydraulic head for the Paluxy Formation in the vicinity of Plant 4 are shown in Figure II-32 through II-34. These maps illustrate the vertically downward hydraulic gradient created by recharge in the eastern portion of Lake Worth.

To assess the local nature of Paluxy Aquifer groundwater flow in the vicinity of Plant 4, a contour map was prepared using water levels obtained from (1) field measurements in Plant 4 monitoring wells, (2) published reports of water-level data from nearby supply-wells (Nordstrom 1982), (3) unpublished reports of supply-well water-level data (Texas Water Commission, Ground Water Data System), and (4) a regional-scale numerical simulation of groundwater flow in the Paluxy Aquifer. The resulting site-scale contour map is shown in Figure 3.8.3-2. The domain and finite difference grid for the regional-scale model are shown in Figure II-30. The outer limits of the model domain correspond to the limits of the contour maps shown in Figures II-28, II-29, and II-31.

For most of the White Settlement municipal wells, three water levels were available over the 37-year period from 1955 to 1991. Typically, each well had one value for the 1950s (or 1960s), one value for the 1970s, and one value for 1991. However, these data were not included in the site-scale contour map (Figure 3.8.3-2) for two reasons. First, water-level data for municipal wells WS-2 and WS-H3 indicated that significant declines had occurred during the 1980s, and that these declines have nearly dewatered the aquifer. Continuous declines in water levels are not consistent with regional and site

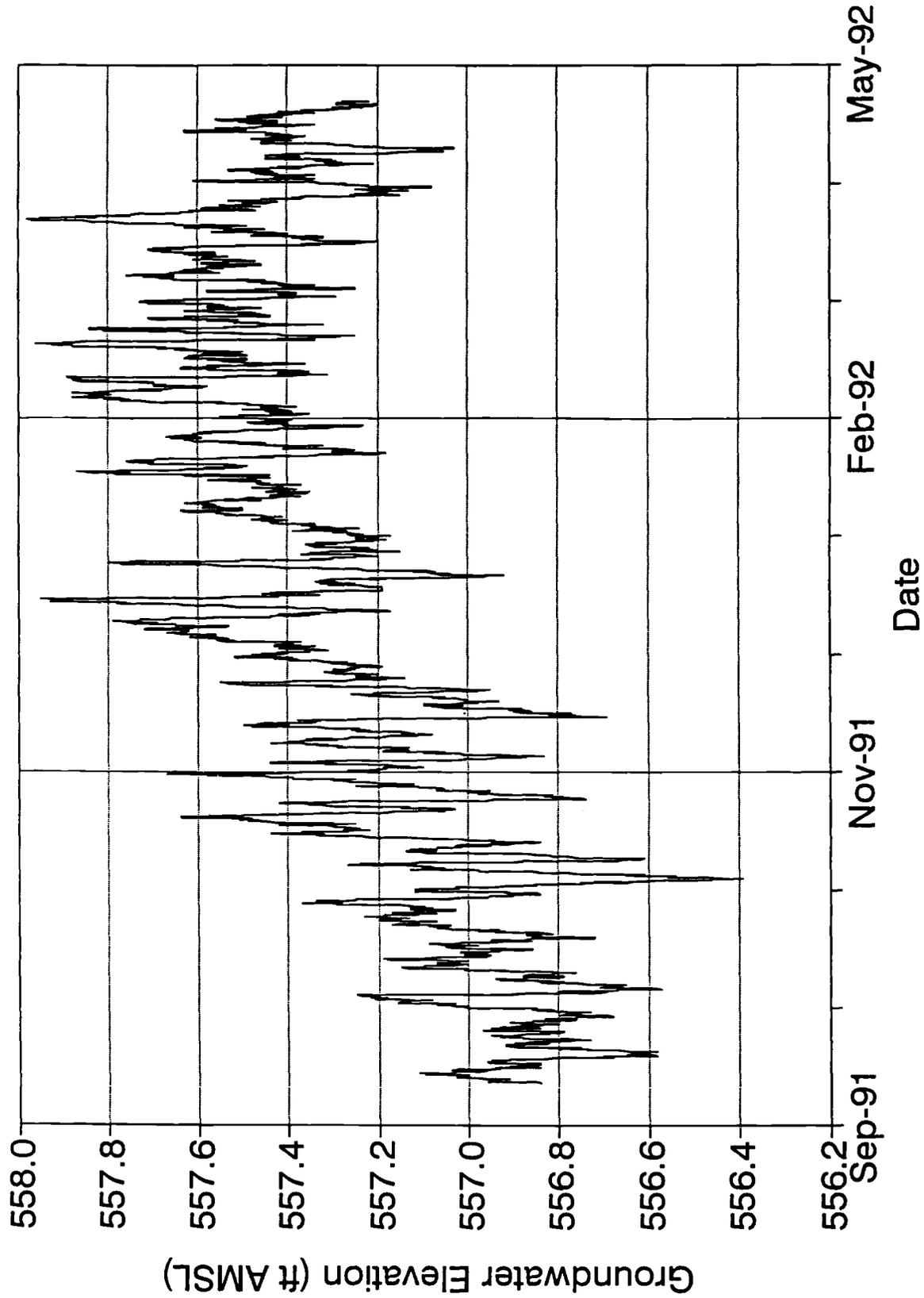


Figure 3.8.3-1. Groundwater Elevations at Monitoring Well P-11U for the Period 12 September 1991 through 19 May 1992.

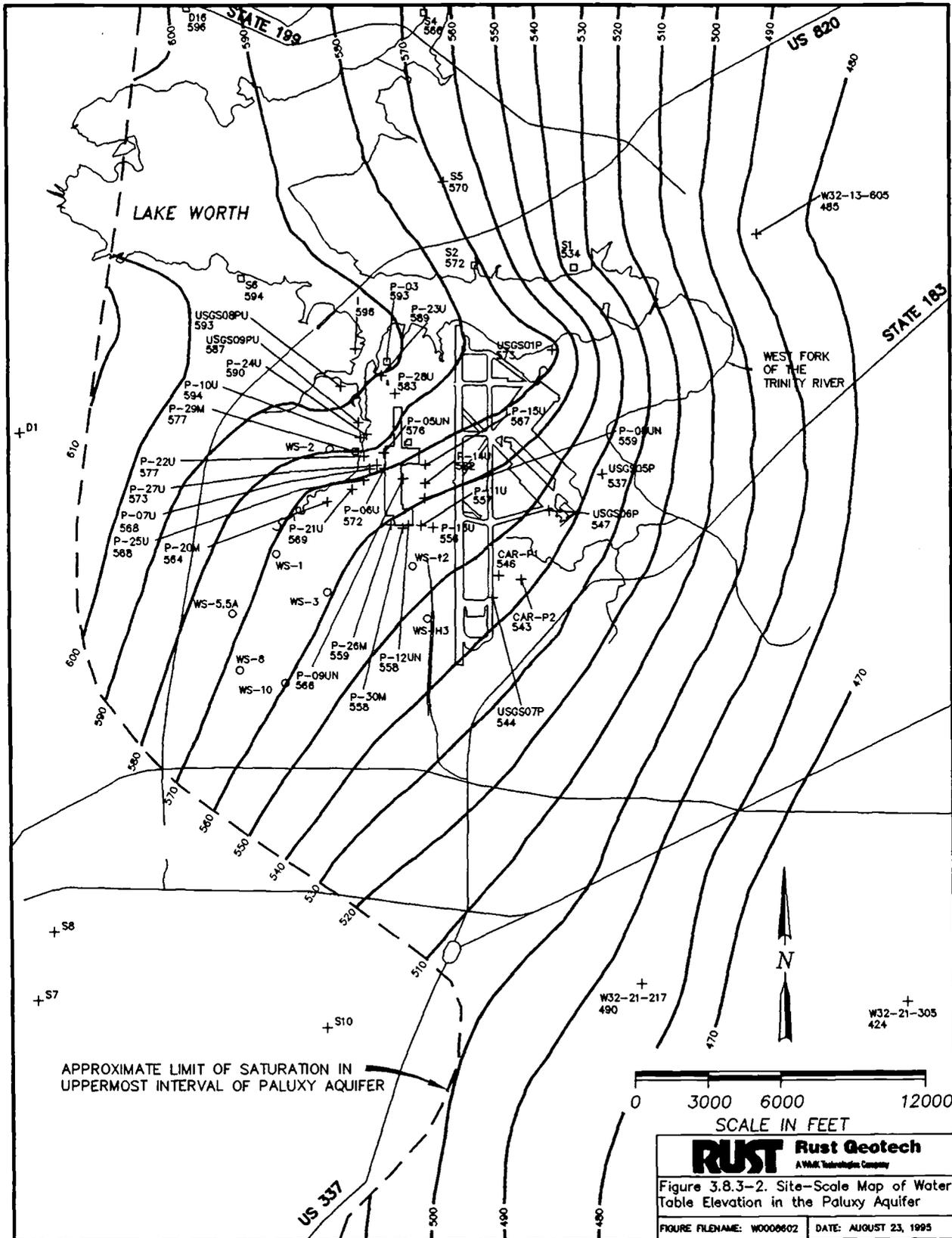


Figure 3.8.3-2. Site-Scale Map of Water Table Elevation in the Paluxy Aquifer in the Immediate Vicinity of Air Force Plant 4.

data that indicate steady-state conditions, as described earlier. Additionally, it seems unlikely that the Paluxy Aquifer could be dewatered by wells pumping only 39 and 45 gallons per minute. Secondly, White Settlement well data were not used because 1991 water levels for two of the wells indicated increasing aquifer head over recent years. In the absence of a regional increase in water levels caused by a major change in pumping withdrawals, increasing water levels are not possible for two isolated wells that have been in continuous, steady operation.

The problems associated with the White Settlement well data indicate that at least some of these water-levels may not reflect actual aquifer conditions. Additional data for the 1980s might have resolved some of these questions. Because the 1980s data were not available, the impact of drawdown caused by the White Settlement wells was accounted for by using the simulation results from the groundwater flow model.

The model results and field data presented in Figure 3.8.3-2 show that drawdown has occurred in response to pumping from WS-3, WS-H3, and WS-12. This drawdown, combined with the effects of recharge from Lake Worth, produce flow directions that range from southerly on the west side of the plant to southeasterly in the flightline area. It is clear from Figure 3.8.3-2 that wells WS-12 and WS-H3 receive Paluxy Formation groundwater that has flowed beneath Plant 4.

Saturated thicknesses in the Paluxy Aquifer are shown in Table 3.8.3-2. With the exception of the relatively small value at P-1, these data are consistent with the regional literature (Leggat 1957, Peckham and others 1963, and Nordstrom 1982), which reports that the Paluxy Aquifer maintains a relatively uniform thickness in the Tarrant County area, except where significant dewatering has occurred.

Table 3.8.3-2 Saturated Thickness of the Paluxy Formation at Locations of Fully Penetrating Monitor Wells

Well Number	Saturated Thickness (Feet)
P-1	119
P-3	168
P-4	148
P-24	155
P-25	145
P-26	143

To determine the horizontal hydraulic conductivity (K_h) of the Paluxy Aquifer, slug tests were conducted on the four new Paluxy Formation monitoring wells. Hydraulic conductivities estimated from the slug tests are shown in Table 3.8.3-3. Vertical hydraulic conductivity (K_z) was estimated via triaxial cell tests on core samples obtained from the monitoring-well boreholes.

As shown in Table 3.8.3-3, the K_h estimates are relatively uniform for the four wells. The minimum value obtained at P-28U is not surprising since the upper portion of the Paluxy Aquifer is typically characterized by a high proportion of low permeability rock (see Section 3.7). However, the difference between the K_h values for "U" and "M" wells is not as great as expected. This may be explained in part by the fact that the well-screens for the two "U" wells were placed at depths containing relatively clean sandstone (see Appendix D-1).

Table 3.8.3-3 Hydraulic Conductivities (K_h) Estimated from Slug Tests

Well Number	K_h (cm/sec)
P-27U	3.84E-03
P-28U	6.63E-04
P-29M	1.83E-03
P-30M	2.73E-03

Additional K_h estimates from pumping tests conducted by Hargis + Associates (1985a) range from 4.7×10^{-3} to 2.7×10^{-2} cm/sec (Table 3.8.3-4). Values from both the Hargis + Associates pumping tests and the Geotech slug tests are consistent with ranges published in the regional hydrogeologic literature.

The hydraulic conductivity corresponding to the logarithmic mean of the slug-test and pumping-test K_h estimates is 6.4×10^{-3} cm/sec (or 18.3 ft/d). Using 1 ft/340 ft to 1 ft/100 ft as a range for the average hydraulic gradient in the Paluxy Formation (Figure 3.8.2-1) and 0.27 as the average effective porosity (Advanced Terra Testing 1991; provided in Appendix P), the average linear velocity [$\bar{v} = K \times dh/dl \times (1/n)$] in the Paluxy Aquifer is likely to be within the range of 0.20 ft/d to 0.68 ft/d. In areas of clean, high-permeability sandstone or large hydraulic gradients, such as near supply wells, average linear velocities will be considerably higher than these estimates.

Vertical hydraulic conductivity estimates (K_z) were obtained from laboratory triaxial cell tests on core samples from wells P-27U, P-28U, and P-30M (Appendix P). The results, shown in Table 3.8.3-5, indicate that K_z is highly variable within the Paluxy Aquifer.

Table 3.8.3-4 Hydraulic Conductivities in the Paluxy Aquifer Estimated from Pumping Tests (Hargis + Associates, 1985a)

Pumping Well	Observation Well	Saturated Thickness (Screen Length) (Feet)	Transmissivity		Average Hydraulic Conductivity	
			Drawdown ft/day	Recovery ft/day	ft/day	cm/sec
P-1	P-1	60	4011	3209	60.2	2.1×10^{-2}
P-2	P-2	40	1872	2273	51.8	1.8×10^{-2}
P-3	P-3	70	NA	1110	15.8	5.6×10^{-3}
P-4	P-4	50	1016	749	17.6	6.2×10^{-3}
P-5M	P-6M	40	2139	1110	40.6	1.4×10^{-2}
P-6M	P-5M	50	3209	989	42.0	1.5×10^{-2}
P-7M	P-7M	40	NA	535	13.4	4.7×10^{-3}
P-8M	P-9M	60	4278	4947	76.9	2.7×10^{-2}
P-9M	P-9M	40	936	1110	25.6	9.0×10^{-3}
P-10M	P-10M	30	334	575	15.2	5.4×10^{-3}

NA = Not Available

Variable K_z estimates were expected, given the interbedded nature of the Paluxy Formation and the fact that the cores were taken from intervals characterized by varied lithologies (Table 3.8.3-5).

Table 3.8.3-5 Vertical Hydraulic Conductivity, K_z , Determined from Laboratory Triaxial Cell Tests on Core Samples Obtained from the Paluxy Aquifer

Well Number	K_z (cm/sec)	Lithology of Core Sample
P-27U	3.3E-10	Siltstone with some clay
P-28U	3.1E-09	Calcareous, fine-grain sand
P-30M	1.2E-05	Quartzose sandstone

The variability in K_z illustrated by Table 3.8.3-5 is also evident in the results of pumping tests conducted by Hargis + Associates (1985a). During a pumping test at the P-7 well

pair, water was pumped from P-7M while water levels were monitored in both P-7M and P-7U. The water level in P-7U, screened above P-7M, showed a rapid and significant decline in response to the pumping from P-7M. This result indicates that the vertical interval between P-7U and P-7M has a relatively high K_z , even though the lithologic log for P-7M reports a 5-foot thick sandy claystone between the screens of the two wells. In similar tests at other well pairs, little or no response was observed in upper well completions during pumping of the lower wells, indicating low K_z values between the monitoring points. These results provide further indication of the variability of K_z in the Paluxy Aquifer.

4.0 Nature and Extent of Contamination

4.1 Introduction

This section summarizes sampling and analysis activities that were conducted to characterize the extent and nature of soil, surface water, tissue, and groundwater contamination associated with the manufacturing operations at Plant 4. PA/SI investigations were conducted at the Assembly Building/Parts Plant and at the underground storage tank sites, and RI studies were conducted at the remaining sites in accordance with the *Final Sampling and Analysis Plan for the Preliminary Assessment/Site Inspection and Remedial Investigations/Feasibility Studies at Air Force Plant No. 4* (UNC Geotech, Inc. 1990).

Results of sampling and analyses and discussions for the various media are presented in each subsection in the following order: Section 4.2, "Field Quality Control for Soil and Water Samples;" Section 4.3, "Source Areas and Soil Contamination;" Section 4.4, "Sediment Contamination;" Section 4.5, "Groundwater Contamination;" Section 4.6, "Surface Water Contamination;" Section 4.7, "Ecological Contamination;" and Section 4.8, "Air Contamination."

Appendix A summarizes soil boring locations, borehole lithology, and sampling intervals. Appendix B presents survey data and well completion logs. Appendix C contains the field records of water-sampling and Appendix D presents water-level measurement data. Appendix E presents laboratory analytical results for soil, stream sediment, and lake sediment samples. Appendix F presents laboratory analytical results for surface water and groundwater. Appendix G presents laboratory data validation information. Appendix H presents analytical results of ecological sampling, and Appendix I presents results of air monitoring.

4.2 Field Quality Control for Soil and Water Samples

Field quality control was implemented to ensure that the samples collected for laboratory analyses adequately represented the environmental media and that the quality of resulting data was maintained. Sample collection, identification, custody, and shipments were performed in accordance with the *Plant 4 Final Sampling and Analysis Plan* (SAP). Field quality control checks employed for the soils investigation consisted of analyses of trip and field blanks, field duplicates, and liquids used to decontaminate and rinse sampling equipment as specified in the SAP. Results of the field quality control analyses for the soil and water samples are presented in Appendix E and Appendix F, respectively. (See appendices for definitions of qualifiers that follow concentration values.)

4.2.1 Quality Control Samples

4.2.1.1 Trip Blanks

Trip blanks consist of samples of laboratory deionized water that accompany the environmental samples through the entire sampling process. Trip blanks were analyzed for VOCs to detect potential contamination during shipment.

For the soil sampling, approximately two trip blanks were prepared for every sampling trip (10 days) at the beginning of the campaign. The frequency was decreased to one trip blank for every sampling trip toward the end of the sampling campaign. A total of 11 trip blanks were submitted with the environmental soil samples. Acetone was detected at relatively low concentrations (5BJ, 11, and 10 $\mu\text{g/L}$) in three trip blanks associated with the soil sampling. Toluene and methylene chloride were also detected at a relatively low concentration of 0.6J and 4J $\mu\text{g/L}$, respectively. No other VOCs were detected. Appendix E summarizes the analytical results for the trip blanks associated with the soil samples.

A total of 18 trip blanks were prepared and submitted with each sample shipment during the water sampling campaign. 2-Butanone, acetone, TCE, and methylene chloride were each detected once at a relatively low concentration of 18, 12, 3, and 10 $\mu\text{g/L}$, respectively. No other VOCs were detected in any of the samples.

4.2.1.2 Field Blanks

Field blanks are samples of deionized water that are prepared at the monitoring well sampling site and are used to detect accidental or incidental contamination. These samples remain with the field samples through the entire sampling and shipping process. Two field blanks were collected during the groundwater monitoring campaign and analyzed for VOCs. No VOCs were detected in any of the field blanks.

Appendix F summarizes the analytical results for the trip and field blanks associated with the water sampling.

4.2.1.3 Decontamination Liquids and Equipment Blanks

One sample of tap water was collected directly from the domestic water supply source and analyzed for VOCs, TPH, and inorganics. This water source was used as the first rinse in the decontamination process. The analytical results indicate the presence of dibromochloromethane (5 $\mu\text{g/L}$), chloroform (7 $\mu\text{g/L}$), and bromodichloromethane (9 $\mu\text{g/L}$). TPH is less than the detection limit (0.5 mg/L). No other VOCs were detected. Copper (14.7B $\mu\text{g/L}$), lead (2.2B $\mu\text{g/L}$), and zinc (98.4 $\mu\text{g/L}$) are the only inorganics detected. These results are presented in both Appendix E and Appendix F.

Methanol used in the decontamination procedure was submitted for volatile organic analyses. 2-Butanone was detected at a concentration of 10,000 $\mu\text{g/L}$. No other VOCs were detected. Results of the VOC analyses on the methanol sample are presented in Appendix E and Appendix F.

Equipment Blanks are samples collected after the last rinse with deionized water is passed over the sampling apparatus after cleaning. This sample is used to check for residual contamination. Appendix E and Appendix F summarize the results for all the equipment blank analyses associated with the soil and water samples, respectively.

Tabulated in Appendix E are the VOCs and semi-VOCs that were detected in the equipment blanks collected during the soil sampling activities. The VOCs detected are acetone, 2-butanone, TCE, methylene chloride, chloroform, and toluene. Semi-VOCs detected are pyrene, nitrobenzene, and bis(2-ethylhexyl)phthalate. Bis(2-ethylhexyl)phthalate, acetone, and nitrobenzene were also detected in the laboratory method blank for some of these samples. In the case of nitrobenzene, all the reported values above the detection limit in the soil equipment blanks and the soil samples are a result of the laboratory inadvertently spiking the samples with the incorrect surrogate solution; nitrobenzene was used instead of the deuterated nitrobenzene-D5. This error resulted in nitrobenzene being reported in the equipment blanks at concentrations ranging from 45 to 60 $\mu\text{g/L}$ and in soil samples at a level of approximately 1,700 $\mu\text{g/kg}$. The first 93 samples analyzed are affected by this error.

Equipment blanks were analyzed for TPH and oil and grease with neither detected (less than 0.5 mg/L) in any of the samples. Eight priority-pollutant metals were detected in numerous equipment blank samples. Most of the results (See Appendix E) are reported above the Instrument Detection Limit (IDL) but less than the Contract Required Detection Limit (CRDL).

Tabulated in Appendix F are the VOCs and inorganic analytes detected in the equipment blanks associated with the water samples. Acetone was detected in three samples at relatively low concentrations of 11J, 6J, and 13 $\mu\text{g/L}$. TCE was also detected in two samples at relatively low concentrations of 11 and 5J $\mu\text{g/L}$. Chloroform and 2-butanone were each detected once at 14 and 9BJ $\mu\text{g/L}$, respectively. No other VOCs were detected. Cadmium, copper, lead, and zinc are the only inorganic constituents detected in the water sample equipment blanks. In most cases, the results are reported above the IDL but less than the CRDL.

Equipment blanks associated with the water sampling were also analyzed for semi-VOCs, TPH, and oil and grease; none were detected in any of the samples.

4.2.1.4 Field Duplicate

A field duplicate (split) sample was used to evaluate the overall precision of the sampling process and to a lesser extent the laboratory analytical variability. Approximately 10 percent of the environmental samples were collected as field duplicates. Duplicate soil and water sample results are summarized in Appendix E and Appendix F, respectively.

The precision is evaluated by the relative standard deviation (RSD), calculated as the standard deviation divided by the mean, then multiplied by 100, for each paired sample having values greater than the Contract Required Quantitation Limit (CRQL) (for organics) or the CRDL (for inorganics). Only those instances where both paired values are greater than the CRQL or CRDL are considered appropriate for calculating the RSD because the CRQL or CRDL is the minimum concentration that is quantitatively meaningful.

An RSD of 30 percent or less is generally considered an acceptable level of precision for field duplicate water samples. Duplicate soil samples are collected after the homogenization step at the site and typically have higher variability than water samples because of the difficulty in collecting an identical homogenized soil sample. An RSD of 50 percent for a soil sample is not unexpected.

The average RSDs for soil samples, summarized in Table 4.2-1, indicate acceptable precision for each type of analysis. In all cases, except for oil and grease, the average RSD is less than 30 percent. The average RSD for oil and grease is less than 50 percent.

**Table 4.2-1 Average RSD for Soil Sample Analyses
Above the CRQL/CRDL**

Analysis	Number of Sample Pairs	Average RSD (%)
Semi-VOCs	10	17.4
VOCs	28	29.2
Oil and Grease	4	38.4
Total Petroleum Hydrocarbons	6	24.6
Priority-Pollutant Metals	130	16.6

The average RSDs for water samples, summarized in Table 4.2-2, indicate acceptable precision for VOCs and priority pollutant metals. The average RSD for these analyses is less than 30 percent. RSDs could not be calculated for the remaining analytes because all results between the paired samples are less than the CRQL.

**Table 4.2-2 Average RSD for Water Sample Analyses
Above the CRQL/CRDL**

Analysis	Number of Sample Pairs	Average RSD (%)
Semi-VOCs	NA	NA
VOCs	28	11.9
Oil and Grease	NA	NA
Total Petroleum Hydrocarbons	NA	NA
Priority-Pollutant Metals	35	15.4

In addition to the field duplicate samples internal to the investigation, twenty samples were also split with EPA Region VI including seven soil samples, two sediment samples, two surface water samples, and nine groundwater samples. These split samples were typically analyzed for TCL VOAs, TCL BNAs, and TAL inorganics. Sample results reported by EPA Region VI are consistent with those reported by Geotech for all but four analytes in three samples. Appendix S contains the data reported by EPA Region VI along with a discussion of the data presented and the discrepancies noted.

4.3 Source Areas and Soil Contamination

In some cases, several sites with associated contamination were combined into the same subsection. Each subsection contains a discussion of previous investigations and if applicable, previous data have been used to assist in the interpretation of the Geotech results. For ease of presentation and interpretation of results, the minimum concentration, maximum concentration, and the number of soil samples analyzed are tabulated in each subsection. Soil samples were analyzed for VOCs, semi-VOCs, TPH, and inorganic constituents.

The number of sample analyses above the CRQL (see Table 2.1.11-1, Section 2.0) are also tabulated for VOC, TPH, and semi-VOC results. The CRQL represents the minimum concentration at which a measurement becomes quantitatively meaningful. Values above this limit are typically indicators of environmental contamination.

Similarly for the inorganic results, the number of sample analyses above the upper limit of natural background concentration of metals in soils from the western USA are tabulated in each subsection. The range in natural background concentrations in the western United States for the twelve priority-pollutant metals are presented in Table 4.3-1. At two Plant 4 locations soil samples were collected in areas that were not suspected to be associated with contamination. These results are presented in Table 4.3-1 for comparison with the range in natural background for the western United States. Also summarized in Table 4.3-1 are the number of samples analyzed at Plant 4

that exceed the upper limit of natural background for the western USA. Values greater than the upper limit of natural background are typically indicators of environmental contamination and are discussed separately in subsections 4.3.1 to 4.3.16.

Table 4.3-1 Concentration Range of Priority Pollutant Metals in Background Soils of the Western United States

Metal	Measured Concentration Range at Plant 4 Background Locations (mg/kg) ^a	Range in Background Soils of Western USA (mg/kg) ^b	Measured Concentration Range at Plant 4 (mg/kg)	Number of Samples Analyzed at Plant 4	Number of Samples Above Upper Background Range for Western USA ^c
Antimony	(12.3) ^d	0.1 - 2.2	(8.0) - 77.5	407	14
Arsenic	3 - 4.4	1.4 - 21.6	(0.6) - 21.7	407	1
Beryllium	0.56B - 0.84B ^e	0.1 - 3.6	(0.21) - 1.5	407	0
Cadmium	(1.1) - 2.4	NA ^f /2.8 ^g	(0.8) - 594	407	29
Chromium	10.6 - 16.2	8.5 - 196.6	1.5B - 3,170	407	9
Copper	3.1B - 6.9	4.9 - 90.0	1.3B - 8,060	407	19
Lead	10.9 - 18.5	5.2 - 55.1	0.87 - 10,400	407	37
Nickel	11.2 - 19.8	3.4 - 66.2	(3.5) - 458	407	11
Selenium	(0.46)	0.04 - 1.4	(0.4) - 0.61B	407	0
Silver	(0.68)	NA/1.4 ^h	(0.64) - 44.3	407	18
Thallium	(0.42) - 0.46B	(50)/0.8 ⁱ	(0.4) - 0.68B	407	0
Zinc	20.2 - 46.5	17.2 - 176.2	2.7B - 17,400	407	26

- Notes:
- ^a Background locations are BG-001 and BG 002; two samples were collected at each location.
 - ^b Based on the geometric mean and the geometric deviation from Shacklette and Boerngen (1984). Mean divided by two deviations (M/D^2) = lower range; mean multiplied by two deviations ($M \times D^2$) = upper range. About 95 percent of the samples in a randomly selected suite should fall between the lower and upper range.
 - ^c The number of samples greater than the instrument detection limit (IDL) that exceed the upper background range. The IDL represents the lowest concentration that can be reliably distinguished from the background noise of the instrument.
 - ^d Value in parentheses indicate the metal was not detected at the reported IDL.
 - ^e B indicates the value is greater than the IDL but less than the Contract Required Detection Limit (CRDL).
 - ^f Not Available.
 - ^g The upper background range for cadmium is estimated at 2.8, which is based on twice the observed mean for the four Plant 4 background samples.
 - ^h The upper background range for silver is estimated at 1.4, which is based on twice the IDL observed for the four Plant 4 background samples.
 - ⁱ The upper background range for thallium is estimated at 0.8, which is based on twice the IDL observed for the four Plant 4 background samples.

4.3.1 Assembly Building/Parts Plant

4.3.1.1 Summary of Investigations

4.3.1.1.1 Previous Investigations: Past spills of TCE have reportedly occurred within the Chemical Process Facility (Building 181) of the Assembly Building/Parts Plant. Trenches, sumps, floor drains, and buried pipelines are also present throughout the manufacturing facility. These are all potential source areas for soil contamination resulting from spills and leaks. Widespread TCE contamination in the groundwater was identified by previous investigators in the area east of the Assembly Building/Parts Plant; however, chemical analyses of soil samples in this area is limited.

Seventy-eight test holes were drilled at Plant 4 between 1942 and 1967 to investigate the subsurface conditions of foundations for proposed building sites. In 1942 and 1952, the Austin Company drilled test holes AC-1 to AC-18 and in 1964 and 1967, Southwestern Laboratories Inc. drilled test holes SL-1 to SL-47. General Dynamics drilled test holes GDC-1 to GDC-13 in 1982. The 78 test holes range in depth from 10 to 113 feet with many of the test holes located in the area of the Assembly Building/Parts Plant and in the East Parking Lot area. These test holes provided soil types and depth to the underlying Walnut Formation.

Numerous upper zone monitoring wells (HM-31, -47, -48, -52, -53, -55 through -59, -64, -69, -70) and Paluxy monitoring wells (P-5, -6, -9) were installed by Hargis + Associates (1985a) to define the lateral and vertical extent of groundwater contamination in the area surrounding the Assembly Building/Parts Plant (Plate 3). Soil sampling and chemical analysis were not reported for the above monitoring well borings.

The U.S. Army Corps of Engineers and Hargis + Associates drilled Paluxy monitoring wells P-12M, P-12U (replaced with P-12UN), and P-12US along the south side of General Warehouse Building No. 188 (Plate 3). Analysis of groundwater samples detected the presence of VOCs and oil and grease. No soil contamination was reported.

Two monitoring wells, F-218 and F-219 (Plate 1), were installed by Intellus at the south end of the east side of the Assembly Building. These wells were drilled to confirm the presence of Chrome Pit No. 1. Soil samples were collected above the saturated zone from both well borings and analyzed for VOCs, total petroleum hydrocarbon, and various metals. The laboratory analyses did not detect any VOCs or hydrocarbons. Inorganic concentrations were found to be within the background range for metals in the United States (Intellus 1986b). Evaluation of data from F-218 and F-219 did not confirm the presence of Chrome Pit No. 1.

Intellus also drilled two shallow soil borings above the saturated zone (FB-5 and FB-6) at the southwest corner of the Process Building No. 181 in the reported vicinity of

Chrome Pit No. 2 (Plate 3). Laboratory analysis did not detect any VOCs and the level of metals present were within the mean range typical for native soils (Intellus 1986b).

In 1986, Radian installed monitoring well HM-103 east of Chrome Pit No. 1 at the northeast corner of Building 188 (Plate 3). Soil samples collected from the saturated zone were analyzed for VOCs and inorganics; results indicate the presence of TCE at 65 and 170 $\mu\text{g}/\text{kg}$. Chromium concentrations were within the range of typical background values for soil. Radian also drilled monitoring well HM-104 at the southwest corner of Building 188. Soil samples from HM-104 were not submitted for chemical analysis.

From 1987 to 1989, Hargis + Associates drilled a number of Paluxy wells in the area of the Assembly Building/Parts Plant. No sample collections or analyses were reported.

4.3.1.1.2 Current Investigation: Previous investigations have concentrated on obtaining groundwater quality data or geotechnical information for the design of building foundations, therefore, the availability of chemical analyses of soil samples in historical data is limited. The main objectives of the PA/SI soil investigation at the Assembly Building/Parts Plant are to identify potential contaminated source areas present in the vadose zone that may have resulted from past manufacturing activities, to obtain chemical information on the nature of the contamination, and to delineate the extent of migration and environmental impact on subsurface soils.

Soil-gas measurements were collected approximately every 200 feet around the entire perimeter of the Assembly Building/Parts Plant to provide screening information on the nature of VOCs that may be present in the soils. Specific areas of potential contamination were then further investigated by drilling 35 soil borings and obtaining soil samples from the vadose zone and the saturated zone for chemical analyses. In some cases, the borings were completed as monitoring wells (see Section 4.5). Sections 4.3.1.2 and 4.3.1.3 discuss the results of the soil-gas surveys and soil sampling, respectively.

4.3.1.2 Results of Assembly Building/Parts Plant Perimeter Soil-Gas Survey

The objective of the soil-gas survey in this area was to search for potential source areas of VOCs that would be indicative of environmental contamination associated with the manufacturing operations. Samples were collected on sorbent tubes approximately every 200 feet around the perimeter of the Assembly Building/Parts Plant and analyzed by the Geotech Analytical Laboratory for the Target Compound List (TCL) VOCs by EPA Method 8240. Samples were collected from a nominal depth of 4 feet below ground level.

Limitations of the soil-gas measurements are dependent on the chemical and physical properties of the organic compounds, vadose zone characteristics, hydrogeologic

parameters, meteorological conditions, and analytical instrumentation. Interpretation of the soil gas results are therefore considered qualitative.

Analytical results indicate that relatively low concentrations (nanograms per liter) of trichloroethene (TCE), tetrachloroethene (PCE), and 1,1,1-trichloroethane (TCA) and various petroleum-related hydrocarbons (micrograms per liter) are present in the soil gas. Concentrations for the chlorinated compounds are summarized in Table 4.3.1-1 and posted in Figure 4.3.1-1. Lines are subjectively drawn around the relatively higher concentrations to delineate anomalies that may be indicative of soil contamination. The patterns revealed by the anomalies suggest two possible source areas for the solvents. One area is located at the south end of the Assembly Building/Parts Plant, just east of Building 12. TCE, PCE, and TCA are associated with this anomalous area. The other possible source area appears to be located near the center of the Assembly Building/Parts Plant, between Building 88 and Building 6. Anomalous concentrations of TCE, PCE, and TCA appear to originate near location SG-14 and SG-16 (see Figure 4.3.1-1).

Table 4.3.1-1 Summary of Total Petroleum Hydrocarbons and Chlorinated Solvents Measured in Soil-Gas Around the Perimeter of the Assembly Building

Parameter	TPH ($\mu\text{g/L}$)	PCE (ng/L)	TCE (ng/L)	1,1,1-TCA (ng/L)
Minimum	(0.003)*	(2.5)	(2.5)	(2.5)
Maximum	1,554	2,800	6,400	54
Total No. Analyses	55	55	55	55
No. Above Detection	53	20	26	33

Note: * Concentration in parentheses indicates the compound was not detected at the reported value.

Slightly elevated concentrations of petroleum-related hydrocarbons, including the aromatic compounds benzene, toluene, ethylbenzene, and xylene (BTEX) and relatively heavier molecular weight compounds such as naphthalene, cyclohexane, 4-methylnonane, methylcyclohexane, decane, pentane, and 1-ethyl-2-methylbenzene were also detected in the soil gas. Results of the measurements are summarized as TPH in Table 4.3.1-1 and plotted in Figure 4.3.1-2. These values represent the sum of all petroleum-related hydrocarbons that were detected by the GC/MS measurement and include estimated and tentatively identified compounds.

The dashed lines in Figure 4.3.1-2 were subjectively drawn around values greater than 300 $\mu\text{g/L}$ to map areas having relatively high TPH concentrations. Two anomalous areas are revealed by these maps. The first TPH anomaly coincides with the southern-most solvent anomaly (see Figure 4.3.1-1). The highest value associated with this anomaly, 1,118 $\mu\text{g/L}$ TPH, is located at SG-45. This location is east of a 1,000,000-gallon fuel oil

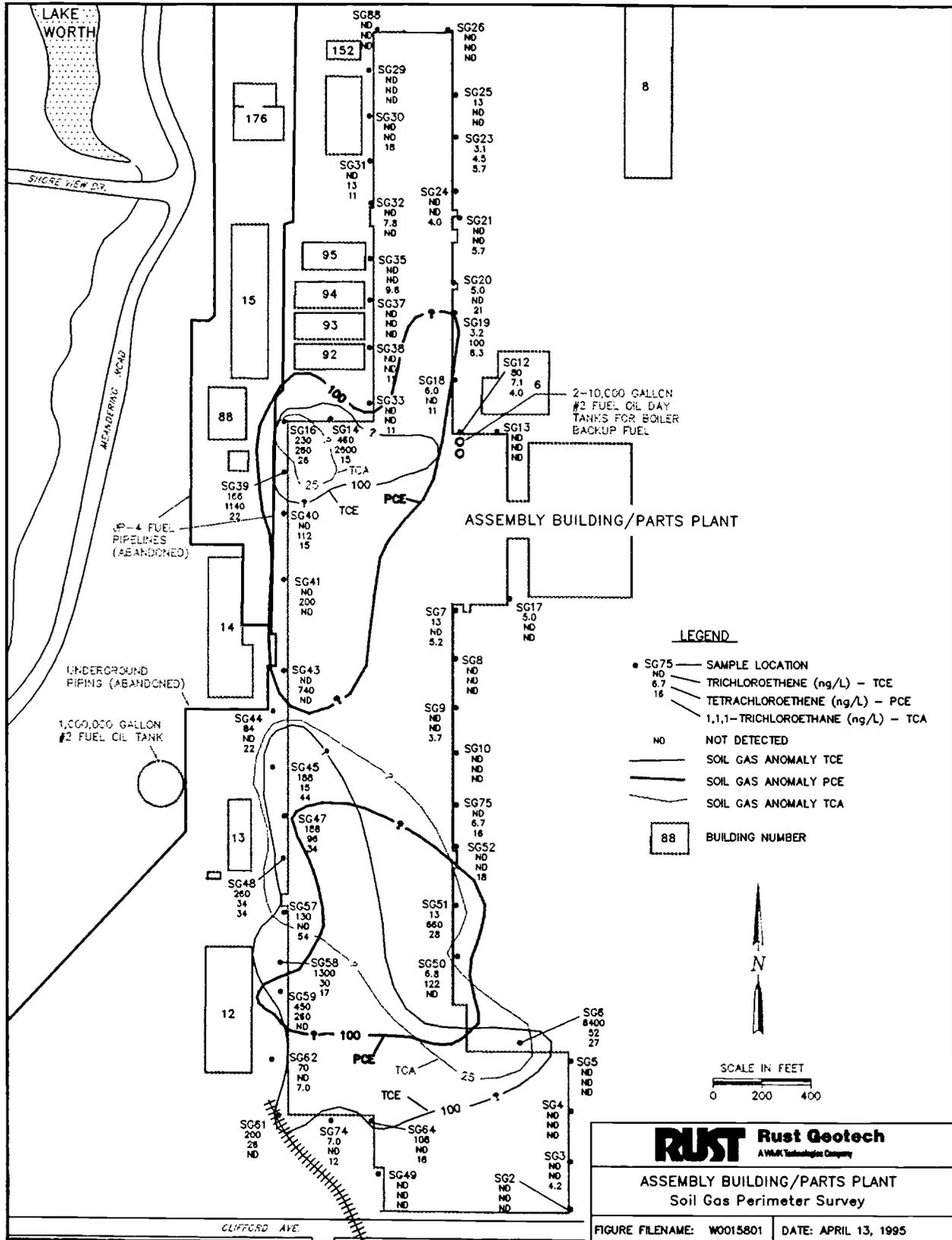


Figure 4.3.1-1. Results of Chlorinated Volatile Organic Compounds Detected in the Soil Gas.

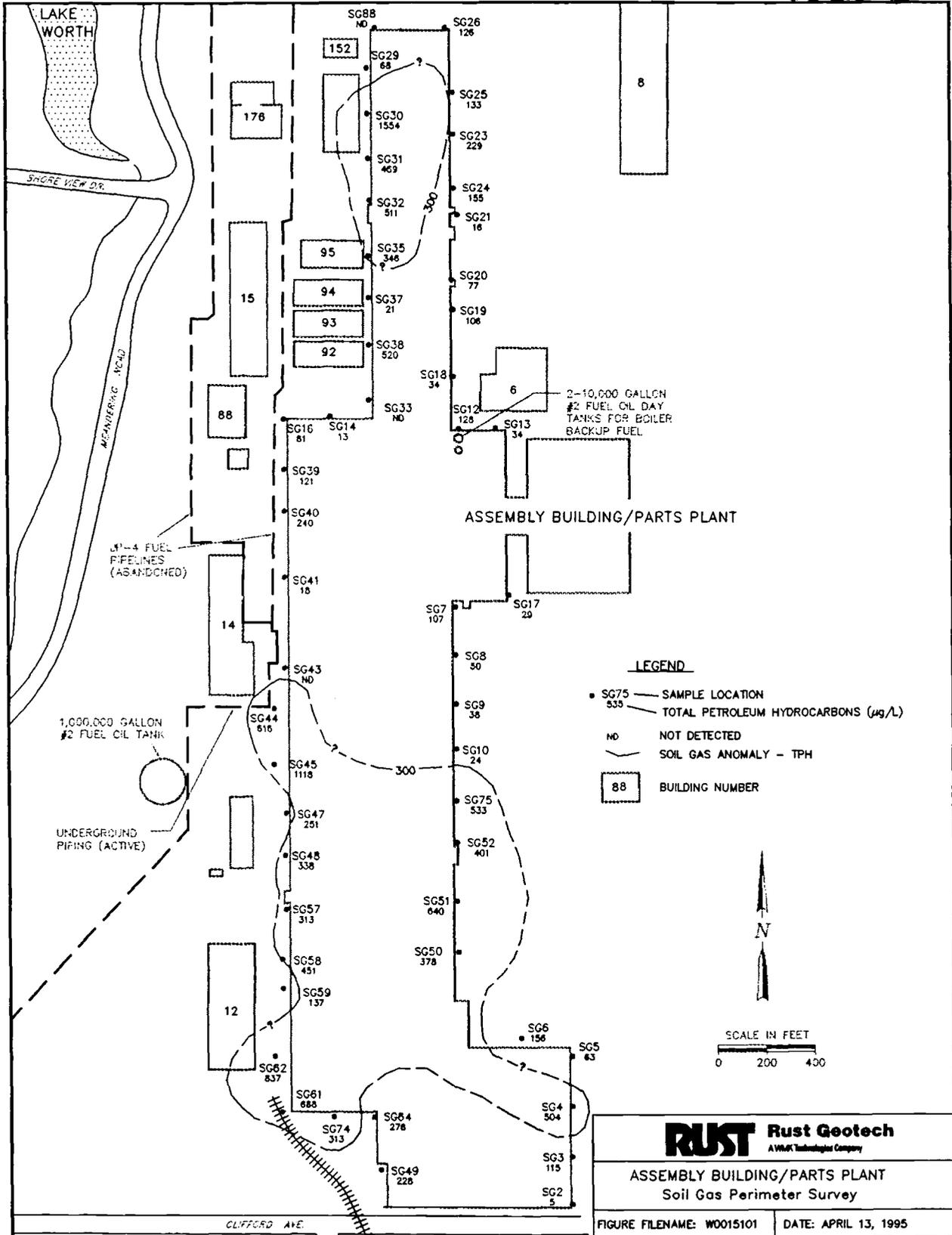


Figure 4.3.1-2. Results of Total Petroleum Hydrocarbons Detected in Soil Gas.

tank, suggesting leaking underground fuel lines are a possible source. USTs 19 and 20 are also located close to this anomaly, however, they are not considered a possible source because historically they did not contain fuel oil.

The second TPH anomaly occurs at the north end of the Assembly Building/Parts Plant, just east of Building 95 and Building 176. This anomaly does not appear to be associated with a solvent source. The highest TPH value in this anomalous area, 1,554 $\mu\text{g}/\text{L}$, was measured at location SG-30. This location is east of abandoned underground JP-4 fuel lines that may be a possible source for this anomaly.

4.3.1.3 Results of Assembly Building/Parts Plant Borehole Soil Sampling

Soil borings were drilled at 35 selected locations to confirm the anomalous chlorinated hydrocarbons and to further evaluate the extent of the petroleum-related hydrocarbons that were detected in the soil gas. The borings were drilled with a truck-mounted, hollow-stem auger rig, from the ground surface to the top of the water table or until bedrock was encountered. Unconsolidated material was collected in 3-inch by 24-inch stainless steel-split barrel samplers for the entire borehole. Borehole lithology and sampling intervals are summarized in Appendix A-2. Samples were composited from each 5-foot interval and analyzed for semi-VOCs, TPH, and inorganics. From each 5-foot interval, one grab sample was collected for VOC analyses. Appendix E presents a summary of the analytical data.

4.3.1.3.1 VOC and TPH Soil Sample Analyses: VOC and TPH analytical results for the soil samples are summarized in Table 4.3.1-2. The only VOCs reported above the CRQL that are associated with the samples are trichloroethene and dichloroethene (DCE). Acetone and 2-butanone were also detected, but because these compounds occur randomly and are common laboratory contaminants (EPA 1988), they are probably not associated with the environmental samples. In addition, a relatively high concentration of 2-butanone (10,000 $\mu\text{g}/\text{L}$) was detected in the methanol used to decontaminate the sampling equipment (see Section 4.2).

Posted by each borehole location shown in Figure 4.3.1-3 are the results of the VOC and TPH analyses (excluding acetone and 2-butanone). Boreholes SB-035 and SB-036 were drilled to test the soils for the presence of petroleum-related compounds that were delineated by the soil-gas anomaly at the north end of the Assembly Building/Parts Plant. These borings were terminated in bedrock and the saturated zone, respectively. Contamination was not detected in any of the samples.

Boreholes SB-034, -037, -038, -039, -042, -043, -044, and -116 were drilled to test the soils for the presence of TCE, PCE, and TCA, which were identified by the soil-gas anomaly located near the center of the Assembly Building/Parts Plant, between Building 88 and Building 6. The only chlorinated solvent detected in soil samples collected from these boreholes is PCE, at a concentration of 5J $\mu\text{g}/\text{kg}$ (see Figure 4.3.1-3).

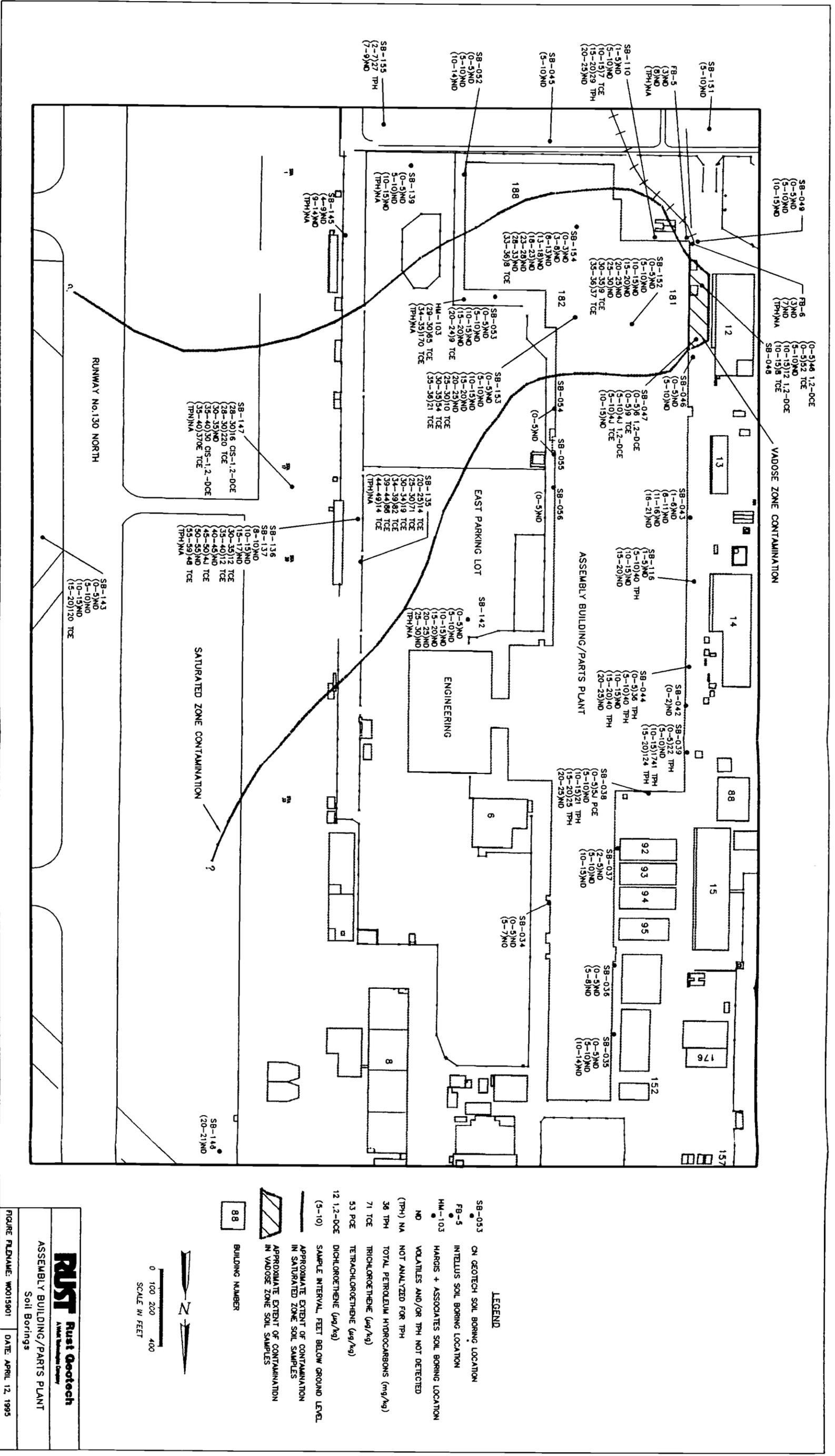


Figure 4.3.1-3. Soil Sample Analytical Results for VOCs and TPH.

**Table 4.3.1-2 Summary of VOC and TPH Analytical Results
for Soil Samples Obtained from the Assembly Building/Parts Plant**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
<i>cis</i> -1,2-Dichloroethene	(5)	30	24	3
1,2-Dichloroethene (total)	(5)	46	112	2
Trichloroethene	(5)	220	136	26
Acetone	(10)	160	136	19
2-Butanone	(10)	180	136	18
Total Petroleum Hydrocarbons	(10) mg/kg	1741 mg/kg	98	12

Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
3) Trichloroethene was identified in the risk assessment as a chemical of concern.

Although this value is qualified as an estimated quantity (J), and therefore not listed in Table 4.3.1-2, the soil sample location (SB-038) coincides with the location where the highest PCE value was detected in soil gas (SG-14, Figure 4.3.1-1). No other VOCs were detected in any soil sample from these boreholes.

Relatively low concentrations of TPH, 21 and 25 mg/kg, were detected in SB-038. TPH was also detected in SB-039, -044, and -116. This contamination is associated with leaking underground fuel lines in the area designated as Fuel Saturation Area No. 1 (FSA-1). For ease of presentation, TPH results associated with these three boreholes are discussed with results of the soil sampling conducted at FSA-1 (See Section 4.3.11).

SB-046, -047, -048, and -049 were drilled east of Building 12 in a north to south line, respectively, where numerous aboveground solvent tanks are present. These four borings penetrated approximately 10 to 15 feet of unconsolidated material before terminating in bedrock. Groundwater was not encountered in any of these borings. Contamination was not detected in any soil sample obtained from the north boring (SB-046) or from the south boring (SB-049). Relatively low concentrations of TCE and 1,2-dichloroethene (total), ranging from 8 to 52 µg/kg and 6 to 46 µg/kg, respectively, were detected in soil samples obtained from SB-047 and -048. Since saturated soils were not encountered, soil contamination occurs only in the vadose zone and appears to decrease with depth, which suggests the source is related to surface spills and/or to shallow underground solvent tanks and associated piping. The area of vadose zone contamination, shown in Figure 4.3.1-3, is approximately 100-foot wide and 400-foot long. Assuming 5 feet as an average depth of contamination, approximately 7,400 cubic yards of soil may be impacted.

Results of previous investigations, as well as the soil-gas survey (See Section 4.3.1.2), and the presence of TCE and TPH within the unsaturated zone between the 10- and 20-foot interval at SB-110 (see Section 4.3.16) suggest soil contamination is much more extensive

than the area of vadose zone contamination outlined in Figure 4.3.1-3. In fact, much of the data indicate that extensive TCE contamination may extend under most of the south end of the Assembly Building/Parts Plant. To test the soils under the facility, SB-152, -153, and -154 were drilled through the concrete floor slab in low traffic areas to minimize impact on daily plant operations. In all three boreholes, TCE was encountered in the saturated soils before terminating in the underlying Walnut Formation; however, TCE contamination was not encountered in any soil sample obtained above the saturated zone. This suggests that soil contamination in the vadose zone is not widespread beneath this portion of the facility but still may occur in localized areas as the result of downward migrating contaminants in the unsaturated zone immediately below potential sources such as underground solvent piping, drains, and degreasing tanks. Soil boring SB-110 indicated the presence of TCE and TPH within the unsaturated zone between the 10- to 20-foot depth interval. The greatest potential for isolated source areas is associated with the numerous acid, solvent, and degreasing tanks located within Chemical Process Building 181. Some larger possible sources are shown in Figure 4.3.1-4.

Previous investigations have shown that TCE contamination in the alluvial groundwater system occurs east of the Assembly Building/Parts Plant and is controlled by an east-northeast trending paleochannel. Unconsolidated sediments within the paleochannel were tested to determine the vertical and horizontal extent of contamination in the vadose and saturated zones. Soil contamination occurs mostly within the saturated zone of the paleochannel, as evidenced by the vertical distribution of TCE measured in boreholes SB-152, -153, -154, -053, and -143 (Figure 4.3.1-3). The only other organic compound detected, *cis*-1,2-dichloroethene, was detected in SB-147.

Control on the southern extent of soil contamination is provided by boreholes SB-151, -045, -052, -139, -155, and -145. Contamination was not detected in any of these borings except for an isolated occurrence at SB-155 where relatively low values of 27 mg/kg TPH and 4.7 mg/kg oil and grease was detected and at SB-151 where 65 mg/kg oil and grease were detected. The relatively low levels of TPH and oil and grease are isolated occurrences and are not related to the extent of TCE soil contamination associated with the alluvial groundwater system that flows within a paleochannel east of the Assembly Building. SB-151 and SB-155 established as background locations adjacent to Clifford Avenue, are relatively shallow in depth, and the TPH/oil and grease are most likely related to the asphalt avenue and vehicular traffic.

Control of the northern boundary of contamination is provided by boreholes SB-054 to -056, -142, and -146. The lateral extent of the saturated zone soil contamination shown in Figure 4.3.1-3 coincides in rough outline to the width and axis of the paleochannel (see Section 4.5).

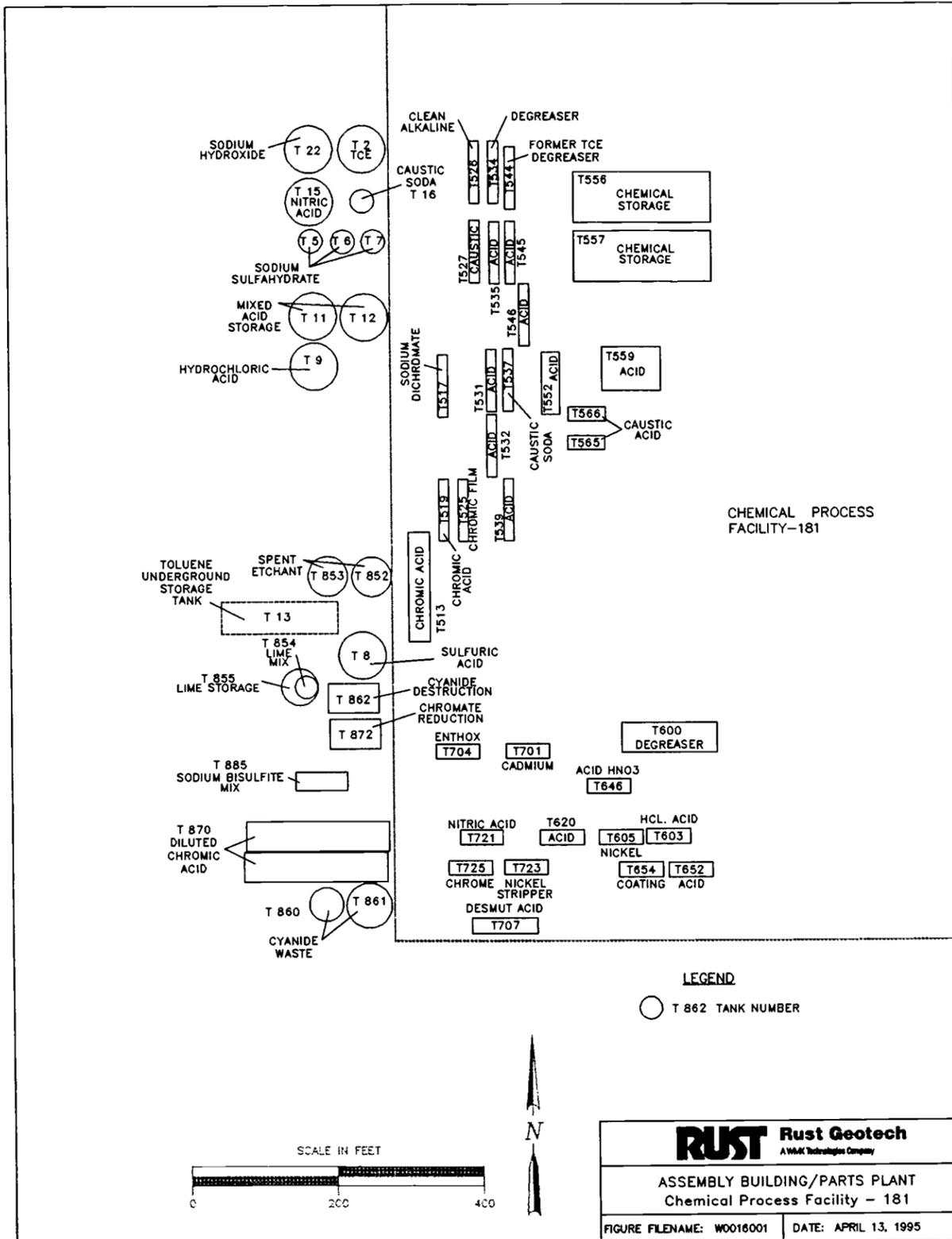


Figure 4.3.1-4. Potential Source Areas Associated with the Chemical Process Facility.

4.3.1.3.2 Semi-VOC Soil Sample Analyses: A summary of the semi-VOC results is presented in Table 4.3.1-3. Bis(2-ethylhexyl)phthalate was reported above the CRQL for numerous cases, however, phthalates are common laboratory contaminants and most likely are not associated with the environmental samples (EPA 1988). This is supported by the duplicate analyses of the sample obtained at 15 to 20 feet from SB-039 that resulted in values of 2,200 and 210J $\mu\text{g}/\text{kg}$. This high variability (an order of magnitude difference) suggests laboratory contamination. Similar poor reproducibility is observed in duplicate samples collected at SB-036 and -046. Other boreholes where bis(2-ethylhexyl)phthalate was reported above the CRQL are SB-034, -035, -049, -116, -143, -152, -153, and -154.

**Table 4.3.1-3 Summary of Semi-VOC Results
for Soil Samples Obtained From the Assembly Building/Parts Plant**

Analyte	Minimum $\mu\text{g}/\text{kg}$	Maximum $\mu\text{g}/\text{kg}$	No. of Samples Analyzed	No. Above CRQL
bis(2-ethylhexyl)phthalate	(690)	3,900	137	28
Pyrene	(690)	2,200	137	2
Benzo(g,h,i)pyrene	(690)	1,000	137	1
Indeno(1,2,3-cd)pyrene	(690)	890	137	1
Benzo(b)fluoranthene	(690)	1,300	137	1
Fluoranthene	(690)	1,700	137	2
Benzo(k)fluoranthene	(690)	1,400	137	1
Chrysene	(690)	1,400	137	2
Phenanthrene	(690)	1,000	137	1

Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
3) Pyrene and fluoranthene were identified in the risk assessment as chemicals of concern.

Several other semi-VOCs such as pyrene, fluoranthene, phenanthrene, and chrysene were reported once or twice above the CRQL. This group of compounds is typically associated with coal tar and crude oil. Because these compounds were detected only in the shallow 0- to 5-foot sample obtained from SB-035 and -055, they are probably the result of very small pieces of asphalt pavement incorporated in the sample and do not indicate contamination associated with manufacturing operations. In either case, they do not represent a significant environmental contaminant.

Semi-VOCs 1,3-dichlorobenzene, pentachlorophenol, and N-nitrosodi-N-propylamine were not detected above the CRQL but were reported as estimated quantities (qualified "J") in three instances (SB-036, -039, and -046). These compounds are typically associated with insecticides, pesticides, and herbicides. The isolated and limited occurrence of these compounds, combined with the fact that duplicate samples do not confirm their presence, suggest they are not associated with environmental

contamination. This is evidenced by the duplicate analyses obtained at SB-039 and -036. In the first case, pentachlorophenol was not detected in the first sample, but the duplicate analysis was reported at 860J $\mu\text{g}/\text{kg}$. Similarly for the second case, N-nitrosodi-N-propylamine was not detected in the first sample, but the duplicate analyses was reported at 94J $\mu\text{g}/\text{kg}$.

4.3.1.3.3 Inorganic Soil Sample Analyses: Results of the soil samples analyzed for priority-pollutant metals, summarized in Table 4.3.1-4, indicate four analytes were detected above the upper limit of natural background concentrations. Silver and lead were detected once above the upper limit of natural background at SB-155 and -034, respectively. Cadmium was detected three times (SB-034, -155, -137) and antimony was detected four times above natural background concentrations (twice at SB-044 and once at -049 and -116). The silver value and all the antimony values above natural background are greater than the IDL but less than the CRDL. In all nine cases the values are very close to the IDL or slightly above the upper limit of natural background. The values also appear isolated and occur randomly, suggesting they are elevated due to natural processes.

**Table 4.3.1-4 Summary of Inorganic Sample Analyses
for Soil Samples Obtained From the Assembly Building/Parts Plant**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background Limit (mg/kg)	No. of Samples Analyzed	No. Above Upper Background Limit for Western USA
Antimony	(8.4)	11.1B	2.2	135	4
Arsenic	(0.64)	10.7	21.6	135	0
Beryllium	(0.21)	1.4	3.6	135	0
Cadmium	(0.84)	4.6	2.8	135	3
Chromium	1.6B	29.2B	196.6	135	0
Copper	1.3B	55.1	90.0	135	0
Lead	0.87	100	55.1	135	1
Nickel	(3.5)	35.4	66.2	135	0
Selenium	(0.42)	(4.9)	1.4	135	0
Silver	(0.64)	1.6B	1.4	135	1
Thallium	(0.42)	0.68B	0.8	135	0
Zinc	4.5	111	176.2	135	0

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
 3) Cadmium, chromium, copper, nickel, and zinc have been identified in the risk assessment as chemicals of concern.

All values above the IDL for the remaining analytes are within the range expected for natural background concentrations.

4.3.1.4 Conclusions

Just east of Building 12, four boreholes (SB-046, -047, -048, and -049) were drilled in a north to south line, respectively, where numerous above-ground solvent tanks are present. These four borings penetrated approximately 10 to 15 feet of unconsolidated material before terminating in bedrock. Groundwater was not encountered in any of these borings. Relatively low concentrations of TCE and 1,2-dichloroethene (total), ranging from 8 to 52 $\mu\text{g}/\text{kg}$ and 6 to 46 $\mu\text{g}/\text{kg}$, respectively, were detected only in the two center borings. In this area, soil contamination occurs only in the vadose zone, since saturated soils were not encountered, and decreases with depth which suggests the source is related to surface spills and/or to shallow underground solvent tanks and associated piping (Figure 4.3.1-3).

Relatively low concentrations of TCE (7 to 220 $\mu\text{g}/\text{kg}$) occur in saturated soils under most of the south end of the Assembly Building and extend east at least as far as Runway Number 130 North (Figure 4.3.1-3). The extent of TCE migration in the saturated soils coincides in rough outline to the width and axis of an east-northeast trending paleochannel. *Cis*-1,2-Dichloroethene ranging from 16 to 30 $\mu\text{g}/\text{kg}$, was detected in SB-147. This soil boring, located near the center of the paleochannel, is also the location where the highest TCE concentration (220 $\mu\text{g}/\text{kg}$) was measured. No other VOCs were detected in the paleochannel.

Several semi-VOCs, such as pyrene, fluoranthene, phenanthrene, and chrysene were reported once or twice at levels slightly above the CRQL. This group of compounds, typically associated with coal tar and crude oil, is believed to be the result of small pieces of asphalt pavement incorporated in the sample and is not indicative of environmental contamination due to manufacturing operations.

TPH was detected in two soil borings at relatively low concentrations (27 and 29 $\mu\text{g}/\text{kg}$) at the south end of the Assembly Building Parts Plant. TPH was also detected in several borings located east of Building 14 (Figure 4.3.1-3). Results associated with these borings are presented in Section 4.3.11 (Fuel Saturation Area No. 1).

All 135 samples analyzed for priority-pollutant metals were less than the upper limit of natural background soil concentrations with the following nine exceptions: silver (one sample), antimony (four samples), lead (one sample), and cadmium (three samples). However, for all nine exceptions, the values are very close to the IDL or slightly above the upper limit of natural background. In addition, occurrence of these values is isolated and random suggesting they are elevated due to natural processes.

4.3.2 Underground Storage Tanks (USTs) (removed)

4.3.2.1 Summary of Investigations

4.3.2.1.1 Previous Investigations: Prior to December 22, 1988, the effective date of Federal Subtitle I regulations, 14 USTs were removed at Plant 4. A total of 12 tanks contained petroleum products and two contained hazardous substances (Hargis + Associates 1989a). Following removal of the tanks, analyses of soil samples collected from the excavations indicated that six of the tank locations (Tank Nos. 19, 20, 24A, 24B, 25A, and 30) have contaminants present in the soil. No further remedial action was performed. After removal of the tanks, the excavations were backfilled and paved.

Tanks 19 and 20 will be discussed in conjunction with FSA-1, UST-30 with FSA-3, and UST-25A with the Jet Engine Test Stand. Tanks 24A and 24B will be discussed in this section. Locations of the removed USTs 24A and 24B are shown in Figure 4.3.2-1.

Tanks 24A and 24B were reported to contain gasoline, and each had a capacity of 8,000 gallons. Contaminants found in the soils during excavation and their maximum reported concentrations include 1,1,1-trichloroethane (8 $\mu\text{g}/\text{kg}$), *trans*-1,2-dichloroethene (15 $\mu\text{g}/\text{kg}$), tetrachloroethene (270 $\mu\text{g}/\text{kg}$), ethylbenzene (11 $\mu\text{g}/\text{kg}$), methylene chloride (11 $\mu\text{g}/\text{kg}$), toluene (67 $\mu\text{g}/\text{kg}$), trichloroethene (8 $\mu\text{g}/\text{kg}$), and total xylenes (160 $\mu\text{g}/\text{kg}$) (Hargis + Associates 1989a).

4.3.2.1.2. Current Investigation: Previous sampling at the former site of Tanks 24A and 24B was insufficient to determine the potential levels and extent of contamination associated with leaks and spills from the tanks. The tank area was evaluated as a potential source for groundwater contamination of the upper zone. Although preliminary sampling has shown that contamination exists, no attempt was made to characterize the extent of contamination prior to backfilling, grading, and paving. This site may have been a significant source of contamination to the soils and groundwater over the years.

As shown in Figure 4.3.2-1, three soil borings (SB-127, -128, and -130) were placed around the perimeter of the former UST location where contamination was reported. One of the soil borings (SB 129) was placed between the former locations of the two tanks. Water was encountered in SB-129 and -130. Soil samples were collected from 5-foot intervals with samples for VOCs collected as grab samples and the remaining samples collected as composites of the entire 5-foot interval. Composite soil samples were analyzed for semi-VOCs and petroleum hydrocarbons. Ten percent of the composite samples were also analyzed for metals. Lithology logs were completed as soil borings were drilled to determine the depth of excavation and to note any visible contamination.

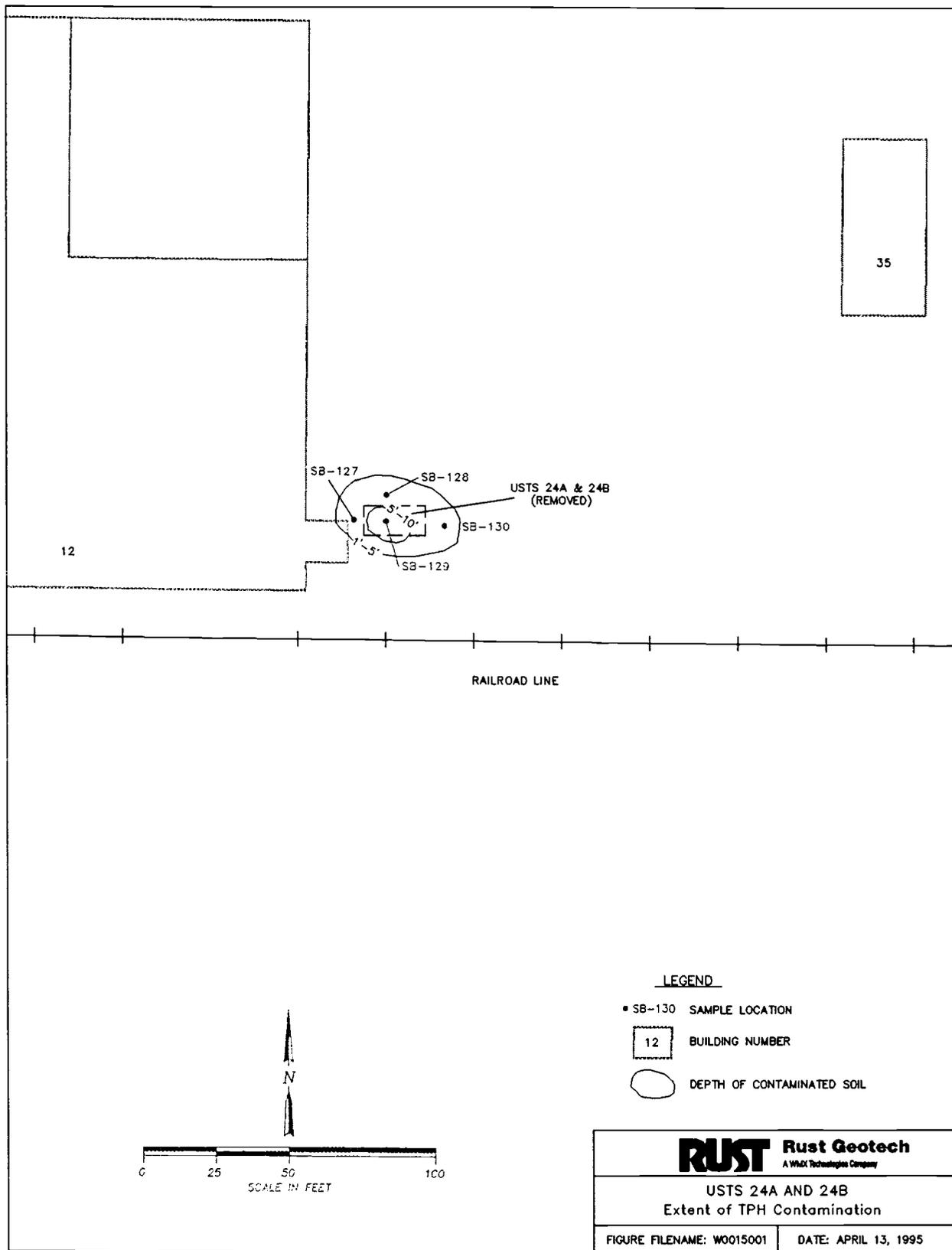


Figure 4.3.2-1. Extent of TPH Contamination at Former USTs 24A and 24B.

4.3.2.2 Summary of Soils

The four soil borings were drilled to total depths ranging from 5.9 feet to 16 feet. The entire area surrounding the former UST site is covered with up to 1.5 feet of concrete, which is underlain by 0.5 feet to 2 feet of fine sand. The remainder of material encountered in the boreholes consists of clay and silty clay with the amount of gravel increasing with depth. It is likely that the unconsolidated material that was penetrated is fill material put in place during excavation of the USTs and construction of adjacent Building 12. Detailed lithology for the four borings may be found on the borehole logsheets included in Appendix A-2. Groundwater was encountered at a depth of 9.5 feet in SB-130.

4.3.2.3 Results of the Investigation

Total petroleum hydrocarbons were detected in all four boreholes with a maximum concentration of 76 mg/kg found in the shallow (2 to 5.5 feet) interval of SB-127 (see Table 4.3.2-1 and Appendix E). TPH was present in the top 5 feet of each borehole with the exception of SB-129 where the sample intervals from 5 to 15 feet are contaminated with hydrocarbons. The areal extent of TPH contamination is shown in Figure 4.3.2-1. There were no significant concentrations of VOCs or semi-VOCs detected at the site that may be correlated with the TPH. Tetrachloroethene was detected at a concentration of 9 $\mu\text{g}/\text{kg}$ in the 5- to 10-foot interval of SB-129. 2-Butanone is a common laboratory contaminant and was found in other laboratory blanks.

**Table 4.3.2-1 Summary of VOC and TPH Analytical Results
for Soil Samples Obtained From USTs 24A & 24B**

Analyte	Minimum $\mu\text{g}/\text{kg}$	Maximum $\mu\text{g}/\text{kg}$	No. of Samples Analyzed	No. Above CRQL
Tetrachloroethene	(6)	9	7	2
2-Butanone	12	160	7	5
Total Petroleum Hydrocarbons	(10) mg/kg	76 mg/kg	7	5

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.

4.3.2.4 Conclusions

Total petroleum hydrocarbons were found in samples from all four boreholes and are considered to be the only significant contaminant present at the former UST site. The total volume of TPH contaminated soil in the vadose zone was calculated by using the area of extent (Figure 4.3.2-1) and the thickness (sample interval) of contamination.

Based on the sampling and analyses, approximately 240 cubic yards of soil is estimated to be contaminated with hydrocarbons.

Concentration levels of metals were within the range for background soils of the western United States as shown in Table 4.3.2-2.

**Table 4.3.2-2 Summary of Inorganic Sample Analyses
for Soil Samples Obtained from USTs 24A and 24B**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background Limit (mg/kg)	No. of Samples Analyzed	No. Above Upper Background Limit for Western USA
Antimony	(9)	(9.8)	2.2	3	0
Arsenic	1.1B	2.4B	21.6	3	0
Beryllium	(0.22)	0.87B	3.6	3	0
Cadmium	(0.9)	1.8	2.8	3	0
Chromium	3.1	15	196.6	3	0
Copper	2.1B	6.7	90.0	3	0
Lead	4	8.1	55.1	3	0
Nickel	(5.6)	(6.1)	66.2	3	0
Selenium	(0.45)	(0.49)	1.4	3	0
Silver	(0.9)	(0.98)	1.4	3	0
Thallium	(0.45)	(0.45)	0.8	3	0
Zinc	4.9	23.3	176.2	3	0

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
 3) Cadmium, chromium, copper, nickel, and zinc were identified in the risk assessment as chemicals of concern.

4.3.3 Landfill No. 1

4.3.3.1 Site History

From 1942 to approximately 1966, several types of hazardous and nonhazardous wastes were disposed in Landfill No. 1, which is located west of Facilities Building 14. This site encompasses about 6 acres and is presently the site of the West Parking Lot (Plate 1).

The majority of the waste disposed at Landfill No. 1 consisted of general refuse, rubble, plaster, lumber, and fill dirt. Potentially hazardous wastes were also disposed in the landfill. These included drums of unspecified liquid wastes, solvents, paint thinners, and paint wastes from tank trucks, all of which were dumped in shallow pits. Oils and fuels

were also dumped in pits and subsequently burned. Aerial photographs show that at least five separate pits were located within the landfill. Sludge from these pits was periodically dredged out and deposited in the landfill area (Radian 1987). Other suspected wastes include mercury and magnesium wastes, chromate sludges, and cyanide.

The landfill was closed in 1966 when the area was graded and paved for vehicle parking. Prior to grading and paving, two 6-inch perforated pipes were laid in trenches on bedrock just east of Meandering Road. These were intended to channel leachate from the landfill to a storm sewer (St. 5) outfall. When contaminants were identified in water samples collected from the St. 5 outfall in 1982, French Drain No. 1 was constructed to prevent contaminated groundwater from entering the storm sewer.

French Drain No. 1 was constructed in November 1982, east of Meandering Road, between Landfills No. 1 and No. 3. A 90-foot section of 4-inch perforated drain pipe was placed on bedrock east of the St. 5 outfall. During excavation, the two 6-inch drain pipes were uncovered and rerouted to the French Drain No. 1 system. The 36-inch storm sewer and north catch basin were lined with polyethylene in late 1983 to eliminate infiltration of leachate to the storm collection system. The south collection basin was lined in February 1985. It should be noted that TCE and toluene both have "moderate" effects on polyethylene. Both of these contaminants have been identified in groundwater samples from nearby monitoring wells. A concentration of 25 $\mu\text{g}/\text{L}$ TCE was identified in water from the St. 5 outfall in April 1990.

In July 1983, a portion of Landfill No. 1 that contained several waste oil pits thought to be the main source of residual contamination was excavated, and the material was removed to an approved hazardous waste disposal facility as an interim remedial action. Approximately 11,000 cubic yards of contaminated soil were removed and transported to Chemical Waste Management's (CWM) Carlyss, Louisiana facility. Liquids were also removed from the excavation and disposed at CWM's Port Arthur, Texas, facility. French Drain No. 2 was constructed within the excavation to intercept contaminated groundwater and pump it to a treatment facility on site. The excavation was then backfilled and the site repaved.

On-site treatment consisted of (1) processing the fluid through a cooling tower to volatilize organic compounds and (2) discharging the effluent to the city of Fort Worth sanitary sewer system. This system ceased operation in May 1990, at which time all pumping from the French Drains was halted (Hargis + Associates 1985a). In the spring of 1992, pumping began again using an activated charcoal treatment system on site.

On the basis of data from previous studies, the following contaminants with concentrations exceeding Federal maximum contamination limits (MCLs) were reported to occur in groundwater at Landfill No. 1:

- Arsenic
- Cadmium
- Chromium
- Lead
- Acenaphthene
- Benzene
- Ethylbenzene
- Fluoranthene
- Tetrachloroethene
- Toluene
- 1,1,1-Trichloroethane
- Trichloroethene (TCE)
- Vinyl Chloride

As evidenced by this list, Landfill No. 1 still contains petroleum hydrocarbons, waste solvents, and process chemical wastes. The interim remedial actions have eliminated only a portion of the potential source area for these contaminants.

4.3.3.2 Previous Investigations

Very little information is available pertaining to soils contamination in the landfill area. Previous investigations consisted of 22 test holes, 12 monitoring wells, and the Waste Oil Pits/French Drain excavations. Soil samples collected from the walls of the French Drain No. 2 excavation at completion indicated soils were still contaminated with VOCs and, at one location, chromium (EPA 1983). Soil samples taken during the drilling of F-216 and F-217 were screened with a photoionization detector (PID) to detect VOCs. The PID indicated VOCs were not present in F-216 but were present in trace amounts in F-217 at the 9- to 14-foot depth range (Radian 1987). Petroleum hydrocarbons were detected in both borings.

4.3.3.3 Current Investigation

During the current investigation, 16 soil borings were drilled and sampled in Landfill No. 1 to determine types and relative concentrations of contamination and to better define the extent of contamination. Drilling and sampling were halted at the water table or bedrock if no water was encountered. All borings were drilled using hollow-stem augers. No new groundwater monitoring wells were installed.

Figure 4.3.3-1 shows the borehole soil sample locations. Boreholes were drilled on a grid designed to cover the Landfill No. 1 area, as identified by previous investigations and old site photographs. The grid was extended when contamination was detected in boreholes outside the previously identified extent. Overhead high voltage lines in the southern section of the West Parking Lot prevented access to several planned drilling locations. Based on old (mid-1950s) aerial photos and borehole lithology, soil borings SB-012, -016, and -020 appear to have been drilled outside the landfill area.

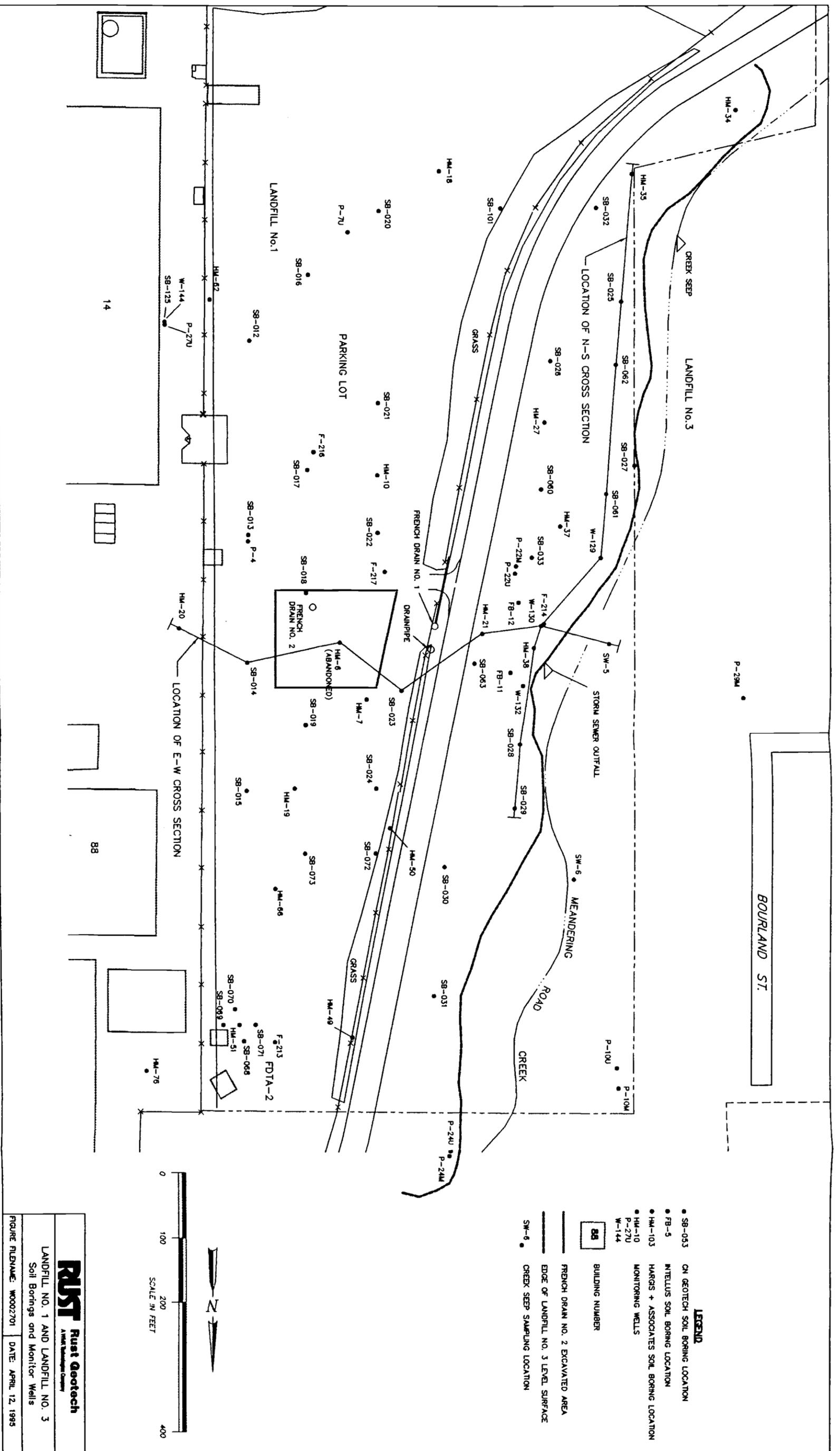


Figure 4.3.3-1. Borehole Soil Sample Locations at Landfills No. 1 and No. 3.

Contaminants in these borings are mostly shallow (0 to 5 feet) semi-VOCs related to asphalt or fuel oil.

Soil samples were composites of 5-foot intervals collected from the surface to the water table. Composite samples were analyzed for semi-VOCs, oil and grease, and metals. A grab sample for volatile organic analysis was collected from within the 5-foot interval where PIDs or visual examination indicated possible contamination.

Lithologic information taken from the existing monitoring wells and the soil borings was used to construct a bedrock surface contour map of the area under Landfills No. 1 and No. 3 (see Figure 4.3.3-2) and to construct two geologic cross sections (see Figures 4.3.3-3 and 4.3.3-4) to illustrate the geology under the landfills. The cross sections show sand, clayey sand, and gravel layers that occur under much of the landfills.

The bedrock surface map indicates areas and direction for subsurface drainage of groundwater and contaminants. The bedrock map also shows the channels cut into the Walnut Formation that drain to Landfill No. 3 and Meandering Road Creek. Soils in the Landfill No. 1 area are mainly clays, silty/sandy clays, or sands. Fill material used to cover the landfill and grade the site ranges from sand to clay with some intermixed gravels and silts. Trash such as wood, plastic, wire, asphalt, glass, and metal was reported in 10 of the 16 soil borings. Also indicated on the cross sections are areas where contamination was detected (see Appendix A-2).

4.3.3.3.1 VOC and Oil and Grease Soil Sample Analysis: Table 4.3.3-1 shows 11 VOCs identified in Landfill No. 1 during the current investigation. VOCs detected were fuels, solvent, and solvent degradation products. Both toluene and TCE were detected and have been identified as chemicals of concern in the site risk assessment. The highest concentrations of VOCs were found in the areas adjacent to French Drain No. 2. Figures 4.3.3-5 and 4.3.3-6 show VOCs and oil and grease concentrations. The oil and grease threshold level for Figure 4.3.3-5 was set at 100 mg/kg (based on agreement discussions with the EPA and State of Texas). SB-023, located downgradient of French Drain No. 2, shows the highest VOC concentrations of all soil borings drilled in Landfill No. 1. An oily sheen was observed on the surface of the fluid in SB-023 at a depth of 8 feet. Concentrations of toluene, 1,2-dichloroethene, and 2-butanone in SB-023 were 350,000 $\mu\text{g}/\text{kg}$, 360,000 $\mu\text{g}/\text{kg}$, and 180,000 $\mu\text{g}/\text{kg}$, respectively, in the 8- to 10-foot depth interval. The oil and grease analysis for the same interval was 6,878 mg/kg. This interval is directly above the bedrock surface (10-feet below ground level) which is thought to both prevent deeper contamination, and in this area, channel the contaminants toward Meandering Road Creek (see Figure 4.3.3-2). Soil samples in the area northwest of the French Drain No. 2 excavation (SB-019, -023, and -024) indicate fuel-related products such as benzene, toluene, ethylbenzene, and xylene are present. These products were not detected in other Landfill No. 1 soil borings.

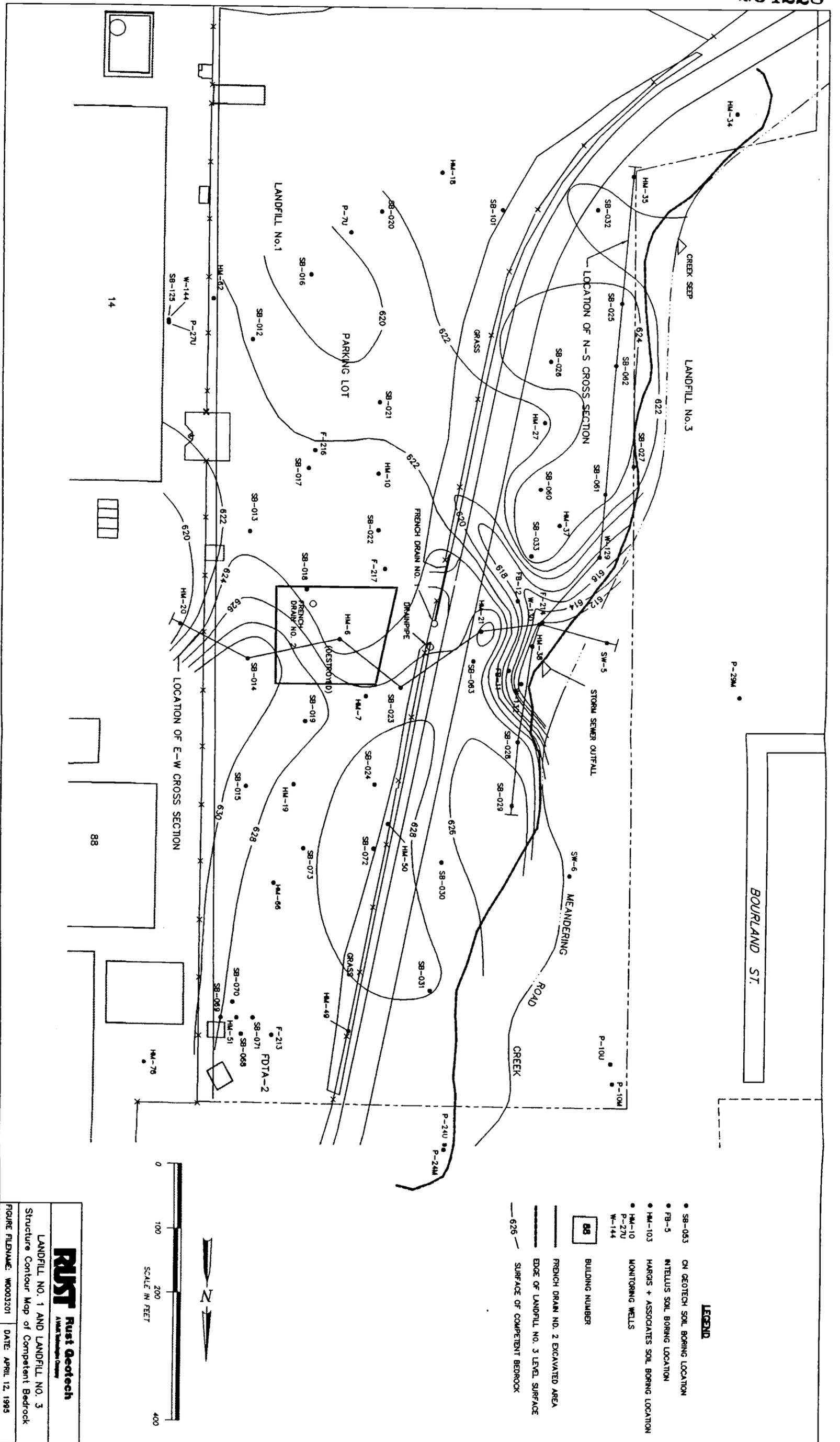
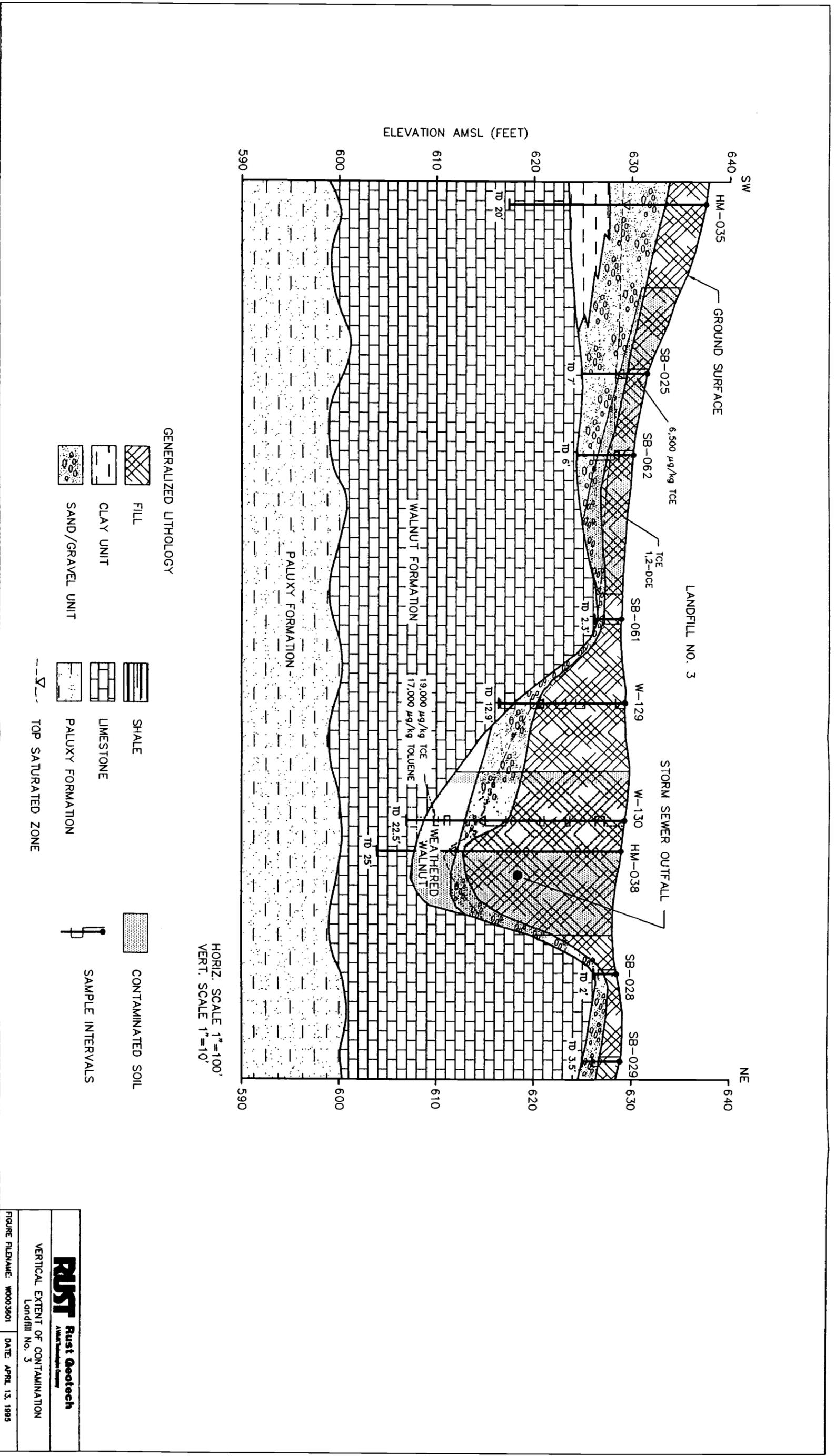


Figure 4.3.3-2. Bedrock Surface Contour Map for Landfills No. 1 and No. 3.

RUST Rust Geotech
ANALYTICAL TECHNOLOGIES COMPANY

LANDFILL NO. 1 AND LANDFILL NO. 3
 Structure Contour Map of Competent Bedrock

FIGURE FILENAME: W0003201 DATE: APRIL 12, 1993



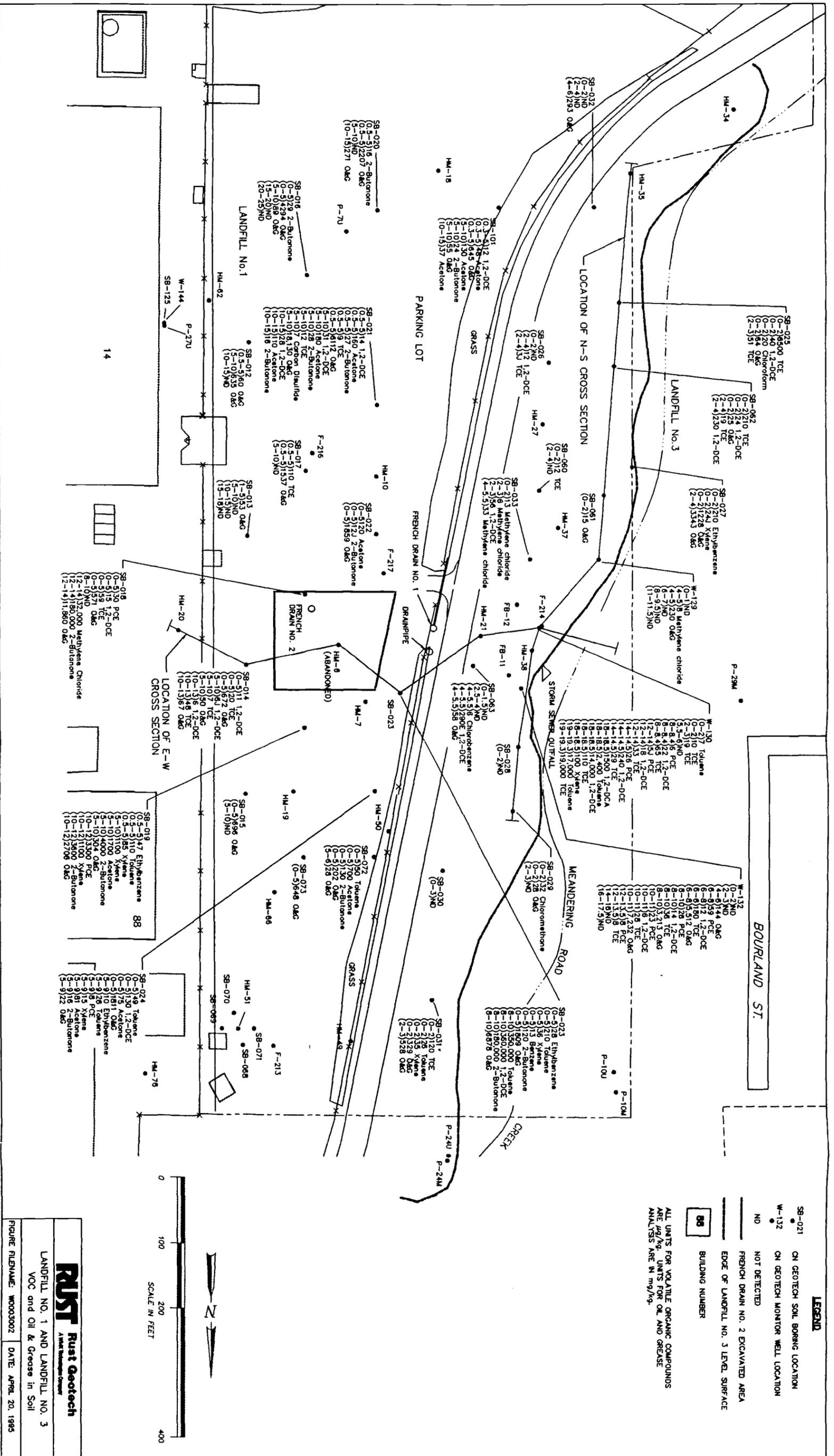


Figure 4.3.3-5. Soil Sample Results for VOCs and Oil and Grease Analyses at Landfills No. 1 and No. 3.

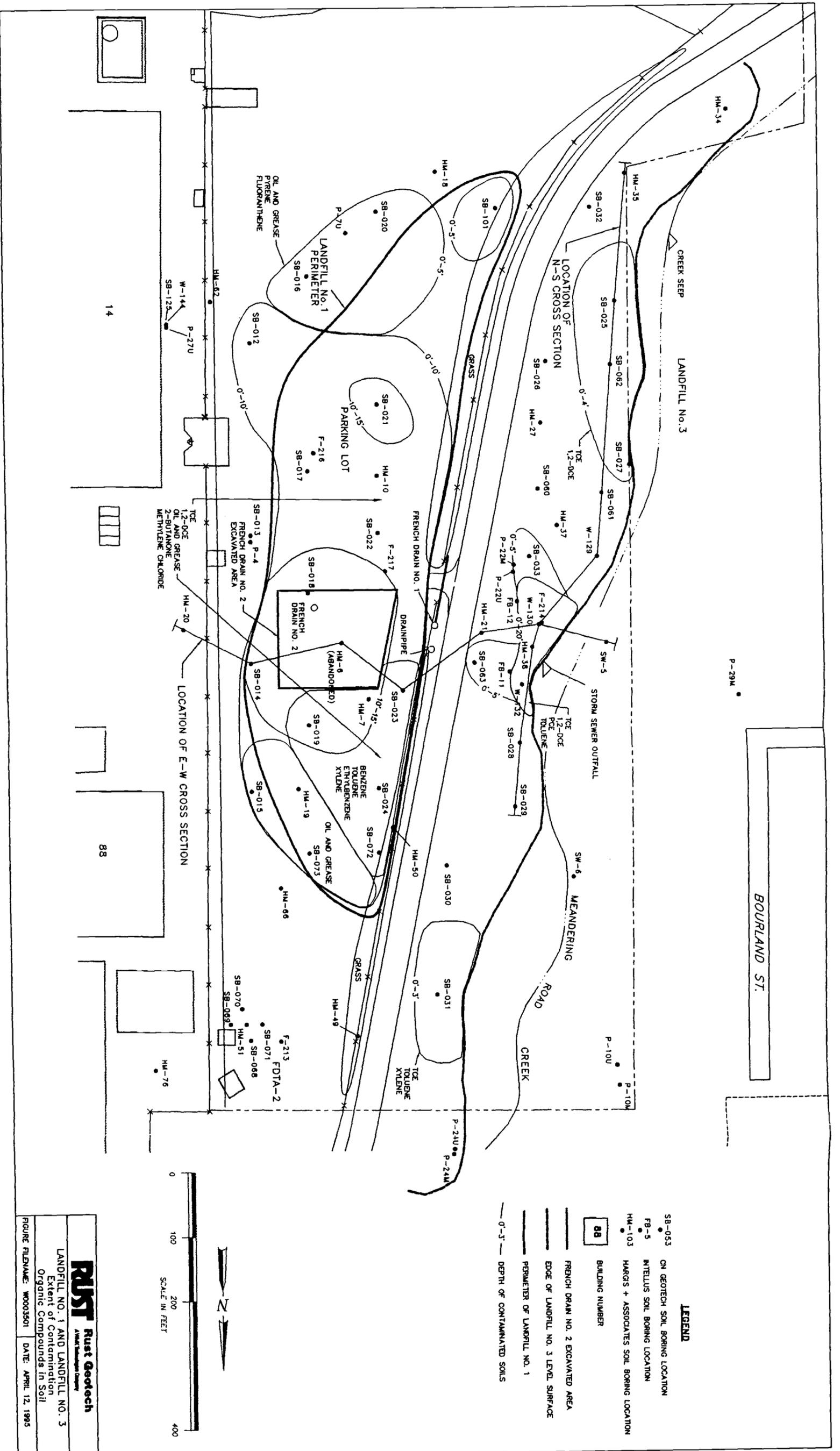


Figure 4.3.3-6. Extent of Organic Contamination in Soil Samples Collected at Landfills No. 1 and No. 3.

**4.3.3-1 Summary of VOC and Oil and Grease Sample Analyses
for Soil Samples Collected from Landfill No. 1**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
1,2-Dichloroethene	(5)	360,000	63	10
2-Butanone	(10)	180,000	65	20
Acetone	(10)	1,700	65	23
Benzene	(5)	13	65	1
Carbon Disulfide	(5)	12	65	3
Ethylbenzene	(5)	750	65	4
Methylene Chloride	(5)	32,000	65	2
Tetrachloroethene	(5)	3,300	65	3
Toluene	(5)	350,000	65	5
Trichloroethene	(5)	110	65	7
Xylene	(5)	1,600	65	7
Oil and Grease	(10) mg/kg	18,130 mg/kg	57	36

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Trichloroethene and toluene have been identified in the risk assessment as chemicals of concern.

Oil and grease were reported in 36 samples collected across Landfill No. 1. Values for oil and grease ranged from none detected to more than 18,130 mg/kg (see Table 4.3.3-1). The highest values were found in soil borings adjacent to French Drain No. 2, which was the former location of waste oil pits. Oil and grease results from other borings across Landfill No. 1 were highest in the top sample of each borehole. Because all of the soil samples collected in Landfill No. 1 were taken from boreholes drilled through asphalt paving, the analytical results from near-surface samples probably reflect the asphalt paving or vehicular motor oil. Landfill No. 1 samples for oil and grease were composites of 5-foot intervals, which resulted in some loss of definition of the contaminated depth intervals.

4.3.3.3.2 Semivolatile Organic Compound Soil Sample Analysis: A summary of the Landfill No. 1 semi-VOC results is presented in Table 4.3.3-2. A total of 16 semivolatile compounds were detected in Landfill No. 1 during the soils investigation. All five semivolatile compounds identified as risk assessment chemicals of concern were detected.

**Table 4.3.3-2 Summary of Semi-VOC Sample Analyses
for Soil Samples Collected from Landfill No. 1**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
1,2-Dichlorobenzene	(700)	25,000	56	6
1,4-Dichlorobenzene	(700)	1,700	56	1
2-Methylnaphthalene	(700)	2,400	56	3
Anthracene	(700)	25,000	56	1
Benzo(a)anthracene	(700)	71,000	56	4
Benzo(a)pyrene	(700)	62,000	56	3
Benzo(g,h,i)perylene	(700)	53,000	56	3
Benzo(k)fluoranthene	(700)	58,000	56	6
bis(2-ethylhexyl)phthalate	(700)	2,500	56	3
Chrysene	(700)	87,000	56	4
Fluoranthene	(700)	190,000	56	7
Fluorene	(700)	1,800	56	3
Indeno(1,2,3-cd)pyrene	(700)	56,000	56	6
Naphthalene	(700)	2,300	56	6
Phenanthrene	(700)	150,000	56	6
Pyrene	(700)	150,000	56	5

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Pyrene, benzo(a)pyrene, fluoranthene, naphthalene, and 2-methylnaphthalene were identified in the Baseline Risk Assessment as chemicals of concern.

The five compounds—pyrene, benzo(a)pyrene, fluoranthene, naphthalene, and 2-methylnaphthalene, were detected in samples across the landfill site. Figure 4.3.3-7 indicates locations and values of semi-VOC results. This figure does not include tentatively identified compounds or bis(2-ethylhexyl)phthalate, which is a common laboratory contaminant. Bis(2-ethylhexyl)phthalate was reported only once in Landfill No. 1 in SB-020 in the 5- to 10-foot interval at 1,700 µg/kg and may be due to laboratory contamination as it does not appear elsewhere. It was tentatively identified in a duplicate sample of the same interval at 130 µg/kg, which is an order of magnitude less than the original sample.

The semi-VOCs appear to be in two areas of the landfill: either in the samples immediately below the asphalt paving, which would not indicate contamination from manufacturing operations, or in the samples collected from boreholes in the area near French Drain No. 2, the former waste oil pits location.

Several semi-VOCs such as pyrene, fluoranthene, chrysene, and phenanthrene are typically associated with coal tar and crude oil. These substances were detected across the landfill, usually in the sample interval immediately below the asphalt pavement and are probably the result of small pieces of asphalt incorporated in the sample.

The samples from SB-012, -013, -014, -015, -016, -017, -020, -024, -072, -073, and -101 have semi-VOC contaminants reported mainly in the sample collected immediately below the pavement. These borings had very few semi-VOCs reported in samples collected below the surface sample. Historical reports of "periodic dredging and depositing in the landfill" material from the former waste oil pits may also account for some of the semi-VOC contamination in these borings. The second set of borings, SB-018, -019, -021, -022, and -023, were located near French Drain No. 2, and have semi-VOC contaminants reported in samples collected at deeper depths. Contaminants from the second set of boreholes include compounds found in manufacturing processes such as benzoic acid and 1,2-dichlorobenzene.

Dibenzofuran, used in insecticides, was identified at low levels in four soil borings grouped at the south end of the landfill (SB-012, -016, -018, and -020) and in SB-072 on the north edge of the landfill. These analytical results were qualified with a "J" to indicate the concentration is an estimated quantity. The 0- to 5-foot sample collected from SB-016 had very high levels of polynuclear aromatic hydrocarbons that created problems with the laboratory's quality control internal standards. Analytical results from this sample interval were treated as estimated values.

4.3.3.3 Inorganic Soil Sample Analyses: Results of the inorganic analyses vary widely across Landfill No. 1. Sample results indicate contaminants that were dumped in the immediate area of the borehole and do not correlate well across the site. Samples with the highest analytical results are in areas where, based on old aerial photographs, dumping was known to occur. Samples from areas where dumping was not thought to occur generally indicate contaminant levels several orders of magnitude lower. Areas where dumping did not occur usually have higher levels of inorganics within 5 feet of the surface and probably indicate some degree of smearing from when the landfill was graded and paved. All five inorganic risk assessment chemicals of concern are found in Landfill No. 1 as shown in Table 4.3.3-3. Figure 4.3.3-8 shows Landfills No. 1 and No. 3 inorganics that were reported at levels greater than the concentration ranges found in the Plant 4 background locations. SB-021 had very high analytical results for inorganics, with cadmium at 594 mg/kg, chromium at 808 mg/kg, copper at 2,550 mg/kg, nickel at 228 mg/kg, lead at 1,760 mg/kg, and zinc at 13,200 mg/kg. Arsenic, beryllium,

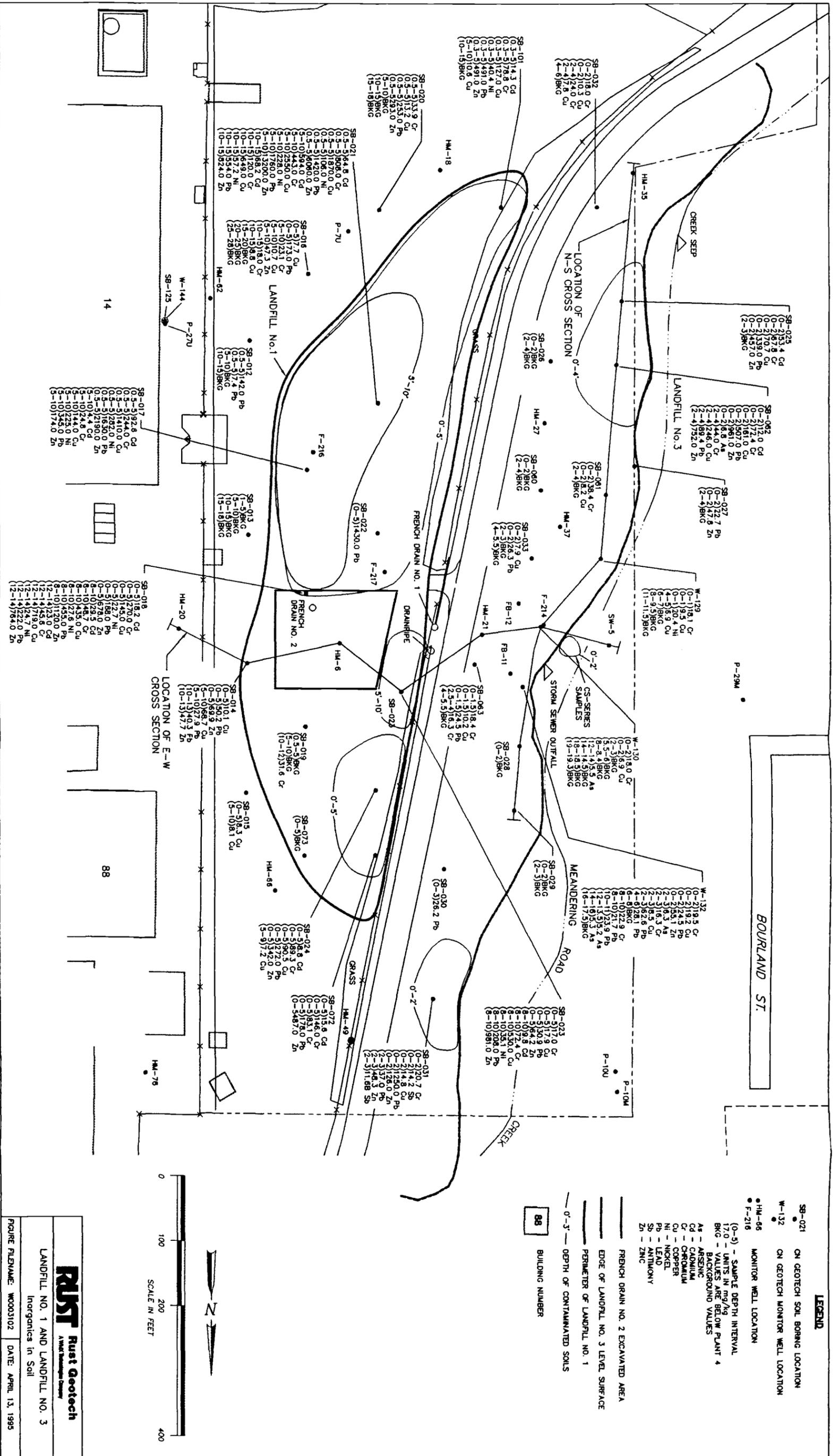


Figure 4.3.3-8. Extent of Inorganic Contamination and Results of Analyses for Soil Samples Collected at Landfills 1 and 3.

and silver were also detected in SB-021 although at much lower levels. Except for chromium, which had its highest result in the 0.5- to 5-foot sample, all of the high values were detected in the 5- to 10-foot sample interval. This soil boring, which had low levels of VOCs, indicates again that contaminants in the landfill are irregularly located.

**Table 4.3.3-3 Summary of Inorganic Sample Analyses
for Soil Samples Collected from Landfill No. 1**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background Limit (mg/kg)	No. of Samples Analyzed	No. Above Upper Background Limit for Western USA
Antimony	(8)	77.5	2.2	57	2
Arsenic	(0.6)	13.8	21.6	57	0
Beryllium	(0.22)	1.1	3.6	57	0
Cadmium	(0.8)	594	2.8	57	12
Chromium	2.4	808	196.6	57	4
Copper	3.1B	2550	90.0	57	11
Lead	1.4	1760	55.1	57	16
Nickel	(5)	282	66.2	57	4
Selenium	(0.4)	(4.7)	1.4	57	0
Silver	(0.8)	44.3	1.4	57	9
Thallium	(0.4)	(0.55)	0.8	57	0
Zinc	2.7B2	13200.1	176.2	57.5	12.1

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
 3) Cadmium, chromium, copper, nickel, and zinc were identified in the Baseline Risk Assessment as chemicals of concern.

4.3.3.3.4 TCLP Analytical Results: Toxicity characteristics leaching procedure analysis for VOCs, semi-VOCs, and inorganics were performed on a sample split from the 8- to 10-foot depth interval in SB-018. VOCs were not detected in the sample. Four semivolatile compounds and three inorganic compounds were detected (Table 4.3.3-4). The four semivolatile compounds all have results of 1 $\mu\text{g}/\text{L}$ flagged with a J, which indicates an estimated value. Barium, cadmium, and lead are the inorganics that were detected. The B flag for barium indicates the value reported is less than the CRDL but greater than or equal to the IDL. All the semi-VOCs and the inorganic constituents that were detected in the sample are less than the regulatory TCLP levels.

Table 4.3.3-4 TCLP Analytical Results

Semivolatile Constituent	Concentration in Extract
Hexachlorobutadiene	1J $\mu\text{g/L}$
Pentachlorophenol	1J $\mu\text{g/L}$
2,4,6-Trichlorophenol	1J $\mu\text{g/L}$
2,4,5-Trichlorophenol	1J $\mu\text{g/L}$
Inorganic Constituent	Concentration in Extract
Barium	338B $\mu\text{g/L}$
Cadmium	115 $\mu\text{g/L}$
Lead	577 $\mu\text{g/L}$

4.3.3.4 Conclusions

A variety of soil contaminants remain in Landfill No. 1. High levels of solvents and solvent degradation products still exist in areas of the landfill. Fuel contaminants were found in the western section of the landfill downgradient of the former waste oil pits. Inorganic contaminants were detected irregularly across the landfill and probably reflect what was dumped in the immediate area. Solvent compounds found in Landfill No. 1 soil borings have also been detected in Landfill No. 3 soil borings and monitoring wells downgradient of Landfill No. 1.

Volume estimates of contaminated soil were made based on Geotech soil sample analytical results, depths of samples, soil boring lithology, and historical photos of landfill use. Soil samples were collected as composites of 5-foot depth intervals, which means volume estimates based on 5-foot intervals may be high, (contamination from 0 to 6 feet would be reported as 0 to 5 feet and 5 to 10 feet). Contaminants detected in adjacent groundwater monitoring wells were also considered to be an indication of possible soil contamination. A threshold value of 100 mg/kg oil and grease was used to delineate extent of contamination if no other organic contaminants were detected.

Approximately 83,400 cubic yards of soil are estimated to be contaminated with organic compounds; of that, an estimated 39,600 cubic yards are also contaminated with inorganic contaminants. These figures take into account the 17,000 cubic yards of material removed during the construction of French Drain No. 2, which was replaced with clean fill.

4.3.4 Landfill No. 3

4.3.4.1 Site History

Contamination was first detected at Landfill No. 3 in 1982 after a local citizen detected odors at a 36-inch storm drain that passed through the landfill and drained into Meandering Road Creek (St. 5 Outfall). Subsequent analysis of water samples collected from the outfall identified several contaminants, the most prevalent of which was trichloroethene (Hargis + Associates 1985a). Remedial action resulted in the lining of the storm drain in late 1983 where it passed between the landfills, excavation of the former Waste Oil Pits (located in Landfill No. 1) in 1983, and the construction of French Drain No. 1 in November 1982 and French Drain No. 2 in 1984.

French Drain No. 1 was pumped daily with a vacuum truck to reduce the amount of groundwater infiltration into the outfall. French Drain No. 2 was equipped with an electric submersible pump that was activated in December 1984. Pumping continued until May 1990 when General Dynamics ceased treatment of the purged fluids. A new charcoal treatment system installed in December 1991 was operated for approximately three weeks before failure in January 1991 because of particulates clogging the equipment. The system was repaired and in operation several months later.

The landfill material is primarily soil fill of variable nature with clay, silt, sand, and gravel all being reported from drilling logs. Some plant material and trash are reported but do not appear to be major components. Asphalt and concrete rubble also occur but apparently only as smaller fragments that are not large enough to stop drilling. Large blocks of broken concrete are visible on the steep western slope of the landfill, apparently placed there to prevent erosion.

The fill was placed on top of both the alluvial deposits and on the Walnut Formation. Drilling logs indicate that the alluvial deposits are primarily present in the southern and central portions of the landfill. The alluvial deposits thin out from the south end to the central portion of the landfill. The alluvium and fill have a maximum thickness of 19 feet at HM-38, which is located in a drainage channel eroded into the Walnut Formation. This channel, which contains the storm sewer, was filled and graded in 1966 and 1967. A 1941 pre-landfill topographic map shows several such drainage channels cut into the surface under Landfill No. 3. Depth of the alluvium ranges from 2 to 7 feet over most of the landfill except where a previous drainage channel was filled in, as at HM-38, F-214, or HM-36. The lithologic logs for all three wells indicate a deep cut in the bedrock surface. A shallower drainage cut is also indicated at the southern end of the landfill near wells HM-26 and HM-27 (Intellus 1987). Figure 4.3.3-2, Surface Contour Map of the Bedrock Surface of Landfills No. 1 and No. 3, shows the channel at this location. The drilling logs indicate that the alluvial deposits thin toward the center of the site and are absent in wells HM-21 and HM-39 and at the northern end of the landfill. These alluvial deposits are extremely variable even within the small area of

Landfill No. 3, consisting of clay and sandy or silty clay in the southern portion of the landfill, grading to sandy gravel lenses, and then only sand and gravel at HM-26 and HM-27. Further north of these wells, the alluvial aquifer grades back to a clayey sand and gravel and then to a silty clay before disappearing from the top of the Walnut Formation. An east-to-west cross section of the landfill, Figure 4.3.3-3, indicates three general layers under the landfill: fill, a sand and gravel unit, and weathered bedrock. Figure 4.3.3-4 shows the geology of the western edge of Landfill No. 3. The cross sections also illustrate how the bedrock channels which are filled with several feet of weathered bedrock, sand, and gravel, act as conduits for the transport of contaminants across the landfill.

4.3.4.2 Previous Investigations

Fourteen soil test borings, 10 alluvial monitoring wells, and 6 Paluxy monitoring wells were drilled in the Landfill No. 3 area during several investigations since 1982. Very few analytical results for soils were reported. Three additional temporary alluvial monitoring wells and 13 soil borings were drilled during the current investigation. General Dynamics Corporation drilled three soil borings near the center of Landfill No. 3 in 1982 to assess subsurface conditions. Findings from these locations led to further investigations at the site.

Hargis & Montgomery drilled nine alluvial aquifer monitoring wells and two Paluxy monitoring wells in Landfill No. 3 during 1983 and 1984 (Hargis + Associates 1985a). Multiple organic contaminants, primarily solvents, fuels, and oil and grease, were detected in water samples from all of the alluvial aquifer wells. No analyses for contaminants in soil samples were reported. Test Holes TH-11 through TH-19 were drilled at the north end of Landfill No. 3 at the site of a suspected burn pit (Hargis & Montgomery 1983b).

Intellus Corporation (1986a) drilled one alluvial aquifer monitoring well, F-214, and two soil borings, FB-11 and FB-12, in 1986. Soil samples from F-214 and FB-12 were found to contain solvents and petroleum hydrocarbons (see Table 4.3.4-1).

This investigation did not evaluate soils below the saturated zone; however, a groundwater sample collected from monitoring well F-214 was found to contain high concentrations of these contaminants (Intellus 1986a). In 1991, monitoring well F-214 had a DNAPL phase consisting mainly of TCE and toluene, with no LNAPL phase detected.

The Radian Corporation drilled one Paluxy monitoring well, P-22U, which was found to contain low concentrations of volatile organics in a water sample taken in 1987. Subsequent analysis of samples from P-22U by Hargis + Associates detected steady levels of TCE. A sample collected in May 1990 also detected TCE (90 $\mu\text{g}/\text{L}$). Water samples from P-22U collected in December 1990 detected 48 $\mu\text{g}/\text{kg}$ of TCE and

**Table 4.3.4-1 Previous Soil Sample Results
Obtained at Landfill No. 3**

Analyte	FB-12 11.0 to 11.5 feet	F-214 18.0 to 18.5 feet
Chlorobenzene	1.29 mg/kg	ND
TPH	200 mg/kg	1500 mg/kg
<i>trans</i> -1,2-Dichloroethene	0.05 mg/kg	1.95 mg/kg
PCE	ND	0.08 mg/kg
Toluene	ND	0.998 mg/kg

150 $\mu\text{g}/\text{kg}$ of 1,2-DCE. Radian also conducted a terrain conductivity geophysical survey over Landfill No. 3 that "indicated a random pattern of anomalies that may be due to relict disposal features" (Radian 1987).

4.3.4.3 Current Investigation

The purpose of the current investigation was to better delineate the extent of contamination as outlined from the previous studies. A total of 16 soil borings were drilled during the RI/FS investigation in 1991 (see Figure 4.3.3-1). Three of these soil borings were converted to temporary monitoring wells to further delineate groundwater contamination. Soil borings were drilled to the top of the Walnut Formation with samples collected every two feet. Samples were analyzed for VOCs, semi-VOCs, TPH, and total metals. Samples collected for volatile analysis were taken from intervals within the 2-foot sample that had elevated PID readings.

4.3.4.3.1 VOC and Oil and Grease Soil Sample Analysis: Eighteen VOCs were detected in soil samples collected from Landfill No. 3 as shown in Table 4.3.4-2. VOCs detected were fuels-related, solvent-related, and solvent degradation products. Both toluene and TCE, which were detected in the landfill, were identified as chemicals of concern in the Baseline Risk Assessment. The highest concentrations of all volatiles in Landfill No. 3 were in soil borings drilled in or adjacent to the bedrock channels. TCE was found in 10 samples, with most of the locations being in the two large buried channels cut into the alluvium and bedrock. The highest concentrations of TCE and toluene were found at the bottom of soil boring/monitoring well W-130, which was drilled into a channel eroded in the Walnut Formation in the center of the landfill (see Figure 4.3.3-2). Monitoring well W-130 was found to contain DNAPL product during the groundwater investigation. TCE was also found in one sample at the north end of the landfill (SB-031) at a concentration of 120 $\mu\text{g}/\text{kg}$, (0 to 2 feet). Figure 4.3.3-5 indicates locations and concentrations of VOCs and oil and gas detected in Landfill No. 3. Several soil boring locations across the landfill were found to have low levels of VOCs,

Table 4.3.4-2 Summary of Landfill No. 3 Soil Samples Collected for VOC and Oil and Grease Analysis

Analyte	Minimum ($\mu\text{g}/\text{kg}$)	Maximum ($\mu\text{g}/\text{kg}$)	No. of Samples Analyzed	No. Above CRQL
1,1-Dichloroethene	(5)	15	57	1
1,1-Dichloroethane	(5)	17	57	1
1,1,2-Trichloroethane	(5)	24	57	1
1,2-Dichloropropane	(5)	16	57	1
1,2-Dichloroethane	(5)	1,500	57	1
1,2-Dichloroethene	(5)	14,000	56	15
2-Butanone	(10)	3,100	57	1
Acetone	(10)	38	57	3
Carbon Disulfide	(5)	15	57	1
Chlorobenzene	(5)	6	57	1
Chloroform	(5)	40	57	1
Chloromethane	(10)	85	57	2
Ethylbenzene	(5)	210	57	2
Methylene Chloride	(5)	8	57	1
Tetrachloroethene	(5)	59	57	7
Toluene	(5)	17,000	57	5
Trichloroethene	(5)	19,000	57	21
Xylene	(5)	100	57	3
Oil and Grease	(10) mg/kg	5,409 mg/kg	26	11

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Trichloroethene and toluene were identified in the Risk Assessment as chemicals of concern.

which could be expected because of the historic usage of the landfill as a liquids dump site and because of smearing when the landfill was graded.

Several isolated results of common laboratory contaminants such as acetone, methylene chloride, and 2-butanone were not shown in Figure 4.3.3-5. These substances were reported where there was agreement with adjacent samples and blanks, or where concentration levels would preclude laboratory contamination.

4.3.4.3.2 Semivolatile Soil Sample Analysis: Seven semivolatile compounds were detected in soil samples collected from Landfill No. 3 as shown in Table 4.3.4-3. Figure 4.3.3-7 shows locations and concentrations of semi-VOCs in Landfill No. 1 and

No. 3. This figure does not show results that were qualified as estimated quantities (J) or results for bis(2-ethylhexyl)phthalate. Fluoranthene and pyrene, identified as chemicals of concern in the Plant 4 risk assessment, were both detected. The remaining semi-VOC chemicals of concern, naphthalene, 2-methylnaphthalene, and benzo(a)pyrene were tentatively identified in several samples collected at the landfill. Most of the semi-VOCs identified in Landfill No. 3 are commonly associated with coal tar or fuel oil and are probably the result of pieces of asphalt paving that were reported in several of the soil boring lithology logs. Compounds such as benzoic acid and 1,3-dichlorobenzene are common manufacturing chemicals and were detected infrequently across the landfill.

Table 4.3.4-3 Summary of Landfill No. 3 Soil Samples Collected for Semivolatile Analysis

Analyte	Minimum (µg/kg)	Maximum (µg/kg)	No. of Samples Analyzed	No. Above CRQL
1,3-Dichlorobenzene	(730)	1,600	31	1
Benzo(b)fluoranthene	(730)	800	31	1
Bis(2-ethylhexyl)phthalate	(750)	2,500	31	1
Chrysene	(730)	950	31	2
Fluoranthene	(730)	3,000	31	3
Phenanthrene	(730)	2,200	31	3
Pyrene	(730)	1,800	31	4

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Pyrene and fluoranthene have been identified in the Baseline Risk Assessment as a chemical of concern.

Bis(2-ethylhexyl)phthalate is a common laboratory contaminant that was reported in Landfill No. 3 in three borings—SB-063, W-129, and W-132. SB-063 had bis(2-ethylhexyl)phthalate at 1,200 µg/kg reported in the 4- to 5.5-foot sample. This compound was also reported in the blank for that depth interval and is probably laboratory contamination. Results for W-129 reported bis(2-ethylhexyl)phthalate in several sample intervals without appearing in any blanks. Values for 4 to 5 feet, 6 to 7 feet, 8 to 9.5 feet, and 11 to 11.5 feet were 1,100, 1,300, 2,500, and 960 µg/kg, respectively. Sample results for W-132 indicated 900 µg/kg of bis(2-ethylhexyl)phthalate at 4 to 6 feet and identified it in four other samples as estimated quantity.

Because of the types of materials encountered during drilling in the landfill, such as gravels and concrete rubble, not all samples that were attempted, could be collected. In W-130 only three out of eight sample spoons had enough soil material for a semi-VOC analysis. In the event that there was not enough sample material, priority was given to collection of the VOC sample.

Several isolated analytical results were reported for chemicals other than the asphalt-related compounds across Landfill No. 3. N-Nitrosodiphenylamine, which may be used as a fuels additive, insecticide, cutting fluid, or solvent, was detected at 1,300 $\mu\text{g}/\text{kg}$ in SB-033 at a depth of 4 to 5.5 feet. This substance was not detected in other soil samples and is not considered a significant environmental hazard because of its low level of occurrence. Dibenzofuran, typically used in insecticides, was identified at 0 to 4 feet in SB-025 (88J $\mu\text{g}/\text{kg}$) and SB-032 (170J $\mu\text{g}/\text{kg}$). Pentachlorophenol, also used in insecticides, was identified at 0 to 4 feet in SB-063 (1,000J and 1,800J $\mu\text{g}/\text{kg}$ in a duplicate sample) and at 11 to 11.5 feet in W-129 (290J $\mu\text{g}/\text{kg}$). 4-Chloro-3-methylphenol, which is used as a germicide and preservative in glues or inks, was identified in W-132 at 6 to 8 feet with a value of 360J $\mu\text{g}/\text{kg}$.

4.3.4.3 Inorganic Soil Sampling Results: Nine inorganic substances were detected in soil samples collected from Landfill No. 3 as shown in Table 4.3.4-4. All five inorganic chemicals of concern were identified in Landfill No. 3 samples. Nickel was reported in only one sample from W-129 at a level slightly above the site background samples (0- to 1-foot at 20.4 mg/kg). Cadmium was reported in two samples: SB-062, 0 to 2 feet at 12.0 mg/kg, and in SB-025, 0 to 2 feet at 53.4 mg/kg. Samples that were collected for the transect of Meandering Road Creek were collected on the west edge of Landfill No. 3 and had some of the highest metals results for all soil samples collected during the field investigation (Section 4.4.2).

Samples collected across Landfill No. 3 indicate the irregular occurrence of the inorganics as shown by Figure 4.3.3-8. This pattern would be expected with the history of the landfill. The highest values were reported in samples collected from three soil borings: SB-025, SB-031, and SB-062. Other soil borings in Landfill No. 3 had inorganic results at background levels or only slightly elevated levels (see Appendix E). SB-025, -031, and -062 were shallow holes drilled to 3 feet, 3 feet, and 4 feet, respectively, with each hole split into two sampling intervals. The highest results were reported in the 0- to 2-foot interval for all three borings. Landfill No. 3 does not appear to be a major source area for inorganic contaminants.

4.3.4.3.4 Toxicity Characteristic Leaching Procedure Analytical Results: One soil sample collected from SB-033 at the 4.0- to 5.5-foot depth interval was split for TCLP analysis. The analysis for TCLP semivolatiles indicated all results were below detection limits. VOC analysis indicated only the presence of methylene chloride at a concentration of 33 $\mu\text{g}/\text{L}$. The analysis for TCLP metals indicated results for barium (283B $\mu\text{g}/\text{L}$) and chromium (28B $\mu\text{g}/\text{L}$). TCLP results for methylene chloride, barium, and chromium are all below the regulatory maximum concentration level.

4.3.4.4 Conclusions

A variety of soil contaminants remain in Landfill No 3. VOCs were detected in soil at levels indicating pure product in the center of the landfill at soil boring location W-130.

**Table 4.3.4-4 Summary of Landfill No. 3 Soil Samples
Collected for Inorganic Analysis**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background Limit mg/kg	No. of Samples Analyzed	No. Above Upper Background Limit for Western USA
Antimony	(8.4)	14.2	2.2	42	2
Arsenic	(0.66)	6.8	21.6	42	0
Beryllium	(0.22)	1.3	3.6	42	0
Cadmium	(0.86)	53.4	2.8	42	2
Chromium	2.4B	72.4	196.6	42	0
Copper	(1.9)	246	90.0	42	2
Lead	2	1,250	55.1	42	5
Nickel	(5.4)	20.4	66.2	42	0
Selenium	(0.42)	(4.4)	1.4	42	0
Silver	(0.84)	1.5B	1.4	42	1
Thallium	(0.42)	0.52B	0.8	42	0
Zinc	3.8B	961	176.2	42	3

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
 3) Cadmium, chromium, copper, nickel, and zinc were identified in the Baseline Risk Assessment as chemicals of concern.

Some of the highest concentrations of metals in soil detected during the RI were found in soil samples collected from the western edge of the landfill near monitoring well F-214. The soil borings drilled in Landfill No. 3 show the irregular levels of contamination found across the site. The highest concentrations of soil contaminants are found where the old drainage channels cut into the Walnut Formation were graded over. These channels have removed the Walnut Formation in Meandering Road Creek just west of the Landfill and have probably exposed the Paluxy Formation. Several attempts were made to verify the presence or absence of the Walnut Formation west of monitor well F-214, but the thick sands and gravels of the creek bed did not allow a determination to be made with hand equipment.

The total amount of contaminated soil is approximately 16,000 cubic yards. Approximately 15,900 cubic yards are estimated to be contaminated with organic compounds and 3,800 cubic yards of soil are estimated to be contaminated with inorganic contaminants.

4.3.5 Landfill No. 4

4.3.5.1 Previous Investigations

Landfill No. 4 is located near the southwest boundary of the Plant 4 facility (Figure 4.3.5-1). This landfill occupies approximately 2 acres of land west of Meandering Road. Landfill No. 4 utilized a low area adjacent to Meandering Road Creek for the disposal of construction rubble from 1956 to the early 1980s. Evidence suggests that other types of wastes may have been disposed from 1966 until approximately 1973 (Radian 1987). These wastes are thought to have included small quantities of hazardous wastes such as solvents, oils, fuels, and thinners. Based on a review of aerial photographs of the landfill when it was still in use, it appears that materials other than construction rubble were deposited in the landfill. Because the landfill is located on the Meandering Road Creek flood plain, a potential exists for migration of contaminants into the surface waters of Meandering Road Creek.

Hargis & Montgomery (1983b) drilled monitoring wells HM-5 and HM-9 in the Landfill No. 4 area (Figure 4.3.5-1). Well HM-5 is located within the landfill while HM-9 was drilled adjacent to Meandering Road Creek north of Landfill No. 4. No soil samples from these wells were collected for analysis. Analysis of groundwater samples from HM-5 in 1983 indicated VOC contamination at this site (TCE - 300 $\mu\text{g/L}$, toluene - 290 $\mu\text{g/L}$, chloroform - 457 $\mu\text{g/L}$, benzene - 7 $\mu\text{g/L}$). Groundwater samples collected from HM-9 in 1983 detected TCE - 154 $\mu\text{g/L}$, tetrachloroethane - 21 $\mu\text{g/L}$, toluene - 51 $\mu\text{g/L}$, and ethylbenzene - 4 $\mu\text{g/L}$. On the basis of IRP Phase II investigations (Radian 1987), a "No Further Action" remedial action alternative was recommended. This recommendation is being reconsidered based on the findings of the RI investigation.

4.3.5.2 Current Investigation

Although this site was recommended for no further action, there were insufficient data to support this decision. The decision was based solely on groundwater monitoring data from two monitoring wells, with one (HM-5) being in the upper (upgradient) portion of the landfill and the other (HM-9) being downgradient of the landfill (Figure 4.3.5-1).

The objective of the sampling at Landfill No. 4 was to evaluate whether leachate is flowing from the landfill into the adjacent soils on the flood plain of Meandering Road Creek.

Five soil borings (SB-001, SB-002, SB-003, SB-004, and SB-005) were drilled evenly spaced on top, and along the length of Landfill No. 4, to collect representative soil samples (Figure 4.3.5-1). Soil borings were drilled to bedrock with samples collected at 2-foot intervals (i.e., 2 to 4, 4 to 6, 6 to 8, and 8 to 10 feet below the surface). With the

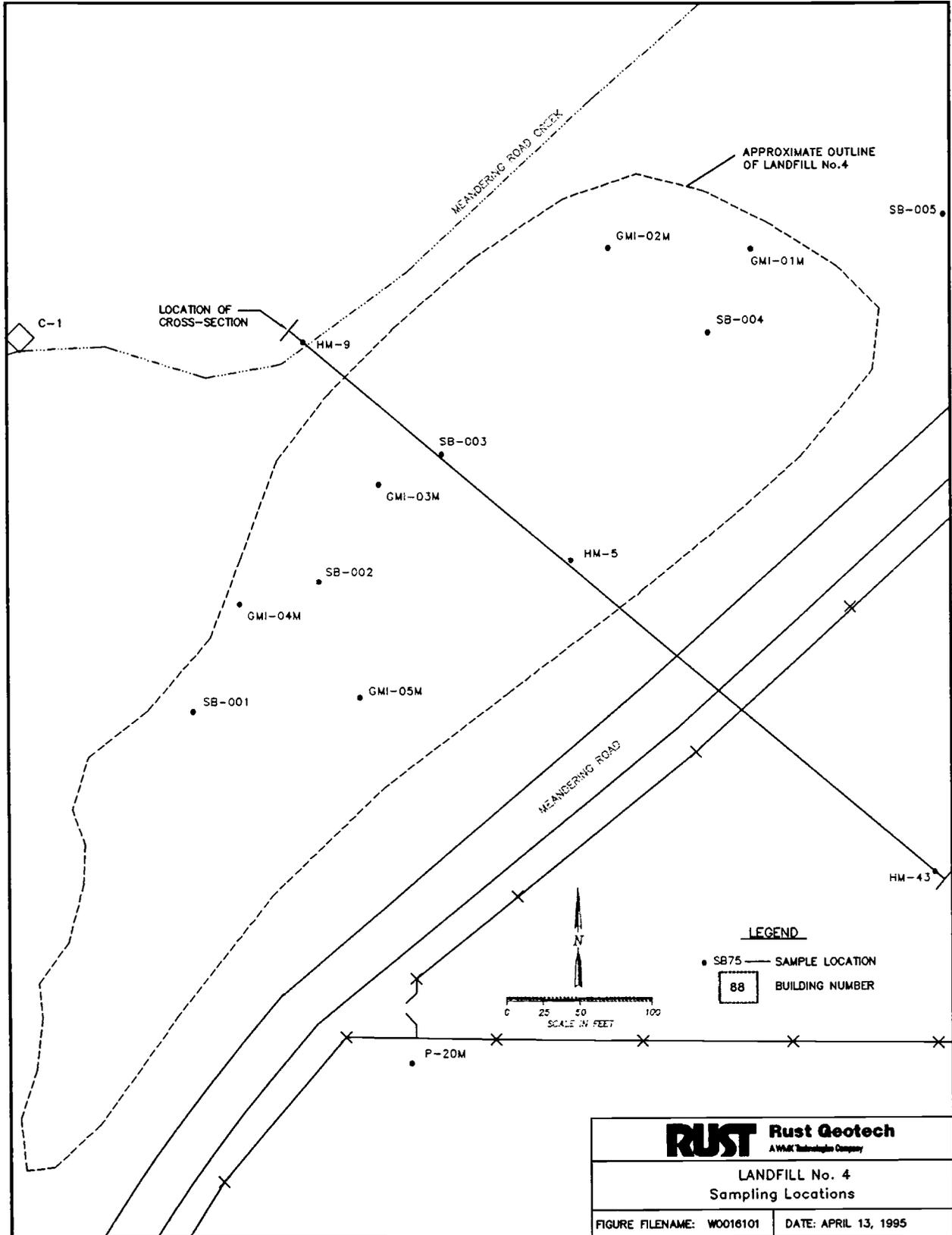


Figure 4.3.5-1. Soil Boring Locations at Landfill No. 4.

exception of the samples for VOCs, each 2-foot interval was composited and analyzed for semi-VOCs, oil and grease, and metals. Samples for VOCs were grab samples from each 2-foot interval and were collected immediately upon opening the split barrel. Lithologic logs were completed while drilling to determine depths of fill materials and to observe any visible contamination.

4.3.5.3 Follow-Up Investigation

Geo-Marine, Inc. drilled five two-inch monitor wells (GMI-01M, -02M, -03M, -04M, and -05M) in July 1994 along the top of Landfill No. 4 for collection of soil and groundwater samples (Figure 4.3.5-1). Each well was continuously cored to bedrock with soil samples collected at approximately 5-foot intervals. Sample depths were chosen on the basis of odor, appearance, and HNu readings. Only one well, GMI-05M, contained enough water to be developed. All samples were analyzed for VOCs, semi-VOCs, oil and grease, total petroleum hydrocarbons, and metals. Soil logs were completed for each well to identify the vertical extent of fill, correlate native soil if any, and characterize the top of bedrock.

4.3.5.4 Summary of Soils Encountered

All five soil borings encountered Goodland Limestone and shale bedrock at total depth with the exception of SB-003 which bottomed out in a white clay. To the south of Landfill No. 4, the Goodland Limestone forms a white escarpment along the north edge of Meandering Road Creek. Subcrop of this steep erosional slope may be seen in Figure 4.3.5-2, which is a cross-section through Landfill No. 4. The cross-section runs southeast to northwest from HM-43, across Meandering Road and Landfill No. 4, to HM-9, located near Meandering Road Creek. Depicted in Figure 4.3.5-2 (vertical exaggeration 10:1) is the structural relief present on the erosional surface of the Goodland Limestone. The interbedded shale and limestone of the Goodland appear to be weathered in the area of Landfill No. 4. Underlying the Goodland is the relatively flat surface of the top of the Walnut Formation.

The unconsolidated overburden consists of fill material dumped in Landfill No. 4 and, in some places, undisturbed Quaternary alluvium. Figure 4.3.5-2 shows the variable thickness of this overburden, which is draped over the erosional scarp of the Goodland Limestone in the subsurface. SB-003 encountered about 17 feet of fill material, 3 feet of dark clay (some silt), and a white plastic clay in the final 4 feet. The section penetrated in SB-001 and SB-002 appears to be entirely fill material (15- to 23-feet thick) that rests directly on limestone bedrock of the Goodland. SB-004 penetrated 12 feet of fill material before passing through one foot of light-brown silty sand resting on bedrock of Goodland Limestone. About 18 feet of fill is present in SB-005, which is underlain by a 3-foot sequence of thinly bedded light-brown and black clays and

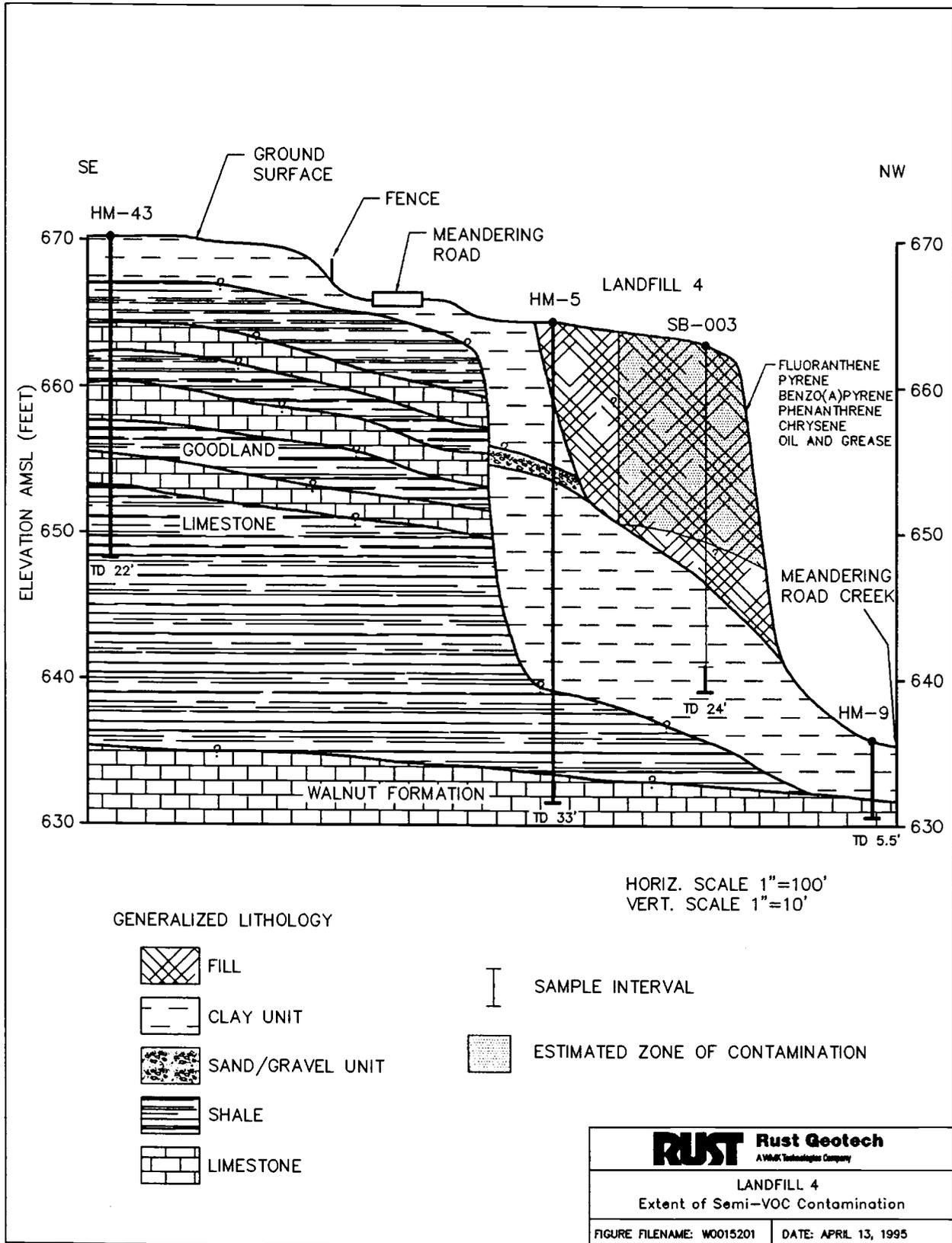


Figure 4.3.5-2. Cross Sectional View Across Landfill No. 4.

limestone bedrock at 21 feet below surface. Composition of the fill material is highly variable, containing a trash mixture of concrete, wood, metal, and organic debris mixed with presumably locally derived clay, silt, sand, and gravel.

4.3.5.5 Results of the Current Investigation

Landfill No. 4 was previously recommended for no further action based on the analytical results of groundwater samples from HM-5 and HM-9. The recent soil sampling and analysis for boreholes SB-001 through SB-005 found contamination of VOCs, semi-VOCs, and metals at the landfill. The data are summarized in Tables 4.3.5-1, 4.3.5-2, and 4.3.5-3. Detailed data are presented in Appendix E.

Table 4.3.5-1 Summary of VOC and Oil and Grease Analytical Results for Soil Samples Obtained from Landfill No. 4

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
Acetone	(10)	89	42	20
2-Butanone	(10)	20	42	4
Tetrachloroethene	(5)	12	42	3
Trichloroethene	(5)	27	42	6
Oil and Grease	11 mg/kg	6,020 mg/kg	32	19

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Trichloroethene was identified in the Risk Assessment as a chemical of concern.

Numerous VOCs and semi-VOCs were detected in soils from SB-001 and SB-003 (see Table 4.3.5-1 and Table 4.3.5-2). TCE was found in SB-001 at sample depths of 4 feet to 14 feet, with a maximum concentration of 27 µg/kg. Numerous additional contaminants are present in soils from SB-001 and include fluoranthene, pyrene, benzo(a)pyrene, phenanthrene, chrysene, benzo(a)anthracene, bis(2-ethylhexyl)phthalate, and oil and grease. Soils from SB-003 were found to contain the same suite of semi-VOCs as reported in SB-001. Significant concentrations of these semi-VOCs were found in SB-003 from 4 feet below surface to 12.5 feet (see Figure 4.3.5-2). The organic contaminant distribution is illustrated in Figure 4.3.5-3.

**Table 4.3.5-2 Summary of Semi-VOC Analytical Results
for Soil Samples Obtained from Landfill No. 4**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
Acenaphthene	(710)	1,200	70	2
Acenaphthylene	(710)	800	70	1
Anthracene	(710)	3,700	70	3
Benzo(a)anthracene	(710)	8,800	69	8
Benzo(a)pyrene	(710)	7,200	70	8
Benzo(b)fluoranthene	(710)	8,600	70	8
Benzo(g,h,i)perylene	(710)	7,000	70	6
Benzo(k)fluoranthene	(710)	5,100	70	7
bis(2-ethylhexyl)phthalate	(710)	6,000	70	8
Chrysene	(710)	9,300	70	8
Dibenz(a,h)anthracene	(710)	1,600	70	1
Dibenzofuran	(710)	1,100	70	1
Fluoranthene	(710)	12,000	70	9
Fluorene	(710)	1,500	70	2
Indeno(1,2,3-cd)pyrene	(710)	4,100	70	5
Naphthalene	(710)	1,200	70	1
Phenanthrene	(710)	11,000	70	7
Pyrene	(710)	7,600	70	8

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Pyrene, benzo(a)pyrene, naphthalene, and fluoranthene were identified in the Risk Assessment as chemicals of concern.

Anomalously high concentrations of all five metals of concern were found in the analyses of soil from SB-001 (see Table 4.3.5-3 and Appendix E). Zinc was detected at more than 60 times the upper range for background soils of the western United States in the soil sample from 6 to 8 feet. Cadmium (31 times), chromium (16 times), and copper (19 times) all exceeded background in soils from SB-001. The depth range of metals contamination in SB-001 is 4 to 14 feet. Lead and silver also were significantly higher than western United States soils. Above-background concentrations of metals were also present in the top 4 feet of fill in SB-002 (see Appendix E). The extent of metals contamination is shown in Figure 4.3.5-4.

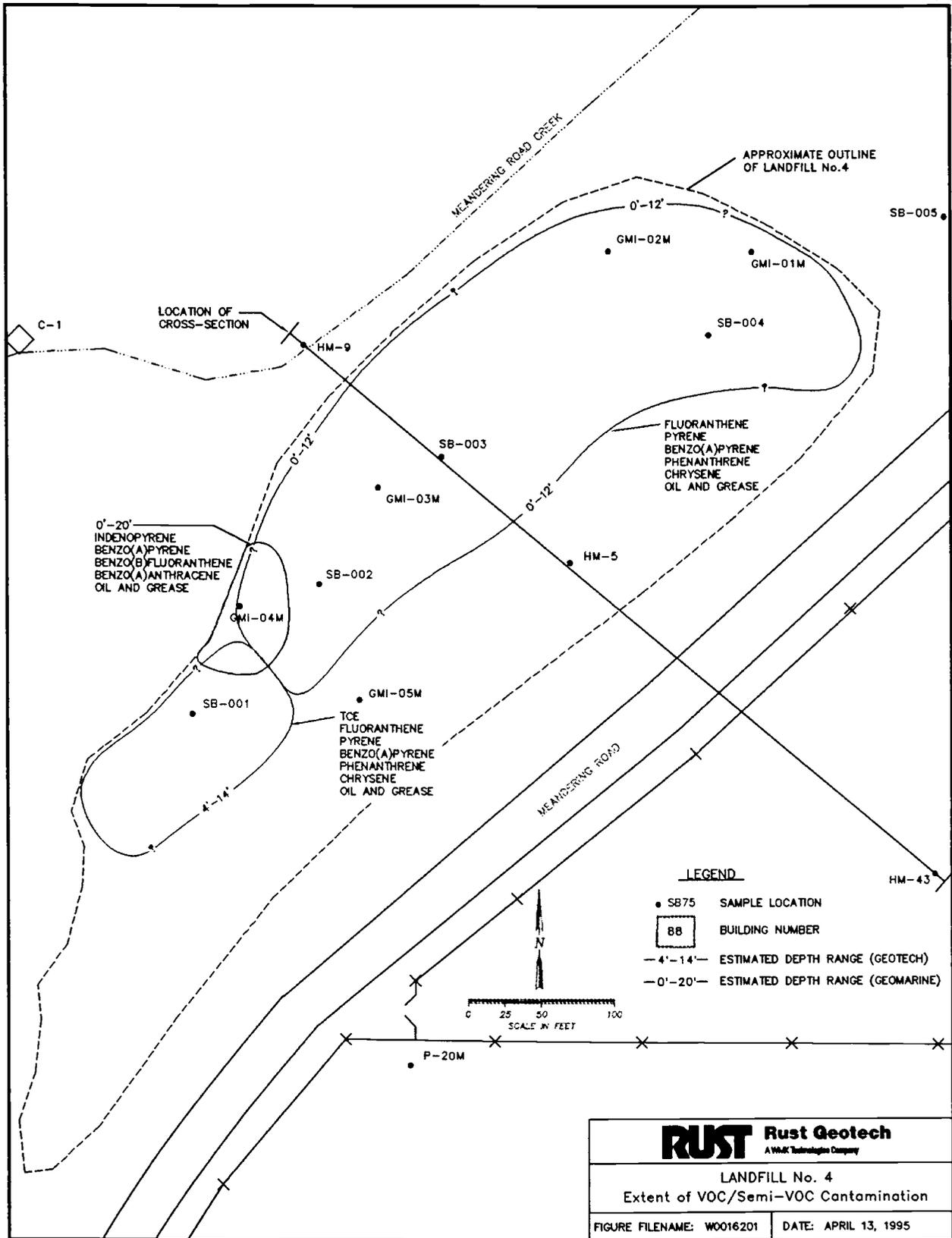


Figure 4.3.5-3. Extent of VOCs and Semi-VOCs Detected at Landfill No. 4.

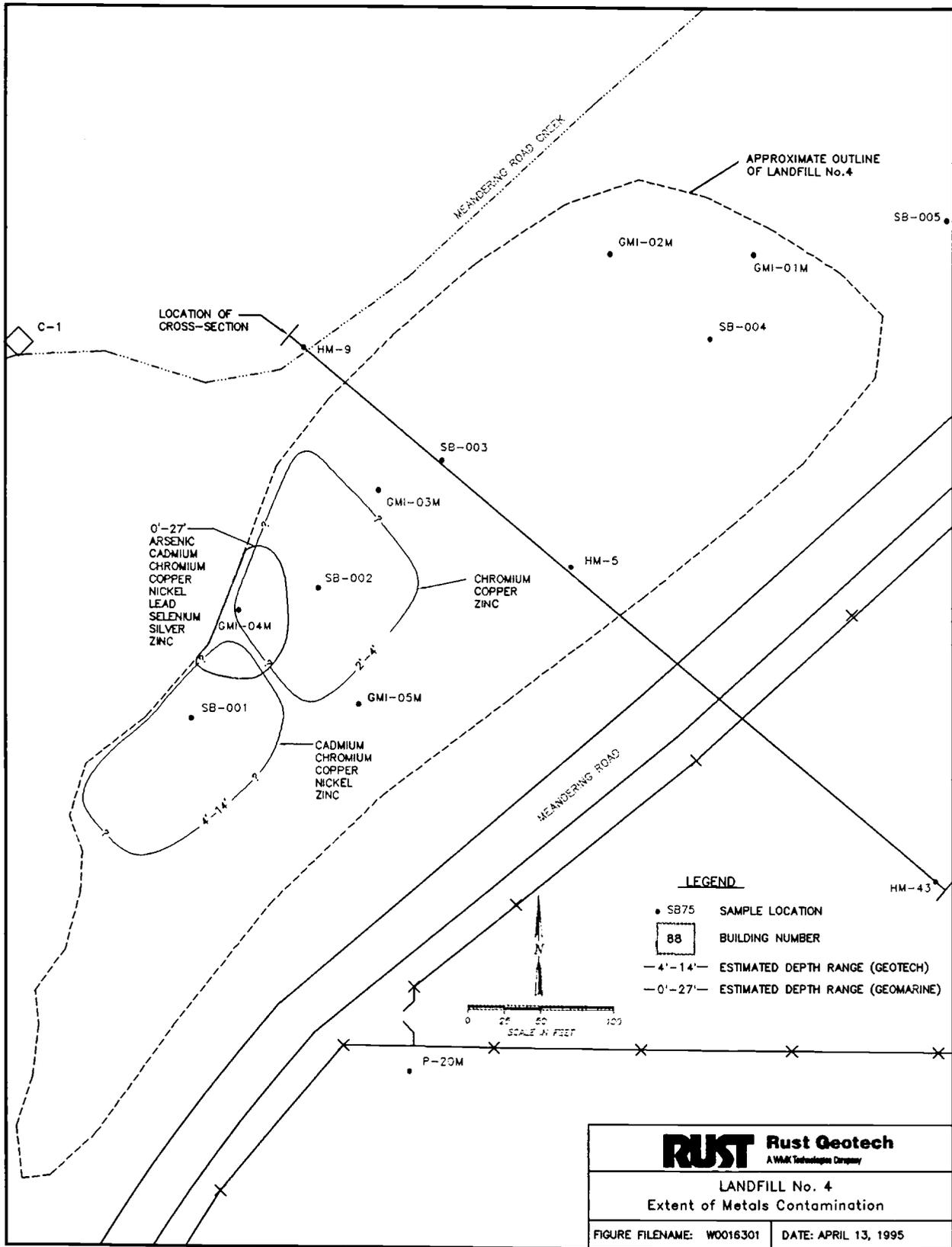


Figure 4.3.5-4. Extent of Metals Detected at Landfill No. 4.

**Table 4.3.5-3 Summary of Inorganic Analytical Results
for Soil Samples Obtained from Landfill No. 4**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background ⁴ Limit mg/kg	No. of Samples Analyzed	No. Above Upper Background for the Western USA ⁴
Antimony	(8)	(11)	2.2	32	1
Arsenic	2.4	12.4	21.6	32	0
Beryllium	(0.23)	1.1	3.6	32	0
Cadmium	(0.8)	87.3	2.8 ⁵	32	8
Chromium	5.5	3,170	196.6	32	4
Copper	3.2B	1,690	90.0	32	5
Lead	4.3	1,560	55.1	32	9
Nickel	5.5B	202	66.2	32	4
Selenium	(0.4)	(4.8)	1.4	32	0
Silver	(0.8)	21.4	1.4 ⁵	32	6
Thallium	(0.4)	(0.55)	0.8 ⁵	32	0
Zinc	10	12,200	176.2	32	6

- Notes:
- 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 - 2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
 - 3) Cadmium, chromium, copper, nickel, and zinc were identified in the Baseline Risk Assessment as chemicals of concern.
 - 4) Upper background from range in Soils of Western USA, Shacklette and Boeringer, 1984.
 - 5) Limit is estimated from the four Plant 4 background samples.

4.3.5.6 Results of Follow-Up Investigation

Analytical results from the Geo-Marine investigation indicate contamination of VOCs, semi-VOCs, oil and grease, metals, and total petroleum hydrocarbons at all locations. Data are summarized in Tables 4.3.5-4, 4.3.5-5, and 4.3.5-6. Detailed data are presented in Appendix E.

Results for VOC and semi-VOC analyses indicate soils from GMI-04M are the most contaminated. Soils from GMI-04M had concentrations above detection limits for 14 semi-VOC and four VOC analytes. Maximum concentrations for phenanthrene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, and benzo(a)pyrene were detected in GMI-04M. Fluorene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, benzo(g,h,i)perylene and 2-butanone were detected only in GMI-04M. Acetone and methylene chloride were detected in all samples. Oil and grease were detected in every well, but not in all samples from each well.

Table 4.3.5-4 Summary of VOC and Oil and Grease Analytical Results for Geo-Marine Soil Samples

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed
Acetone	1,100	32,000	25
2-Butanone	(1,000)	3,800	25
Carbon Disulfide	(500)	1,400	25
Chloroethane	(500)	540	25
Chloromethane	500	2,700	25
Methylene Chloride	2,600	12,000	25
Oil and Grease	(10) mg/kg	1,100 mg/kg	25

Notes: 1) Concentrations in parentheses indicate the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.

Table 4.3.5-5 Summary of Semi-VOC Analytical Results for Geo-Marine Soil Samples

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed
Anthracene	(330)	540	25
Benzo(a)anthracene	(330)	12,000	25
Benzo(a)pyrene	(330)	13,000	25
Benzo(b)fluoranthene	(330)	21,000	25
Benzo(g,h,i)perylene	(330)	4,800	25
Benzo(k)fluoranthene	(330)	10,000	25
bis(2-ethylhexyl)phthalate	(330)	15,000	25
Chrysene	(330)	14,000	25
Din-n-butylphthalate	(330)	750	25
Dibenz(a,h)anthracene	(330)	460	25
Fluoranthene	(330)	21,000	25
Fluorene	290	(330)	25
Indeno(1,2,3-cd)pyrene	(330)	5,200	25
Phenanthrene	(330)	12,000	25
Pyrene	(330)	33,000	25

Notes: 1) Concentrations in parentheses indicate the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
3) Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene were identified in the Risk Assessment as chemicals of concern.

**Table 4.3.5-6 Summary of Inorganic Analytical Results
for Geo-Marine Soil Samples**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background Limit ³ mg/kg	No. of Samples Analyzed
Antimony	1.2	40	2.2	25
Arsenic	5.9	170	21.6	25
Cadmium	(1.0)	160	2.8	25
Chromium	5.1	570	196.6	25
Copper	(1.0)	3,200	90.0	25
Cyanide	(1.0)	1.6	NA ⁴	25
Lead	2.1	460	55.1	25
Nickel	2.7	260	66.2	25
Selenium	(1.0)	38	1.4	25
Silver	(0.5)	10	1.4	25
Zinc	4.6	4,200	176.2	25

- Notes: 1) Concentrations in parentheses indicate the compound was not detected at the reported value.
 2) Cadmium, chromium, copper, lead, nickel, and zinc were identified in the Risk Assessment as chemicals of concern.
 3) Upper background from range in Soils of Western USA, Shacklette and Boermgen, 1984.
 4) Not Available.

Maximum concentrations for all metals detected were from GMI-04M soils (see Table 4.3.5-6 and Appendix E). Three of the five chemicals of concern (cadmium, copper, and zinc) had anomalously high concentrations in the soils from GMI-04M. Cadmium was detected at more than 50 times the upper range for background soils of the Western USA in the 0-5 foot sample. Copper (36 times), selenium (28 times), and zinc (24 times) all exceeded background in soils from GMI-04M.

Soils from the four other Geo-Marine wells also contained concentrations greater than background for antimony and arsenic. Chromium was not detected above background at any of the other wells. Zinc, copper, and cadmium were detected at concentrations greater than background at all locations except GMI-05M. Cyanide was detected only at GMI-04M. Silver and lead also were detected at GMI-01M and GMI-02M in concentrations greater than background. Well GMI-03M was the only location to exceed the background concentration for nickel. Selenium was detected at GMI-02M in concentrations greater than background. Figure 4.3.5-4 presents extent of metals contamination. The estimated extent for Geo-Marine data has been outlined separately because the analytical data could not be validated by Geotech.

4.3.5.7 Conclusions

Current Investigation

The heterogenous composition of Landfill No. 4 makes characterization of the soil contamination difficult. Figures 4.3.5-3 and 4.3.5-4 show the interpreted extent of significant contamination for VOCs and semi-VOCs, and metals, respectively. Horizontal limits of contamination were constrained by distances to adjacent boreholes and by the landfill boundaries. Vertical extent of contamination determinations were complicated by poor sample recovery caused by concrete rubble, boulders, or trash in the landfill. In borehole intervals with no recovery, contamination was assumed if adjacent samples were contaminated. Significant concentrations of contaminants of concern are present in SB-001, SB-002, and SB-003. This evidence proves that other wastes in addition to construction rubble were deposited in Landfill No. 4.

The volume of contaminated material was estimated using the areal extent of the envelopes shown in Figures 4.3.5-3 and 4.3.5-4 and thickness of contamination (depth range). The estimated volume of VOC and semi-VOC contamination is approximately 32,000 cubic yards. Metals contamination was found in SB-001 (same area and volume as calculated for VOCs and semi-VOCs) and SB-002. The estimated volume of metals contaminated soil is 5,300 cubic yards, which is included in the volume of VOC contamination. The combined total volume of soil contaminated with VOCs, semi-VOCs, and metals for Landfill No. 4 is 32,000 cubic yards.

The most significant contamination at Landfill No. 4 is lead, benzo(a)pyrene, benzo(b)fluoranthene, and benzo(a)anthracene. The probability of migration of contaminants into the groundwater system or the surface waters of Meandering Road Creek has not been determined.

Follow-Up Investigation

The Geo-Marine data could not be validated because only a portion of the quality control data was available. This data indicated results were not within prescribed limits for quality control parameters for both metals and organic analyses. Nevertheless, areas of contamination and contaminants were substantially consistent with previous investigations, although contaminants were found deeper than previously reported. At GMI-04M, both organics and metals concentrations were elevated at 20 feet. The most significant contamination is lead and polynuclear aromatic hydrocarbons.

4.3.6 Fire Department Training Area No. 2 (FDTA-2)

4.3.6.1 *Summary of Previous Investigations*

FDTA-2 was a 50-foot-diameter earthen ring located north of Landfill No. 1 (Figure 4.3.6-1) in the west parking lot. This site was used for fire training exercises from 1955 to 1956. Exercises were held twice a year with approximately 250 gallons of waste oils and fuels used for each exercise. It is suspected that disposal of oils and fuels and uncontrolled burns may have been more frequent (CH2M Hill 1984). The site is currently located under the pavement of the west parking lot.

Hargis + Associates (1985a) drilled monitoring wells HM-49, HM-51, HM-65, HM-66, and HM-76 near the suspected location of FDTA-2 (see Figure 4.3.6-1). Well HM-51 is believed to be located within FDTA-2 based on chemical analyses of groundwater samples. Hargis + Associates believes lateral contaminant migration from FDTA-2 would be limited by the low hydraulic conductivity of sediments encountered at the site.

One test boring (FB-7) and one monitoring well (F-213) were installed by Intellus during a 1986 field investigation. Analysis of soil samples from both drill holes detected total petroleum hydrocarbons (200 mg/kg) from the 3- to 3.5-foot depth, but none were detected in the lower soil sample (7.5 feet to 8 feet). VOCs were not detected in soils from F-213 or FB-7. Soil samples were not analyzed for metals. The Intellus study revealed shallow soil contamination (3 feet to 4 feet) surrounding HM-51. Intellus estimated the volume of contaminated soil to range from 3,500 to 4,500 cubic yards.

Radian performed a terrain conductivity survey in 1985 to determine the presence and configuration of FDTA-2. The geophysical survey detected an anomalous zone in the general area of the site that is interpreted to reflect shallow soil contamination and/or a chemical reaction between contamination and subsurface materials (Radian 1987).

Previous investigations found soil contaminated with petroleum hydrocarbons in soil boring FB-7 and monitoring well F-213. Groundwater contamination in HM-51 may be from the disposal of oils and fuels in FDTA-2.

4.3.6.2 *Current Investigation*

Four soil borings (SB-68 to SB-71) were drilled surrounding monitoring well HM-51, which is located near what is believed to be the approximate center of FDTA-2 (see Figure 4.3.6-1). The borings were located 25 feet north, south, east, and west of existing well HM-51. Soil samples were collected from the borings to determine the vertical extent of contamination and provide preliminary information on the horizontal extent of contamination. The soil samples were collected from the surface to bedrock in 2-foot intervals. Grab samples for VOCs were collected from each interval, and the remaining

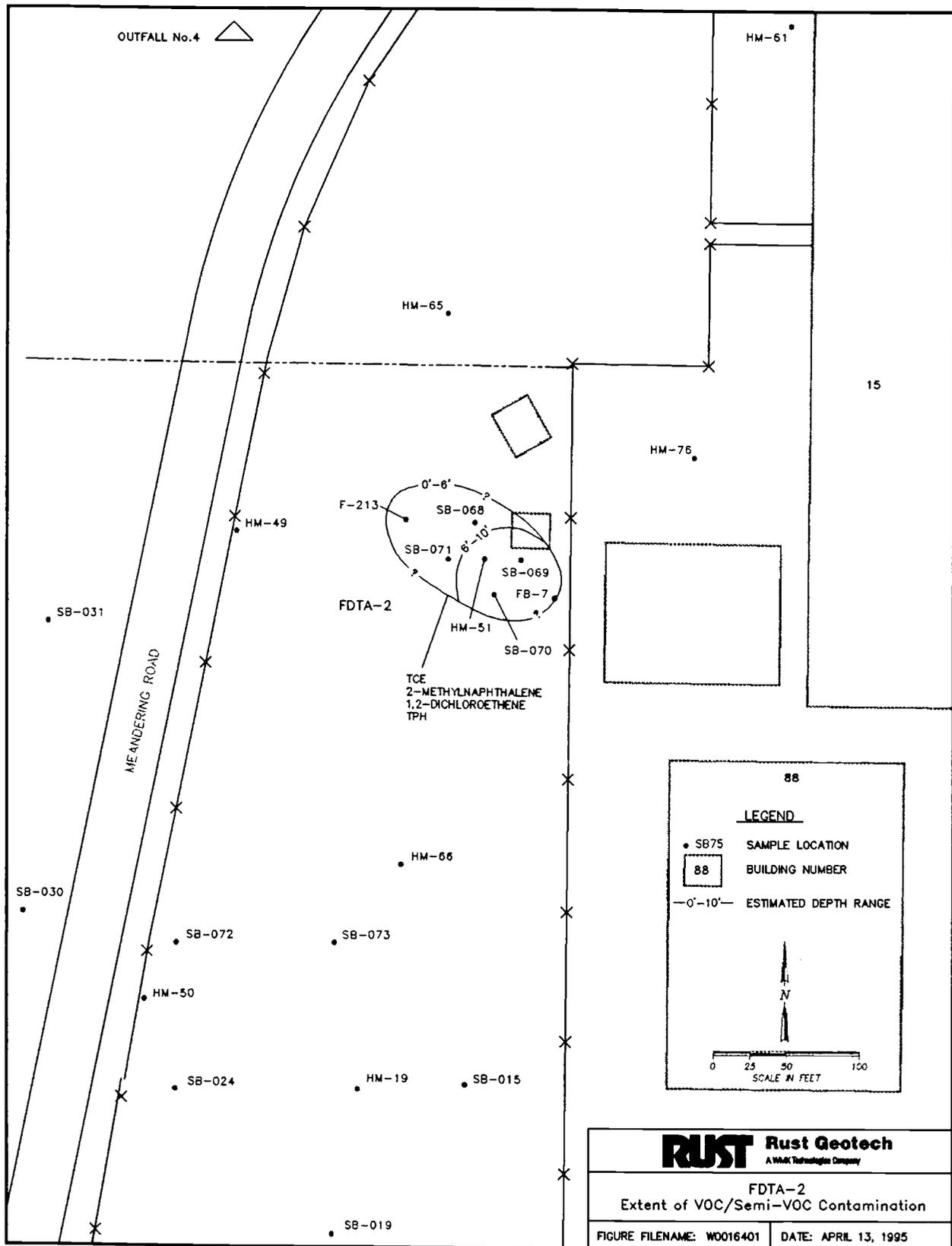


Figure 4.3.6-1. Extent of VOCs, Semi-VOCs, and TPH Detected at FDTA-2.

material was composited and analyzed for semi-VOCs, petroleum hydrocarbons, and metals. Lithology logs were completed to determine any visual contamination and examine the depth of any excavations. Groundwater samples were to be collected from inside the hollow stem augers following soil sampling, however, there was no water in the borings at the time of drilling. Each soil boring was left open for several hours and, in at least one case, overnight to allow water to accumulate, but no measurable water was evident.

In a variance from the *Sampling and Analysis Plan*, four additional soil borings that were to have been drilled outward from the initial soil borings when contamination was detected, were not drilled. In the vadose zone, contamination associated with a fire training area will be very localized and tend to migrate vertically downward to the water table. TPH contamination was detected in the shallow soils at FDTA-2 and below 2 feet only in relatively low concentrations (less than 100 mg/kg) except for SB-069 where the TPH concentrations dropped below the detection limit at 2 feet and remained low until 10 to 12 feet where the TPH level rose to 234 mg/kg. This is believed to indicate the presence of groundwater contamination that may not be associated with FDTA-2 but may come from the abandoned JP-4 pipeline south of this site. Additional borings were not drilled because they would have been too far from FDTA-2 to detect the localized contamination. Additionally, nearby downgradient monitoring wells did not indicate elevated levels of contamination related to a fire training area.

4.3.6.3 Summary of Soils

Soil borings SB-068, SB-069, SB-070, SB-071 were drilled to bedrock with a hollow stem auger to depths of 10 feet, 12 feet, 12 feet, and 11 feet below surface, respectively. Borehole information and lithologic descriptions are contained on the borehole logsheets (see Appendix A-2).

Underneath a thin asphalt cover, each borehole encountered 2 feet to 3.5 feet of black, organic-rich clayey-silt and clayey-sand. The remainder of Quaternary alluvium consists primarily of olive to yellowish-brown silty clay (sandy in part) with some thin interbeds of limestone and limestone gravels. Light gray limestone and shale bedrock of the Walnut Formation was reached at 10 to 11 feet below surface in the four boreholes. HM-51, reportedly drilled in the center of FDTA-2, encountered the Walnut Formation at 12 feet below surface.

4.3.6.4 Results of the Investigation

Analyses of the Geotech soil samples detected VOCs, semi-VOCs, TPH, and metals (see Table 4.3.6-1, Table 4.3.6-2, Table 4.3.6-3, and Appendix E).

Analysis of the shallow sample (0 feet to 2 feet) from SB-069 detected 1,300 $\mu\text{g}/\text{kg}$ of 2-methylnaphthalene, a common JP-4 compound (see Table 4.3.6-2). Total petroleum

hydrocarbons were detected at shallow depths in all four boreholes as well as FB-7 and F-213. The maximum concentration of petroleum hydrocarbons is 917 mg/kg (see Table 4.3.6-1). Hydrocarbons were also detected at 8 feet to 10 feet in SB-069. This isolated detection at depth may be attributed to groundwater contamination. Average depth to the water table is about 6 feet in the FDTA-2 area. TCE (20 µg/kg) was found in the upper 2 feet of SB-70. Figure 4.3.6-1 shows the extent of contamination of VOCs, semi-VOCs, and hydrocarbons.

Table 4.3.6-1 Summary of VOC and TPH Analytical Results for Soil Samples Obtained from FDTA-2

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
4-Methyl-2-pentanone	(11)	16	24	1
1,2-Dichloroethene	(6)	9	24	2
Acetone	(11)	210	24	12
2-Butanone	(11)	140	24	10
Trichloroethene	(6)	20	24	1
Total Petroleum Hydrocarbons	(10) mg/kg	917 mg/kg	23	13

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Trichloroethene was identified in the Baseline Risk Assessment as a chemical of concern.

Table 4.3.6-2 Summary of Semi-VOC Analytical Results for Soil Samples Obtained from FDTA-2

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
2-Methylnaphthalene	(750)	1300	29	2

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.

The concentration of all metals of concern was significantly more than background in the first 2 feet of soil in SB-068 (Table 4.3.6-3). The maximum level for copper was more than 90 times the upper background range for soil of the western United States in the shallow soil sample from SB-068. Other metals of concern were elevated 3 to 25 times background in this borehole. Silver, lead, and antimony were also elevated in one or two boreholes. The areal extent of metals contamination defined by SB-068 is illustrated in Figure 4.3.6-2.

4.3.6-3 Summary of Inorganic Analytical Results for Soil Samples Obtained from FDTA-2

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background ⁴ mg/kg	No. of Samples Analyzed	No. Above Upper Background Limit for Western USA ⁴
Antimony	(9.1)	14.8	2.2	23	1
Arsenic	1.6B	13.3	21.6	23	0
Beryllium	0.3B	1.5	3.6	23	0
Cadmium	(0.92)	69.8	2.8	23	4
Chromium	8.8	549	196.6	23	1
Copper	(1.8)	8060	90.0	23	1
Lead	3.2	84.6	55.1	23	2
Nickel	(5.7)	413	66.2	23	1
Selenium	(0.46)	(2.3)	1.4	23	0
Silver	(0.91)	8.7	1.4	23	1
Thallium	(0.46)	0.6B	0.8	23	0
Zinc	5.4	2060	176.2	23	1

- Notes:
- 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 - 2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
 - 3) Cadmium, chromium, copper, nickel, and zinc were identified in the Base Risk Assessment as chemicals of concern.
 - 4) Upper background from range in Soils of Western USA, Shacklette and Boerngen, 1984.

4.3.6.5 Conclusions

Analyses of soils from the recently drilled boreholes confirmed the presence of petroleum hydrocarbons at shallow depths in all four boreholes. TCE was detected in the 0- to 2-foot interval in SB-070 and 2-methylnaphthalene was found in soil from the surface interval in SB-069. The areal extent of VOCs, semi-VOCs, and hydrocarbon contamination is shown in Figure 4.3.6-1. The estimated volume of soil contaminated with organics was computed using the product of the area and thickness, and equals 1,350 cubic yards.

The shallow sample from SB-068 contained high levels of metals of concern. About 90 cubic yards of soil contaminated with metals is estimated to surround borehole SB-068.

4.3.7 Fire Department Training Area No. 5 (FDTA-5)

4.3.7.1 Summary of Previous Investigations

FDTA-5, located near the Die Yard area south of Facilities Building No. 12 (Figure 4.3.7-1), consisted of a shallow pit about 35 feet by 45 feet in size, which received waste fuels, oils, and unspecified chemicals that were burned for fire extinguisher training exercises during the mid-1960s. It has since been graded and paved.

In 1983, Hargis + Associates drilled monitoring well HM-25 in the vicinity of FDTA-5 (Figure 4.3.7-1). No analyses for soil samples were reported for this well. Laboratory analyses of groundwater samples from HM-25 indicate the presence of benzene, chlorobenzene, ethylbenzene, trichloroethene, *trans*-1,2-dichloroethene, dichlorobenzenes, oil and grease, and fuel hydrocarbons. Results of chemical analyses and water elevation data suggest that upper-zone groundwater contamination at HM-25 is primarily the result of historic waste disposal practices at FDTA-5, with possible contribution from the Die Yard Chemical Pits (Hargis + Associates 1985a).

Intellus (1986) installed monitoring well F-221 adjacent to FDTA-5 (Figure 4.3.7-1). Field organic vapor readings indicate levels of VOCs from 1 to 5 ppm in the soils from the surface to a depth of 11 feet. From a depth of 11 to 19 feet readings indicate levels 1 to 70 ppm of VOCs. Laboratory analyses of the soils did not indicate any VOCs or TPH. Trace metals were found at levels typical of native soils (Intellus 1986). Laboratory analysis of the water sample from F-221 did not detect the presence of any volatiles. A concentration of 103 ppm of TPH was found in the water sample.

Soil boring SB-5 was drilled by Radian in 1986, east of FDTA-5 (Figure 4.3.7-1). Based on color, odor, and organic vapor readings, selected soil samples were submitted for laboratory analyses. No significant concentrations of contaminants in the soil samples were found by the analyses. However, analyses of groundwater samples from monitoring wells in the area indicate the presence of trace metals and organic contaminants in excess of Federal MCL criteria.

Analytical results from soil samples collected from F-221 and SB-5 indicate that the shallow soils do not contain significant concentrations of contaminants. Groundwater samples, however, contained concentrations of VOCs, semi-VOCs, and fuel related hydrocarbons.

4.3.7.2 Current Investigation

Five soil borings (SB-064, SB-065, SB-066, SB-067, and SB-078) were drilled at FDTA-5 to help define the lateral extent of soil contamination. The soil borings are located 50 feet northeast, northwest, southeast, and southwest of monitoring well HM-25, which is located near the reported center of the training area (Figure 4.3.7-1).

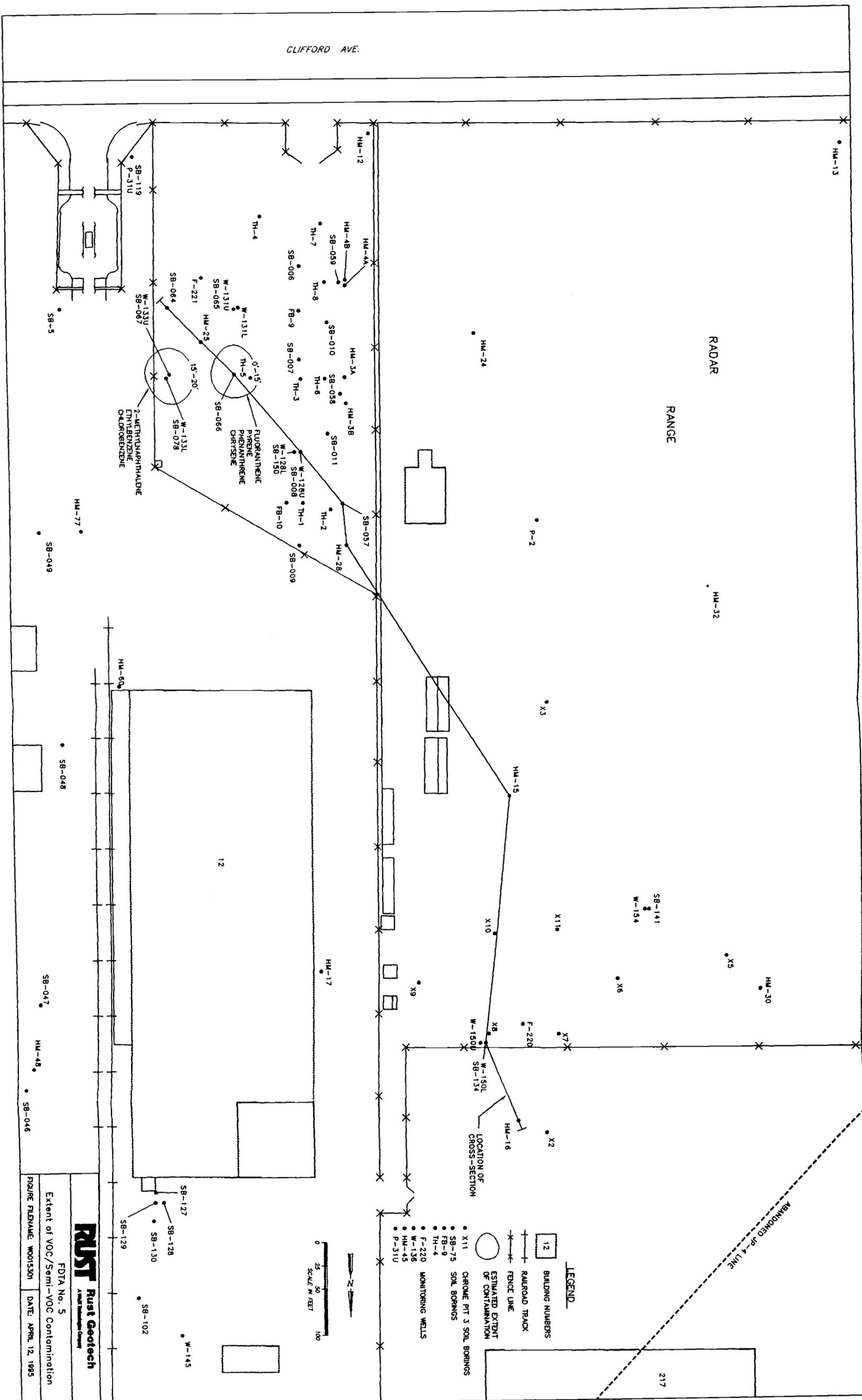


Figure 4.3.7-1. Extent of VOCs and Semi-VOCs Detected at FDTA No. 5.

The borings were drilled to the water table or bedrock, and soil samples were collected in 5-foot intervals. Samples for VOC analysis were grab samples taken from each 5-foot interval. The remaining samples were composite samples representing the entire 5-foot interval. The composite samples were analyzed for semi-VOCs, oil and grease, and metals.

4.3.7.3 Summary of Soils Encountered

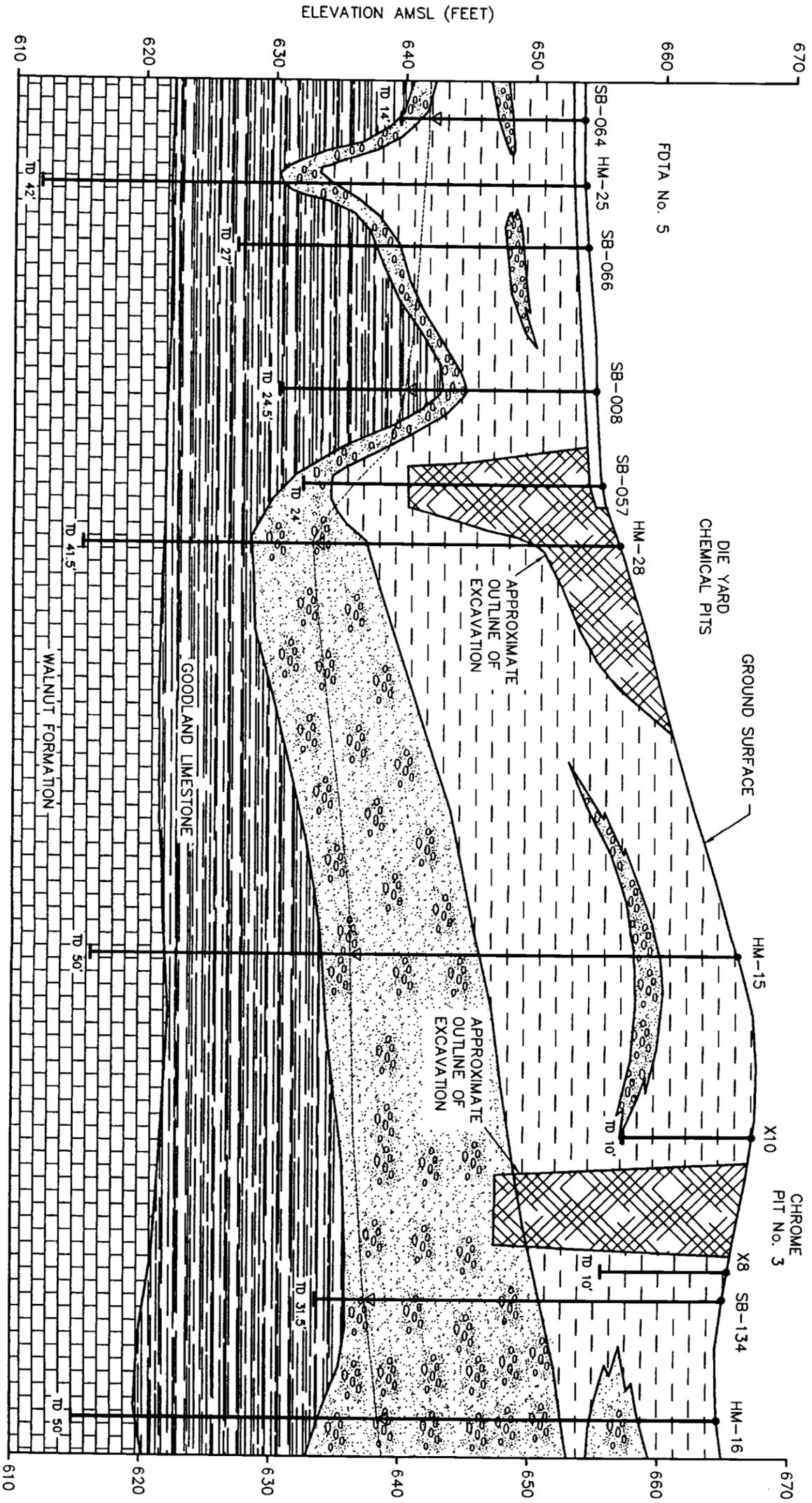
The five soil borings penetrated a variable thickness of concrete and fill material followed by 12 to 15 feet of silty clay with some thin interbeds of sand and limestone gravel. The coarser grained basal sequence consists of sand and gravel units interbedded with some clay stringers with a total thickness of 1 to 4 feet in the FDTA-5 area. Calcareous shale bedrock (Goodland Limestone) was found in SB-066 and SB-078 at depths of 15 and 25 feet, respectively. Detailed lithologies and well summary information may be found on the Borehole Lithologic Log Sheets (see Appendix A-2).

Figure 4.3.7-2 depicts the generalized subsurface geology interpreted for the subsurface of the FDTA-5, Die Yard, and Chrome Pit No. 3 areas. FDTA-5 is located at the southeast end of the cross section and appears to be situated in a saddle between two bedrock highs composed of limestone and shale of the Goodland Limestone. A basal sequence of sand and gravel thins over the bedrock high to the northeast. Figure 4.3.7-3 is a structure contour map of competent bedrock that shows the configuration of these bedrock highs. An interpretation of the subcrop pattern of the Goodland Limestone and Walnut Formation is also presented in Figure 4.3.7-3.

4.3.7.4 Results of the Investigation

Laboratory analysis of the soil samples revealed the presence of three semi-VOC chemicals of concern (see Table 4.3.7-1 and Appendix E). Fluoranthene (2,000 $\mu\text{g}/\text{kg}$) and pyrene (1,600 $\mu\text{g}/\text{kg}$) were found in the upper 5 feet of SB-066, and 2-methylnaphthalene (1,900 to 2,000 $\mu\text{g}/\text{kg}$) was detected in the 18- to 20-foot and 15- to 20-foot intervals of SB-067 and SB-078, respectively.

A summary of laboratory results for analysis of VOCs and oil and grease is included in Table 4.3.7-2. Ethylbenzene, 92 $\mu\text{g}/\text{kg}$, was detected in the 18- to 20-foot interval of SB-067 and 69 $\mu\text{g}/\text{kg}$ in the 15- to 20-foot interval of SB-078. Chlorobenzene (80 $\mu\text{g}/\text{kg}$) was also found in SB-067 while oil and grease (154 mg/kg) were present in the corresponding interval of SB-078. The interpreted areal distribution of VOC/semi-VOC contaminants is shown in Figure 4.3.7-1.



HORIZ. SCALE 1"=100'
 VERT. SCALE 1"=10'

RUST Rust Geotech
A Rust Technology Company

FDIA No. 5
 Geologic Cross Section

FIGURE FILENAME: W0015401 DATE: APRIL 13, 1995

Figure 4.3.7-2. Cross Section of Generalized Subsurface Geology at FDTA No. 5.



Figure 4.3.7-3. Structure Contour Map Showing Subcrop of Competent Bedrock at FDTA No. 5.

**Table 4.3.7-1 Summary of Semi-VOC Analytical Results
for Soil Samples Obtained from FDTA-5**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
2-Methylnaphthalene	(730)	2,000	20	2
Benzo(b)fluoranthene	(730)	920	20	1
Bis(2-ethylhexyl)phthalate	(730)	1,300	20	2
Chrysene	(730)	940	20	1
Fluoranthene	(730)	2,000	20	2
Phenanthrene	(730)	1,600	20	1
Pyrene	(730)	1,600	20	1

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Pyrene, fluoranthene, and 2-methylnaphthalene were identified in the Baseline Risk Assessment as chemicals of concern.

**Table 4.3.7-2 Summary of VOC and Oil and Grease Analytical Results
for Soil Samples Obtained from FDTA-5**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
2-Butanone	(11)	47	19	3
Acetone	(12)	930	19	17
Chlorobenzene	(5)	80	19	1
Ethylbenzene	(5)	140	19	3
Oil and Grease	(10) (mg/kg)	154 (mg/kg)	19	3

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.

Concentrations of metals in the FDTA-5 samples were found to be within the range for background soils for the western United States (see Table 4.3.7-3).

4.3.7.5 TCLP Analytical Results

The EPA Toxicity Characteristic Leaching Procedure (TCLP) was used for analysis of VOCs, semi-VOCs, and inorganic constituents for sample SB-067-04, obtained 18 to 20 feet below ground level. Analysis of the liquid TCLP extract indicated that barium, at

**Table 4.3.7-3 Summary of Inorganic Analytical Results
for Soil Samples Obtained From FDTA-5**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background (mg/kg)	No. of Samples Analyzed	No. Above Upper Background Limit for Western USA
Antimony	(8.8)	(9.9)	2.2	19	0
Arsenic	2.5	8.7	21.6	19	0
Beryllium	0.36B	0.69B	3.6	19	0
Cadmium	(0.88)	2	2.8	19	0
Chromium	6.3	33.3	196.6	19	0
Copper	4.7B	8.5	90.0	19	0
Lead	4.5	15.4	55.1	19	0
Nickel	(5.5)	14.2	66.2	19	0
Selenium	(0.46)	(2.2)	1.4	19	0
Silver	(0.88)	(0.99)	1.4	19	0
Thallium	(0.44)	(0.49)	0.8	19	0
Zinc	11.6	28.5	176.2	19	0

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
 3) Cadmium, chromium, copper, nickel, and zinc were identified in the Baseline Risk Assessment as chemicals of concern.

a concentration of 538B $\mu\text{g/L}$, was the only inorganic analyte detected. This value is below the 100,000 $\mu\text{g/L}$ regulatory level. VOCs or semi-VOCs were not detected in the sample.

4.3.7.6 Conclusions

Laboratory analyses of the soil samples from the FDTA-5 area indicate the presence of semi-VOCs and VOCs. The shallow contamination in SB-066 of fluoranthene and pyrene is likely the result of fire training activities at FDTA-5 or possibly asphalt related. The chemicals 2-methylnaphthalene and ethylbenzene, found in SB-067 and SB-078, are common JP-4 compounds that may have migrated vertically from FDTA-5. The sample depth interval of 15 to 20 feet is close to the water table depth of 23 feet that was encountered in SB-078. It is possible that this deeper contamination is related to groundwater.

The estimated extent of contamination is shown in Figure 4.3.7-1. The volume of contaminated material was estimated by using the areal extent and the thickness of contamination (depth range). A total volume of approximately 900 cubic yards is estimated for the two areas sampled by SB-066, SB-067, and SB-078.

4.3.8 Fire Department Training Area No. 6 (FDTA-6)

4.3.8.1 Summary of Previous Investigations

FDTA-6 was the primary fire department training area at Plant 4 from the late 1960s to 1980 (CH2M Hill 1984). It was located on the northwestern side of Plant 4 adjacent to Meandering Road and Lake Worth (Figure 4.3.8-1). FDTA-6 consisted of a 50-foot square gravel-lined ring that was approximately 2-feet deep and surrounded by an earthen berm (Hargis & Montgomery 1983). The training area was used from the late 1960's to 1980 for periodic training exercises that used approximately 250 gallons of waste fuels and oils per exercise. Before 1970 training exercises were conducted twice a year, and after 1970 exercises were conducted at monthly intervals (Radian 1987). VOCs or semi-VOCs were not detected in the sample.

The IRP Phase I investigation (CH2M Hill 1984) indicated that unknown quantities of fuels and oils were likely deposited in FDTA-6 between training exercises.

In 1982, Hargis & Montgomery collected soil samples from test hole TH-26, which was drilled to a depth of 6 feet in the fire-training burn pit (Figure 4.3.8-1). The sample from 2 to 3 feet was submitted for chemical analysis. Methylene chloride (217 $\mu\text{g}/\text{kg}$), di-n-butylphthalate (170 $\mu\text{g}/\text{kg}$), and oil and grease (0.379 mg/kg) were detected in soils from TH-26.

Interim remedial action was performed at FDTA-6 in 1983 when oil-and-fuel contaminated soils were removed and hauled to an approved hazardous waste landfill. Although most of the contamination may have been removed, there were insufficient data to verify that remaining contaminants did not pose a potential risk to the environment or human health.

In 1986, Intellus Corporation drilled test borings FB-1, FB-2, and FB-3 (Figure 4.3.8-1) at the reported location of FDTA-6. Laboratory analysis of the soil samples failed to identify any contaminants. As shown in Figure 4.3.8-1, these borings may not have been properly located.

The IRP Phase II investigation was carried out by Radian Corporation in 1985 and 1986. Activities included hand augering and collection of soil samples from six holes in May 1986 from 6 to 18 inches deep: HA-1, HA-2, HA-3, HA-4, HA-5, and HA-6 (Figure 4.3.8-1). Results of the analyses are presented in Radian 1987. Five of six soil samples show

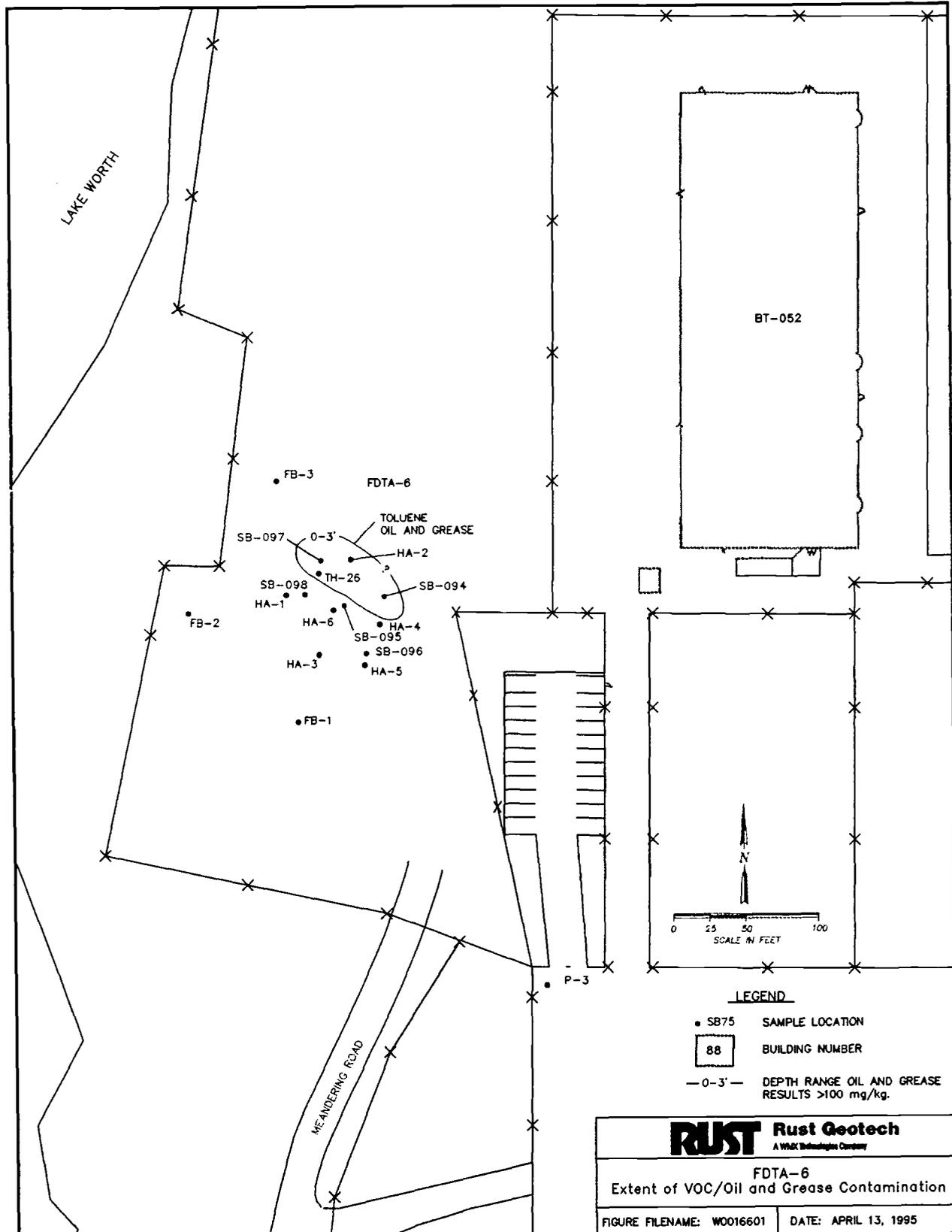


Figure 4.3.8-1. Extent of Toluene and Oil and Grease Detected at FDTA-6.

evidence of residual contamination associated with past activities at FDTA-6. Significant concentrations of hydrocarbon fuels (14,000 mg/kg), oil and grease (13,000 mg/kg), TCE (21 $\mu\text{g}/\text{kg}$), naphthalene (2,300 $\mu\text{g}/\text{kg}$), and phenanthrene (830 $\mu\text{g}/\text{kg}$) were detected in the soil samples.

Analytical results of previous investigations indicate that the soils around FDTA-6 are contaminated with VOCs, semi-VOCs, fuel hydrocarbons, and oil and grease. The following contaminants have been identified at FDTA-6: fuel-related hydrocarbons, oil and grease, trichloroethene, naphthalene, and phenanthrene. Data from these investigations were evaluated, but as the exact location of the borings was not known, the data were not used to define extent of contamination. The three FB- series borings drilled by Intellus (Figure 4.3.8-1) were used to demonstrate contamination was not spreading.

4.3.8.1.1 Current Investigation: During the current investigation it was noted that the area of FDTA-6 was used as a temporary storage area for fill dirt. This fill material was piled over an area covering part of the former FDTA-6 site and the area just to the south. This material was removed by May 1991.

On the basis of a review of information concerning the interim remedial action, five soil borings (SB-094, SB-095, SB-096, SB-097, SB-098) were drilled inside and around the perimeter of the excavated portion of FDTA-6 (see Figure 4.3.8-1). The borings were drilled to the top of the Walnut Formation and a single soil sample was collected; VOCs were sampled immediately as grab samples, and the remaining sample material was composited over the entire length of the boring. The composited soils were analyzed for semi-VOCs, oil and grease, and metals. A single boring (SB-095) drilled in the approximate center of the excavated portion of FDTA-6 was sampled and analyzed using the same protocol specified for the other borings at FDTA-6 to determine if contamination exists below the excavated zone.

4.3.8.2 Summary of Soils Encountered

Bedrock is very shallow in the area of FDTA-6. The Walnut Formation was reached at 2 to 2.5 feet in all five Geotech boreholes. The Walnut Formation consists of gray shale and fossiliferous limestone which is mantled by a thin veneer of soft weathered bedrock. The unconsolidated material overlying bedrock is primarily fill which varies from roadbase sand and gravel at the surface to a mottled clay with some limestone fragments underneath. No visual evidence of contamination, such as oil-stained soil was observed at the site.

4.3.8.3 Results of the Investigation

Toluene was the only chemical of concern identified by laboratory analyses (see Table 4.3.8-1 and Appendix E). A toluene concentration of 11 $\mu\text{g}/\text{kg}$ was detected in the soil sample from SB-094. Oil and grease were found in four of five boreholes with a maximum concentration of 2,300 mg/kg in SB-097. An outline of the extent of contamination of toluene and oil and grease are shown in Figure 4.3.8-1.

The concentrations of metals detected are within the expected range of background soils for the area (see Table 4.3.8-2).

**Table 4.3.8-1 Summary of VOC Analytical Results
for Soil Samples Obtained From FDTA-6**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
Acetone	(11)	11	5	1
Toluene	(5)	11	5	1

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
1) Toluene was identified in the Baseline Risk Assessment as a chemical of concern.

**Table 4.3.8-2 Summary of Inorganic Analytical Results
for Soil Samples Obtained from FDTA-6**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background ⁴ (mg/kg)	No. of Samples Analyzed	No. Above Upper Background Limit for the Western USA ⁴
Antimony	(9.1)	(9.7)	2.2	5	0
Arsenic	1.7B	5.7	21.6	5	0
Beryllium	0.59B	0.95B	3.6	5	0
Cadmium	1.2	2.8	2.8	5	0
Chromium	11.5	18	196.6	5	0
Copper	4.5B	9.8	90.0	5	0
Lead	8.2	31	55.1	5	0
Nickel	6.9B	12.5	66.2	5	0
Selenium	(0.46)	(2.3)	1.4	5	0
Silver	(0.91)	(0.97)	1.4	5	0
Thallium	(0.45)	(0.48)	0.8	5	0
Zinc	19.3	40.5	176.2	5	0

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
3) Cadmium, chromium, copper, nickel, and zinc were identified in the Baseline Risk Assessment as chemicals of concern.
4) Upper background from range in Soils of Western USA, Shacklette and Boerngen, 1984.

4.3.8.4 Conclusions

The previous interim remedial action and various earth moving activities in the FDTA-6 area resulted in either removal or redistribution of contaminated soil. Relatively low levels and limited extent of toluene and oil and grease were found in two boreholes.

4.3.9 Chrome Pit No. 3

4.3.9.1 Summary of Previous Investigations

Chrome Pit No. 3, located on the Radar Range west of Facilities Building No. 12 (see Figure 4.3.9-1), was used from 1957 to 1973 for the disposal of chromate, barium-chromate sludge, dilute metal solutions, and drums of unidentified liquids. The pit measured 66 feet wide by 165 feet long by 15 feet deep (Hargis + Associates 1985).

Soil samples were collected by Hargis & Montgomery (1983) during the drilling of monitoring well HM-1, whose location is shown in Plate 3. Four of 21 samples collected, ranging in depth from 9 to 27 feet, were analyzed for trace metals, cyanide, and organics. The principal contaminants and maximum concentrations reported are: TCE (172,500 $\mu\text{g}/\text{kg}$), toluene (55 $\mu\text{g}/\text{kg}$), xylene (1,073 $\mu\text{g}/\text{kg}$), benzene (139 $\mu\text{g}/\text{kg}$), diethyl phthalate (328,399 $\mu\text{g}/\text{kg}$), di-n-butyl phthalate (16,650 $\mu\text{g}/\text{kg}$), methylene chloride (44,420 $\mu\text{g}/\text{kg}$), cyanide (0.11 $\mu\text{g}/\text{g}$), chromium (0.84 mg/L), copper (0.33 mg/L), nickel (0.93 mg/L), and zinc (0.99 mg/L)[units provided by Hargis & Montgomery (1983)].

Hargis + Associates (1985) drilled monitoring wells HM-15, HM-16, HM-17, and HM-30 in the area surrounding Chrome Pit No. 3 (see Figure 4.3.9-1). From December 1983 through January 1984, approximately 8,900 cubic yards of contaminated soil was excavated and removed from the chrome pit as an interim remedial action. The approximate outline of the excavation is illustrated in Figure 4.3.9-1. Analytical results of samples collected during the excavation indicate that the greatest concentrations of contaminants were removed (CH2M Hill 1984). However, some contaminants may remain in the soils and groundwater adjacent to the excavated portion of the pit. Monitoring well HM-1 was destroyed during the excavation.

Intellus (1986) drilled a test boring (FB-8, Plate 3), which has been destroyed, and monitoring well (F-220) at Chrome Pit No. 3. Organic vapor readings of soil samples did not indicate the presence of VOCs to a depth of 13 and 23 feet for FB-8 and F-220, respectively. VOCs were indicated from 13 to 26 feet in FB-8 and from 23 to 29 feet in F-220. Laboratory analyses of soil samples failed to detect the presence of any VOCs.

Analysis of the water sample from F-220 identified levels of trichloroethene and other VOCs. The levels of metals found were within the mean range typical for native soils (Intellus 1986).

Versar, under contract to UNC Geotech, collected 12 soil samples (X1, X2, X3, X4, X5, X6, X7, X8, X9, X10, X11, X99) from 11 locations in December 1989 around the perimeter of the former excavation and the additional area to be occupied by a proposed chemical waste treatment process building (see Figure 4.3.9-1). Sample X99 was a duplicate/blank sample collected at boring X11. A single composite sample was taken from each of the 11 borings. Borings X1 and X4 (shown in Plate 3) are located west of boring X5 and just off Figure 4.3.9-1. Lithologic logs for each of the 11 shallow borings (10 feet or less) are in Appendix K. As each sample was removed from the borehole and the split-spoon was opened, a portable organic vapor analyzer was used to determine the presence of VOCs. All readings indicated that the soil samples did not contain elevated levels of volatile organics. Each sample was analyzed for volatiles, total extractable halogens, and Contract Laboratory Program (CLP) metals (including hexavalent chromium). Results of laboratory analyses indicated that none of the samples contained high concentrations of toxic organics or inorganics. The sample from boring X10 had 72.5 mg/kg total extractable halogens.

Although remedial action was performed at Chrome Pit No. 3, the amount of samples collected within the excavated area was not sufficient to determine that the site no longer poses a threat to human health or the environment.

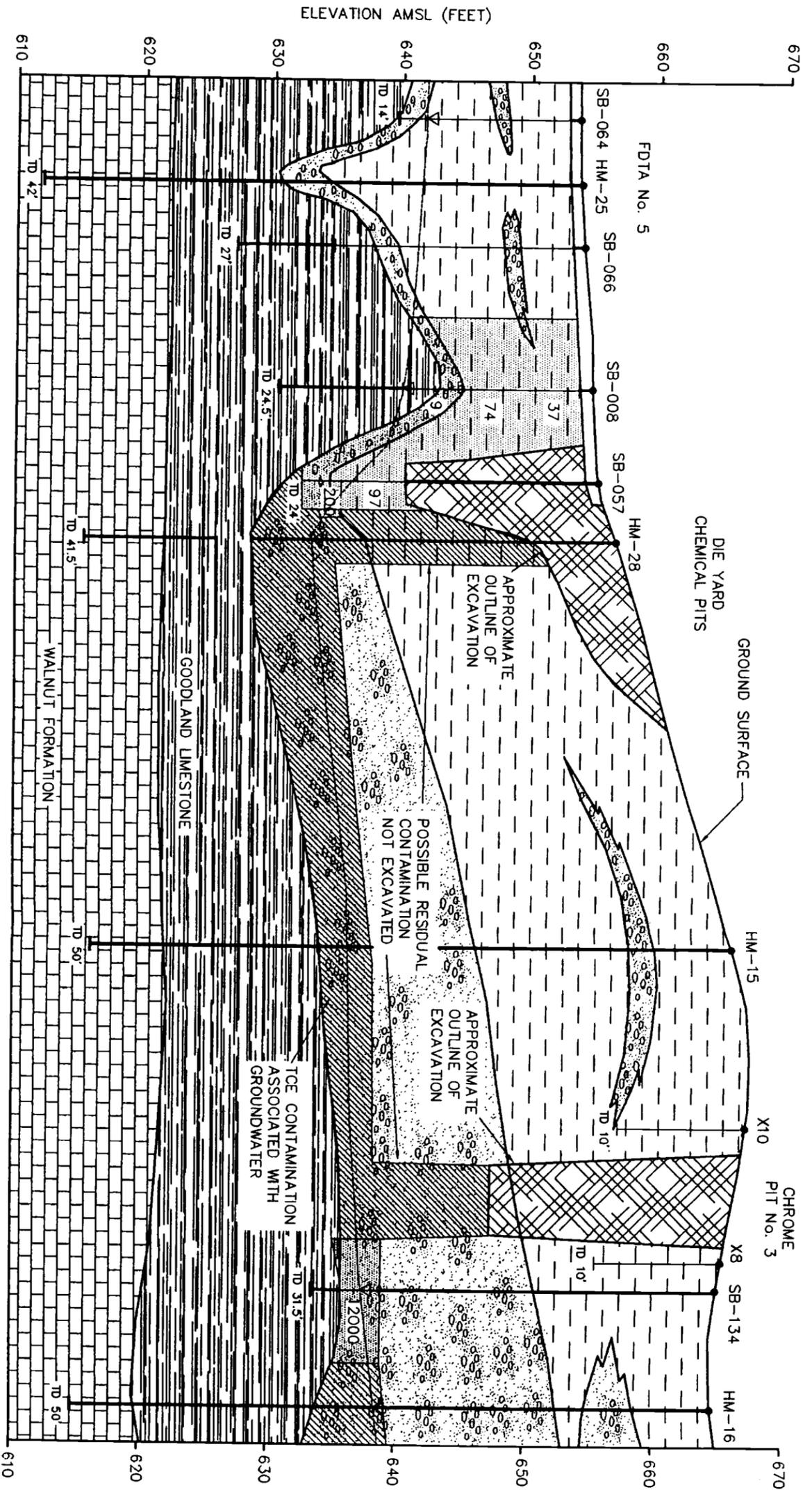
4.3.9.1.1 Current Investigation: During the current investigation, two soil borings were drilled and completed as monitoring wells (SB-134/W-150 and SB-141/W-154). The two wells were installed as upgradient and downgradient wells to help determine the source of contaminants in the groundwater in the Chrome Pit No. 3 area. One soil sample was collected from the depth interval of 26 to 29 feet in SB-134. The water table was found at 28 feet. The single sample was analyzed for VOCs, semi-VOCs, and metals.

4.3.9.2 Summary of Soils Encountered

Boreholes SB-134 and SB-141 were drilled northeast and southwest, respectively, of the former Chrome Pit No. 3 site. Competent shale bedrock of the Goodland Limestone was found 29 feet below the surface in SB-134 and at 32 feet below the surface in SB-141. Figure 4.3.9-2 shows the surface of competent bedrock in the area of Chrome Pit No. 3 and the Die Yard areas. Chrome Pit No. 3 appears to be located over a broad, subtle, bedrock high that plunges gently to the southwest in the direction of SB-141. The subtle relief on this bedrock high is also evident on the cross section presented in Figure 4.3.9-3. Location of the cross section is shown in Figure 4.3.9-1. The generalized stratigraphy of the Quaternary sediments in the Chrome Pit No. 3 area is shown in Figure 4.3.9-3 and the Borehole Lithologic Log Sheets in Appendix A-2.



Figure 4.3.9-2. Structure Contour Map Showing Subcrop of Competent Bedrock at Chrome Pit No. 3.



HORIZ. SCALE 1"=100'
 VERT. SCALE 1"=10'

RUST Geotech
AMT Technology Company

CHROME PIT No. 3
 TCE Contamination

FIGURE FILENAME: W0016901 DATE: APRIL 12, 1995

- GENERALIZED LITHOLOGY
- FILL
 - CLAY UNIT
 - SAND/GRAVEL UNIT
 - SHALE
 - LIMESTONE
 - TOP SATURATED ZONE
 - DETECTED CONTAMINATION
 - INFERRED CONTAMINATION
 - SAMPLE INTERVAL
 - 12000 TCE CONCENTRATION ($\mu\text{g}/\text{kg}$)

Figure 4.3.9-3. Cross Section of Generalized Subsurface Geology at DYCP and Chrome Pit No. 3.

The soils may be described as follows: approximately 14 feet of silty clay with occasional sand stringers and traces of sand and limestone fragments, which is underlain by 15 feet of clayey sand interbedded with limestone gravels and some silty clay. This unconsolidated alluvium rests on a thin veneer of weathered shaley material of the Goodland Limestone, which mantles the bedrock high present in the area.

Figure 4.3.9-3 shows the outline of fill material resulting from excavation of Chrome Pit No. 3. The approximate boundaries of the excavation were derived by using the surface area (Versar 1990) and calculating the average depth reached by removal of the reported 8,900 cubic yards of material.

4.3.9.3 Results of the Investigation

Results of laboratory analysis of the single sample (26 to 29 feet) from SB-134 are in Table 4.3.9-1, Table 4.3.9-2, and Appendix E. TCE was detected at a concentration of 12,000 $\mu\text{g}/\text{kg}$ in the soil sample. Figure 4.3.9-3 shows the location of the sample interval with TCE contamination with respect to the water table. The sample interval (26 to 29 feet) spans the depth to water level (28 feet) found in the borehole. The TCE contamination is most likely related to groundwater. Acetone and 2-butanone were also detected in the soil sample. These two contaminants are likely to be laboratory contaminants. Metals were found to be within the range for background soils of the western United States.

**Table 4.3.9-1 Summary of VOC Analytical Results
for the Soil Sample Obtained from Chrome Pit No. 3**

Analyte	Minimum $\mu\text{g}/\text{kg}$	Maximum $\mu\text{g}/\text{kg}$	No. of Samples Analyzed	No. Above CRQL
Acetone	2,300	2,300	1	1
2-Butanone	3,900	3,900	1	1
Trichloroethene	12,000	12,000	1	1

Notes: 1) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
2) Trichloroethene was identified in the Baseline Risk Assessment as a chemical of concern.

4.3.9.4 Conclusions

The concentration of TCE detected in the soil sample from SB-134 is likely to be associated with groundwater. However, field screening of soils found above the sample depth in SB-134 showed 9 to 23 ppm VOC from the 20- to 26-foot depth. Further inspection of Figure 4.3.9-3 shows the location of the inferred excavation with respect to the closest sample intervals of SB-134, X8, and X10. The average depth of the excavation is estimated to be 18 feet. HM-1 previously was located within Chrome Pit No. 3 and subsequently destroyed with the excavation of contaminated soil. Significant

**Table 4.3.9-2 Summary of Inorganic Analytical Results
for the Soil Sample Obtained from Chrome Pit No. 3**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background (mg/kg)	No. of Samples Analyzed	No. Above Upper Background Limit for Western USA
Antimony	(9.1)	(9.1)	2.2	1	0
Arsenic	7.8	7.8	21.6	1	0
Beryllium	0.49B	0.49B	3.6	1	0
Cadmium	0.94B	0.94B	2.8	1	0
Chromium	24.5	24.5	196.6	1	0
Copper	6.5	6.5	90.0	1	0
Lead	4.6	4.6	55.1	1	0
Nickel	(5.7)	(5.7)	66.2	1	0
Selenium	(0.45)	(0.45)	1.4	1	0
Silver	(0.91)	(0.91)	1.4	1	0
Thallium	(0.45)	(0.45)	0.8	1	0
Zinc	17.3	17.3	176.2	1	0

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
 3) Cadmium, chromium, copper, nickel, and zinc were identified in the Baseline Risk Assessment as chemicals of concern.
 4) Cyanide was detected in the SB-134 sample at a concentration of 0.05 mg/kg.

contamination was detected in soils from 22 to 27 feet in HM-1, including TCE at a concentration of 63,500 $\mu\text{g}/\text{kg}$ at 22 to 23 feet in depth. This previously reported TCE contamination is below the estimated base of the excavation and is above the water table at 22 to 23 feet. The peripheral sampling performed by Versar was limited to 10 feet total depth and is unlikely to intersect any residual contamination that may have migrated vertically downward from Chrome Pit No. 3.

4.3.10 Die Yard Chemical Pits (DYCP)

4.3.10.1 Summary of Previous Investigations

DYCP site is located east of the Radar Range and south of Facilities Building No. 12 (Figure 4.3.10-1). Three pits with approximate dimensions of 20 by 90 feet were constructed in 1956 and used for the disposal of chromate sludges, metal solutions, and other chemical wastes. In 1962, the site was graded and the entire DYCP was paved (second shift parking lot, Lot No. 9). On the basis of the IRP Phase I investigation, it is suspected that contaminated soils from the pits may have been spread around the DYCP area during the grading activities. The site of the original pits was excavated and 1,100 cubic yards of contaminated soil were removed and transported to an approved hazardous waste landfill for disposal (CH2M Hill 1984). Confirmation sampling was not conducted to verify that the area was adequately remediated.

Test Holes TH-1 through TH-8 were drilled by Hargis & Montgomery in December 1982 to locate the chemical waste pits in the DYCP (Figure 4.3.10-1). No analyses of soil samples are reported for these test holes, and only one groundwater sample was collected and analyzed for VOCs and trace metals from TH-3. The results from this sample are reported in Hargis & Montgomery (1983) as follows: 34 $\mu\text{g/L}$ benzene, 157 $\mu\text{g/L}$ chloroform, 12,000 $\mu\text{g/L}$ 1,1-dichloroethene, 20,000 $\mu\text{g/L}$ methylene chloride, 4,000 $\mu\text{g/L}$ TCE, 0.90 mg/L chromium, 0.059 mg/L iron, 0.011 mg/L manganese, and 0.210 mg/L strontium.

In December 1982, Hargis & Montgomery drilled monitoring wells HM-3A and HM-4A to determine the residual concentrations of contaminants at the site. Lithologic logs for the test holes (TH-1 through TH-8) and monitoring wells HM-3A and HM-4A are in Appendix K. At well HM-3A, soil samples collected from depth intervals of 3 to 4 feet, 7 to 8 feet, 9 to 10 feet, and 14 to 15 feet were analyzed for trace metals, cyanide, and organics. Equivalent analyses were performed on HM-4A samples from depth intervals of 3 to 4 feet, 7 to 8 feet, 11 to 12 feet, 14 to 15 feet, and 16 to 25 feet. Results of the analyses are reported in Hargis & Montgomery (1983). The principal contaminants and maximum reported concentrations are as follows: TCE (11,000 $\mu\text{g/kg}$), toluene (20,000 $\mu\text{g/kg}$), methylene chloride (30,000 $\mu\text{g/kg}$), m,p-xylene (20,000 $\mu\text{g/kg}$), ethylbenzene (430 $\mu\text{g/kg}$), cyanide (0.38 mg/kg), zinc (0.48 mg/L), and chromium (0.13 mg/L). Wells HM-3A and HM-4A were destroyed by excavation of the die pits in 1983 and 1984.

In 1983, Hargis + Associates drilled monitoring wells HM-12, HM-24, HM-25, and HM-28 in the vicinity of the DYCP (see Figure 4.3.10-1). No analyses of soil samples are reported for these wells. Laboratory analyses of groundwater samples from HM-25 indicate the presence of benzene, chlorobenzene, ethylbenzene, trichloroethene, *trans*-1,2-dichloroethene, and dichlorobenzenes. The proximity of HM-25 to FDTA-5 suggests the primary source for this contamination is FDTA-5 with some contribution

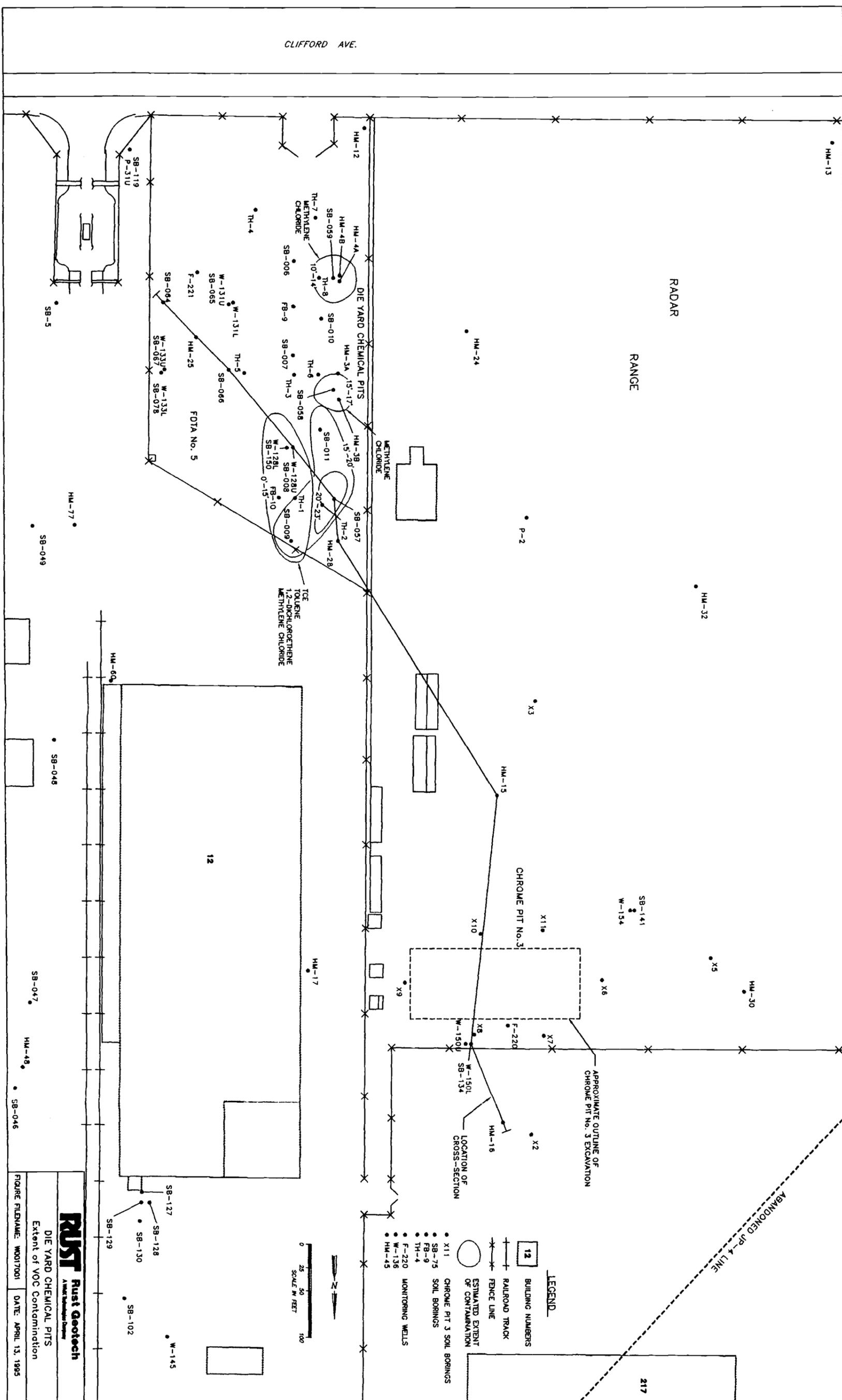


Figure 4.3.10-1. Extent of VOCs Detected at the DYCP.

RUST
 Rust Geotech
 A Rust Industries Company
 DIE YARD CHEMICAL PITS
 Extent of VOC Contamination
 FIGURE FILENAME: W007001 DATE: APRIL 13, 1995

from the DYCP. Because the advective flow is to the northeast from HM-25, it is unlikely that leaks in solvent tanks at the south end of the Assembly Building/Parts Plant contributed to the contamination at HM-25. TCE was also detected in groundwater from HM-28. No significant concentrations of organic compounds were detected in groundwater from HM-12 and HM-24.

Intellus (1986) drilled two test borings, FB-9 and FB-10, adjacent to the eastern edge of the DYCP (see Figure 4.3.10-1). The lithologic logs for these two borings are in Appendix K. Organic vapor readings indicate VOCs (1 to 20 ppm) in FB-9 from 11 to 22 feet and from the ground surface to the Goodland Limestone at a depth of 17 feet in FB-10. Laboratory analyses detected a concentration of 297 $\mu\text{g}/\text{kg}$ of TCE at 8 to 8.5 feet in FB-10. No VOC contamination was indicated by analyses of soil samples from FB-9. Trace metals were found to be within levels typical of native soils (Intellus 1986). Organic vapor readings taken during drilling of monitoring well F-221 indicate that VOCs (1 to 15 ppm) were present in the drill cuttings from the surface to a depth of 11 feet. Between 11 and 19 feet, readings indicate levels of 15 to 25 ppm of VOCs in the soil. Laboratory analyses did not detect the presence of VOCs in the soils from F-221. It is not known whether the VOCs volatilized before the samples could be preserved. The proximity of F-221 to FDTA-5 suggests that a majority of any contaminants detected in the soils or groundwater were from FDTA-5. Because the advective flow from F-221 is to the northeast, it is unlikely that leaks in solvent tanks at the south end of the Assembly Building/Parts Plant contributed to the contamination at F-221.

Sampling and analysis of the soils in the entire DYCP pit area were needed to determine if contaminants exceeding background concentrations are present and if they are present, to determine their lateral and vertical extent. Results of previous investigations indicate that contaminants are still present following the interim remedial action of the pits.

4.3.10.1.1 Current Investigation: Ten soil borings (SB-006 through SB-011, SB-057 through SB-059, and SB-150) were drilled near the area of the excavated pits to determine the lateral and vertical extent of contamination (see Figure 4.3.10-1). No soil borings were drilled on the west side of the former pits because of extensive underground utilities in the area. The borings were drilled to the top of the water table and soil samples were collected from 5-foot intervals. Samples collected for VOCs were grab samples collected immediately upon opening the split-barrel sampler. The remaining samples were collected as composites from each 5-foot interval. The composite samples were analyzed for metals, cyanide, and semi-VOCs. The soil borings located within the excavated pits (SB-010, SB-011, SB-057, SB-058) were sampled only from the 15- to 20-foot interval.

4.3.10.2 Summary of Soils

Geotech soil borings drilled in the DYCP area encountered competent bedrock at 6 feet to 16 feet below the surface (see Figure 4.3.10-2). The DYCP is situated on the west and northwest flanks of a bedrock high that is discussed in Section 4.3.7.3.

The generalized subsurface geology in the vicinity of this bedrock high is illustrated in Figure 4.3.10-3, which is a cross section that passes through the DYCP and the bedrock high. The location of the cross section is shown in Figure 4.3.10-1. The DYCP was paved over with asphalt and concrete that covers the upper sequence that includes silty clay, sandy clay, and occasional thin beds of limestone gravel. The thickness of this upper fine-grained unit ranges from a minimum of 4 feet in SB-007, near the top of the bedrock high, to more than 20 feet in SB-009, which is on the northwest flank of the bedrock structure. As a result of the previous excavation and grading of the site, there is an unknown amount of fill material and redistribution of the surficial Quaternary material. Up to 15 feet of fill was found in SB-010, SB-011, SB-057, SB-058, and SB-059. A basal sand and limestone gravel unit varies in thickness from 1 to 6 feet in the DYCP area and lies directly on bedrock of the Goodland Limestone.

4.3.10.3 Results of the Investigation

Two organic chemicals of concern (TCE and toluene) were detected in significant concentrations in the DYCP area (see Table 4.3.10-1 and Appendix E). TCE was found in soil samples from SB-008 (0 to 15 feet), SB-009 (0 to 20 feet), SB-011 (15 to 16.5 feet), and SB-057 (15 to 23 feet), while toluene was present only in SB-011 at a 15- to 16.5-foot depth. 1,2-Dichloroethene was found in SB-008 and SB-009, with a maximum concentration detected at a depth of 15 to 16.5 feet in SB-011. Benzene, ethylbenzene, and xylene were detected in SB-011 from 15 to 16.5 feet. Low levels of methylene chloride were detected in all samples from SB-009, SB-010, and SB-011; somewhat elevated methylene chloride concentrations were found at SB-058 (1,600 $\mu\text{g}/\text{kg}$ from 15- to 17-foot depth), and the maximum concentration (40,000 $\mu\text{g}/\text{kg}$) was detected at a depth of 10 to 14 feet in SB-059. The areal extent of VOC contamination is shown Figure 4.3.10-1.

The maximum concentration of TCE detected is 200 $\mu\text{g}/\text{kg}$, which was found at a depth of 20 to 23 feet in SB-057. Figure 4.3.10-3 is a cross section that shows the cumulative sample interval for each borehole, the concentration of TCE present in soil and groundwater samples, and the estimated outline of contamination based on the current sampling and analyses. The TCE concentration appears to increase downward in SB-008 until the borehole encounters relatively impermeable limestone and shale bedrock. Borehole SB-057 is located to the northwest and is downgradient or downdip in respect to the bedrock high. SB-057 was sampled only below the expected clean fill

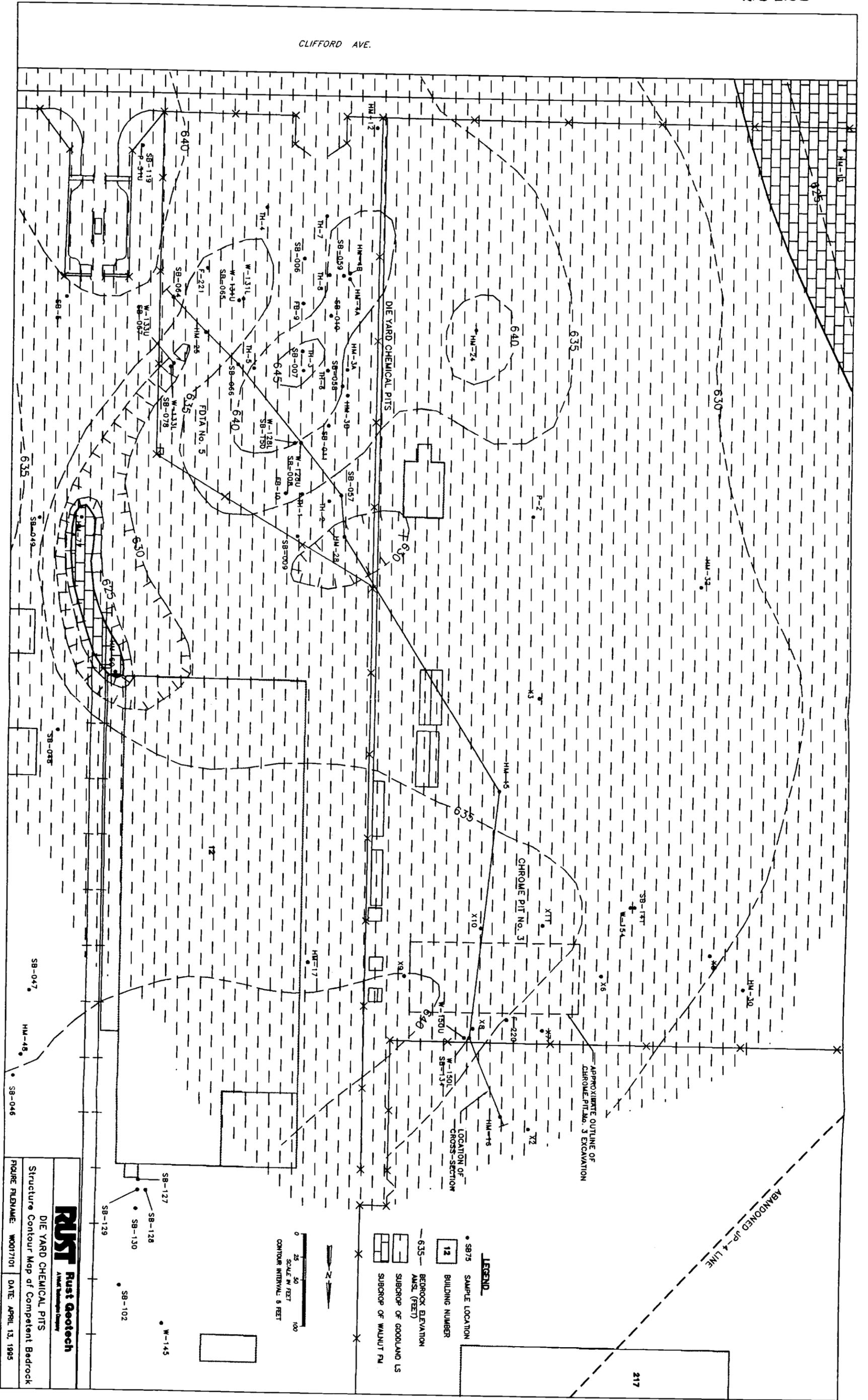
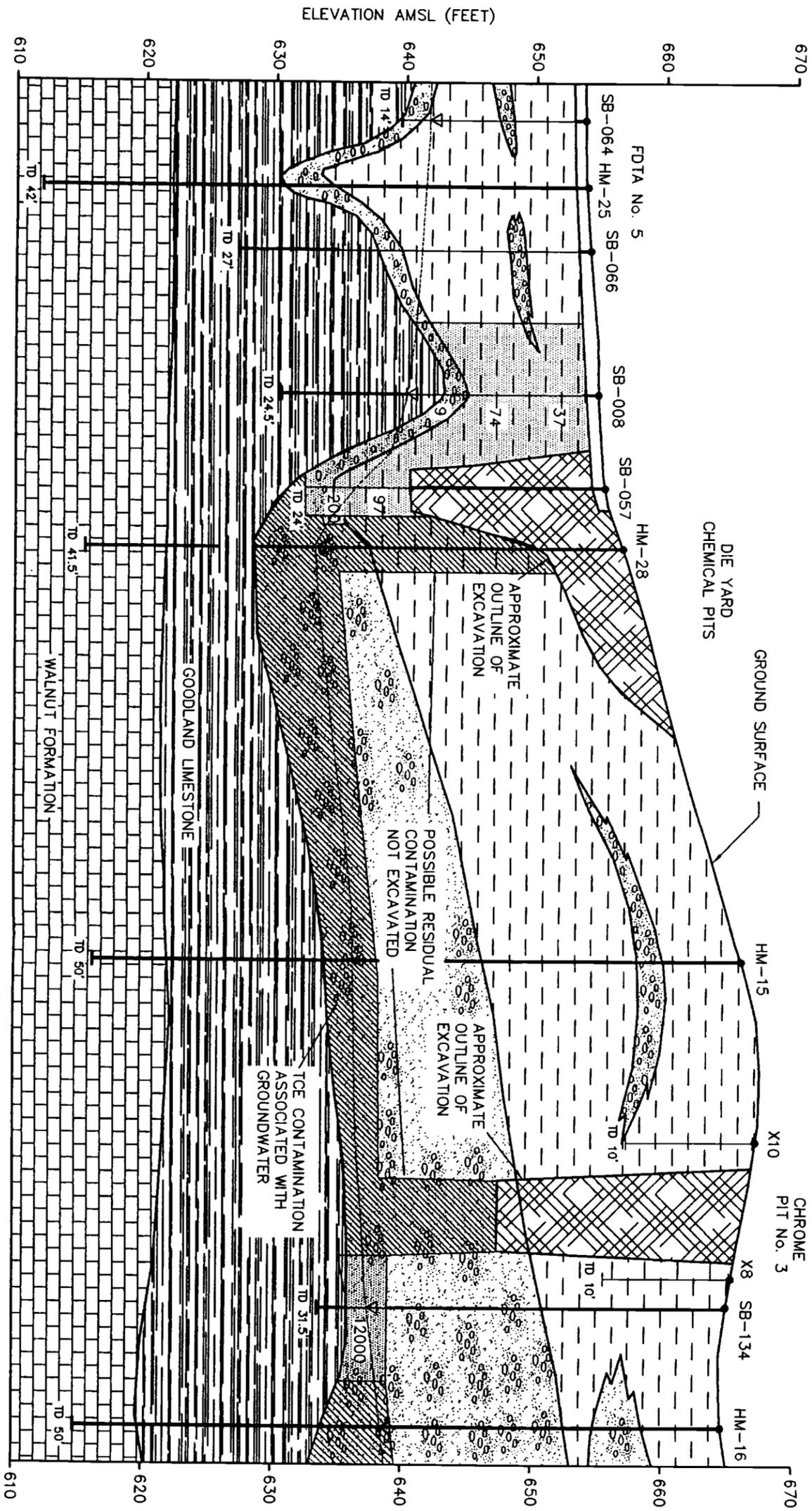


Figure 4.3.10-2. Structure Contour Map Showing Subcrop of Competent Bedrock at DYCP.

RUST Rust Geotech
 AMEC Environmental Group
 DIE YARD CHEMICAL PITS
 Structure Contour Map of Competent Bedrock
 FIGURE FILENAME: W0017101 DATE: APRIL 13, 1995



HORIZ. SCALE 1"=100'
VERT. SCALE 1"=10'

GENERALIZED LITHOLOGY

- FILL
- CLAY UNIT
- SAND/GRAVEL UNIT
- SHALE
- LIMESTONE
- TOP SATURATED ZONE
- DETECTED CONTAMINATION
- INFERRED CONTAMINATION
- SAMPLE INTERVAL
- 12000 TCE CONCENTRATION (µg/kg)

Rust Geotech
Amet Technology Group

DIE YARD CHEMICAL PITS
TCE Contamination

FIGURE FILENAME: W0017201 DATE: APRIL 12, 1995

Figure 4.3.10-3. Cross Section of Generalized Subsurface Geology at DYCP.

**Table 4.3.10-1 Summary of VOC Analytical Results
for Soil Samples Obtained from the DYCP**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
1,1,2-Trichloroethane	(6)	18	25	3
1,2-Dichloroethene	(5)	310	25	3
Acetone	(11)	1,100	25	5
Benzene	(5)	8	25	1
Ethylbenzene	(5)	8	25	1
Methylene Chloride	(5)	40,000	25	9
Toluene	(5)	63	25	1
Trichloroethene	(6)	200	25	12
Xylene	(5)	28	25	1

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Trichloroethene and toluene were identified in the Baseline Risk Assessment as chemicals of concern.

and also indicates an increase in the concentration of TCE with depth. This observed trend of TCE concentration suggests that the DYCP is a source for TCE, which sinks because of its relative high density, and migrates downdip from the structurally high position in the DYCP toward SB-057. SB-057 and HM-28, from which concentrations of TCE are found in upper zone groundwater samples, are located on the northwest flank of the bedrock high, and adjacent to a poorly defined bedrock low.

Laboratory analyses did not reveal any significant contamination of semi-VOCs (see Table 4.3.10-2). 1,2-Dichlorobenzene was found in only one sample, while bis(2-ethylhexyl)phthalate was also found in laboratory blanks.

The concentrations of metals found in DYCP soil samples are within the upper range for background soils of the western United States (see Table 4.3.10-3).

4.3.10.4 TCLP Analytical Results

TCLP was used for analysis of VOCs, semi-VOCs, and inorganic constituents for sample SB-006-04, obtained 15 to 18 feet below ground level. Analysis of the liquid TCLP extract indicated all inorganic and organic analytes were below detection limit.

**Table 4.3.10-2 Summary of Semi-VOC Analytical Results
for Soil Samples Obtained from the DYCP**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
Bis(2-ethylhexyl)phthalate	(760)	2,900	22	5
1,2-Dichlorobenzene	(740)	1,000	22	1

Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.

**Table 4.3.10-3 Summary of Inorganic Analytical Results
for Soil Samples Obtained from the DYCP**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background mg/kg	No. of Samples Analyzed	No. Above Upper Background Limit for the Western USA
Antimony	(9)	(12.3)	2.2	23	0
Arsenic	2.9	6.1	21.6	23	0
Beryllium	0.45B	0.88B	3.6	23	0
Cadmium	(0.9)	2	2.8	23	0
Chromium	5.8	95	196.6	23	0
Copper	3.1B	8.2	90.0	23	0
Lead	5.5	10.8	55.1	23	0
Nickel	5.1B	11.3	66.2	23	0
Selenium	(0.45)	(4.6)	1.4	23	0
Silver	(0.68)	(0.97)	1.4	23	0
Thallium	(0.45)	(0.49)	0.8	23	0
Zinc	12.3	24.4	176.2	23	0

Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
3) Cadmium, chromium, copper, nickel, and zinc were identified in the Baseline Risk Assessment as chemicals of concern.

4.3.10.5 Conclusions

The sampling and analyses have shown that significant contamination is still present in the DYCP area. A major concern is TCE, which has been found in soils from surface to bedrock depths and is present in groundwater throughout the area. Based on the analytical data, it appears that the DYCP site is a source for TCE contamination, which migrates downdip off the bedrock high. TCE contamination was identified adjacent to and below the excavated pits and in groundwater samples. The extent of contamination on the west side of the excavation has not been determined because underground utilities in the area impede sample collection. Because of the high density of underground utilities along the west side of the DYCP, sampling by mechanized methods could not be done safely. Sampling in this area would have to be conducted using hand methods, which generally would be restricted to use of shovels. Sampling even by hand auger methods could puncture plastic conduit, exposing utility wires and cables.

The volume of contaminated soils identified by the borings is approximately 4,750 cubic yards contaminated with TCE. An additional volume of contaminated soil may exist to the west of the excavation, where samples were not acquired because of the presence of extensive underground utilities. Methylene chloride was identified in a 4-foot interval (10 to 14 feet) from SB-059 and in a 2-foot interval (15 to 17 feet) from SB-058. The estimated volume of detected contamination from the two intervals is 360 cubic yards.

4.3.11 Fuel Saturation Area No. 1 and Former USTs No. 19 and No. 20

4.3.11.1 Summary of Investigations

4.3.11.1.1 Previous Investigations: Fuel Saturation Area No. 1 (FSA-1) is located south and east of Facilities Building 14 (see Figure 4.3.11-1). Groundwater in this area reportedly became contaminated by fuels leaking from the underground distribution system during the mid-1970s to the early 1980s. The piping, consisting of 4-inch-diameter JP-4 lines, was abandoned in 1988. In addition, a fuel pumping station and two 12,000-gallon-capacity underground storage tanks, Nos. 19 and 20, were removed prior to December 22, 1988, which was the effective date of Federal Subtitle I regulations. These tanks were formerly located south of Facilities Building 14 and contained 2-butanone (Tank 19) and xylene (Tank 20).

Following removal of the underground storage tanks, analytical results of soil samples collected from the tank excavations indicate the presence of 2-butanone and xylene, compounds that are consistent with the former contents of the tanks. Ethylbenzene was also detected, which could indicate JP-4 contamination from the adjacent leaking underground piping. The soil samples were collected above the saturated zone at a depth of 8 feet below ground level. No further remedial action was performed after removal of the tanks. The excavations were backfilled and paved (Hargis + Associates 1989).

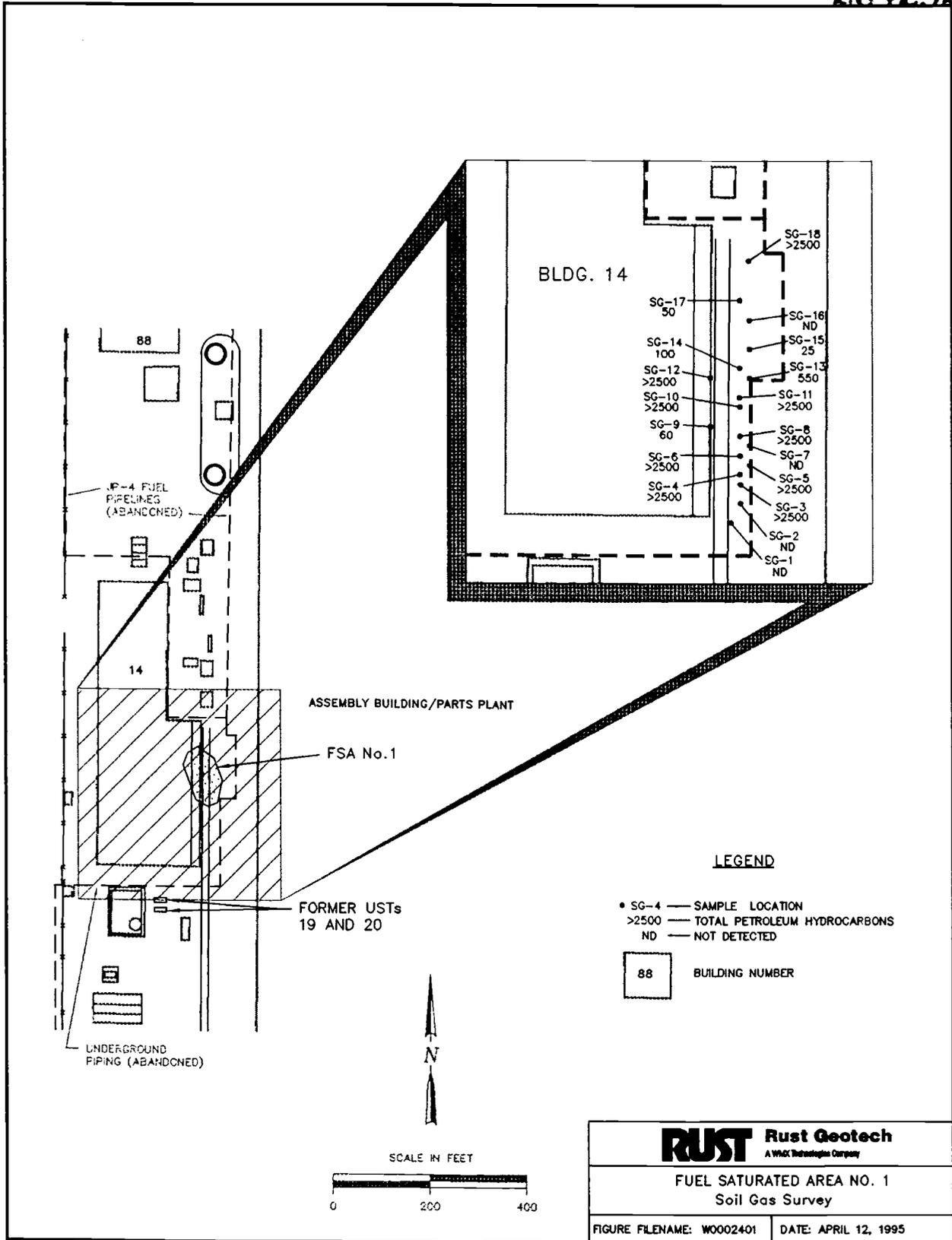


Figure 4.3.11-1. Results of the Soil Gas Survey at FSA-1.

Prior to removal in 1984, Hargis + Associates installed monitoring wells HM-53, HM-55, P-6U, and P-6M, east of Building 14. Soil samples for chemical analyses were not collected from these borings. Intellus (1986) installed monitoring wells F-203, F-204, F-205, F-206, F-207, and F-211 around the perimeter of Building 14, but soil samples were not collected for chemical analyses. Radian Corporation (1987) drilled soil boring SB-4 east of Building 14 and collected two soil samples: one from the vadose zone at 9 to 10 feet below ground level and one from the saturated zone at 25 to 25.5 feet below ground level. Hydrocarbons were detected only in the saturated zone sample. Plate 3 shows boring locations and monitoring wells installed by previous investigations.

4.3.11.1.2 Current Investigation: Previous investigations concentrated on obtaining groundwater quality data; therefore, soil data were limited to a single soil boring (Radian, SB-4) and a few grab samples associated with the USTs excavation. The objective of the current investigation was to provide chemical analyses on soil samples that will more fully define the areal extent of potential contaminant source areas associated with leaks in the underground fuel lines and the former USTs. In addition, previous sampling at the former USTs was insufficient to determine if the saturated zone was impacted from the solvent products in the tanks.

Soil-gas measurements were performed along 300 feet of underground JP-4 fuel lines in an area suspected as the source of groundwater contamination. Soil samples for chemical analyses were obtained from follow-up borings located adjacent to the fuel line and in the immediate area of the former USTs. The following sections describe the results of these investigations.

4.3.11.2 Soil-Gas Survey

Soil-gas sampling was conducted along 300 feet of an active underground fuel line, just east of Building 14. Soil-gas was measured directly, at a nominal depth of 4 feet below ground level, with Draeger specific-indicator detectors that are sensitive to TPH. Measurement results are posted in Figure 4.3.11-1 and summarized in Table 4.3.11-1. Relatively high TPH values (greater than 2,500 ppm) were observed along most of the line. TPH was not detected in the two most southern locations, SG-1 and SG-2. Based on these results, several areas were selected for follow-up auger drilling to evaluate the extent of petroleum contaminated soils.

**Table 4.3.11-1 TPH Measured in Soil-Gas
at the FSA-1 and Former USTs No. 19 and 20**

Sample Location	TPH (ppm)	Sample Location	TPH (ppm)
SG-1	ND	SG-10	>2,500
SG-2	ND	SG-11	>2,500
SG-3	>2,500	SG-12	>2,500
SG-4	>2,500	SG-13	550
SG-5	>2,500	SG-14	100
SG-6	>2,500	SG-15	25
SG-7	ND	SG-16	ND
SG-8	>2,500	SG-17	50
SG-9	60	SG-18	>2,500

Note: ND is not detected.

4.3.11.3 FSA-1 and Former UST Nos. 19 and 20 — Borehole Soil Sampling

Four boreholes, SB-120, -122, -123, and -124, were drilled around the perimeter of the former USTs excavation to determine the areal extent of contaminant migration. To test the soils for residual contamination in the vadose zone and to evaluate if the depth of contamination extends to the saturated zone, borehole SB-121 was located in the approximate center of the former tank excavation. Based on all current available data at the time the Work Plan was prepared, SB-133 was drilled to characterize the soils upgradient of the former USTs and downgradient conditions were tested from SB-131, -118, and -043. After completion of the RI field work the data indicate that this area of the site is characterized by a very flat water table with groundwater flow directions that are difficult to predict at a local scale. However, at a larger scale the data indicate flow is generally from south to north in the vicinity of Building 14. An east or west component of this flow cannot be predicted. Under conditions of flat hydraulic gradients temporal changes in recharge and hydraulic head can lead to flow directions which change as a function of time. Any particular point could therefore, have been upgradient or downgradient from the area of interest.

Eight boreholes, SB-039, -042, -132, -044, -109, -112, -116, and -079, were drilled in a north-to-south line adjacent to approximately 1,000 feet of underground piping. SB-111 and -125 were drilled west of the underground piping.

Soil samples were collected from the ground level to the top of the water table or until bedrock was encountered. Unconsolidated material was collected in 3-inch by 24-inch stainless-steel-split barrel samplers for the entire borehole. Borehole lithology and sampling intervals are summarized in Appendix A-2. Samples from each five-foot interval were composited and analyzed for semi-VOCs, TPH, and inorganics. From each 5-foot interval, one grab sample was collected for VOC analyses. A summary of the analytical data is presented in Appendix E.

4.3.11.3.1 VOC and TPH Soil Sample Results: Examination of the VOC and TPH soil sample analyses that are summarized in Table 4.3.11-2 reveal concentrations of 2-butanone, toluene, chloroform, and bromodichloromethane. The maximum values shown in Table 4.3.11-2 for these compounds were measured in soil samples obtained in the vicinity of the former USTs, at the south end of Building 14.

Table 4.3.11-2 Summary of VOC and TPH Analytical Results for Soil Samples Obtained from the FSA-1 and Former USTs No. 19 and 20

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
1,1-Dichloroethene	(5)	10	104	1
2-Butanone	(10)	1,800,000	104	35
Acetone	(10)	61	104	18
Benzene	(5)	87	104	1
Bromodichloromethane	(5)	600,000	104	1
Chloroform	(5)	1,900,000	104	5
Ethylbenzene	(5)	670	104	6
Methylene Chloride	(5)	8	104	2
Toluene	(5)	12,000,000	104	5
Xylene	(5)	830	104	4
Total Petroleum Hydrocarbons	(10) mg/kg	8,781 mg/kg	102	44

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Toluene was identified by the Baseline Risk Assessment as a chemical of concern.

Figure 4.3.11-2 shows the results of the VOC analyses posted at each borehole location. The highest 2-butanone values occur at SB-122 and -133. SB-133 also contains the highest concentration of toluene (12,000,000 µg/kg). The one instance where bromodichloromethane exceeds the CRQL (600,000 µg/kg) and the highest chloroform value (1,900,000 µg/kg) occurs in this area, at SB-122.

In addition to the maximum value (1,800,000 µg/kg) reported for 2-butanone at SB-133, this compound also occurs in a high frequency of samples (SB-079, -120, -121, -123, -124, and -131), although at much lower levels. 2-Butanone in these samples reflects contamination from the former UST No. 19, as shown by the brown line in Figure 4.3.11-2. Xylene found in these samples is probably associated with contamination from the former UST No. 20. Chloroform is commonly added to potable water supplies as treatment and may explain the occurrence of this compound. The source of the bromodichloromethane and toluene found in SB-122 and SB-133 is

somewhat troublesome because historical records do not indicate storage of these compounds in USTs No. 19 or 20, and is probably indicative of an unknown source unrelated to the former USTs or the underground piping. Benzene (87 $\mu\text{g}/\text{kg}$) and the occurrences of ethylbenzene and TPH are most likely related to the JP-4 underground piping.

These data indicate that the vadose zone in the vicinity of the former tank excavation is contaminated with 2-butanone, chloroform, toluene, and bromodichloromethane, as shown by the area delineated in Figure 4.3.11-2. The extent of contamination is approximately 100-feet wide by 200-feet long and extends to the saturated zone which varies between 20 to 25 feet below ground level. The extent of relatively high VOC contamination is associated with SB-122 and -133 and limited to a zone between 15 and 25 feet below the ground surface. Soil sampling from this zone indicates 2-butanone fails the TCLP as discussed in Section 4.3.11.3.4.

Volatiles were also detected at two isolated locations (SB-125 and -132) at the north end of Building 14. 2-Butanone concentrations, ranging from 19 to 230E $\mu\text{g}/\text{kg}$, were detected in every sample obtained from SB-125 and -132. At location SB-125, 1,1-dichloroethene was detected at concentrations of 1J and 10 $\mu\text{g}/\text{kg}$. These are two isolated locations that do not appear to be related to each other or to the source of the contamination found in adjacent borings. The concentrations are relatively low which suggest possible contamination or cross-contamination of field equipment after sampling the USTs No. 19 and 20 where extremely high levels of 2-butanone were detected in saturated zone samples. However, because the entire soil column for both boreholes indicates 2-butanone contamination, a groundwater pathway is not probable. On the other hand, a surface spill cannot be ruled out. During field activities at least one spill of 2-butanone was noted by the Geotech field crew.

Acetone was detected in 18 samples above the CRQL and methylene chloride detected in two samples, but these compounds are common laboratory contaminants (EPA 1988), and their random occurrence at relatively low concentrations is probably not indicative of environmental contamination. The maximum value for acetone is 61 $\mu\text{g}/\text{kg}$ and 8 $\mu\text{g}/\text{kg}$ for methylene chloride. For these reasons, results for these compounds are not posted in Figure 4.3.11-2.

Benzene, toluene, ethylbenzene, and xylene (BTEX) contamination is associated with a portion of the underground fuel piping in the vicinity of the USTs No. 19 and 20 excavation and extends northeast to SB-109 (Figure 4.3.11-2). BTEX contamination in these borings occurs mostly in samples from the saturated zone (10 to 23 feet below surface) and in relatively low concentrations, except for toluene in SB-133, which is probably related to a source other than the underground piping. This area of contamination is approximately 100-feet wide by 500-feet long.

Relatively high TPH concentrations associated with leaks in the underground piping occur in SB-122 (up to 5,464 mg/kg), SB-123 (up to 785 mg/kg), and SB-133 (up to 8,781 mg/kg). TPH also appears more widespread than BTEX, occurring in both vadose- and saturated-zone samples, 0-25 feet below ground level. The area of TPH contamination is approximately 200-feet wide by 300-feet long. The TPH contamination occurring at two borings north of the BTEX plume (SB-044 and -039) reflects multiple leaks in different parts of the underground piping. TPH values from SB-044 are relatively low, ranging from 36 mg/kg for the 0- to 5-foot sample to 40 mg/kg for the 5- to 10-foot and 15- to 20-foot samples. Higher values, up to 1,741 mg/kg for the 10- to 15-foot sample, are observed at SB-039.

4.3.11.3.2 Semi-VOC Soil Sample Results: Results of the semi-VOC analyses are summarized in Table 4.3.11-3. The most numerous semi-VOC reported above the CRQL is bis(2-ethylhexyl)phthalate. However, because phthalates are common laboratory contaminants (EPA 1988), this compound is most likely not associated with environmental contamination. This assumption is further supported by the fact that bis(2-ethylhexyl)phthalate occurs randomly, and results of duplicate analyses are inconsistent. For example, analytical results for the sample obtained at the 15- to 20-foot depth interval from SB-039 was reported at 210J $\mu\text{g}/\text{kg}$. The duplicate analysis of this sample was reported at 2,200 $\mu\text{g}/\text{kg}$, an order of magnitude higher.

Table 4.3.11-3 Summary of Semi-VOC Analytical Results for Soil Samples Obtained from the FSA No. 1 and USTs No. 19 and 20

Analyte	Minimum $\mu\text{g}/\text{kg}$	Maximum $\mu\text{g}/\text{kg}$	No. of Samples Analyzed	No. Above CRQL
2-Methylnaphthalene	(680)	50,000	103	9
Benzo(a)anthracene	(680)	1,300	103	3
Benzo(b)fluoranthene	(680)	11,000	103	3
Benzo(g,h,i)perylene	(680)	6,400	103	1
Benzo(k)fluoranthene	(680)	6,400	103	1
Bis(2-ethylhexyl) phthalate	(720)	6,500	103	40
Chrysene	(680)	1,700	103	3
Fluoranthene	(680)	3,900	103	4
Indeno(1,2,3-cd)pyrene	(680)	6,200	103	1
Naphthalene	(680)	1,100	103	2
Phenanthrene	(680)	3,500	103	3
Pyrene	(680)	8,100	103	4

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Pyrene, fluoranthene, naphthalene, and 2-methylnaphthalene were identified by the Baseline Risk Assessment as chemicals of concern.

The remaining semi-VOCs reported above the CRQL are typically related to coal tar, crude oil, and petroleum products. These compounds occur only in the boreholes that are associated with the most southern TPH contamination delineated in Figure 4.3.11-2 and probably reflect contamination from the leaking underground piping. In some cases, these semi-VOCs may also be indicative of small pieces of asphalt incorporated in the sample. Evidence of asphalt was noted by the field geologist for SB-121 at 14.7-foot below ground level (see Appendix A-2). Asphalt at this location is probably part of the pad for the underground storage tanks, since concrete was encountered immediately below the asphalt.

Dibenzofuran and pentachlorophenol are the only semi-VOCs detected that are not associated with coal tar, crude oil, and petroleum product. Dibenzofuran was detected in one sample in both SB-131 and -122. Pentachlorophenol was detected in one sample in SB-039. In both cases they were not detected above the CRQL but were reported as estimated quantities (qualified "J"). The limited occurrence of these compounds, combined with the fact that field duplicates and laboratory re-analyses do not confirm their presence, suggest they are not associated with environmental contamination. For example, dibenzofuran was detected at 300J and 130J $\mu\text{g}/\text{kg}$ in SB-131 and -122, respectively, but the compound was not detected by the laboratory re-analyses of the samples. Similarly, pentachlorophenol was detected at 860J $\mu\text{g}/\text{kg}$ in SB-039 but was not detected in the field duplicate.

4.3.11.3.3 Inorganic Soil Sample Results: Results of soil sample analyses for the 12 priority pollutant metals are summarized in Table 4.3.11-4. Silver and selenium were not detected in any sample. Except for antimony, all the values reported for the remaining analytes are within the range expected for natural background concentrations. Five samples exceeded the upper limit of natural background for antimony (twice at SB-044, and once at SB-111, -116, and -121). For these cases, all values were above the IDL but less than the CRDL. The values also appear isolated and random, suggesting they are elevated because of natural processes.

4.3.11.3.4 TCLP Analytical Results: VOC analyses on soils collected from SB-122 reveal extremely high concentrations of 2-butanone that resulted from product leaking from the former USTs (Section 4.3.11.3.1). In addition, the highest concentration of bromodichloromethane and chloroform are observed at this location. Therefore, TCLP analyses was performed on a soil sample collected from SB-122 at a depth of 15 to 20 feet below ground level. The TCLP, designed to determine the mobility of contaminants present in waste material, was submitted for VOC and semi-VOC determinations. Materials that fail the TCLP test are classified as hazardous waste.

Results of the TCLP analyses indicate the presence of 2-butanone at a concentration of 440,000 $\mu\text{g}/\text{L}$ in the liquid extract. The TCLP regulatory level for this compound is

**Table 4.3.11-4 Summary of Inorganic Analytical Results for Soil Samples
Obtained from the FSA No. 1 and Former USTs No. 19 and 20**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background Limit (mg/kg)	No. of Samples Analyzed	No. Above Upper Background Limit for Western USA
Antimony	(8.4)	11.1B	2.2	74	5
Arsenic	(0.64)	5.5	21.6	74	0
Beryllium	(0.21)	1.2	3.6	74	0
Cadmium	(0.84)	1.8	2.8	74	0
Chromium	1.5B	29.2B	196.6	74	0
Copper	1.3B	21.4	90.0	74	0
Lead	0.87	37	55.1	74	0
Nickel	(3.5)	16.1	66.2	74	0
Selenium	(0.42)	(4.6)	1.4	74	0
Silver	(0.65)	(0.98)	1.4	74	0
Thallium	(0.42)	0.54B	0.8	74	0
Zinc	4.5	65.3	176.2	74	0

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
 3) Cadmium, chromium, copper, nickel, and zinc were identified by the Baseline Risk Assessment as chemicals of concern.

200,000 $\mu\text{g}/\text{L}$ (40 CFR Part 261.24, Table 1), therefore, the soil is considered a toxicity characteristic waste. No other VOCs or any semi-VOCs were detected in this sample.

4.3.11.4 Conclusions

Vadose and saturated zone soil samples collected in the vicinity of the former USTs No. 19 and 20 indicate the presence of 2-butanone, toluene, chloroform, ethylbenzene, xylene, and bromodichloromethane (see Figure 4.3.11-2). Concentrations of 2-butanone, toluene, chloroform, and bromodichloromethane up to 1,800,000, 12,000,000, 1,900,000, and 600,000 $\mu\text{g}/\text{kg}$, respectively, were detected in SB-122 and -133 from a zone between 15 and 25 feet below ground surface. A sample obtained from this zone failed the TCLP test for 2-butanone.

Petroleum-related hydrocarbons found in soil samples reflect leaks in different parts of the underground fuel pipeline. Relatively low concentrations of BTEX occur mostly in samples obtained from the saturated zone. TPH appear more widespread than BTEX, occurring in both vadose and saturated zone samples. TPH concentrations occur up to 5,464 $\mu\text{g}/\text{kg}$ (SB-122), 785 $\mu\text{g}/\text{kg}$ (SB-123), 8,781 $\mu\text{g}/\text{kg}$ (SB-133), and 1,741 $\mu\text{g}/\text{kg}$ (SB-039).

Several semi-VOCs that are typically related to petroleum products were detected above the CRQL. These compounds are present only in soil samples associated with the most southern TPH contamination delineated in Figure 4.3.11-2, which indicates the source is related to fuel leaks in the underground piping.

Five samples exceeded the upper limit of natural background for antimony (twice at SB-044, and once at SB-111, -116, and -121). For these cases, all values were above the IDL but less than the CRDL. The values also appear isolated and random, suggesting they are elevated because of natural processes. No other priority pollutant metal was detected at a concentration greater than the upper limit of natural background.

4.3.12 Fuel Saturation Area No. 2

4.3.12.1 Summary of Investigations

4.3.12.1.1 Previous Investigations: Fuel Saturation Area No. 2 (FSA-2), located northwest of Facilities Building No. 176, is a site which reportedly was saturated by fuels leaking from a buried fuel pipeline in the 1970s and early 1980s (CH2M Hill 1984).

Well HM-80 was drilled by Hargis + Associates (1985) at the suspected location of FSA-2 (Figure 4.3.12-1). No soil contamination was reported.

Intellus (1986) drilled one test boring (FB-4) and one monitoring well (F-212). Analyses of soil samples did not reveal the presence of fuel constituents. These negative findings together with results from analyses of previously drilled HM-80 suggest that FSA-2 had not been properly located.

IRP Phase II Stage I activities by Radian in 1986 consisted of drilling three boreholes (SB-1, SB-2, SB-3) along the length of the buried fuel line. Soil samples were collected and analyzed for halogenated volatiles and aromatics, and hydrocarbon fuels (Radian 1987, Table 4.3.8-2). Organic compounds were detected at low levels with the exception of the SB-2 interval from 5 to 6 feet, where hydrocarbon fuels (4,600 mg/kg) and 1,1-dichloroethene (12 $\mu\text{g}/\text{kg}$) were detected in the soils. The concentration of contaminants decreased below the 5- to 6-foot interval. No remediation or removal of soils was reported.

4.3.12.1.2 Current Investigation: Soil-gas sampling was performed east of the area delineated in 1985 by Hargis + Associates. Samples were collected at 14 locations from a nominal depth of four feet below ground level and analyzed directly in the field with Draeger specific-indicator detectors that are sensitive to total petroleum hydrocarbons (TPH). Figure 4.3.12-2 shows the locations where the Draeger measurements were performed. TPH was not detected in any sample, therefore, additional samples were

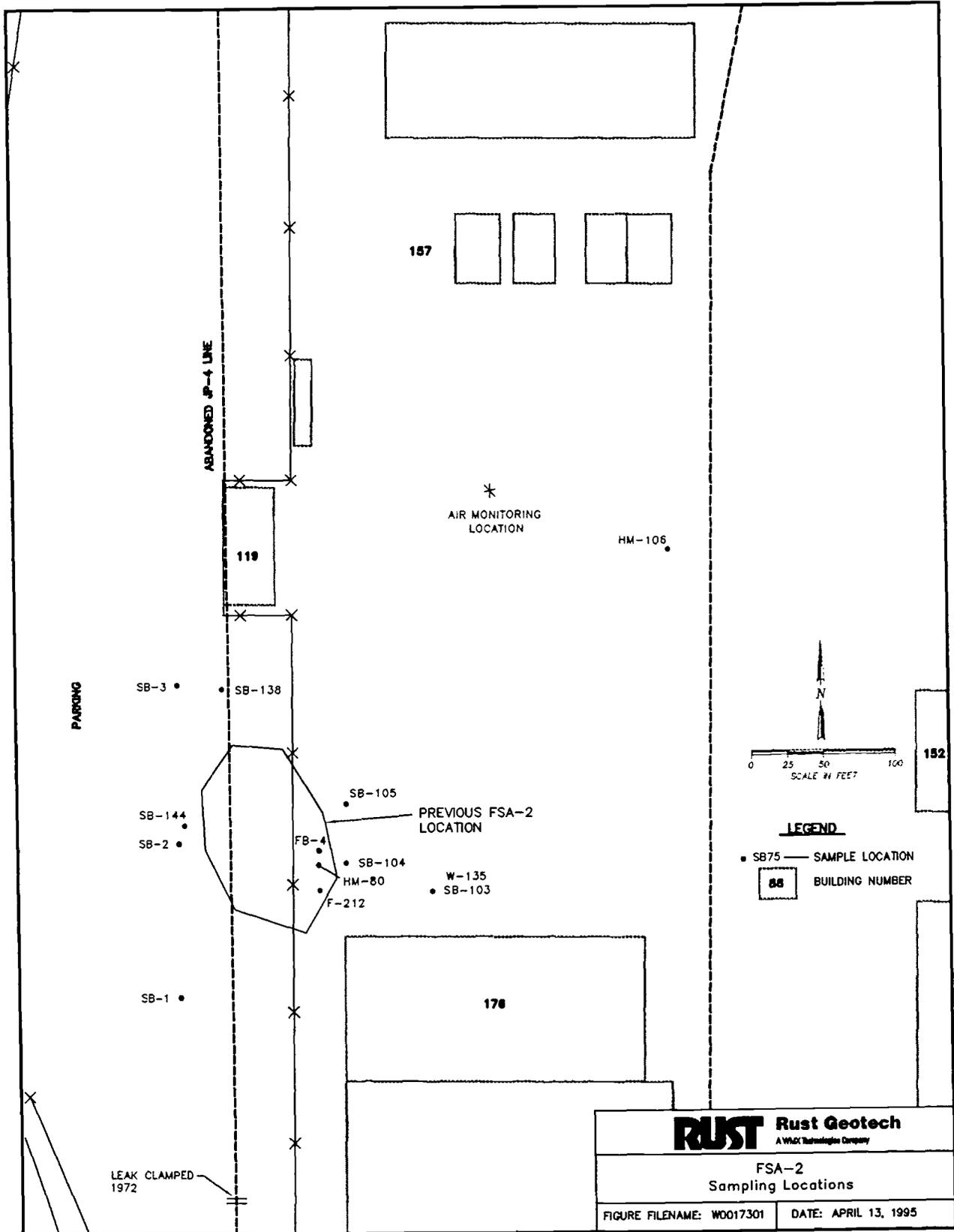


Figure 4.3.12-1. Borehole Soil Sample Locations at FSA-2.

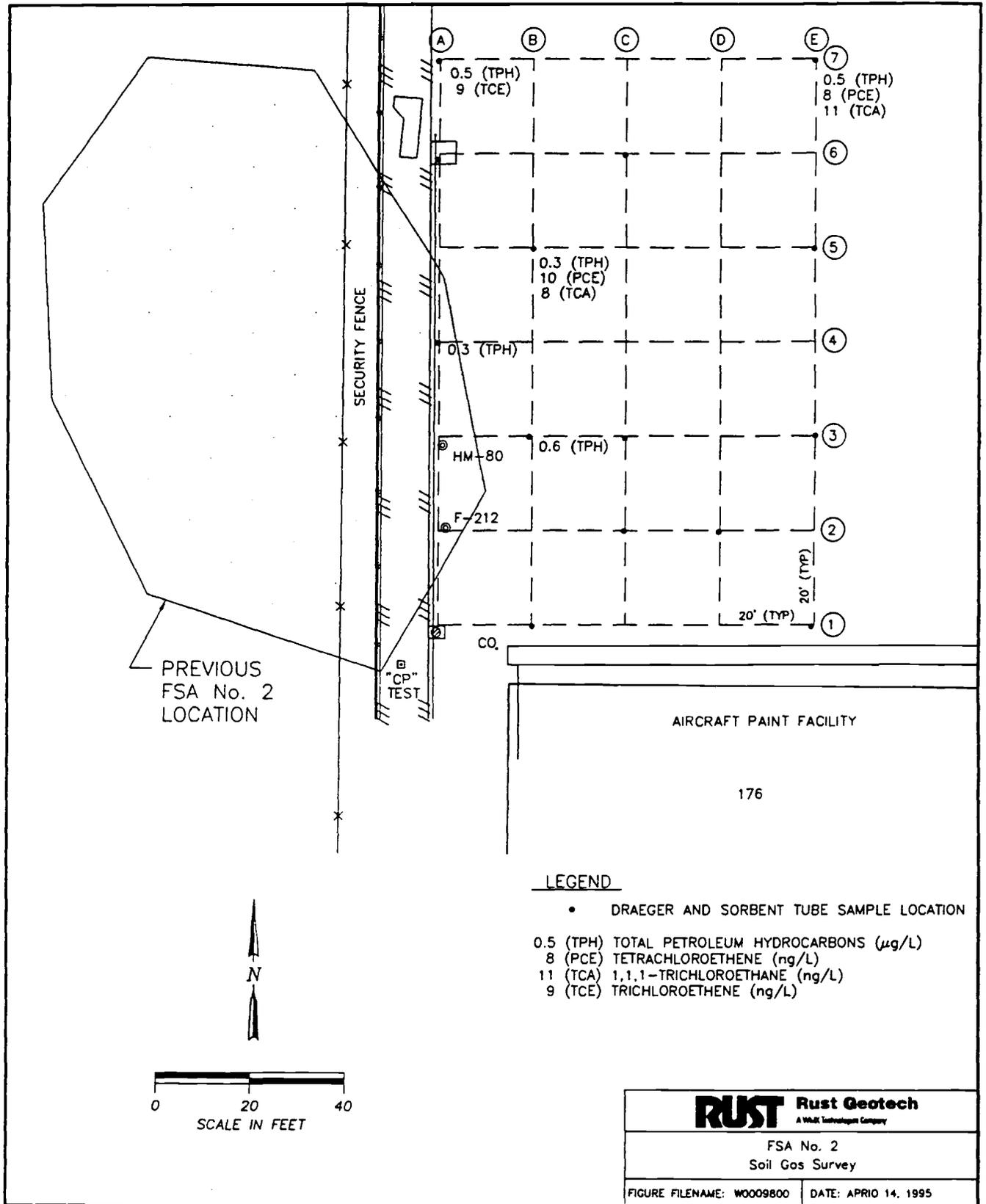


Figure 4.3.12-2. Soil Gas Sample Locations at FSA No. 2.

collected on sorbent tubes, at five selected locations, and returned to the laboratory for more definitive analyses by GC/MS.

Concentrations of petroleum related hydrocarbons, including the aromatic compounds benzene, toluene, ethylbenzene, and xylene (BTEX), and relatively heavier molecular weight compounds such as cyclohexane, 4-methylheptane, and methylcyclohexane, were detected in all five samples analyzed by GC/MS. Concentrations of tetrachloroethene (PCE), trichloroethene (TCE), and 1,1,1-trichloroethane (TCA) were also detected in three of the five samples analyzed by GC/MS; however, these chlorinated hydrocarbons are not typically associated with petroleum products. Results of the GC/MS analyses are summarized in Table 4.3.12-1 and plotted in Figure 4.3.12-2. TPH values presented in the table and figure represent the sum of all petroleum related hydrocarbons measured by GC/MS and may include estimated and tentatively identified compounds.

Table 4.3.12-1. Results of Soil-Gas Measurements Performed at Fuel Saturation Area No. 2

SAMPLE LOCATION	TPH (µg/L)	PCE (ng/L)	TCE (ng/L)	1,1,1-TCA (ng/L)
E7	0.5	8	(5)	11
B5	0.3	18	(5)	14
B5-DUP	0.3	(5)	(5)	(5)
B3	0.6	(5)	(5)	(5)
A4	0.5	(5)	(5)	(5)
A7	0.5	(5)	9	(5)

- Notes:
- 1) Concentration in parentheses indicates the compound was not detected at reported value.
 - 2) B5-DUP is a field duplicate at location B5. The value plotted in Figure 4.3.12-2 represents the mean for the duplicate samples. For below detection data, one-half the detection limit has been used to calculate the mean.

Results of the soil-gas survey were used to guide the placement of soil borings. An EPA representative reviewed previous data collected at FSA-2, evaluated results of the soil-gas investigation, and in agreement with Geotech, selected five soil boring locations in the FSA-2 area (Figure 4.3.12-1). SB-103, SB-104, SB-105 were drilled at grid points where soil-gas measurements indicated anomalous amounts of contamination. Boring SB-103 was converted into monitoring well W-135. SB-138 and SB-144 were drilled to the north and west, respectively, of the FSA-2 area in a parking lot outside the

security fence. Soil borings were drilled from the surface to the top of the bedrock and samples collected in 3-foot intervals. Samples for VOCs were grab samples from each 3-foot interval. The remaining samples were composites of each interval and were analyzed for semi-VOCs and TPH.

4.3.12.2 Summary of Soils

The locations of the five soil borings are covered with 4 inches to 2 feet of concrete or asphalt. Below pavement there are 2 feet to 6 feet of unconsolidated sediments and fill. The poorly sorted material may be described as mostly clay mixed with some gravel, sand, and silt. This unconsolidated material overlies weathered shale and limestone of the Goodland Limestone which varies in thickness from 1.5 feet to 7 feet in SB-103, SB-104, and SB-105. Hard limestone of the Walnut Formation was reached at 11.5 feet below the surface in SB-103. Boreholes SB-138 and SB-144 are located downslope to the northwest and are in a topographically lower position relative to SB-103, SB-104, and SB-105. The alluvium and fill in SB-138 and SB-144 lie directly on hard, gray Walnut Formation which was encountered at 4.5- to 5.5-foot depth. Lithologies encountered in the FSA-2 area are contained in the Borehole Lithology Logs (see Appendix A-2).

4.3.12.3 Results of the Investigation

Laboratory analyses of the soil samples from FSA-2 failed to detect significant contamination of the chemicals of concern. Semi-VOC bis(2-ethylhexyl)phthalate was detected in soil samples from the surface to a depth of 11 feet in SB-103, at concentrations up to 2,600 $\mu\text{g}/\text{kg}$ (Table 4.3.12-2). However, this compound was measured at a higher concentration in the laboratory blank (Appendix E).

**Table 4.3.12-2 Summary of Semi-VOC Analytical Results
for Soil Samples Obtained from FSA-2**

Analyte	Minimum $\mu\text{g}/\text{kg}$	Maximum $\mu\text{g}/\text{kg}$	No. of Samples Analyzed	No. Above CRQL
Bis(2-ethylhexyl)phthalate	(760)	2,600	12	3

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.

Low levels (17 to 38 mg/kg) of TPH were measured in the upper 10 feet of soil from all five borings (see Table 4.3.12-3). Low levels of acetone and 2-butanone, which are common laboratory contaminants, were detected in the samples.

**Table 4.3.12-3 Summary of VOC and TPH Analytical Results
for Soil Samples Obtained from FSA-2**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
Acetone	(11)	68	12	8
2-Butanone	(11)	20	12	2
Total Petroleum Hydrocarbons	(10) mg/kg	38 mg/kg	12	6

Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.

4.3.12.4 Conclusions

The sampling and analysis of soil from five boreholes in the FSA-2 area did not find significant contamination. The compound bis(2-ethylhexyl)phthalate is a common laboratory contaminant and was also found in laboratory blanks for these samples. The concentration of TPH detected in soil samples is relatively low, although apparently widespread.

The fuel-related contamination reported in Radian borehole SB-2 may be attributed to a previous leak in the now abandoned JP-4 line. A General Dynamics map shows the location of a reported leak to the south of FSA-2 that was clamped in 1972 (see Figure 4.3.12-1). SB-2 appears to be in a topographically lower position than the JP-4 line. Drainage of leaking fuel might collect downslope in the vicinity of SB-2. An alternative source for contamination could be a surface spill in the area that migrated to the SB-2 location.

The detection of a significant concentration of hydrocarbon fuels in SB-2 and the reported location of a leak in the JP-4 line to the south of FSA-2 indicates the need for additional sampling in this area.

4.3.13 Fuel Saturation Area No. 3 and UST-30

4.3.13.1 Summary of Investigations

4.3.13.1.1 Previous Investigations: Fuel Saturation Area No. 3 (FSA-3) located immediately east of Meandering Road between Facilities Building Nos. 135 and 142 (Figure 4.3.13-1) is a site contaminated by fuels from buried fuel pipelines that leaked during the 1970s and early 1980s. The FSA-3 area also has numerous underground utilities and several UST sites.

Fuel-related floating product has been observed in 7 of 13 wells in the area of FSA-3. Analytical results of groundwater samples show that the groundwater at FSA-3 contains anomalous concentrations of VOCs, semi-VOCs, and fuel hydrocarbons. Contaminants found in groundwater at FSA-3 in concentrations that exceed Federal standards include benzene, ethylbenzene, toluene, chlorobenzene, trichloroethene, and naphthalene.

Hargis + Associates drilled monitoring well HM-78 north of Building No. 134 to monitor groundwater conditions in the reported vicinity of FSA-3 (see Figure 4.3.13-2). Fuel saturation was discovered with about two feet of product floating on top of the upper zone groundwater. Contaminants identified include benzene, ethylbenzene, toluene, chlorobenzene, and trichloroethene. Soil sampling and analysis was not reported.

Intellus completed a geophysical conductivity survey over the FSA-3 area to help delineate the extent of contamination. Cone penetrometer soundings were taken to aid in the identification of vertical and horizontal changes in lithology, to determine the Upper Zone/Walnut Formation contact, and to aid in location and design of monitoring wells. Six wells (F-200, F-201, F-202, F-208, F-209, and F-210) were drilled to monitor groundwater contamination (see Figure 4.3.13-2). A layer of JP-4 was present at F-201, F-202, and HM-78, with low concentrations of JP-4 found in F-200 and F-210. Trichloroethene was detected in F-200, F-202, F-210, and HM-78. Chlorinated solvent contamination is reported in well F-208. Soil sampling and analysis was not reported.

In June 1988, Hargis + Associates drilled 2 soil borings (FSA3-5 and FSA3-9) and 10 upper-zone monitoring wells (FSA3-1, -4, -6, -7, -8, -10, -11, and -12) in the area downgradient of FSA-3 (see Figure 4.3.13-2). The purpose for drilling these boreholes was to further define the lateral and vertical extent of free product, to delineate subsurface lithology and groundwater flow directions, and to determine a suitable location for a pipeline cut-off wall system to prevent the spread of contamination. The relative concentrations of fuel vapor in boreholes and drill cuttings were monitored using a PID. Fuel vapor and floating product were detected in the subsurface throughout the Fuel Test Area.

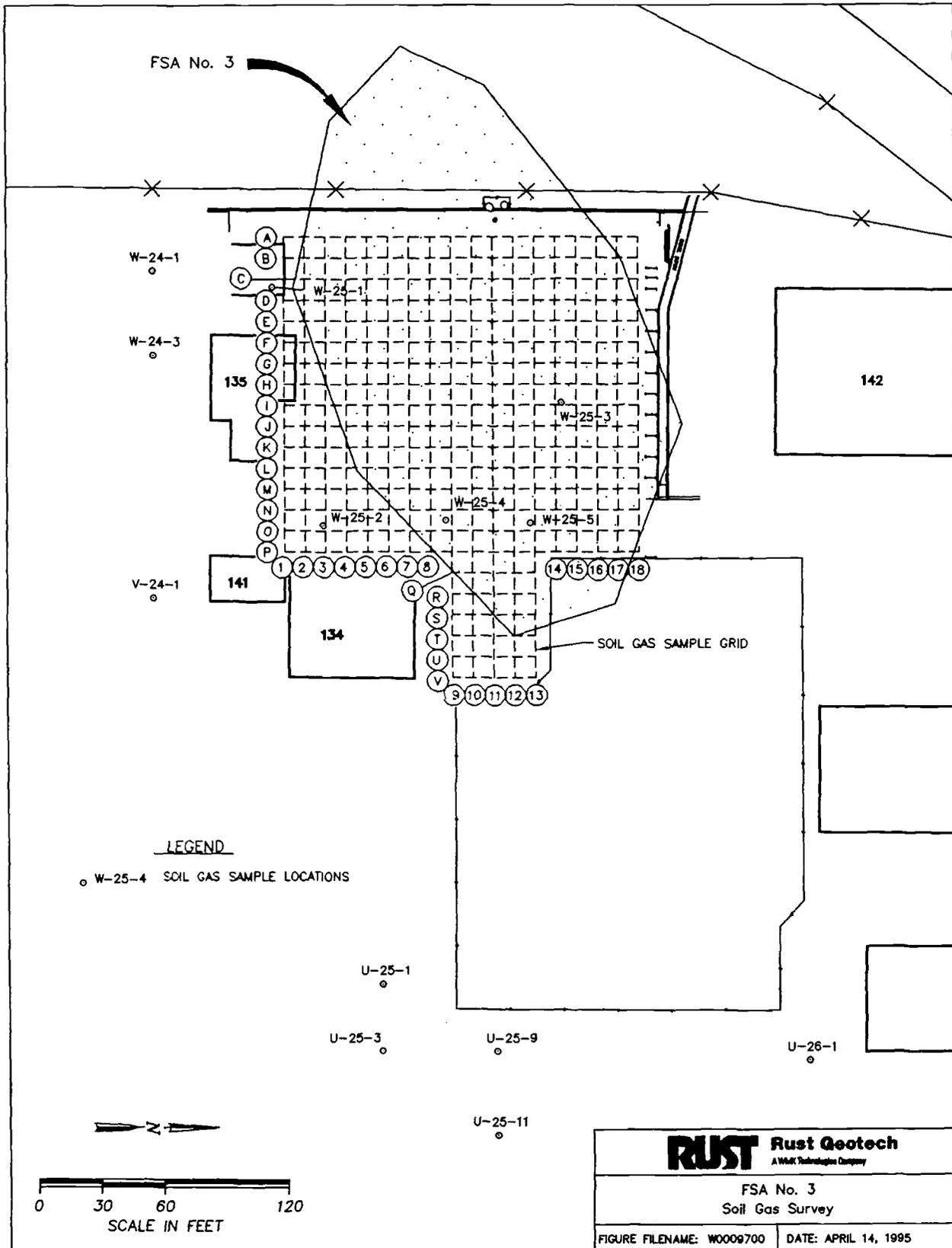


Figure 4.3.13-1. Soil Gas Sample Locations at FSA No. 3.

UST-30, located to the southeast of FSA-3, was removed prior to December 22, 1988. A soil sample (6-501B) taken from the bottom of the excavation was found to be contaminated with benzene, ethylbenzene, toluene, and xylene. No soil was removed.

4.3.13.1.2 Current Investigation: Twenty monitoring wells from previous investigations provide information throughout FSA-3. However, additional soil sample data were required around the perimeter of FSA-3 to better define the lateral and vertical extent of contamination. Prior investigations on the north side of FSA-3 provided sufficient data to define the extent of contamination in that direction. Shallow bedrock to the west and northwest limits the investigation on those sides but allows definition to the edge of contamination. The current investigation concentrated on the south and east sides of FSA-3. A limited soil gas investigation was conducted on the west side of FSA-3.

The soil-gas survey was conducted as a screening tool across the FSA-3 area to help define the lateral extent of soils contamination. A sampling grid was set over the extent of contamination as mapped by prior investigations. Samples were collected from a nominal depth of four feet below ground level and analyzed directly in the field with Draeger specific indicator detectors that are sensitive to TPH. When contamination was found to extend past the grid, selected points were investigated to better define the extent of contamination. Numerous underground utilities and storage of structural steel in the area investigated restricted the locations available for sampling. The sampling locations are shown in Figure 4.3.13-1. Results of the TPH measurements are shown in Table 4.3.13-1.

Table 4.3.13-1 Results of Soil-Gas Measurements Performed at Fuel Saturation Area No. 3

Sample Location	TPH (ppm)	Sample Location	TPH (ppm)
W24-1	ND	U26-1	ND
W24-3	ND	U26-2	ND
W24-6	ND	U25-13 (4 feet)	ND
W25-1	ND	U25-13 (1.5 feet)	25
U25-1	ND	U25-15	ND
U25-3	ND	U25-9	ND
W25-3	ND	U25-11	ND
W25-5	100	T25-1	25
W25-4	ND	V24-1	30
W25-2	ND	V24-3	ND

Note: ND is not detected.

On the basis of previous data and the approximate extent of contamination outlined by the soil-gas survey, 13 soil borings (SB-84, SB-86 to SB-93, SB-107, SB-108, SB-148, SB-149) were drilled at locations in the FSA-3 area to help define the lateral and vertical extent of contamination. Soil samples were collected at 3-foot intervals from the surface to the top of the water table. The samples for VOCs were grab samples from each 3-foot interval. The remaining samples were composites of each interval. Composite samples were analyzed for semi-VOCs and TPH. One sample from SB-149 was analyzed for TCLP characteristics to determine the effects of leaching for various remedial action technologies.

Four borings (SB-080 to SB-083) were placed around the perimeter of the site of former UST-30, which is located to the southeast of the FSA-3 area. Soil samples were collected at 5-foot intervals with samples for VOCs collected as grab samples, and the remaining samples were composites of the entire 5-foot interval. Composite samples were analyzed for semi-VOCs and petroleum hydrocarbons. Ten percent of the composite samples were analyzed for metals.

One new source area was detected during the FSA-3 site investigation. When borehole SB-102 was drilled, contamination was detected with a PID and later confirmed by analytical results to be petroleum hydrocarbons. Investigation of the area found an abandoned 1942 aviation fuel pipeline that passed east of the borehole site (see Figure 4.3.13-2). The pipeline was marked on an old underground utility map but not on current maps of abandoned fuel lines in the area. Two more soil borings (SB-115, SB-117) were drilled 50 feet on either side of the original boring and parallel to the 1942 pipeline. Both of these borings also indicated petroleum hydrocarbons although at lower levels. A soil boring (SB-113) was drilled on the east side of the pipeline and did not detect any contamination. This last soil boring was converted to a monitoring well (W-143). This area was not investigated further as contaminant levels were low (benzene at 74 $\mu\text{g}/\text{kg}$, xylene at 110 $\mu\text{g}/\text{kg}$), and levels dropped east of the line and in the adjacent borings.

4.3.13.2 Summary of Soils

A generalized cross section of the upper-zone sediments may be seen in Figure 4.3.13-3. Orientation of the section is from southwest to northeast and extends from the FSA-3 area to the Jet Engine Test Stand (see Figure 4.3.13-2).

The FSA-3 area appears to be located over a local bedrock high of Walnut Formation limestone with relief of 8 to 10 feet. The approximate extent and configuration of this bedrock structural high is shown in plan view on Figure 4.3.13-4. This structure-contour map of competent basement shows a north-trending elongated high in the FSA-3 area. The steeply-dipping eastern side of the high forms the western boundary of an apparent saddle which deepens toward Meandering Road to the north and also to the south-southeast in the direction of the Assembly Building. To the northeast of FSA-3 is a

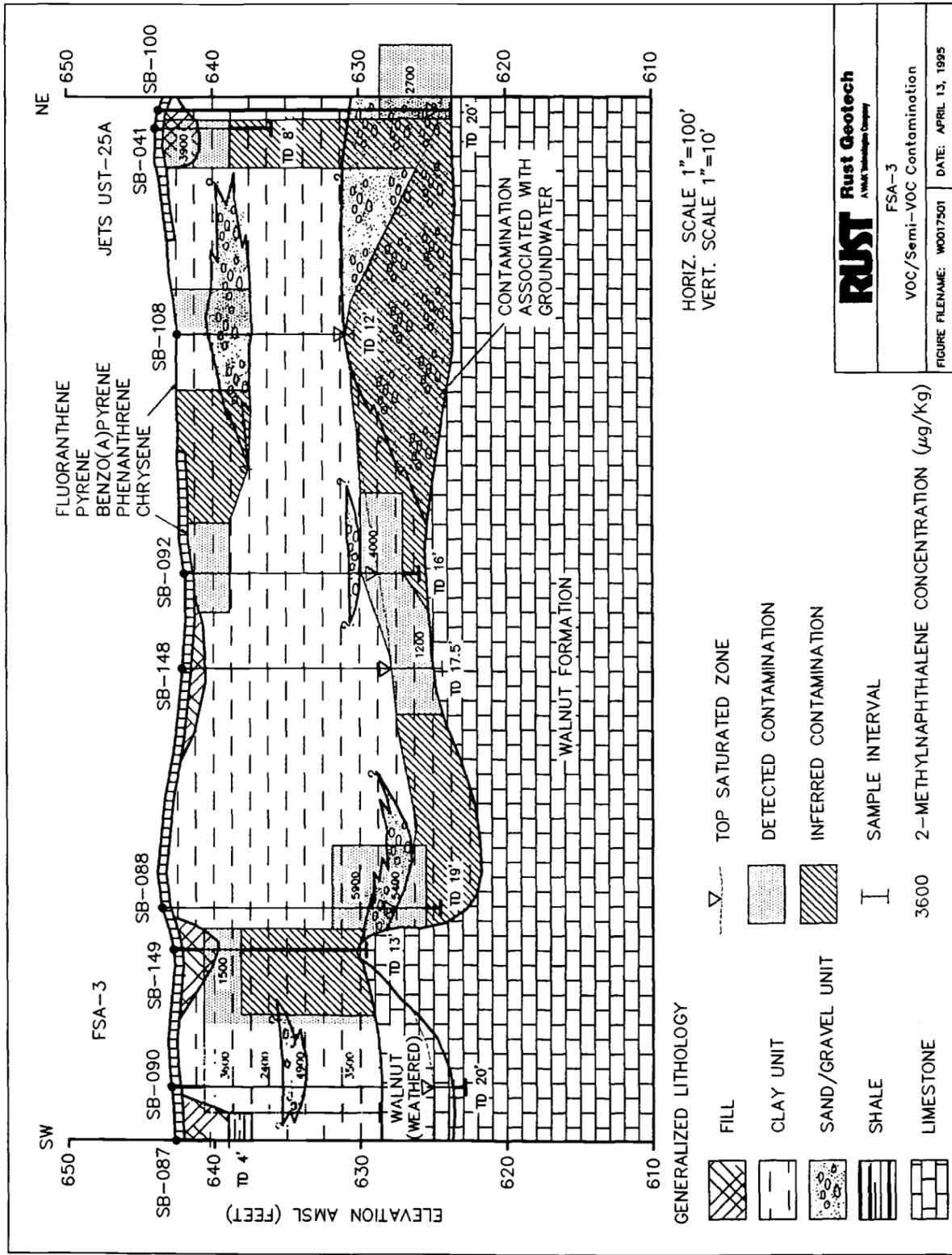


Figure 4.3.13-3. Cross Sectional View of FSA-3 Showing VOCs and Semi-VOCs Results.

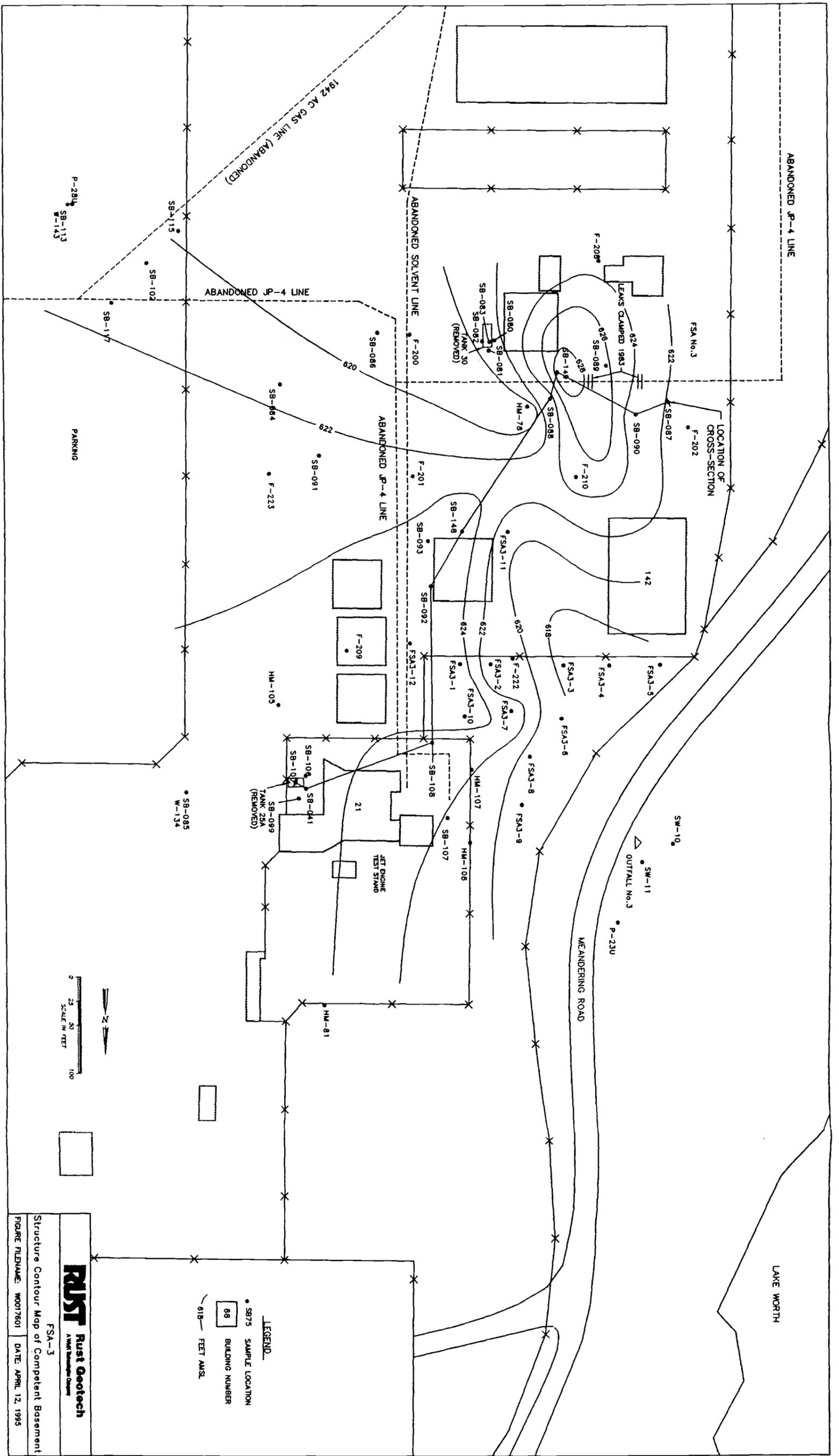


Figure 4.3.13-4. Structure Contour Map of Competent Bedrock Surface at FSA-3.

broad, low relief bedrock high positioned under the Jet Engine Test Stand. Competent Walnut limestone appears to immediately underlie unconsolidated Quaternary alluvium throughout the area with the exception of the western flank of the FSA-3 bedrock high. Boring SB-090 penetrated approximately 5 feet of a weathered Walnut shale, fossiliferous limestone, and a sandy conglomeratic unit lying directly on competent Walnut limestone bedrock.

The upper-zone Quaternary sediments in the FSA-3 area are covered with up to 2 feet of concrete. The generalized stratigraphy of the Quaternary alluvium, as shown in Figure 4.3.13-3 and on the borehole logsheets in Appendix A-2 consists of 10 to 20 feet of brownish clay and silty-clay with occasional beds of fine-grained sand and poorly sorted gravels. Historical earth-moving activities have resulted in redistribution of the natural alluvium and placement of an unknown thickness of fill material at the surface. Interpreted fill material is shown in places on the cross section immediately below the concrete cover.

The UST-30 site, located southeast of FSA-3, contains four soil borings that were drilled to 10 to 13-feet total depth. The borehole logsheets, included in Appendix A-2, depict mixed lithologies. All four borings encountered a sequence of interbedded clays, silts, sands, and gravels, with no clear correlation of units between the closely spaced boreholes. A possible explanation for this apparent rapid facies change is the proximity of the UST-30 site to a local bedrock high seen in Figure 4.3.13-4. UST-30 was located over the steep eastern flank of an erosional bedrock high that may have shed coarse debris that intermingled with fine-grained fluvial sediments.

4.3.13.3 Results of the Investigation

Several volatile and semivolatile fuel-related compounds were detected by laboratory analyses of soil samples from the FSA-3 area. Identified compounds common to JP-4 include 2-methylnaphthalene, naphthalene, benzene, ethylbenzene, and xylene. Maximum concentrations of these and additional detected organic compounds are found in Table 4.3.13-2, Table 4.3.13-3, and Appendix E.

Figure 4.3.13-2 shows the extent of contamination of VOCs and semi-VOCs within the vadose zone of the FSA-3 area. There are three separate areas of contamination shown. The westernmost area sampled by SB-088, SB-090, and SB-149 had high levels of JP-4 related compounds at depths ranging from 2 to 15 feet within the vadose zone. The extent of contamination in the deeper vadose zone (10 feet to 15 feet) has been extended to the southeast to include the UST-30 area, where JP-4 related contamination was found at 13 feet in depth following excavation. Maximum concentrations of semi-VOCs, 2-methylnaphthalene (5,900 $\mu\text{g}/\text{kg}$) and naphthalene (2,700 $\mu\text{g}/\text{kg}$), were found in soils from 12 to 15-feet in depth in SB-088. Benzene, ethylbenzene, xylene, and JP-4 compounds, were found in boreholes SB-091 and SB-102, located to the east of the main FSA-3 area.

**Table 4.3.13-2 Summary of Semi-VOC Analytical Results
for Soil Samples Obtained from FSA-3**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
2-Methylnaphthalene	(710)	5,900	80	11
Benzo(a)anthracene	(710)	1,800	80	1
Benzo(a)pyrene	(710)	930	80	1
Benzo(b)fluoranthene	(710)	1,800	80	1
Benzo(g,h,i)perylene	(710)	1,400	80	1
Benzo(k)fluoranthene	(710)	1,500	80	1
Bis(2-Ethylhexyl)phthalate	(710)	4,300	80	2
Chrysene	(710)	2,200	80	2
Fluoranthene	(710)	4,500	80	2
Indeno(1,2,3-cd)pyrene	(710)	1,500	80	1
Naphthalene	(710)	2,700	80	8
Phenanthrene	(710)	2,900	80	2
Pyrene	(710)	3,600	80	2

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Pyrene, fluoranthene, naphthalene, and 2-methylnaphthalene were identified in the Baseline Risk Assessment as chemicals of concern.

**Table 4.3.13-3 Summary of VOC and TPH Analytical Results
for Soil Samples Obtained from FSA-3**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
Ethylbenzene	(5)	960	81	10
Xylene	(5)	1,100	81	8
Acetone	(11)	220	81	63
Benzene	(5)	180	81	8
2-Butanone	(11)	190	81	11
Total Petroleum Hydrocarbons	(10) mg/kg	945 mg/kg	78	38

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.

Figure 4.3.13-3 illustrates a cross-sectional view of the extent of contamination of VOCs and semi-VOCs in the FSA-3 area. Shown in this figure are the borehole sample intervals, areas of detected and inferred contamination, types of contamination (JP-4 or asphalt related), interpreted level of the water table, and an outline of generalized geology. JP-4 contamination found in SB-090, SB-149, and SB-088 appears to be from the adjacent fuel line that is suspected to have leaked. Areas of deeper contamination throughout the length of the cross section are interpreted to be associated with groundwater.

FSA-3 soil samples were also analyzed for TPH. Results of these analyses are shown on Figures 4.3.13-5 and 4.3.13-6, which illustrate the extent of TPH contamination in cross-sectional view and plan view, respectively. The horizontal extent of TPH contamination (see Figure 4.3.13-6) appears to correlate with the location of fuel lines and UST-30. The blue colored contaminant envelope pertains to the higher concentrations of TPH (greater than 100 mg/kg), while the lower concentrations are designated by a red line. The maximum TPH concentration (945 mg/kg) is found in SB-088 and corresponds to JP-4 contamination suspected to have leaked from the adjacent fuel line. Relatively low levels of TPH in the FSA-3 area (red line envelopes) may be attributed to minor fuel line leaks, spills of fuels from surface activities, asphalt contamination, or a combination of these potential sources. The vertical extent of TPH contamination (see Figure 4.3.13-5) corresponds well with that for VOCs and semi-VOCs. The reported levels of TPH are posted adjacent to boreholes on the cross section. Zones with high levels of TPH correlate well with identified areas of JP-4 contamination.

The levels of metals found in FSA-3 soil samples are within the range for background soil of the western United States (see Table 4.3.13-4).

4.3.13.4 Toxicity Characteristic Leaching Procedure Analytical Results

The EPA Toxicity Characteristic Leaching Procedure (TCLP) was used to analyze for VOCs, semi-VOCs, and inorganic constituents for sample SB-149-01, obtained 2 to 4 feet below ground level. Analysis of the liquid TCLP extract indicated all inorganic constituents, except barium, were reported below detection limit. Barium was detected at a concentration of 1,750B $\mu\text{g/L}$, a value that is less than the 100,000 $\mu\text{g/L}$ regulatory limit. All VOC and semi-VOC analytes were below detection limit.

4.3.13.5 Conclusions

Significant contamination from JP-4 related compounds was found in soils from the FSA-3 area. The highest levels of contamination occur in SB-088, near the suspected location of leakage from an underground fuel line. This westernmost source area is believed to be the main contributor to the widespread groundwater contamination with floating product found to exist in the FSA-3 area. Two additional areas of fuel-related

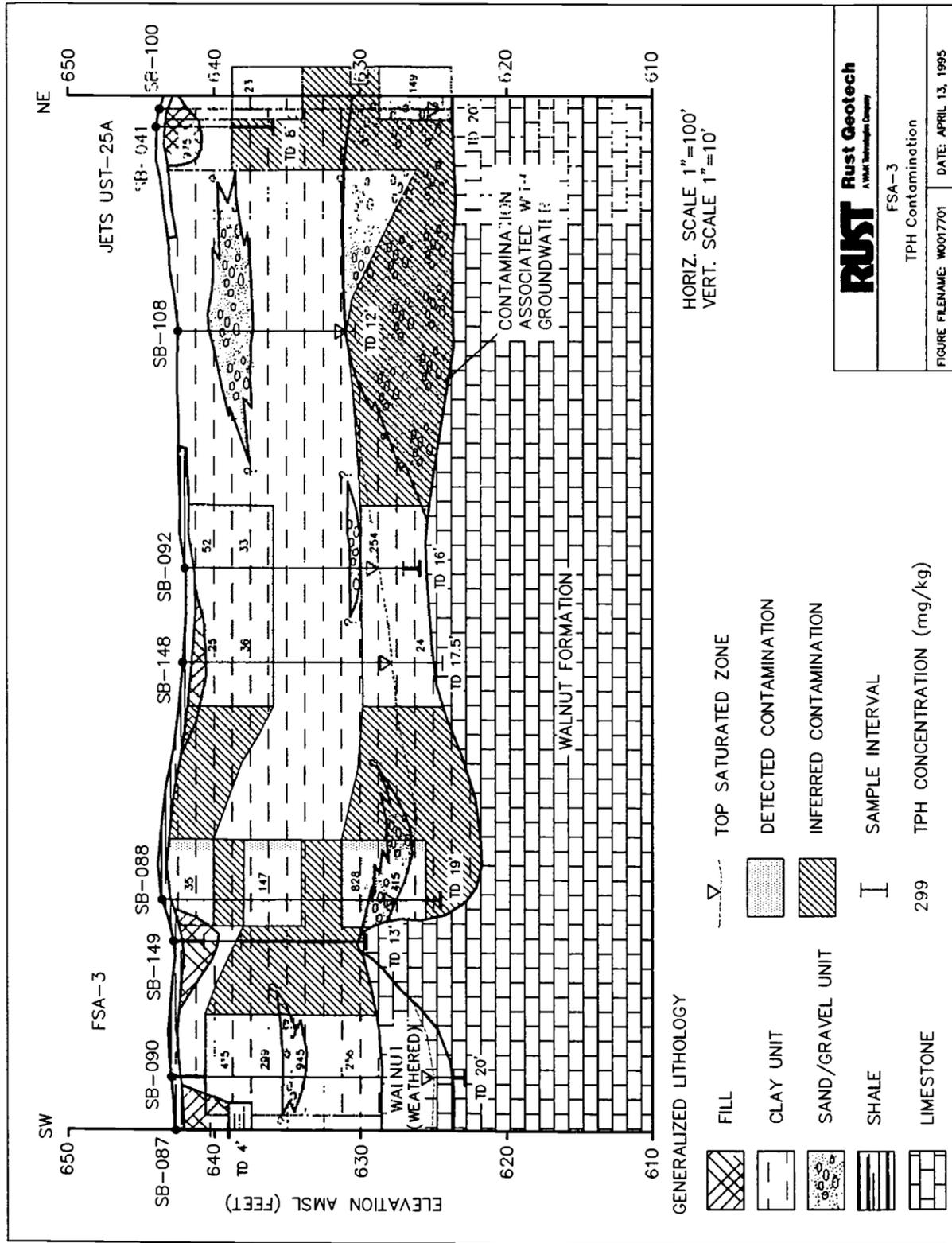


Figure 4.3.13-5. Cross Sectional View of FSA-3 Showing TPH Results.

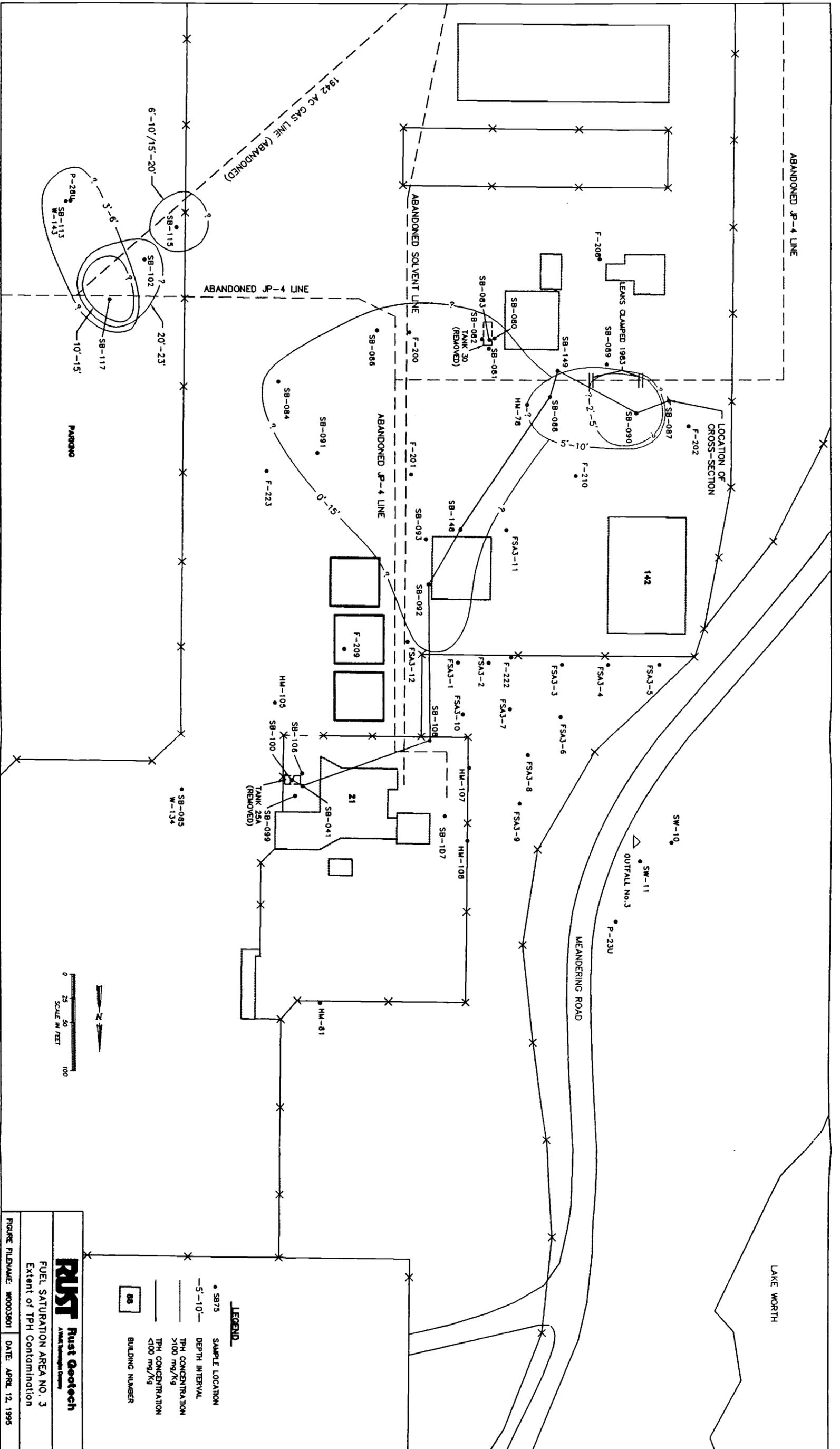


Figure 4.3.13-6. Extent of TPH in the Vadose Zone Detected at FSA No. 3.

**Table 4.3.13-4 Summary of Inorganic Analytical Results
for Soil Samples Obtained from FSA-3**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background (mg/kg)	No. of Samples Analyzed	No. Above Upper Background Limit for the Western USA
Antimony	(8.6)	(13.3)	2.2	15	0
Arsenic	2.6	7.1	21.6	15	0
Beryllium	0.3B	1.2B	3.6	15	0
Cadmium	(0.89)	1.7	2.8	15	0
Chromium	5.3	17.2	196.6	15	0
Copper	(1.8)	7.8	90.0	15	0
Lead	3.7	(13)	55.1	15	0
Nickel	(5.7)	11.9	66.2	15	0
Selenium	(0.45)	(2.3)	1.4	15	0
Silver	(0.74)	(0.98)	1.4	15	0
Thallium	(0.43)	(0.49)	0.8	15	0
Zinc	11.6	29.2	176.2	15	0

Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
 3) Cadmium, chromium, copper, nickel, and zinc were identified in the Baseline Risk Assessment as chemicals of concern.

contamination were identified to the east of the main FSA-3 area. These areas were penetrated by boreholes SB-091 and SB-102. The sources for these areas of contamination are likely to be minor leaks of fuel lines or fuel-related activities at the surface.

Estimates of the volume of contaminated material in the vadose zone have been calculated for the individual areas described. The volume was derived by using the approximate width, length, and thickness of the areas shown on Figure 4.3.13-2. Area A (SB-090, SB-149, SB-088, 6-501B) contains an estimated 5,200 cubic yards of soil that is contaminated with JP-4. The remaining two areas, B (SB-091) and C (SB-102), have estimated volumes of 700 and 500 cubic yards, respectively. The total estimated volume of soil contaminated with TPH as shown in Figure 4.3.13-6 is approximately 40,000 cubic yards. However, the estimated volume of contamination greater than 100 ppm is 5,200 cubic yards for Area A. The remaining TPH contamination is less than 100 ppm.

4.3.14 Former Fuel Storage Area

4.3.14.1 Summary of Investigations

4.3.14.1.1 Previous Investigations: A 100,000-gallon above-ground JP-4 storage tank was located at the southwest corner of Plant 4 near the center of the Radar Range (see Figure 4.3.14-1). In use from the early 1940s to 1962, the storage tank was suspected to have leaked. The tank was removed from the site and relocated in 1962. Soil beneath the tank was reportedly observed to be saturated with jet fuel at the time of removal (Hargis & Montgomery 1983). Hargis & Montgomery reports that the buried pipeline transporting fuel from the area leaked on several occasions. This site is identified as the Former Fuels Storage Area (FFSA).

Hargis & Montgomery drilled one test hole (TH-9) and one monitoring well (HM-8) in December 1982, under the previous site of the fuel tank (Figure 4.3.14-1). No contamination was detected in TH-9. HM-8 soil samples were collected from four depth intervals and analyzed for trace metals, cyanide, organic compounds, oil and grease, and jet fuel. No significant trace metals or cyanide were detected. Relatively low levels of VOCs, semi-VOCs, and oil and grease were found in HM-8 soil samples taken from the surface to a depth of 26 feet (Hargis & Montgomery 1983). The primary contaminants found include oil and grease (149 mg/kg), methylene chloride (200 µg/kg), and di-n-butyl phthalate. Removal of the soils was not reported.

4.3.14.1.2 Current Investigation: Four soil borings (SB-074, SB-075, SB-076, SB-077) were drilled 25 feet north, south, east, and west, respectively, of monitoring well HM-8 (Figure 4.3.14-1) to determine the lateral and vertical extent of contamination. SB-074 and SB-075 were drilled from the surface to the top of the water table with samples collected in 5-foot intervals. SB-076 and SB-077, upgradient of the site, were drilled and sampled to 16 feet. Samples for VOCs were grab samples from each 5-foot interval. Other samples were composited over each 5-foot interval. Composite samples were analyzed for fuel hydrocarbons and oil and grease.

4.3.14.2 Summary of Soils

Limestone of the Walnut Formation was found at 49 feet below surface in monitoring well HM-8, drilled near the center of FFSA. The recent borings were drilled to depths of 16 feet to 38 feet and failed to reach bedrock. The lithologic sequence encountered may be generalized as silty clays interbedded with 1- to 4-foot thick lenses of limestone gravel and stringers of fine-grained silty sands. Description of the soils encountered may be found on the borehole logsheets in Appendix A-2.

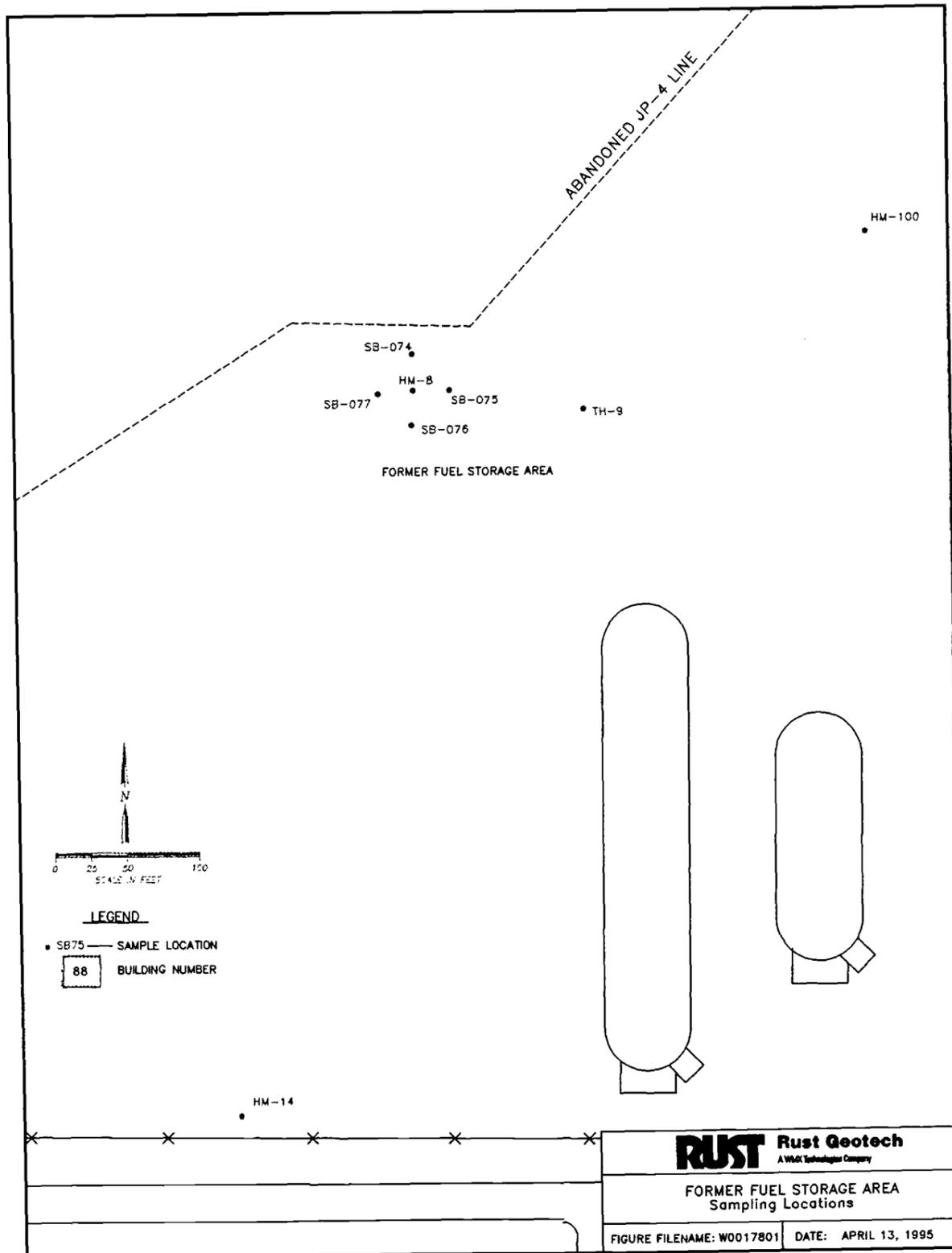


Figure 4.3.14-1. Borehole Soil Sample Locations at the Former Fuel Storage Area.

4.3.14.3 Results of the Investigation

Few organic contaminants were detected by analyses of the FFSA samples (see Table 4.3.14-1, Table 4.3.14-2, and Appendix E). Low levels of TPH (67 mg/kg) and oil and grease (24 mg/kg) were detected in FFSA soil samples (see Table 4.3.14-1). Bis(2-ethylhexyl)phthalate, a common lab contaminant, was detected in concentrations up to 1,900 µg/kg in soil samples from SB-075 (see Table 4.3.14-2). However, bis(2-ethylhexyl)phthalate was also detected in associated laboratory blanks.

Table 4.3.14-1 Summary of VOC and TPH Analytical Results for Soil Samples Obtained from FFSA

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
Acetone	(11)	12	24	1
Oil and Grease	24 mg/kg	24 mg/kg	23	1
Total Petroleum Hydrocarbons	(10) mg/kg	67 mg/kg	23	2

Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.

Table 4.3.14-2 Summary of Semi-VOC Analytical Results for Soil Samples Obtained from FFSA

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
Bis(2-ethylhexyl)phthalate	(710)	1900	29	5

Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.

4.3.14.4 Conclusions

No significant concentrations of chemicals of concern or other contaminants were found by the sampling and analyses. This evidence suggests that soil previously reported as saturated with jet fuel was removed from the site.

4.3.15 Jet Engine Test Stand and UST Site 25A

4.3.15.1 Summary of Investigations

4.3.15.1.1 Previous Investigations: The Jet Engine Test Stand (JETS) site, located northeast of Facilities Building No. 142 and east of Meandering Road (see Figure 4.3.15-1), was identified by Radian (1987) during the IRP Phase II investigation as a site containing fuel-related contamination in soil and groundwater. The site is located north of a fuel test area and a known area of fuel contamination (FSA-3). Facilities Building No. 21 near the site has a sump, constructed in 1975, that collects water for cooling, noise suppression, and building cleanup, and pumps it to an industrial waste line. Adjacent to the site and Building No. 21 is UST Site 25A which consisted of two vertical underground tanks once used for fuel storage. Just to the north of the JETS is an active underground JP-4 tank. There appear to be several possible sources for contamination at the JETS. Both the sump and the abandoned tanks were suspected sources of contaminants. Soil samples collected from five borings in the vicinity of the JETS contained anomalous concentrations of fuel hydrocarbons and oil and grease. Groundwater samples collected from four monitoring wells in the vicinity of JETS indicated that two of the wells contained fuel-related hydrocarbons (HM-107 and HM-108).

Three monitoring wells (HM-105, HM-107, and HM-108) and two soil borings (SB-9 and SB-10) were installed by Radian near JETS in August 1986 (see Figure 4.3.15-1). Soil samples were collected and analyzed for hydrocarbon fuels and oil and grease. Hydrocarbon fuels (1,700 mg/kg) were found in soils from HM-107 at a depth of 14 to 15 feet. Oil and grease were detected at HM-107 and SB-9. Results of the chemical analyses may be found in Table 4.3.19-5 of the Radian 1987 report.

UST Site 25A tanks were removed prior to December 22, 1988, which was the effective date of Federal Subtitle I regulations. After removal of the tanks, soil samples were collected at a depth of 10 feet from five sampling locations. The soil was found to be contaminated with benzene, toluene, and xylene. The removed tanks had fist-sized holes in them (Hargis + Associates 1989). The pipeline supplying the tanks also leaked. No soil was removed.

4.3.15.1.2 Current Investigation: Additional soil borings and soil samples were needed at the site to better define the extent of contamination. During the current investigation seven soil borings were drilled around the JETS area. SB-041, SB-099, SB-100, and SB-106 were drilled to investigate the former underground tanks (UST Site 25A) next to Building 21, the JETS. SB-107 and SB-108 were drilled immediately west of JETS and SB-085, east of Building 21, was completed as monitoring well W-134.

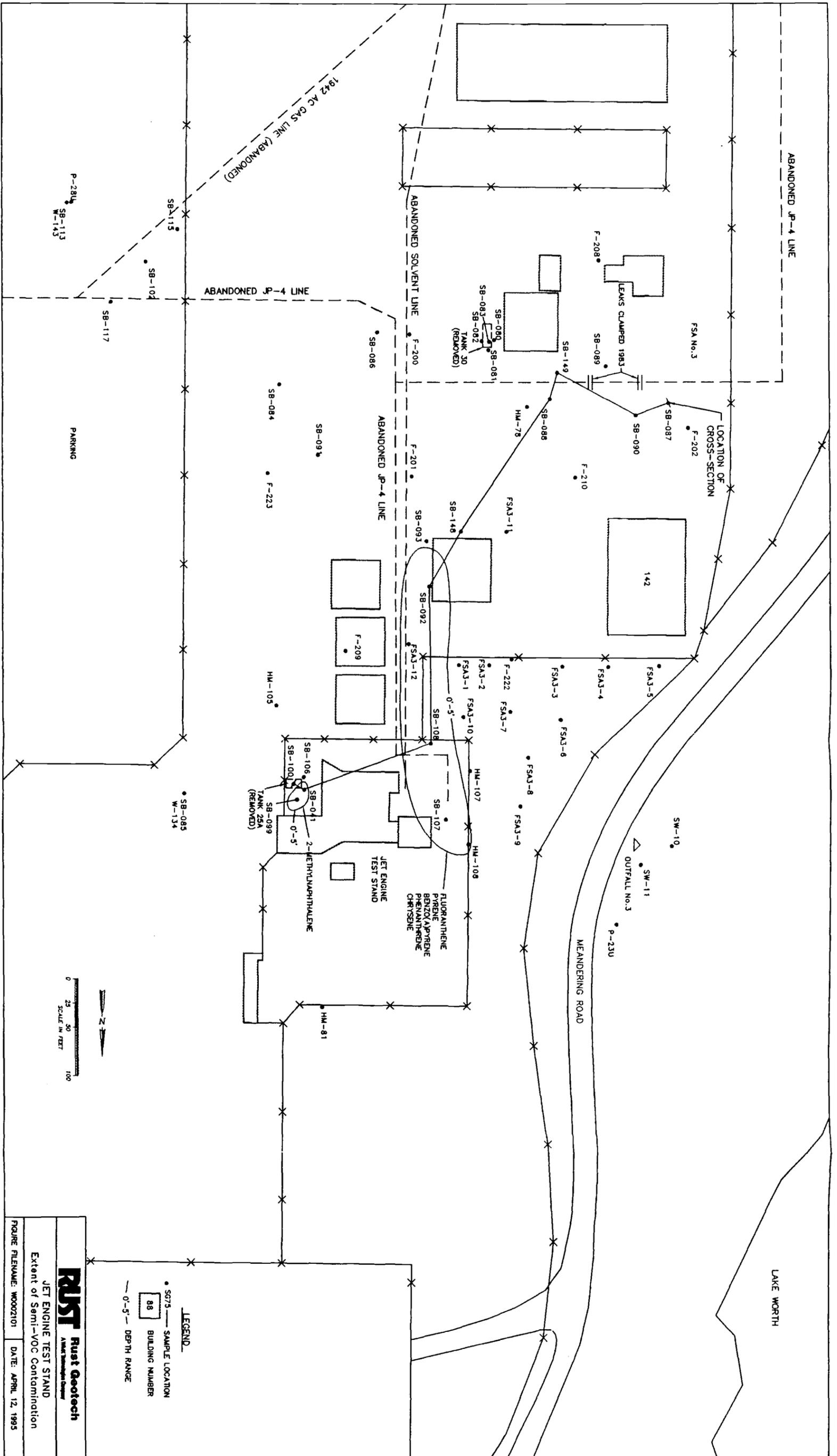


Figure 4.3.15-1 Extent of Semi-VOCs at the Jet Engine Test Stand

Soil borings were drilled and sampled around the perimeter of JETS. Soil borings and monitoring well data from a prior investigation (Radian 1987) were used on the west and north side. The Geotech borings were sampled in 5-foot intervals from the surface to the top of the water table. A grab sample for VOCs was taken from each interval. The remaining sample was a composite of each 5-foot interval. Composite soil samples were analyzed for semi-VOCs, petroleum hydrocarbons, and oil and grease.

4.3.15.2 Summary of Soils

Figure 4.3.15-2 is a generalized geologic cross section that is oriented southwest-northeast and extends from the FSA-3 area to JETS. The upper-zone sediments depicted in the cross section and borehole logsheets consist of up to 14 feet of silty clay with occasional sand and gravel intervals and traces of black organic material. Soil borings in the vicinity of the removed UST Site 25A tanks encountered a 1- to 7-foot thick basal unit of limestone gravels and sand that rests directly on Walnut Formation limestone found at 18.7 feet below surface. Competent gray limestone bedrock was reached in SB-106 at 18.7 feet below surface. In some areas, as shown on the cross section, the Quaternary alluvium is covered by concrete pavement and a variable thickness of fill material. JETS is positioned on the flank of a low relief bedrock erosional high.

4.3.15.3 Results of the Investigation

Sample results from three soil borings drilled around the perimeter of JETS and four located at UST Site 25A are summarized in Table 4.3.15-1, Table 4.3.15-2, Table 4.3.15-3, and Appendix E.

Two semi-volatile chemicals of concern, fluoranthene and pyrene, were detected in the shallow samples from SB-107 and SB-108. Maximum concentrations for fluoranthene (5,100 $\mu\text{g}/\text{kg}$), pyrene (3,700 $\mu\text{g}/\text{kg}$), and phenanthrene (5,000 $\mu\text{g}/\text{kg}$) were found in SB-107. The semi-VOC contamination found in SB-107 and SB-108 extends south and includes SB-092. An outline of the extent of contamination is shown in Figure 4.3.15-1. Figure 4.3.15-2 illustrates the vertical extent of contamination in boreholes SB-041, SB-092, and SB-108.

Significant levels of 2-methylnaphthalene were found in three of four boreholes drilled at the UST Site 25A. A maximum concentration of 3,900 $\mu\text{g}/\text{kg}$ 2-methylnaphthalene was found in the shallow sample (0 to 5 feet) of SB-041. The extent of contamination in the vadose zone is defined by SB-041 and SB-099 and shown in Figure 4.3.15-1. The cross section in Figure 4.3.15-2 shows the contamination in SB-041 which is interpreted to extend to the groundwater zone where 2-methylnaphthalene was detected in the saturated soil zone of SB-100.

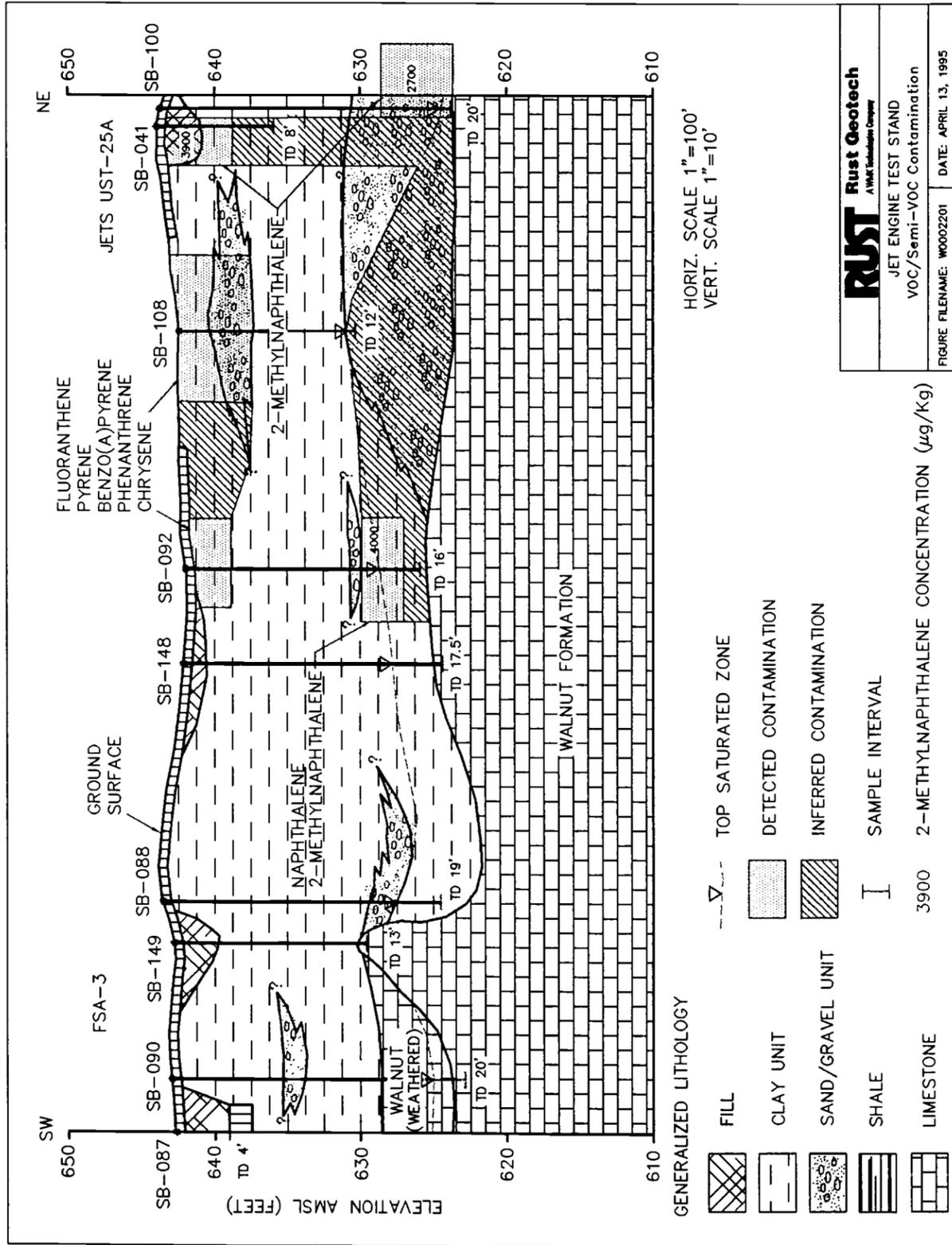


Figure 4.3.15-2. Cross Sectional View Showing VOCs and Semi-VOCs Detected at the Jet Engine Test Stand.

Rust Geotech
A HNTB Company

RUST
JET ENGINE TEST STAND
VOC/Semi-VOC Contamination

FIGURE FILENAME: W0002201 DATE: APRIL 13, 1995

**Table 4.3.15-1 Summary of Semi-VOC Analytical Results
for Soil Samples Obtained from JETS and UST Site 25A**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
2-Methylnaphthalene	(740)	3,900	18	2
Benzo(a)Anthracene	(740)	1,800	18	2
Benzo(b)Fluoranthene	(740)	1,400	18	1
Benzo(g,h,i)Perylene	(740)	1,300	18	1
Benzo(k)Fluoranthene	(740)	1,100	18	1
Chrysene	(740)	1,700	18	2
Fluoranthene	(740)	5,100	18	2
Indeno(1,2,3-cd)Pyrene	(740)	1,100	18	1
Phenanthrene	(740)	5,000	18	2
Pyrene	(740)	3,700	18	2

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
3) Pyrene, fluoranthene, and 2-methylnaphthalene were identified in the Baseline Risk Assessment as chemicals of concern.

**Table 4.3.15-2 Summary of VOC and TPH Analytical Results
for Soil Samples Obtained from JETS and UST Site 25A**

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
Acetone	(11)	200	19	14
2-Butanone	(11)	67	19	4
Ethylbenzene	98	98	19	1
Total Petroleum Hydrocarbons	(10) mg/kg	975 mg/kg	19	9

TPH were detected in all boreholes at UST Site 25A. Low concentrations (17 to 21 mg/kg) of TPH were detected in SB-085 from sample depths of 2 to 18 feet. The horizontal and vertical extent of TPH contamination is shown in Figures 4.3.15-3 and 4.3.15-4. There appears to be a good correlation between the relative levels of TPH and 2-methylnaphthalene. Ethylbenzene (98 µg/kg) was detected in the top 5 feet of SB-041.

**Table 4.3.15-3 Summary of Inorganic Analytical Results
for Soil Samples Obtained from JETS and UST Site 25A**

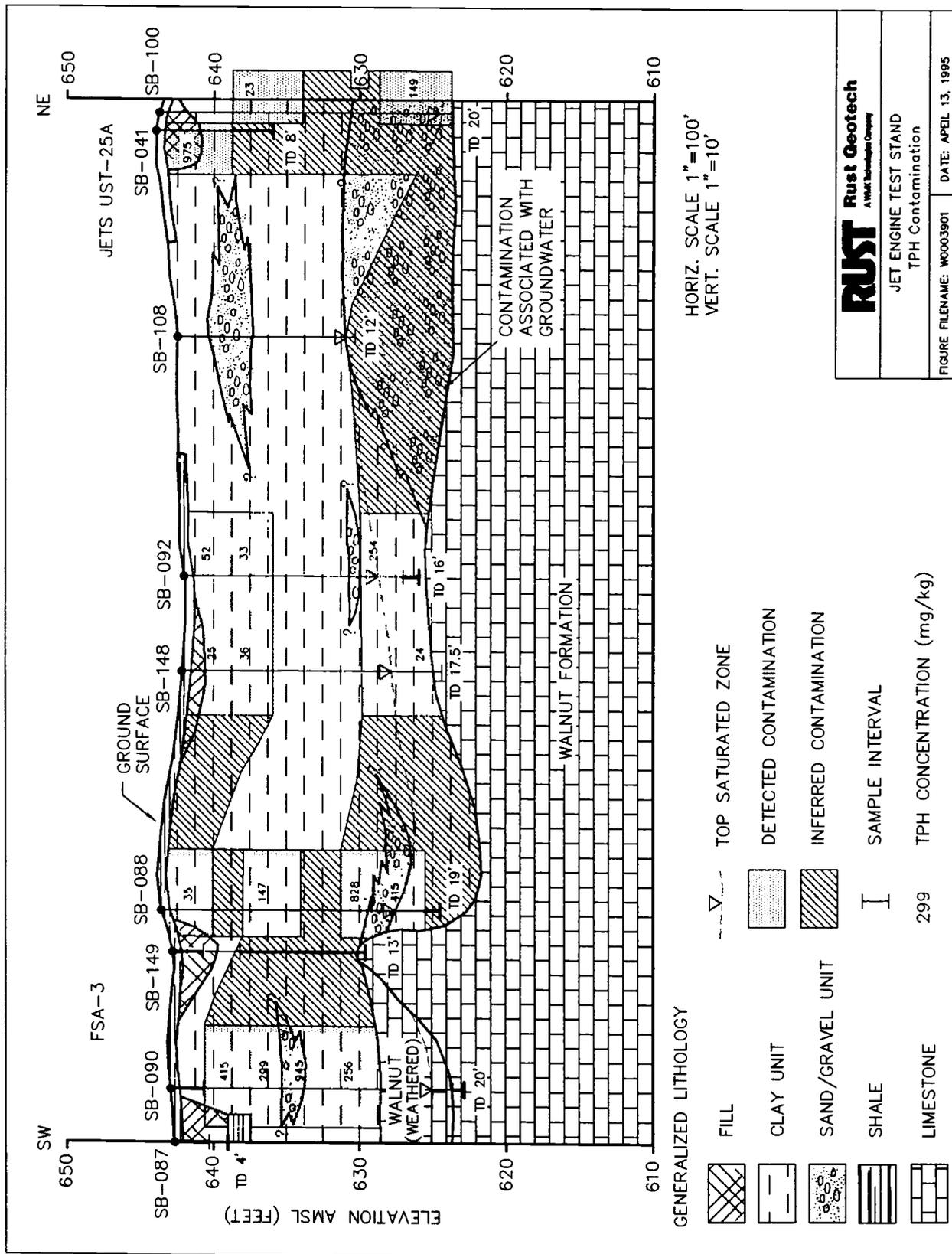
Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background Limit (mg/kg)	No. of Samples Analyzed	No. Above Upper Background Limit for Western USA
Antimony	(8.8)	(9.4)	2.2	8	0
Arsenic	2.7	4	21.6	8	0
Cadmium	(0.88)	1.4	2.8	8	0
Chromium	4.5	14.1	196.6	8	0
Copper	(1.8)	9.7	90.0	8	0
Lead	3.3	12	55.1	8	0
Nickel	(5.5)	9.7	66.2	8	0
Selenium	(0.45)	(2.2)	1.4	8	0
Silver	(0.88)	(0.94)	1.4	8	0
Thallium	(0.44)	(0.47)	0.8	8	0
Zinc	11.9	32	176.2	8	0

Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) Cadmium, chromium, copper, nickel, and zinc were identified in the Baseline Risk Assessment as chemicals of concern.

Concentrations of metals are within the range for background soils of the western United States.

4.3.15.4 Conclusions

The north trending elongated envelope located to the west of JETS reflects shallow contamination (0 to 5 feet) detected in soil samples from SB-092, SB-108, and SB-107. Chemicals found in this area include fluoranthene, pyrene, benzo(a)pyrene, phenanthrene, and chrysene. All of these contaminants are coal-tar derivatives and are not commonly found in jet fuel. The coal-tar association coupled with the shallow depth of detection suggest that this contamination is related to asphalt. An estimate of the volume of contaminated material in the vadose zone is approximately 3,000 cubic yards.



The other area of significant contamination in the vadose zone is associated with the removed UST Site 25A. The extent of fuel-related contamination is shown in Figure 4.3.15-1, and the volume of material is approximately 100 cubic yards.

4.3.16 Waste Water Collection Basins (WWCBs)

4.3.16.1 Previous Investigations

The WWCB, located south of the Process Building (Facilities Building No. 181) (see Figure 4.3.16-1), consist of two lined, concrete waste basins, each with an approximate capacity of 85,000 gallons, designed to collect and settle suspended solids from plant waste water. Processed water is then discharged to the Fort Worth sewer system. IRP Phase I investigations determined that several spills from vapor degreasers in the Process Building (primarily TCE) have flowed to the basins via floor drains that empty into the waste water collection basins. Other chemical spills may have entered the basins via the floor drains. The integrity of the liner coating the concrete basins had not been evaluated for several years. It is suspected that cracks in the basin floor or wall may allow contaminants to leak to the surrounding soils.

Groundwater samples from monitoring well HM-47 east of the basins, indicate that the groundwater is contaminated with VOCs. It is uncertain whether the VOCs in the groundwater at this location can be attributed to the waste water basins. The presence of TCE in the groundwater indicates that the source is related to the Process Building (vapor degreaser spills). A sanitary sewer line runs on an east-west line under the site, and a storm drain, which runs northwest-southeast, is approximately 75 feet south of the basins.

The drilling log from HM-47 shows clayey silt or sandy clay to 16 feet, then sand and gravel to bedrock. No soil samples were analyzed. Intellus Corp. drilled two soil borings, FB-5 and FB-6, in the area of suspected Chrome Pit No. 2, approximately 100 feet west of the WWCB. Both borings found undisturbed soils at a depth of 2 feet. Soils were generally sandy silts with a sandy gravel zone at about 14 feet. A field PID was used to screen soil every half-foot. No response above background was noted. Laboratory analysis for total chromium and barium indicated background levels. Both borings terminated above water level.

4.3.16.2 Current Investigation

Solvent and other chemical spills may potentially enter the basins and through leakage enter soils. To evaluate whether the basins have been a source of TCE and other contaminants, additional subsurface soil sampling and upper-zone groundwater sampling was needed both upgradient and downgradient of the basins. The initial objective of the data collection in the basins area was to determine if the basins are a source of contamination or if the source exists upgradient of the basins. In addition, a visual

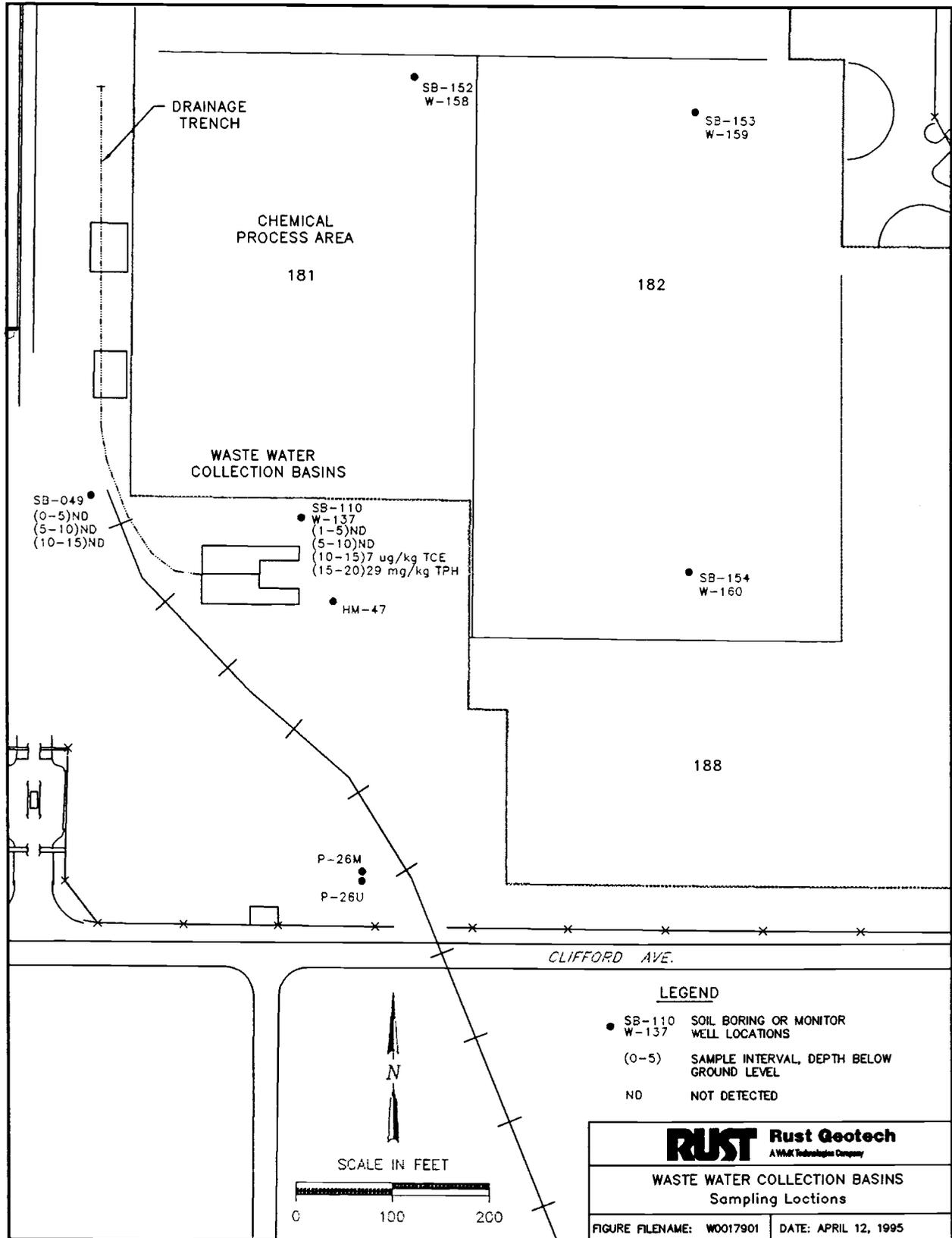


Figure 4.3.16-1. Borehole Soil Sample Locations at the Waste Water Collection Basins.

inspection of the integrity of the basin walls and floor was made to determine if significant leakage may be occurring from these basins.

One soil boring (SB-110) was drilled immediately north and east (downgradient) of the WWCB. The location for this boring was based on groundwater contour maps from a prior investigation (Hargis + Associates 1989). The boring was drilled to the top of the water table with soil samples collected from 5-foot intervals. A second soil boring, SB-049, was drilled west of the WWCB (upgradient) and sampled for the same analytes. Samples for VOCs were grab samples from each 5-foot interval; the remaining samples were composites of each interval. Composite samples were analyzed for semi-VOCs, TPH, and metals. SB-049 was drilled through silty clay with little sand or gravel and encountered bedrock at 15 feet. SB-110 was drilled through silty clay to 16 feet, then clayey sands, sands, and gravels until bedrock at 29 feet (Appendix A-2).

4.3.16.3 Results of the Investigation

Analytical results from the two borings do not show elevated levels of organic or inorganic contaminants. Low amounts of TCE (7 $\mu\text{g}/\text{kg}$) were reported in SB-110 at the 10- to 15-foot depth and 29 mg/kg of TPH were reported at the 15- to 20-foot depth interval (see Table 4.3.16-1).

Table 4.3.16-1 Summary of VOC and TPH Analytical Results for the Waste Water Collection Basins

Analyte	Minimum $\mu\text{g}/\text{kg}$	Maximum $\mu\text{g}/\text{kg}$	No. of Samples Analyzed	No. Above CRQL
bis(2-ethylhexyl) phthalate	(750)	1,300	11	1
Trichloroethene	(5)	7	11	1
TPH	(10) mg/kg	29 mg/kg	11	1

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 2) TCE was identified by the Baseline Risk Assessment as a chemical of concern.

4.3.16.4 Inspection of the WWCB

A TCE leak in the process building was reported by General Dynamics in June 1991. TCE had leaked from a tank and through the drain system into the WWCB. Contaminated water and sludge from the basins was pumped into portable tanks for treatment and the basins were cleaned. While the basins were empty, a visual examination of the basin walls and floors was made on June 15-16, 1991. The concrete appeared in good shape, with no cracks. The liner was missing over large areas of the

floor (60 percent gone on the north basin floor) and was cracked in places on the walls. The floor of the south basin was not examined by Geotech personnel but General Dynamics personnel stated the south basin had less liner over the floor than the north. No cracks were evident on the south basin. The concrete behind the liner could not be examined. As the basins were being refilled from a fire hose, the water from the hose was washing sections of the liner off the concrete ramp, which would indicate the liner is not bonded to the concrete effectively. The drainage trench system on the outside of the Building, leading to the WWCB, was also examined and several small sections of the concrete trench were observed to be open to the soil where the concrete had been etched by acids. The trench is more likely to allow contamination to pass through to the underlying soils than are the WWCB. The trench sections open to the soil were near the north end of building 181 and would not contribute to soil contamination adjacent to the WWCB.

4.3.16.5 Conclusions

SB-049 sample results did not indicate soil contamination. Also, it should be noted that SB-049 was drilled at the suspected location of Chrome Pit No. 2 and did not indicate elevated levels of contaminants that may have been related to that area. Samples collected from SB-110 had only minor amounts of contamination at depths of 10 to 15 feet (TCE — 7 $\mu\text{g}/\text{kg}$) and 15 to 20 (TPH — 29 mg/kg). Soil sample results from these boreholes do not indicate soil contamination in the vicinity of the WWCB.

4.3.17 Other Source Areas

A variety of contaminant sources exist at Plant 4. Because the plant has been in continuous operation since 1942, significant quantities of contaminants may have been released to the environment from past disposal practices, fire training activities, numerous leaks in buried fuel lines, process lines and tanks, or spills. The sites previously identified in this section appear to be the major contributors to the contaminants already observed in contaminant pathways.

Because there are numerous sources of contaminants, it should be noted that many areas of Plant 4 will potentially contain a mixture of contaminants from several source areas.

One new source area was detected during the FSA-3 site investigation. The Sampling and Analysis Plan called for one monitoring well to be placed east (upgradient) of the FSA-3 site to aid in determining groundwater flow direction. When the borehole, SB-102, was drilled, contamination was detected with PIDs and later confirmed by analytical results to be petroleum hydrocarbons. At 17 feet to 20 feet, benzene, ethylbenzene, and xylene were detected at concentrations of 14, 74, and 64 $\mu\text{g}/\text{kg}$, respectively. At 20 to 23 feet in depth the concentrations were 16, 82, and 110 $\mu\text{g}/\text{kg}$. No TPH was detected in the 17- to 20-foot sample, but the 20- to 23-foot and 23- to 26-foot samples were 58 and 13 mg/kg , respectively. Inorganic and semi-VOC results for

SB-102 were very low or below the detection limit. Investigation of the area revealed an abandoned 1942 aviation fuel pipeline that passed east of the borehole site. The pipeline was marked on an old underground utility map but not on current maps of abandoned fuel lines in the area. Two more soil borings, SB-115 and SB-117, were drilled 50 feet on either side of the original boring and parallel to the 1942 pipeline. Both of these borings also indicated petroleum hydrocarbons, although at lower levels. A soil boring was drilled on the east side of the pipeline and did not detect any contamination. This last soil boring was converted to a monitoring well (W-143). This area was not investigated further as contaminant levels were low (benzene at 74 $\mu\text{g}/\text{kg}$, xylene at 110 $\mu\text{g}/\text{kg}$), and levels dropped east of the line and in the adjacent borings.

No additional source areas were discovered during the current investigation, which concentrated on the previously identified sites.

4.4 Sediment Contamination

4.4.1 Lake Worth Sediment Sampling

4.4.1.1 Introduction

Contaminants from Plant 4 may be entering Lake Worth via surface water drainage and upper-zone groundwater discharge. Because Lake Worth is a source of public water supply and is also a source of recharge to the Paluxy Aquifer, additional data were needed to evaluate the potential risk to human health and the environment from contaminants in the sediments of Lake Worth. Sediment samples were collected from the lake bottom in areas where contamination was most likely to be found to determine if past contaminant spills or releases have reached Lake Worth. The data from the samples were used to assess potential risk associated with contaminated sediments.

Samples were collected from sediments in areas where contamination was likely to be found based on surface drainage patterns. These areas included outfalls, tributaries, and areas adjacent to known hazardous waste sites. Sampling locations and the type of sample analysis performed were selected in agreement with U.S. Fish and Wildlife and EPA Region VI personnel.

A total of 25 locations, including one location in Meandering Road Creek and one location in the drainage above the lake background location, (see Figure 4.4.1-1) were sampled for the Lake Worth investigation. Six coves of Lake Worth with drainage originating at Plant 4 were sampled, with samples collected from three locations at each cove. One sample was taken 10 feet from shore at the head of the cove, adjacent to the drainage, and two more samples were taken evenly spaced out toward the middle of the cove. Three locations were sampled offshore from the Nuclear Aerospace Research Facility (NARF) area, and one location was sampled off the north shore of the site. The maximum depth samples could be taken was 17 feet, which was the length of the

sampling device. Samples were collected from the lake bottom to 22 inches below the lake bottom, the length of the sampler, and split into two 11-inch samples for analysis. The sampler was returned to the bottom several times to gather sufficient material for composite samples. If the sample was gravelly or very sandy, it was thrown out and a new sample collected that contained a greater amount of sediment (silt or clay).

The type of analysis performed was dependent on the sampling location (see Table 4.4.1-1) with some sites having special analysis, such as radioisotope analysis for NARF area samples. Seven samples were analyzed for VOCs, semi-VOCs, oil and grease, TPH, and metals. VOC samples were bottled immediately from the sample barrel, and the remainder of the material was composited for other analyses. Samples collected from the drainage near the NARF area were also analyzed for radioisotopes. A field scan was performed for alpha, beta, and gamma radiation on all samples collected from sediments near the former NARF site, with no radiation levels above background detected. Twenty-one samples were analyzed for polynuclear aromatic hydrocarbons (PAHs) and three were analyzed for PCBs and pesticides. A background sediment sample was collected at a location 0.5 mile west of the Lockheed Lake Worth pumping station and was analyzed for all analytes except selected metals (Al, Cd, Cr, Ni, and Pb).

Tissue sample collection from the lake and creek sampling locations and analyses are discussed in Section 4.7, "Ecological Tissue Contamination."

4.4.1.2 Sampling Results

4.4.1.2.1 Results of Lake Worth Background Location Sediment Sampling: The location of the background sampling site was chosen with the agreement of EPA personnel. The site was to be close enough to Plant 4 to be considered a similar habitat but far enough away to be unaffected by potential contamination from Plant 4 or other industrial sites. However, contaminants were detected at the background location (Location No. 1, see Figure 4.4.1-1), with both organic and inorganic contaminants detected. TCE, TPH, and oil and grease at the background location were found only in the deeper sample with results of 160 $\mu\text{g}/\text{kg}$, 169 mg/kg , and 290 mg/kg , respectively (see Table 4.4.1-2).

Acetone and 2-butanone were found in both depth intervals at relatively the same concentration (see Table 4.4.1-3). Inorganic results at the background location were elevated for chromium, lead, and zinc, with levels for sample intervals 0- to 11-inches/11- to 22-inches of 23.6/16.2 mg/kg (Cr), 84.1/164 mg/kg (Pb), and 74.3/43.5 mg/kg (Zn). Sampling Location 24 was located several hundred yards up drainage from the lake background site and was sampled for PAH and PCB/pesticides. Fourteen PAH compounds were detected at levels ranging from 10 $\mu\text{g}/\text{kg}$ to 130 $\mu\text{g}/\text{kg}$. The drainage leading to the background location was also examined for possible sources

**Table 4.4.1-1 Summary of Lake Worth Sediment Samples
Lake Worth Sediment Sampling Matrix**

LOCATION	TYPE OF ANALYSIS										
1	BKG	VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs	PCBs/Pesticide			TOC
2		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs	PCBs/Pesticide			TOC
3									Metals (2)		TOC
4							PAHs		Metals (2)		TOC
5		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs				TOC
6							PAHs		Metals (2)		TOC
7							PAHs		Metals (2)		TOC
8		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs				TOC
9							PAHs		Metals (2)		TOC
10							PAHs		Metals (2)		TOC
11		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs				TOC
12		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs			RAD	TOC
13							PAHs		Metals (2)		TOC
14							PAHs		Metals (2)		TOC
15										RAD	TOC
16										RAD	
17										RAD	
18		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs				TOC
19							PAHs		Metals (2)		TOC
20							PAHs		Metals (2)		TOC
21		VOCs	Semi-VOCs	Metals (1)	TPH	O&G	PAHs				TOC
22							PAHs		Metals (2)		TOC
23							PAHs		Metals (2)		TOC
24							PAHs	PCBs/Pesticide			TOC
25	Tissue sampling only, also sampled as SW-5										
26							PAHs				TOC
27	Biotoxicity Sampling										
28	Tissue sampling only										

Notes:
 Metals (2) - Metals analysis for aluminum, cadmium, chromium, lead, and nickel.
 Metals (1) - Priority-Pollutant Metals as in Sampling Plan
 O&G - Oil and Grease
 PAHs - Polynuclear Aromatic Hydrocarbons
 RAD - Radioisotope Analysis
 Semi-VOCs - Semivolatile Organic Compounds
 TPH - Total Petroleum Hydrocarbons
 Grain - Grain Size Analysis
 TOC - Total Organic Content
 Moisture - % Moisture

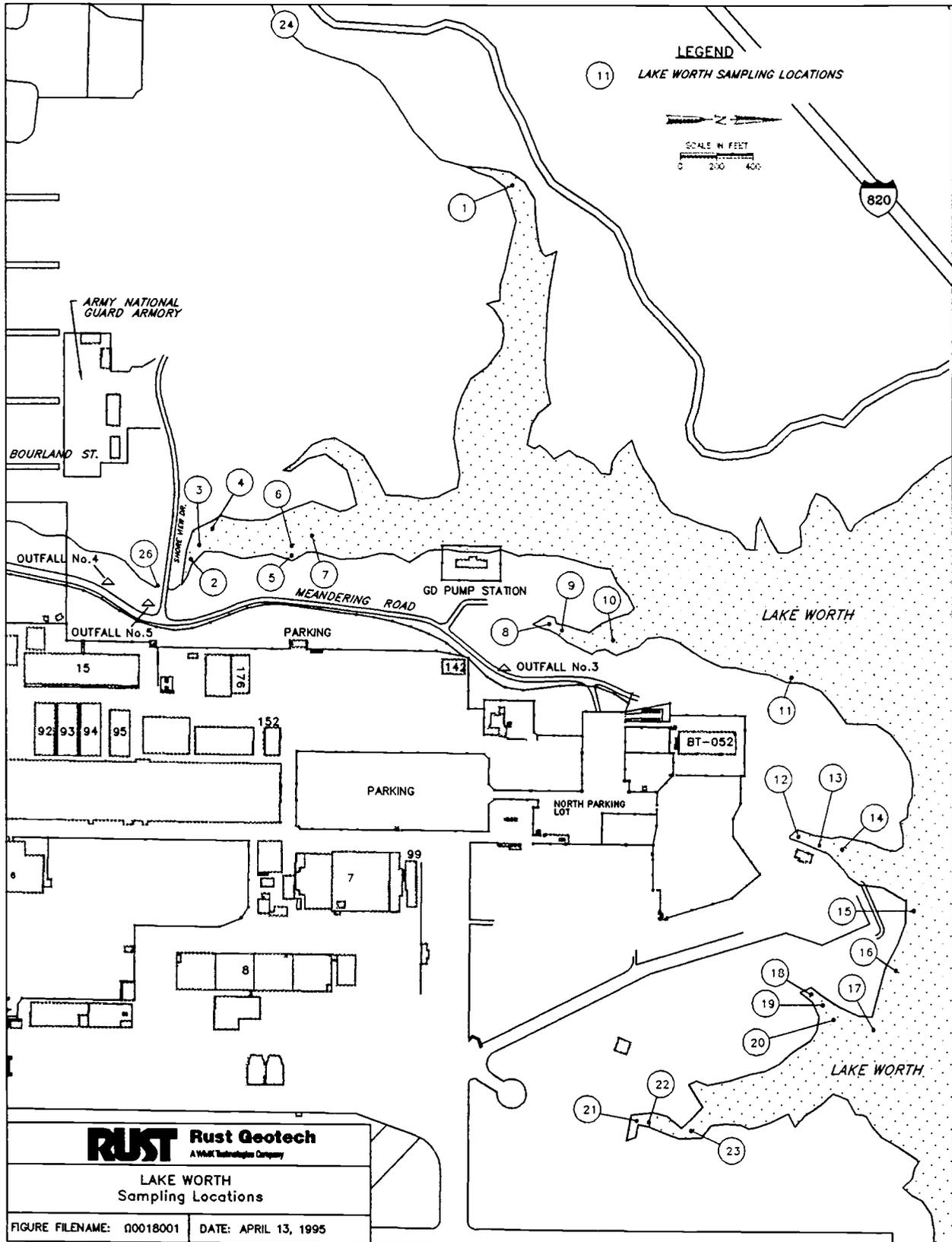


Figure 4.4.1-1. Lake Worth Sampling Locations.

**Table 4.4.1-2 Location Summary of VOC, Oil and Grease,
and TPH Sediment Samples Collected from Lake Worth**

Location	VOCs	0 to 11 inches ($\mu\text{g}/\text{kg}$)	11 to 22 inches ($\mu\text{g}/\text{kg}$)	Oil and Grease (mg/kg)	TPH (mg/kg)
1 BKG Site	acetone 2-butanone TCE	230 53 ND	190 46 160	NS/NA / 290	NS/NA / 169
2	acetone carbon disulfide 2-butanone TCE	57 ND 16 44	NS 24 ND ND	476/740	323/616
3	sampled for inorganics				
4	sampled for inorganics / PAH				
5	acetone	41	44	602/893	412/623
6	sampled for inorganics / PAH				
7	sampled for inorganics / PAH				
8	acetone	33	NS	266/NS	199/NS
9	sampled for inorganics / PAH				
10	sampled for inorganics / PAH				
11	acetone 2-butanone	85 22	ND 35	ND/ND	ND/ND
12	acetone	15	28	96/13	61/ND
13	sampled for inorganics / PAH				
14	sampled for inorganics / PAH				
15	radioisotope only				
16	radioisotope only				
17	radioisotope only				
18	acetone	ND	43	15/80	
19	sampled for inorganics / PAH				
20	sampled for inorganics / PAH				
21	acetone 2-butanone	47 18	47 23	ND/ND	ND/ND
22	sampled for inorganics / PAH				
23	sampled for inorganics / PAH				
24	sampled for PAH, PCB/pesticide				
25	no sediment sampling				
26	sampled for inorganics / PAH				

ND = Not detected; NS = Not sampled; NA = Not analyzed

Table 4.4.1-3 Summary of Lake Worth VOC, TPH, and Oil and Grease Sediment Sampling Analytical Results

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. above CRQL
Acetone	(11)	230	16	12
Carbon Disulfide	(6)	24	16	1
2-Butanone	(11)	53	16	7
Trichloroethene	(6)	160	16	2
Oil and Grease	(10) mg/kg	893 mg/kg	15	11
Total Petroleum Hydrocarbons	(10) mg/kg	623 mg/kg	15	10

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Trichloroethene was identified by the Baseline Risk Assessment as a chemical of concern.

of contaminants, with nothing unusual observed that may have caused or contributed to contamination levels. This area does receive flow from a permanent creek that drains a large area.

4.4.1.2.2 Results of Lake Worth Sediment Sampling for Organic Compounds:

Contaminants above the CRQL were detected in the sediments of Lake Worth at seven of the eight locations that were sampled for VOCs (see Tables 4.4.1-3 and 4.4.1-4). Eight of the 23 lake sampling locations were sampled for VOCS, TPH, and oil and grease (see Table 4.4.1-2). TPH was detected at five locations, and oil and grease were detected at six locations. Samples were collected for semivolatile analysis at 8 locations and PAH analysis at 21 locations. The PAH analysis also indicates semivolatile compounds that were detected at all 21 locations (see Table 4.4.1-5). Three sediment samples were analyzed for PCB/pesticides, with two results slightly over the detection limit (see Table 4.4.1-6) for the PCBs Aroclor-1260 and -1254. Aroclor-1260 was detected at both Location 1 (background location) and Location 2 (mouth of creek). Aroclor-1254 was detected only at Location 2.

4.4.1.2.3 Results of Lake Worth Sediment Sampling for Inorganic Compounds:

Sample results from the lake coves and from three locations just off-shore indicate high levels of aluminum, copper, lead, and zinc at several of the lake sediment sampling locations (see Table 4.4.1-7). Locations with the highest results were in the cove of the lake where Meandering Road Creek flows into Lake Worth. The background location also had elevated results for metals. These were the only sampling locations with permanent creeks flowing into the lake. Other lake sampling locations receive storm runoff only. Table 4.4.1-8 presents significant results by location.

Table 4.4.1-4 Summary of Lake Worth Semivolatile Sediment Sampling Analytical Results

Analyte	Minimum µg/kg	Maximum µg/kg	Number of Samples Analyzed	Number above CRQL
Anthracene	(860)	1,500	19	1
Benzo(a)anthracene	(900)	7,900	19	4
Benzo(a)pyrene	(900)	4,900	19	4
Benzo(b)fluoranthene	(900)	6,200	19	4
Benzo(g,h,i)perylene	(860)	5,100	19	4
Benzo(k)fluoranthene	(900)	4,700	19	4
Bis(2-Ethylhexyl) phthalate	920	2,400	19	3
Chrysene	(860)	6,200	19	4
Dibenz(a,h)anthracene	(900)	1,300	19	1
Fluoranthene	960	7,300	19	7
Indeno(1,2,3-cd)pyrene	(860)	4,200	19	3
Phenanthrene	(900)	4,500	19	5
Pyrene	1100	7,000	19	6

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Pyrene, fluoranthene, and benzo(a)pyrene have been identified in the Risk Assessment as a chemical of concern.

Two types of metals analysis were run on selected samples. Aluminum, cadmium, chromium, nickel, and lead were selected for analysis using procedures specified by the U.S. Department of the Interior, Fish and Wildlife Service to aid in their evaluation of the inorganic data. Analysis was to be by the more stringent of either FWS-9-OAS-91-111 (USFWS) or the EPA Method 7000 Series. The selected metals were analyzed by a USFWS contract laboratory using the EPA Method 7000 Series. These metals are used in aircraft production, are constituents in fuels, or were identified as chemicals of concern in the risk assessment. This group of selected metals was analyzed in addition to the Priority-Pollutant Metals (PPMTL). Sampling location LWS 3-01 was sampled for both PPMTL and selected metals with cadmium, chromium, and lead analyzed in both tests. The select metals analysis results for chromium and lead were 35 and 56 mg/kg, respectively. The PPMTL results were 124 and 444 mg/kg. These samples were collected on two different days at approximately the same location. Lake sampling locations were established by lining up with landmarks on shore. Samples with a higher proportion of silts and sands (see Table 4.4.1-9) usually had elevated analytical results over samples with a high proportion of clay.

Table 4.4.1-5 Summary of Lake Worth Sediment Samples Collected for Polynuclear Aromatic Hydrocarbon Analysis

Analyte	Minimum mg/kg	Maximum mg/kg	No. of Samples Analyzed	No. above CRQL
1,2-Benzanthracene	(0.01)	1.7	23	16
1,2,5,6-Dibenzanthracene	(0.01)	0.45	23	16
Anthracene	0.01	0.57	23	15
Benzo(a)pyrene	0.01	1.3	23	18
Benzo(b)fluoranthene	0.02	1.9	23	18
Benzo(e)pyrene	0.01	1.6	23	17
Benzo(g,h,i)perylene	0.01	1.8	23	18
Benzo(k)fluoranthene	0.01	0.91	23	17
Chrysene	0.01	2.3	23	17
Fluoranthene	(0.01)	5.6	23	17
Fluorene	0.01	0.39	23	13
Naphthalene	(0.01)	0.12	23	16
Phenanthrene	(0.01)	4.4	23	15
Pyrene	(0.01)	4.5	23	17

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Pyrene, fluoranthene, naphthalene, and benzo(e)pyrene have been identified in the Risk Assessment as chemicals of concern.

Table 4.4.1-6 Summary of Lake Worth Sediment Samples Collected for PCB/Pesticide Analysis

Analyte	Minimum mg/kg	Maximum mg/kg	No. of Samples Analyzed	No. above CRQL
Aroclor-1260	(0.05)	0.11	3	2
Aroclor-1254	(0.05)	0.1	3	1

- Notes: 1) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 2) Concentration in parentheses indicates the compound was not detected at the reported value.

4.4.1.2.4 Results of Lake Worth Sediment Sampling for Radioisotopes: Samples collected from drainages near the former NARF area were scanned in the field for alpha, beta, and gamma radiation to determine if special personnel protection or shipping methods were required. No levels over background were detected. All radioisotope sediment samples were dried and analyzed for cobalt-60, cesium-137, radium-226, thorium-230, and uranium. Table 4.4.1-10 lists the results of the analysis by sample location. All results are indicative of background levels of radiation in soil. Uranium analysis was by EPA method 6010 with results reported in mg/kg. Background values for uranium in soil are based on a range of 0.86 to 7.25 mg/kg (mean \pm 2 standard deviations) for the western USA, (Shacklette and Boerngen 1984) with a mean value of 2.5 mg/kg. The mean value for Plant 4 uranium analysis was 1.19 mg/kg.

**Table 4.4.1-7 Summary of Lake Worth Inorganic Sediment
Sampling Analytical Results**

Analyte	Minimum Lake Worth Sediment mg/kg	Maximum Lake Worth Sediment mg/kg	Range in Background Soils ³ (mg/kg)	No. of Samples Analyzed	No. Above Natural Background for the Western USA ³
Aluminum	2750	11750	14,500 - 232,000	14	0
Arsenic	3.5	6	1.4 - 21.6	18	0
Cadmium	0.4	11.4	NA - 2.8 ⁴	32	11
Chromium	4.7	124	8.5 - 196.6	32	0
Copper	8.5	88.4	4.9 - 90.0	18	0
Lead	8	444	5.2 - 55.1	32	12
Nickel	(6)	18.1	3.4 - 66.2	32	0
Silver	(1.1)	13	NA - 1.4 ⁵	18	2
Zinc	21.9	303	17.2 - 176.2	18	3

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Cadmium, chromium, copper, nickel, and zinc have been identified in the risk assessment as chemicals of concern.
 3) From range in Background Soils of Western USA, Shacklette and Boerngen (1984).
 4) Upper Background range for cadmium is estimated at 2.8 which is based on twice the observed mean for the four Plant 4 background samples.
 5) Upper Background range for silver is estimated at 1.4 which is based on twice the IDL observed mean for the four Plant 4 background samples.

The cobalt-60, cesium-137, and radium-226 analysis were by gamma spectroscopy and the thorium-230 analysis was by alpha spectrometry. All results except uranium were reported in units of pCi/g (pico Curies per gram). Cobalt-60 was not included in Table 4.4.1-10 as it was not detected in any sample. All analytical results for radiologic samples were within two standard deviations of the samples collected from the background location.

4.4.1.3 Conclusions

Sample results indicate some contamination of Lake Worth sediments is present in near-shore sediments at Plant 4. The VOC contaminants include acetone and 2-butanone (common laboratory contaminants), TCE, and carbon disulfide. TPH and oil and grease were also detected in the lake sediment samples and are also commonly detected at Plant 4. The organic chemicals of concern benzo(a)pyrene, fluoranthene, pyrene, and TCE were identified in lake sediment samples. Semivolatile compounds detected in the lake are frequently related to asphalt and could be a result of storm runoff. The

Table 4.4.1-8 Location and Analytical Results of Inorganic Sediment Samples Collected from Lake Worth

Sample ID	Cadmium	Chromium	Copper	Lead	Zinc	Aluminum	Nickel
Background Western United States	NA	8.5-196.6	4.9-90	5.2-55.1	17.2-176.2	14,500-232,000	3.4-66.2
LWS 1-01	2.3	23.6	19.2	84.1	74.3		
LWS 1-02		16.2	12.4	164	43.5		
LWS 2-01	5.5	81.7	88.4	153	209		
LWS 2-02	7.3	73	58.1	49.1	249		
LWS 3-01	3.45	35		56		6,400	14.8
LWS 3-01	11.4	124	68.6	444	303		
LWS 3-02	4.4	44.5	40.5	228	157		
LWS 4-01	5.6	40		35.5		7,600	16.8
LWS 5-01	2.8	12.7	13.6	104	69		
LWS 5-02	2.2	29.2	18.6	113	90.4		
LWS 6-01	0.6	9.5		20.5		2,750	9.4
LWS 7-01	4.25	56.5		125		8,600	18.1
LWS 8-01	2.3	25.3	12.3	15.2	33.9		
LWS 9-01	2.75	20		90		4,150	11.3
LWS 10-01	0.5	8.95		19.5		9,450	14.3
LWS 11-01	3.5	23.3	12.8	17.8	56.2		
LWS 11-02	4.6	22.2	15.9	27.9	44.9		
LWS 12-01	1.6	17.9	6.4B	10.1	40.8		
LWS 12-02	ND	12.2	5.3B	158	24		
LWS 13-01	0.55	12.15		22		9,450	11.6
LWS 13-02	0.5	7.5		23		5,750	9.3
LWS 14-01	0.75	12.25		25.5		11,750	12.4
LWS 18-01	1.9	14.7	20.5	34.3	48.7		
LWS 18-02	ND	13.5	13.6	21.3	41.9		
LWS 18-03	1.6	9.1	11.8	16.2	34.9		
LWS 19-01	0.9	10.75		27.5		6,000	10.5
LWS 20-01	0.65	4.7		16.6		4,750	8.3
LWS 21-01		8.3	7.4B	12.3	27.6		
LWS 21-02		10.3	8.5	8	21.9		
LWS 22-01	1.0	70		43		4,900	8.1
LWS 23-01	0.4	6.85		16.1		4,450	14
LWS 23-01D	3.35	35		56.5		6,450	14.7

- Notes:
- 1) Concentrations are reported in mg/kg.
 - 2) Cd, Cr, Cu, Ni, and Zn have been identified in the Baseline Risk Assessment as chemicals of concern.
 - 3) ND = Not detected. Blank means not sampled.
 - 4) Minimum and Maximum are based on all values above the CRQL and those qualified U and B.
 - 5) Al, Cd, Cr, Ni, and Pb were analyzed as selected metals. These metals were selected in agreement with US Fish and Wildlife and EPA Region VI personnel because they are used in aircraft manufacturing, are constituents in fuels, or were identified as chemicals of concern in the risk assessment.

Table 4.4.1-9 Summary of Lake Worth Ecological Sediment Samples

Sample ID	TOC (%)	Moisture (%)	Grain Size Analysis		
			Clay (%)	Silt (%)	Sand (%)
LWS1-01	2.0	54.0	31.1	55.5	13.4
LWS2-01	1.8	28.2	17.4	31.0	51.6
LWS2-02	2.1	29.6	23.2	40.5	36.2
LWS4-01	3.0	39.0	21.5	38.3	40.2
LWS5-01	2.3	39.6	16.5	33.9	49.6
LWS6-01	1.0	42.6	20.8	32.2	47.0
LWS7-01		53.0			
LWS8-01	1.9	35.2	13.2	24.8	62.0
LWS9-01	0.4	28.0	8.0	21.4	70.6
LWS10-01	1.0	29.6	13.5	31.5	55.0
LWS11-01	0.9	42.2	45.5	17.7	36.8
LWS12-01	0.6	30.0	21.6	43.2	35.2
LWS13-01	0.6	39.0	15.7	18.3	66.0
LWS13-02		30.8			
LWS14-01	0.9	49.4	16.4	19.8	63.8
LWS18-01	1.9	38.8	21.0	38.1	40.9
LWS19-01	2.2	37.6	29.8	45.0	25.2
LWS20-01		54.2			
LWS21-01	2.4	30.2	21.3	40.3	38.3
LWS22-01	1.1	41.0	12.7	22.0	65.2
LWS23-01	1.7	28.8	18.5	25.7	55.9
LWS24-01		33.0			
LWS26-01	1.1	28.4	14.2	22.7	63.3

a - Numerical average of multiple values.

inorganic chemicals of concern, chromium, copper, and zinc were all detected at levels above the site average. Levels of some metals are high when compared to other reported values for Plant 4 soil samples. Concentrations of metals in the sediments did not appear to follow a pattern; samples collected close to shore at the six coves were not consistently higher than samples collected further out in the lake. Samples collected for radiation level analysis from areas adjacent to the former NARF site did not indicate any levels of radiation above background. Samples collected at the background location had some of the highest VOC and metals levels of all sediment samples collected from the lake and may indicate a source of contamination not associated with Plant 4. The background location was selected in agreement with EPA Region VI and Geotech representatives, and was chosen to be as close as possible to Plant 4 to be of similar habitat, but far enough away to be unaffected by potential contamination from Plant 4 or other industrial sites.

**Table 4.4.1-10 Summary of Lake Worth
Radioisotope Sediment Sampling Results**

Sample ID	Cesium-137 pCi/g	Radium-226 pCi/g	Thorium-230 pCi/g	Uranium mg/kg
LWS 1-01	.53	1.19	1.1	1.4
LWS 12-01	ND	.86	1.5	.81B
LWS 15-01	ND	.7	2	2.7
LWS 16-01	ND	.45	.8	.58B
LWS 17-01	0.1	.47	.6	.37B
LWS 18-01	ND	.94	1.2	1.3
LWS 18-02	ND	.82	1.2	1.1

Note: 1) "B" indicates value is below CRDL but is greater than or equal to the IDL.
 2) Cobalt-60 analysis for all samples were less than 0.04 pCi/g.
 3) ND = Not detected.

4.4.2 Meandering Road Creek Sediment Sampling

4.4.2.1 Introduction

Upper-zone groundwater is known to discharge from Plant 4 through seeps located along the Meandering Road Creek drainage. Much of the upper-zone groundwater upgradient of the seeps is known to be contaminated with fuels, solvents, oil and grease, and metals. A potential exists for contamination of surface waters and sediments as a result of this discharge. It is also suspected that the creek is providing recharge to the Paluxy Aquifer. A potential exists for contaminant migration into the Paluxy Aquifer, which is used for domestic water supplies in surrounding communities.

The objective of the Meandering Road Creek study was to determine the extent of creek sediment and surface-water contamination originating from Plant 4. Samples along the creek channel were needed to better define the locations of contamination entering Meandering Road Creek from Plant 4. Surface water and sediment samples were collected upstream of Landfill No. 4 to determine potential contamination to the surface-water pathway from sources located upstream from where the creek enters the Plant 4 facility boundary. Several seeps were identified and sampled in addition to those previously sampled to assist in the upper zone characterization.

New sampling locations were established both upstream of Landfill No. 4 and between previously established sampling locations (C-X) to better define the distribution of contaminants (see Figure 4.4.2-1).

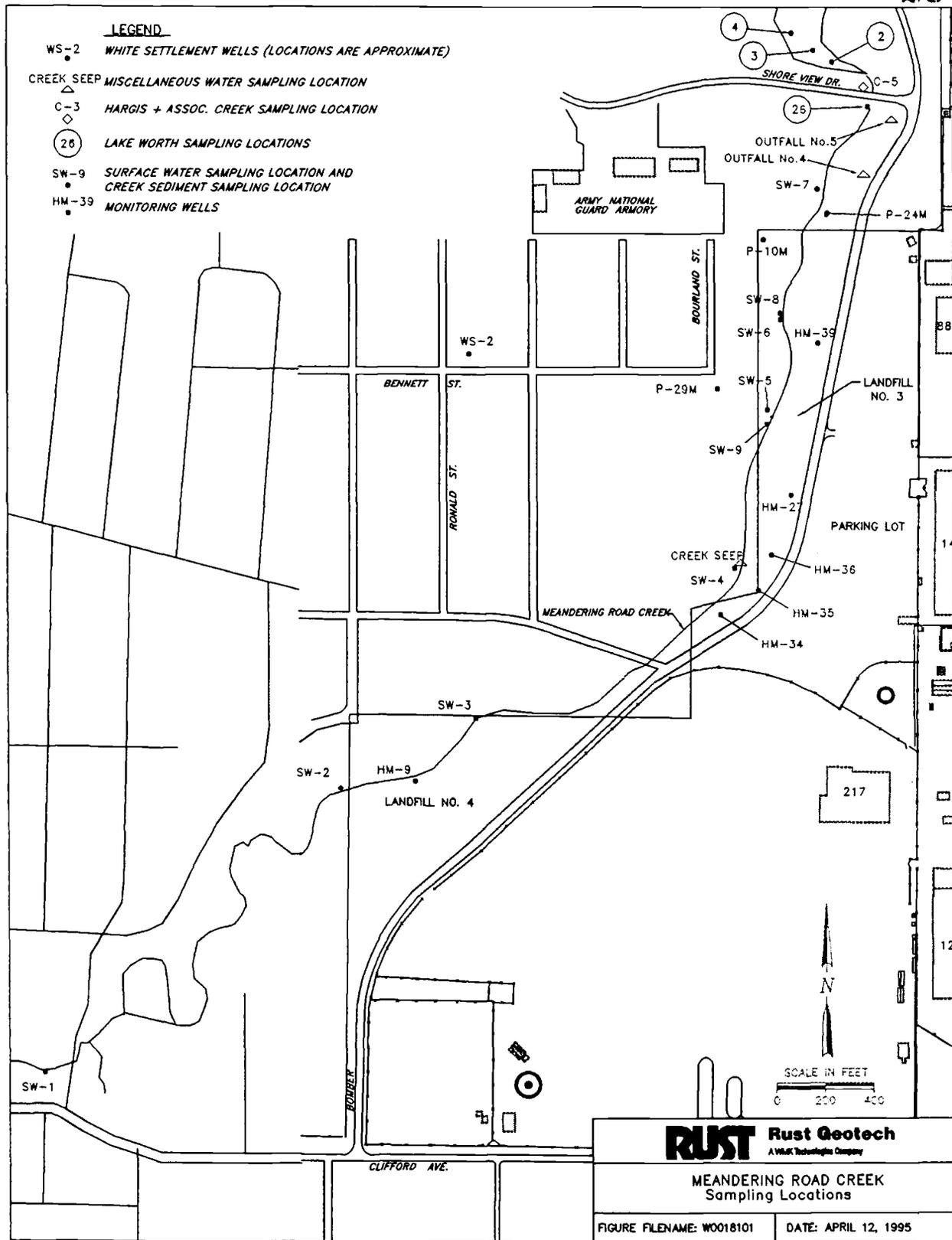


Figure 4.4.2-1. Meandering Road Creek Sampling Locations.

4.4.2.2 Sediment Sampling

Sediment samples were collected from seven locations along Meandering Road Creek (SW-1 to SW-7) (see Figure 4.4.2-1) and analyzed for VOCs, semi-VOCS, metals, TPH, and oil and grease. No sediment samples were collected from seep locations SW-08 and SW-09. Locations SW-10 and SW-11 are west of Meandering Road next to Outfall No. 3 (near FSA-3) and water samples were collected for analysis to determine if seeps from the FSA-3 area were contaminated.

Soil samples were collected from sampling locations SW-01 through SW-07 along Meandering Road Creek. Results above the CRQL were reported for VOCs and TPH at several locations (see Table 4.4.2-1). Oil and grease (209 mg/kg), TPH (110 mg/kg), and toluene (290 $\mu\text{g}/\text{kg}$), were found in the sediment at SW-01, which is south and upgradient of Landfill No. 4. At location SW-2, also upgradient of Landfill No. 4, the concentrations of oil and grease and TPH were approximately half that of location SW-01.

SW-2 semivolatile results indicated 4-methylphenol (380J $\mu\text{g}/\text{kg}$), which is commonly used as a disinfectant or fumigant along with several asphalt or coal tar semivolatiles such as fluoranthene and pyrene at 100 $\mu\text{g}/\text{kg}$ each. No semivolatiles were detected at SW-3, just downstream from Landfill No. 4. In the area above Landfill No. 4, the creek receives runoff from several streets and parking lots, which may contribute to fuel or asphalt related contaminants (see Table 4.4.2-2).

Samples taken adjacent to Landfill No. 3 and further downstream indicate increasing levels of VOCs. Sample results from SW-04 at the south end of Landfill No. 3 show small amounts of semi-VOCs, no VOCs, and TPH at 73 mg/kg. At location SW-05 only VOCs in soil were analyzed, indicating *cis*-1,2-DCE at 150 $\mu\text{g}/\text{kg}$, vinyl chloride at 20 $\mu\text{g}/\text{kg}$, and acetone at 24 $\mu\text{g}/\text{kg}$. Location SW-06 soil samples indicated *cis*-1,2-DCE at 15 $\mu\text{g}/\text{kg}$, acetone at 20 $\mu\text{g}/\text{kg}$, elevated levels of two semi-VOCs, (see Table 4.4.2-2), oil and grease at 58 mg/kg, and TPH at 14 mg/kg. Location SW-07, north of Landfill No. 3, had low levels of contaminants, with acetone at 38 $\mu\text{g}/\text{kg}$ being the only VOC reported. Results above the CRDL for inorganics were reported at several locations (see Table 4.4.2-3). Inorganics with values higher than the natural background (from Range in Soils of Western USA, Shacklette and Boerngen 1984) were reported at three locations. Silver was reported at SW-02 (2.9B mg/kg) and SW-06 (6.9 mg/kg). At SW-07, lead levels higher than the background range were detected with values of 77.4 mg/kg.

Table 4.4.2-1 Summary of VOC, TPH, and Oil and Grease Analytical Results for Meandering Road Creek SW-01 through SW-07 Sediment Samples

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
2-Butanone	(11)	17	10	1
Acetone	(11)	58	10	8
<i>cis</i> -1,2-Dichloroethene	(5)	150	10	2
Toluene	(5)	290	10	1
Vinyl Chloride	(11)	20	10	1
Oil and Grease	12 mg/kg	209 mg/kg	7	7
Total Petroleum Hydrocarbons	(10) mg/kg	110 mg/kg	7	5

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Toluene was identified in the Baseline Risk Assessment as a chemical of concern.

Table 4.4.2-2 Summary of Semivolatile Analytical Results for Meandering Road Creek SW-01 through SW-07 Sediment Samples

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
Fluoranthene	(830)	1,400	9	2
Pyrene	(830)	1,200	9	1

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Pyrene and fluoranthene were identified in the Risk Assessment as chemicals of concern.

4.4.2.3 Transect Sampling Site

Seven soil samples were collected from the surface to a depth of 2 feet at six locations on the west side of Landfill No. 3, near monitoring well F-214, to determine how contamination was distributed in the creek channel area. The five transect sampling locations were on an east-west line, approximately 30-feet long, that originated at

**Table 4.4.2-3 Summary of Inorganic Results
for Meandering Road Creek SW-01 through SW-07 Sediment Samples**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background (mg/kg)	No. of Samples Analyzed	No. Above Natural Background ²
Antimony	(11.2)	(16.3)	2.2	7	0
Arsenic	3.1	6.1	21.6	7	0
Cadmium	(1.1)	2.4	3.6	7	0
Chromium	8.9	72.7	2.8	7	0
Copper	15.9	17.8	196.6	7	0
Lead	10	77.4	90.0	7	1
Nickel	(7)	(10.2)	55.1	7	0
Selenium	(.56)	(.82)	66.2	7	0
Silver	(1.1)	6.9	1.4	7	2
Thallium	(.56)	(.82)	1.4	7	0
Zinc	17.8	87	0.8	7	0

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Cadmium, chromium, copper, nickel, and zinc were identified in the Baseline Risk Assessment as chemicals of concern.
 3) Range in Background Soils of the Western USA, (Shacklette and Boerngen 1984).
 4) Upper Background range for cadmium is estimated at 2.8 which is based on twice the observed mean for the four Plant 4 background samples.
 5) Upper Background range for silver is estimated at 1.4 which is based on twice the IDL observed mean for the four Plant 4 background samples.

CS-002, adjacent to the SW-5 creek sampling location, and extended to CS-005, which was about 10 feet below the surface of Landfill No. 3 (Figure 4.4.2-2). Transect samples were collected from a gully in the edge of the landfill that was approximately 5-feet deep. An attempt was made to collect samples on an even spacing, but the amount of concrete rubble on the edge of the landfill made this difficult. Soil samples were analyzed for VOCs, semi-VOCs, metals, and oil and grease. CS-001 was collected approximately 60-feet south of the transect site near suspected seep SW-09. CS-004 was collected as a duplicate of CS-003.

VOC results above the CRQL were reported for three compounds at this site (Table 4.4.2-4). VOC results for CS-001 indicated 63 $\mu\text{g}/\text{kg}$ of chlorobenzene and an estimated value for 1,2-DCE at 290J $\mu\text{g}/\text{kg}$. CS-002 had 1,2-DCE reported at 180 $\mu\text{g}/\text{kg}$. CS-003, -004, -005, -006, and -007 had negligible levels of VOCs. Oil and grease results for the seven samples were as follows: CS-001 and -002, not detected; CS-003 and -004, 56 and 63 mg/kg, respectively; and CS-005, -006, and -007, were

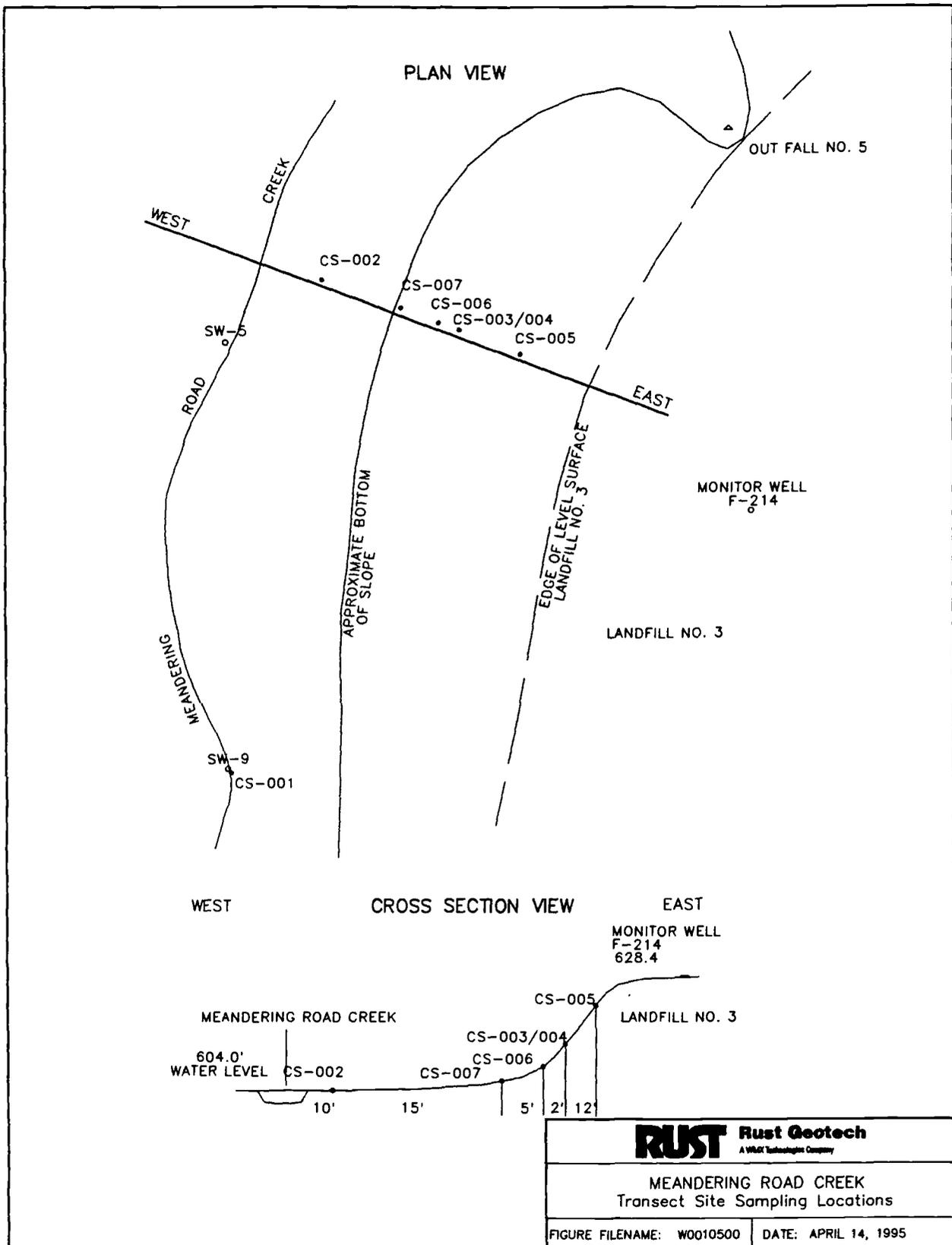


Figure 4.4.2-2. Meandering Road Creek Transect Site Sampling Locations.

956, 632, and 638 mg/kg, respectively. Soil samples from the transect sampling were taken within 25 feet of the SW-05 site with the CS-002 sediment samples collected within 10 feet of the creek at the SW-05 site. CS-002 VOC results indicated 1,2-DCE at 180 $\mu\text{g}/\text{kg}$, and vinyl chloride at 6 $\mu\text{g}/\text{kg}$ (with a "J" QA qualifier indicating an estimated quantity). Semi-VOC results above the CRQL were reported at several locations (see Table 4.4.2-5). The semi-VOCs reported are those commonly found in asphalt, such as pyrene and fluoranthene. Asphalt pavement fragments and particles were observed during sampling in this area.

Table 4.4.2-4 Summary of VOC and Oil and Grease Analytical Results for Soil Samples Collected at the Transect Site Adjacent to Meandering Road Creek

Analyte	Minimum $\mu\text{g}/\text{kg}$	Maximum $\mu\text{g}/\text{kg}$	No. of Samples Analyzed	No. Above CRQL
1,2-Dichloroethene	(6)	180	7	1
Acetone	(11)	40	7	1
Chlorobenzene	(6)	63	7	1
Oil and Grease	(10) mg/kg	956 mg/kg	7	5

Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.

Several of the samples collected from this site had analytical results for metals that were higher than the range in background soils (Table 4.4.2-6). Sample CS-001, collected from sediments at suspected seep SW-09, 60 feet south of the transect site, had metals results that were approximately at background levels. Samples CS-002 through CS-007 had analytical results ranging from 4 to 600 times the background values for metals. The sample collected at CS-007 had results of 17,400 mg/kg for zinc, 10,400 mg/kg for lead, and 369 mg/kg for chromium. Other metals were also reported at elevated levels. CS-005 had results for chromium—347 mg/kg, copper—5,590 mg/kg, nickel—458 mg/kg, lead—5,800 mg/kg, and zinc—2,690 mg/kg. When CS-003 and -004 were collected, bits of asphalt were detected in the soil, which is indicated by the semi-VOC analytical results.

4.4.2.4 Conclusions

Sample results indicate some contamination of Meandering Road Creek sediments may result from sources above Plant 4, such as runoff from parking lots and roads. Volatile organic compounds detected in sediment samples upstream from Landfill No. 3 are fuels related such as toluene (290 $\mu\text{g}/\text{kg}$ at SW-01), low levels of oil and grease, (209 mg/kg at SW-01 upstream from Landfill No. 4, and dropping to 134 mg/kg just above

Table 4.4.2-5 Summary of Semi-VOC Analytical Results for Soil Samples Collected at the Transect Site Adjacent to Meandering Road Creek

Analyte	Minimum µg/kg	Maximum µg/kg	No. of Samples Analyzed	No. Above CRQL
Anthracene	(780)	1,800	7	2
Benzo(a)anthracene	(780)	6,100	7	2
Benzo(a)pyrene	(780)	5,700	7	2
Benzo(b)fluoranthene	(780)	7,500	7	3
Benzo(g,h,i)perylene	(780)	3,600	7	2
Bis(2-ethylhexyl) phthalate	(960)	1,500	7	1
Chrysene	(780)	4,100	7	2
Fluoranthene	(780)	15,000	7	3
Indeno(1,2,3-cd)pyrene	(780)	4,900	7	2
Phenanthrene	(780)	11,000	7	2
Pyrene	(780)	9,200	7	3

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) Minimum and Maximum are based on all values above the CRQL and those qualified U, D, or E.
 3) Pyrene, fluoranthene, and benzo(a)pyrene were identified in the Baseline Risk Assessment as chemicals of concern.

Landfill No. 3), and low levels (13 to 58 µg/kg) of acetone. Sample data in the area of Landfill No. 3 clearly indicate creek sediment contamination from VOCs, semi-VOCs, and metals. At SW-5 the VOCs in sediments indicate solvent-related contaminants such as *cis*-1,2-DCE (150 µg/kg) and vinyl chloride (20 µg/kg). The sample from the SW-6 location, west of the northern section of Landfill No. 3, also detected low levels of *cis*-1,2-DCE (15 µg/kg), along with many asphalt related semivolatiles. These contaminants are commonly detected in soil and water samples from Landfills Nos. 1 and 3, which are the probable source areas for the creek sediment contamination adjacent to Landfill No. 3 and downstream.

The transect samples indicate irregular contamination levels that are typical of a landfill; they represent the material that was dumped at that particular location and may have results different from a sample collected a few feet away. The transect samples were collected from a gully that is actively being eroded by storm runoff, approximately 20 feet from the edge of the creek. This clearly demonstrates soil contaminant transport toward and into the creek.

**Table 4.4.2-6 Summary of Inorganic Analytical Results
for Soil Samples CS-01 through CS-07 Collected at the
Transect Site Adjacent to Meandering Road Creek**

Analyte	Minimum mg/kg	Maximum mg/kg	Upper Background Limit (mg/kg)	No. of Samples Analyzed	No. Above Natural Background ⁴
Antimony	(12.2)	54	2.2	7	1
Arsenic	2.6	21.7	21.6	7	1
Cadmium	1.5	96.2	3.6	7	4
Chromium	11.6	369	2.8	7	2
Copper	13.4	5,590	196.6	7	4
Lead	10.6	10,400	90.0	7	4
Nickel	11.8	458	55.1	7	2
Selenium	(.45)	(4.7)	66.2	7	0
Silver	(.7)	23.1	1.4	7	4
Thallium	(.45)	(.55)	1.4	7	0
Zinc	22.7	17,400	0.8	7	4

- Notes: 1) Concentration in parentheses indicates the compound was not detected at the reported value.
 2) B qualifier indicates the analyte was detected above the IDL but less than the CRDL.
 3) Cadmium, Chromium, Copper, Nickel, and Zinc are identified in the Baseline Risk Assessment as chemicals of concern.
 4) Upper range in Background Soils of Western USA, (Shacklette and Boerngen 1984).

4.5 Groundwater Contamination

This section describes the nature and extent of groundwater contamination at Plant 4. Results of sampling are presented for the two groundwater flow systems potentially impacted by Plant 4 operations, the upper-zone flow system and the Paluxy Formation.

Contaminant transport within the upper-zone groundwater system is controlled in part by the locations of groundwater divides. The locations of these divides correspond closely to the locations of topographic highs in the buried bedrock surface. Hydraulic head data gathered during the Remedial Investigation show that a groundwater divide exists west of the Main Assembly Building/Parts Plant and encroaches into Landfill No. 1 (see Figure II-24). The divide trends southwest near Building 12 and southeast across Clifford Avenue. This divide separates groundwater into components flowing east and west.

Another divide trending east to west is located at the north end of the Assembly Building. On the local scale, a northerly component of flow exists north of this divide.

The three distinct flow directions within the upper-zone groundwater system have resulted in three separate areas where contamination may exist (see Figure II-12).

These areas are referred to as (1) East Parking Lot Plume, (2) West Plume, and (3) North Plume. The boundary between the East Parking Lot Plume and the West Plume is a wide zone of flat hydraulic gradient in two areas: the area west of the Assembly Building and between Buildings 14 and 88, and the area west and north of Building 12. Within each plume area, there may exist elevated concentrations of one or more of the following: chlorinated solvents (approaching maximum solubility levels in some areas), degradation products of chlorinated solvents, fuel compounds, fire extinguishing agents, and inorganics.

Groundwater contamination in the Paluxy Aquifer forms two relatively distinct plumes at Plant 4, the West Paluxy Plume and the East Paluxy Plume (Figures II-19a through II-19d). The West Paluxy Plume occurs within the regional Paluxy Aquifer whereas the East Paluxy Plume occurs largely within the Paluxy Upper Sand beneath the East Parking Lot. It is the lower portion of the regional Paluxy Aquifer that is pumped for water supply by municipal wells south and west of Plant 4.

The top of the regional Paluxy Aquifer is defined as the water table surface within the Paluxy Formation and typically occurs at depth of 10 to 20 feet below the bottom of the Walnut Formation. Contamination in the West Paluxy Plume is suspected to have entered the aquifer either as recharge through the lower reach of Meandering Road Creek, or as vertical migration down the well bore in P-22U and/or P-22M. P-22M was recently abandoned to eliminate the potential for vertical migration along the well bore.

The Paluxy Upper Sand is a local feature in the Paluxy Formation characterized by well-indurated sandstone highly interbedded with shale, siltstone, and claystone. The Upper Sand occurs mainly in the East Parking Lot area, extending west to the west side of the Assembly Building/Parts Plant, east to the flightline area, south to Clifford Avenue, and north past the engineering building. The Paluxy Upper Sand is variably saturated, behaves much like an extension of the Walnut Formation Aquitard, and produces water only in wells completed in the East Parking Lot and flightline areas. As noted above, contamination in the East Paluxy Plume occurs mainly in the Paluxy Upper Sand. This contamination is suspected to have entered the Upper Sand via vertical migration from the Upper Zone passing through the thin section of Walnut Formation referred to as the window area (Figure 3.8.1-1). Contaminant migration in the Paluxy Upper Sand is discussed in Section 5.3.

The window area is defined as zone where the Walnut Formation has been eroded to a thickness of only 0.5 to 2.5 feet. Beyond the zone referred to as the window area, the thickness of the Walnut Formation generally increases rapidly. Southeast of the window area, the Walnut Formation remains approximately five feet thick out to the vicinity of the flightline area (see lithologic log for P-19US in Appendix K and cross-section 8, Figure II-8). Because the dip of the formation contact (37 ft/mile) exceeds the flightline area relief in the erosional surface of the Walnut Formation (5 ft/mile; see Figure II-27),

the aquitard thickness does increase beyond the flightline as one approaches the CAFB golf course (see lithologic log for CAR-P1 and CAR-P2).

Although all borings through the Walnut Formation have documented aquitard thicknesses of five feet or more outside of the window area, additional areas where the aquitard is thin or absent may yet remain undetected.

Groundwater contamination in the upper zone and the Paluxy Formation is discussed separately for organic and inorganic contamination. Discussions of organic contamination include volatiles and semivolatiles, TPH, and oil and grease.

Groundwater has been monitored at Plant 4 since 1985. The frequency of sampling individual monitoring wells has been monthly, quarterly, semiannually, or annually, depending upon the location of the monitoring well and the sampling objectives. Because of the duration of environmental sampling at Plant 4, various contractors have been involved; consequently, the laboratory analytical methods and data quality objectives have changed over the years. Geotech recognized that information collected by others may be useful for mapping and discussing the extent of contamination at Plant 4. Therefore, the maps and tables which are referenced in the text contain both Geotech data and selected data collected by others.

Groundwater samples collected at Plant 4 by Geotech have been analyzed using EPA Analytical Level III requirements with Level IV reporting for the Target Compound List (TCL) volatile and semivolatile organic compounds and the Target Analyte List (TAL) metals. Beginning in September 1991 the analyte list for volatile organic compounds was revised to isolate the *cis* and *trans* isomers of 1,2-DCE, and the ortho (*o*-) isomer of xylene. These revisions were made to assess the relative abundance of these isomers, because *trans*-1,2-DCE is approximately twice as toxic as *cis*-1,2-DCE (Verschueren 1983) and *o*-xylene is considered a developmental toxicant (U.S. EPA 1991a).

4.5.1 Upper-Zone Groundwater: Volatile Organic Contamination

A summary of organic contamination detected within upper-zone groundwater is presented in Table 4.5.1-1. TCE is the most common contaminant at the site. Detailed discussions of groundwater contamination within the three contaminant areas are presented in the following sections. NAPLs found floating on or pooled below upper-zone groundwater are summarized in Table 4.5.1-2. The locations of monitoring wells containing NAPLs are shown in Figure II-15.

**Table 4.5.1-1 Summary of VOC Concentrations Reported
Above the CRQL in the Upper-Zone Flow System**

Chemical Name	Minimum Result (µg/L)	Maximum Result (µg/L)	MCL (µg/L)	Number of Samples Analyzed	Number of Samples Exceeding CRQL	Number of Samples Exceeding MCL
<i>o</i> -Xylene	5U	170	—	70	4	—
Trichloroethene	1U	87,000	5	177	134	111
1,1,2-Trichloroethane	1U	660	5	177	2	1
2-Butanone	10	750	—	167	8	—
1,2-Dichloropropane	5U	610	5	167	2	2
1,1-Dichloroethene	1U	2,100	7	177	29	18
1,1-Dichloroethane	1	620	—	177	9	—
Carbon Disulfide	5U	20	—	167	1	—
Methylene Chloride	1U	98,000	5	177	11	9
Vinyl Chloride	2U	6,500	2	177	17	16
1,1,1-Trichloroethane	1U	380	200	177	20	4
Benzene	1U	730	5	177	16	11
Chloroform	1	90	100	177	9	0
Acetone	10U	7,600	—	167	14	—
Carbon Tetrachloride	5U	400	5	167	1	1
1,2-Dichloroethene	5U	69,000	—	97	20	—
<i>trans</i> -1,2-Dichloroethene	1U	22	100	80	11	0
<i>cis</i> -1,2-Dichloroethene	1U	1,500	70	80	42	24
Xylene	1U	12,000	10,000	177	13	2
Tetrachloroethene	1U	450	5	177	4	4
Dibromochloromethane	5U	550	100	167	1	1
Chlorobenzene	1	2,600	100	177	13	4
Toluene	1U	25,000	1,000	177	7	2
1,2-Dichloroethane	5U	30,000	5	167	11	8
Styrene	5U	27	100	167	1	0
Ethylbenzene	5U	5,500	700	167	14	4

Table 4.5.1-2 Summary of Non-Aqueous Phase Liquids Detected in Plant 4 Monitoring Wells

Well ID	Site	Type	Thickness (FT)		
			September 1991	March 1991	April 1990
F-202	FSA-3	LNAPL	0.03	NM*	0.26
F-203	FSA-1	LNAPL	0.01	3.53	2.83
F-205	FSA-1	LNAPL	0.36	NM	NM
F-206	FSA-1	LNAPL	0.12	NM	NM
F-210	FSA-3	LNAPL	0.46	NM	0.36
F-222	FSA-3	LNAPL	1.21	NM	NM
FSA3-11	FSA-3	LNAPL	1.01	NM	NM
HM-21	LF-3	LNAPL	0.00	NM	0.01
HM-38	LF-3	LNAPL	0.26	NM	0.01
HM-78	FSA-3	LNAPL	1.14	NM	NM
W-139U	FSA-1	LNAPL	1.01	NM	NM
F-214	LF-3	DNAPL/LNAPL	NM	NM	4.08
W-130	LF-3	DNAPL	NM	1.97 on 4/24/91	NM

NM* = Not Measured

4.5.1.1 East Parking Lot Plume: Volatile Organics

The largest plume of groundwater contamination is referred to as the East Parking Lot Plume. This plume begins at the groundwater divide located south and west of the Parts Plant and Building 12 (see Figures II-12a, II-12b, II-13a and II-13b). The plume also has source areas west of the Assembly Building in the vicinity of Buildings 14 and 88. From the main source area south of the Parts Plant, the plume extends in an easterly and northeasterly direction towards the East Parking Lot and later spreads east and southeast in the direction of CAFB. On CAFB, the plume may have merged with CAFB source areas located at CAFB Landfills 4 and 5, Landfill 6 north of Farmers Branch Creek, and the North Apron.

The extent of the East Parking Lot plume is defined by elevated concentrations of trichloroethene (TCE), *cis*- and *trans*-1,2-dichloroethene, vinyl chloride, 1,1,2-trichloroethane (TCA), 1,1-dichloroethane (DCA), 1,1-dichloroethene (DCE), methylene chloride, tetrachloroethene (PCE), benzene, toluene, xylene, acetone, chlorobenzene, and chloroform. By far the greatest occurrence of any single organic compound is TCE. The extent of TCE contamination in the upper zone is shown in

Figures II-12a, II-12b, II-13a and II-13b for sampling periods between 1990 and 1995. During the RI, TCE has been detected in concentrations exceeding the CRQL in 50 monitoring wells. A list of wells within the East Parking Lot Plume for which TCE concentrations exceed the CRQL is presented in Table 4.5.1-3. All TCE results listed exceed the EPA maximum contaminant level (MCL) of 5 $\mu\text{g}/\text{L}$.

The East Parking Lot Plume appears to have several sources of contamination. One major potential source is the degreaser tanks T-534 and T-544 located within Building 181. One documented release from tank T-534 was discovered in June 1991. The volume of this release was estimated to be approximately 20,000 gallons of TCE. The size of the East Parking Lot Plume indicates other releases of organic solvents may have occurred at this location during the past 40 years of operation.

Other potential sources of volatile organic contamination in the East Parking Lot Plume include Chrome Pits Nos. 1, 2, and 3, Die Yard Chemical Pits (DYCP), FDTA-2, FDTA-5, and the Waste Water Collection Basins. Except for FDTA-2, these potential sources are located along the groundwater divide in the south central portion of Plant 4. Historically, high concentrations (approaching saturation) of TCE have been reported in the south central portion of Plant 4. Groundwater monitoring results from existing wells in the area indicate that contamination may be migrating from the East Parking Lot Plume toward Meandering Road Creek.

Examination of bedrock topography (Figure 3.8.1-2) indicates the presence of a bedrock channel extending from FDTA-2 and running between Buildings 88 and 14. The bedrock channel then extends beneath the Assembly Building/Parts Plant and reemerges in the vicinity of monitoring well HM-56. Since TCE is a DNAPL, it is capable of flowing against the hydraulic gradient, along the base of the bedrock channel in the vicinity of monitoring wells HM-20, HM-29, and F-215. As a dissolved constituent, TCE can be transported by advection beneath the Assembly Building/Parts Plant. East of the Assembly Building, dissolved TCE from FDTA-2 will merge with the main portion of the East Parking Lot Plume.

During the RI, the highest TCE concentrations detected within the East Parking Lot Plume were from monitoring wells located along the axis of the buried East Parking Lot channel, including wells HM-094, W-149, W-158, and W-159. TCE concentrations in these monitoring wells ranged from 15,000 to 31,000 $\mu\text{g}/\text{L}$. The fact that concentrations of these magnitudes are found along the axis of the buried channel suggests that TCE may be migrating along the channel in the form of a DNAPL. Prior to the RI, TCE concentrations exceeding 10,000 $\mu\text{g}/\text{L}$ were reported in monitoring wells F-218, F-220, and HM-082. Of particular importance is monitoring well F-220, in which TCE concentrations in excess of 100,000 $\mu\text{g}/\text{L}$ were reported. Monitoring well F-220 is located within Chrome Pit No. 3.

**Table 4.5.1-3 Upper-Zone Monitoring Wells Within the East Parking Lot Plume
where TCE Concentrations Exceeded the CRQL**

Site ID	Sample ID	Sample Date	Result ($\mu\text{g/L}$)
F-218	NAA157	27-Apr-90	3,000
F-219	NAA158	26-Apr-90	67
F-219	NAA260	26-Apr-90	71
HM-029	NAA162	27-Apr-90	1,400
HM-031	NAA163	27-Apr-90	920
HM-047	NAA164	27-Apr-90	4,400
HM-047	NAA269	27-Apr-90	7,100
HM-056	NAA168	28-Apr-90	150
HM-060	NAA169	27-Apr-90	170
HM-071	NAA172	28-Apr-90	420
HM-086	NAA173	28-Apr-90	250
HM-087	NAA174	29-Apr-90	350
HM-088	NAA175	01-May-90	6,700
HM-088	NAA271	01-May-90	6,000
HM-089	NAA176	01-May-90	4,500
HM-089	NAA261	01-May-90	4,800
HM-089	NAA272	01-May-90	3,600
HM-094	NAA180	29-Apr-90	19,000
HM-095	NAA181	25-Apr-90	1,900
HM-096	NAA182	25-Apr-90	1,200
HM-097	NAA183	25-Apr-90	440
HM-099	HM-99	25-Oct-91	720
HM-099	NAA185	25-Apr-90	2,100
HM-099	QM-006	14-Mar-91	1,200
HM-099	WQM004	05-Dec-90	2,300
HM-103	NAA186	01-May-90	1,900
HM-110	NAA188	01-May-90	23
HM-111	NAA189	30-Apr-90	410
HM-111	NAA273	30-Apr-90	420
HM-112	NAA190	30-Apr-90	3,700
HM-112	NAA274	30-Apr-90	3,400
HM-113	NAA191	30-Apr-90	380
HM-115	NAA192	01-May-90	110
HM-115	QM-008DL	18-Mar-91	240
HM-115	WQM010	07-Dec-90	320
HM-116	NAA193	01-May-90	860
HM-117	NAA194	01-May-90	640
HM-118	NAA195	01-May-90	180
HM-119	NAA196	01-May-90	25
HM-119	QM-009	18-Mar-91	62
HM-119	WQM007	06-Dec-90	66
HM-121	QM-010DL	19-Mar-91	450
HM-121	WQM009	06-Dec-90	500
HM-122	QM-011DL	19-Mar-91	870

Table 4.5.1-3 (continued) Upper-Zone Monitoring Wells Within the East Parking Lot Plume where TCE Concentrations Exceeded the CRQL

Site ID	Sample ID	Sample Date	Result ($\mu\text{g/L}$)
HM-122	WQM022	10-Dec-90	890
HM-123	HM-123	25-Oct-91	2,000
HM-123	QM-012	19-Mar-91	120
HM-123	QM-012DL	19-Mar-91	1,900
HM-123	WQM011	07-Dec-90	2,100
HM-125	QM-013	18-Mar-91	66
HM-125	WQM024	10-Dec-90	36
HM-126	NAA203	01-May-90	2,600
HM-127	NAA204	01-May-90	55
LF04-02	LF04-02	27-Oct-91	3,800
LF04-04	LF04-04	27-Oct-91	1,800
LF05-01	LF05-01	28-Oct-91	880
LF05-5A	LF05-5A	27-Oct-91	1,600
W-128L	W-128L-01	12-Sep-91	19
W-128L	W-128L-11	19-Oct-91	19
W-131L	W-131L-01	11-Sep-91	6
W-131U	W-131U-11	24-Oct-91	21
W-131U	W-131U-11EB	24-Oct-91	11
W-131U	W-131U-12	24-Oct-91	20
W-137	W-137-01	16-Sep-91	76
W-137	W-137-11	24-Oct-91	56
W-145	W-145-01	15-Sep-91	8
W-149	W-149-01	18-Sep-91	20,000
W-149	W-149-11	17-Oct-91	21,000
W-150L	W-150-11D	20-Oct-91	4,100
W-150L	W-150L-01DL	14-Sep-91	4,900
W-151	W-151-01DL	13-Sep-91	510
W-151	W-151-11D	21-Oct-91	520
W-153	W-153-01	18-Sep-91	1,500
W-153	W-153-02	18-Sep-91	1,300
W-153	W-153-11D	23-Oct-91	1,000
W-153	W-153-12D	23-Oct-91	1,000
W-154	W-154-01DL	14-Sep-91	2,800
W-154	W-154-02DL	14-Sep-91	2,700
W-154	W-154-11D	21-Oct-91	2,500
W-156	W-156-01DL	17-Sep-91	3,900
W-156	W-156-11D	22-Oct-91	3,600
W-158	W-158-01DL	14-Sep-91	15,000
W-158	W-158-11D	20-Oct-91	13,000
W-159	W-159-01DL	14-Sep-91	15,000
W-159	W-159-11D	20-Oct-91	31,000
W-160	W-160-01DL	14-Sep-91	480
W-160	W-160-11D	23-Oct-91	400
WP07-10A	WP07-10A	27-Oct-91	1,300

The RI results show that the central portion of the East Parking Lot Plume, delineated by the 1,000 $\mu\text{g/L}$ TCE contour, extends approximately 4,000 feet in a northeasterly direction from the potential source area. The southeasterly trending portion of the plume extends southeast over 6,000 feet, onto CAFB (see Figure II-13b). Assessment of TCE results for wells and sample locations on CAFB confirms the interpreted extent of the TCE plume on CAFB. The distribution of TCE shown in Figures II-12a, II-12b, II-13a, and II-13b suggests that the sources of contamination are present on both Plant 4 and CAFB property and that these sources have been present for many years.

Monitoring wells located outside the 1,000 $\mu\text{g/L}$ TCE concentration line are typified by low to unquantifiable levels of TCE. Because of the laterally abrupt transition between the upper-zone flow system and the bedrock margin of the buried stream channel, TCE concentrations decrease to below the CRQL over a relatively short distance. The abrupt concentration gradient in the transverse direction is most apparent on Plant 4 property (see Figures II-12 and II-13). Where the plume trends southeast across CAFB, the southwest margin of the plume is also distinct due to the presence of the upper-zone flow-system boundary formed by the intersection of the water table and upsloping rock of the Goodland Formation. However, the eastern margin of the plume appears rather diffuse, perhaps resulting from an open or more gradual valley margin in that direction.

Since the completion of the RI field work, data collected during a quarterly sampling program (Jacobs Engineering Group Inc. December 1992) shows increased TCE concentrations for eight upper-zone wells in the vicinity of the East Parking Lot and Buildings 181 and 182 (Figure II-12B). The largest increase occurred at F-218 where the TCE concentration increased from 3,000 $\mu\text{g/L}$ to 180,000 $\mu\text{g/L}$ in October 1992. As shown by Figures II-26 and II-27, this well is located along the axis of the buried channel and is downgradient from the degreaser tanks located in Building 181. Other wells showing increased TCE concentrations during post-RI sampling include HM-31 (increased from 920 to 2,400 $\mu\text{g/L}$ in April 1992), HM-110 (23 to 860 $\mu\text{g/L}$ in July 1992), HM-112 (3,700 to 7,200 $\mu\text{g/L}$ in July 1992), HM-103 (1,900 to 3,300 $\mu\text{g/L}$ in October 1992), HM-24 (ND to 5 $\mu\text{g/L}$ in April 1992), W-152 (ND to 2.2 $\mu\text{g/L}$ in October 1992), and HM-104 (ND to 2.0 $\mu\text{g/L}$ in April 1992). With the exceptions of HM-24 and W-152, these increases are likely the result of renewed TCE migration originating with the release that was discovered in June 1991. The small increase at HM-24 may be due to dispersion of TCE originating at Chrome Pit No. 3. The increase at W-152 is likely the result of dispersive transport of TCE originating at FDTA-2.

In the downgradient portion of the East Parking Lot TCE Plume, data collected since the completion of the RI field work shows decreasing TCE concentrations at six wells (Figure II-12B). These include HM-99 (decreased from 2,300 to 310 $\mu\text{g/L}$ in October 1992), LF05-19 (decreased from 1,300 to 500 and then 45 $\mu\text{g/L}$ in October 1992), HM-116 (decreased from 860 to 560 $\mu\text{g/L}$ in October 1992), HM-119 (decreased from 110 to 94 $\mu\text{g/L}$ in October 1992), HM-121 (decreased from 500 to 470 $\mu\text{g/L}$ in October 1992), and HM-125 (decreased from 94 to 76 $\mu\text{g/L}$ in

October 1992). These near-steady or decreasing levels of TCE near the downgradient boundary suggest that the frontal portions of the East Parking Lot TCE Plume may have reached a maximum distance from the source area. It is possible that in the time required for TCE to migrate from the source areas to the locations of the wells noted above, all or most of the TCE is naturally biodegraded to daughter products such as 1,2-DCE, 1,1-DCE, and vinyl chloride.

Degradation products of TCE are also present within the East Parking Lot Plume. Degradation products include 1,1-DCE, *cis*- and *trans*-1,2-DCE (also reported as total 1,2-DCE), and vinyl chloride (Vogel and McCarty 1985). Table 4.5.1-4 lists the wells within the East Parking Lot Plume for which concentrations of TCE degradation products exceed CRQLs. Occurrences of these compounds within the East Parking Lot Plume are presented in Figure II-14.

Analytical results for wells located within the East Parking Lot Plume indicate 1,2-DCE concentrations exceed 1,000 $\mu\text{g/L}$ in monitoring wells HM-099, HM-122, and HM-123, and *cis*-1,2-DCE exceeded 1,000 $\mu\text{g/L}$ in monitoring well W-149 (see Table 4.5.1-4 and Figure II-14). Analytical results obtained prior to the RI showed that *cis*-1,2-DCE also exceeded 1,000 $\mu\text{g/L}$ in monitoring well HM-089, located within the East Parking Lot. Ten monitoring wells in the East Parking Lot Plume contained *cis*-1,2-DCE in concentrations exceeding 100 $\mu\text{g/L}$, and seven monitoring wells contained *cis*-1,2-DCE in concentrations ranging between the CRQL and 100 $\mu\text{g/L}$ (see Figure II-14).

The East Parking Lot Plume also contains low concentrations of 1,1-DCE, *trans*-1,2-DCE and vinyl chloride. RI monitoring results for monitoring wells HM-099, HM-123, LF04-02, LF04-04, LF05-01, LF05-5A, W-150L, W-160, and WP07-10A show that the ratio of *cis*-1,2-DCE to *trans*-1,2-DCE is very high (see Figure II-14). In some cases this ratio approaches 20:1, as the *cis*-1,2-DCE isomer exceeds the MCL of 70 $\mu\text{g/L}$. RI monitoring of TCE-degradation products further indicates that vinyl chloride exceeds the MCL of 2 $\mu\text{g/L}$ in monitoring wells HM-122, HM-123, LF04-02, LF05-01, LF05-5A, W-160, and WP07-10A.

**Table 4.5.1-4 Upper-Zone Monitoring Wells Within the East Parking Lot Plume
where TCE Degradation Product Concentrations Exceeded CRQLs**

Chemical Name	Site ID	Sample ID	Sample Date	Result (µg/L)
1,1-Dichloroethene	LF04-02	LF04-02	27-Oct-91	2
1,1-Dichloroethene	LF04-04	LF04-04	27-Oct-91	2
1,1-Dichloroethene	LF05-01	LF05-01	28-Oct-91	2
1,1-Dichloroethene	LF05-5A	LF05-5A	27-Oct-91	3
1,1-Dichloroethene	WP07-10A	WP07-10A	27-Oct-91	2
1,2-Dichloroethene	HM-099	QM-006	14-Mar-91	250
1,2-Dichloroethene	HM-099	WQM004	05-Dec-90	1,100
1,2-Dichloroethene	HM-115	QM-008	18-Mar-91	28
1,2-Dichloroethene	HM-115	WQM010	07-Dec-90	9
1,2-Dichloroethene	HM-121	QM-010	19-Mar-91	13
1,2-Dichloroethene	HM-121	WQM009	06-Dec-90	9
1,2-Dichloroethene	HM-122	QM-011DL	19-Mar-91	3800
1,2-Dichloroethene	HM-122	WQM022	10-Dec-90	290
1,2-Dichloroethene	HM-123	QM-012DL	19-Mar-91	1000
1,2-Dichloroethene	HM-123	WQM011	07-Dec-90	670
<i>cis</i> -1,2-Dichloroethene	HM-099	HM-99	25-Oct-91	440
<i>cis</i> -1,2-Dichloroethene	HM-123	HM-123	25-Oct-91	230
<i>cis</i> -1,2-Dichloroethene	LF04-02	LF04-02	27-Oct-91	390
<i>cis</i> -1,2-Dichloroethene	LF04-04	LF04-04	27-Oct-91	350
<i>cis</i> -1,2-Dichloroethene	LF05-01	LF05-01	28-Oct-91	110
<i>cis</i> -1,2-Dichloroethene	LF05-5A	LF05-5A	27-Oct-91	600
<i>cis</i> -1,2-Dichloroethene	W-131L	W-131L-01	11-Sep-91	7
<i>cis</i> -1,2-Dichloroethene	W-137	W-137-01	16-Sep-91	16
<i>cis</i> -1,2-Dichloroethene	W-137	W-137-11	24-Oct-91	29
<i>cis</i> -1,2-Dichloroethene	W-139L	W-139L-01	16-Sep-91	11
<i>cis</i> -1,2-Dichloroethene	W-139L	W-139L-11	19-Oct-91	9
<i>cis</i> -1,2-Dichloroethene	W-149	W-149-01	18-Sep-91	1,500
<i>cis</i> -1,2-Dichloroethene	W-149	W-149-11	17-Oct-91	1,500
<i>cis</i> -1,2-Dichloroethene	W-150L	W-150-11	20-Oct-91	19
<i>cis</i> -1,2-Dichloroethene	W-150L	W-150L-01	14-Sep-91	34
<i>cis</i> -1,2-Dichloroethene	W-151	W-151-01	13-Sep-91	28
<i>cis</i> -1,2-Dichloroethene	W-151	W-151-01DL	13-Sep-91	25
<i>cis</i> -1,2-Dichloroethene	W-151	W-151-11	21-Oct-91	23
<i>cis</i> -1,2-Dichloroethene	W-151	W-151-11D	21-Oct-91	37
<i>cis</i> -1,2-Dichloroethene	W-153	W-153-01	18-Sep-91	130
<i>cis</i> -1,2-Dichloroethene	W-153	W-153-02	18-Sep-91	120
<i>cis</i> -1,2-Dichloroethene	W-153	W-153-11	23-Oct-91	110
<i>cis</i> -1,2-Dichloroethene	W-153	W-153-11D	23-Oct-91	87
<i>cis</i> -1,2-Dichloroethene	W-153	W-153-12	23-Oct-91	110
<i>cis</i> -1,2-Dichloroethene	W-153	W-153-12D	23-Oct-91	100
<i>cis</i> -1,2-Dichloroethene	W-156	W-156-01	17-Sep-91	170
<i>cis</i> -1,2-Dichloroethene	W-156	W-156-01DL	17-Sep-91	170
<i>cis</i> -1,2-Dichloroethene	W-156	W-156-11	22-Oct-91	170

Table 4.5.1-4 (continued) Upper-Zone Monitoring Wells Within the East Parking Lot Plume where TCE Degradation Product Concentrations Exceeded CRQLs

Chemical Name	Site ID	Sample ID	Sample Date	Result (µg/L)
<i>cis</i> -1,2-Dichloroethene	W-158	W-158-01	14-Sep-91	18
<i>cis</i> -1,2-Dichloroethene	W-158	W-158-11	20-Oct-91	19
<i>cis</i> -1,2-Dichloroethene	W-159	W-159-01	14-Sep-91	20
<i>cis</i> -1,2-Dichloroethene	W-159	W-159-11	20-Oct-91	20
<i>cis</i> -1,2-Dichloroethene	W-160	W-160-01	14-Sep-91	170
<i>cis</i> -1,2-Dichloroethene	W-160	W-160-01DL	14-Sep-91	180
<i>cis</i> -1,2-Dichloroethene	W-160	W-160-11	23-Oct-91	120
<i>cis</i> -1,2-Dichloroethene	W-160	W-160-11D	23-Oct-91	110
<i>cis</i> -1,2-Dichloroethene	WP07-10A	WP07-10A	27-Oct-91	440
<i>trans</i> -1,2-Dichloroethene	HM-099	HM-99	25-Oct-91	2
<i>trans</i> -1,2-Dichloroethene	HM-123	HM-123	25-Oct-91	13
<i>trans</i> -1,2-Dichloroethene	LF04-02	LF04-02	27-Oct-91	15
<i>trans</i> -1,2-Dichloroethene	LF04-04	LF04-04	27-Oct-91	11
<i>trans</i> -1,2-Dichloroethene	LF05-01	LF05-01	28-Oct-91	10
<i>trans</i> -1,2-Dichloroethene	LF05-5A	LF05-5A	27-Oct-91	16
<i>trans</i> -1,2-Dichloroethene	W-150L	W-150L-01	14-Sep-91	22
<i>trans</i> -1,2-Dichloroethene	W-160	W-160-01	14-Sep-91	5
<i>trans</i> -1,2-Dichloroethene	WP07-10A	WP07-10A	27-Oct-91	13
Vinyl Chloride	HM-122	QM-011	19-Mar-91	14
Vinyl Chloride	HM-123	HM-123	25-Oct-91	7
Vinyl Chloride	HM-123	QM-012	19-Mar-91	27
Vinyl Chloride	LF04-02	LF04-02	27-Oct-91	3
Vinyl Chloride	LF04-04	LF04-04	27-Oct-91	3
Vinyl Chloride	LF05-01	LF05-01	28-Oct-91	15
Vinyl Chloride	LF05-5A	LF05-5A	27-Oct-91	7
Vinyl Chloride	W-160	W-160-01	14-Sep-91	98
Vinyl Chloride	W-160	W-160-01DL	14-Sep-91	91
Vinyl Chloride	W-160	W-160-11	23-Oct-91	86
Vinyl Chloride	W-160	W-160-11D	23-Oct-91	78
Vinyl Chloride	WP07-10A	WP07-10A	27-Oct-91	4

During sampling conducted since the completion of the RI fieldwork (Jacobs Engineering Group, Inc. December 1992) *cis*- and *trans*-1,2-DCE were the only TCE degradation products detected in upper-zone groundwater (Figure II-14B). The *cis*-1,2-DCE isomer was detected in 12 monitoring wells distributed throughout the East Parking Lot Plume. The *trans*- isomer was detected in only one well, HM-31. For the 12 wells containing *cis*-1,2-DCE contamination, 6 wells showed increased concentrations relative to prior levels, and 4 wells showed decreased concentrations relative to prior levels. Two of the 12 wells had not been sampled during the RI. Of the 4 wells showing decreased concentrations, the largest decrease occurred at LF05-19 where *cis*-1,2-DCE

decreased by a factor of 15 from 280 to 18 $\mu\text{g/L}$. LF05-19 is the furthest downgradient well in the East Parking Lot TCE Plume. As shown in Figure II-14B, there is no obvious trend associated with the spatial distribution of increasing or decreasing *cis*-1,2-DCE concentrations. The largest increase in concentration occurred at HM-112, where *cis*-1,2-DCE increased from ND to 310 $\mu\text{g/L}$ in July 1992 (Figure II-14B).

In addition to TCE and its degradation products, 1,1,2-TCA, 1,1-DCA, 1,2-dichloropropane (DCP), methylene chloride, benzene, ethylbenzene, *o*-xylene, toluene, xylene, acetone, chlorobenzene, and chloroform were detected in concentrations exceeding the CRQL in upper-zone monitoring wells in the East Parking Lot Plume area. The concentrations at which these compounds were detected are listed in Table 4.5.1-5 and displayed in Figure II-15.

As shown in Figure II-15, the VOCs are concentrated in two regions. One region is adjacent to FDTA-5, south of Building 12, where monitoring wells W-131L and W-133L contain 1,100 $\mu\text{g/L}$ and 2,600 $\mu\text{g/L}$ chlorobenzene, respectively, 320 $\mu\text{g/L}$ and 1,900 $\mu\text{g/L}$ methylene chloride, respectively, and lesser amounts of benzene, toluene, ethylbenzene, and xylene. FDTA-5 is the most likely potential source for the VOC contamination identified in upper-zone groundwater in this area.

Monitoring well HM-047 located approximately 300 feet downgradient of FDTA-5 also contained 1,2-dichlorobenzene at a concentration of 300J $\mu\text{g/L}$ and methylene chloride at a concentration of 1,400 $\mu\text{g/L}$. Further downgradient, monitoring well W-160 contained 15 $\mu\text{g/L}$ benzene, 150 $\mu\text{g/L}$ acetone, and 57 $\mu\text{g/L}$ methylene chloride. It is uncertain whether the contamination at W-160 is associated with FDTA-5. Monitoring well HM-090, located in the East Parking Lot, contains chloroform, benzene, and xylene at concentrations of 18 $\mu\text{g/L}$, 270E $\mu\text{g/L}$, and 23 $\mu\text{g/L}$, respectively. Evaluations of the groundwater contaminant distribution presented on Figure II-15 and water table elevations presented on Figure II-24 suggest that the contamination in monitoring well HM-90 may be originating from USTs 19 and 20 and FSA-1. These potential sources are located along the groundwater divide between the East Plume and West Plume areas where monitoring wells W-139L and W-141L are located. An easterly component of groundwater flow may transport contamination from FSA-1 to the East Parking Lot Plume. The path of that transport would lie directly below the main Assembly Building and could also explain the 89 $\mu\text{g/L}$ benzene detected in monitoring well HM-56.

The second area where VOC contamination, other than TCE, was detected was on CAFB (see Figure II-15). VOC contamination was detected at monitoring wells HM-123, LF05-01, LF05-5A, LF05-02, WP07-10A, LF05-5C, LF04-02, and LF04-04 (see Figure II-15). Volatile organic compounds were present in very low concentrations at these locations.

Table 4.5.1-5 Upper-Zone Monitoring Wells Within the East Parking Lot Plume Area where Other VOC Concentrations Exceeded CRQLs

Chemical Name	Site ID	Sample ID	Sample Date	Result ($\mu\text{g/L}$)
1,1,2-Trichloroethane	LF04-02	LF04-02	27-Oct-91	3
1,1-Dichloroethane	LF04-02	LF04-02	27-Oct-91	1
1,1-Dichloroethane	W-139L	W-139L-01	16-Sep-91	9
1,2-Dichloropropane	W-131L	W-131L-01	11-Sep-91	8
Acetone	HM-024	HM-24-11	13-Nov-91	87
Acetone	HM-024	HM-24-12	13-Nov-91	87
Acetone	HM-115	QM-008	18-Mar-91	14
Acetone	HM-119	QM-021	18-Mar-91	12
Acetone	HM-125	QM-013	18-Mar-91	16
Acetone	W-131L	W-131L-01DL	11-Sep-91	150
Acetone	W-133L	W-133L-11	19-Oct-91	39
Acetone	W-155	W-155-01	18-Sep-91	22
Acetone	W-160	W-160-01	14-Sep-91	110
Acetone	W-160	W-160-01DL	14-Sep-91	150
Benzene	HM-090	NA-177	28-Apr-90	2,70E
Benzene	HM-056	NAA168	28-Apr-90	89
Benzene	W-131L	W-131L-01	11-Sep-91	38
Benzene	W-133L	W-133L-11	19-Oct-91	37
Benzene	W-139L	W-139L-01DL	16-Sep-91	280
Benzene	W-139L	W-139L-11DL	19-Oct-91	520
Benzene	W-141L	W-141L-01DL	16-Sep-91	730
Benzene	W-141L	W-141L-11DL	18-Oct-91	670
Benzene	W-160	W-160-01	14-Sep-91	15
Chlorobenzene	LF05-5A	LF05-5A	27-Oct-91	1
Chlorobenzene	W-131L	W-131L-01DL	11-Sep-91	1,100
Chlorobenzene	W-133L	W-133L-11D	19-Oct-91	2,600
Chloroform	HM-024	HM-24-11	13-Nov-91	51
Chloroform	HM-024	HM-24-12	13-Nov-91	52
Chloroform	HM-090	NAA177	29-Apr-90	18
Chloroform	LF04-02	LF04-02	27-Oct-91	1
Chloroform	LF05-01	LF05-01	28-Oct-91	2
Chloroform	W-131L	W-131L-01	11-Sep-91	8
Chloroform	W-133L	W-133L-11	19-Oct-91	5
Chloroform	WP07-10A	WP07-10A	27-Oct-91	1
Ethylbenzene	W-131L	W-131L-01	11-Sep-91	25
Ethylbenzene	W-133L	W-133L-11	19-Oct-91	25
Ethylbenzene	W-139L	W-139L-01DL	16-Sep-91	1,600
Ethylbenzene	W-139L	W-139L-11DL	19-Oct-91	3,500
Ethylbenzene	W-141L	W-141L-01DL	16-Sep-91	5,500
Ethylbenzene	W-141L	W-141L-11DL	18-Oct-91	5,200
Methylene Chloride	HM-047	NAA269	27-Apr-90	1,400
Methylene Chloride	W-128L	W-128L-01	12-Sep-91	9
Methylene Chloride	W-131L	W-131L-01DL	11-Sep-91	320
Methylene Chloride	W-133L	W-133L-11D	19-Oct-91	1,900

Table 4.5.1-5 (continued) Upper-Zone Monitoring Wells Within the East Parking Lot Plume Area where Other VOC Concentrations Exceeded CRQLs

Chemical Name	Site ID	Sample ID	Sample Date	Result ($\mu\text{g/L}$)
Methylene Chloride	W-160	W-160-01	14-Sep-91	42
Methylene Chloride	W-160	W-160-01DL	14-Sep-91	57
<i>o</i> -Xylene	W-131L	W-131L-01	11-Sep-91	23
<i>o</i> -Xylene	W-133L	W-133L-11	19-Oct-91	21
<i>o</i> -Xylene	W-141L	W-141L-01	16-Sep-91	170
<i>o</i> -Xylene	W-141L	W-141L-11	18-Oct-91	120
Tetrachloroethene	LF04-02	LF04-02	27-Oct-91	23
Toluene	W-131L	W-131L-01	11-Sep-91	60
Toluene	W-133L	W-133L-11	19-Oct-91	57
Xylene	HM-090	NAA177	29-Apr-90	23
Xylene	W-131L	W-131L-01	11-Sep-91	73
Xylene	W-133L	W-133L-11	19-Oct-91	68
Xylene	W-139L	W-139L-01DL	16-Sep-91	500
Xylene	W-139L	W-139L-11	19-Oct-91	350
Xylene	W-141L	W-141L-01DL	16-Sep-91	12,000
Xylene	W-141L	W-141L-11D	18-Oct-91	10,000

The results of sampling conducted after completion of the RI fieldwork (Jacobs Engineering Group, Inc. December 1992) showed no significant changes in the concentrations or distribution of VOCs.

4.5.1.2 East Parking Lot Plume: Semi-VOCs, TPH, and Oil and Grease

Semi-VOCs were detected in six monitoring wells in the East Parking Lot Plume area. A list of compounds detected in these wells is presented in Table 4.5.1-6. Monitoring wells W-131L, W-131U, and W-133L contained high concentrations of chlorobenzenes, naphthalenes, and di-n-butylphthalates, suggesting a potential source in close proximity, probably the DYCPs and FDTA-5. A map showing the locations of these monitoring wells is presented in Figure II-16.

Semivolatile organic compounds detected in monitoring wells F-204, W-136, W-139L, and W-141L are probably derived from the source of fuel contamination at FSA-1. The semivolatile contamination at this location is located in an area of nearly flat hydraulic gradient. Consequently, the contamination in this area may eventually flow towards the East Parking Lot Plume or the West Plume area.

A summary of oil and grease and TPH monitoring in the East Parking Lot Plume is presented in Table 4.5.1-7. A posting of sampling locations and monitoring results for oil and grease and TPH is presented in Figure II-16. Oil and grease and TPH in monitoring well F-218 were at the limit of detection at 0.2 mg/L. Oil and grease and

Table 4.5.1-6 Semi-VOCs Detected in the East Parking Lot Plume Area

Chemical Name	Site ID	Sample ID	Sample Date	Result (µg/L)
Naphthalene	F-204	NAA284	26-Apr-90	56
2-Methylnaphthalene	F-204	NAA284	26-Apr-90	75
Naphthalene	F-204	NAA305	26-Apr-90	45
2-Methylnaphthalene	F-204	NAA305	26-Apr-90	62
1,2-Dichlorobenzene	W-131L	W-131L-11	19-Oct-91	88
1,4-Dichlorobenzene	W-131U	W-131U-01	12-Sep-91	12
1,2-Dichlorobenzene	W-131U	W-131U-01	12-Sep-91	81
1,4-Dichlorobenzene	W-131U	W-131U-02	12-Sep-91	12
Di-n-Butylphthalate	W-131U	W-131U-02	12-Sep-91	23
1,2-Dichlorobenzene	W-131U	W-131U-02	12-Sep-91	74
1,2-Dichlorobenzene	W-131U	W-131U-11	24-Oct-91	73
1,2-Dichlorobenzene	W-131U	W-131U-12	24-Oct-91	62
1,4-Dichlorobenzene	W-133L	W-133L-01	11-Sep-91	590
1,3-Dichlorobenzene	W-133L	W-133L-01	11-Sep-91	33
Naphthalene	W-133L	W-133L-01	11-Sep-91	16
2-Methylnaphthalene	W-133L	W-133L-01	11-Sep-91	24
1,2-Dichlorobenzene	W-133L	W-133L-01	11-Sep-91	2,000
1,4-Dichlorobenzene	W-133L	W-133L-11	19-Oct-91	370
1,2-Dichlorobenzene	W-133L	W-133L-11	19-Oct-91	1,300
Naphthalene	W-136	W-136-01	15-Sep-91	51
2-Methylnaphthalene	W-136	W-136-01	15-Sep-91	91
Naphthalene	W-136	W-136-11	18-Oct-91	12
2,4-Dimethylphenol	W-139L	W-139L-01	16-Sep-91	20
Naphthalene	W-139L	W-139L-01	16-Sep-91	77
2-Methylnaphthalene	W-139L	W-139L-01	16-Sep-91	79
Naphthalene	W-139L	W-139L-11	19-Oct-91	64
2-Methylnaphthalene	W-139L	W-139L-11	19-Oct-91	42
2,4-Dimethylphenol	W-141L	W-141L-01	16-Sep-91	130
Naphthalene	W-141L	W-141L-01	16-Sep-91	36
2-Methylnaphthalene	W-141L	W-141L-01	16-Sep-91	48
2,4-Dimethylphenol	W-141L	W-141L-11	18-Oct-91	79
Naphthalene	W-141L	W-141L-11	18-Oct-91	21
2-Methylnaphthalene	W-141L	W-141L-11	18-Oct-91	20
Bis(2-ethylhexyl)phthalate	W-160	W-160-01	14-Sep-91	13

Table 4.5.1-7 Oil and Grease and TPH Analytical Results in the East Parking Lot Plume Area

Chemical Name	Site ID	Sample ID	Sample Date	Result (mg/L)
Oil and Grease	F-204	NAA284	26-Apr-90	20.0
Oil and Grease	F-218	F-218	19-Oct-91	0.2
Total Petroleum Hydrocarbons	F-218	F-218	19-Oct-91	0.2
Oil and Grease	HM-104	QM-007	13-Mar-91	3.0
Oil and Grease	HM-125	QM-013	18-Mar-91	0.6
Oil and Grease	LF05-01	LF05-01	28-Oct-91	0.3
Oil and Grease	W-131U	W-131U-02	11-Sep-91	0.59
Oil and Grease	W-131U	W-131U-11	24-Oct-91	0.53
Oil and Grease	W-133L	W-133L-01	11-Sep-91	7.31
Total Petroleum Hydrocarbons	W-133L	W-133L-01	11-Sep-91	3.7
Oil and Grease	W-133L	W-133L-11	19-Oct-91	5.01
Total Petroleum Hydrocarbons	W-133L	W-133L-11	19-Oct-91	2.12
Total Petroleum Hydrocarbons	W-136	W-136-01	15-Sep-91	2.67
Total Petroleum Hydrocarbons	W-136	W-136-11	18-Oct-91	2.24
Total Petroleum Hydrocarbons	W-139L	W-139L-01	16-Sep-91	4.71
Total Petroleum Hydrocarbons	W-139L	W-139L-11	19-Oct-91	3.37
Total Petroleum Hydrocarbons	W-141L	W-141L-01	16-Sep-91	5.99
Total Petroleum Hydrocarbons	W-141L	W-141L-11	18-Oct-91	2.22

TPH in monitoring wells HM-125, LF05-01, and W-131U were also very low. However, monitoring wells HM-104 and W-133L contained significant concentrations of oil and grease, and both oil and grease and TPH, respectively. In the vicinity of W-133L the potential source of these contaminants is possibly attributable to either the Die Yard Chemical Pits or the FDTA-5. The potential source in the vicinity of monitoring well HM-104 is unknown.

Oil and grease and TPH concentrations detected in monitoring wells F-204, W-136, W-139L, and W-141L are probably originating at FSA-1. The contamination in this area may eventually flow toward the East Parking Lot Plume or the West Plume area, depending on the exact location of the groundwater divide between these two areas.

The results of sampling conducted after the completion of the RI field work (Jacobs Engineering Group, Inc. December 1992) showed no significant changes in the concentrations or distribution of semi-VOCs, TPH, or oil and grease.

4.5.1.3 West Plume: Volatile Organic Compounds

The second largest plume of groundwater contamination in the upper-zone flow system is referred to as the West Plume. This plume originates at the groundwater divide located within the west-central portion of the Assembly Building/Parts Plant and Building 14 (see Figure II-12). The West Plume is a broad area of contaminated groundwater that spreads westward across Meandering Road toward Meandering Road Creek.

This plume may receive contamination from four potential sources. One important source of chlorinated organic solvent contamination is FDTA-2. Two potential sources of leachate contamination include Landfill No. 1 and Landfill No. 3. A fourth source is located between Building 14 and the Parts Plant, where fuel-related contamination may have been introduced from leaking fuel lines.

Groundwater in the West Plume flows towards Meandering Road Creek. Groundwater discharge to Meandering Road Creek is restricted by a bedrock high along Meandering Road Creek. However, a bedrock channel cuts the bedrock and provides a pathway to Meandering Road Creek.

The extent of the West Plume is defined by elevated concentrations of TCE, 1,2-DCA, 1,2-DCE, *cis*-1,2-DCE, vinyl chloride, 1,1,1-TCA, 1,1-DCA, 1,1-DCE, methylene chloride, tetrachloroethene, benzene, ethylbenzene, *o*-xylene, toluene, xylene, 2-butanone, acetone, carbon disulfide, chlorobenzene, chloroform, and styrene. Most of these compounds were detected above their MCL during the RI (see Figures II-12 through II-16).

In the vicinity of Building 217 and wells HM-30 and HM-41, the southwest boundary of the West Plume has not been defined. The most downgradient wells that were sampled in this area (HM-30 and HM-41) contained contamination. Monitoring wells located west of HM-30 and HM-41 were not sampled during the RI (in an effort to reduce analytical costs) so recent concentration data are not available.

TCE was the most prevalent VOC detected in the West Plume during the RI. TCE was detected at 14 monitoring wells. Upper-zone monitoring wells in the West Plume area that contained TCE at concentrations exceeding the CRQL are listed in Table 4.5.1-8. TCE concentrations exceeded the MCL of 5 $\mu\text{g}/\text{L}$ at each well. The highest TCE concentration reported in the West Plume occurred in monitoring well HM-51 (Figures II-12 and II-13). Two samples collected from this monitoring well indicate TCE concentrations of 87,000 and 78,000 $\mu\text{g}/\text{L}$. This monitoring well is located within FDTA-2, which is a potential source for contamination of upper-zone groundwater.

**Table 4.5.1-8 Upper-Zone Monitoring Wells in the West Plume Area
where TCE Concentrations Exceeded the CRQL**

Site ID	Sample ID	Sample Date	Result ($\mu\text{g/L}$)
F-207	QM-001	19-Mar-91	9
F-207	QM-017	19-Mar-91	8
F-207	WQM001	05-Dec-90	13
F-215	QM-002DL	14-Mar-91	780
F-215	WQM002DL	05-Dec-90	970
F-216	NAA268	28-Apr-90	13
F-217	NAA156	02-May-90	10
F-217	NAA267	02-May-90	33
HM-010	NAA160	27-Apr-90	9
HM-010	QM-003	14-Mar-91	6
HM-010	WQM006	06-Dec-90	9
HM-020	NAA161	27-Apr-90	240
HM-020	NAA256	27-Apr-90	230
HM-021	QM-004	20-Mar-91	130
HM-029	NAA162	27-Apr-90	1,400
HM-050	NAA165	27-Apr-90	35
HM-051	NAA166	28-Apr-90	87,000
HM-051	NAA257	28-Apr-90	78,000
HM-063	NAA170	29-Apr-90	15
HM-066	NAA171	28-Apr-90	48
W-129	W-129-01	10-Sep-91	90
W-144	W-144-01	17-Sep-91	45
W-144	W-144-11D	17-Oct-91	150

Just west of the Parts Plant and between Buildings 14 and 88, there appears to be additional groundwater contamination by TCE (see Figures II-12 and II-13). Three monitoring wells, HM-020, HM-029, and F-215 contained 240 $\mu\text{g/L}$, 1,400 $\mu\text{g/L}$, and 970 $\mu\text{g/L}$ TCE, respectively, in the upper-zone groundwater. The source of this contamination in the upper zone is probably FDTA-2. TCE concentrations in the remaining monitoring wells within the West Plume were relatively low. The low concentrations surrounded by relatively high point-concentrations suggests that advective

transport is very slow as a result of the flat hydraulic gradient in this area. For example, monitoring well HM-29 is located in the transition zone between the East Parking Lot Plume and the West Plume area. Depending upon the exact location of the hydrologic divide, the advective transport may move the TCE towards either one of the two plumes.

Degradation products of TCE were also identified within the West Plume. These compounds included 1,1-DCE, *cis*-1,2-DCE, *trans*-1,2-DCE (also reported as total 1,2-DCE), and vinyl chloride. Upper-zone monitoring wells in the West Plume area at which TCE degradation product concentrations exceeded CRQLs are listed in Table 4.5.1-9 and posted in Figure II-14. The monitoring wells that contained the highest levels of TCE degradation products were HM-051, located near FDTA-2, and HM-021, located within Landfill No. 3. Samples collected from monitoring well HM-051 in April 1990 contained *cis*-1,2-DCE at a concentration of 80,000J $\mu\text{g/L}$. The "J" qualifier indicates the concentration could only be estimated as a result of the high concentrations of VOCs in the sample. Samples collected in monitoring well HM-021 in March 1991 contained up to 69,000 $\mu\text{g/L}$ 1,2-DCE and up to 6,500 $\mu\text{g/L}$ vinyl chloride. Monitoring well F-217, also located within Landfill No. 1, contained vinyl chloride at a concentration of 260 $\mu\text{g/L}$. Lower levels of 1,2-DCE were detected in monitoring wells F-215 and HM-010. *cis*-1,2-DCE was detected at a concentration of 180 $\mu\text{g/L}$ in monitoring well W-129, located within Landfill No. 3. Potential sources for TCE and TCE-degradation products identified in the West Plume area include FDTA-2 and Landfills No. 1 and No. 3.

Analytical results also indicated the presence of other VOCs, some of which are organic solvents, while others are fuel-related contaminants and intermediate products that may represent byproducts of the solvent compounds. VOCs, other than TCE and its degradation products, identified during the RI include 1,1,1-TCA, 1,1-DCA, 1,2-DCA, methylene chloride, PCE, benzene, ethylbenzene, *o*-xylene, toluene, xylene, 2-butanone, acetone, carbon disulfide, chlorobenzene, chloroform, and styrene. Upper-zone monitoring wells in the West Plume area where concentrations of these compounds were reported above CRQLs are listed in Table 4.5.1-10 and shown in Figure II-15.

Additional VOCs detected in well HM-051, located in FDTA-2, include methylene chloride (98,000 $\mu\text{g/L}$); 1,2-DCA (30,000 $\mu\text{g/L}$); and toluene (25,000 $\mu\text{g/L}$). The source of these compounds may have been seepage into the ground of incompletely combusted liquids used during fire training exercises.

Table 4.5.1-9 Upper-Zone Monitoring Wells Within the West Plume Area where TCE-Degradation Product Concentrations Exceeded CRQLs

Chemical Name	Site ID	Sample ID	Sample Date	Result (µg/L)
1,1-Dichloroethene	F-207	NAA153	25-Apr-90	1,200
1,1-Dichloroethene	F-207	NAA259	25-Apr-90	1,100
1,1-Dichloroethene	F-207	NAA270	25-Apr-90	860
1,1-Dichloroethene	F-207	QM-001DL	19-Mar-91	930
1,1-Dichloroethene	F-207	QM-017DL	19-Mar-91	970
1,1-Dichloroethene	F-207	WQM001DL	05-Dec-90	700
1,1-Dichloroethene	F-215	QM-002	14-Mar-91	120
1,1-Dichloroethene	F-215	QM-002DL	14-Mar-91	110
1,1-Dichloroethene	F-215	WQM002	05-Dec-90	85
1,1-Dichloroethene	F-215	WQM002DL	05-Dec-90	83
1,1-Dichloroethene	F-217	NAA267	02-May-90	39
1,1-Dichloroethene	HM-010	QM-003	14-Mar-91	50
1,1-Dichloroethene	HM-010	WQM006	06-Dec-90	30
1,1-Dichloroethene	HM-020	NAA161	27-Apr-90	290
1,1-Dichloroethene	HM-020	NAA256	27-Apr-90	260
1,1-Dichloroethene	HM-021	QM-004	20-Mar-91	89
1,1-Dichloroethene	W-144	W-144-01DL	17-Sep-91	2,100
1,1-Dichloroethene	W-144	W-144-11D	17-Oct-91	1,100
1,2-Dichloroethene	F-215	QM-002	14-Mar-91	18
1,2-Dichloroethene	F-215	WQM002	05-Dec-90	16
1,2-Dichloroethene	HM-010	QM-003	14-Mar-91	74
1,2-Dichloroethene	HM-010	WQM006	06-Dec-90	11
1,2-Dichloroethene	HM-021	NAA102	27-Feb-90	280
1,2-Dichloroethene	HM-021	QM-004DL2	20-Mar-91	69,000
<i>cis</i> -1,2-Dichloroethene	W-129	W-129-01	10-Sep-91	160
<i>cis</i> -1,2-Dichloroethene	W-129	W-129-01DL	10-Sep-91	180
<i>cis</i> -1,2-Dichloroethene	W-132	W-132-01	10-Sep-91	25
<i>cis</i> -1,2-Dichloroethene	W-132	W-132-02	10-Sep-91	24
<i>cis</i> -1,2-Dichloroethene	W-132	W-132-11	23-Oct-91	9
<i>cis</i> -1,2-Dichloroethene	W-139L	W-139L-01	16-Sep-91	11
<i>cis</i> -1,2-Dichloroethene	W-139L	W-139L-11	19-Oct-91	9

Table 4.5.1-9 (continued) Upper-Zone Monitoring Wells Within West Plume Area where TCE-Degradation Product Concentrations Exceeded CRQLs

Chemical Name	Site ID	Sample ID	Sample Date	Result ($\mu\text{g/L}$)
<i>cis</i> -1,2-Dichloroethene	W-132	W-132-02	10-Sep-91	24
<i>cis</i> -1,2-Dichloroethene	W-132	W-132-11	23-Oct-91	9
<i>cis</i> -1,2-Dichloroethene	W-139L	W-139L-01	16-Sep-91	11
<i>cis</i> -1,2-Dichloroethene	W-139L	W-139L-11	19-Oct-91	9
<i>trans</i> -1,2-Dichloroethene	W-132	W-132-01	10-Sep-91	8
<i>trans</i> -1,2-Dichloroethene	W-132	W-132-02	10-Sep-91	7
Vinyl Chloride	F-217	NAA100	27-Feb-90	260
Vinyl Chloride	HM-021	NAA102	27-Feb-90	980
Vinyl Chloride	HM-021	QM-004DL	20-Mar-91	5,600
Vinyl Chloride	HM-021	QM-004DL2	20-Mar-91	6,500

High concentrations of benzene were detected at monitoring wells W-141L and W-139L, located between Building 14 and the Parts Plant. Plant 4 records indicate that fuel pipeline leakage has occurred in this area. Contamination reported in upper-zone groundwater at this location likely represents residual contamination from those leaks. Depending upon the precise location of the hydrologic divide, the benzene may either migrate towards the East Parking Lot Plume or the West Plume area.

Several VOCs were detected in monitoring wells HM-021 and W-132, located in Landfill No. 3. Elevated concentrations of 1,2-dichlorobenzene, vinyl chloride, 1,2-DCE, chlorobenzene, and 1,2-DCA were found in well HM-021. Styrene was detected in monitoring well W-132. The presence of these compounds further suggests that Landfill No. 3 may be a continuing source for groundwater contamination within the West Plume area of the upper-zone flow system.

Monitoring wells completed in and around Landfill No. 1 indicate low levels of chlorinated compounds. The most prevalent VOCs, other than TCE and TCE-degradation products, identified in this area include PCE, 1,1,1-TCA, 1,1-DCA, 1,2-DCA, and chlorobenzene. Low concentrations of 2-butanone, acetone, and methylene chloride were also detected in several monitoring wells; however, these compounds may not be indicative of environmental contamination because these compounds are common laboratory contaminants.

**Table 4.5.1-10 Upper-Zone Monitoring Wells in the West Plume Area
where Other VOC Concentrations Exceed CRQLs**

Chemical Name	Site ID	Sample ID	Sample Date	Result (µg/L)
1,1,1-Trichloroethane	F-207	NAA259	25-Apr-90	380
1,1,1-Trichloroethane	F-207	NAA270	25-Apr-90	340
1,1,1-Trichloroethane	F-207	QM-001DL	19-Mar-91	200
1,1,1-Trichloroethane	F-207	QM-017	19-Mar-91	110
1,1,1-Trichloroethane	F-207	QM-017DL	19-Mar-91	240
1,1,1-Trichloroethane	F-207	WQM001	05-Dec-90	160
1,1,1-Trichloroethane	F-207	WQM001DL	05-Dec-90	150
1,1,1-Trichloroethane	F-215	QM-002	14-Mar-91	20
1,1,1-Trichloroethane	F-215	WQM002	05-Dec-90	15
1,1,1-Trichloroethane	F-217	NAA267	02-May-90	12
1,1,1-Trichloroethane	HM-010	QM-003	14-Mar-91	12
1,1,1-Trichloroethane	HM-010	WQM006	06-Dec-90	7
1,1,1-Trichloroethane	HM-020	NAA161	27-Apr-90	98
1,1,1-Trichloroethane	HM-020	NAA256	27-Apr-90	100
1,1,1-Trichloroethane	HM-021	QM-004	20-Mar-91	16
1,1,1-Trichloroethane	W-144	W-144-01	17-Sep-91	200
1,1,1-Trichloroethane	W-144	W-144-01DL	17-Sep-91	230
1,1,1-Trichloroethane	W-144	W-144-11	17-Oct-91	140
1,1,1-Trichloroethane	W-144	W-144-11D	17-Oct-91	120
1,1-Dichloroethane	F-207	QM-001	19-Mar-91	18
1,1-Dichloroethane	F-207	QM-017	19-Mar-91	18
1,1-Dichloroethane	F-207	WQM001	05-Dec-90	13
1,1-Dichloroethane	HM-021	QM-004	20-Mar-91	22
1,1-Dichloroethane	W-139L	W-139L-01	16-Sep-91	9
1,1-Dichloroethane	W-144	W-144-01	17-Sep-91	16
1,1-Dichloroethane	W-144	W-144-11	17-Oct-91	13
1,2-Dichloroethane	F-207	QM-001	19-Mar-91	57
1,2-Dichloroethane	F-207	QM-001DL	19-Mar-91	60
1,2-Dichloroethane	F-207	QM-017	19-Mar-91	60
1,2-Dichloroethane	F-207	QM-017DL	19-Mar-91	64
1,2-Dichloroethane	F-207	WQM001	05-Dec-90	30
1,2-Dichloroethane	F-207	WQM001DL	05-Dec-90	28
1,2-Dichloroethane	HM-051	NAA166	28-Apr-90	30,000
1,2-Dichloroethane	HM-051	NAA257	28-Apr-90	26,000
1,2-Dichloroethane	W-144	W-144-01	17-Sep-91	25
1,2-Dichloroethane	W-144	W-144-11	17-Oct-91	20
2-Butanone	F-217	NAA120	27-Mar-90	130
2-Butanone	HM-007	NAA101	27-Feb-90	10
2-Butanone	W-129	W-129-01DL	10-Sep-91	750
2-Butanone	W-132	W-132-02	10-Sep-91	13
Acetone	HM-021	QM-004	20-Mar-91	22

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Table 4.5.1-10 (continued) Upper-Zone Monitoring Wells in the West Plume Area where Other VOC Concentrations Exceed CRQLs

Chemical Name	Site ID	Sample ID	Sample Date	Result ($\mu\text{g/L}$)
Acetone	HM-021	QM-004DL2	20-Mar-91	7,600
Acetone	W-129	W-129-01	10-Sep-91	25
Benzene	HM-007	NAA121	27-Mar-90	7
Benzene	HM-007	NAA159	02-May-90	16
Benzene	HM-021	QM-004	20-Mar-91	33
Benzene	W-139L	W-139L-01DL	16-Sep-91	280
Benzene	W-139L	W-139L-11D	19-Oct-91	520
Benzene	W-141L	W-141L-01DL	16-Sep-91	730
Benzene	W-141L	W-141L-11D	18-Oct-91	670
Carbon Disulfide	W-136	W-136-11	18-Oct-91	20
Chlorobenzene	F-217	NAA156	02-May-90	14
Chlorobenzene	F-217	NAA267	02-May-90	21
Chlorobenzene	HM-007	NAA101	27-Feb-90	26
Chlorobenzene	HM-007	NAA159	02-May-90	6
Chlorobenzene	HM-021	NAA102	27-Feb-90	550
Chlorobenzene	HM-021	QM-004DL	20-Mar-91	350
Chloroform	HM-021	QM-004	20-Mar-91	90
Ethylbenzene	HM-007	NAA101	27-Feb-90	190
Ethylbenzene	HM-007	NAA118	27-Feb-90	480
Ethylbenzene	HM-007	NAA121	27-Mar-90	28
Ethylbenzene	HM-021	QM-004	20-Mar-91	88
Ethylbenzene	W-139L	W-139L-01DL	16-Sep-91	1,600
Ethylbenzene	W-139L	W-139L-11D	19-Oct-91	3,500
Ethylbenzene	W-141L	W-141L-01DL	16-Sep-91	5,500
Ethylbenzene	W-141L	W-141L-11D	18-Oct-91	5,200
Methylene Chloride	HM-051	NAA166	28-Apr-90	98,000
Methylene Chloride	HM-051	NAA257	28-Apr-90	83,000
<i>o</i> -Xylene	W-141L	W-141L-01	16-Sep-91	170
<i>o</i> -Xylene	W-141L	W-141L-11	18-Oct-91	120
Styrene	W-132	W-132-11	23-Oct-91	27
Tetrachloroethene	HM-021	QM-004	20-Mar-91	18
Tetrachloroethene	HM-050	NAA165	27-Apr-90	6
Toluene	HM-007	NAA101	27-Feb-90	71
Toluene	HM-021	QM-004	20-Mar-91	170
Toluene	HM-051	NAA166	28-Apr-90	25,000
Toluene	HM-051	NAA257	28-Apr-90	23,000
Xylene	HM-007	NAA101	27-Feb-90	16
Xylene	HM-007	NAA159	02-May-90	59
Xylene	HM-021	QM-004	20-Mar-91	75
Xylene	HM-090	NAA-177	29-Apr-90	23

Table 4.5.1-10 (continued) Upper-Zone Monitoring Wells in the West Plume Area where Other VOC Concentrations Exceed CRQLs

Chemical Name	Site ID	Sample ID	Sample Date	Result ($\mu\text{g/L}$)
Xylene	W-139L	W-139L-01DL	16-Sep-91	500
Xylene	W-139L	W-139L-11	19-Oct-91	350
Xylene	W-141L	W-141L-01DL	16-Sep-91	12,000
Xylene	W-141L	W-141L-11D	18-Oct-91	10,000

Sampling conducted after completion of the RI field work (Jacobs Engineering Group, Inc. December 1992) did not include any upper-zone monitoring wells in the West Plume.

4.5.1.4 West Plume Area: Semi-VOCs, TPH, and Oil and Grease

Semi-VOCs were detected in five monitoring wells in the West Plume area. A list of compounds detected in these wells is presented in Table 4.5.1-11. Low levels of naphthalene, 2-methylnaphthalene, and 2,4-dimethylphenol were detected in monitoring wells F-204, W-136, W-139L, and W-141L. Each of these wells are located adjacent to FSA-1, the likely source of the semi-VOC contamination in this area. These constituents may eventually migrate east or west depending upon the location of the hydrologic divide.

Semi-VOCs were also detected in relatively high concentrations in monitoring well HM-021. The compounds 1,4-dichlorobenzene and 1,2-dichlorobenzene were detected at concentrations of 310 and 1,600 $\mu\text{g/L}$, respectively. Monitoring well HM-021 is located at Landfill No. 3, the potential source of the semi-VOC. A map showing the locations of each of the monitoring wells in the West Plume area is presented as Figure II-16.

TPH and oil and grease were also detected in the West Plume area. A summary of the oil and grease and TPH monitoring for the West Plume is presented in Table 4.5.1-12. Monitoring wells F-204, W-136, W-139L, and W-141L, located in FSA-1, were found to contain significant levels of oil and grease and TPH. The source of this contamination is most likely FSA-1. A map showing the locations of these monitoring wells in the West Plume area is presented in Figure II-16.

Sampling conducted after completion of the RI field work (Jacobs Engineering Group, Inc. December 1992) did not include any upper-zone monitoring wells in the West Plume.

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**Table 4.5.1-11 Upper-Zone Monitoring Wells in the West Plume Area
where Semi-VOC Concentrations Exceeded CRQLs**

Chemical Name	Site ID	Sample ID	Sample Date	Result (µg/L)
Naphthalene	F-204	NAA284	26-Apr-90	56
2-Methylnaphthalene	F-204	NAA284	26-Apr-90	75
Naphthalene	F-204	NAA305	26-Apr-90	45
2-Methylnaphthalene	F-204	NAA305	26-Apr-90	62
1,4-Dichlorobenzene	HM-021	QM-004	20-Mar-91	310
1,2-Dichlorobenzene	HM-021	QM-004	20-Mar-91	1,600
Naphthalene	W-136	W-136-01	15-Sep-91	51
2-Methylnaphthalene	W-136	W-136-01	15-Sep-91	91
Naphthalene	W-136	W-136-11	18-Oct-91	12
2,4-Dimethylphenol	W-139L	W-139L-01	16-Sep-91	20
Naphthalene	W-139L	W-139L-01	16-Sep-91	77
2-Methylnaphthalene	W-139L	W-139L-01	16-Sep-91	79
Naphthalene	W-139L	W-139L-11	19-Oct-91	64
2-Methylnaphthalene	W-139L	W-139L-11	19-Oct-91	42
2,4-Dimethylphenol	W-141L	W-141L-01	16-Sep-91	130
Naphthalene	W-141L	W-141L-01	16-Sep-91	36
2-Methylnaphthalene	W-141L	W-141L-01	16-Sep-91	48
2,4-Dimethylphenol	W-141L	W-141L-11	18-Oct-91	79
Naphthalene	W-141L	W-141L-11	18-Oct-91	21
2-Methylnaphthalene	W-141L	W-141L-11	18-Oct-91	20

**Table 4.5.1-12 Oil and Grease and TPH Analytical Results in the West Plume Area
(TPH and Oil and Grease were detected in Reportable Quantities)**

Chemical Name	Site ID	Sample ID	Sample Date	Result (µg/L)
Oil and Grease	F-204	NAA284	26-Apr-90	20.0
Total Petroleum Hydrocarbons	W-136	W-136-01	15-Sep-91	2.67
Total Petroleum Hydrocarbons	W-136	W-136-11	18-Oct-91	2.24
Total Petroleum Hydrocarbons	W-139L	W-139L-01	16-Sep-91	4.71
Total Petroleum Hydrocarbons	W-139L	W-139L-11	19-Oct-91	3.37
Total Petroleum Hydrocarbons	W-141L	W-141L-01	16-Sep-91	5.99
Total Petroleum Hydrocarbons	W-141L	W-141L-11	18-Oct-91	2.22

4.5.1.5 North Plume: Organic Contamination

Upper-zone groundwater in the North Plume area is part of the groundwater flow system that originates along a hydrologic divide that trends east to west across the north end of the Main Assembly Building (see Figure II-24). Analytical results for upper-zone groundwater in this area indicate that monitoring wells F-209 and W-135 contain VOC concentrations greater than CRQLs. A list of the VOCs that exceeded CRQLs in these two monitoring wells is presented in Table 4.5.1-13. Well locations and monitoring results are presented in Figures II-12, -13, -14, and -15.

Table 4.5.1-13 Upper Zone Monitoring Wells in the North Plume Area where VOC Concentrations Exceeded CRQLs

Chemical Name	Site ID	Sample ID	Sample Date	Result ($\mu\text{g/L}$)
1,1,2-Trichloroethane	F-209	NAA302	26-Apr-90	660
1,1-Dichloroethane	F-209	NAA302	26-Apr-90	620
1,2-Dichloropropane	F-209	NAA302	26-Apr-90	610
2-Butanone	W-135	W-135-01	14-Sep-91	69
2-Butanone	W-135	W-135-11	22-Oct-91	120
Carbon Tetrachloride	F-209	NAA302	26-Apr-90	400
Chlorobenzene	F-209	NAA302	26-Apr-90	590
Chloroform	F-209	NAA302	26-Apr-90	620
Dibromochloromethane	F-209	NAA302	26-Apr-90	550
Methylene Chloride	F-209	NAA302	26-Apr-90	610
Tetrachloroethene	F-209	NAA302	26-Apr-90	450
Trichloroethene	F-209	NAA302	26-Apr-90	530

Analytical results for monitoring well F-209 indicate 530 $\mu\text{g/L}$ TCE, 450 $\mu\text{g/L}$ PCE, 610 $\mu\text{g/L}$ methylene chloride, 550 $\mu\text{g/L}$ dibromochloromethane, 620 $\mu\text{g/L}$ chloroform, 590 $\mu\text{g/L}$ chlorobenzene, 400 $\mu\text{g/L}$ carbon tetrachloride, 610 $\mu\text{g/L}$ 1,2-dichloropropane, 620 $\mu\text{g/L}$ 1,1-dichloroethane, and 660 $\mu\text{g/L}$ 1,1,2-trichloroethane. Monitoring well W-135 was sampled in September 1991 and October 1991; on both occasions 2-butanone was detected. Although 2-butanone is a common laboratory contaminant, the laboratory reports did not indicate laboratory blank contamination. The source of the VOC contamination reported in these monitoring wells is unknown.

Results of previous investigation (Hargis + Associates 1988) indicated that monitoring wells in the vicinity of the North Plume area, including F-201, F-202, F-209, F-210, F-222, and F-223 each contained varying thicknesses of LNAPL at the water table. Thicknesses of the floating material ranged from a mere sheen to greater than one foot. During the RI, a sample of the LNAPL was collected from monitoring well FSA-3-11 and submitted for analysis. Samples of diesel No. 2, fuel oil No. 2, unleaded gasoline, JP-4, and JP-5 were also submitted for use as comparison standards. The peak profile

for the sample from FSA-3-11 most closely resembled the peak profile obtained for JP-4. The source of the floating product contamination in the North Plume area is suspected to be the fuel lines extending to the jet engine test facility.

Sampling conducted after completion of the RI field work (Jacobs Engineering Group, Inc. December 1992) did not include any upper-zone monitoring wells in the North Plume.

4.5.1.6 North Plume: Semi-VOCs, TPH, and Oil and Grease

Semi-VOCs were detected in two monitoring wells, F-209 and HM-107. Monitoring well F-209 contained 16 $\mu\text{g/L}$ of 2-methylnaphthalene, which is a fuel component. Monitoring well HM-107 contained 12 $\mu\text{g/L}$ of bis(2-ethylhexyl) phthalate, a common laboratory contaminant. A potential source of the 2-methylnaphthalene is leaking fuel supply lines and storage tanks surrounding the Jet Engine Test facility. The two monitoring wells that contained these contaminants are listed in Table 4.5.1-14 and shown on Figure II-16.

Table 4.5.1-14 Analytical Results of Semi-VOCs Detected Above CRQLs in the North Plume Area

Chemical Name	Site ID	Sample ID	Sample Date	Result ($\mu\text{g/L}$)
2-Methylnaphthalene	F-209	NAA302	26-Apr-90	16
Bis(2-ethylhexyl)phthalate	HM-107	HM-107-01	15-Sep-91	12

A summary of the oil and grease and TPH monitoring results in the North Plume area is presented in Table 4.5.1-15. Monitoring well F-209 contained 11 mg/L oil and grease, while monitoring well HM-107 contained 12 mg/L TPH. The source for oil and grease and TPH in this location may be attributable to leaking lines and storage tanks near the Jet Engine Test facility. A map showing the locations of both monitoring wells F-209 and HM-107 is presented in Figure II-16.

Table 4.5.1-15 Oil and Grease and TPH Analytical Results in the North Plume Area

Chemical Name	Site ID	Sample ID	Sample Date	Result
Oil and Grease	F-209	NAA302	26-Apr-90	11
Total Petroleum Hydrocarbons	HM-107	HM-107-01	15-Sep-91	12

4.5.2 Upper-Zone Groundwater: Inorganic Contamination

Water samples collected during the 1990–1991 monitoring events from wells in the upper-zone flow system were analyzed for selected inorganic chemicals, including those on the EPA priority-pollutant list. Results of the analyses are summarized in Table 4.5.2–1 and presented in Appendix F. The action levels listed in Table 4.5.2–1 refer to the EPA MCL or the secondary maximum contaminant level (SMCL) (EPA drinking water standards). For purposes of comparison, the number of samples that were found to exceed the action level are tabulated.

Seven priority pollutants, including antimony, arsenic, cadmium, chromium, lead, nickel, and thallium, were detected above their respective action levels. The action level was exceeded for chromium in 12 samples, for lead in 9 samples, for arsenic in 3 samples, and for the remaining analytes in 1 sample. In addition to the priority pollutants, aluminum and iron exceeded the secondary drinking water standards in 25 samples and manganese in 13 samples. Table 4.5.2–2 lists all the samples that were found to exceed drinking water standards.

Figure II–17 shows analytical results of inorganic priority pollutants, excluding chromium. Chromium results are shown in Figure II–18. The posted results are based on samples collected from new wells that were installed and monitored during the 1990–1991 Remedial Investigation in addition to the results for samples that were collected by previous contractors for the 1988–1991 monitoring period. In all cases, the values reported are the most recent analytical results available during the 1988–1991 monitoring period.

Examination of Figure II–17 reveals that zinc and copper occur widespread over the area, including the East Parking Lot Plume, the West Plume, and the North Plume. However, these values are relatively low in concentration and in all cases are less than the secondary standards. Analytes that were detected at concentrations exceeding drinking water standards in the upper-zone flow system are described below.

4.5.2.1 East Parking Lot Plume

Monitoring wells W–133L and CAR–LF05–02, located near the western and southeastern margin of the East Parking Lot Plume area, respectively, contain arsenic at concentrations in excess of the MCL (see Figure II–17). Arsenic was detected at a concentration of 72.8 $\mu\text{g}/\text{L}$ in well W–133L, slightly above the 50 $\mu\text{g}/\text{L}$ MCL. The possible source area for arsenic is the FDTA–5. Arsenic was detected in monitoring well CAR–LF–05–02 at a concentration of 53 $\mu\text{g}/\text{L}$. This well is located on CAFB at the southeastern margin of the East Parking Lot Plume.

Table 4.5.2-1 Results of Inorganic Analyses for Upper-Zone Groundwater Collected During the 1990-1991 Sampling Events

Chemical Name	Minimum Result (µg/L)	Maximum Result (µg/L)	Action Level (µg/L)	Number of Samples Analyzed	Number of Samples Above Action Level
Aluminum ^a	100	13,500	NA	29	NA
Antimony ^b	56U ^c	100	10	84	1
Arsenic ^d	3U	134	50	84	3
Barium ^b	100U	980	2,000	29	0
Beryllium ^d	1U	5U	1	84	0
Cadmium ^e	2U	5.9	5	84	1
Calcium	66,000	592,000	NA	41	NA
Chromium ^b	5U	1,040	100	105	12
Cobalt	50U	50U	NA	29	NA
Copper ^a	5U	130	NA	84	NA
Cyanide ^b	0.01U	17	200	10	0
Iron ^a	16U	14,000	NA	41	NA
Lead ^f	2U	140	15	84	9
Magnesium	2,500	54,500	NA	41	NA
Manganese ^a	15U	750	NA	29	NA
Mercury ^e	0.2U	0.3	2	29	0
Nickel ^b	22U	113	100	85	1
Potassium	938U	64,000	NA	41	NA
Selenium ^e	3U	2.1B ^g	50	84	0
Silver ^a	4U	10U	NA	84	NA
Sodium	12,000	797,000	NA	41	NA
Thallium ^b	2U	2.8B	2	84	1
Vanadium	50U	50U	NA	29	NA
Zinc ^a	7U	3,860	NA	84	NA

- ^a No action level exists for this chemical because it is regulated by secondary standards.
- ^b Action level for this chemical is the Maximum Contaminant Level (MCL) (FR V.57 No. 138)
- ^c U indicates the chemical was not detected.
- ^d Action level for this chemical is the MCL (40 CFR 141.11).
- ^e Action level for this chemical is the MCL (FR. V.56 No. 20).
- ^f Action level for this chemical is the MCL (FR. V.56 No. 110)
- ^g B indicates the result is above or equal to the Instrument Detection Limit but less than the Contract Required Detection Limit.

**Table 4.5.2-2 Summary of Inorganic Analytes that Exceeded the Action Level
in Samples Collected from Upper-Zone Groundwater
During the 1990-1991 Sampling Events**

Chemical Name	Well ID	Sample ID	Date Sampled	Result ($\mu\text{g/L}$)
Antimony	F-217	NAA156	02-May-90	100
Arsenic	W-133L	W-133L-11	19-Oct-91	72.8
	F-204	NAA284	26-Apr-90	79
	W-133L	W-133L-01	11-Sep-91	134
Cadmium	F-217	NAA156	02-May-90	5.9
Chromium	HM-029	NAA162	27-Apr-90	105
	F-215	QM-002	14-Mar-91	113
	HM-096	NAA182	25-Apr-90	142
	F-215	WQM002	05-Dec-90	151
	W-159	W-159-11	20-Oct-91	164
	W-159	W-159-01	14-Sep-91	188
	F-218	F-218	19-Oct-91	400
	HM-094	NAA180	29-Apr-90	380
	W-149	W-149-01	18-Sep-91	578
	W-149	W-149-11	17-Oct-91	629
	W-154	W-154-11	20-Oct-91	838
	W-154	W-154-01	14-Sep-91	1030
	W-154	W-154-02	14-Sep-91	1040
	Lead	W-137	W-137-01	16-Sep-91
W-149		W-149-11	17-Oct-91	17.1
HM-020		NAA256	27-Apr-90	18
W-150L		W-150L-01	14-Sep-91	19.3
HM-020		NAA161	27-Apr-90	22
HM-094		NAA180	29-Apr-90	29
HM-024		HM-24-11	13-Nov-91	53.5
HM-086		NAA173	28-Apr-90	100
Nickel	F-217	NAA156	02-May-90	140
Nickel	W-150L	W-150L-01	14-Sep-91	113
Thallium	W-131U	W-131U-02	12-Sep-91	2.8B*

* B indicates the result is above or equal to the IDL but less than the CRDL.

Thallium was detected at a concentration of 2.8B $\mu\text{g/L}$ in monitoring well W-131U, also located in the FDTA-5. The B qualifier for this value indicates that the concentration is greater than the IDL but less than the CRDL. This qualified value is only slightly above the 2 $\mu\text{g/L}$ MCL.

Lead concentrations in the East Parking Lot Plume that are above the 15 $\mu\text{g/L}$ MCL (at the tap) range from 15.4 to 100 $\mu\text{g/L}$. These values were measured from samples collected from a monitoring well completed in Chrome Pit No. 3 (W-150L), a well east

of the DYCP (HM-24), and in a well adjacent to the WWCB (W-137). Lead values above the MCL also occur in monitoring wells HM-86, HM-94, and W-149, located near the center of the East Parking Lot Plume area, and in wells CAR-LF-05-01 and CAR-LF05-14, located near the southeastern margin of the East Parking Lot Plume area on CAFB.

Nickel was detected in the water sample collected from monitoring well W-150L at a concentration of 113 $\mu\text{g/L}$, which is above the 100 $\mu\text{g/L}$ MCL. This well is located in Landfill No. 1, the probable source for this analyte.

Seven monitoring wells reported chromium concentrations in excess of the 100 $\mu\text{g/L}$ MCL (see Figure II-18). The majority of these wells, W-159, F-218, W-149, HM-94, and HM-96 are located near the center of the East Parking Lot Plume and downgradient from Chrome Pits Nos. 1 and 2, which may be possible source areas. The distribution of the chromium values in the plume appear to be controlled by geometry of the buried paleochannel. The highest chromium value, 1,040 $\mu\text{g/L}$, was detected at monitoring well W-154, located near the most upgradient extent of the East Parking Lot Plume. The well is adjacent to Chrome Pit No. 3, which is a potential source area for chromium. The most downgradient well having a chromium value (200 $\mu\text{g/L}$) exceeding the MCL is CAR-FT08-11B, located near the southeastern extent of the plume on CAFB. However, the presence of chromium was not detected in this well during the subsequent monitoring campaign.

Only two of the upper-zone wells included in the post-RI sampling program contained priority-pollutant metals. HM-103 contained 22 $\mu\text{g/L}$ of lead, and F-218 contained 310 $\mu\text{g/L}$ of chromium. The chromium concentration of 310 $\mu\text{g/L}$ in F-218 is consistent with the 400 $\mu\text{g/L}$ concentration found during the RI (Figure II-18). HM-103 had not been sampled previously so no conclusions can be drawn regarding the lead contamination. Because the distribution of priority pollutant metals in upper-zone groundwater is limited and only a small number of wells were included in the post-RI sampling, no significant assessment of metals migration after the RI field work is possible.

4.5.2.2 West Plume

Cadmium and antimony were detected in monitoring well F-217 at concentrations of 5.9 and 100 $\mu\text{g/L}$, respectively (see Figure II-17). The possible source area for these analytes is Landfill No. 1. Lead was detected in the Landfill No. 1 area at concentrations of 22 and 140 $\mu\text{g/L}$ in HM-020 and F-217, respectively (Figure II-17). Arsenic was detected in F-204 at a concentration of 79 $\mu\text{g/L}$ (Figure II-17). F-204 is located near the site of former storage tanks UST Nos. 19 and 20. Chromium was detected at a concentration of 151 $\mu\text{g/L}$ in well F-215 and at 105 $\mu\text{g/L}$ in well HM-29 (Figure II-18). These wells are located between Buildings 14 and 88, just east of Landfill No. 1.

4.5.2.3 North Plume Area

Arsenic was detected in monitoring well W-134 at a concentration of 19.5 $\mu\text{g/L}$, which is below the MCL (see Figure II-17). This well is located just south of the Jet Engine Test Stands, which is a potential source area for arsenic. No metals, including chromium, were detected above the MCL in the North Plume area (see Figure II-18).

4.5.3 Paluxy Formation Groundwater: Organic Contamination

4.5.3.1 Volatile Organic Compounds

VOCs reported above the CRQL in groundwater samples collected from wells completed within the Paluxy Formation include TCE, *cis*- and *trans*-1,2-DCE, vinyl chloride, toluene, methylene chloride, 1,1-DCA, 1,2-DCA, 2-hexanone, and chloroform. These compounds are primarily found in the upper part of the flow system where vertical hydraulic gradients and downward flow components exist between the upper zone and the Paluxy Formation. The VOCs present in the Paluxy Formation are considered to be attributable to vertical leakage from the upper-zone flow system. A summary of VOCs detected above CRQLs in Paluxy Formation groundwater is presented in Table 4.5.3-1.

Table 4.5.3-1 VOCs Detected at Concentrations Above CRQLs in Paluxy Formation Groundwater

Chemical Name	Minimum ($\mu\text{g/L}$)	Maximum ($\mu\text{g/L}$)	MCL ($\mu\text{g/L}$)	Number of Samples	Number of Samples Exceeding CRQL	Number of Samples Exceeding MCL
Trichloroethene	1U	4,300	5	122	69	67
1,1-Dichloroethane	1U	20	—	79	2	—
Methylene Chloride	1U	2,500	5	79	3	3
Vinyl Chloride	2U	22	2	79	2	2
Chloroform	1	1	100	79	1	0
2-Hexanone	2U	2,200	—	63	1	—
1,2-Dichloroethene	5U	390	—	46	4	—
<i>trans</i> -1,2-Dichloroethene	1U	2	100	45	1	0
<i>cis</i> -1,2-Dichloroethene	1U	420	70	45	20	10
Toluene	1U	800	3000	79	5	0
1,2-Dichloroethane	1U	1,500	5	63	1	1

Contamination in the Paluxy Formation may be grouped into three categories: TCE; degradation products of TCE, such as *cis*- and *trans*-1,2-DCE, and vinyl chloride; and other organics that include methylene chloride, toluene, 2-hexanone, chloroform, and 1,1-DCA.

TCE was the most commonly encountered VOC in Paluxy Formation groundwater. Monitoring wells in which TCE was detected above the CRQL during the Remedial Investigation are presented in Table 4.5.3-2. TCE was also detected in two equipment blanks (see Section 4.2) at concentrations of 5J $\mu\text{g/L}$ and 11 $\mu\text{g/L}$. The TCE data presented in Table 4.5.3-2 and data collected by others were combined to prepare a map showing the approximate extent of elevated TCE concentrations in Paluxy Formation groundwater (see Figures II-19a through d). This map depicts two areas with elevated TCE concentrations in groundwater. The largest area encompasses the East Parking lot; the second area is located northwest of Building 14.

**Table 4.5.3-2 Paluxy Formation Monitoring Wells
Where TCE Was Detected ABOVE CRQLs**

Well ID	Sample ID	Sample Date	TCE ($\mu\text{g/L}$)
P-05M	NAA206	28-Apr-90	14
P-08UN	NAA266	28-Apr-90	22
P-08UN	P-8UN	19-Oct-91	30
P-08US	NAA213	29-Apr-90	550
P-08US	P-08US2/04/92D	04-Feb-92	210
P-08US	P-08US1/26/93D	26-Jan-93	1900
P-08US	P-08US6/10/93	10-Jun-93	3000
P-08US	P-08US1/23/94	23-Jan-94	950
P-08US	P-08US7/23/94	23-Jul-94	1700
P-09US	NAA215	29-Apr-90	4,300
P-09US	WQM005	05-Dec-90	1,900
P-09US	QM-014	13-Mar-91	980
P-09US	P-09US10/20/91A	20-Oct-91	300
P-09US	P-09US	02-Feb-92	400
P-09US	P-09US7/27/92A	27-Jul-92	200
P-09US	P-09US7/27/92B	27-Jul-92	240
P-09US	P-09US7/27/92C	27-Jul-92	289
P-09US	P-09US7/27/92D	27-Jul-92	299.5
P-09US	P-09US7/27/92E	27-Jul-92	310
P-09US	P-09US	26-Jan-93	200
P-09US	P-09USD	26-Jan-93	240
P-09US	P-09US6/08/93	08-Jun-93	1000
P-09US	P-09US1/22/94	22-Jan-94	210
P-09US	P-09US7/22/94	22-Jul-94	8.4
P-10M	NAA217	30-Apr-90	13
P-12M	AFR-005	12-Jun-91	3
P-12M	NAA221	29-Apr-90	7
P-14US	NAA225	02-May-90	320
P-14US	P-14US2/04/92	04-Feb-92	2100
P-14US	P-14US7/29/92	29-Jul-92	230

**Table 4.5.3-2 (continued) Paluxy Formation Monitoring Wells
Where TCE Was Detected Above CRQLs**

Well ID	Sample ID	Sample Date	TCE ($\mu\text{g/L}$)
P-14US	P-14US	26-Jan-93	200
P-14US	P-14US5/25/93	25-May-93	130
P-14US	P-14US1/23/94A	23-Jan-94	150
P-14US	P-14US1/23/94B	23-Jan-94	150
P-14US	P-14US7/26/94	26-Jul-94	130
P-15US	NAA226	02-May-90	40
P-15US	P-15US1/31/92	31-Jan-92	430
P-15US	P-15US5/24/93A	24-May-93	1600
P-15US	P-15US5/24/93B	24-May-93	1680
P-15US	P-15US5/24/93C	24-May-93	1690
P-16US	NAA228	02-May-90	860
P-16US	WQM021	09-Dec-90	900
P-16US	P-16US	26-Oct-91	510
P-16US	QM-016	13-Mar-91	780
P-16US	P-16US	31-Jan-92	1100
P-16US	P-16US	28-Jul-92	1000
P-16US	P-16US	26-Jan-93	950
P-16US	P-16US5/24/93	24-May-93	750
P-16US	P-16US1/24/94	24-Jan-94	1000
P-16US	P-16US7/26/94	26-Jul-94	680
P-19US	P-19US1/31/92	31-Jan-92	8400
P-19US	P-19US	28-Apr-92	8900
P-19US	P-19US7/29/92	29-Jul-92	8500
P-19US	P-19US1/26/93	26-Jan-93	11000
P-19US	P-19US10/09/93	09-Oct-93	7100
P-19US	P-19US1/24/94	24-Jan-94	9000
P-19US	P-19US7/26/94A	26-Jul-94	8400
P-19US	P-17/26/949USB	26-Jul-94	9200
P-22M	NAA275	01-May-90	10
P-22M	P-22M	22-Oct-91	2
P-22M	WQM015	08-Dec-90	7
P-22U	NAA230	01-May-90	90
P-22U	NAA264	01-May-90	69
P-22U	P-22UPPER	27-Jan-90	100
P-22U	WQM017	08-Dec-90	48
P-24M	NAA233	30-Apr-90	8
P-27U	P27U-11	18-Oct-91	69
P-27U	P27U-11D	18-Oct-91	74

Within the East Parking Lot area only P-9US contained TCE at a concentration exceeding 1,000 $\mu\text{g/L}$ during the RI sampling. Other Paluxy wells in the East Parking Lot had lower TCE concentrations ranging from 100 to 1,000 $\mu\text{g/L}$.

TCE was also detected in the groundwater northwest of Building 14. One monitoring well (P-22U) contained TCE in concentrations approaching 100 $\mu\text{g/L}$. However, TCE concentrations in this area were generally lower than concentrations in the East Parking Lot area (0.2J $\mu\text{g/L}$ for well P-6M to 10 $\mu\text{g/L}$ for well P-22M, and 74 $\mu\text{g/L}$ for well P-27U). TCE was not detected in the remaining monitoring wells completed in the Paluxy Formation.

The TCE detected in P-22U and P-27U defines what is referred to as the West Paluxy Plume (Figures II-19b and II-19d). Given the presence of 25 feet of Walnut Formation at this location, leakage through the aquitard had not been regarded as a likely source for the West Paluxy Plume. However, during fieldwork conducted in the spring of 1995, the surface completion of P-22M was found to be loose, suggesting a lack of or incomplete placement of annular grout. The well has recently been abandoned.

As shown in Table 4.5.3-2 and Figure II-19a through d, occurrences of TCE were most commonly observed in the uppermost portion of the Paluxy Formation, referred to as the Upper Sand. However, low concentrations of isolated occurrences of TCE were also reported in wells completed in the regional Paluxy aquifer. Within the East Parking Lot area, deeper monitoring wells at which low TCE concentrations were detected included wells P-8UN and P-12M. West of the Assembly Building, monitoring wells P-5M, P-10M, P-22M, and P-24M contained low concentrations of TCE. These occurrences suggest that TCE contamination may be migrating to deeper zones within the Paluxy Formation. Contamination at P-10M carries the implication that the contamination may be originating as seepage from Meandering Road Creek. Monitoring well P-10M was resampled twice during post-RI sampling (Jacobs Engineering Group, Inc. December 1992) to determine if TCE was still present. TCE was detected at 0.1 JB $\mu\text{g/L}$ (also found in the blank) in October 1991. TCE was not detected in P-10M during the October 1992 sampling event.

The results of post-RI sampling at other Paluxy Formation wells showed little change at P-8UN, P-16US, and P-22M. Decreasing concentrations were observed at P-9US (from 4,300 $\mu\text{g/L}$ in 1990 to 8.4 $\mu\text{g/L}$ in July 1994), P-14US (2,100 $\mu\text{g/L}$ in January 1992 to 130 $\mu\text{g/L}$ in July 1994), and P-27U (from 74 $\mu\text{g/L}$ in 1992 to 16 $\mu\text{g/L}$ in July 1994).

The declining trend at P-09US is noteworthy in the sense that the origin of TCE observed in this well has always been somewhat elusive. Water levels at P-09US have consistently exceeded those of all other Upper Sand wells. This feature precludes attributing the P-09US contamination to lateral migration of TCE that entered via the window area. The current low concentrations in the Upper Zone also preclude the hypothesis involving ongoing vertical migration along the well bore. The declining trend

in TCE at P-09US suggests that the contamination may have been introduced to the Paluxy via vertical migration through the open hole during the installation of the well. However, the presence of a source for the vertical migration at the time of installation, namely Upper Zone TCE contamination at levels equal to or above the historic maximum at P-09US (7,000 $\mu\text{g/L}$ in October 1989) is questionable, given the low or nonexistent concentrations in nearby HM-5U and HM-57 (see Figures II-12A, II-12B, II-13A, and II-13B).

Noteable increases in TCE concentrations occurred at P-8US, P-15US, and P-19US. The TCE concentration at P-8US increased from 550 $\mu\text{g/L}$ in April 1990 to 1,900, 3,000, 950, and 1,700 $\mu\text{g/L}$ in January 1993, June 1993, January 1994, and July 1994, respectively. Similarly, P-15US increased from 40 $\mu\text{g/L}$ in May 1990 to over 1,600 $\mu\text{g/L}$ in May 1993. These increases can likely be attributed to renewed vertical leakage of TCE-contaminated groundwater in the window area. Alternatively, the increase in TCE at P-08US and P-15US could simply reflect the arrival of laterally migrating TCE that had entered the Paluxy Upper Sand via the window area at some point in the past. TCE in P-19US ranged from 8,400 to 8,900 $\mu\text{g/L}$ between January and July 1992. In January 1993, the concentration increased to 11,000 $\mu\text{g/L}$ then declined to 8,400 and 9,200 $\mu\text{g/L}$ in July 1994.

The contamination at P-19US is noteworthy for two reasons. The concentrations are the highest detected in any of the Upper Sand wells, and P-19US has historically been dry, only recently providing sufficient water from which to collect a sample (after purging only one bore volume). The contamination at P-19US is likely derived via one or a combination of four scenarios. The TCE could be entering the Upper Sand through an undocumented thin or absent section of the Walnut Formation in the vicinity of P-19US. Similar to P-22M, contamination could be migrating downward along an improperly completed well installation (at P-19US). The weakness in these first two hypotheses is that nearby Upper Zone wells (HM-110, HM-111, and HM-112) do not show the Upper Zone containing high enough concentrations to be acting as a source for the 8,000 to 11,000 $\mu\text{g/L}$ concentrations in P-19US (Figures II-12A, II-12B, II-13A, and II-13B).

A third possibility is that the contamination observed at P-19US entered the Upper Sand in the window area prior to initiation of environmental sampling and travelled to the P-19US area via lateral-downgradient advection (head at P-19US is approximately 20 to 30 feet lower than Upper Sand head in the window area; see Appendix D).

The last explanation for the source of high TCE concentrations at P-19US is that the contamination entered the Upper Sand during drilling, and has essentially remained in this area due to the low permeability, aquitard-like behavior of the Upper Sand. Variations in concentration from a low of 7,100 $\mu\text{g/L}$ in October 1993 to a high of 11,000 $\mu\text{g/L}$ in January 1993 are not necessarily inconsistent with this scenario, although a declining trend would be more compatible with this fourth hypothesis.

Degradation products of TCE, including *cis*- and *trans*-1,2-DCE and vinyl chloride, were detected above CRQLs in approximately the same two areas that were found to contain elevated TCE. None of these compounds were detected in the equipment blank samples. Results for DCE and vinyl chloride are presented in Table 4.5.3-3. The monitoring data collected by others were combined with the recent data to compile a map of TCE degradation products within the Paluxy Formation (see Figure II-20).

**Table 4.5.3-3 TCE Degradation Products Detected
in Paluxy Formation Groundwater**

Well ID	Sample ID	Sample Date	Chemical Name	Result ($\mu\text{g/L}$)
P-06M	P-6M	26-Oct-91	Vinyl Chloride	5
P-06M	P-6M	26-Oct-91	<i>cis</i> -1,2-Dichloroethene	11
P-08US	P-08US2/4/92	04-Feb-92	<i>cis</i> -1,2-Dichloroethene	32
P-08US	P-08US6/9/93	09-Jun-93	<i>cis</i> -1,2-Dichloroethene	140
P-08US	P-08US1/22/94	22-Jan-94	<i>cis</i> -1,2-Dichloroethene	120
P-08US	P-08US7/23/94	23-Jul-94	<i>cis</i> -1,2-Dichloroethene	120
P-08UN	P-8UN	19-Oct-91	<i>cis</i> -1,2-Dichloroethene	4
P-09US	WQM005	05-Dec-90	1,2-Dichloroethene	21
P-09US	P-09US6/8/93	08-Jun-93	<i>cis</i> -1,2-Dichloroethene	13
P-16US	P-16US	26-Oct-91	<i>trans</i> -1,2-Dichloroethene	2
P-16US	P-16US	26-Oct-91	<i>cis</i> -1,2-Dichloroethene	290
P-16US	QM-016	13-Mar-91	1,2-Dichloroethene	390
P-16US	WQM021	09-Dec-90	1,2-Dichloroethene	360
P-19US	P-19US1/31/92	31-Jan-92	<i>cis</i> -1,2-Dichloroethene	620
P-19US	P-19US4/28/92	28-Apr-92	<i>cis</i> -1,2-Dichloroethene	680
P-19US	P-19US7/29/92	29-Jul-92	<i>cis</i> -1,2-Dichloroethene	870
P-19US	P-19US1/26/93	26-Jan-93	<i>cis</i> -1,2-Dichloroethene	930
P-19US	P-19US10/09/93	9-Oct-93	<i>cis</i> -1,2-Dichloroethene	940
P-19US	P-19US1/22/94	22-Jan-94	<i>cis</i> -1,2-Dichloroethene	710
P-19US	P-19US7/26/94	26-Jul-94	<i>cis</i> -1,2-Dichloroethene	640
P-22M	P-22M	22-Oct-91	<i>cis</i> -1,2-Dichloroethene	4
P-22M	P-22MIDDLE	27-Jan-90	<i>cis</i> -1,2-Dichloroethene	2
P-22U	P-22UPPER	27-Jan-90	<i>cis</i> -1,2-Dichloroethene	240
P-22U	WQM017	08-Dec-90	1,2-Dichloroethene	150
P-27U	P-27U-01	16-Sep-91	<i>cis</i> -1,2-Dichloroethene	390
P-27U	P-27U-01DL	16-Sep-91	<i>cis</i> -1,2-Dichloroethene	360
P-27U	P27U-11	18-Oct-91	Vinyl Chloride	22
P-27U	P27U-11	18-Oct-91	<i>cis</i> -1,2-Dichloroethene	410
P-27U	P27U-11D	18-Oct-91	<i>cis</i> -1,2-Dichloroethene	420

Within the upper part of the Paluxy Formation near the East Parking Lot, analytical results for samples collected in October 1991 indicated that well P-16US contained 290 $\mu\text{g/L}$ *cis*-1,2-DCE and 2 $\mu\text{g/L}$ *trans*-1,2-DCE, and that well P-08UN contained 4 $\mu\text{g/L}$ *cis*-1,2-DCE. Prior to the October 1991 sampling event, 1,2-DCE was reported as total 1,2-DCE. For example, total 1,2-DCE was 390 $\mu\text{g/L}$ in March 1991 and 360 $\mu\text{g/L}$ in December 1990 in well P-16US. Well P-09US contained 21 $\mu\text{g/L}$ total 1,2-DCE in December 1990.

High concentrations of *cis*-1,2-DCE are reported for P-19US starting in January 1992. Prior to this date, P-19US was not sampled because it only contained a few inches of water and could not be properly purged. Since 1992, samples collected by the sampling contractor have shown very high elevations of TCE as well as the DCE reported in Table 4.5.3-3. The DCE detected in P-19US is likely derived from natural degradation of TCE at this location.

West of the Assembly Building and Building 14, VOC results indicated that well P-06M contained 11 $\mu\text{g/L}$ *cis*-1,2-DCE and 5 $\mu\text{g/L}$ vinyl chloride in October 1991. Monitoring well P-22U contained 240 $\mu\text{g/L}$ *cis*-1,2-DCE in January 1990 and 150 $\mu\text{g/L}$ total 1,2-DCE in December 1990. The middle Paluxy well P-22M also was found to contain low levels of *cis*-1,2-DCE in October 1991 and January 1990, indicating that the TCE degradation products may be migrating into the middle Paluxy aquifer at this location. *cis*-1,2-DCE was also detected on two occasions at concentrations of 390 and 410 $\mu\text{g/L}$ in well P-27U.

Additional VOCs detected above CRQLs in Paluxy Formation groundwater include 1,2-DCA, methylene chloride, toluene, 2-hexanone, chloroform, and 1,1-DCA. Table 4.5.3-4 summarizes the results for these compounds in the Paluxy Formation. Figure II-21 shows occurrences of these additional VOCs.

The highest concentrations of these compounds were identified in the East Parking Lot area in monitoring well P-09US, which contained 800 $\mu\text{g/L}$ toluene, 1,500 $\mu\text{g/L}$ 1,2-DCA, 2,200 $\mu\text{g/L}$ 2-hexanone, and 2,500 $\mu\text{g/L}$ methylene chloride (April 1990 sampling).

These VOC concentrations together with the concentrations of TCE and TCE-degradation products (Tables 4.5.3-2 and 4.5.3-3) show that P-09US contains the highest levels of organic contamination in the Paluxy Aquifer. As shown in Appendix D, P-9US also contains the highest water levels of any East Parking Lot well in the Paluxy Formation. These observations reveal that the contamination found in P-09US must originate near the location of this well. The declining trend in TCE concentration at P-09US (Table 4.5.3-2) also suggests a local source that has become or is becoming exhausted. As noted earlier, likely sources include vertical migration through the open borehole during construction of the well, or migration along the surface casing due to incomplete sealing of the annular space between the surface casing and the borehole wall.

Table 4.5.3-4 Other VOCs Detected in the Paluxy Formation Groundwater

Well ID	Sample ID	Sample Date	Chemical Name	Result ($\mu\text{g/L}$)	MCL ($\mu\text{g/L}$)
P-09US	NAA215	29-Apr-90	Toluene	800	1,000
P-09US	NAA215	29-Apr-90	2-Hexanone	2,200	—
P-09US	NAA215	29-Apr-90	Methylene Chloride	2,500	5
P-09US	NAA215	29-Apr-90	1,2-Dichloroethane	1,500	5
P-11U	NAA218	30-Apr-90	Methylene Chloride	6	5
P-12M	AFR-005	12-Jun-91	Toluene	2	1,000
P-12M	AFR-005	12-Jun-91	1,1-Dichloroethane	14	5
P-12M	WQM016	08-Dec-90	1,1-Dichloroethane	20	5
P-16US	NAA228	02-May-90	Methylene Chloride	120	5
P-22M	NAA275	01-May-90	Toluene	12	1,000
P-22M	P-22M	22-Oct-91	Toluene	19	1,000
P-22M	WQM015	08-Dec-90	Toluene	7	1,000
P-24M	AFR-008	12-Jun-91	Chloroform	1	100

The trend of increasing TCE concentrations at P-08US and P-15US is likely a reflection of renewed vertical migration of TCE through the eroded section of Walnut Formation limestone in the window area. The apparent recent loss of 20,000 gallons of TCE in Building 181 may have provided the source for this vertical TCE flux via DNAPL migration down the East Parking Lot paleochannel and into the window area.

TCE concentrations between 7,100 $\mu\text{g/L}$ and 11,000 $\mu\text{g/L}$ at P-19US appear as a dramatic increase because no values have been reported for this well prior to the quarterly sampling program performed by Jacobs Engineering Group, Inc. However, the lack of data prior to the quarterly sampling program is due to absence of samples collected from this well. Sampling was not performed previously because the well had only a few inches of water and could not be purged, a requirement for conventional sample collection. Since 1992, water levels have increased, providing three to four feet of water from which to collect a sample after purging a single bore volume (slow recovery precludes purging the standard three bore volumes). Although a sound explanation for the sudden increase in the water level at P-19US is not readily explained in the absence of increasing water levels elsewhere in the upper sand or in the upper zone, several hypothesis exist for the presence of contamination at P-19US. These include:

- a one-time contaminant migration down the open borehole during well installation;
- ongoing contaminant migration along the surface casing due to a defect in the well installation;

- lateral migration of contamination that entered the upper sand in the window area;
- contaminant migration through an undetected zone in the vicinity of P-19US where the Walnut Formation is thin or absent.

Resolution of this uncertainty is expected to be accomplished during remedial design data collection that is scheduled to be performed after completion of the RI/FS.

Low levels of toluene and methylene chloride were detected in monitoring wells P-11U and P-12M, respectively. Monitoring well P-16US contained 120 $\mu\text{g}/\text{L}$ methylene chloride. Well P-22M, west of Assembly Building and Building 14, contained low levels of toluene, and well P-24M contained very low levels of chloroform. These wells are within Landfill No. 3.

Although methylene chloride and toluene are common laboratory contaminants (EPA 1988), and 2-hexanone is a common laboratory solvent, results for these occurrences were not qualified, suggesting that a source may exist for these compounds. Methylene chloride may have been used as a solvent at Plant 4. The levels in the Paluxy Formation are quite low with the exception of monitoring well P-09US.

Low levels of 1,1-DCA were present on two occasions above the CRQL in monitoring well P-12M. The organic solvent 1,1,1-TCA degrades to 1,1-DCA through a dehalogenation process and may be a source for the 1,1-DCA. Since the groundwater in the Paluxy Formation flows south in the vicinity of well P-12M, the likely source for the 1,1-DCA would be the 1,1,1-TCA plume located in the upper-zone flow system west of the Assembly Building/Parts Plant. The migration of the 1,1-DCA would occur by vertical flow between the upper-zone flow system and the Paluxy Formation.

In sampling conducted after the completion of the RI field work (Jacobs Engineering Group, Inc. December 1992), no significant changes were found in the distribution or detection of VOCs other than TCE.

4.5.3.2 Semi-VOCs, TPH, Oil and Grease

This section presents the results of sampling and analyses for semi-VOCs, TPH, and oil and grease in the Paluxy Formation. A summary of the number of samples collected, number of samples exceeding CRQL, and minimum and maximum values is presented in Table 4.5.3-5.

As shown in the table, the only semi-VOCs detected in groundwater of the Paluxy Formation is bis(2-ethylhexyl)phthalate, a common laboratory contaminant. This compound was detected in upgradient monitoring wells, P-29M and P-30M (see Table 4.5.3-6). In addition to being a common laboratory contaminant,

Table 4.5.3-5 Summary of Analytical Results for Semi-VOCs, TPH, and Oil and Grease in the Paluxy Formation

Chemical Name	Minimum	Maximum	Number of Samples	Number of Samples Exceeding CRQL
Bis(2-ethylhexyl)phthalate	10U µg/L	22 µg/L	15	4
Total Petroleum Hydrocarbons	0.2 mg/L	0.6 mg/L	17	11
Oil and Grease	0.2 mg/L	2.2 mg/L	18	13

bis(2-ethylhexyl)phthalate is also a common field contaminant because the plastic (high density polyethylene) used in the manufacture of water jugs dissolves into the distilled water used to rinse sampling equipment.

Table 4.5.3-6 Analytical Results for Bis(2-ethylhexyl)phthalate in the Paluxy Formation

Well ID	Sample ID	Sample Date	Result (µg/L)
P-29M	P-29M-01	19-Sep-91	11
P-29M	P-29M-11	15-Oct-91	22
P-30M	P-30M-01	16-Sep-91	21

One potential but unlikely source of phthalate contamination in P-29M is due to leakage of surface water and upper zone groundwater through the incised bedrock along Meandering Road Creek. However, hydraulic head measurements suggest that P-29M is upgradient from Plant 4. Further, numerical modeling results suggest that the drawdown in White Settlement water supply well WS-2 will not extend to monitoring well P-29M, and therefore it is unlikely that the cone of depression in WS-2 could pull contaminants upgradient from the P-29M/Meandering Road Creek location.

For sampling conducted after the completion of the RI field work, semi-VOC analyses were conducted only on a limited basis for Paluxy Formation wells. No semi-VOCs were detected.

Groundwater samples were also collected from the Paluxy Formation for TPH and oil and grease analysis. TPH and oil and grease results are presented in Table 4.5.3-7 and posted in Figure II-22. The detection limit for both TPH and oil-and-grease measurements was 0.2 mg/L. Monitoring well WS-02 contained 0.2 mg/L oil and grease. The highest concentrations reported were found in wells WS-02 and P-11U. Monitoring well P-11U contained 0.6 mg/L TPH and 0.6 mg/L oil and grease. All other occurrences of oil and grease and TPH were at or near the detection limit.

Table 4.5.3-7 Analytical Results for TPH and Oil and Grease in the Paluxy Formation

Chemical Name	Site ID	Sample ID	Sample Date	Result (mg/L)
Oil and Grease	P-05M	P-5M	24-Oct-91	0.2
Total Petroleum Hydrocarbons	P-05M	P-5M	24-Oct-91	0.2
Oil and Grease	P-08M	P-8M	19-Oct-91	0.2
Total Petroleum Hydrocarbons	P-08M	P-8M	19-Oct-91	0.2
Oil and Grease	P-08UN	P-8UN	19-Oct-91	0.3
Total Petroleum Hydrocarbons	P-08UN	P-8UN	19-Oct-91	0.2
Oil and Grease	P-09UN	P-9UN	20-Oct-91	0.2
Total Petroleum Hydrocarbons	P-09UN	P-9UN	20-Oct-91	0.2
Oil and Grease	P-09US	P-9US	20-Oct-91	0.2
Total Petroleum Hydrocarbons	P-09US	P-9US	20-Oct-91	0.2
Oil and Grease	P-10M	P-10M	21-Oct-91	0.2
Total Petroleum Hydrocarbons	P-10M	P-10M	21-Oct-91	0.2
Oil and Grease	P-11M	P-11M	18-Oct-91	0.2
Total Petroleum Hydrocarbons	P-11M	P-11M	18-Oct-91	0.2
Oil and Grease	P-11U	WQM013	08-Dec-90	0.6
Total Petroleum Hydrocarbons	P-11U	WQM013	08-Dec-90	0.6
Oil and Grease	P-12UN	P-12UN	18-Oct-91	0.3
Total Petroleum Hydrocarbons	P-12UN	P-12UN	18-Oct-91	0.2
Oil and Grease	P-15U	P-15U	21-Oct-91	0.2
Total Petroleum Hydrocarbons	P-16US	P-16US	26-Oct-91	0.2
Oil and Grease	P-24M	P-24M	22-Oct-91	0.3
Oil and Grease	WS-02	WS-2	24-Oct-91	0.2
Total Petroleum Hydrocarbons	WS-02	WS-2	24-Oct-91	0.2
Oil and Grease	WS-12	WS-12	24-Oct-91	0.2

In sampling conducted after the completion of the RI field work, only the January 1993 sample from P-27U was found to contain oil and grease at 1.2 mg/L. TPH was not detected in any of the post-RI samples that were analyzed for this analyte.

Because only isolated occurrences of oil and grease and TPH were reported in Paluxy Formation groundwater, the low levels detected most likely represent contamination from the dedicated submersible pumps installed in those monitoring wells.

4.5.4 Paluxy Formation Groundwater: Inorganic Contamination

Four monitoring wells completed in the Paluxy Formation during the Remedial Investigation and three wells installed by previous contractors were selected for inorganic analyses (see Appendix F). Table 4.5.4-1 summarizes the results of the 1990-1991 sampling campaigns. The action levels listed in Table 4.5.4-1 refer to the EPA drinking water standards. For purposes of comparison, the number of samples that exceed the action level are tabulated.

Figure II-23 shows analytical results of inorganic priority pollutants for samples collected during the 1990-1991 Remedial Investigation and for samples collected by previous contractors over the 1988-1992 monitoring period. In all cases, the posted values represent the most recent analytical results available.

The data collected during the 1990-1991 monitoring period and presented in Table 4.5.4-1 indicate that no priority-pollutant inorganic constituents, except for lead, were detected above drinking water standards in any of the groundwater samples collected from the Paluxy groundwater. Lead was detected in one sample from P-27U at a concentration of 15.1 $\mu\text{g/L}$, a value that is essentially the same as the drinking water standard of 15 $\mu\text{g/L}$ (at the tap). Over the 1988-1991 monitoring period, as shown in Figure II-23, lead, zinc, arsenic, copper, nickel, antimony, and silver have been detected in Paluxy Formation groundwater. Antimony and lead are the only analytes that exceed MCLs. Lead was detected at 370 $\mu\text{g/L}$ and antimony at 370 $\mu\text{g/L}$ in monitoring well P-12UN. Antimony was also detected in well P-8UN at 220 $\mu\text{g/L}$.

During sampling conducted after completion of the RI field work, lead (0.016 mg/L in P-14US, January 1993) was the only priority pollutant metal detected above the MCL.

Aluminum and iron were detected above their respective SMCLs in samples collected during the 1990-1991 sampling period (see Table 4.5.4-1). Aluminum was detected in monitoring well P-08US at a concentration of 980 $\mu\text{g/L}$. This well is located in the center of the East Parking Lot Plume, and the elevated value is potentially the result of vertical leakage from the upper-zone flow system. Evidence supporting this position is provided by several monitoring wells located near P-08US that were completed in the upper-zone flow system and exhibited elevated concentrations of aluminum. For example, groundwater collected from the upper-zone well HM-093, located approximately 850 feet northwest of P-08US, was found to contain the highest aluminum concentration (13,500 $\mu\text{g/L}$) measured during the 1990-1991 sampling campaign (see Table 4.5.2-1). In the vicinity of well HM-093, Paluxy Formation groundwater flows southeast, toward monitoring well P-08US.

Iron was also detected above the SMCL during the 1990-1991 sampling events, at concentrations ranging from 447 to 512 $\mu\text{g/L}$ (well P-29). However, these values are not considered to be elevated above natural concentrations but rather are typical of water quality found in the Paluxy Formation (Nordstrom 1982).

Table 4.5.4-1 Results of Inorganic Analyses for Paluxy Groundwater Collected During the 1990-1991 Sampling Events

Chemical Name	Minimum Result (µg/L)	Maximum Result (µg/L)	Action Level (µg/L)	Number of Samples Analyzed	Number of Samples Above Action Level
Aluminum ^a	980	980	NA	1	NA
Antimony ^b	56U ^c	60U	10	10	0
Arsenic ^d	3U	6.3B	50	10	0
Barium ^d	100U	100U	2,000	1	0
Beryllium ^b	1U	5U	1	10	0
Cadmium ^e	2U	5U	5	10	0
Calcium	75,000	89,100	NA	5	NA
Chromium ^f	5U	32.7	100	14	0
Cobalt	50U	50U	NA	1	NA
Copper ^g	5U	9B	NA	10	NA
Iron ^h	140	512	NA	5	NA
Lead ^b	2U	15.1	15	10	1
Magnesium	1,000U	31,500U	NA	5	NA
Manganese ⁱ	15U	15U	NA	1	NA
Mercury ^j	0.2U	0.2U	2	1	0
Nickel ^b	22U	55.4	100	10	0
Potassium	4,610B	13,000	NA	5	NA
Selenium ^k	3U	30U	50	10	0
Silver ^l	4U	10U	NA	10	NA
Sodium	25,200	31,000	NA	5	NA
Thallium ^b	2U	2B ^m	2	10	0
Vanadium	50U	50U	NA	1	NA
Zinc ⁿ	8B	83.6	NA	10	NA

^a No action level exists for this chemical because it is regulated by secondary standards.

^b Action level for this chemical is the Maximum Contaminant Level (MCL) (FR V.57 No. 138)

^c U indicates the chemical was not detected.

^d Action level for this chemical is the MCL (40 CFR 141.11).

^e Action level for this chemical is the MCL (FR. V.56 No. 20).

^f Action level for this chemical is the MCL (FR. V.56 No. 110)

^g B indicates the result is above or equal to the Instrument Detection Limit but less than the Contract Required Detection Limit.

4.6 Surface Water Contamination

This section discusses the occurrences of contamination identified in surface waters located adjacent to Plant 4, including Meandering Road Creek, Lake Worth, and Farmers Branch. These features were selected for the investigation based on the current hydrogeologic model for the site. The model suggests that interactions between groundwater and surface water systems may have resulted in contaminants being transported to these surface waters.

Surface water sampling locations along Meandering Road Creek and Lake Worth are shown in Figure 4.6-1. The sampling site established on Farmers Branch is located near the outlet of the aqueduct that conveys water under the runway at CAFB.

Analytical results for surface water samples collected between February 1990 and October 1991 are presented in Appendix F-1. Assessments of the nature and extent of contamination identified in Lake Worth, Meandering Road Creek, and Farmers Branch are discussed separately below.

4.6.1 Meandering Road Creek

Surface water samples collected along Meandering Road Creek included 40 samples collected directly from the creek and three samples collected from a seep located on the east margin of the stream near the boundary of Landfill No. 3 (see Figure 4.6-1). Although the quality of water originating at the seep is more indicative of local groundwater quality, analytical results for samples obtained at the seep are included in this section because water from the seep is tributary to the stream.

4.6.1.1 Volatile Organic Compounds

VOCs detected in surface water samples collected along Meandering Road Creek are listed in Table 4.6.1-1. TCE and *cis*-1,2-DCE were the most frequently detected VOCs during the sampling period. Concentrations of TCE ranged from 8 $\mu\text{g/L}$ at sample site Creek Seep to 140 $\mu\text{g/L}$ at site ST5, the storm sewer outfall. *cis*-1,2-DCE was detected at concentrations ranging from 6 $\mu\text{g/L}$ at site SW-07 to 430 $\mu\text{g/L}$ at site SW-08. The VOCs detected at concentrations exceeding MCLs included TCE, vinyl chloride, *cis*-1,2-DCE, and 1,2-DCA.

Concentrations of VOCs detected in surface water samples collected along Meandering Road Creek are presented in Table 4.6.1-2. VOC concentrations above MCLs were reported at sample sites C-4 (TCE), Creek Seep (TCE), SS-01 (1,2-DCA, vinyl chloride, TCE, 1,2-DCE), SW-08 (*cis*-1,2-DCE, vinyl chloride), and ST5 (TCE). The highest VOC concentrations were detected in samples collected at sites SS-01, SW-08, and ST5. These three sites are located along the reach of Meandering Road Creek that borders the central portion of Landfill No. 3.

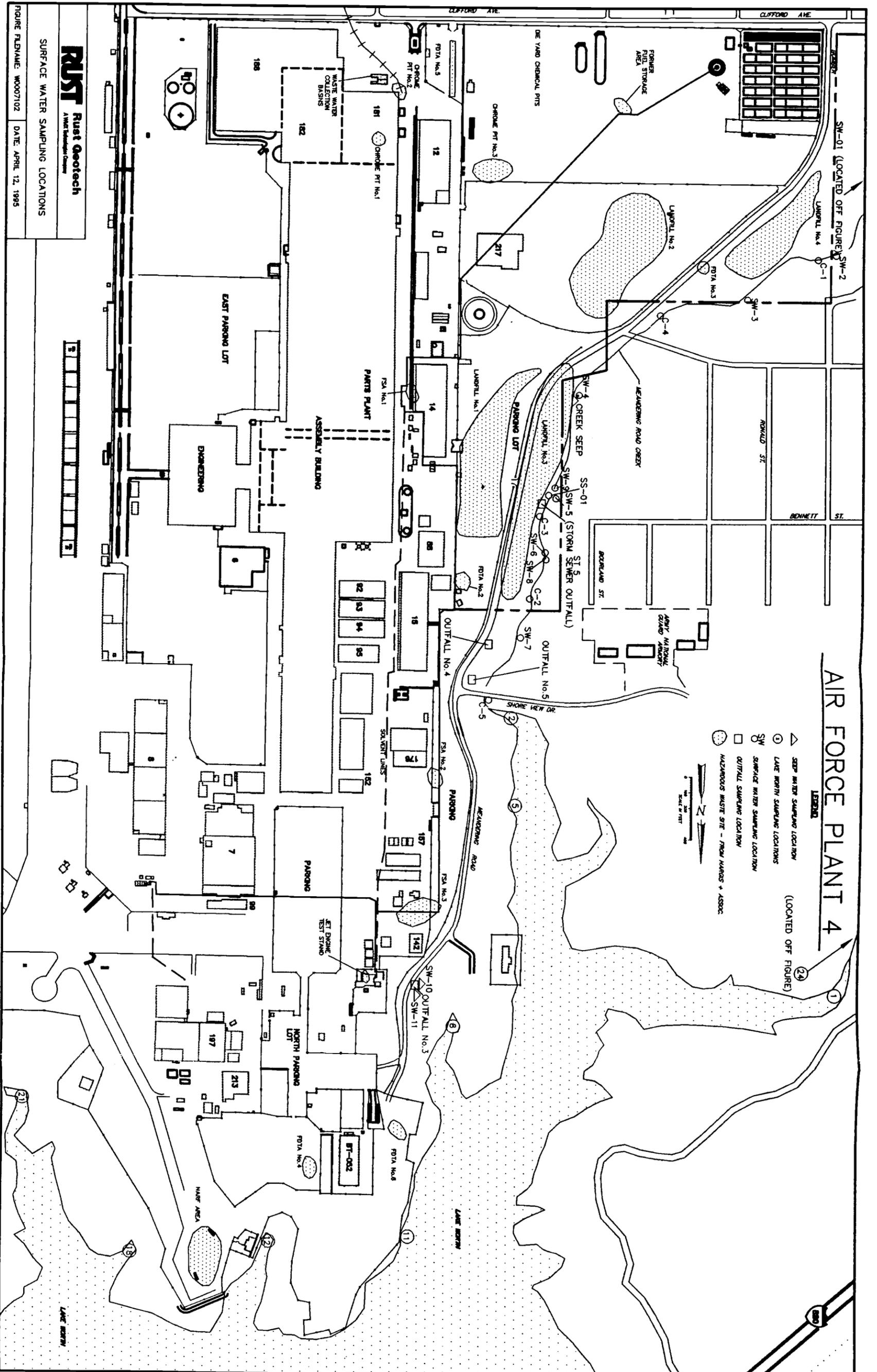


Figure 4.6-1. Surface Water Sampling Locations.

Table 4.6.1-1 VOCs Detected in Surface Water Samples Collected Along Meandering Road Creek Between February 1990 and October 1991

Chemical Name	Minimum Concentration Detected $\mu\text{g/L}$	Maximum Concentration Detected $\mu\text{g/L}$	No. of Samples Analyzed	No. of Samples Above CRQL	No. of Samples Above MCL
Trichloroethene	8	140	41	7	7
2-Butanone	12	16	41	4	-
Methylene Chloride	1	1	43	1	0
Vinyl Chloride	14	120	43	3	3
Acetone	12	13	41	2	-
1,2-Dichloroethene	41	1,800	27	2	-
<i>trans</i> -1,2-Dichloroethene	3	3	16	1	0
<i>cis</i> -1,2-Dichloroethene	6	430	16	9	3
Chlorobenzene	1	1	43	1	0
1,2-Dichloroethane	14	14	41	1	1

A comparison of surface water results (see Table 4.6.1-2) and surface water sampling locations along Meandering Road Creek (see Figure 4.6-1) indicates that VOC contamination is entering the creek in the vicinity of Plant 4. Acetone, at a concentration of 12 $\mu\text{g/L}$, was the only VOC found upstream of the site. It was detected in the sample collected at SW-01, which is located approximately 1,000 feet upstream from the Plant 4 boundary. As the stream approaches Plant 4, the first VOC reported was TCE, which was detected at a concentration of 14 $\mu\text{g/L}$ in a sample collected directly from the creek at sample site C-4. As stated above, the highest VOC concentrations were reported along the reach of Meandering Road Creek that borders Landfill No. 3. Along this portion of the creek, VOCs were detected in samples collected directly from the creek (sites SS-01 and SW-08), the storm sewer outfall (site ST5), and the seep (site Creek Seep). The lower levels of VOC contamination detected in samples collected downstream of Landfill No. 3 are likely a combined result of dilution, volatilization, and less contamination entering the creek downstream of the landfill. Contaminated upper-zone groundwater is the most likely source for VOC contamination in Meandering Road Creek.

4.6.1.2 Semivolatile Organic Compounds

The only semi-VOCs detected in surface water samples collected along Meandering Road Creek were 4-methylphenol and 1,2-dichlorobenzene. 4-Methylphenol was detected at one sample site, SS-01, at a concentration of 14 $\mu\text{g/L}$. 1,2-dichlorobenzene was detected at one sample site, SW-08, at a concentration of 3 $\mu\text{g/L}$. Samples SS-01 and SW-08 were collected directly from the stream adjacent to Landfill No. 3. Discharge of contaminated upper-zone groundwater into Meandering Road Creek near Landfill No. 3 is a potential source for this contamination.

**Table 4.6.1-2 Concentrations of VOCs Detected in Surface Water
Along Meandering Road Creek Between February 1990 and October 1991**

Sample Site	Sample Date	Concentration $\mu\text{g/L}$	Chemical Name
C-1	28-Feb-90	16	2-Butanone
C-2	28-Feb-90	14	2-Butanone
C-4	28-Feb-90	13	2-Butanone
C-4	30-Apr-90	14	Trichloroethene
C-5	28-Feb-90	12	2-Butanone
Creek Seep	28-Feb-90	8	Trichloroethene
Creek Seep	28-Mar-90	9	Trichloroethene
Creek Seep	30-Apr-90	12	Trichloroethene
SS-01	01-Mar-91	14	1,2-Dichloroethane
SS-01	01-Mar-91	41	1,2-Dichloroethane
SS-01	01-Mar-91	120	Vinyl Chloride
SS-01	01-Mar-91	13	Trichloroethene
SS-01	01-Mar-91	1,800	1,2-Dichloroethene
SW-01	02-May-91	12	Acetone
SW-03	02-May-91	13	Acetone
SW-05	22-Oct-91	1	Methylene Chloride
SW-05	01-May-91	21	<i>cis</i> -1,2-Dichloroethene
SW-05	01-May-91	40	<i>cis</i> -1,2-Dichloroethene
SW-05	02-May-91	57	<i>cis</i> -1,2-Dichloroethene
SW-06	01-May-91	42	<i>cis</i> -1,2-Dichloroethene
SW-07	01-May-91	6	<i>cis</i> -1,2-Dichloroethene
SW-08	22-Oct-91	1	Chlorobenzene
SW-08	22-Oct-91	150	<i>cis</i> -1,2-Dichloroethene
SW-08	22-Oct-91	3	<i>trans</i> -1,2-Dichloroethene
SW-08	22-Oct-91	17	Vinyl Chloride
SW-08	02-May-91	500E	<i>cis</i> -1,2-Dichloroethene
SW-08	02-May-91	14	Vinyl Chloride
SW-08	02-May-91	430	<i>cis</i> -1,2-Dichloroethene
SW-09	02-May-91	33	<i>cis</i> -1,2-Dichloroethene
STS	28-Mar-90	140	Trichloroethene
STS	30-Apr-90	25	Trichloroethene

4.6.1.3 TPH and Oil and Grease

TPH were detected in 3 of 11 samples analyzed for TPH. Two of the samples containing detectable concentrations of TPH were collected directly from the creek at sites SW-01 and SW-02 located upstream of Plant 4. TPH concentrations reported for samples SW-01 and SW-02 were 1 and 2 mg/L, respectively. Potential sources for this contamination are unknown but are not considered to be associated with Plant 4 operations. The third sample in which TPH were detected was collected at site SW-08, located near Landfill No. 3. The TPH concentration reported for SW-08 was at the

method reporting limit, 0.2 mg/L. TPH were not detected in other samples collected along the portion of Meandering Road Creek that is adjacent to Plant 4.

Oil and grease were detected in 10 of 28 samples analyzed for oil and grease. Samples collected in May 1991 at sites SW-01 and SW-02, located upstream of Plant 4, contained oil and grease at concentrations of 2 and 3 mg/L, respectively. Sample sites located adjacent to Plant 4 and at which oil and grease were detected include C-2 (6, 10, and 16 mg/L), C-3 (6 mg/L), C-4 (10 mg/L), C-5 (10 mg/L), SW-06 (0.5 mg/L), and SW-08 (0.2 mg/L).

Samples were collected for oil and grease analysis at C-2, C-3, C-4, and C-5 in February, March, and April 1990. Oil and grease were detected at each of these sample sites only during the March 1990 sampling event. During the subsequent sampling event, oil and grease were detected only at sample site C-2. Oil and grease results at these sample sites suggest that oil and grease contamination may be a transitory condition in the reach of Meandering Road Creek that borders Plant 4. The most likely pathway for oil and grease to be discharged to the stream in the vicinity of Plant 4 is the storm sewer outfall.

Oil and grease concentrations at SW-06 and SW-08 were reported in samples collected in May and October 1991, respectively. No subsequent sampling events have been performed to confirm the low levels of oil and grease contamination identified at these sample sites.

4.6.1.4 Metals

The analytes included in metals analyses were antimony, arsenic, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc. A summary of metals results in surface water samples collected along Meandering Road Creek is presented in Table 4.6.1-3. As shown, the only metals detected were zinc, lead, and chromium. All metal concentrations were reported at values below SMCLs (zinc) and MCLs (lead and chromium). Zinc was reported at concentrations above the method detection limit in each of the eight samples submitted for metals analysis. Lead and chromium were detected in one and three samples, respectively.

Concentrations of metals detected in surface water samples collected along Meandering Road Creek are listed in Table 4.6.1-4. Zinc concentrations of 22.6 and 49.6 $\mu\text{g/L}$ were detected upstream of Plant 4 at sample sites SW-01 and SW-02, respectively. Zinc concentrations in samples collected from the stream near Plant 4 ranged from 24.2 $\mu\text{g/L}$ at SW-04 to 60.5 $\mu\text{g/L}$ at SW-06. These results suggest that surface water runoff and groundwater discharge to Meandering Road Creek in the vicinity of Plant 4 do not significantly impact zinc concentrations in the stream.

Table 4.6.1-3 Summary of Metals Analytical Results for Surface Water Samples Collected Along Meandering Road Creek

Analyte	Minimum Concentration Detected $\mu\text{g/L}$	Maximum Concentration Detected $\mu\text{g/L}$	Maximum Contaminant Level (MCL) $\mu\text{g/L}$	No. of Samples Analyzed	No. of Samples Above Detection Limit
Antimony	ND ^a	ND	6	8	0
Arsenic	ND	ND	50	8	0
Beryllium	ND	ND	4	8	0
Cadmium	ND	ND	5	8	0
Chromium	12.7	15.8	100	8	3
Copper	ND	ND	1,300 ^b	8	0
Lead	6.7	6.7	15	8	1
Nickel	ND	ND	100	8	0
Selenium	ND	ND	50	8	0
Silver	ND	ND	100 ^b	8	0
Thallium	ND	ND	2	8	0
Zinc	22.6	60.5	5,000 ^b	8	8

Notes: ^aND = not detected
^b = secondary standard

Table 4.6.1-4 Concentrations of Metals Detected in Surface Water Samples Collected Along Meandering Road Creek

Sample Site	Sample Date	Concentration $\mu\text{g/L}$	Analyte
SW-01	02-May-91	22.6	Zinc
SW-02	02-May-91	49.6	Zinc
SW-03	02-May-91	35.6	Zinc
SW-04	01-May-91	12.7	Chromium
SW-04	01-May-91	39.0	Zinc
SW-04	01-May-91	15.8	Chromium
SW-04	01-May-91	41.2	Zinc
SW-04	02-Jul-91	12.8	Chromium
SW-04	02-Jul-91	6.7	Lead
SW-04	02-Jul-91	24.2	Zinc
SW-06	01-May-91	60.5	Zinc
SW-07	01-May-91	30.5	Zinc

The remaining metals listed in Table 4.6.1-4 were detected at SW-04, located near Landfill No. 3. Chromium was detected at SW-04 during two separate sampling events at concentrations ranging from 12.8 to 15.8 $\mu\text{g/L}$. Lead was detected at SW-04 during one sampling event at a concentration of 6.7 $\mu\text{g/L}$. Contaminated upper-zone groundwater is the suspected source for this contamination.

4.6.2 Lake Worth

A total of nine surface water samples were collected from Lake Worth in October 1991. Lake Worth sampling locations are shown in Figure 4.6-1. Seven of the sample sites (LW-02, LW-05, LW-08, LW-11, LW-12, LW-18, and LW-21) were located along the northern boundary of Plant 4. Samples at the remaining two sites, LW-01 and LW-24, were obtained to assess background conditions. One of the background samples was collected west of the site and north of the community of White Settlement. The second background sample was taken from a tributary draining into the lake.

Lake Worth samples were submitted for VOC, semi-VOC, TPH, oil and grease, and metals analysis. In addition, samples collected at sites LW-01, LW-02, and LW-24 were also submitted for pesticide analysis. Carbon disulfide and oil and grease were the only analytes detected above method reporting limits. No semi-VOCs, metals, or pesticides were detected in samples collected from Lake Worth.

Carbon disulfide was reported at concentrations of 200, 18, and 160 $\mu\text{g/L}$ at sites LW-05, LW-12, and LW-18, respectively. All of these sites are located along the north boundary of Plant 4. The distribution of carbon disulfide results implies that the contamination did not originate from a common source. Although potential sources have not been identified, the relatively high concentrations reported suggest that the sources are likely to be near the points of sample collection.

Oil and grease were reported at a concentration of 2.01 mg/L at the background sampling location LW-01. The source for this low-level contamination is unknown.

In addition to samples taken directly from the lake, samples were also collected from Outfall No. 3 and seeps SW-10 and SW-11, located upslope of Lake Worth near the northwestern boundary of Plant 4 (see Figure 4.6-1). Samples from Outfall No. 3 and SW-10 were analyzed for VOCs, semi-VOCs, TPH, oil and grease, and metals. Samples from SW-11 were analyzed for TPH and oil and grease. No target analytes were detected in samples from Outfall No. 3 or SW-11. However, concentrations of zinc (44.2 $\mu\text{g/L}$), arsenic (11.2 $\mu\text{g/L}$), and silver (133 $\mu\text{g/L}$) were reported in the seep sample collected at SW-10. The concentrations reported for zinc and arsenic were confirmed in duplicate sample analyses. The high silver concentration reported for SW-10, which exceeds the secondary standard established for silver, was not confirmed in the duplicate sample. Contaminated upper-zone groundwater is the most likely source for the metals contamination reported at SW-10.

4.6.3 Farmers Branch Creek

Farmers Branch Creek is a small stream that flows easterly along the southern portion of the plant and CAFB. Immediately upon entering the CAFB boundary just east of Grants Lane, it flows through an aqueduct under the runway and taxiway, resurfacing near the Carswell Air Force Base golf course. It then flows through the golf course and empties directly into the West Fork of the Trinity River.

Up to five locations have been sampled in the Farmers Branch drainage during the quarterly groundwater sampling performed by Jacobs Engineering Group from 1992 to the present (see Plate 2). The farthest upstream location (EGL-1) is at the mouth of the aqueduct as the creek enters CAFB property. The farthest downstream location (LF05-S6) is in the golf course area, east of Carswell Landfills 4 and 5.

Organic contaminants measured in Farmers Branch Creek include trichloroethene (TCE), and *cis*- and *trans*-1,2-dichloroethene. Vinyl chloride has not been detected. Concentrations are lowest at location EGL-1 with values at or near detection limits. As the creek flows through the aqueduct, shallow groundwater recharges the creek as indicated by elevated TCE concentrations at EGL-2. The highest values have been measured in an unnamed tributary southeast of CAFB Landfills 4 and 5 (sample location LF05-S7). In 1992 TCE was measured at 880 $\mu\text{g/L}$ at this location. Since 1992, concentrations of TCE have varied between 100 and 500 $\mu\text{g/L}$. Table 4.6.3-1 shows values measured for TCE and *cis*-DCE from April 1992 to February 1995. The most recent TCE value measured is 100 $\mu\text{g/L}$ (February 1995). The highest value of TCE measured in the creek is 67 $\mu\text{g/L}$, measured in March 1994 at a location downstream of the unnamed tributary (LF05-S6). The apparent trend of decreasing concentrations in the Farmers Branch drainage may be associated with contaminant removal by the Landfill 4 and 5 pump and treat system.

Cis-1,2-dichloroethene (*cis*-DCE) values follow TCE values, the highest being 380 $\mu\text{g/L}$ at location LF05-S7 in the unnamed tributary. The highest *cis*-DCE value measured in the creek is 29 $\mu\text{g/L}$ measured at LF05-S6.

Concentrations of inorganic compounds are at or near levels measured at SW-01, a location considered unaffected by Plant 4 activities.

4.7 Ecological Contamination

4.7.1 Toxicity Testing

Surface water samples were collected for toxicity tests from three locations: one on Meandering Road Creek 100-200 feet downstream of Landfill No. 4 (Lake Worth Sampling Location 25), one on Meandering Road Creek upstream of Plant 4 (Location 27), and a background location on Live Oak Creek (Location 28). These locations were selected to provide a worst-case sample, a local background sample, and a

Table 4.6.3-1 Farmers Branch Creek Surface Water

Farmers Branch Creek												
Sample	4/6/92	6/29/92	9/1/92	12/10/92	5/24/93	11/1/93	3/15/94	7/8/94	10/14/94	2/3/95		
TCE	µg/L											
EGL-1	<1	1	<1	1.6	3.1	<1	1	<1	<1	<1		
EGL-2	NA	9	16	27	42	7	14	36	7.4	22		
LF05-S5			15		23	13			6			
LF05-S6		62	64	54	56	40	67	39	13	20		
LF05-S7	880	500		460	270		360	220	110	100		
cis-DCE	µg/L											
EGL-1	<1	<1	<1	<1	1.5	<1	<1	<1	<1	<1		
EGL-2	NA	7	7	5.3	11	2.5	3.2	5.8	<1	4.7		
LF05-S5			4		5.8	3.4			<1			
LF05-S6		26	29	19	18	19	23	12	3.6	3.9		
LF05-S7	380	250		190	150		200	120	58	84		

control sample, respectively. Appendix H-3 includes a discussion of the tests performed and results. Tests were performed by TRAC Laboratories, Inc. Table 4.7.1-1 summarizes the toxicity test results.

Water samples from Location 27 had some toxic effect on *Pimephales promelas* (fathead minnow) in that the mortality rate increased notably over that of the control sample. This may suggest that some toxicity exists in Meandering Road Creek upstream of Plant 4.

Samples from Location 25 had no significant toxic effects at 50 percent exposure but proved toxic to both *Ceriodaphnia dubia* (water flea) and *P. promelas* at 100 percent exposure. At 100 percent exposure, the mean neonate production in *C. dubia* was notably lower than the mean neonate production of the control sample, and there was a significant increase in the mortality rate of *P. promelas*. These findings may suggest that the toxicity of Meandering Road Creek increases as it flows through the Plant 4 area.

Samples from background Location 28 showed no toxic effects on either *C. dubia* or *P. promelas*.

4.7.2 Fish Tissue Contamination

Fish tissue samples were collected from five locations, two of which, Location 1 and Location 28, were background locations. Locations 2, 25, and 26 were sited at the west boundary of Plant 4, along Meandering Road Creek. Mosquito fish specimens were collected for tissue analysis; samples were submitted to the Mississippi State Chemical Laboratory (MSCL), where they were composited into five samples for whole-tissue analysis. Constituents of interest were those agreed upon by USFWS and EPA representatives prior to sample collection. These constituents included organochlorines/PCBs, polynuclear aromatic hydrocarbons (PAHs), and five metals—aluminum, cadmium, chromium, lead, and nickel. Table 4.7.2-1 is a summary of the results of tissue analyses; only those constituents that were detected in any of the five tissue samples are listed. Appendix H provides a summary of the tissue analyses.

Organochlorines/PCBs were investigated in three of the five tissue samples—those from Locations 28 (background), 25, and 2. Arochlor 1254 and Arochlor 1260 were detected in both on-site tissue samples but not in the background sample. The dichlorodiphenyltrichloroethane (DDT) degradation product p,p'-dichlorodiphenyldichloroethylene (DDE) was measured at the lower level of detection in all three samples, while the degradation product p,p'-dichlorodiphenyldichloroethane (DDD) was measured at the lower level of detection only in the background sample. Dieldrin was measured at the lower level of detection only in the on-site sample from Location 25.

**Table 4.7.1-1 Results of Toxicity Tests on Samples
(from TRAC Laboratories, Inc., 1991)**

Sample ID	Concentration (%)	<i>Ceriodaphnia dubia</i>		<i>Pimephales promelas</i>	
		S ^a n = 10	R ^b	S n = 40	W ^c
Location 25	100	90	23.4 ^d (34) ^f	70 ^d (16)	NC ^e
	50	90	24.9 (36)	95 (6)	0.34 (8)
Location 27	100	90	26.7 (30)	73 ^d (21)	NC ^e
Location 28	100	100	26.9 (20)	83 (12)	0.27 (21)
Control	NA ^g	100	29.4 (16)	95 (6)	0.31 (5)

^a S = % survival

^b R = mean neonate production per female

^c W = mean final dry weight (mg) per fish

^d = significantly different from the control (P < 0.05)

^eNC = value not calculated to significant lethal effects

^f = Values in parentheses are % coefficient variation

^gNA = not applicable

Table 4.7.2-1 Summary of the Results of MSCL's Fish Tissue Analyses

Organochlorines/PCBs (ppm-as received wet weight)	Location 1 (Background)	Location 28 (Background)	Location 25	Location 2	Location 26
Arochlor 1254	NA ^a	ND ^b	0.32	0.16	NA
Arochlor 1260	NA	ND	0.09	0.09	NA
p,p'-DDE	NA	0.01	0.01	0.01	NA
Dieldrin	NA	ND	0.01	ND	NA
p,p'-DDD	NA	0.01	ND	ND	NA
PAHs (ppm-as received wet weight)					
Naphthalene	0.01	0.01	0.02	ND	ND
Phenanthrene	ND	ND	0.03	ND	ND
Chrysene	0.01	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	0.01	ND
Metals (mg/kg)					
Cadmium	0.17	0.08	0.16	0.12	0.08
Chromium	0.34	0.76	0.32	0.16	0.12
Lead	2.0	2.0	2.0	1.4	2.0
Aluminum	104	96.8	20.4	1.6	27.6
Nickel	1.6	1.6	1.2	0.60	0.76

^aND = Not detected

^bNA = Not analyzed

Lower level of detection = 0.01 ppm, except 0.05 ppm for PCBs

All five tissue samples were investigated for polynuclear aromatic hydrocarbons (PAHs). Naphthalene was measured at the lower level of detection in the samples from background locations 1 and 28 and at a slightly greater concentration in the sample from on-site location 25. Phenanthrene was detected only in the sample from on-site location 25. Chrysene was found at the lower level of detection in the sample from background location 1. Benzo(b)fluoranthene was found at the lower level of detection in the sample from on-site location 2. No PAH compounds were detected in the sample from on-site location 26.

Investigations for inorganic compounds included five metals—cadmium, chromium, lead, aluminum, and nickel. Table 4.7.2-1 shows that, for the most part, levels of cadmium, lead, and nickel were consistent over all samples, while levels of chromium and aluminum were distinctively higher in the samples from background locations 1 and 28.

Levels of Arochlor 1254, Arochlor 1260, dieldrin, naphthalene, phenanthrene, and benzo(b)fluoranthene in on-site tissue samples were elevated compared with background levels of these organic compounds, which may indicate that Plant 4 contributes to the contamination of the aquatic community of Lake Worth. However, the tissue data cannot be considered conclusive for several reasons. At the time of sample collection, Lake Worth was in flood stage and temperatures were unseasonably cool. Mosquito fish tend to occupy territorial areas in warm weather conditions; flood conditions may have displaced the populations that inhabited the sampling locations throughout the summer and introduced new, unrepresentative populations. In addition, the mosquito fish collected may not have inhabited the area long enough to allow toxic compounds to accumulate in their fatty tissues. Finally, the selection of background sampling locations may have ignored nearby industry, which may have minimized the contrast between background contaminant levels and on-site contaminant levels.

4.8 Air Contamination

4.8.1 Introduction

Two air monitoring stations were established to provide information on the general air quality for the White Settlement area and to assess the contribution of air contaminants from Plant 4. The air monitoring station established to monitor the offsite concentrations of contaminants was set up inside the security fence at White Settlement municipal well WS-6T approximately 0.75 mile west of Plant 4. The air monitoring station established to monitor the onsite concentrations of contaminants, and the contribution made from the operations at Plant 4, was set up inside Plant 4 approximately 300 feet north of Building 176. Each station was equipped to collect samples for VOCs, total particulates, and select metals. Sampling was initiated in mid-February 1992 and continued through mid-May 1992. A total of 15 sampling sets were collected during this time period on a 6-day rotation. Appendix I-1 provides the analytical data reports.

In addition to the collection of air-quality monitoring data, daily wind speed and wind direction data were obtained from the meteorological station at Carswell Air Force Base (CAFB) for the period in which the air monitoring was conducted. Table 4.8-1 summarizes the hourly wind data collected on the days that each air-quality sampling period was initiated. Appendix I-2 contains a summary of the meteorological data obtained from CAFB.

4.8.2 Field and Laboratory Quality Control

Samples for VOC analysis were collected using evacuated SUMMA® passivated stainless steel canisters, and consequently, no trip blanks were required because any positive analytical result from a trip blank canister would indicate only that the individual canister leaked/lost its vacuum, and that result would be canister specific.

Samples for total particulates and metals analyses were collected using Whatman EPM-2000 ultrahigh purity glass fiber filters originating from the same batch. After collection each filter was placed in a sealed envelope and stored in a secure location so that chain of custody could be maintained until the samples could be batched for efficient analysis. Two blank filters were analyzed for total particulates, cadmium, chromium, lead, and zinc to provide data on the inherent metals content of the filters themselves. The analytical values (measured in $\mu\text{g}/\text{filter}$) for these parameters were as follows: cadmium—0.41 and <0.24, chromium—7.3 and 3.6, lead—2.0 and 1.9, zinc—75.3 and 67. The metals data in Table 4.8-2 presents total concentrations and also modified data to reflect the averages of these inherent contaminant concentrations.

Table 4.8-1 Summary of Carswell Air Force Base
Wind Direction and Speed Data

TIME	FEB 11		FEB 18		FEB 24		MAR 01		MAR 07		MAR 13		MAR 19		MAR 25	
	DIR	SPEED														
0055	160	4	220	5	100	3	80	1	0	0	30	7	360	6	40	14
0155	140	4	220	6	10	3	0	0	0	0	50	2	330	8	40	20
0255	100	3	210	8	0	0	0	0	0	0	70	2	330	16	80	12
0355	130	2	210	9	0	0	0	0	200	1	60	1	0	0	100	10
0455	130	2	220	9	0	0	170	1	190	4	60	5	330	4	120	10
0555	120	3	230	10	0	0	0	0	0	0	50	2	360	10	130	2
0655	150	10	290	4	0	0	0	0	260	2	70	1	360	7	0	0
0755	160	8	300	5	0	0	0	0	0	0	0	0	310	6	0	0
0855	170	9	0	0	0	0	0	0	280	2	0	0	0	12	270	2
0955	160	8	0	0	340	4	0	0	0	0	0	0	350	15	330	4
1055	160	3	0	0	340	4	0	0	0	0	0	0	330	12	10	2
1155	160	8	0	0	350	5	0	0	0	0	0	0	330	13	330	3
1255	150	8	0	0	350	2	0	0	0	0	0	0	330	10	330	3
1355	150	11	0	0	10	4	0	0	0	0	0	0	330	18	330	2
1455	150	9	330	3	40	6	0	0	0	0	160	8	340	18	330	4
1555	170	7	330	2	10	6	180	2	0	0	150	8	360	18	330	6
1655	170	9	340	6	30	10	0	0	0	0	170	12	330	18	330	4
1755	170	5	350	14	40	8	230	8	180	8	170	10	360	13	20	10
1855	180	10	310	13	10	12	190	8	200	12	200	10	360	14	20	8
1955	170	13	310	12	10	10	190	8	160	12	170	9	330	14	30	8
2055	180	14	350	12	10	14	170	12	170	11	160	3	330	7	10	6
2155	180	10	340	9	340	13	170	14	150	10	170	4	340	6	10	4
2255	170	16	340	9	350	14	170	14	160	12	160	10	340	6	10	6
2355	160	10	340	6	360	13	180	12	150	11	160	8	340	7	0	0
0055	150	14	310	2	10	11	160	10	160	8	160	6	330	6	0	0

Wind direction	1-day		5-day													
	DIR	SPEED														
CALM	0	11	6	23	7	24	13	14	13	29	7	23	1	10	4	17
S ±20	15	35	0	47	0	1	9	71	8	22	10	46	0	18	0	37
N ±20	0	29	6	9	14	54	0	1	0	24	0	5	20	47	8	13
E ±20	1	6	0	4	1	1	1	4	0	2	2	18	0	6	2	9
W ±20	0	6	1	4	0	12	0	0	2	5	0	1	1	3	1	3
S ±40	21	47	5	64	0	2	9	93	10	35	11	56	0	30	0	56
N ±40	0	33	8	13	17	73	0	1	0	36	1	7	23	57	16	24
E ±40	4	14	0	10	1	1	1	9	0	10	6	27	0	18	4	18
W ±40	0	15	6	10	0	20	2	3	2	10	0	7	1	5	1	5

1 Wind direction is measured in degrees (clockwise from the north), and indicates the direction from which the wind is blowing. A zero (0) indicates calm conditions.
2 Wind speed is measured in knots.
(The numbers indicate the number of hourly readings during each period where the indicated wind direction was observed.)

Table 4.8-1 (continued) Summary of Carswell Air Force Base
Wind Direction and Speed Data

TIME	MAR 31		APR 06		APR 12		APR 18		APR 24		APR 30		MAY 06		MAY 12	
	DIR	SPEED														
0055	350	5	70	8	150	10	130	4	160	6	50	6	90	1	210	10
0155	10	3	80	5	140	7	140	6	150	6	0	0	0	0	210	10
0255	0	0	120	10	140	8	0	0	150	7	0	0	40	8	220	12
0355	0	0	90	5	130	6	0	0	160	8	0	0	40	4	0	0
0455	0	0	150	4	130	6	80	3	160	12	0	0	30	6	0	0
0555	0	0	20	2	120	8	180	2	170	12	0	0	40	4	130	3
0655	0	0	80	5	110	9	0	0	150	7	170	2	40	10	130	6
0755	0	0	90	4	130	9	120	6	140	8	170	2	40	10	130	6
0855	0	0	80	5	140	13	120	3	140	6	0	0	40	8	140	6
0955	0	0	70	2	160	8	160	2	140	6	0	0	30	10	160	6
1055	200	1	70	4	110	4	140	4	140	2	0	0	20	8	140	6
1155	0	0	60	2	110	4	150	4	140	2	0	0	30	10	150	4
1255	0	0	50	3	100	4	160	10	350	3	0	0	30	8	150	8
1355	140	2	50	2	100	4	180	11	230	2	80	2	40	7	170	8
1455	110	3	70	1	120	6	170	12	230	2	150	3	50	11	180	8
1555	170	4	10	6	80	4	170	10	230	4	130	5	90	8	190	8
1655	180	3	350	3	80	4	150	15	350	6	130	5	10	8	240	6
1755	60	3	330	3	20	8	180	18	340	10	120	4	50	8	160	8
1855	340	1	330	4	30	8	160	16	10	7	150	9	60	6	140	8
1955	30	2	310	3	50	4	150	16	10	8	110	9	50	5	100	8
2055	40	5	360	8	340	8	160	14	10	10	110	11	40	9	70	10
2155	40	5	10	7	330	10	170	16	10	13	110	11	50	6	40	6
2255	90	4	20	4	320	13	160	16	10	12	120	9	50	5	60	5
2355	40	6	0	0	340	15	160	14	10	10	140	10	30	7	90	9
0055	50	4	60	3	330	15	150	12	20	10	130	11	40	5	130	11

1 Wind direction is measured in degrees (clockwise from the north), and indicates the direction from which the wind is blowing. A zero (0) indicates calm conditions.
2 Wind speed is measured in knots.

FREQUENCY TABLE (The numbers indicate the number of hourly readings during each period where the indicated wind direction was observed.)

Wind direction	1-day	5-day														
CALM	10	29	1	10	0	2	3	24	0	20	10	18	1	12	2	22
S ±20	3	23	0	59	1	64	12	31	4	11	2	43	0	58	5	23
N ±20	3	31	6	6	2	21	0	14	9	39	0	12	2	1	0	0
E ±20	2	5	9	18	7	7	1	6	0	7	4	10	2	3	3	19
W ±20	0	15	0	0	0	0	0	12	0	0	0	0	0	0	0	0
S ±40	4	29	1	72	5	73	18	43	12	23	5	50	0	77	13	46
N ±40	7	37	8	8	7	26	0	25	10	47	0	29	16	16	1	2
E ±40	4	7	14	29	13	18	4	10	0	27	10	21	8	14	8	47
W ±40	0	18	1	1	0	1	0	18	3	3	0	2	0	1	1	3

Table 4.8-2 Summary of Inorganic Contaminants in Air Samples

INORGANIC CONTAMINANT	FEB 11		FEB 18		FEB 24		MAR 01		MAR 07		MAR 13		MAR 19		MAR 25	
	GD	WS														
Sample Volume (m ³)	1631	1631	6291	6291	6155	6155	6153	6153	8394	7973	8767	8155	7951	7951	10390	8359
Total Particulate (µg/m ³)	13.0	12.0	18.0	18.0	6.9	8.7	10.0	10.0	13.0	17.0	19.0	20.0	13.0	15.0	13.0	16.0
Total Cadmium Concentration (µg/m ³)	0.00053	0.00037	0.00030	0.00031	0.00021	0.00020	0.00023	0.00020	0.00020	0.00030	0.00030	0.00020	0.00020	0.00020	0.00020	0.00020
Total Cadmium (µg)	0.8644	0.6035	2.4873	2.5702	1.7128	1.631	1.8752	1.6308	1.6788	2.3919	2.6301	1.631	1.5902	1.5902	2.072	1.6718
Net Cadmium (µg)	0.5984	0.3365	2.2223	2.3052	1.4478	1.398	1.6102	1.3658	1.4138	2.1298	2.3951	1.398	1.3252	1.3252	1.807	1.4098
Net Cadmium Concentration (µg/m ³)	0.00037	0.00021	0.00027	0.00028	0.00018	0.00017	0.00020	0.00017	0.00017	0.00027	0.00027	0.00017	0.00017	0.00017	0.00017	0.00017
Total Chromium Concentration (µg/m ³)	0.0055	0.0074	0.0019	0.0081	0.0088	0.0080	0.0022	0.0088	0.0023	0.0011	0.0082	0.0010	0.0012	0.0009	0.0027	0.0007
Total Chromium (µg)	8.9705	12.089	15.753	67.157	70.133	65.24	17.837	71.748	19.308	8.7703	84.355	6.155	8.5412	7.1959	27.872	5.8513
Net Chromium (µg)	3.5205	6.6184	10.303	61.707	64.883	59.79	12.487	86.286	13.856	3.3203	48.805	2.705	4.0812	1.7059	22.522	4.4013
Net Chromium Concentration (µg/m ³)	0.0022	0.0041	0.0012	0.0074	0.0079	0.0073	0.0015	0.0081	0.0017	0.0004	0.0056	0.0003	0.0006	0.0002	0.0022	0.0000
Total Lead Concentration (µg/m ³)	0.0059	0.0086	0.0048	0.0039	0.0032	0.0032	0.0036	0.0042	0.0043	0.0044	0.0087	0.0055	0.0087	0.0085	0.0042	0.0053
Total Lead (µg)	9.8229	14.027	39.797	32.335	28.088	28.088	30.881	34.243	36.094	36.081	78.273	44.853	83.272	67.964	43.512	44.303
Net Lead (µg)	7.8729	12.077	37.847	30.385	24.148	24.148	28.031	32.293	34.144	33.131	74.323	42.903	51.322	65.634	41.562	42.353
Net Lead Concentration (µg/m ³)	0.0047	0.0074	0.0048	0.0037	0.0030	0.0030	0.0038	0.0040	0.0041	0.0042	0.0085	0.0053	0.0085	0.0083	0.0040	0.0051
Total Zinc Concentration (µg/m ³)	0.028	0.032	0.023	0.023	0.016	0.016	0.023	0.021	0.022	0.028	0.024	0.022	0.028	0.024	0.021	0.028
Total Zinc (µg)	45.888	52.162	190.89	190.89	130.48	130.48	187.92	171.21	184.87	207.3	210.41	179.41	222.83	190.82	217.56	234.05
Net Zinc (µg)	0 *	0 *	118.54	118.54	59.33	59.33	118.37	100.08	113.52	138.15	138.28	108.28	151.48	118.87	148.41	162.9
Net Zinc Concentration (µg/m ³)	0 *	0 *	0.014	0.014	0.007	0.007	0.014	0.012	0.014	0.017	0.016	0.013	0.018	0.015	0.014	0.019

GD = Sample obtained from the General Dynamics site
 WS = Sample obtained from the White Settlement site
 * Cadmium was not detected in this sample at this reporting limit
 * Zinc concentration cannot be quantified due to the limited sample volume
 NS = No sample was collected because of circuit failure
 m³ = Cubic meter
 µg = Microgram
 NA = Not analyzed for
 ND = Analyzed for but not detected

Table 4.8-2 (continued) Summary of Inorganic Contaminants in Air Samples

SAMPLE DATE	MAR 31		APR 08		APR 12		APR 18		APR 24		APR 30		MAY 06		MAY 12		
	GD	WS	GD	WS	GD	WS	GD	WS	GD	WS	GD	WS	GD	WS	GD	WS	
INORGANIC CONTAMINANT																	
Sample Volume (m ³)	6082	8280	3875	6481	7951	8237	8359	8085	NS	NS	8984	8984	8984	NS	11288	10873	
Total Particulates (µg/m ³)	22.0	14.0	6.3	18.0	23.0	24.0	11.0	15.0	NS	NS	19.0	17.0	16.0	NS	18.0	18.0	
Total Cadmium Concentration (µg/m ³)	0.00013	0.00013	0.00037	0.00018	0.00018	0.00018	0.00013	0.00018	NS	NS	0.00019	0.00017	0.00019	NS	0.00013	0.00015	
Total Cadmium (µg)	1.0481	1.0764	1.4336	1.523	1.4312	1.3211	1.0687	1.0971	NS	NS	1.8382	1.8428	1.8382	NS	1.4868	1.631	
Net Cadmium (µg)	0.7631	0.8114	1.1868	1.258	1.1862	1.0561	0.8217	0.8321	NS	NS	1.5712	1.3778	1.5712	NS	1.2038	1.368	
Net Cadmium Concentration (µg/m ³)	0.00010	0.00010	0.00030	0.00015	0.00015	0.00013	0.00010	0.00014	NS	NS	0.00018	0.00014	0.00016	NS	0.00011	0.00013	
Total Chromium Concentration (µg/m ³)	0.0018	0.0014	0.0042	0.0013	0.0031	0.0011	0.0021	0.0015	NS	NS	0.0020	0.0029	0.00098	NS	0.0011	0.00051	
Total Chromium (µg)	14.512	11.592	16.275	10.999	24.948	9.0827	17.854	9.1425	NS	NS	18.328	2.8028	9.2774	NS	12.428	5.5452	
Net Chromium (µg)	9.0816	6.142	10.825	5.5493	18.188	3.6327	12.104	3.8625	NS	NS	13.878	-2.647	3.8274	NS	8.9789	0.9852	
Net Chromium Concentration (µg/m ³)	0.0011	0.0007	0.0028	0.0007	0.0024	0.0004	0.0014	0.0006	NS	NS	0.0014	-0.0003	0.0004	NS	0.0006	0.00030	
Total Lead Concentration (µg/m ³)	0.0050	0.0081	0.0088	0.0058	0.0080	0.0088	0.0032	0.0048	NS	NS	0.0085	0.0085	0.0050	NS	0.0048	0.0049	
Total Lead (µg)	40.31	50.508	34.1	47.362	47.708	56.148	26.748	26.037	NS	NS	53.152	53.152	48.32	NS	54.235	53.278	
Net Lead (µg)	38.38	48.558	32.15	45.432	45.756	54.186	24.798	26.087	NS	NS	51.202	51.202	48.37	NS	52.285	51.328	
Net Lead Concentration (µg/m ³)	0.0048	0.0059	0.0063	0.0054	0.0056	0.0066	0.0030	0.0043	NS	NS	0.0053	0.0053	0.0048	NS	0.0048	0.0047	
Total Zinc Concentration (µg/m ³)	0.020	0.019	0.034	0.024	0.021	0.022	0.013	0.021	NS	NS	0.019	0.018	0.018	NS	0.018	0.020	
Total Zinc (µg)	181.24	157.32	131.75	203.08	188.87	181.85	108.87	128	NS	NS	183.82	173.85	154.82	NS	180.78	217.48	
Net Zinc (µg)	90.09	86.17	80.8	131.81	95.821	110.5	37.517	56.645	NS	NS	112.47	102.8	83.474	NS	108.83	146.31	
Net Zinc Concentration (µg/m ³)	0.011	0.010	0.018	0.018	0.012	0.013	0.004	0.009	NS	NS	0.012	0.011	0.009	NS	0.010	0.013	

GD = Sample obtained from the General Dynamics site
 WS = Sample obtained from the White Settlement site
 † Cadmium was not detected in this sample at this reporting limit
 NS = No sample was collected because of circuit failure
 m³ = Cubic meter
 µg = Microgram
 NA = Not analyzed for
 ND = Analyzed for but not detected

Table 4.8-2 (continued) Summary of Inorganic Contaminants in Air Samples

INORGANIC CONTAMINANT	ONSITE - General Dynamics			OFFSITE - White Settlement			
	# of Hits # of Samples	Concentrations Min. - Max.		# of Hits # of Samples	Concentrations Min. - Max.		Average
		Average					
Total Particulates ($\mu\text{g}/\text{m}^3$)	15/15	6.3 - 23.0	14.7	14/14	8.7 - 24.0	15.8	
Total Cadmium Concentration ($\mu\text{g}/\text{m}^3$)	14/15	ND - .00053	0.00025	12/14	ND - .00037	0.00025	
Total Chromium Concentration ($\mu\text{g}/\text{m}^3$)	15/15	.00098 - .00308	0.00308	14/14	.00029 - .0086	0.0030	
Total Lead Concentration ($\mu\text{g}/\text{m}^3$)	15/15	.0032 - .0088	0.0053	14/14	.0032 - .0086	0.0055	
Total Zinc Concentration ($\mu\text{g}/\text{m}^3$)	15/15	.013 - .034	0.022	14/14	.018 - .032	0.023	

GD = Sample obtained from the General Dynamics site
 WS = Sample obtained from the White Settlement site
 † Cadmium was not detected in this sample at this reporting limit
 ‡ Zinc concentration cannot be quantified due to the limited sample volume
 NS = No sample was collected because of circuit failure
 m³ = Cubic meter
 μg = Microgram
 NA = Not analyzed for
 ND = Analyzed for but not detected

Laboratory quality controls, in the form of "Standard Reference Solutions" for metals analysis and "Method Blanks" and "Surrogate Recoveries" for VOC analysis, were quantified for each set of samples analyzed. Appendix I-1 provides the actual values and individual quality control discussions.

4.8.3 VOC Contaminants in Air

All VOC samples were analyzed for the target compound list of VOCs. Table 4.8-3 presents the analytical data and the frequency of detection for the 23 VOCs that were detected in the air samples from either location. Five compounds (chlorodifluoromethane, *cis*-1,2-dichloroethene, chloroform, n-nonane, and Freon 114) were only detected in one sample and thus do not represent a significant air contaminant. Eight additional compounds (chloromethane, carbon tetrachloride, tetrachloroethene, chlorobenzene, ethylbenzene, *m*- and/or *p*-xylene, *o*-xylene, and styrene) were detected in the offsite samples at the same frequency and concentrations as in the onsite samples and thus do not represent a significant air contaminant. It should be noted that the concentrations of xylenes at the onsite sample are generally higher when the wind is from the south than when it is from other directions, primarily north. This indicates a lack of activity that can be directly associated with the presence of Lake Worth.

Concentrations of the ten remaining compounds vary widely in the samples collected from both locations. The frequency of detection at the offsite location for each of these compounds roughly equals that of the onsite location, however, the concentrations seen from the onsite samples are generally significantly higher than those seen from the offsite samples. This difference ranges from a factor of two for methylene chloride, benzene, toluene, trichlorofluoromethane, 1,3,5-trimethylbenzene, and 1,2,4-trimethylbenzene, up to an order of magnitude for dichlorodifluoromethane, Freon 113, 1,1,1-trichloroethane, and trichloroethene. These differences indicate that the activities at Plant 4 are contributing significantly to the levels of the aforementioned contaminants in the air. Appendix I-1 provides the analytical data reports.

Wind direction appears to have little effect on the downwind concentrations of dichlorodifluoromethane and 1,1,1-trichloroethane, indicating that there are sources of these compounds located both north and south of the on-site air monitoring station location. In contrast, significant increases in concentrations are noted for Freon 113 and trichloroethene when the winds are blowing from the south (the predominant wind direction at Plant 4).

Table 4.8-3 Summary of Organic Contaminants in Air Samples

CONTAMINANT (ppb)	FEB 11		FEB 18		FEB 24		MAR 01		MAR 07		MAR 13		MAR 19		MAR 25	
	GD	WS														
Dichlorodifluoromethane	0.66	0.46	3.30	0.60	11.00	0.57	1.90	0.81	1.00	0.54	2.00	0.90	1.10	0.54	3.00	0.84
Chlorodifluoromethane	0.56	<0.20	<0.40	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Chloromethane	<0.50	<0.50	<1.00	<0.50	<0.50	<0.50	0.82	0.81	0.55	0.59	0.49 J	0.46 J	0.46 J	0.56	0.50	0.56
Freon 113 ¹	2.80 B	<0.20	<0.40	0.10 J	0.34	0.13 J	0.56	0.10 J	1.40	<0.20	1.30	0.21	0.13 J	0.10 J	0.34	0.28
Methylene Chloride	0.20	0.14 J	<0.40	<0.20	<0.20	0.15 J	0.22	0.14 J	0.18 J	0.14 J	0.20	0.18 J	0.24 J	0.14 J	0.19 J	0.16 J
cis-1,2-Dichloroethane	<0.30	<0.30	<0.80	<0.30	<0.30	<0.30	0.10 J	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Chloroform	0.10 J	<0.30	<0.80	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
1,1,1-Trichloroethane	0.78	0.28 J	<0.80	0.22 J	0.31	0.30 J	0.41	0.23 J	0.52	0.24 J	0.57 B	0.45 B	0.32 B	0.32 B	0.40 J	0.36
Carbon Tetrachloride	0.10 J	0.10 J	<0.40	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Benzene	0.45	0.36	0.74	0.67	0.56	0.66	0.66	0.36	1.00	0.46	0.75	0.78	0.31	0.40	0.62	0.70
Trichloroethene	2.80	<0.20	<0.40	<0.20	<0.20	<0.20	0.43	<0.20	0.96	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Toluene	2.60	0.55	1.30	1.10	1.00	1.10	2.30	0.50	3.30	0.72	2.10	1.40	0.44	0.60	1.20 B	1.30 B
Tetrachloroethene	<0.20	<0.20	<0.40	<0.20	<0.20	<0.20	<0.20	0.56	0.17 J	<0.20	0.24	0.20 J	<0.20	<0.20	0.16 J	0.10 J
Chlorobenzene	<0.20	<0.20	<0.40	<0.20	<0.20	<0.20	<0.20	<0.20	0.11 J	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Ethylbenzene	0.41	0.17 J	0.21 J	0.29	0.16 J	0.23	0.36	0.24	0.55	0.36	0.37	0.46	<0.20	0.53	0.16 J	0.52
m +/or p-Xylene	1.60	0.62	0.64	1.20	0.52	0.82	1.40	1.10	2.00	1.60	1.30	1.90	0.25	2.30	0.81	2.20
n-Nonane	<0.20	<0.20	<0.40	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
o-Xylene	0.50	0.16 J	0.32 J	0.36	0.20	0.26	0.51	0.24	0.71	0.36	0.48	0.75	<0.20	0.94	0.25	0.64
Styrene	<0.20	<0.20	<0.40	<0.20	<0.20	<0.20	<0.20	<0.20	0.14 J	<0.20	<0.20	<0.20	<0.20	0.11 J	<0.20	<0.20
Freon 114 ²	<0.20	<0.20	<0.40	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Trichlorofluoromethane	5.70	0.57	0.36 J	0.22	0.26	0.26	0.60	0.27	0.46	0.27	0.44	0.31	0.26	0.36	0.30	0.43
1,3,5-Trimethylbenzene	<0.20	<0.20	<0.40	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.10 J	0.13 J	<0.20	<0.20	<0.20	<0.20
1,2,4-Trimethylbenzene	0.18 J	0.14 J	0.35 J	0.29	0.21	0.25	0.44	0.14 J	0.55	0.20	0.37	0.43	0.12 J	0.25	0.26	0.37

B = Detected in analytical method blank
 J = Detected at or below the analytical method reporting limit
 NA = Not analyzed for
 ND = Analyzed for but not detected
 NS = No sample was collected because of circuit failure

GD = Sample obtained from the General Dynamics site
 WS = Sample obtained from the White Settlement site
 ppb = Parts per billion (volume per volume)
¹ Freon 113 = 1,1,2-Trichloro-1,1,2,2-tetrafluoroethane
² Freon 114 = 1,2-Dichloro-1,1,2,2-tetrafluoroethane

Table 4.8-3 (continued) Summary of Organic Contaminants in Air Samples

CONTAMINANT (ppb)	MAR 31		APR 06		APR 12		APR 16		APR 24		APR 30		MAY 06		MAY 12	
	GD	WS	GD	WS	GD	WS	GD	WS	GD	WS	GD	WS	GD	WS	GD	WS
Dichlorodifluoromethane	6.30	0.77	3.70	0.37	1.70	0.26	0.32	0.22	NS	NS	1.80	0.35	0.23	0.14 J	0.28	0.42
Chlorodifluoromethane	<0.20	<0.20	<0.20	<0.20	<2.00	<0.20	<0.20	<0.20	NS	NS	NA	NA	NA	NA	<0.20	<0.20
Chloromethane	0.52	0.95	<0.50	<0.50	<5.00	<0.50	<0.50	<0.50	NS	NS	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Freon 113 ¹	0.46	0.26	0.42	0.29 J	4.40	0.11 J	0.60	<0.20	NS	NS	1.60 J	0.16 J	0.12 J	0.12 J	0.11 J	0.79
Methylene Chloride	0.46	0.25	0.16 J	0.17 J	<2.00	<0.20	0.15 J	<0.20	NS	NS	0.30 J	0.21	0.14 J	0.17 J	<0.20	0.15 J
cis-1,2-Dichloroethane	<0.30	<0.30	<0.30	<0.30	<3.00	<0.30	<0.30	<0.30	NS	NS	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Chlorobrom	<0.30	<0.30	<0.30	0.07 J	<3.00	<0.30	<0.30	<0.30	NS	NS	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
1,1,1-Trichloroethane	0.69 E	0.48 E	0.45 E	0.44 E	2.50 E	0.30 E	0.59 E	0.27 J E	NS	NS	0.72 E	0.43 E	0.33 E	0.34 E	0.34 E	0.51 E
Carbon Tetrachloride	0.10 J	0.10 J	0.11 J	0.11 J	<2.00	0.10 J	0.10 J	0.10 J	NS	NS	0.11 J	0.12 J				
Benzene	0.94	0.94	0.74	0.74	1.00 J	0.34	0.31	0.26	NS	NS	1.50	1.10	0.25	0.70	0.39	0.36
Trichloroethene	0.20	0.33	<0.20	<0.20	2.60	<0.20	2.30	<0.20	NS	NS	0.54	0.15 J	<0.20	<0.20	<0.20	0.64
Toluene	2.10 E	2.10 E	1.50	1.30	4.10	0.56	1.40	0.50	NS	NS	4.10	2.40	0.56	1.20	0.85	1.40
Tetrachloroethene	0.50	0.32	0.33	0.25	<2.00	<0.20	<0.20	<0.20	NS	NS	0.41	0.30	<0.20	<0.20	<0.20	<0.20
Chlorobenzene	<0.20	<0.20	<0.20	<0.20	<2.00	<0.20	0.15 J	<0.20	NS	NS	0.13 J	<0.20	0.11 J	<0.20	<0.20	0.14 J
Ethylbenzene	0.35	0.81	0.19 J	0.36	<2.00	0.22	0.36	0.24	NS	NS	0.66	0.75	0.25	0.36	0.66	0.19 J
m + for p-Xylene	1.20	2.50	0.62	1.60	2.00	0.85	1.20	1.10	NS	NS	2.10	2.30	0.10 J	1.50	2.60	0.83
n-Nonane	<0.20	<0.20	<0.20	<0.20	0.71 J	<0.20	<0.20	<0.20	NS	NS	NA	NA	NA	NA	<0.20	<0.20
o-Xylene	0.46	0.97	0.24	0.80	<2.00	0.37	0.50	0.44	NS	NS	0.64	0.60	<0.20	0.62	1.10	0.24
Styrene	0.12 J	0.16 J	<0.20	0.05 J	<2.00	<0.20	<0.20	<0.20	NS	NS	0.10 J	0.13 J	<0.20	<0.20	<0.20	<0.20
Freon 114 ²	<0.20	<0.20	0.05 J	<0.20	<2.00	<0.20	<0.20	<0.20	NS	NS	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Trichlorofluoromethane	0.35	0.81	0.27	0.28	0.36 J	0.27	0.32	0.25	NS	NS	0.32	0.26	0.26	0.25	0.26	0.34
1,3,5-Trimethylbenzene	0.14 J	0.16 J	0.07 J	0.06 J	0.37 J	0.04 J	0.21	<0.20	NS	NS	0.25	0.17 J	<0.20	<0.20	0.66	<0.20
1,2,4-Trimethylbenzene	0.46	0.53	0.23	0.32	0.59 J	0.14 J	0.76	0.15 J	NS	NS	0.64	0.60	<0.20	0.16 J	1.10	<0.20

GD = Sample obtained from the General Dynamics site
 WS = Sample obtained from the White Settlement site
 ppb = Parts per billion (volume per volume)
¹ Freon 113 = 1,1,2-Trichloro-1,1,2,2-Tetrafluoroethane
² Freon 114 = 1,2-Dichloro-1,1,2,2-Tetrafluoroethane
 B = Detected in analytical method blank
 J = Detected at or below the analytical method reporting limit
 NA = Not analyzed for
 ND = Analyzed for but not detected
 NS = No sample was collected because of circuit failure

Table 4.8-3 (continued) Summary of Organic Contaminants in Air Samples

CONTAMINANT (ppb)	ONSITE - General Dynamics		OFFSITE - White Settlement	
	# of Hubs # of Samples	Concentrations Min. - Max.	# of Hubs # of Samples	Concentrations Min. - Max.
Dichlorodifluoromethane	15/15	.23 - 11.0	15/15	.14J - .77
Chlorodifluoromethane	1/13	ND - .56	0/13	ND
Chloromethane	6/15	ND - .62	6/15	ND - .61
Freon 113 *	14/15	.34 - 4.40	12/15	ND - .79
Methylene Chloride	11/15	ND - .48	12/15	ND - .25
cis-1,2-Dichloroethene	1/15	ND - .10J	0/15	ND
Chloroform	1/15	.ND - .10J	1/15	ND - .07J
1,1,1-Trichloroethane	14/15	.31 - 2.508	15/15	.22J - .51B
Carbon Tetrachloride	7/15	ND - .11J	8/15	ND - .12J
Benzene	15/15	.25 - 1.50	15/15	.26 - 1.10
Trichloroethene	7/15	ND - 2.60	5/15	ND - .64
Toluene	15/15	.44 - 4.10	15/15	.50 - 2.40
Tetrachloroethene	6/15	ND - .50	6/15	ND - .56
Chlorobenzene	4/15	ND - .13J	1/15	ND - .14J
Ethylbenzene	13/15	ND - .68	15/15	.17J - .75
m +/or p-Xylene	15/15	.10J - 2.60	15/15	.62 - 2.50
n-Nonane	1/13	ND - .71J	0/13	ND
o-Xylene	12/15	ND - 1.10	15/15	.16J - .97
Styrene	3/15	ND - .14J	5/15	ND - .21
Freon 114 *	1/15	ND - .06J	0/15	ND
Trichlorofluoromethane	15/15	.26 - 5.70	15/15	.22 - .91
1,3,5-Trimethylbenzene	7/15	ND - .69	5/15	ND - .17J
1,2,4-Trimethylbenzene	14/15	ND - 1.10	14/15	ND - .60
		Average		Average
		2.55		0.47
		0.12		NA
		0.36		0.36
		0.69		0.20
		0.19		0.15
		0.10		NA
		0.10		0.07
		0.61		0.35
		0.10		0.10
		0.70		0.56
		0.71		0.18
		1.92		1.12
		0.16		0.18
		0.11		0.10
		0.33		0.37
		1.22		1.51
		0.14		NA
		0.43		0.54
		0.10		0.11
		0.05		NA
		0.70		0.33
		0.16		0.11
		0.44		0.27

B = Detected in analytical method blank
 J = Detected at or below the analytical method reporting limit
 NA = Not analyzed for
 ND = Analyzed for but not detected
 NS = No sample was collected because of circuit failure

GD = Sample obtained from the General Dynamics site
 WS = Sample obtained from the White Settlement site
 ppb = Parts per billion (volume per volume)
 * Freon 113 = 1,1,2-Trichloro-1,2,2-Trifluoroethane
 * Freon 114 = 1,2-Dichloro-1,1,2,2-Tetrafluoroethane

4.8.4 Total Particulates and Metal Contaminants in Air

All particulate sample filters were analyzed for total particulates, cadmium, chromium, lead, and zinc. Table 4.8-2 presents a summary of the analytical data and the frequency of detection for the analyses performed. Concentrations of these analytes vary widely in the samples collected from both locations. Wind direction appears to have little effect on the concentrations noted at both sites based on the 5-day period wind direction frequencies depicted in Table 4.8-1. When evaluated, these data indicate that no significant increase in analyte concentrations is noted due to the activities at Plant 4. Appendix I-1 provides the analytical data reports.

5.0 Contaminant Fate and Transport

5.1 Introduction

The fate and transport of contaminants at Plant 4 were assessed to facilitate the Baseline Risk Assessment (see Section 6.0) and to provide data to support the evaluation of remedial alternatives in the FS. Components of the assessment included (1) an evaluation of the physicochemical properties of the organic chemicals of concern (COCs) at the site, (2) an evaluation of physicochemical processes resulting in contaminant transformation, (3) an evaluation of contaminant transport mechanisms, and (4) numerical modeling of contaminant transport.

5.2 Contaminant Fate

In analysis of contaminant fate, knowledge of the physicochemical properties of COCs is combined with knowledge of physicochemical processes to form a qualitative representation of the environmental fate of the COCs. The physicochemical properties and processes impacting contaminant fate are discussed in the following sections.

5.2.1 Physicochemical Properties

Physical and chemical properties that are helpful in understanding which processes will be important under environmental conditions are solubility, specific gravity, vapor pressure, Henry's Law constant (H), octanol/water partition coefficient (K_{ow}), and the organic carbon/water partition coefficient (K_{oc}). Table 5.2.1- lists the physicochemical properties of the organic chemicals of human-health and environmental concern identified in the various media at Plant 4. Section 6.0 discusses the media in which each of the COCs was identified.

5.2.1.1 Solubility

Solubility in water is the saturated concentration of a compound in pure water at a given temperature and pressure. Above this concentration, two phases exist: a saturated aqueous phase and a solid or a liquid phase (a nonaqueous phase liquid [NAPL]). Solubility in water is affected by temperature, salinity, dissolved organic matter, and pH (Lyman and others 1982). Compounds with high water solubility tend to be distributed to a wider extent, have low soil adsorption coefficients, have low bioconcentration factors, and are less likely to volatilize than compounds with low water solubility. Water solubility may also affect transformation by photolysis, hydrolysis, oxidation/reduction, and biodegradation (Howard 1990).

Table 5.2.1-1 Physicochemical Properties of Organic Chemicals of Concern Identified at Plant 4

Chemical	Solubility mg/L (°C)	Specific Gravity Unitless (°C)	Vapor Pressure mm (°C)	Henry's Law Constant atm · m ³ /mole (°C)	Log K _{ow}	Log K _{oc}
Acenaphthene	3.47 (25°)	1.0242 (90/4°)	1.55x10 ³ (25°)	1.5x10 ⁻⁴	3.92-4.33	1.25
Benzene	1,780 (20°)	0.8786 (20/4°)	76 (20°)	5.48x10 ⁻³ (25°)	2.13	1.92
Benzo(a)anthracene	0.057 (20°)	1.274 (20/4°)	22x10 ⁻⁴ (20°)	6.6x10 ⁻⁷	5.61-5.91	6.14
Benzo(a)pyrene	3.8x10 ⁻³ (25°)	1.351	5.49x10 ⁻⁴ (25°)	4.9x10 ⁻⁷ (25°)	5.81-6.50	5.60-6.29
Benzo(b)fluoranthene	0.014 (25°)	No Data Found	5x10 ⁻⁷ (20°)	1.2x10 ⁻⁵ (20-25°)	6.57	5.74
Benzo(k)fluoranthene	5.5x10 ⁻⁴ (25°)	No Data Found	9.59x10 ⁻¹¹ (25°)	1.04x10 ⁻³	6.85	6.64
Chrysene	0.006 (25°)	1.274 (20/4°)	6.3x10 ⁻⁷ (20°)	7.26x10 ⁻²⁰	5.60-5.91	5.39
cis-1,2-Dichloroethene	800 (20°)	1.28	200 (25°)	3.37x10 ⁻³	1.86	1.69
1,2-Dichlorobenzene	100 (20°)	1.305 (20/4°)	1 (20°)	1.2x10 ⁻³ (20°)	3.38	2.26-3.23
1,4-Dichlorobenzene	49 (22°)	1.458 (20/4°)	0.6 (20°)	1.5x10 ⁻³ (20°)	3.39	2.20
1,1-Dichloroethane	5,500 (20°)	1.174 (20/4°)	180 (20°)	5.87x10 ⁻³	1.79	1.48
1,1-Dichloroethene	400 (20°)	1.218 (20/4°)	500 (20°)	0.0301	2.13	1.81
trans-1,2-Dichloroethene	600 (20°)	1.26	340 (25°)	6.72x10 ⁻³	2.06	1.77
2,4-Dimethylphenol	4,200 (20°)	1.036 (20/4°)	0.062 (20°)	1.7x10 ⁻⁵ (20-25°)	2.30-2.50	2.07
Ethylbenzene	161 (25°)	0.867 (20/4°)	7 (20°)	8.44x10 ⁻³	3.15	1.98-2.41
Fluoranthene	0.265 (25°)	1.252 (0/4°)	0.01 (20°)	0.0169 (25°)	5.22	4.62
Freon 113	170 (25°)	1.56	270 (20°)	0.526 (25°)	3.16	No Data Found
Methylene Chloride	20,000 (20°)	1.3266 (20/4°)	349 (20°)	2.68x10 ⁻³	1.25	0.94

Table 5.2.1-1 (cont'd.) Physicochemical Properties of Organic Chemicals of Concern Identified at Plant 4

Chemical	Solubility mg/L (°C)	Specific Gravity Unitless (°C)	Vapor Pressure mm (°C)	Henry's Law Constant atm · m ³ /mole (°C)	Log K _{ow}	Log K _{oc}
2-Methylnaphthalene	24.6 (25°)	1.0058 (20/4°)	No Data Found	No Data Found	3.86-4.11	3.87-3.93
Methylphenol	24,500 (20°)	1.047 (20/4°)	0.24 (25°)	1.6x10 ⁻⁴	1.95	1.34
Naphthalene	30	1.152	0.82 (25°)	4.83x10 ⁻⁴	3.01-3.45	2.74-3.52
Phenanthrene	0.816 (21°)	1.179 (20/4°)	2.1x10 ⁻⁴ (20°)	2.56x10 ⁻⁴ (25°)	4.16-4.57	3.72-4.59
Pyrene	0.032 (24°)	1.271 (23/4°)	6.85x10 ⁻⁷ (25°)	1.09x10 ⁻⁵	4.88-5.32	4.66-5.13
Toluene	515 (20°)	0.867 (20/4°)	22 (20°)	5.94x10 ⁻³	2.69	2.06-2.18
1,1,1-Trichloroethane	4,400 (20°)	1.35 (20/4°)	100 (20°)	8x10 ⁻³	2.49	2.017-2.18
Trichloroethene	1,100 (25°)	1.4642 (20/4°)	60 (20°)	1.03x10 ⁻²	2.42	1.81-2.10
1,2,4-Trimethylbenzene	57 (20°)	0.88	No Data Found	No Data Found	No Data Found	No Data Found
1,3,5-Trimethylbenzene	No Data Found	0.865	No Data Found	No Data Found	No Data Found	No Data Found
Vinyl Chloride	1,100 (25°)	0.9121 (15/4°)	2,660 (25°)	1.07x10 ⁻³	1.38	0.39
m-Xylene	146 (25°)	0.864	6 (20°)	7.68x10 ⁻³	3.20	3.20
o-Xylene	175 (25°)	0.88	5 (20°)	5.1x10 ⁻³	2.77	2.11
p-Xylene	156 (25°)	0.86	6 (20°)	7.68x10 ⁻³	3.15	2.31

Sources:

- Howard, P.H., 1990, *Handbook of Environmental Fate and Exposure Data for Organic Chemicals*, Lewis Publishers, Inc., 2 volumes.
- Montgomery, J.H., and Walkom, L.M., 1990, *Groundwater Chemicals Desk Reference*, Lewis Publishers, Inc.
- U.S. Environmental Protection Agency (EPA), 1986, *Superfund Public Health Evaluation Manual*, EPA/540/1-88/001, Office of Solid Waste and Emergency Response Directive 9285.4-1.
- EPA, 1982, *Aquatic Fate Process Data for Organic Priority Pollutants*, Final Report, 407 pp.
- Vercheuren, K., 1983, *Handbook of Environmental Data on Organic Chemicals*, Van Nostrand Reinhold, Second Edition.

On the basis of their solubilities, benzene, 1,1-dichloroethane, 2,4-dimethylphenol, methylene chloride, methylphenol, 1,1,1-TCA, and TCE would be expected to be the most mobile of the organic COCs. Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and pyrene would be expected to be the least mobile (see Table 5.2.1-1).

Cosolvency is a process whereby the solubility of a solute in water increases when an organic solvent is present (Leinonen and MacKay 1973). Experimental results show that the cosolvent must be at concentrations greater than 5×10^{-3} on a mole fraction basis for the cosolvency effect to be significant.

5.2.1.2 Specific Gravity

Specific gravity, or specific density, is the ratio of the mass of a given volume of a compound at a specified temperature, to the mass of the same volume of water at a given temperature. The temperatures of the compound and of water are indicated in parentheses after the value for specific gravity (see Table 5.2.1-1). An immiscible compound with a specific gravity greater than 1 (a dense NAPL [DNAPL]) will sink in water, and an immiscible compound with a specific gravity less than 1 (a light NAPL [LNAPL]) will float on water.

Benzene, ethylbenzene, toluene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, vinyl chloride, and *m*-, *o*-, and *p*-xylenes, have specific gravities less than 1, and, therefore, will tend to form LNAPLs when their solubility in water is exceeded (see Table 5.2.1-1). The remaining chemicals in Table 5.2.1-1 have specific gravities greater than 1 and will tend to form DNAPLs when their solubility in water is exceeded.

5.2.1.3 Vapor Pressure

The vapor pressure is the pressure exerted by the vapor phase of a compound in equilibrium with the liquid or solid phase at a given temperature. Vapor pressure values provide a means of assessing the relative volatility of pure compounds. Vapor pressure data and solubility data are used to determine values of *H*, which describe the volatilization of chemicals from water.

Compounds with relatively low vapor pressures, high adsorption on solids, or high solubility in water are less likely to vaporize than compounds with high vapor pressures, low adsorption to solids, or low water solubility. The latter chemicals are less likely to biodegrade or hydrolyze but have a higher potential to undergo significant photolysis. Nonvolatile compounds are less frequently involved in significant atmospheric transport, so an analysis of their fate should focus on soil and water processes (Verschueren 1983).

Benzo(k)fluoranthene has the lowest vapor pressure, 9.57×10^{-11} millimeter (mm), of the organic COCs listed in Table 5.2.1-1. Vinyl chloride is the organic COC with the highest vapor pressure, 2660 mm at 25 degrees C.

5.2.1.4 Henry's Law Constant

Henry's Law constant, H, also referred to as the air/water partition coefficient, is the ratio of atmospheric concentration of a compound expressed in atmospheres (atm) to the solution concentration expressed in moles per cubic meter (mol/m^3). The larger the H value, the more the compound will tend to partition into the vapor phase. Compounds with an H value less than $10^{-7} \text{ atm}\cdot\text{m}^3/\text{mol}$ are essentially nonvolatile. Compounds with an H value between 10^{-7} and $10^{-5} \text{ atm}\cdot\text{m}^3/\text{mol}$ volatilize slowly. If a compound's H value lies between 10^{-5} and $10^{-3} \text{ atm}\cdot\text{m}^3/\text{mol}$, then volatilization is a significant transfer mechanism. Compounds with an H value greater than $10^{-3} \text{ atm}\cdot\text{m}^3/\text{mol}$ are considered to be highly volatile.

Chrysene is the only organic COC with an H value less than $10^{-7} \text{ atm}\cdot\text{m}^3/\text{mol}$ and, therefore, considered nonvolatile (see Table 5.2.1-1). The organic COCs expected to volatilize slowly include benzo(a)anthracene, benzo(a)pyrene, and methylphenol. Volatilization is considered a significant transfer mechanism for acenaphthene, benzo(b)fluoranthene, 2,4-dimethylphenol, naphthalene, phenanthrene, and pyrene. All remaining organic COCs have H values greater than $10^{-3} \text{ atm}\cdot\text{m}^3/\text{mol}$ and, therefore, are considered highly volatile. The process of volatilization is discussed further in Section 5.2.2.1.

5.2.1.5 Octanol/Water Partition Coefficient

The octanol/water partition coefficient, K_{ow} , is the ratio of a compound's concentration in octanol to its concentration in water in a two-phase (octanol and water) system. K_{ow} is measured at low solute concentrations where it is a weak function of solute concentration. At solute concentrations much greater than 0.01 moles per liter (mol/L), K_{ow} is a function of solute concentration (Lyman and others 1982). Because values of K_{ow} can span several orders of magnitude, K_{ow} is usually expressed in terms of the logarithm of K_{ow} ($\log K_{ow}$). K_{ow} is an indicator of a compound's hydrophobicity and can be correlated with soil/sediment adsorption coefficients and bioconcentration factors (Howard 1990). Compounds with K_{ow} values less than 10 ($\log K_{ow} < 1$) are considered relatively hydrophilic and tend to have high solubilities in water. Compounds with K_{ow} values greater than 10^4 ($\log K_{ow} > 4$) are very hydrophobic (Lyman and others 1982).

All of the organic COCs have $\log K_{ow}$ values less than 10 and, therefore, tend to have high solubilities in water (see Table 5.2.1-1). Benzo(k)fluoranthene has the highest $\log K_{ow}$ value, 6.85, and methylene chloride has the lowest $\log K_{ow}$ value, 1.25.

5.2.1.6 Organic Carbon/Water Partition Coefficient

The organic carbon/water partition coefficient, K_{oc} , is the ratio of the amount of a compound adsorbed per unit mass organic carbon in the soil or sediment to the concentration of the compound in solution at equilibrium. K_{oc} values are used in estimating the partitioning of a compound onto soil or sediment on the basis of empirical data, which indicates that adsorption of a compound often depends on the mass of organic carbon in the soil. For this reason, K_{oc} is often referred to as the soil/sediment partition coefficient. As with K_{ow} , K_{oc} values span several orders of magnitude and are usually expressed in terms of the logarithm of K_{oc} ($\log K_{oc}$).

5.2.2 Physicochemical Processes

Physicochemical processes include the physical, chemical, and biological mechanisms by which organic chemicals and inorganic constituents transform from one physical phase to another or degrade to form new compounds. The primary physicochemical processes impacting the environmental fate of the constituents at Plant 4 are discussed in the following sections.

5.2.2.1 Volatilization

Volatilization, the evaporative loss of a chemical, depends upon the vapor pressure, solubility, and diffusivity coefficients of the chemical. Volatilization is also dependent on environmental conditions (temperature, water depth, soil moisture, air flow rate over the surface, and humidity) and on modifying materials (absorbants, emulsions) that influence diffusion from the evaporative surface. The effect of a rise in temperature on volatilization is variable. In general, an increase in temperature usually increases the vapor concentration. However, for compounds for which adsorption is an endothermic process, an increase in temperature will decrease the vapor concentration (Lyman and others 1982). Air flow increases the volatilization rate by removing vapor from the surface faster than molecular diffusion. Volatilization decreases under conditions of low humidity because sorption is increased as soil water content is decreased.

Volatilization is an important process contributing material for airborne transport that may lead to the distribution of a chemical over wide areas. As discussed in Section 5.2.1.3, compounds with relatively low vapor pressures, high adsorptivity onto solids, or high solubility in water are less likely to vaporize and become airborne than chemicals with high vapor pressures or with less affinity for solution in water or adsorption to solids and sediments.

Volatilization at the interface between the capillary fringe and the unsaturated zone can be approximated by the value of H . Studies indicate that the value of H should be greater than approximately 0.005 to 0.024 atm·m³/mol for significant volatilization from an aquifer to the unsaturated zone to occur (Kerfoot 1988). A comparison of H values

can be used to predict that benzene, 1,1-DCA, 1,1-DCE, *trans*-1,2 DCE, ethylbenzene, fluoranthene, freon, toluene, 1,1,1-TCA, TCE, and vinyl chloride are the organic COCs with the greatest tendency for volatilization from the aquifer to the unsaturated zone (see Table 5.2.1-1).

5.2.2.2 Adsorption

Adsorption onto solids is an important aspect of compound transport because it reduces chemical mobility in both solution and vapor phases. Conversely, desorption from solids increases chemical concentration in solution and vapor phases. Adsorption may be fully or partially reversible. For weakly polar or nonionic compounds, soil moisture acts to displace the compounds from surfaces of soil particles increasing the concentration of the compounds in the soil gas. As the soil dries, weakly polar or nonionic compounds are sorbed onto the soil (Lyman and others 1982).

The mass of a compound adsorbed to the soil has been shown to be directly related to the soil particle surface area and organic matter content in the soil (Lyman and others 1982). In particular, the sorption of nonpolar organic compounds to soil is significantly affected by the organic carbon content of soils (Jury and Valentine 1986). At least 0.1 percent of organic carbon content (fraction organic carbon [f_{oc}] greater than 0.001) in aquifer sediments is required for carbon adsorption to be significant (Newsom 1985).

The amount of a given organic compound adsorbed to soils varies directly with its K_{ow} and inversely with its solubility in water (Newsom 1985; Karickhoff, Brown, and Scott 1979). Generally, for solute concentrations less than 0.01 millimolar, linear isotherms are produced, and the distribution coefficient, K_d , will describe partitioning between liquids and solids. Above the 0.01 millimolar concentration limit, sorption may be nonlinear, and Freundlich or Langmuir isotherms are needed to describe solute behavior. The empirically derived Freundlich equation is

$$S = K_d C^b \quad \text{Equation 5-1}$$

"where S is the mass of the solute species adsorbed or precipitated on the solids per unit bulk dry mass of the porous medium, C is the solute concentration, and K_d and b are coefficients that depend on the solute species, nature of the porous medium, and other conditions" (Freeze and Cherry 1979).

K_d can be related to the fraction organic carbon of the soil and to the octanol/water partition coefficient of the compound by the equation

$$K_d = f_{oc} K_{oc} \quad \text{Equation 5-2}$$

(Ward and others 1988).

For volatile halogenated organic compounds, K_d may also be predicted by

$$\log K_d = 0.72 \log K_{ow} + \log f_{oc} + 0.5 \quad \text{Equation 5-3}$$

(Ward and others 1988).

Laboratory studies have documented that a large proportion of adsorption of organic compounds takes place on silt- and clay-sized particles. The quantity of material adsorbed is directly related to the surface area of the solid or to the particle size and particle size distribution and associated organic carbon content (Karickhoff and others 1979). It is difficult to distinguish the effects of adsorption of organic compounds on the mineral fraction from the adsorption by the mass-fraction organic carbon. No quantitative method for determining adsorption of organic COCs onto mineral surfaces has yet been devised.

When a solute adsorbs to a solid, its velocity with respect to the velocity of groundwater is retarded. The degree of retardation is described by the retardation factor, R , where

$$R = 1 + \frac{\rho_b K_d}{n} = \frac{v}{v_c} \quad \text{Equation 5-4}$$

and ρ_b is the bulk mass density, n is the porosity, K_d is the distribution coefficient, and v/v_c is the ratio of velocities of a conservative tracer to a sorbing solute. A retardation factor equal to 1 means that a solute velocity is not retarded (the solute velocity equals groundwater velocity).

Attempts were made to quantify K_d values using field measurements for various contaminants identified in the alluvial aquifer at Plant 4. Contaminant concentrations in soil samples collected at various depths during drilling and in groundwater during

subsequent well sampling were used to calculate K_d estimates using the following equation:

$$K_d = \frac{C_s}{C_L} \quad \text{Equation 5-5}$$

where C_s is the contaminant concentration in micrograms in the solid phase per gram of solid, and C_L is the contaminant concentration in the liquid phase in micrograms per liter of liquid (Equation 12.33; Domenico and Schwartz 1990).

However, the resulting K_d estimates were highly variable across the site, and an accurate estimate could not be obtained. This result is not surprising because Equation 5-5 assumes the concentrations in the discrete solid and liquid phases are known. However, complete separation of the solid and liquid phases prior to analysis is logistically impossible. As a result, only a total contaminant concentration within the coexisting solid and liquid phases is measured. The mass of contaminant contributed to the total concentration by residual water in the soil can be significant, especially for weakly adsorbed (low K_d) compounds. Correction of Equation 5-5 for the contaminant contributed by water trapped within the soil requires moisture content measurements, which were not performed during soil analysis.

Although quantitative estimates of K_d could not be obtained, K_{oc} values can be used to qualitatively assess both K_d and R values for the organic COCs listed in Table 5.2.1-1. Given a mean f_{oc} value for soil at the site, Equation 5-2 indicates that K_d is directly proportional to K_{oc} . Similarly, given a porosity and bulk mass density of the soil, Equation 5-4 indicates that R is primarily influenced by K_d . Therefore, chemicals with high K_{oc} values will exhibit higher K_d and R values than chemicals with low K_{oc} values. Of the chemicals listed in Table 5.2.1-1, vinyl chloride ($K_{oc} = 0.39$) is expected to have the lowest K_d and R values, and benzo(k)fluoranthene is expected to have the highest K_d and R values.

5.2.2.3 *Photolysis*

Photolysis is a chemical transformation process whereby a compound is broken down directly by absorbing a photon of light or indirectly by reacting with a sensitized humic substance or with a photochemical oxidant, such as hydroxyl and peroxy radicals and singlet oxygen (Swann and Eschenroeder 1983). The rate of photolysis is affected by the organic compound's photochemical reactivity, its extent of light absorption, and the properties of the environment, such as the intensity and spectrum of solar radiation. For these reasons, photolysis is generally important only in surface waters, soils, and the atmosphere.

The following organic COCs are capable of undergoing direct photolysis (Howard 1990; EPA 1982):

acenaphthene	chrysene	naphthalene
benzo(a)anthracene	2,4-dimethylphenol	phenanthrene
benzo(a)pyrene	fluoranthene	pyrene
benzo(b)fluoranthene	2-methylnaphthalene	
benzo(k)fluoranthene	methylphenol	

Several of the remaining organic COCs listed in Table 5.2.1-1 are capable of undergoing indirect photolysis. For example, benzene, ethylbenzene, and toluene will react with photochemically derived hydroxyl radicals with half-lives of 13.4 days, 0.5 hours to 2 days, and 3 hours to 1 day, respectively. Products of benzene photolysis include phenol, formic acid, nitrophenols, nitrobenzene, and peroxyacetyl nitrate. Products of ethylbenzene photolysis include ethylphenol, benzaldehyde, acetophenone, and *m*- and *p*-ethyl-nitrobenzene. Products of toluene photolysis include nitrophenols, nitrocresols, nitrotoluenes, cresols, benzaldehyde, and benzyl nitrate (Howard 1990). TCE, *cis*- and *trans*-1,2-DCE, and 1,1-DCE also react with photochemically derived hydroxyl radicals with half-lives of up to 8 days. TCE photolysis produces phosgene, dichloroacetyl chloride, and formyl chloride; photolysis of *cis*- and *trans*-1,2-DCE produces formyl chloride; and photolysis of 1,1-DCE produces chloroacetyl chloride, phosgene, formaldehyde, formic acid, hydrochloric acid, carbon monoxide, and nitric acid (Howard 1990).

5.2.2.4 Hydrolysis

Hydrolysis refers to the reaction of an organic compound with water resulting in the formation of a new carbon-oxygen bond and the elimination of a leaving group (chloride, bromide, phenoxide, etc.) (Lyman and others 1982). At environmental pHs (pH 5 to 9), hydrolysis may be significant for alkyl halides, amides, carbamates, carboxylic acids, epoxides and lactones, phosphate esters, and sulfonic acid esters (Howard 1990). Data are not available on the hydrolytic half-lives of the organic COCs listed in Table 5.2.1-1; however, these compounds are expected to be resistant to hydrolysis in natural waters (EPA 1979; Howard 1990).

5.2.2.5 Oxidation/Reduction

Organic compounds generally undergo oxidation reactions; however, halogenated compounds tend to undergo reduction reactions because of the electronegative nature of the halogen atoms. Metals may undergo oxidation or reduction reactions. For example, hexavalent chromium may be reduced to trivalent chromium, or trivalent chromium may be oxidized to hexavalent chromium. In either case, the chromium cation may combine with anions in the groundwater or with negatively charged particles and precipitate out of solution.

5.2.2.6 Biotransformation

Biotransformation converts organic compounds into new organic compounds that may be either innocuous or toxic. If inorganic compounds are formed, the conversion is termed mineralization. Biotransformation can occur through the action of microorganisms attached to soil particles or suspended in groundwater (Kobayashi and Rittman 1982). The potential for biodegradation of a particular compound depends on the types and number of microorganisms present in the soil, the physiological capabilities of the microorganisms, the acclimatization of the microorganisms, the chemical character and concentration of the compound, and the geochemical environment of the unsaturated or saturated zone.

Chemical characteristics that affect biodegradability include the compound's solubility, vapor pressure, and K_{ow} . Insoluble compounds are not readily available to organisms for biodegradation (Kobayashi and Rittman 1982). High concentrations of a compound may be toxic to organisms while low concentrations may yield insufficient energy to sustain continued microbial growth (Wilson and others 1983). Trace concentrations of secondary substrates may be transformed during the metabolism of primary substrate present at a higher concentration.

Factors present in the geochemical environment include the dissolved oxygen content, oxidation-reduction potential, temperature, pH, availability of other compounds and of nutrients, salinity, particulate matter, and presence of competing organisms (Kobayashi and Rittman 1982).

Studies using natural soil samples demonstrated that benzene could be mineralized (EPA 1979) and that toluene may be used as a cosubstrate during the aerobic, oxidative degradation of benzene. Ethylbenzene also biodegrades under aerobic conditions. Results of field experiments using in situ biodegradation columns installed in anaerobic, leachate-impacted aquifers at North Bay, Ontario, and at Canada Forces Base Borden indicated that several aromatic hydrocarbons, including toluene, ethylbenzene, and 1,2,4-trimethylbenzene, also biodegrade under anaerobic conditions (Acton and Barker 1992).

TCE is degradable under anaerobic and aerobic conditions. The anaerobic pathway is one of reductive dechlorination; TCE is transformed to 1,1-DCE, *cis*- and/or *trans*-1,2-DCE, which may then be transformed to vinyl chloride (Kobayashi and Rittman 1982; Vogel and McCarty 1985). Aerobic degradation is thought to lead to the formation of carbon dioxide and nonvolatile products (Nelson and others 1986).

5.3 Contaminant Transport

This section presents a discussion of the mechanisms, rates, and impacts of contaminant transport via the air, surface water, and groundwater pathways at Plant 4. The following sections discuss the three transport pathways separately and include descriptions of the physical transport mechanisms associated with each pathway and an assessment of the impact that each pathway has on contaminant migration at Plant 4.

5.3.1 Contaminant Migration in Groundwater

As discussed in the risk assessment (see Section 6.0), the groundwater pathway poses the greatest risk, in terms of human health, of the contaminant pathways active at Plant 4. The physical mechanisms influencing the transport and fate of contaminants in groundwater at Plant 4 are discussed below.

5.3.1.1 Transport Mechanisms

There are three mechanisms of contaminant transport in groundwater: advection, mechanical dispersion, and molecular diffusion. Advection is the movement of solute by the bulk flow of groundwater, such that the component of contaminant transport can be described by the average velocity of groundwater. As discussed in Section 3.8.1.2, contaminant transport via advection occurs at a rate equal to the average linear velocity of the groundwater. In a uniform flow field (parallel flow lines), advective transport does not alter the size and shape of a particular plume. In a non-uniform flow field (converging or diverging flow lines), advective transport will likely alter plume geometries. For example, advective transport will cause plumes to spread laterally under conditions of diverging flow, possibly resulting in dilution of contaminant concentrations.

Advection is the dominant component of groundwater solute transport in most flow systems. Exceptions include flow systems that are characterized by extremely *small* flow velocities (i.e., low-gradient, massive clay formations) or extremely *variable* flow velocities (i.e., fractured rock formations). Because the upper-zone and Paluxy Aquifer flow systems are not characterized by these conditions, advection is expected to be the dominant means of groundwater contaminant transport at Plant 4.

Mechanical dispersion is the mixing process that occurs within a plume as a result of the complex nature of groundwater flow through porous media. Mechanical dispersion causes contaminant mass to spread laterally and thereby contributes to the dilution of contaminant plumes. The spreading is caused by the variability in groundwater velocities at the pore scale (because of grain roughness, path tortuosity, and pore-size variability) and at the macro scale (because of small-scale heterogeneity). Mechanical dispersion is proportional to the average linear velocity of groundwater and the concentration gradient for the contaminant. The coefficient of proportionality is termed the dispersivity, an empirical parameter. Dispersivity values are obtained from literature, tracer tests, or

transport model calibration. Mechanical dispersion does contribute to the movement of contaminants in the Plant 4 groundwater system.

Molecular diffusion is the third mechanism of contaminant transport in groundwater. Molecular diffusion is the movement of solute in water resulting from the random motion of the solute particles and concentration gradients in the solution. Molecular diffusion generally leads to the dilution of contaminant plumes; however, the associated dilution is only significant in settings where groundwater velocities are very low. Molecular diffusion is not expected to be a significant transport mechanism in the Plant 4 groundwater system.

5.3.1.2 Effect on Plant 4 Contaminants

The results of the baseline risk assessment presented in Section 6 indicate that the majority of the health risk associated with the RI/FS waste sites at Plant 4 is attributable to three groundwater contaminants. These contaminants are, in order of decreasing risk, TCE, 1,2-DCE (*cis* and *trans* isomers), and chromium(VI). The distribution of these and other groundwater contaminants is discussed in Section 4.5. The following discussion describes the transport of TCE, 1,2-DCE, and chromium(VI) in the upper-zone flow system, the Walnut Formation Aquitard, and the Paluxy Aquifer.

Contaminant Transport in the Upper-Zone Flow System

The discussion presented in Section 4.5 describes three contaminant plumes within the upper-zone flow system: the East Parking Lot Plume, the West Plume, and the North Plume. Upper-zone contaminant transport within each of these plumes is discussed separately below. Each discussion addresses likely source areas, contaminant velocity estimates, contaminant discharge areas, travel times to discharge areas, and qualitative assessments of plume longevity.

The East Parking Lot Plume

The East Parking Lot Plume is shown in Figures II-12 through II-18. The plume contains varying concentrations of several contaminants. Concentrations of TCE are presented in Figures II-12 and II-13. Concentrations of 1,2-DCE and chromium are presented in Figures II-14 and Figure II-18, respectively.

The near-surface source areas for TCE, the most widespread compound in this plume, appear to be the south end of the Parts Plant (where large TCE vapor degreasers are used), Chrome Pit No. 3, and possibly Chrome Pits Nos. 1 and 2. TCE reaching groundwater in these source areas migrates primarily northeast beneath the East Parking Lot. The only possible exception to this migration trend occurs in the vicinity of Chrome Pit No. 3. As shown on the overlay map of groundwater elevation contours (see Figure II-24), Chrome Pit No. 3 and the associated high TCE concentrations are located

west of the groundwater divide in the vicinity of Building 12. It appears from this information that some TCE could be advected northwest from Chrome Pit No. 3 toward Meandering Road Creek. However, analytical results obtained during the RI and during previous investigations (see Figures II-12 and II-13) show that significant northwesterly migration of TCE has not yet occurred in this area.

Comparison of 1989 and 1991 TCE concentrations (see Figures II-13 and II-12, respectively) indicates that the distribution of TCE in the East Parking Lot Plume did not change significantly over the 3-year period. This distribution appears to be the result of a combination of (1) nonaqueous-phase TCE flowing northeast along the base of the paleo-channel beneath the East Parking Lot, and (2) aqueous-phase (dissolved) TCE advected east and southeast by the bulk movement of groundwater flowing beneath the East Parking Lot. This two-part transport process is illustrated in Figures II-12 and II-13.

The migration of TCE as a nonaqueous phase is suggested by several features that are noted by Cohen and Mercer (1993) as being indicators of DNAPL. One of these indicator features is the presence of TCE in groundwater at concentrations that equal or exceed one percent of the solubility limit for TCE. For example, Figures II-12 and II-13 show a total of six different monitoring wells in the East Parking Lot with concentrations in excess of 10,000 $\mu\text{g/L}$ (solubility limit is approximately 1,100,000 $\mu\text{g/L}$). Jacobs (December 1992) also reported TCE values as high as 180,000 $\mu\text{g/L}$ in October of 1992 (well F-218). Another feature suggesting the migration of nonaqueous-phase TCE is the location of the very highly-contaminated monitoring wells. As shown in Figures II-12, II-13, and II-25, all of the wells with TCE concentrations exceeding 10,000 $\mu\text{g/L}$ are located in the paleo-channel that was eroded into the competent rock beneath the East Parking Lot. This distribution of TCE is consistent with the tendency for DNAPLs to migrate downslope along low-permeability rock or sediment strata. Lastly, the apparent migration of DNAPL seems to terminate in the vicinity of wells HM-82 and HM-94. In this area, there appears to be a shallow, localized depression in the competent bedrock (see lithologic logs for nearby borings in Appendices A-2 and K), and this depression is apparently acting as a collection point for DNAPL.

Taken together, the East Parking Lot TCE data suggest that a significant mass of nonaqueous-phase TCE has migrated from the Building 181/182 area to the northeast where the DNAPL migration apparently terminates in a shallow bedrock depression near wells HM-82 and HM-94. This DNAPL migration appears to be continuing as concentrations are again increasing in wells near Building 181 (Jacobs, December 1992). This migration of nonaqueous-phase TCE has left and will continue to leave a distribution of residual DNAPL that is spread over the entire migration route. This residual DNAPL then acts as a subsurface source area for dissolved TCE that is subsequently advected to the east and southeast via groundwater flow (Figures II-12 and II-13).

TCE concentrations for wells in the East Parking Lot and Building 181/182 areas are shown as a function of time in Figures 5.3.1-1 through 5.3.1-3. Figure 5.3.1-1 shows relatively high concentrations between 1,000 and 10,000 $\mu\text{g/L}$ up through 1990, when concentrations increase to as high as 820,000 $\mu\text{g/L}$ at F-218. The results suggest that the source area is slowly contributing contamination to the groundwater from residual DNAPL that is trapped in pore spaces by interfacial tension. The increase to 820,000 $\mu\text{g/L}$ at F-218 in 1993 indicates renewed DNAPL migration, which is most likely the result of an apparent TCE release discovered in June of 1991.

Figure 5.3.1-2 shows TCE concentrations up to 75,000 $\mu\text{g/L}$ for three wells located in or southeast of the paleo-channel. The concentrations in HM-88 and HM-89 are likely associated with residual DNAPL that was left in pore spaces during earlier migration of non-aqueous phase TCE along the paleo-channel. The increase after 1990 in concentrations at HM-088 indicate this well has been impacted by DNAPL migration following the 1990-1991 TCE release. The time series for HM-87 shows that this well is located in an area dominated by advective-dispersive transport of dissolved TCE which originated along the paleo-channel migration path of non-aqueous TCE.

The temporal behavior of TCE concentrations in the vicinity of the window area is shown in Figure 5.3.1-3. At HM-94, located in the bedrock depression that defines the window area, concentrations are relatively high (indicative of DNAPL) and steady. This trend supports the hypothesis that DNAPL migration terminates and forms a subsurface pool in the bedrock depression. The DNAPL pool then acts as a new source area for dissolved TCE migration in the upper-zone and into the Paluxy Formation. At HM-86, located 450 feet south of HM-94, the Walnut Formation is thicker (six feet) and extends to a higher elevation. Figure 5.3.1-3 shows that concentrations at HM-86 are slowly decreasing after an increase in late 1986. This trend suggests that the source for TCE in this part of the plume is residual DNAPL left in the paleo-channel during earlier migration of a DNAPL slug. The declining trend should continue until DNAPL currently in the vicinity of F-218 reaches the northeast end of the paleo-channel that is situated upgradient of HM-86.

The low concentrations at HM-86 may also reflect low permeability deposits in this area which tend to deflect and slow the migration of TCE-laden water migrating from the suspected DNAPL zone.

Examination of the northern extent of the East Parking Lot Plume (see Figures II-12 and II-13) and the overlay map of groundwater elevation contours (see Figure II-24) reveals that TCE is found in wells that are not located along flow lines originating in the apparent source areas. Examples include wells HM-117, HM-118, HM-119, and HM-121. Contamination in these wells could have originated at the apparent source areas only if (1) local groundwater flow directions differ from those indicated in the groundwater elevation contour map or (2) cross-gradient transport has occurred as a result of mechanical dispersion. The configuration of the bedrock surface shown in

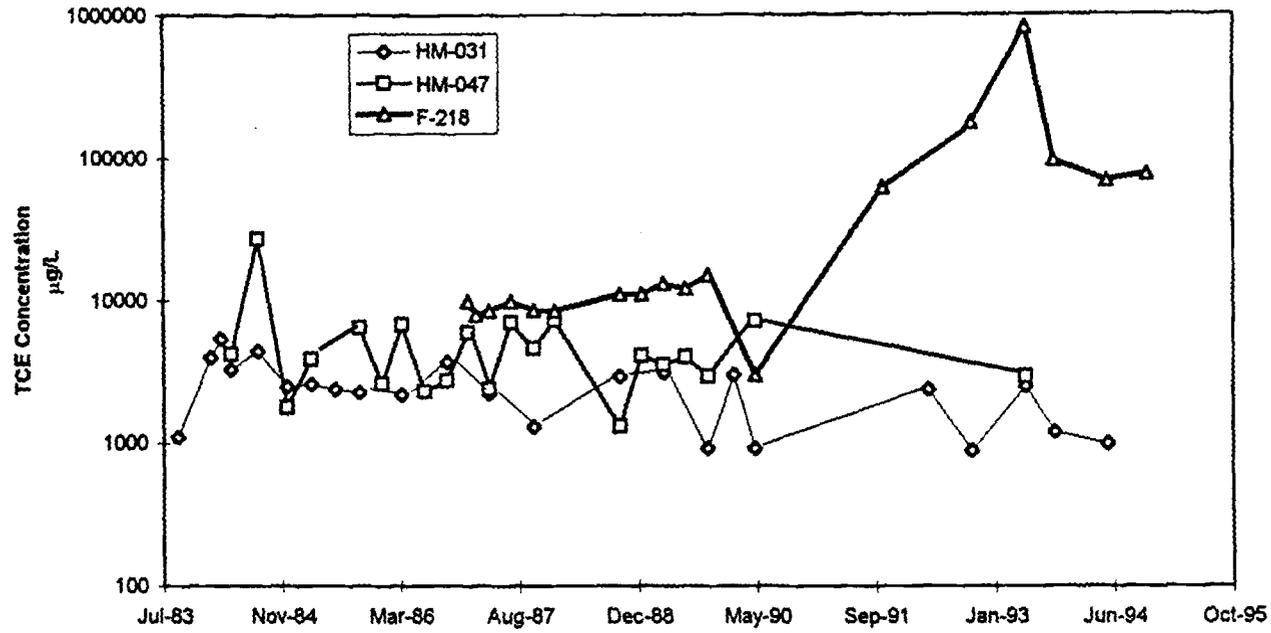
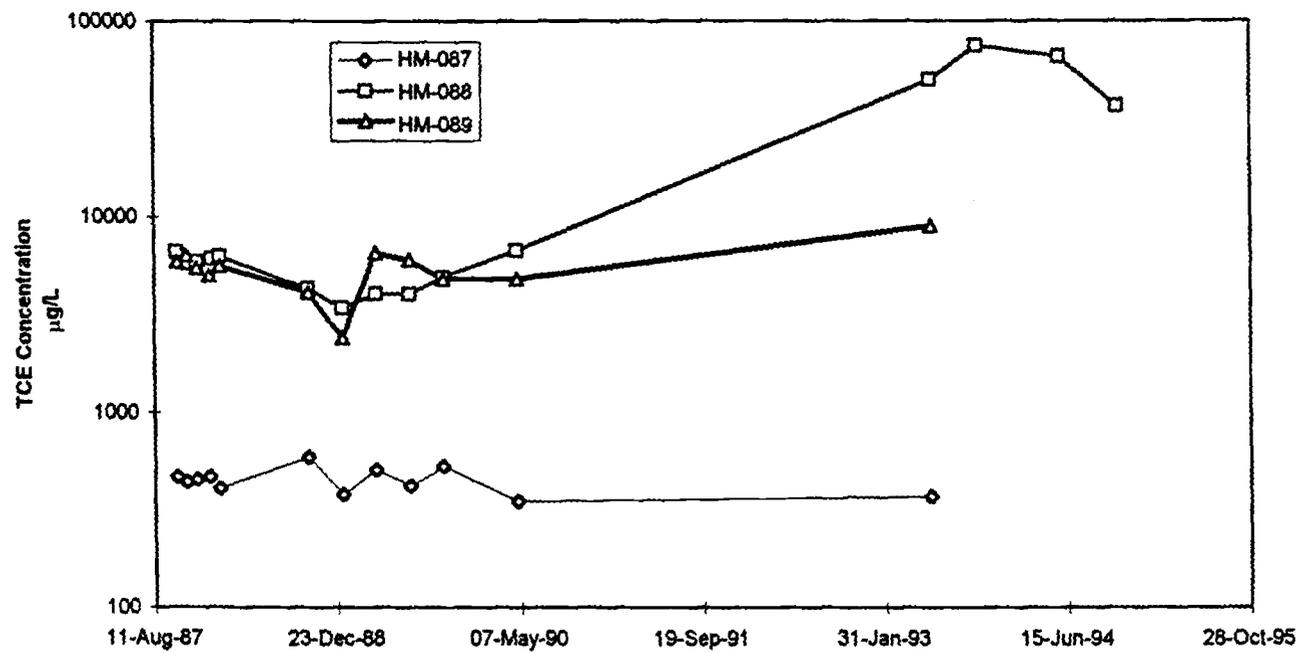
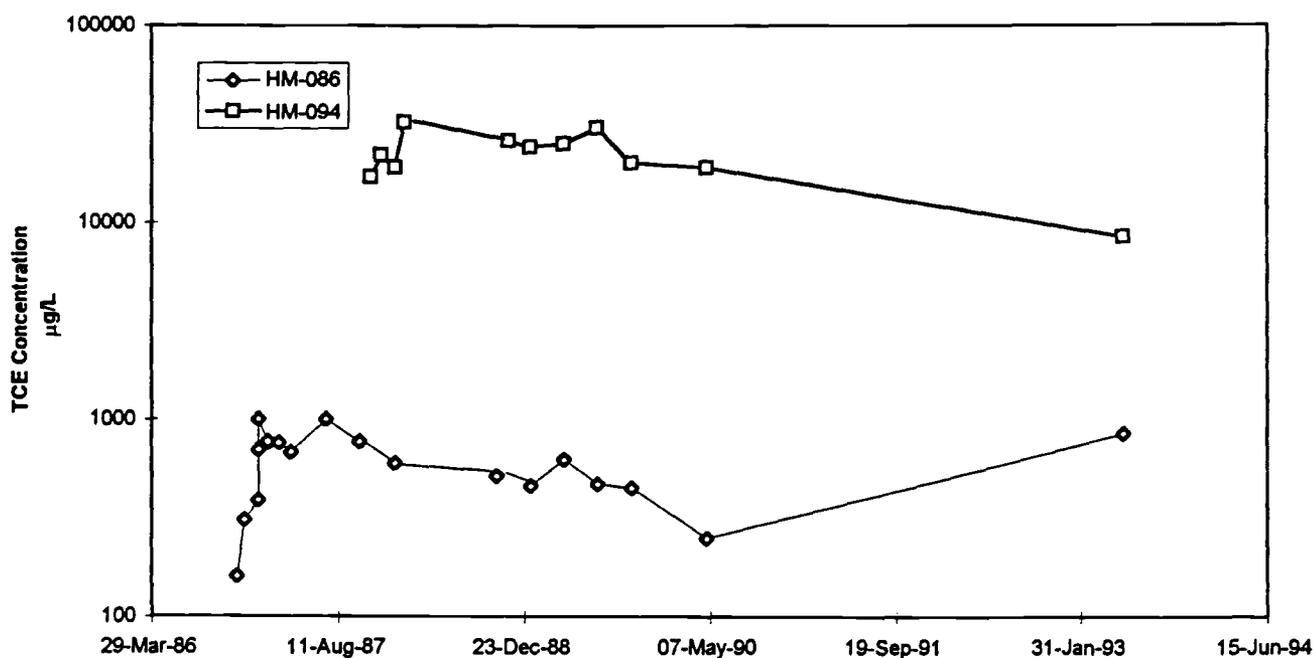


Figure 5.3.1-1 Chemical Time-Series for Upper-Zone TCE in Source Area of the East Parking Lot Plume.



HM-88 is located in the bedrock Paleo-Channel. HM-87 and HM-89 are located southeast of the Paleo-Channel in an area dominated by dissolved contaminant transport.

Figure 5.3.1-2 Chemical Time-Series for Upper-Zone TCE in the Central East Parking Lot Area.



HM-94 is located in the window area bedrock depression; HM-86 is located south of the window area.

Figure 5.3.1-3 Chemical-Time Series for Upper-Zone TCE in the Vicinity of the Window Area

Figure II-24 suggests that a limb of the bedrock channel may extend in a northeasterly direction from the window area toward well HM-121. Preferential flow would be expected along this limb of the channel because higher transmissivities are expected within the channel limb than in the surrounding bedrock. However, evaluation of local groundwater flow directions and refinement of bedrock contours require more resolution than existing data will allow. The second possibility listed above, cross-gradient transport resulting from mechanical dispersion, is considered unlikely because the magnitude of cross-gradient transport required to achieve the observed distribution would have to exceed the downgradient advective *and* the dispersive transport.

The most likely explanation for the TCE contamination identified in the northern portion of the East Parking Lot Plume is that it originated at FDTA-2 in the West Plume. Figures II-12 and II-13 show high concentrations of TCE at F-211, HM-29, and HM-51. These wells define a southeast-trending, high-concentration lobe of the West Plume TCE distribution. Examination of Figures II-25 and 3.8.1-1 show that the high-concentration lobe defined by these three wells overlies a shallow, east-trending channel in the competent bedrock. As shown by Figure 3.8.1-2, the bedrock channel dips in a direction that is opposite the direction of groundwater flow. This combination of hydrogeology and

contaminant distribution again suggests the possibility of DNAPL migration. If nonaqueous phase TCE has migrated southeastward in the shallow bedrock channel, it would have passed beneath the groundwater divide that forms the boundary between the East Parking Lot Plume and the West Plume. Once east of this flow divide, dissolved TCE would migrate east and contribute to the formation of the northern portion of the East Parking Lot Plume. This hypothesis is supported by the "non-detects" obtained for TCE at HM-57, HM-93, and W-152 (Figures II-12 and II-13); these three wells are located between the migration pathways originating at the Building 181/182 and FDTA-2 source areas.

As shown in Figure II-13b, the downgradient extent of the East Parking Lot Plume extends onto CAFB. It is apparent from this figure that TCE source areas are located on CAFB near the north apron, Landfill 6 north of Farmers Branch Creek, and Landfills 4 and 5.

The compound 1,2-DCE is the second most common contaminant found in the East Parking Lot Plume (see Figure II-14). The distribution of 1,2-DCE and the absence of a clearly defined, high-concentration area suggest that 1,2-DCE has not originated from a localized above-ground source area. Rather, it appears likely that the distribution of 1,2-DCE has resulted largely from the biodegradation of TCE.

The most probable source areas for chromium found in the East Parking Lot Plume are Chrome Pits Nos. 1, 2, and 3 (see Figure II-18). Although the data were reported as total chromium, it is assumed that the majority of the dissolved chromium in the groundwater is hexavalent chromium [chromium(VI)] because chromium(VI) compounds, such as chromic acid used in electroplating processes, are highly soluble in water (solubility of CrO_3 in cold water is 617 mg/cm^3 [Lide 1990]).

Contaminant velocities in the East Parking Lot Plume are governed largely by the average linear velocities of upper-zone groundwater. As shown in Table 3.8.1-4, estimates of average linear velocities in the upper-zone flow system range from 0.05 to 0.11 foot per day. Higher velocities, and therefore more rapid advection of contaminants within the plume, are anticipated in areas that contain significant gravel deposits such as the East Parking Lot paleochannel.

Because of the tendency for organic compounds to adsorb onto solid particles (see Section 5.2.2.2), the actual contaminant velocities of TCE and 1,2-DCE are less than the groundwater velocities. Under adsorption conditions, the average contaminant velocity, \bar{v}_c , is given by Equation 5-4. As noted in Section 5.2.2.2 (see Equation 5-5), defensible estimates of the distribution coefficient, K_d , were not obtained from soil and groundwater analytical results. However, estimates of contaminant retardation as a result of adsorption can be obtained using parameter estimates from published data. The distribution coefficient is estimated from Equation 5-2. On the basis of the following

estimates for parameters in Equations 5-2 and 5-4, the retardation coefficients, R, for TCE and 1,2-DCE are approximately 13 and 6, respectively:

- Bulk density: $\rho_b = 1.86 \text{ g/cm}^3$ (Freeze and Cherry 1979, Equation 8.26)
- Porosity: $n = 0.3$ (dimensionless) (Section 3.8)
- Organic carbon content: $f_{oc} = 0.017$ (dimensionless)(Mercer 1988; Jury and others 1983)
- Organic carbon-water partition coefficient for TCE: $K_{oc} = 126 \text{ mL/g}$ (EPA 1986, *Superfund Public Health Evaluation Manual*)
- Organic carbon-water partition coefficient for *cis*-1,2-DCE: $K_{oc} = 49 \text{ mL/g}$ (EPA 1986)
- Organic carbon-water partition coefficient for *trans*-1,2-DCE: $K_{oc} = 59 \text{ mL/g}$ (EPA 1986)

Because the *cis* isomer of DCE is more prevalent than the *trans* isomer, the retardation coefficient was based on the octanol-carbon partition coefficient, K_{oc} , value for *cis*-1,2-DCE, leading to a conservative estimate for overall retardation of 1,2-DCE.

The estimates for TCE and 1,2-DCE contaminant velocities, shown in Table 5.3.1-1, are derived by scaling the average linear groundwater velocities (see Table 3.8.1-4) by their respective retardation coefficients.

Table 5.3.1-1 Estimates of Retarded Contaminant Velocities for TCE and 1,2-DCE in the East Parking Lot Plume

Compound	Minimum Average Linear Velocity (feet per day)	Maximum Average Linear Velocity (feet per day)	Retardation Coefficient (R)	Minimum Retarded Velocity (feet per day)	Maximum Retarded Velocity (feet per day)
TCE	0.05	0.17	14	0.004	0.01
1,2-DCE	0.05	0.17	6	0.008	0.03

The estimates shown in Table 5.3.1-1 suggest that 1,2-DCE is more readily transported by the flowing groundwater than TCE. However, it appears that contaminant velocities obtained from this simple analysis are too low to account for the axial length of the East Parking Lot Plume. For example, the total migration distance for contaminants transported from near Building 182 to the window area and then south to the Landfill No. 5 area is in excess of 7,000 feet. If migration is assumed to have begun in 1940 and continued for the subsequent 50 years, the average contaminant velocity would be in excess of 7,000 feet per 50 years, or 0.4 feet per day. This estimate exceeds the maximum retarded velocity estimate shown in Table 5.3.1-1 (0.03 ft/d) by a factor greater than 13.

The discrepancy observed in contaminant velocity is most likely the result of two factors. The first concerns the high TCE concentrations reported in the paleochannel area, which suggest the presence of DNAPL. If TCE is present in this channel as pure-phase product, then the past migration of this product would have been governed by the topography of the paleochannel (relatively steep as shown in Figure II-25) and the high intrinsic permeability of the basal sediments (mostly gravel). This combination of steep bedrock slopes and high intrinsic permeability could produce high DNAPL migration rates in the vicinity of the paleochannel and the window area.

The second factor concerns the maximum average linear velocity calculated on the basis of the logarithmic mean of the hydraulic conductivity, K (see Table 3.8.1-4). The logarithmic mean K does not account for the relatively large but localized areas of basal gravel deposits in which higher K values are expected. The discrepancy in contaminant velocity estimates described above suggests that the localized gravel deposits have played a significant role in the evolution of the East Parking Lot Plume. The impact of localized heterogeneity on flow and transport are being addressed in the site-scale modeling of the flow system.

For chromium(VI), retardation from adsorption is minimal because of the high solubility of this ion. The transport velocity for chromium is therefore approximately equal to the average linear velocity of the groundwater. However, Figure II-18 shows that the extent of chromium in the East Parking Lot Plume is not equal to that of TCE or 1,2-DCE. This is most likely because chromium transport occurs at rates nearly equal to the average linear velocity of the groundwater, while TCE transport appears to have been accelerated as a result of DNAPL flow along the axis of the paleochannel. It is also possible that chromium(VI) was introduced to the groundwater system after the introduction of TCE.

The ultimate discharge point for the East Parking Lot Plume is the West Fork of the Trinity River. However, the downgradient extent of the plume has not been defined. Consequently, the travel time required for the plume to reach the river cannot be accurately predicted. Using the contaminant velocity of 0.4 feet per day obtained above, the travel time from well CAFB-LF05-19 to the West Fork of the Trinity River is approximately 40 years. The time required for the plume to reach the river will likely be less than 40 years because the plume is known to extend beyond well CAFB-LF05-19.

The West Plume

The West Plume is shown in Figures II-12 through II-18. TCE concentrations are presented in Figures II-12 and II-13; concentrations of 1,2-DCE and chromium are presented in Figures II-14 and II-18, respectively.

There are five source areas that appear to be contributing to groundwater contamination in the West Plume. These source areas and the contaminants they are likely contributing are as follows:

- FDTA-2: chlorinated solvents, VOCs, and chromium
- Landfill No. 1: chlorinated solvents, VOCs, semi-VOCs, and possibly chromium
- Landfill No. 3: chlorinated solvents, VOCs, semi-VOCs, and possibly chromium
- FSA-1: VOCs
- Tank 19: 2-butanone, and possibly VOCs and semi-VOCs

The most contaminated sections of the West Plume are associated with two of the source areas, the central portion of Landfill No. 3 and FDTA-2 (see Figures II-12, II-13, and II-14).

In Landfill No. 3, DNAPL was detected in wells F-214, HM-38, and W-130. All three of these wells are located in a small depression or channel incised into the Walnut Formation (see Figure II-25). This depression apparently serves as a collection point for TCE that may have been disposed in the landfill. A sample of DNAPL was collected from well F-214 in the spring of 1991. Results of a qualitative analysis performed on the sample indicated that the DNAPL layer in well F-214, which has been reported to be as much as 3 feet thick, consists of 64 percent TCE, 23 percent toluene, and smaller percentages of several other VOCs.

In the vicinity of FDTA-2, TCE concentrations as high as 340,000 $\mu\text{g/L}$ (Hargis + Associates 1989d) have been reported at well HM-51. The magnitude of these concentrations indicates that TCE is likely present as pure product. TCE concentrations on the order of thousands of micrograms per liter are also found in an elongate area extending southeast of HM-51 to F-211 and HM-29 (see Figures II-12 and II-13 and Hargis + Associates 1989d).

The compound 1,2-DCE has been detected at concentrations of 69,000 and 80,000 $\mu\text{g/L}$ in wells HM-21 and HM-51, respectively, suggesting that solvent-grade 1,2-DCE may have been burned at FDTA-2 and disposed in Landfill No. 3. Lower concentrations of 1,2-DCE, found throughout the rest of the plume, are most likely the result of TCE degradation.

Chromium has been found at concentrations below 50 $\mu\text{g/L}$ throughout much of the West Plume (see Figure II-18 and Hargis + Associates 1989b). However, chromium concentrations of 50, 151, and 105 $\mu\text{g/L}$ have been reported at wells HM-20, F-215, and HM-29, respectively. These higher concentrations are not readily associated with any known waste site but coincide with the location of elevated TCE concentrations extending southeast of HM-51 and FDTA-2. This correlation is discussed below.

The direction of groundwater transport of dissolved contaminants in the West Plume is predominantly to the west and southwest (see Figure II-24). Although the hydraulic gradient is relatively small over much of the plume (evidenced by the lack of contour lines), the westerly flow direction was confirmed by contouring water-level elevations at a 2-foot contour interval. Spot checking of individual groundwater elevations (see Appendix D-1) also confirms the westerly flow direction.

Given the presence of westerly groundwater flow and transport, and the observation that FDTA-2 is a likely source for TCE contamination, the apparent southeasterly migration of TCE from FDTA-2 (see Figures II-12 and II-13) appears anomalous. One explanation for this apparent anomaly is provided by Figure II-25, which shows a bedrock depression or trough extending southeast and east of FDTA-2. As noted above, the high TCE concentrations at HM-51 indicate that DNAPL TCE entered the upper-zone flow system in the FDTA-2 area. After reaching the bedrock surface, this DNAPL has apparently flowed into the bedrock channel, moving in a southeasterly direction relative to FDTA-2. Along this migration route, residual DNAPL left at the base of the upper-zone flow system contributes dissolved TCE to the overlying groundwater, resulting in the contaminant distribution shown in Figures II-12 and II-13. The lower concentrations of TCE found in downgradient portions of the West Plume can be explained by westerly and southwesterly advection of TCE that was derived from the elongate DNAPL migration path.

This two-component migration hypothesis for TCE originating at FDTA-2 is supported by the chemical time-series graphs shown in Figures 5.3.1-4 and 5.3.1-5. In the immediate vicinity of the source area, concentrations are very high at HM-51 (Figure 5.3.1-4). In HM-029 and F-215, located near the bedrock channel that dips southeastward from FDTA-2, TCE levels are moderately high and steady, suggesting the presence of small amounts of DNAPL derived from non-aqueous phase migration along the channel axis. Downgradient from the elongate area defined by the paleo-channel (Figure II-25), wells F-207, -216, and -217 show moderate to low TCE levels that are generally decreasing with time (Figure 5.3.1-5). These concentrations and the trends they display indicate that dissolved TCE in this portion of the plume is derived from residual non-aqueous TCE in the paleo-channel. It is also possible that TCE in wells such as F-216 and F-217 is derived from wastes in Landfill No. 1, although the most contaminated portions of this landfill were excavated in 1986 (see Section 4.3.3.1). The slight increase in concentrations at the end of the time series for F-216 and F-217 may reflect changes in sampling and analysis procedures between 1990 and 1993.

Because of the small hydraulic gradients and the east-trending bedrock channel near the upgradient limit of the West Plume, it is also possible that TCE originating at FDTA-2 could have migrated beneath the Assembly Building. Hydraulic gradients and bedrock topography would then act to move this contamination in a northeasterly direction toward the north end of the runway.

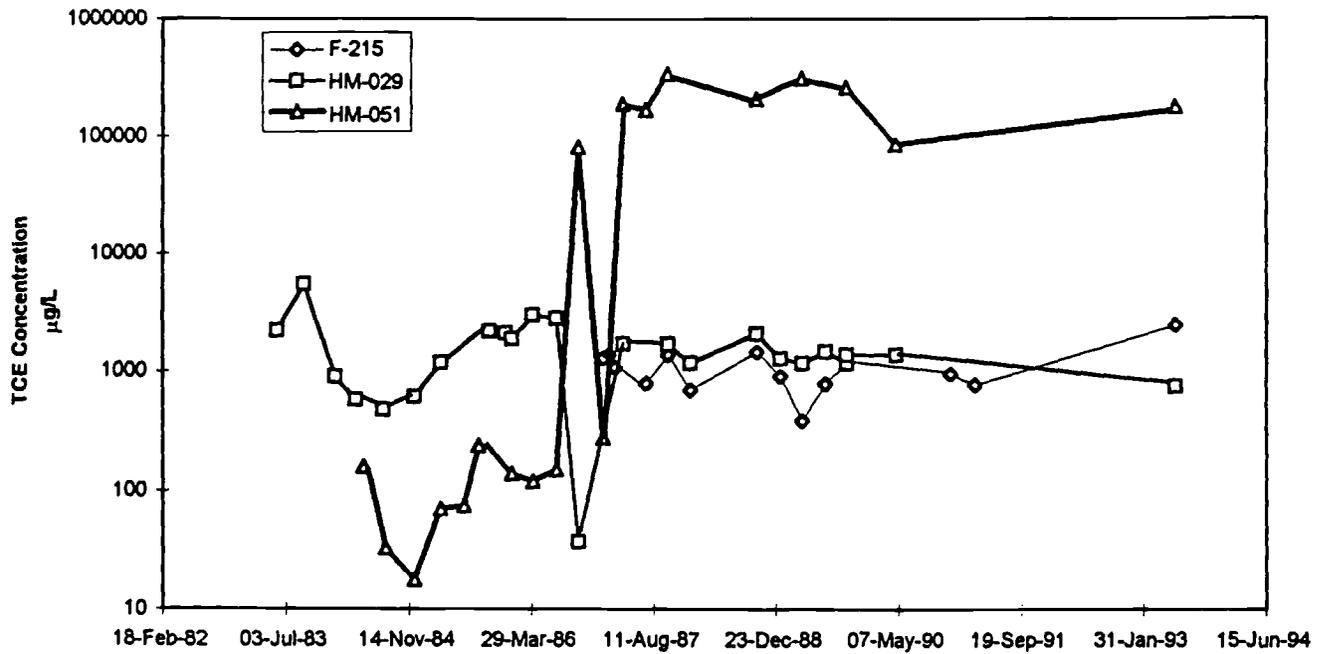


Figure 5.3.1-4 Chemical Time-Series for Upper-Zone TCE in the Vicinity of FDTA-2 and the Nearby Bedrock Channel

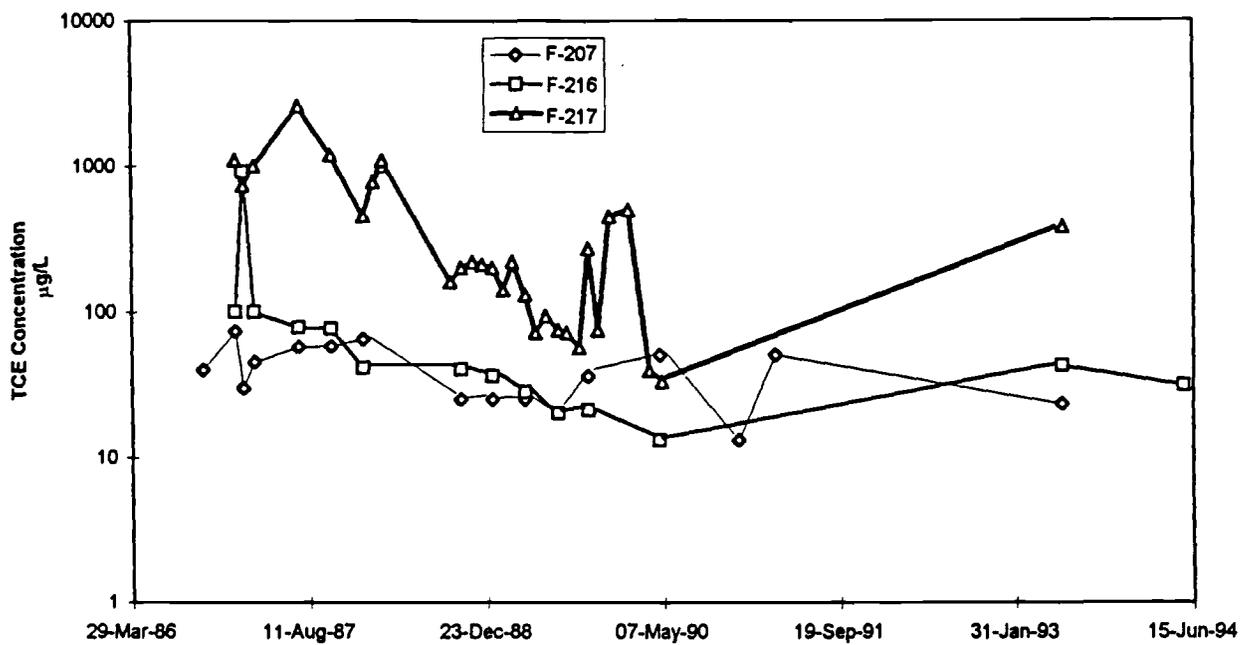


Figure 5.3.1-5 Chemical Time-Series for Upper-Zone TCE Downgradient from the FDTA-2 Paleo-Channel

The southeasterly migration of DNAPL TCE from FDTA-2 also provides a possible explanation for the elevated chromium found in the vicinity of well F-215. If production activities at Plant 4 included processes in which chromium-plated parts came into contact with TCE (during vapor degreasing, for instance), then the TCE disposed at FDTA-2 would likely have contained chromium. As DNAPL TCE migrates southeast from FDTA-2, the chromium will migrate with the TCE until sufficient mixing has occurred to allow the chromium to dissolve into the overlying groundwater. Advection to the west and southwest would then lead to the low concentrations found in the downgradient areas of the West Plume.

Contaminant velocities within the West Plume for the dissolved phases of TCE, 1,2-DCE, and chromium are tabulated in Table 5.3.1-2. For TCE and 1,2-DCE, retarded contaminant velocities were calculated from Equation 5-4, Table 3.8.1-4, and retardation coefficients calculated above. For chromium, the contaminant velocity shown is equal to the average linear velocity. This is based on the assumption noted earlier that chromium in the groundwater is in the hexavalent form, which is relatively soluble and not subject to significant sorptive retardation (i.e., $R = 1$).

Table 5.3.1-2 Estimates of Retarded Contaminant Velocities for TCE and DCE in the West Plume

Compound	Minimum Average Linear Velocity (feet per day)	Maximum Average Linear Velocity (feet per day)	Retardation Coefficient (R)	Minimum Retarded Velocity (feet per day)	Maximum Retarded Velocity (feet per day)
TCE	0.09	6.77	14	0.006	0.48
1,2-DCE	0.09	6.77	6	0.015	1.13
Chromium	0.09	6.77	1	0.09	6.77

Maximum contaminant velocities occur in the small channel near well F-214 where hydraulic gradients are as high as 0.2 ft/ft. This steeply sloping section of the upper-zone flow system is clearly evident in Figure II-24. The steep hydraulic gradients occur in the channel incised into the Walnut Formation near Meandering Road Creek (see Figures II-25, 4.3.3-2, and 4.3.3-3). Minimum contaminant velocities in the West Plume occur in the area just north and west of Building 14 where hydraulic gradients are relatively low.

During the RI/FS field investigations, seeps along Meandering Road Creek were observed at several locations along the west boundary of Landfill No. 3. These seeps are discharge points for upper-zone groundwater. The most significant discharge point, in terms of contaminant transport, is located near well F-214. A Walnut Formation bedrock high, extending north-south between Meandering Road Creek and Plant 4, impedes much of the groundwater flow to the creek. However, in the vicinity of well

F-214, a channel incised into the bedrock has removed most of the Walnut Formation. Historical aerial photographs reveal that the channel was forming as an incipient tributary to the creek. The channel was later filled with construction rubble after manufacturing activities began at Plant 4. The areal plan views and cross-sectional views shown in Figures II-25, 4.3.3-2, and 4.3.3-3 illustrate the capacity of the channel to act as a major point of groundwater discharge for the West Plume.

The North Plume

The North Plume is shown in Figures II-12 through II-18. As shown in Figures II-12 and II-13, TCE was detected in only one well (F-209). The source for the isolated occurrence of TCE is not known. TCE-degradation products and chromium were not detected in any of the North Plume wells.

Several wells in the North Plume area were found to contain LNAPL. Samples of the LNAPL were collected and submitted for qualitative analysis. Results of those analyses indicated that jet fuel, tentatively identified as JP-4, was the most commonly occurring substance. The likely source for this contamination is a fuel spill. Groundwater samples were not collected from the wells containing LNAPL, therefore the impact of the spilled fuel on groundwater quality cannot be assessed at these wells. However, groundwater samples were collected from a number of wells both upgradient and downgradient of the apparent fuel spill area. The reported VOC concentrations exceeding CRQLs in these wells are shown in Figure II-15. Of the wells sampled, only well F-209 contained significant groundwater contamination, which is most likely attributed to the LNAPL that was formerly detected in this well (Hargis + Associates 1988b).

Surface water sample locations SW-10, SW-11 (groundwater discharge seeps), and Outfall No. 3 are also shown in Figure II-15. As discussed in Section 3.6, samples from these locations were found to be virtually free of VOC contamination. These sample points are located downgradient from FSA-3 where discharge of upper-zone groundwater occurs (see Figure II-24).

The analytical and field data for the North Plume area indicate that even in the presence of a significant fuel-related LNAPL plume, dissolved contaminant migration of compounds such as BTEX has been minimal. The lack of dissolved contaminant migration may be attributed to two factors. First, hydraulic gradients in the North Plume area are relatively flat, resulting in low advective groundwater velocities (see Figure II-24 and Table 3.8.1-4). Secondly, low contaminant velocities are anticipated because significant adsorptive retardation is associated with BTEX compounds. For example, K_{oc} values for BTEX compounds range from 132 to 1,830. For comparison, the K_{oc} for TCE is 126. The associated retardation factors and contaminant velocity estimates for the BTEX components of fuel are shown in Table 5.3.1-3 (on the basis of average linear velocity estimates from Table 3.8.1-4).

Table 5.3.1-3 Estimates of Retarded Contaminant Velocities for BTEX Compounds in the North Plume

Compound	Minimum Average Linear Velocity (feet per day)	Maximum Average Linear Velocity (feet per day)	Retardation Coefficient (R)	Minimum Retarded Velocity (feet per day)	Maximum Retarded Velocity (feet per day)
Benzene	0.05	0.23	15	0.003	0.02
Ethylbenzene	0.05	0.23	150	0.0003	0.002
Toluene	0.05	0.23	58	0.0009	0.004
Xylenes	0.05	0.23	194	0.0002	0.001

The migration of dissolved fuel compounds derived from FSA-3 is not expected to be significant because of these low contaminant velocity estimates. Those contaminants that do migrate will ultimately be discharged via seeps located north and west of the North Plume area. Seeps at SW-10 and SW-11 are two examples of such discharge points. It is likely that additional groundwater seeps, concealed by vegetation, are present in the area northwest of the North Plume, particularly where the ground surface slopes toward Lake Worth.

Contaminant Transport Through the Walnut Formation Aquitard

Contaminant transport through the Walnut Formation Aquitard is likely occurring in two locations at Plant 4. These locations are the window area and the lower reaches of Meandering Road Creek. In both of these areas, the Walnut Formation has been extensively eroded and is thin or absent. Low concentrations of organic contaminants commonly found in upper-zone groundwater and Meandering Road Creek, such as TCE, 1,2-DCE, and vinyl chloride, have been detected in Paluxy Formation groundwater in both of these areas. The presence of these compounds in the Paluxy Aquifer suggests the hypothesis that migration through the Walnut Formation is occurring in these areas. Alternatively, one or both of the Paluxy Aquifer monitoring wells in LF-3 (P-22U and P-22M) may be providing a conduit across the Walnut Formation. This situation could have resulted from completion difficulties such as sloughing, or from the drillers lack of adherence to design specifications.

In Section 3.8.3.1, the volumetric flux through the window area was estimated using hydraulic head data in upper-zone and Paluxy Formation monitoring wells. This flux estimate, between 0.54 and 54 ft³/day, can be combined with the Walnut Formation retardation coefficient and the average TCE concentration for upper-zone groundwater in the window area (20,000 µg/L) to provide an estimate of TCE flux through the window area and into the Paluxy Formation. Assuming the Walnut Formation has a bulk density of 1.9 g/cm³, a porosity of 0.075 (Advanced Terra Testing, Inc. 1991), and a fraction organic-carbon content of 0.012 (Huffman Laboratories, Inc. 1991),

Equations 5-2 and 5-4 result in an R value of 40. Scaling the volumetric flux estimates by an R value of 40 and multiplying by the average TCE concentration of 20,000 $\mu\text{g/L}$ results in a mass flux estimate between 0.0003 and 0.03 ounces per day (0.008 to 0.8 g/d). If retardation is not occurring due to a lack of organic carbon or exhaustion of sorption sites, the contaminant mass flux estimates are 0.011 to 1.1 oz/day (0.30 to 30 g/d).

The relative accuracy of the window area contaminant mass flux estimate can be checked by estimating the contaminant mass within the Paluxy Formation. Because the majority of the contaminant mass is in the Paluxy upper sand, the estimate will be computed only for the upper sand. From Figures II-19a and II-19c, the area of the plume was estimated as:

$$\begin{aligned}\text{Area within 1000ppb contour} &= 2,260,000 \text{ ft}^2 \\ \text{Area between 1000ppb and 100ppb contour} &= 1,459,000 \text{ ft}^2\end{aligned}$$

Assuming a seven-foot saturated thickness and a porosity of 0.3 for the upper sand, the mass of TCE within these two contours is computed as follows (incremental area between 1000 and 100 ppb contour assigned median value of 550 ppb):

$$\begin{aligned}\text{Mass within 1000ppb contour} &= 1000 \mu\text{g/L} * \text{Volume} \\ \text{Volume} &= 2,260,000 \text{ ft}^2 * 7 \text{ ft} * 0.30 = 4,746,000 \text{ ft}^3 \\ &= 134,407,000 \text{ L} \\ \text{Mass} &= 1000 \mu\text{g/L} * 134,407,000 \text{ L} = 134\text{E}09 \mu\text{g} = 134,400 \text{ g}\end{aligned}$$

$$\begin{aligned}\text{Mass between 1000 and 100 ppb contour} &= 550 \mu\text{g/L} * \text{Volume} \\ \text{Volume} &= 1,459,000 \text{ ft}^2 * 7 \text{ ft} * 0.30 = 3,063,900 \text{ ft}^3 \\ &= 86,770,000 \text{ L} \\ \text{Mass} &= 550 \mu\text{g/L} * 86,770,000 \text{ L} = 477\text{E}08 \mu\text{g} = 47,720 \text{ g}\end{aligned}$$

$$\text{Total TCE mass in upper sand} = 134,400 \text{ g} + 47,720 \text{ g} = 182,120 \text{ g}$$

Assuming 20,000 $\mu\text{g/L}$ for the average upper zone TCE concentration in the window area, and ignoring retardation, the contaminant mass flux rate from the upper zone to the upper sand is

$$\begin{aligned}\text{Mass flux} &= 20,000 \mu\text{g/L} * 54 \text{ ft}^3/\text{d} * 28.32 \text{ L}/\text{ft}^3 = 30.6\text{E}06 \mu\text{g}/\text{d} = 30.6 \text{ g}/\text{d} \\ &= 11,000 \text{ g}/\text{yr}\end{aligned}$$

Given 182,120 g as an estimate of the total TCE mass *in* the upper sand, and 11,170 g/yr as an estimate of the contaminant mass flux rate *into* the upper sand, an estimate of the duration of this flux is $(182,120 \text{ g}) / (11,000 \text{ g}/\text{yr}) = 16 \text{ yrs}$. Assuming that TCE release into the subsurface likely began shortly after the plant was built, and leakage into the upper sand likely began not long afterward, the 16 year estimate for the duration of TCE

flux into the upper sand is recognized as too short. This can be explained by the realization that migration of TCE through the window area Walnut Formation would likely have begun at a rate considerably smaller than the current or maximum rate estimated above. Stated another way, 11,000 g/yr is a conservatively large estimate for the average TCE mass flux rate into the upper sand. TCE flux into the upper sand is certain to have begun at a slower rate, likely in the 1950's or 1960's, and increased to a rate less than or equal to 11,000 g/yr. The mass balance calculation above provides a means of testing the retardation factor of 40 estimated previously. If $R = 40$ accurately quantifies the retardation process and if that process has been occurring continuously over the duration of TCE migration through the window area Walnut Formation, the annual mass flux rate would be 275 g/d and the duration of the flux needed to contribute 182,120 g of TCE to the upper sand would be 640 years. Clearly, $R = 40$ overestimates the average retardation process, most likely due to lower-than-estimated organic carbon content or exhaustion of sorption sites during the later years of leakage through the window area. On the basis of this reasoning, 30.6 g/d (1.1 oz/d) will be considered to provide a reasonable upper bound to the rate of TCE migration into the upper sand.

To provide a basis for estimating cleanup levels in the Upper Zone above the window area that will not result in excessive degradation of the Paluxy Aquifer, the 30.6 g/d mass flux can be used in a simple mixing or dilution model. This calculation provides a means of relating Upper Zone discharge in the window area to Paluxy aquifer water quality after flowing beneath the upper sand TCE plume (Figures II-19a and II-19c). The mixing model is based on the following equation:

$$Q_{UZ}C_{UZ} + Q_{P,INFLOW}C_{P,INFLOW} = (Q_{P,OUTFLOW})C_{P,OUTFLOW}$$

where,

- Q_{UZ} = volumetric flux through Walnut Formation in window area (54ft³/d),
- C_{UZ} = TCE concentration for upper zone in window area (20,000µg/L),
- $Q_{P,INFLOW}$ = volumetric flux for water in Paluxy Aquifer flowing into zone beneath upper sand TCE plume,
- $C_{P,INFLOW}$ = TCE concentration for water in Paluxy Aquifer prior to flowing beneath upper sand TCE plume (0 µg/L),
- $Q_{P,OUTFLOW}$ = volumetric flux for water in Paluxy Aquifer flowing out from zone beneath upper sand TCE plume (= $Q_{UZ} + Q_{P,INFLOW}$),
- $C_{P,OUTFLOW}$ = TCE concentration for water in Paluxy Aquifer prior to flowing beneath upper sand TCE plume.

This model is based on the assumption that the Paluxy upper sand provides no permanent storage of water or contaminant mass: every thing that drains into the upper sand ultimately drains out. This assumption is reasonable given the perched setting of the upper sand relative to the Paluxy Aquifer (Figure 5.3.1-6). It is also conservative, given

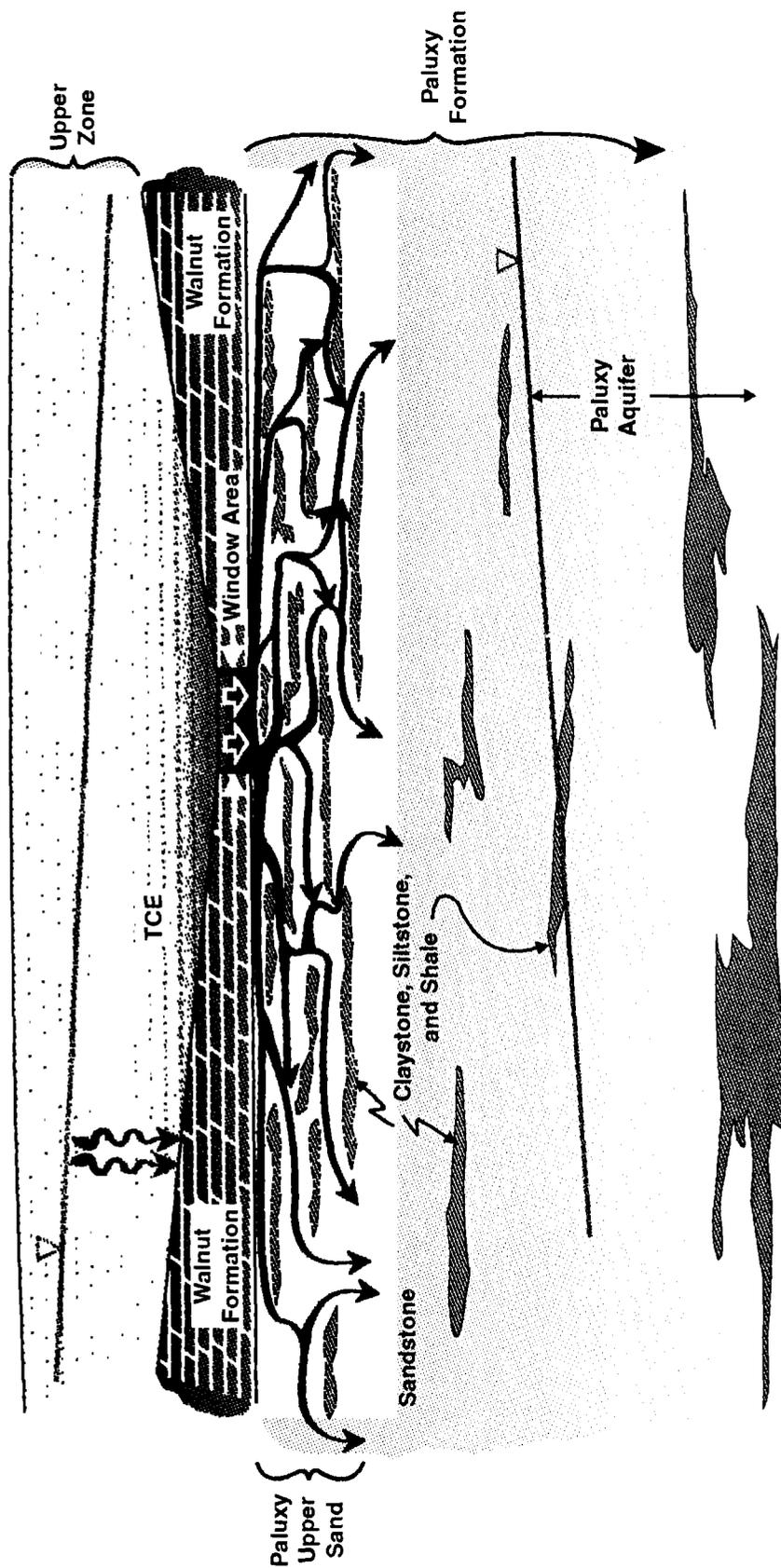


Figure 5.3.1-6 Conceptual Model of Contaminant Migration Through the Window Area, Into and Out of the Paluxy Upper Sand, and Into the Paluxy Aquifer.

that *some* contaminant mass undoubtedly will sorb onto the solid phase within the upper sand. For the model shown in Figure 5.3.1-6, all of the contaminant mass discharged into and mixed with groundwater in the Paluxy Aquifer. The Paluxy aquifer flux, Q_P , with which the upper zone flux, Q_{UZ} , mixes is illustrated in Figure 5.3.1-7.

The width of the inflow face, 2000 ft is the width of the upper sand TCE plume measured orthogonal to the Paluxy Aquifer hydraulic gradient. The height of the inflow face, 20 ft, is based on the assumption that mixing occurs over the uppermost 20 ft of saturated thickness within the aquifer as water is drawn to a water supply well screened in the top 20 ft of the aquifer. Using the Paluxy Aquifer hydraulic conductivity of 0.006 cm/s (17 ft/d) and the average gradient of 0.0065 (dimensionless) from Section 3.8, $Q_{P,INFLOW}$ can be calculated from

$$Q_{P,INFLOW} = K * dh/dx * A$$

where

$$\begin{aligned} A &= \text{cross-sectional area orthogonal to flow} \\ &= 20 \text{ ft} * 2000 \text{ ft} \\ &= 40,000 \text{ ft}^2 \end{aligned}$$

giving

$$\begin{aligned} Q_{P,INFLOW} &= 17\text{ft/d} * 0.0065 * 40,000 \\ &= 4422 \text{ ft}^3/\text{d} \end{aligned}$$

Substituting this into the mixing equation and solving for $C_{P,OUTFLOW}$ gives

$$\begin{aligned} C_{P,OUTFLOW} &= ((54\text{ft}^3/\text{d} * 20,000\mu\text{g/L}) + (4422\text{ft}^3/\text{d} * 0)) / (54\text{ft}^3/\text{d} + 4422\text{ft}^3/\text{d}) \\ &= 241 \mu\text{g/L} \end{aligned}$$

This result shows that if TCE contamination from the upper zone is allowed to continue migrating unabated through the window area, TCE concentrations in the Paluxy Aquifer can be expected to reach as high as 240 $\mu\text{g/L}$. Assuming the upper zone is to be remediated to an extent such that window area discharge does not cause TCE concentrations ($C_{P,OUTFLOW}$) in the Paluxy Aquifer to exceed the MCL of 5 $\mu\text{g/L}$, the mixing equation can be solved in reverse to estimate the required target concentration for the upper zone:

$$\begin{aligned} C_{UZ} &= (54\text{ft}^3/\text{d} + 4422\text{ft}^3/\text{d}) * 5\mu\text{g/L} / 54\text{ft}^3/\text{d} \\ &= 414 \mu\text{g/L} \end{aligned}$$

414 $\mu\text{g/L}$ represents the maximum TCE concentration that can be permitted in upper zone if leakage through the window area is not to cause TCE concentrations in the Paluxy Aquifer to exceed 5 $\mu\text{g/L}$. It is important to note that this estimate is conservative in that it ignored the attenuation processes of sorption, dispersion, and biodegradation. Proof that at least some combination of these attenuation mechanisms

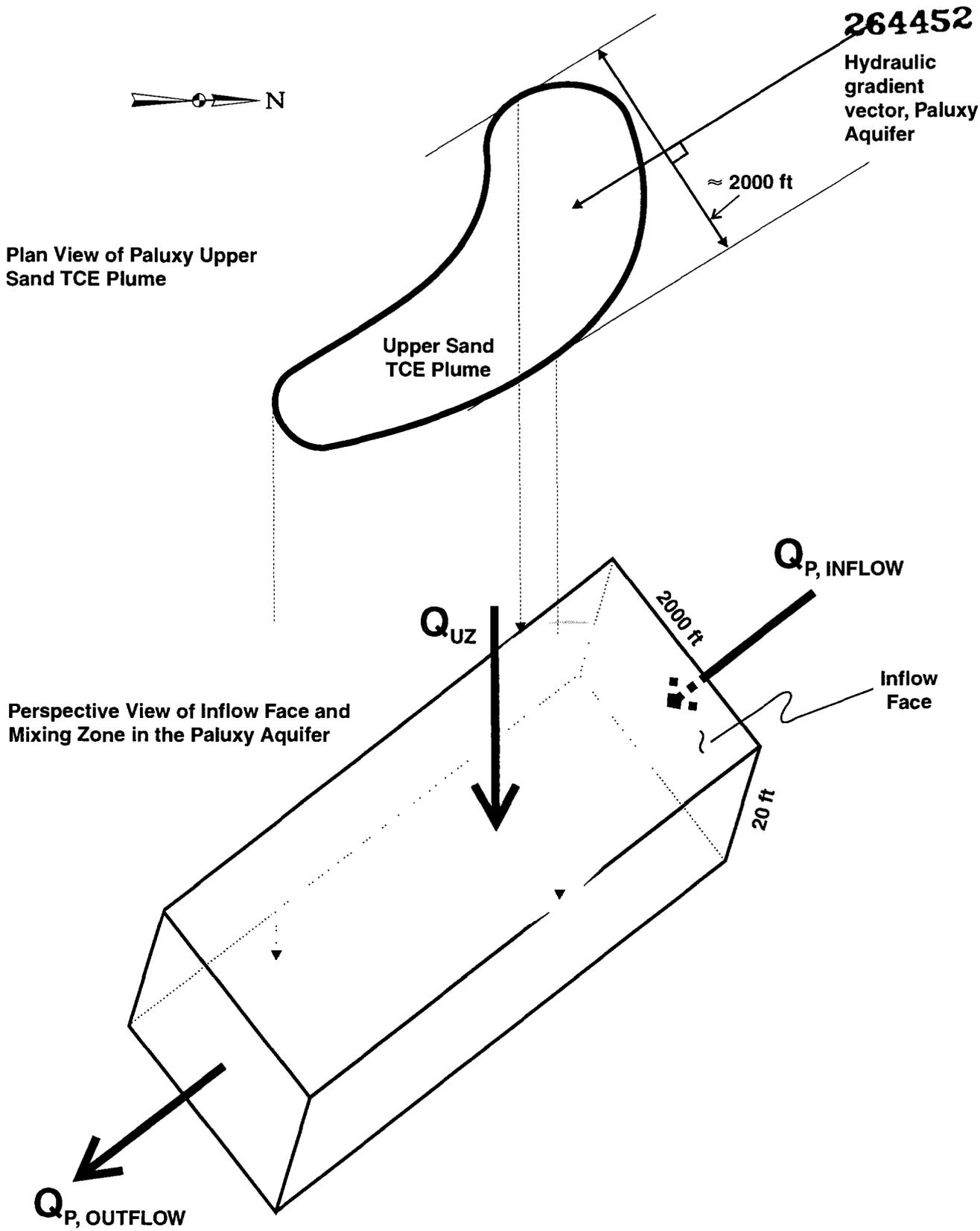


Figure 5.3.1-7 Schematic of Conceptual Model for Mixing/Dilution Calculation for Upper Zone, Window Area, Upper Sand, and Paluxy Aquifer.

are acting to reduce the rate of contaminant migration is provided by noting that window area monitoring wells in the alluvium show TCE concentrations exceeding 20,000 $\mu\text{g/L}$. Monitoring wells completed at the same location as the upper zone wells but screened below the Walnut Formation show at least an order of magnitude decrease in TCE concentration (concentrations typically less than or near 2000 $\mu\text{g/L}$). This characteristic, in a unit that receives all or most of its water from the upper zone in the window area, is most attributable to the attenuation mechanisms discussed above.

In the vicinity of lower Meandering Road Creek, flow into the Paluxy Formation from the creek is not as well understood because the thickness of the Walnut Formation is not known and vertical flow is likely occurring under partially saturated conditions. Because the hydraulic conductivity associated with unsaturated flow is much smaller than for saturated flow, vertical flow velocities in the creek area are likely much smaller than in the window areas. The low hydraulic heads associated with stagnant water pools in the creek also tend to produce relatively small vertical flux rates in this area. Therefore, given the small flux rates and low contaminant concentrations in the creek (compared to those in window area of the upper zone), the vertical mass flux from the creek into the Paluxy Formation is most likely smaller than that estimated for the window area.

The location of the west plume, centered around P-22U and P-22M, suggests that vertical migration along a well bore may be the main cause of contamination in the Paluxy on the west side of Plant 4. P-22M was recently abandoned to eliminate the opportunity for contaminant migration down the borehole annulus.

Contaminant Transport in the Paluxy Aquifer

Contaminant transport in the Paluxy Aquifer was evaluated using an analytical groundwater transport model. Results of the analytical model, presented in Appendix J, were used in preparation of the baseline risk assessment presented in Section 6.0. This approach was taken because the Paluxy Formation water-supply wells in White Settlement have the potential to be impacted by contamination originating at Plant 4. The analytical model used hydraulic head data for the Paluxy Formation generated during the RI and previous investigations. These data included only rough approximations for heads at the White Settlement wells. The analytical modeling indicated that TCE and 1,2-DCE are likely to reach maximum concentrations at all seven of the Paluxy Formation supply wells within 60 years. These estimates are considered very conservative because the model assumes (1) TCE and 1,2-DCE would migrate as conservative tracers with no retardation occurring as a result of adsorption, and (2) one-dimensional flow, which ignores the mixing and dilution that occur in two- or three-dimensional flow.

As previously discussed, TCE and 1,2-DCE adsorption can reduce contaminant migration velocities by more than an order of magnitude. In the Paluxy Formation, this retardation is greatest for the vertical component of flow because the vertical component

of flow forces contaminants to move through the interbedded shale and siltstone/claystone deposits. As reported by Huffman Laboratories, Inc. (1991), the organic carbon content of these layers can be as high as 0.22 percent, indicating considerable adsorption capacity. Because contaminants enter the Paluxy Formation at its upper surface and water is withdrawn from the supply wells at the bottom of the formation, the role of vertical flow and retardation is important and will be further analyzed.

For horizontal flow through the cleaner sandstones, the low organic carbon content of 0.06 percent or less (Huffman Laboratories, Inc. 1991) will offer minimal capacity for retardation from adsorption.

5.3.2 Contaminant Migration in Surface Water

The surface water pathway at Plant 4 involves three primary features: Meandering Road Creek, Farmers Branch, and Lake Worth. The transport mechanisms associated with the surface water pathway and the significance of those mechanisms at Plant 4 are discussed in the following sections.

5.3.2.1 Transport Mechanisms

The surface water migration pathway includes transport mechanisms associated with overland flow, stream flow, and lake circulation. Transport via overland flow occurs during rainfall events that are large enough to generate storm-water runoff. Mobile contaminants present at the ground surface are commonly transported in the runoff water. Transport via surface water runoff can be significant in areas where erosion of contaminated surface soil is not inhibited by the presence of surface cover or vegetation. Because the waste sites at Plant 4 are largely covered with pavement or vegetation, overland flow is not considered a significant transport mechanism for contaminants associated with these waste sites. However, contaminants derived from non-point sources at Plant 4 and in the surrounding area can be transported by overland flow. Examples include petroleum hydrocarbons, oil and grease, and other organic compounds commonly derived from parking lots and along roadways.

Transport via stream flow occurs when contaminants that have reached a stream (via groundwater discharge, for example) are advected downstream by the flowing water. This process occurs in Meandering Road Creek, along the west boundary of Plant 4, and also in Farmers Branch, on CAFB. While groundwater discharge to these streams may occur on a nearly continuous basis, the rate of this discharge is so small that contaminant transport within the streams is largely limited to intermittent flows caused by rainfall events. During such events, stagnant water that has collected in the stream channels is diluted by and advected downstream with the storm-water discharge. Contaminants entering Meandering Road Creek are ultimately discharged into Lake Worth.

Contaminants entering Farmers Branch are discharged to the West Fork of the Trinity River.

Contaminant transport within Lake Worth involves contaminants that have been discharged to the lake from Meandering Road Creek and other drainages as well as contaminants from non-point sources that reach the lake via overland flow (direct runoff). Once contaminants are in the lake, a number of transport mechanisms act to mix contaminated and uncontaminated water, thereby decreasing influent contaminant concentrations. These mechanisms include the following (Linsley and others 1982):

- Density-current mixing caused by stream inflow
- Near-surface vertical mixing caused by wave action
- Near-shore lateral transport caused by wave action (littoral currents)
- Deep mixing caused by wave-setup and return-flow
- Large-scale mixing caused by semiannual turn-over

5.3.2.2 *Effect on Plant 4 Contaminants*

Contaminant transport via the surface water pathway at Plant 4 is primarily controlled by stream flow along Meandering Road Creek and Farmers Branch and lake circulation in Lake Worth. As explained above, overland flow is not considered a significant transport mechanism at Plant 4.

Meandering Road Creek

Table 4.6.1-1 lists VOCs detected in Meandering Road Creek. The contaminants most commonly reported for samples collected from the creek include TCE, 2-butanone, vinyl chloride, and *cis*-1,2-DCE. These contaminants are commonly found in upper-zone groundwater east of Meandering Road Creek (Landfill No. 3 area) and are likely derived from Plant 4 waste sites. The most frequently detected VOC was *cis*-1,2-DCE. The relatively frequent detections of *cis*-1,2-DCE in the creek can be attributed to both the discharge of *cis*-1,2-DCE in contaminated upper-zone groundwater and the degradation of TCE *after* TCE-contaminated groundwater has been discharged to the creek. Once VOCs have been discharged to the creek and are exposed to sunlight and air, volatilization of the compounds will increase. Biodegradation of TCE, 1,2-DCE, and vinyl chloride to their respective degradation products may increase or decrease upon exposure to sunlight and air depending on the nature of the site-specific biological degradation process. Future contaminant concentrations in Meandering Road Creek are not likely to increase because contaminant levels are not expected to increase at the principle source, Landfill No. 3, located adjacent to the creek. Contaminants present in the creek are transported via stream flow and ultimately discharged to Lake Worth.

Farmers Branch

Farmers Branch was sampled at various locations in the spring of 1990 (Radian Corp. 1990) and in October 1991 and February 1992 (Jacobs Engineering Group, Inc. 1991, 1992). Samples collected at the inlet to the aqueduct beneath the runway showed no evidence of organic contamination. Samples at the aqueduct outlet and other downstream locations contained TCE ranging from 13 to 1400 $\mu\text{g/L}$, and *cis*-1,2-DCE ranging from 5.8 to 380 $\mu\text{g/L}$. The highest concentrations were measured in downstream samples collected from an area where upper-zone groundwater discharges from Landfill No. 5. Landfill No. 5 is a known source of TCE contamination and is most likely the source of the high TCE and 1,2-DCE concentrations in the nearby portion of Farmers Branch.

Concentrations of TCE and DCE in samples collected between Landfill No. 5 and the aqueduct outlet were typically between 5 and 50 $\mu\text{g/L}$. These concentrations are indicative of contaminants entering Farmers Branch via discharge of upper-zone groundwater from within the boundary of the East Parking Lot Plume. Because the East Parking Lot Plume originates from a large and highly contaminated source area, TCE concentrations (and those of its degradation products) may still be increasing in the vicinity of the runway and Farmers Branch. Any such increases will likely be accompanied by increases in TCE and DCE concentrations in the segment of Farmers Branch located upstream from Landfill No. 5. As in Meandering Road Creek, volatilization of VOCs will increase after the compounds are discharged into Farmers Branch and exposed to sunlight and air. Biodegradation of VOCs discharged to Farmers Branch may increase or decrease as a result of the exposure to sunlight and air. Contaminants present in Farmers Branch are transported via stream flow and are ultimately discharged to the Trinity River.

Lake Worth

As noted in Section 4.6.2, carbon disulfide and oil and grease were the only two analytes detected in nine samples collected from Lake Worth. The carbon disulfide found in the lake was apparently derived from nearby localized sources and does not indicate a widespread contamination problem in the lake. The same applies to oil and grease, which were found in only one background sample and which may be derived from non-point source runoff from urban unpaved areas and which may be derived from power boats operated on the lake.

These results suggest that the lake transport mechanisms, the large volume of water stored in the lake, and the continuous through-flow provided by the West Fork of the Trinity River combine to dilute virtually all contaminants entering the lake from Meandering Road Creek and other non-point source areas.

5.3.3 Contaminant Migration in Air

As discussed in the baseline risk assessment (see Section 6.0), contaminant migration via the air pathway at Plant 4 does not increase human-health risks beyond regulatory standards for the general public. The primary transport mechanisms associated with the air pathway and the effect of those pathways on contaminants at Plant 4 are discussed below.

5.3.3.1 Transport Mechanisms

The air migration pathway includes three transport mechanisms: advection, mechanical dispersion, and molecular diffusion. Advection and mechanical dispersion require movement of air mass and are functions of wind speed and turbulence, respectively. Contaminant migration via molecular diffusion is of concern only in settings characterized by very low air-flow velocities. Because calm conditions occur infrequently at Plant 4 (see Table 4.8-1), advection and mechanical dispersion are considered the dominant transport mechanisms.

5.3.3.2 Effect on Plant 4 Contaminants

The results of the air monitoring presented in Section 4.8 show that Plant 4 does have an impact on the concentration of airborne contaminants. However, several factors indicate that this impact is associated with ongoing industrial activities at the facility and is not related to the 21 RI/FS waste sites.

Except for the compounds dichlorodifluoromethane (Freon 12) and 1,1,1-TCA, contaminant concentrations exceeding background levels were observed only when winds were from the south (see Section 4.8). Likely sources for elevated contaminant concentrations in southerly winds are chemicals used in manufacturing and testing processes in the vicinity of the Parts Plant/Assembly Building.

Freon 12 and 1,1,1-TCA were found at elevated concentrations in both northerly and southerly winds (see Section 4.8). Freon 12 is likely derived from tanks of Freon compounds that are stored and used throughout the area surrounding the on-site air monitoring station. The compound 1,1,1-TCA may be attributed to laboratory contamination because this compound was found in the laboratory blanks associated with all but four of the samples containing elevated concentrations of 1,1,1-TCA.

Lastly, it should be noted that all of the 21 RI/FS waste sites are covered with asphalt, concrete, or established vegetation such as grass. These surface coverings reduce the potential for significant volatilization or wind erosion at the waste sites.

6.0 Baseline Risk Assessment

6.1 Site Description

Plant 4 is located in Tarrant County, Texas, seven miles northwest of Fort Worth. Plant 4 covers 602 acres and is bounded on the north by Lake Worth, on the east by CAFB, and on the south and west by the city of White Settlement (UNC Geotech 1990).

Plant 4 became operational in 1942 with the manufacturing of the B-24 bomber during World War II. In 1953, GD took over operation of the plant from the previous owners, Consolidated Aircraft. Since then, Plant 4 has produced B-36, B-58, F-11, and F-16 aircraft. The plant also produces spare parts, radar units, and missile components (UNC Geotech 1990).

The operations at Plant 4 have resulted in the generation of various hazardous wastes. Waste oils, fuels, spent solvents, paint residues, and spent process chemicals are some of these wastes. For most of the plant's history, waste oils, solvents, and fuels were disposed in four on-site landfills ranging from two to eight acres located in various places on Plant 4, or burned in fire training exercises in five different FDTA. Chemical wastes were released into the sanitary sewer system which went to the Fort Worth treatment system. These chemical process wastes were treated at a new on-site chemical waste treatment system beginning in the 1970s. Waste oils are now disposed by a contractor and are no longer burned on site (UNC Geotech 1990).

6.1.1 RI/FS

Under the RI/FS, 31 sites, including landfills, FDTAs, chrome pits, and fuel spill sites were investigated for contamination. During the preparation of this risk assessment, four of those 31 sites, FDTA No. 4 (Chem-Nuclear Geotech 1991a), Landfill No. 2 (Chem-Nuclear Geotech 1991b), Chrome Pit No. 1 (Chem-Nuclear Geotech 1991c), and Chrome Pit No. 2 (Chem-Nuclear Geotech 1991d), were identified as not requiring any further action. Since the completion of the risk assessment, three other sites—solvent lines, West Compass Rose, and Nuclear Aerospace Research Facility—were also identified as no action sites. The No Action documents for all seven sites are presented in Appendix N. The other 24 sites, however, may be contaminated sites that present unacceptable risk to human health and the environment. Figure 6.1-1 presents an overview of the contaminated sites covered in this risk assessment using a site conceptual model.

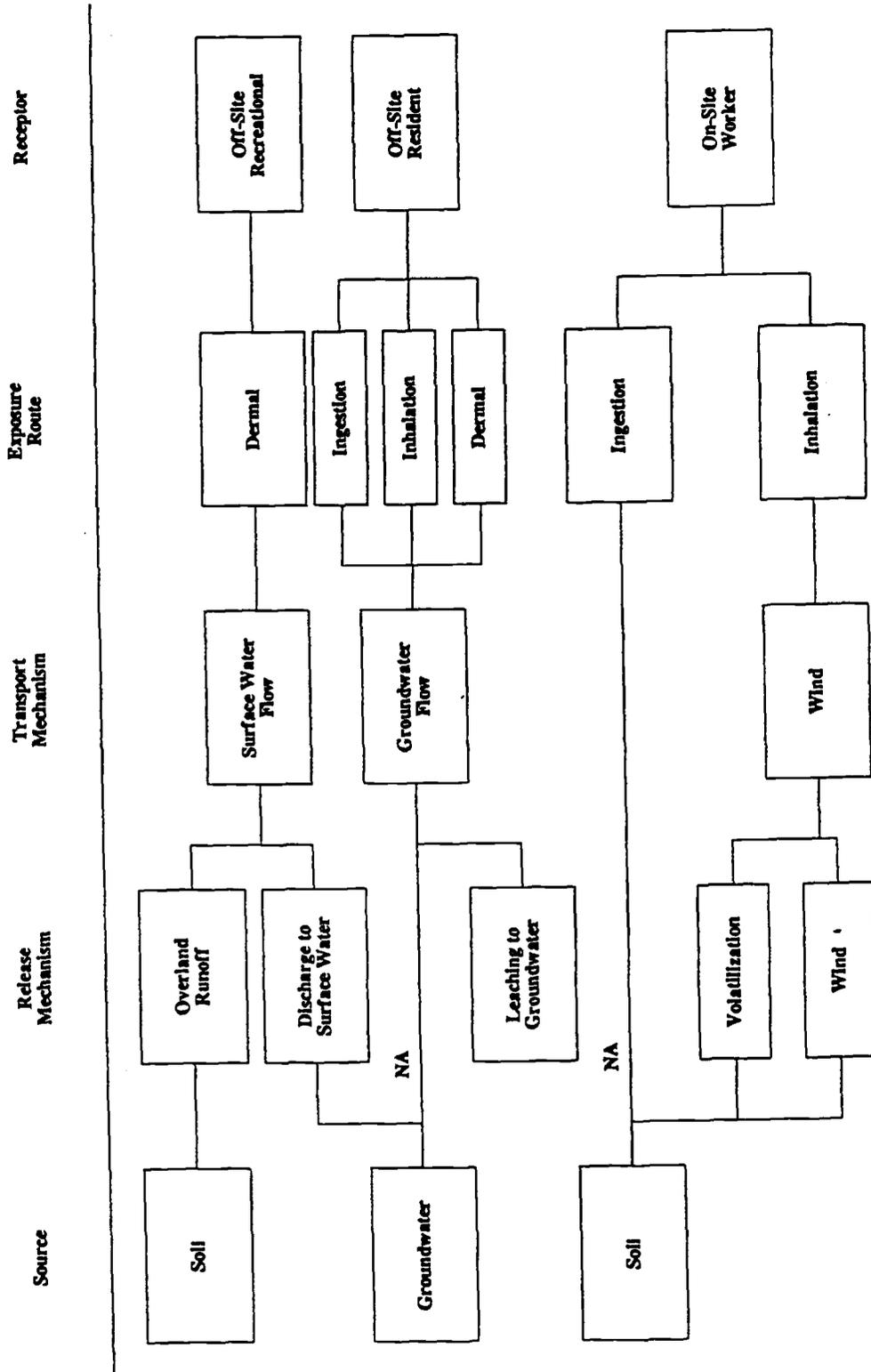


Figure 6.1-1 Site Conceptual Model.

6.1.2 Risk Assessment Methodology

This study has been conducted primarily using the methods described in *EPA Risk Assessment Guidance for Superfund — Human Health Evaluation Manual* (EPA 1989a). A risk assessment performed using these methods should consist of five parts: (1) Data Validation and Evaluation, resulting in lists of chemicals of concern for human health and ecological risk; (2) Exposure Assessment, resulting in potential migration pathways for exposure to residential and commercial receptors, both now and in the future; (3) Toxicity Assessment, containing toxicological profiles and risk parameters, including slope factors and reference doses; (4) Human Health Risk Assessment, quantifying the risk to maximally exposed individuals; and (5) Ecological Risk Assessment, a qualitative study of the effects of significant ecological communities at and near Plant 4.

6.1.3 Report Organization

Section 6.1 of this document provides background information on the site of the risk assessment, the RI/FS, and guidance methods recommended by the EPA and used in this risk assessment. Section 6.2 describes the process of screening the data and provides a brief summary of the usable data. The exposure assessment, Section 6.3, describes pathways to receptors, source terms, model calculations, residential and commercial receptor guidance standards, information on Lake Worth and water wells, and future scenario modeling. Section 6.4, the toxicity assessment, provides toxicological profiles and risk parameters for the chemicals of potential concern. The human health risk assessment, Section 6.5, discusses the methodology and results of the assessment of risks to human health. The ecological risk assessment, Section 6.6, describes the risk to different ecological communities near the site, community structure, food webs and nutrient cycles, and ecological receptors.

6.2 Data Validation and Evaluation

6.2.1 Data Validation

The analytical data obtained for soil and water samples collected by Geotech from February 1990 through September 1991 were validated using the methods prescribed in *Laboratory Data Validation Functional Guidelines for Evaluating Organic Samples* (Bleyler 1988a) and *Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Samples* (Bleyler 1988b). Forty percent of all samples were validated. All of the data packages reporting water sample results were validated. The few analyses that were assigned the qualifier "R" (unusable) were eliminated from further consideration.

6.2.2 Data Evaluation

Data evaluation was conducted using methods delineated in the "Human Health Evaluation Manual" (EPA 1989a) in order to derive medium-specific lists of chemicals of potential concern for human health. Elimination of chemicals from the lists of chemicals of potential concern were based on the following criteria (EPA 1989a):

- Chemicals for which analyses were performed but which were not detected in any sample for a medium were excluded from the list of chemicals of potential concern.
- Quantitative risks for nonspecific parameters (e.g., total petroleum hydrocarbons) were not calculated; however, the impacts of their exclusion from the quantitative risks were included in the uncertainties discussion.
- Uncertain identifications (e.g., tentatively identified compounds [TIC]) were excluded from further consideration. When the number of TICs is small compared to the Target Analyte List and Target Compound List chemicals, and no site information indicates the TICs may be present, the TICs may be omitted from consideration in the risk assessment (EPA 1989a).
- Essential nutrients (EN), such as iron, magnesium, and calcium, were excluded from further consideration when detected in low concentrations (less than 1 ppm).
- Sample data were compared with blank data, and chemicals that were detected in samples at concentrations less than ten times the concentration(s) in any blank associated with the samples for common laboratory contaminants (i.e., acetone, 2-butanone, methylene chloride, toluene, and phthalate esters) were assumed to be nondetects at the sample quantitation limit (SQL) (EPA 1989a).
- Because of the large number of chemicals and samples associated with Air Force Plant 4, chemicals detected in 5 percent or fewer samples in a medium were excluded from further consideration except for Class A carcinogens (EPA 1989a).
- Natural occurring chemicals detected at concentrations comparable to literature-based background concentrations were excluded.

6.2.2.1 Organic Chemical Analyses

Tables 6.2-1 through 6.2-4 summarize the results of analyses for organic chemicals in environmental samples of groundwater, surface water, soil, and air, respectively. Table 6.2-3 also contains the soil analysis results from analyses of background soil samples. No chemicals were eliminated from further consideration through comparison of environmental sample analyses with background. Chemicals of potential concern for

human health are summarized later in this section, and chemicals of potential concern for the ecosystems in the area are discussed in detail in Section 6.6.

When the laboratory or data validation processes indicate that there is some variance of quality of the data, qualifiers are assigned to the values. The qualifiers used in the tables in this section are defined for organic chemical data as follows (EPA 1989a):

- J-Value is estimated when a compound is present (spectral identification criteria are met), but the value is less than the contract required quantitation limit.
- B-Analyte is found in an associated blank as well as in the sample.
- E-Concentration exceeds calibration range of the gas chromatograph/mass spectrometer instrument.

Table 6.2-1 Organic Chemicals Sampled in Groundwater at Plant 4

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SQLs ¹ (µg/L)	RANGE OF CONCENTRATIONS (µg/L)
ND ²	83-32-9	Acenaphthene	0/36	10-20	ND
ND	208-96-8	Acenaphthylene	0/36	10-20	ND
ND	67-64-1	Acetone	0/193	2-10,000	ND
ND	120-12-7	Anthracene	0/36	10-20	ND
A ³ /CPC ⁴	71-43-2	Benzene	5/192	1-5,000	7-270(E ⁵)
ND	205-99-2	Benzo(b)Fluoranthene	0/36	10-20	ND
ND	191-24-2	Benzo(g,h,i)Perylene	0/36	10-20	ND
ND	207-08-9	Benzo(k)Fluoranthene	0/36	10-20	ND
ND	65-85-0	Benzoic Acid	0/36	50-100	ND
ND	56-55-3	Benzo[a]Anthracene	0/36	10-20	ND
ND	50-32-8	Benzo[a]Pyrene	0/36	10-20	ND
ND	100-51-6	Benzyl Alcohol	0/36	10-20	ND
ND	111-91-1	bis(2-Chloroethoxy)methane	0/36	10-20	ND
ND	111-44-4	bis(2-Chloroethyl)ether	0/36	10-20	ND
ND	39638-32-9	bis(2-Chloroisopropyl)Ether	0/36	10-20	ND
ND	117-81-7	bis(2-Ethylhexyl)phthalate	0/36	10-20	ND
TIC ⁶	314-40-9	Bromacil (Herbicide)	1/1	-	21(J ⁷)
ND	75-27-4	Bromodichloromethane	0/192	1-5,000	ND
ND	75-25-2	Bromoform	0/192	1-5,000	ND
ND	74-83-9	Bromomethane	0/192	2-10,000	ND
ND	101-55-3	4-Bromophenylphenylether	0/36	10-20	ND
A	78-93-3	2-Butanone	4/192	2-10,000	240(B ⁸)-2,800(B)

Table 6.2-1 (continued) Organic Chemicals Sampled in Groundwater

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SQLs ¹ (µg/L)	RANGE OF CONCENTRATIONS (µg/L)
TIC	104-51-8	Butylbenzene	1/1	-	70(J)
ND	85-68-7	Butylbenzylphthalate	0/36	10-20	ND
ND	75-15-0	Carbon Disulfide	0/192	1-5,000	ND
A	56-23-5	Carbon Tetrachloride	1/192	1-5,000	400
C'	NA	Chloride	3/3	-	28.3-406
ND	106-47-8	4-Chloroaniline	0/36	10-20	ND
A	108-90-7	Chlorobenzene	7/192	1-5,000	6-590
ND	75-00-3	Chloroethane	0/192	2-10,000	ND
TIC	593-63-5	Chloroethylene	1/1	-	400(J)
A	67-66-3	Chloroform	4/192	1-5,000	1-620
ND	74-87-3	Chloromethane	0/192	2-10,000	ND
ND	59-50-7	4-Chloro-3-Methylphenol	0/33	10-20	ND
ND	91-58-7	2-Chloronaphthalene	0/36	10-20	ND
A	95-57-8	2-Chlorophenol	1/33	10-20	2(J)
ND	7005-72-3	4-Chlorophenylphenylether	0/36	-	ND
ND	218-01-9	Chrysene	0/36	10-20	ND
ND	156-59-2	cis-1,2-Dichloroethene	0/8	1-5	ND
TIC	1192-18-3	cis-1,2-Dimethylcyclopentane	1/1	-	80(J)
ND	10061-01-5	cis-1,3-Dichloropropene	0/192	1-5,000	ND
TIC	98-82-8	Cumene	3/3	-	100(J)
D ¹⁰	NA	Cyanide	2/2	-	0.015-0.017
TIC	110-82-7	Cyclohexane	1/1	-	600(J)

Table 6.2-1 (continued) Organic Chemicals Sampled in Groundwater

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SQLs ¹ (µg/L)	RANGE OF CONCENTRATIONS (µg/L)
TIC	108-87-2	Cyclohexylmethane	1/1	-	90(J)-400(J)
TIC	287-92-3	Cyclopentane	1/1	-	90(J)
A	132-64-9	Dibenzofuran	1/36	10-20	2(J)
ND	53-70-3	Dibenzo[a,h]Anthracene	0/36	10-20	ND
A	124-48-1	Dibromochloromethane	1/192	1-5,000	550
CPC	95-50-1	1,2-Dichlorobenzene	10/37	10-20	5(J)-3,000
A	541-73-1	1,3-Dichlorobenzene	1/1	10-20	33
CPC	106-46-7	1,4-Dichlorobenzene	2/37	10-20	310-600
ND	91-94-1	3,3'-Dichlorobenzidine	0/36	20-40	ND
CPC	75-34-3	1,1-Dichloroethane	7/192	1-5,000	13-620
A	107-06-2	1,2-Dichloroethane	7/192	1-5,000	30-30,000
CPC	75-35-4	1,1-Dichloroethene	17/192	1-5,000	5(J)-1,200
CPC	540-59-0	1,2-Dichloroethene	21/170	5-5,000	5(J)-69,000
ND	120-83-2	2,4-Dichlorophenol	0/33	10-20	ND
A	78-87-5	1,2-Dichloropropane	1/192	1-5,000	610
ND	84-66-2	Diethylphthalate	0/36	10-20	ND
CPC	105-67-9	2,4-Dimethylphenol	2/33	10-20	20-130
ND	131-11-3	Dimethylphthalene	0/36	10-20	ND
A	84-74-2	Di-n-Butylphthalate	1/36	10-20	4(J)
ND	534-52-1	4,6-Dinitro-2-Methylphenol	0/33	50-100	ND
ND	51-28-5	2,4-Dinitrophenol	0/33	50-100	ND
ND	121-14-2	2,4-Dinitrotoluene	0/36	10-20	ND

Table 6.2-1 (continued) Organic Chemicals Sampled in Groundwater

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SOLs* (µg/L)	RANGE OF CONCENTRATIONS (µg/L)
ND	606-20-2	2,6-Dinitrotoluene	0/36	10-20	ND
ND	117-84-0	Di-n-Octylphthalate	0/36	10-20	ND
TIC	611-15-4	1-Ethynyl-2-Methylbenzene	1/1	-	50(J)
A	100-41-4	Ethylbenzene	4/192	1-5,000	28-480
TIC	1678-91-7	Ethylcyclohexane	1/1	-	70(J)
TIC	1758-88-9	2-Ethyl-1,4-Dimethylbenzene	1/1	-	70(J)
TIC	934-80-5	4-Ethyl-1,2-Dimethylbenzene	1/1	-	100(J)
ND	206-44-0	Fluoranthene	0/36	10-20	ND
ND	86-73-7	Fluorene	0/36	10-20	ND
C	NA	Fluoride	3/3	-	0.12-0.29
A	591-78-6	2-Hexanone	1/192	2-10,000	2,200
ND	118-74-1	Hexachlorobenzene	0/36	10-20	ND
ND	87-68-3	Hexachlorobutadiene	0/36	10-20	ND
ND	77-47-4	Hexachlorocyclopentadiene	0/36	10-20	ND
ND	67-72-1	Hexachloroethane	0/36	10-20	ND
ND	193-39-5	Indeno(1,2,3-cd)Pyrene	0/36	10-20	ND
ND	78-59-1	Isophorone	0/36	10-20	ND
TIC	108-67-8	Mesitylene	1/1	-	20(J)
A	75-09-2	Methylene Chloride	6/192	1-5,000	120-98,000
TIC	535-77-3	1-Methyl-3-(1-Methylethyl)benzene	1/1	-	60(J)
CPC	91-57-6	2-Methylnaphthalene	8/37	10-20	6(J)-91
ND	108-10-1	4-Methyl-2-Pentanone	0/192	2-10,000	ND

Table 6.2-1 (continued) Organic Chemicals Sampled in Groundwater

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SOLs ¹ (ug/L)	RANGE OF CONCENTRATIONS (ug/L)
CPC	95-48-7	2-Methylphenol	2/36	10-20	8(J)-1,600
A	106-44-5	4-Methylphenol	1/36	10-20	14
TIC	1074-43-7	1-Methyl-3-Propylbenzene	1/1	-	20(J)
TIC	1074-55-1	1-Methyl-4-Propylbenzene	1/1	-	80(J)
TIC	3728-57-2	1-Methyl-2-Propylcyclopentane	1/1	-	100(J)
CPC	91-20-3	Naphthalene	7/37	10-20	4(J)-77
C	NA	Nitrate	3/3	-	0.5-35.4
C	NA	Nitrite	1/3	0.01	0.12
ND	88-74-4	2-Nitroaniline	0/36	50-100	ND
ND	99-09-2	3-Nitroaniline	0/36	50-100	ND
ND	100-01-6	4-Nitroaniline	0/36	50-100	ND
ND	98-95-3	Nitrobenzene	0/36	10-20	ND
ND	88-75-5	2-Nitrophenol	0/33	10-20	ND
ND	100-02-7	4-Nitrophenol	0/33	50-100	ND
ND	621-64-7	n-Nitroso-Di-n-propylamine	0/36	10-20	ND
ND	86-30-6	n-Nitrosodiphenylamine	0/36	10-20	ND
TIC	103-65-1	n-Propylbenzene	3/3	-	80(J)-100(J)
ND	95-47-6	o-Xylene	0/8	1-5	ND
C	NA	Oil and Grease	23/61	0.5-10	0.5-956
TIC	99-87-6	P-Cumene	1/1	-	20(J)
ND	87-86-5	Pentachlorophenol	0/33	50-100	ND
ND	85-01-8	Phenanthrene	0/36	10-20	ND

Table 6.2-1 (continued) Organic Chemicals Sampled in Groundwater

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SOLs ^a (µg/L)	RANGE OF CONCENTRATIONS (µg/L)
A	108-95-2	Phenol	1/33	10-20	2(J)
TIC	135-98-8	2-Phenylbutane	1/1	-	40(J)
C	NA	Phosphate	1/3	0.1	0.10
ND	129-00-0	Pyrene	0/36	10-20	ND
ND	100-42-5	Styrene	0/192	1-5,000	ND
C	NA	Sulfate	3/3	-	45.7-86.8
ND	79-34-5	1,1,2,2-Tetrachloroethane	0/192	1-5,000	ND
A	127-18-4	Tetrachloroethene	5/192	1-5,000	1(J)-450
TIC	488-23-3	1,2,3,4-Tetramethylbenzene	1/1	-	90(J)
CPC	108-88-3	Toluene	8/192	1-5,000	2-25,000
C	NA	Total Petroleum Hydrocarbon	6/33	0.5	0.6-12.01
ND	156-60-5	trans-1,2-Dichloroethene	0/8	1-5	ND
ND	10061-02-6	trans-1,3-Dichloropropene	0/192	1-5,000	ND
ND	120-82-1	1,2,4-Trichlorobenzene	0/36	10-20	ND
CPC	71-55-6	1,1,1-Trichloroethane	13/192	1-5,000	7-380
A	79-00-5	1,1,2-Trichloroethane	1/192	1-5,000	660
CPC	79-01-6	Trichloroethene	109/192	1-1,000	3-87,000
ND	95-95-4	2,4,5-Trichlorophenol	0/36	50-100	ND
ND	88-06-2	2,4,6-Trichlorophenol	0/33	10-20	ND
TIC	526-73-8	1,2,3-Trimethylbenzene	1/1	-	20(J)
TIC	NA	Unknown	3/3	-	10(J)-50(J)
TIC	Unk - 25.67	Unknown	1/1	-	46(J)

Table 6.2-1 (continued) Organic Chemicals Sampled in Groundwater

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SQLs ¹ (µg/L)	RANGE OF CONCENTRATIONS (µg/L)
TIC	Unk - 15.92	Unknown	1/1	-	25(J)
TIC	NA	Unknown Aromatic	1/1	-	60(J)
TIC	NA	Unknown Hydrocarbon	1/1	-	300(J)
TIC	NA	Unknown Organic	8/8	-	3(J)-300(J)
ND	108-05-4	Vinyl Acetate	0/192	2-10,000	ND
A	75-01-4	Vinyl Chloride	6/192	2-10,000	14-5,600
TIC	1330-20-7	Xylene	4/192	1-5,000	16-75

1. SQL= Sample Quantitation Limit

2. ND= Not detected

3. A= Infrequent (less than 5 percent) detection

4. CPC= Chemical of Potential Concern

5. E= Concentration exceeds calibration range of the gas chromatograph/mass spectrometer

6. TIC= Tentatively Identified Compound

7. J = Value is estimated when a compound is present (spectral identification criteria are met), but the value is less than the contract required quantitation limit

8. B = Analyte is found in an associated blank as well as in the sample

9. C = Nonspecific parameter

10. D = Below action level (EPA, 1990a)

Table 6.2-2 Organic Chemicals Sampled in Surface Water

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SQLs ¹ (µg/L)	RANGE OF CONCENTRATIONS (µg/L)
ND ²	83-32-9	Acenaphthene	0/11	10-20	ND
ND	208-96-8	Acenaphthylene	0/11	10-20	ND
LC ³	67-64-1	Acetone	2/11	2-10,000	12-13
ND	120-12-7	Anthracene	0/11	10-20	ND
ND	71-43-2	Benzene	0/11	1-5,000	ND
ND	56-55-3	Benzo[a]Anthracene	0/11	10-20	ND
ND	50-32-8	Benzo[a]Pyrene	0/11	10-20	ND
ND	205-99-2	Benzo(b)Fluoranthene	0/11	10-20	ND
ND	191-24-2	Benzo(g,h,i)Perylene	0/11	10-20	ND
ND	65-85-0	Benzoic Acid	0/11	50-100	ND
ND	207-08-9	Benzo(k)Fluoranthene	0/11	10-20	ND
ND	100-51-6	Benzyl Alcohol	0/11	10-20	ND
ND	111-91-1	bis(2-Chloroethoxy)methane	0/11	10-20	ND
ND	111-44-4	bis(2-Chloroethyl)ether	0/11	10-20	ND
ND	39638-32-9	bis(2-Chloroisopropyl)Ether	0/11	10-20	ND
ND	117-81-7	bis(2-Ethylhexyl)phthalate	0/11	10-20	ND
ND	75-27-4	Bromodichloromethane	0/11	1-5,000	ND
ND	75-25-2	Bromoform	0/11	1-5,000	ND
ND	101-55-3	4-Bromophenylphenylether	0/11	10-20	ND
ND	74-83-9	Bromomethane	0/11	2-10,000	ND
ND	78-93-3	2-Butanone	0/11	2-10,000	ND
ND	85-68-7	Butylbenzylphthalate	0/11	10-20	ND

Table 6.2-2 (continued) Organic Chemicals Sampled in Surface Water

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SOLs ¹ (µg/L)	RANGE OF CONCENTRATIONS (µg/L)
ND	75-15-0	Carbon Disulfide	0/11	1-5,000	ND
ND	56-23-5	Carbon Tetrachloride	0/11	1-5,000	ND
ND	106-47-8	4-Chloroaniline	0/11	10-20	ND
ND	108-90-7	Chlorobenzene	0/11	1-5,000	ND
ND	75-00-3	Chloroethane	0/11	2-10,000	ND
ND	67-66-3	Chloroform	0/11	1-5,000	ND
ND	74-87-3	Chloromethane	0/11	2-10,000	ND
ND	59-50-7	4-Chloro-3-Methylphenol	0/11	10-20	ND
ND	91-58-7	2-Chloronaphthalene	0/11	10-20	ND
ND	95-57-8	2-Chlorophenol	0/11	10-20	ND
ND	7005-72-3	4-Chlorophenylphenylether	0/11	-	ND
ND	218-01-9	Chrysene	0/11	10-20	ND
CPC	156-59-2	cis-1,2-Dichloroethene	4/11	1-5	6-430
ND	10061-01-5	cis-1,3-Dichloropropene	0/11	1-5,000	ND
ND	53-70-3	Dibenzo[a,h]Anthracene	0/11	10-20	ND
ND	132-64-9	Dibenzofuran	0/11	10-20	ND
ND	124-48-1	Dibromochloromethane	0/11	1-5,000	ND
ND	95-50-1	1,2-Dichlorobenzene	0/11	10-20	ND
ND	106-46-7	1,4-Dichlorobenzene	0/11	10-20	ND
ND	91-94-1	3,3'-Dichlorobenzidine	0/11	20-40	ND
ND	75-34-3	1,1-Dichloroethane	0/11	1-5,000	ND
ND	107-06-2	1,2-Dichloroethane	0/11	1-5,000	ND

Table 6.2-2 (continued) Organic Chemicals Sampled in Surface Water

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SOL _s ^a (µg/L)	RANGE OF CONCENTRATIONS (µg/L)
ND	75-35-4	1,1-Dichloroethene	0/11	1-5,000	ND
ND	540-59-0	1,2-Dichloroethene	0/11	5-5,000	ND
ND	120-83-2	2,4-Dichlorophenol	0/11	10-20	ND
ND	78-87-5	1,2-Dichloropropane	0/11	1-5,000	ND
ND	84-66-2	Diethylphthalate	0/11	10-20	ND
ND	105-67-9	2,4-Dimethylphenol	0/11	10-20	ND
ND	131-11-3	Dimethylphthalene	0/11	10-20	ND
ND	84-74-2	Di-n-Butylphthalate	0/11	10-20	ND
ND	534-52-1	4,6-Dinitro-2-Methylphenol	0/11	50-100	ND
ND	51-28-5	2,4-Dinitrophenol	0/11	50-100	ND
ND	121-14-2	2,4-Dinitrotoluene	0/11	10-20	ND
ND	606-20-2	2,6-Dinitrotoluene	0/11	10-20	ND
ND	117-84-0	Di-n-Octylphthalate	0/11	10-20	ND
ND	100-41-4	Ethylbenzene	0/11	1-5,000	ND
ND	206-44-0	Fluoranthene	0/11	10-20	ND
ND	86-73-7	Fluorene	0/11	10-20	ND
ND	118-74-1	Hexachlorobenzene	0/11	10-20	ND
ND	87-68-3	Hexachlorobutadiene	0/11	10-20	ND
ND	77-47-4	Hexachlorocyclopentadiene	0/11	10-20	ND
ND	67-72-1	Hexachloroethane	0/11	10-20	ND
ND	591-78-6	2-Hexanone	0/11	2-10,000	ND
ND	193-39-5	Indeno(1,2,3-cd)Pyrene	0/11	10-20	ND

Table 6.2-2 (continued) Organic Chemicals Sampled in Surface Water

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SQLs ¹ (µg/L)	RANGE OF CONCENTRATIONS (µg/L)
ND	78-59-1	Isophorone	0/11	10-20	ND
ND	75-09-2	Methylene Chloride	0/11	1-5,000	ND
ND	91-57-6	2-Methylnaphthalene	0/11	10-20	ND
ND	108-10-1	4-Methyl-2-Pentanone	0/11	2-10,000	ND
ND	95-48-7	2-Methylphenol	0/11	10-20	ND
ND	106-44-5	4-Methylphenol	0/11	10-20	ND
ND	91-20-3	Naphthalene	0/11	10-20	ND
ND	88-74-4	2-Nitroaniline	0/11	50-100	ND
ND	99-09-2	3-Nitroaniline	0/11	50-100	ND
ND	100-01-6	4-Nitroaniline	0/11	50-100	ND
ND	98-95-3	Nitrobenzene	0/11	10-20	ND
ND	88-75-5	2-Nitrophenol	0/11	10-20	ND
ND	100-02-7	4-Nitrophenol	0/11	50-100	ND
ND	621-64-7	n-Nitroso-Di-n-propylamine	0/11	10-20	ND
ND	86-30-6	n-Nitrosodiphenylamine	0/11	10-20	ND
C'	NA	Oil and Grease	3/11	0.5-10	0.5-3
ND	95-47-6	o-Xylene	0/11	1-5	ND
ND	87-86-5	Pentachlorophenol	0/11	50-100	ND
ND	85-01-8	Phenanthrene	0/11	10-20	ND
ND	108-95-2	Phenol	0/11	10-20	ND
ND	129-00-0	Pyrene	0/11	10-20	ND
ND	100-42-5	Styrene	0/11	1-5,000	ND

Table 6.2-2 (continued) Organic Chemicals Sampled in Surface Water

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SQL ¹ (µg/L)	RANGE OF CONCENTRATIONS (µg/L)
ND	79-34-5	1,1,2,2-Tetrachloroethane	0/11	1-5,000	ND
ND	127-18-4	Tetrachloroethene	0/11	1-5,000	ND
ND	108-88-3	Toluene	0/11	1-5,000	ND
C	NA	Total Petroleum Hydrocarbon	2/11	0.5	1-2
ND	156-60-5	trans-1,2-Dichloroethene	0/11	1-5	ND
ND	10061-02-6	trans-1,3-Dichloropropene	0/11	1-5,000	ND
ND	120-82-1	1,2,4-Trichlorobenzene	0/11	10-20	ND
ND	71-55-6	1,1,1-Trichloroethane	0/11	1-5,000	ND
ND	79-00-5	1,1,2-Trichloroethane	0/11	1-5,000	ND
ND	79-01-6	Trichloroethene	0/11	1-1,000	ND
ND	95-95-4	2,4,5-Trichlorophenol	0/11	50-100	ND
ND	88-06-2	2,4,6-Trichlorophenol	0/11	10-20	ND
ND	108-05-4	Vinyl Acetate	0/11	2-10,000	ND
CPC	75-01-4	Vinyl Chloride	1/11	2-10,000	14
ND	1330-20-7	Xylene	0/11	1-5,000	ND

1. SQL = Sample Quantitation Limit
2. ND = Not detected
3. LC = Common laboratory contaminant
4. C = Nonspecific parameter

Table 6.2-3 Organic Chemicals Sampled in Soil

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SOILS ¹ (µg/kg)	RANGE OF CONCENTRATIONS (µg/kg)	BACKGROUND CONCENTRATIONS (µg/kg)
A ²	83-32-9	Acenaphthene	13/568	690-27,000	88(J) ³ -11,000(J)	86(J)
A	208-96-8	Acenaphthylene	3/566	680-24,000	210(J)-1,500(J)	ND
A	67-64-1	Acetone	1/244	10-1,400,000	670,000(J)	ND
A	120-12-7	Anthracene	13/566	680-24,000	81(J)-25,000	ND
A/CPC	71-43-2	Benzene	9/244	5-700,000	4(J)-180	ND
CPC	56-55-3	Benzo[a]anthracene	44/568	700-27,000	40(J)-71,000	55-170
CPC	50-32-8	Benzo[a]pyrene	25/569	680-22,000	74(J)-62,000	140
CPC	205-99-2	Benzo(b)fluoranthene	36/566	680-27,000	65(J)-67,000	160(J)
A	191-24-2	Benzo(g,h,i)Perylene	18/566	700-27,000	160(J)-53,000	ND
CPC	207-08-9	Benzo(k)fluoranthene	30/566	680-27,000	65(J)-58,000	160(J)
A	65-85-0	Benzoic Acid	2/568	3,400-130,000	330(J)-590(J)	ND
ND ⁴	100-51-6	Benzyl Alcohol	0/20	690-24,000	ND	ND
ND	111-91-1	bis(2-Chloroethoxy)Methane	0/566	690-24,000	ND	ND
ND	111-44-4	bis(2-Chloroethyl)Ether	0/566	680-24,000	ND	ND
ND	117-81-7	bis(2-Ethylhexyl)Phthalate	0/566	690-24,000	ND	110(J)
A	75-27-4	Bromodichloromethane	3/244	5-700,000	3(J)-600,000	ND
ND	75-25-2	Bromoform	0/244	5-700,000	ND	ND
ND	74-83-9	Bromomethane	0/244	10-1,400,000	ND	ND
ND	101-55-3	4-Bromophenylphenylether	0/566	680-24,000	ND	ND
A	78-93-3	2-Butanone	7/244	10-60	130,000-1,800,000 ⁵	ND
A	85-68-7	Butylbenzophthalate	1/566	690-27,000	130(J)	ND
ND	75-15-0	Carbon Disulfide	0/244	5-700,000	ND	ND

Table 6.2-3 (continued) Organic Chemicals Sampled in Soil

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SOLs ¹ (µg/kg)	RANGE OF CONCENTRATIONS (µg/kg)	BACKGROUND CONCENTRATIONS (µg/kg)
ND	56-23-5	Carbon Tetrachloride	0/244	5-700,000	ND	ND
ND	106-47-8	4-Chloroaniline	0/20	680-24,000	ND	ND
A	108-90-7	Chlorobenzene	2/244	5-700,000	63-80	ND
ND	75-00-3	Chloroethane	0/244	10-1,400,000	ND	ND
A	67-66-3	Chloroform	9/244	5-700,000	4(J)-1,900,000	ND
ND	74-87-3	Chloromethane	0/244	10-1,400,000	ND	ND
A	59-50-7	4-Chloro-3-Methylphenol	1/566	690-24,000	360(J)	ND
ND	91-58-7	2-Chloronaphthalene	0/566	680-24,000	ND	ND
A	95-57-8	2-Chlorophenol	2/570	680-27,000	55(J)-480(J)	ND
CPC	218-01-9	Chrysene	49/566	680-27,000	47(J)-87,000	190(J)
CPC	156-59-2	cis-1,2-Dichloroethene	4/43	5-28	15-150	ND
D ⁶	NA	Cyanide	1/1	-	0.05	ND
A	541-73-1	1,3-Dichlorobenzene	4/566	680-27,000	190(J)-1,600	ND
A	106-46-7	1,4-Dichlorobenzene	2/566	680-24,000	290(J)-1,200	ND
ND	120-83-2	2,4-Dichlorophenol	0/566	680-24,000	ND	ND
ND	84-74-2	Di-n-Butylphthalate	0/572	690-22,000	ND	39(B ⁷ ,J) 46(B,J) 74(B,J)
A	117-84-0	Di-n-Octylphthalate	1/566	680-23,000	360(J)	ND
A	132-64-9	Dibenzofuran	20/566	680-24,000	50(J)-7,400(J)	ND
A	53-70-3	Dibenzo[a,h]anthracene	5/566	680-27,000	170(J)-11,000(J)	ND
ND	124-48-1	Dibromochloromethane	0/244	5-700,000	ND	ND
ND	91-94-1	3,3'-Dichlorobenzidine	0/566	1,300-48,000	ND	ND
A	95-50-1	1,2-Dichlorobenzene	5/566	680-24,000	100(J)-12,000	ND

Table 6.2-3 (continued) Organic Chemicals Sampled in Soil

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SOI _s ¹ (µg/kg)	RANGE OF CONCENTRATIONS (µg/kg)	BACKGROUND CONCENTRATIONS (µg/kg)
ND	75-34-3	1,1-Dichloroethane	0/244	5-700,000	ND	ND
ND	107-06-2	1,2-Dichloroethane	0/244	5-700,000	ND	ND
A	75-35-4	1,1-Dichloroethene	2/244	5-700,000	1(J)-10	ND
A	540-59-0	1,2-Dichloroethene	2/244	5-700,000	180-290(E ²)	ND
ND	78-87-5	1,2-Dichloropropane	0/244	5-700,000	ND	ND
ND	84-66-2	Diethylphthalate	0/244	10-39,000	ND	ND
ND	105-67-9	2,4-Dimethylphenol	0/565	690-24,000	ND	ND
ND	131-11-3	Dimethylphthalate	0/566	690-24,000	ND	ND
ND	534-52-1	4,6-Dinitro-2-Methylphenol	0/565	3,300-120,000	ND	ND
ND	51-28-5	2,4-Dinitrophenol	0/566	3,300-110,000	ND	ND
ND	121-14-2	2,4-Dinitrotoluene	0/566	680-23,000	ND	ND
ND	606-20-2	2,6-Dinitrotoluene	0/566	690-24,000	ND	ND
CPC	100-41-4	Ethylbenzene	17/244	5-340,000	3(J)-290(E)	ND
CPC	206-44-0	Fluoranthene	76/566	680-27,000	31(J)-190,000	110(J), 410(J)
A	86-73-7	Fluorene	21/568	680-27,000	52(J)-12,000(J)	ND
ND	118-74-1	Hexachlorobenzene	0/566	680-24,000	ND	ND
ND	87-68-3	Hexachlorobutadiene	0/566	690-24,000	ND	ND
ND	77-47-4	Hexachlorocyclopentadiene	0/566	690-24,000	ND	ND
ND	67-72-1	Hexachloroethane	0/566	680-27,000	ND	ND
ND	591-78-6	2-Hexanone	0/244	10-690,000	ND	ND
A	193-39-5	Indeno(1,2,3-cd)Pyrene	15/566	680-27,000	130(J)-56,000	150(J)
ND	78-59-1	Isophorone	0/566	690-24,000	ND	ND

Table 6.2-3 (continued) Organic Chemicals Sampled in Soil

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SQLS ¹ (µg/kg)	RANGE OF CONCENTRATIONS (µg/kg)	BACKGROUND CONCENTRATIONS (µg/kg)
A	75-09-2	Methylene Chloride	1/244	5-700,000	260(J)	ND
CPC	91-57-6	2-Methylnaphthalene	52/576	600-27,000	54(J)-50,000	ND
ND	108-10-1	2-Methyl-4-Pentanone	0/244	10-1,400,000	ND	ND
ND	95-48-7	2-Methylphenol	0/566	680-24,000	ND	ND
A	106-44-5	4-Methylphenol	2/566	690-24,000	180(J)-380(J)	ND
CPC	91-20-3	Naphthalene	40/566	680-27,000	62(J)-8,000(J)	ND
ND	99-09-2	3-Nitroaniline	0/566	3,300-120,000	ND	ND
ND	88-74-4	2-Nitroaniline	0/566	3,300-120,000	ND	ND
ND	100-01-6	4-Nitroaniline	0/566	3,400-110,000	ND	ND
ND	98-95-3	Nitrobenzene	0/550	700-27,000	ND	ND
ND	88-75-5	2-Nitrophenol	0/566	680-24,000	ND	ND
ND	100-02-7	4-Nitrophenol	0/565	3,400-120,000	ND	ND
A	621-64-7	n-Nitroso-Di-n-propylamine	1/566		94(J)	ND
A	86-30-6	n-Nitrosodiphenylamine	1/566	690-27,000	1,300	ND
ND	95-47-6	o-Xylene	0/22	5-28	ND	ND
C'	NA	Oil and Grease	22/32	10	12-6,020	11,43,63
A	87-86-5	Pentachlorophenol	13/566	3,400-130,000	290(J)-3,600(J)	ND
CPC	85-01-8	Phenanthrene	58/558	700-27,000	35(J)-150,000	56-230
A	108-95-2	Phenol	1/565	690-23,000	500(J)	ND
CPC	129-00-0	Pyrene	88/566	680-27,000	42(J)-150,000	170(J), 390(J)
ND	100-42-5	Styrene	0/244	5-700,000	ND	ND
A	127-18-4	Tetrachloroethene	7/244	5-700,000	1(J)-10	ND

Table 6.2-3 (continued) Organic Chemicals Sampled in Soil

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SQLs ¹ ($\mu\text{g}/\text{kg}$)	RANGE OF CONCENTRATIONS ($\mu\text{g}/\text{kg}$)	BACKGROUND CONCENTRATIONS ($\mu\text{g}/\text{kg}$)
CPC	108-88-3	Toluene	13/244	5-700,000	0.8(J)-1,200,000	ND
C	NA	Total Petroleum Hydrocarbon	45/115	10	14-8,781	33
ND	156-60-5	trans-1,2-Dichloroethene	0/22	5-28	ND	ND
ND	120-82-1	1,2,4-Trichlorobenzene	0/566	690-23,000	ND	81(J)
ND	71-55-6	1,1,1-Trichloroethane	0/244	5-700,000	ND	ND
ND	79-00-5	1,1,2-Trichloroethane	0/244	5-700,000	ND	ND
ND	79-34-5	1,1,2,2-Tetrachloroethane	0/244	5-700,000	ND	ND
CPC	79-01-6	Trichloroethene	29/244	5-700,000	6-12,000	ND
ND	95-95-4	2,4,5-Trichlorophenol	0/566	3,300-120,000	ND	ND
ND	88-06-2	2,4,6-Trichlorophenol	0/566	690-24,000	ND	ND
ND	108-05-4	Vinyl Acetate	0/244	10-1,400,000	ND	ND
A	75-01-4	Vinyl Chloride	3/244	10-1,400,000	5(J)-20	ND
A	1330-20-7	Xylene	9/244		3(J)-4,200(E)	ND

- SQL = Sample Quantitation Limit
- A = Infrequent (less than 5 percent) detection
- J = Value is estimated when a compound is present (spectral identification criteria are met), but the value is less than the contract-required quantitation limit
- ND = Not detected
- 2-Butanone is a common laboratory contaminant that was found in high concentrations in laboratory blanks as well as environmental samples
- D = Below action level (EPA, 1990a)
- B = Analyte is found in an associated blank as well as in the sample
- E = Concentration exceeds calibration range of the gas chromatograph/mass spectrometer
- C = Nonspecific parameter

Table 6.2-4 Volatile Organic Chemicals Sampled in Air

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SQLs ^a (ppb)	RANGE OF CONCENTRATIONS (ppb)	OFF SITE (ppb)
CPC ^c	71-43-2	Benzene	15/15	0.2-0.4	0.25-1.5	0.26-1.1
ND ^d	100-44-7	Benzyl Chloride	0/15	0.2-0.4	ND	ND
ND	75-27-4	Bromodichloromethane	0/13	0.2-0.4	ND	ND
ND	75-25-2	Bromoform	0/13	0.2-0.4	ND	ND
ND	74-83-9	Bromomethane	0/15	0.3-0.6	ND	ND
ND	106-99-0	1,3-Butadiene	0/13	0.5-1	ND	ND
ND	75-15-0	Carbon Disulfide	0/13	0.2-0.4	ND	ND
F ^e	56-23-5	Carbon Tetrachloride	7/15	0.2-0.4	ND-0.11	ND-0.12
D ^f	108-90-7	Chlorobenzene	4/15	0.2-0.4	ND-0.15	ND-1.4
A ^g	75-45-6	Chlorodifluoromethane	1/13	0.2-0.4	0.56	ND
ND	75-00-3	Chloroethane	0/15	0.5-1	ND	ND
A	67-66-3	Chloroform	1/15	0.3-0.6	ND-0.10	ND-0.07
F	74-87-3	Chloromethane	6/15	0.5-1	ND-0.62	ND-0.61
ND	107-05-1	3-Chloropropene	0/13	0.5-1	ND	ND
A	72-54-8	cis-1,2-Dichloroethene	1/15	0.3-0.6	ND-0.10	ND
ND	10061-01-5	cis-1,3-Dichloropropene	0/15	0.4-0.8	ND	ND
ND	98-82-8	Cumene	0/13	0.2-0.4	ND	ND
ND	124-18-5	Decane	0/13	0.2-0.4	ND	ND
ND	124-48-1	Dibromochloromethane	0/13	0.2-0.4	ND	ND
ND	106-93-4	Dibromoethane	0/15	0.2-0.4	ND	ND
ND	106-93-4	1,2-Dibromomethane	0/13	0.2-0.4	ND	ND
ND	95-50-1	1,2-Dichlorobenzene	0/15	0.1-0.2	ND	ND

Table 6.2-4 (continued) Volatile Organic Chemicals Sampled in Air

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SQLs ¹ (ppb)	RANGE OF CONCENTRATIONS (ppb)	OFF SITE (ppb)
ND	541-73-1	1,3-Dichlorobenzene	0/15	0.1-0.2	ND	ND
ND	106-46-7	1,4-Dichlorobenzene	0/15	0.1-0.2	ND	ND
ND	75-34-3	1,1-Dichloroethane	0/15	1-5,000	ND	ND
ND	75-35-4	1,1-Dichloroethene	0/15	0.3-0.6	ND	ND
ND	540-59-0	1,2-Dichloroethene	0/15	0.3-0.6	ND	ND
D	75-71-8	Dichlorodifluoromethane (Freon 12)	15/15	0.2-0.4	0.23-11	0.14-0.77
ND	78-87-5	1,2-Dichloropropane	0/15	0.3-0.6	ND	ND
A	76-14-2	1,2-Dichloro-1,1,2,2-Tetrafluoroethane (Freon 114)	1/15	0.2-0.4	ND-0.05	ND
F	100-41-4	Ethylbenzene	13/15	0.2-0.4	ND-0.68	0.17-0.75
ND	87-68-3	Hexachlorobutadiene	0/15	0.2-0.4	ND	ND
ND	110-54-3	Hexane	0/13	0.4-0.8	ND	ND
ND	463-82-1	Iso-pentane	0/13	0.5-1	ND	ND
CPC	75-09-2	Methylene Chloride	11/15	0.2-0.4	ND-0.48	ND-0.25
F	NA	m- and/or p-xylene	15/15	0.2-0.4	0.10-2.6	0.6-2.5
ND	91-20-3	Naphthalene	0/13	0.2-0.4	ND	ND
ND	106-97-8	n-Butane	0/13	0.5-1	ND	ND
ND	112-40-3	n-Dodecane	0/13	0.2-0.4	ND	ND
ND	142-62-5	n-Heptane	0/13	0.2-0.4	ND	ND
A	111-84-2	n-Nonane	1/13	0.2-0.4	ND-0.71	ND
ND	111-65-9	n-Octane	0/13	0.2-0.4	ND	ND
ND	109-66-0	n-Pentane	0/13	0.5-1	ND	ND

Table 6.2-4 (continued) Volatile Organic Chemicals Sampled in Air

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SOLs ¹ (ppb)	RANGE OF CONCENTRATIONS (ppb)	OFF SITE (ppb)
ND	112-21-4	n-Undecane	0/13	0.2-0.4	ND	ND
D	95-47-6	o-Xylene	12/15	0.2-0.4	ND-1.1	0.16-0.97
F	100-42-5	Styrene	3/15	0.2-0.4	ND-0.21	ND-0.13
ND	542-75-6	1-1,3-Dichloropropene	0/15	0.4-0.8	ND	ND
ND	79-34-5	1,1,2,2-Tetrachloroethane	0/15	0.2-0.4	ND	ND
F	127-18-4	Tetrachloroethene	6/15	0.2-0.4	ND-0.50	ND-0.59
D	108-88-3	Toluene	15/15	0.2-0.4	0.44-4.1	0.50-2.4
ND	156-60-5	trans-1,2-Dichloroethene	0/15	0.3-0.6	ND	ND
ND	120-82-1	1,2,4-Trichlorobenzene	0/15	0.2-0.4	ND	ND
D	71-55-6	1,1,1-Trichloroethane	14/15	0.3-0.6	ND-2.5	0.22-0.51
ND	79-00-5	1,1,2-Trichloroethane	0/15	0.3-0.6	ND	ND
CPC	79-01-6	Trichloroethene	7/15	0.2-0.4	ND-2.8	ND-0.64
D	75-69-4	Trichlorofluoromethane	15/15	0.2-0.4	0.26-5.7	0.22-0.61
CPC	76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	14/15	0.2-0.4	ND-4.4	ND-0.79
CPC	95-63-6	1,2,4-Trimethylbenzene	14/15	0.2-0.4	ND-1.1	ND-0.6
CPC	108-67-8	1,3,5-Trimethylbenzene	7/15	0.2-0.4	ND-0.69	ND-0.17
ND	75-01-4	Vinyl Chloride	0/15	0.3-0.6	ND	ND

1. SOL = Sample Quantitation Limit

2. CPC = Chemical of Potential Concern

3. ND = Not detected

4. F = Concentration on site is indistinguishable from or lower than the concentration off site (IT, 1992)

5. D = Below action level (EPA, 1990a)

6. A = Infrequent (less than 7 percent) detection (1 detection in 15 samples)

6.2.2.2 *Inorganic Chemical Analyses*

Table 6.2-5 summarizes data on inorganic chemicals sampled in Plant 4 groundwater. No background samples were analyzed for metals in water at Plant 4. Average concentration values were compared with maximum contaminant levels (MCLs) (EPA 1990c), where available. In summary, note that

- Calcium, magnesium, manganese, copper, iron, sodium, potassium, and zinc were found at low concentrations and are essential nutrients. They were eliminated from further consideration.
- Aluminum is ubiquitous and at low concentrations in the water samples. There is no regulatory standard for aluminum in water. Aluminum was eliminated from further consideration.

Table 6.2-6 summarizes data on inorganic chemicals sampled in soils and sediments from Plant 4. No background samples were analyzed for metals in soils at Plant 4. Average concentration values were compared with regional background concentrations published in Shacklette and Boerngen (1984), where available, and otherwise, with action levels from Appendix A to EPA's proposed corrective action regulation for hazardous waste management facilities (EPA 1990a). In summary, note that

- The average values for arsenic and beryllium were lower than the background levels presented in Shacklette and Boerngen (1984). They were eliminated from further consideration.
- A background level was not available for silver. The average value for silver, which was detected in 12 samples, was 9.85 mg/kg. An EPA action level for silver in soil is 200 mg/kg (EPA 1990a). Silver was eliminated from further consideration.
- A background level was not available for cadmium. An EPA proposed action level for cadmium in soil is 40 mg/kg (EPA 1990a). All values for cadmium were an order of magnitude below this action level, except for the surface samples taken from the transect across the creek (CS-001 through CS-007) and the samples from site location SB-001 (samples SB-001-01 through SB-001-06) at Landfill No. 4. Therefore, cadmium was retained as a chemical of potential concern.

Table 6.2-5 Inorganic Chemicals Sampled in Groundwater

ANALYTE STATUS	ANALYTE	FREQUENCY OF DETECTION	RANGE OF SOLs ¹ (mg/L)	RANGE OF CONCENTRATIONS (mg/L)	MCL ² (µg/L)
C ³	Aluminum	29/30	0.1	0.1-13.5	
A ⁴	Antimony	1/36	0.06-40.0	0.1	
CPC	Arsenic	3/36	0.01-3	0.012-0.079	50
CPC	Barium	18/30	0.1	0.1-0.98	2,000
ND ⁵	Beryllium	0/36	0.005-1	ND	
EN ⁶	Calcium	30/30	-	66-592	
CPC	Cadmium	2/36	0.002-4	0.0023-0.0059	5
ND	Cobalt	0/30	0.05	ND	
CPC	Chromium	34/61	0.01-6	0.01-151	100
EN	Copper	9/36	0.025-8	0.05-8	
EN	Iron	30/30	-	0.05-14	
CPC	Lead	9/36	0.005-2.0	0.009-0.14	15
EN	Magnesium	29/30	1.0	2.5-54.5	
EN	Manganese	20/30	0.015	0.015-0.750	
CPC	Mercury	2/30	0.0002	0.0002-0.0003	2
ND	Nickel	0/36	0.04-25.0	ND	
EN	Potassium	16/30	1.0	1.1-64	
ND	Silver	0/36	0.01-4	ND	
EN	Sodium	30/30	-	12-797	
ND	Selenium	0/36	0.005-2.0	ND	

Table 6.2-5 (continued) Inorganic Chemicals Sampled in Groundwater

ANALYTE STATUS	ANALYTE	FREQUENCY OF DETECTION	RANGE OF SQLs ¹ (mg/L)	RANGE OF CONCENTRATIONS (mg/L)	MCL ² (µg/L)
ND	Thallium	0/36	0.01-2.0	ND	
ND	Vanadium	0/30	0.05	ND	
EN	Zinc	31/36	0.02	0.02-60.5	

1. SQL = Sample Quantitation Limit

2. MCL = Maximum contaminant level (EPA, 1990c)

3. C = (Average) concentration is below regulatory concern

4. A = Infrequent (less than 5 percent) detection

5. ND = Not detected

6. EN = Essential nutrient

Table 6.2-6 Inorganic Chemicals Sampled in Soils

ANALYTE STATUS	ANALYTE	FREQUENCY OF DETECTION	RANGE OF SQLs ¹ (mg/kg)	RANGE OF CONCENTRATIONS (mg/kg)	BACKGROUND LEVELS (mg/kg)
A ²	Antimony	4/113	8.8-16.3	9.4(B ³)-11.4	<1
BL ⁴	Arsenic	137/142	0.66-61	0.74(B)-10.7	8.5
G ⁵	Barium	1/1	--	1750(B)	500
BL	Beryllium	137/141	0.22-0.23	0.24(B)-1.4	<1
CPC ⁶	Cadmium	72/142	0.88-4	0.94(B)-96	40 ⁷
CPC	Chromium	141/142	6	1.6(B)-3170	<30
CPC	Copper	140/141	1.8	1.3(B)-5590	<15
CPC	Lead	133/133	--	2.6-1560	10
ND ⁸	Mercury	0/1	0.19	ND	0.061
CPC	Nickel	77/141	3.5-6.9	3.5(B)-458	10
ND	Selenium	0/142	0.43-20	ND	ND
D ⁹	Silver	12/142	0.65-3	1.6-21.4	200 [*]
A	Thallium	6/128	0.43-0.82	0.45(B)-0.56(B)	6-7
CPC	Zinc	131/131	--	4.9-17400	28

1. SQL = Sample Quantitation Limit
2. A = Infrequent (less than 5 percent) detection
3. B = Analyte is found in an associated blank as well as in the sample
4. D = Average concentration is less than background level
5. G = Barium was analyzed for in only one sample and was eliminated from further consideration
6. CPC = Chemical of Potential Concern
7. Concentration meeting EPA criteria for action levels (EPA, 1990a)
8. ND = Not detected
9. D = Below action level (EPA, 1990a)

- Only one sample was analyzed for barium. There is no evidence that barium was used in past site activities at Air Force Plant 4, and it is not expected to be a widespread contaminant. The sample (SB-149-01) is not a surface sample. Therefore, barium was eliminated from further consideration.
- Chromium, copper, nickel, and zinc were detected at concentrations comparable to background, except in the surface soil samples taken from the transect across the creek (CS-001 through CS-007) and in samples from site location SB-001 (samples SB-001-01 through SB-001-06) at Landfill No. 4. Therefore, chromium, copper, nickel, and zinc were retained as chemicals of potential concern.
- Lead was detected at concentrations comparable to background, except in samples from site location SB-001 (samples SB-001-01 through SB-001-06) at Landfill No. 4 and in the creek sediment sample locations (SW-01 through SW-07). No information was available for the surface samples taken from the transect across the creek (CS-001 through CS-007). Lead was retained as a chemical of potential concern.

Table 6.2-7 presents the list of inorganic chemicals sampled on particulates from the air at Plant 4. The respirable fraction was collected. Analyses were done for the four metals suspected of being chemicals of potential concern, and three of those were found in concentrations high enough to be listed.

6.2.3 Chemicals of Potential Concern

Table 6.2-8 presents the list of chemicals of potential concern for human health at Plant 4 for groundwater, surface water, soil, and air. Section 6.6 presents detailed information on chemicals of concern to the ecosystems at and near Plant 4.

6.2.4 Uncertainties

Uncertainties associated with the collection and laboratory analysis of the sampling data may have impacts on the results of the selection process. These uncertainties result from the potential for contamination of samples during collection, preparation, or analysis, and normal error in the analytical techniques. These uncertainties are minimized by the laboratory validation process. Additional uncertainties occur from the selection process for chemicals of potential concern. Compounds detected infrequently (generally less than 5 percent of the time) or at concentrations close to those in the associated blanks were assumed to be artifacts produced during sample collection or analysis and were deleted from the final list of chemicals of potential concern. This results in a list of chemicals of potential concern that have been found most consistently and at the highest concentrations.

Table 6.2-7 Inorganic Chemicals Sampled in Air (Particulates)

CHEMICAL STATUS	CAS NO.	COMPOUND	FREQUENCY OF DETECTION	RANGE OF SQLs ¹ (ppb)	RANGE OF CONCENTRATIONS (ppb)	OFF SITE (ppb)
D ²	7440-43-9	Cadmium	15/15	0.00002	<0.00013-0.00053	<0.00013-0.00037
CPC ³	7440-47-3	Chromium	15/15	0.00006	0.00096-0.0086	0.00029-0.0088
CPC	7439-92-1	Lead	15/15	0.0003	0.0032-0.0088	0.0032-0.0086
CPC	7440-66-6	Zinc	15/15	0.0004	0.013-0.034	0.016-0.032

1. SQL = Sample Quantitation Limit
2. D = Below action level (EPA, 1990a)
3. CPC = Chemical of Potential Concern

Table 6.2-8 Chemicals of Potential Concern*

CAS NO.	CHEMICAL	GROUNDWATER	SURFACE WATER	SOIL	AIR
7440-38-2	Arsenic	X			
513-77-9	Barium	X			
71-43-2	Benzene	X		X	X
56-55-3	Benzo(a)anthracene			X	
50-32-8	Benzo(a)pyrene			X	
205-99-2	Benzo(b)fluoranthene			X	
207-08-9	Benzo(k)fluoranthene			X	
7440-43-9	Cadmium	X		X	
7440-47-3	Chromium	X		X	X
218-01-9	Chrysene			X	
156-59-2	cis-1,2-Dichloroethene		X	X	
7440-50-8	Copper			X	
95-50-1	1,2-Dichlorobenzene	X			
106-46-7	1,4-Dichlorobenzene	X			
75-34-3	1,1-Dichloroethane	X			
75-35-4	1,1-Dichloroethene	X			
540-59-0	1,2-Dichloroethene	X			
105-67-9	2,4-Dimethylphenol	X			
100-41-4	Ethylbenzene			X	
206-44-0	Fluoranthene			X	
76-13-1	Freon 113				X
7439-92-1	Lead	X		X	X

Table 6.2-8 (continued) Chemicals of Potential Concern

CAS NO.	CHEMICAL	GROUNDWATER	SURFACE WATER	SOIL	AIR
7439-97-6	Mercury	X			
75-09-2	Methylene Chloride				X
91-57-6	2-Methylnaphthalene	X		X	
95-48-7	Methylphenol	X			
91-20-3	Naphthalene	X		X	
7440-02-0	Nickel			X	
85-01-8	Phenanthrene			X	
129-00-0	Pyrene			X	
108-88-3	Toluene	X		X	
71-55-6	1,1,1-Trichloroethane	X			
79-01-6	Trichloroethene	X		X	X
95-63-6	1,2,4-Trimethylbenzene				X
108-67-8	1,3,5-Trimethylbenzene				X
75-01-4	Vinyl Chloride		X		
7440-66-6	Zinc			X	X

* Exposure concentrations are provided on Tables 6.3-5 through 6.3-8 for chemicals/media marked with an X.

6.3 Exposure Assessment

This section presents the estimation of potential exposures of human receptors to chemicals found at the site. Exposure is defined as the contact of a receptor with a chemical. Exposure assessment is the estimation of the magnitude, frequency, and duration for each identified exposure pathway. The magnitude of an exposure is determined by estimating the amount of a chemical available at the receptor exchange boundaries (i.e., lungs, gastrointestinal tract, or skin) during a specified time period. The general procedure for conducting an exposure assessment consists of characterization of the exposure setting, identification of exposure pathways, and quantification of exposure, where possible (EPA 1989a).

6.3.1 Characterization of Exposure Setting

The following sections describe the physical setting of Plant 4 and discuss the present and assumed future demographics. Section 6.6 contains a detailed discussion of the ecosystems at the site.

6.3.1.1 Physiography

Plant 4 is located within the Western Cross Timbers Section and the Grand Prairie Section of the Central Lowlands Physiographic Province. Most of Plant 4 is within the Grand Prairie Section, which is typically a broad, gently sloping terrace of sedimentary rock mantled by a thin layer of light brown to black loamy soil. The Grand Prairie Section is typically grass covered with isolated stands of upland timber (UNC Geotech 1990).

The northwest corner of Plant 4 lies within the Western Cross Timbers Section, which is characterized by rolling to hilly topography that is dissected into steep hills and deep ravines. This section is typified by sandy soils supporting a heavy growth of post oak and blackjack oak (UNC Geotech 1990).

Topography at Plant 4 is generally flat except for areas adjacent to Meandering Road Creek. Elevations range from 590 ft above mean sea level (MSL) along the shore of Lake Worth to approximately 670 ft MSL at the southwest corner of Plant 4 (UNC Geotech 1990).

6.3.1.2 Geology and Hydrogeologic Setting

The geology of the Plant 4 area is characterized by a thin veneer of Quaternary detrital alluvial deposits overlying a sequence of Cretaceous sedimentary formations, which in turn overlies a thick sequence of undifferentiated Paleozoic rocks. Cretaceous rocks at the site consist of the Fredericksburg Group, which includes the Goodland Limestone and the underlying Walnut Formation. Underlying the Fredericksburg Group is the

Cretaceous Trinity Group, which comprises the Paluxy Formation, the Glen Rose Formation, and the Twin Mountains Formation (UNC Geotech 1990).

The hydrogeologic units of interest in the vicinity of Plant 4 are, in descending order, the upper zone, the Walnut aquitard, the Paluxy aquifer, the Glen Rose aquitard, and the Twin Mountains aquifer. The upper zone is the uppermost hydrologic unit at Plant 4. This unit is an unconfined aquifer contained mainly within the Quaternary alluvium. The Goodland Limestone, which underlies the Quaternary sediments, is sufficiently weathered to provide good hydrologic communication between the Quaternary sands and the limestone and is therefore considered to be part of the upper zone hydrologic unit. Beneath the upper zone is the Walnut Formation, which acts as an aquitard between the upper zone and the Paluxy aquifers (UNC Geotech 1990). The Walnut Formation consists of limestones and shales that have very low permeabilities. The Paluxy aquifers which underlie the Walnut aquitard consist of several distinct sand units, separated by discontinuous clay and shale layers. These units comprise an important source of potable groundwater for the community of White Settlement (UNC Geotech 1990). Below the Paluxy aquifers are the fine-grained limestones, shale, marl, and sandstone beds of the Glen Rose Formation, which acts as a aquitard restricting groundwater movement between the Paluxy aquifers and the underlying Twin Mountains aquifer. The Twin Mountains aquifer consists of a basal conglomerate that grades upward into coarse- to fine-grained sand interbedded with shale.

6.3.1.3 Climate

Plant 4 is located in north-central Texas, which is characterized by a sub-humid climate with hot summers and dry winters. The mean annual precipitation is approximately 32 inches. The wettest months are May and September, and the driest months are November and January (UNC Geotech 1990).

Winds in the Dallas-Fort Worth area are predominantly from the south. The next most prevalent wind direction is from the north. Most winds are below 18 knots (Larkin and Bomar 1983).

6.3.1.4 Surface Water

Surface water drainage at Plant 4 is mainly by storm drains and culverts which discharge to Lake Worth, Meandering Road Creek, or a tributary of Farmers Branch of the West Fork of the Trinity River. Lake Worth, which supplies drinking water to the City of Fort Worth, borders Plant 4 on the north. Meandering Road Creek, which borders Plant 4 on the west, drains into Lake Worth to the north. Meandering Road Creek receives storm runoff during periods of precipitation. The stream also receives groundwater discharge from the upper zone aquifer, as evidenced by several seeps along the bank of the drainage (UNC Geotech 1990).

6.3.1.5 Present and Future Demography

Plant 4 is adjacent to residential communities on the south and west sides. The public has recreational access to Lake Worth, which borders the north side of the site. Carswell Air Force Base lies to the east of the site. Approximately 20,000 individuals work at Plant 4. Plant 4 has been a military facility since 1941. It covers 605 acres of which 80 to 85 percent is covered by asphalt, concrete, or buildings. (This estimate is based on a review of land use maps of Plant 4.) Because of the history of this facility and the existing military/industrial infrastructure, it is anticipated that Plant 4 and CAFB will continue to be used for industrial purposes while the surrounding areas will continue to be residential.

6.3.2 Identification of Exposure Pathways

For exposures to occur, complete exposure pathways must exist. A complete exposure pathway requires (EPA 1989a):

- A source and mechanism for release of the chemical,
- A transport medium,
- A point of human or environmental contact, and
- An exposure route at the exposure point.

If any one of these four elements is missing, the pathway is not complete. The identified potential pathways are summarized in Table 6.3-1. A brief explanation of each potential exposure pathway and the reasons for its inclusion or exclusion in the risk assessment follows.

6.3.2.1 Groundwater and Surface Water

Analysis of water samples from monitoring wells and surface water at and adjacent to Plant 4 indicates the presence of 19 chemicals of potential concern in groundwater and two chemicals of potential concern in surface water. The chemicals are primarily solvents used in the manufacture of airplanes and (probable) degradation products of those chemicals.

Exposure to chemicals in surface water at and near the site may occur through four pathways:

- Ingestion of surface water
- Dermal contact with surface water while swimming
- Ingestion of local fish
- Inhalation of volatile organic compounds from surface water during swimming

Table 6.3-1 Summary of Potential Exposure Pathways

POTENTIALLY EXPOSED POPULATION	EXPOSURE PATHWAY	INCLUSION IN RISK ASSESSMENT	REASON FOR EXCLUSION
<i>Current Land Use</i>			
Residents	Ingestion of surface water or inhalation of volatile compounds while swimming or ingestion of fish from surface water	No	Dilution of creek water in the lake would lower concentrations to well below hazardous levels.
Residents	Dermal exposure to surface water while swimming	Yes	
Residents Industrial Workers	Ingestion of groundwater from downgradient wells	No	There is currently no contamination in production wells. Therefore, no route for contact exists.
Residents	Other exposures to contaminated groundwater (i.e., inhalation of chemicals volatilized during home use, dermal contact during showering, ingestion of vegetables contaminated by irrigation)	No	There is currently no contamination in production wells. Therefore, no route for contact exists.
Industrial Workers	Ingestion of soil, dermal contact with soil, inhalation of fugitive dust and VOCs	Yes	
Residents	Ingestion of soil, dermal contact with soil, inhalation of fugitive dust	No	Direct contact is restricted by fence line, and exposure potential decreases with distance.
<i>Future Land Use</i>			
Residents	Dermal exposure or ingestion of surface water or inhalation of volatile compounds while swimming or ingestion of fish from surface water	No	Risks are comparable to current exposure potential.
Residents Industrial Workers	Ingestion of groundwater from downgradient wells	Yes	
Residents	Inhalation of chemicals volatilized during showering	Yes	
Residents	Dermal exposure to chemicals in shower water	Yes	
Residents	Ingestion of vegetables contaminated by irrigation	No	There is no evidence of residential soil contamination.
Industrial Workers Residents	Ingestion of soil, dermal contact with soil, inhalation of VOCs and fugitive dust	No	Risks comparable to current exposure potential.

Exposure to chemicals in the groundwater at and near the site may occur through four pathways:

- Ingestion of water from production wells
- Inhalation of VOCs during indoor water use
- Ingestion of vegetables irrigated with contaminated water
- Dermal exposure to water during showering

The potential for each of these pathways to be complete, given current and potential future conditions, is evaluated in the following sections.

6.3.2.1.1 Potential Current Exposure Pathways: Two chemicals of potential concern have been identified for surface water: vinyl chloride and *cis*-1,2-dichloroethene. Exposure to contaminated surface (lake) water by swimming and/or fish consumption is possible. However, the exposure duration and frequency of these activities would limit the total exposure. It is important to note that the bioconcentration factors for vinyl chloride and *cis*-1,2-dichloroethene are quite small (1.17 and 1.6 respectively [EPA 1986]). In addition, it is not likely that swimming would occur in the water adjacent to Plant 4 where the concentration of the chemicals of concern in surface water will be the highest. Direct contact with seeps along Meandering Road Creek was not considered because (1) low probability of this occurring, (2) limited skin surface area potentially exposed, (3) low duration of exposure, and (4) very low exposure frequency. Finally, any contaminated water from Plant 4 will be significantly diluted in Lake Worth. Inflows to Lake Worth include the West Fork of the Trinity River, precipitation, direct runoff, inflow from creeks (including Meandering Road Creek), and groundwater inflow. Outflows include releases from the Lake Worth Dam, withdrawals for Fort Worth water supply, evapotranspiration, and groundwater outflow. A flow estimate is available only for the Dam Release, and this is 265 cfs. (This was obtained by subtracting any discharge from Clear Fork of the Trinity River at Fort Worth, Texas, from average discharge of the West Fork of the Trinity River at Fort Worth, Texas.) Considering that the reservoir is essentially at steady state storage, inflows must be at least equal to dam release of 265 cfs. No data is available for Meandering Road Creek. However, an estimate can be made by assuming 30 inches of runoff per year, for the Meandering Road Creek drainage basin (approximately 6 square miles). The area receives 31.6 inches per year of precipitation. Therefore, this very conservative estimate assumes that 95 per cent of the precipitation in the drainage ends up in Meandering Road Creek and ultimately in Lake Worth. This yields a conservative overestimate of average discharge for Meandering Road Creek equal to 13.3 cfs. Considering that total inflow to Lake Worth must exceed 265 cfs and Meandering Road Creek discharge is less than 13.3 cfs, the Meandering Road Creek discharge accounts for less than 5 per cent of the total Lake Worth inflow, and hence the relatively small concentrations of contaminants in Meandering Road Creek water are even further diluted upon discharge to Lake Worth.

Dermal exposure to contaminated water is evaluated because swimming exposes most of the body surface; this is discussed in Section 6.3.3.2. Potential environmental exposure is discussed in Section 6.6.

The chemicals detected in the groundwater monitoring wells at Plant 4 have not migrated to any on- or off-base production wells. Therefore, there is currently no contact point for human or environmental exposure to these chemicals from groundwater.

6.3.2.1.2 Potential Future Exposure Pathways: Based on the rationale given above for the current exposure pathway for surface water, the future exposure potential is limited. Consequently, it was assumed that there is no significant future contact point for human exposure to these chemicals from surface water.

Analytical modeling of the hydrogeology was conducted to assess the potential for future exposure to contamination in groundwater. Modeling results are summarized below, and Appendix J contains details of the calculations.

For calculating receptor concentrations, only the contaminants that have been measured in the Paluxy aquifer were considered. This approach was selected because the only identified potential receptor wells in the Paluxy aquifer are the White Settlement production wells; there are no production wells in the alluvial aquifer. Note that two drinking water supply wells for White Settlement are within one-quarter mile of the Plant 4 boundary. Details on the number and locations of the groundwater wells in the area and the fate and transport between aquifers were presented in Sections 3.7, 3.8, and 5.

Contaminants measured in the Paluxy are barium, chromium, lead, trichloroethene, toluene, 1,1-dichloroethane, and 1,2-dichloroethene (see Table 6.3-2). The chemicals of potential concern that are not found in Paluxy wells have no reasonable future exposure point and are not considered further. In addition, lead was not considered further because it was not detected in the Paluxy in concentrations above MCLs, and because approved toxicity values are not currently available. Different concentrations of the remaining chemicals of potential concern were measured in a number of Paluxy wells. For transport modeling, the source concentration and location was determined by the well with the maximum concentration upgradient of a receptor well. (The exposure concentration for barium was not modeled; instead, the maximum concentration detected in the Paluxy [0.1 mg/L] was used.)

Receptor wells identified for transport modeling were the White Settlement wells generally located to the south and to the west of the site. These production wells are completed in either the Paluxy or Twin Mountains Formations. Only those White Settlement wells completed in the Paluxy Formation were included in modeling efforts. One White Settlement well, WS-5, is described as being completed in the Trinity Group. Because the Paluxy Formation is part of the Trinity Group, this well was also identified as a potential receptor well.

Table 6.3-2 Chemicals of Potential Concern Found in Paluxy Wells **264497**

CAS NO.	CHEMICAL	FOUND IN PALUXY	FOUND IN UPPER ZONE ONLY*
7440-38-2	Arsenic		X
513-77-9	Barium	X	
71-43-2	Benzene		X
7440-43-9	Cadmium		X
7440-47-3	Chromium	X	
95-50-1	1,2-Dichlorobenzene		X
75-34-3	1,1-Dichloroethane	X	
75-35-4	1,1-Dichloroethene		X
540-59-0	1,2-Dichloroethene	X	
106-46-7	1,4-Dichlorobenzene		X
105-67-9	2,4-Dimethylphenol		X
7439-92-1	Lead	X	
7439-92-1	Mercury		X
91-57-6	2-Methylnaphthalene		X
95-48-7	Methylphenol		X
91-20-3	Naphthalene		X
108-88-3	Toluene	X	
71-55-6	1,1,1-Trichloroethane		X
79-01-6	Trichloroethene	X	

*Chemicals not found in the Paluxy aquifer were not considered further because they will not impact the White Settlement production wells.

Modeling results show that within the next 60 years almost all of the receptor wells will receive the maximum concentration found in Paluxy wells. These estimated values are the maximum concentrations which can be expected at the receptor wells provided that the concentration measured in the source well is representative of the maximum concentration in the Paluxy aquifer. This also assumes that there will be no future recharge of the Paluxy aquifer by more highly contaminated water from another source such as the upper zone. Predicted concentrations of the contaminants found in the Paluxy aquifer at receptor wells for thirty years from now are listed in Table 6.3-3.

**Table 6.3-3 Predicted Contaminant Concentrations
at Thirty Years in Receptor Wells***

RECEPTOR WELL	TRICHLOROETHENE ($\mu\text{g/L}$)	TOLUENE ($\mu\text{g/L}$)	1,2-DICHLOROETHENE ($\mu\text{g/L}$)	1,1-DICHLOROETHANE ($\mu\text{g/L}$)	CHROMIUM ($\mu\text{g/L}$)
WS-1	47.84	6.976	149.5	-	-
WS-2	48	7	150	-	-
WS-3	47.92	6.988	149.7	-	-
WS-5	22.23	3.242	69.47	-	-
WS-8	3.114	0.4541	9.73	-	-
WS-12	979.8	2	371.1	14	6.699
WS-H3	240.7	1.992	13.34	13.94	1.646

* Because barium was not modeled, the highest concentration of barium detected in the Paluxy (0.1 mg/L) will be used as the exposure concentration.

Geotech took approximately 570 soil samples during its sampling effort for the Plant 4 RI/FS. Soil samples taken by other contractors in earlier investigations were not considered for this risk assessment because the information needed to validate the data was not available. Two conditions are met by the samples used in the soil exposure analysis: (1) the samples are surface soil samples, and (2) the samples are from areas of bare soil or grass, and not covered by concrete (see Table 6.3-4). The CS sample number series are grab samples from a transect across the creek. The samples are composite samples for intervals ranging from 0 - 1 foot or 0 - 5 feet. For the purposes of the exposure assessment, it was assumed that contaminants in the subsurface soil did not have the potential to migrate to the air. In addition, soil that is covered by concrete is considered to have no potential to migrate through the air or to the groundwater, so those samples were eliminated from the air exposure assessment. Potential exposure to the chemicals found in the subsurface soil, in soil covered by concrete, or during repair work, excavation, building or construction activity is limited because of the industrial land use scenario (this scenario dictates the use of a low estimate for exposure frequency and duration). The justification for using a future industrial land use scenario was described in Section 6.3.1.5. Nevertheless chemicals found in hazardous quantities in the soil, even without the current potential to migrate, were retained as chemicals of potential concern, and discussed in the toxicity assessment. Table 6.3-4 shows the chemicals of potential concern that were evaluated for surface soil. Those chemicals found in subsurface soils only were eliminated from further evaluation because they do not have the potential to migrate to the air. If areas with contamination are uncovered in the future, contaminants could become airborne or be transported toward groundwater.

Chemicals present in the soil may become available via three potential exposure routes:

- Direct ingestion of the soil
- Dermal contact with the soil
- Inhalation of volatilized compounds or fugitive dust.

The inhalation exposure evaluated in this risk assessment route includes contributions from both the contaminated soil and chemicals in the air that are in excess of background. The analysis is based on the results of air monitoring conducted as a part of the remedial investigation activities (IT 1992). The potential for each of these pathways to be complete given current and potential future conditions is evaluated in the following sections.

6.3.2.2.1 Potential Current Exposure Pathways: Access to soil at Plant 4 is limited by fencing. Therefore, residents of nearby areas are discouraged from contacting the soil. However, it is possible that workers in these areas may contact the soil and be exposed to site-related chemicals by ingestion and dermal contact. This evaluation considers worker exposures on site, and therefore the analysis will be more conservative than it would be from examining residential exposure to contaminated soil transported by air.

Table 6.3-4 Chemicals of Potential Concern Evaluated for Surface Soil

CAS NO.	CHEMICAL	SURFACE	SUBSURFACE SOILS ONLY
71-43-2	Benzene	X	
56-55-3	Benzo(a)anthracene	X	
50-32-8	Benzo(a)pyrene	X	
205-99-2	Benzo(b)fluoranthene	X	
207-08-9	Benzo(k)fluoranthene	X	
7440-43-9	Cadmium	X	
7440-47-3	Chromium	X	
218-01-9	Chrysene	X	
156-59-2	<i>cis</i> -1,2-Dichloroethene		X
7440-50-8	Copper	X	
100-41-4	Ethylbenzene		X
206-44-0	Fluoranthene	X	
7439-92-1	Lead	X	
91-57-6	2-Methylnaphthalene		X
91-20-3	Naphthalene	X	
7440-02-0	Nickel	X	
85-01-8	Phenanthrene	X	
129-00-0	Pyrene	X	
108-88-3	Toluene		X
79-01-6	Trichloroethene		X
7440-66-6	Zinc	X	

Site workers and nearby residents may also be currently exposed to VOCs and fugitive dust. Other potential receptors (visitors and other Plant 4 personnel) may also be exposed to airborne chemicals. However, airborne concentrations will decrease outside the site boundary and these receptors will tend to be transient (i.e., they will not remain at the fence line for prolonged periods). Therefore, only the potential occupational exposure of site workers was evaluated for this pathway since an industrial scenario was assumed as described in Section 6.3.1.5.

6.3.2.2.2 Potential Future Exposure Pathways: Potential future exposure pathways are assumed to be the same as current pathways because no change in land use is anticipated.

6.3.2.3 Summary

A summary of all potential human exposure pathways in the risk assessment is given in Table 6.3-1. The potentially completed pathways evaluated in this baseline risk assessment are:

- Ingestion of groundwater by future residents from White Settlement production wells.
- Inhalation of and dermal contact with VOCs from groundwater by future residents during showering in water from White Settlement production wells.
- Dermal contact with contaminated surface water by residents.
- Ingestion and dermal contact with contaminated soil by future Plant 4 personnel.
- Ingestion and dermal contact with contaminated soil by current Plant 4 personnel.
- Inhalation of contaminated air by current Plant 4 personnel.

6.3.3 Estimation of Exposure

This section describes the concentration estimation of individual site-related chemicals of concern that may reach human receptors. The process involves:

- Determining the concentration of each chemical in the identified environmental medium at the point of human exposure.
- Identifying applicable human exposure models and input parameters.
- Estimating human intakes.

For each identified pathway, a reasonable maximum exposure (RME) scenario has been developed. This scenario gives a reasonable upper-bound estimate of the potential magnitude of an individual exposure to chemicals from the site. Moreover, when applicable, an exposure estimate using central tendency data was developed. Central tendency provides a more typical or average value than RME.

The primary source for the exposure models used for this risk assessment are those detailed in the *Risk Assessment Guidance for Superfund Human Health Evaluation Manual* (EPA 1989a).

6.3.3.1 Chemical Concentrations

Concentrations used in the exposure scenarios for the chemicals of potential concern in groundwater, surface water, soil, and air are listed in Tables 6.3-5 through 6.3-8, respectively. A description of the approach used to estimate exposure concentrations follows.

Table 6.3-5 Concentrations for Chemicals of Potential Concern In Groundwater

CAS NO.	CHEMICAL	CONCENTRATION ($\mu\text{g/L}$)	RECEPTOR WELL
7440-39-3	Barium	100	P-12UN
7440-47-3	Chromium	6.699	WS-12
75-34-3	1,1-Dichloroethane	14	WS-12
540-59-0	1,2-Dichloroethene	371.1	WS-12
108-88-3	Toluene	7	WS-2
79-01-6	Trichloroethene	979.8	WS-12

6.3.3.1.1. Groundwater and Surface Water: A 30-year interval was used to estimate potential future exposures. This time period was set at the initial Risk Assessment scoping meeting held in October 1991 involving representatives from Air Force, U.S. Environmental Protection Agency, and the State of Texas. A 30-year scenario was selected because it is the longest time period to be reasonably sure that the industrial scenario would still apply at Plant 4 and to obtain a fairly accurate modeling of the contamination migration (the accuracy of contaminate migrate estimates decreases as the duration is increased).

Table 6.3-6 Concentrations for Chemicals of Potential Concern In Surface Water

CAS NO.	CHEMICAL	CONCENTRATION ($\mu\text{g/L}$)
156-59-2	<i>cis</i> -1,2-Dichloroethylene	430
75-01-4	Vinyl Chloride	14

To estimate the potential risks associated with using water from White Settlement production wells thirty years from now, the concentrations calculated in the analytical groundwater contaminant transport modeling (see Section 6.3.2.1.2) were used (except for barium, as discussed previously). Because the domestic water supply would not be a mixture from production wells, it is conservative to use the highest projected concentrations

instead of averaged values. For all modeled chemicals except toluene, the well with the highest concentrations is WS-12. For toluene, the highest concentration is projected to be in WS-2.

Surface water exposures were modeled for swimming only. The highest reported concentrations were used in the model. The areas where surface water contamination are greatest are not recreational areas. The exposure potential for contaminated surface water is largely limited to environmental receptors, discussed in Section 6.6.

Table 6.3-7 Concentrations for Chemicals of Potential Concern in Soil

CAS NO.	CHEMICAL	CONCENTRATION (mg/kg)
71-43-2	Benzene	0.180
56-55-3	Benzo(a)anthracene	1.662
50-32-8	Benzo(a)pyrene	1.590
205-99-2	Benzo(b)fluoranthene	1.868
207-08-9	Benzo(k)fluoranthene	1.551
206-44-0	Fluoranthene	2.701
7440-43-9	Cadmium	3.963
7440-47-3	Chromium	206.1
218-01-9	Chrysene	1.704
7440-50-8	Copper	2070.0
7439-92-1	Lead	14.20
91-20-3	Naphthalene	1.376
7440-02-0	Nickel	193.3
85-01-8	Phenanthrene	2.570
129-00-0	Pyrene	1.915
7440-66-6	Zinc	6174.0

6.3.3.1.2 Soil and Air: The upper 95 percent confidence limit of the arithmetic means of the concentrations of chemicals in the soil was used to estimate the potential for dermal exposure to soil for human receptors. A concentration of one-half the sample quantitation limit was used for all nondetects in the soil samples. For fugitive dust and VOC inhalation, concentrations were determined in the same manner as for soil using measured on-site air data (IT 1992).

Table 6.3-8 Concentrations for Chemicals of Potential Concern In Air

CAS NO.	CHEMICAL	CONCENTRATION ($\mu\text{g}/\text{m}^3$)
71-43-2	Benzene	0.89
7440-47-3	Chromium	0.0043
76-13-1	Freon 113	1.66
7439-92-1	Lead	0.00624
75-09-2	Methylene Chloride	0.245
79-01-6	Trichloroethene	1.26
95-63-6	1,2,4-Trimethylbenzene	0.60
108-67-8	1,3,5-Trimethylbenzene	0.269
7440-66-6	Zinc	0.0253

6.3.3.2 Other Exposure Parameters

A combination of RME and average exposure parameters have been used in each scenario to result in a combined RME. The exposure parameters used are summarized in Table 6.3-9 and explained in the sections below.

Increased cancer risks were not quantified for children because the exposure duration associated with childhood is minuscule in relation to the 70-year averaging time used to quantify risk. In addition, hazard indices also were not quantified for children. Current hazard indices were not quantified because children do not presently have access to the site on a chronic basis. Future hazard indices were not quantified because the only future exposure medium is groundwater. Because the changes in groundwater exposure parameter values from adult to child only shift the exposure by a factor of approximately 2, future child hazards may be evaluated by comparison to the adult hazards.

The averaging time used is dependent on the toxic endpoint of the constituent of concern. For constituents judged to be potential carcinogens, intakes were averaged over the estimated lifetime of the receptor (70 years) (EPA 1991b). For constituents designated noncarcinogens, intakes were averaged over the duration of the exposure.

6.3.3.2.1 Scenario—Ingestion of Groundwater from White Settlement Wells in Thirty Years: Exposure to groundwater was assumed to occur daily (350 days/year) for 30 years (9 years for central tendency [CT]). The estimated average body weight of an adult (70 kg) was used. Children were not considered separately for groundwater exposure as their exposure is not anticipated to be significantly different from that of adults. Where adult

Table 6.3-9 Parameters Used to Estimate Exposure

PARAMETER	VALUE USED*		RATIONALE
	RME	Central Tendency	
<i>Ingestion of Groundwater from White Settlement Production Wells in Thirty Years</i>			
Adult/Child ^b Water Ingestion Rate (L/day)	2/1	1.4	EPA 1991b/EPA 1989c, and Rauscher 1992 for CT
Exposure Frequency (days/year)	350		Exposure is assumed to be daily
Exposure Duration (years)	30	9.0	Upper 90th percentile for time spent in one residence (EPA 1991b), and Rauscher 1992 for CT
Adult/Child ^b Body Weight (kg)	70/16		EPA 1991b
<i>Occupational Exposure: Adult Ingestion of Contaminated Soil</i>			
Adult Ingestion Rate (mg/day)	50		EPA 1991b
Exposure Frequency (days/year)	250		Assumes workers are exposed 5 days/week, 50 weeks/yr
Exposure Duration (years)	25	9.0	Assumes 25 year work period, and Rauscher 1992 for CT
Body Weight (kg)	70		EPA 1991b
<i>Inhalation of Volatile Organic Compounds During Showering (White Settlement Wells, Thirty Years in the Future)</i>			
Adult Inhalation Rate (m ³ /hour)	0.6		Upper-bound rate for daily, indoor, residential activities (EPA 1991b)
Exposure Time (hours/day)	0.2		Reasonable maximum (EPA 1991b)
Exposure Frequency (days/year)	350		Reasonable maximum
Exposure Duration (years)	30	9.0	Upper 90th percentile for time spent in one residence (EPA 1991b), and Rauscher 1992 for CT
Body Weight (kg)	70		EPA 1991b
<i>Dermal Exposure While Showering</i>			
Skin Surface Area (m ²)	1.94		50th percentile total body surface area (EPA 1989)
Exposure Time (hours/day)	0.2		Reasonable maximum
Exposure Frequency (days/year)	350		Reasonable maximum
Exposure Duration (years)	30	9.0	Upper 90th percentile for time spent in one residence (EPA 1991b), and Rauscher 1992 for CT
Body Weight (kg)	70		EPA 1991b
<i>Dermal Exposure to Contaminated Surface Water During Swimming</i>			
Skin Surface Area (m ²)	1.94		50th percentile total body surface area (EPA 1989)
Exposure Time (hours/day)	0.5		Reasonable maximum
Exposure Frequency (days/year)	60		Reasonable maximum
Exposure Duration (years)	30	9.0	Upper 90th percentile for time spent in one residence (EPA 1991b), and Rauscher 1992 for CT
Body weight (kg)	70		EPA 1991b
<i>Occupational Exposure: Adult Inhalation of Contaminated Air</i>			
Adult Inhalation Rate (m ³ /hour)	2.5		Upper-bound occupational rate (EPA 1991b)
Exposure Time (hours/day)	8		Worst-case assumption
Exposure Frequency (days/year)	250		Assumes workers are exposed 5 days/week, 50 hours/year
Exposure Duration (years)	25	9.0	Assumes 25 year work period, and Rauscher 1992 for CT
Body Weight (kg)	70		EPA 1991b

* The left side of this column contains data for reasonable maximum exposure (RME) calculations, and the right side is for central tendency (CT) calculations. CT data are only provided when applicable.

^b Child exposure values provided for comparison.

and juvenile exposure scenarios are similar, the lower intake rates and lower body weights of children offset each other in the exposure models (EPA 1991b). For drinking water ingestion, an ingestion rate of 2 L/day was used (EPA 1991b). A value of 1.4 was used for CT (Rauscher 1992).

6.3.3.2.2 Scenario—Inhalation of Vapors While Showering: Exposure to groundwater via showering was assumed to occur daily (350 days/year) for 30 years (9 years for CT). The estimated average body weight of an adult (70 kg) was used. Children were not considered separately for groundwater exposure as their exposure is not anticipated to be significantly different from that of adults. This scenario requires the use of the following cross-media transfer equation to calculate the concentration of volatile chemicals in the air during and after showering (Andelman 1987; Giardino et al. 1990):

$$C_{sa} = \frac{C_w \cdot Fl \cdot t}{V} \quad (6.3-1)$$

where:

- C_{sa} = Concentration in bathroom at end of shower ($\mu\text{g}/\text{m}^3$);
- C_w = Concentration in shower water ($\mu\text{g}/\text{L}$);
- V = Bathroom volume (9 m^3);
- Fl = Flow rate of shower water (600 L/hour); and
- t = Shower duration (0.20 hours).

For exposure during showering, an inhalation rate representative of light activity of $0.6 \text{ m}^3/\text{hour}$ was used with the upper 90th percentile estimate for a showering time of 12 minutes. A 100% volatilization rate was conservatively assumed.

6.3.3.2.3 Scenario—Dermal Exposure While Showering: Dermal exposure to groundwater was assumed to occur daily (350 days/year) for 30 years (9 years for CT). The estimated average body weight of an adult (70 kg) was used, and the average skin surface area for an adult was assumed to be 1.94 m^2 . The exposure duration and other parameters were assumed to be the same as for the inhalation scenario for showering. When available, permeability coefficient values (see Table 6.3-10) were used to estimate the dermal uptake more realistically (EPA 1992). When permeability coefficients were not available, a default value of $8.4 \times 10^{-4} \text{ cm/hr}$ was used (EPA 1989a).

Table 6.3-10 Dermal Permeability Coefficients

CHEMICAL	PERMEABILITY (cm/hr)
Chromium Compounds	2×10^{-3}
Toluene	1
Trichloroethene	2×10^{-1}

Source: EPA 1992

6.3.3.2.4 Scenario—Dermal Exposure to Contaminated Surface Water: Dermal exposure to surface water was assumed to occur for one-half hour each day, 60 days per year, for 30 years (9 years for CT). The adult skin surface area used was 1.94 m², with estimated average adult body weight of 70 kg. Dilution of 10⁶ was assumed for stream concentrations in Lake Worth. As dermal permeability coefficients for the surface water contaminants of potential concern were not available, a default value of 8.4 x 10⁻⁴ cm/hr was used.

6.3.3.2.5 Scenario—Occupational Ingestion of Contaminated Soil: Exposure via ingestion of soil was assumed to occur 5 days/week for 50 weeks/year. This is an upper-bound estimate as it does not account for holidays beyond a two week vacation, sick leave, or time spent at other areas of Plant 4. The exposure duration was assumed to be 25 years (9 years for CT). This is an upper-bound estimate of the length of time people work in one place (EPA 1991b). An estimated average adult body weight of 70 kg was used.

Workers were assumed to be engaged in activities that result in soil contact and to consume 50 mg of soil/day (EPA 1991b). The receptors' entire daily soil ingestion was assumed to occur at Plant 4 for a diet fraction of 100 percent.

6.3.3.2.6 Scenario—Occupational Inhalation of Contaminated Air: For inhalation exposure, an average inhalation rate of 2.5 m³/hour was used (EPA 1991b).

6.3.3.3 Results of the Exposure Assessment

The results of the exposure assessment are presented in Tables 6.3-11, 6.3-12, and 6.3-13, for ingestion, inhalation, and dermal exposures, respectively.

6.3.3.4 Uncertainties in the Exposure Assessment

The evaluation of reasonable maximum potential exposures under future land-use conditions is included in the baseline risk assessment to provide a basis for developing protective exposure levels. The EPA recommends the use of future land-use assumptions

Table 6.3-11A Results of the Exposure Assessment—Ingestion

POTENTIALLY EXPOSED POPULATION	CONSTITUENT	CHRONIC DAILY INTAKE (mg kg ⁻¹ day ⁻¹)	
		CARCINOGENIC EFFECTS	NONCARCINOGENIC EFFECTS
<i>Ingestion of Groundwater from White Settlement Production Wells in Thirty Years</i>			
Residents Plant 4 Workers	Barium	— ^a	2.7 x 10 ⁻³
	Chromium	— ^a	1.8 x 10 ⁻⁴
	1,1-Dichloroethane	— ^a	3.8 x 10 ⁻⁴
	1,2-Dichloroethene	— ^a	1.0 x 10 ⁻²
	Toluene	— ^a	1.9 x 10 ⁻⁴
	Trichloroethene	1.2 x 10 ⁻²	— ^b
<i>Ingestion of Contaminated Soil</i>			
Plant 4 Workers	Benzene	3.1 x 10 ⁻⁴	8.8 x 10 ⁻⁴
	Benzo(a)anthracene	2.9 x 10 ⁻⁷	— ^b
	Benzo(a)pyrene	2.8 x 10 ⁻⁷	— ^b
	Benzo(b)fluoranthene	3.3 x 10 ⁻⁷	— ^b
	Benzo(k)fluoranthene	2.7 x 10 ⁻⁷	— ^b
	Cadmium	— ^a	1.9 x 10 ⁻⁶
	Chromium	— ^a	1.0 x 10 ⁻⁴
	Copper	— ^a	1.0 x 10 ⁻³
	Fluoranthene	— ^a	1.3 x 10 ⁻⁶
	Naphthalene	— ^a	6.7 x 10 ⁻⁷
	Nickel	— ^a	9.5 x 10 ⁻³
	Phenanthrene	— ^a	— ^b
	Pyrene	— ^a	9.4 x 10 ⁻⁷
	Zinc	— ^a	3.0 x 10 ⁻³

^aCDI for carcinogenic effects not calculated for chemicals not considered to be potential carcinogens or chemicals without slope factors.

^bCDI for noncarcinogenic effects not calculated because RfDs not available.

that will result in a scenario that is both reasonable and may be associated with the highest risk in order to be protective. Because the future land-use scenario results in estimation of potential rather than actual exposures, the EPA also recommends that an evaluation of the likelihood of the exposure actually occurring be included in the analysis. This assessment also presents exposures based on central tendency data, which is less conservative than reasonable maximum exposures. This provides useful input for remediation decisions.

Table 6.3-11B Results of the Exposure Assessment—Ingestion (Central Tendency)

POTENTIALLY EXPOSED POPULATION	CONSTITUENT	CHRONIC DAILY INTAKE (mg kg ⁻¹ day ⁻¹)	
		CARCINOGENIC EFFECTS	NONCARCINOGENIC EFFECTS
<i>Ingestion of Groundwater from White Settlement Production Wells in Thirty Years</i>			
Residents Plant 4 Workers	Barium	— ^a	1.9 x 10 ⁻³
	Chromium	— ^a	1.3 x 10 ⁻⁴
	1,1-Dichloroethane	— ^a	2.7 x 10 ⁻⁴
	1,2-Dichloroethene	— ^a	7.0 x 10 ⁻⁵
	Toluene	— ^a	1.3 x 10 ⁻⁴
	Trichloroethene	2.5 x 10 ⁻³	— ^b
<i>Ingestion of Contaminated Soil</i>			
Plant 4 Workers	Benzene	1.1 x 10 ⁻⁴	8.8 x 10 ⁻⁴
	Benzo(a)anthracene	1.0 x 10 ⁻⁷	— ^b
	Benzo(a)pyrene	1.0 x 10 ⁻⁷	— ^b
	Benzo(b)fluoranthene	1.2 x 10 ⁻⁷	— ^b
	Benzo(k)fluoranthene	9.7 x 10 ⁻⁸	— ^b
	Cadmium	— ^a	1.9 x 10 ⁻⁶
	Chromium	— ^a	1.0 x 10 ⁻⁴
	Copper	— ^a	1.0 x 10 ⁻³
	Fluoranthene	— ^a	1.3 x 10 ⁻⁶
	Naphthalene	— ^a	6.7 x 10 ⁻⁷
	Nickel	— ^a	9.5 x 10 ⁻⁵
	Phenanthrene	— ^a	— ^b
	Pyrene	— ^a	9.4 x 10 ⁻⁷
	Zinc	— ^a	3.0 x 10 ⁻³

^aCDI for carcinogenic effects not calculated for chemicals not considered to be potential carcinogens or chemicals without slope factors.

^bCDI for noncarcinogenic effects not calculated because RfDs not available.

Uncertainties associated with the estimated groundwater exposures are primarily due to the uncertainties involved in predicting future primary land use. The use of the 95 percent upper confidence limit (UCL) on the monitoring data will compensate for these uncertainties by providing a reasonable maximum estimate of potential exposure. Another major area of uncertainty that will also result in conservative potential exposures is the assumption that the concentrations will remain constant and that no biodegradation will occur.

Table 6.3-12A Results of the Exposure Assessment—Inhalation

POTENTIALLY EXPOSED POPULATION	CONSTITUENT	CHRONIC DAILY INTAKE (mg kg ⁻¹ day ⁻¹)	
		CARCINOGENIC EFFECTS	NONCARCINOGENIC EFFECTS
<i>Inhalation of Volatile Organic Compounds During Showering with Groundwater (White Settlement Wells in Thirty Years)</i>			
	1,1-Dichloroethane	— ^a	3.1 x 10 ⁻⁴
	1,2-Dichloroethene	— ^a	— ^b
	Toluene	— ^a	1.5 x 10 ⁻⁴
	Trichloroethene	9.2 x 10 ⁻³	— ^b
<i>Inhalation of Chemicals in Air</i>			
Plant 4 Workers	Benzene	6.2 x 10 ⁻³	1.7 x 10 ⁻⁴
	Chromium	3.0 x 10 ⁻⁷	8.4 x 10 ⁻⁷
	Freon 113	— ^a	— ^b
	Lead	— ^a	— ^b
	Methylene Chloride	1.7 x 10 ⁻³	4.8 x 10 ⁻³
	Trichloroethene	8.8 x 10 ⁻³	— ^b
	1,2,4-Trimethylbenzene	— ^a	— ^b
	1,3,5-Trimethylbenzene	— ^a	— ^b
	Zinc	— ^a	5.0 x 10 ⁻⁶

^aCDI for carcinogenic effects not calculated for chemicals not considered to be potential carcinogens.

^bCDI for noncarcinogenic effects not calculated because RfDs not available.

The largest source of uncertainty associated with the estimated soil concentrations is due to the small number of soil borings and lack of surface soil data. Soil borings were taken as close as possible to the assumed chemical source. The concentrations found in these samples should represent a greater than average concentration for the area. Also, the exposure scenarios do not take into account the fact that most of the site area is covered with either concrete or grass. The use of the 95th percentile UCL instead of the average should also result in an overestimate of actual exposure.

Table 6.3-12B Results of the Exposure Assessment—Inhalation (Central Tendency)

POTENTIALLY EXPOSED POPULATION	CONSTITUENT	CHRONIC DAILY INTAKE (mg kg ⁻¹ day ⁻¹)	
		CARCINOGENIC EFFECTS	NONCARCINOGENIC EFFECTS
<i>Inhalation of Volatile Organic Compounds During Showering with Groundwater (White Settlement Wells in Thirty Years)</i>			
	1,1-Dichloroethane	— ^a	3.1 x 10 ⁻⁴
	1,2-Dichloroethene	— ^a	— ^b
	Toluene	— ^a	1.5 x 10 ⁻⁴
	Trichloroethene	2.8 x 10 ⁻³	— ^b
<i>Inhalation of Chemicals in Air</i>			
Plant 4 Workers	Benzene	2.2 x 10 ⁻³	1.7 x 10 ⁻⁴
	Chromium	1.1 x 10 ⁻⁷	8.4 x 10 ⁻⁷
	Freon 113	— ^a	— ^b
	Lead	— ^a	— ^b
	Methylene Chloride	6.1 x 10 ⁻⁶	4.8 x 10 ⁻⁵
	Trichloroethene	3.2 x 10 ⁻³	— ^b
	1,2,4-Trimethylbenzene	— ^a	— ^b
	1,3,5-Trimethylbenzene	— ^a	— ^b
	Zinc	— ^a	5.0 x 10 ⁻⁶

^aCDI for carcinogenic effects not calculated for chemicals not considered to be potential carcinogens.

^bCDI for noncarcinogenic effects not calculated because RfDs not available.

For the air concentrations, the major areas of uncertainty are the sampling locations compared to the wind direction and differentiating between sources of the contaminants (i.e., was the source from the units at Plant 4 covered in this risk assessment, other operations/areas at Plant 4, or offsite sources).

Table 6.3-13A Results of the Exposure Assessment—Dermal

POTENTIALLY EXPOSED POPULATION	CONSTITUENT	CHRONIC DAILY INTAKE (mg kg ⁻¹ day ⁻¹)	
		CARCINOGENIC EFFECTS	NONCARCINOGENIC EFFECTS
<i>Dermal Exposure to Chemicals of Concern During Showering with Groundwater (White Settlement Wells in Thirty Years)</i>			
Residents	Barium	— ^a	4.5 x 10 ⁻⁶
	Chromium	— ^a	7.1 x 10 ⁻⁷
	1,1-Dichloroethane	— ^a	6.3 x 10 ⁻⁷
	1,2-Dichloroethene	— ^a	1.7 x 10 ⁻⁵
	Toluene	— ^a	3.7 x 10 ⁻⁴
	Trichloroethene	4.5 x 10 ⁻³	— ^b
<i>Dermal Exposure to Chemicals of Concern While Swimming in Lake Water</i>			
Residents	cis-1,2-Dichloroethene	— ^a	8.2 x 10 ⁻⁶
	Vinyl Chloride	1.1 x 10 ⁻⁷	— ^b

^aCDI for carcinogenic effects not calculated for chemicals not considered to be potential carcinogens.

^bCDI for noncarcinogenic effects not calculated because RfDs not available.

Table 6.3-13B Results of the Exposure Assessment—Dermal (Central Tendency)

POTENTIALLY EXPOSED POPULATION	CONSTITUENT	CHRONIC DAILY INTAKE (mg kg ⁻¹ day ⁻¹)	
		CARCINOGENIC EFFECTS	NONCARCINOGENIC EFFECTS
<i>Dermal Exposure to Chemicals of Concern During Showering with Groundwater (White Settlement Wells in Thirty Years)</i>			
Residents	Barium	— ^a	4.5 x 10 ⁻⁶
	Chromium	— ^a	7.1 x 10 ⁻⁷
	1,1-Dichloroethane	— ^a	6.3 x 10 ⁻⁷
	1,2-Dichloroethene	— ^a	1.7 x 10 ⁻⁵
	Toluene	— ^a	3.7 x 10 ⁻⁴
	Trichloroethene	1.4 x 10 ⁻³	— ^b
<i>Dermal Exposure to Chemicals of Concern While Swimming in Lake Water</i>			
Residents	cis-1,2-Dichloroethene	— ^a	8.2 x 10 ⁻⁶
	Vinyl Chloride	3.3 x 10 ⁻⁴	— ^b

^aCDI for carcinogenic effects not calculated for chemicals not considered to be potential carcinogens.

^bCDI for noncarcinogenic effects not calculated because RfDs not available.

6.4 Toxicity Assessment

This section presents information on the toxicity of the chemicals of potential concern that have been identified for Plant 4. Several of the chemicals described are of potential concern because they are present in the soil or water, but do not, under current circumstances, pose a threat to human receptors. For example, several of the water contaminants are not found in the aquifer used for drinking water, and some of the soil contaminants are not exposed to erosion at this time. Changes in site conditions could modify the exposure potential for these chemicals. It should be noted that oral toxicity data (i.e., slope factors and reference doses) will be used to represent dermal toxicity data for this risk assessment. This is because there currently are no dermal toxicity data that are approved for use. On the whole, the assumptions made in this risk assessment are likely to lead to an overestimation of the risks. Table 6.4-1 summarizes the available toxicity data.

This results in the use of an absorbed dose (the exposure) in conjunction with an oral toxicity value.

6.4.1 Toxicity of Mixtures

In most pathways to human receptors, agents occur in mixtures. In a mixture of toxic agents, there exists a potential for interactions among the toxic effects of its components. This potential depends on the components of the mixture, on the carriers along the environmental pathway from source to receptor, and on the way the contaminant enters the body. For carcinogens that lead to the same endpoint (e.g., cancer of the same organ) there is a considerable potential for synergistic or antagonistic interactions. It has been shown, however, that for small cancer probabilities, the interaction is generally antagonistic, which leads to a lower probability of cancer. They can, thus, be considered negligibly small, leading to a risk for the mixture that is approximately equal to the sum of the individual risks.

6.4.2 Toxicity Profiles

Benzene, CAS No. 71-43-2. Benzene is a clear colorless liquid with a melting point of 5.5 °C and a boiling point of 80 °C (Sax 1984). It has wide-spread use in the chemical and drug industries and as a solvent for paints, resins, lacquers, and plastics. Exposures in man occur mostly by inhalation of the highly volatile benzene. In acute exposure, benzene toxicity appears to be due primarily to its effects on the central nervous system, and an exposure of 20,000 ppm is usually fatal to man within five to ten minutes. Symptoms of intoxication are drowsiness, dizziness, headache, and loss of consciousness (Doull et al. 1980). Chronic, rather than acute, exposure to benzene is the primary concern in industry. It is also a leukemogen. Daily exposure to a concentration of 100 ppm or less will usually

Table 6.4-1 Summary of Toxicity Values ^a

Chemical of Potential Concern	Slope Factor (mg/kg-day) ⁻¹			Reference Dose (mg/kg-day) ⁻¹	
	Ingestion ^b	Inhalation	Weight of Evidence ^c	Ingestion ^b	Inhalation
Benzene	2.9x10 ⁻²	2.9x10 ⁻²	A	1.0x10 ⁻¹	1.0x10 ⁻¹
Benzo(a)anthracene ^d	5.79 x 10 ⁻¹		B2		
Benzo(a)pyrene	5.79		B2		
Benzo(b)fluoranthene ^d	5.79 x 10 ⁻¹		B2		
Benzo(k)fluoranthene ^d	5.79 x 10 ⁻¹		B2		
Cadmium		6.1	B1	1.0x10 ⁻³	
Chromium		4.1x10 ¹	A	5.0x10 ⁻³	2.0x10 ⁻⁶
Chrysene			B2		
Cis-1,2-dichloroethene			D	1.0x10 ⁻²	
Copper			D	3.7x10 ⁻²	
1,2-dichlorobenzene			D	9x10 ⁻²	4.0x10 ⁻²
1,4-dichlorobenzene			C	2.4x10 ⁻²	1.4x10 ⁻¹
1,1-dichloroethane			C	1.0x10 ⁻¹	5x10 ⁻¹
1,1-dichloroethene			C	9x10 ⁻³	
1,2-dichloroethene				1x10 ⁻²	
2,4-dimethylphenol				2.0x10 ⁻²	
Ethylbenzene			D		
Fluoranthene			D	4.0x10 ⁻²	
Freon					
Lead			B2	6.9x10 ⁻⁴	4.3x10 ⁻⁴
Methylene chloride	7.5x10 ⁻³	1.6x10 ⁻³	B2	6.0x10 ⁻²	9x10 ⁻¹
2-methylnaphthalene					
Methylphenol			C	5x10 ⁻²	
Naphthalene			D	4.0x10 ⁻²	
Nickel		8.4x10 ⁻¹	A	2.0x10 ⁻²	
Phenanthrene			D		
Pyrene				3.0x10 ⁻²	
Toluene			D	2.0x10 ⁻¹	6x10 ⁻¹
1,1,1-trichloroethane			C	9.0x10 ⁻²	3x10 ⁻¹
Trichloroethene	1.1x10 ⁻²	1.7x10 ⁻²	B2		
1,2,4-trimethylbenzene					
1,3,5-trimethylbenzene					
Vinyl chloride	1.9		A		
Zinc				2.0x10 ⁻¹	

^aA blank means that it is not applicable or that data do not exist.

^bOral toxicity data was used for dermal exposure as necessary.

^cGroup A - Human carcinogen (sufficient evidence of carcinogenicity in humans).

Group B - Probable Human Carcinogen (B1 - limited evidence of carcinogenicity in humans; B2 - sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans).

Group C - Possible Human Carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of human data).

^dSlope factor based on a benzo(a)pyrene toxicity equivalency factor of 0.1 (from US EPA Region 6 guidance).

cause damage if continued over a prolonged period of time. The early symptoms of chronic benzene poisoning consist of headache, fatigue, and loss of appetite (Sax 1984). Benzene is a class A human carcinogen with a slope factor of $2.9 \times 10^{-2}(\text{mg}/\text{kg}\cdot\text{d})^{-1}$ for both inhalation and ingestion (EPA 1992b).

Benzo(a)anthracene, CAS No. 56-55-3. Benzo(a)anthracene, a polycyclic aromatic hydrocarbon, is a crystalline solid at room temperature (it melts at 160 °C and boils at 400 °C). It occurs in crude oil, coal tar, flue dust, coal-derived products, and as a pyrolysis product in tobacco smoke at 6.0 to 8.0 $\mu\text{g}/100$ cigarettes. It is more toxic than anthracene, but less so than phenanthrene by dermal or subcutaneous route. In dermal long-term studies in mice, signs of carcinogenic effects have been recorded, but not when administered intravenously or by similar parenteral routes. Benzo(a)anthracene is suspected to be a carcinogen in man (Class B2) based on short-term mammalian cell transformation tests that demonstrated positive mutagenicity (Clayton and Clayton 1981).

Benzo(a)pyrene, CAS No. 50-32-8. Benzo(a)pyrene (BaP) is a ubiquitous by-product from the combustion of fossil fuels, wood, and garbage. At room temperature, it is a solid (melting point 179 °C, boiling point 312 °C), and is very lipophilic and highly soluble in water. BaP has been found to be strongly carcinogenic in laboratory animals by inhalation, ingestion, or dermal contact. Inhalation leads to cancer of the respiratory tract, ingestion causes cancers of the stomach, and dermal contact with BaP may result in skin tumors (Doull et al. 1980; EPA 1986). Benzo(a)pyrene has not been directly shown to cause cancer in humans, but mixtures containing benzo(a)pyrene, such as cigarette smoke, diesel exhaust (Mauderly et al. 1987), emissions of roofing tar pots and coke ovens, have been shown to be carcinogenic (Doll and Peto 1981; Doull et al. 1980). BaP is a complete carcinogen in animals, acting both as an initiator and promoter, and is classified as a probable human carcinogen (Class B2).

Benzo(b)fluoranthene, CAS No. 205-99-2, and Benzo(k)fluoranthene, CAS No. 207-08-9. Benzo(b)fluoranthene (melting point 168 °C) and benzo(k)fluoranthene (melting point 217 °C, boiling point 480 °C), both polycyclic aromatic hydrocarbons, are considered to be probable human carcinogens (Class B2). Each compound produced tumors after lung implantation in mice and when administered with a promoting agent in skin-painting studies. Benzo(k)fluoranthene is mutagenic in bacteria. Although there are no data linking exposure to the chemical to human cancers, benzo(b)fluoranthene and benzo(k)fluoranthene are components of suspected carcinogenic mixtures such as coal tar, soots, coke oven emissions, and cigarette smoke. The carcinogenic data available do not allow the determination of slope factors (EPA 1991a).

Cadmium, CAS No. 7440-43-9. Cadmium is a metal with a level of toxicity similar to that of lead and its compounds. It is present in most foods and tissues, leading to an average daily intake of about 0.2 mg (ICRP 1975). The element and its compounds are toxic by inhalation, ingestion, and subcutaneous application. The kidney is the most sensitive organ, damaged by excessive loss of both low and high molecular mass proteins (proteinuria). A

number of effects in other organs such as the lung have also been reported. In the lung, tissue loss occurs at high exposures and chronic tissue inflammation at lower levels, leading to emphysematous and fibrotic changes (Doull et al. 1980). The reference dose (RfD) for ingestion is 5×10^{-4} mg/kg/day for water and 1×10^{-3} mg/kg/day for food. No RfD for inhalation is available. There is sufficient evidence of carcinogenic action in man, mostly in smelter workers, to classify cadmium as a B1 inhalation carcinogen. Excess lung cancer risks were observed in several epidemiological studies; confounding factors such as smoking were not sufficiently accounted for to make the causal connection certain enough. Evidence for excess prostate cancers is even more questionable, and there is no evidence for carcinogenic action after exposure to cadmium by ingestion. The inhalation slope factor is $6.1 \text{ (mg/kg/day)}^{-1}$ (IRIS 1992).

Chromium, CAS No. 7440-47-3. Chromium is an industrially important metal, most widely used in metal plating. It exists in several valence states, but only trivalent and hexavalent chromium is of biological importance. This is because only the conversion from the 6^+ to the 3^+ valence state occurs in the human body at an appreciable rate. Trivalent chromium is an essential nutrient. Total body intake of chromium lies between 30 and 100 μg ; the uptake in the gut, however, is only about one percent (Doull et al. 1980; ICRP 1975).

EPA classifies hexavalent chromium as a Class A human carcinogen by the inhalation route (IRIS 1992). There is insufficient evidence for carcinogenicity of the other valence states. The slope factor for Cr(VI) is $41 \text{ (mg/kg/day)}^{-1}$ for inhalation; no slope factor is available for oral intake.

Reference doses are available for a chronic intake of Cr(III) and Cr(VI). For Cr(III), the oral RfD is 1 mg/kg/day and the reference concentration (RfC) for inhalation is 2×10^{-6} mg/m³. For Cr(VI) the oral RfD is 5×10^{-3} mg/kg/day and the RfC is 2×10^{-6} mg/m³ for inhalation (EPA 1991a).

Chrysene, CAS No. 218-01-9. Chrysene is a solid material at room temperature, isolated from crude petroleum and coal tar. It also occurs in cigarette smoke and has been detected at 1.5 to 13.3 ng/m³ in community air. Chrysene exerts low acute toxicity orally, dermally, to the eye, and by inhalation. It has been shown to exhibit some carcinogenic potential in laboratory animals, sufficient for a B2 classification, but the data are not sufficient at present for a quantitative risk assessment for carcinogenic or noncarcinogenic health effects (EPA 1991a).

cis-1,2-Dichloroethene, CAS No. 158-59-2. Cis-1,2-dichloroethene (1,2-c-dichloroethylene) is a colorless liquid with a sweet pleasant odor. It has a boiling point of 60.3 °C and a melting point of -80.5°C (Weast 1987). At the present time there is no evidence that it is a human carcinogen and therefore has a D classification. At the present time there are no slope values available for cis-1,2-dichloroethene. Cis-1,2-dichloroethene has an oral RfD value of $1 \times 10^{-2} \text{ (mg/kg/d)}^{-1}$ (EPA 1991a).

Copper CAS No. 7440-50-8. Copper occurs as a metal and as oxides, carbonate, and sulfide compounds. As a metal, it has a wide variety of industrial uses due to its physico-chemical properties, most notably its high electrical conductivity. Copper is a necessary trace metal in the nutrition of humans, animals, and plants. Normal human intake in diet is about 0.7 to 5 mg daily (ICRP 1975). If the level of intake is much higher, toxic effects are seen in brain, liver, and kidneys (Doull et al. 1980). Numerical data on these effects are inadequate, however, to define RfDs. The Health Effects Assessment Summary Tables list a maximum level in water of 1.3 mg/L, based on taste (EPA 1991a), resulting in an acceptable intake of $0.037 \text{ mg kg}^{-1} \text{ day}^{-1}$ for ingestion for a 70 kg person drinking two liters of water per day (EPA 1989a). Copper is not classifiable as a human or animal carcinogen (Class D).

1,2-Dichlorobenzene, CAS No. 95-50-1. 1,2-Dichlorobenzene, *o*-dichlorobenzene, is a clear liquid at room temperature (melting point $-17.5 \text{ }^\circ\text{C}$, boiling point $180 \text{ }^\circ\text{C}$). It is commonly used as a solvent and degreasing agent for metals. The principal acute and chronic toxicity of 1,2-dichlorobenzene by the oral route is to the liver; and at higher concentrations it is a central nervous system depressant. EPA classifies 1,2 dichlorobenzene as a Class D human carcinogen (not classifiable as to human-carcinogenicity). An oral exposure study in which rats received $12.5 \text{ mg kg}^{-1} \text{ day}^{-1}$ of 1,2-dichlorobenzene, 5 days per week for 13 weeks, produced a no observed adverse effect level (NOAEL) of $89 \text{ mg kg}^{-1} \text{ day}^{-1}$. On the basis of this study of lower toxicity, EPA applied an uncertainty factor of 1,000 and set the chronic oral RfD at $9 \times 10^{-2} \text{ mg/kg/day}$ in humans (EPA 1991a). For inhalation, the RfC for chronic exposure is 0.2 mg/m^3 , corresponding to an RfD of $4 \times 10^{-2} \text{ mg/kg/day}$ (EPA 1991a).

1,4-Dichlorobenzene, CAS No. 106-46-7. 1,4-Dichlorobenzene forms white crystals at standard temperature and pressure. It has a distinctive aromatic odor which becomes very strong at concentrations above 60 ppm. 1,4-Dichlorobenzene has a melting point of $53.1 \text{ }^\circ\text{C}$ and a boiling point of $174 \text{ }^\circ\text{C}$ (Weast 1987). Upon inhalation it is an irritant to the upper respiratory tract, and excessive exposure may cause depression and damage to the kidney and liver. 1,4-Dichlorobenzene has an inhalation RfC value of $1.4 \times 10^{-1} \text{ mg/kg/d}$ and an oral slope factor of $2.4 \times 10^{-2} (\text{mg/kg/d})^{-1}$ (EPA 1991a).

1,1-Dichloroethane, CAS No. 75-34-3. 1,1-Dichloroethane is an oily colorless liquid with a chloroform-like odor (Merck 1983). Upon inhalation 1,1-Dichloroethane may cause sneezing, coughing, dizziness, nausea, and vomiting. Prolonged or repeated skin contact can produce a slight burn. At the present time, ingestion incidental to industrial handling is not considered to be a problem. The weight-of-evidence classification for human carcinogenicity is C (possible human carcinogen) (IRIS 1992). 1,1-Dichloroethane has an inhalation RfC value of $1.0 \times 10^{-1} \text{ mg/kg/d}$, and an oral RfD value of $1.0 \times 10^{-1} \text{ mg/kg/d}$ (EPA 1991a). Presently there are no slope factors available.

1,1-Dichloroethene, CAS No. 75-35-4. 1,1-Dichloroethene, also called 1,1-dichloroethylene, or vinylidene chloride (melting point $-122.5\text{ }^{\circ}\text{C}$, boiling point $31.7\text{ }^{\circ}\text{C}$), is used as a chemical intermediate, particularly as a monomer in the production of plastics. It is a clear, colorless liquid with a molecular weight of 96.95. Exposure to high concentrations results in central nervous system depression and the associated symptoms of drunkenness. Chronic exposure to low concentrations results primarily in injury to the liver and kidneys. Short-term exposure to vapor at high concentrations is moderately irritating to the eyes of rabbits, and will cause pain, conjunctival irritation, and some transient corneal injury. Permanent damage to the eyes is not likely. In liquid form, it is irritating to the skin of rabbits after only a few minutes (Clayton and Clayton 1981). For chronic ingestion a reference dose of 9×10^{-3} mg/kg/day has been set. 1,1-Dichloroethene is classified as a Class C carcinogen (possible human carcinogen).

1,2-Dichloroethene, CAS No. 540-59-0. 1,2-Dichloroethene, also called 1,2-dichloroethylene or acetylene dichloride, occurs in the environment as two isomers: *cis* and *trans*. The *cis*-isomer is reported to occur at higher levels in groundwater than the *trans*-isomer (CAS No. 156-60-5). For Plant 4, there were no detections of *trans*-1,2-dichloroethene in water samples, so it is assumed that all detections of 1,2-dichloroethene at Plant 4 were the *cis*-isomer. The *cis*-isomer (CAS No. 156-59-2) of 1,2-dichloroethene (melting point $-80.5\text{ }^{\circ}\text{C}$, boiling point $60.25\text{ }^{\circ}\text{C}$) has been used as solvents and chemical intermediates. The *cis*-isomer has not developed wide industrial usage in the United States partly because of its flammability. It is a liquid with a molecular weight of 96.95. For short-term exposure, unpublished data indicate a low to moderate hematological toxicity at relatively high exposures (Clayton and Clayton 1981). On the basis of the hematological effects, the oral reference dose for the *cis*-isomer is 1×10^{-2} mg/kg/day, and the corresponding value for the *trans*-isomer is 2×10^{-2} mg/kg/day (EPA 1991a).

2,4-Dimethylphenol, CAS No. 105-67-9. 2,4-Dimethylphenol forms colorless crystals at standard temperature and pressure. It has a boiling point of $211.5\text{ }^{\circ}\text{C}$ and a melting point of $25.4\text{ }^{\circ}\text{C}$ (Weast 1987). 2,4-Dimethylphenol appears to be a topical cocarcinogen, but its role as a primary cancer-producing agent is uncertain. The NOAEL value is $50\text{ mg kg}^{-1}\text{ d}^{-1}$ and the lowest observed adverse effect level (LOAEL) value is $250\text{ mg kg}^{-1}\text{ d}^{-1}$. 2,4-Dimethylphenol has an oral RfD value of 2.0×10^{-2} mg/kg/d (IRIS 1992). At the present time there is no slope factor available.

Ethylbenzene, CAS No. 100-41-4. Ethylbenzene is a colorless, flammable liquid (boiling point $136.2\text{ }^{\circ}\text{C}$), with an aromatic odor. It is primarily used in the production of styrene and synthetic polymers, as a solvent, and as a component in fuels (Sax 1984). Ethylbenzene is absorbed primarily through the respiratory system. In low concentrations, the vapor is an irritant to the eyes, nose, and throat, which may cause dizziness and lead to a sense of constriction of the chest. In chronic exposures, the compound is a kidney and liver toxin with a reference dose of 0.1 mg/kg/d and an uncertainty factor of 1000 (EPA 1991c). On the basis of the information available, the compound is not considered to be a potential human carcinogen (EPA 1991a).

Fluoranthene, CAS No. 206-44-0. Fluoranthene (melting point 120 °C, boiling point 367 °C) is a colorless, solid, polycyclic hydrocarbon. It is toxic by intravenous route, and moderately toxic by ingestion and skin contact. Fluoranthene is an experimental tumorigen (Sax and Lewis 1987). It is combustible when exposed to heat or flame, and when heated to decomposition it emits acrid smoke and fumes (Sax and Lewis 1987). It is a Class D carcinogen, i.e., not classifiable as a human carcinogen. However, fluoranthene is a liver toxin, also leading to hematological changes and has a reference dose for chronic oral exposure of 4×10^{-2} mg/kg/day, with an uncertainty factor of 3000 (EPA 1991a).

Freon 113, CAS No. 76-13-1. Freon 113 is a colorless gas. It has nearly no odor, except at high concentrations where it is similar to carbon tetrachloride. It has a boiling point of 47.7 °C and a melting point of -36.4 °C (Weast 1987). It is primarily used as a coolant material. At the present time there are no RfDs or slope factors available.

Lead, CAS No. 7439-92-1. The toxicity of lead and its compounds has probably received more attention than that of most other metals, leading to a number of standards for air and water. Lead is a regular contaminant in most foods, resulting in a daily intake of about 0.4 mg (ICRP 1975). However, even at low levels of exposure, some human responses corresponding to low-level chronic lead poisoning have been found. The toxic effects of lead are widespread, encompassing the central nervous system, the peripheral nervous system, the kidneys, and the blood. As there seem to be no thresholds for some of the dose-effect relationships, there are no accepted values for the inhalation and ingestion reference doses (IRIS 1992). Former values for lead and its inorganic compounds are 1.4×10^{-3} mg/kg/day for ingestion and 1.4×10^{-3} mg/kg/day for inhalation (EPA 1986). An assessment of the allowable daily intake of lead in drinking water (Marcus 1986) leads to a surrogate reference dose of 6.9×10^{-4} mg/kg/day for ingestion, and 4.3×10^{-4} mg/kg/day for inhalation.

There is sufficient evidence of carcinogenicity in animal experiments with lead compounds to classify lead and its inorganic compounds as probable human carcinogens, class B2. Mostly kidney tumors were observed in these experiments, usually only at high doses. However, due to problems with dosimetry, no estimates for the slope factors are available at present.

Methylene Chloride, CAS No. 75-09-2. Methylene chloride is a colorless, highly volatile liquid with a boiling point of 39.8 °C (Sax 1984). It is widely used as a solvent, aerosol propellant, and paint stripper. At high levels of exposure it is a strong narcotic and central nervous system depressant. At low exposures, the effects to man are still uncertain (Doull et al. 1980). The RfC for ingestion is 6.0×10^{-2} mg/kg/d and the inhalation RfD is 9×10^{-1} mg/kg/d (IRIS 1992). The slope factor for ingestion is 7.5×10^{-3} (mg/kg/d)⁻¹ and for inhalation is 1.6×10^{-3} (mg/kg/d)⁻¹ (IRIS 1992).

2-Methylnaphthalene, CAS No. 91-57-6. 2-Methylnaphthalene is an isomer of methylnaphthalene with a melting point of 34.6 °C. Acute exposure to high levels of 2-methylnaphthalene may result in headache, nausea, vomiting, anorexia, and coma. In human offspring, teratogenic effects such as hemolytic anemia and cataracts have been reported (IRIS 1992).

Methylphenol, CAS No. 95-48-7. Methylphenol (cresol) is a colorless/white crystal at standard temperature and pressure with a sweet tarry odor. It has a boiling point of 190.95 °C and a melting point of 30.9 °C (Sax 1984). It is a central nervous system depressant and at high concentrations may cause muscular weakness, gastroenteric disturbances, convulsion, and death. It has an oral RfD value of 5×10^{-2} mg/kg/d (IRIS 1992). The carcinogenic-weight-of-evidence is C (possible human carcinogen) but no slope values exist at this time.

Naphthalene, CAS No. 91-20-3. Naphthalene is a white solid found in the roots of some plants and in crude oil. It has a melting point of 80.6 °C, and may volatilize and sublime at room temperature. It is flammable in both solid and liquid form. Naphthalene is widely used as a raw material in the chemical industry. It occurs also in combustion products, coke oven emissions, and cigarette smoke. Cancer has not been found in humans or animals exposed to naphthalene (ATSDR 1990). Chronic exposure produces cataracts, hemolytic anemia, and kidney disease. Naphthalene can cross the placenta and produce health effects in newborns. Using a 13-week study on the toxicity of naphthalene in rats by oral gavage, EPA found that $35.7 \text{ mg kg}^{-1} \text{ day}^{-1}$ was a NOAEL. After applying an uncertainty factor of 10,000, EPA estimated the chronic oral RfD at 4.0×10^{-3} mg/kg/day (IRIS 1992).

Nickel, CAS No. 7440-02-0. Nickel and some of its compounds, such as nickel carbonyl, are rated as Class A carcinogens, based mostly on epidemiological evidence for nickel refinery workers suffering from lung and nose cancer. These data were confirmed in animal experiments. The slope factor for inhalation of nickel dust is $0.84 \text{ mg}^{-1} \text{ kg day}$; for inhalation of nickel subsulfide, it is $1.7 \text{ mg}^{-1} \text{ kg day}$ (IRIS 1992); no value for ingestion is available (EPA 1991a).

Phenanthrene, CAS No. 85-01-8. Phenanthrene is a polycyclic aromatic hydrocarbon which is not classified as to human carcinogenicity (Class D). Data from animal studies have shown ambiguous results. Evidence from in vivo assays indicates that phenanthrene metabolites have relatively low mutagenic and tumorigenic potential, but current theories regarding the mechanisms of metabolic activation of polycyclic aromatic hydrocarbons lead to predictions of a carcinogenic potential for phenanthrene (IRIS 1992). It is poisonous intravenously, and moderately toxic by ingestion. It also photosensitizes human skin (Sax and Lewis 1987).

Pyrene, CAS No. 129-00-0. Pyrene is a colorless solid, soluble in organic solvents. It occurs in pyrolysis or cooking processes at the lower cooling temperatures, and has been detected in the ambient atmosphere in 12 U.S. cities from trace amounts to 35 ng/m³. Rats consuming oral doses near the LD₅₀ died in two to five days, and at inhalation doses near LD₅₀, rats died in one to two days; a dose of 10 g/kg on mouse skin was found to have low toxicity. Inhalation also caused hepatic, pulmonary, and intragastric pathologic changes (Clayton and Clayton 1981). The reference dose for chronic oral exposure is 3 x 10⁻² mg/kg/day, with an uncertainty factor of 3000 (EPA 1991a).

Toluene, CAS No. 108-88-3. Toluene is a colorless, volatile liquid at room temperature (boiling point 110.4 °C), which is widely used as a solvent in paints, varnishes, and glues (Sax 1984). It also serves as an intermediate compound in the synthesis of organic substances. At high levels of exposure, toluene is a narcotic and affects the central nervous system, leading to fatigue, weakness, and confusion. In low chronic exposures, toluene can cause damage to the liver and kidneys. It has a reference dose for chronic ingestion of 0.2 mg kg⁻¹ day⁻¹ and a reference dose for chronic inhalation of 2 mg m⁻³, corresponding to a reference dose of 0.6 mg/kg/day for a 70 kg adult breathing 20 m³ day⁻¹ (EPA 1991a). Toluene is not classified as a human carcinogen (Class D).

1,1,1-Trichloroethane, CAS No. 71-55-6. Also called methyl chloroform, 1,1,1-trichloroethane is a highly volatile, colorless liquid at room temperature (boiling point 74.1 °C). It is used as a solvent to replace carbon tetrachloride in metal cleaning, pesticide, and textile processing. It has also been used as an aerosol propellant. At high levels of exposure, trichloroethane is moderately toxic by depressing the central nervous system, but it is considerably less toxic than its isomer, 1,1,2-trichloroethane (CAS No. 79-00-5). In low exposures, trichloroethane does not show any sizeable toxic effects (Doull et al. 1980). Its reference doses are 0.09 mg/kg/day for ingestion, and 0.3 mg/kg/day for inhalation (IRIS 1992). Methyl chloroform is not suspected to be a carcinogen, whereas its isomer, 1,1,2-trichloroethane, is a Class C carcinogen.

Trichloroethene, CAS No. 79-01-6. Trichloroethene, or trichloroethylene, is a nonflammable mobile liquid with an odor resembling that of chloroform. It solidifies at -84.8 °C and boils at 86.7 °C. It is used as a solvent for most fixed and volatile oils, fats, waxes, resins, paints, and varnishes. Studies concerning the health effects of chronic oral exposure to trichloroethene could not be found in the literature. Animal studies indicate that the liver, kidney, and immunological system are the principal target organs of oral exposure to trichloroethene. Mice were administered drinking water with 0, 0.1, 1.0, 2.5, and 5 mg/L of trichloroethene for 4 to 6 months. All of the exposed mice had depressed immune function. The LOAEL is 18 mg kg⁻¹ day⁻¹. This value is lower than the NOAEL reported by other studies (IRIS 1992). On the basis of experiments in mice, trichloroethylene is classified as a B2 carcinogen. The slope factor for inhalation is 1.7 x 10⁻² (mg/kg/day)⁻¹; for ingestion it is 1.1 x 10⁻² (mg/kg/day)⁻¹ (EPA 1991a).

1,2,4-Trimethylbenzene, CAS No. 85-63-6. 1,2,4-Trimethylbenzene is a liquid with a boiling point of 171 °C and a melting point of -43.8 °C (Sax 1984). It is known to be harmful both by ingestion and inhalation. Prolonged contact can cause dermatitis, nausea, headache, dizziness, and narcotic effects. Presently, no RfDs or slope factors exist.

1,3,5-Trimethylbenzene, CAS No. 108-67-8. 1,3,5-Trimethylbenzene is a clear, colorless liquid with a boiling point of 164.7 °C and a melting point of -44.8 °C (Merck 1983). The liquid is primarily a skin irritant, but systemic intoxication due to absorption through the skin is not probable. Presently, no slope values or RfDs exist.

Vinyl Chloride, CAS No. 75-01-4. Vinyl Chloride is a flammable liquid with a faintly sweet odor. It is a colorless liquid or gas (when inhibited) with a melting point of -160 °C and a boiling point of -13.9 °C (Sax and Lewis 1987). Vinyl chloride is a potent carcinogenic agent in man and animals and is now considered to be a liver toxicant. Vinyl chloride is considered to have a low order of acute toxicity. Central nervous system depression will occur when animals and man are exposed to moderately high level of the gas.

Zinc, CAS No. 7440-66-6. Zinc is used in the manufacture of galvanized iron, bronze, white paint, rubber, and paper. It is an essential trace element in the human diet, and occurs widely in foodstuffs, the abundance being particularly high in meats, seafood, dairy products, and vegetables. Its daily intake through the human diet is 6 to 40 mg (ICRP 1975). Zinc is not an inherently toxic element. However, some of its compounds are of generally low toxicity, causing at high exposures dermatitis by skin contact and intestinal disorders and diarrhea upon ingestion. In high-level inhalation exposures, "metal fume fever" is observed; however, no chronic effects have been reported. The acceptable daily intake rate is 0.2 mg kg⁻¹ day⁻¹ for ingestion (EPA 1991a). Some zinc compounds are suspected of being carcinogenic.

6.4.3 Uncertainties Related to Toxicity Information

Insufficient information is currently available to adequately address the risk to children. A 70-year exposure interval and appropriate intake values during early childhood will bound the exposure to children, and it is expected that the conservative values used to calculate the chronic hazard index (HI) and risk will be able to absorb the rest of this type of uncertainty.

The use of oral slope factors and reference doses to represent dermal absorption is a source of uncertainty. This substitution basically ignores the "port of entry", but is necessary because there are currently no approved dermal slope factors or reference doses. This substitution probably results in an overestimation of risks and hazards for the dermal pathways.

As discussed above, the probabilities of adverse effects are low enough so that for both carcinogenic and noncarcinogenic effects, the result of combinations can be approximated

by using the sum of probabilities. Synergisms must be of extreme magnitude to be noticeable at the low doses of concern here.

The largest systematic uncertainties, however, arise from the use of data developed from other species to estimate health effects in humans. In the definitions of the Reference Doses, these concerns are accounted for by using uncertainty and modifying factors. In the slope factors for carcinogenic risk, no such corrections are applied explicitly, resulting in two main sources of uncertainty. One is the systematic error introduced by the extrapolation to low doses, the other is the uncertainty introduced by the cross-species extrapolation. Both are unknown, but are mitigated in some measure by the calculation of the slope factor as the upper limit of the 95 percent confidence interval.

6.5 Human Health Risk Assessment

This section provides a characterization of the potential health risks associated with the intake of the chemicals of potential concern at Plant 4. In accordance with the methods described by EPA, a conservative approach that is likely to overestimate risk was used to evaluate potential health effects.

6.5.1 Carcinogens

Incremental lifetime cancer risks (ILCR) were estimated for each chemical of potential concern. ILCR is expressed in terms of additional cancers that might be anticipated as a result of specific exposure to an external influence. Thus, a 1×10^{-6} ILCR indicates a one in a million increase in the probability that an individual will develop some form of cancer from exposure to chemicals of potential concern at the site. Estimation of ILCR is given by:

$$ILCR = SF \cdot CDI \quad (6.5-1)$$

where:

ILCR = Incremental lifetime cancer risk (unitless);
 SF = Slope factor $(\text{mg}/\text{kg}/\text{day})^{-1}$; and
 CDI = Chronic daily intake $(\text{mg}/\text{kg}/\text{day})$.

The slope factors used are the most recent values cited in the IRIS data base (IRIS 1992) and Health Effects Assessment Summary Tables (EPA 1991a).

In weighing acceptable residential exposures to potentially carcinogenic compounds, EPA recommends the use of an acceptable risk range of 10^{-6} to 10^{-4} for CERCLA sites (EPA 1990b). EPA also uses an incremental lifetime risk level of one in a million as the bottom of the acceptable range for developing drinking water standards (EPA 1989a). The maximum acceptable incremental lifetime cancer risk recommended by EPA for drinking water is 10^{-4} (EPA 1989a).

EPA recommends that site-specific factors, such as the likelihood that the exposure assumptions used will be fulfilled, be considered when deciding where in the risk range of 10^{-6} to 10^{-4} a specific site should fall to be acceptable (EPA 1990b).

The results of the quantitative risk characterization for chemicals considered to be carcinogenic are shown in Tables 6.5-1 and 6.5-2. Chromium contributes the most to the cancer risk for current land use. For future scenarios, trichloroethene contributes the most risk due to exposure to the groundwater.

6.5.2 Noncarcinogens

Chemicals that produce health effects other than cancer were evaluated in terms of their relative hazard when compared to acceptable exposure levels. The hazard index (HI) for exposure to noncarcinogens is based on the ratio of the estimated daily intake to an acceptable daily exposure:

$$HQ_{i,p} = \frac{D_{i,p}}{RfD_{i,p}} \quad (6.5-2)$$

where:

$HQ_{i,p}$ = Individual hazard quotient for exposure to constituent i through exposure pathway p ;

$D_{i,p}$ = Daily intake by way of the specific pathway p for constituent i ($\text{mg kg}^{-1} \text{ day}^{-1}$);

$RfD_{i,p}$ = Reference Dose for the specific exposure pathway p for constituent i ($\text{mg kg}^{-1} \text{ day}^{-1}$).

The HQ does not define intake response relationships and its numerical value should not be construed to be a direct estimate of risk. It represents a comparison to acceptable limits of exposure or the degree to which acceptable exposure levels are exceeded. As this quotient approaches one, concern for potential hazard of the constituent increases. Exceeding one does not in itself imply a potential hazard; however, it does suggest that a given situation should be more closely scrutinized.

The EPA advocates the use of a total HI for a mixture of components based on the assumption of response additivity. The total HI is calculated by summing the individual HQs as shown below:

$$HI = \sum_p \sum_i HQ_{i,p} \quad (6.5-3)$$

where:

HI = Total hazard index

Table 6.5-1A Summary of Potential Incremental Lifetime Cancer Risks (ILCR) Associated with Plant 4: Current Land Use

Constituent	Estimated Average Daily Intake* (mg/kg/day)	Slope Factor (mg/kg/day) ⁻¹	Weight of Evidence	Chemical Specific ILCR	Total Pathway ILCR	Total Exposure ILCR
<i>Exposure Pathway: Occupational Ingestion of Soil</i>						
Benzene	3.1 x 10 ⁴	2.9 x 10 ²	A	9.0 x 10 ⁻¹⁰		
Benzo(a)anthracene	2.9 x 10 ⁷	0.579	B2	1.7 x 10 ⁻⁷		
Benzo(a)pyrene	2.8 x 10 ⁷	5.79	B2	1.6 x 10 ⁻⁶		
Benzo(b)fluoranthene	3.3 x 10 ⁷	0.579	B2	1.9 x 10 ⁻⁷		
Benzo(k)fluoranthene	2.7 x 10 ⁷	0.579	B2	1.6 x 10 ⁻⁷		
					2.1 x 10 ⁻⁶	
<i>Exposure Pathway: Occupational Inhalation of Contaminated Air</i>						
Benzene	6.2 x 10 ⁵	2.9 x 10 ²	A	1.8 x 10 ⁻⁶		
Chromium	3.0 x 10 ⁷	4.1 x 10 ¹	A	1.2 x 10 ⁻³		
Methylene Chloride	1.7 x 10 ⁵	1.6 x 10 ⁻³	B2	2.7 x 10 ⁻⁸		
Trichloroethene	8.8 x 10 ⁵	1.7 x 10 ²	B2	1.5 x 10 ⁻⁶		
					1.5 x 10 ⁻³	
<i>Exposure Pathway: Dermal Exposure During Swimming</i>						
Vinyl Chloride	1.1 x 10 ⁷	1.9	A	2.1 x 10 ⁻⁷		
					2.1 x 10 ⁻⁷	
<i>Current Occupational Exposure: Total Potential ILCR (weight of evidence predominantly A)</i>						1.7 x 10 ⁻³

* The parameter values used to calculate the Estimated Average Daily Intakes are provided on Table 6.3-9.

**Table 6.5-1B Summary of Potential Incremental Lifetime Cancer Risks (ILCR) (Central Tendency)
Associated with Plant 4: Current Land Use**

Constituent	Estimated Average Daily Intake* (mg/kg/day)	Slope Factor (mg/kg/day) ⁻¹	Weight of Evidence	Chemical Specific ILCR	Total Pathway ILCR	Total Exposure ILCR
<i>Exposure Pathway: Occupational Ingestion of Soil</i>						
Benzene	1.1 x 10 ⁻⁶	2.9 x 10 ⁻²	A	3.2 x 10 ⁻¹⁰		
Benzo(a)anthracene	1.0 x 10 ⁻⁷	0.579	B2	6.0 x 10 ⁻⁸		
Benzo(a)pyrene	1.0 x 10 ⁻⁷	5.79	B2	5.8 x 10 ⁻⁷		
Benzo(b)fluoranthene	1.2 x 10 ⁻⁷	0.579	B2	6.9 x 10 ⁻⁸		
Benzo(k)fluoranthene	9.7 x 10 ⁻⁸	0.579	B2	5.6 x 10 ⁻⁸		
					7.7 x 10 ⁻⁷	
<i>Exposure Pathway: Occupational Inhalation of Contaminated Air</i>						
Benzene	2.2 x 10 ⁻⁵	2.9 x 10 ⁻²	A	6.5 x 10 ⁻⁷		
Chromium	1.1 x 10 ⁻⁷	4.1 x 10 ¹	A	4.4 x 10 ⁻⁶		
Methylene Chloride	6.1 x 10 ⁻⁶	1.6 x 10 ⁻³	B2	9.8 x 10 ⁻⁹		
Trichloroethene	3.2 x 10 ⁻⁵	1.7 x 10 ⁻²	B2	5.4 x 10 ⁻⁷		
					5.6 x 10 ⁻⁶	
<i>Exposure Pathway: Dermal Exposure During Swimming</i>						
Vinyl Chloride	3.3 x 10 ⁻⁶	1.9	A	6.3 x 10 ⁻⁸		
					6.3 x 10 ⁻⁸	
<i>Current Occupational Exposure: Total Potential ILCR (weight of evidence predominantly A)</i>						6.4 x 10 ⁻⁶

* The parameter values used to calculate the Estimated Average Daily Intakes are provided on Table 6.3-9.

Table 6.5-2A Summary of Potential Incremental Lifetime Cancer Risks (ILCR) Associated with Plant 4: Future Land Use

Constituent	Estimated Average Daily Intake* (mg/kg/day)	Slope Factor (mg/kg/day) ⁻¹	Weight of Evidence	Chemical Specific ILCR	Total Pathway ILCR	Total Exposure ILCR
<i>Exposure Pathway: Ingestion of Groundwater from White Settlement Production Wells</i>						
Trichloroethene	1.2 x 10 ²	1.1 x 10 ²	B2	1.3 x 10 ⁻⁴		
					1.3 x 10 ⁻⁴	
<i>Exposure Pathway: Inhalation of Volatile Organic Compounds During Showering with Groundwater from White Settlement Production Wells</i>						
Trichloroethene	9.2 x 10 ⁻³	1.7 x 10 ²	B2	1.6 x 10 ⁻⁴		
					1.6 x 10 ⁻⁴	
<i>Exposure Pathway: Dermal Exposure During Showering</i>						
Trichloroethene	4.5 x 10 ⁻³	1.1 x 10 ²	B2	5.0 x 10 ⁻⁵		
					5.0 x 10 ⁻⁵	
<i>Future Residential Exposure: Total Potential ILCR (weight of evidence predominantly A)</i>						3.4 x 10 ⁻⁴

* The parameter values used to calculate the Estimated Average Daily Intakes are provided on Table 6.3-9.

Table 6.5-2B Summary of Potential Incremental Lifetime Cancer Risks (ILCR) (Central Tendency) Associated with Plant 4: Future Land Use

Constituent	Estimated Average Daily Intake ^a (mg/kg/day)	Slope Factor (mg/kg/day) ⁻¹	Weight of Evidence	Chemical Specific ILCR	Total Pathway ILCR	Total Exposure ILCR
<i>Exposure Pathway: Ingestion of Groundwater from White Settlement Production Wells</i>						
Trichloroethene	2.5 x 10 ⁻³	1.1 x 10 ²	B2	2.8 x 10 ⁻⁵		
					2.8 x 10 ⁻⁵	
<i>Exposure Pathway: Inhalation of Volatile Organic Compounds During Showering with Groundwater from White Settlement Production Wells</i>						
Trichloroethene	2.8 x 10 ⁻³	1.7 x 10 ²	B2	4.7 x 10 ⁻⁵		
					4.7 x 10 ⁻⁵	
<i>Exposure Pathway: Dermal Exposure During Showering</i>						
Trichloroethene	1.4 x 10 ⁻³	1.1 x 10 ²	B2	1.5 x 10 ⁻⁵		
					1.5 x 10 ⁻⁵	
<i>Future Residential Exposure: Total Potential ILCR (weight of evidence predominantly A)</i>						9.0 x 10 ⁻⁵

^a The parameter values used to calculate the Estimated Average Daily Intakes are provided on Table 6.3-9.

Summation of the individual HQs could result in an HI that exceeds one, even if no single chemical exceeds one. Technically, it is not appropriate to sum HQs unless the constituents that make up the mixture have similar modes of action on the same organ. Consequently, the summing of HQs for a mixture of compounds that are not expected to induce the same type of effects could overestimate the potential risk. The EPA recommends that if the total HI is greater than one, the components of the mixture should be grouped by critical effect and separate HIs derived for each effect. Critical effects are described in IRIS (1991).

The results of the quantitative risk characterization for health risks other than cancer are shown in Tables 6.5-3, 6.5-4A, and 6.5-4B. Note that a central tendency table is not included as part of Table 6.5-3. This is because for the current scenarios (i.e., those not involving the injection of groundwater), the exposure duration is the only parameter that changes. When estimating HI, the exposure duration in the numerator is set equal to the averaging time in the denominator (therefore, they cancel out). Central tendency for injection of groundwater for the future scenario in 6.5-4B is included because the water injection rate changes from 2 liter/day to 1.4 liters/day. None of the estimated individual HQs for the current land-use scenario involving occupational exposure from ingestion exceeds one. For the potential future land use scenario, the hazard index is 1.1 for the standard scenario, and 7.7×10^{-1} for the central tendency scenario. It is dominated by the contribution from 1,2-dichloroethene.

6.5.3 Uncertainties

The primary uncertainties associated with the risk characterization are:

- The extrapolation of toxic effects observed at the high doses necessary to conduct animal studies to effects that might occur in animals at much lower, more realistic doses.
- The extrapolation from toxic effects in animals to toxic effects in man (i.e., responses of animals may be different from responses of man).

These extrapolations form the basis for the derivation of toxicological factors used to estimate risks. Uncertainties are taken into account when deriving RfDs and slope factors. Another factor that contributed to the uncertainties was the exclusion of quantitative risks for nonspecific parameters (e.g., total petroleum hydrocarbons, oil and grease). The risk assessment was based on EPA guidance and published standards and criteria to minimize the uncertainties.

A risk assessment is an integrated evaluation of historical, chemical, analytical, environmental, demographic, and toxicological data. To minimize the effect of uncertainties in the evaluation, each step is biased toward health protective estimations. Because each step builds on the previous one, this biased approach over compensates for risk assessment uncertainties. In addition, these calculations do not represent currently existing or expected future exposure or health risks. Rather, they are estimates of potential risk only if all the conservative assumptions are realized.

Table 6.5-3 Summary of Potential Hazard Indices (HI) Associated with Plant 4: Current Land Use

Constituent	Estimated Average Daily Intake* (mg/kg/day)	Reference Dose (mg/kg/day) ¹	Chemical Specific HI	Total Pathway HI	Total Exposure HI
<i>Exposure Pathway: Occupational Ingestion of Soil</i>					
Cadmium	1.9 x 10 ⁻⁶	1.0 x 10 ⁻³	1.9 x 10 ³		
Chromium	1.0 x 10 ⁻⁶	5.0 x 10 ⁻³	2.0 x 10 ⁶		
Copper	1.0 x 10 ⁻³	3.7 x 10 ⁻²	3.0 x 10 ²		
Fluoranthene	1.3 x 10 ⁻⁶	4.0 x 10 ⁻²	3.3 x 10 ⁵		
Naphthalene	6.7 x 10 ⁻⁷	4.0 x 10 ⁻³	1.7 x 10 ⁴		
Nickel	9.5 x 10 ⁻⁵	2.0 x 10 ⁻²	4.7 x 10 ³		
Pyrene	9.4 x 10 ⁻⁷	3.0 x 10 ⁻²	3.1 x 10 ⁵		
Zinc	3.0 x 10 ⁻³	2.0 x 10 ⁻¹	1.5 x 10 ²	5.2 x 10 ²	
<i>Exposure Pathway: Occupational Inhalation of Contaminated Air</i>					
Benzene	1.7 x 10 ⁻⁴	1.0 x 10 ⁻¹	1.7 x 10 ³		
Chromium	8.4 x 10 ⁻⁷	2.0 x 10 ⁻⁶	4.2 x 10 ¹		
Methylene Chloride	4.8 x 10 ⁻⁵	9.0 x 10 ⁻¹	5.3 x 10 ⁵		
Zinc	5.0 x 10 ⁻⁶	2.0 x 10 ⁻¹	2.5 x 10 ⁵	4.2 x 10 ¹	
<i>Current Occupational Exposure: Total Potential HI</i>					
<i>Exposure Pathway: Dermal Exposure While Swimming</i>					
Cis-1,2-Dichloroethene	8.2 x 10 ⁻⁶	1.0 x 10 ⁻²	8.2 x 10 ⁴	8.2 x 10 ⁴	0.5
<i>Current Occupational Exposure: Total Potential HI</i>					

¹ The parameter values used to calculate the Estimated Average Daily Intakes are provided on Table 6.3-9.

Table 6.5-4A Summary of Potential Hazard Indices (HI) Associated with Plant 4: Future Land Use

Constituent	Estimated Average Daily Intake* (mg/kg/day)	Reference Dose (mg/kg/day) ¹	Chemical Specific HI	Total Pathway HI	Total Exposure HI
<i>Exposure Pathway: Ingestion of Groundwater from White Settlement Production Wells</i>					
Barium	2.7 x 10 ⁻³	7.0 x 10 ⁻²	3.9 x 10 ⁻²		
Chromium	1.8 x 10 ⁻⁴	5.0 x 10 ⁻³	3.6 x 10 ⁻²		
1,1-Dichloroethane	3.8 x 10 ⁻⁴	1.0 x 10 ⁻¹	3.8 x 10 ⁻³		
1,2-Dichloroethane	1.0 x 10 ⁻²	1.0 x 10 ⁻²	1.0		
Toluene	1.9 x 10 ⁻⁴	2.0 x 10 ⁻¹	9.5 x 10 ⁻⁴		
				1.1	
<i>Exposure Pathway: Inhalation of Volatile Organic Compounds During Showering with Groundwater from White Settlement Production Wells</i>					
1,1-Dichloroethane	3.1 x 10 ⁻⁴	1.0 x 10 ⁻¹	3.1 x 10 ⁻³		
Toluene	1.5 x 10 ⁻⁴	6.0 x 10 ⁻¹	2.5 x 10 ⁻⁴		
				3.4 x 10 ⁻³	
<i>Exposure Pathway: Dermal Exposure to Groundwater During Showering</i>					
Barium	4.5 x 10 ⁻⁶	7.0 x 10 ⁻²	6.4 x 10 ⁻³		
Chromium	7.1 x 10 ⁻⁷	5.0 x 10 ⁻³	1.4 x 10 ⁻⁴		
1,1-Dichloroethane	6.3 x 10 ⁻⁷	1.0 x 10 ⁻¹	6.3 x 10 ⁻⁶		
1,2-Dichloroethane	1.7 x 10 ⁻⁵	1.0 x 10 ⁻²	1.7 x 10 ⁻³		
Toluene	3.7 x 10 ⁻⁴	2.0 x 10 ⁻¹	1.9 x 10 ⁻³		
				3.8 x 10 ⁻³	
<i>Future Residential Exposure: Total Potential HI</i>					1.1

* The parameter values used to calculate the Estimated Average Daily Intakes are provided on Table 6.3-9.

**Table 6.5-4B Summary of Potential Hazard Indices (HI) (Central Tendency)
Associated with Plant 4: Future Land Use**

Constituent	Estimated Average Daily Intake* (mg/kg/day)	Reference Dose (mg/kg/day) ¹	Chemical Specific HI	Total Pathway HI	Total Exposure HI
<i>Exposure Pathway: Ingestion of Groundwater from White Settlement Production Wells</i>					
Barium	1.9 x 10 ³	7.0 x 10 ²	2.7 x 10 ²		
Chromium	1.3 x 10 ⁴	5.0 x 10 ³	2.5 x 10 ²		
1,1-Dichloroethane	2.7 x 10 ⁴	1.0 x 10 ¹	2.7 x 10 ³		
1,2-Dichloroethene	7.0 x 10 ³	1.0 x 10 ²	7.0 x 10 ¹		
Toluene	1.3 x 10 ⁴	2.0 x 10 ¹	6.6 x 10 ⁴	7.7 x 10 ¹	
<i>Exposure Pathway: Inhalation of Volatile Organic Compounds During Showering with Groundwater from White Settlement Production Wells</i>					
1,1-Dichloroethane	3.1 x 10 ⁴	1.0 x 10 ¹	3.1 x 10 ³		
Toluene	1.5 x 10 ⁴	6.0 x 10 ¹	2.5 x 10 ⁴	3.4 x 10 ³	
<i>Exposure Pathway: Dermal Exposure to Groundwater During Showering</i>					
Barium	4.5 x 10 ⁶	7.0 x 10 ²	6.4 x 10 ³		
Chromium	7.1 x 10 ⁷	5.0 x 10 ³	1.4 x 10 ⁴		
1,1-Dichloroethane	6.3 x 10 ⁷	1.0 x 10 ¹	6.3 x 10 ⁶		
1,2-Dichloroethene	1.7 x 10 ⁵	1.0 x 10 ²	1.7 x 10 ³		
Toluene	3.7 x 10 ⁴	2.0 x 10 ¹	1.9 x 10 ³	3.8 x 10 ³	7.7 x 10 ¹
<i>Future Residential Exposure: Total Potential HI</i>					7.7 x 10 ¹

* The parameter values used to calculate the Estimated Average Daily Intakes are provided on Table 6.3-9.

6.6. Ecological Risk Assessment

The Plant 4 ecological risk assessment was conducted according to the methods outlined in EPA's *Framework for Ecological Risk Assessment* (EPA 1992a). Risk to ecological receptors was assessed with a weight-of-evidence approach, in which several types of data were used together to describe overall ecological risk. The ecological risk assessment focused on the relatively natural areas of Plant 4; these included terrestrial and riparian communities near Landfills Nos. 3 and 4 and aquatic communities in Meandering Road Creek and Lake Worth.

6.6.1. Ecological Description of the Site

Plant 4 is a highly developed industrial site bounded on the east by Carswell Air Force Base and on the south by the city of White Settlement. The north and west sides of Plant 4 are bounded by Lake Worth and Meandering Road Creek, respectively. Meandering Road Creek enters Lake Worth through a narrow inlet. Relatively natural areas remain on the north and west boundaries of the site; these areas sustain both terrestrial and aquatic communities (see Figure 6.6-1). Only these few relatively natural areas were considered in this risk assessment.

In disturbed upland areas, the terrestrial community is dominated by native and introduced grasses, including *Andropogon*, *Digitaria*, and *Cynodon* species. Oaks (*Quercus* spp.) remain in less disturbed upland areas.

The riparian communities near Meandering Road Creek and Lake Worth are dominated by trees and shrubs, including oaks, hackberries (*Celtis* sp.), Osage orange (*Maculara pomifera*), and wild roses (*Rosa* spp.).

Meandering Road Creek is an ephemeral stream (U.S. Geological Survey 1955, photorevised 1982; and field observations) that drains storm-water runoff from White Settlement and the western portion of Plant 4. Seeps on the east side of the creek draw (nearest Plant 4) indicate that water may percolate through hazardous waste disposal areas at Plant 4 and carry contaminants into Meandering Road Creek. Areas adjacent to these seeps are vegetated. Submergent and emergent vegetation are absent in the stream community; however, small fish occur in some pools in the creek, indicating that an active trophic system is present.

Several inlets form the interface between the terrestrial system and the Lake Worth system. Meandering Road Creek Inlet, through which Meandering Road Creek enters Lake Worth, is the largest. In community structure, this inlet probably is more similar to the lake system than to the stream system.

Lake Worth is a large, steep-sided, relatively shallow, human-made lake on the West Fork of the Trinity River. The ecological conditions and biotic community of the lake are assumed to be typical of the region. The food web is expected to contain all trophic levels, from

algae and macrophytes to zooplankton, macroinvertebrates, aquatic and riparian predatory vertebrates (e.g., fish, turtles, and piscivorous birds and mammals), and invertebrate and microbial decomposers. Lake Worth is the largest aquatic community near Plant 4.

Detailed ecological surveys have not been conducted at Plant 4. For the purposes of this risk assessment, it is assumed that the species composition of Plant 4 is similar to that of the Dallas/Fort Worth area in general. Lists of the plant and animal species that occur in the Dallas/Fort Worth area (U.S. Department of the Interior 1989) are presented in Appendix T, page T1-1.

6.6.2 Receptors of Potential Concern

Receptors of Potential Concern (RoPCs) were selected from the list of animal species that occur in the Dallas/Fort Worth area (see Appendix T, page T1-3). The following criteria were used to select RoPCs:

- High likelihood of exposure
- High ecological significance
- Availability of toxicological literature for the species or appropriate surrogate
- Possibility of population-level adverse effects from Plant 4 stressors.

The list of RoPCs includes largemouth bass (*Micropterus salmoides*), red-tailed hawk (*Buteo jamaicensis*), red fox (*Vulpes fulva*), raccoon (*Procyon lotor*), and prey species.

The largemouth bass was selected because of its high ecological significance (it is a top predator, which makes it important to the structure and function of the ecosystem). Also, ecotoxicity data for the largemouth bass are readily available in the scientific literature. It is possible that the large number of contaminants in Plant 4 media could result in adverse effects to this species.

The red-tailed hawk was selected because of its high ecological significance (it is a top predator, which makes it important to the structure and function of the ecosystem). Red-tailed hawks are relatively common and are expected to visit the site to feed on rodents. Hawks are sensitive to organic and inorganic contaminants.

The red fox was selected because it is expected to have a complete exposure pathway; a fox has been observed on the Plant 4 facility in the past and it is expected that foxes forage and hunt near Meandering Road Creek and Landfills 3 and 4. Ecotoxicity data for a good surrogate species, the domestic dog, are available in the scientific literature. Also, Plant 4 contaminants produce adverse effects in mammals.

The raccoon was selected because it is likely to have complete exposure pathways for both aquatic terrestrial contaminants (the raccoon could eat fish from Meandering Road Creek and Lake Worth and could eat a variety of terrestrial foods from riparian and upland areas of Plant 4). Because raccoons are tolerant of human activity, they are expected to be one of the more common wildlife species in the area; it is one of the few wildlife species that has been sighted at Plant 4. Also, Plant 4 contaminants produce adverse effects in mammals.

Aquatic and terrestrial prey species were selected because they are ecologically significant (they form the base of the food chain). Also, because prey species have small home ranges, it is possible for these animals to spend all of their time in contaminated area. Aquatic prey species are expected to be sensitive to all Plant 4 contaminants. Terrestrial prey species are expected to be sensitive to some organics and most metals at Plant 4.

6.6.3 Environmental Media Sampling

Field investigations that were conducted at Plant 4 are described in section 2.0 of this document; nature and extent of contamination is presented in section 4.0 of this document. Environmental data that were used to support this ecological risk assessment include (1) soil data from Landfills Nos.3 and 4, (2) surface water data from Meandering Road Creek and Lake Worth, (3) sediment data from Meandering Road Creek and Lake Worth, (4) fish tissue data from Meandering Road Creek and Lake Worth, and (5) toxicity test data from Meandering Road Creek and Lake Worth. Sediment and soil samples collected along a cross section of Meandering Road Creek were integrated into the sediment and Landfill No. 3 data sets. Fish tissue sampling was collocated in space, but not in time, with abiotic media sampling.

Environmental media sampling locations are shown in Figures 2.19.1-2 and 4.4.1-1. A summary of sediment sampling locations is provided in Table 4.4.1-2. The rationale for these locations is provided in Sections 2.0 and 4.0. Analytical results for soils and sediments are presented in Appendix E. Analytical results for surface water and groundwater are presented in Appendix F. Analytical results for fish tissue and toxicity test results are presented in Appendix H.

The sample mean and worst case (defined as the sample mean plus two sample standard deviations; there is a 2.28 percent chance that any sample concentration would exceed this worst-case concentration) concentration data that were used in this risk assessment are presented in Appendix T, pages T2-1 through T2-5. Sample mean and worst case data were calculated for contaminants that were detected at least one location. One-half the detection limit was used at locations where the contaminant was not detected. In some cases, the sample mean or worst case concentration was greater than the maximum detected concentration; in these cases, the maximum detected concentration was used instead of the sample mean and/or worst case concentration.

6.6.4 Contaminants of Potential Concern

Contaminants of Potential Concern (CoPCs) were selected by screening the lists of contaminants detected in environmental media samples. Contaminants in surface water and sediment samples were removed from the CoPC list if any of the following conditions existed:

- The highest concentration of the contaminant was detected at a background location
- The analytical parameter was not a specific contaminant (i.e., oil and grease or total petroleum hydrocarbons)
- The analytical parameter was redundant (i.e., when 1,2-dichloroethene, *cis*-1,2-dichloroethene, and *trans*-1,2-dichloroethene were analytical parameters in a single medium, only 1,2-dichloroethene was retained as a CoPC)
- The contaminant was not related to site processes (this criterion only was used for radionuclides)

Additionally, contaminants in sediment were removed from the CoPC list if maximum sample concentrations were below Long and Morgan (1990) Effects Range-Low levels.

Contaminants in the upper 2 feet of Landfill No. 3 and No. 4 soils were retained as CoPCs unless the analytical parameter was not a specific contaminant (i.e. oil and grease or total petroleum hydrocarbons).

Tables 6.6-1 through 6.6-4 summarize the CoPC screening for surface water, sediment, and Landfill No. 3 and No. 4 soils.

**Table 6.6-1 Summary of CoPC Screening
for Meandering Road Creek Surface Water**

Contaminant in Water	CoPC Status	Reason if No
1,2-Dichlorobenzene	Yes	
1,2-Dichloroethane	Yes	
1,2-Dichloroethene	Yes	
2-Butanone	Yes	
2-Methylphenol	Yes	

**Table 6.6-1 (cont'd) Summary of CoPC Screening
for Meandering Road Creek Surface Water**

Contaminant in Water	CoPC Status	Reason if No
4-Methylphenol	Yes	
Acetone	Yes	
Arsenic	Yes	
Bis(2-ethylhexyl)phthalate	Yes	
Chlorobenzene	Yes	
Chromium	Yes	
<i>cis</i> -1,2-Dichloroethene	No	Redundant contaminant
Lead	Yes	
Methylene chloride	Yes	
Oil and Grease	No	Unspecific contaminant
Phenol	Yes	
Total petroleum hydrocarbons	No	Unspecific contaminant
<i>trans</i> -1,2-Dichloroethene	No	Redundant contaminant
Trichloroethene	Yes	
Vinyl Chloride	Yes	
Zinc	Yes	

**Table 6.6-2 Summary of Contaminant of Potential Concern Screening
for Meandering Road Creek and Lake Worth Sediment**

Contaminant in Sediment	CoPC Status	Reason if No
1,2,5,6-Dibenzanthracene	Yes	
1,2-Benzanthracene	Yes	
1,2-Dichloroethene	Yes	
2-Butanone	No	Highest hit at background (maximum on-site concentration of 35 $\mu\text{g}/\text{kg}$ at LW-11, maximum background concentration of 53 $\mu\text{g}/\text{kg}$ at LW-01)
2-Methylnaphthalene	Yes	
4-Methylphenol	Yes	
Acenaphthene	Yes	
Acenaphthylene	Yes	
Acetone	No	Highest hit at background (maximum on-site concentration of 220 $\mu\text{g}/\text{kg}$ at LW-11, maximum background concentration of 230 $\mu\text{g}/\text{kg}$ at LW-01)
Aluminum	Yes	
Anthracene	Yes	
Aroclor-1254	Yes	
Aroclor-1260	No	Highest hit at background (maximum on-site concentration 0.10 ppm at LW-02, maximum background concentration of 0.11 ppm at LW-01).
Arsenic	Yes	
Benzo(a)anthracene	Yes	

**Table 6.6-2 (cont'd) Summary of Contaminant of Potential Concern Screening
for Meandering Road Creek and Lake Worth Sediment**

Contaminant in Sediment	CoPC Status	Reason if No
Benzo(a)pyrene	Yes	
Benzo(b)fluoranthene	Yes	
Benzo(e)pyrene	Yes	
Benzo(g,h,i)perylene	Yes	
Benzo(k)fluoranthene	Yes	
Beryllium	Yes	
Bis(2-ethylhexyl)phthalate	Yes	
Butylbenzylphthalate	Yes	
Cadmium	Yes	
Carbon disulfide	Yes	
Cesium-137	No	Not related to site processes
Chlorobenzene	Yes	
Chromium	Yes	
Chrysene	Yes	
<i>cis</i> -1,2-Dichloroethene	No	Redundant contaminant
Copper	Yes	
Di-n-butylphthalate	Yes	
Dibenz(a,h)anthracene	Yes	
Dibenzofuran	Yes	
Fluoranthene	Yes	
Fluorene	Yes	
Indeno(1,2,3-cd)pyrene	Yes	

**Table 6.6-2 (cont'd) Summary of Contaminant of Potential Concern Screening
for Meandering Road Creek and Lake Worth Sediment**

Contaminant in Sediment	CoPC Status	Reason if No
Lead	Yes	
Methylene chloride	Yes	
Naphthalene	Yes	
Nickel	Yes	
Oil and grease	No	Unspecific contaminant
Phenanthrene	Yes	
Pyrene	Yes	
Radium-226	No	Not related to site processes
Silver	Yes	
Thallium	Yes	
Thorium-230	No	Not related to site processes
Total petroleum hydrocarbons	No	Unspecific contaminant
Trichloroethene	Yes	
Uranium	No	Not related to site processes
Vinyl chloride	Yes	
Zinc	Yes	

**Table 6.6-3 Summary of Contaminant of Potential Concern Screening
for Landfill No. 3 Soils**

Contaminant in Soil	CoPC Status	Reason if No
1,1,2-Trichloroethane	Yes	
1,2-Dichloroethene	Yes	
2-Butanone	Yes	
2-Methylnaphthalene	Yes	
Acenaphthene	Yes	
Acetone	Yes	
Anthracene	Yes	
Antimony	Yes	
Arsenic	Yes	
Benzo(a)anthracene	Yes	
Benzo(a)pyrene	Yes	
Benzo(b)fluoranthene	Yes	
Benzo(g,h,i)perylene	Yes	
Benzo(k)fluoranthene	Yes	
Beryllium	Yes	
Bis(2-ethylhexyl)phthalate	Yes	
Butylbenzylphthalate	Yes	
Cadmium	Yes	
Chloroform	Yes	
Chloromethane	Yes	
Chromium	Yes	
Chrysene	Yes	

Table 6.6-3 (cont'd) Summary of Contaminant of Potential Concern Screening for Landfill No. 3 Soils

Contaminant in Soil	CoPC Status	Reason if No
Copper	Yes	
Di-n-butylphthalate	Yes	
Dibenzofuran	Yes	
Ethylbenzene	Yes	
Fluoranthene	Yes	
Fluorene	Yes	
Indeno(1,2,3-cd)pyrene	Yes	
Lead	Yes	
Methylene chloride	Yes	
Naphthalene	Yes	
Nickel	Yes	
Oil and grease	No	Unspecific contaminant
Pentachlorophenol	Yes	
Phenanthrene	Yes	
Pyrene	Yes	
Silver	Yes	
Toluene	Yes	
Trichloroethene	Yes	
Vinyl chloride	Yes	
Xylene	Yes	
Zinc	Yes	

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**Table 6.6-4 Summary of Contaminant of Potential Concern Screening
for Landfill No. 4 Soils**

Contaminant in Soil	CoPC Status	Reason if No
Anthracene	Yes	
Arsenic	Yes	
Benzo(a)anthracene	Yes	
Benzo(a)pyrene	Yes	
Benzo(b)fluoranthene	Yes	
Beryllium	Yes	
Bis(2-ethylhexyl)phthalate	Yes	
Cadmium	Yes	
Chloromethane	Yes	
Chromium	Yes	
Chrysene	Yes	
Copper	Yes	
Fluoranthene	Yes	
Indeno(1,2,3-cd)pyrene	Yes	
Lead	Yes	
Nickel	Yes	
Nitrobenzene	Yes	
Oil and grease	No	Unspecific Contaminant
Phenanthrene	Yes	
Pyrene	Yes	
Zinc	Yes	

6.6.5 Conceptual Site Model

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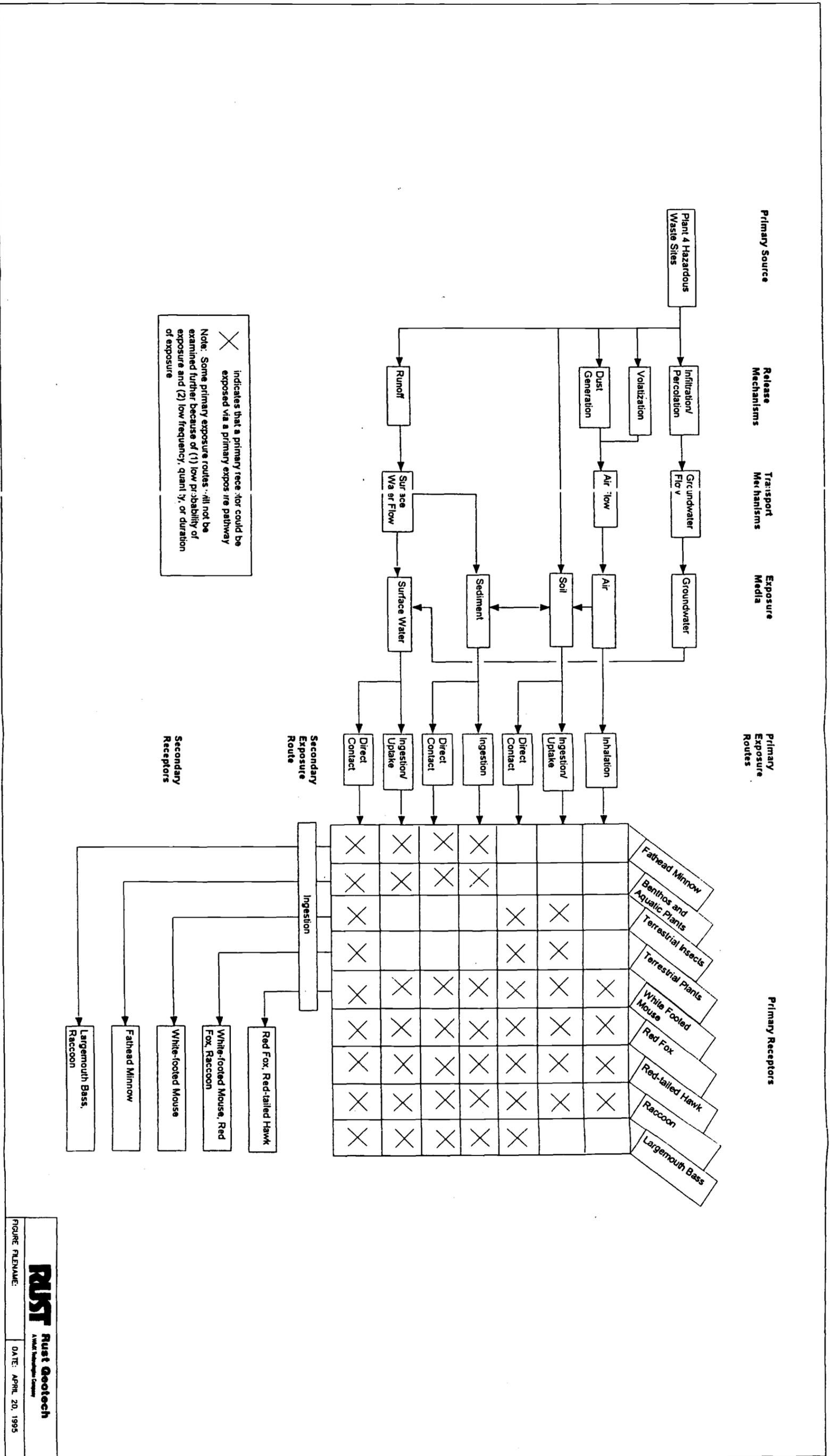
A conceptual site model (Figure 6.6-2) was developed to illustrate the pathways by which RoPCs could be exposed to CoPCs. The model shows how contaminants move from Plant 4 sources into (1) abiotic media (groundwater, surface water, sediment, and air), (2) primary receptors (fathead minnows, benthos and aquatic plants, terrestrial insects, terrestrial plants, white-footed mice, red foxes, red-tailed hawks, raccoons, and largemouth bass) that eat, drink, or breathe the abiotic media, and (3) secondary receptors (white-footed mice, red foxes, red-tailed hawks, and raccoons) that eat the primary receptors.

6.6.6 Endpoints

Receptor-specific assessment and measurement endpoints were selected for Plant 4. These endpoints are presented in Table 6.6-5.

Table 6.6-5 Measurement and Assessment Endpoints for Air Force Plant 4

Assessment Endpoint	Measurement Endpoints
Protection of largemouth bass populations from deleterious effects associated with elevated concentrations of metals and organics	<ul style="list-style-type: none"> • Measure contaminant concentrations in fish tissue, sediment, and surface water • Model food web contaminant uptake by largemouth bass and compare to ecotoxicity values • Assess direct toxicity of sediment and surface water
Protection of red-tailed hawk populations from deleterious effects associated with elevated concentrations of metals and organics	<ul style="list-style-type: none"> • Measure contaminant concentrations in soil and surface water • Model food web contaminant uptake by red-tailed hawk and compare to ecotoxicity values
Protection of red fox populations from deleterious effects associated with elevated concentrations of metals and organics	<ul style="list-style-type: none"> • Measure contaminant concentrations in soil and surface water • Model food web contaminant uptake by red fox and compare to ecotoxicity values
Protection of raccoon populations from deleterious effects associated with elevated concentrations of metals and organics	<ul style="list-style-type: none"> • Measure contaminant concentrations in soil and surface water • Model food web contaminant uptake by raccoon and compare to ecotoxicity values
Protection of overall aquatic and terrestrial prey populations from deleterious effects associated with elevated concentrations of metals and organics	<ul style="list-style-type: none"> • Conduct surface water toxicity testing with water fleas and fathead minnows • Model food web contaminant uptake by white-footed mouse and compare to ecotoxicity values • Assess direct toxicity of soil, sediment, and surface water



RUST Rust Geotech
ANALYTICAL SERVICES COMPANY

FIGURE FILENAME: DATE: APRIL 20, 1995

Figure 6.6-2. Ecological Conceptual Site Model for Air Force Plant 4.

6.6.7 Exposure Assessment

Food web modeling was used to characterize risk without collecting additional data. Food web models are intended to illustrate a conservative exposure scenario for ecological receptors. Some of the modeling incorporated empirical fish tissue data, which made the modeling less conservative. Fish tissue concentrations were available for aluminum, cadmium, chromium, lead, nickel, chrysene, and naphthalene. For all other contaminants, exposure was determined from modeling only. The models use sediment, surface water, soil, and fish tissue data from Plant 4 in conjunction with transfer coefficients, ingestion rates, and area-use factors from the scientific literature to estimate contaminant doses to the RoPCs.

6.6.7.1 Aquatic Models

Aquatic food web models address the largemouth bass's consumption of contaminated fathead minnows or mosquitofish. Mosquitofish were used because empirical tissue data were available for some contaminants in mosquitofish. Fathead minnows were used for contaminants that were not analytes in mosquitofish. Fathead minnows were selected for the model because they feed on benthos and plants, and, therefore, provide a more conservative exposure scenario than mosquitofish, which feed on insects near the water surface. Detailed explanations of the aquatic food web models and complete results are presented in Appendix T, page T5-1.

Fathead minnows or mosquitofish could have been contaminated by Plant 4 by being exposed to either contaminated sediment or contaminated surface water. Three exposure pathways were considered in the risk assessment: fish tissue-to-largemouth bass, sediment-to-largemouth bass, and surface water-to-largemouth bass. For the fish tissue-to-largemouth bass pathway, it was assumed that the largemouth bass's entire diet was composed of mosquitofish having the same contaminant concentrations as those measured in mosquitofish samples collected at Plant 4. For the sediment-to-largemouth bass pathway, it was assumed that the largemouth bass's entire diet was composed of fathead minnows from areas with contaminated sediment. For the surface water-to-largemouth bass pathway, it was assumed that the largemouth bass's entire diet was composed of fathead minnows exposed to surface water in Meandering Road Creek.

In the sediment-to-largemouth bass pathway assessment, sample mean and worst case sediment concentration data from Meandering Road Creek and Lake Worth were used to estimate the contaminant concentration in fathead minnows. The following equations were used:

$$(1) \quad CD_{\text{minnow}} = (CS \times 0.33) + (CS \times BCF_{\text{plant}} \times 0.33) + (CS \times BCF_{\text{benthos}} \times 0.33)$$

where: CD_{minnow} = contaminant dose, in mg/kg;
 CS = contaminant concentration in sediment, in mg/kg;
 BCF_{plant} = contaminant-specific bioconcentration factor for plants; and
 BCF_{benthos} = contaminant-specific bioconcentration factor for benthos.

$$(2) \quad D_{\text{minnow}} = CD_{\text{minnow}} \times IR_{\text{minnow}} \times 1/BW_{\text{minnow}}$$

where: D_{minnow} = dietary contaminant dose to the fathead minnow, in mg/kg/day;
 IR_{minnow} = ingestion rate of the fathead minnow, in kg/day; and
 BW_{minnow} = body mass of the fathead minnow, in kg.

It was assumed that the fathead minnows' diet was composed of 1/3 sediment, 1/3 plants, and 1/3 benthic organisms and that the fathead minnows spent 100% of their time in areas of contaminated sediment. Because food-to-minnow transfer coefficients could not be found, it was assumed that the daily contaminant dose, D_{minnow} , equals the contaminant concentration in the fathead minnow tissues.

In the surface water-to-largemouth bass pathway assessment, sample mean and worst case surface water concentration data from Meandering Road Creek were used to estimate the contaminant concentration in fathead minnows. The following equation was used:

$$(3) \quad C_{\text{minnow}} = CW \times BCF_{\text{minnow}}$$

where: C_{minnow} = contaminant concentration in the fathead minnow, in mg/kg;
 CW = concentration of the contaminant in Meandering Road Creek surface water in mg/L; and
 BCF_{minnow} = contaminant-specific bioconcentration factor for a fathead minnow in water.

It was assumed that fathead minnows spend 100% of their lives in Meandering Road Creek.

The largemouth bass's dietary contaminant dose from any of these pathways was estimated with the following equation:

$$(4) \quad D_{\text{bass}} = CD_{\text{bass}} \times IR_{\text{bass}} \times 1/BW_{\text{bass}}$$

where: D_{bass} = dietary contaminant dose to the largemouth bass, in mg/kg/day;
 CD_{bass} = contaminant dose to the largemouth bass. CD_{bass} is equal to the contaminant concentration that was measured in mosquitofish tissue samples or the calculated dose to the fathead minnow based on contaminant uptake from sediment see equations 2 and 3) or surface water (see equation 4); and
 BW_{bass} = body mass of the largemouth bass, in kg.

The terrestrial food web models used at Plant 4 were adapted from models used for the Fernald, Ohio Site (U.S. Department of Energy 1993). Detailed explanations of the terrestrial food web models, including calculations for estimating contaminant concentrations in food items, and complete results are presented in Appendix T, page T5-15.

Plant 4-specific data that were used in the terrestrial models included sample mean and worst case soil concentration data from the upper two feet of Landfills Nos. 3 and 4, and sample mean and worst case Meandering Road Creek surface water concentration data. Five types of numbers were calculated in the terrestrial modeling effort: (1) dietary contaminant doses for the white-footed mouse, which were used for hazard quotient calculation; (2) contaminant concentrations in white-footed mouse, which were used in dose calculations for red fox and red-tailed hawk; (3) dietary contaminant doses for the red fox, which were used for hazard quotient calculation; (4) dietary contaminant doses for the red-tailed hawk, which were used for hazard quotient calculation; and (5) dietary contaminant doses for the raccoon, which were used for hazard quotient calculation.

The basic equation used in the terrestrial model was:

$$(5) \quad D_{\text{receptor}} = \{(\text{Conc}_{\text{foodA}})(\% \text{Diet}_{\text{foodA}})(\text{IR}_{\text{food}})(\text{FI}) + (\text{Conc}_{\text{foodB}})(\% \text{Diet}_{\text{foodB}})(\text{IR}_{\text{food}})(\text{FI}) + (\text{CS})(\% \text{Diet}_{\text{soil}})(\text{IR}_{\text{food}})(\text{FI}) + (\text{CW})(\text{IR}_{\text{water}})(\text{FI})\} / \text{BW}_{\text{receptor}}$$

where: D_{receptor} = dietary dose to the receptor, in mg/kg/day;
 $\text{Conc}_{\text{foodA}}$ = contaminant concentration in food item A, in mg/kg;
 $\% \text{Diet}_{\text{foodA}}$ = percent of the receptor's diet consisting of food item A, in percent;
 IR_{food} = receptor's ingestion rate for food, in kg/day;
 FI = fraction of the receptor's ingestion that occurs in contaminated areas;
 $\text{Conc}_{\text{foodB}}$ = contaminant concentration in food item B, in mg/kg;
 $\% \text{Diet}_{\text{foodB}}$ = percent of the receptor's diet consisting of food item B, in percent;
 CS = contaminant concentration in soil, in mg/kg;
 $\% \text{Diet}_{\text{soil}}$ = percent of the receptor's diet consisting of soil, in percent;
 CW = contaminant concentration in Meandering Road Creek surface water, in mg/L;
 IR_{water} = receptor's ingestion rate for water, in L/day; and
 $\text{BW}_{\text{receptor}}$ = receptor's body mass, in kg.

The following receptor-specific factors were used in the general equation:

White-footed Mouse

- Diet is composed of 68.9% invertebrates, 29.1% plants, and 2.0% soil (U.S. Department of Energy 1993 and Beyer *et al.* 1992)
- Ingestion rate for food is 0.0327 kg/day (U.S. Department of Energy 1993)

- Ingestion rate for water is 0.00357 L/day (U.S. Department of Energy 1993)
- Fraction of ingestion from contaminated areas is 100% (based on home range in Burt and Grossenheider 1980)
- Body mass is 0.021 kg (U.S. Department of Energy 1993)

Red Fox

- Diet is composed of 88% mice, 9.2% vegetation, and 2.8% soil (U.S. Department of Energy 1993 and Beyer *et al.* 1992)
- Ingestion rate for food is 1.0 kg/day (U.S. Department of Energy 1993)
- Ingestion rate for water is 0.37 L/day (U.S. Department of Energy 1993)
- Fraction of ingestion from contaminated areas is 0.005 (based on the home range listed in Burt and Grossenheider 1980)
- Body mass is 4.7 kg (U.S. Department of Energy 1993)

Red-tailed Hawk

- Diet is composed of 97.2% mice and 2.8% soil (for mice, U.S. Department of Energy 1993. It was assumed that the red-tailed hawk ingests the same percentage of soil as the red fox because both animals eat mice that could have soil in their fur.
- Ingestion rate for food is 0.49 kg/day (U.S. Department of Energy 1993)
- Ingestion rate for water is 0.37 L/day (U.S. Department of Energy 1993)
- Fraction of ingestion from contaminated areas is 0.004 (based on the home range listed in Johnsgard 1990)
- Body mass is 1.13 kg (U.S. Department of Energy 1993)

Raccoon

- Diet is composed of 25.3% fish, 65.3% vegetation, and 9.4% soil (U.S. Department of Energy 1993 and Beyer *et al.* 1992)
- Ingestion rate for food is 1.14 kg/day (U.S. Department of Energy 1993)
- Ingestion rate for water is 0.44 L/day (U.S. Department of Energy 1993)
- Fraction of ingestion from contaminated areas is 0.01 (based on the home range listed in Burt and Grossenheider 1980)
- Body mass is 5.8 kg (U.S. Department of Energy 1993)

6.6.8 Effects Assessment

Ecological effects were evaluated through a direct toxicity assessment and toxicity testing. In addition, ecotoxicological profiles were compiled from the literature. These profiles, and a table that identifies which data were used in the risk assessment, are presented in Appendix T, pages T3-1 and T4-1, respectively.

6.6.8.1 Direct Toxicity Assessment

Direct toxicity assessments were conducted to identify the possible ecological risks associated with elevated concentrations of non-bioaccumulative CoPCs at Plant 4. For the purposes of this risk assessment, contaminants with bioconcentration factors (BCFs) of 10 or less were considered to be non-bioaccumulative. This cut-off number was chosen because, in the scientific literature (Hall and Rumack 1995), contaminants with BCFs lower than 10 often are said to have a negative bioaccumulation potential.

Sample mean and worst case concentrations of non-bioaccumulative CoPCs in surface water were compared to Federal Ambient Water Quality Criteria (40 CFR 131, pp. 288-94). Concentrations of non-bioaccumulative CoPCs in sediment were compared to Effects Range-Low criteria as listed in *Potential for Biological Effects of Sediment-sorbed Contaminants Tested in the National Status and Trends Program* (Long and Morgan 1990). Because soil criteria could not be identified, non-bioaccumulative contaminants in soils were not evaluated for direct toxicity.

Detailed explanations of the direct toxicity assessments are presented in Appendix T, pages T5-50 through T5-52.

6.6.8.2 Toxicity Testing

Toxicity testing involved exposing water fleas (*Ceriodaphnia dubia*) and fathead minnows (*Pimephales promelas*) to surface water samples. Surface water samples were collected at three locations: on-site, upstream, and background (Locations 25, 27, and 28, respectively; see Figure 2.19.1-2 and Plate 1). Three water samples were collected at each location. Samples were submitted to TRAC Laboratories, Inc. of Denton, Texas, for analysis. Twenty-four-hour toxicity tests were conducted, after which mean survival was calculated for both species, mean neonate production per female was calculated for water fleas, and mean final dry weight was calculated for fathead minnows. One-tailed statistical comparisons between control samples and field samples were made using TOXSTAT 3.0 statistical software (TRAC Laboratories, Inc. 1991).

These toxicity tests were selected because many of the contaminants, particularly the metals, that have been detected in surface water samples at Plant 4 are toxic to aquatic organisms. Reduced growth and reduced reproduction are common indicators of non-lethal toxicity. Reduced survival is the indicator for lethal toxicity. The fathead minnow and water flea are readily available test organisms that are frequently used in measuring the toxicity of the contaminants that have been detected at Plant 4.

The results of the toxicity tests conducted in support of this risk assessment are presented in Table 6.6-6. No lethal effects were observed in water fleas after their exposure to any of the water samples. However, reduced reproduction was observed in water fleas that were exposed to the 100% concentration water sample from Location 25 (on-site).

Lethal effects were observed in fathead minnows exposed to 100% concentration water sampled from Location 25 (on-site) and Location 27 (upstream).

Table 6.6-6 Toxicity Test Results
(from TRAC Laboratories, Inc., 1991)

Sample Location	Concentration (%)	Water Flea (<i>Ceriodaphnia dubia</i>)		Fathead Minnow (<i>Pimephales Promelas</i>)	
		S ^a n = 10	R ^b	S n = 40	W ^c
Location 25 (on-site)	100	90	23.4 ^d (64.0) ^f	70 (0.013)	NC ^e
	50	90	24.9 (81.4)	95 (0.003)	0.34 (0.001)
Location 27 (upstream)	100	90	26.7 (62.6)	73 (0.023)	NC
Location 28 (reference)	100	100	26.9 (29.6)	83 (0.009)	0.27 (0.003)
Control	NA	100	29.4 (23.6)	95 (0.003)	0.31 (0.000)

^aS = Percent survival

^bR = Mean neonate production per female

^cW = Mean final dry weight (mg) per fish

^dShading indicates value is significantly different from control

^eNC = Value not calculated because of high mortality

^f Values in parentheses are variances

^gNA = Not applicable

While toxicity test results indicate that water at the on-site location (Location 25) may yield reduced survivability in water fleas and fathead minnows, the tests are considered inconclusive for the purposes of this risk assessment because (1) the upstream location (Location 27) also may yield reduced survivability in fathead minnows, and (2) the high variance for water flea reproduction in the on-site sample (Location 25) indicates that the data for this location are unreliable. Toxicity testing was not considered further in the ecological risk assessment.

6.6.9 Risk Characterization

6.6.9.1 Risk Description

Risk was estimated based on food web models and the direct toxicity assessment. Food web models were used to evaluate exposure to CoPCs through ingestion of food, water, soil, sediment, and fish tissue. These models are applicable only to bioaccumulative contaminants. The direct-toxicity assessment was used to characterize risk from non-bioaccumulative contaminants in sediment, surface water, and soil.

Risk was quantified by calculating hazard quotients with the equation:

$$(6) \quad HQ = \text{Calculated Dose or Concentration} \div \text{Ecotoxicity Benchmark Value}$$

A hazard quotient that exceeds 1.0 indicates a potential or actual ecological risk from a particular contaminant. Hazard indices (HIs) were calculated for each exposure pathway, such that HI is the sum of all HQs. A hazard index that exceeds 1.0 indicates potential ecological risk from exposure to all contaminants in a given exposure scenario.

Four hazard quotients were calculated for each contaminant and each exposure pathway that was addressed in the food web models. Hazard quotients were calculated using two types of ecotoxicity benchmark values (Lowest Observed Adverse Effects Levels [LOAELs] to indicate actual risk and No Observed Adverse Effects Levels [NOAELs] to indicate potential risk) and two environmental media concentrations (sample mean and worst case).

These calculations produced four hazard quotients for each contaminant and exposure pathway, which were intended to represent the possible range of ecological risk levels. The most conservative hazard quotient was calculated with worst case environmental media concentrations and NOAELs (column 3 in Table 6.6-7). The least conservative hazard quotient was calculated with sample mean environmental media concentrations and LOAELs (column 2 in Table 6.6-7). The ecotoxicity data and uncertainty factors that were used to obtain LOAELs and NOAELs are presented in the ecotoxicity profiles and tables in Appendix T, pages T3-1 and T4-1.

Contaminants for which hazard quotients exceed 1.0 are presented in Table 6.6-7. The numerators and denominators from the hazard quotient calculations are presented in Appendix T; page numbers are provided under the Exposure Pathway column of Table 6.6-7.

Table 6.6-7 Contaminants for which Hazard Quotients Exceed 1.0 for Ecological Risk

Exposure Pathway	Contaminant for which Hazard Quotients Exceed 1.0	Hazard Quotients at Sample Mean Environmental Media Concentrations		Hazard Quotients at Worst Case Environmental Media Concentrations	
		Column 1	Column 2	Column 3	Column 4
		using NOAEL value	using LOAEL value	using NOAEL value	using LOAEL value
Water to Largemouth Bass (see Appendix T, pages T5-10 and T5-11)	1,2-Dichlorobenzene	4.84e+00	4.84e-01	4.84e+00	4.84e-01
	1,2-Dichloroethene	4.70e-02	4.70e-03	1.13e+00	1.13e-01
Fish Tissue to Largemouth Bass (see Appendix T, pages T5-5 and T5-6)	Lead	1.98e+00	1.98e-01	2.20e+00	2.20e-01
Sediment to Largemouth Bass (see Appendix T, pages T5-1 and T5-2)	Arochlor 1254	1.15e+01	1.15e+00	1.84e+01	1.84e+00
	1,2-Benzanthracene	3.67e-01	3.67e-02	1.21e+00	1.21e-01
	Benzo(a)anthracene	3.66e-02	3.66e-03	1.40e+00	1.40e-01
	Beryllium	1.49e+00	1.49e-01	2.64e+00	2.64e-01

Table 6.6-7 (continued) Contaminants for which Hazard Quotients Exceed 1.0 for Ecological Risk

Exposure Pathway	Contaminant for which Hazard Quotients Exceed 1.0	Hazard Quotients at Sample Mean Environmental Media Concentrations		Hazard Quotients at Worst Case Environmental Media Concentrations	
		Column 1	Column 2	Column 3	Column 4
		using NOAEL value	using LOAEL value	using NOAEL value	using LOAEL value
Landfill No. 3 Soil to White-footed Mouse (see Appendix T, pages T5-15 and T5-16)	Arsenic	1.52e+00	1.52e-01	4.45e+00	4.45e-01
	Benzo(a)anthracene	3.08e+00	3.08e-02	1.50e+00	1.50e-01
	Cadmium	9.32e-01	9.32e-02	4.58e+00	4.58e-01
	Copper	6.28e+00	6.28e-01	4.85e+01	4.85e+00
	Lead	4.35e+00	4.35e-01	2.84e+01	2.84e+00
	Silver	4.63e-01	4.63e-02	2.63e+00	2.63e-01
	Zinc	1.06e+01	1.06e+00	8.28e+01	8.28e+00
Landfill No. 4 Soil to White-footed Mouse (see Appendix T, pages T5-17 and T5-18)	Acetone	4.44e-01	4.44e-02	2.40e+00	2.40e-01
	Arsenic	2.83e+01	2.83e+00	5.84e+01	5.84e+00
	Cadmium	2.16e+01	2.16e+00	1.21e+01	1.21e+00

Table 6.6-7 (continued) Contaminants for which Hazard Quotients Exceed 1.0 for Ecological Risk

Exposure Pathway	Contaminant for which Hazard Quotients Exceed 1.0	Hazard Quotients at Sample Mean Environmental Media Concentrations		Hazard Quotients at Worst Case Environmental Media Concentrations	
		Column 1	Column 2	Column 3	Column 4
		using NOAEL value	using LOAEL value	using NOAEL value	using LOAEL value
Landfill No. 4 Soil to White-footed Mouse (see Appendix T, pages T5-17 and T5-18)	Copper	3.10e+00	3.10e-01	1.00e+01	1.00e+00
	Lead	8.81e-01	8.81e-02	2.30e+00	2.30e-01
	Silver	4.69e-01	4.69e-02	1.79e+00	1.79e-01
	Zinc	1.20e+00	1.20e-01	4.74e+00	4.74e-01
Landfill No. 3 Soil to Red-tailed Hawk (see Appendix T, pages T5-28 and T5-29)	None				

Table 6.6-7 (continued) Contaminants for which Hazard Quotients Exceed 1.0 for Ecological Risk

Exposure Pathway	Contaminant for which Hazard Quotients Exceed 1.0	Hazard Quotients at Sample Mean Environmental Media Concentrations		Hazard Quotients at Worst Case Environmental Media Concentrations	
		Column 1	Column 2	Column 3	Column 4
		using NOAEL value	using LOAEL value	using NOAEL value	using LOAEL value
Landfill No. 4 Soil to Red-tailed Hawk (see Appendix T, pages T5-30 and T5-31)	None				
Landfill No. 3 Soil to Red Fox (see Appendix T, pages T5-35 and T5-36)	None				
Landfill No. 4 Soil to Red Fox (see Appendix T, pages T5-37 and T5-38)	None				

Table 6.6-7 (continued) Contaminants for which Hazard Quotients Exceed 1.0 for Ecological Risk

Exposure Pathway	Contaminant for which Hazard Quotients Exceed 1.0	Hazard Quotients at Sample Mean Environmental Media Concentrations		Hazard Quotients at Worst Case Environmental Media Concentrations	
		Column 1	Column 2	Column 3	Column 4
		using NOAEL value	using LOAEL value	using NOAEL value	using LOAEL value
Landfill No. 3 Soil to Raccoon (see Appendix T, pages T5-42 and T5-43)	None				
Landfill No. 4 Soil to Raccoon (see Appendix T, pages T5-44 and T5-45)	None				

Note: Shading indicates a hazard quotient that exceeds 1.0.

Hazard quotients exceed 1.0 for five food web pathways: fish tissue-to-largemouth bass, water-to-largemouth bass, sediment-to-largemouth bass, Landfill No. 3 soil to white-footed mouse, and Landfill No. 4 soil to white-footed mouse. No hazard quotients or hazard indices exceed 1.0 for the red-tailed hawk, red fox, or raccoon.

The direct toxicity assessment produced two hazard quotients: one for the sample mean environmental medium concentration and one for the worst case environmental medium concentration (see Table 6.6–8). Hazard quotients could not be calculated for soil direct toxicity. The numerators and denominators for the direct toxicity hazard quotients are presented in Appendix T, pages T5-50 and T5-51. Hazard quotients and hazard indices that exceed 1.0 for the direct toxicity assessment are presented in Table 6.6–8.

Hazard quotients exceeded 1.0 for direct toxicity of silver in sediment. No hazard quotients exceeded 1.0 for direct toxicity in water. It is uncertain whether hazard quotients would exceed 1.0 for direct toxicity of soils because hazard quotients could not be calculated.

In the feasibility study, ecologically-protective contaminant concentrations are calculated for those contaminants and abiotic media that caused hazard quotients to exceed 1.0 in the food web models or direct toxicity assessments.

6.6.9.2 Uncertainty

Food web models

Uptake models produce uncertain results because they incorporate many literature-based factors that are not specific to site conditions. Also, the transfer coefficients and bioaccumulation factors used in these models do not account for variables that affect contaminant bioavailability, such as pH, acid-volatile sulfide content, total organic carbon, and metals speciation. One must know the bioavailability of contaminants if one is to determine their toxicity. If contaminants are not bioavailable, they generally are not toxic.

Most animals are able to reduce levels of contaminants in their tissues either by metabolizing them (especially PAHs) or by excreting them. Because contaminant elimination was not addressed by the food web models, calculated tissue concentrations of these contaminants probably were very conservative.

Calculated contaminant doses were compared to literature-based ecotoxicity data to obtain hazard quotients. The ecotoxicity data in the scientific literature are variable. Often the only data that could be found were for surrogate species (i.e., laboratory rat as surrogates for red fox) or inappropriate endpoints (i.e., LC50s or LDLoS). Uncertainty factors were applied to these data to ensure that the LOAELs and NOAELs used in the model were protective of the receptor of concern.

Table 6.6-8 Hazard Quotients for the Direct Toxicity Assessment

Sediment					
Contaminant	Sample Mean Sediment Concentration (ppm)	Hazard Quotient at Sample Mean Concentration	Worst Case Sediment Concentration (ppm)	Hazard Quotient at Worst Case Concentration	Toxicity Benchmark Value (ppm)
Carbon Disulfide	4.58E-3	N/A	1.31E-2	N/A	N/A
Copper	2.04E+1	2.91E-1	6.38E+1	9.12E-1	7.00E+1
Methylene Chloride	4.22E-3	N/A	9.59E-3	N/A	N/A
Silver	1.94E+0	1.94E+0 ^a	7.80E+0	7.80E+0	1.0E+0
Vinyl Chloride	7.74E-3	N/A	1.41E-2	N/A	N/A
Hazard Index (Metals)		2.30E+0		8.71E+0	
Hazard Index (Organics)		N/A		N/A	
Water					
Contaminant	Sample Mean Water Concentration (mg/L)	Hazard Quotient at Sample Mean Concentration	Worst Case Water Concentration (mg/L)	Hazard Quotient at Worst Case Concentration	Toxicity Benchmark Value (mg/L)
1,2-Dichloroethane	9.88E-3	4.94E-4	1.40E-2	7.00E-4	2.00E+1
Chromium	6.7E-3	3.20E-2	1.60E-2	7.52E-2	2.10E-1
Methylene Chloride	1.00E-3 ^b	6.25E-4	1.00E-3 ^b	6.25E-4	1.60E+0
Vinyl Chloride	2.25E-2	4.29E-2	1.20E-1	2.29E-1	5.25E-1
Hazard Index (Metals)		3.20E-2		7.52E-2	
Hazard Index (Organics)		4.40E-2		2.30E-1	

^a Shading indicates that a hazard quotient or hazard index exceeds 1.0.

^b The maximum detected concentration of methylene chloride exceeded the sample mean and worst case concentrations (which were calculated using one-half the detection limit when concentrations were below detection limits), so the maximum detected concentration of 1.00E-3 mg/L was used in both cases.

The following uncertainty factors were applied to ecotoxicity benchmark values:

- LD₅₀ and LC₅₀ values were multiplied by 0.1 to obtain LOAEL values;
- LOAEL values were multiplied by 0.1 to obtain NOAEL values;
- Values were multiplied by 0.1 if the benchmark was for a taxonomic class different from that of the receptor of concern.

The derivations of the LOAELs and NOAELs, including the uncertainty factors used for each benchmark, are provided in Appendix T, pages T5-8, T5-13, T5-21, T5-33, T5-40, and T5-48.

Because the uncertainty factors often reduced the presumed toxic dose by several orders of magnitude, the uncertainty factors made the uptake models very conservative.

In some cases, the LOAELs and NOAELs were not clearly comparable to the data collected at Plant 4. For example, freshwater Long and Morgan sediment ecotoxicity values were not available for silver; the sediment ecotoxicity benchmark value that was used for silver is a concentration in marine sediments that is known to cause mortality in a species of clam. Because freshwater organisms often are more or less sensitive than marine organisms, the hazard quotient generated by this comparison is uncertain.

Several of the Landfill No. 4 soil samples were collected from the top 5 feet of the landfill rather than the top 2 feet. It was assumed that the RoPCs were exposed only to the top 2 feet of soil. Because contaminant concentrations 5 feet below the surface could be different from concentrations in the top 2 feet, concentrations from these samples may not be representative of the soil to which organisms were exposed.

Direct Toxicity

The direct toxicity assessment is based on nation-wide criteria for sediment and surface water. These criteria do not account for differences in factors that affect contaminant bioavailability, such as pH, acid-volatile sulfide content, total organic carbon, and metals speciation. If contaminants are not bioavailable, they generally are not toxic.

Because soil criteria could not be identified and non-bioaccumulative contaminants in soils were not evaluated for direct toxicity, the direct toxicity of Plant 4 soils is uncertain.

In some cases, the criteria are not clearly comparable to the data collected at Plant 4. For example, the sediment criterion for silver is a concentration in marine sediments that is known to cause mortality in a species of clam; because aquatic organisms often are less sensitive than marine organisms, the hazard quotient generated by this comparison may be overly conservative.

6.6.10 Risk Summary

This section focuses on hazard quotients that were calculated with worst case environmental media concentrations and LOAELs, where applicable.

Evaluation of the measurement endpoints in Table 6.6-5 indicates that worst case concentrations of metals and organics in soil, sediment, and surface water at Plant 4 are protective of red-tailed hawk, red fox, and raccoon populations when the calculated dose is compared to the LOAEL. However, this evaluation indicates that worst case concentrations in Plant 4 soil and sediment may not be protective of local terrestrial and aquatic prey species populations when the calculated dose is compared to the LOAEL.

The results of the food web modeling effort indicate that there is a potential risk to white-footed mice living on Landfills Nos. 3 and 4. Figures 6.6-3 and 6.6-4 show the Landfill No. 3 and No. 4 locations at which hazard quotients exceed 1.0 for arsenic, cadmium, copper, lead, and zinc. The results of food web modeling also indicate that there is a potential risk to largemouth bass living in Lake Worth when the calculated dose is compared to the LOAEL. Figure 6.6-5 shows the location in Lake Worth at which the hazard quotient exceeds 1.0 for Arochlor-1254.

The results of the direct toxicity assessment indicate that there is a potential risk to aquatic organisms living in Meandering Road Creek and Meandering Road Creek Inlet. Figure 6.6-5 shows the locations at which hazard quotients exceed 1.0 for silver.

6.7 Farmers Branch Creek Risk Assessment

6.7.1 Human Health Risk Assessment

An assessment of risk from contaminants in Farmers Branch Creek was not performed as part of the original risk evaluation; however, risk can be determined using the same risk assumptions made for Meandering Road Creek and Lake Worth.

6.7.1.1 Chemicals of Concern

TCE and *cis*-1,2-DCE are the only chemicals of concern measured in Farmers Branch Creek. Table 6.7-1 presents the list of chemicals of concern for human health and maximum concentrations measured in Farmers Branch Creek.

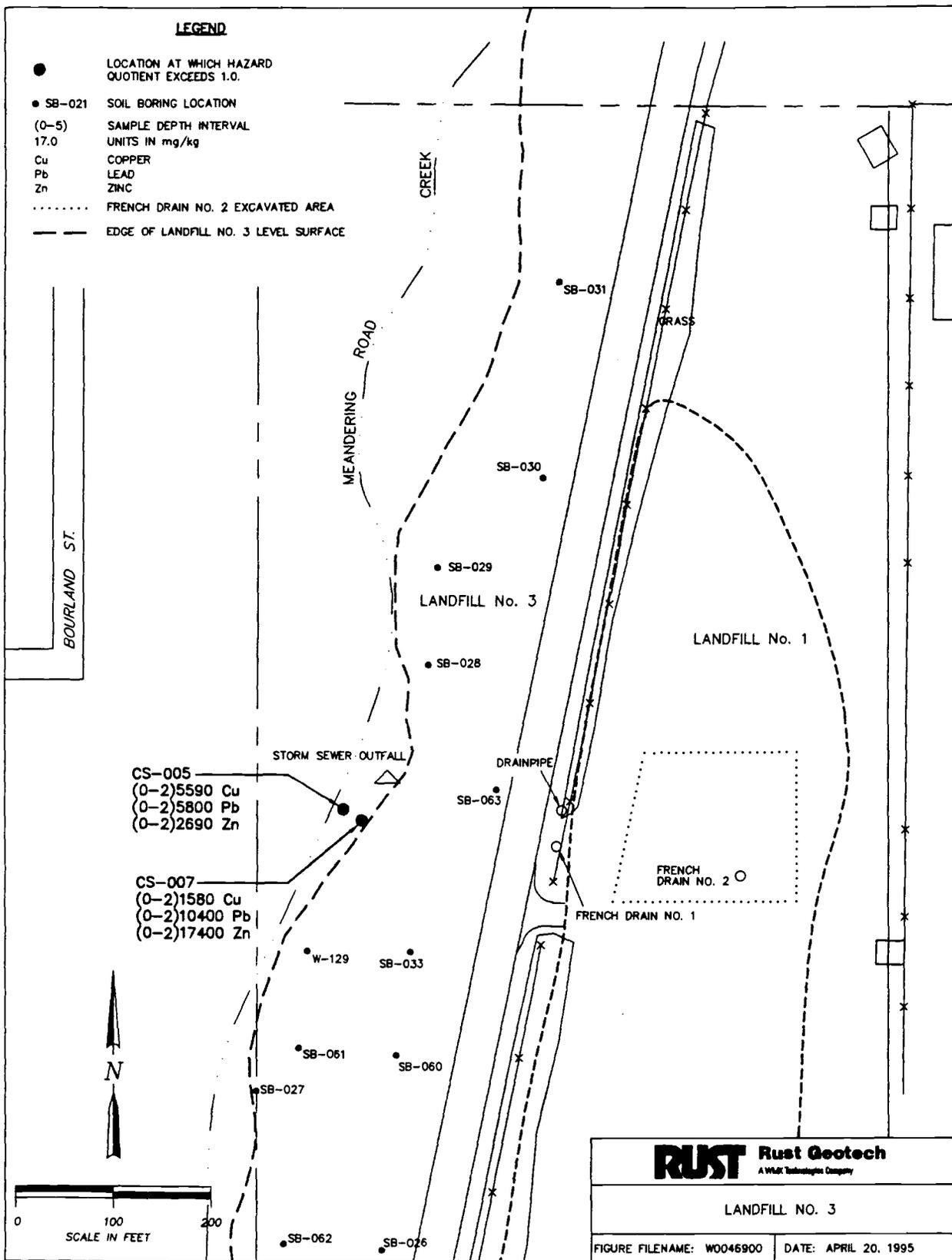


Figure 6.6-3. Locations and Contaminants in Landfill 3 for which Hazard Quotients Exceed 1.0.

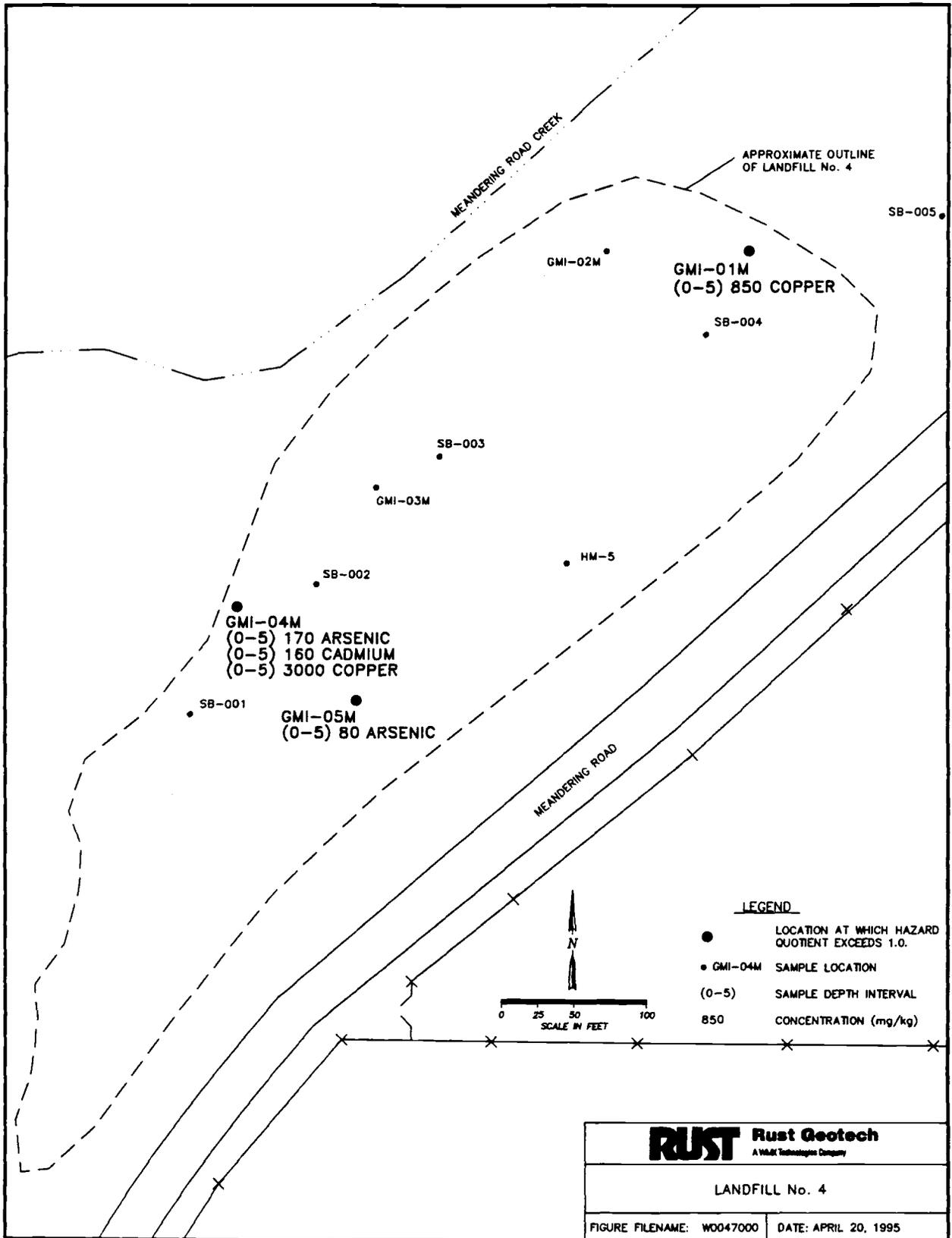


Figure 6.6-4. Locations and Contaminants in Landfill 4 for which Hazard Quotients Exceed 1.0.

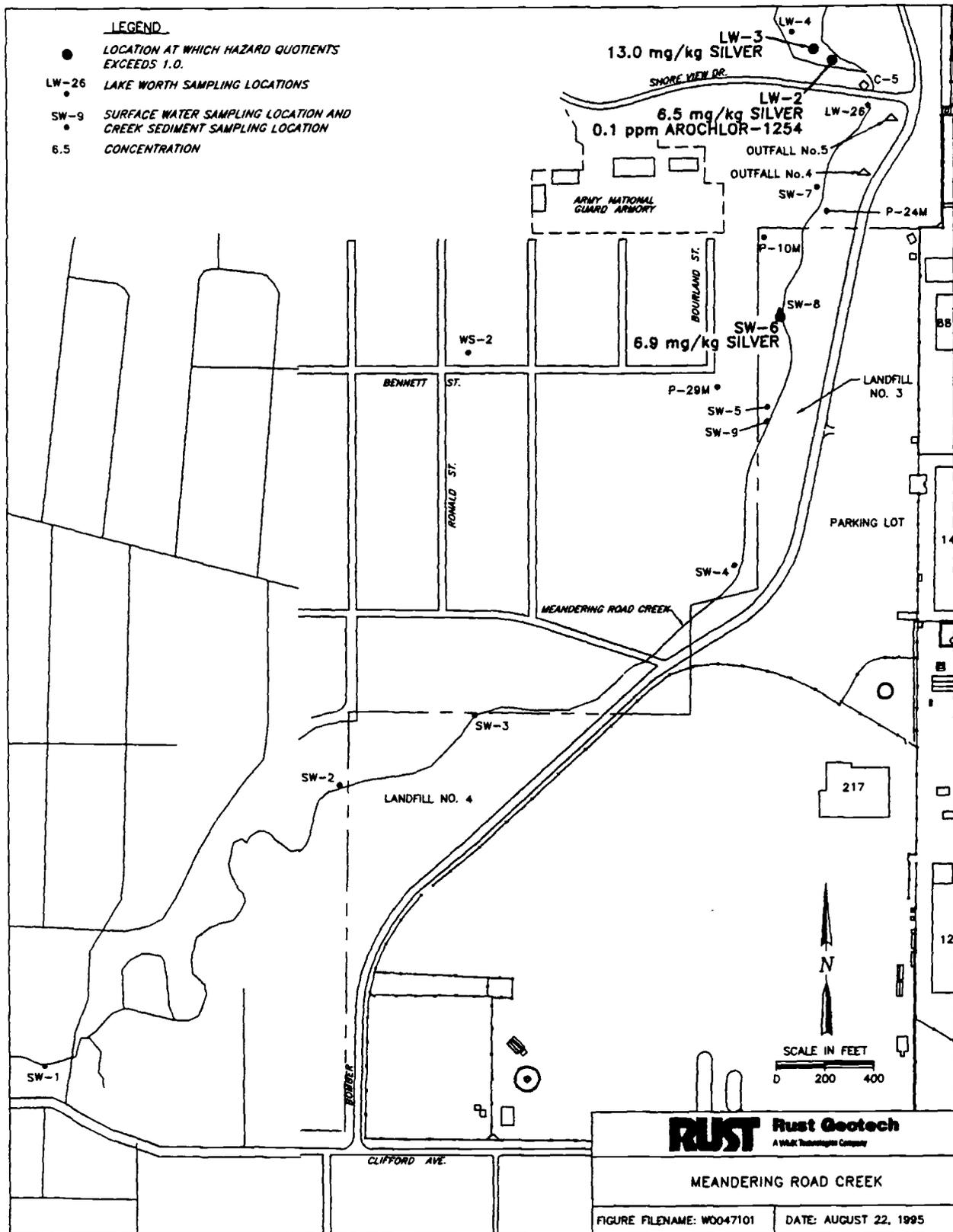


Figure 6.6-5. Locations and Contaminants in Sediment for which Hazard Quotients Exceed 1.0.

6.7.1.2 Potential Exposure Pathways

There are no potential pathways for human health exposure from contaminants in Farmers Branch Creek. This assumes that the area adjacent to the creek will remain industrial and access will be restricted. The exposure potential for contaminated surface water is limited to environmental receptors, discussed in Section 6.8.

Swimming and fishing in Farmers Branch Creek are not likely to occur given the current use of the area. The creek flows through the golf course over most of its length, consequently, access and usage are restricted. It is not used for drinking water nor is it likely to be a drinking water source in the future.

6.7.2 Ecological Risk Assessment

Farmers Branch is a small creek that drains part of Plant 4 and eventually flows into the west fork of the Trinity River. Bluegill sunfish and turtles have been observed in the creek. It is expected that the creek supports many other aquatic organisms as well.

Ecological risk to fish from Farmers Branch surface water was assessed using the surface water-to-largemouth bass food web model that was used for Meandering Road Creek (see Section 6.6.7.1). In the model, it was assumed that fathead minnows from Farmers Branch Creek comprise 100% of the diet of the largemouth bass.

The only ecological CoPCs detected in Farmers Branch were trichloroethene and zinc. Maximum detected concentrations of these contaminants (67 $\mu\text{g/L}$ and 0.028 mg/L, respectively) were used in the food web model.

Risk was quantified using both the LOAEL and the NOAEL ecotoxicological benchmark values (see Section 6.6.7.1). Hazard quotients are presented in Table 6.7-1.

Table 6.7-1 Hazard Quotients for Farmers Branch Creek Fish

Contaminant in Surface Water	Hazard Quotient (using NOAEL)	Hazard Quotient (using LOAEL)
Trichloroethene	1.29E-01	1.29E-02
Zinc	6.16E-04	6.16E-05

No hazard quotients exceeded 1.0 for fish in Farmers Branch Creek. This indicates that the fish living in Farmers Branch Creek are not at risk from Plant 4 contaminants.

7.0 Summary and Conclusions

7.1 Introduction

The PA/SI/RI for Plant 4 was conducted from August 1990 through May 1992. In addition to field investigations conducted in accordance with the requirements of the RI, the results of previous and subsequent investigations were utilized to characterize the site. Characterization data were used to estimate contaminant fate and transport. A risk assessment was performed to estimate exposure and risk to human health and the environment from past environmental practices.

7.2 Summary

7.2.1 Nature and Extent of Contamination

Groundwater contamination at Plant 4 consists of VOCs, some semi-VOCs, and inorganic compounds. The most prevalent VOC is TCE and to a lesser extent 1,1,1-TCA. Also common in the groundwater are the environmental degradation byproducts of these compounds, including *cis*- and *trans*-1,2-DCE; 1,1-DCE; 1,1-DCA; and vinyl chloride. Other organic solvent compounds such as methylene chloride, acetone, and fuel-related BTEX compounds were also detected. Semi-VOCs detected in the groundwater include 1,2-dichlorobenzene; 1,4-dichlorobenzene; naphthalene; 2-methylnaphthalene; and 2,4-dimethylphenol.

Chromium is the most prevalent inorganic priority pollutant detected above the MCL in the upper-zone groundwater. Six other priority pollutants in upper zone groundwater—antimony, arsenic, cadmium, lead, nickel, and thallium—were also found to exceed their respective MCLs on a limited basis. Aluminum, manganese, and iron frequently exceed the secondary drinking water standards.

Three major organic contaminant plumes are described: the East Parking Lot Plume, the West Plume, and the North Plume. The highest concentrations of groundwater contamination occur in the upper-zone flow system near source areas in each plume. TCE concentrations approaching saturation were detected in the south-central part of Plant 4 where numerous potential sources exist. Areas of decreasing concentrations of TCE and its degradation products extend downgradient parallel to the direction of groundwater flow. The East Parking Lot Plume originates at the south-central and west-central portions of Plant 4 and extends in an easterly direction beyond the facility boundary, onto CAFB. The extent and shape of the plume is controlled by the presence of a buried paleochannel cut through the Goodland Limestone and into and possibly through the Walnut Formation. The West Plume originates near Landfill No. 1 and the western portion of FSA-1 and extends in a westerly direction towards Meandering Road

Creek. The FDTA-2 source area is located within the West Plume. Dissolved constituents originating at FDTA-2 flow into the West Plume, while DNAPL constituents may flow along the bedrock surface toward the East Parking Lot Plume. The North Plume consists of moderately elevated concentrations of solvent compounds adjacent to the JETS. Light NAPLs, suspected to be fuel compounds, are also present in several monitoring wells in the North Plume.

Contamination enters the Paluxy Formation primarily through vertical leakage near the East Parking Lot window area. The window area is a location where the Walnut Formation is almost, if not completely, removed by erosion within the paleochannel of the ancestral West Fork of the Trinity River. Estimates of the volumetric flux rate through the thinnest portion of the Walnut Formation indicate that the rate of groundwater leakage into the Paluxy Formation is in the range of 0.54 to 54 ft³/d. Assuming recharge passes through the window area Walnut Formation with a contaminant concentration of 20,000 µg/L (based on window area wells in the upper zone), the mass flux of contaminants into the upper portion of the Paluxy Formation would be between 0.0003 and 0.03 ounces per day. The leakage of contaminated water into the Paluxy Formation has led to the detection of relatively high TCE concentrations in the upper-most portion of the Paluxy Formation. Since the upper-most portion of the Paluxy Formation is variably saturated within the Plant 4 area, vertical migration of contamination to the deeper, saturated portions of the Paluxy Formation is relatively slow. Consequently, there is very little contamination that has actually impacted the regional Paluxy Aquifer thus far.

TCE is also the most prevalent VOC contaminant in soils. Widespread occurrence of this compound, at relatively low concentrations, is associated with saturated soils beneath the south end of the Assembly Building/Parts Plant, the East Parking Lot, and at least as far as Runway No. 130 North. Relatively high concentrations of TCE occur in vadose-zone soil samples at two sites: Chrome Pit No. 3 and Landfill No. 3.

Other VOCs detected at relatively high concentrations in soils include toluene, 2-butanone, methylene chloride, and 1-2 DCE. Some or all of these compounds were detected at Landfills No. 1 and No. 3, the former USTs No. 19 and No. 20, and the DYCP. In addition, chloroform and bromodichloromethane were detected at relatively high concentrations at the former USTs No. 19 and No. 20.

TPH contamination was detected in soil samples obtained from the JETS, FDTA-2, FSA-1, and FSA-3. The areas of TPH contamination associated with the JETS, FSA-1, and FSA-3 reflect JP-4 leaks in underground fuel lines. TPH contamination at FDTA-2 resulted from fire training activities.

The most frequent group of semi-VOCs that were detected in soil samples are those typically associated with petroleum products. These semi-VOCs were commonly found at fuel-oil contaminated sites (i.e., FSA-3, JETS, and FSA-1), reflecting contamination

from leaking underground storage tanks or fuel lines. Another group of semi-VOCs that were detected are typically associated with asphalt. The highest concentrations of these semi-VOC contaminants were detected at Landfills No. 1 and No. 4.

Inorganic soil contamination is characterized by the presence of antimony, cadmium, chromium, copper, lead, nickel, silver, and zinc at concentrations greater than the upper range in natural background. Elevated concentrations of these constituents appear to be limited to Landfills No. 1, No. 3, and No. 4, and the FDTA-2.

Minimal soil contamination was detected at FSA-2 and FDTA-6, and no soil contamination was detected at the WWCB and FFSA. Additionally, the WWCB were examined in June 1991 when they were drained and cleaned due to a TCE release. No evidence of cracks were noted in the concrete, however, the liner was missing over much of the WWCB's surface area.

Surface-water contamination in the vicinity of Plant 4 is primarily associated with Meandering Road Creek. The most contamination identified in the creek results from elevated concentrations of VOCs. The primary VOCs of concern included TCE; *cis*-1,2-DCE; 1,2-DCE; and vinyl chloride. Discharge of contaminated upper-zone groundwater into the creek is the most likely source of VOC contamination. Lower concentrations of other contaminants, including one semi-VOC (4-methylphenol), TPH, and oil and grease, were reported as isolated occurrences in the creek during the RI. In addition to upper-zone groundwater, other potential sources for this contamination are surface-water runoff and storm sewer discharge.

The only target analyte reported in surface-water samples collected from Lake Worth was carbon disulfide. Carbon disulfide was detected in samples obtained at three locations along the northern boundary of Plant 4. The magnitude of the concentrations reported and the distribution of sampling sites suggest that sources for the contamination are not related, but rather are located near the points of sample collection.

Surface water samples collected during the period 1991 through 1994 indicate volatile organic contamination in Farmers Branch Creek, primarily TCE and *cis*-1,2-DCE.

The results of the ambient-air monitoring program conducted at Plant 4 indicated that plant activities are contributing anomalous quantities of four volatile organic compounds to the air when compared to the respective off-site concentrations measured. Maximum on-site concentrations of dichlorodifluoromethane; Freon 113; 1,1,1-trichloroethane; and trichloroethene ranged from 4 to 14 times greater than the maximum off-site concentrations. Additionally, the results of the program indicated that the activities at Plant 4 do not contribute significant quantities of particulates to the air.

7.2.2 Risk Assessment

The Baseline Risk Assessment examined 15 current and future exposure pathways, however, only six were found to be complete (i.e., contains a contaminant release to the environment, an environmental transport mechanism, a point of exposure by a receptor, and a route of exposure). Three of these pathways involved current use and three involved future use, based on a 30-year land-use scenario. Exposure point concentrations were estimated using a combination of site-specific contamination data and conservative contaminant transport models and media transport equations.

Quantitative risk calculations were done to estimate the potential for adverse human health effects for the six complete exposure pathways. Estimates were done for both RME and central tendency. Carcinogenic risks exceeded a 1×10^{-6} level for two exposure pathways involving current land use for RME and one for central tendency; none of these exposures exceeded 1×10^{-4} . Carcinogenic risks exceeded a 1×10^{-6} level in the three exposure pathways involving future land use, with two of these three exceeding 1×10^{-4} for RME and none exceeding 1×10^{-4} for central tendency. Trichloroethene is the only chemical that contributes to the risk for carcinogens involving future land use.

For noncarcinogens, the Hazard Indices were 0.5 for current and 1.1 for future residential exposure for RME; both hazard indices were less than one for central tendency. Chromium (assuming 100 percent hexavalent state) is a considerable contributor to the total risk for noncarcinogens under the current scenario, and 1,2-dichloroethene is the largest contributor to the total risk for noncarcinogens under the future scenario.

The Plant 4 ecological risk assessment focused on the relatively natural areas near Meandering Road Creek and Lake Worth. In addition, the risk assessment addressed the aquatic community in Farmers Branch Creek.

Contaminants detected in Landfill No. 3 and No. 4 soils, Meandering Road Creek and Lake Worth surface water, and Meandering Road Creek and Lake Worth sediments were screened to form medium-specific lists of contaminants of potential concern (CoPCs).

Receptors of potential concern (RoPCs) were selected using the following criteria: (1) high likelihood of exposure to CoPCs, (2) high ecological significance, (3) availability of toxicological literature for the species or surrogate, and (4) possibility of population-level adverse effects from Plant 4 stressors. RoPCs for Plant 4 include the largemouth bass (*Micropterus salmoides*), the red-tailed hawk (*Buteo jamaicensis*), the red fox (*Vulpes fulva*), the raccoon (*Procyon lotor*), terrestrial prey species (i.e. small mammals), and aquatic prey species (i.e. benthic macroinvertebrates and small fish).

Assessment endpoints (actual environmental values that are to be protected) were selected to represent the receptors of concern. Plant 4 assessment endpoints include the protection of largemouth bass, red-tailed hawk, red fox, and raccoon populations, and protection of overall aquatic and terrestrial prey populations.

Measurement endpoints (characteristics of the ecological system that can be related to assessment endpoints) for Plant 4 included (1) measuring contaminant concentrations in surface water, sediment, soil, and fish tissue; (2) modeling food web uptake of contaminants; (3) assessing direct toxicity of environmental media; and (4) conducting surface water toxicity tests.

Ecological risk was characterized using a weight-of-evidence approach in which all of the data generated by the measurement endpoints were considered. In the food web models and direct toxicity assessments, ecological risk was quantified by calculating hazard quotients (HQs) such that HQ equals the measured dose or concentration divided by an ecotoxicological benchmark value. A hazard quotient that exceeds 1.0 indicates potential ecological risk.

The results of the toxicity tests were inconclusive, so they were not used to quantify risk.

Hazard quotients exceeded 1.0 for mice exposed to soil at two locations in Landfill No. 3 and at three locations in Landfill No. 4, for the largemouth bass exposed to sediments at one location in Lake Worth, and for aquatic organisms exposed to sediments at one location in Meandering Road Creek and at two locations in Meandering Road Creek Inlet. Hazard quotients did not exceed 1.0 for the largemouth bass, the red-tailed hawk, the red fox, or the raccoon.

To address ecological risk in Farmers Branch Creek, maximum concentrations of the CoPCs detected in Farmers Branch Creek were compared to concentrations at which the hazard quotient equalled 1.0 in the Meandering Road Creek model. Based on this comparison, no hazard quotients would exceed 1.0 for fish in Farmers Branch Creek. Therefore, it is unlikely fish in Farmers Branch Creek are at risk from Plant 4 contaminants.

7.3 Conclusions

The data collected during the RI and previous investigations effectively characterize the chemical and physical conditions at Plant 4 and support the determination of contamination-related risks.

7.3.1 Data Limitations and Recommendations for Future Work

In a project of this magnitude, additional data needs are inevitable; however, the data collected during the RI and previous IRP investigations are adequate to determine the

risk associated with documented levels of contamination and a reasonable response action. The following sections provide discussion on areas where additional data may be required during post RI/FS activities.

7.3.1.1 Soil Data Gaps

Seven areas have been identified where additional information may be necessary to accurately quantify the total extent of soils contamination if soils remediation is required based on the FS.

The total extent of soils contamination at FDTA-2 is uncertain because levels of TPH in soil boring SB-069 (upgradient from FDTA-2) increased with depth to the bottom of the hole. The elevated levels of TPH in the boring may reflect soils contamination associated with leaks in the abandoned JP-4 line located to the south of FDTA-2 which is beyond the scope of this investigation.

Residual contamination may exist at Chrome Pit 3 below the level at which the site was previously excavated (18 feet) to remove contaminated soils. There is evidence (soils from monitoring well HM-1) that suggests contamination may exist up to 27 feet below ground surface.

The total extent of soils contamination at the DYCP is uncertain because a large underground utility corridor immediately west of and adjacent to the DYCP prohibited the completion of subsurface investigations. Consequently, contaminant information for soils located immediately west of the DYCP could not be collected.

The total extent of soils contamination at FSA-2 is uncertain because of levels of TPH in soil boring SB-2 located west of FSA-2. The elevated levels of TPH in this boring may reflect soils contamination associated with known leaks in the abandoned JP-4 line that traversed the area. Investigations of this line are beyond the scope of this investigation.

The total extent of soils contamination at FSA-3 is uncertain because levels of TPH in several soil borings indicate possible sources of contamination other than those previously associated with FSA-3. These areas may reflect soils contamination associated with additional leaks in several of the abandoned fuel lines located within the area.

The total extent of soils contamination at the JETS and UST-25A is uncertain because underground utilities prohibited the completion of subsurface investigations north of the JETS and other subsurface obstacles prohibited the completion of subsurface investigations immediately adjacent to UST-25A.

7.3.1.2 Groundwater Data Gaps

Existing data reveals that the plume extends east of the Plant 4 property line and onto CAFB. Recent and past data have revealed several likely source areas on CAFB, including the North Apron, Landfill 6 area, and Landfills 4 and 5. Existing data do not allow one to define where the Plant 4 plume ends and where the CAFB plumes begin.

Additional data gaps are present in the southwestern portion of the East Parking Lot Plume (south of Building 188 and Clifford Avenue).

Lastly, as a result of apparent TCE releases beneath Building 181 in the recent past, the distribution of high-concentrations of TCE in the East Parking Lot Plume determined during the RI is expected to change. This transient behavior of TCE in the East Parking Lot Plume has not yet been adequately defined on the basis of samples collected during the RI and during previous and subsequent investigations.

7.3.2 Recommended Remedial Action Objectives

Remedial action objectives (RAOs) were developed for each area of contamination that exceeded risk threshold values. The RAOs incorporate the contaminants of concern, a quantitative cleanup level, and an exposure pathway. The primary contaminants of concern in the Paluxy aquifer are trichloroethene (TCE) and dichloroethene (DCE). The RAO for the Paluxy aquifer is to prevent human exposure from ingestion, inhalation during showering, and dermal exposure from showering to TCE concentrations exceeding 3.0 micrograms per liter ($\mu\text{g}/\text{L}$) and to DCE concentrations exceeding 70 $\mu\text{g}/\text{L}$ for *cis*-1,2-DCE and 100 $\mu\text{g}/\text{L}$ for *trans*-1,2-DCE.

Aqueous phase TCE and TCE dense nonaqueous phase liquid (DNAPL) are the primary contaminants of concern for the East Parking Lot Plume. The RAOs for the East Parking Lot Plume are to prevent TCE concentrations in the Window Area of the East Parking Lot Plume from exceeding 250 $\mu\text{g}/\text{L}$, to remove TCE DNAPL in the East Parking Lot Plume, and prevent groundwater with contamination above maximum contaminant levels (MCLs) from migrating off Plant 4 or Carswell Air Force Base (CAFB) boundaries. Removal of DNAPL will be demonstrated by dissolved TCE concentrations of less than 10,000 $\mu\text{g}/\text{L}$.

RAOs were developed separately for each of the four soil/sediment contamination areas. The contaminants of concern at Landfill No. 4 are benzo(a)pyrene (BAP), arsenic, cadmium, and copper. The RAOs for Landfill No. 4 are to prevent ingestion of BAP contaminated soils with concentrations exceeding the preliminary remediation goal (PRG) of 1.0 milligram per kilogram (mg/kg) and prevent the exposure of mice to arsenic, cadmium, and copper at levels which exceed 29.1 mg/kg , 132 mg/kg , and 563 mg/kg , respectively.

Copper, lead, and zinc are the contaminants of concern at Landfill No. 3. The RAO for Landfill No. 3 is to prevent exposure of mice to copper, lead, and zinc at levels which exceed 563 mg/kg, 2,000 mg/kg, and 1,000 mg/kg, respectively. Silver is the contaminant of concern in the sediments in Meandering Road Creek and Lake Worth. The RAO for Meandering Road Creek and Lake Worth is to prevent exposure of aquatic organisms to concentrations of silver above 1.0 mg/kg in the sediments. TCE in the vadose zone is the contaminant of concern at Building 181. The RAO for Building 181 is to prevent TCE concentrations in the soil exceeding 11.5 mg/kg, the level which could produce leachate above allowable levels in the Upper Zone groundwater.

8.0 References

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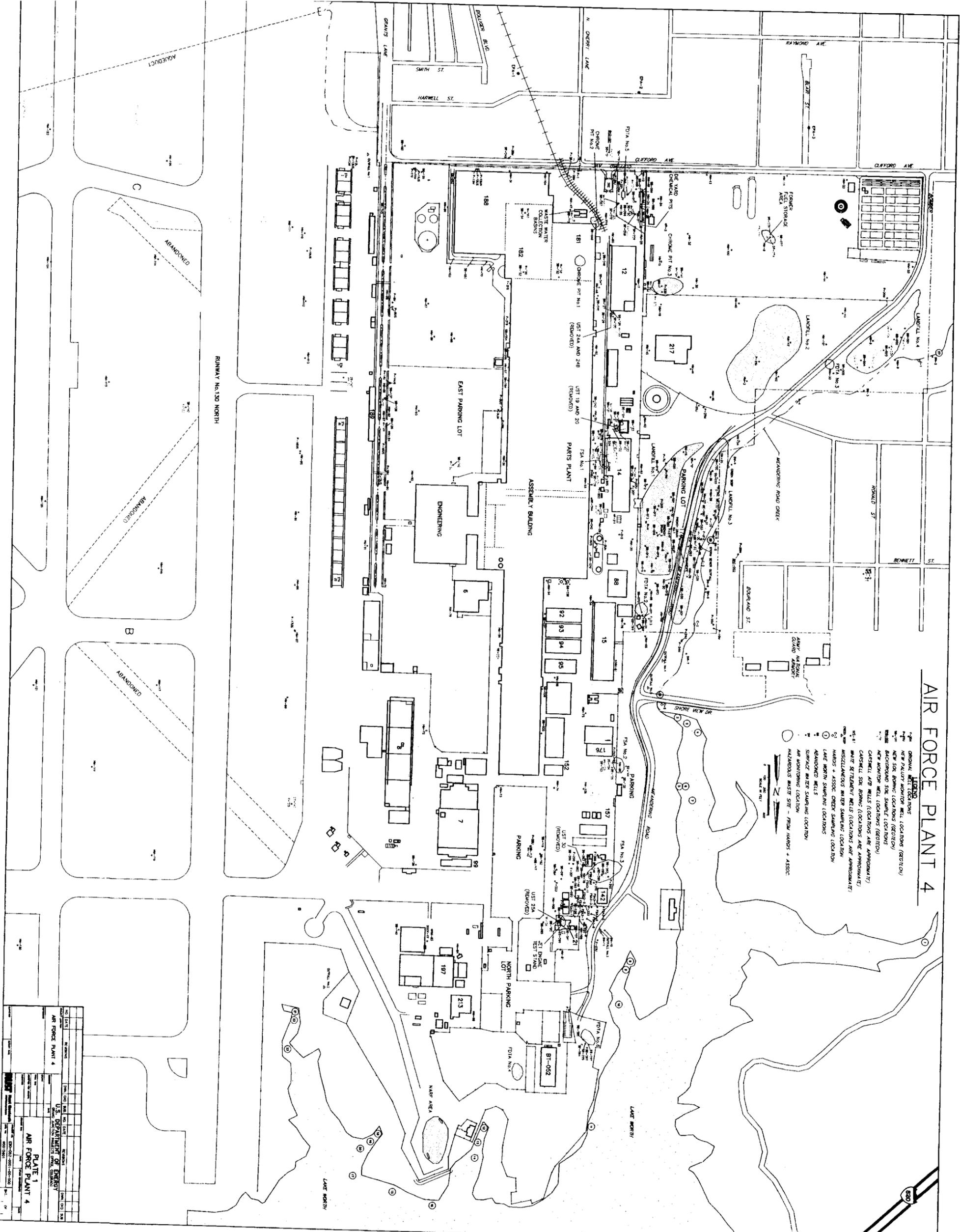
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AIR FORCE PLANT 4

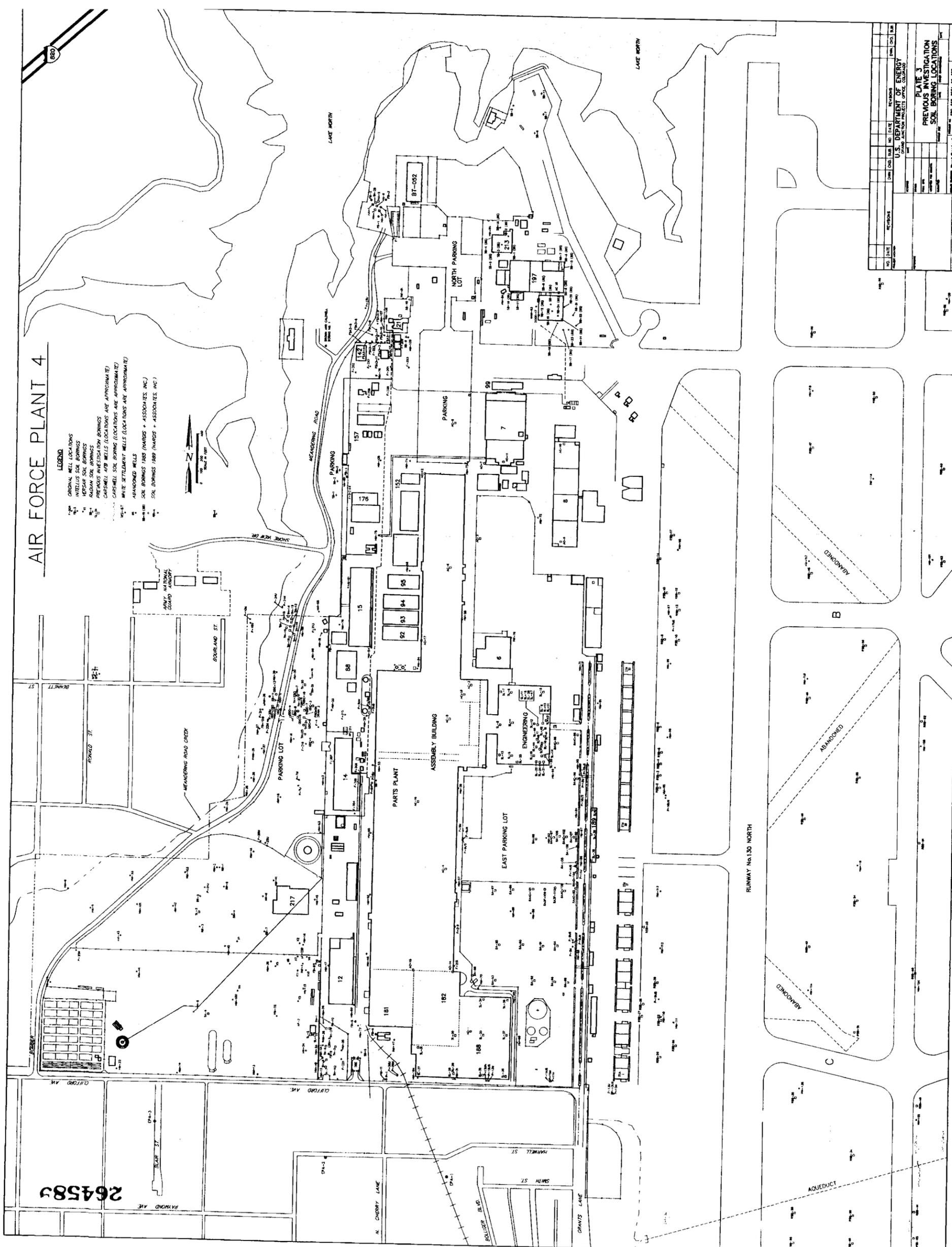


- ORIGINAL WELL LOCATIONS
- NEW PALEY MONITOR WELL LOCATIONS (REMOVED)
- NEW SOIL BORING LOCATIONS (REMOVED)
- REMOVED SOIL BORING LOCATIONS
- MONITOR WELL LOCATIONS (REMOVED)
- CASSELL AFB WELLS (LOCATIONS ARE APPROXIMATE)
- WHITE SETTLEMENT WELLS (LOCATIONS ARE APPROXIMATE)
- MISCELLANEOUS WATER SAMPLING LOCATIONS
- MAROS + ASSOC. CHECK SAMPLING LOCATION
- LAKE NORTH SAMPLING LOCATION
- ABANDONED WELLS
- SURFACE WATER SAMPLING LOCATION
- AIR MONITORING LOCATION
- HAZARDOUS WASTE SITE - FRESH HANDS + ASSOC.

NO. DATE		REVISED	BY	DATE	REVISION
1	10/1/50				
U.S. DEPARTMENT OF ENERGY					
AIR FORCE PLANT 4					
PLATE 1					
AIR FORCE PLANT 4					
SCALE: AS SHOWN					
DRAWN BY: [Name]					
CHECKED BY: [Name]					
DATE: [Date]					

AIR FORCE PLANT 4

- LEGEND**
- ORIGINAL WELL LOCATIONS
 - INTELLIGENT SOIL BORINGS
 - KESKAR SOIL BORINGS
 - PALDAN SOIL BORINGS
 - PREVIOUS INVESTIGATION BORINGS
 - CASWELL ATB WELLS (LOCATIONS ARE APPROXIMATE)
 - WHITE SETTLEMENT WELLS (LOCATIONS ARE APPROXIMATE)
 - ABANDONED WELLS
 - SOIL BORINGS 1988 (HARDS + ASSOCIATES, INC.)
 - SOIL BORINGS 1989 (HARDS + ASSOCIATES, INC.)



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NO.		DATE		REVISIONS		BY		CHECKED	

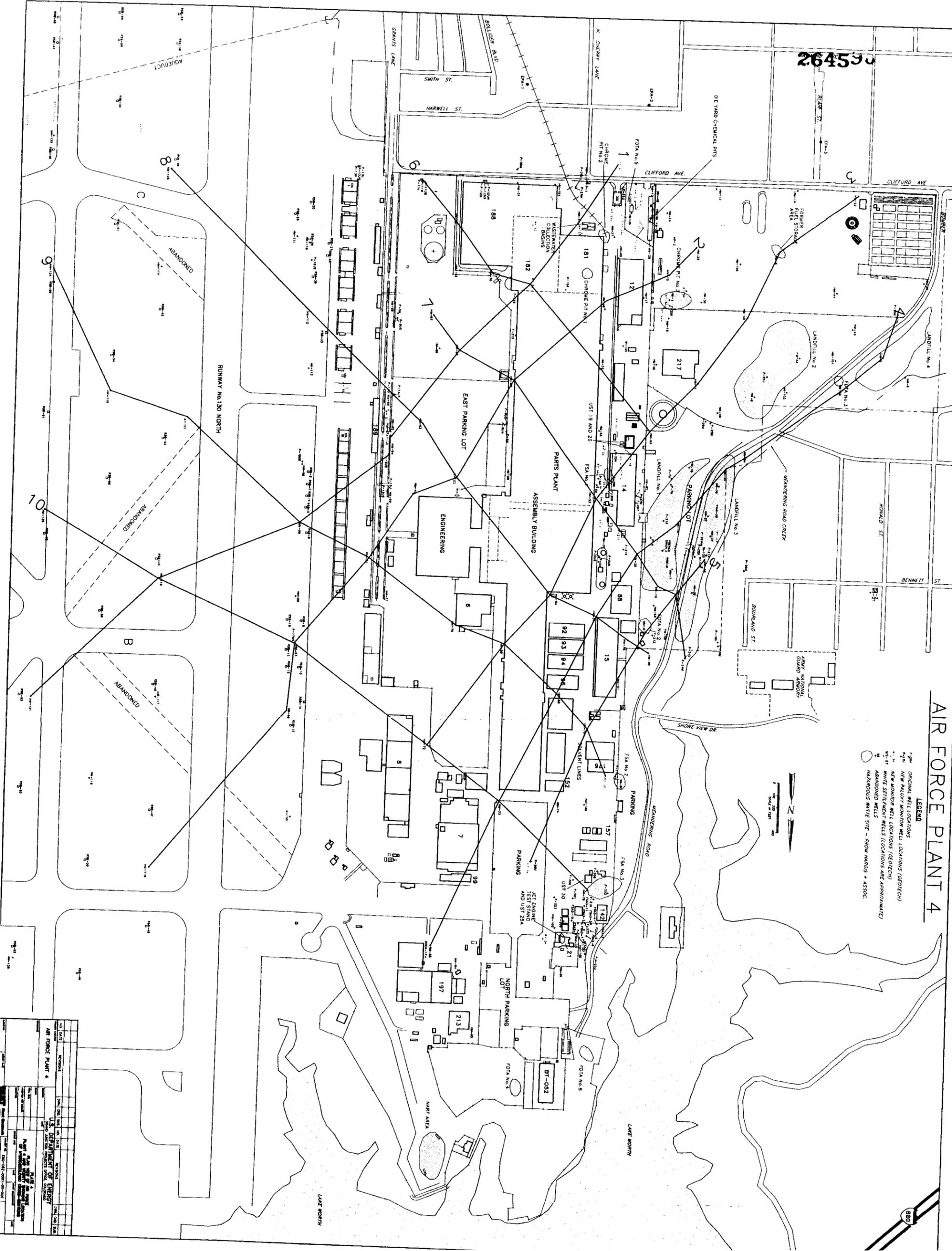
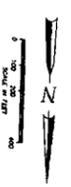
U.S. DEPARTMENT OF ENERGY
 OIL AND MINERAL RESOURCES PROJECT OFFICE, OIL AND GAS DIVISION

PLATE 3
 PREVIOUS INVESTIGATION
 SOIL BORING LOCATIONS

Scale: 1" = 100'-0" (1:12000)
 Date: 10/11/89
 Sheet: 1 of 1

AIR FORCE PLANT 4

- LEGEND**
- ORIGINAL WELL LOCATIONS
 - NEW PALUXY MONITOR WELL LOCATIONS (GEOTECH)
 - NEW AUSTON WELL LOCATIONS (GEOTECH)
 - NEW SETTLEMENT WELLS LOCATIONS (GEOTECH)
 - ABANDONED WELLS
 - HAZARDOUS WASTE SITE - FROM HARRIS + ASSOC.



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AIR FORCE PLANT 4	
NO. 1	NO. 2
NO. 3	NO. 4
NO. 5	NO. 6
NO. 7	NO. 8
NO. 9	NO. 10
NO. 11	NO. 12
NO. 13	NO. 14
NO. 15	NO. 16
NO. 17	NO. 18
NO. 19	NO. 20
NO. 21	NO. 22
NO. 23	NO. 24
NO. 25	NO. 26
NO. 27	NO. 28
NO. 29	NO. 30
NO. 31	NO. 32
NO. 33	NO. 34
NO. 35	NO. 36
NO. 37	NO. 38
NO. 39	NO. 40
NO. 41	NO. 42
NO. 43	NO. 44
NO. 45	NO. 46
NO. 47	NO. 48
NO. 49	NO. 50
NO. 51	NO. 52
NO. 53	NO. 54
NO. 55	NO. 56
NO. 57	NO. 58
NO. 59	NO. 60
NO. 61	NO. 62
NO. 63	NO. 64
NO. 65	NO. 66
NO. 67	NO. 68
NO. 69	NO. 70
NO. 71	NO. 72
NO. 73	NO. 74
NO. 75	NO. 76
NO. 77	NO. 78
NO. 79	NO. 80
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NO. 91	NO. 92
NO. 93	NO. 94
NO. 95	NO. 96
NO. 97	NO. 98
NO. 99	NO. 100

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FINAL PAGE

ADMINISTRATIVE RECORD

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ADMINISTRATIVE RECORD

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