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REMEDIAL INVESTIGATION REPORT FOR THE LEE ACRES LANDFILL

Volume I

Executive Summary
Sections 1 through 13

DRAFT

Prepared For

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ACRONYMS

ACGIH	American Congress of Governmental Industrial Hygienists
AEPCO	Advanced Engineering and Planning Corp., Inc.
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
BLM	Bureau of Land Management
BNA	base-neutral acid
BTEX	benzene, toluene, ethylbenzene, and xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CGI	combustible gas indicator
CLP	Contract Laboratory Program
COC	contaminant of concern
CPT	cone penetrometer test
DCA	dichloroethane
DCE	dichloroethene
DQO	data quality objective
EIS	environmental impact statement
EM	electromagnetic
EP	Extraction Procedure
EPA	U.S. Environmental Protection Agency
EWS	electronic weather station
FFA	Federal Facilities Agreement
FS	feasibility study
FWS	Fish and Wildlife Service
G	gamma
GBR	Giant-Bloomfield Refinery
GC	gas chromatography
GCL	Geoscience Consultants, Ltd.
H_2S	hydrogen sulfide
HELP	Hydrologic Evaluation of Landfill Performance (computer model)
HHS	(New Mexico) human health standard
HI	hazard index
IRIS	Integrated Risk Information System
K	hydraulic conductivity
K-S	Kolmogorov - Smirnov (test)
K_d	partition coefficient
MCL	maximum contaminant level
MS	mass spectroscopy
MSL	mean sea level
n	effective porosity
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NMED	New Mexico Environment Department
NMEID	New Mexico Environmental Improvement Division
NMOCD	New Mexico Oil Conservation District
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List

OSHA	Occupational Safety and Health Administration
OU	operable unit
OVA	organic vapor analyzer
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PI	preliminary investigation
PID	photoionization detector
PM 10	particulates less than 10 micrometers in size
PMF	possible maximum flood
PMP	probable maximum precipitation
PRP	potentially responsible party
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RI	remedial investigation
RIR	RI report
ROD	Record of Decision
S	storativity
SAPP	sampling and analysis project plan
SARA	Superfund Amendments and Reauthorization Act
SCS	U.S. Soil Conservation Service
SDWA	Safe Drinking Water Act
SOP	standard operating procedure
SWRDAT	Soil Water Retention Data (computer model)
T	transmissivity
TBC	to be considered
T_c	time of concentration
TCA	trichloroethane
TCA	trichloroethane
TCE	trichloroethene
TCL	target compound list
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TLV-TWA	threshold limit value - time weighted average
Tnc	Tertiary Nacimiento Formation claystone/siltstone
Tns	Tertiary Nacimiento Formation sandstone
TSP	total suspended particulates
TTLC	total threshold limit concentration
USGS	U.S. Geological Survey
VOA	volatile organic analysis
VOC	volatile organic compound

EXECUTIVE SUMMARY

In October 1989, the Bureau of Land Management (BLM) began a comprehensive remedial investigation (RI) at the former Lee Acres Landfill to characterize environmental conditions and contaminant migration pathways. This investigation was completed in July 1991. The BLM conducted this RI according to the Comprehensive Environmental Restoration, Compensation, and Liability Act/Superfund Amendments and Reauthorization Act and the National Contingency Plan, with appropriate U.S. Environmental Protection Agency (EPA) guidance in anticipation of the site's placement on the National Priorities List (NPL). In August 1990, the former Lee Acres Landfill was, in fact, placed on the NPL by EPA. This RI is part of an overall remedial investigation/feasibility study (RI/FS) being conducted by the BLM to determine the extent of contamination at the landfill and to select a preferred remedial action that will eliminate or significantly reduce to acceptable levels any threat to human health and the environment. The RI was designed to characterize all media, sources, and potential contaminant migration pathways for the landfill.

Data collection activities conducted during the RI focused on groundwater and soil contamination and included air photo interpretation, geophysical surveys, cone penetrometer tests, hydrocone groundwater sampling, soil boring installation and sampling, monitoring well installation and sampling, waste trench studies, hydrogeologic investigations, and an air quality investigation. The technical rationale and procedures for completing these activities are presented in the Sampling and Analysis Project Plan for the Lee Acres Landfill, issued by the BLM in March 1990.

The RI resulted in several important findings. First, upgradient background alluvial aquifer groundwater contains elevated levels of chromium and dichloromethane. Second, a mass of organic groundwater contamination is approximately 250 ft south of the landfill (Figure ES-1). This mass, referred to as the southern area of contamination at Site 1, is identified as a contaminant slug because there is currently no continuous upgradient contaminant mass to indicate an available constant contaminant source. This southern area of contamination consists of organic petroleum and chlorinated hydrocarbons at ranges of up to approximately 200 µg/L. Because this organic groundwater contamination is not continuous, it is concluded that its source may have been a single or an isolated release event.

RI results also show that manganese forms a contaminant plume in alluvial groundwater within Site 1 at the former Lee Acres Landfill (Figure ES-1). Upgradient background manganese concentrations range up to 423 µg/L, which is approximately twice the New Mexico human health standard of 200 µg/L. Within and south of the landfill is an elevated plume of manganese. Well BLM-57 is within the area of the former northern liquid waste lagoon. At well BLM-57, an average manganese concentration of 7,905 µg/L indicates that past liquid waste lagoon operations have introduced manganese into the alluvial aquifer. This manganese plume decreases in concentration to the south at wells BLM-78, BLM-67, and BLM-68, where the manganese plume is generally measured at or below the upgradient background concentration range (Figure ES-1).

The Site 1 manganese plume is attributed to past disposal of liquid petroleum byproduct (brine waters) in the former liquid waste lagoons. It is a continuous plume; concentrations are measured highest near the former liquid waste lagoon source area and decrease southward. The manganese source was most likely added to the lagoons for an extended period during the liquid waste lagoon operations. Boyer (1986) documents the existence of elevated levels of manganese in petroleum brine waters up to 2,800 µg/L. Groundwater modeling results and groundwater quality data show that the Site 1 manganese contamination has migrated from the former lagoons to its existing location.

Organic contamination measured at the Site 1 southern area is centered around Giant-Bloomfield Refinery (GBR) wells GBR-32, GBR-48, and GBR-49 (Figure ES-1). At these wells, measured 1,2-dichloroethene concentrations range from 1.2 to 200 µg/L. Adjacent BLM wells installed during the RI show comparatively lower levels ranging up to 16 µg/L at well BLM-74. RI data show that this mass of contamination is disconnected from the former landfill. Well clusters located at the southern perimeter of the former landfill and between the former liquid waste lagoons and the Site 1 southern area are free of organic contamination. The lack of a continuous plume indicates that there is currently no active migration of organic contaminants from the landfill to the Site 1 southern area (Figure ES-1).

A third important finding of the RI is the presence of two masses of groundwater contamination at the former Giant-Bloomfield Refinery (Site 2). One contaminant mass is a gasoline plume containing free-floating product located approximately 1,000 ft south of well BLM-68. The other mass is a groundwater plume (diesel fuel components) located more than 3,000 ft south of the landfill, with free-floating product at the southern part of the Giant-Bloomfield Refinery property. This plume extends south across U.S. 64 into the subdivisions and is being investigated and remediated by Giant Industries, Inc., under the regulatory guidance of the New Mexico Oil Conservation Division; it contains both petroleum and chlorinated hydrocarbons. RI results indicate that these Site 2 contaminant masses are derived from a source or sources separate and unrelated to the former Lee Acres Landfill.

Groundwater modeling results show that approximately 22 years would be required for the leading plume edge of the organic plume to migrate from the former landfill liquid waste lagoons to the area just south of U.S. 64. In 1969, liquid waste lagoons were not in existence at the landfill, and solid waste disposal was not in an active phase until approximately 1975. Liquid waste lagoons came into existence in 1979 and were active until 1985. The RI report documents the past existence of a number of local Site 2 contaminant sources within the former Giant-Bloomfield Refinery, such as tanks and storage facilities, that contained both petroleum and chlorinated hydrocarbons. Also, it is shown that Site 2 contamination found in wells

BLM-65 and BLM-66 may be derived from former production well sites on adjacent San Juan County Fairground property. This possibility is supported by the fact that manganese concentrations measured in these wells are elevated, and range up to 3,400 μg/L.

The magnitude of Site 2 groundwater contamination indicates that it is unrelated to the landfill. Site 2 contamination is generally 1 or 2 orders of magnitude higher in concentration than that in Site 1. Additionally, no northward and increasing concentration gradient is present in Site 2 groundwater that would indicate that Site 2 contamination is derived from the former landfill. Additionally, Site 2 wells show floating petroleum product on the water table. In summary, there is no evidence that a highly contaminated mass left the former landfill and spread south of U.S. 64, more than 3,600 ft downgradient, at current Site 2 plume locations. For this reason, any risk or hazard associated with Site 2 contamination is not estimated or considered further as part of the risk assessment or FS process.

This report presents a conceptual site model identifying two potential contaminant migration pathways. These are (1) any future leaching of contaminants from the former landfill to the alluvial aquifer and (2) ingestion, inhalation, or dermal contact with Site 1 groundwater. Ingestion of contaminated soils within the landfill is rejected as a potential pathway because public access is secure and waste cells at the landfill have been covered with 2 to 10 ft of native material. The surface water pathway is identified as a dormant pathway because landfill contents would not be in physical contact with any surface water drainage in the unnamed arroyo, and the landfill is protected from significant flood events by gabion walls. The air pathway is rejected as an active pathway because results of the RI air monitoring program show no contaminant vapors being released from the former landfill.

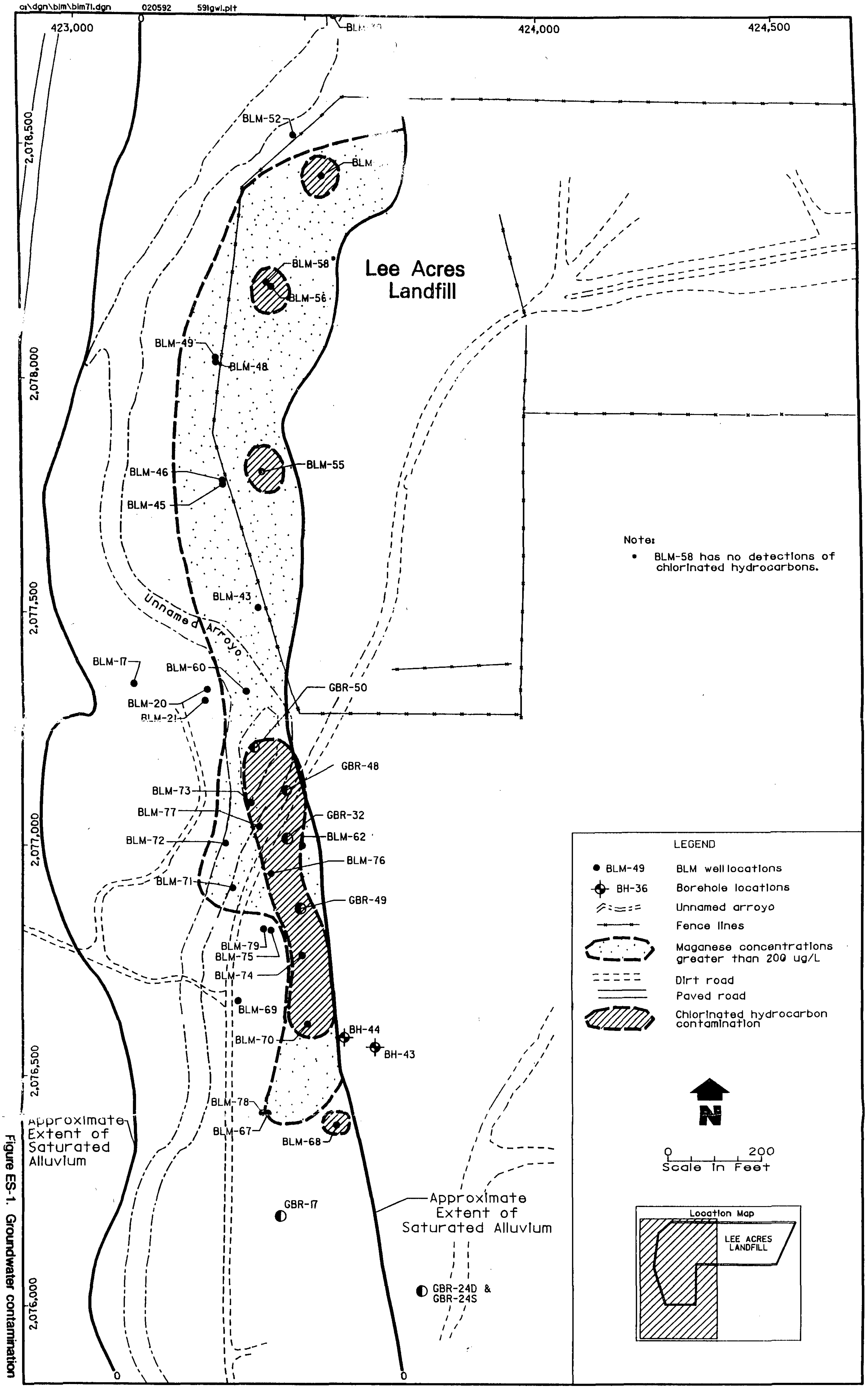
Between 1979 and 1985, the former liquid waste lagoons were active. During this period, lagoons provided the moisture and the release mechanism required to induce the leaching of landfill contaminants to groundwater. In 1985, the lagoons were evaporated, treated with ferric chloride, and filled with native material. A simulation of the landfill leaching process resulted in the lack of any apparent effect on the quality of the alluvial aquifer because of the current lack of any available moisture to drive a downward leaching process. Although leaching of contaminants from the former landfill to groundwater through the vadose zone is not an active process and is not expected to be, this pathway is not eliminated from further consideration. Any future addition of moisture to the landfill may provide a flow mechanism that will reactivate the leaching pathway. Consequently, the leaching pathway is retained as a potential pathway. Elimination of any future potential risk posed by contaminant leaching to groundwater is identified as a primary remedial objective and is identified as Operable Unit (OU) 1. As presented above, RI data show that there is currently no migration of organic contaminants from the landfill to the Site 1 southern area.

The second potential pathway, Site 1 groundwater, is identified as OU 2. OU 2 is defined as the alluvial aquifer groundwater contamination beneath and immediately south of the former Lee Acres Landfill.

A baseline risk assessment was completed as part of the RI. Maximum and average risk estimates indicate that ingestion, inhalation, and dermal contact with Site 1 groundwater exceed acceptable risk. Maximum risk to a hypothetical future resident who is assumed to use Site 1 groundwater for domestic supply exceeds a 1-in-1,000 carcinogenic risk; average carcinogenic risk exceeds a 1-in-10,000 risk. There is currently no actual risk for this pathway because no residents are living in proximity to Site 1 who would use Site 1 groundwater for any purpose. However, reduction of the risk posed by the Site 1 groundwater pathway is accepted as a primary remedial objective because in the absence of remedial action the potential exists that Site 1 contamination may mix with Site 2 contamination in the future.

The Lee Acres Landfill FS consists of three phases to allow integration of results from interim data collection activities during the FS process. After an initial screening for technical feasibility and implementability, remedial alternatives will be retained for OU 1 and OU 2. These retained alternatives will provide a combination of process options and technology types for each OU that includes institutional actions, containment, treatment, collection, and disposal actions. A detailed analysis of alternatives will be completed for these alternatives as part of Phase III of the FS.

In summary, the only active pathway that can be attributed to past Lee Acres Landfill disposal practices is the migration of manganese from former liquid waste lagoons to the Site 1 southern area of groundwater contamination located south of the southern landfill property boundary. Within the Site 1 southern area of contamination, organic compounds occur in the groundwater at levels which exceed the Safe Drinking Water Act maximum contaminant levels. However, no active source for this contamination has been identified. This contaminant migration pathway is off BLM property and exceeds acceptable risk, and contaminant levels currently exceed federal Safe Drinking Water Act maximum contaminant levels or New Mexico human health standards. Site 1 groundwater contamination poses no immediate threat to human health and the environment. However, it is recommended that the FS and remediation be established according to a rigorous schedule to minimize any further migration of Site 1 contaminants.



Note:
- BLM-58 has no detections of chlorinated hydrocarbons.

Figure ES-1. Groundwater contamination in the Site 1 alluvial aquifer.

1. LEE ACRES LANDFILL RI/FS PROGRAM

1.1. GENERAL INFORMATION

1.1.1. Program Description

In September 1988, the Bureau of Land Management (BLM) contracted with Roy F. Weston, Inc. (WESTON) to complete a remedial investigation (RI) and feasibility study (FS) for the former Lee Acres Landfill near Farmington, New Mexico (Figure 1-1). The RI/FS is being conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), and with various documents containing U.S. Environmental Protection Agency (EPA) guidance. The general purpose of the Lee Acres RI/FS program is to evaluate, select, and plan a remedy or remedies in compliance with CERCLA/SARA to reduce risks associated with contamination resulting from activities at the former Lee Acres Landfill to acceptable levels.

On August 30, 1990, the EPA added the former Lee Acres Landfill to the National Priorities List (NPL). Although the RI/FS program was started prior to being listed on the NPL, the BLM chose to conduct this RI/FS in a manner that will satisfy all technical, administrative, and regulatory requirements for an NPL-listed site.

The following is a list of the primary guidance documents used to design and implement the RI/FS activities within the Lee Acres Landfill Study Area:

- The National Oil and Hazardous Substances Pollution Contingency Plan (NCP), Final Rule, 55 FR 8666, 8 March 1990.
- Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final, OSWER Dir. No. 9355.3-01, October 1988 (EPA 1988a).
- Interim Guidance on Superfund Selection of Remedy, OSWER Dir. No. 9355.0-19, December 1986 (EPA 1986a).
- Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites, OSWER Dir. No. 9283.1-2, December 1988 (EPA 1988b).
- Remedial Investigation/Feasibility Study Improvements and Follow-up, OSWER Dir. No. 9355.3-05, February 1989 (EPA 1989a).

The Lee Acres Landfill RI/FS is being conducted in phases designed to follow the process that the Superfund program has established for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites and for evaluating potential remedial options. The RI activities are designed to define the nature and extent of sources and contamination through field sampling and laboratory analysis.

This characterization program was implemented according to data quality objectives (DQOs) summarized in this RI Report (RIR) and defined in the Data Quality Objectives/Applicable or Relevant and Appropriate Requirements Working Paper (WESTON 1989a). This process does not attempt to achieve the goal of removing all technical uncertainty associated with the final selection of the remedial alternative. It is designed to gather sufficient information to make an informed risk management decision for remedy selection.

The Lee Acres Landfill Study Area is classified geographically into two sites and three study subareas (Plate 1). The two sites are (1) the 60-acre former Lee Acres Landfill and contamination migrating from the former landfill and (2) all property within the study area south of the former landfill and south of monitoring well BLM-68 to the San Juan River, including the former Giant-Bloomfield Refinery. Each of the four study subareas represents a distinct geographic region, as detailed below:

- Site 1, subarea 1: Defined as the area north of the northern Lee Acres Landfill property boundary. Results of groundwater sampling events and other activities in this subarea are considered background data.
- Site 1, subarea 2: Defined as the area of the former Lee Acres Landfill and the area west of the landfill to Crouch Mesa Road. This subarea contains the well network within the former landfill and wells in the unnamed arroyo adjacent to and west of the landfill.
- Site 1, subarea 3: Defined as the area south of the landfill property boundary and north of Giant-Bloomfield Refinery (GBR) monitoring well GBR-17. This subarea contains the downgradient well network west of the former fire water storage ponds, and north of the former Giant-Bloomfield Refinery, located north of and adjacent to U.S. 64.
- Site 2: Defined as the area south of and including well GBR-17 to the southern study area boundary at the San Juan River. The former Giant-Bloomfield Refinery and the Lee Acres Subdivision are the primary features of this subarea.

These study subareas are shown on Plate 1 and referred to frequently in this RIR to allow general comparison of data sets, and to simplify references to study area wells, boreholes, or other sampling points or features.

The RI field program involved a daily evaluation of current data to identify data gaps and implement subsequent data collection activities to fill them. The data collection program was adjusted to place wells, soil borings, and other sampling stations in locations considered most likely to measure contamination and provide important information regarding any migration of contamination from the landfill.

A Record of Decision (ROD) will be prepared to certify that the remedy selection process was carried out in accordance with CERCLA and to provide the public with a consolidated source containing information about the site, technical details about the chosen remedy, and the rationale for selection of the chosen remedy. Prior to the ROD being issued, the BLM will implement a program to satisfy public participation requirements specified in Section 117 of CERCLA. This process will provide the public with reasonable opportunity to make relevant comments regarding the proposed remedial action through the issuing of the Proposed Plan for Public Comment. Additionally, project documents will be made available for public review in the form of an Administrative Record. The BLM will include public comments in the Administrative Record file. A more detailed description of the Lee Acres Landfill community relations program is presented in subsection 1.3 of this RIR and in the Community Relations Plan (WESTON 1989b).

1.1.2. Program Schedule

The Lee Acres Landfill RI/FS program schedule is presented in the form of a Gantt chart that shows anticipated start and stop dates for major program milestones (Figure 1-2). A detailed schedule of all activities was presented in the Data Management/Project Management Plan (WESTON 1990a). However, there have been changes to this schedule since the Data Management/Project Management Plan was issued. These changes to the schedule are reflected on Figure 1-2. RI activities were performed from May 1989 through July 1991. This work period includes a temporary stop work order that delayed field activities from May to November 1989. Initial RI activities were completed in May 1990. Additional data collection activities were performed from April 1991 through July 1991.

1.1.3. Program Documents

Previously issued documents represent important components of the CERCLA RI/FS process and the Lee Acres Landfill RI/FS program. These reports and plans are listed and described below.

The Lee Acres Landfill RI/FS program initially included a requirement for an environmental impact statement (EIS). However, due to the opinion recently issued by the Department of Justice that an EIS is not required, the EIS has been dropped from Lee Acres Landfill RI/FS program. However, a majority of program documents were published in anticipation of an EIS and therefore have EIS in their titles.

- Quality Assurance/Quality Control Work Plan for the Lee Acres Landfill RI/FS/EIS (WESTON 1989c): This plan contains all elements required by CERCLA to define sampling procedures, sample custody, the quality assurance sampling and analytical program, internal quality control, and performance audits.

- Scoping Report for the Lee Acres Landfill RI/FS/EIS (WESTON 1989d): The Scoping Report presents a summary of the site history and conditions, initiates the community relations program, presents public comments and responses to initial public RI scoping meetings, and plans subsequent project phases.

- Data Quality Objectives/Applicable or Relevant and Appropriate Requirements Working Paper for the Lee Acres Landfill RI/FS/EIS (WESTON 1989a): This report presents data quality objectives and preliminary identification of applicable or relevant and appropriate requirements (ARARs) for the RI and FS.

- Preliminary Investigation Report, Lee Acres Landfill, Farmington, New Mexico (WESTON 1989e): This report presents the results of the preliminary investigation conducted from September 1987 to September 1988. The investigation includes installation and sampling of 19 groundwater monitoring wells at the study area.

- Community Relations Plan for the Lee Acres Landfill RI/FS/EIS (WESTON 1989b): Key issues, past involvement, community concerns, key persons, and the timing of public involvement are presented in a detailed description of the planned community relations program.

- Background Report for the Lee Acres Landfill RI/FS/EIS (WESTON 1990k): This report summarizes landfill history and all existing studies and data used as part of the scoping process and as the basis for the design of the RI.

- Environmental Impact Statement Work Plan for the Lee Acres Landfill RI/FS/EIS (WESTON 1990b): The EIS Work Plan presents National Environmental Policy Act requirements and plans activities leading to the completion of the draft EIS.

- Health and Safety Plan for the Lee Acres Landfill RI/FS/EIS (WESTON 1990c): Safety procedures for all RI activities are presented to satisfy all CERCLA and Occupational Safety and Health Administration (OSHA) requirements. Levels of protection, responsible personnel, upgrade procedures, and required personal protective equipment are included.

- Sampling and Analysis Project Plan (SAPP) for the Lee Acres Landfill RI/FS/EIS (WESTON 1990d): This plan presents the rationale, approach, technical details, and procedures for all activities that comprise the RI. A description of the standard operating procedures (SOPs) used for these activities are presented in Appendix A. A preliminary baseline risk assessment and a presentation of general response actions, technologies, and process options are also included in this plan.

- Data Management/Project Management Plan for the Lee Acres Landfill RI/FS/EIS (WESTON 1990a): This plan presents the procedures for project documentation and information flow including field records, chain of custody, the technical database system, and the project document control system. Reporting requirements for the analytical program and health and safety program are included.

- Remedial Investigation Briefing Document for the Lee Acres Landfill (WESTON 1991): This briefing document summarizes RI results completed through December 1990. Examination of RI data collected revealed insufficient information to adequately characterize and explain contamination directly south of the landfill. Additional data collection activities designed to address the data gaps are outlined.

- Lee Acres Landfill Erosion Protection, Final Summary Report (WESTON 1990h): This report presents the final as-built drawings and details of the construction of gabion walls along the northwestern and southwestern corners of the former Lee Acres Landfill.

- The Scoping Report for the Lee Acres Landfill EIS Scoping Meeting (WESTON 1990e): This report summarizes and analyzes the issues and concerns expressed by the citizens attending the EIS scoping meeting.

- Potentially Responsible Parties (PRPs) Search and Source Identification Plan for the Lee Acres Landfill RI/FS/EIS (WESTON 1989f). This plan details the activities to search for and identify PRPs and sources for the surface and subsurface contamination within the Lee Acres Landfill Study Area May 1989.

- Potentially Responsible Parties Search and Source Identification Baseline Report for the Lee Acres Landfill RI/FS/EIS (WESTON 1990j). This report provides a summary of procedures used, and the information obtained from the baseline search activities for identifying PRPs for surface and subsurface contamination at the Lee Acres Landfill Study Area.

These documents are referenced in or tiered to this RIR and are considered to be important components of all Lee Acres Landfill RI/FS program phases. Consequently, a complete understanding of the technical approach and results presented in this RIR requires a certain level of familiarity with each of these reports or plans. The reports and plans may be reviewed at public information repositories established as part of the community relations program (see subsection 1.3 for list).

1.1.4. RI/FS Goals

The primary goals of the Lee Acres Landfill RI/FS program are to determine the extent and magnitude of contamination at the former Lee Acres Landfill and any contamination from the landfill and select a preferred remedial action that will eliminate or significantly reduce any threat to human health and the environment. The objective of the RI/FS process is to gather information sufficient to support an informed risk management decision leading to the selection of a remedy.

The RI serves as the mechanism for collecting data to characterize site conditions, to determine the chemical and physical nature of the landfill waste, to define pathways and rates of migration, and to assess risk to human health and the environment. If necessary, it also serves as the mechanism for conducting treatability testing to evaluate the potential performance and cost of treatment technologies being considered. All these activities support the selection and design of a preferred remedial action. The FS serves as the mechanism for the development, screening, and detailed analysis of alternative remedial actions.

In accordance with SARA, an emphasis will be placed on remedial actions that

- protect human health and the environment,
- meet ARARs (or provide grounds for obtaining a waiver),
- are cost effective,
- use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent possible, and

- significantly reduce the toxicity, mobility, or volume of waste.

In addition to the goals listed above, specific technical data requirements have been established for the RI. These data requirements are as follows:

- determine the horizontal and vertical extent of contamination within the former landfill,
- estimate the volume and boundaries of waste contained in the former landfill,
- determine the chemical and physical characteristics of waste in the former landfill,
- determine the pathways of migration and rates of movement, and
- determine if contamination is migrating from the former landfill and, if so, delineate downgradient contaminant mass.

All the activities described above are being conducted according to the NCP and CERCLA/SARA. The community relations program is designed to satisfy Section 117 of CERCLA and to provide the public with reasonable opportunity to comment on a proposed plan for remedial action and its impacts. Subsection 1.3 summarizes past and future community relations activities for the Lee Acres Landfill RI/FS program.

1.1.5. Purpose of the RI Report

This RIR follows the completion of the Lee Acres Landfill RI. The general purpose of this RIR is to report and describe results that satisfy the technical data requirements listed in subsection 1.1.4. Listed below are the primary purposes of this document. Report sections where these items are addressed are shown in parentheses.

- Provide a comprehensive summary of all previous studies and data collection activities (subsection 1.2).
- Present the technical rationale and location for each RI data collection activity (Section 2).
- Present results and interpretation of RI data collection activities (Sections 3, 4, 5, and 6).
- Provide an estimate of the vertical and horizontal extent of waste at the former Lee Acres Landfill (Section 5).
- Present a characterization of the physical and chemical nature of contamination in the former Lee Acres Landfill (Section 5).
- Define active contaminant migration pathways and the extent of contamination measured in each pathway (Section 8).
- Provide a characterization of background water quality (Section 6).

- Define the vertical and horizontal extent of any groundwater contamination migrating from the former Lee Acres Landfill (Section 6).
- Present an overall picture of how the site operates in the form of a site conceptual model that is represented by data collected during the RI (Section 9).
- Present results of a baseline risk assessment for selected pathways that evaluate the risk to human health and the environment in the absence of remedial action (Section 10).
- Identify any data gaps (Section 11).
- Provide a summary of future Lee Acres Landfill RI/FS program activities and planned milestones (Section 11).

This RIR is preceded by the SAPP (WESTON 1990d), issued in March 1990, and was reviewed and approved by the BLM and the New Mexico Environment Department (NMED) (formerly New Mexico Environmental Improvement Division [NMEID]). The next planned major project deliverable is the Phase I/II FS Working Paper, which will present the results of the development and screening of remedial alternatives for the contamination at the former Lee Acres Landfill. The Phase I/II FS Working Paper will be published concurrently with this RIR. This RIR may be modified or supplemented if treatability testing or further data collection is considered necessary to complete a detailed analysis of possible remedial alternatives. Subsection 1.9 summarizes the RIR format.

1.2. SITE BACKGROUND

1.2.1. Site Description

The former Lee Acres Landfill is approximately 4.5 miles east of the city of Farmington, in Section 22, Township 29 North, Range 12 West (T29 N, R12 W) of San Juan County, New Mexico (Figure 1-1) (USGS 1979a). The study area consists of approximately 611 acres. It includes the former Giant-Bloomfield Refinery and four residential subdivisions (F. L. Lee, Lee Acres No. 1, Lee Acres No. 2, and Suburban Heights; all located south of the landfill property). U.S. 64 (Bloomfield Highway), located south of the former Giant-Bloomfield Refinery, divides the study area and provides access to the study area from the cities of Farmington and Bloomfield (Plate 1).

The former landfill is located in the eastern portion of San Juan County, which consists of a dissected high plateau within the Navajo section of the Colorado Plateau. This high plateau is dissected by the San Juan and Animas Rivers. These rivers originate in the San Juan Mountains of southern Colorado, merge near Farmington, and flow west to the Colorado River. The former landfill is located on the southern drainage basin of the interfluvial ridge between the two rivers, just east of the intersection of Gallegos Canyon and the San Juan River. Surficial waters from the study area drain toward and through an unnamed arroyo system that joins the San Juan River south of the Lee Acres subdivisions.

The elevation within the study area ranges from 5,340 ft to 5,500 ft above mean sea level. The site and vicinity are characterized by nearly level to gently sloping terrain, consisting of shallow, well-drained soils formed by alluvial and eolian deposits.

The former Lee Acres Landfill overlies alluvial deposits and bedrock formations. The alluvial deposits consist of sand, gravel, and cobbles. The bedrock Nacimiento Formation underlies the alluvium and can be traced almost continuously from the Animas Valley south across the San Juan River, then southeast and east to the point of Cuba Mesa. The bedrock Ojo Alamo Formation underlies the Nacimiento Formation and outcrops to the west of the study area.

1.2.2. Site History

1.2.2.1. Physical Appearance

For the Lee Acres Landfill RI/FS project, an area larger than the former landfill itself was defined for all RI field and data collection activities. The evolution of the Lee Acres Landfill Study Area from approximately 3,000 acres to its current size of approximately 611 acres is presented in Appendix B. Plate 1 shows the current study area based on the RI activities.

As part of the RI data collection activities, air photos for the study area were acquired and reviewed. The air photo study presents the history of the study area through the identification of industrial activities through time, potential contaminant releases, physical changes within the study area, and changes in the former Lee Acres Landfill and its operation. The history of the study area through the air photos is presented in detail in Appendix B. However, the major activities that occurred within the Lee Acres Landfill Study Area are summarized below.

The major surface activities within the Lee Acres Landfill Study Area occurred during the 1970s. The area between U.S. 64 and the San Juan River developed from an agricultural area during the 1950s to a residential and commercial area in the early 1960s. However, the most activity occurred at the Giant-Bloomfield Refinery. The refinery was fully developed by 1975, although it did not reach its maximum size until 1981 when the number of tanks had increased and the fire water ponds were in existence. Pits, trenches, and excavated areas on refinery property were identified from the air photos.

The air photo study also attempted to identify potential releases into the environment, including soil discoloration and vegetation stress. The major location of apparent surface staining was at the Giant-

Bloomfield Refinery. From 1975 through 1980 air photos, numerous potential stained areas were identified around refinery tanks, along refinery roads, and in the area between U.S. 64 and the main refinery processing facility. In addition, liquid was apparent in containment areas around two tanks from 1981 to 1986. One other area with apparent staining is at the El Paso Natural Gas substation located north of the Lee Acres Landfill. Stains appeared at the El Paso Natural Gas substation in air photos from 1950 through 1986.

An additional objective of the air photo study was to identify changes in the unnamed arroyo. Only the major and most obvious changes in the arroyo were identified. These changes included the alteration of an island north and west of the former landfill by water erosion, rerouting of the arroyo due to a new road to the landfill, and rerouting due to the addition of fill material at the northwestern corner of the landfill.

The air photo study also documented the operational history of the former Lee Acres Landfill through the identification of pit and trenching operations during three time periods: 1964 to 1974, 1975 to 1980, and 1981 to 1986. Figures 1-3, 1-4, and 1-5 illustrate the major waste disposal areas thought to be present at the former Lee Acres Landfill during these periods. Due to constraints involved in transferring the information from the various photographic scales to the figures, the locations of the pits and trenches are approximate. Appendix B presents in detail the Lee Acres Landfill operation history, including the history of the former solid waste disposal areas, the former liquid waste lagoons, and the liquid waste lagoon breach. The operational history descriptions are summarized below and incorporate information gained from the air photo study and reports from inspections of the Lee Acres Landfill by the BLM and the NMEID.

1.2.2.2. Operational History

In May 1962, San Juan County leased 20 acres (W1/2 NW1/4 SW1/4 section of section 22, T29 N, R12 W) from the BLM for a county landfill called Lee Acres Landfill (BLM 1962). By 1980, the activities at the landfill had increased and San Juan County required additional land for the landfill and leased an adjacent 40 acres of land (S1/2 SW1/4 NW1/4; NW1/4 NE1/4 SW1/4; and NE1/4 NW1/4 SW1/4 sections of section 22, T29 N, R12 W) (BLM 1981).

Two types of waste disposal areas were present at the landfill: solid waste disposal areas and liquid waste lagoons. Tables 1-1 and 1-2 present the chronology of events pertaining to the history of the former solid waste disposal areas and the former liquid waste lagoons, respectively. Activity in the landfill was minimal during the 1960s. However, by the early 1970s, approximately 4 acres in the center part of the landfill were in use (Table 1-1). Approximately 14 trenches and one dead animal pit existed at various times from 1964 to 1974 (Figure 1-3).

Between 1975 and 1980, activities at the landfill increased and the areal extent of the landfill expanded to approximately 20 acres (Table 1-1, Figure 1-4). A series of trenches along the landfill edges and berming activities along the northern and western edges also appeared during this time, as shown in Figure 1-4. The exact number of pits and trenches is unknown.

From 1981 through 1986, the disposal activities increased at the Lee Acres Landfill. In 1981, San Juan County leased additional land adjacent to the landfill (BLM 1981). Unlike the previous lease, the 1981 lease required a development and operation plan for the landfill. Details of the plan requirements are provided in Appendix B. With the acquisition of additional land, the Lee Acres Landfill expanded to approximately 30 acres. Figure 1-5 shows several large east-west trenches and other trenching activities along the northern, eastern, and southern fence lines.

From 1981 through 1986, liquid waste disposal was being conducted at the Lee Acres Landfill, as both the air photos (Figure 1-5) and the inspection reports (Table 1-2) indicate. The exact date liquid disposal began at the Lee Acres Landfill is unknown; however, air photos indicate the first evidence of liquid waste disposal was in 1979. Berms were noted in the 1980 air photos along the western and northern edges of the landfill (Figure 1-5). By 1985, two liquid waste lagoons existed at the landfill: one in the northern portion, and one in the southern portion of the landfill (Figure 1-5). Between these two lagoons, two additional bermed and terraced areas also existed, which may have been either additional lagoon areas or areas created to hold overflow (Figure 1-5). Throughout the early 1980s, several complaints were received and inspections were conducted regarding the liquid waste lagoons; these are summarized in Table 1-2.

On April 18, 1985, the Farmington field office of the NMEID received information that a lagoon at the Lee Acres Landfill had been breached (NMEID 1985a). This incident is described in Appendix B. The incident occurred from April 18 to May 3, 1985. The area was sealed off, the breach was sealed, and sampling activities were performed. Eleven people were treated for nausea, vomiting, and dizziness, symptoms of hydrogen sulfide poisoning (NMEID 1985a). The NMEID, National Guard, State Police, San Juan County and EPA responded to the incident. After the incident concluded, the NMEID restricted the Lee Acres Landfill to solid waste disposal only, and in April 1986, the BLM suspended the leases for the Lee Acres Landfill (BLM 1986).

As a result of the lagoon breach incident at the Lee Acres Landfill in April 1985, a number of investigations have been conducted for the BLM by private contractors, the NMEID, and other agencies. Table 1-3 presents a list of the eight investigations conducted previous to the RI, the objective of the investigation, and the types of samples collected. During these investigations, information was obtained concerning the contamination at the Lee Acres Landfill, including liquid waste lagoon analyses, groundwater monitoring, and hydrogeologic investigations; this information is summarized in Appendix C. These data collection activities provided preliminary data for developing the RI activities. However, the eight investigations did not provide sufficient information to meet the RI goals and technical data requirements outlined in subsection 1.1.4. Specifically, the investigations did not gather sufficient information to support an informed risk management decision for the selection of a remedial action. The results from these various investigations did, however, initiate the issuance of a consent decree by the NMEID. The BLM responded to the consent decree by immediately supplying bottled water to 12 residents in the Lee Acres Subdivision. In December 1986, an agreement was reached between the BLM and the Lee Acres Water Users Association to permanently connect 14 Lee Acres residents to the community water supply system (WESTON 1989g).

1.3. COMMUNITY RELATIONS

To comply with CERCLA requirements, community relations activities have been conducted according to the Community Relations Plan issued in May 1989 (WESTON 1989b). This plan was prepared to aid the BLM in developing a community relations program tailored to the needs of the community in the Lee Acres Landfill Study Area. The prime focus of the community relations activities is to increase the public's understanding of technical issues and address their comments on and perceptions of the events and risks posed by the former Lee Acres Landfill and the RI/FS project. The opportunities for public comment and involvement are in the form of public meetings, publication of fact sheets, and access to information repositories. In addition, the BLM maintains a mailing list to disseminate information to concerned agencies and individuals, such as local and state government legislators, newspapers, radio stations, and residents.

Community relations activities from October 1988 through March 1990 are described in subsection 1.3.1. Future community relations activities are described in subsection 1.3.2, information repositories in subsection 1.3.3, and the Administrative Record for the RI/FS in subsection 1.3.4.

1.3.1. Past Community Relations Activities

Community relations activities from October 1988 through July 1991 have included public meetings and the publication of fact sheets. Four public meetings were held during this period. Three meetings were held in October and November 1988, prior to the beginning of the project, to provide the public with an overview of the project, increase the understanding of technical issues, and initiate public involvement. They were held in Farmington, Santa Fe, and Albuquerque, New Mexico. A summary and analysis of these meetings is provided in a scoping report (WESTON 1989d).

A fourth public meeting was held in Farmington on February 22, 1990. One purpose of this meeting was to detail the progress being made in the investigation at the former landfill. Another purpose of the meeting was to present the scoping of the EIS that was to have been prepared for the project. Copies of the EIS work plan (WESTON 1990b) were provided to those meeting attendees that requested a copy. A scoping report was also prepared to summarize and analyze the issues and concerns expressed by the citizens at this meeting (WESTON 1990e). The current opinion by the Department of Justice is that an EIS is no longer required and the EIS has been dropped from the program.

In addition to public meetings, fact sheets have been distributed to the residents within the study area. The fact sheet is a newsletter that presents the progress of the project to date. It also reiterates the need for community involvement, and gives the name and address of the BLM public affairs officer, who can be contacted for additional information concerning the project. Four fact sheets were published on the following dates: October 1988, January 1989, February 1990, and April 1991. These four fact sheets are presented in Appendix D.

1.3.2. Future Community Relations Activities

Future activities will be coordinated between the BLM and EPA and will comply with CERCLA Sections 113(k), 117(a), and 121(f). Specifically, CERCLA requires the publication of a notice of any proposed remedial action in a local newspaper of general circulation, a reasonable opportunity for submission of written and oral comments, and an opportunity for a public meeting or hearing at or near the facility (EPA 1988a).

These community relations activities will commence upon the completion of the feasibility study, when the selection of a proposed remedy will be documented in the Proposed Plan. The Proposed Plan will be filed with the EPA and, at the same time, will be made available for comment to the public and to concerned agencies through the information repositories. A notice of the filing of the Proposed Plan will be published in the *Federal Register* and in the local newspaper. After a comment period and the receipt of comments, a public meeting will be held if sufficient interest is demonstrated. Depending upon the degree of concern expressed through the comments, the public meeting may be changed to a public hearing that requires legal notification in the *Federal Register* and will include a legal transcript (CEQ 1986).

Response to the comments on the Proposed Plan will be incorporated in the ROD. The ROD certifies that the remedy selection process was completed in accordance with CERCLA, and provides the public with concise information about the site, technical details about the remedy, and the rationale regarding the selection of the remedy.

1.3.3. Public Information Repositories

As part of the Community Relations Plan and to aid in keeping the public informed, seven publicly accessible information repositories have been established. These repositories, three in Farmington, one in Aztec, two in Santa Fe, and one in Albuquerque, New Mexico, have been established so the public may have access to project documents in order to increase their understanding of the project. Addresses for the seven repositories are provided in Table 1-4. Final versions of project documents will be maintained at each repository. A current list of available project documents is provided in subsection 1.1.3.

1.3.4. Administrative Record

The BLM maintains an Administrative Record for the Lee Acres Landfill RI/FS project in accordance with CERCLA Section 113(k) at the BLM Albuquerque District Office, 435 Montaño Road, N.E., Albuquerque, New Mexico. An Administrative Record serves two purposes. First, the basis for the remedial action selection is set forth in the record, and judicial review of any issue concerning the adequacy of a selection is limited to this record. Secondly, the Administrative Record acts as a vehicle for public participation in the selection of a response action. The Administrative Record for the Lee Acres Landfill RI/FS project is established according to "Interim Guidance on Administrative Records for the Selection of CERCLA Response Actions" (EPA 1989c). The Administrative Record includes documents that were considered or relied on in selecting the response action and documents that show that the public had an opportunity to participate in and comment on the selection of the response action.

1.4. DATA QUALITY OBJECTIVES

DQOs are quantitative and qualitative statements specified to ensure that data of known and appropriate quality are obtained during RI activities to support the selection of a remedial action alternative. DQOs for all phases of the Lee Acres Landfill RI/FS are determined based on the end uses of the data collected. Although the term connotes quality, DQOs also clarify the objectives of the RI. A working paper was published in March 1989 (WESTON 1989a) to develop the DQOs for the general scope of the RI/FS and specifically for the RI. The DQO working paper developed the DQOs for the RI using a three-stage process:

1) Identifying the objectives of the overall RI/FS and each of its components.
2) Identifying the specific uses for which data must be collected and the data quality required for each use.
3) Developing a sampling and analysis plan that will meet the RI/FS objectives in the most efficient and effective manner possible.

Stage 1 of the DQO process identified the key RI/FS decision as remedy selection, and the primary data users as those individuals responsible for and involved in the ongoing RI/FS process, including BLM and WESTON personnel. A conceptual model identifying the source of contamination, the pathways it may take, and the potential receptors of the contamination was developed from available information before the RI began. This model has been refined based on RI data and is presented in Section 9 of this report.

Stage 2 of the DQO process determined that the data collected during the RI/FS will be used for the following:

- waste characterization,
- site characterization,
- development of alternative remedial action technologies,
- development of remedial alternatives,
- screening and evaluation of remedial alternatives,
- risk assessment, and
- remedial design.

The specific data types and quality and quantity needs that were selected to make possible these data uses are presented in the discussion of RI data collection activities (Section 2 of this report). The uses to which the data collected during RI activities will be put make it necessary that the data be of certain levels of quality. To achieve these levels of quality, all data were gathered or developed using appropriate procedures and techniques. To reduce the effects of many factors that critically affect data quality, such as sample variability and the use of different sample collection and analytical preparation techniques, SOPs have been developed (subsection 1.8). The SOPs (WESTON 1988a) include procedures for monitoring well installation, drilling of boreholes, and other field activities, as well as instrument calibration and sampling techniques. The SOPs ensure the level of data quality and maintain known and acceptable levels of precision, accuracy, representativeness, completeness, and comparability for all data sets.

The analytical techniques by which results are obtained must also provide data of sufficient quality. Analytical results are required to confirm and quantify suspected contamination. A screening technique would not provide data of sufficient quality to complete a risk assessment. However, a more rigorous analytical method with a known detection limit and supporting documentation would provide the level of data quality necessary for such an assessment. Therefore, analytical techniques have been divided into five analytical levels, each appropriate to different RI/FS data uses (EPA 1987a). These analytical levels are distinguished by type of technology and documentation, as well as by degree of sophistication, and are defined as follows:

- Level I: Field screening or analysis using portable instruments. Results are often not compound-specific and not quantitative, but they are available in real time.
- Level II: Field analyses using more sophisticated portable analytical instruments or a mobile onsite laboratory.
- Level III: Analyses performed in an offsite analytical laboratory. If the analytical laboratory is a Contract Laboratory Program (CLP) laboratory, CLP procedures may or may not be used. When CLP procedures are used, the data package does not include the extensive documentation required by CLP, but it is available from the laboratory.
- Level IV: CLP routine analytical services. Analyses are performed in an offsite CLP analytical laboratory following CLP procedures, including rigorous quality assurance/quality control protocols. Extensive documentation is provided.
- Level V: Analyses by nonstandard methods. Analyses are performed in an offsite laboratory that may or may not be a CLP laboratory. Method development or method modification may be required for specific constituents or detection limits. CLP special analytical services are Level V (EPA 1987a).

Table 1-5 identifies the data uses that correspond to each analytical level for the Lee Acres Landfill RI/FS. The highest quality of data is required for determining risk to public health and the environment and for engineering design. Several analytical levels are appropriate for each data use, and all levels have been used for this remedial investigation, with Levels IV and V the most applicable.

Stage 3 of the DQO process is the SAPP for the Lee Acres Landfill RI/FS (WESTON 1990d). Results of the data collection program outlined in the SAPP are presented in Sections 2 through 6 of this RIR.

1.5. OPERABLE UNITS

The EPA defines an operable unit (OU) as "portions of an overall response action that by itself eliminates or mitigates a release, a threat of release, or an exposure pathway" (EPA 1988b). Two OUs are defined for the former Lee Acres Landfill (Site 1) that coincide with two types of anticipated response actions. First, it is possible that source control measures will be implemented at the former landfill to eliminate or significantly reduce the impact of future releases of contaminants from the landfill. This anticipated response action defines OU 1 as any selected remedial action or actions implemented as source control measures at the former landfill.

Secondly, it is possible that any contaminated groundwaters in the alluvial aquifer system beneath the former landfill location will require restoration or some other form of remedial action. OU 2 is defined as the response to groundwater contamination in the uppermost alluvial aquifer system beneath and immediately south of the former Lee Acres Landfill that is considered to be directly related to past activities at the landfill. Such a response would be implemented to include the alluvial groundwater in study subareas 2 and 3, from the northern landfill fence line southward to monitoring well BLM-68 (Plate 1).

These two OUs are defined for Site 1, as the Lee Acres Landfill and any contamination migrating from the landfill, on the basis of current and available data collected before and during the RI. OUs for Site 2, the property south of well BLM-68, including the former Giant-Bloomfield Refinery, have not been defined because contamination occurring within Site 2 is not a result of activities at the former Lee Acres Landfill.

1.6. CONTAMINANTS OF CONCERN

A major task of the RI is the identification of contaminants found in soil and groundwater that may have resulted from past disposal activities conducted at the former Lee Acres Landfill. This section presents the strategy and process used to identify contaminants of concern (COCs) within the Lee Acres Landfill Study Area. Figures 1-6 and 1-7 present the process decision trees for identifying COCs in soil and groundwater, respectively. The data collection activities conducted for the RI that identify contamination are presented in Section 2 of this RIR. The integration and analysis of the results from RI data collection activities are presented in Sections 5 and 6. The nature and extent of contamination in the landfill soils and in groundwater are characterized through the review and analysis of laboratory data. The contaminants identified as describing the nature and extent of contamination in soil and groundwater media are defined as COCs and the results of the COC identification process presented in this section are in Sections 5 and 6. The initial list of COCs is then refined to identify those contaminants that pose a risk to human health and the environment. The refinement process of COCs is performed in the baseline risk assessment (Section 10) and is based on comparison with regulatory standards and on carcinogenic and noncarcinogenic toxicity.

The Lee Acres Landfill Study Area is divided geographically into Site 1 (study subareas 1, 2, and 3) and Site 2 (Plate 1). COCs are identified for the three study subareas in Site 1 and for Site 2. The criteria used for identifying COCs are dependent upon the chemical group of the contaminant. Generally in nature, organic compounds are not expected, whereas inorganics such as iron and sulfate are relatively common and abundant in nature. Therefore, two different types of criteria are used for the identification of COCs based on two contaminant groups: inorganic compounds (metals and ions) and organic compounds (volatile and semivolatile organic compounds, pesticides and polychlorinated biphenyls [PCBs]). Subsections 1.6.1 and 1.6.2 describe the criteria used in identifying COCs in soil and in groundwater, respectively.

1.6.1. Identifying COCs in Soil

Soil samples were collected and analyzed from boreholes and monitoring wells. The analytical programs for borehole and wellbore soil samples are presented in subsections 2.4 and 2.7, respectively. Only one soil sample can be collected from any one depth in any one borehole. Therefore, due to the nature of collecting and analyzing soil samples, frequency of detection is not a viable screening criterion for identifying COCs. To identify COCs for soils, concentrations are compared with proposed regulatory standards. Promulgated regulatory standards for soils do not currently exist; however, there are proposed soil action levels from the Corrective Action Rule of the Resource Conservation and Recovery Act (RCRA) (55 FR 30865).

All analytical results reported above laboratory detection limits or identified as present but below the laboratory detection limit are considered. The soil analytical results are first screened to eliminate concentrations considered invalid due to laboratory contamination (Figure 1-6), as described in subsection 2.4.3. In general, organic compounds do not occur naturally in soils. Therefore, any organic compound detected in soil is considered a potential COC. The criterion for identifying COCs in soil is the comparison of concentrations with proposed regulatory standards (Figure 1-6). COCs in soil are identified if their concentrations exceed the proposed soil action level for that contaminant. If no proposed action level exists, then the contaminant is also identified as a COC (Figure 1-6).

Metals analyses for soil samples were performed by Extraction Procedure (EP) Toxicity and by Toxicity Characteristic Leaching Procedure (TCLP) methods (subsections 2.4 and 2.7). Therefore, metals concentrations were compared with TCLP standards. Those metals exceeding the TCLP standard are identified as COCs. Discussions for the landfill source characterization and identification of COCs in soil are presented in Section 5 of this report.

1.6.2. Identifying COCs in Groundwater

The identification of COCs in groundwater is performed for each subarea in Site 1 and for Site 2 (Plate 1). COCs are also separated by the two aquifers that have been identified below the Lee Acres Landfill Study Area: an alluvial aquifer and a bedrock aquifer. Details regarding the hydrogeology of the study area are presented in subsection 4.2 of this report.

Subsection 2.9 describes the groundwater monitoring program implemented for the RI. The RI was conducted in stages with monitoring wells installed and sampled during each stage. The program included a total of 11 sampling events. A preliminary investigation (PI) was also conducted within the Lee Acres Landfill Study Area prior to the RI that included 10 monthly sampling events (Appendix B). Therefore, groundwater analytical results are available for 64 BLM and 5 GBR monitoring wells at a frequency ranging from 3 to 21 sampling events (subsection 2.9). Frequency of detection of a contaminant is the main criterion used in identifying organic COCs for groundwater.

The data reviewed for COCs are groundwater analytical results detected above laboratory detection limits. Concentrations that are identified as present below detection limits are also considered. A preliminary screening to eliminate concentrations considered invalid due to laboratory contamination is performed as described in subsection 2.9.3 (Figure 1-7). The data sets (by aquifer and subarea or site) are then divided according to inorganic and organic compounds. The criteria for identifying inorganic and organic COCs are presented below (Figure 1-7).

1.6.2.1. Inorganic COCs in Groundwater

Because metals and ionic compounds such as sulfate are relatively common in groundwater, the frequency at which they occur does not generally provide information regarding contamination. Therefore, three comparison criteria are used to identify inorganic COCs: comparison of inorganic analytical results to regulatory standards, to regional background concentrations, and to study area background concentrations. The three criteria for identifying inorganic COCs are implemented as described below, following the process shown in Figure 1-7.

Inorganic analytical results for all four study subareas are initially compared with New Mexico human health standards (HHSs) (NMWQCC 1988) and promulgated Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs) (40 CFR 141). However, it is also necessary to compare concentrations to regional background concentration ranges because in some cases the regional background concentrations are higher than the regulatory standards. The aquifers at the Lee Acres Landfill Study Area are high in total dissolved solids (TDS) and generally of poor quality (subsection 6.1). Therefore, exceeding the drinking water regulatory standard alone does not necessarily indicate that the constituent is a COC. The regional background concentration ranges used for inorganics in groundwater are from "Hydrogeology and Water Resources of San Juan Basin, New Mexico" (Stone et al. 1983).

The third comparison is the study area background groundwater results (study subarea 1) to the inorganic groundwater analytical results from the remaining subareas in Site 1 and Site 2. Monitoring wells BLM-14, BLM-15, and BLM-39 (Plate 1) are considered background alluvial aquifer wells because they are located upgradient of the Lee Acres Landfill. Monitoring wells BLM-16 and BLM-40 (Plate 1) are background bedrock wells. Minimum and maximum concentrations for inorganic compounds from these wells are determined to establish a study area background concentration range. Inorganic data from monitoring wells within the other two subareas (2 and 3) and Site 2 are then compared to the background ranges.

Study area background concentrations for inorganics are determined in order to provide information regarding the nature of groundwater before it reaches the Lee Acres Landfill. This strategy allows COCs to be more clearly identified.

The three comparison criteria (to regulatory standards, to regional background, and to study area background concentrations) are implemented almost simultaneously, although Figure 1-7 shows two distinct steps. As stated above, exceeding a regulatory standard alone does not indicate contamination when the regional concentrations for the area also exceed the standard. Also, establishing a study area background concentration provides information on groundwater before it reaches the landfill area. If an inorganic compound exceeds the regulatory standard and the regional background concentrations, it may be within the range for the study area background concentrations.

The results of the COC determination are presented in subsections 6.3, 6.4, and 6.5 of this report. Discussion of background groundwater quality (alluvial and bedrock aquifers) is presented in subsection 6.1.

1.6.2.2. Organic COCs in Groundwater

In general, organics are not naturally found in groundwater; therefore, their presence indicates potential contamination. However, there is the possibility that groundwater samples may become contaminated during sample collection, during laboratory analysis, or from upgradient sources. Therefore, the frequency that a contaminant is present is used as the criterion to identify organic COCs. Frequency is defined as the number of times a contaminant is detected per the total number of samples from each or all wells analyzed for that contaminant.

The frequency criterion for identifying COCs is an elimination-type of screening process. All contaminants detected above the laboratory detection limits or below detection limits are identified for each aquifer and subarea and site. Due to modifications made during the groundwater monitoring program (subsection 2.9), the total number of samples analyzed varies from subarea to subarea, site to site, and contaminant to contaminant. The frequency of detection is then calculated for each contaminant.

Generally, one-time detections are eliminated as COCs (Figure 1-7). The number of sampling events per well ranges from 3 to 21. In most cases when a contaminant was detected once, it was in an early sampling event and the nondetections in later groundwater samples provide confirmation of the absence of the contaminant.

The second elimination step is the review of where detections occurred and their concentration. For example, a contaminant may be detected in 3 of 52 samples, and the occurrence of detection was once in three different wells in the middle of the monitoring program. Because of the one time detection per well, this contaminant may be eliminated from the COCs (Figure 1-7). In addition, concentrations reported as present but below the laboratory detection limit have a degree of uncertainty associated with them as they are only estimated concentrations that are limited by the analytical instrument.

The implementation of the frequency criterion for identifying COCs in groundwater, along with justification of the elimination of a COC, is presented in the groundwater characterization section of this RIR (Section 6). Where frequency is not a strict elimination criterion, an analysis of trends in a well, subarea, site, or region is also discussed in Section 6.

1.7. APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

1.7.1. Preliminary ARARs

The 1990 revision to the NCP requires that CERCLA remedial actions "attain or exceed applicable or relevant and appropriate environmental requirements to the extent practicable" (55 FR 8666, March 1990). EPA guidance that defines the process by which requirements are determined to be either applicable or relevant and appropriate is contained within the "CERCLA Compliance With Other Laws Manual" (EPA 1987b). Section 120 of SARA states that federal facilities shall comply with applicable or relevant and appropriate requirements (ARARs) in the same manner and extent that a nongovernmental entity shall. The Data Quality Objectives/Applicable or Relevant and Appropriate Requirements Working Paper (WESTON 1989a) provides detailed rationales and criteria for the selection of ARARs for the Lee Acres Landfill RI/FS program, and presents a comprehensive list of preliminary ARARs.

To determine if compliance with an ARAR is practicable, the revised NCP specified two factors that determine practicability. The factor of urgency is evaluated to determine whether appropriate remedial activities must be identified and implemented quickly to ensure protection of human health and the environment, without complete attainment of ARARs. No receptors are immediately threatened as a result of the Lee Acres Landfill site and, at this time, urgency is not considered an important factor. Receptors are identified as being affected by groundwater contamination on Giant-Bloomfield Refinery property. However, ARARs are not identified for Site 2.

The second factor is the scope of the remedial action. ARARs may not be attained by certain remedial actions, but the remedial action may minimize and mitigate potential harm rather than totally eliminate it. For both factors, attainment of ARARs "to the extent practicable" requires that protection of human health and the environment be ensured. In selecting remedies, the NCP emphasizes criteria for long-term effectiveness and permanence and for reduction of mobility, toxicity, or volume. The Phase III FS will present the rationale and technical strategy used to identify final ARARs and select a final remedy. If a remedy or remedies are selected that do not attain ARARs, this presentation will include an examination of the factors of urgency and scope to establish that protection of human health and the environment is ensured.

Subsection 1.5 presents the technical and regulatory rationale for defining two OUs within the former Lee Acres Landfill (Site 1). OU 1 is defined as the landfill soils; OU 2 is defined as groundwater beneath and immediately south of the former landfill that is considered contaminated due to past activities at the landfill. The body of data collected during the RI allows selection of preliminary chemical-specific ARARs for groundwater for those contaminants identified as contaminants of concern in Table 1-6. These ARARs are generally considered applicable to OU 2. This section presents an updated revision of chemical-specific ARARs based on results from the RI.

Preliminary location-specific and activity-specific ARARs that may be applied as part of any selected remedial action at the former Lee Acres Landfill are presented in the ARARs Working Paper described above (WESTON 1989a). Location-specific ARARs may restrict certain remedial actions because of where they occur, such as within a floodplain or an archaeological resource area. Activity-specific ARARs are technology- or activity-based requirements that are particular to specific remedial actions. Because a remedy has not been selected, these types of ARARs are not discussed in this RIR, but will be presented as part of the detailed analysis and selection of remedial alternatives during the Phase III FS.

1.7.2. Groundwater Classification

The EPA classifies groundwater according to general use (EPA 1988b). Class I or II groundwater is a current or potential source of drinking water. Groundwater immediately downgradient and adjacent to the former Lee Acres Landfill meets the requirements for Class IIB groundwater, based on current knowledge of groundwater use and site conditions. It is potentially available for drinking water, agricultural, or other beneficial use. It is not irreplaceable; the public water supply is not currently being used for drinking water purposes immediately south of the former landfill. It is also not considered at this time to be ecologically vital because it does not supply the base flow for a particularly sensitive ecological system that, if polluted, would destroy a unique habitat. This classification may be upgraded in the future to represent more knowledge about site conditions as it becomes available.

1.7.3. Selection of Preliminary Groundwater ARARs

During the RI, preliminary groundwater ARARs were established that represented current knowledge of site conditions (EPA 1988b). These levels are modified during subsequent phases of the RI/FS process as more information is collected. It is possible that further examination of data may reveal that aggregate affects should be considered, and aggregate risk should be calculated to define final groundwater ARARs. Preliminary ARARs are usually based on available chemical-specific ARARs. Where no promulgated chemical-specific requirements for groundwater exist, an alternative type of requirement is a factor to be considered (TBC). TBCs include nonpromulgated or proposed standards that may be selected as applicable requirements that are relevant and appropriate. Table 1-6 lists federal and state of New Mexico ARARs and TBCs according to each COC. This table also presents selected preliminary groundwater ARARs, and the basis for their selection.

The SDWA MCLs and New Mexico HHS provide a comprehensive set of enforceable standards for groundwater at the Lee Acres Landfill Study Area. Proposed and secondary MCLs are classified as TBCs. Table 1-6 identifies whether each preliminary groundwater ARAR was selected on protection- or promulgation-based criteria. Specific guidelines used for ARAR selection were derived from the "CERCLA Compliance With Other Laws Manual" (EPA 1987b), and are summarized below:

<u>Protection criteria</u>:

- Comparison of stringency for two or more promulgated ARARs resulted in selection of the most stringent requirement.
- Comparison of both ARARs and TBCs resulted in selection of the most stringent promulgated requirement.
- Availability of a single TBC resulted in the selection of that TBC as the protective ARAR.

<u>Promulgated criteria</u>:

- Comparison of promulgated relevant and appropriate New Mexico HHSs and federal TBCs resulted in the selection of the state-promulgated HHSs.
- Comparison of a single federal relevant and appropriate requirement and TBCs resulted in the selection of the federal promulgated relevant and appropriate requirement.
- Availability of a single promulgated relevant and appropriate requirement resulted in the selection of that requirement as the protective ARAR.

Final ARARs will be presented as part of the Phase III FS and will reflect factors related to exposure, uncertainty, and technical limitations. These factors are as follows:

- technical limitations associated with measurement of contaminant levels in groundwater;
- uncertainty, reliability, and technical limitations of available remedial actions;

- frequency of expected exposure; and
- reliability of exposure data.

Federal SDWA MCLs and New Mexico HHSs are considered to provide a level of protection associated with an acceptable risk to human health and the environment. Preliminary groundwater ARARs presented in this RI report provide a basis for developing final cleanup levels for each identified contaminant of concern for OU 2.

1.7.4. Contaminated Waste and Soil ARARs

There are no promulgated chemical-specific ARARs for contaminated wastes or soils that may be applied at the former Lee Acres Landfill. Therefore, soil ARARs for OU 1 will be determined according to a calculated risk of danger to groundwater, or established according to recent proposed RCRA corrective action level standards, or other standards to be considered. Table 1-7 provides proposed RCRA soil action levels for COCs listed for OU 1 that are identified in Section 5 of this RIR. RCRA TCLP soil contaminant levels were promulgated by EPA in March 1990 (55 FR 11798). These levels were established to assess whether or not contaminated soils are subject to RCRA Land Ban treatment requirements, and may be used as a soil ARAR for the former Lee Acres Landfill. Final soil cleanup standards that will be used as part of a selected remedial action will be presented as part of the Phase III FS.

1.8. STANDARD OPERATING PROCEDURES

The Lee Acres Landfill RI used EPA technical guidelines and American Society for Testing and Materials (ASTM) methodology to perform field activities, sampling, chemical analyses, and data compilation. The most pertinent of these technical procedures have been compiled in WESTON's Southwest Operations SOPs (WESTON 1988a). The SOPs include procedures for field operations; equipment decontamination; sample collection and preservation; handling, shipping and packaging of samples; documentation of field activities; and meeting health and safety requirements.

The SOPs provide field personnel with a list of activities to be performed before, during, and after a field procedure. Included within an SOP are references to any associated SOPs, a checklist of equipment and supplies, and instructions for performing the procedure. Also included are examples of data collection forms to be completed and instructions for completing the forms. Appendix A provides the title and a brief description of all the WESTON Southwest Operations SOPs.

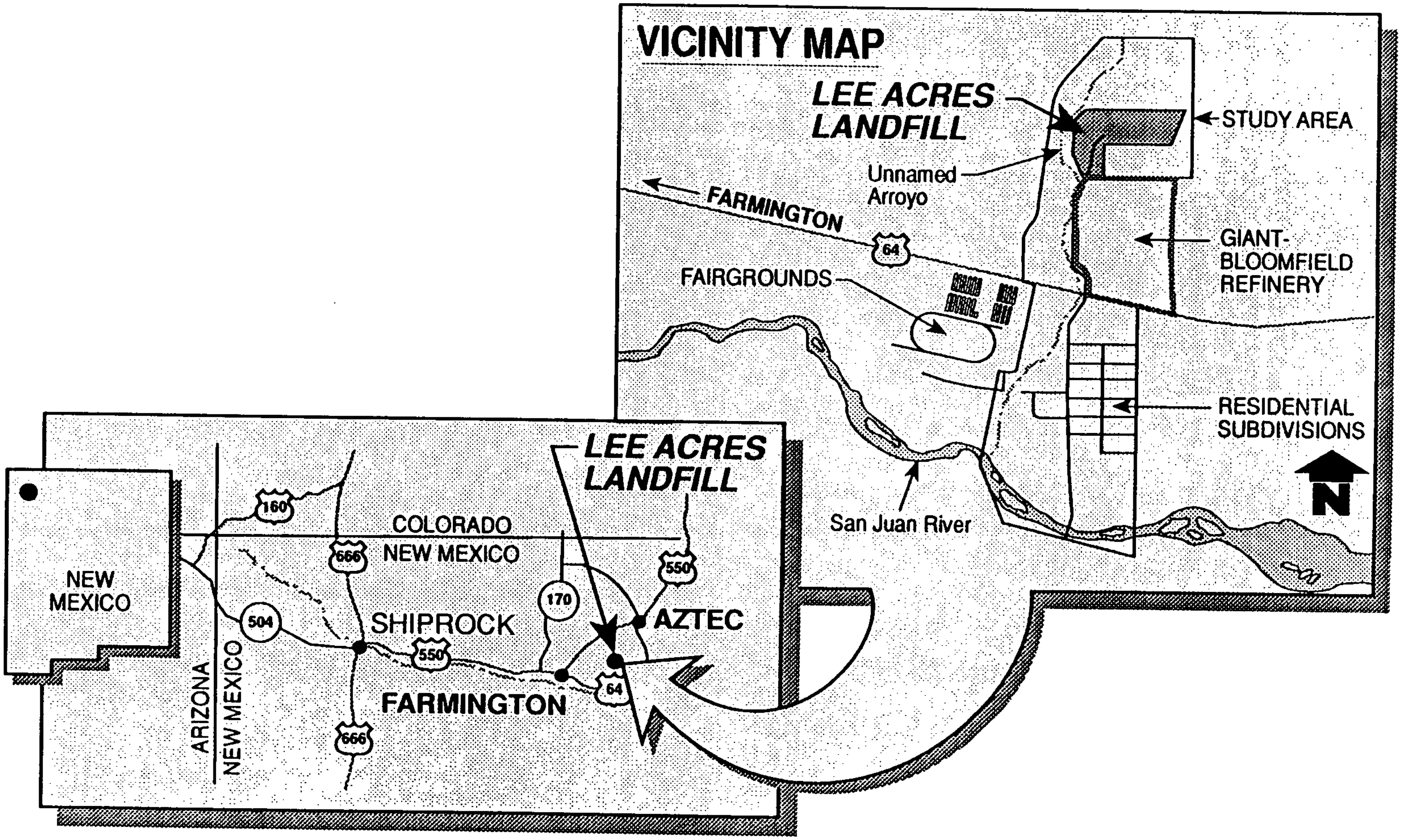
1.9. REPORT ORGANIZATION

EPA format presented in "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988a) was followed as closely as possible in designing the format of this RIR. Presented below is an annotation of the general content of each RIR section..

> Section 1, Lee Acres Landfill RI/FS Program: Lee Acres Landfill RI/FS program description, purpose, goals, and site background. DQOs, ARARs, SOPs, and the community relations program are described to provide important technical, administrative, and institutional information before RI data results and interpretation are presented in subsequent sections.
>
> Section 2, RI Data Collection Activities: The technical rationale and strategy used for the design and implementation of all RI data collection activities is presented. Locations, methods, protocols, and schedules are included with a complete technical description of each data collection activity.
>
> Section 3, Environmental and Ecological Study Activities and Results: This section provides the rationale, technical approach, and results for air quality, ecologic, and archeologic investigations.
>
> Section 4, Geologic and Hydrogeologic Characterization: RI and previous data sets are integrated, compared, and interpreted to present the geologic and hydrogeologic site characteristics.
>
> Section 5, Source Characterization: RI data sets are integrated, compared, and interpreted to present the physical and chemical characteristics of Lee Acres Landfill waste (OU 1) and of Site 1, southern area soils. Estimated former landfill boundaries and volumes are presented.
>
> Section 6, Groundwater Characterization: RI and previous data sets are integrated, compared, and interpreted to describe background groundwater quality and the nature and extent of groundwater contamination beneath the former Lee Acres Landfill and south of the landfill (OU 2) and in Site 2.
>
> Section 7, Contaminant Fate and Transport: This section presents the results of modeling efforts to predict the rate and concentration of selected contaminants in the landfill leaching to the groundwater and to predict the rate and concentration of selected contaminants in groundwater migrating from the former landfill to the San Juan River.
>
> Section 8, Pathway Analysis: An evaluation of all potential contaminant migration pathways and their combinations is presented in an analysis of contaminant fate and transport for the former Lee Acres Landfill. Sources, transport mechanisms, receptors, and operating processes are described, and active pathways are identified that will be quantitatively evaluated in the baseline risk assessment.
>
> Section 9, Site Conceptual Model: A site conceptual model is presented that integrates site characteristics, source characteristics, the nature and extent of contamination, and pathway analysis to present a current picture of how the site operates.

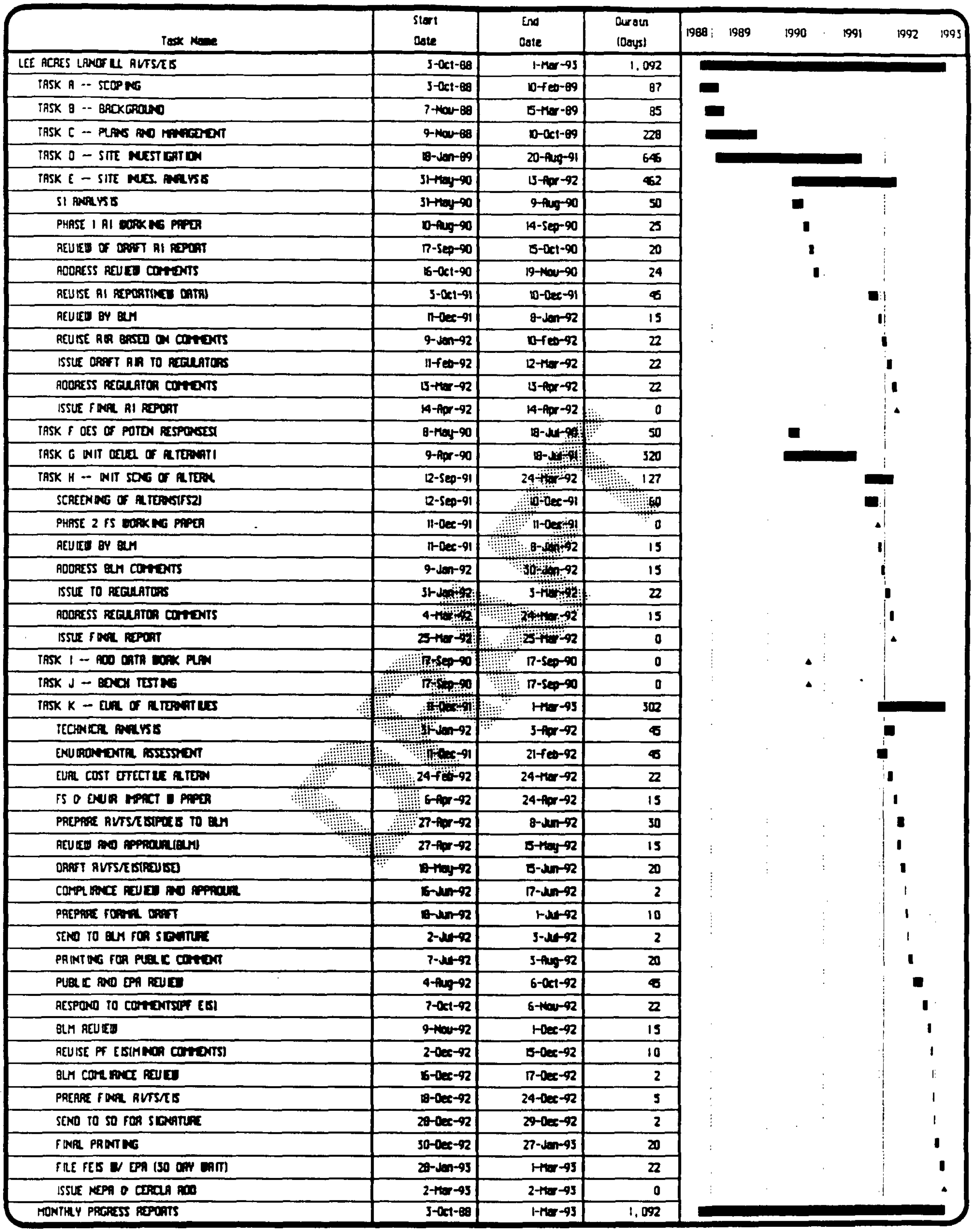
Section 10, Baseline Risk Assessment: An evaluation is presented of the potential threat to human health and the environment for active pathways in the absence of remedial action. Three major components are the exposure assessment, the toxicity assessment, and the risk characterization.

Section 11, Summary and Conclusions: The nature and extent of contamination and potential contaminant migration from the former Lee Acres Landfill are summarized presentations of Sections 5, 6 and 7. The baseline risk assessment is also summarized, and preliminary remedial action alternatives for the FS are recommended.



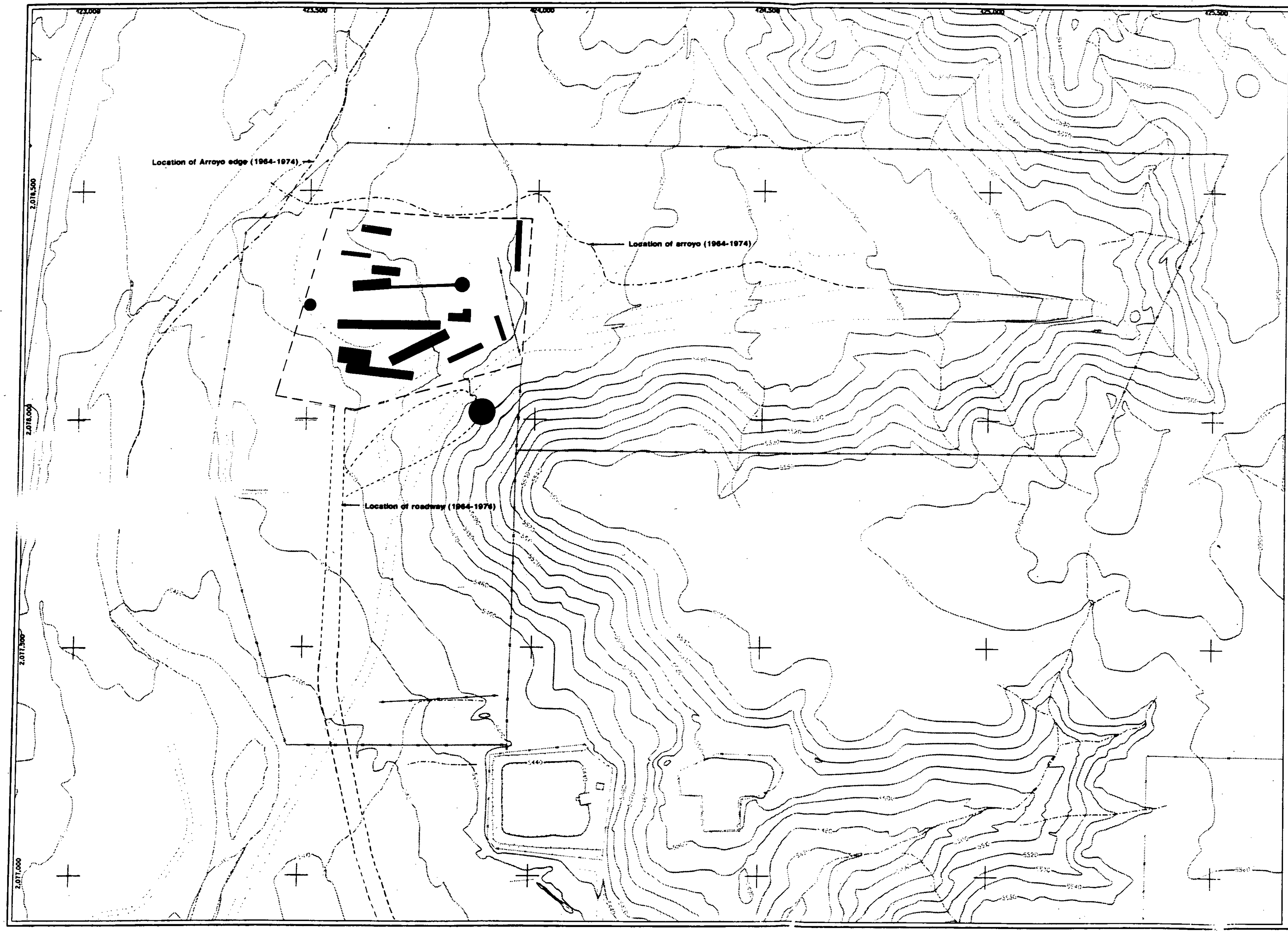
BLM site location map 11-21-91

Figure 1-1. Location of the Lee Acres Landfill Study Area.



Task Name	Start Date	End Date	Duratn (Days)
LEE ACRES LANDFILL RI/FS/EIS	3-Oct-88	1-Mar-93	1,092
TASK A -- SCOPING	3-Oct-88	10-Feb-89	87
TASK B -- BACKGROUND	7-Nov-88	15-Mar-89	85
TASK C -- PLANS AND MANAGEMENT	9-Nov-88	10-Oct-89	228
TASK D -- SITE INVESTIGATION	18-Jan-89	20-Aug-91	646
TASK E -- SITE INVES. ANALYSIS	31-May-90	13-Apr-92	462
SI ANALYSIS	31-May-90	9-Aug-90	50
PHASE I RI WORKING PAPER	10-Aug-90	14-Sep-90	25
REVIEW OF DRAFT RI REPORT	17-Sep-90	15-Oct-90	20
ADDRESS REVIEW COMMENTS	16-Oct-90	19-Nov-90	24
REVISE RI REPORT(NEW DATA)	3-Oct-91	10-Dec-91	45
REVIEW BY BLM	11-Dec-91	8-Jan-92	15
REVISE RIR BASED ON COMMENTS	9-Jan-92	10-Feb-92	22
ISSUE DRAFT RIR TO REGULATORS	11-Feb-92	12-Mar-92	22
ADDRESS REGULATOR COMMENTS	13-Mar-92	13-Apr-92	22
ISSUE FINAL RI REPORT	14-Apr-92	14-Apr-92	0
TASK F DES OF POTEN RESPONSES(	8-May-90	18-Jul-90	50
TASK G INIT DEVEL OF ALTERNATI	9-Apr-90	18-Jul-91	320
TASK H -- INIT SCNG OF ALTERN.	12-Sep-91	24-Mar-92	127
SCREENING OF ALTERNS(FS2)	12-Sep-91	10-Dec-91	60
PHASE 2 FS WORKING PAPER	11-Dec-91	11-Dec-91	0
REVIEW BY BLM	11-Dec-91	8-Jan-92	15
ADDRESS BLM COMMENTS	9-Jan-92	30-Jan-92	15
ISSUE TO REGULATORS	31-Jan-92	3-Mar-92	22
ADDRESS REGULATOR COMMENTS	4-Mar-92	24-Mar-92	15
ISSUE FINAL REPORT	25-Mar-92	25-Mar-92	0
TASK I -- ADD DATA WORK PLAN	17-Sep-90	17-Sep-90	0
TASK J -- BENCH TESTING	17-Sep-90	17-Sep-90	0
TASK K -- EVAL OF ALTERNATIVES	11-Dec-91	1-Mar-93	302
TECHNICAL ANALYSIS	31-Jan-92	3-Apr-92	45
ENVIRONMENTAL ASSESSMENT	11-Dec-91	21-Feb-92	45
EVAL COST EFFECTIVE ALTERN	24-Feb-92	24-Mar-92	22
FS & ENVIR IMPACT W PAPER	6-Apr-92	24-Apr-92	15
PREPARE RI/FS/EIS(PDEIS TO BLM	27-Apr-92	8-Jun-92	30
REVIEW AND APPROVAL(BLM)	27-Apr-92	15-May-92	15
DRAFT RI/FS/EIS(REVISE)	18-May-92	15-Jun-92	20
COMPLIANCE REVIEW AND APPROVAL	16-Jun-92	17-Jun-92	2
PREPARE FORMAL DRAFT	18-Jun-92	1-Jul-92	10
SEND TO BLM FOR SIGNATURE	2-Jul-92	3-Jul-92	2
PRINTING FOR PUBLIC COMMENT	7-Jul-92	3-Aug-92	20
PUBLIC AND EPA REVIEW	4-Aug-92	6-Oct-92	45
RESPOND TO COMMENTS(PF EIS)	7-Oct-92	6-Nov-92	22
BLM REVIEW	9-Nov-92	1-Dec-92	15
REVISE PF EIS(MINOR COMMENTS)	2-Dec-92	15-Dec-92	10
BLM COMLIANCE REVIEW	16-Dec-92	17-Dec-92	2
PREARE FINAL RI/FS/EIS	18-Dec-92	24-Dec-92	5
SEND TO SO FOR SIGNATURE	28-Dec-92	29-Dec-92	2
FINAL PRINTING	30-Dec-92	27-Jan-93	20
FILE FEIS W/ EPA (30 DAY WAIT)	28-Jan-93	1-Mar-93	22
ISSUE NEPA & CERCLA ROD	2-Mar-93	2-Mar-93	0
MONTHLY PRGRESS REPORTS	3-Oct-88	1-Mar-93	1,092

Figure 1-2. Lee Acres Landfill RI/FS project schedule Gantt chart.



BLM
Lee Acres Landfill
RI/FS
Historical Landfill Development 1964-1974

■ Landfill features from 1964 through 1974

Base map information derived from 1988 photogrammetric data. Map produced in 1990 by Roy F. Weston, Inc., Albuquerque, New Mexico, from information compiled and interpreted from aerial photography dated 1964-1988. Trench and pit locations are approximate.

LEGEND

Buildings
Roads
Hydrology
Property lines
Fence lines
Wall
Depression contour
Extent of landfill area

N

0 200
Scale in Feet

TOWNSHIP 29N, RANGE 12W,
SECTION 22

WESTON
MANAGERS DESIGNERS/CONSULTANTS

6501 Americas Parkway, NE.
Suite 800
Albuquerque, New Mexico 87110
(505) 884-5050

Figure 1-3. Historical landfill development 1964-1974.

BLM
Lee Acres Landfill
RI/FS
Historical Landfill Development
1975-1980

■ Landfill features from 1975 through 1980

Base map information derived from 1988 photogrammetric data. Map produced in 1990 by Roy F. Weston, Inc., Albuquerque, New Mexico, from information compiled and interpreted from aerial photography dated 1964-1988. Trench and pit locations are approximate.

LEGEND

Buildings
Roads
Hydrology
Property lines
Fence lines
Wall
Depression contour
Extent of landfill area

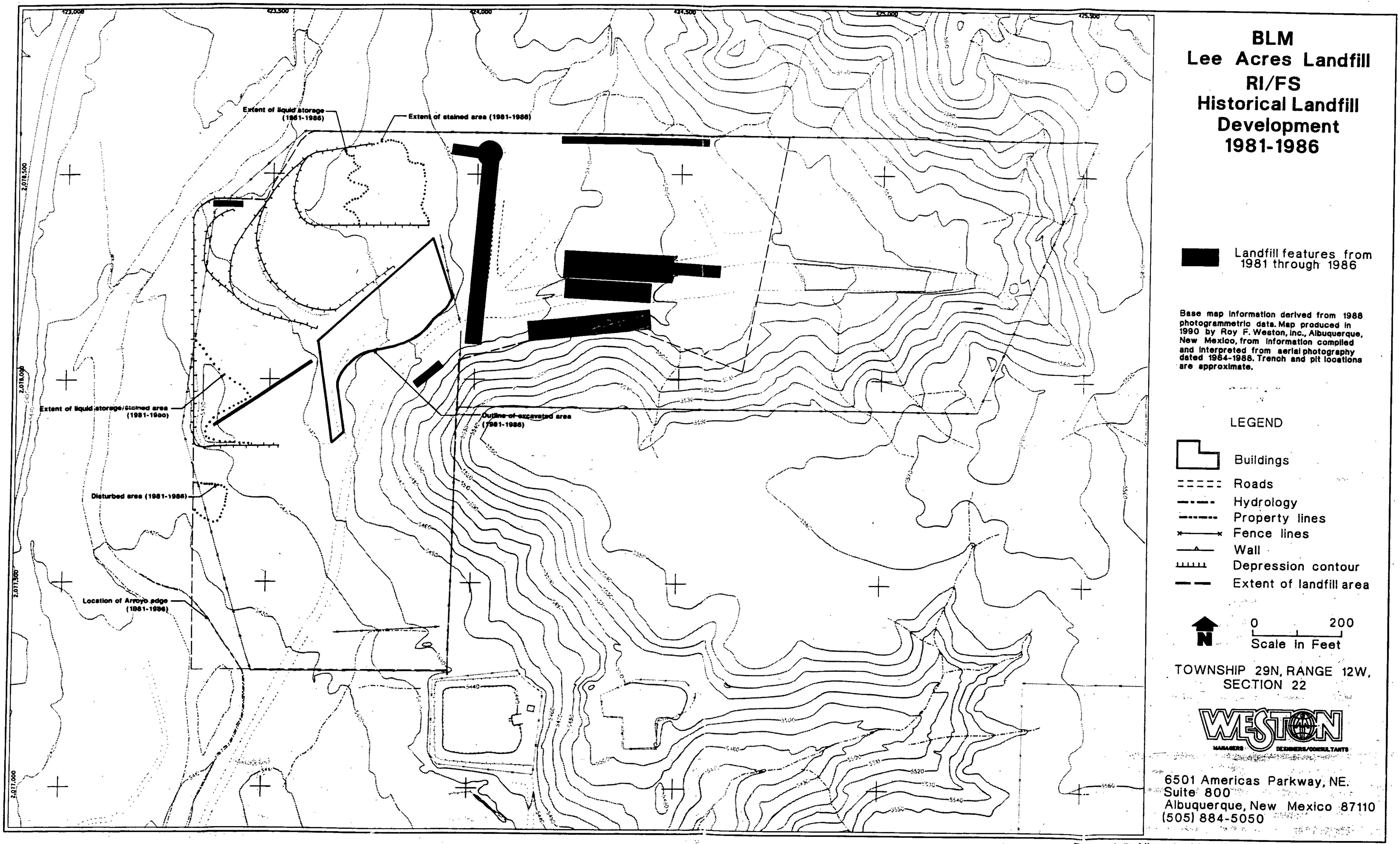
N
0 200
Scale in Feet

TOWNSHIP 29N, RANGE 12W,
SECTION 22

WESTON
MANAGERS DESIGNERS/CONSULTANTS

6501 Americas Parkway, NE.
Suite 800
Albuquerque, New Mexico 87110
(505) 884-5050

Figure 1-4. Historical landfill development 1975-1980.



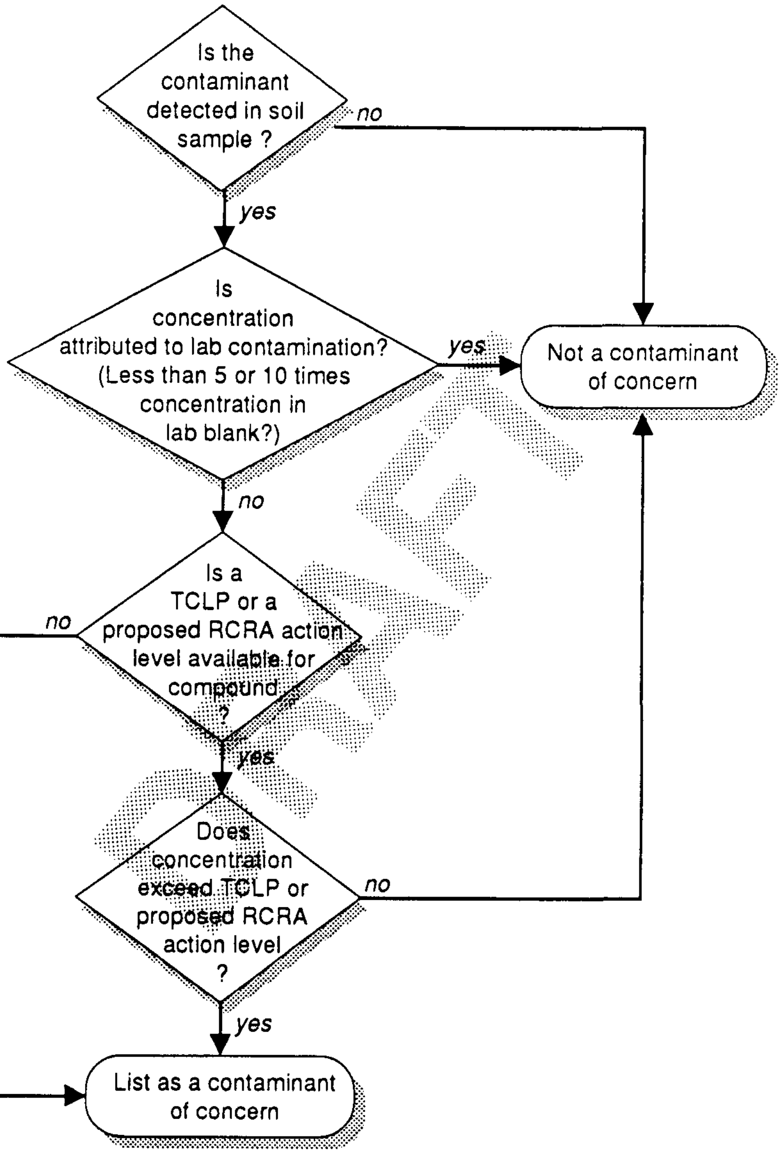
BLM
Lee Acres Landfill
RI/FS
Historical Landfill
Development
1981-1986

Base map information derived from 1988 photogrammetric data. Map produced in 1990 by Roy F. Weston, Inc., Albuquerque, New Mexico, from information compiled and interpreted from aerial photography dated 1984-1988. Trench and pit locations are approximate.

TOWNSHIP 29N, RANGE 12W,
SECTION 22

6501 Americas Parkway, NE.
Suite 800
Albuquerque, New Mexico 87110
(505) 884-5050

Figure 1-5. Historical landfill development 1981-1986.



BLM-decision tree

Figure 1-6. Decision tree for identifying contaminants of concern in soil.

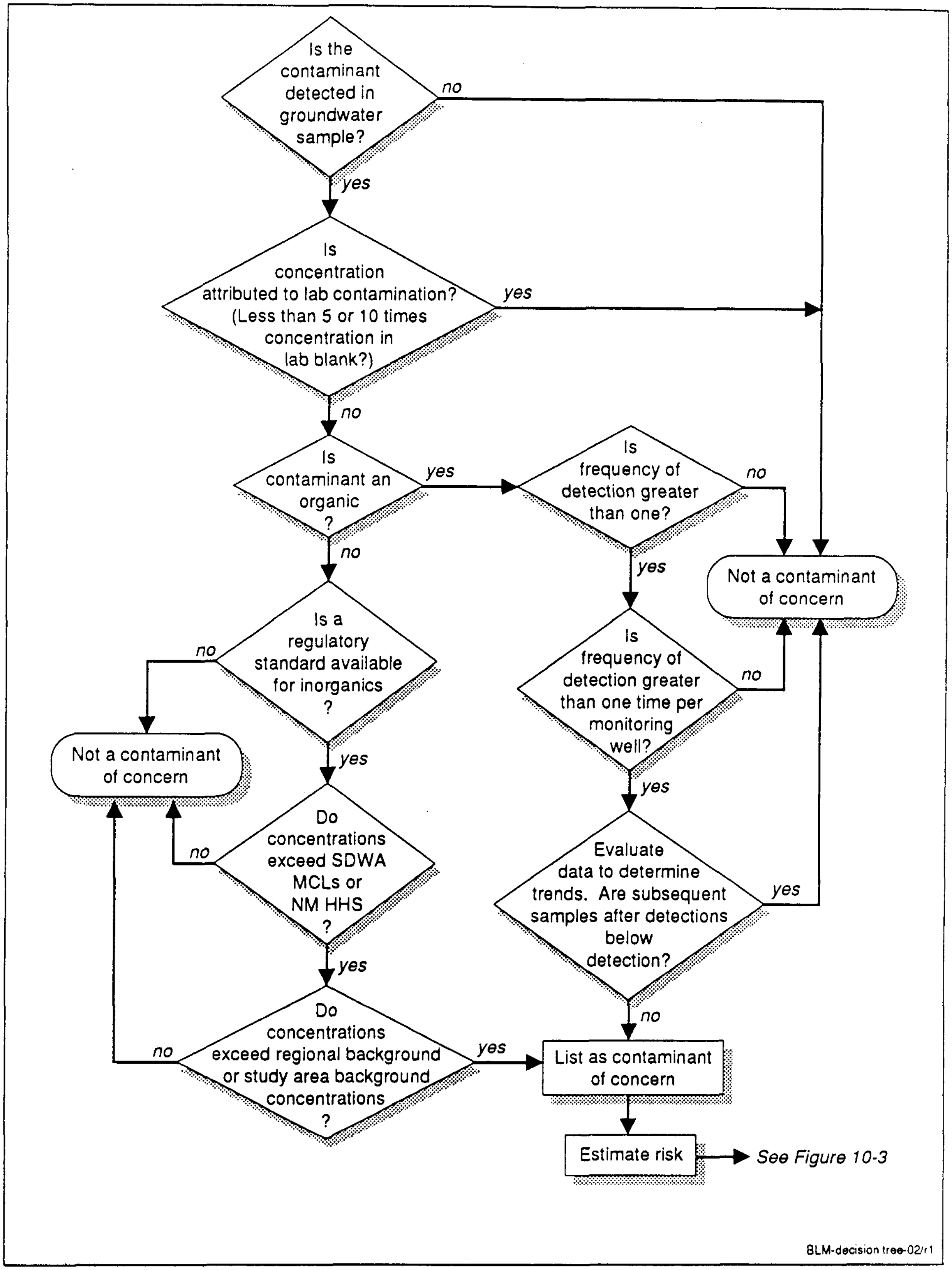


Figure 1-7. Decision tree for identifying contaminants of concern in groundwater.

Table 1-1. Former Solid Waste Disposal Chronology

Date	Description of Events
May 1, 1962	Lee Acres Landfill officially opened. San Juan County Board of Commissioners leased from the BLM the W1/2, NW1/4, SW1/4 section in section 22, T29 N, R12 W for the Lee Acres Landfill. The lease number was NM 088452 (BLM 1962).
1964	Landfill activity was minimal with one trench and one pit (1964 photo).
Feb. 2, 1968	BLM inspection indicated the Lee Acres Landfill site was not being used as a sanitary landfill (BLM-DLM 1968).
Apr. 23, 1968	Reply from San Juan County stated the Lee Acres Landfill had been used and future use was anticipated (SJC 1968).
1971	Landfill was graded and defined. Pits and trenches existed along the northwestern corner and northern edge (1971 photo).
1972 - 1973	Center of the landfill was heavily used (1972-1973 photos).
1975 - 1980	Pit and trenching activities occurred in the central and southern portions of the leased area (1975-1980 photos).
1978	Activities at the Lee Acres Landfill extended southward to the lease boundaries (1978 photo).
Aug. 13, 1980	NMEID-Farmington inspection found a new pit had been constructed near the entrance to the landfill; however, this pit was not adequate for the high volume of waste entering the landfill (NMEID 1980a).
Nov. 10, 1980	NMEID-Farmington inspection reported a refuse pit was almost full and had not been compacted or covered at the required frequency. The NMEID suggested the County acquire either additional land for expansion or a new location as the landfill was nearing the end of its usable life (NMEID 1980b).
Apr. 25, 1980	Development plan was submitted as part of the documents of application for additional area for the Lee Acres Landfill. San Juan County Department of Public Works signed the Lee Acres Sanitary Landfill Development and Operational Plan filed with the BLM on October 30, 1980 (SJC 1980, BLM 1980a).
Apr. 16, 1981	Second lease obtained for additional area for the Lee Acres Landfill. San Juan County Department of Public Works leased from the BLM the S1/2, SW1/4, NW1/4 section, the NW1/4, NE1/4, SW1/4 section, and the NE1/4, NW1/4, SW1/4 section in section 22, T29 N, R12 W. The lease number was NM 40709 (BLM 1981).
1981 - 1986	Lee Acres Landfill was very active. Trenching activities occurred along the northern and eastern edges of the leased area (1981-1986 photos).
Sept. 9, 1981	NMEID Solid Waste Evaluation Report noted noncompliance regarding the required 2 ft of final cover over the area in the first lease. The old leased area had not been adequately reclaimed or reseeded (NMEID 1981a).
1982	Trenching activities occurred along the northern, eastern, and southern fence lines. Material piles, pits, and trenching existed in the southern area of the landfill (1982 photo).
March 1985	Lee Acres Landfill extended eastward. One east-west trench existed (1985 photo).
Apr. 25, 1986	Lee Acres Landfill officially closed. Decision from BLM to San Juan County Department of Public Works suspending NM 40709 and NM 088452 leases, except for a 5-acre area for a transfer station. The transfer station area is the W1/2, NE1/4, NW1/4, SW1/4 section in section 22, T29 N, R12 W (BLM 1986).
Mar. 12, 1987	NMEID inspection reported the solid waste trench was still present; however, the site had not received solid waste since April 1986 (NMEID 1987).

Table 1-2. Former Liquid Waste Lagoons Chronology

Date	Description of Events
May 1, 1962	Lee Acres Landfill officially opened. San Juan County Board of Commissioners leased from the BLM the W1/2, NW1/4, SW1/4 section in section 22, T29 N, R12 W for the Lee Acres Landfill. The lease number was NM 088452 (BLM 1962).
1979	Air photos showed first evidence of liquid waste disposal at the Lee Acres Landfill.
Apr. 25, 1980	Development plan was submitted as part of the documents of application for additional area for the Lee Acres Landfill. San Juan County Department of Public Works signed the Lee Acres Sanitary Landfill Development and Operational Plan filed with the BLM on October 30, 1980. The plan included provisions for a combined pit for sludge and dead animals (SJC 1980, BLM 1980a).
Aug. 12, 1980	NMEID-Farmington inspection reported large puddles of septic material flowing toward the arroyo (NMEID 1980a).
Nov. 10-12, 1980	NMEID-Farmington inspection reported toxic chemicals (acids and caustics) being disposed of in the dead animal pit (NMEID1980a).
Apr. 16, 1981	Second lease obtained for additional area for the Lee Acres Landfill. San Juan County Department of Public Works leased from the BLM the S1/2, SW1/4, NW1/4 section, the NW1/4, NE1/4, SW1/4 section, and the NE1/4, NW1/4, SW1/4 section in section 22, T29 N, R12 W. The lease number was NM 40709 (BLM 1981).
June 30, 1981	EPA Potential Hazardous Waste Site Identification reports surface impoundments (lagoons) existed at the Lee Acres Landfill that contained oil and oily wastes (NMEID 1981b).
Aug. 5, 1981	Anonymous memo to the NMEID stated the sludge pit was overflowing into the arroyo (NMEID 1981c).
Aug. 24, 1981	EPA Potential Hazardous Waste Site Inspection report submitted by NMEID found a surface impoundment existed with liquids, sludge, oily wastes, drilling fluids, and drilling muds. The lagoon was described as a free-form pond without embankments or liner which increased and decreased capacity with the dumping practices and weather conditions (NMEID 1981d).
Mar. 22, 1982	NMEID-Farmington inspection reported there was not a well defined area for septage disposal (NMEID 1982).
Apr. 23, 1984	Complaint received by the BLM concerned waste petroleum products being dumped in a shallow unfenced pit at the Lee Acres Landfill (BLM 1984).
Apr. 18, 1985	Lagoon breach and vapor release incident occurred at the Lee Acres Landfill. Eleven people treated for hydrogen sulfide poisoning (NMEID 1985a).
May 8, 1985	A BLM compliance exam reported the sludge pit was fenced and a 'No Dumping' sign posted. Two pits contained liquids, one by the solid waste trench and one near the wash (BLM 1985).
July 8, 1985	NMEID inspection reported the liquid waste lagoon was 95% evaporated (NMEID 1985b).
Oct. 4, 1985	NMEID inspection reported the liquid waste lagoon was 96 to 97% evaporated (NMEID 1985c).
Jan. 14, 1986	NMEID inspection reported the liquid waste disposal site was being covered (NMEID 1986a).
Apr. 24, 1986	NMEID inspection reported the liquid waste lagoon was completely covered with soil (NMEID 1986b).
Apr. 25, 1986	Lee Acres Landfill officially closed. Decision from BLM to San Juan County Department of Public Works suspending NM 40709 and NM 088452 leases, except for a 5-acre area for a transfer station. The transfer station area is the W1/2, NE1/4, NW1/4, SW1/4 section in section 22, T29 N, R12 W (BLM 1986).

Table 1-3. Summary of Previous Investigations

Investigator	Date of Investigation	Type of Sample Collected	Objective
IT Corporation	April 1985	Pretreatment analyses of lagoon samples	Emergency action for lagoon breach and remedial action recommendations
	May 1985	Post-treatment analyses of lagoon samples	
NMOCD	January 1985	Lagoon samples	Regulatory oversight
	February 1985	Lagoon samples	
	September 1985	*Surface water samples*	
	October 1985	EM terrain conductivity survey (with NMEID)	
	November 1986	Groundwater samples from four residential wells	
	June 1986	Groundwater samples from nine GBR monitoring wells	
	June 1988	Groundwater samples from GBR monitoring wells, samples from 3 tanks, seep, and the airstripper influent and effluent.	
NMEID	April 1985	Lagoon samples	Regulatory oversight
	September 1985	EM terrain conductivity survey (w/NMOCD)	
	April 1985-August 1989	*Residential well sampling program*	
	August 1987	Groundwater samples from GBR monitoring wells	
	April 1988	Groundwater samples from GBR monitoring wells	
	August 1988	Groundwater samples from GBR monitoring wells	
AEPCO	November 1985	Air monitoring 13 waste/sediment/soil samples Two liquid waste/surface water samples Groundwater samples from two residential wells	Site investigation to define types and estimate quantities of hazardous material or wastes at landfill; status of contaminant migration; determine site compliance with federal and state regulations
Tracer Research	July 1986	Soil gas samples from 46 locations at the landfill and on Giant-Bloomfield Refinery property	Delineate the distribution of VOCs in the subsurface

Table 1-3. (page 2 of 2)

Investigator	Date of Investigation	Type of Sample Collected	Objective
USGS	June-March 1987	Test drilling, piezometers, seismic refraction, and EM survey	Hydrologic investigation of the Lee Acres Landfill to provide information to evaluate hazards posed by VOCs in the liquid waste lagoons and potential actions
	May 1987	Groundwater samples from piezometers	
	October 1987	San Juan River samples	
Giant-Bloomfield Refinery	1985-1991	Groundwater samples	Quarterly groundwater monitoring of the Giant-Bloomfield Refinery facility since 1985
Preliminary Investigation (WESTON)	September 1987 - September 1988	Groundwater monitoring program - 19 new monitoring wells plus residential wells	Evaluate the presence and extent of groundwater contamination in the area of the Lee Acres Landfill and interpret the hydrogeologic setting

EM: electromagnetic
NMEID: New Mexico Environmental Improvement Division
NMOCD: New Mexico Oil Conservation Division
USGS: U.S. Geological Survey
VOC: volatile organic compound

Table 1-4. Lee Acres Landfill RI/FS Information Repositories

Bureau of Land Management Contact: Bob Moore/Charlie Beecham 1235 La Plata Highway Farmington, New Mexico 87401
Alturian Public Library Contact: Suzy Horvath 201 W. Chaco Aztec, New Mexico 87410
Bureau of Land Management Contact: Bill Murphy 435 Montano NE Albuquerque, New Mexico 87107
Bureau of Land Management Contact: Kay Thomas Bureau of Land Management P.O. Box 1449, Mail Code 943 Santa Fe, New Mexico 87504
New Mexico Environment Department Groundwater Protection and Remediation Bureau Contact: Dale M. Doremus 1190 St. Francis Drive Santa Fe, New Mexico 87503
Environmental Improvement Division Contact: Dave Tomko 724 W. Animas Farmington, New Mexico 87401
Farmington Public Library Contact: Nancy Gorman 100 W. Broadway Farmington, New Mexico 87401

Table 1-5. Summary of Analytical Levels Appropriate to Data Uses for Lee Acres Landfill RI/FS

Data Uses	Analytical Level	Type of Analysis	Limitations	Data Quality	RI Data Collection Activity
Site characterization Monitoring during implementation	Level I	Total organic/inorganic vapor detection using portable instruments and/or field test kits	Instruments respond to naturally occurring compounds	If instruments calibrated and data interpreted correctly, can provide indication of contamination	Vapor concentrations in the landfill monitored using an HNu, a PID, an OVA, a CGI, and an H_2S meter during the Soil Boring Program (subsection 2.4)
Site characterization Evaluation of alternatives Engineering design Monitoring during implementation	Level II	Variety of organics by GC, inorganics by AA, or onsite mobile laboratory	Tentative Identification	Dependent on QA/QC steps employed	Hydrocone groundwater sampling performed with an onsite mobile lab used for the groundwater analysis (subsection 2.3)
			Techniques/instruments limited mostly to volatiles and metals	Data typically reported in concentration ranges	
			Detection limits vary from low ppm to low ppb		
Risk assessment PRP determination Site characterization Evaluation of alternatives Engineering design Monitoring during implementation	Level III	Organics/inorganics using EPA procedures other than CLP can be analyte-specific	Tentative Identification in some cases	Similar detection limits to CLP	No Level III activities performed
		RCRA characteristic tests	Can provide data of same quality as Level IV	Less rigorous QA/QC	
Risk assessment PRP determination Evaluation of alternatives Engineering design	Level IV	TCL organics/inorganics by GC/MS, AA, and/or ICP	Tentative identification of non-TCL parameters	Goal is data of known quality	CLP protocol and data packages requested for all groundwater and soil analyses (subsections 2.4, 2.6, 2.7, and 2.9)
		Low ppb detection limit	Some time may be required for validation of packages	Rigorous QA/QC	

Table 1-5. (page 2 of 2)

Data Uses	Analytical Level	Type of Analysis	Limitations	Data Quality	RI Data Collection Activity
Site characterization Risk assessment Engineering design PRP determination Evaluation of alternatives	Level V	Non-conventional parameters	May require method development/modification	Method-specific	Grain size distribution, dry density, and permeability tests performed on select soil samples using ASTM methods (subsection 2.4)
		Method-specific detection limits; modification of existing methods	Mechanism to obtain services requires special lead time		
		Soil physical property tests by ASTM or other methods			

Reference: EPA 1987a
ppb: parts per billion
ppm: parts per million
AA: atomic absorption analysis
ASTM: American Society for Testing Materials
CGI: combustible gas indicator
CLP: Contract Laboratory Program
EPA: U.S. Environmental Protection Agency
GC: gas chromatograph analysis
ICP: inductively coupled plasma - atomic emission spectrometric method
MS: mass spectrometer analysis
OVA: organic vapor analyzer
PID: photo ionization detector
PRP: potentially responsible party
QA/QC: quality assurance/quality control
RCRA: Resource Conservation and Recovery Act
TCL: target compound list

BLRIPD11.16 February 13, 1992

Table 1-6. Lee Acres Landfill Chemical-Specific ARARs for Groundwater - Site 1, Operable Unit 2 Contaminants of Concern

Contaminant of Concern	Federal Citation	New Mexico Citation	Requirement	ARAR Type	ARAR Standard	Basis for ARAR Selection
Inorganics:						
Chloride	none	WQCCR 3-103	HHS = 250 mg/L	A	250 mg/L	Promulgated
Metals:						
Chromium	40 CFR 264.94 40 CFR 141.11	WQCCR 3-103	RCRA MCL = 0.05 mg/L SDWA MCL = 0.05 mg/L HHS = 0.05 mg/L	RA A A	0.05 mg/L	Promulgated
Cobalt	none	WQCCR 3-103	HHS = 0.05 mg/L	A	0.05 mg/L	Promulgated
Manganese	none	WQCCR 3-103	HHS = 0.2 mg/L	RA A	0.2 mg/L	Promulgated
Nickel	40 CFR 141.61	WQCCR 3-103	SDWA MCL = 0.1 mg/L p	RA A	0.2 mg/L	Promulgated
Selenium	40 CFR 264.94 40 CFR 141.61	WQCCR 3-103	RCRA MCL = 0.01 mg/L p SDWA MCL = 0.01 mg/L HHS = 0.2 mg/L	RA A A	0.01 mg/L	Promulgated
Volatile Organic Compounds:						
1,1-Dichloroethane	none	WQCCR 3-103	HHS = 0.025 mg/L	A	0.025 mg/L	Promulgated
1,2-*cis*-Dichloroethene	40 CFR 141.61	none	SDWA MCL = 0.07 mg/L	A	0.07 mg/L	Promulgated
1,2-*trans*-Dichloroethene	40 CFR 141.61	none	SDWA MCL = 0.1 mg/L	A	0.1 mg/L	Promulgated
1,1,1-Trichloroethane	40 CFR 264.94 40 CFR 141.61	WQCCR 3-103	RCRA MCL = 0.2 mg/L p SDWA MCL = 0.2 mg/L HHS = 0.06 mg/L	RA A A	0.06 mg/L	Promulgated
Benzene	40 CFR 264.94 40 CFR 141.61	WQCCR 3-103	RCRA MCL = 0.005 mg/L p SDWA MCL = 0.005 mg/L HHS = 0.01 mg/L	RA A A	0.005 mg/L	Promulgated
Dicholoromethane (methylene chloride)	40 CFR 141.61	WQCCR 3-103	SDWA MCL = 0.005 mg/L p HHS = 0.1 mg/L	RA A	0.1 mg/L	Promulgated
Tetrachloroethene (PCE)	40 CFR 141.61	WQCCR 3-103	SDWA MCL = 0.005 mg/L p HHS = 0.02 mg/L	RA A	0.02 mg/L	Promulgated

Table 1-6. (page 2 of 2)

Contaminant of Concern	Federal Citation	New Mexico Citation	Requirement	ARAR Type	ARAR Standard	Basis for ARAR Selection
Trichloroethene (TCE)	40 CFR 264.94 40 CFR 141.61	WQCCR 3-103	RCRA MCL = 0.002 mg/L p SDWA MCL = 0.005 mg/L HHS = 0.1 mg/L	RA A A	0.005 mg/L	Promulgated
Trichloromethane (chloroform)	none	WQCCR 3-103	HHS - 0.1 mg/L	A	0.1 mg/L	Promulgated
Vinyl chloride	40 CFR 264.94 40 CFR 141.61	WQCCR 3-103	RCRA MCL = 0.002 mg/L p SDWA MCL = 0.002 mg/L HHS = 0.001 mg/L	RA A A	0.001 mg/L	Promulgated

A: applicable
ARARs: applicable or relevant and appropriate requirements
CFR: Code of Federal Regulations
HHS: New Mexico promulgated human health standard
p: proposed standard
RA: relevant and appropriate
RCRA MCL: Resource Conservation and Recovery Act maximum concentration limit
SDWA MCL: Safe Drinking Water Act maximum contaminant level
WQCCR: New Mexico State Water Quality Control Commission regulation

Table 1-7. Proposed RCRA Soil Action Levels

Contaminant Analytical Group	Operable Unit 1 Contaminant of Concern	RCRA Action Level[a] (mg/kg)
Volatile Organic Compounds:	1,1-Dichloroethane	NA
	1,2-*trans*-Dichloroethene	NA
	Benzene	24
	Chloroethane	NA
	Chloroethene (vinyl chloride)	>0.2 mg/L[b]
	Chloromethane	NA
Semivolatile Organic Compounds:	1,2-Dichlorobenzene	NA
	1,3-Dichlorobenzene	NA
	1,4-Dichlorobenzene	>7.5 mg/L[b]
	2,4-Dimethylphenol	NA
	2-Methylnaphthalene	NA
	2-Methylphenol	NA
	4-Methylphenol	NA
	Acenaphthene	NA
	Anthracene	NA
	Benzo(a)anthracene	NA
	Benzo(a)pyrene	NA
	Benzo(b)fluoranthene	NA
	Benzo(g,h,i)perylene	NA
	Benzo(k)fluoranthene	NA
	Benzoic acid	NA
	Chrysene	NA
	Dibenzofuran	NA
	Di-n-butyl phthalate	NA
	Di-n-octyl phthalate	NA
	Fluoranthene	NA
	Fluorene	NA
	Indeno(1,2,3-cd)pyrene	NA
	Naphthalene	NA
	Phenanthrene	NA
	Pyrene	NA

Table 1-7. (page 2 of 2)

Contaminant Analytical Group	Operable Unit 1 Contaminant of Concern	RCRA Action Level[a] (mg/kg)
Pesticides:	Beta-BHC	4.0
	Delta-BHC	NA
	Dieldrin	0.04
Metals:	Strontium	NA
	Tin	NA

[a] Taken from: RCRA Proposed Corrective Action Rule 55 FR 30798, 27 July 1990.

[b] Concentration that will not leach by TCLP.

NA: not available

RCRA: Resource Conservation and Recovery Act

2. RI DATA COLLECTION ACTIVITIES

The RI consists of three stages: 1) the Accelerated Program, 2) the major stage of the RI during which the main data collection activities occurred, and 3) a secondary stage of the RI focused on Giant-Bloomfield Refinery property. Prior to the RI, a PI was performed from December 1987 through September 1988 resulting in the installation of 19 monitoring wells (BLM-14 through BLM-32) and a 10-month groundwater monitoring program. A summary of the PI and other investigations relating to the former Lee Acres Landfill is presented in Appendix C. After the completion of the PI, the BLM elected to conduct an RI/FS.

Data collection activities for the RI began in January 1989 with the Accelerated Program and continued through July 1991 with two additional stages of RI activities. Four groundwater monitoring wells were installed during the Accelerated Program: BLM-33, BLM-34, BLM-35, and BLM-37. Monitoring wells BLM-33 through BLM-35 are bedrock wells located inside the landfill along the southern fence line (Plate 1). The fourth well, BLM-37, is an alluvial well located south of U.S. 64 in the northern part of the Lee Acres residential area (Plate 1). The 10-ft well screen in BLM-37 covers the entire saturated thickness of the alluvium; therefore, the shallow alluvial well (BLM-36) with the well screen located at the top of the saturated zone was not installed (WESTON 1990d). A description of the sampling and analysis performed during the Accelerated Program is provided in subsection 3.2 of the SAPP. Soil and groundwater analytical results from the Accelerated Program are considered part of the RI and are integrated and compared with the PI and RI data sets as appropriate.

The Lee Acres Landfill RI data collection activities included

- an air photo interpretation study,
- an air quality investigation,
- geophysical surveys,
- cone penetrometer tests (CPTs),
- hydrocone sampling,
- soil boring installation and sampling,
- a waste trench study,
- lysimeter installation and sampling,
- monitoring well installation,
- a hydrogeologic investigation,
- a groundwater monitoring program,

- a surface water program, and
- fire water pond sediment sampling.

Procedures and methodologies for the planned RI activities are described in the SAPP (WESTON 1990d) and the RI Briefing Document (WESTON 1991). Table 2-1 presents a summary of the planned and actual RI data collection activities. The overall technical strategy of the RI was to examine and compare sample results as they were obtained with previous data in order to select subsequent sampling locations in areas of potential migration pathways or sources. For example, the selection of locations for wells BLM-65 and BLM-66 (Plate 1) was based on groundwater data showing low-level contamination that was collected from upgradient hydrocone sampling points in the unnamed arroyo (subsection 2.3). CPTs, which revealed the lack of moisture in the shallow subsurface, helped define alluvial aquifer boundaries and played an important role in the design of the alluvial aquifer monitoring well network. Other examples of this staged process are presented in following subsections and provide the technical rationale for the design and implementation of each RI activity. The goals of this strategy were to avoid subsequent phases of remedial investigation by evaluating and responding to data as they became available and integrating new findings into the ongoing work, and to obtain the data required to satisfy the RI goals presented in subsection 1.1.4.

The following subsections present the technical rationale, summarize each activity, and describe the analytical program. Detailed descriptions of theory, methods, and procedures not fully described in the SAPP are included in the appendixes of this report. Also provided, where appropriate, is a presentation of results that excludes interpretation or comparison with other data sets. Results are compared and integrated in Sections 4, 5, and 6 of this report, which present the detailed analyses of study area hydrogeology, source characterization, nature and extent of groundwater contamination, contaminant migration pathways, and the site conceptual model.

The air photo study was conducted prior to RI field work to identify disposal or industrial activities that may represent contaminant sources within the study area. The methods and results of the air photo study are presented in Appendix B and summarized in Section 1.2. The information obtained from the air photos provided guidance in the placement of initial sampling locations.

To support the risk assessment (Section 10) portion of the Lee Acres Landfill RI/FS project, an air quality investigation was performed during the RI activities. The results of this air quality investigation are presented in Section 3.1 of this report.

2.1. GEOPHYSICAL SURVEYS

Three types of geophysical surveys were performed as part of the RI at the Lee Acres Landfill Study Area. Magnetometer and electromagnetic (EM) 31 (metal detection and terrain conductivity) surveys were performed in the former landfill to identify buried waste, trenches, and lagoons. In addition, a seismic refraction survey was performed in the arroyo to the west of the former landfill to identify bedrock channels that may provide preferential pathways for contaminant migration.

2.1.1. Magnetometer and Terrain Conductivity Surveys

Magnetometer and EM 31 surveys were performed by WESTON from November 2 through 8, 1989, at the former Lee Acres Landfill. Results of the geophysical surveys were used to

- delineate horizontal landfill boundaries,
- provide data needed to estimate landfill waste volumes,
- delineate trench locations and buried waste boundaries,
- guide the placement of subsequent soil borings and cone penetrometer stations, and
- identify potential paths of waste migration.

The data obtained with each geophysical technique were analyzed individually and then interactively to characterize the nature and distribution of buried wastes at the former Lee Acres Landfill. This subsection presents the field acquisition, interpretation and comparison of geophysical data sets. Integration of geophysical data with other data sets is provided as part of the source characterization in Section 5.

The magnetometer and EM 31 surveys were confined to the landfill (Figure 2-1), and were performed with a model EM 31 terrain conductivity meter manufactured by Geonics, Ltd., and two model GS-19 magnetometers manufactured by Gem, Inc. Table 2-2 presents the type of information provided by EM 31 and magnetometer surveys. Procedures for the acquisition and interpretation of data for the EM 31 and magnetometer surveys are presented in Appendix E-1.

2.1.1.1. Cultural Interference

One of the greatest obstacles to surface geophysical investigations in populated areas is cultural interference. Overhead powerlines, metal fences, underground utilities, and concentrations of scrap metal all create interference for magnetometers and EM instruments. There is scattered metal debris on the surface throughout the former Lee Acres Landfill and the area is surrounded by a metal fence. Figure 2-1 shows the location of metal debris and other cultural features visually located at the landfill. In interpreting the data, the effects of proximal metals on discrete instrument readings were evaluated.

The fencelines within and surrounding the landfill posed the greatest cultural interference problem for interpretation of geophysical data. Geophysical signatures consistent with disposal activities were identified near fencelines. However, it was difficult to accurately resolve trench boundaries adjacent to the fence.

2.1.1.2. EM 31 Survey

The EM 31 survey was performed along north-south traverses spaced 25 ft apart, with measurements taken every 6.25 ft. Quadrature component and in-phase values were measured simultaneously at each point to determine apparent conductivity of materials and proximity to buried metals, respectively. Values measured during the survey were automatically recorded on a data logging system, allowing for rapid and efficient data acquisition. The theoretical foundations of terrain conductivity instruments and the operation of the EM 31 instrument at the former Lee Acres Landfill are presented in Appendix E-1.

2.1.1.2.1. Apparent Conductivity Anomalies

The quadrature component of the EM 31 instrument measured apparent conductivity of shallow materials across the former landfill. Apparent conductivity values ranged from -187.8 to 407.2 millisiemens per meter (mS/m), with a mean value of 53.2 mS/m. Data were numerically plotted on postings maps, and zones of anomalous conductivity were identified (Figure 2-2). The cross-hatched areas on Figure 2-2 show zones where apparent conductivity is greater than 100 mS/m (highly conductive soils). The other shaded areas are zones where readings were above or below background values for the landfill. Based on careful analysis of readings over areas of undisturbed soil and base station readings, it was determined that background EM 31 apparent conductivity values range from 15 to 50 mS/m at the former Lee Acres Landfill.

There are several zones with anomalous apparent conductivity throughout the former landfill. While some of these zones are attributed to buried wastes, some anomalies are caused by shallow underlying bedrock. An anomaly exists in the southern portion of the former landfill where mudstone bedrock outcrops were observed. An anomalous zone also occurs in the easternmost portion of the landfill over shallow bedrock (Figure 2-2). Bedrock depths determined from three boreholes in this area range from 0 to 1.8 ft. The bedrock underlying the former Lee Acres Landfill is thought to be more conductive than the unconsolidated sediments. Table 2-3 presents the conductivities of various materials. Clean quartz sandstones tend to exhibit low conductivities relative to unsorted, unconsolidated sediments, while sandstones with a clay matrix and mudstones have relatively high conductivities (Table 2-3). Rock units of the Nacimiento Formation sampled in the landfill soil borings are immature sandstones and mudstones that contain clay and, therefore, are relatively conductive. The assumption that the underlying bedrock at the former landfill is more conductive than the unconsolidated sediments is substantiated by two other EM studies conducted prior to the RI.

The NMEID conducted a study that involved an EM 34 survey at the former Lee Acres Landfill in October 1985 (McQuillan and Longmire 1986). Measurements were taken with vertical coils at 40- and 20-m intercoil spacings across the former landfill and adjacent land. The wider of the two coil spacings provides deeper penetration than the narrower spacing. The data from this study consistently showed higher conductivity readings for the 40-m coil spacing, indicating an increase in conductivity with depth. The increase in conductivity may be attributed to conductive bedrock, saturated materials, or groundwater with high TDS at depth. A study conducted by the U.S. Geological Survey (USGS) showed that conductivity generally increases with depth in areas where major response for both coil separations was in the saturated zone (Peter et al. 1987). This information indicates that bedrock is more conductive than overlying unconsolidated sediments at the former landfill.

Finally, the RI EM 31 data indicate that bedrock is more conductive than overlying sediments. Throughout most of the former landfill, bedrock is deeper than the major response envelope of the EM 31. However, elevated conductivities were observed over bedrock outcrops and where bedrock is shallow.

Conductive anomalies not attributed to groundwater, bedrock, or cultural interference indicate the presence of buried, conductive wastes. Conductive wastes may consist of buried metal, liquid waste, bulk waste, or a combination. High conductivity readings may also indicate water that is high in TDS. To distinguish among these possibilities, an interactive comparison of quadrature phase EM 31 readings with other geophysical data is presented in subsection 2.1.1.4.

2.1.1.2.2. In-Phase Anomalies

EM 31 in-phase data provide locations of buried metal at the landfill, including nonferrous metals such as copper, brass, and aluminum. In-phase values are also somewhat affected by large-scale variations in conductivity. Readings across the former landfill ranged from -32.2 to 44.7 parts per thousand (ppt), with an average value of 3.6 ppt.

Figure 2-3 shows zones of anomalous in-phase EM 31 readings across the former landfill. After examination of readings at the base station and over areas of undisturbed soil, a background range of in-phase values from -2 to 7 ppt was selected to resolve buried metal targets in the former landfill. The shaded areas on Figure 2-3 indicate where in-phase readings differed from background, but do not include areas with cultural interference (metal) on the surface.

While the in-phase component of the EM 31 is effective for identifying buried metals, it is limited by a shallow penetration depth. The depth at which targets can be detected depends on the mass and dimensions of the metal objects in question, but penetration is generally limited to approximately 5 to 8 ft below the instrument. Therefore, with the instrument held at waist height, penetration is limited to about 3 to 6 ft below the ground surface at the former landfill. Because of this shallow depth of penetration and relative insensitivity to changes in bulk conductivity, in-phase readings are compared with conductivity and magnetometer data in subsection 2.1.1.4 to provide the most comprehensive evaluation of site conditions.

2.1.1.3. Magnetic Surveys

The magnetic survey at the former Lee Acres Landfill was conducted along north-south traverse lines, with measurements taken every 12.5 ft. The survey was performed using two Gem model GS-19 proton precession magnetometers, one for field measurements and the other as a dedicated base station. Both vertical gradient (gradiometer) and total field (magnetometer) measurements were taken at each point. The theory of magnetometer surveys and the operation of the GEM GS-19 instrument at the former Lee Acres Landfill are presented in Appendix E-1.

2.1.1.3.1. Residual Magnetic Field Anomalies

Residual magnetic field values were derived by subtracting field readings from simultaneous base station readings after the two magnetometer were synchronized. Readings are affected by the presence of ferrous metals and geologic units containing large amounts of pyrhotite, magnetite, or other magnetic minerals. Because geologic materials at the site have low magnetic susceptibilities, magnetic anomalies at the former landfill are believed to result from buried ferrous wastes. Measured values across the landfill ranged from -52,352 to 89,727 gammas (G), with an average value of 596.0 G.

Figure 2-4 provides a map showing anomalous zones identified in the residual magnetic field data. Selected background values range from -50 to +50 G to resolve objects as small as a single, buried 55-gallon drum. Anomalous residual field readings were present over a large portion of the former landfill. These were caused by cultural interference, such as fences and metal debris on the surface, and by the presence of buried ferrous waste. The resolution of the residual field measurements was not precise enough to differentiate individual zones of buried waste at the former landfill. However, the data indicate that the eastern-most portion of the former landfill is free from buried ferrous waste (Figure 2-4).

The residual total magnetic field data are useful for defining large-scale variations in the magnetic field, but are not well-suited for defining discrete anomalies at sites where cultural interference may be a problem. Because of the low resolution of residual total magnetic field readings, greater emphasis is placed on the magnetic vertical gradient information to locate distinct zones containing buried ferrous wastes.

2.1.1.3.2. Magnetic Vertical Gradient Anomalies

Magnetic vertical gradient measurements do not require information from a base station magnetometer because they are based on the difference between readings of sensors at two different heights over the same point at the same moment in time. Vertical gradient values measured at the former landfill range from -1000 to 999.3 gammas per meter (G/m), with an average value of -6.0 G/m.

Figure 2-5 is an anomaly map for the magnetic vertical gradient data with cultural effects removed. Selected background values range from -20 to +20 G/m to resolve objects as small as a single, buried 55-gallon drum. Dimensions of the anomalous zones (those above or below background) are more clearly resolved in this figure than on the residual magnetic field anomaly map (Figure 2-4) because of the higher resolution of magnetic vertical gradient measurements.

The eastern portion of the former landfill is free of vertical gradient anomalies other than those related to cultural interference (Figure 2-5). Several anomalous zones exist across the rest of the former landfill, indicating the presence of buried ferrous wastes.

2.1.1.4. Comparison of EM 31 and Magnetometer Data Sets

Magnetic data were used to locate buried ferrous wastes. Areas of buried nonferrous metallic wastes were identified with the in-phase component of the EM 31, and conductive nonmetallic wastes were identified with the quadrature component of the EM 31. An interactive comparison of the geophysical data sets is necessary to characterize and locate waste anomalies across the former landfill.

Anomaly maps for each geophysical data set were digitized and stored on computer disk for comparison and processing. In this way, they could be combined and compared to provide information regarding the location and composition of buried wastes at the former landfill. Figure 2-6 compares anomalies identified with the in-phase component of the EM 31 with the anomalies identified with magnetic vertical gradient measurements. Each instrument defined some anomalous areas not defined by the other, while some areas were identified by both.

Areas defined as anomalous by the in-phase component of the EM 31 are interpreted as zones containing buried nonferrous metallic waste such as aluminum, copper, or brass. Anomalous zones identified by the magnetic measurements probably represent areas where ferrous metallic wastes are buried, but are deeper than the effective penetration of the EM 31 instrument. Zones defined as anomalous in both data sets contain buried ferrous wastes and may also contain non-ferrous metallic waste. These areas contain buried metal at relatively shallow depths. While Figure 2-6 provides locations and some properties of buried metallic wastes, a comparison with the quadrature component EM 31 data set is necessary to define areas of nonmetallic, conductive wastes.

A comparison of the magnetic vertical gradient data with both the quadrature and in-phase components of the EM 31 provides the most comprehensive information about the location and nature of buried wastes at the former landfill. Figure 2-7 shows the locations of buried conductive waste, buried metallic waste, and buried conductive and metallic waste anomalies. Metallic anomalies are those identified by the in-phase component of the EM 31 and/or the magnetometer, but not strongly identified by the quadrature component of the EM 31. The conductive anomalies are those identified with the quadrature component of the EM 31 only. Conductive and metallic anomalies are those detected by the magnetometer and/or the in-phase EM 31 and the quadrature component of the EM 31.

Conductive anomalies indicate the presence of buried nonmetallic conductive wastes, such as liquid waste or water high in TDS. Metallic waste anomalies indicate areas containing buried metallic waste that are not associated with large quantities of conductive liquid waste or water high in TDS. Conductive and metallic anomalies may define areas containing buried metals and liquid waste, or areas containing large concentrations of metallic waste only.

Several anomalous zones exist throughout the western and central portions of the former landfill. Conductive waste anomalies in the southwestern and west-central portions of the former landfill may represent buried lagoons that received liquid waste. The association of some of these areas with metallic anomalies indicates that scrap metal or metal containers were also buried in these areas.

An east-west oriented linear anomaly is present in the northwestern portion of the former landfill. The anomaly runs from 23500 east to 24075 east and has an approximate axis of 78525 north. The axis of the anomaly is also evident in the apparent conductivity anomaly map (Figure 2-2), as readings of greater than 100 mS/m are present in the central portion of the area. The center of the anomaly is both conductive and metallic, while the perimeter is conductive only. This may be related to a central trench from which liquid waste has spread laterally over time. Another explanation would be a central trench containing metallic waste that was filled in and later excavated to a shallower depth for liquid waste disposal. These preliminary interpretations are based solely on the geophysical data. Conclusions based on a combination of geophysical and other data will be presented in the source characterization (subsection 5.4).

A profile showing quadrature and in-phase EM 31 values along line 23800 east (A-A' on Figure 2-1) that crosses this zone is shown in Figure 2-8. Anomalous in-phase readings are present from 78175 north to 78375 north, while quadrature readings remain fairly consistent over this interval. Quadrature readings begin to increase at about 78475 north, while in-phase readings increase somewhat further north. The in-phase anomaly is narrower than the quadrature component anomaly and is centered on the same axis. Elevated values at the northern end of the line are the result of proximity to a metal fence.

Another linear anomaly, oriented north-south, is present to the east of the east-west trending zone. This feature is also defined on the apparent conductivity anomaly map (Figure 2-2). The axis of this linear anomaly is at approximately 24150 east, and runs from 78150 to 78450 north. It appears that metallic wastes and bulk waste with high conductivity are both present in this area.

A broad anomalous zone is present to the east of the two linear anomalous zones. It extends from approximately 24300 east to 24800 east, and from 78150 north to 78475 north. The central portion of this zone is primarily metallic and conductive, while areas on the perimeter contain primarily metallic wastes.

Figure 2-9 is a north-south profile of magnetic vertical gradient measurements along line 24500 east (B-B' on Figure 2-1) that crosses this zone. The profile shows a number of strong positive and negative anomalies in succession. The data show similar features in other north-south profiles across the zone. The net effect is a number of subparallel zones of alternating positive and negative signature. These zones run approximately east-west and may be related to a number of trenches with the same orientation. The positive anomalies occur above the covered trenches and the negative anomalies occur between the trenches.

Figure 2-10 is a profile of EM 31 quadrature and in-phase values along the same (B-B') line. The in-phase data show sharp fluctuations across the zone, while the quadrature values increase across the zone but do not fluctuate as sharply. Again, the data indicate the presence of several subparallel trenches across the zone. It appears that the trenches primarily contain metallic wastes, although some liquid waste may be associated.

2.1.1.5. Summary

Several anomalous zones were identified through geophysical investigation at former Lee Acres Landfill. General characteristics of wastes associated with these anomalous areas were derived from the geophysical data. However, an additional objective of the geophysical study was to use the data to guide the placement of auger boreholes and cone penetrometer holes. Figure 2-11 shows the borehole locations with respect to the integrated waste anomalies. Figure 2-12 shows the cone penetrometer locations with respect to the integrated waste anomalies identified from the EM and magnetometer surveys. Sites were selected to provide information about anomalous zones as well as background areas. While the geophysical data provide information about the characteristics and lateral distribution of buried wastes, borehole and cone penetrometer data provide additional information, including thickness of buried waste and physical properties of waste materials. In addition, analyses of water samples from wells at selected locations are used in conjunction with geophysical, borehole, and cone penetrometer data to identify potential paths of waste migration. Interpretations of historical air photos and their relationship to geophysical data also provide important information about waste disposal in the former landfill.

The integration of geophysical data with other information to provide quantitative information about the hydrogeology of the site is discussed in Section 4 and in Section 5 to determine the volume and characteristics of wastes in the former landfill, hydrogeology of the site, history of waste disposal at the landfill, and potential paths of contaminant migration. The use of geophysical data to guide other field efforts was an important component of a cost-effective and efficient approach to characterizing contamination at the former Lee Acres Landfill.

2.1.2. Seismic Refraction Survey

A seismic refraction survey was performed from March 5 through 9, 1990, as part of the RI at the former Lee Acres Landfill to delineate the top of bedrock beneath the unnamed arroyo to the west and south of the landfill. Bedrock elevation profiles were generated based on the seismic refraction data to locate bedrock channels that might provide preferential pathways for contaminant migration. When possible, seismic lines were located adjacent to existing boreholes to provide a direct comparison between known lithology and geophysical interpretations. Additional boreholes were placed along some seismic lines for verification of geophysical interpretations. Locations of seismic lines and boreholes are shown in Figure 2-13. Seismic lines were placed in an west-east orientation across the unnamed arroyo, and two additional seismic lines were placed along the northwestern and western perimeter of the former landfill. Lengths of seismic lines represented in Figure 2-13 are based on measurements from the first to the last geophone in the array, with each array consisting of either 24 or 36 geophones. Depths below end shot points are omitted in the interpretations because "end effects" may introduce error into the interpretations. Figure 2-14 shows a typical unprocessed field record. The theory and limitations of seismic refraction are presented in Appendix E-1, and seismic refraction profiles are presented in Appendix E-2.

The individual discussions of each seismic refraction line are provided in Appendix E-1. Table 2-4 presents velocities of seismic wave propagations along the eight seismic lines (Figure 2-13). Seismic velocities represent an average value for the array, and may vary along the seismic profile. Three layers with distinct velocities of seismic wave propagation were measured along each line. Layer 1 consists of loosely packed alluvium with propagation velocities ranging from 800 to 1,060 feet per second (ft/s). Layer 2 consists of more compact alluvium with propagation velocities ranging from 1,400 to 2,040 ft/s. Layer 3 consists of Nacimiento Formation bedrock with velocities ranging from 6,740 to 8,600 ft/s (Table 2-4). Changes in seismic velocity through bedrock may be explained by differences in weathering of the bedrock surface or by lithologic changes, such as a change from mudstone to sandstone. A layer of saturated alluvium was identified overlying bedrock in several boreholes, but the layer was not detected in the seismic refraction survey. The significance of this layer is discussed in the following subsection.

2.1.2.1. Correlation of Seismic Refraction Results with Borehole Data

Seismic refraction profiles were collected adjacent to monitoring wells and boreholes where possible, and several additional wells and exploratory boreholes were drilled after completion of the seismic refraction survey. Bedrock depths independently determined from seismic data are accurate in areas where saturated alluvium is not present. However, in areas where saturated alluvium is present above the bedrock surface, predicted depths were consistently too shallow.

In the saturated alluvium, seismic waves propagate through pore waters at an approximate velocity of 5,000 ft/s, while in unsaturated alluvium seismic waves propagate through the grains at a much lower velocity. Velocities of seismic wave propagation through unsaturated alluvium were measured during the geophysical survey as were velocities through bedrock. However, the velocity through saturated alluvium was not measured, and this zone represents a hidden layer with an intermediate velocity that can not be detected by the seismic refraction technique. A more detailed discussion of the hidden layer effect is presented in Appendix E-1. Because predicted bedrock depths do not include the intermediate velocity zone, bedrock depths independently derived from seismic refraction data were too shallow where saturated alluvium is present above the bedrock surface.

When the elevation of the water table is known or can be estimated, layered earth elevation profiles may be corrected to include the thickness of saturated alluvium. The process is based on an assumed seismic wave velocity (5,000 ft/s) through saturated alluvium, and on the assumption that the water table is flat along a given line. Water table elevations were derived through measurement in boreholes and wells adjacent to seismic refraction profiles, or through an extrapolation from water table measurements in wells or boreholes that are offset from the lines.

The amount of time required for refracted waves to reach geophones was accurately measured in all cases. However, the component of the ray-path in which the velocity of wave propagation was approximately 5,000 ft/s (saturated alluvium) was not measured. The difference between the time it would take a ray to reach the measured water table elevation and the time it took to reach the predicted bedrock surface can be measured, and for this length of time the velocity of propagation is assumed to be 5,000 ft/s. Thus, the additional depth not measured as a result of the hidden layer can be defined, and the profiles can be corrected to include the saturated alluvial thickness. Where the depth to the water table is greater than the interpreted bedrock depth, there is no saturated alluvium present and the original predicted depth is correct. Table 2-5 presents the correlation of the bedrock depths logged in boreholes with the bedrock depths estimated from the seismic refraction data. All of the elevation profiles presented in Appendix E-2 are corrected based on water table measurements from wells and exploratory boreholes.

2.1.2.2. Location of Bedrock Channels

The seismic line locations and the interpreted axis of the bedrock channel, derived from results of the seismic refraction survey are shown on Figure 2-13. The axis was identified by locating the deepest portions along each seismic profile. The center of the bedrock channel is 60 to 80 ft from the northwest corner of the former landfill at the intersection with seismic lines 1, 2, and 3. At the intersection with line 4, the axis of the channel is approximately 200 ft from the west boundary of the landfill. At line 5, the channel axis is approximately 175 ft from the western landfill boundary, and the channel runs parallel to the west fenceline to the southern boundary of the former landfill. The bedrock channel appears to split into two less incised channels on the east and west sides of a wide depression between lines 6 and 7. The broad depression in the bedrock surface persists southward to line 8. A more detailed description of the topography of the bedrock surface, based on an integration of geophysics and borehole data, is presented in subsection 4.1.

2.2. CONE PENETROMETER TESTS

From November 1989 through January 1990, 139 CPTs were performed at the former Lee Acres Landfill in conjunction with the hydrocone sampling (subsection 2.3). The CPTs ranged from 3 to 54.5 ft below ground surface and were located within and adjacent to the study area (Plate 1).

2.2.1. Activity Description and Technical Rationale

The electronic CPT is a soil property sensing technique that has been used for over 40 years in geotechnical applications (Robertson and Campanella 1984), but has only recently been applied to environmental studies. A detailed explanation of CPT theory and procedures is provided in Appendix F with measured cone penetrometer profiles. Figure 2-15 is a schematic of the cone penetrometer used for this study. For the RI, CPTs were conducted within and outside the former landfill for different purposes.

CPTs within the landfill were used to

- help characterize the horizontal and vertical extent of buried waste within the fence boundaries,
- determine stratigraphy,
- confirm the geophysical interpretation,
- determine depth to and lateral boundaries of the water table in the alluvial aquifer system,
- determine if perched water tables exist, and
- help determine locations for boreholes.

At locations outside the landfill, the CPTs were used to

- characterize the properties of unconsolidated alluvium and colluvium using the Soil Behavior Type Chart (Figure 2-16),
- determine stratigraphy,
- establish the lateral boundaries of the alluvial aquifer system,
- determine depth to groundwater for hydrocone groundwater sampling, and
- help locate permanent groundwater monitoring wells.

CPT data were one facet of a multidisciplinary study of landfill contents consisting of geophysical surveys (subsection 2.1), an air photo study (Appendix B), borehole sampling and analyses (subsection 2.4), and trench excavation and description (subsection 2.5). Surface geophysical data collected in the former landfill resulted in a map of waste anomalies (Figure 2-7). CPT locations were then chosen to confirm the geophysical interpretation as shown in Figure 2-12 and to establish depths to the bottom of solid waste. As the CPT data from the former landfill did not allow the exact identification of subsurface materials, borehole sampling was necessary to describe chemical and physical characteristics of the solid waste.

In addition to geophysics, an air photo study (Appendix B) was used to map areas of former solid waste burial and trench activity (Figures 1-3, 1-4, and 1-5). CPT locations were also chosen to confirm burial trench locations identified from the air photo study. CPTs were conducted at the former Lee Acres Landfill on a grid of approximate 200-ft centers in areas identified from the geophysical data (Figure 2-12). The data obtained from inside the landfill boundary were evaluated as they were collected and, if needed, additional testing points using 100-ft centers (inside the landfill boundary) were added. CPTs were not performed for locations at or near bedrock outcrops, near fencelines, or where the ground surface was too steep for the CPT rig to operate safely.

2.2.2. Data Analysis

As described in Appendix F, the CPT data are automatically logged by a computer that can then generate profiles showing lithology versus depth. The data logged were continuous readings of tip and friction resistance in kilograms per square centimeter (kg/cm^2), and conductivity in micromhos per meter (μmhos/m) versus depth. Computer-generated lithologic descriptions of the CPT profiles are an approximation. A typical 40-ft profile might identify as many as 50 to 60 "lithologic intervals." In order to develop a more usable format for the profiles, the data were analyzed using a computer program developed by a private consultant. This program allows the handpicking of intervals by grouping similar intervals on the profile into one interval. The refined profile typically contained 5 to 10 lithologic intervals for a depth of 40 ft. This data compilation made the profiles more manageable, the multi-profile comparisons more valuable, and comparisons to adjacent borehole logs more meaningful. Refined CPT profiles are given in Appendix F. In addition to providing lithologic information, the depth to groundwater was determined by examining conductivity (μmhos/m) versus depth profiles. The conductivity recorded on the CPT profile shows a background increase to over 30 μmhos/m when the cone encountered the saturated zone. Direct field testing helped substantiate this relationship. A water level obtained from the conductivity reading of a CPT adjacent to an existing well was usually within 1 ft of the static water level in that well. This relationship was used for hydrocone groundwater sampling by generating a conductivity plot to determine if the alluvial aquifer was present. CPT conductivity data were also used to determine the depth at which the hydrocone screen should be set to collect a water sample. The conductivity profile also indicated, at some CPT locations, the presence of conductive solid waste. Material with high tip resistance and low friction resistance is interpreted as sand on Robertson and Campanella's Soil Behavior Type Chart (Figure 2-16). Commonly, spikes occurred on the conductivity plot within these sand intervals when conductive (metal) debris was encountered. Further analysis and integration of CPT data will be presented in subsection 5.4, where the profiles are used to help determine the boundaries and volume of buried solid waste in the former landfill. Also presented in subsection 5.4 is a general characterization of the subsurface conditions in the study area. CPTs were primarily conducted to provide a preliminary picture of subsurface conditions at the former Lee Acres Landfill that could be used to design a groundwater monitoring well network and other data collection activities.

2.3. HYDROCONE GROUNDWATER SAMPLING

From December 1989 through January 1990, the hydrocone groundwater sampler was used to collect samples at 39 locations within Lee Acres Landfill Study Area in conjunction with the CPTs. The samples were obtained from 2 to 5 ft below the water table of the alluvial aquifer system using the CPT rig to push the sampler.

2.3.1. Activity Description and Technical Rationale

A hydrocone groundwater sampling device is a fast and relatively inexpensive method for geochemical sampling of groundwater, to locate permanent monitoring wells, or to define the areal extent of contaminant plumes. Samples are collected from a retractable hydrocone tip (similar to the CPT apparatus) that is pushed into the saturated alluvium. The tip has a 1-ft-long well screen that is protected as it is advanced, but is exposed when the casing is pulled back approximately 1 to 2 ft toward the surface. Hydrocone sampling can provide accurate, expeditious, and cost-efficient sampling of a large area, especially when water analysis is completed at an onsite mobile lab, as was done for this project. The methodology and analytical results for the hydrocone sampling are provided in Appendix G.

As part of the RI, hydrocone locations were sampled covering four geographic areas, each with a distinct data strategy. Hydrocone sample locations are shown on Figure 2-17. Table 2-6 presents the sampling strategies for the following areas:

- within or near the unnamed arroyo upgradient of the former Lee Acres Landfill in study subarea 1 (for background characterization),
- within the unnamed arroyo south of the former landfill and north of the highway in study subarea 3 and Site 2 (to trace potential contamination),
- within the arroyo south of the highway in Site 2 (to trace the furthest downgradient extent of potential contamination), and
- within the subdivisions east of the unnamed arroyo in Site 2 (to characterize the potential dispersion of contaminants).

Nine samples were collected in and adjacent to the unnamed arroyo upgradient of the former landfill. Fifteen samples were collected in and adjacent to the unnamed arroyo from the southern boundary of the landfill to the highway (Plate 1). At 3 of the 15 locations (HP-13, HP-14, and HP-15, approximately 10 ft apart), samples were collected at two depths: just below the water table, and approximately 5 ft below the first sample. This was done to test the accuracy of hydrocone sampling (by checking the reproducibility of water samples) and to determine any variations in groundwater chemistry with depth. Three samples were collected in or near the unnamed arroyo south of the highway, and 14 samples were collected in the subdivisions east of the arroyo.

2.3.2. Analytical and Quality Control Program

Groundwater samples were collected in two 40-mL glass vials for VOC analysis, and a 1-liter plastic bottle for TDS, chloride, and sulfate analyses. In addition, approximately 500 mL was collected for field measurements of temperature, pH, and conductivity.

Most of the samples collected with the hydrocone sampler were analyzed onsite in the WESTON mobile laboratory. The mobile laboratory was equipped to perform volatile organic analyses (VOAs) and chloride analysis. The samples were analyzed by EPA Methods 8010 and 8020 using a Varian gas chromatograph equipped with a photoionization detector (PID) and a Hall electrolytic detector (Hall). The PID was used to determine the concentration of the aromatic volatile compounds (Method 8020), and the Hall was used to determine the concentration of the halogenated organic compounds (Method 8010). The samples were usually analyzed within 24 hours. The availability of analytical results in real-time provided the capability of changing or adding hydrocone locations based on those results.

The analyses for TDS and sulfate were performed by WESTON's laboratory in Stockton, California. In addition, four samples were sent to the Stockton laboratory when the mobile lab was not operational (HP1331, HP1336, HP1431, and HP4131). These samples were analyzed for volatile organic compounds (VOCs), chloride, TDS, and sulfate.

Quality assurance/quality control (QA/QC) samples collected in the field consisted of one duplicate and one rinsate blank for every ten samples collected. In the mobile laboratory, daily QA/QC procedures included a method blank, calibration blank, matrix spike, and replicate samples. In addition, surrogate spikes were added to all samples at concentrations of 50 µg/L.

2.3.3. Results

All hydrocone sample analytical results are presented in Appendix G. The positive results for VOCs and inorganics are summarized in Table 2-7. Chlorinated hydrocarbons were detected at six sampling locations that fall into two geographical groups (Figure 2-17). One area is located in the center of the unnamed arroyo, immediately southwest of the southwest corner of the landfill fence. The other area is located south of U.S. 64, in the center of the arroyo, 200 ft east of the arroyo, and 400 ft west of the arroyo. Interpretation of hydrocone geochemical data is presented in subsection 6.5. The detection of chlorinated hydrocarbons in hydrocone samples south of U.S. 64 in the unnamed arroyo resulted in the placement of two additional permanent monitoring wells as part of the RI (subsection 2.7). The results at three hydrocone sample locations (HP-23, HP-24, and HP-40) prompted the installation of BLM-65 and BLM-66. The position of these two wells sufficiently identified the downgradient extent of any detectable concentrations of chlorinated solvents in unnamed arroyo groundwater between U.S. 64 and the San Juan River. The hydrocone samples with chlorinated hydrocarbons found in the unnamed arroyo adjacent to the southwest corner of the former landfill prompted the installation of wells BLM-59 and BLM-60 within 100 ft of HP-13. Trichloromethane was detected in 14 samples, some of which were rinsate blanks. Because it was detected in the rinsate blanks, the source of the trichloromethane is attributed to the potable water supply used for decontamination. The other contaminants detected in the hydrocone samples were not detected in the rinsate blanks. Discussion of the potable water analysis and potential contamination in rinsate blanks are discussed in subsection 2.4.3, the Soil Boring QA/QC requirements.

2.4. SOIL BORING PROGRAM

A total of 53 exploratory boreholes, BH-01 through BH-53, were drilled in and around the landfill area during two periods (Plate 1). From November 1989 through March 1990, 39 boreholes were drilled, and from April 1991 through May 1991, an additional 14 boreholes were drilled. The 1991 drilling program included five boreholes located on Giant-Bloomfield Refinery property south of the former landfill, and nine boreholes located within the unnamed arroyo (Plate 1).

2.4.1. Activity Description and Technical Rationale

The borehole data were used to define the alluvium and bedrock structural, lithologic, and permeability characteristics; provide vertical control for existing landfill boundaries; and detect subsurface contamination in the unnamed arroyo. The placement of the boreholes was based on (1) geophysical information from magnetometer, electromagnetic terrain conductivity, and seismic refraction surveys; (2) air photo study information; (3) data gaps existing from previous investigations conducted by the BLM; and (4) CPT profiles.

Twenty-nine boreholes (BH-01 through BH-29) were drilled within the former landfill area (Site 1). The geophysical investigation (subsection 2.1) identified anomalous areas within the landfill where both solid and liquid waste may have been disposed of. Borehole locations were selected to provide information about both the anomalous and background areas of the landfill. Figure 2-11 shows boreholes locations with respect to the anomalous areas identified by the geophysical investigation. Soil samples were collected to describe the physical and chemical characteristics of the landfill subsurface materials, as well as the area lithology.

Nine boreholes were located on Giant-Bloomfield Refinery property south of the landfill (subarea 3). Four boreholes, BH-30 through BH-33, were drilled west of the former Giant-Bloomfield Refinery firewater storage ponds (Plate 1) to determine whether subsurface contamination exists south of the landfill due to the firewater storage ponds. Three boreholes were drilled adjacent to existing monitoring wells installed by the Giant-Bloomfield Refinery: BH-40 located approximately 15 ft south of GBR-48, BH-41 located approximately 15 ft north of GBR-49, and BH-42 located approximately 15 ft north of GBR-32 (Plate 1). These three boreholes were drilled to identify possible localized contaminant sources near these three wells. Two boreholes (BH-43 and BH-44) were drilled in the attempt to install a monitoring well east of BLM-70 (Plate 1); however, both boreholes were dry.

Sixteen boreholes, BH-34 through BH-39 and BH-45 through BH-53, were drilled in two north-south lines within the unnamed arroyo (subareas 2 and 3) (Plate 1). These boreholes were drilled and sampled to determine whether subsurface contamination exists in the arroyo.

Discussions of the drilling, sampling, and logging methods and disposal of cuttings are presented in Appendix H. Borehole logs are also provided in Appendix H.

2.4.2. Analytical Program

Geochemical samples were collected from 2 to 5 ft below the surface at the start of each borehole and at subsequent 5 to 10 ft intervals, depending on the desired position of vertical characterization within the vadose zone. Geochemical samples were collected from specific depths in the following cases: (1) where positive readings were obtained from monitoring instruments during screening of the core, (2) where some visual indication of soil/sediment contamination (staining, residues, waste, etc.) was recognized, and (3) at the top of the zone of saturation of the alluvial aquifer. At each sample point, one geochemical sample suite was collected for offsite laboratory analysis. These samples were collected immediately after the split barrel was opened according to SOP 5.1, Soil and Rock Borehole Logging and Sampling (revision 2) (WESTON 1988a). No compositing of samples was performed.

Geochemical samples collected during drilling of boreholes BH-01 through BH-39 were analyzed for VOCs and semivolatile organic compounds, pesticides/PCBs, and metals. Soil samples were analyzed for VOCs using EPA Methods 8010 and 8020. EPA Method 8270 was performed on soil samples to detect the presence of any semivolatile priority pollutants, such as base-neutral acids (BNAs). EPA Method 8080 was performed on soil samples to detect organochloride pesticides and PCBs. Soil samples were also analyzed for metals by the EP Toxicity method. Samples collected during drilling of boreholes BH-40 through BH-53 were analyzed for VOCs (EPA Methods 8010 and 8020), TCLP metals, chloride, and sulfate.

In cases where the sample recovery was limited, the available sample material was selected for VOC analysis only. All samples collected for geochemical analysis were labeled with the borehole ID, sample ID, date and time collected, and analysis requested. Details of the soil boring analytical program are presented in Section 6 of the SAPP (WESTON 1990d), and Section 5 of the RI Briefing Document (WESTON 1991). Table 2-8 provides a summary of the borehole geochemical sampling and analytical program including borehole ID, sample date, borehole depth, sample interval, geochemical analyses requested, chain-of-custody ID, and laboratory analytical batch number. Table 2-8 also presents the number of samples identified in the two work plans and the actual number of samples collected. The geochemical analytical results are provided in Appendix I-1. Results are interpreted and summarized in Section 5.

For selected boreholes, geotechnical samples were also collected during drilling and were analyzed for selected geotechnical parameters in accordance with their respective standard methods and protocols. Analytical procedures included the following:

- grain size distribution, and hydrometer, ASTM D 422-63 (reapproved 1990),
- Atterberg limits, ASTM D 4318-84,
- dry density, ASTM D 2937-83 (reapproved 1990),
- moisture content, ASTM D 2216-90,
- triaxial permeability, EM 11110-2-1906 App. VII, U.S. Army Corp of Engineers, Engineers Manual, and
- percent organic carbon, ASTM D2974.

In addition, some samples were tested to determine moisture content when the *in situ* moisture content was preserved.

Geotechnical samples were collected at 5-ft intervals and at observed changes in lithology. Bedrock geotechnical samples were collected just below the alluvium/bedrock contact, and from the archived bedrock core. To help determine the saturated permeability of the sandstone with respect to depth, samples of sandstone from within the archived core were selected that represented relative changes in grain size and degree of cementation of rock. Upon retrieval, geotechnical samples contained within brass sleeves were sealed with plastic end caps and were coated with paraffin wax to preserve the *in situ* moisture condition of the sample. Geotechnical samples not contained within brass sleeves were wrapped in aluminium foil and coated with paraffin wax. Samples were selected from archived bedrock core approximately 1 month after collection. These samples were wrapped in aluminium foil and contained in sealed plastic bags.

Only samples that were coated with paraffin wax immediately upon collection were tested for moisture content. All samples collected for geotechnical analysis were labeled with the borehole ID, depth interval, and sample ID. The sample identification sequence included a sample-type indicator letter, the borehole number, and the end depth of the sample interval. For example, a geotechnical sample was collected from exploratory borehole BH-36 at a depth interval of 44.7 to 45.0 ft; the sample was designated G36450. Select geotechnical samples collected in 1990 were submitted to Chen-Northern, Inc., in Denver, Colorado. Geotechnical samples collected in 1991 were analyzed by WESTON's Lionville Laboratory. Table 2-9 provides a summary of the borehole geotechnical sampling and analytical program, including borehole ID, sample ID, sample date, borehole depth, sample interval, geotechnical analyses requested, and total number of samples. Appendix J provides all geotechnical test results. Subsection 4.1 presents a discussion of the geotechnical test results.

2.4.3. QA/QC Requirements and Results

In addition to the samples collected from each borehole for laboratory analysis, the following QA/QC samples were taken to satisfy CLP requirements and to augment laboratory QA/QC samples in documenting and ensuring the quality of sample collection, decontamination, and analysis.

- One field duplicate for every 10 samples was analyzed for all analyses.
- One equipment rinsate sample for every 10 samples.
- One trip blank per shipment of VOCs.

The potable water supply used for decontamination and steam-cleaning of drilling equipment was also sampled. One sample was collected on March 21, 1990, during the first drilling program. During the 1991 drilling program, a sample was collected on April 24, 1991. Table 2-10 presents a summary of the potable water supply analytical results. Bromodichloromethane and dichloromethane were detected at 4.9 and 5.3 µg/L, respectively, in the March 1990 sample. Trichloromethane was detected in both water supply samples at 45 and 37 µg/L.

In addition to performing field QA/QC procedures, the analytical laboratory, in accordance with CLP protocols, must comply with CLP QA/QC requirements. These requirements are not sample dependent; they specify performance requirements on matters that should be fully under a laboratory's control. These specific areas include blanks, calibration standards, performance evaluation standard materials, and tuning (EPA 1988c). These performance requirements must be met before, during, and after analysis. For example, satisfactory instrument calibration ensures that the instrument is capable of producing acceptable quantitative data. Initial calibration demonstrates that the instrument is capable of acceptable performance in the beginning, and continuing calibration checks document satisfactory maintenance and adjustment of the instrument on a day-to-day basis. Reanalysis is the result of noncompliance. Noncompliance and corrections are reported on the case narrative of the CLP data package.

However, the use of method blanks not only confirms the acceptable performance of the analytical instrument, but also defines the level of laboratory background contamination. A method blank is an analytical control sample consisting of all reagents and laboratory standards that is carried through the entire analytical procedure. No contaminants should be present in the blank(s). However, if problems with a blank exist, all associated data must be carefully evaluated. This evaluation is not performed by the laboratory, but is part of data validation procedures conducted prior to the interpretation of the analytical results by technical personnel. The lab blank evaluation for the RI analytical data is performed as described in the following paragraphs and according to "Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses" (EPA 1988c).

During the review of the analytical results, the results of all associated blanks are also reviewed. In both the samples and blanks, compounds attributed to lab contamination are flagged by the laboratory with a "B" qualifier. If a compound is found in a blank, but not found in the sample, no action is taken. For samples with compounds identified as present in the blank, the results are not considered to be a positive detection unless the sample concentration of the compound exceeds 5 or 10 times the amount in the laboratory blank, depending on the compound (EPA 1988b).

Five compounds are considered to be common lab contaminants: dichloromethane (methylene chloride), acetone, toluene, 2-butanone (methyl ethyl ketone), and common phthalate esters. The common phthalate esters include *bis*(2-ethylhexyl) phthalate, di-n-butyl phthalate, and di-n-octyl phthalate. If the contaminant in the lab blank is any of these five common lab contaminants, then only sample concentrations exceeding 10 times the lab blank concentration are considered to be positive detections.

For any other compound present in the lab blank, sample concentrations exceeding five times the lab blank concentration are considered to be positive detections. In the instances where more than one lab blank is associated with a given sample, the lowest concentration was used for a conservative evaluation.

The soil analytical results presented in Appendix I-1 include all compounds flagged as also being present in the lab blank. Appendix I-2 presents the lab blank evaluation, including the sample concentration, the lab blank concentration, the 5- or 10-times calculation, and whether the sample concentration is considered to be a positive detection.

2.5. TRENCH STUDY

Three trenches were excavated within the former landfill area during mid-January 1990 to help define the location, nature, and extent of waste contained within the northwest portion of the landfill, including verification of former liquid waste lagoons suspected to contain hydrocarbon residues. The location of the trench network was based on a review of air photos (Figure 1-5) and exploratory borehole information (Figure 2-18).

2.5.1. Activity Description and Technical Rationale

The air photo study was conducted to identify and confirm both landfill and industrial-related historical activities that may have generated or contributed to contamination sources within the study area (see

Appendix B). The presence of two former liquid waste lagoons within the northwest and southwest portions of the landfill was confirmed. A secondary containment berm surrounded the northern lagoon (Figure 1-5).

A total of 29 exploratory boreholes (BH-1 through BH-29) were drilled within the landfill area (Plate 1). The boreholes defined the subsurface lithology and characterized the chemical and physical nature of landfill waste. Exploratory borehole data verified that the two former liquid waste lagoons contain hydrocarbon residues. The secondary containment berm was suspected to contain hydrocarbon residues; however, the borehole data were unable to confirm this. The trench configuration was designed to span the area for the secondary containment associated with the former northern liquid waste lagoon to examine the possibility that remnant hydrocarbon residues exist, and to provide coverage in areas where borehole data are unavailable (Figure 2-18).

2.5.2. Trench Study Results

Stewart Brothers Drilling Co. was subcontracted to excavate the trench network under direction of WESTON personnel. Three trenches, TR-1 through TR-3, were excavated with a backhoe (Figure 2-18). TR-1 was excavated to 300 ft in length and 3 to 5 ft in depth along an easterly trend. TR-2 intersected the approximate center of TR-1 and was excavated 170 ft in length and 4 to 5 ft in depth along a northeast trend. TR-3 intersected TR-1 and TR-2 and was excavated 151 ft in length and 5 ft in depth along a north-south trend (Figure 2-18). Due to health and safety requirements for excavations, the trench depths were restricted to less than 6 ft depths.

The cross-sectional area exposed along the walls of each trench revealed various types of solid waste debris that were recorded and mapped by field personnel. Mapping information included the length, depth, and thickness, and descriptions of layers, lenses, and capsules of solid waste debris identified within each trench. Cross sections of TR-1, TR-2, and TR-3, illustrating the distribution of waste debris in each trench, are shown in Figures 2-19, 2-20, and 2-21, respectively. All three trenches were backfilled with native sediment upon completion of mapping.

The trench study confirmed the absence of hydrocarbon residues within the bermed area south of the former northern liquid waste lagoon. No hydrocarbon residues were observed in the bermed area during trenching activities. The bermed area appears to have been a secondary containment area that probably never received liquid hydrocarbon wastes.

The waste debris encountered in the trenches consists of common municipal landfill materials, such as concrete, wire, paper, plastic, wood, glass, and metal. No hydrocarbon contaminant sources were identified and, therefore, no sampling was conducted. The distribution and types of waste debris encountered in the trenches are presented in Figures 2-19, 2-20, and 2-21.

2.6. LYSIMETER INSTALLATION PROGRAM

From late January to mid-February 1990, six lysimeters were installed within the former liquid waste lagoons to create two, three-lysimeter clusters. The lysimeters were used to collect vadose zone moisture within the landfill for chemical analysis.

2.6.1. Activity Description and Technical Rationale

The lysimeters were located to monitor any residual vadose zone contamination associated with the two former liquid waste lagoons (Figure 2-18). These former lagoons are the landfill features considered most likely to contain residual contamination. The former lagoon locations were identified by the air photo study (Appendix B) and exploratory borehole tasks (subsection 2.4). The upper lysimeter in the cluster was installed about 4 to 5 ft below ground surface. The middle lysimeter in the cluster was installed about 25 to 30 ft below ground surface, and the lower lysimeter was installed about 35 to 40 ft below ground surface (Figure 2-22). Two clusters of three lysimeters were installed within the areas of former liquid waste lagoons, one cluster in each lagoon. Table 2-11 provides a summary of lysimeter installation information, including the lysimeter ID, installation date, total depth of the lysimeter, depth interval of the porous lysimeter cup, and lysimeter assemblies, which include a transfer vessel. Appendix K presents the installation and sample methodology, as well as the analytical results. Subsection 5.2.2 discusses the analytical results from the lysimeter sample analyses in relation to the former liquid waste lagoons.

2.6.2. Analytical Program

Typically, the vadose zone does not contain enough soil moisture to provide sufficient sample volume for all parameters of the analytical suite. Based on available soil moisture, samples were analyzed on a priority basis. The prioritized analytical program is presented in Table 2-12.

VOC samples were collected first because they are generally found to be the most mobile. VOC analysis requires a sample volume of 80 mL. Inorganic compound samples were second priority because they provide a fingerprint of the vadose zone moisture as part of contaminant source analysis. The remaining parameters are prioritized in order of importance to the contaminant source characterization study of the site.

Lysimeter sampling was conducted on April 4 and 5 (early April), April 24 and 25 (late April), and May 18, 1990. In early April 1990, a total of 360 mL of water was obtained from LS-5, 55 mL from LS-6, and 85 mL from LS-7. The 55 mL collected from LS-6 was obtained on two separate days. The total amount collected on either day was insufficient to completely fill a 40-mL VOA vial, and no sample was submitted. Samples for VOA EPA Methods 8010 and 8020 were submitted from LS-5 and LS-7. In late April 1990, two lysimeters produced water. A total of 65 mL was obtained from LS-3, and 2 mL from LS-6. A sample for VOA EPA Method 8010 was submitted only for LS-3. In May 1990, 38 mL of water was obtained from LS-5, 20 mL from LS-6, and 25 mL from LS-7. An insufficient amount of sample to fill the 40-mL vials for VOA EPA Methods 8010 and 8020 resulted in no samples being submitted for the May 1990 sampling event. Table 2-13 provides a summary of the lysimeter sampling and analytical program, including lysimeter ID, sample date, sample depth, the geochemical analysis requested, chain-of-custody ID, and laboratory analytical batch number. Analytical results of the lysimeter sampling program are presented and discussed in subsection 5.2.2.

2.7. WELL INSTALLATION PROGRAM

A total of 64 groundwater monitoring wells (BLM-14 through BLM-35, BLM-37, and BLM-39 through BLM-79) were installed within the Lee Acres Landfill Study Area (Plate 1). The purpose of installing the well network was to collect subsurface soil samples, to define subsurface lithology, to provide vertical control for existing landfill boundaries, to determine the depth to the top of bedrock that underlies the study area, to determine hydraulic properties and flow gradients, and to define the extent of any groundwater contamination migrating from the former landfill. The activity description and technical rationale for the RI monitoring well installation program, the well completion description, and the analytical program for soil samples collected during well installation are presented in the following subsections. The RI groundwater monitoring program is presented in subsection 2.9.

2.7.1. Activity Description and Technical Rationale

The monitoring well installation program for the former Lee Acres Landfill was performed by WESTON and consisted of 1) a PI, 2) an Accelerated Program, and 3) the RI. Stewart Brothers Drilling Co. was subcontracted by WESTON to complete the installation of 64 monitoring wells during these three stages. The PI included the installation of monitoring wells BLM-14 through BLM-32 from mid-October through mid-December 1987. The Accelerated Program included the installation of monitoring wells BLM-33 through BLM-35 and BLM-37 during January 1989. During the RI, monitoring wells BLM-39 through BLM-66 were installed from late November 1989 through mid-March 1990, and monitoring wells BLM-67 through BLM-79 were installed from April through mid-May 1991. All project monitoring well locations are shown on Plate 1.

The rationale for the placement of monitoring wells installed during the PI and the Accelerated Program are presented in the Preliminary Investigation Report (WESTON 1989e) and the SAPP (WESTON 1990d), respectively. Table 2-14 summarizes the objectives of well placement for these two investigations and for the RI. Section 6 of the SAPP (WESTON 1990d) presents the RI work plan for the monitoring well installations conducted in 1990. In addition, the air photo study, geophysical surveys, boreholes, hydrocone sampling information, and data gaps existing from previous investigations conducted by the BLM and others were combined to promote optimum placement of the RI monitoring well locations. The RI Briefing Document (WESTON 1991) identifies the second stage of RI well installation activities. A brief description of the rationale for well placement is presented below. Table 2-14 summarizes the planned monitoring well installation activities from Section 6 of the SAPP and Section 5 of the RI Briefing Document with the actual RI monitoring wells installed in the Lee Acres Landfill Study Area.

Monitoring wells were required within the Lee Acres Landfill Study Area to further establish background groundwater quality (BLM-39 and BLM-40) and monitor the movement of contaminants from the former landfill (BLM-41 through BLM-49, and BLM-59 through BLM-64) (Table 2-14 and Plate 1). In addition, two former liquid waste lagoons were identified within the landfill (Figure 1-5) by the air photo study. Exploratory borehole data verified that each of the two former lagoons contains hydrocarbon residues that have percolated downward through the vadose zone (see borehole logs in Appendix H). Wells BLM-53 through BLM-58 were placed in suspected former lagoon locations (Plate 1). One alluvial well (BLM-57) was installed at the southwest edge of the northern lagoon. A secondary containment berm surrounds the northern lagoon and was also suspected to contain hydrocarbon residues. Two alluvial wells (BLM-56 and BLM-58) were installed at the southwest edge of the secondary containment berm. However, hydrocarbon residue in the soils were not revealed during the drilling of these two wells located within the secondary berm area. Bedrock wells were not installed in the areas of the former liquid waste lagoons to prevent any potential cross-contamination of the bedrock aquifer. One bedrock well (BLM-53) was installed approximately 150 ft east-southeast and cross gradient from BLM-56 and BLM-58 to sample the bedrock aquifer but not induce potential contaminant migration. One bedrock well (BLM-54) and one alluvial well (BLM-55) were installed approximately 50 ft south of the southern edge of the southern lagoon. No evidence of contaminant migration in the form of stained soils or elevated air monitoring instrument readings was detected in the alluvial sediments during the drilling of the well borehole for BLM-54, so consequently, the bedrock was cored and a bedrock monitoring well was installed.

In addition, one well cluster (BLM-50, BLM-51, and BLM-52) was placed in a bedrock channel determined by a preliminary top-of-bedrock contour map (Plate 2). Additional wells were located at data gaps determined from previous monitoring well investigations conducted by the BLM and others.

Hydrocone groundwater sampling data confirmed the existence of low-level contamination within the alluvial aquifer that lies below the southern portion of the unnamed arroyo located south of U.S. 64 and west of the San Juan County Fairgrounds (Plate 1). Alluvial well BLM-65 was installed downgradient from the contaminated hydrocone wellpoint. Alluvial well BLM-66 was installed approximately 2,000 ft southwest of BLM-65 to determine if contamination has migrated in the unnamed arroyo channel past BLM-65 to the San Juan River.

After the initial stage of the RI was completed in March 1990 and the data were reviewed and analyzed, it was determined that additional monitoring wells south of the former landfill were required. The RI Briefing Document, issued in January 1991 (WESTON 1991), summarized the findings of the initial stage of the RI. Identification of an area of contamination around Giant-Bloomfield Refinery monitoring wells GBR-32, GBR-48, and GBR-49 resulted in the need to define its southernmost extent between monitoring well GBR-49 and monitoring well GBR-17 (Plate 1). Based on the recommendations presented in the RI Briefing Document, 13 additional monitoring wells, BLM-67 through BLM-79, were installed in April and May 1991 (Plate 1). Of the 13 additional monitoring wells, four wells, BLM-74 through BLM-77, were installed as 5-inch-diameter wells in order to serve in the future as pumping wells if remedial action is determined to be necessary. Bedrock wells were not installed during the second stage of the RI.

2.7.2. Well Completion

WESTON's Southwest Operations SOPs (WESTON 1988a) were followed while performing soil sampling, monitoring well installation, well development, chemical analyses, and data compilation. The SAPP (WESTON 1990d) outlines the general field investigation methods and presents the RI work plan with respect to monitoring well installation. As stated in the SAPP, the drilling methods used were hollow-stem auger and conventional air rotary techniques. A Failing F-10 drill rig was used to advance augers through artificial fill and alluvial sediments to the top of bedrock. An air rotary technique was used to core the bedrock to the approximate well depth with the augers acting as a temporary surface casing. The drilling fluid consisted of air misted with water, and no additives were used during rotary coring. The air supply was filtered to remove any organic materials, and the recirculated water was contained within a lined sump.

During drilling operations, vapor concentration monitoring, decontamination of well materials and equipment, and disposal of soil cutting were conducted as presented in the discussion of soil boring methodologies in Appendix H. A summary of the type and quantity of vapors encountered during drilling operations is presented in subsection 5.5.

The monitoring wells were installed in clusters, usually consisting of one shallow alluvial well, one deep alluvial well, and one bedrock well as described in subsection 5.3.9 of the SAPP. Figure 2-23 illustrates the typical well cluster design for shallow alluvial, deep alluvial, and bedrock wells. Within each cluster, the shallow alluvial well was installed so that the upper 3 ft of the well screen extended above the water table. The deep alluvial well was installed so that the bottom of the well screen was located flush with the alluvium/bedrock contact. The bedrock well in each cluster was installed so that the screened interval spanned the top of the first saturated bedrock zone. Each well cluster configuration was designed with respect to the inferred hydrologic gradient; the deep alluvial well was located downgradient of the shallow alluvial well, and the bedrock well was located downgradient of the deep alluvial well. This was done to prevent grout contamination between wells during well completion.

In certain locations of the study area, the alluvium was dry and, consequently, only bedrock monitoring wells were installed. These wells are BLM-35, BLM-53, BLM-61, BLM-63, and BLM-64 (Plate 1). In some cases, the saturated thickness of the alluvial aquifer was less than the length of the well screen and, therefore, only one shallow alluvial well was required to span the alluvial aquifer. These wells are BLM-39, BLM-55, BLM-57, BLM-60, BLM-62, BLM-65, BLM-66, BLM-68 through BLM-74, BLM-76, and BLM-77.

The three monitoring wells in each well cluster were installed approximately 10 ft apart. The bedrock well was drilled and installed first, with geochemical and geotechnical samples collected at prescribed intervals as described in subsection 2.7.3. The two alluvial wells were subsequently drilled and installed using the hollow-stem augers, without geochemical or geotechnical sampling. In cases where a bedrock monitoring well was not installed within the well cluster, geochemical and geotechnical samples were collected at prescribed intervals from the deep alluvial borehole.

The subsurface lithologies of all borings were visually described and recorded as specified in SOP 5.1 (WESTON 1988a). In locations where a bedrock monitoring well was not installed, the subsurface lithology of the deep alluvial well was visually described and recorded. The bedrock core was placed in core boxes, then labeled with the well borehole number, date, depth of sample interval, property location, the words "Roy F. Weston," and the initials of the geologist logging and recording the core data. The core was photographed prior to its delivery to the BLM Farmington Resource Area Office warehouse. Core photographs are archived in WESTON's document control files. Lithology of the soils and bedrock is discussed in subsection 4.1.

The monitoring wells were completed as described in subsection 5.3.9 of the SAPP. Figures 2-24 and 2-25 illustrate the well completion used. Sixty monitoring wells, (BLM-14 through BLM-73), were completed using 2-inch-diameter, 316-L stainless steel, flush-threaded, blank casing and a 10-ft length of 0.010-inch wire-wrap screen. Four monitoring wells, BLM-74 through BLM-77, were completed as 5-inch wells using 5-inch-diameter, 316-L stainless steel, flush-threaded, blank casing and a 10-ft length of 0.010-inch wire-wrap screen. Table 2-15 presents the monitoring well completion information for the 64 BLM monitoring wells. Well logs are presented in Appendix L.

Once the grout seal had set for a minimum of 24 hours, newly installed wells were developed to remove natural aquifer fines and drill cuttings from the well screen and sand pack. Well development was performed as described in subsection 5.3.10 of the SAPP and according to SOP 4.4. Conductivity and pH readings were recorded throughout the development process. Stabilization of these measurement readings was used as an additional indication that development was complete. Once the development process was complete, water level measurements were taken in each new well (subsection 5.3.11 of the SAPP).

2.7.3. Analytical Program

The analytical program for soil samples collected during monitoring well installation consisted of two types of analyses: geochemical and geotechnical. During the drilling of all bedrock and some deep alluvial well boreholes, soil samples were collected for geochemical analysis. However, the frequency of sample collection for geochemical analysis varied during the RI. For the initial stage of the RI, in accordance with Section 6 of the SAPP, samples from monitoring wells BLM-39 through BLM-66 were collected from 2 to 5 ft below the surface at the start of each borehole and at subsequent 5- to 10-ft intervals within alluvial sediments, depending on the desired precision of vertical characterization within the vadose zone. Additional geochemical samples were collected from specific depths in the following cases: 1) where positive readings were obtained from monitoring instruments during screening of the core; 2) where some visual indication of soil contamination (staining, residues, or waste) was recognized; and 3) at the top of the zone of saturation of the alluvial aquifer.

For the second stage of the RI conducted in 1991, in accordance with the RI Briefing Document (WESTON 1991), samples from monitoring wells BLM-67 through BLM-77 were collected only at the top of the zone of saturation of the alluvial aquifer. Soil samples were not collected from BLM-78 and BLM-79 as they are the shallow alluvial wells adjacent to BLM-67 and BLM-75, respectively.

The analytical program for soil samples collected from the well boreholes used the standard analytical procedures established by the EPA SW-846 (EPA 1986b) and the EPA CLP. Samples were labeled, packaged and shipped according to SOPs 1.3 and 1.5. Table 2-16 provides a summary of geochemical sample information, including well ID, sample date, analysis requested, laboratory analytical batch number, and chain-of-custody ID.

For the initial stage of the RI (monitoring wells BLM-39 through BLM-66), soil samples were analyzed for VOCs (EPA Methods 8010 and 8020), semivolatile organic compounds (EPA Method 8270), pesticides/PCBs (EPA Method 8080), and metals (EP Toxicity). In cases where the sample recovery was limited, the available sample material was selected for VOC analysis only. WESTON's laboratory in Stockton, California, performed the analyses. For the second stage of the RI (BLM-67 through BLM-79), soil samples were analyzed for VOCs (EPA Methods 8010 and 8020), metals (TCLP), chloride and sulfate. WESTON's laboratory in Lionville, Pennsylvania performed the 1991 analyses. Soil sample analytical results above detection are provided in Appendix I-1. Data interpretation is presented in Section 5.

Geotechnical samples were also collected during drilling. Thirteen geotechnical samples were collected from six wells, BLM-50, BLM-51, BLM-61, BLM-68, BLM-71, and BLM-76. These samples were subjected to tests to determine grain size distribution, *in situ* density, saturated permeability, and percent organic carbon. Sampling and test methods for the geotechnical samples are presented in subsection 2.4 and Appendix J.

2.7.4. QA/QC Requirements and Results

The QA/QC requirements for the soil samples collected during the drilling of the monitoring wells are the same requirements for soil borings presented in subsection 2.4.3. Field QA/QC requirements include one duplicate sample and one equipment rinsate sample for every ten samples collected, and a set of trip blanks for each shipment of VOC samples.

The analytical laboratories used for the RI geochemical analyses follow CLP protocol. The CLP QA/QC requirements are summarized in subsection 2.4.3. The evaluation of the monitoring well soil analytical results for possible laboratory contamination was performed as described in subsection 2.4.3. Appendix I-1 presents all analytical results, except for the nondetections. Included with the results are those compounds identified as present in the laboratory blank. Appendix I-2 presents the lab blank evaluation.

2.8. HYDROGEOLOGIC INVESTIGATION

To analyze data relating to the distribution and movement of contaminants in the subsurface, or to predict future aquifer conditions at the former Lee Acres Landfill, it is necessary to obtain a working knowledge of the local hydrogeology. A working knowledge is generally defined as knowledge of the physical properties and three-dimensional characteristics of water-bearing geologic units; the locations of recharge and discharge zones; the piezometric surfaces for each hydrogeologic unit; seasonal or long-term fluctuations in water levels; groundwater velocity and flow properties; and aquifer characteristics. The culmination of these items is an assessment of the ability of aquifer systems at the Lee Acres Landfill Study Area to transmit and store water.

Subsection 4.2 presents the overall hydrogeologic characterization of the Lee Acres Landfill Study Area by integrating and comparing a number of data sets. This section outlines RI data and past data sets, activities, and strategies that are used to present the hydrogeologic characterization. Presented below is a discussion of the data and strategy used to evaluate various hydrogeologic properties at the Lee Acres Landfill Study Area.

2.8.1. Groundwater Occurrence

Groundwater occurrence at the Lee Acres Landfill Study Area is generally defined by two aquifers, the uppermost alluvial aquifer in the unnamed arroyo and the lower bedrock aquifer. The unconfined alluvial aquifer system is found in the unnamed arroyo and is bounded by bedrock on both sides of the arroyo channel. The bedrock aquifer consists of a poorly sorted gray sandstone that is partially confined below the arroyo alluvium by a discontinuous shale unit. Depth from ground surface to the water table in the alluvial aquifer varies from approximately 30 to 40 ft. Depth from ground surface to the bedrock aquifer piezometric surface varies from approximately 25 to 40 ft.

The primary data set that helps define the lateral and vertical extent of groundwater at the study area consists of water level elevation data collected from the groundwater monitoring well network during sampling events. The most recent events are the most valuable because they include wells drilled during the latest phases of drilling completed in May 1991. CPTs performed during December 1989 and January 1990 allowed the delineation of areas where alluvial groundwater does and does not occur, and subsequent well locations were based on CPT results.

The piezometric surface contour maps presented in subsection 4.2 for the alluvial and bedrock aquifers were developed from water elevation data collected during RI groundwater sampling events. These maps illustrate the lateral distribution of groundwater at the Lee Acres Landfill Study Area, and represent the most comprehensive site coverage. The cross sections presented in subsection 4.1 were developed from well logs, borehole logs, geophysical data, and the water elevation data for the sampling event described above. These sections illustrate the vertical distribution of groundwater at the former Lee Acres Landfill.

2.8.2. Hydrostratigraphy

Subsection 4.2 discusses hydrostratigraphic relationships found at the Lee Acres Landfill Study Area. The discussion is based on interpretation of geologic logs and a comparison of hydrographs for selected wells completed in the alluvial and bedrock aquifers. Confinement of the bedrock aquifer is discontinuous. In some locations along the unnamed arroyo, the lower bedrock aquifer is hydraulically connected to the alluvial system, and no upward or downward hydraulic gradient is apparent. In other locations along the arroyo, an upward gradient is observed, suggesting that the bedrock aquifer recharges the alluvial system.

Subsection 4.2 also provides an assessment of hydrostratigraphic relationships and the distribution of upward and downward gradients within the alluvial aquifer, and between the alluvial aquifer and the underlying bedrock aquifer. Well hydrographs, water-elevation contours, and geologic cross sections are used to establish vertical gradients and identify areas of hydraulic connection between aquifers.

2.8.3. Groundwater Movement

Groundwater in the alluvial aquifer system is controlled by the unnamed arroyo bedrock channel and moves south from the former landfill toward the San Juan River (Plate 1). Flow in the bedrock aquifer is generally to the southwest and is controlled by regional gradient and topography. Subsection 4.2 uses piezometric surface contours, a bedrock topographic contour map, and geologic cross sections to define flow pattern and direction for both aquifer systems. Flow velocities are estimated using hydraulic conductivities calculated from aquifer and slug tests conducted adjacent to and south of the former Lee Acres Landfill in both the alluvial and bedrock aquifer systems. Horizontal gradients are calculated using water elevation data collected during past groundwater sampling events.

2.8.4. Aquifer Characteristics

Geoscience Consultants, Ltd., conducted three aquifer tests in the alluvial aquifer south of the former Lee Acres Landfill on Giant-Bloomfield Refinery property in 1986 for Giant. Based on these tests, an average transmissivity of 1,690 gallons per day per foot (gpd/ft) was used to characterize the unconfined alluvial aquifer system (GCL 1988). WESTON conducted a series of slug tests in 11 wells in December 1987, in 6 wells in March 1990, and in 11 wells in June 1991. In subsection 4.2, these data are integrated and compared to establish a range of hydraulic conductivity and transmissivity values that can be used to characterize the alluvial and bedrock aquifer or to simulate future groundwater conditions at the Lee Acres Landfill Study Area.

Physical characteristics of subsurface materials are estimated from geotechnical test data collected from a number of core samples during the RI. Core samples were retrieved from boreholes, sealed with wax, and transported to Chen-Northern, Inc., in Denver for analysis. Subsection 4.1.7 presents a summary of grain-size analysis, permeability, porosity, specific gravity, bulk density, and moisture content data for materials.

2.9. GROUNDWATER MONITORING PROGRAM

RI groundwater monitoring well locations were selected to characterize impacts from suspected contaminant sources and to establish upgradient background groundwater quality (Plate 1). Subsection 2.7.1 and Table 2-14 present rationale for well placement. At most locations, monitoring well clusters consisting of three wells and using 10-ft screens were constructed. Three-well clusters were constructed where the saturated alluvial interval exceeded 8 ft in thickness. In such cases, one alluvial well was screened so that the middle of the screen intersected the top of the alluvial water table, another alluvial well was screened from the bedrock/alluvium contact, and the third well was screened at the top of the first bedrock saturated zone. If the saturated alluvial thickness was less than 8 ft thick, a two-well cluster was constructed. In this case, the alluvial well was screened over the entire saturated thickness, extending across the water table. If the alluvium was dry, only a bedrock well was installed. Typical well construction design for the three types of wells is presented in subsection 2.7. Monitoring wells were constructed in clusters to enable characterization of the top and bottom of the alluvial aquifer and the bedrock aquifer.

The RI groundwater monitoring program activities and technical rationale, analytical program strategy, and QA/QC requirements are presented in the following subsections. Appendix M presents the groundwater monitoring program according to sampling event. Analytical results for the RI groundwater monitoring program are presented in Appendix N-1. A discussion of these results is presented in Section 6, where the horizontal and vertical extent of groundwater contamination migrating from the former Lee Acres Landfill is discussed.

2.9.1. Activity Description and Technical Rationale

The RI groundwater monitoring program began in 1989 and consisted of 11 total sampling events with four events in 1989 (February, May, September, and December) and four events in 1990 (February/March, April, May, and August), and concluded with three events in 1991 (May, June, and July). The analytical program strategy for the program is described in subsection 2.9.2. The wells included in each of the groundwater monitoring program sampling events are presented in Appendix M and are described below.

The wells sampled during 1989 included the 19 PI wells (BLM-14 through BLM-32) and the wells installed during the Accelerated Program (BLM-33 through BLM-35, and BLM-37). In mid-1989, Giant-Bloomfield Refinery installed two monitoring wells south of U.S. 64 (SHS-1 and SHS-2) in response to the contamination and petroleum product found in BLM-37. Wells SHS-1 and SHS-2 were sampled as part of the RI groundwater monitoring program in September and December 1989.

The wells sampled during 1990 included the PI wells, the Accelerated Program wells, and the newly installed RI wells (BLM-39 through BLM-66). Giant-Bloomfield Refinery monitoring wells GBR-48 through GBR-50, GBR-32, and GBR-18 were also added to the RI groundwater monitoring program in 1990. Wells GBR-48 through GBR-50, (Plate 1), were installed during 1989 by Giant-Bloomfield Refinery and were found to have detectable concentrations of chlorinated solvents. Previous groundwater analytical results for GBR-32, collected by Giant-Bloomfield Refinery, also indicated concentrations of chlorinated solvents. Wells GBR-32, and GBR-48 through GBR-50 are located immediately south of the Lee Acres Landfill fence line, and therefore, were added to the RI groundwater monitoring program in order to characterize the contamination in the area south of the former landfill. GBR-18 is a bedrock monitoring well located east of the former firewater storage ponds (Plate 1) and was added to the groundwater monitoring program to determine whether contamination was migrating from the ponds.

During the August 1990 sampling event, GBR-17 was added to the RI groundwater monitoring program to define the southern extent of any contaminant migration before it reached known contaminated wells on Giant-Bloomfield Refinery property.

The second stage of the RI included the installation of 13 additional monitoring wells in April and May 1991. Sampling of the 13 new wells (BLM-67 through BLM-79), a subset of the existing BLM wells, and Giant-Bloomfield Refinery wells GBR-17, GBR-32, and GBR-48 through GBR-50 was conducted during May, June, and July 1991. The groundwater monitoring program for 1991 is described in Section 5 of the RI Briefing Document (WESTON 1991). All monitoring wells existing prior to 1991 had been sampled at least four times. Therefore, during 1991, only shallow and deep alluvial wells north of U.S. 64, and selected bedrock wells BLM-61, BLM-63, and BLM-64 were sampled. The bedrock well BLM-47 was sampled in May 1991 for confirmation of pesticides that were detected in the April 1990 sample. Alluvial wells BLM-65, and BLM-66, located south of U.S. 64 (Plate 1), were sampled in May 1991 to provide additional information concerning contamination downgradient of the known plume migrating from the former Giant-Bloomfield Refinery. Bedrock wells BLM-33 and BLM-59 were added to the groundwater monitoring program in July 1991 to determine whether contamination has impacted the bedrock aquifer.

The wells sampled for each sampling event, the geochemical analyses performed, the laboratory analytical batch number, and the chain-of-custody ID are presented in Appendix M. Groundwater analytical results above detection are presented in Appendix N-1, and the groundwater characterization based on these results is presented in Section 6.

Groundwater sampling protocols are presented in subsection 5.3.12 of the SAPP. WESTON's SOPs were followed for conducting all activities associated with the collection of groundwater samples from monitoring wells. These activities include presample purging of wells (SOP 2.1); field measurements (SOP

2.2); sampling with bailers, bladders or submersible pumps (SOPs 2.3 through 2.5); sample control and documentation (SOP 1.3); sample containers and preservation (SOP 1.4); sample handling, packaging, and shipping (SOP 1.5); and equipment decontamination (SOP 1.6). All sampling equipment was decontaminated between each well, and as an additional precaution against cross contamination, well sampling progressed from wells considered to be least contaminated to those most contaminated.

The actual sampling method varied slightly for the 1991 sampling events. A Grundfos 2-inch diameter stainless steel submersible pump was used for sample collection. Previous sampling events used a bladder pump, a Teflon bailer or a stainless steel bailer for sample collection. During the May 1991 sampling event, samples from the five GBR wells were collected by bailer. In June 1991, samples from the five GBR wells and BLM-68 were collected by both bailer and submersible pump. In July 1991, samples from the five GBR wells and six of the 1991 wells, BLM-68, BLM-70, BLM-73, BLM-74, BLM-76, and BLM-77, were also collected by both bailer and submersible pump. The six BLM wells were selected because, of the new wells, they were the only ones with positive VOC results. Previously existing BLM wells were not sampled by both collection methods because data from previous sampling events were sufficient to determine the existence of contamination. Table 2-17 presents the analytical data collected during 1991 for those wells that were sampled by both bailer and submersible pump. Samples collected by bailer are identified with a sample ID of 1111. Samples collected by submersible pump are identified with a sample ID of 0001. In most cases, sample collection by pump resulted in a higher concentration of VOCs compared to those samples collected by bailer. Therefore, it is concluded that the submersible pump did not cause the organics to volatilize and this method of sample collection resulted in data that were acceptable for comparison with previous data sets.

2.9.2. Analytical Program Strategy

This section presents the technical objectives and regulatory strategy for selection of particular chemical-specific analytical methods developed for the RI. Appropriate analytical strategy was chosen based on technical data requirements, DQOs, desired detection limits, and known or suspected contaminants of concern. The RI program used CLP QA/QC and analytical requirements except where substituted for standard EPA VOC analytical methods (8010 and 8020). This substitution was made to enable lower analytical detection limits to be attained for this group of compounds. EPA Methods 8010 and 8020 are the recommended methods, as specified in "Test Methods for Evaluating Solid Waste (SW-846)" (EPA 1986b), for VOC analytical testing activities under Subtitle C of RCRA, and are also applicable under CERCLA/SARA. The CLP-specified method for conducting VOC analyses is EPA Method 8240. EPA Method 8240 is performed using gas chromatography/mass spectrometry (GC/MS), whereas 8010 and 8020 are GC methods. In general, the difference between GC and GC/MS analytical methods is that GC methods are compound-specific and detection limits are low. In contrast, GC/MS methods screen for a large variety of chemicals, but detection limits are higher. EPA Method 8240 has detection limits that exceed SDWA MCLs in many cases. Based on groundwater data collected during the PI, the suspected contaminants of concern were relatively known (WESTON 1990d). Much of past groundwater samples collected at the study area were analyzed with GC/MS methods. This fact, and the value in obtaining lower detection limits resulted in the decision to use GC methods for VOCs during the RI. A more detailed discussion on rationale for selection of GC versus GC/MS for the RI methods is presented in Section 4 of the SAPP (WESTON 1990d).

All samples collected during the RI were analyzed for selected parameters in accordance with the procedures established by EPA SW-846 (EPA 1986b) and the EPA CLP. CLP protocols are designed to provide analytical data of a known level of quality to determine the nature and extent of contamination, perform risk assessments, and select and design remedial actions. Details concerning data reduction, validation, reporting, and electronic data management are presented in the Lee Acres Data Management/Project Management Plan (WESTON 1990a). The various analyses performed during the RI groundwater monitoring program include VOCs (EPA Methods 8010 and 8020), BNA extractables (EPA Method 8270), organochlorine pesticides/PCBs (EPA Method 8080), dissolved metals (as outlined in SW-846 and EPA 1979), general water chemistry parameters (as outlined in SW-846 and EPA 1979), isotopic sulfur, and isotopic strontium. Tables 2-18, 2-19, 2-20, and 2-21 present the analytes that are analyzed and reported for each analytical method listed above. Appendix M presents, by sampling event, the analyses that have been performed for each monitoring well during the Accelerated Program and RI. The RI groundwater monitoring program began upon completion of the Accelerated Program wells in the first quarter of 1989. Analytes from particular wells that were present in concentrations below required CLP reporting levels for two consecutive quarterly sampling periods were dropped from subsequent sampling events.

An occasional deviation from this analytical program was made when Giant-Bloomfield Refinery wells were sampled and Giant-Bloomfield Refinery personnel were given split samples. This was to ensure that similar data were obtained for both split samples. Analytical suites similar to those conducted by Giant-Bloomfield Refinery personnel were selected. The deviations included analyzing the Giant-Bloomfield Refinery wells for total rather than dissolved metals.

In addition to the laboratory analytical protocol described above, a set of field parameters was measured by the monitoring well sampling crew. Parameters measured in the field included pH, redox potential (Eh), specific conductance, alkalinity, and temperature.

2.9.3. QA/QC Requirements and Results

In addition to the investigative samples collected from each well, the following samples were taken to satisfy CLP requirements and to augment the laboratory-prepared spikes and blanks in documenting and ensuring the quality of sample collection, decontamination, and analysis.

- One field duplicate for every 10 samples was analyzed for VOCs and select inorganic compounds.
- One equipment rinsate sample for every 10 samples.
- One trip blank per shipment of VOCs.

Data collected during the field work are managed as presented in the project QA/QC Plan (WESTON 1989c), Data Management/Project Management Plans (WESTON 1990a), and the SAPP for the Lee Acres Landfill (WESTON 1990d). Data management protocols outlined in these plans, such as document preparation, record maintenance, and documentation of field observations were followed. Appendix O presents the QA/QC sample identification and analytical batch number for the QA/QC samples collected during the RI.

Laboratory QA/QC requirements for groundwater analyses follow CLP protocol and are the same requirements presented in subsection 2.4.3 for soil analyses. The CLP QA/QC requirements specify performance on matters that should be fully under a laboratory's control. Noncompliance and corrective actions are documented on the case narrative in the CLP data package. The corrective action for noncompliance is reanalysis; therefore, all data meet QA/QC requirements before being released by the analytical laboratory.

Lab contamination, however, cannot be corrected. As described in subsection 2.4.3, a method blank is an analytical control sample that is carried through the entire analytical procedure. No contaminants should be present in the blanks. However, lab contamination of samples is a common occurrence and data validation procedures were developed by EPA to correct the problem (EPA 1988c). The lab evaluation described in subsection 2.4.3 is also used for the RI groundwater analytical results. For samples with compounds identified as present in the blank, the results are not considered to be a positive detection unless the sample concentration exceeds 5 or 10 times the amount in the laboratory blank, depending on the compound (EPA 1988c). The 10-times rule is used if the compound is one of the five common lab contaminants (dichloromethane, acetone, toluene, 2-butanone or phthalate esters).

If the compound is not one of the common lab contaminants, the 5-times rule is used. The groundwater analytical results are presented in Appendix N-1 and include all results above detection limits and those identified as present in the lab blank. Appendix N-2 presents the lab blank evaluation. Only 25 samples of the 318 samples identified as being lab contaminated are considered to be positive detections.

2.10. SURFACE WATER PROGRAM

A surface water sampling program was planned for the RI if flow in the unnamed arroyo was encountered during RI field activities. However, no surface water flow occurred, and no samples were collected.

In March 1990, surface water samples were obtained from the San Juan River south of the landfill at the approximate confluence of the unnamed arroyo. These samples were analyzed for ions, TDS, isotopic strontium, and isotopic sulfur. The isotopic strontium and sulfur analyses were performed to compare with similar analyses conducted on monitoring well groundwater samples and are described in subsection 6.6. VOAs were not performed on the San Juan River samples due to the type of upstream sources, such as refineries.

2.11. FIRE WATER POND STUDY

Giant-Bloomfield Refinery used fire water ponds to comply with OSHA requirements for fire fighting capabilities. The two fire water ponds were located nearly due east of monitoring well GBR-32, which is contaminated with organic hydrocarbons. Several empty drums and what appeared to be drilling mud residues have been observed within the westernmost fire water pond since it has been dry. On March 26, 1990, a soil/sediment sampling program was conducted in the westernmost fire water pond on Giant-Bloomfield Refinery property (Plate 1) to evaluate whether this feature was once or is now a potential source of contamination.

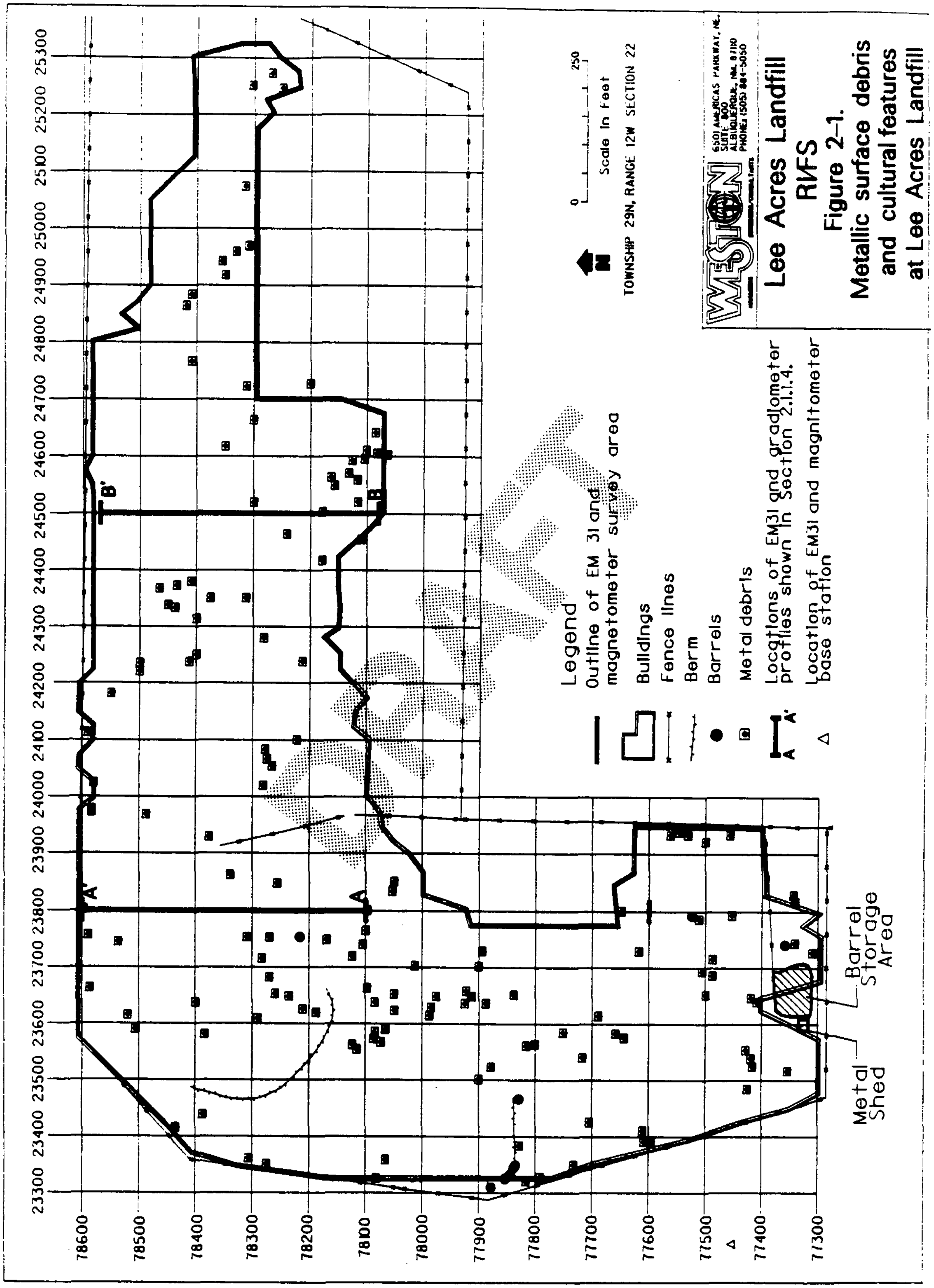
Five soil/sediment shallow subsurface samples were obtained from the bottom of the pond. The samples were obtained from the four corners and the middle of the square pond. Sample locations are shown on Figure 2-26, and sample location details are presented in Table 2-22.

Channel samples along the entire depth of the hole were obtained at each location. The VOC samples were obtained first by forcing soil/sediment directly into the sample container. The soil/sediment in VOC containers was firmly packed to minimize the potential for volatile loss. The remaining samples at each location were obtained by placing equal aliquots from each depth interval into a stainless steel bowl. This material was then homogenized and placed into the appropriate laboratory containers.

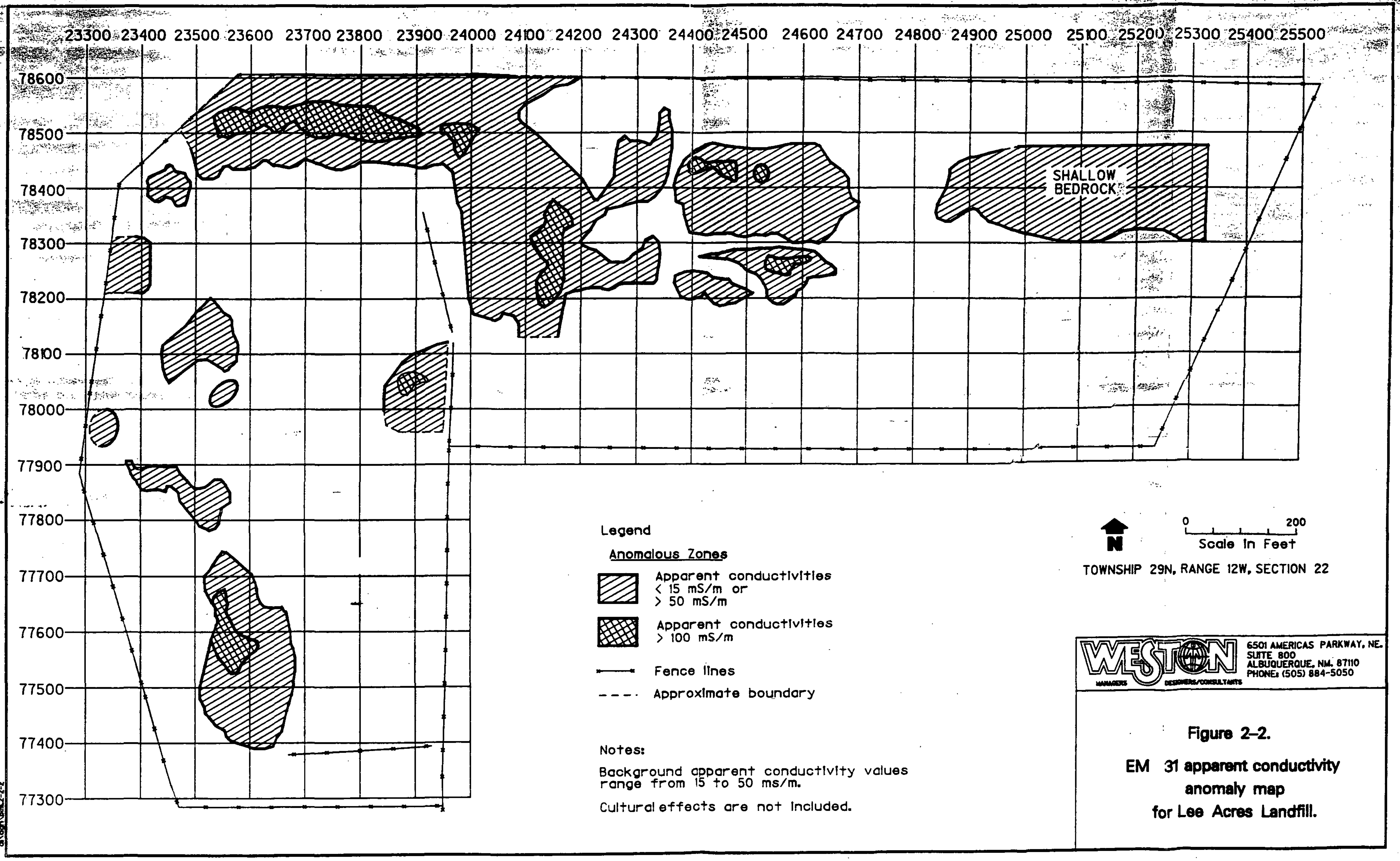
Approximately 4 to 8 inches of very thinly bedded (1-2 mm) brown to gray clay was encountered just beneath the surface in each of the four corners of the fire pond. Silty clay with no discernible laminations was present in the center sample location. The laminated material is thought to represent cyclic periods of clay deposition in the fire pond. Beneath the laminated clay in each of the sampling locations, sandstone bedrock was present less than 1.5 ft below the surface.

Each sample was analyzed for VOCs (EPA Methods 8010 and 8020), semivolatile organic compounds (EPA Method 8270), organochlorine pesticides/PCBs (EPA Method 8080), EP Toxicity metals (silver, arsenic, barium, cadmium, total chromium, mercury, lead, selenium, strontium, and tin), and inorganics (chloride, sulfate) (Table 2-23). Analytical results are presented in Appendix I and summarized below.

Analytical results for the five fire pond sediment samples show no indication that the ponds acted as a primary contaminant source. Samples F001, F003, and F004 contained relatively low levels of xylenes ranging up to 56 μg/kg (Appendix I-1). EP toxicity results show detected levels of strontium and selenium up to 1440 and 212 μg/L, respectively. Neither exceed former EP Toxicity characteristic levels.



Lee Acres Landfill
RI/FS
Figure 2-1.
Metallic surface debris and cultural features at Lee Acres Landfill



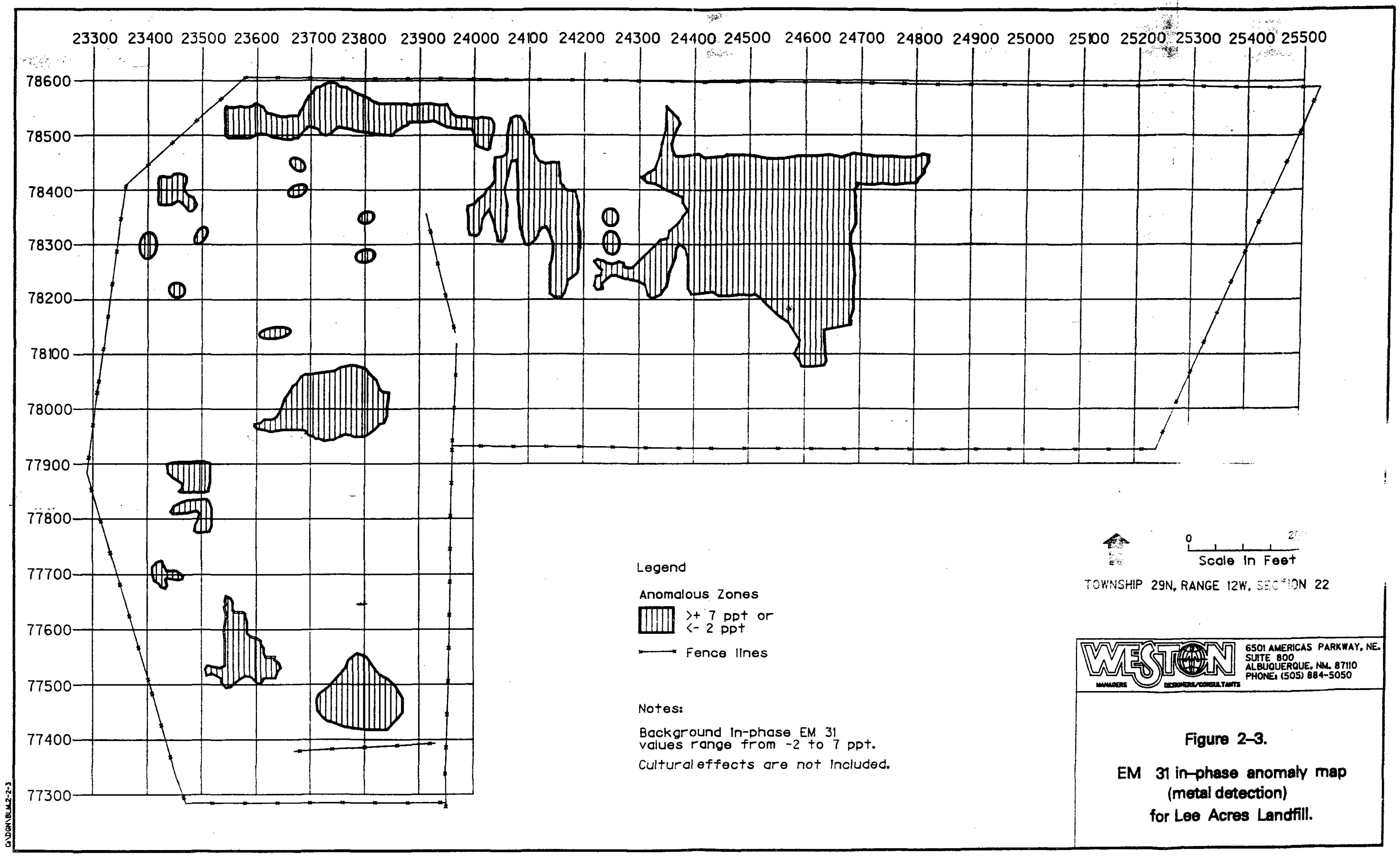
Notes:

Background apparent conductivity values range from 15 to 50 ms/m.

Cultural effects are not included.

Figure 2-2.

EM 31 apparent conductivity anomaly map for Lee Acres Landfill.



Notes:

Background In-phase EM 31 values range from -2 to 7 ppt.

Cultural effects are not included.

Figure 2-3.

EM 31 in-phase anomaly map (metal detection) for Lee Acres Landfill.

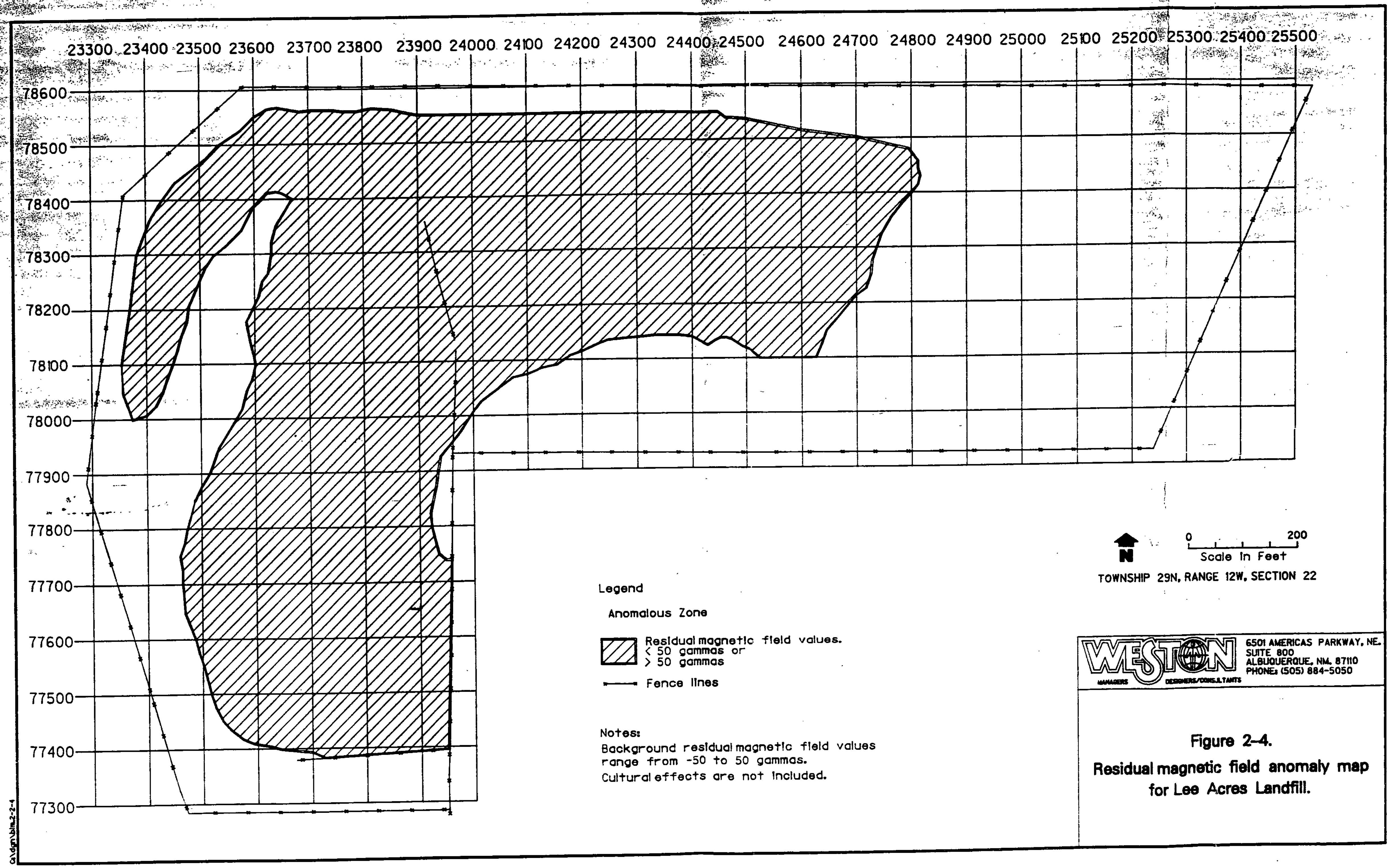


Figure 2-4.

Residual magnetic field anomaly map for Lee Acres Landfill.

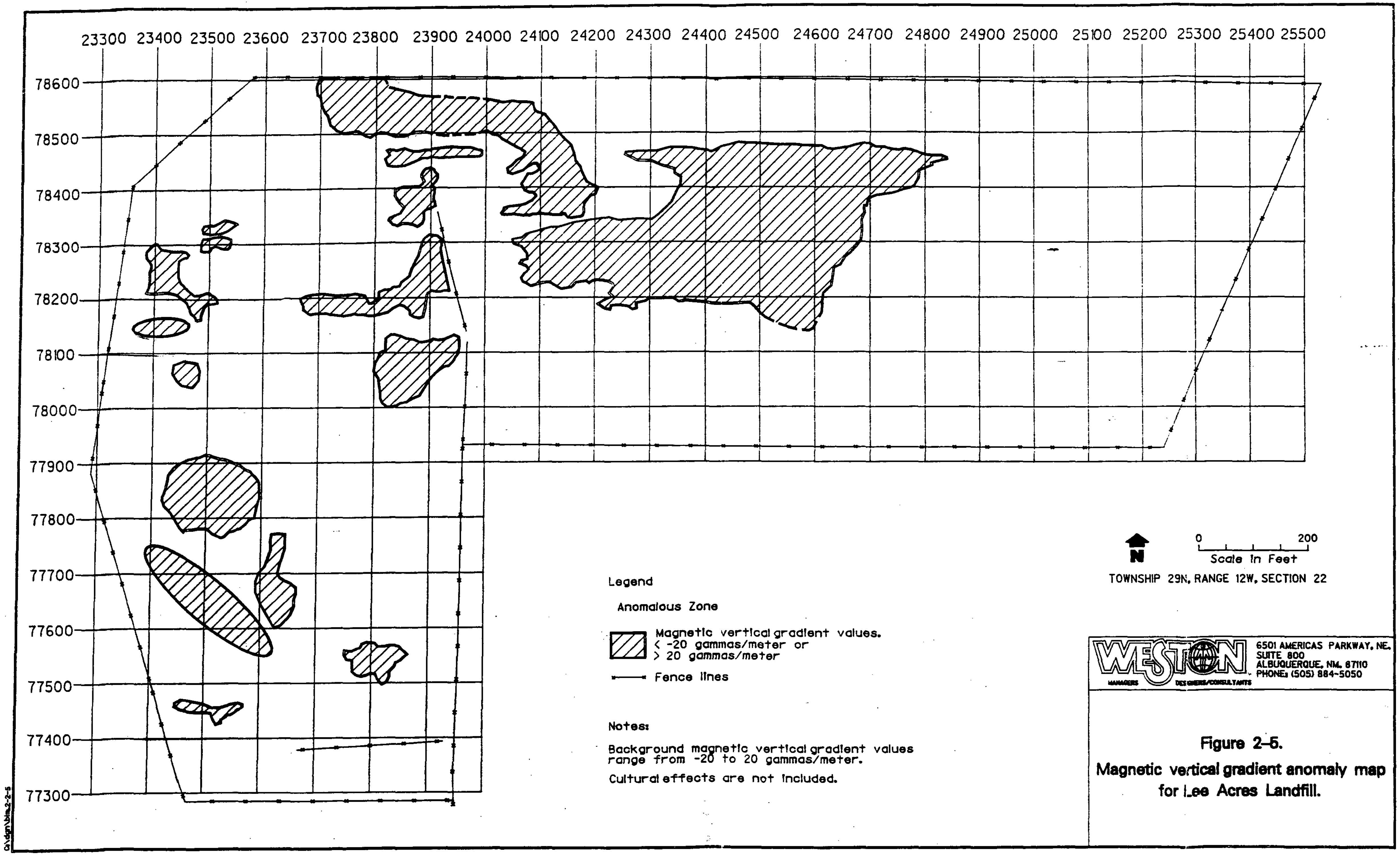


Figure 2–6.
Magnetic vertical gradient anomaly map for Lee Acres Landfill.

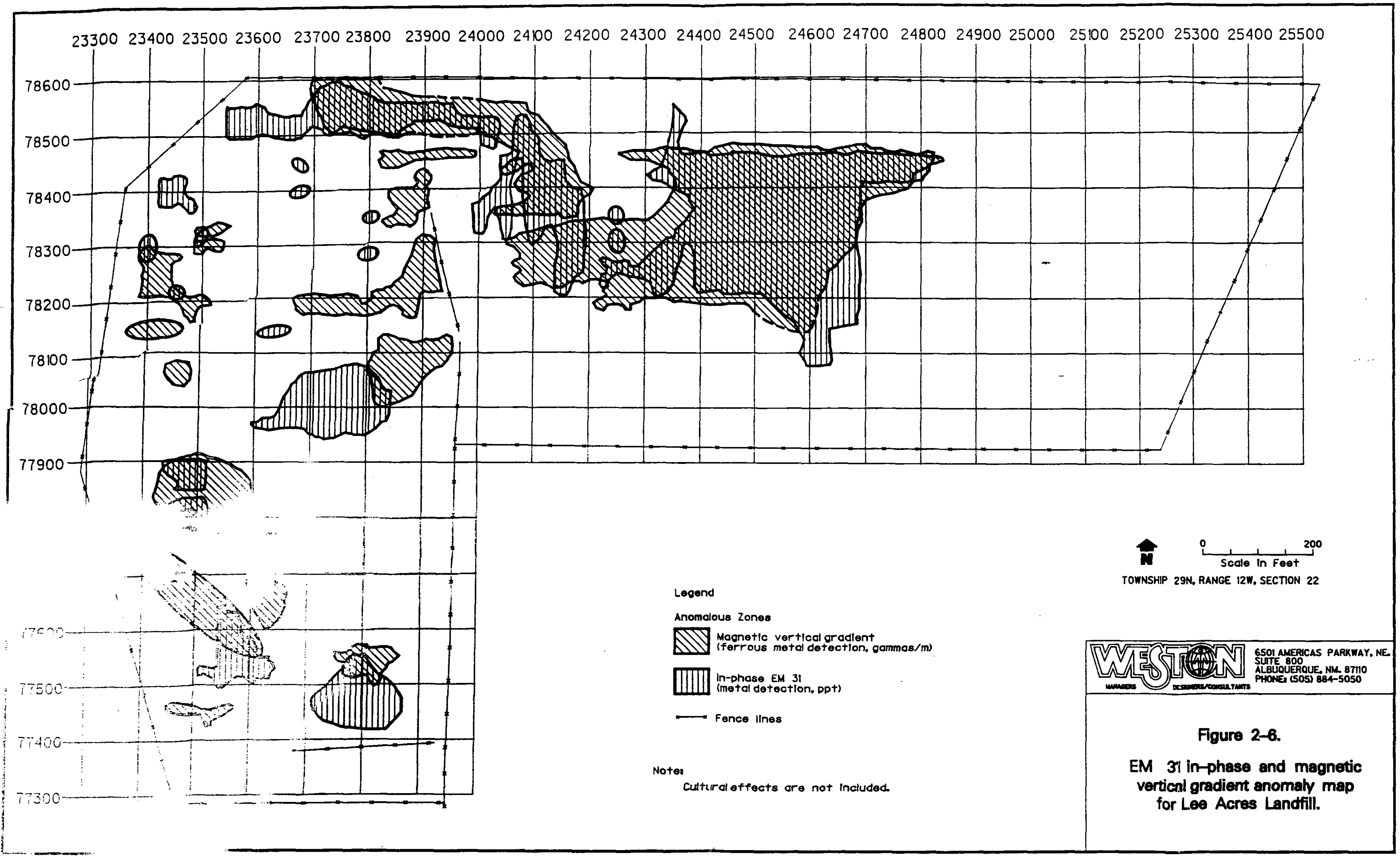


Figure 2-6.

EM 31 in-phase and magnetic vertical gradient anomaly map for Lee Acres Landfill.

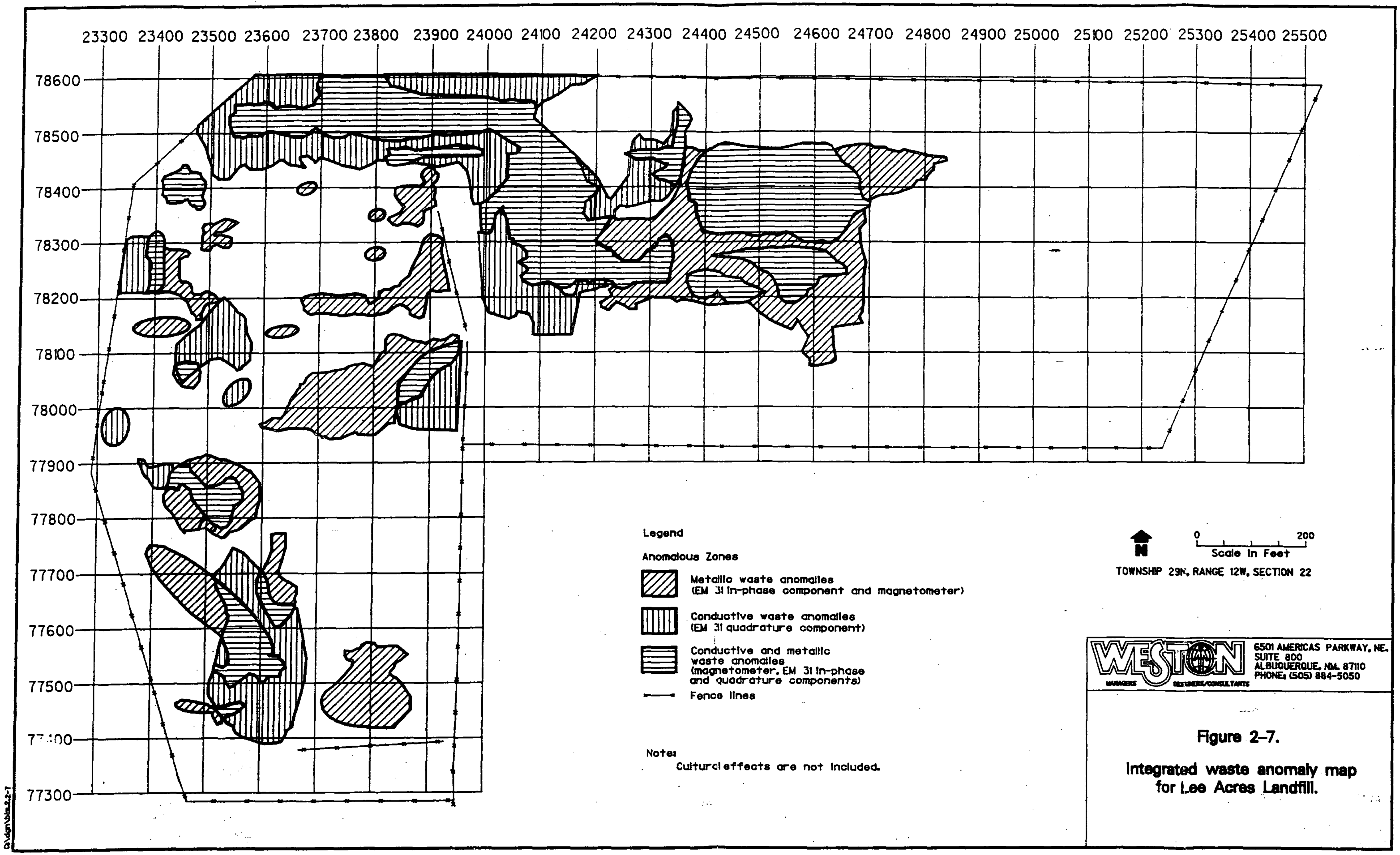
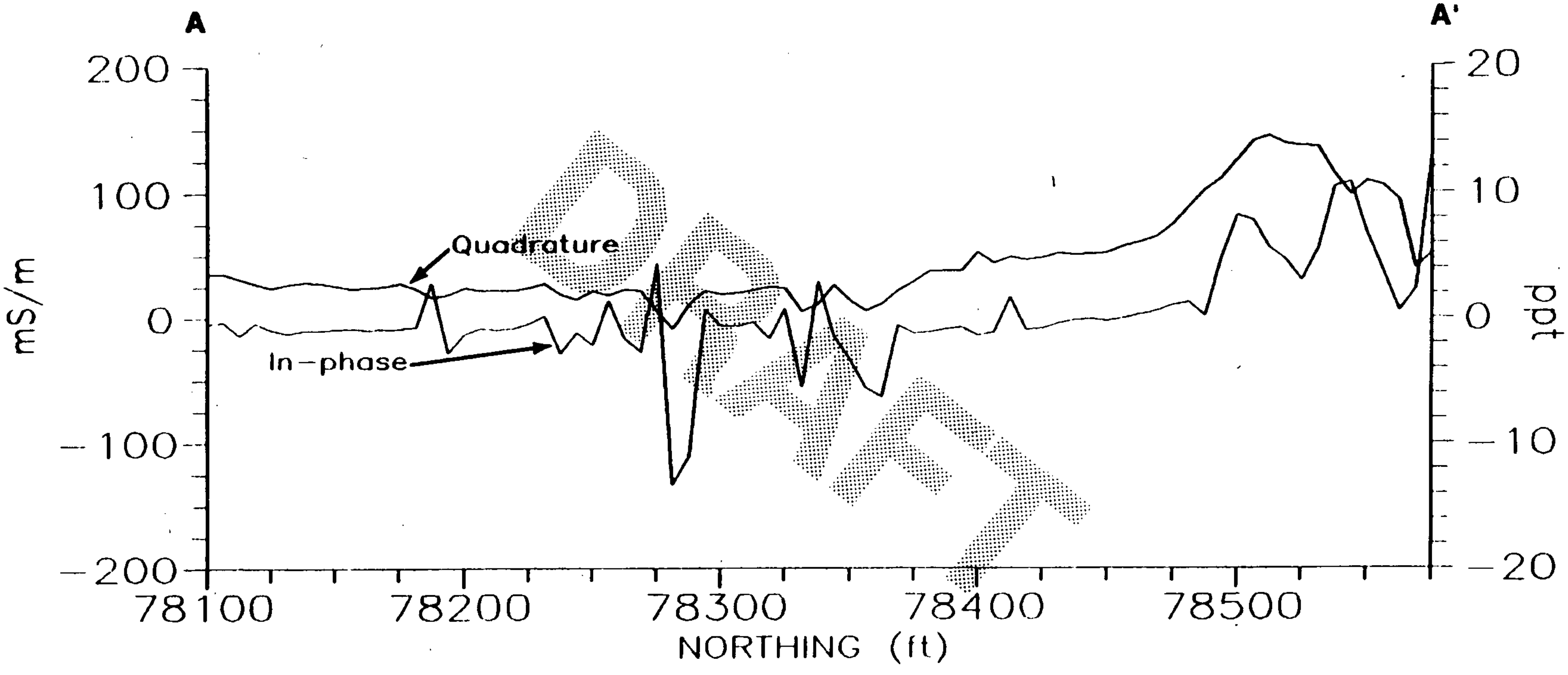


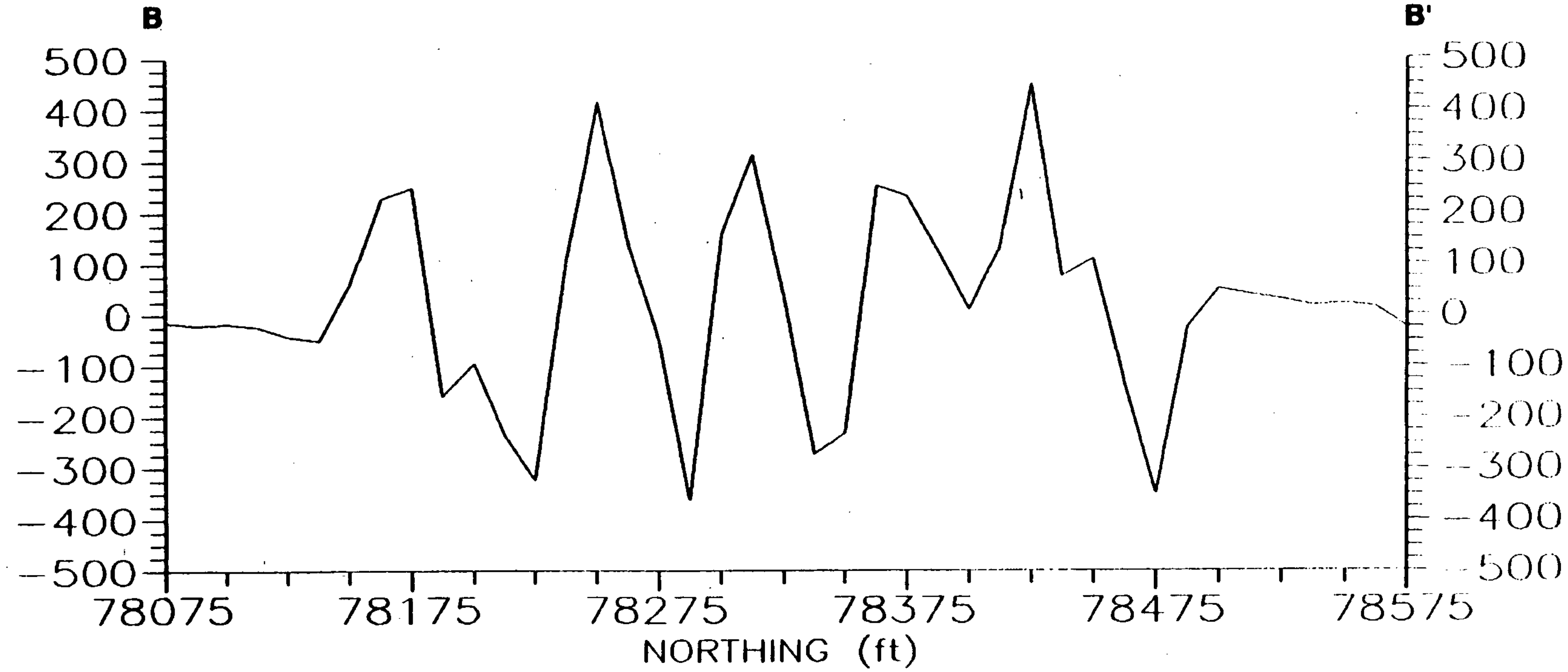
Figure 2-7.

Integrated waste anomaly map for Lee Acres Landfill.



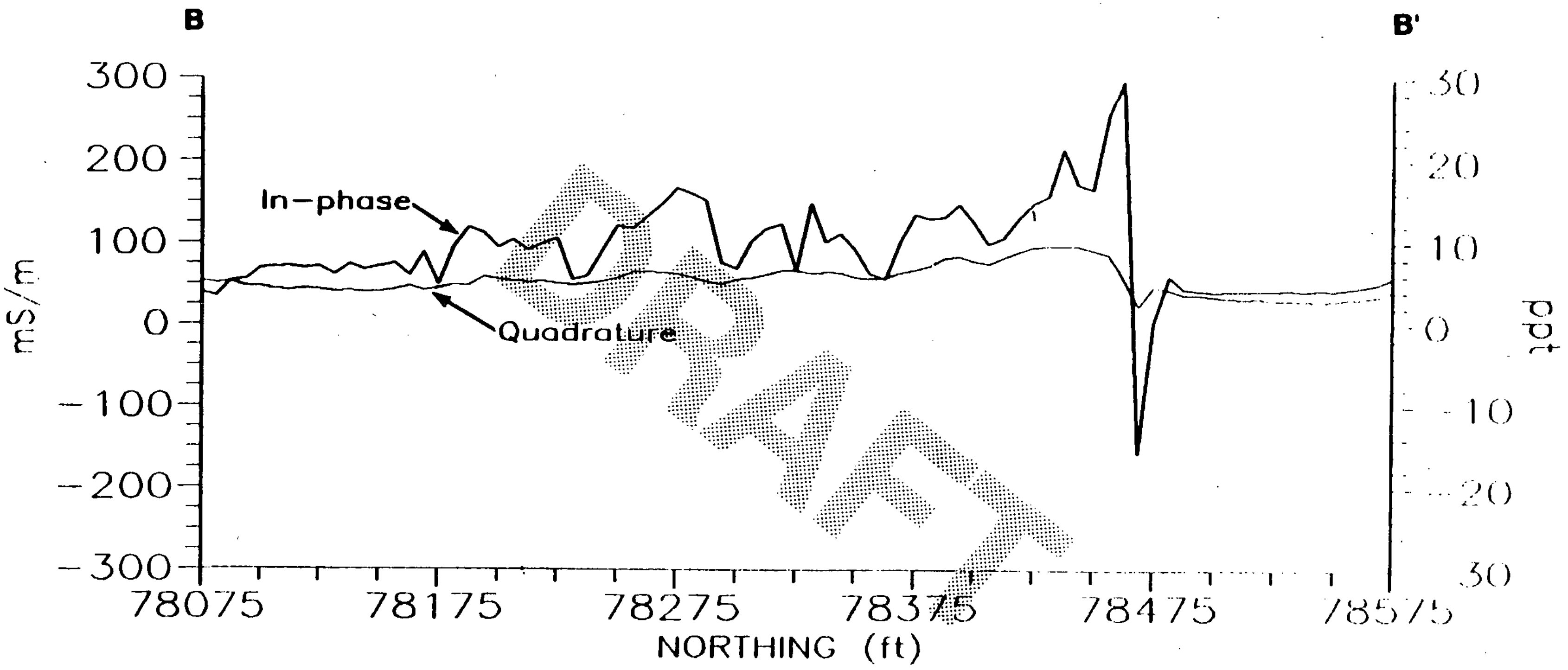
(see Figure 2-1)

Figure 2-8. Quadrature and in-phase EM 31 along line 23800E.



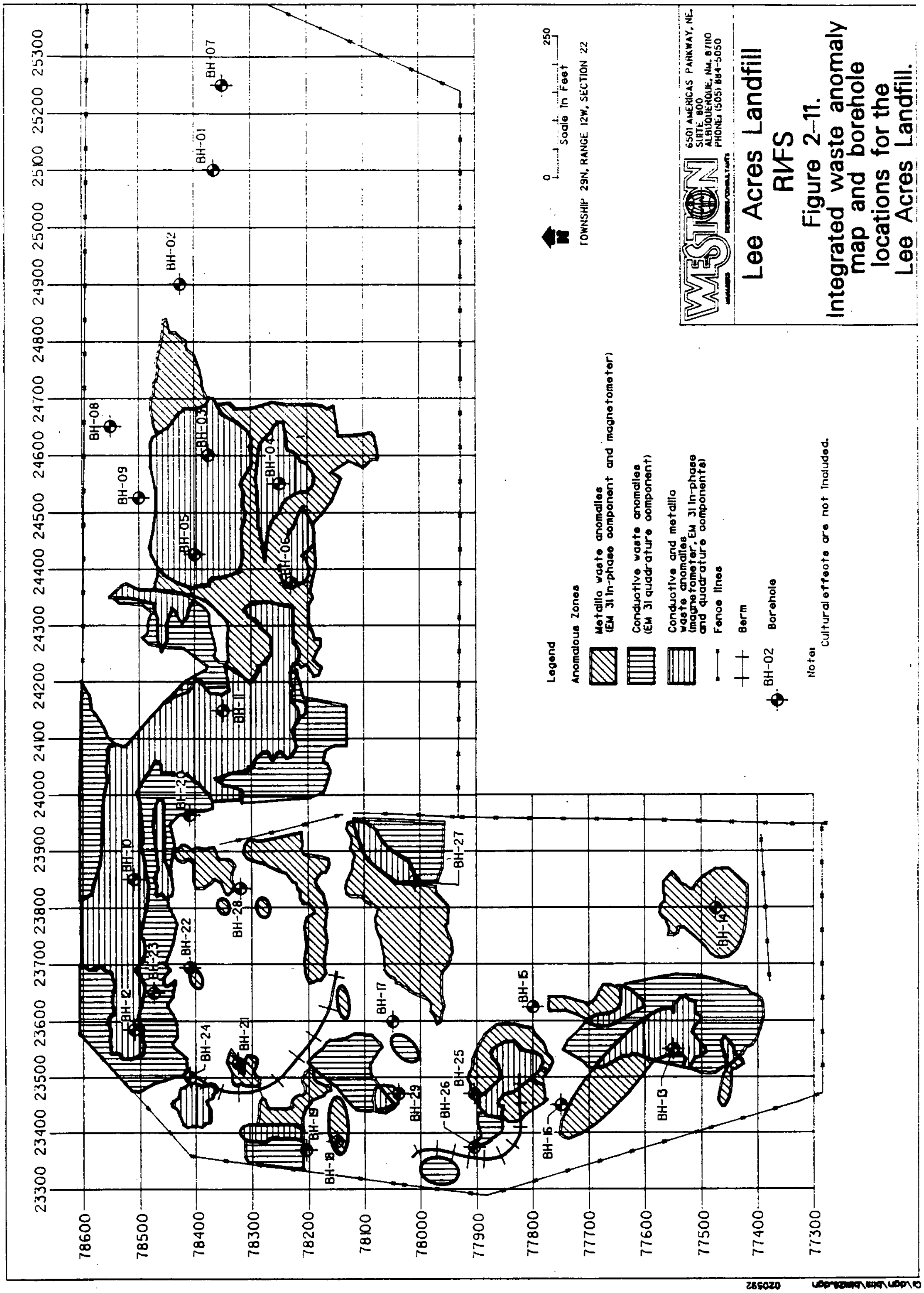
(see Figure 2-1)

Figure 2-9. Magnetic vertical gradient along line 24500E.



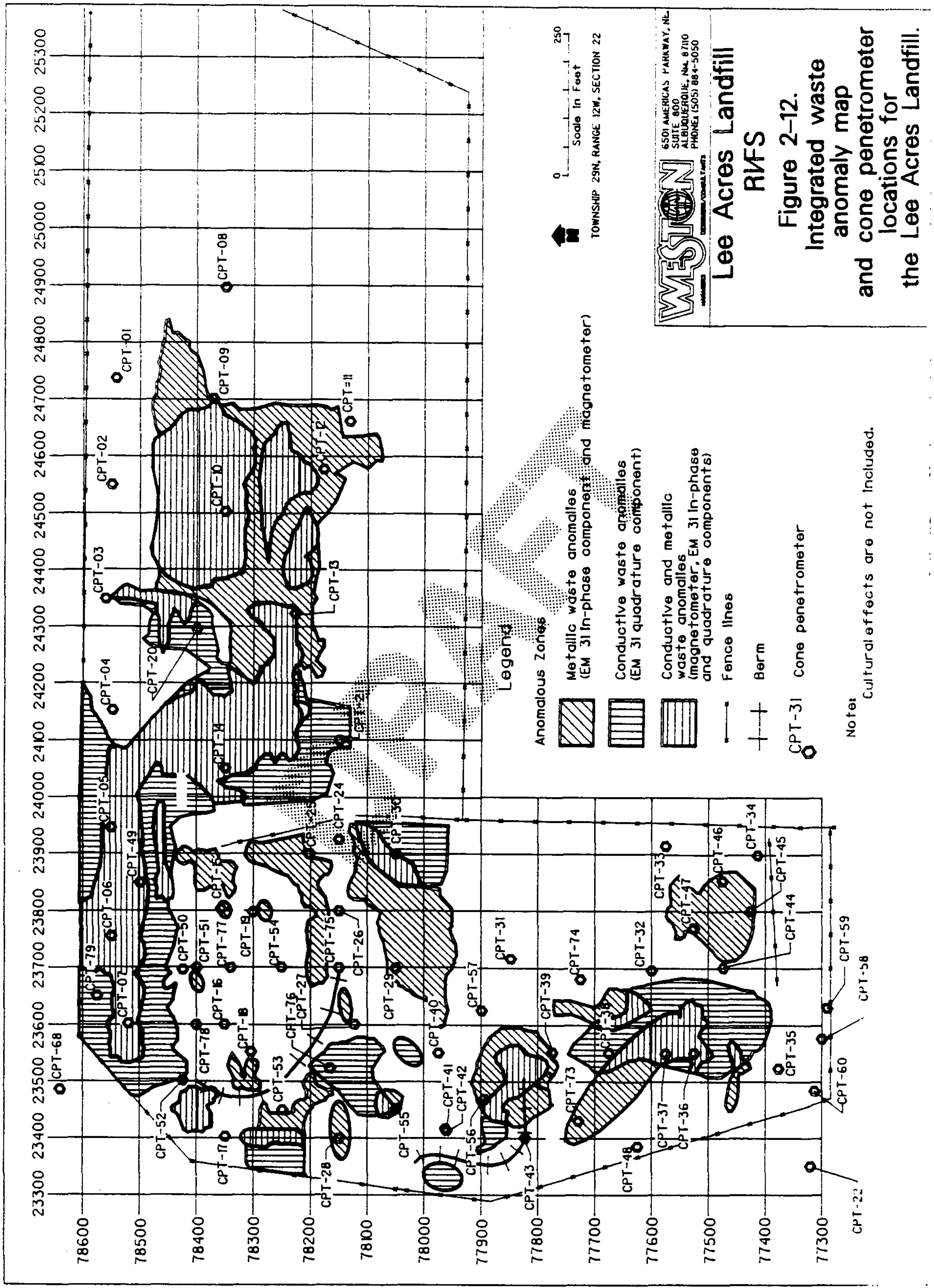
(see Figure 2-1)

Figure 2-10. Quadrature and in-phase EM 31 along line 24500E.



Lee Acres Landfill
RI/FS

Figure 2-11. Integrated waste anomaly map and borehole locations for the Lee Acres Landfill.



Lee Acres Landfill
RI/FS

Figure 2-12.
Integrated waste anomaly map and cone penetrometer locations for the Lee Acres Landfill.

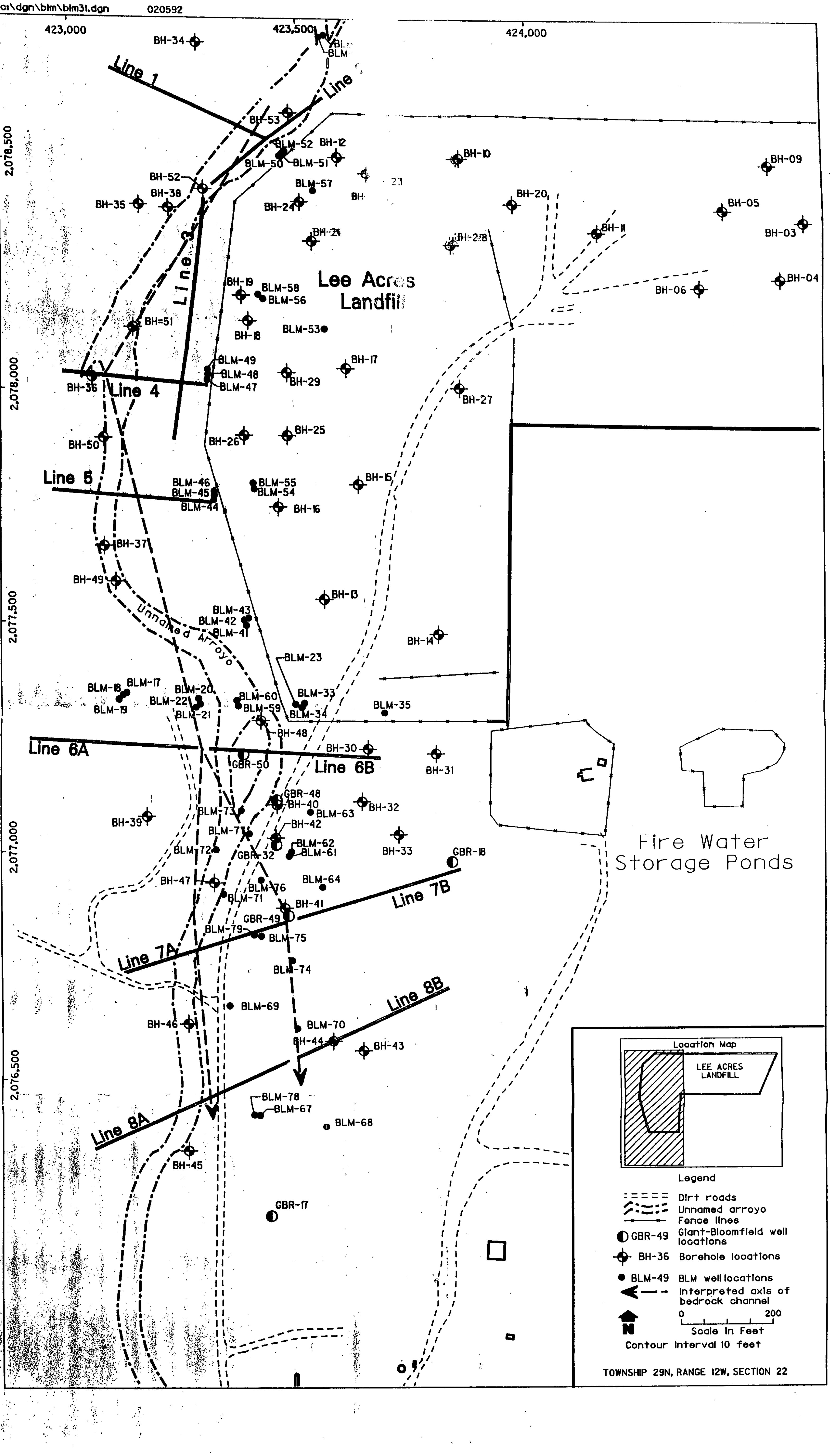


Figure 2-13. Location of seismic refraction lines and interpreted bedrock channel

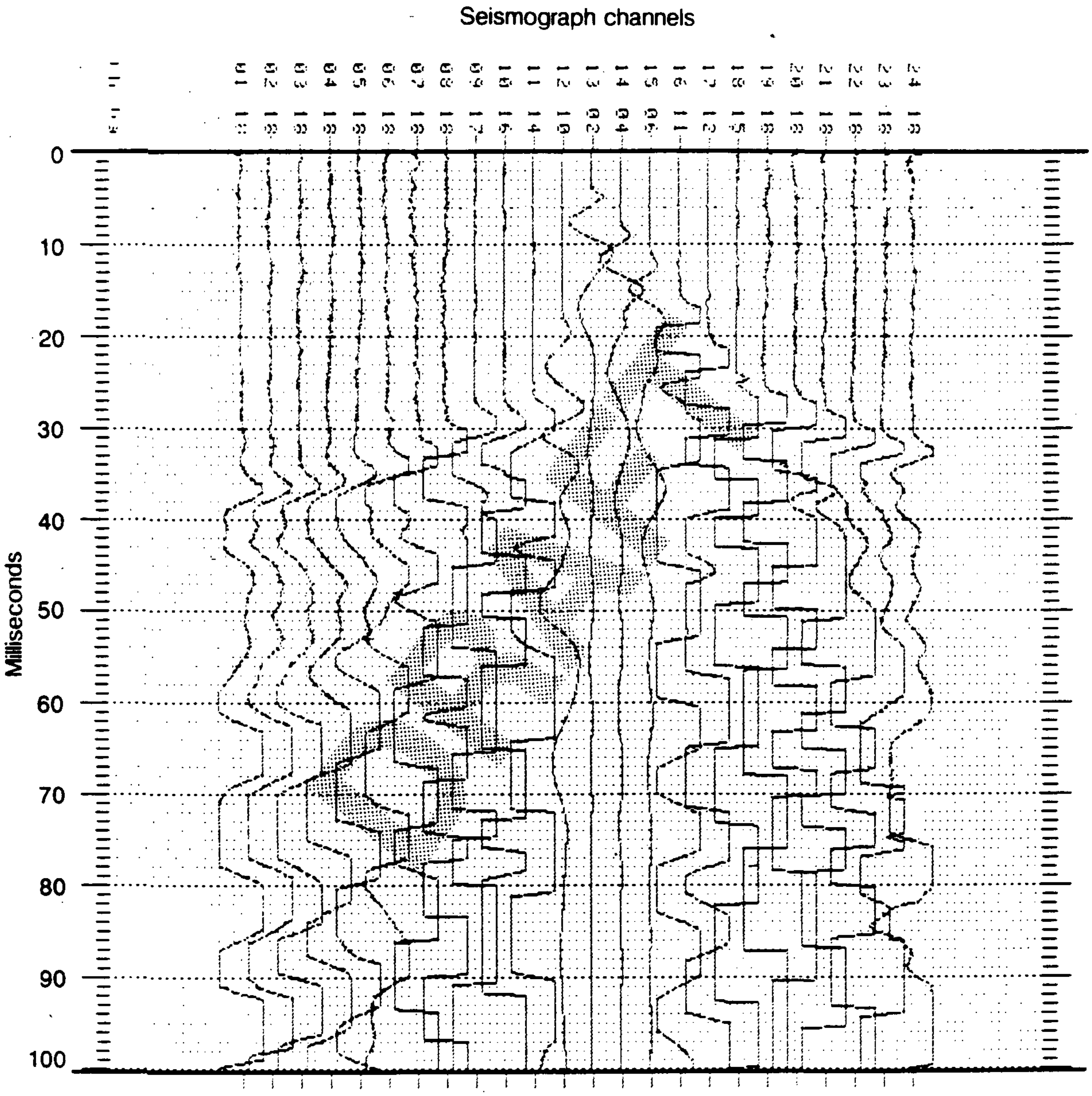


Figure 2-14. Representative unprocessed seismograph record.

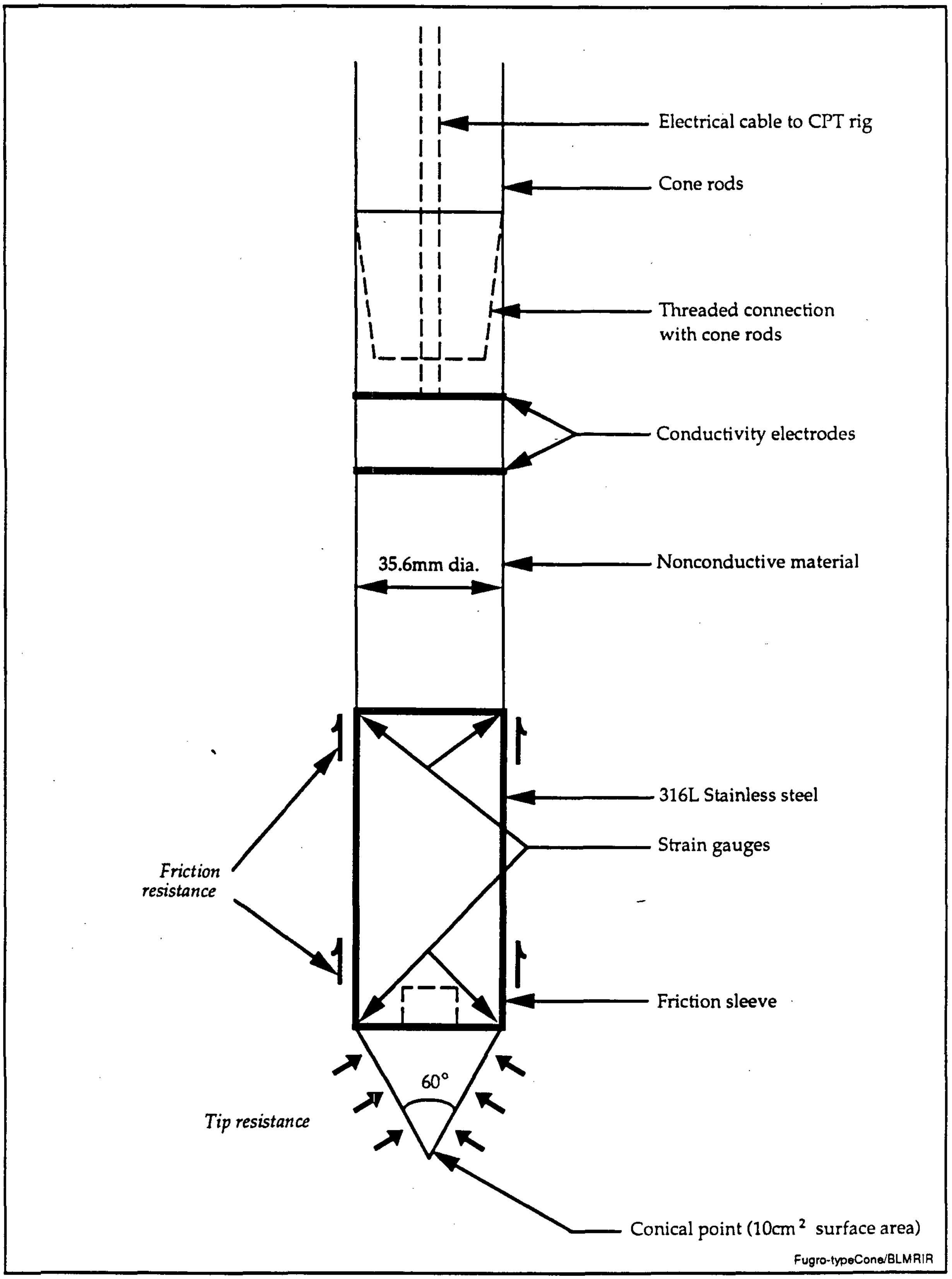
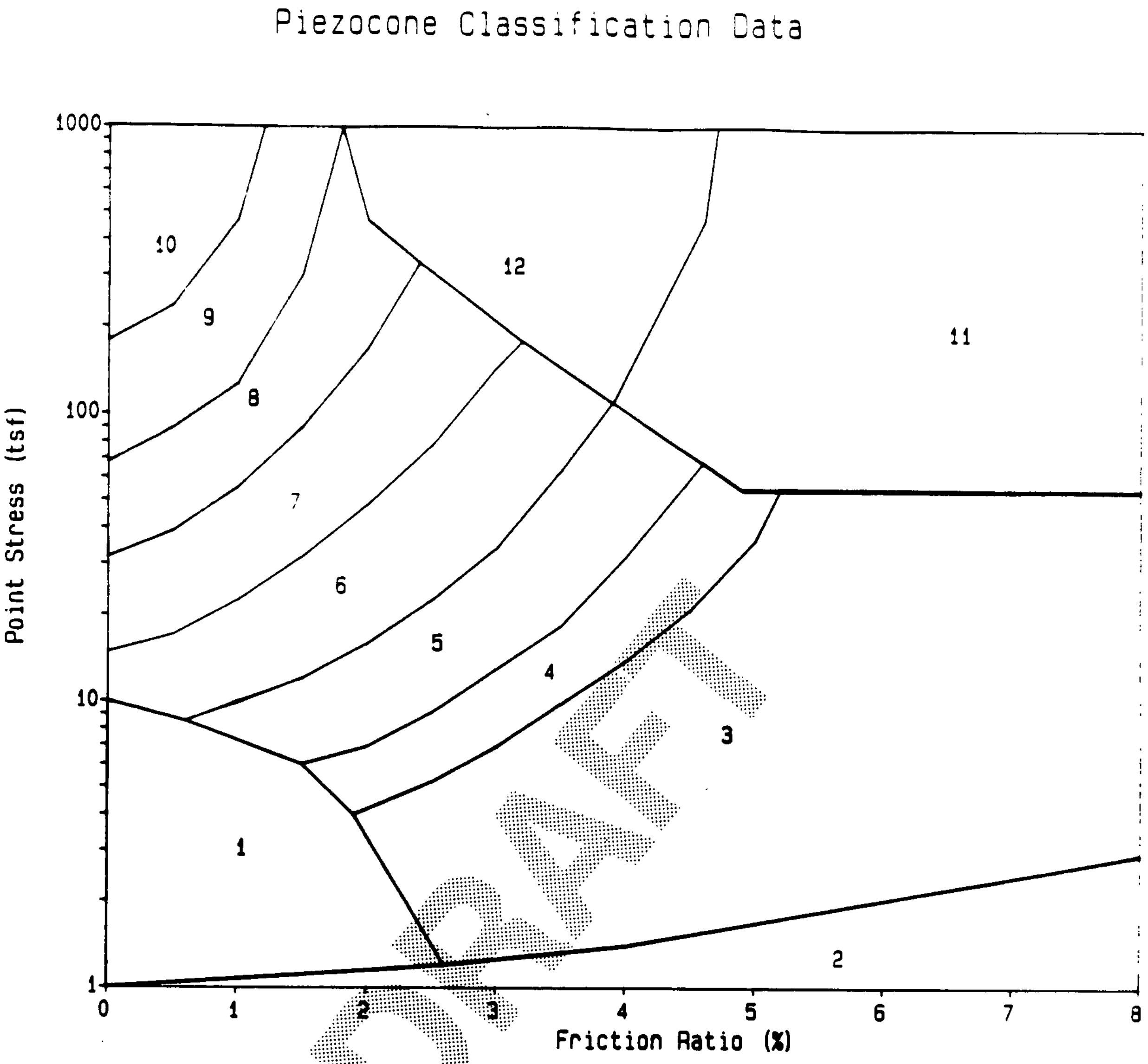


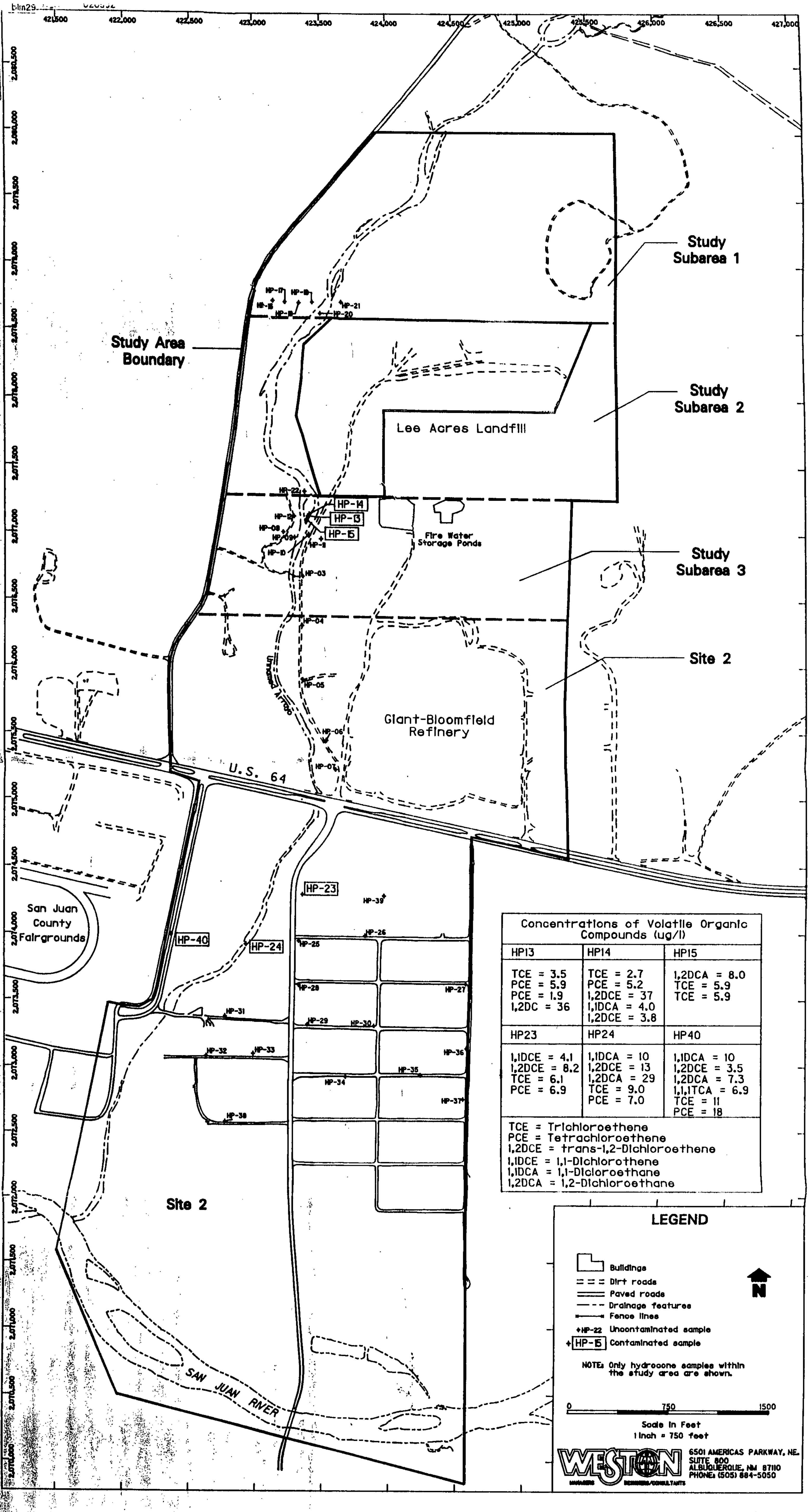
Figure 2-15. Schematic of Fugro-type cone penetrometer.



Zone	Soil Behavior Type
1	**Sensitive Fine-Grained Soil**
2	Organic Material
3	**Clay**
4	Silty Clay to Clay
5	Clayey Silt to Silty Clay
6	Sandy Silt to Clayey Silt
7	Silty Sand to Sandy Silt
8	**Sand to Silty Sand**
9	**Sand**
10	Gravelly Sand to Sand
11	Hard Fine-Grained Soil
12	Cemented Sand to Clayey Sand

Ref.: Robertson and Campanella 1982

Figure 2-16. Soil Behavior Type chart.

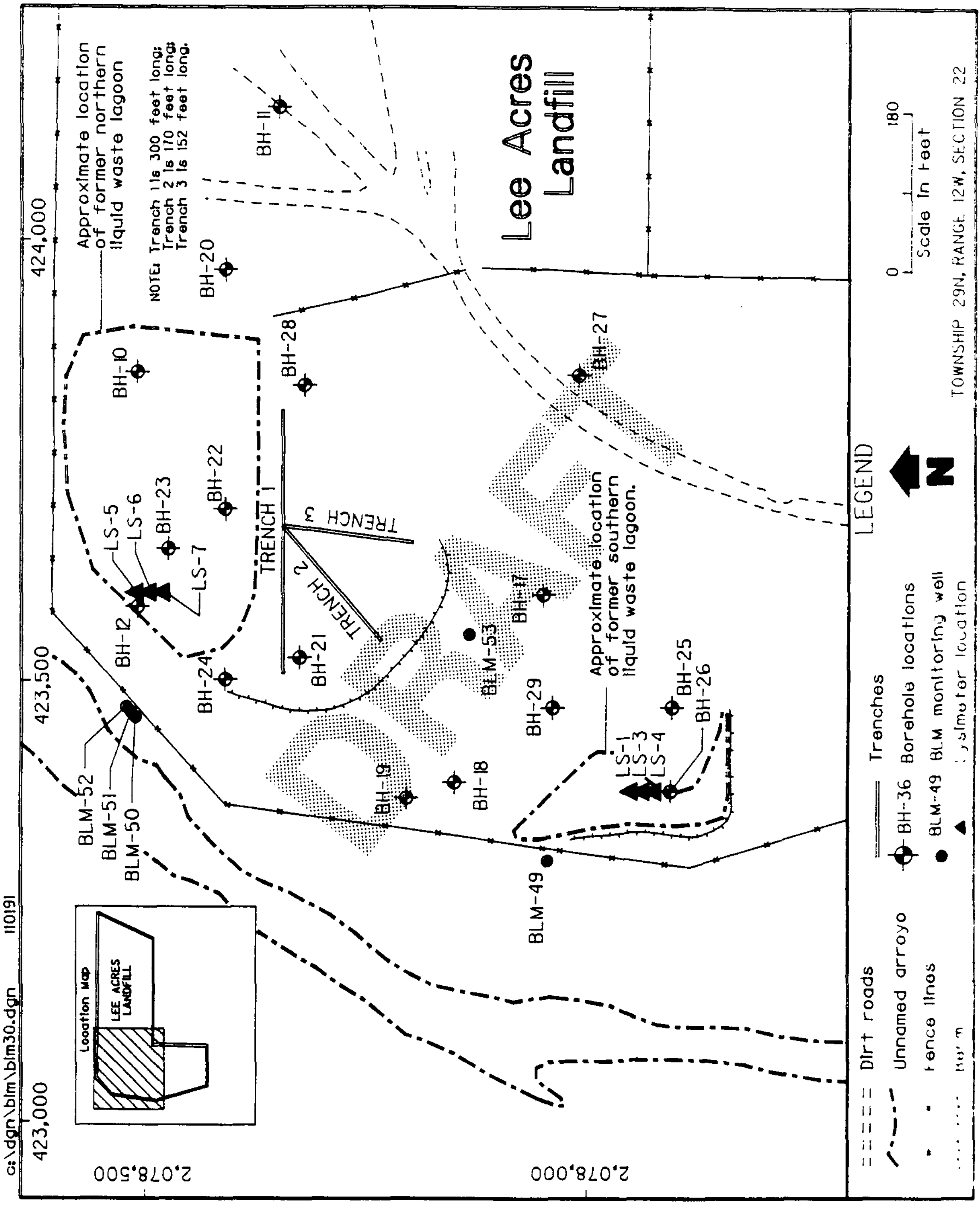


Concentrations of Volatile Organic Compounds (ug/l)

HP13	HP14	HP15
TCE = 3.5 PCE = 5.9 PCE = 1.9 1,2DC = 36	TCE = 2.7 PCE = 5.2 1,2DCE = 37 1,1DCA = 4.0 1,2DCE = 3.8	1,2DCA = 8.0 TCE = 5.9 TCE = 5.9
HP23	**HP24**	**HP40**
1,1DCE = 4.1 1,2DCE = 8.2 TCE = 6.1 PCE = 6.9	1,1DCA = 10 1,2DCE = 13 1,2DCA = 29 TCE = 9.0 PCE = 7.0	1,1DCA = 10 1,2DCE = 3.5 1,2DCA = 7.3 1,1,1TCA = 6.9 TCE = 11 PCE = 18

TCE = Trichloroethene
PCE = Tetrachloroethene
1,2DCE = trans-1,2-Dichloroethene
1,1DCE = 1,1-Dichlorothene
1,1DCA = 1,1-Dicloroethane
1,2DCA = 1,2-Dichloroethane

Figure 2-17. Volatile organic compounds detected in hydrocone sampling analysis.



NOTE: Trench 1 is 300 feet long; Trench 2 is 170 feet long; Trench 3 is 152 feet long.

Figure 2.18. Trench and former liquid waste lagoon locations.

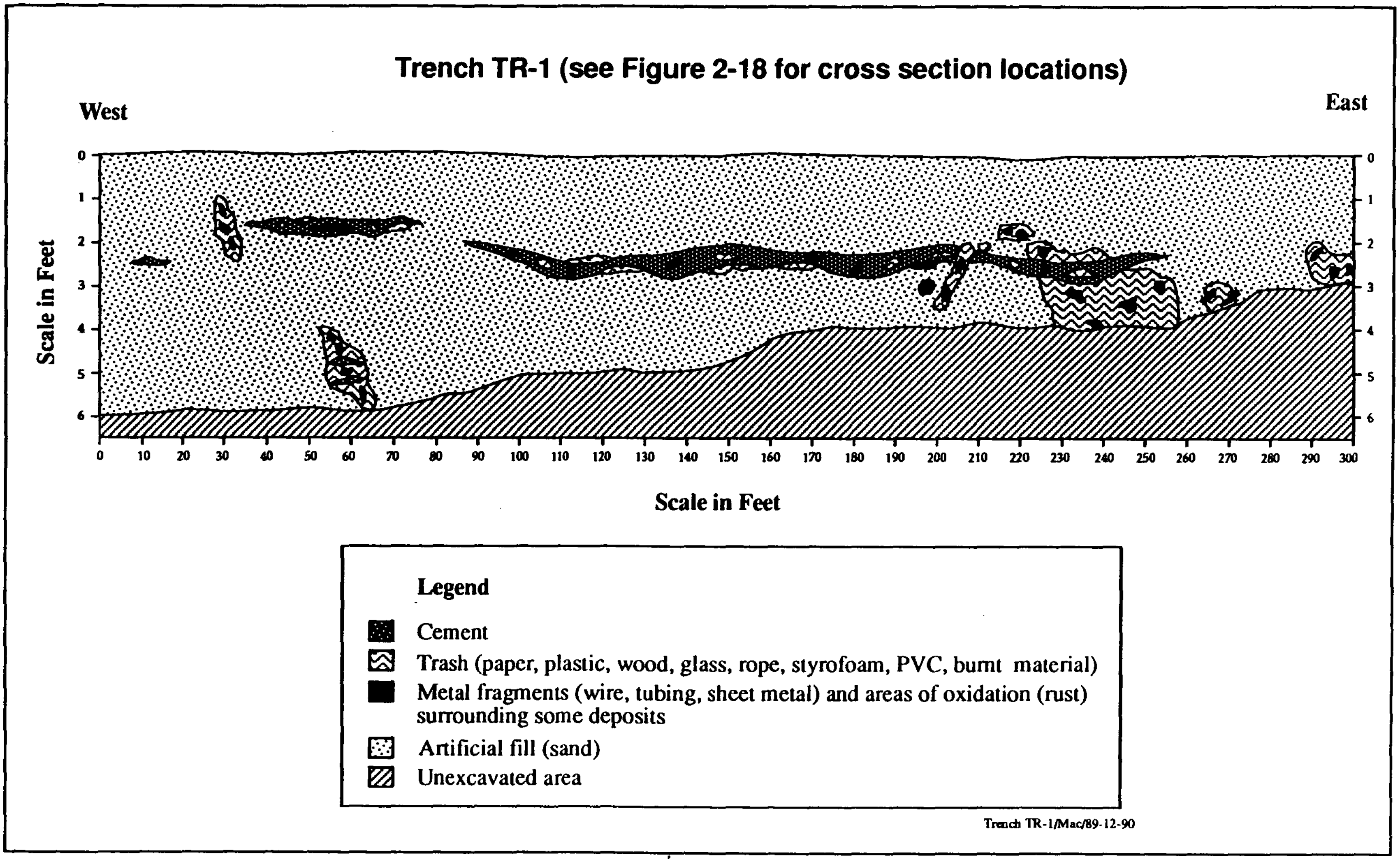


Figure 2-19. Trench TR-1: cross-sectional map of excavated area showing distribution of waste debris.

Trench TR-2 (see Figure 2-18 for cross section location)

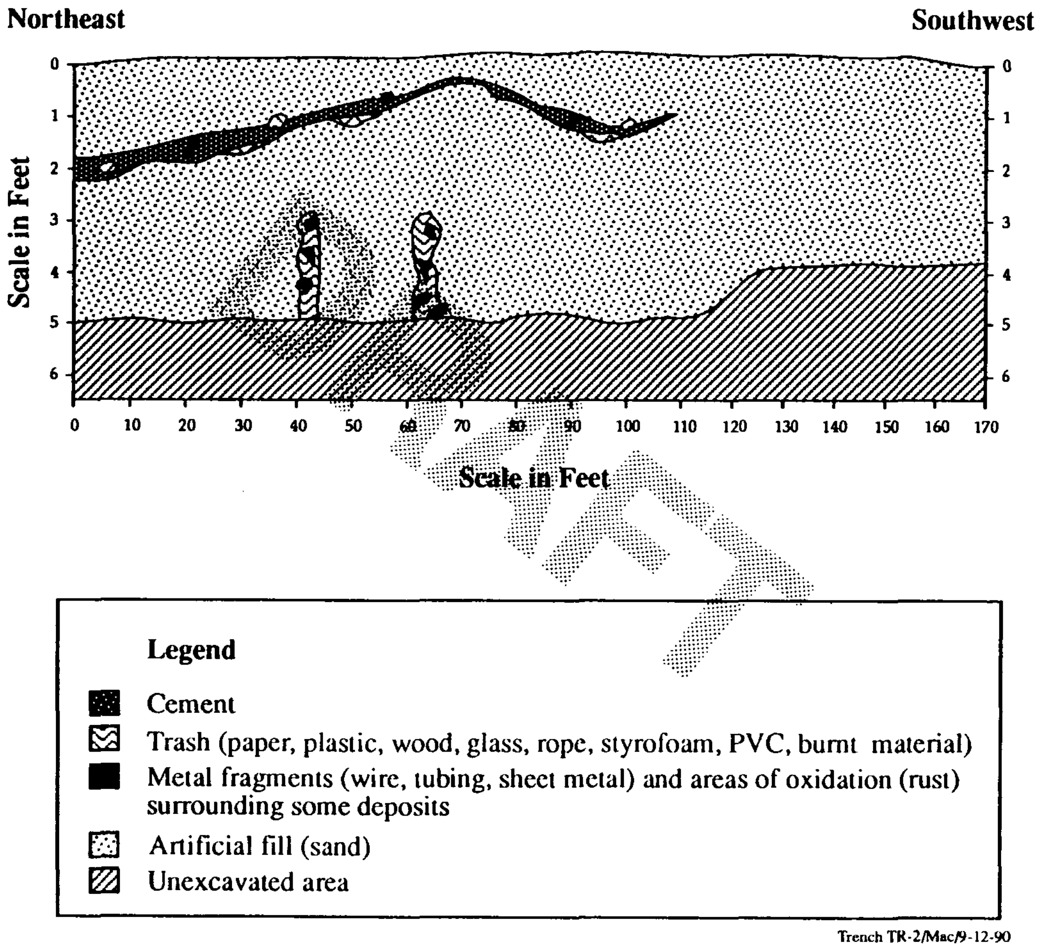
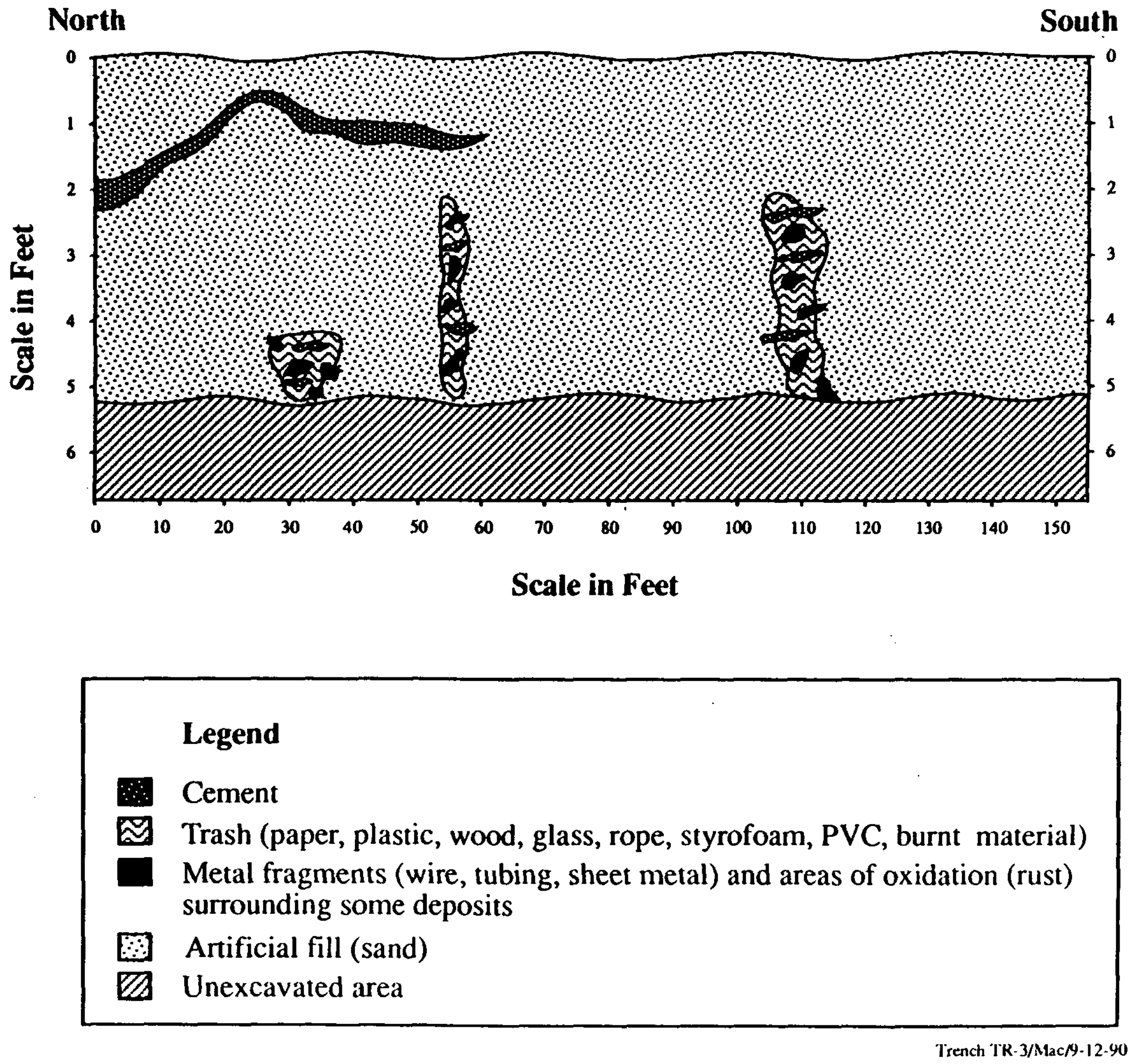


Figure 2-20. Trench TR-2: cross-sectional map of excavated area showing distribution of waste debris.


Trench TR-3 (see Figure 2-18 for cross section location)

Trench TR-3/Mac/9-12-90

Figure 2-21. Trench TR-3: cross-sectional map of excavated area showing distribution of waste debris.

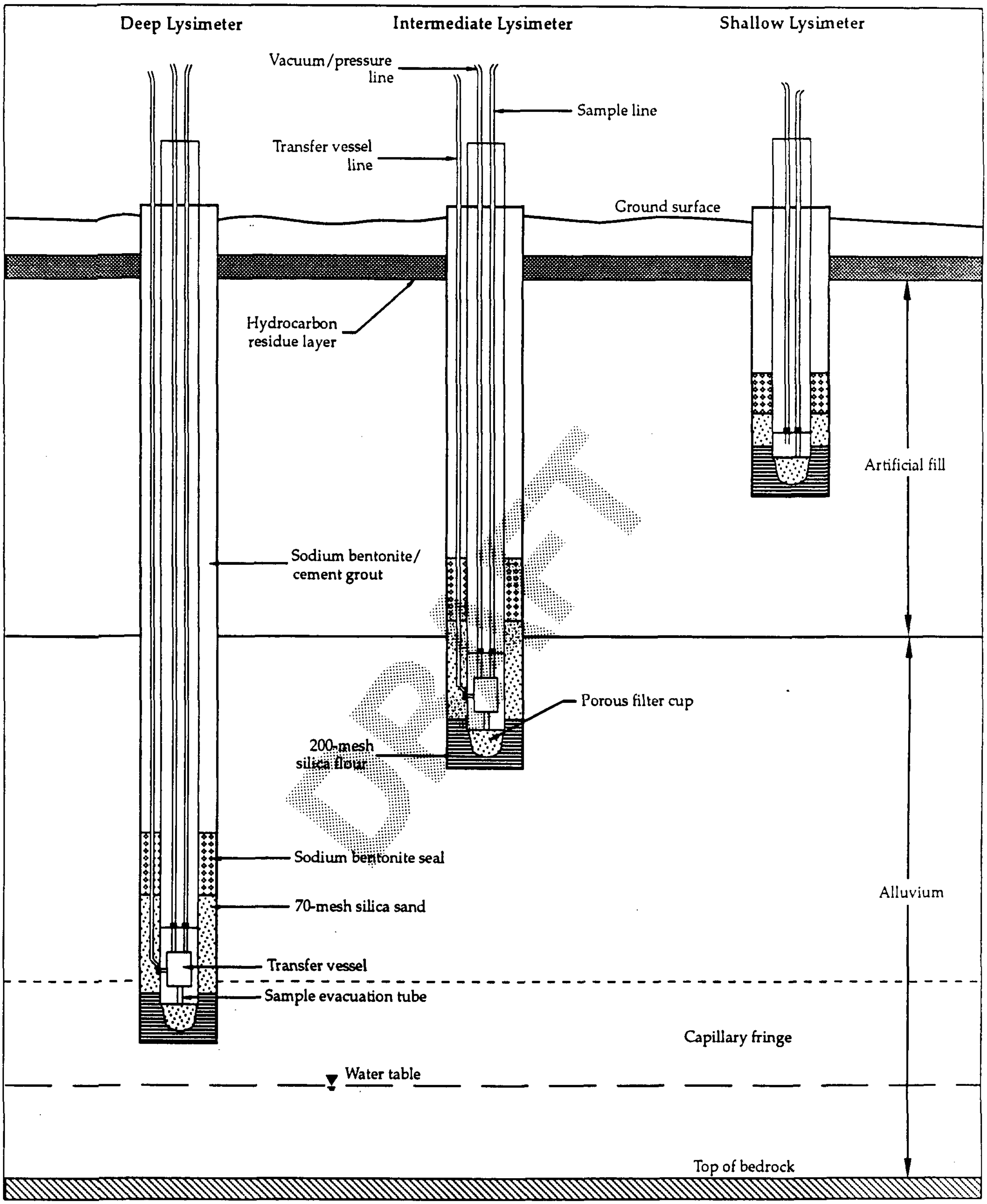


Figure 2-22. Lysimeter cluster schematic.

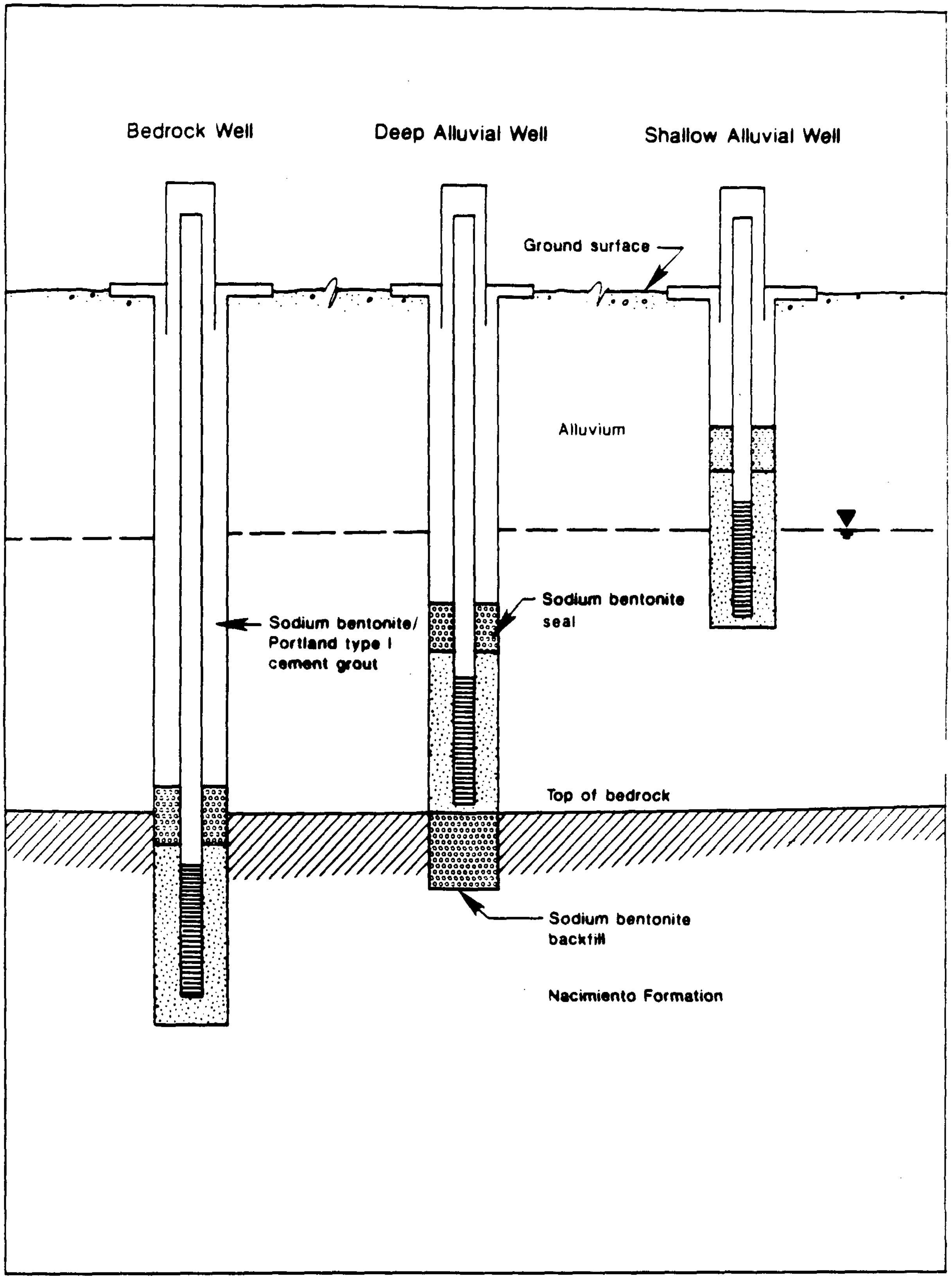


Figure 2-23. Well cluster schematic.

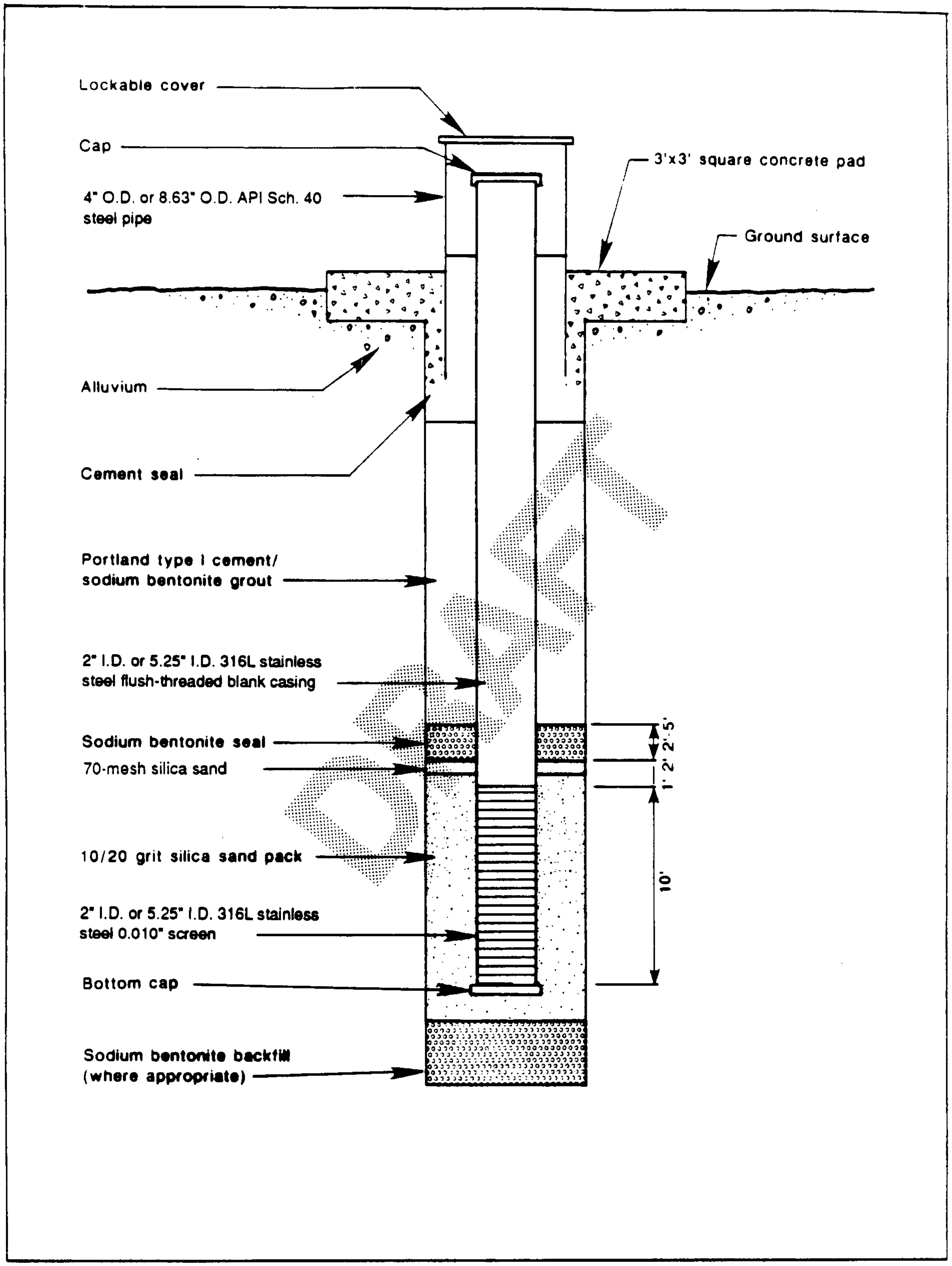


Figure 2-24. Typical well construction diagram.

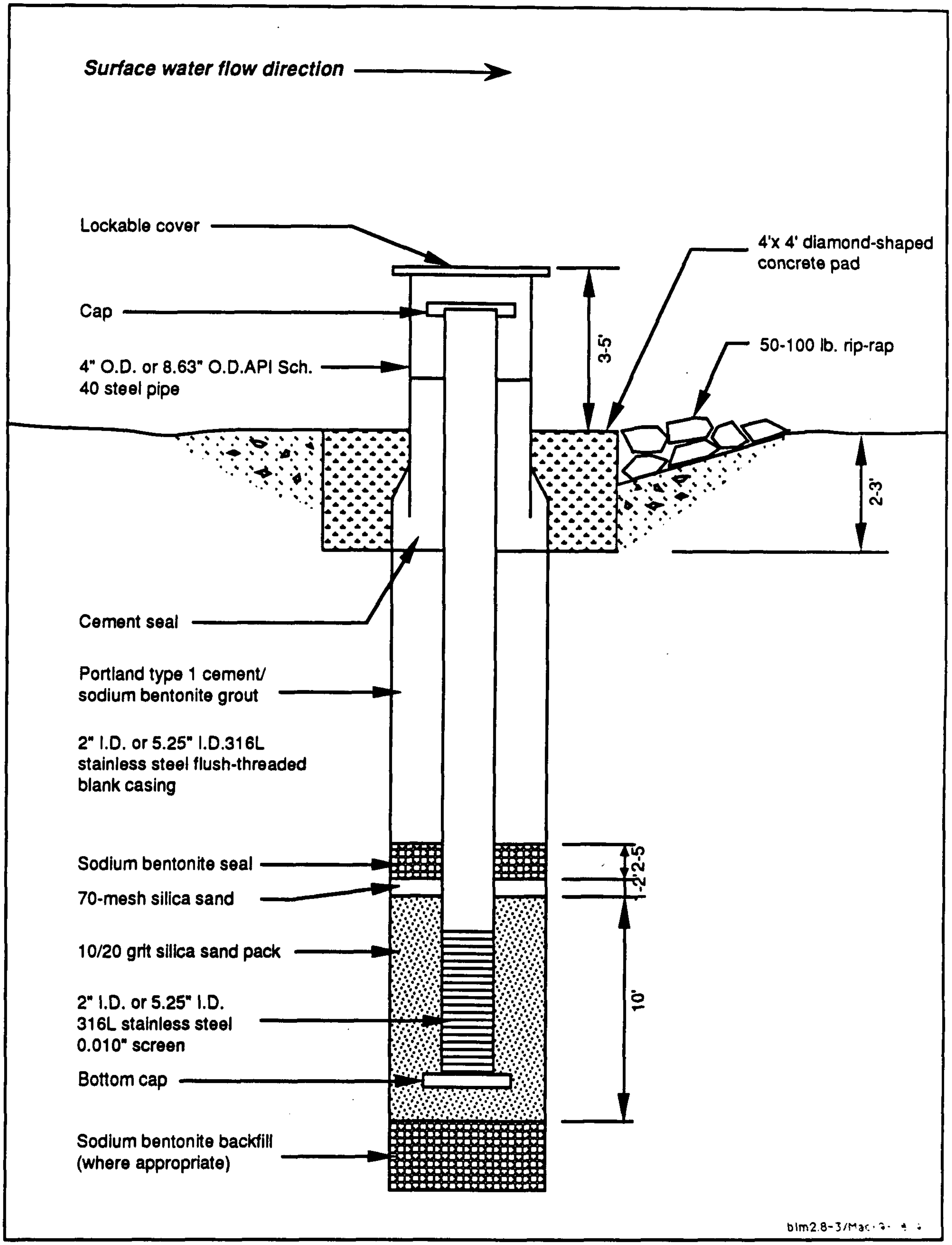


Figure 2-25. Typical well construction diagram in unnamed arroyo.

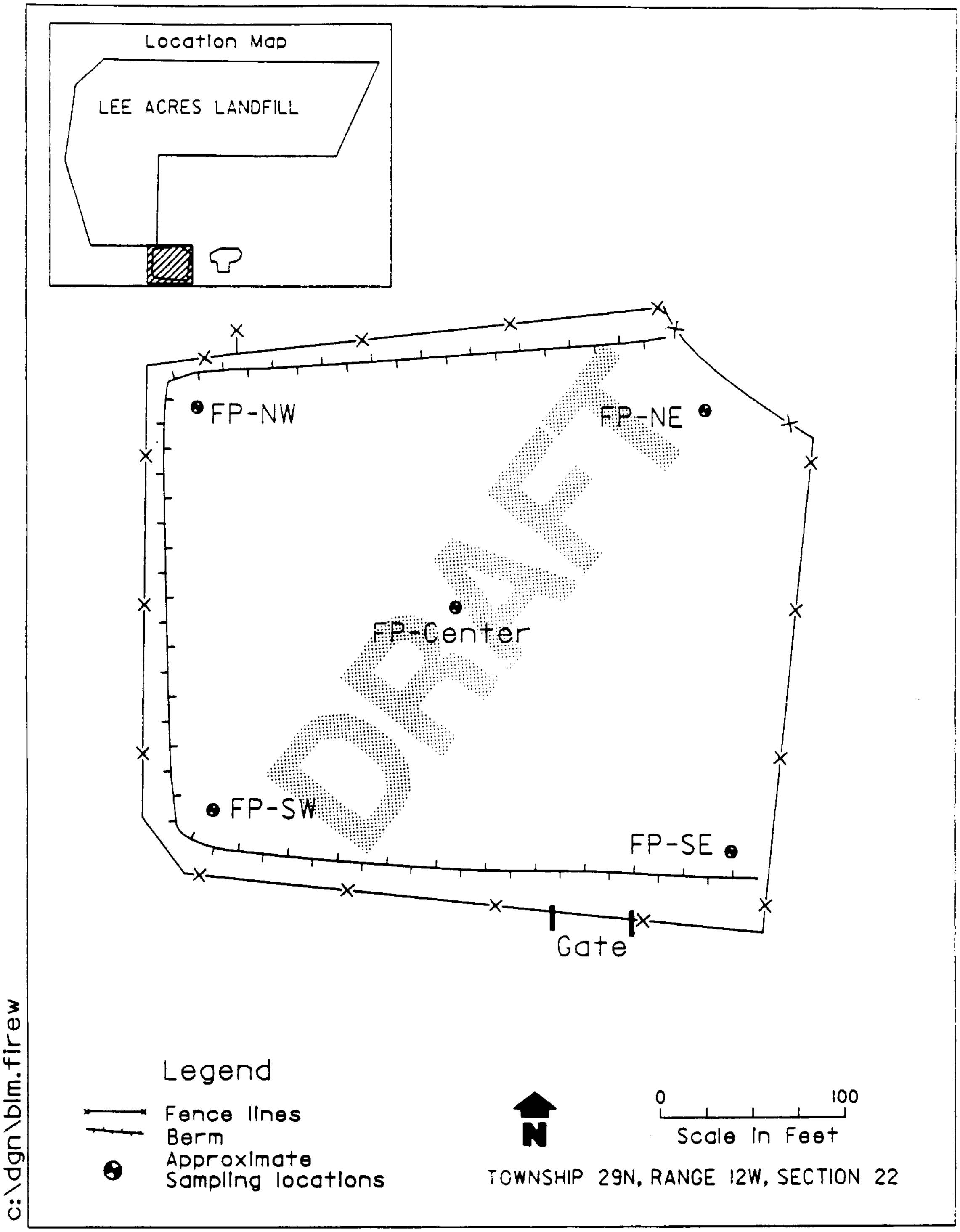


Figure 2-26. Western fire water pond sampling locations.

Table 2-1. Summary of Planned and Actual RI Data Collection Activities

Study Areas	Data Collection Activity	Sample Matrix	Planned[a]		Actual[b]	
			Number of Sample Locations	Total Number of Samples[c]	Number of Sample Locations	Total Number of Samples[c]
Site 1, subarea 1	Monitoring wells	Groundwater	5	20	5	40
	Hydrocones	Groundwater	9	9	9	9
	Wellbores	Soil	1	8	1	7
	CPTs	Soil	0	0	16[d]	16
Site 1, subarea 2	Monitoring wells	Groundwater	30	120	30	219
	Lysimeters	Groundwater	6	24	6	9[e]
	Boreholes	Soil	41	206	41	155
	Wellbores	Soil	10	47	12	55
	CPTs	Soil	72	72	73	73
Site 1, subarea 3	Monitoring wells	Groundwater	18	72	17	125
	Hydrocones	Groundwater	12	12	12	13[f]
	Boreholes	Soil	10	58	12	56
	Wellbores	Soil	23	19	14	20
	CPTs	Soil	23	23	23	23
Site 2	Monitoring wells	Groundwater	10	40	12	108
	Hydrocones	Groundwater	20	20	20	20
	Wellbores	Soil	1	5	3	4
	CPTS	Soil	26	26	26	26

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Table 2-1 (page 2 of 2)

Study Areas	Data Collection Activity	Sample Matrix	Planned^a		Actual^b	
			Number of Sample Locations	Total Number of Samples^c	Number of Sample Locations	Total Number of Samples^c
Program Summary	Monitoring wells	Groundwater	63	252	64	492
	Hydrocones	Groundwater	41	41	41	42
	Lysimeters	Groundwater	6	24	6	9^e
	Boreholes	Soil	51	264	53	211^{c,f}
	Wellbores	Soil	35	175^g	30	86
	CPTs	Soil	121	121	138	138

Note: In general, laboratory analysis performed included VOCs, BNAs, pesticides/PCBs, inorganics, and metals. Specific analytical programs are presented in section 2 of this report.

[a] Planned values from SAPP, Table 6-1 (WESTON 1990d) and RI Briefing Document (WESTON 1991).
[b] Actual values based on RI data collection activities presented in section 2 of this report.
[c] Number of samples per location varied for monitoring wells and soil boring samples; therefore, number is an average value.
[d] Includes area around El Paso Natural Gas Substation.
[e] Three events were performed; however, only a total of nine samples were collected. See Table 2-13.
[f] Three duplicate samples collected, see subsection 2.3.1.
[g] Between 75 and 100 samples were selected for analysis (WESTON 1990d).

BNA: base-neutral acids
CPT: cone petrometer test
PCB: polychlorinated biphenyls
RI: remedial investigation
SAPP: Sampling and Analysis Project Plan for the Lee Acres Landfill RI/FS/EIS (WESTON 1990d).
VOC: volatile organic compounds

Table 2-2. Comparison of EM 31 and Magnetometer Survey Methods

Measurement	Depth of Investigation	Property Measured	Materials Detected
EM 31 In-Phase Component	6 to 8 ft below the instrument	Proximity to metals	Metals including those that are non-ferrous; such as copper and aluminum.
EM 31 Quadrature Component	18 ft below the instrument	Apparent conductivity	Conductive geologic materials, saline soils, water with high TDS, large concentrations of metal.
Magnetic Vertical Gradient	Can detect single 55-gallon drum at approx. 6 to 8 ft	Vertical gradient of the earth's magnetic field	Ferrous metals, ferrous geologic materials, objects with high remanent magnetization.
Total Magnetic Field	Can detect single 55-gallon drum at approx. 8 to 12 ft	Intensity of the earth's magnetic field	Ferrous metals, ferrous geologic materials, objects with high remanent magnetization.

TDS: total dissolved solids

Table 2-3. Conductivities of Various Materials

Material	Conductivity (mmhos/m)
Sandy soil	0.14 (dry) to 6.9 (wet)
Loamy soil	0.11 (dry) to 21 (wet)
Clayey soil	0.27 (dry to 50 (wet)
Permafrost	0.27 (dry to 50 (wet)
Alluvium and sand	1.3 (dry) to 100 (wet)
Shale	0.5 to 50
Sandstone	< 0.01 to 1000
Limestone	< 0.01 to 20
Dolomite	0.2 to 2.8
Granite	< 0.01 to 3.3
Diorite	< 0.01
Andesite	0.22 to 5.9
Gabbro	< 0.01 to 1.0
Basalt	< 0.01 to 100
Tuff	0.01 to 0.5
Schist	0.1 to 100
Slate	< 0.01 to 0.15
Gneiss	< 0.01 to 0.15
Marble	< 0.01 to 10
Quartzite	< 0.01 to 100
Pure water	0.1 to 30
Seawater	4000
Copper	5.8×10^{10}
Iron	1.0×10^{9}

Ref: adapted from Telford et al. 1976 and Ulriksen 1982

Table 2-4. Seismic Refraction Survey Velocities

Line Number[a]	Number of Geophones	Total Length (ft)	Ground Surface Elevation Range (ft)	Interpreted Bedrock Elevation Range[b] (ft)	Seismic Velocities			
					Layer 1: loosely packed alluvium (sand & gravel) (ft/s)	Layer 2: more compact alluvium (sand with some clay layers) (ft/s)	Layer 3: saturated alluvium (assumed velocity) (ft/s)	Layer 4: bedrock (Nacimiento Formation) (ft/s)
1	24	375	5434.4 - 5436.9	5386 - 5405	800	1500	5,000	8420
2	24	315	5393.8 - 5401.5	5385 - 5397	960	1675	5,000	7790
3	36	530	5424.7 - 5431.9	5382 - 5385	930	1400	5,000	7800
4	24	320	5425.9 - 5428.7	5378 - 5402	970	1400	5,000	7780
5	24	365	5421.3 - 5425.1	5363 - 5395.1	830	1400	5,000	6740
6A	24	375	5413.3 - 5428.7	5376 - 5393.5	930	1490	5,000	7800
6B	24	375	5412.2 - 5417.1	5374 - 5402	910	1790	5,000	6900
7A	24	375	5404.1 - 5410.1	5368 - 5384	1060	1600	5,000	7300
7B	24	375	5405.6 - 5420.5	5364.5 - 5396.4	910	2040	5,000	8600
8A	36	470	5399.1 - 5404.9	5365.3 - 5382	810	1540	5,000	7840
8B	24	365	5403.8 - 5411.2	5368.4 - 5393.9	820	1780	5,000	7730

[a] Seismic refraction lines are shown on Figure 2-12.

[b] Interpreted from seismic profiles presented in Appendix E-2

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Table 2-5. Correlation of Borehole Bedrock Depths with Bedrock Depths Estimated from Seismic Refraction Data

Location	Measured Bedrock Depth (ft)	Estimated Bedrock Depth (ft)	Percentage Error
BH-30	18.5	18.0	2.7
BH-36	44.6	42.6[b]	4.5
BH-41	36	41[b]	13.8
BH-44	26.4	27.3	3.4
BH-52	44.5	46.6[b]	4.7
BH-53	49.0	49.5[b]	1.0
BLM-44	45.4	42[b]	7.4
BLM-47	48.9	46[b]	5.9
BLM-75	39.3	37.8[b]	3.8
GBR-18	10/25[a]	25	150/0[a]
GBR-50	35.4	36	1.6

[a] Claystone-mudstone contact at 25 ft; top of sandstone at 10 ft (see Appendix E-2)

[b] Values adjusted based on measured water table elevations (see subsection 2.1.2.1)

Table 2-6. Hydrocone Sample Location Rationale

Hydrocone Sample Location[a]	Location Rationale	Observed Trends
HP-16, -17, -18, -19, -20, -21, -01, -02, -41	Background characterization north of the Lee Acres Landfill boundary (study subarea 1).	No VOCs were detected other than trichloromethane.
HP-08, -09, -10, -13, -14, -15, -22, -03, -04	Trace potential contamination in unnamed arroyo south of landfill and north of U.S. 64 (study subarea 3).	Chlorinated hydrocarbons were detected at locations in the northern part of this area.
HP-05, -06, -07, -23, -24, -40	Trace potential contamination in unnamed arroyo north and south of U.S. 64 (Site 2).	Chlorinated hydrocarbons were detected at all three of these locations.
HP-25, -26, -27, -28, -29, -30, -31, -32, -33, -34, -35, -36, -37, -38	Trace potential contamination in subdivisions south of U.S. 64 (Site 2).	No VOCs were detected.

[a] Hydrocone sample locations are shown on Figure 2-15.

VOCs: volatile organic compounds

Table 2-7. Hydrocone Sampling Summary and Results

Hydrocone Location ID	North (ft)	East (ft)	Surface Elevation (ft MSL)	Sample Depth (ft below ground surface)	Sample Date	Chain-of-Custody Sample ID	VOA µg/L	Chloride mg/L	TDS mg/L	Sulfate mg/L
HP-01	2082195	425660	5502.5	35.8 - 36.8	12/17/89	HP0136	U	67	1210	512
HP-02	2081755	425660	5497.0	34.0 - 35.0	12/17/89	HP0234	U	45	1310	950
HP-03	2076685	423335	5410.0	34.7 - 35.7	12/18/89	HP0335	U	82	2390	1310
HP-04	2076310	423330	5403.0	33.9 - 34.9	12/18/89	HP0434	U	100	2080	1280
HP-05	2075905	423335	5397.0	31.0 - 32.0	12/18/89	HP0537	U	44	2400	931
HP-06	2075450	423515	5388.0	34.0 - 35.0	12/19/89	HP0634	U	160	1950	627
HP-07	2075225	423585	5390.0	38.0 - 39.0	12/19/89	HP0738	U	190	1790	793
HP-08	2077015	423190	5415.0	32.0 - 33.0	12/18/89	HP0832	U	41	1980	727
HP-09	2076975	423275	5411.0	30.8 - 31.8	12/20/89	HP0931	U	88	2310	804
HP-10	2076995	423380	5412.0	33.0 - 34.0 33.0 - 34.0 NA	12/20/89 12/20/89 12/20/89	HP1033 HP10DUP HP10RB	U U U	200 200 <1	1660 1650 42.0	484 497 17.4
HP-11	2076965	423475	5408.0	28.7 - 29.7	01/03/90	No Sample	-	-	-	-
HP-12	2077135	423270	5414.0	31.0 - 32.0	01/04/90	No Sample	-	-	-	-
HP-13	2077135	423375	5413.0	30.5 - 31.5	01/04/90	HP1331S	TCE=3.5 PCE=5.9 1,2-DCE=36	150	3090	883
				35.5 - 36.5	01/04/90	HP1336S	PCE=1.9	130	2610	786
HP-14	2077150	423385	5413.0	30.5 - 31.5	01/04/90	HP1431S	TCE=2.7 PCE=5.2 1,2-DCE=37 CF* =9.5	150	2540	911
				34.3 - 35.3	01/05/90	HP1435	1,1-DCA=4.0 1,2-DCE=3.8 CF=7.2	140	2730	892

Table 2-7. (page 2 of 4)

Hydrocone Location ID	North (ft)	East (ft)	Surface Elevation (ft MSL)	Sample Depth (ft below ground surface)	Sample Date	Chain-of-Custody Sample ID	VOA µg/L	Chloride mg/L	TDS mg/L	Sulfate mg/L
HP-15	2077110	423365	5413.0	30.5 - 31.5	01/05/90	HP1531	1,2-DCA=8.0 TCE=5.9 CF=7.5	220	2450	622
				35.5 - 36.5	01/05/90	HP1536	CF=11	250	2770	790
HP-16	2078735	423130	5437.0	35.7 - 36.7	01/07/90	HP1636	CF=46	26	3180	727
HP-17	2078725	423220	5437.5	43.0 - 44.0 43.0 - 44.0 NA	01/07/90 01/07/90 01/07/90	HP1743 HP1743DUP HP1743RB	CF=143 CF=167 CF=358	30 31	3200 3280 240	700 852 14.4
HP-18	2078720	423325	5440.5	47.9 - 48.9	01/07/90	HP1848	CF=160	48	2850	674
HP-19	2078725	423425	5441.0	43.5 - 44.5	01/08/90	HP1944	CF=4.7	49	2430	545
HP-20	2078640	423485	5437.0	35.0 - 36.0	01/08/90	HP2035	CF=120	37	1970	597
HP-21	2078730	423650	5447.5	49.1 - 50.1	01/08/90	HP2149	CF=4.8	44	2550	645
HP-22	2077320	423350	5415.0	31.4 - 32.4	01/08/90	HP2231	CF=4.6	110	2180	1320
HP-23	2074300	423335	5314.0	44.0 - 45.0	01/09/90	HP2344	1,1-DCE=4.1 1,2-DCE=8.2 TCE=6.1 PCE=6.9	520	3270	1580
HP-24	2073925	423915	5356.0	28.3 - 29.3	01/09/90	HP2428	1,1-DCA=10 1,2-DCE=13 1,2-DCA=29 TCE=9.0 PCE=7.0	1800	3170	563
HP-25	2073950	423310	5370.0	41.0 - 42.0	01/09/90	HP2541	U	250	2170	940
HP-26	2073990	423810	5369.0	36.3 - 37.3	01/09/90	HP2636	U	32	1550	865
HP-27	2073625	424565	5369.0	29.0 - 30.0	01/10/90	HP2729	U	32	3800	2400
HP-28	2073615	423310	5366.0	34.5 - 35.5	01/10/90	HP2835	U	160	2160	995

Table 2-7. (page 3 of 4)

Hydrocone Location ID	North (ft)	East (ft)	Surface Elevation (ft MSL)	Sample Depth (ft below ground surface)	Sample Date	Chain-of-Custody Sample ID	VOA µg/L	Chloride mg/L	TDS mg/L	Sulfate mg/L
HP-29	2073318	423377	5361.0	32.4 - 33.4 32.4 - 33.4 NA	01/10/90 01/10/90 01/10/90	HP2932 HP2932DUP HP2932RB	U U U	35 36 <1	3430 3100 41.0	1880 1460 3.8
HP-30	2073310	423875	5359.0	31.0 - 32.0	01/11/90	HP3031	U	35	2180	1020
HP-31	2073380	422760	5359.0	32.0 - 33.0	01/11/90	HP3132	U	41	2490	1140
HP-32	2073083	422618	5352.0	27.5 - 28.5	01/11/90	HP3228	U	150	13800	9240
HP-33	2073100	422970	5354.0	25.5 - 26.5	01/11/90	HP3326	U	42	3610	2210
HP-34	2072925	423665	5352.0	22.0 - 23.0	01/11/90	HP3422	U	32	1770	2800
HP-35	2072940	424225	5351.0	16.7 - 17.7	01/12/90	HP3517	U	30	2130	127
HP-36	2073140	424470	5352.5	19.9 - 20.9	01/12/90	HP3620	U	28	2200	1180
HP-37	2072755	424545	5348.0	15.9 - 16.9	01/12/90	HP3716	U	24	1220	569
HP-38	2072583	422760	5341.0	15.5 - 16.5	01/12/90	HP3816	U	72	3470	3050
HP-39	2074290	423950	5374.0	35.7 - 36.7 35.7 - 36.7 NA	01/12/90 01/12/90 01/12/90	HP3936 HP3936DUP HP3936RB	U U U	25 27 <1	 1310 52.0	 556 2.8
HP-40	2073995	422350	5358.0	32.1 - 33.1	01/13/90	HP4032	1,1-DCA = 10 1,2-DCE = 3.5 CF = 5.6 1,2-DCA = 7.3 1,1,1- TCA = 6.9 TCE = 11 PCE = 18	27	4330	1530

Table 2-7. (page 4 of 4)

Hydrocone Location ID	North (ft)	East (ft)	Surface Elevation (ft MSL)	Sample Depth (ft below ground surface)	Sample Date	Chain-of-Custody Sample ID	VOA µg/L	Chloride mg/L	TDS mg/L	Sulfate mg/L
HP-41	2081100	425585	5483.5	31.4 - 32.4	01/15/90	HP4131	U	92.8	1290	825

Note: Hydrocone sampling locations are shown on Figure 2-17.
*: also present in field rinsate blank
1,1-DCA: 1,1-dichloroethane
1,1-DCE: 1,1-dichloroethene
1,2-DCA: 1,2-dichloroethane
1,2-DCE: 1,2-*trans*-dichloroethene
1,1,1-TCA: 1,1,1-trichloroethane
CF: chloroform
DUP: field duplicate sample
NA: not applicable
PCE: tetrachloroethene
RB: field rinsate blank
S: VOA completed by Stockton Lab
TCE: trichloroethene
TDS: total dissolved solids
U: value less than detection limit
VOA: volatile organic analysis

Table 2-8. RI Sampling and Analytical Program - Boreholes (1989-1991)

Borehole ID[a]	Database Location and Sample ID	Location North (ft)	Location East (ft)	Total Depth (ft)[b]	Sample Interval (ft)[b]	Sample Date	Geochemical Analyses[c]	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
								Planned[d]	Actual[e]		
BH-01	H001-0002 H001-0003	2078365.00	425100.00	10.0	4-5 9-10	1/17/89 1/17/89	VOA, BNA, P/P, EP Toxicity Metals, IN	2	2	H0104 H0109	8911L556
BH-02	H002-0004	2078425.00	424900.00	7.5	4-5	1/17/89	VOA, BNA, P/P, EP Toxicity Metals, IN	1	1	H0204	8911L556
BH-03	H003-0001 H003-0002 H003-0003 H003-0004	2078375.00	424600.00	31.5	2.0-3.1 7-8 26-27 29-30	1/18/89 1/18/89 1/18/89 1/18/89	VOA, BNA, P/P, EP Toxicity Metals, IN	6	4	H0303 H0308 H0326 H0330	8911L587
BH-04	H004-0005 H004-0006 H004-0008	2078250.00	424550.00	23.6	2-3 8-9 22.8-23.6	1/18/89 1/18/89 1/18/89	VOA, BNA, P/P, EP Toxicity Metals, IN	4	3	H0403 H0409 H0424	8911L587
BH-05	H005-0009 H005-0010 H005-0011 H005-0012	2078400.00	424425.00	22.5	2.9-3.9 6-7 15.5-16.5 21-22	1/19/89 1/19/89 1/19/89 1/19/89	VOA, BNA, P/P, EP Toxicity Metals, IN	4	4	H0504 H0507 H0517 H0522	8911L587
BH-06	H006-0013 H006-0003 H006-0001	2078230.00	424375.00	21.2	2.3-3.3 14-15 20.0-20.9	1/19/89 1/20/89 1/20/89	VOA, BNA, P/P, EP Toxicity Metals, IN	4	3	H0603 H0615 H0621	8911L587 8911L591
BH-07	H007-0002	2078350.00	425250.00	5.0	1-2	1/20/89	VOA, BNA, P/P, EP Toxicity Metals, IN	1	1	H0702	8911L591
BH-08	H008-0004 H008-0005	2078550.00	424650.00	10.0	2.7-3.7 9-10	1/20/89 1/20/89	VOA, BNA, P/P, EP Toxicity Metals, IN	2	2	H0804 H0810	8911L591
BH-09	H009-0006	2078500.00	424525.00	10.0	4-5	1/20/89	VOA, BNA, P/P, EP Toxicity Metals, IN	2	1	H0905	8911L591

Table 2-8. (Page 2 of 9)

Borehole ID^a	Database Location and Sample ID	Location North (ft)	Location East (ft)	Total Depth (ft)^b	Sample Interval (ft)^b	Sample Date	Geochemical Analyses^c	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
								Planned^d	Actual^e		
BH-10	H010-0007	2078510.00	423850.00	5.0	2.5-3.5	1/21/89	VOA, BNA, P/P, EP Toxicity Metals, IN	1	1	H1004	8911L591
BH-11	H011-0010 H011-0008 H011-0009	2078350.00	424150.00	29.6	3.3-4.3 20.0-20.6 28.1-29.0	1/21/89 1/21/89 1/21/89	VOA, BNA, P/P, EP Toxicity Metals, IN	5	3	H1104 H1121 H1129	8911L591
BH-12	H012-0001 H012-0002 H012-0003 H012-0004 H012-0005 H012-0006 H012-0007 H012-0008 H012-0001	2078510.00	423585.00	54.8	0-2 5.5-6.0 14.0-14.6 21.0-22.5 25.0-27.5 35.0-36.5 40-41 41.5-42.5 49-50	12/13/89 12/13/89 12/14/89 12/14/89 12/14/89 12/14/89 12/14/89 12/14/89 12/14/89	VOA, BNA, P/P, EP Toxicity Metals, IN	10	9	H1202 H1205 H1214 H1220 H1226 H1235 H1241 H1242 H1250	8911L591 8912L908
BH-13	H013-0001 H013-0002 H013-0003 H013-0004 H013-0005 H013-0006	2077550.00	423550.00	35.0	5-6 15-16 20-21 24-25 28-29 33-34	12/15/89 12/15/89 12/16/89 12/16/89 12/16/89 12/16/89	VOA, BNA, P/P, EP Toxicity Metals, IN	7	6	H1305 H1315 H1320 H1325 H1329 H1334	8912L943
BH-14	H014-0007	2077475.00	423800.00	11.0	3-4	12/16/89	VOA, BNA, P/P, EP Toxicity Metals, IN	2	1	H1404	8912L943
BH-15	H015-0001 H015-0002 H015-0003	2077800.00	423620.00	25.0	5-6 15-16 22-23	12/17/89 12/17/89 12/17/89	VOA, BNA, P/P, EP Toxicity Metals, IN	5	3	H1506 H1516 H1523	8912L944
BH-16	H016-0001 H016-0002 H016-0003 H016-0004	2077750.00	423450.00	46.0	5-6 15-16 25-26 37.5-38.5	12/18/89 12/18/89 12/18/89 12/18/89	VOA, BNA, P/P, EP Toxicity Metals, IN	9	4	H1605 H1615 H1625 H1638	8912L976

Table 2-8. (Page 3 of 9)

Borehole ID[a]	Database Location and Sample ID	Location North (ft)	Location East (ft)	Total Depth (ft)[b]	Sample Interval (ft)[b]	Sample Date	Geochemical Analyses[c]	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
								Planned[d]	Actual[e]		
BH-17	H017-0004	2078050.00	423600.00	31.0	3.5-4.5	12/19/89	VOA, BNA, P/P, EP Toxicity Metals, IN	6	2	H1704	8912L944
	H017-0005				14-15	12/19/89				H1714	
BH-18	H018-0005	2078150.00	423387.00	10.0	4-5	12/19/89	VOA, BNA, P/P, EP Toxicity Metals, IN	1	1	H1805	8912L976
BH-19	H019-0006	2078205.00	423370.00	50.0	10-11	12/19/89	VOA, BNA, P/P, EP Toxicity Metals, IN	10	2	H1910	8912L976
	H019-0007				41-42	12/19/89				H1944	
BH-20	H020-0001	2078410.00	423965.00	30.0	4-5	12/20/89	VOA, BNA, P/P, EP Toxicity Metals, IN	6	3	H2005	8912L991
	H020-0002				10-11	12/21/89				H2011	
	H020-0003				18-19	12/21/89				H2019	
BH-21	H021-0001	2078325.00	423525.00	37.5	10-11	1/2/90	VOA, BNA, P/P, EP Toxicity Metals, IN	7	3	H2110	9001L060
	H021-0002				18-19	1/2/90				H2119	
	H021-0003				30-31	1/2/90				H2131	
BH-22	H022-0001	2078410.00	423695.00	58.0	7.5-8.7	1/3/90	VOA, BNA, P/P, EP Toxicity Metals, IN	11	5	H2210	9001L069
	H022-0002				20-21	1/3/90				H2221	
	H022-0003				28-29	1/3/90				H2229	
	H022-0004				35-36	1/4/90				H2236	
	H022-0005				55.0-55.8	1/4/90	VOA			H2256	
BH-23	H023-0001	2078475.00	423650.00	55.0	5.8-6.8	1/5/90	VOA, BNA, P/P, EP Toxicity Metals, IN	11	7	H2307	9001L090
	H023-0002				20.0-20.7	1/5/90				H2321	9001L091
	H023-0003				30-31	1/5/90				H2331	
	H023-0001				41-42	1/6/90				H2342	
	H023-0002				41-42	1/6/90				H2342D	
	H023-0003				45-46	1/6/90				H2346	
	H023-0004				50-51	1/6/90				H2351	

Table 2-8. (Page 4 of 9)

Borehole ID[a]	Database Location and Sample ID	Location North (ft)	Location East (ft)	Total Depth (ft)[b]	Sample Interval (ft)[b]	Sample Date	Geochemical Analyses[c]	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
								Planned[d]	Actual[e]		
BH-24	H024-0001 H024-0002 H024-0003 H024-0004	2078410.00	423500.00	42.5	5.0-5.7 15.0-16.4 15.0-16.4 41.4-42.0	1/7/90 1/7/90 1/7/90 1/7/90	VOA VOA, BNA, P/P, EP Toxicity Metals, IN	8	4	H2406 H2417 H2417D H2442	9001L108
BH-25	H025-0005 H025-0006 H025-0007 H025-0008	2077905.00	423470.00	35.0	8.0-8.8 17.7-18.5 17.7-18.5 28-29	1/8/90 1/8/90 1/8/90 1/8/90	VOA, BNA, P/P, EP Toxicity Metals, IN	7	4	H2509 H2519 H2519D H2529	9001L108
BH-26	H026-0008 H026-0009 H026-0001 H026-0002	2077905.00	423375.00	47.0	1.2-1.8 13.5-14.5 24-30 40.0-40.6	1/9/90 1/9/90 1/11/90 1/11/90	VOA, BNA, P/P, EP Toxicity Metals, IN VOA	9	4	H2602 H2615 H2630 H2641	9001L122 9001L152
BH-27	H027-0001 H027-0002 H027-0003	2078010.00	423848.00	15.0	2.5-3.3 8.5-9.0 12.5-13.5	1/9/90 1/9/90 1/9/90	VOA, BNA, P/P, EP Toxicity Metals, IN	3	3	H2704 H2709 H2714	9001L134
BH-28	H028-0004 H028-0005 H028-0006	2078320.00	423835.00	26.0	3.5-4.5 17.0-17.5 17.0-17.5	1/10/90 1/10/90 1/10/90	VOA, BNA, P/P, EP Toxicity Metals, IN	5	3	H2805 H2818 H2818D	9001L134
BH-29	H029-0007 H029-0008 H029-0009 H029-0010 H029-0011	2078040.00	423470.00	45.0	4.0-4.8 13.0-14.5 13.0-14.5 28-29 40-41	1/16/90 1/16/90 1/16/90 1/16/90 1/16/90	VOA, BNA, P/P, EP Toxicity Metals, IN	9	5	H2905 H2915 H2915D H2929 H2941	9001S038
BH-30	H030-0001 H030-0002	2077225.00	423645.00	22.5	5.0-5.6 15.3-15.9	3/13/90 3/13/90	VOA, BNA, P/P, EP Toxicity Metals, IN	4	2	H3006 H3016	9003S038
BH-31	H031-0003	2077210.00	423795.00	10.0	2.7-3.2	3/13/90	VOA, BNA, P/P, EP Toxicity Metals, IN	2	1	H3104	9003S038

Table 2-8. (Page 5 of 9)

Borehole ID[a]	Database Location and Sample ID	Location North (ft)	Location East (ft)	Total Depth (ft)[b]	Sample Interval (ft)[b]	Sample Date	Geochemical Analyses[c]	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
								Planned[d]	Actual[e]		
BH-32	H032-0004	2077110.00	423630.00	10.0	7.5-8.2	3/14/90	VOA, BNA, P/P, EP Toxicity Metals, IN	2	2	H3208	9003S038
BH-33	H033-0005	2077035.00	423713.00	12.5	3.5-4.0	3/14/90	VOA, BNA, P/P, EP Toxicity Metals, IN	2	1	H3304	9003S038
BH-40	H040-0001 H040-0002 H040-0003 H040-0004 H040-0005 H040-0006 H040-0007	2077103.34	423447.64	38.8	4-5 9.6-10.0 14.5-15.0 19.5-20.0 24.5-25.0 29.0-29.4 38.4-38.7	4/19/91 4/19/91 4/19/91 4/19/91 4/19/91 4/19/91 4/19/91	VOA, Metals by TCLP, TCLP Sr, IN	8	7	BLM01-H040-0001 BLM01-H040-0002 BLM01-H040-0003 BLM01-H040-0004 BLM01-H040-0005 BLM01-H040-0006 BLM01-H040-0007	9104L243
BH-41	H041-0001 H041-0002 H041-0003 H041-0004 H041-0044 H041-0005 H041-0006 H041-0007 H041-0008 H041-0009	2076877.09	423463.99	36.0	1.0-1.5 5.0-5.5 9.5-10.0 15-16 15-16 19.5-20.0 24.5-25.0 29.2-29.7 34.5-35.0 35.60-35.85	4/10/91 4/10/91 4/10/91 4/10/91 4/10/91 4/10/91 4/10/91 4/10/91 4/10/91 4/10/91	VOA, Metals by TCLP, TCLP Sr, IN	8	10	BLM01-H041-0001 BLM01-H041-0002 BLM01-H041-0003 BLM01-H041-0004 BLM01-H041-0044 BLM01-H041-0005 BLM01-H041-0006 BLM01-H041-0007 BLM01-H041-0008 BLM01-H041-0009	9104L243

Table 2-8. (Page 6 of 9)

Borehole ID[a]	Database Location and Sample ID	Location North (ft)	Location East (ft)	Total Depth (ft)[b]	Sample Interval (ft)[b]	Sample Date	Geochemical Analyses[c]	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
								Planned[d]	Actual[e]		
BH-42	H042-0001	2077030.67	423444.80	39.0	4.4-4.8	4/12/91	VOA, Metals by TCLP, TCLP Sr, IN	8	10	BLM01-H042-0001	9104L276
	H042-0002				9.5-10.0	4/12/91				BLM01-H042-0002	
	H042-0003				14-15	4/12/91				BLM01-H042-0003	
	H042-0033				14-15	4/12/91				BLM01-H042-0033	
	H042-0004				19.5-20.0	4/12/91				BLM01-H042-0004	
	H042-0005				25.2-25.7	4/12/91				BLM01-H042-0005	
	H042-0006				29.5-30.0	4/12/91				BLM01-H042-0006	
	H042-0007				32.5-33.0	4/12/91				BLM01-H042-0007	
	H042-0008				34-35	4/12/91				BLM01-H042-0008	
	H042-0009				37.5-37.9	4/12/91				BLM01-H042-0009	
BH-43	H043-0001	2076563.17	423634.67	18.9	3.6-3.9	4/15/91	VOA, Metals by TCLP, TCLP Sr, IN	0	2	BLM01-H043-0001	9104L291
	H043-0002				17.4-17.8	4/15/91				BLM01-H043-0002	
BH-44	H044-0001	2076584.65	423568.07	28.0	8.6-9.0	4/15/91	VOA, Metals by TCLP, TCLP Sr, IN	0	1	BLM01-H044-0001	9104L299
BH-45	H045-0001	2076339.03	423250.18	35.4	1.0-1.5	5/7/91	VOA, Metals by TCLP, TCLP Sr, IN	8	7	BLM01-H045-0001	9105L542
	H045-0002				5.5-6.0	5/7/91				BLM01-H045-0002	
	H045-0003				10.0-10.5	5/7/91				BLM01-H045-0003	
	H045-0004				15.0-15.5	5/7/91				BLM01-H045-0004	
	H045-0005				20.0-20.5	5/7/91				BLM01-H045-0005	
	H045-0006				25.0-25.5	5/7/91				BLM01-H045-0006	
	H045-0007				30.0-30.5	5/7/91				BLM01-H045-0007	
BH-46	H046-0001	2076624.33	423250.25	33.6	1.0-1.5	5/7/91	VOA, Metals by TCLP, TCLP Sr, IN	8	7	BLM01-H046-0001	9105L542
	H046-0002				5.0-5.5	5/7/91				BLM01-H046-0002	
	H046-0003				10.0-10.5	5/7/91				BLM01-H046-0003	
	H046-0004				15.0-15.5	5/7/91				BLM01-H046-0004	
	H046-0005				20.0-20.5	5/7/91				BLM01-H046-0005	
	H046-0006				25.0-25.5	5/7/91				BLM01-H046-0006	
	H046-0007				32.5-33.0	5/7/91				BLM01-H046-0007	

Table 2-8. (Page 7 of 9)

Borehole ID[a]	Database Location and Sample ID	Location North (ft)	Location East (ft)	Total Depth (ft)[b]	Sample Interval (ft)[b]	Sample Date	Geochemical Analyses[c]	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
								Planned[d]	Actual[e]		
BH-47	H047-0001	2076933.31	423308.56	37.5	1.0-1.5	5/8/91	VOA, Metals by TCLP, TCLP Sr, IN	8	6	BLM01-H047-0001	9105L567
	H047-0002				7.0-7.5	5/8/91				BLM01-H047-0002	
	H047-0003				13.0-13.5	5/8/91				BLM01-H047-0003	
	H047-0004				16.0-16.5	5/8/91				BLM01-H047-0004	
	H047-0005				22.0-22.5	5/8/91				BLM01-H047-0005	
	H047-0006				27.5-28.0	5/8/91				BLM01-H047-0006	
BH-48	H048-0001	2077286.23	423411.35	33.4	5.0-5.5	5/8/91	VOA, Metals by TCLP, TCLP Sr, IN	8	6	BLM01-H048-0001	9105L567
	H048-0002				10.5-11.0	5/8/91				BLM01-H048-0002	
	H048-0003				16.0-16.5	5/8/91				BLM01-H048-0003	
	H048-0004				20.0-20.5	5/8/91				BLM01-H048-0004	
	H048-0005				27.5-28.0	5/8/91				BLM01-H048-0005	
	H048-0006				31.7-32.2	5/8/91				BLM01-H048-0006	
BH-49	H049-0001	2077587.20	423093.78	48.0	1-2	5/9/91	VOA, Metals by TCLP, TCLP Sr, IN	8	11	BLM01-H049-0001	9105L582
	H049-0011				1-2	5/9/91				BLM01-H049-0011	
	H049-0002				6.0-6.5	5/9/91				BLM01-H049-0002	
	H049-0003				10.5-11.0	5/9/91				BLM01-H049-0003	
	H049-0004				16.0-16.5	5/9/91				BLM01-H049-0004	
	H049-0005				21.0-21.5	5/9/91				BLM01-H049-0005	
	H049-0006				26.5-27.0	5/9/91				BLM01-H049-0006	
	H049-0007				31.0-31.5	5/9/91				BLM01-H049-0007	
	H049-0008				36.0-36.5	5/9/91				BLM01-H049-0008	
	H049-0009				42.5-43.5	5/9/91				BLM01-H049-0009	
	H049-0010				45.3-45.8	5/9/91				BLM01-H049-0010	

Table 2-8. (Page 8 of 9)

Borehole ID[a]	Database Location and Sample ID	Location North (ft)	Location East (ft)	Total Depth (ft)[b]	Sample Interval (ft)[b]	Sample Date	Geochemical Analyses[c]	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
								Planned[d]	Actual[e]		
BH-50	H050-0001	2077897.59	423066.84	49.6	1.5-2.0	5/9/91	VOA, Metals by TCLP, TCLP Sr, IN	8	11	BLM01-H050-0001	9105L582
	H050-0002				6.5-7.0	5/9/91				BLM01-H050-0002	
	H050-0003				12.5-13.0	5/9/91				BLM01-H050-0003	
	H050-0004				18.5-19.0	5/9/91				BLM01-H050-0004	
	H050-0005				21-22	5/9/91				BLM01-H050-0005	
	H050-0055				21-22	5/9/91				BLM01-H050-0055	
	H050-0006				28.5-29.0	5/9/91				BLM01-H050-0006	
	H050-0007				32.5-33.0	5/9/91				BLM01-H050-0007	
	H050-0008				36.0-36.5	5/9/91				BLM01-H050-0008	
	H050-0009				41.0-41.5	5/9/91				BLM01-H050-0009	
	H050-0010				45.5-46.0	5/9/91				BLM01-H050-0010	
BH-51	H051-0001	2078133.36	423133.41	50.5	5.5-6.0	5/10/91	VOA, Metals by TCLP, TCLP Sr, IN	8	11	BLM01-H051-0001	9105L587
	H051-0002				11.0-11.5	5/10/91				BLM01-H051-0002	
	H051-0003				16-17	5/10/91				BLM01-H051-0003	
	H051-0033				16-17	5/10/91				BLM01-H051-0033	
	H051-0004				20.0-20.5	5/10/91				BLM01-H051-0004	
	H051-0005				27.5-28.0	5/10/91				BLM01-H051-0005	
	H051-0006				33.2-33.7	5/10/91				BLM01-H051-0006	
	H051-0007				35.5-36.5	5/10/91				BLM01-H051-0007	
	H051-0077				35.5-36.5	5/10/91				BLM01-H051-0077	
	H051-0008				41.5-42.0	5/10/91				BLM01-H051-0008	
	H051-0009				48.0-48.5	5/10/91				BLM01-H051-0009	
BH-52	H052-0001	2078436.17	423289.64	44.8	2.5-3.0	5/11/91	VOA, Metals by TCLP, TCLP Sr, IN	8	11	BLM01-H052-0001	9105L601
	H052-0002				7-8	5/11/91				BLM01-H052-0002	
	H052-0022				7-8	5/11/91				BLM01-H052-0022	
	H052-0003				11.0-11.5	5/11/91				BLM01-H052-0003	
	H052-0004				18.5-19.0	5/11/91				BLM01-H052-0004	
	H052-0005				22.5-23.0	5/11/91				BLM01-H052-0005	
	H052-0006				29.0-29.5	5/11/91				BLM01-H052-0006	
	H052-0007				31.5-32.5	5/11/91				BLM01-H052-0007	
	H052-0077				31.5-32.5	5/11/91				BLM01-H052-0077	
	H052-0008				37.0-37.5	5/11/91				BLM01-H052-0008	
	H052 0009				44.0-44.5	5/11/91				BLM01-H052-0009	

Table 2-8. (Page 9 of 9)

Borehole ID[a]	Database Location and Sample ID	Location North (ft)	Location East (ft)	Total Depth (ft)[b]	Sample Interval (ft)[b]	Sample Date	Geochemical Analyses[c]	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
								Planned[d]	Actual[e]		
BH-53	H053-0001	2078606.68	423481.74	50.5	2.0-2.5	5/11/91	VOA, Metals by TCLP, TCLP Sr, IN	8	11	BLM01-H053-0001	9105L601
	H053-0002				6.5-7.0	5/11/91				BLM01-H053-0002	
	H053-0003				12.5-13.0	5/11/91				BLM01-H053-0003	
	H053-0004				18.5-19.5	5/11/91				BLM01-H053-0004	
	H053-0044				18.5-19.5	5/11/91				BLM01-H053-0044	
	H053-0005				21.0-21.5	5/11/91				BLM01-H053-0005	
	H053-0006				27.3-27.8	5/11/91				BLM01-H053-0006	
	H053-0007				32.0-32.5	5/11/91				BLM01-H053-0007	
	H053-0008				36.5-37.0	5/11/91				BLM01-H053-0008	
	H053-0009				45.0-45.5	5/11/91				BLM01-H053-0009	

[a] Boreholes shown on Plate 1.

[b] Depth from ground surface.

[c] Geochemical Analyses:

VOA: Volatile organics, EPA Methods 8010 and 8020
BNA: Base-neutral acid, semivolatile organics, EPA Method 8270
P/P: Pesticides/PCBs, EPA Method 8080
Metals by Toxicity Characteristic Leaching Procedure (TCLP): silver, arsenic, barium, cadmium, chromium, lead, mercury, selenium
TCLP Sr: Strontium by TCLP
EP Toxicity Metals: silver, arsenic, barium, cadmium, chromium, mercury, lead, selenium, strontium, tin
IN: Inorganics (chloride and sulfate)

[d] Number of planned samples based on collecting a sample approximately every 5 ft. Only a select number of samples were sent for laboratory analysis, based on screening results. (WESTON 1990d, WESTON 1991)

[e] Number of actual samples sent for laboratory analysis.

Table 2-9. RI Sampling and Analytical Program - Geotechnical Samples (1990-1991)

Location ID[a]	Sample ID	North (ft)	East (ft)	Total Depth (ft)	Sample Interval (ft)[b]	Sample Date	Geotechnical Tests[c]	Number of Samples[d]	
								Planned	Actual
Borehole:									
BH-32	G32098	2077110.00	423630.00	10.0	9.3-9.8	3/14/90	MC, DD, CP, LL, GSA	1	1
BH-36	G36443	2078030.00	423040.00	45.0	43.8-44.3	3/17/90	MC, DD, CP, LL, GSA	2	2
	G36450								
BH-39	G39402	2077080.00	423160.00	40.2	40.0-40.2	3/19/90	MC, DD, CP, LL, GSA	1	1
BH-42	H042-0008	2077030.67	423444.80	39.0	34-35	4/12/91	% OC	1	1
BH-46	H046-0007	2076624.33	423250.25	33.6	32.5-33	5/07/91	% OC	1	1
BH-49	H049-0009	2077587.20	423093.78	48.0	42.5-43.5	5/09/91	% OC	1	1
BH-51	H051-0007	2078133.36	423133.41	50.5	35.5-36.5	5/10/91	% OC	1	1
Monitoring Well:									
BLM-50	G50614	2077212.01	423372.38	96.0	61.0-61.4	2/16/90	MC, DD, CP, LL, GSA	6	6
	G50668				66.0-66.8	2/16/90	MC, DD, CP, LL, GSA		
	G50725				71.9-72.5	2/16/90	MC, DD, CP, LL, GSA		
	G50774				77.0-77.4	2/16/90	MC, DD, CP, LL, GSA		
	G50833				82.9-83.3	2/16/90	MC, DD, CP, LL, GSA		
	G50882				87.5-88.2	2/16/90	MC, DD, CP, LL, GSA		
BLM-51	G51613	2078516.59	423465.00	61.3	60.8-61.3	2/16/90	MC, DD, CP, LL, GSA	1	1

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Location ID[a]	Sample ID	North (ft)	East (ft)	Total Depth (ft)	Sample Interval (ft)[b]	Sample Date	Geotechnical Tests[c]	Number of Samples[d]	
								Planned	Actual
BLM-61	G61436	2076990.54	423472.98	55.6	43.1-43.6	2/27/90	MC, DD, CP, LL, GSA	3	3
	G61471				46.5-47.1	2/27/90	MC, DD, CP, LL, GSA		
	G61507				50.0-50.7	2/27/90	MC, DD, CP, LL, GSA		
BLM-68	B068-0001	2076392.27	423552.50	38.5	32.2-32.7	4/13/91	% OC, GSA	1	1
BLM-71	B071-0001	2076908.19	423328.09	40.0	29.4-29.9	4/16/91	% OC, GSA	1	1
BLM-76	B076-0001	2076938.78	423410.88	40.85	29-30	4/26/91	GSA	1	1

[a] Sample locations shown on Plate 1

[b] Depth below ground surface

[c] Geotechnical Tests:
MC: Moisture content
DD: Dry density
CP: Coefficient of permeability
LL: Liquid limit
GSA: Grain-size analysis
% OC = % Organic carbon

[d] Planned number of samples from WESTON 1990d

Table 2-10. Summary of Potable Water Supply Analytical Results[a]

Parameter	Sample Date	
	March 21, 1990	April 24, 1991
Bromodichloromethane	4.9	U
Trichloromethane	45	37
Dichloromethane (methylene chloride)	5.3	U

Notes: Analytical data presented in Appendix N-1.
Concentrations in μg/L.
[a]Concentrations above detection limit only.
U: value less than detection limit

Table 2-11. Lysimeter Summary

Lysimeter ID	North (ft)	East (ft)	Ground Surface Elevation (ft MSL)	Depth of Borehole	Depth Interval of Porous Cup	Transfer Vessel	Date Installed
LS-1	2077935	423375	5,449	4.3	3.5-3.9 (u)	No	23 Jan 1990
LS-3	2077930	423375	5,449	27.35	26.55-26.95 (m)	Yes	31 Jan 1990
LS-4	2077925	423375	5,449	36.4	35.2-35.6 (l)	Yes	1 Feb 1990
LS-5	2078500	423,600	5,426	6.34	5.2-5.6 (u)	No	2 Feb 1990
LS-6	2078495	423600	5,429	29.9	29.2-29.6 (l)	Yes	7, 8 Feb 1990
LS-7	2078490	423600	5,429	39.81	39.2-39.6 (m)	Yes	13, 14 Feb 1990

Note: Lysimeter locations shown on Plate 1.
u: upper lysimeter
m: middle lysimeter
l: lower lysimeter
MSL: mean sea level

Table 2-12. Analytical Methods for Lysimeter Sample Analysis in Order of Priority

Priority	Parameter	EPA Method	Required Sample Volume (mL)
1	VOCs	8010/8020[a]	80
2	Inorganics	310.1, 429, 353.1, 376.1, 160.1[b]	1000
3	Semivolatile organic compounds	8270[a]	1000
4	Pesticides/PCBs	8080[a]	1000
5	Dissolved metals	6010 (tin, strontium), and as described in EPA CLP Statement of Work 7/87[a]	1000

[a] Test Methods for Evaluating Solid Waste, EPA SW-846, (EPA 1986b).

[b] Handbook for Analytical Quality Control in Water and Wastewater Laboratories, (EPA 1979).

CLP : Contract Laboratory Program
EPA : U.S. Environmental Protection Agency
PCB : polychlorinated biphenyl
VOC: volatile organic compound

Table 2-13. RI Sampling and Analytical Program - Lysimeters (1990)

Lysimeter ID[a]	Database Location and Sample ID	North (ft)	East (ft)	Sample[b] Depth (ft)	Sample Date	Geochemical[c] Analyses	Chain-of-Custody ID	Laboratory Analytical Batch Number
LS-5 (Shallow)	L005-0001 L005-0004	2078509.76	423599.57	5.60	4/5/90	VOA, IN	BLM L-5 (Shallow)	9004S034
LS-7 (Deep)	L007-0002	2078479.57	423600.00	39.60	4/4/90	VOA	BLM L-7 (Deep)	9004S034
LS-3 (Intermediate)	L003-0024	2077935.79	423375.00	26.95	4/25/90	VOA	BLM L-3	9005S007
LS-3 (Intermediate)	L003-0025	2077935.79	423375.00	26.95	4/27/90	VOA	BLM L-3	9005S007
LS-7 (Deep)	L007-0001	2078479.57	423600.00	39.60	5/18/90	VOA	BLM L-7 (Deep)	9005S104
LS-5 (Shallow)	L005-0002	2078509.76	423599.57	5.60	5/18/90	VOA	BLM L-5 (Shallow)	9005S104
LS-6 (Intermediate)	L006-0003	2078495.00	423600.00	29.60	5/18/90	VOA	BLM L-6 (Intermediate)	9005S104
LS-7 (Deep)	L007-0001	2078479.57	423600.00	39.60	6/26/90	VOA	BLM L-7	9006S095
LS-5 (Shallow)	L005-0002	2078509.76	423599.57	5.60	6/26/90	VOA	BLM L-5	9006S095

[a] Sample locations shown on Plate 1

[b] Depth below ground surface

[c] <u>Geochemical Analyses:</u>

VOA: volatile organics, EPA Methods 8010 and 8020

IN: inorganics (chloride and sulfate)

Table 2-14. Summary of Well Location Objectives and Activities

Study Subarea[a]	Well ID	Well Type	Program	Well Location Objectives	Planned Number of Well Clusters	Actual Numbers of Well Clusters
Site 1, subarea 1	BLM-14 BLM-15 BLM-16	SA DA BR	PI PI PI	Establish background groundwater quality upgradient of the landfill.	2[b]	2
	BLM-39 BLM-40	SA BR	RI RI			
Site 1, subarea 2 (outside landfill fence)	BLM-17 BLM-18 BLM-19	SA DA BR	PI PI PI	Monitor movement of contaminants from landfill, in the unnamed arroyo at the southern property boundary.	7[b]	7
	BLM-20 BLM-21 BLM-22	SA DA BR	PI PI PI			
	BLM-41 BLM-42 BLM-43	BR DA SA	RI RI RI	Monitor lateral movement of contaminants from landfill sources to the unnamed arroyo.		
	BLM-44 BLM-45 BLM-46	BR DA SA	RI RI RI			
	BLM-47 BLM-48 BLM-49	BR DA SA	RI RI RI			
	BLM-50 BLM-51 BLM-52	BR DA SA	RI RI RI	Monitor groundwater at confluence of bedrock flow channels in the northwest landfill area.		
	BLM-59 BLM-60	BR SA	RI RI	Monitor movement of contaminants from landfill, in the unnamed arroyo at the southern property boundary.		
Site 1, subarea 2 (inside landfill fence)	BLM-23 BLM-33 BLM-34	BR BR BR	PI AP AP	Monitor movement of contaminants from landfill, in the unnamed arroyo at the southern property boundary.	5[b]	5
	BLM-35	BR	AP			

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Table 2-14 (page 2 of 3)

Study Subarea[a]	Well ID	Well Type	Program	Well Location Objectives	Planned Number of Well Clusters	Actual Numbers of Well Clusters
Site 1, subarea 2 (inside landfill fence continued)	BLM-53 BLM-56 BLM-58	BR DA SA	RI RI RI	Characterize alluvial and bedrock groundwater immediately below and adjacent to former lagoons within the landfill.	5^b	5
	BLM-54 BLM-55	BR SA	RI RI	Characterize alluvial and bedrock groundwater immediately below and adjacent to former lagoons within the landfill.		
	BLM-57	SA	RI			
Site 1, subarea 3	BLM-61 BLM-62	DA SA	RI RI	Locate remnant contamination south of landfill; confirm historical contamination found in well GBR-32; determine hydrologic relationship and potential contamination from fire water storage ponds.	0^b	3
	BLM-63 BLM-64	BR BR	RI RI			
	BLM-67 BLM-78	DA SA	RI	Define the southernmost extent of the area of contamination around wells GBR-32, GBR-48, and GBR-49.	5^b	4
	BLM-68	DA	RI			
	BLM-69	DA	RI			
	BLM-70	DA	RI			
	BLM-71 BLM-72 BLM-73	DA DA DA	RI RI RI	Define the western extent of the area of contamination around wells GBR-32, GBR-48, and GBR-49.	3^c	3
	BLM-74	DA	RI	A 5-inch diameter well located approximately 100 ft south of well GBR-49 to further define the southern extent of the area of contamination around wells GBR-32, GBR-48, and GBR-49.	1^c	1

Table 2-14 (page 3 of 3)

Study Subarea[a]	Well ID	Well Type	Program	Well Location Objectives	Planned Number of Well Clusters	Actual Numbers of Well Clusters
Site 1, subarea 3 (continued)	BLM-75	DA	RI	Monitor contamination immediately downgradient of wells GBR-32, GBR-48, and GBR-49. Wells BLM-75, BLM-76, and BLM-77 are 5-inch diameter wells and may serve as pumping wells.	4[c]	3
	BLM-79	SA	RI			
	BLM-76	DA	RI			
	BLM-77	DA	RI			
Site 2	BLM-24	SA	PI	Differentiate between contaminant sources migrating from Giant- Bloomfield Refinery and the landfill.	3[b]	4
	BLM-25	DA	PI			
	BLM-26	BR	PI			
	BLM-27	SA	PI			
	BLM-28	DA	PI			
	BLM-29	BR	PI			
	BLM-30	SA	PI			
	BLM-31	DA	PI			
	BLM-32	BR	PI			
	BLM-37	SA	AP			
	BLM-65	SA	RI	Evaluate potential for migration of contaminants in the unnamed arroyo south of U.S. 64.	0[b]	2
	BLM-66	SA	RI			

[a] Study areas and well locations are shown on Plate 1.

[b] Planned number of samples from section 6 of SAPP (WESTON 1990d).

[c] Planned number of samples from section 5 of Briefing Document (WESTON 1991).

AP: Accelerated Program
BR: bedrock aquifer
DA: deep alluvial aquifer
PI: Preliminary Investigation
RI: Remedial Investigation
SA: shallow alluvial aquifer

Table 2-15. Monitoring Well Completion Data
SITE: BLM01 BLM (Lee Acres)
REPORT DATE: 12/11/91

LOCATION ID	NORTH COORDINATE (FT)	EAST COORDINATE (FT)	GROUND ELEVATION (FT MSL)	BOREHOLE DEPTH (FT) *	CASING STICKUP (FT)	CASING ELEVATION (FT MSL)	CASING DEPTH (FT) *	CASING + DIAMETER (INCHES)	SCREEN * BEGINNING DEPTH (FT)	SCREEN LENGTH (FT)	FLOW CODE	FORMATION OF COMPLETION
B014	2079762.31	424077.29	5459.8	40.5	1.79	5461.59	40.48	2.0	29.91	10.33	1	SA
B015	2079753.14	424082.04	5459.8	62.5	1.87	5461.67	61.25	2.0	55.90	5.11	1	DA
B016	2079746.66	424073.66	5459.8	100.0	1.46	5461.26	100.00	2.0	89.46	10.30	1	BR
B017	2077347.81	423116.23	5418.0	37.4	2.20	5420.20	37.42	2.0	26.88	10.31	2	SA
B018	2077341.40	423108.66	5418.0	44.4	1.82	5419.82	42.50	2.0	37.34	5.14	2	DA
B019	2077334.73	423101.58	5418.0	100.5	1.40	5419.40	100.25	2.0	89.91	10.24	2	BR
B020	2077335.90	423273.74	5417.0	38.2	2.11	5419.11	38.22	2.0	26.78	11.21	2	SA
B021	2077326.13	423276.53	5417.0	49.0	1.85	5418.85	43.67	2.0	38.13	5.22	2	DA
B022	2077318.27	423268.43	5417.0	100.0	1.80	5418.80	100.00	2.0	89.43	10.33	2	BR
B023	2077322.70	423485.04	5417.5	101.3	1.78	5419.28	100.00	2.0	89.43	10.43	2	BR
B024	2074511.48	423048.24	5372.6	45.1	1.82	5374.42	45.11	2.0	34.56	10.33	4	SA
B025	2074501.51	423046.97	5372.6	75.0	1.83	5374.43	59.23	2.0	53.64	5.35	4	DA
B026	2074506.28	423038.66	5372.6	99.7	1.47	5374.07	99.74	2.0	89.18	10.32	4	BR
B027	2074540.46	423425.37	5376.8	43.2	2.21	5379.01	43.15	2.0	32.58	10.33	4	SA
B028	2074540.85	423415.39	5376.8	73.0	2.09	5378.89	70.00	2.0	64.39	5.61	4	DA
B029	2074527.65	423414.47	5376.8	100.1	2.20	5379.00	100.00	2.0	89.43	10.34	4	BR
B030	2074500.32	424019.28	5367.8	34.7	1.95	5369.75	34.70	2.0	24.29	10.31	4	SA
B031	2074491.33	424023.40	5367.8	41.5	1.99	5369.79	39.53	2.0	34.23	5.30	4	DA
B032	2074495.46	424009.92	5367.8	99.9	2.01	5369.81	99.91	2.0	89.09	10.58	4	BR
B033	2077327.39	423503.95	5417.3	60.0	1.99	5419.29	60.00	2.0	48.73	10.01	2	BR
B034	2077317.34	423501.74	5417.0	83.0	1.98	5418.98	80.28	2.0	70.04	10.01	2	BR
B035	2077303.73	423680.65	5423.2	67.0	1.81	5425.01	66.89	2.0	56.20	10.44	2	BR
B037	2074825.48	423781.15	5381.6	40.8	1.86	5383.46	39.16	2.0	28.37	10.55	4	SA
B039	2078780.24	423561.41	5439.3	50.0	4.40	5443.70	47.35	2.0	37.31	9.87	1	SA
B040	2078778.25	423550.95	5438.9	79.5	4.70	5443.60	77.23	2.0	66.98	10.02	1	BR
B041	2077494.24	423379.52	5419.9	64.7	3.18	5423.08	64.68	2.0	53.81	10.63	2	BR
B042	2077505.04	423374.12	5420.1	49.0	2.63	5422.73	47.20	2.0	37.03	9.94	2	DA
B043	2077509.73	423384.22	5420.2	43.0	3.27	5423.47	42.38	2.0	31.49	10.65	2	SA
B044	2077764.99	423308.19	5421.8	76.1	2.58	5424.38	74.01	2.0	63.78	9.60	2	BR
B045	2077774.66	423309.38	5422.2	45.3	2.52	5424.72	42.56	2.0	32.60	9.54	2	DA
B046	2077783.48	423308.91	5422.4	40.4	2.47	5424.87	39.37	2.0	29.00	10.15	2	SA
B047	2078023.44	423294.82	5430.1	82.0	2.96	5433.06	80.09	2.0	69.85	10.02	2	BR
B048	2078034.97	423296.89	5430.3	50.0	3.16	5433.46	44.76	2.0	34.78	9.56	2	DA
B049	2078044.70	423296.39	5430.3	44.9	3.13	5433.43	42.90	2.0	32.93	9.54	2	SA
B050	2078511.47	423459.16	5442.7	96.0	2.80	5445.50	91.77	2.0	81.79	9.55	2	BR
B051	2078516.59	423465.00	5442.7	61.5	2.66	5445.36	60.18	2.0	50.22	9.53	2	DA
B052	2078522.17	423470.44	5442.7	55.0	2.80	5445.50	47.00	2.0	37.05	9.43	2	SA
B053	2078133.93	423553.14	5439.0	91.2	2.77	5441.77	90.90	2.0	80.94	9.48	2	BR
B054	2077789.24	423397.34	5428.7	89.5	2.71	5431.41	85.00	2.0	75.14	9.46	2	BR
B055	2077801.66	423394.81	5428.6	43.0	2.73	5431.33	42.00	2.0	31.79	9.79	2	SA

* DEPTH GIVEN IN FEET BELOW GROUND SURFACE

\+ CASING DIAMETER = INSIDE DIAMETER

FORMATION OF COMPLETION CODE:
SA - SHALLOW ALLUVIAL AQUIFER
DA - DEEP ALLUVIAL AQUIFER
BR - BEDROCK AQUIFER

FLOW RELATIONSHIP CODE:
1 - SUBAREA 1
2 - SUBAREA 2
4 - SUBAREA 4

Table 2-15. Monitoring Well Completion Data
SITE: BLM01 BLM (Lee Acres)
REPORT DATE: 12/11/91

LOCATION ID	NORTH COORDINATE (FT)	EAST COORDINATE (FT)	GROUND ELEVATION (FT MSL)	BOREHOLE DEPTH (FT) *	CASING STICKUP (FT)	CASING ELEVATION (FT MSL)	CASING DEPTH (FT) *	CASING + DIAMETER (INCHES)	SCREEN * BEGINNING DEPTH (FT)	SCREEN LENGTH (FT)	FLOW CODE	FORMATION OF COMPLETION
B056	2078197.55	423418.70	5434.1	47.5	3.50	5437.60	46.33	2.0	36.36	9.54	2	DA
B057	2078434.40	423530.57	5443.7	51.9	2.54	5446.24	49.03	2.0	39.07	9.53	2	SA
B058	2078207.44	423407.78	5434.0	42.7	2.76	5436.76	42.02	2.0	32.49	9.10	2	SA
B059	2077319.19	423360.55	5415.5	75.0	4.55	5420.05	61.04	2.0	50.99	9.59	2	BR
B060	2077331.49	423357.27	5415.4	40.0	4.74	5420.14	38.02	2.0	28.05	9.56	2	SA
B061	2076990.54	423472.98	5409.6	55.6	2.84	5412.44	55.30	2.0	45.35	9.53	3	BR
B062	2076999.82	423478.33	5411.3	35.6	1.37	5412.67	35.00	2.0	25.04	9.54	3	SA
B063	2077086.74	423520.20	5411.3	56.1	2.62	5413.92	54.00	2.0	44.05	9.52	3	BR
B064	2076923.20	423546.11	5406.5	57.0	2.65	5409.15	54.45	2.0	44.49	9.54	3	BR
B065	2073445.54	422428.61	5357.3	43.1	2.58	5359.88	40.02	2.0	30.05	9.54	4	SA
B066	2072549.47	421853.46	5335.9	24.0	3.19	5339.09	22.20	2.0	12.24	9.53	4	SA
B067	2076418.41	423406.40	5403.4	42.3	3.01	5406.41	42.01	2.0	32.07	9.59	3	DA
B068	2076392.27	423552.50	5405.2	38.5	3.44	5408.64	37.82	2.0	27.86	9.61	3	DA
B069	2076663.31	423340.43	5407.3	40.7	3.22	5410.52	38.09	2.0	28.15	9.59	3	DA
B070	2076613.18	423489.79	5407.7	36.8	3.44	5411.14	36.66	2.0	26.71	9.60	3	DA
B071	2076908.19	423328.09	5408.8	40.0	4.50	5413.30	38.58	2.0	28.62	9.60	3	DA
B072	2077004.92	423312.76	5408.4	37.0	3.35	5411.75	36.59	2.0	26.63	9.6	3	SA
B073	2077090.31	423367.87	5409.6	37.7	3.16	5412.76	27.05	2.0	27.05	9.59	3	SA
B074	2076761.36	423478.98	5408.5	35.75	2.98	5411.48	33.58	5.25	23.21	9.97	3	SA
B075	2076815.53	423410.83	5408.6	40.0	1.90	5410.50	39.73	5.25	29.37	9.96	3	SA
B076	2076938.78	423410.88	5411.9	40.85	2.43	5414.33	39.49	5.25	29.10	9.99	3	SA
B077	2077039.90	423385.67	5411.0	37.0	3.33	5414.33	35.05	5.25	24.76	9.99	3	SA
B078	2076419.76	423393.94	5403.4	36.68	3.50	5406.90	36.68	2.0	26.72	9.60	3	SA
B079	2076818.3	423394.9	5409.1	37.5	2.73	5411.83	37.15	2.0	27.20	9.59	3	SA

* DEPTH GIVEN IN FEET BELOW GROUND SURFACE

+ CASING DIAMETER = INSIDE DIAMETER

FORMATION OF COMPLETION CODE:
DA - DEEP ALLUVIAL AQUIFER
SA - SHALLOW ALLUVIAL AQUIFER
BR - BEDROCK AQUIFER

FLOW RELATIONSHIP CODE:
2 - SUBAREA 2
3 - SUBAREA 3
4 - SUBAREA 4

DATA FILE: K:\DART\BLMX\BLM01\MWI10000.DAT

Table 2-16. RI Sampling and Analytical Program - Monitoring Well Soils (1989-1991)

Monitoring Well ID[a]	Database Location and Sample ID	North (ft)	East (ft)	Well Type[b]	Total Depth (ft)[c]	Sample Interval (ft)[c]	Sample Date	Geochemical Analyses[d]	Number of Samples: Planned[e]	Number of Samples: Actual[f]	Chain of Custody ID	Laboratory Analytical Batch Number
BLM-33	B033-0001	2077327.39	423503.95	BR	60.0	8.7-9.7	1/19/89	VOA, BNA, P/P, Metals by TCLP	6	5	B3310	8901S046
	B033-0002					18.7-19.7	1/19/89				B3320	
	B033-0003					28.5-29.5	1/19/89	VOA, Metals by TCLP			B3330	
	B033-0004					39.6-40.5	1/19/89				B3340	
	B033-0005					49-50	1/19/89	Metals by TCLP			B3350	
BLM-34	B034-0003	2077317.34	423501.74	BR	83.0	59.50-60.25	1/21/89	Metals by TCLP	2	2	B3460	8901S054
	B034-0004					74.65-75.00	1/21/89				B3475	
BLM-35	B035-0001	2077303.73	423680.65	BR	67.0	8.8-9.8	1/17/89	VOA, BNA, P/P, Metals by TCLP	6	6	B3510	8901S039
	B035-0002					19-20	1/17/89				B3520	
	B035-0003					29-30	1/17/89	VOA, Metals by TCLP			B3530	
	B035-0004					39-40	1/17/89				B3540	
	B035-0005					49-50	1/17/89	Metals by TCLP			B3550	
	B035-0006					59-60	1/17/89				B3560	
BLM-37	B037-0001	2074825.48	423781.15	DA	40.8	38.5-39.0	1/22/90	Metals by TCLP	4	2	B3740	8901S054
	B037-0002					39.25-40.75	1/22/90				B3741	
BLM-40	B040-0002	2078778.25	423550.95	BR	80.5	12.5-13.3	11/30/89	VOA, BNA, P/P, EP Toxicity Metals, IN	8	7	B4013	8912L676
	B040-0003					19-20	11/30/89				B4019	8912L683
	B040-0004					27.5-28.5	11/30/89				B4028	
	B040-0005					39-40	11/30/89				B4039	
	B040-0006					50-51	12/1/89				B4050	
	B040-0001					60.0-60.8	12/2/89				B4060	
	B040-0003					69.5-70.0	12/2/89				B4070	

Table 2-16. (Page 2 of 5)

Monitoring Well ID[a]	Database Location and Sample ID	North (ft)	East (ft)	Well Type[b]	Total Depth (ft)[c]	Sample Interval (ft)[c]	Sample Date	Geochemical Analyses[d]	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
									Planned[e]	Actual[f]		
BLM-41	B041-0001	2077494.24	423379.52	BR	64.7	10-11	12/4/89	VOA, BNA,	6	5	B4110	8912L723
	B041-0002					21-22	12/4/89	P/P, EP			B4121	
	B041-0003					29-30	12/4/89	Toxicity			B4129	
	B041-0004					47.5-48.5	12/5/89	Metals, IN			B4148	
	B041-0005					50-51	12/5/89				B4151	
BLM-44	B044-0001	2077764.99	423308.19	BR	76.1	12.5-13.6	12/14/89	VOA, BNA,	7	4	B4413	8912L912
	B044-0003					28.0-29.5	12/14/89	P/P, EP			B4429	
	B044-0004					41-42	12/14/89	Toxicity			B4442	
	B044-0005					45.5-46.5	12/14/89	Metals, IN			B4446	
BLM-47	B047-0001	2078023.44	423294.82	BR	82.0	15.5-16.5	1/2/90	VOA, BNA,	8	4	B4716	9001L059
	B047-0002					20.5-21.5	1/2/90	P/P, EP			B4721	
	B047-0003					30.5-31.5	1/2/90	Toxicity			B4731	
	B047-0004					40-41	1/2/90	Metals, IN			B4741	
BLM-50	B050-0001	2077212.01	423372.38	BR	96.0	11.0-11.8	1/16/90	VOA, BNA,	6	7	B5012	9002S038
	B050-0002					20.8-21.6	1/16/90	P/P, EP			B5022	
	B050-0007					30.4-30.9	1/16/90	Toxicity			B5031	
	B050-0003					40.0-41.5	1/16/90	Metals, IN			B5041	
	B050-0004					40.0-41.5	1/16/90				B5041D	
	B050-0005					52.5-53.5	1/16/90				B5053	
	B050-0006					59.0-59.9	1/16/90				B5064	
BLM-53	B053-0001	2078133.93	423553.14	BR	91.15	7.7-8.7	1/8/90	VOA, BNA,	5	5	B5308	9001L122
	B053-0003					20.1-21.4	1/8/90	P/P, EP			B5321	
	B053-0004					20.1-21.4	1/8/90	Toxicity			B5321D	
	B053-0005					30.1-31.1	1/8/90	Metals, IN			B5331	
	B053-0006					38.8-39.3	1/8/90				B5339	
BLM-54	B054-0001	2077789.2	423397.34	BR	89.5	7.00-7.85	1/16/90	VOA, BNA,	4	5	H5408	9001S037
	B054-0002					19.0-19.8	1/16/90	P/P, EP			H5419	9001S038
	B054-0003					29-30	1/16/90	Toxicity			H5429	
	B054-0004					29-30	1/16/90	Metals, IN			H5429D	
	B054-0007					37.5-38.7	1/17/90				H5438	

Table 2-16. (Page 3 of 5)

Monitoring Well ID[a]	Database Location and Sample ID	North (ft)	East (ft)	Well Type[b]	Total Depth (ft)[c]	Sample Interval (ft)[c]	Sample Date	Geochemical Analyses[d]	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
									Planned[e]	Actual[f]		
BLM-56	B056-0007 B056-0008 B056-0009 B056-0010 B056-0011	2078197.55	423418.70	DA	47.5	6-7 6-7 17.2-18.0 30.2-31.0 40.5-41.5	1/19/90 1/19/90 1/19/90 1/19/90 1/19/90	VOA, BNA, P/P, EP Toxicity Metals, IN	4	5	B5607 B5607D B5618 B5631 B5642	9001S041
BLM-57	B057-0001 B057-0002 B057-0003 B057-0004	2078434.40	423530.57	SA	53.6	5.5-6.1 17-18 28.3-29.0 41.5-42.0	1/17/90 1/17/90 1/17/90 1/17/90	VOA, BNA, P/P, EP Toxicity Metals, IN	4	4	B5706 B5718 B5729 B5742	9001S037
BLM-59	B059-0001 B059-0002 B059-0003	2077319.19	423360.55	BR	75.0	5-6 15-16 30.0-31.2	1/29/90 1/29/90 1/29/90	VOA, BNA, P/P, EP Toxicity Metals, IN	3	3	B5906 B5916 B5932	9001S041
BLM-61	B061-0001 B061-0002 B061-0003	2076990.54	423472.98	BR	55.6	15-16 23.5-24.5 40-41	2/27/90 2/27/90 2/27/90	VOA, BNA, P/P, EP Toxicity Metals, IN	4	3	B6115 B6124 B6140	9003S005
BLM-63	B063-0001 B063-0002	2077086.74	423520.20	BR	56.1	15-16 15-16	3/2/90 3/2/90	VOA, BNA, P/P, EP Toxicity Metals, IN	2	2	B6315 B6315D	9003S015
BLM-64	B064-0002 B064-0003	2076923.20	423546.11	BR	57.0	12.5-13.5 12.5-13.5	3/7/90 3/7/90	VOA, BNA, P/P, EP Toxicity Metals, IN	2	2	B6413 B6413D	9003S025
BLM-65	B065-0001	2073445.54	422428.61	SA	44.8	31.5-32.5	3/14/90	VOA, BNA, P/P, EP Toxicity Metals, IN	1	1	B6532	9003S044
BLM-66	B066-0001	2072549.47	421853.46	SA	23.6	22.3-23.0	3/15/90	VOA	1	1	B6623	9003S044
BLM-67	B067-0001	2076418.41	423406.40	DA	42.3	29.4-29.7	4/10/91	VOA, Metals by TCLP, TCLP Sr, IN	1	1	BLM01-B067-0001	9104L258

Table 2-16. (Page 4 of 5)

Monitoring Well ID^a	Database Location and Sample ID	North (ft)	East (ft)	Well Type^b	Total Depth (ft)^c	Sample Interval (ft)^c	Sample Date	Geochemical Analyses^d	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
									Planned^e	Actual^f		
BLM-68	B068-0001 B068-0011	2076392.27	423552.50	DA	38.5	32.2-32.7 32.2-32.7	4/13/91 4/13/91	VOA, Metals by TCLP, TCLP Sr, IN	1	2	BLM01-B068-0001 BLM01-B068-0011	9104L281
BLM-69	B069-0001	2076663.31	423340.43	DA	40.7	35.0-35.5	4/14/91	VOA, Metals by TCLP, TCLP Sr, IN	1	1	BLM01-B069-0001	9104L291
BLM-70	B070-0001	2076613.18	423489.79	DA	37.0	31.4-31.8	4/14/91	VOA, Metals by TCLP, TCLP Sr, IN	1	1	BLM01-B070-0001	9104L291
BLM-71	B071-0001 B071-0011	2076908.19	423328.09	DA	40.0	29.4-29.9 29.4-29.9	4/16/91 4/16/91	VOA, Metals by TCLP, TCLP Sr, IN	1	1	BLM01-B071-0001 BLM01-B071-0011	9104L299
BLM-72	B072-0001	2077004.92	423312.76	SA	37.3	29.5-30.0	4/22/91	VOA, Metals by TCLP, TCLP Sr, IN	1	1	BLM01-B072-0001	9104L372
BLM-73	B073-0001	2077090.31	423367.87	SA	37.7	27.7-28.3	4/23/91	VOA, Metals by TCLP, TCLP Sr, IN	1	1	BLM01-B073-0001	9104L388
BLM-74	B074-0001	2076761.36	423478.98	SA	35.75	30.6-31.5	4/25/91	VOA, Metals by TCLP, TCLP Sr, IN	1	1	BLM01-B074-0001	9104L407
BLM-75	B075-0001	2076815.53	423410.83	SA	40.0	29.0-30.5	4/26/91	VOA, Metals by TCLP, TCLP Sr, IN	1	1	BLM01-B075-0001	9104L411

Table 2-16. (Page 5 of 5)

Monitoring Well ID[a]	Database Location and Sample ID	North (ft)	East (ft)	Well Type[b]	Total Depth (ft)[c]	Sample Interval (ft)[c]	Sample Date	Geochemical Analyses[d]	Number of Samples		Chain of Custody ID	Laboratory Analytical Batch Number
									Planned[e]	Actual[f]		
BLM-76	B076-0001 B076-0011	2076938.78	423410.88	SA	40.85	29-30 29-30	4/28/91 4/28/91	VOA, Metals by TCLP, TCLP Sr, IN	1	2	BLM01-B076-0001 BLM01-B076-0011	9104L424
BLM-77	B077-0001	2077039.90	423385.67	SA	37.0	28.6-29.2	4/30/91	VOA, Metals by TCLP, TCLP Sr, IN	1	1	BLM01-B077-0001	9105L451

Note: Analytical data presented in Appendix I

[a] Monitoring wells shown on Plate 1

[b] Well type:

- SA: Shallow Alluvial Aquifer
- DA: Deep Alluvial Aquifer
- BR: Bedrock Aquifer

[c] Depth from ground surface

[d] Geochemical Analyses:

- VOA: Volatile organics, EPA Methods 8010 and 8020
- BNA: Base-neutral acids, semivolatile organics, EPA Method 8270
- P/P: Pesticides/PCBs, EPA Method 8080
- Metals by Toxicity Characteristic Leaching Procedure (TCLP): silver, arsenic, barium, cadmium, chromium, lead, mercury, selenium
- TCLP Sr: Strontium by TCLP
- EP Toxicity Metals: silver, arsenic, barium, cadmium, chromium, mercury, lead, selenium, strontium, tin
- IN: Inorganics (chloride and sulfate)

[e] Planned number samples are based on collecting a sample approximately every 10 ft to top of bedrock (WESTON 1990d), except for wells BLM-67 through BLM-77. Planned samples for BLM-67 through BLM-77 are at the soil/water interface (WESTON 1991).

[f] Number of actual samples sent for laboratory analysis.

Table 2-17. Comparison of Groundwater Sample Methods

Parameter Name	Monitoring Well ID	Database Location ID	Log Date	Sample Method Concentrations	
				Submersible Pump[a] (μg/L)	Stainless Steel Bailer[b] (μg/L)
1,1,1-Trichloroethane	GBR-48	G048	06/21/91 07/18/91	1.2 U (1.0)	U (1.0) 1.3
1,1-Dichloroethane	BLM-68	B068	06/19/91 07/16/91	5.4 4.6	4.7[c] 3.6
	GBR-32	G032	06/21/91 07/18/91	2.8 3.7	2.7 4.1
	GBR-48	G048	06/21/91 07/18/91	7.55[d] 5.8[d]	2.9 5.1
1,2-trans-Dichloroethene	BLM-68	B068	06/19/91 07/16/91	150 125	96[c] 96
	BLM-70	B070	07/16/91	11	11
	BLM-73	B073	07/17/91	1.4	1.5
	BLM-74	B074	07/16/91	14	7.5
	BLM-76	B076	07/16/91	10	10
	GBR-32	G032	06/21/91 07/18/91	78 130	70 140
	GBR-48	G048	06/21/91 07/18/91	96[d] 196.7[d]	81 190
	GBR-50	G050	07/18/91	U (1.0)	1.2
Trichloromethane	BLM-68	B068	06/19/91 07/16/91	1.7 1.6	1.8 1.4
	GBR-32	G032	07/18/91	1.6	1.8
	GBR-48	G048	06/21/91 07/18/91	3.1[d] 2.4[d]	U (1.0) 2.6
Dichloromethane (methylene chloride)	BLM-74	B074	07/16/91	5.6	5.3
	BLM-76	B076	07/16/91	6.7	6.4
	GBR-17	G017	06/21/91 07/18/91	B 13 5.0	B 14 5.8
	GBR-48	G048	06/21/91 07/18/91	9.6[d] U (4.0)	U (4.0) 15
	GBR-50	G050	07/18/91	14	13
Tetrachloroethene	BLM-68	B068	06/19/91 07/16/91	14 12	13[c] 9.7
	BLM-70	B070	07/16/91	3.1	3.3
	BLM-74	B074	07/16/91	2.7	2.3
	BLM-76	B076	07/16/91	3.4	3.3

Table 2-17. (page 2 of 2)

Parameter Name	Monitoring Well ID	Database Location ID	Log Date	Sample Method Concentrations	
				Submersible Pump[a] (µg/L)	Stainless Steel Bailer[b] (µg/L)
Tetrachloroethene (continued)	GBR-32	G032	06/21/91	6.0	12
			07/18/91	10	12
	GBR-48	G048	06/21/91	16.5[d]	9.6
			07/18/91	13.7[d]	14
Toluene	GBR-17	G017	07/18/91	1.4	1.6
Trichloroethene	BLM-68	B068	06/19/91	9.4	8.2[c]
			07/16/91	7.9	6.1
	BLM-70	B070	07/16/91	1.6	1.8
	BLM-74	B074	07/16/91	2.0	1.4
	BLM-76	B076	07/16/91	1.7	1.6
	GBR-32	G032	06/21/91	4.3	6.9
			07/18/91	6.5	7.3
	GBR-48	G048	06/21/91	14.5[d]	7.5
			07/18/91	11.3[d]	11

Note: Sample locations shown on Plate 1.
Groundwater analytical results presented in Appendix N.
U = Value less than detection limit. Detection limit follows in parentheses.

[a] Database sample ID = 0001 for submersible pump samples collected in 1991. Sample IDs for duplicate samples are 0002 and 0004.

[b] Database sample ID = 1111 for bailer samples collected in 1991.

[c] Bailed sample collected 06/22/91.

[d] Average of duplicate samples.

Table 2-18. Volatile Organic Compounds Analyzed and Reported by EPA Methods 8010 and 8020

Method 8010	Method 8020
Bromodichloromethane	Benzene
Bromoform	Chlorobenzene
Bromomethane	1,2-dichlorobenzene
Carbon tetrachloride	1,3-dichlorobenzene
Chlorobenzene	1,4-dichlorobenzene
Chloroethene (vinyl chloride)	Ethylbenzene
2-Chloroethylvinylether	Toluene
Chloromethane	Xylene (all isomers)
1,2-dichlorobenzene	
1,3-dichlorobenzene	
1,4-dichlorobenzene	
Dichlorofluoromethane	
1,1-dichloroethane	
1,2-dichloroethane	
1,1-dichloroethene	
1,2-*trans*-dichloroethene	
Dichloromethane (methylene chloride)	
1,2-dichloropropane	
1,3-*cis*-dichloropropene	
1,3-*trans*-dichloropropene	
1,1,2,2-tetrachloroethane	
Tetrachloroethene	
1,1,1-trichloroethane	
1,1,2-trichloroethane	
Trichloroethane	
Trichloromethane	

EPA: U.S. Environmental Protection Agency

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Table 2-19. Semivolatile Organics (BNAs) Analyzed and Reported by EPA Method 8270

Semivolatile Organics

- Phenol
- 2-Chlorophenol
- 1,4-Dichlorobenzene
- 1,2-Dichlorobenzene
- bis(2-chloroisopropyl)ether
- N-Nitroso-di-n-propylamine
- Nitrobenzene
- 2-Nitrophenol
- Benzoic Acid
- 2-4-Dichlorophenol
- Naphthalene
- Hexachlorobutadiene
- Hexachlorocyclopentadiene
- 2,4,5-Trichlorophenol
- 2-Nitroaniline
- Acenaphthylene
- Acenaphthene
- 4-Nitrophenol
- 2,4-Dinitrotoluene
- Diethlphthalate
- Fluorene
- 4,6-Dinitro-2-methylphenol
- 4-Bromophenyl-phenylether
- Pentachlorophenol
- Anthracene
- Fluoranthene
- Butyl benzyl phthalate
- Benzo(a)anthracene
- Chrysene
- Benzo(b)fluoranthene
- Benzo(a)pyrene
- Dibenzo(a,h)anthracene
- 2-Methylnaphthalene
- bis(2-chloroethyl)ether
- 1,3-Dichlorobenzene
- Benzyl alcohol
- 2-Methylphenol
- 4-Methylphenol
- Hexachloroethane
- Isophorone
- 2,4-Dimethylphenol
- bis(2-chloroethoxy) methane
- 1,2,4-Trichlorobenzene
- 4-Chloroaniline
- 4-Chloro-3-methylphenol
- 2,4,6-Trichlorophenol
- 2-Chloronaphthalene
- Dimethyl phthalate
- 3-Nitroaniline
- 2,4-Dinitrophenol
- Dibenzofuran
- 2,6-Dinitrotoluene
- 4-Chlorophenyl-phenylether
- 4-Nitroaniline
- N-Nitrosodiphenylamine
- Hexachlorobenzene
- Phenanthrene
- di-n-butyl phthalate
- Pyrene
- 3,3'-Dichlorobenzidine
- bis(2-ethylhexyl) phthalate
- di-n-octyl phthalate
- Benzo(k)fluoranthene
- Indeno(1,2,3-cd)pyrene
- Benzo(g,h,i)perylene

BNA: base-neutral acid
EPA: U.S. Environmental Protection Agency

Table 2-20. Pesticides and Polychlorinated Biphenyls Analyzed and Reported by EPA Method 8080

Pesticides	PCBs
Alpha-BHC	Aroclor-1016
Beta-BHC	Aroclor-1221
Delta-BHC	Aroclor-1232
Gamma-BHC (lindane)	Aroclor-1242
Heptachlor	Aroclor-1248
Aldrin	Aroclor-1254
Heptachlor epoxide	Aroclor-1260
Endosulfan I	
dieldrin	
4,4'-DDE	
Endrin	
Endosulfan II	
4,4'-DDT	
Methoxychlor	
Endrin ketone	
Alpha chlordane	
Gamma chlordane	
Toxaphene	

EPA: U.S. Environmental Protection Agency
PCBs: polychlorinated biphenyls

Table 2-21. Inorganics Analyses

Metals Groundwater (Soluble)	General Chemical Parameters	Isotopes
Silver	Chloride	Isotopic sulfur
Aluminum	Nitrate/nitrite	Isotopic strontium
Arsenic	Sulfate	
Barium	Iodide	
Calcium	Sulfide	
Cadmium	Total dissolved solids	
Cobalt	Bicarbonate	
Chromium	Carbonate	
Copper	Bromide	
Iron	Total Kjeldahl nitrogen	
Mercury		
Potassium		
Magnesium		
Manganese		
Sodium		
Nickel		
Lead		
Selenium		
Strontium		
Tin		
Vanadium		
Zinc		

Table 2-22. Fire Water Pond Sample Location Descriptions

Sample ID	Depth (ft)	Soil/Sediment Description
FP-SE	1.5	0.2 ft of topsoil underlain by 0.7 ft of laminated, brown to light gray clay; underlain by well cemented, orange stained, sandstone.
FP-NE	1.5	0.3 ft of topsoil underlain by 0.7 ft of fissile, laminated, dark brown clay; underlain by well cemented, orange stained, sandstone.
FP-NW	1.5	0.2 ft of topsoil underlain by 0.3 ft of fissile, laminated, dark brown clay; underlain by 0.6 ft orange stained, sandy soil; underlain by 0.4 ft of light gray, well cemented sandstone.
FP-SW	1.0	0.1 ft of topsoil underlain by 0.6 ft of laminated, fissile, dark brown to light gray clay; underlain by 0.3 ft of orange stained sandy soil; underlain by light gray sandstone.
FP-C	1.0	0.2 ft of topsoil underlain by 0.3 ft of green silty clay with orange staining; underlain by light gray sandstone bedrock.

Table 2-23. RI Sampling and Analytical Program - Surface Soil (1990)

Sampling Location[a]	Database Location and Sample ID	Sample Interval (ft)	Sample Date	Geochemical Analyses[b]	Chain-of-Custody ID	Laboratory Analytical Batch Number
Fire Pond (Center)	F001-0001	0 - 0.5	03/21/90	VOA, BNA, P/P, EP Toxicity Metals, IN	FPC	9003S085
Fire Pond (Northwest)	F005-0002	0 - 0.5	03/21/90	VOA, BNA, P/P, EP Toxicity Metals, IN	FPNW	9003S085
Fire Pond (Northeast)	F002-0003	0 - 0.5	03/21/90	VOA, BNA, P/P, Toxicity Metals, IN	FPNE	9003S085
Fire Pond (Southeast)	F003-0004	0 - 0.5	03/21/90	VOA, BNA, P/P, EP Toxicity Metals, IN	FPSE	9003S085
Fire Pond (Southwest)	F004-0005	0 - 0.5	03/21/90	VOA, BNA, P/P, EP Toxicity Metals, IN	FPSW	9003S085

[a] Sampling locations shown on Figure 2-26 and Plate 1.

[b] Geochemical Analyses:

VOA: Volatile Organics, EPA Methods 8010 and 8020
BNA: Base-neutral acid, semivolatile organics, EPA Method 8270
P/P: Pesticides/PCBs, EPA Method 8080
IN: Inorganics (chloride and sulfate)
EP Toxicity Metals: silver, arsenic, barium, cadmium, mercury, lead, selenium, strontium, and tin.

3. ENVIRONMENTAL AND ECOLOGICAL STUDY ACTIVITIES AND RESULTS

To support the baseline risk assessment (Section 10 of this report) and the FS, several environmental and ecological investigations were performed during the RI. An air quality and meteorological investigation was conducted within the Lee Acres Landfill Study Area, and a summary of the investigations and their results are presented in subsection 3.1. Subsection 3.2 presents the land use and demographics within the study area; subsection 3.3 presents the ecology, including threatened, endangered, and rare species; and subsection 3.4 presents the archaeological, historical, and cultural resources found within the study area. The latter three subsections are intended to provide an overview of the environmental information required for the FS. Detailed analysis of the environmental impacts resulting from a remedial alternative will be presented in the Phase III FS to be issued after remedial action alternatives have been developed, screened, and evaluated.

3.1. AIR QUALITY AND METEOROLOGY

In October 1989, a monitoring program was implemented to characterize the air quality and the meteorology at the former Lee Acres Landfill. The monitoring program continued through May 1991. The purpose of the air quality and meteorological investigation was to determine the concentration of airborne contaminants both onsite and offsite in the Lee Acres Landfill Study Area, to monitor onsite meteorology, and, as necessary, to correlate the air quality and meteorological data to estimate dispersion of contaminants and determine the potential exposure to local residents and the public.

Potential landfill wastes were reviewed prior to designing the air quality monitoring program. This review identified that wastes containing VOCs and metals had been disposed of at the site. An initial screening survey using an HNu P-101 was used to screen for the presence of VOCs. Soil samples identified a list of metals that could be present in airborne particulates. A list of the potential airborne contaminants (VOCs and metals) for which samples were analyzed is shown in Table 3-1.

Four different air sampling techniques were used to quantify and qualify the air quality at the Lee Acres Landfill and at a background monitoring location (Figure 3-1). A survey for VOCs was conducted with an HNu PID. Ambient air VOC samples were collected with SUMMA evacuated canisters. Ambient air particulate and metals concentrations were measured using total suspended particulate (TSP) samplers and samplers for inhalable particulates of 10 microns or less (PM 10). Finally, VOC emissions from the soil surface were measured using flux chambers and SUMMA evacuated canisters. All measurements followed EPA guidelines whenever possible.

3.1.1. Air Quality Investigation

3.1.1.1. HNu Survey

Through previous investigations, it is believed that wastes containing VOCs had been disposed of in the former Lee Acres Landfill. Therefore, as part of the RI, the landfill was surveyed using an HNu P-101 PID to screen for the presence of VOCs. The HNu has an electric pump that pulls an air sample past an ultraviolet light source. The sample constituents are ionized proportional to their ionization potential. A relative instrument response is produced when the ionization potential is equal to or less than the ionizing energy supplied by the ultraviolet light source.

A 25- by 25-ft grid was established within the Lee Acres Landfill boundary for the HNu survey. Approximately 1,300 nodes (grid intersections) were monitored for VOCs using the HNu. Readings were taken 2 to 6 inches above the soil surface. Significant VOC concentrations above background levels were detected only at one node, which is identified as canister sampling location 2 (Figure 3-1). The soil at this location was composed of a black carbonaceous material.

3.1.1.2. Ambient Air VOC Sampling

In October 1989, ambient air samples were collected in 2-liter stainless steel SUMMA canisters (EPA Method T0-14). Six onsite canister locations were sampled: locations 1, 2, 3, 4, 5, and the meteorological site (met site) (Figure 3-1). A stainless steel canister sample was also collected from the offsite background monitoring location at the fire station (Figure 3-1). The seven stainless steel canister samples were analyzed for 40 VOCs by Southwest Research Institute, San Antonio, Texas. The air canister analytical results from Southwest Research Institute are presented in Appendix P. Results for ambient air VOC concentrations are presented in subsection 3.1.1.4.

3.1.1.3. Ambient Air Particulates and Metals Sampling

While the VOC screening was being conducted, three particulate monitoring locations were installed. Two locations were within the landfill, one at the southern end near the meteorological site (met site) and one at the center of the landfill (mid site) approximately 300 yards north of the met site (Figure 3-1). The third location was established as a background location at the Lee Acres Fire Station, approximately .75 mile south of the landfill (Figure 3-1). The Lee Acres Fire Station was selected as a background location because it was representative of the air quality at the nearest community to the landfill. At each location, two particulate samples were installed. One high-volume air sampler collected particulate matter of less than 10 micrometers (μ) in size (PM 10), and one collected TSP. In addition, at the beginning of the program, a PM 10 sampler was alternated among the three sites to collect a duplicate PM 10 sample. The high-volume samplers collected the particulates by pulling ambient air directly through an 8-inch by 10-inch glass fiber filter at a flow rate of 40 cubic feet per minute (cfm). In the PM 10 sampler, particles are accelerated through multiple circular impactor nozzles. Particles smaller than 10μ are carried vertically upward with the air flow through an impaction chamber and down through multiple vent tubes, and are deposited on the filter. By virtue of their greater momentum, particles larger than 10μ settle in the impaction chamber where they are subsequently removed during cleaning and maintenance. Both the PM 10 and TSP samplers operated at a flow rate of approximately 40 cfm using a mass flow controller for approximately 24 hours. During sampling, the filters were located in the breathing zone, approximately 6 ft above the ground surface.

The high volume samplers were operated continuously for seven days during late October 1989 in order to obtain a relative assessment of particulate and trace metal contaminants in the ambient air. Subsequently, the samplers were operated for five days in November 1989, two days in December 1989, two days in January 1990, and one day per month from January through September 1990. Weighing the dry filters prior to and after sampling provided the weight of particulate collected on the filters. Dividing this weight by the volume of air sampled provides the concentration of particulate in the ambient air. After determining the total weight of particulate on the filters, each filter was analyzed to determine the respective concentration of the 12 trace metals. Subsequently, the total weight of each trace metal was determined and its concentration calculated. Ambient air particulate trace metal analytical results are presented in Appendix Q. The following subsections present the data and statistical analysis performed on the ambient air particulate trace metal analytical results.

3.1.1.3.1. Data Preprocessing - Metals

Prior to any data manipulation, all results were checked for consistency. As part of the quality control program, the individual TSP and PM 10 concentrations were compared for each location. The total mass of PM 10 was compared with the total mass of TSP collected by the collocated sampler. For the samples to be valid, the PM 10 sample must have a total mass less than or equal to the total TSP mass, because the PM 10 sample is only a fraction of total TSP. No samples were rejected based on this criterion. Additionally, prior to statistical analysis, the raw data were preprocessed to account for media contamination and analytical non-detects. Metals classified as not detected in 75 percent or more of samples after preprocessing were removed from consideration.

Media contamination was corrected using analyses of unexposed blank filters. Total amounts of each metal for all blank filters analyzed during the study were tabulated. For each metal, the arithmetic mean and standard deviation of the amounts found in the blanks were calculated. The blank correction was conservatively defined by taking the mean blank value minus two standard deviations. This correction was then subtracted from exposed sample results before calculating concentrations. This approach conservatively underestimates the true mean contamination level, using instead the lower 95 percent confidence bound for the mean blank value. This assumption is conservative in that it will result in slightly higher ambient concentrations when the lower corrections are subtracted from the measurements. This approach was applied only to results where compounds were detected by the analysis.

Analytical non-detects result when the laboratory analysis is unable to positively identify and quantify an analyte. Non-detects are typically reported as the lowest quantity of the analyte that can be positively detected. The approach used for this study was to incorporate all values reported by the laboratory (including non-detects), then apply the blank filter corrections. Subsequently, values less than or equal to zero are classified as non-detects and one-half of the compound-specific detection limit reported by the laboratory (less the blank correction) is used. This approach is more conservative than replacing the non-detects with zero (a physically unrealistic approach) or excluding the data entirely.

After these preprocessing steps, a final cut was made to remove any compounds not routinely found at a sampling location. If a compound was not detected consistently at a sampling site, statistical analyses of the compound are not practical and are of reduced value due to the interference from non-detected values. Therefore, any compound with more than 75 percent non-detects (i.e., found in less than 25 percent of all samples at a location) was eliminated from consideration. A single element (nickel) was eliminated from consideration on this basis.

3.1.1.3.2. Statistical Analysis - Metals

The goal of the statistical analysis of the metals data is to determine whether the site is a discernable source of air contaminants. This is achieved by conducting hypothesis tests to determine whether the air levels of metals are higher at the meteorological tower and/or at the mid site locations, when they are compared with air levels of the same metals at the fire station (located well away from the site influence).

The first statistical test used in the analysis is the Wilcoxon test, which determines whether the median (50th percentile) concentration at the onsite locations (taken as a single group) is greater than the median concentration at the offsite location. The Wilcoxon test is a robust, non-parametric test that performs a similar function to the traditional t-test. Unlike the t-test, the Wilcoxon test is more generalized in that it does not rely on assumptions of normally distributed data. If the Wilcoxon test indicates that there are generally higher concentrations on the site, it must be determined whether the site and activities on the site are the source of the increases.

The Wilcoxon test results for all metals indicated that none of the median concentrations was higher at the onsite locations than at the offsite location (fire station). The actual median concentrations for each metal by group are tabulated on Table 3-2, along with whether the Wilcoxon test indicated a difference in the medians. The median concentrations for several of the 11 metals considered were different at the 96 percent confidence level; in these cases, the median was always greater at the offsite background location (Table 3-2). This indicates that the background site is affected by localized particulate sources (i.e, woodburning stoves) that do not influence the onsite monitors on a routine basis. Therefore, it can be concluded that the site or activities on the site are not a significant source of toxic metals, relative to the ambient background levels at the fire station.

In the absence of evidence that the site is a detectable source of trace metals, all data were pooled and analyzed to determine appropriate concentrations for use in health risk calculations. Typically, air pathway risk assessments focus on the inhalable fraction of airborne particulate matter (i.e., the PM 10 fraction). Therefore, only data from PM 10 samples were considered. To be conservative, risk assessments often estimate exposures using the upper 96 percent confidence bound (i.e., for a normally distributed variable, the mean value plus 1.96 standard deviations) for individual sample concentrations.

Before calculating an upper bound concentration for risk analyses, the underlying assumption that the data follow a normal distribution must be validated. Many environmental data sets are not normally distributed. Rather, they follow a log-normal distribution in which the logarithms of the actual values have a bell-shaped distribution. In this case, the distribution can be determined by analyzing the logarithms of the original values rather than the original values themselves.

For the PM 10 data, each metal was tested for normal and log-normal distribution using the Kolmogorov-Smirnov (K-S) test. The K-S test is a non-parametric test used to evaluate the data distribution and to determine whether arithmetic or geometric means and standard deviations were most appropriate for determining the upper bound concentrations. If the K-S test showed that the data closely followed a standard normal distribution, the arithmetic mean and standard deviation were used. If the test indicated a log-normal distribution, the geometric mean and standard deviation were used. If the K-S test showed that the actual distribution was not similar to either distribution, a standard normal distribution was assumed as a default.

The results of the K-S test are summarized on Table 3-3, along with the appropriate statistics. The second and third column show which distribution assumption was used, based on the K-S tests for each metal. The next columns show the appropriate mean, standard deviation, and upper bound limits. The final column shows the maximum concentration measured for comparison with the upper 96 percent bound. If the log-normal assumption was used, the mean, deviation, and upper bound were first calculated as logarithms and then transformed back (exponentiated) into the original units. Due to the nature of the geometric mean and standard deviation, the upper 96 percent bound can be calculated by multiplying the geometric standard deviation raised to the 1.96 power by the geometric mean. This will only approximate the number shown in Table 3-3 due to rounding errors. The original metals data were reported in nanograms (10^{-9}g) per cubic meter, but the results for Table 3-3 were calculated in picograms (10^{-12}g) per cubic meter. This unit change was made to offset the small magnitude of the concentrations to be used in the statistical computations.

One general conclusion regarding the results of the K-S test is that the PM10 particulate and TSP appear to be naturally occurring. This conclusion can be made because the data are generally log-normal or normally distributed and do not appear to be skewed. In addition, the data are not distributed abnormally in response to local airborne contaminant sources.

3.1.1.4. Surface VOC Emissions

The sampling for VOCs at the former Lee Acres Landfill was divided into two techniques: 1) ambient air and 2) soil emissions. The goal of the ambient air sampling was to determine if levels of VOCs in air at and adjacent to the former landfill are higher than typical ambient VOC levels, thus posing a possible health risk. The methodology for ambient air sampling is presented in subsection 3.1.1.2. However, due to the similarity in techniques for ambient air and surface soil emission sampling, the results of both techniques are discussed below.

The goal of the soil emissions sampling was to determine whether the landfill substrate is producing emissions of toxic VOCs that may be of concern. Surface VOC emissions were monitored using a surface isolation flux chamber (EPA Method TO-14). The isolation flux chamber collects gaseous emissions from an isolated surface over a specified period. The flux chamber is 16 inches in diameter and 10.8 inches in height from the soil surface to the top of its dome. The top of the chamber is clear Plexiglass, which allows solar heating of the ground surface. Prior to sampling, inert gas is swept through the chamber at a rate of 5 liters per minute for 24 minutes to purge the chamber. During purging, the flow rate and the internal temperature are monitored, and the air in the chamber is stirred to promote good mixing for the subsequent collection of a representative sample. Following purging, the air and gas mixture is drawn through an exit port into an evacuated 2-liter stainless steel canister for analysis.

In October and November 1989, five locations were sampled using a surface isolation flux chamber. These sampling locations are shown in Figure 3-1. Three onsite locations (met site and canister sampling locations 1 and 6) and one offsite location were sampled for surface VOC emissions. The fifth sampling location was the HNu survey node, canister sampling location 2, where VOC concentrations significantly higher than background levels were detected. The offsite location was the Lee Acres Fire Station approximately .75 mile south of the Lee Acres Landfill. In July 1990, two additional isolation flux chamber samples were collected at canister sampling location 7 and met site (Figure 3-1). Samples were also collected in August 1990 south of U.S. 64 at canister sampling locations 8 and 9 (Figure 3-1).

The results of the ambient air VOC sampling are presented in Table 3-4. The mean, median, and maximum concentrations by compound are given for the nine ambient air samples collected. Most of the compounds were rarely if ever detected, and were predominantly presented at low single-digit, part-per-billion (volume) levels. There are no known ARARs for VOCs in ambient air; however, the American Conference of Governmental Industrial Hygienists (ACGIH) has established the threshold limit value - time-weighted average (TLV-TWA) for VOCs as the TWA concentration for a normal 8-hour workday and a 40-hour work week to which nearly all workers may be repeatedly exposed daily without adverse effect (ACGIH 1990). The VOC concentrations detected in the isolation flux chamber samples and the ambient air samples were significantly below the respective TLV-TWAs.

The Lee Acres Landfill ambient air sample results are compared with results from similar studies in Table 3-5. The National Ambient Air VOC Database (EPA 1988d) was used to obtain information from canister-based studies of ambient air. The results from the Lee Acres Landfill samples fall within the typical ranges found in these other studies, indicating no unusually high levels of volatile air toxics are associated with the Lee Acres Landfill.

The flux chamber results are summarized on Table 3-6. The values are reported as for the ambient air: mean, median, and maximum concentrations by compound. Many of the compounds found in the ambient air samples are present in the flux chamber samples. This indicates that the landfill itself is a weak source of these compounds. However, the levels of the emitted compounds in the ambient air are generally higher than those collected by the flux chambers. Since emissions are diluted by atmospheric turbulence, this relative comparison indicates that the landfill is not a major source of VOCs. Other local sources are suggested to be more significant contributors to ambient VOC levels.

3.1.1.5. Impact of Other Sources

The former Giant-Bloomfield Refinery located south of the Lee Acres Landfill has not been in operation as a refinery since 1982, and is currently used as office space only. According to Giant-Bloomfield Refinery personnel, operations at the refinery produced leaded, unleaded, and premium gasoline; number six fuel oil; diesel fuel; and kerosene. The tanks are all empty, except for occasional bottom sediment and water. It is doubtful that this facility is producing emissions that could impact the air quality at the sampling locations.

Giant-Bloomfield Refinery personnel also indicated that the air stripper at the refinery is automated. The air stripper extracts groundwater (50 gpm to 1,000 cfm of air) and strips VOCs, specifically benzene, toluene, ethylbenzene, and xylene (BTEX) aromatic, from the water. The water exiting the stripper is returned to the ground through an infiltration gallery, and the compounds stripped are released to the atmosphere. A typical benzene concentration found in the water is $\leq$10 ppb, and meets the New Mexico groundwater standards. No records are kept of the hours of operation or the emissions; therefore, it is not possible to determine the air stripper's contribution of potential contaminants to the air pathway during the air quality investigation.

In addition to the former Giant-Bloomfield Refinery, there are other refineries and industries nearby. U.S. 64 also runs through the study area and is a highly travelled road. The contribution of potential contaminants from these sources to the air pathway during the air quality investigation was not determined.

3.1.2. Meteorological Investigation

3.1.2.1. Instrumentation

From October 1989 to May 1991, a Climatronics electronic weather station (EWS) was in operation at the former Lee Acres Landfill to continuously monitor and record weather conditions. Meteorological sensors were installed at the top of a 10-meter (33-foot) tower. The tower was erected away from structures that could obstruct or influence wind flow. The tower location is identified as met site and is shown in Figure 3-1.

The meteorological parameters monitored at the site included wind speed, wind direction, standard deviation of wind direction, and temperature. Wind speed is sensed by a photochopper using a solid-state light source, and wind direction is sensed by a precision potentiometer with 540 degrees of output to eliminate the problem of crossover. The temperature sensor uses a precision thermistor with $\pm 0.2^{\circ}$F accuracy.

Sensors were oriented via a compass, siting scope, and topographic maps to ensure proper orientation. A digital voltmeter was used to ensure that instrument output reflected the actual sensor direction. Sensor orientation was visually checked on a monthly basis. The tower was audited three times during the program, at which time all sensors were replaced.

All sensors were connected to a Campbell CR10 data logger that continuously monitored the output of the meteorological system. The data logger calculated hourly averages for scaler wind speed, scaler wind direction, temperature, and the standard deviation (sigma theta) used in stability classification. The meteorological data were also recorded on a chart recorder on the EWS.

The Climatronics EWS includes a method for onsite calibration during use, which was performed approximately every 30 days. Each parameter is calibrated against a precision internal reference source. The calibration is conducted by adjusting specific potentiometers contained on an extender board within the recorder. The EWS is powered by two solid-state 6-volt DC batteries that permitted continuous operation of the unit for approximately 30 days.

During the meteorological investigation, the EWS had several problems that interrupted continuous data collection. In mid-November 1989, data were not recorded due to dead batteries. In early December, the meteorology station became inoperable when the tower was struck by a vehicle. A new tower was installed on January 9, 1990, and the EWS operated until January 23, at which time the batteries failed again. This problem was not discovered and corrected until February 13. During approximately 14 days in late March and early April 1990, the EWS was malfunctioning, and therefore, the unit had to be replaced. Shortly after replacement, the wind direction sensor did not function properly until it was again replaced on May 17, 1990. The EWS operated properly from mid-May 1990 until mid-May 1991, when the program was complete and the tower was dismantled. These problems do not affect the quality of the data presented or put in question the validity of the program.

3.1.2.2. Meteorological Results

Meteorology data for the months of January through May 1991 are presented in Appendix R. Figure 3-2 presents a wind rose prepared from onsite data collected April 4, 1990 through May 20, 1991. The distribution of wind appears to be fairly even, although the prevailing winds are westerly. Northerly winds are generally the weakest. Winds are strongest during the afternoon hours of 2 to 5 p.m. The highest wind speed recorded for this period was 32.1 miles per hour at 3 p.m. on March 19, 1991. The maximum recorded temperature for this period was 99°F (June 25, 26, and 27, 1990) and the minimum recorded temperature was - 23°F (December 24, 1990).

3.1.2.3. Climatology

The terrain at the former Lee Acres Landfill is generally dry and dusty, particularly during the summer months. Vegetation is sparse and the soil is sandy with small rocks.

The climate in the area is semi-arid: temperatures are moderate with extremely warm or cold weather of short duration. On the average in the Farmington area, daily summer temperatures range from 53.5 to 92.7°F and winter temperatures range from 17.8 to 48.1°F (NOAA 1982; NOAA 1987).

Average annual precipitation in the Lee Acres Landfill area is 8.37 inches per year. Normal precipitation ranges from a minimum of 0.28 inches in June to a maximum of 1.27 inches in August (NOAA 1982; NOAA 1987). Summer precipitation occurs mainly as short, intense thunderstorms. Snowfall generally occurs from November through April. Evaporation for May through October averages 49 inches in Farmington, but may be as much as 25 percent higher on the plateau due to increased winds (USDA 1977).

3.1.3. Summary

Three types of ambient air samplers were used: isolation flux chamber, stainless steel canister, and high-volume particulate samplers. Isolation flux chamber samples were collected in October 1989, November 1989, July 1990, and August 1990. VOCs were detected in the October 1989 and November 1990 samples. VOCs were not detected in the July 1990 samples, although propane was identified. All VOC concentrations are below ACGIH TLV-TWA levels for ambient air.

Seven stainless steel canister samples were collected in October 1989. VOCs were detected in the ambient air samples and were below ACGIH TLV-TWA levels for ambient air.

High-volume air samples were collected monthly from October 1989 to September 1990 for trace metals analyses and particulate concentrations. Particulate concentrations occasionally exceeded the 24-hour National Ambient Air Quality Standards. All trace metal concentrations are below the ACGIH TLV-TWAs. Because air quality results for VOCs and trace metals are consistently below ACGIH TLV-TWA levels, the air pathway is rejected as an active contaminant migration pathway at the Lee Acres Landfill.

3.2. LAND USE AND DEMOGRAPHICS

The Lee Acres Landfill Study Area (Figure 1-1 and Plate 1) is in eastern San Juan County, New Mexico, where much of the land is publicly owned open rangeland. Residential, commercial, and industrial developments are concentrated in the incorporated municipalities of Aztec, Bloomfield, and Farmington, adjacent to the transportation corridors among these towns. Land use zoning in the county is currently limited to the incorporated areas; therefore, there are no land use plans or zoning maps of the study area (Kephart 1990). Figure 3-3 is a general land use map of the study area prepared on the basis of 1988 air photos and surface reconnaissance.

The land in the region of the study area is used predominantly as open rangeland for wildlife and livestock. It is also used for 1) industrial purposes by the Giant-Bloomfield Refinery, which is within the study area, and by the El Paso Natural Gas Substation, which is north of the study area (Plate 1); 2) residential purposes at a development south of U.S. 64 and north of the San Juan River; and 3) public recreational purposes at the San Juan County Fairgrounds west of the study area (Plate 1). The rangeland vegetation in the study area is not well suited to supporting large amounts of livestock; approximately 12 acres are required per animal-unit-month (Hansen 1990). Oil and gas wells are present in the region of the landfill. A north-to-south trending natural gas pipeline is approximately 500 feet west of the landfill site (Figure 3-3).

Approximately eight percent of eastern San Juan County is irrigated and used for cultivated agriculture. The closest agricultural land to the study area is along the San Juan River at the southern edge of the study area. Irrigation water for this land is diverted from the San Juan River (Keetch 1980). The U.S. Department of Agriculture has identified prime farmland in San Juan County on the basis of soil suitability for crop growth. Five soil types in the county have been identified as prime farmland when the soils are adequately irrigated (Hacher 1989). The nearest location of potential prime farmland is approximately 2.5 miles northwest of the landfill site in a Doak loam soil type with a one to three percent grade. It is unlikely that this area is irrigated and it probably cannot be considered prime farmland. The next closest potential area of prime farmland is south of the study area on the San Juan River floodplain.

No public schools, prisons, or hospitals are within 3 miles of the former Lee Acres Landfill. The nearest educational facility is a private school operated by the Mennonite community. This school is approximately 1 mile north of the landfill. The San Juan County Fairgrounds are adjacent to the Lee Acres Landfill Study Area boundary.

Several governmental agencies, developers, and private citizens own or lease land within the study area (Plate 2). No Indian reservations, tribal lands, or railroad land grants are within the study area.

The major vehicular transportation route in the vicinity of the former landfill is U.S. 64 (Bloomfield Highway), which transects the study area approximately 2,250 feet south of the landfill (Plate 1 and Figure 3-3). The average 1988 daily (24-hour) traffic in both directions on the Bloomfield Highway within the study area was 13,182 vehicles (McQuarie 1990).

The social and economic information from the 1990 federal census is not available until 1992. Therefore, demographic information is presented from the 1980 federal census. The "1980 Census of Population" for New Mexico (DOC 1980) indicated that there were 81,433 people in San Juan County. Table 3-7 contains population estimates and projections for San Juan County from 1980 to 2010. The Bureau of Business and Economic Research, University of New Mexico, recently projected that San Juan County has a 1990 population of 98,000; this is expected to increase to approximately 153,000 by 2010 (UNM 1989). As indicated by the Bureau of the Census estimates contained in Table 3-7, it is believed there has been a decline in the county population during the past 5 years due to decreasing employment in the petroleum industry.

Table 3-8 shows the 1980 census and the 1988 estimated population for the incorporated municipalities of Aztec, Bloomfield, and Farmington, New Mexico. All three towns had population increases during the 1980s.

The F. L. Lee Subdivision No. 2 and the Suburban Heights Subdivision are in the Lee Acres residential area, which is south of U.S. 64 in the southern portion of the study area. Based on a count of the residential addresses, it is estimated that these two subdivisions contain approximately 150 single-family housing units. The 1980 census indicates there were 3.24 residents per household in San Juan County; thus, a population of 486 people is estimated to live in the study area (Rodriquez 1989).

3.3. ECOLOGY

The following assessment of ecological resources in the Lee Acres Landfill Study Area is based on discussions with natural resource personnel from federal and state agencies and from the private sector, and on a review of the pertinent literature. In addition, vegetation and wildlife species observed during reconnaissance surveys of the area were recorded.

3.3.1. Vegetation

The native rangeland vegetation has been removed from a significant portion of the study area by residential and industrial developments, road and highway construction, and other activities. In addition, undeveloped portions of the study area have been impacted by overgrazing (BLM 1980b; Kinsky 1977; DOI 1980). Off-road vehicle use has contributed to impacts on vegetation in the area (BLM 1980b). These activities have caused a breakdown in the sod cover and have enhanced the growth and intrusion of various forbs and shrubs.

The study area is in the juniper woodlands association of the Colorado Plateau (Kuchler 1975). A preliminary assessment of the vegetation in the study area indicates that three plant community types are present. The first type is represented by the landfill site itself, which consists of highly disturbed land with little vegetation. Early successional grasses and herbaceous species occur in this type.

The second type is represented by the unnamed arroyo to the west of and adjacent to the former landfill. This arroyo is dry most of the year, carries water only during periods of heavy precipitation, and has a high rate of erosion. Plant species inhabiting the arroyo include rubber rabbitbrush (*Chrysothamnus nauseosus*), black greasewood (*Sarcobatus vermiculatus*), and pale wolfberry (*Lycium pallidum*) (Kinsky 1977). Riparian species such as willow (*Salix* sp.) do not occur in the unnamed arroyo.

The third plant community type is represented by the juniper woodlands, which are characterized by widely scattered juniper (*Juniperus osteosperma*) with shrub species such as sage brush (*Artemisia* sp.) and saltbush (*Atriplex* sp.) interspersed throughout the juniper woodlands (Kinsky 1977; BLM 1980b). Juniper become more common on the hills that rise to a height of a few hundred feet above the landfill. Grass species that occur in the area are galleta (*Hillaria jamesii*), blue grama (*Bouteloua gracilis*), Indian ricegrass (*Oryzopsis hymenoids*), and cheat grass (*Bromus tectorum*).

On June 1, 1989, biologists from BLM and WESTON conducted a reconnaissance survey of the vegetation in the area. Table 3-9 lists the plant species that were observed growing in the area of the unnamed arroyo located just west of the former Lee Acres Landfill. Observations revealed that the arroyo channel is sandy and mostly devoid of vegetation. The width of the channel varies from approximately 50 to 100 feet. Sand sagebrush (*Artemisia filifolia*) is very common in the sandy areas next to the wash. In the more elevated areas, four-wing saltbush *(Artiplex canescens)*, big sagebrush (*Artemisia tridentata*), rubber rabbitbrush (*Chrysothamnus nauseosus*) and Greene rabbitbrush (*Chrysothamnus greeni*) were common (WESTON 1989f).

As observed, the juniper woodlands were composed of both hilly areas and more level areas containing scattered juniper (*Juniperus oskosperma*). The juniper did not grow in dense stands, and there were no pinon pine observed. Big sagebrush (*Artemisia tridentata*), shadscale saltbush (*Atriplex confertifolia*), prickly pear (*Opuntia sp.*), yucca, and antelope bitterbrush (*Purshia tridentata*) were the more common shrub species observed (WESTON 1989i).

3.3.2. Wildlife

The density and diversity of wildlife species in the Lee Acres Landfill Study Area are relatively low due to the highly disturbed nature of the area resulting from development, grazing, and off-road vehicle use. Reptile species that inhabit the unnamed arroyo and the juniper woodlands include the sagebrush lizard (*Sceloporus graciosus*), the lesser earless lizard (*Holbrookia maculata*), the plateau striped whiptail (*Cnemidophorus velox*), the desert shorthorned lizard (*Phynosoma douglassi*), and gopher snake (*Pituophis melanoleucus*) (Jones 1970; Albee 1982).

Nesting bird species typical of these habitat types are the horned lark (*Eremophila alpestris*), the black-throated sparrow (*Amphispiza bilineata*), the mourning dove (*Zenaida macroura*), and the rock wren

(*Salpinctes obsoletus*). Birds of prey that would nest in the area include the American kestrel (*Falco sparverius*), the ferruginous hawk (*Buteo regalis*), and the red-tailed hawk (*Buteo jamaicensis*). The only gamebird species that occurs in the area is the Gambel's quail (*Lophortyx gambelii*) (Kinsky 1977; Albee 1982).

Small- to medium-sized mammals that may inhabit the Study Area include such species as the black-tailed jackrabbit (*Lepus californicus*), the desert cottontail (*Sylvilagus audubonii*), the pocket mouse (*Perognathus* sp.), the kangaroo rat (*Dipodomys* sp.), and the desert ground squirrel (*Ammospermophilus* sp.). Larger mammals, such as the coyote (*Canis latrans*) and the badger (*Taxidea taxus*), also may inhabit the study area (Kinsky 1977; Albee 1982). Regarding large game species, the pronghorn antelope (*Antilocapra americana*) do not inhabit the study area; however, the muledeer (*Odocoileus hemionus*) may occasionally be found within Study Area boundaries (Ramakka 1988).

Various wildlife species were observed during a walk around the former Lee Acres Landfill site by a WESTON biologist, during surveys for federal threatened and endangered and candidate wildlife species, and during reconnaissance surveys in the area to locate prairie dog (*Cynomys gunnisonii*) colonies that could provide habitat for black-footed ferrets (*Mustela nigripes*). Table 3-10 is a list of the wildlife observed in the local region (within approximately a 3-mile radius) of the Lee Acres Landfill site (WESTON 1989g,h; 1990f,g). In addition to wildlife, cattle and domestic dogs were also observed during surveys for black-footed ferrets (Heil et al. 1990). Black-footed ferrets were not found within the study area. Subsection 3.3.4 addresses threatened, endangered, and rare species at the Lee Acres Landfill Study Area.

3.3.3. Aquatic Ecology

The San Juan River, located near the southern boundary of the Lee Acres Landfill Study Area, provides the only aquatic habitat in the study area. The San Juan River originates in the San Juan Mountains of southwestern Colorado. The river flows south into the Navajo Reservoir, which is on the New Mexico side of the Colorado-New Mexico border. The Navajo Reservoir dam is approximately 30 miles upstream from the study area. The river turns west from the Navajo Reservoir and flows through northwestern New Mexico, a small portion of Colorado, and across southern Utah before joining the Colorado River at Lake Powell (Platania and Young 1989).

San Juan River flow in the study area is controlled by releases from the Navajo Reservoir dam. The river has averaged an annual flow rate of 1,190 cubic feet per second (1963 to 1985) since the closing of the dam at the Navajo Reservoir in 1963. The average gradient of the San Juan River in the region between the Navajo Reservoir and Farmington, New Mexico, is approximately 12 feet per mile. Riparian vegetation along the river primarily consists of grama (*Bouteloua* spp.) galleta (*Hilaria* spp.) grasses, cottonwood (*Populus* spp.), willows (*Salix* spp.), and Russian olive (*Eleagnus angustifolia*) (Platania and Young 1989).

In October 1989, Steven P. Platania and Douglas A. Young of the University of New Mexico conducted a fisheries survey of the San Juan River from Archuleta, approximately 5 miles below the Navajo Reservoir dam, to approximately 0.5 mile below the confluence of the San Juan River with the Animas River at Farmington (Figure 3-4). Their report states that the river from Archuleta to Blanco (approximately 10 miles) is generally confined to a single stream; the substrate is predominantly cobble; and the water is cold, clear, and fast flowing. These habitat conditions favor cold water species such as trout (*Salmonidae*). From Blanco to Farmington, the river, which traverses the Lee Acres Landfill Study Area, is braided, its substrate is composed of sandy silt, its water velocity decreases, and its water temperature and suspended silt content increase. There is greater habitat diversity in this stretch, and the habitat is more characteristic of a warm-water fishery (Platania and Young 1989).

During the fisheries survey, fish were collected from 10 sampling sites on the San Juan River. As shown in Figure 3-4, the sites were at approximate 4-mile intervals from Archuleta to Farmington. In addition, as shown in Figure 3-4, four sites on the Animas River were also sampled. The length of the river sampled at each site varied from 200 to 500 yards, depending on habitat variability and fish density. Using small mesh seines, 12 species of fish were collected from the 10 San Juan River sampling sites during the survey. Table 3-11 contains a list of the fish species collected in the San Juan River and their resident status. No state or federal threatened or endangered fish species were observed or collected in the San Juan or Animas rivers during the survey. The most abundant species collected in the San Juan River was the flannelmouth sucker (*Catostomus latipinnis*) (917 of 1,548 fish collected, or 59 percent), while the bluehead sucker (*Pantoskusdisco bulas*) was the most common species, being found at 9 of the 10 sampling sites. Four rainbow trout (*Onclorhynchus mykiss*) and two brown trout (*Sulmo trutta*) were the only salmonids collected; salmonids were the only fish species collected at sampling Site 1, the farthest sampling site upstream. The only other gamefish collected in the San Juan River during the survey was one largemouth bass (*Micropterus salmoides*) at Site 6 (Platania and Young 1989).

Sampling Site 8 was within the Lee Acres Landfill Study Area at the bridge where San Juan County Road 5500 crosses the San Juan River (Figure 3-4). As shown in Table 3-12, 126 fish were collected at this site. The flannelmouth sucker was the most abundant species. Of the 10 sampling sites, sampling Site 8 ranked fourth in abundance (126 of 1,548 fish collected, 8.1 percent) and along with sites 9 and 10 had the greatest species diversity (seven species). Sampling Site 9 was the only sampling station downstream of the Lee Acres Landfill Study Area and upstream of the confluence of the Animas River with the San Juan River. Sampling Site 9 yielded 322 fish (20.8 percent). The flannelmouth sucker was also the most abundant species collected at this site. The greatest number of fish were collected at sampling Site 10 (519 fish, 33.5 percent) (Platania and Young 1989). The primary reason for the greater abundance of fish at sampling Site 10 is thought to be due to the confluence of the Animas and San Juan rivers just upstream from this sampling site.

The fisheries study conducted by Platania and Young (1989) provides a relative indication of habitat and species diversity and abundance in the San Juan River in the Lee Acres Landfill Study Area. It can be concluded that of the 1,548 fish collected in the San Juan River, there were no threatened and endangered species, indicating that if such species are present, their density is very low. Trout are uncommon in the study area as indicated by the fish sampling program and by the observations of limited habitat in the study area. The only other gamefish observed during the fisheries survey was limited to one largemouth bass out of the 1,548 fish collected. Therefore, it can be concluded that the San Juan River in the Lee Acres Landfill Study Area is not a high-quality or a highly productive game fishery.

3.3.4. Threatened, Endangered, and Rare Species

In written communication from WESTON to the U.S. Department of the Interior, Fish and Wildlife Service (FWS), dated December 19, 1988, WESTON consulted with the FWS regarding threatened and endangered species that could occur in the area of the Lee Acres Landfill site (WESTON 1988b)). The FWS responded in a letter dated January 6, 1989, stating that the Colorado squawfish (*Ptychocheilus lucius*) and the bald eagle (*haliaceetus leucocephalus*) may occur in the project area (Peterson 1989). An enclosure to the letter described the two respective species as follows:

- Colorado Squawfish (*Ptychocheilus lucius*) - The Colorado squawfish occurs in New Mexico in the San Juan River near the Utah-New Mexico border. In 1987, two squawfish were collected in the San Juan River of New Mexico near the mouth of the Mancos River. This species prefers big river habitats with warm, swift, and often turbid waters. Adults are found in pools and eddies just outside the main current and young are found in backwater areas.
- Bald Eagle (Haliaeetus leucocephalus) - The bald eagle occupies New Mexico primarily as a winter resident, but also occurs as a migrant with several nesting areas in the state. Roosts occur in large trees which may or may not be close to their feeding areas. Bald eagles are found in riparian areas adjacent to rivers, reservoirs, and ponds. Rabbits, fish, and waterfowl are their primary prey.

The bald eagle winters along the San Juan River (Grubb and Kennedy 1982); however, no important roost sites are known to occur along the river near the Lee Acres Landfill Study Area (Ramakka 1988).

Three small colonies of the Gunnison prairie dog (*Cynomys gunnisonii*) totaling approximately 41 acres are within approximately 1 mile of the landfill site. Prairie dog colonies provide potential habitat for the endangered black-footed ferret (*Mustela nigripes*). Therefore, diurnal and nocturnal surveys for black-footed ferrets were conducted at the prairie dog communities during March 6 to 14, 1990, to examine the communities for signs of black-footed ferret activity and inhabitation, and to evaluate the quality of the habitat for black-footed ferrets. The black-footed ferret survey found no evidence of any ferret activity within the three prairie dog colonies. The survey report states, "The lack of mustelid sign, the lack of observational support, and the small area occupied by prairie dogs radically reduces the probability that black-footed ferrets reside in this area. It is, therefore, our conclusion that the black-footed ferret is not a local inhabitant at the three colonies examined during this investigation" (Heil et al. 1990).

In addition to the above federally listed species, the peregrine falcon (*Falco peregrinus*) may migrate through the area and an occasional bird could stop over briefly in the study area.

A review of federal candidate species indicates that the beautiful gilia (*Gilia formosa*) may occur in the Lee Acres Landfill Study Area (NMNPPAC 1984; Knight and Cully 1986; EES 1987). In addition, a new species of milkweed (*Asclepias sanjuanensis*) was recently discovered at San Juan College and is known to occur within 3 miles of the Lee Acres Landfill Study Area (Heil et al. 1989). This federal candidate species is known to occur in habitats similar to those found in the study area (Heil 1988). A final candidate species that could occur near the site is the ferruginous hawk (*Buteo regalis*). This species nests mostly on the ground in northwest New Mexico and appropriate nesting habitat for the species may occur in the hills near the study area (Ramakka 1988). An additional species of concern to the state of New Mexico is the state-endangered gray vireo (*Vireo vicinior*) (Montoya 1988). This species occurs in piñon-juniper woodlands in San Juan County (Hubbard et al. 1979).

On June 1, 1990, biologists from BLM and WESTON conducted a survey for *Gilia formosa* and *Asclepias sanjuanensis*. Neither species was found to occur in the Lee Acres Landfill Study Area. *Asclepias sanjuanensis* was observed in bloom and bearing fruit approximately 4 miles east of the study area (WESTON 1989i).

The ferruginous hawk generally nests on the ground in northwestern New Mexico, even when juniper trees are available for nest sites. Ground nesting hawks nest on pinnacles, high points, and low cliffs. On June 7, 1990, a WESTON biologist surveyed an extensive area around the Lee Acres Landfill site, including high points and cliff areas. No ferruginous hawks or their nests were observed during the survey (WESTON 1989g).

Also on June 7, 1990, the WESTON biologist surveyed an extensive area of open juniper woodland in the study area for the gray vireo. The gray vireo was neither heard nor observed during the survey. It is believed that the juniper woodlands in the study area are too open to provide suitable nesting habitat for this species (WESTON 1989h).

3.4. ARCHAEOLOGICAL, HISTORICAL, AND CULTURAL RESOURCES

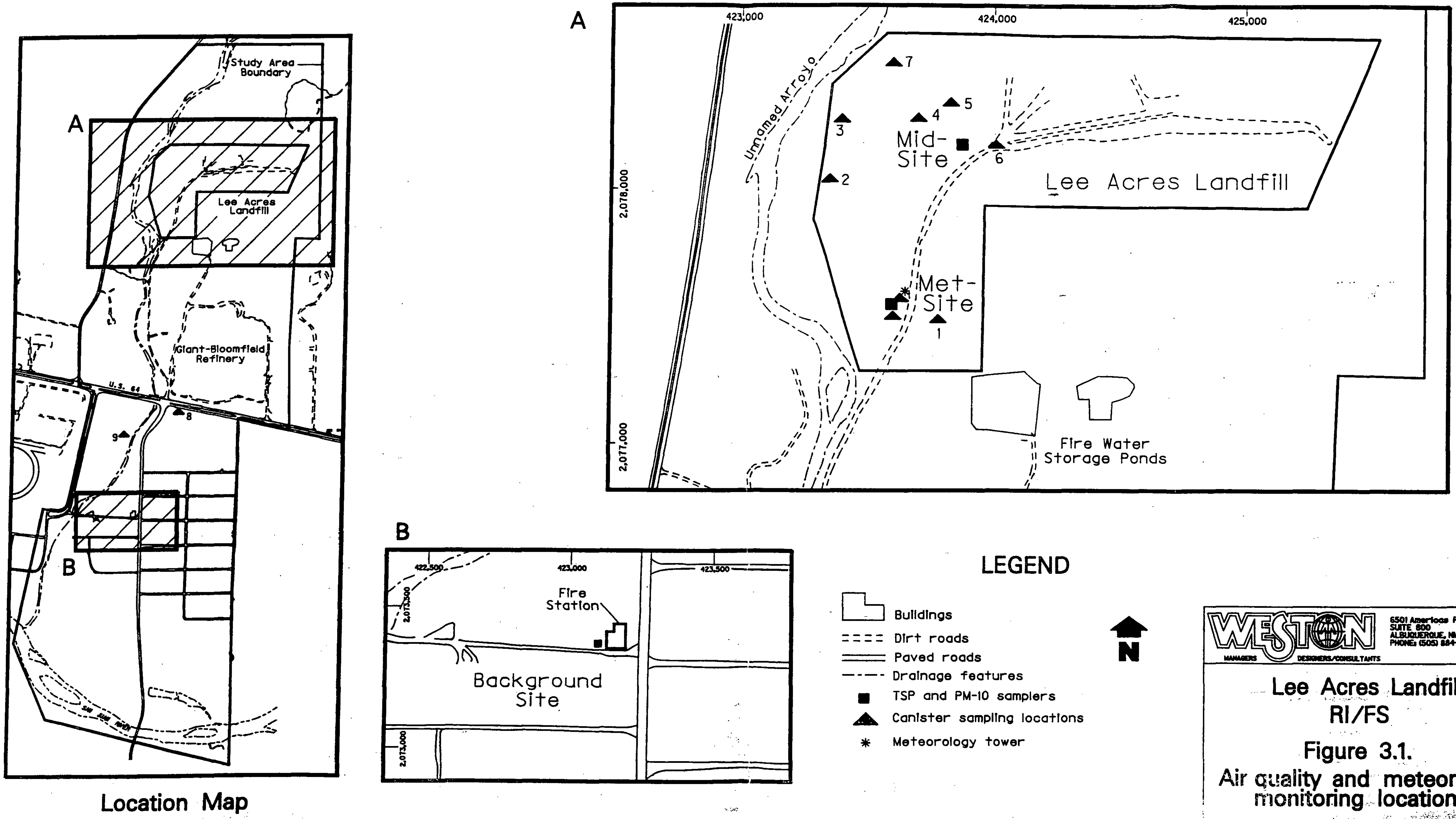
Record searches and onsite field surveys have been conducted to locate archaeological, historical, and cultural resource sites in the vicinity of the Lee Acres Landfill Study Area. Record searches were conducted at the Farmington Resource Area Office of the BLM, Farmington, New Mexico, and at the Museum of New Mexico at Santa Fe.

The following field surveys have been conducted in the vicinity of the study area.

- An archaeological clearance survey was conducted by L. Jean Hooton, of the Cultural Resource Management Program at the San Juan campus of New Mexico State University, on a 40-acre parcel to be included in a new lease at the Lee Acres Landfill. No cultural resources were found and full archaeological clearance was recommended for the 40-acre area (Hooton 1979).
- An archaeological survey was conducted on 14 proposed well locations for Amoco Production Company in the vicinity of the landfill. Archaeological clearance was recommended for these 14 drill pads and access road (Martin 1985).
- An archaeological survey was conducted by the Cultural Resources Management Program at San Juan College for three proposed well locations and one access road for Amoco Production Company. The Amoco lease--Gallegos Canyon Unit #269--is located between the landfill property and the El Paso Natural Gas Kutz Plant to the north (CRMP 1984).
- Approximately 48 acres of BLM-administered land were inventoried on January 8-9, 1987, by M. L. Botsford, BLM. No cultural resources were identified. It was recommended that the USGS could proceed with drilling and well construction, as proposed (Botsford 1987).
- An archaeological survey was conducted by Complete Archaeological Service Associates on a proposed borrow source area located adjacent to the Lee Acres Landfill and on six proposed test and monitoring well locations. No cultural resources were located during the survey and cultural resource clearance was recommended (Hammack 1990a).
- An archaeological survey was conducted by the Cultural Resources Management Program at San Juan College for the proposed Crouch Mesa County Road for San Juan County. Six cultural resource sites were located during the survey, and all were determined to be eligible for listing in the National Register of Historic Places (Watson et al. 1983).

Table 3-13 describes the archaeological, historical and cultural resource sites in the study area and within a 1-mile radius of the study area (Hammack 1990b). A map of the surveyed areas and the cultural resource sites is not included herein, in order to assist in protecting the resources at those sites. This information is available from the Farmington Resource Area Office of the BLM as needed.

The majority of the surface within the study area has not been surveyed for archaeological and historical resources. A significant portion of the study area has been disturbed by transportation corridors, the San Juan County Fairgrounds, and commercial, industrial, and residential developments. As necessary, additional resource surveys will be conducted in the unsurveyed areas prior to any additional surface disturbance.



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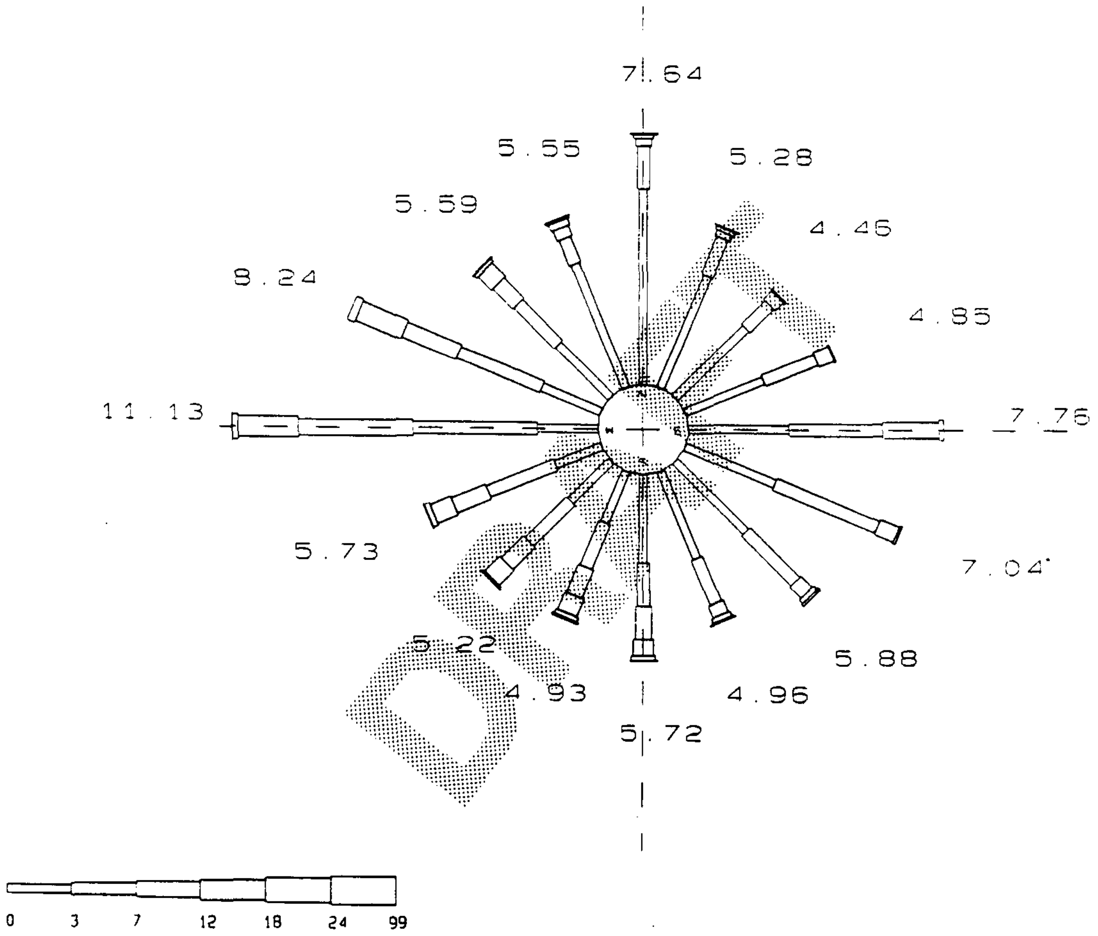
Lee Acres Landfill
RI/FS

Figure 3.1.
Air quality and meteorology monitoring locations.



	WIND SPEED (MPH) PERCENT OCCURRENCE					
	0-3	3-7	7-12	12-18	18-24	>24
N	5.95	1.31	0.23	0.12	0.02	0.01
NNE	3.71	1.22	0.19	0.12	0.02	0.01
NE	3.04	1.01	0.35	0.06	0.00	0.00
ENE	2.58	1.74	0.50	0.04	0.00	0.00
E	3.05	2.86	1.71	0.14	0.00	0.00
ESE	2.96	3.39	0.62	0.07	0.00	0.00
SE	3.04	2.15	0.46	0.15	0.07	0.00
SSE	2.88	1.48	0.40	0.15	0.04	0.01

	WIND SPEED (MPH) PERCENT OCCURRENCE					
	0-3	3-7	7-12	12-18	18-24	>24
S	2.71	1.31	1.03	0.49	0.15	0.03
SSW	1.70	1.49	0.95	0.58	0.15	0.06
SW	1.74	1.79	0.96	0.53	0.06	0.03
WSW	1.51	2.23	1.13	0.58	0.17	0.02
W	1.86	3.80	3.47	1.82	0.18	0.01
WNW	1.95	2.75	1.78	1.51	0.24	0.00
NW	2.28	1.74	0.87	0.56	0.12	0.03
NNW	4.07	0.83	0.34	0.22	0.07	0.01

Figure 3-2. Wind rose for April 4, 1990, through May 20, 1991 (calms included).

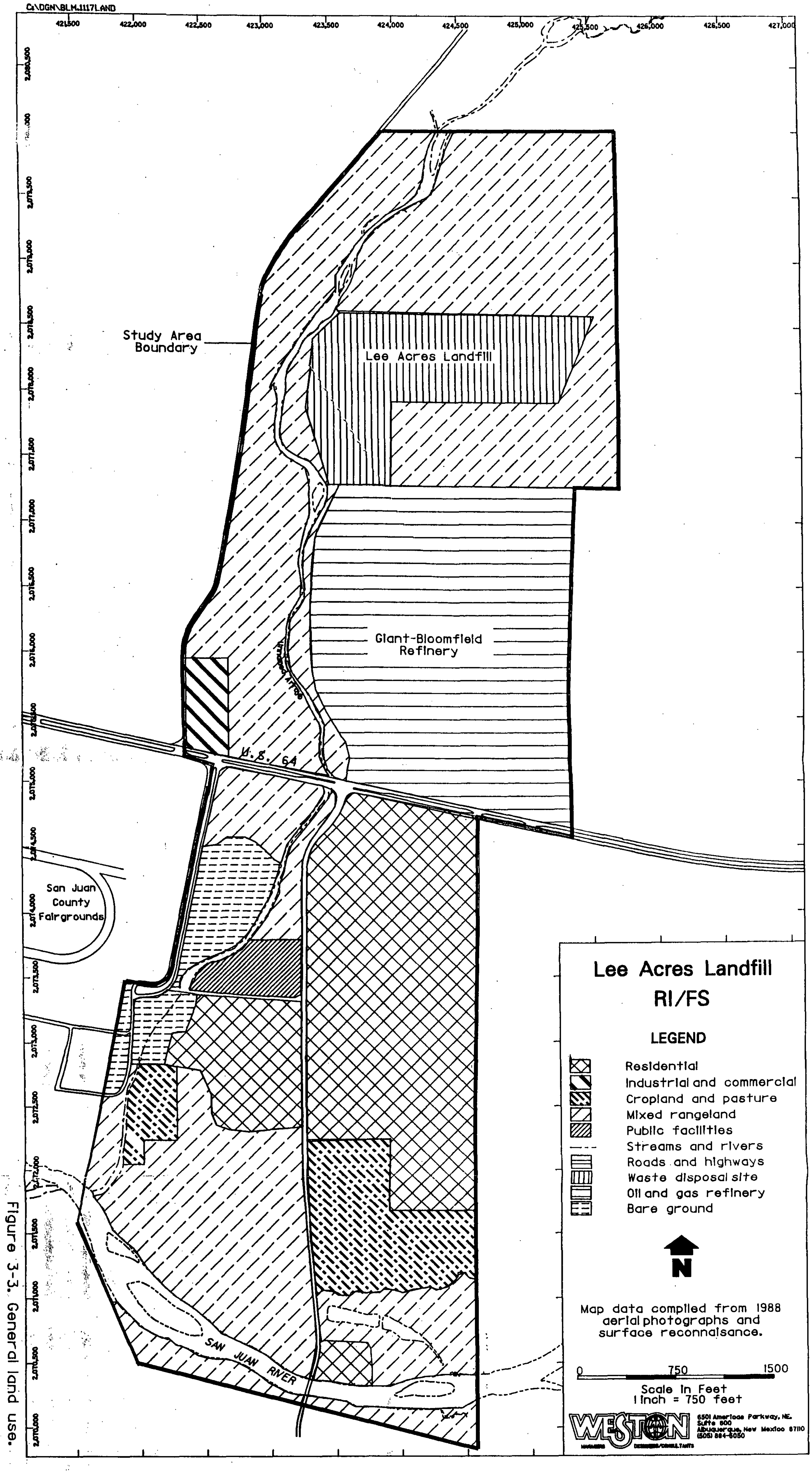
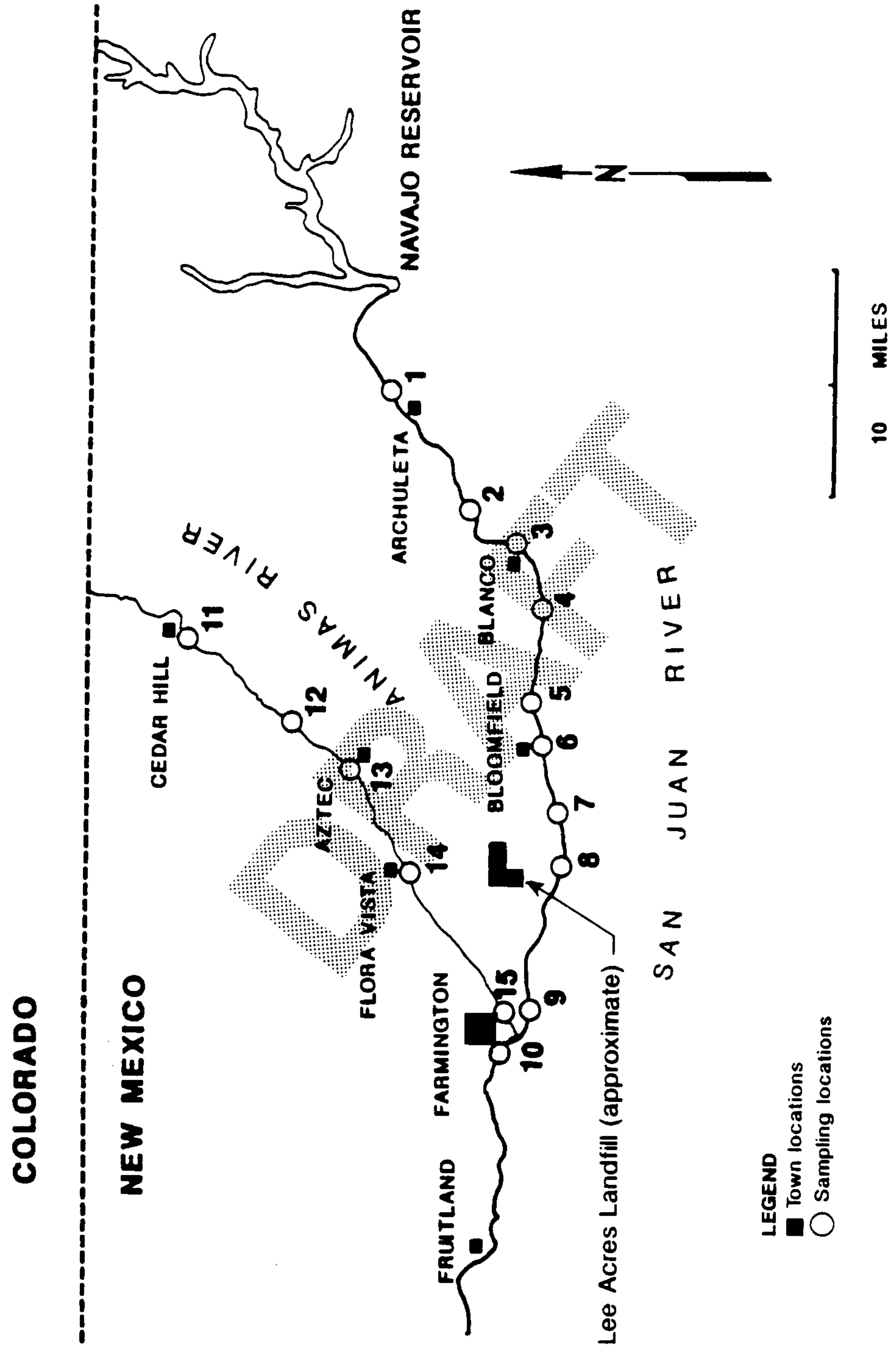


Figure 3-3. General land use.



Ref: Platania and Young 1989.

Figure 3-4. Fisheries survey study area.

Table 3-1. Potential Airborne Contaminants

Volatile Organic Compounds
Benzene
Benzyl chloride
Chlorobenzene
p-Dichlorobenzene
Ethylbenzene
Trichlorofluoromethane (Freon 11)
Dichlorodifluoromethane (Freon 12)
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)
1,2-Dichloro-1,1,2,2-tetrafluoroethane (Freon 114)
Methyl chloride
Styrene
Trichloroethene
Tetrachloroethene
Toluene
1,2,4-Trichlorobenzene
1,1,1-Trichloroethane
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
m,p-Xylene
o-Xylene
Metals
Arsenic
Cadmium
Chromium
Copper
Mercury
Manganese
Nickel
Lead
Antimony
Selenium
Vandium
Zinc

Table 3-2. Ambient Air Particulates - Median Concentrations for Metals

Metals	PM 10 (pg/m^3)			TSP (pg/m^3)		
	Fire Station	Onsite	Difference[a]	Fire Station	Onsite	Difference[a]
Arsenic	0.297	0.123	No	0.437	0.149	No
Cadmium	0.184	0.104	Yes	0.286	0.117	Yes
Chromium	2.90	2.16	Yes	3.21	2.37	Yes
Copper	51.1	45.2	No	162.0	17.8	No
Mercury	0.0484	0.0431	No	0.145	0.0416	No
Manganese	17.1	9.15	Yes	37.1	19.2	Yes
Lead	5.65	5.45	No	6.04	5.62	No
Antimony	145.00	142.00	Yes	145.0	143.0	Yes
Selenium	0.214	0.151	No	0.331	0.283	No
Vanaduim	1.03	1.00	Yes	1.03	0.999	Yes
Zinc	23.4	16.4	Yes	38.3	19.0	Yes

[a] Based on Wilcoxon sample test at 96% confidence level.
pg/m^3: picograms per cubic meter
PM 10: particulates less than 10 micrometers in size
TSP: total suspended particulates

Table 3-3. K-S Test Distribution Statistics for PM 10 and TSP Metal Analyses

Metals	PM 10	TSP	Mean (pg/m^3)	Standard Deviation	Maximum (pg/m^3)	Upper 96%
Arsenic	STD[a]	LOG	0.287	0.307	1.2	0.889
Cadmium	LOG	LOG	0.125	2.41	10.0	0.704
Chromium	STD	LOG	2.42	0.860	4.22	4.11
Copper	STD	LOG[b]	48.2	29.2	15.4	105
Mercury	STD[a]	STD[a]	0.0303	0.0743	0.474	0.216
Manganese	LOG	LOG	9.04	3.86	108	128
Lead	STD[a]	STD[a]	12.8	28.4	212	68.5
Antimony	STD[a]	STD[a]	15.4	26.9	241	207
Selenium	LOG	LOG	0.172	5.19	2.24	4.37
Vanadum	STD[a]	STD[a]	1.12	0.342	3.22	1.79
Zinc	STD[a]	LOG	27.6	50.5	392	127

Note: Values for log normal distributions are transformed back to common units. Six-decimal logs were transformed or calculated and transformed, retaining three significant digits.

[a] Neither hypothesis accepted; standard normal assumed.

[b] Standard normal rejected; log normal P=0.091 accepted.

pg/m^3: picograms per cubic meter.
LOG: log-normal distribution
PM 10: particulates less than 10 micrometers in size
STD: normal distribution
TSP: total suspended particulate

Table 3-4. Ambient Air VOC Sampling Results

Compound[a]	Median (ppb)	Mean (ppb)	Maximum (ppb)	TLV-TWA[b] (ppb)
Benzene	3.5	3.9	9.4	10,000[c]
Chlorobenzene	0.25	1.2	3.3	75,000[d]
Ethylbenzene	0.99	0.7	1.6	100,000
Trichlorofluoromethane (Freon 11)[e]	0.2	NA	NA	1,000,000
Dichlorodifluoromethane (Freon 12)[f]	0.15	NA	1.1	1,000,000
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)[e]	0.15	NA	NA	1,000,000
1,2-Dichloro-1,1,2,2-tetrafluoroethane (Freon 114)[e]	0.15	NA	NA	1,000,000
Methyl chloride[f]	0.25	NA	1.3	50,000
Styrene	1.4	1.9	4.1	50,000
Trichloroethene	0.25	0.68	1.5	50,000
Tetrachloroethene	0.2	0.4	1.1	50,000
Toluene	4.5	4.5	8.8	100,000
1,2,4-Trichlorobenzene	0.15	0.27	1.2	5,000
1,1,1-Trichloroethane[e]	0.2	NA	NA	350,000
1,2,4-Trimethylbenzene	0.25	0.63	1.7	25,000
1,3,5-Trimethylbenzene[f]	0.25	0.27	0.44	25,000
m,p-Xylene	2	3	8.1	100,000
o-Xylene	0.3	0.77	1.8	100,000

[a] Non-detect values included as one half the detection limit.
[b] Ref: ACGIH 1990
[c] The proposed TLV-TWA for 1990-1991 for benzene is 100 parts per billion (ppb).
[d] The proposed TLV-TWA for 1990-1991 for chlorobenzene is 10,000 ppb.
[e] Compound never detected; median is Detection Limit/2, no mean or maximum reported.
[f] Compound detected only once; median is Detection Limit/2, no mean reported.
ppb: parts per billion
TLV-TWA: threshold limit value - time-weighted average
VOC: volatile organic compounds

Table 3-5. Ambient VOC Concentrations from Other Canister Studies

Compound Name	Value	Concentrations (ppbv)				
		Remote	Rural	Suburban	Urban	Lee Acres Landfill, NM
Benzene	Average value Median value	1.445 1.425		3.876 2.730	3.112 2.355	3.9 3.5
Ethylbenzene	Average value Median value				1.415 1.130	0.7 0.99
Tetrachloroethene	Average value Median value	0.032 0.032	0.158 0.214	0.353 0.157	0.644 0.465	0.4 0.2
1,1,1-Trichloroethane	Average value Median value	0.149 0.138	0.205 0.130	0.123 0.160	0.560 0.400	0.2 0.2
Trichloroethene	Average value Median value	0.014 0.015	0.493 0.025	0.466 0.040	0.243 0.139	0.68 0.25
Toluene	Average value Median value		0.661 0.614	1.582 0.807	5.795 4.470	4.5 4.5
o-xylene	Average value Median value		0.080 0.069	0.161 0.102	1.006 0.885	0.77 0.3
p-xylene	Average value Median value		0.091 0.069	0.271 0.190	2.422 2.040	3.0 2.0

Ref: Derived from the National Ambient Air VOC Database Update, January 1988 (EPA 600/3-88-10(a)) (EPA 1988d)

VOC: volatile organic compound

Table 3-6. Surface VOC Emission Sampling Results

Compound[a]	Median (ppb)	Mean (ppb)	Maximum (ppb)	TLV-TWA[b] (ppb)
Benzene	1	1.3	5.1	10,000[c]
Benzyl chloride	0.5	1	3.3	1,000
Chlorobenzene	1	1.5	7.7	75,000[d]
p-Dichlorobenzene[e]	0.4	-	1.7	75,000
Ethylbenzene	1.5	1.8	7.4	100,000
Trichlorofluoromethane (Freon 11)[e]	0.45	-	1.5	1,000,000
Dichlorodifluoromethane (Freon 12)	0.5	0.87	3.8	1,000,000
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	0.3	3.2	20	1,000,000
1,2-Dichloro-1,1,2,2-tetrafluoroethane (Freon 114)[e]	0.35	-	0.87	1,000,000
Methyl chloride[f]	2	-	-	50,000
Styrene[e]	0.5	-	1.2	50,000
Trichloroethene[f]	0.5	-	-	50,000
Tetrachloroethene[f]	0.5	-	-	50,000
Toluene	3.6	5.3	32	100,000
1,2,4-Trichlorobenzene	0.35	-	1.6	5,000
1,1,1-Trichloroethane	0.5	3.1	11	350,000
1,2,4-Trimethylbenzene	0.5	2.6	9.1	25,000
1,3,5-Trimethylbenzene	0.5	0.89	2.3	100,000
m,p-Xylene	6.5	6.5	27	100,000
o-Xylene	2.4	2.3	10	100,000

[a] Non-detect values included as Detection Limit/2.

[b] Ref: ACGIH 1990

[c] The proposed TLV-TWA for 1990-1991 for benzene is 100 parts per billion (ppb).

[d] The proposed TLV-TWA for 1990-1991 for chlorobenzene is 10,000 ppb.

[e] Compound detected only once; median is one half the detection limit, no mean reported.

[f] Compound never detected; median is one half the detection limit, no mean or maximum reported.

Table 3-7. Estimated Populations for San Juan County, New Mexico

Year	Population	Source
1980	81,433	1980 Census of Population, Bureau of Census
1981	86,600	Bureau of Census estimate
1982	89,400	Bureau of Census estimate
1983	90,900	Bureau of Census estimate
1984	91,300	Bureau of Census estimate
1985	91,500	Bureau of Census estimate
1986	91,100	Bureau of Census estimate
1987	88,800	Bureau of Census estimate
1988	86,700	Bureau of Census estimate
1990	98,000	UNM 1989, projection
1995	110,900	UNM 1989, projection
2000	123,800	UNM 1989, projection
2005	138,400	UNM 1989, projection
2010	153,100	UNM 1989, projection

Ref: Shore 1990

Table 3-8. Populations for Aztec, Bloomfield, and Farmington, New Mexico

Incorporated Municipality	Population	
	1980 Actual	1988 Estimated
Aztec	5,512	7,070
Bloomfield	4,881	6,550
Farmington	32,677	38,470

Ref: Shore 1990; UNM 1989

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Table 3-9. Vegetation Species Observed in Unnamed Arroyo Just West of the Lee Acres Landfill Site in the Lee Acres Study Area

Scientific Name	Common Name
Artemisia filifolia	sand sagebrush
artemisia tridentata	big sagebrush
atriplex canescens	fourwing saltbush
atriplex confertifolia	shad scale salt bush (mostly in uplands)
Chrysothamnus greenei	Greene rabbitbrush
Chysothamnus nauseosus	rubber rabbitbrush
Elaeagnus angustifolia	Russian olive
Forestiera neomexicana	New Mexico forestiera
Gutierrezia sarothrae	broom snakeweed
Juniperus sp.	Juniper (mostly in uplands)
Lycium pallidum	pale wolfberry
Opuntia sp.	cholla
Opuntia sp.	prickly pear
Populus angustifolia	narrowleaf cottonwood
Populus femonti	Fremont cottonwood
Purshia tridentata	antelope bitterbrush (uplands only)
Rhus trilobata	skunkbush sumac
Sarcobatus vermiculatus	black greasewood
Tamarix pentandra	salt cedar
Yucca glauca	small soapweed
Ephedra sp.	Morman tea
Aristida sp.	threeawn
Bouteloua gracilis	blue grama (uplands)
Hilaria jamesii	galleta grass
Oryzopsis hymenoides	Indian rice grass
Stipa comata	needle and thread
Sporobolus airoides	alkali sacaton
Astragalus sp.	milkvetch
Asclepias sp.	milkweed
Abronia sp.	sandverbena
Sphaeralcea coccinea	scarlet globemallow
Stanleya pinnata	desert princeplume

Ref: WESTON 1989g,h; 1990f,g

Table 3-10. Wildlife Observed in the Local Region of Lee Acres Landfill[a]

Scientific Name	Common Name	Date Observed
REPTILES:		
Cnemidophorus sp.	whiptail	June 1 & 2, 1989
Crotaphytus collaris	collared lizard	June 1 & 2, 1989
Uta stansburiana	side blotched lizard	June 1, 1989
BIRD:		
Buteo sp.	buteo	June 1, 1989
Accipiter cooperli	Cooper's hawk	November 8, 1989
Lophortyx gambelii	Gambel's quail	June 1 & 2, 1989
Zenaidura macoroura	mourning dove	June 1, 1989 (nesting)
Chordeiles minor	common nighthawk	June 2, 1989
Colaptes sp.	flicker	November 8 & 9, 1989
Tachycineta thalassina	voilet-green swallow	June 2, 1989
Aphelocoma coerulescens	scrub jay	June 2, 1989, November 9, 1989
Pica pica	black-billed magpie	June 1 & 2, 1989, November 8, 1989
Corvus corax	common raven	November 9, 1989
Gymnorhinus cyanocephala	pinon jay	June 2, 1989
Parus inoratus	plain titmouse	November 8 & 9, 1989
Mimus polyglottos	mockingbird	June 2, 1989
Toxostoma bendirei	Bendire's thrasher	June 2, 1989
Lanius ludovicianus	loggerhead shrike	November 8, 1989
Eremophila alpestris	horned lark	November 8 & 9, 199
Carpodacus mexicanus	house finch	June 2, 1989
Junco sp.	junco	November 8 & 9, 1989
Chondestes grammacus	lark sparrow	June 2, 1989
MAMMALS:		
Syvilagus auduboni	desert cottontail	June 2, 1989, November 8 & 9, 1989
Citellus sp.	ground squirrel	June 2, 1989
Cynomys gunnisonnii	Gunnison prairie dog	June 1, 1989, November 8 & 9, 1989, March 12, 1990
Lepus californicus	black-tailed jack rabbit	November 8 & 9, 1989, March 7-14, 1990
Odocoileus hemionus	mule deer	March 6 & 7, 1990

Ref: WESTON 1989g,h; 1990f,g

[a] Observed within approximately a 3-mile radius of the Lee Acres Landfill site.

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Table 3-11. Fish Collected in the San Juan River

Scientific Name	Common Name	Date Observed
Order Salmoniformes **Family Salmonidae**	**trout**	
Oncorhynchus mykiss	rainbow trout	Introduced
Salmo trutta	brown trout	Introduced
Order Cypriniformes **Family Cyprinidas**	**carps and minnows**	
Cyprinella	red shiner	Introduced
Cyprinus carpio	common carp	Introduced
Gila robusta	roundtial chub	Native
Pimephales promelas	fathead minnow	Introduced
Ptychocheilus lucius	Colorado squawfish	Native
Rhinichthys osculus	speckled dace	Introduced
Family Catostomidae	**suckers**	
Catostomus latipinnis	flannelmouth sucker	Native
Pantosteus discobolus	bluehead sucker	Native
Xyrauchen texanus	razorback sucker	Native
Order Atheriniformes **Family Cyprinodontidae**	**killifish**	
Fundulus zebrinus	plains killifish	Introduced
Family Poeciliidae	**livebearers**	
Gambusia affinis	mosquitofish	Introduced
Order Perciformes **Family Centrarchidae**	**sunfishes**	
Lepomis cyanellus	green sunfish	Introduced
Micropterus salmoides	largemouth bass	Introduced
Family Cottidae	**sculpins**	
Cottus bairdi	mottled sculpin	Native

Ref: Platania and Young 1989

Table 3-12. Fish Collected at Sampling Sites 8, 9, and 10, San Juan River

Species	Site 8	Site 9	Site 10
Red shiner	1	13	2
Common carp		1	1
Fathead minnow	3	1	3
Speckled dace	9	45	164
Flannelmouth sucker	36	223	325
Bluehead sucker	21	25	18
Plains killifish	27	0	0
Mosquitofish	29	14	0
Mottled sculpin	0	0	6
TOTAL:	126	322	519

Ref: Platania and Young 1989

Table 3-13. Archaeological, Historical, and Cultural Resource Sites Located within 1 Mile of Lee Acres Study Area

Site No.	Culture	Description	National Register Status
LA2609	Anasazi, Pueblo II - Pueblo III	Multi-component habitation (Jacque Ruin)	Listed on National Register
LA2610	Unknown prehistoric	Sherd and lithic scatter 2/possible structure	Not yet determined
LA3026	Unknown prehistoric	Lithic scatter	Not yet determined
LA3028	Anasazi Pueblo II/historic Navajo	Habitation w/sherd & lithic scatter/hogan	Not yet determined
LA5604	Unknown prehistoric/historic Navajo	Lithic and burned rock scatter/hogan	Not yet determined
LA5608	Anasazi	Habitation w/sherd and lithic scatter	Not yet determined
LA8587	Archaic	Lithic and burned rock scatter	Not yet determined
LA8588	Anasazi Pueblo II/historic	Habitation w/sherd and lithic scatter/trail/burial	Not yet determined
LA8590	Archaic/unknown Anasazi	Lithic and burned rock scatter/ceramic scatter	Not yet determined
LA8591	Archaic	Lithic scatter	Not yet determined
LA13430	Anasazi, Pueblo III	Habitation w/sherd and lithic scatter	Not yet determined
LA16660	Anasazi, Pueblo III	Habitation w/ceramic scatter	Determined eligible
LA16661	Historic Navajo	Unspecified	Not yet determined
LA44120	Anasazi	Sherd and lithic scatter	Determined eligible
LA44166	Anasazi, Pueblo II	Sherd and lithic scatter w/rock alignment	Determined eligible
LA44167	Anasazi, Pueblo I - Pueblo III	Sherd and lithic scatter	Determined eligible
LA44168	Anasazi, Pueblo III	Possible habitation w/ceramic scatter	Determined eligible
LA44169	Anasazi, Pueblo III	Possible habitation w/ceramic scatter	Determined eligible
LA44170	Anasazi, Pueblo III	Possible habitation w/sherd and lithic scatter	Determined eligible
LA55022	Anasazi, Pueblo II - Pueblo III	Habitation	Determined eligible
LA55992	Anasazi, Pueblo II - Pueblo III	Habitation or field house	Not yet determined
LA65904	Hispanic, 1945-pres.	House and corral	Not yet determined

Ref: Hammack 1990b

4. GEOLOGIC AND HYDROGEOLOGIC CHARACTERIZATION

Some of the activities performed during the RI are designed to characterize site conditions within the study area and are presented in Section 2 of this report. The following section integrates the results from each data collection activity to characterize the geology and hydrogeology of the study area and the two sites. The geologic description includes the regional geologic setting, the geomorphology, the soils, and the surface and subsurface geology of the study area (subsection 4.1). The physical characteristics of alluvial and bedrock groundwater aquifers and groundwater behavior within the Lee Acres Landfill Study Area is also described (subsection 4.2). A floodplain analysis is also performed to characterize the impact of flood events upon the erosion protection constructed at the northern and southern corners of the landfill and on the landfill itself (subsection 4.3).

4.1. GEOLOGY

To better understand the alluvial and bedrock groundwater systems in the Lee Acres Landfill Study Area, it is necessary to understand the geologic, geomorphic, and geochemical controls on the hydrologic system. Geologic controls include lithology, sedimentary structures, fractures, and faulting. Geomorphologic controls include topographic relief and the shape and position of former and present bedrock channels. Geochemical controls include organic content, grain composition, degree of cementation, and composition of cement.

This geologic description moves from the general to the specific. Included in this discussion are the regional geologic setting, the geomorphology, the soils, and the surface and subsurface geology of the study area. The hydrology of alluvial and bedrock aquifers is discussed in detail in subsection 4.2, and groundwater geochemistry is discussed in Section 6.

4.1.1. Regional Tectonic Setting

The Lee Acres Landfill Study Area is located in the San Juan Basin of the Colorado Plateau (Figure 4-1). The San Juan Basin is a tectonic as well as hydrologic and topographic basin. Structurally, the San Juan Basin is bounded on the southeast by the Puerco fault zone, to the east by the Nacimiento uplift and the Gallina-Archuleta Arch, to the north by the Hogback Monocline, to the west by the Hogback Monocline-Defiance uplift, and to the southwest and south by the Chaco Slope-Zuni uplift (Woodward and Callender 1977). The San Juan structural basin dates back to the Paleozoic Era; however, the existing tectonic setting results from the Laramide orogeny during late Cretaceous and early Tertiary time (Turner-Peterson 1989).

Throughout the region, the Laramide orogeny consisted of two major tectonic pulses, one during the late Cretaceous to Paleocene (about 75 to 63 million years ago), and the other during the late Paleocene to early Eocene (about 60 to 52 million years ago). These two tectonic pulses are reflected in the stratigraphy of the San Juan Basin. The earliest pulse deposited the Ojo Alamo Sandstone and the Nacimiento Formation, and the second pulse deposited the San Jose Formation (Martinez 1989). The two pulses are differentiated not only by time but by the magnitude and style of uplift. The earlier pulse included large-scale, broadly arching, basement-cored uplifts in the vicinity of the present day San Juan Mountains and the Brazos-Sangre de Cristo area (Figure 4-1). The second pulse was dominated by numerous uplifts of smaller scale such as the Zuni, Nacimiento, and Defiance uplifts, and the formation of monoclines such as the Hogback Monocline. Tectonically, the second pulse seems to be directly related to the northeastward translation of the Colorado Plateau in relation to the North American Craton (Martinez 1989).

The remainder of tectonic development of the San Juan Basin consisted of relatively quiet, regional uplift to its present elevation. Since Eocene time (about 40 million years ago), the elevation of the San Juan Basin (as with all of the Colorado Plateau) has increased from just above sea level to over a mile high. This increase in elevation has been explained as isostatic rebound of the thickened continental crust after subduction along the western edge of North America ceased (Woodward and Callender 1977). Raising of the Colorado Plateau caused the exhumation of Laramide structures that had been covered with synorogenic deposits. The San Juan Basin has been spared much of the Miocene through Holocene extensional tectonism readily found in the Rio Grande Rift to the east and the Basin and Range Province to the south.

Holocene seismic activity in the region is limited to the margin of the San Juan Basin. Faults associated with the Archuleta Arch (Figure 4-1) produced one of New Mexico's largest-magnitude earthquakes (4.29 on the Richter scale) for the years 1962 through 1980. Seismic activity is also prevalent at the southern boundary of the San Juan Basin in the vicinity of the west-northwest trending Zuni uplift. In addition, since 1849, a few earthquakes of small magnitude have been documented in the west central part of the Basin. These quakes have had a magnitude of less than 3.0 (measured on the Richter scale) at six epicenters mostly west of the study area (Williams 1986). No faults are exposed at the surface, within, or immediately adjacent to the study area.

4.1.2. Regional Stratigraphy

The only stratigraphic units exposed in the Lee Acres Landfill Study Area are clastic units of Paleocene (early Tertiary) and Quaternary age. Older Precambrian, Paleozoic, and Mesozoic formations are only important to this study as source material for the sedimentary units deposited in the study area (Figure 4-2). Precambrian rocks are exposed in the San Juan Mountains and Brazos uplift to the north and east of the San Juan Basin, and consist of gneiss, granite, metasediments, and metavolcanics. The Paleozoic rocks exposed along the perimeter of the San Juan Basin are approximately 4,100 ft thick and consist mostly of fine- to coarse-grained clastic deposits with volumetrically minor amounts of carbonates, most notably in Pennsylvanian strata. Mesozoic rocks are the most extensive units in area exposed in the San Juan Basin, in addition to having the thickest deposits (9,500 ft). These rocks are predominantly continental to shallow marine, fine- to coarse-grained clastic units, with minor carbonate and evaporite deposits in the Triassic and Jurassic strata and extensive coal deposits in the Cretaceous strata.

Cenozoic deposits in the San Juan Basin are 6,600 ft thick and consist of Paleocene, Eocene, and Quaternary continental fine- to coarse-grained deposits. The Tertiary deposits are basin sediments associated with Laramide tectonics (the Ojo Alamo Sandstone, Animas, Nacimiento, and San Jose Formations). The San Juan Mountains to the north are a complex terrain of uplifted Precambrian through Cenozoic strata as well as Tertiary volcanic rocks that continues to be a source area for Quaternary deposits. Due to the high elevation of the San Juan Basin during the Quaternary, the basin is actively eroding rather than remaining as an area of extensive deposition. Therefore, Quaternary deposits are limited in area and consist mostly of alluvial and terrace deposits associated with ephemeral and perennial streams. Quaternary deposits will be discussed further in subsection 4.1.5, while the rest of this section will be used to discuss the stratigraphic setting of the older Cenozoic deposits.

The Late Cretaceous and Paleocene stratigraphy of the San Juan Basin is quite complex and has been the subject of controversy. The most thoroughly studied unit is the Ojo Alamo Sandstone, which is well-known for its dinosaur bones. Over the past 70 years, the age of this formation has been changed back and forth from late Cretaceous to Paleocene, and finally to Cretaceous-Tertiary. The most recent work indicates that it should remain Cretaceous-Tertiary. Pollen studies indicate a Paleocene age, yet this unit contains *in situ* remains of dinosaurs that were believed to have been extinct before the Paleocene started. In either case, the stratigraphic markers need to be redefined (Fassett et al. 1987).

The Ojo Alamo Sandstone unconformably overlies the Cretaceous Kirtland Formation and consists of 20 to 400 ft of buff, tan, and brown, medium- to very coarse-grained sandstone and conglomerate. The clasts are poorly sorted, angular to subangular, are predominantly quartz with some red, gray, and green chert, and are weakly to moderately cemented with silica, clay, gypsum, and ferricrete. Locally, the Ojo Alamo Sandstone contains thin lenses of gray and olive-green shale (Baltz 1967). Other characteristic features of Ojo Alamo exposures include large petrified logs, beds of bentonitic volcanic ash, and abundant carbonaceous material (Sikkink 1987). The Ojo Alamo in the vicinity of the study area consists of massive ledges over 100 ft thick.

The Ojo Alamo Sandstone thickens toward the north, presumably the source area for the sediments. Paleocurrent analysis collaborates a northern source for streams (Baltz 1967; Powell 1973; Sikkink 1987). The sandstones and conglomerate of this formation are mainly overlapping trough-crossbedded stream-channel deposits of a high-energy braided fluvial system; these deposits coalesced into a pediment surface (Martinez 1989). The Ojo Alamo was deposited as alluvial fans at the mouth of sediment-laden streams as they flowed out of the highlands to the north into a depositional basin to the south (Baltz 1967). Sediment sources for the Ojo Alamo Sandstone include the La Plata Mountains and the Needles Mountains in southwestern Colorado. The Ojo Alamo Sandstone is conformable with and transitional into the overlying Nacimiento Formation. The uppermost Ojo Alamo beds and the basal Nacimiento beds can be seen to intertongue near Farmington (Baltz 1967; Fassett et al. 1977; Sikkink 1987).

The Nacimiento Formation consists of 800 to 1,750 ft of silty to sandy clay and shale with interbedded sandstone. Thicker deposits of coarser sediments are found at northern exposures of this formation (Martinez 1989). The finer-grained facies consists of variegated brownish-gray, olive-gray, bluish-gray, and maroon, argillaceous, sometimes micaceous, sometimes carbonaceous claystone and siltstone. The coarse-grained facies consists of gray-white, orange-brown, and bluish-gray, fine- to very coarse-grained, sometimes gravelly, crossbedded sandstone. The lithology of the Nacimiento is very similar to Cretaceous rocks nearby and presumably was derived by erosion of these rocks (Baltz 1967).

The Nacimiento is thought to represent lacustrine and alluvial deposits laid down in a structural basin following deposition of the majority of the Ojo Alamo Sandstone (Figure 4-3) (Fassett et al. 1977). The two sedimentary facies of the Nacimiento Formation were probably deposited in slightly different terrestrial environments with possibly different source areas. The coarse sandstone facies was deposited in an apron of volcanic and orogenic debris from highlands to the north. The shaley facies was deposited at the distal edge of the apron and may have fine-grained Cretaceous deposits to the south and northwest as a source. The lenticular sandstones are stream-channel deposits, and the finer-grained facies was deposited in floodplains and ephemeral lakes. The occurrence of coal and carbonaceous shales within this formation probably reflects a basin that was poorly drained and swampy (Baltz 1967).

It is not known whether bedrock in the study area is exclusively of the Nacimiento Formation or if parts are the intertongues of Ojo Alamo Sandstone. Published maps (Stone et al. 1983) show the Ojo Alamo Sandstone outcropping one mile west of the study area. The stratigraphy seen while driving west on U.S. 64 from the study area is progressively down section, with fairly continuous exposure of the Nacimiento Formation and the Ojo Alamo Sandstone. Reconnaissance of this area revealed that sandstone beds become coarser and more common, whereas the claystone and siltstone facies become less common.

The deepest holes in each monitoring well cluster are completed in thick sandstone bodies quite often below the last thick, fine-grained intervals. The stratigraphically deepest boreholes within the study area (BLM-26, BLM-29, and BLM-32; see Appendix L) show extensive coarse facies with little or no fine-grained facies below an elevation of 5,330 ft. These lithologies (coarse gravels and no claystone or siltstone) more closely resemble published descriptions of Ojo Alamo Sandstone. Whether these coarse sands are of the lower Nacimiento Formation or upper Ojo Alamo Sandstone is academic and not imperative to this study. However, it is apparent that thick, areally extensive, fine-grained facies do not underlie these coarse sands. Therefore, these sandstones are probably hydrologically related to the Ojo Alamo Sandstone and reflect characteristics of the Ojo Alamo Sandstone aquifer (further discussed in subsection 4.2).

4.1.3. Geomorphology

The Lee Acres Landfill Study Area lies within the Navajo Section of the Colorado Plateau Physiographic Province. Major landforms in the Navajo Section include scarp-bounded plateaus, mesas, and buttes, as well as cuestas, hogbacks, valleys and canyons. Most of these landforms are carved in sedimentary rocks. Broad rolling plains form on easily eroded silts and muds, whereas cuestas and mesas form on more resistant sandstones. The only major perennial streams in the Navajo Section are within entrenched, narrow valleys and include the San Juan River and its two main tributaries, the Animas and La Plata rivers. These rivers have retained their courses since Middle Miocene (Pastuszak 1969), and are flanked by multiple Pleistocene terraces. Terrace remnants are sometimes limited to coarse gravels that form a stepped sequence of river-cut benches at elevations of as much as 600 ft above the present floodplain (USDA 1977). In addition to erosional and alluvial geomorphic features in the Navajo Section, there are extensive active dune fields capping the upland surfaces at some localities (Williams 1986).

The study area is divided into two local geomorphic subareas: the alluvial basin of the unnamed arroyo, and the floodplain of the San Juan River (Figure 4-4). U.S. 64 divides these two subareas. Deposits from the unnamed arroyo form an alluvial fan just south of U.S. 64. A small portion of the study area drains east-southeast to a very small (less than a square mile) arroyo system that parallels the unnamed arroyo. A quantitative description of the alluvial basin of the unnamed arroyo, including an examination of subbasins and hydrologic analysis, is presented in subsection 4.3.

4.1.3.1. Unnamed Arroyo Alluvial Basin

The unnamed arroyo alluvial basin covers 5.8 square miles and cuts into the high mesa (locally referred to as Crouch Mesa) that separates the Animas River drainage from the San Juan River drainage (Figure 4-4). This basin ranges in elevation from 5,930 ft to 5,385 ft above sea level, for a total relief of 545 ft. The basin extends from U.S. 64 to a point 5.4 stream miles northeast. The drainage pattern of the basin is generally subdendritic, with the basin separated into two morphologically distinct segments. The southern segment of the basin is narrow with steep bedrock slopes and only a few tributary arroyos. The northern segment of the basin opens up into badlands with broad, open terrain having many narrow tributary arroyos and steep-sided bedrock ridges.

4.1.3.2. River Terraces

The unnamed arroyo alluvial basin is flanked by a series of high terraces genetically related to the San Juan River. Five major terrace sequences have been identified by outcrops at elevations of about 5,440, 5,560, 5,620, 5,700, and 5,760 ft (Figure 4-4). Each terrace level is separated by relatively steep scarps. These erosional terraces have preserved maximum thickness of 10 ft, often exhibiting a thin veneer of terrace gravels on the surface. The terraces dip down toward the river, and also slope downstream to the west. The highest terrace has an elevation of approximately 5,810 ft 2 miles east of the unnamed arroyo, and an elevation of 5,740 ft 1.5 miles west of the unnamed arroyo. The calculated slope is 20 ft per mile, which contrasts with the present grade of the San Juan River of about 11.8 ft per mile for the stretch of river between the city of Bloomfield and the study area.

There is little relationship between the stream terrace levels and the underlying bedrock. While terraces exist on both sandstone and shale, gravel deposits are more extensively preserved on coarse-grained or conglomeratic sandstone such as the Ojo Alamo Sandstone. Gravels on softer shaley units, such as the claystone-siltstone facies of the Nacimiento Formation, are easily eroded or let down by colluvial processes (Pastuszak 1969). Although terraces are well preserved on the north side of the San Juan River, they are poorly preserved on the south side of the river for unknown reasons.

The terraces are a regional feature that extend from the San Juan Mountains to as far west as the Hogback Monocline west of Farmington. At the hogback, the terraces coalesce and become less distinct (Pastuszak 1969). In the San Juan Mountains, the terraces have been correlated with Pleistocene age moraines from Illinoisan through Wisconsin glaciations. The successive glaciations provided outwash sediment for streams originating at the terminus of the glaciers, such as the San Juan, Animas, and La Plata rivers. This increase in sediment load caused the valley floor to widen and the stream bed to be choked with gravel derived from glacial till and outwash. During interglaciations, the discharge and sediment load decreased, causing a narrower stream channel and floodplain. This left the older, higher floodplain as a river terrace (Bandoian 1969). Latter glacial and interglacial periods would continue the development of the multiple terrace levels seen in the study area. Since the older terraces are further from the San Juan River, the terrace gravels must have been deposited by a river that meandered much more broadly than the present stream. Lateral planation by the river has removed terraces on the south side of the San Juan River.

Exposed bedrock was more easily eroded than terraces armored with gravel-caps. This can be seen at the study area, where the unnamed arroyo cut headward from the San Juan River through the Pleistocene terraces. Having eroded headward to the areas topographically above terrace development, the unnamed arroyo cut deeply and pervasively into the bedrock at the surface. Ultimately, the unnamed arroyo preferentially eroded an area that was once topographically higher than the terraces which presently stand higher. This process is responsible for the morphological differences in the northern and southern segments of the alluvial basin of the unnamed arroyo. This preferential erosion of bedrock over terraces armored with gravel has been noted at other locations along the San Juan and Animas Rivers (Bandoian 1969).

Terraces are covered in many places by loess (up to 12 ft thick) related to Wisconsin glaciation, as well as postglacial eolian deposits of sand, silt, and clay (Pastuszak 1969). Much of the wind-blown sediment was derived from the modern river floodplain and may form dunes a few feet high. Sieve analysis of eolian deposits from two locations in the region showed the deposits to be from 50 to 75 percent silt and clay, and 16 to 25 percent very fine sand (Bandoian 1969).

4.1.3.3. San Juan River Floodplain

South of U.S. 64, the floodplain of the San Juan River and the alluvial fan from the unnamed arroyo are the dominant geomorphic features (Figure 4-4). At the mouth of the unnamed arroyo is a small (less than 1/4 square mile), relatively low-lying alluvial fan on which the Lee Acres subdivision was built. Historical air photos show the alluvial fan extended well into the floodplain of the San Juan River (Figure 4-4). The surface of the fan had many radiating distributary channels. These channels were abandoned when the present arroyo channel was restricted by the culvert built under U.S. 64, and later covered by construction of the subdivision. The development of this alluvial fan results from historic, sediment-laden water flowing from the relatively narrow confines north of U.S. 64 to the flat, open floodplain south of U.S. 64. When this flow becomes unconfined on the fan surface, the width of the channel increases, which causes a decrease in the channel depth and flow velocity. The loss of depth and velocity causes the capacity of the stream to decrease to the point that it can no longer transport the sediment load. In addition, the permeable surface of the alluvial fan may allow for water to seep underground, causing further deposition of sediments. This may explain why some of the relic arroyo channels disappear before they leave the fan (Figure 4-4).

The floodplain of the San Juan River is currently characterized by a braided stream with a network of anastomosing channels around temporarily stabilized islands. Development of braided streams is most likely due to erodible banks (due to a lack of, or sparse, vegetation), large volumes of bedload, and rapid and frequent fluctuations in discharge (Ritter 1978). The San Juan River flows a little over 175 miles from its source on the continental divide in the San Juan Mountains to the Lee Acres Landfill Study Area (Pastuszak

1969) and drops over a mile in elevation. This great amount of relief exposes a large amount of bedrock, which is responsible for the amount of bedload material in the San Juan River. The Holocene terrace level of the San Juan River is characterized by alluvial cut-and-fill terraces and moderately well sorted sand and gravel deposits. There are a series of cut banks and point bars 10 to 25 ft above the present river channel near Lee Acres (Pastuszak 1969).

Channels of the San Juan River have changed dramatically since 1950. Figure 4-5 shows one of the channels in the vicinity of the subdivision was over 1,000 ft north of its present location. The present channel of the river has been relatively stable since 1963, when Navajo Dam was built upstream for irrigation, flood control, discharge control, and sediment control (Stone et al. 1983).

4.1.3.4. Late Cenozoic Geomorphic History of the Study Area

During late Cenozoic time, a portion of the San Juan Basin in the vicinity of the study area was actively being eroded by the San Juan River and its tributaries. By Pliocene time (around 5 million years before the present) the entire San Juan region had been eroded to an area of moderate relief known as the San Juan peneplain (Pastuszak 1969). The Pleistocene period (beginning about 1.6 million years before present) had cyclical glacial and interglacial periods with alternate periods of dissection and alluviation along the San Juan River. In the study area, this is evidenced by the five terrace levels shown on Figure 4-4. Postglacial time was marked by a cessation of outwash deposition and a beginning of trenching of the outwash. Extensive dissection and reworking of the Late Wisconsin terrace gravels took place as the San Juan River downcut, forming tributary arroyos from knickpoint migration. The Holocene terrace level has been influenced by climatic fluctuation, as is indicated by evidence of erosional-depositional cycles (Pastuszak 1969).

Holocene erosion is responsible for the 600 ft of relief in the unnamed arroyo basin from the highest point in the northeast portion of the study area to the deepest bedrock channel in the southern part of the study area. The coarse gravels deposited on the terraces acted for the underlying bedrock as armor against erosional forces and made nonarmored bedrock easier to erode, such as that of the northern segment of the unnamed arroyo basin. This explains the difference in morphology of the upper and lower parts of the basin, with badlands forming in nonterraced areas, and tighter, more restricted arroyo cutting in the lower basin.

Climatic changes may be responsible for changing depositional features in the unnamed arroyo. Clay deposits up to 12 ft thick found in boreholes and CPT profiles (subsection 4.1.5) are difficult to explain in light of the configuration of the present arroyo system. Nowhere in the arroyo drainage are there extensive or thick clays being deposited, and no unequivocal explanation of these clay deposits is apparent.

However, the clay layers may be related to the loess deposits found in the region, either as preserved eolian features or as eolian sediments re-worked by alluvial processes.

4.1.4. Surface Soils

The soils in the Lee Acres Landfill Study Area generally belong to two units, the Fruitland-Riverwash-Stumble Complex, and the Haplargids-Blackston-Torriorthents Complex. The first unit consists of deep, nearly level to moderately steep, well drained to somewhat excessively drained soils that formed in alluvium and are now found on fans and in valleys. The second unit consists of very shallow to deep, nearly level to steep, well drained to excessively drained soils that formed in alluvium and residuum and are now found on terraces and mesas (USDA 1977). A detailed description of the soil units and a map of their distribution in the study area can be found in the Background Report for the Lee Acres RI/FS/EIS (WESTON 1990k).

4.1.5. Surface Geology

As part of RI, the surface geology of the Lee Acres Landfill Study Area and adjoining areas was mapped at a scale of 1 inch equals 200 ft (Plate 3). Tertiary bedrock and Quaternary surficial deposits were mapped to better understand stratigraphic relationships at the study area. The Tertiary stratigraphy was roughly divided into coarse-grained (sandstone) and fine-grained facies (claystone and siltstone) for mapping purposes. Surficial deposits were mapped as alluvium, colluvium, terrace gravels, man-moved deposits, or combined into undifferentiated deposits. The following descriptions were made from surface exposures and reflect weathering characteristics of the units. A description of the stratigraphic position of these units in the subsurface is presented below.

4.1.5.1. Description of Map Units

Quaternary alluvium consists of Holocene deposits of stream deposition. Deposits range from 0 ft to 72 ft thick, with the greatest thickness found in the center of the unnamed arroyo south of U.S. 64. Lithologically, the alluvium consists of brown, yellowish-brown, and orangish-brown sediments. Clast size ranges from clay through gravel, with most clasts being coarse sands. These sediments are poorly cemented in some thin layers, but are mostly noncemented. Areas labeled as alluvium on the surface geologic map may locally include colluvial, eolian, and man-moved deposits. No distinction between alluvium deposited by the San Juan River and that deposited by the unnamed arroyo is made.

Quaternary colluvium consists of Holocene deposits placed predominantly by gravity. Colluvium is composed of weathered bedrock and, quite often, terrace gravel deposits let down from their original level.

Colluvium varies greatly in composition, ranging from silt to very coarse gravel (up to 2 ft in diameter) depending on the source material. The thickness of colluvium throughout the study area is mostly unknown, but in some exposed locations (road cuts, stream cuts) it is only 1 to 2 ft thick. Areas labeled as colluvium on the surface geologic map may locally include eolian, terrace, alluvial, and man-moved deposits.

Quaternary terrace deposits consist of Pleistocene gravels deposited on terraces of the San Juan River (see discussion in subsection 4.1.3). These clast-supported gravels are approximately 10 ft thick and are composed of rounded, often flattened clasts of varied lithology. The source area of these gravels is the San Juan Mountains of southwestern Colorado. The lithology of the gravels reflects the complex geology of these mountains and includes Precambrian conglomerates, banded iron formation, metasediments, metavolcanics; Paleozoic, Mesozoic, and Cenozoic sandstones, siltstones, and carbonates; and Tertiary and Quaternary volcanic rocks. The matrix consists of subangular to rounded, poorly sorted silts to fine gravels. In some surface drainages, the matrix has been removed by water or wind, leaving piles of coarse gravel a few ft thick.

Man-moved deposits were differentiated from other surficial deposits, and consist of all Quaternary deposits and Tertiary deposits that have been disturbed by human activity. These deposits were mapped only when the natural deposit was obscured by their presence. Quaternary undifferentiated deposits are composed of alluvial, colluvial, eolian, man-moved, and terrace deposits.

The Tertiary Nacimiento Formation sandstone facies (Tns) consists of medium- to coarse-grained sandstone. The color varies for this unit from pale yellowish-orange to grayish-green. This unit contains a trace to some gravel, is massive to finely bedded, is often cross-bedded, is channeled in places, and has rip-up clasts (interformational conglomerate) of siltstone/claystone in some layers. Some areas mapped as Tertiary Nacimiento Formation sandstone facies contain thin (usually less than 5 ft thick) beds of the finer-grained facies; the map scale did not allow for the separation of these intertongued deposits. The sandstone facies varied from poorly cemented to well cemented. Cement materials included hematite, limonite, calcite, gypsum, and clay minerals (authigenic). The sandstones commonly contain hematite nodules weathered to limonite. Exposures sometimes contain well developed vertical fractures in addition to partings on the bedding surfaces. A fossilized log replaced with hematite, limonite, and gypsum was found at one location.

The Tertiary Nacimiento Formation claystone/siltstone facies (Tnc) consists of reddish-brown, dark to light olive-green or, infrequently, yellowish-orange clay to coarse silt. These sediments are fissile to thinly bedded, sometime interbedded with thin layers of sandstone. The claystone is usually easily eroded noncemented to poorly cemented, whereas the siltstone is sometimes well cemented. Some areas mapped as Tertiary Nacimiento Formation claystone/siltstone contain thin (usually less than 5 ft thick) beds of the coarser-grained facies; the map scale did not allow for separating these intertongued deposits at this level of detail.

4.1.5.2. Distribution of Units

Quaternary deposits: As mentioned in subsection 4.1.3, the terrace gravels are more frequently preserved on the harder sandstone facies. The softer claystone/siltstone facies tends to let down the gravels to form the colluvial deposits on the hill slopes. Colluvium is found capping bedrock and between bedrock cliffs and surface drainages. Alluvium is restricted to the floodplain of the San Juan River, the unnamed arroyo, and the larger surface drainages entering the unnamed arroyo.

An isopach map of saturated alluvium (Plate 5) was constructed using borehole and wellbore data from this RI (Appendixes H and L) and Giant-Bloomfield Refinery reports (GCL 1988). The saturated alluvium in the unnamed arroyo is elongated north-south and is narrow (500 to 700 ft) across the arroyo and is usually 10 to 20 ft thick, with a maximum thickness of 30 ft or more at GBR-17 and BLM-19. The contours show that saturated alluvium is controlled by the shape of the bedrock channel (compare to Plate 5) and reflects the same steep gradient of this channel (as seen in the area of BLM-61, BLM-63, and BLM-64). South of U.S. 64, the saturated alluvium contours spread out and appear to be controlled more by flow of the San Juan River.

Tertiary bedrock: Compared to the claystone/siltstone facies, the sandstone facies is more often exposed, most likely due to its greater resistance and ability to form cliffs as opposed to slopes. Both sandstone and claystone/siltstone facies are usually exposed on the steep slopes of the unnamed arroyo or on small peaks eroded below the main terrace levels (Plate 3). Exceptions include exposures of Tns in cut banks of the unnamed arroyo at two locations. Tns occurs immediately north of U.S. 64 (in a road cut) on the steep west side of the unnamed arroyo. The other location is in the cut bank at a bend in the unnamed arroyo 300 ft south of wells BLM-14, BLM-15, and BLM-16.

Tertiary strata has been folded and faulted at other locations in the San Juan Basin (subsection 4.1.1). However, detailed geologic mapping did not reveal any faulting or folding at surface exposures of Tertiary bedrock in the study area. Although bedrock exposures are limited, small-scale features associated with larger structures are usually detectable on outcrop scales; however, none were found in the study area.

4.1.6. Study Area Stratigraphy

Borehole information such as depth to bedrock and bedrock lithology was combined with the surficial geology map to create a topographic top-of-bedrock map. This map is an approximate representation of what the land surface would look like if all surficial deposits were removed. The topography beneath the surficial deposits includes a bedrock channel that varies from moderately incised to wide and shallow (Plate 5). The location of the present arroyo channel correlates closely with the paleotopographic channel. The shape and depth of the topographic channel shown on cross section A-A′ (Plate 6a) generally corresponds with those shown on seismic refraction profiles 6A and 6B (Appendix E-2). Profiles 6A and 6B transects the arroyo approximately 100 ft south (downstream) of cross section A-A′, so the shape and depth of the paleotopograhic channel does not correspond exactly (see Plate 6a).

Borehole descriptions of the alluvium show it to be a heterogeneous stack of clay, silt, fine to coarse sand, and fine gravel. BLM-29 (Appendix L) has the greatest thickness (72 ft) of alluvium so far identified in the Lee Acres Landfill Study Area. A few boreholes in the eastern part of the landfill do not have any alluvium. Perhaps the most enigmatic characteristic of the alluvium is the thick intervals of clay seen in some boreholes and even some CPTs (Appendix F). CPT-68 has 11.2 ft of clay identified, while borehole BLM-54 shows 10 ft of clay (Appendix L; cross section D-D′ Plate 6b). Extensive clay deposition such as this can not be found in the present day arroyo, and it is uncertain how such thick clay layers were deposited.

Most of the alluvium in the landfill and the unnamed arroyo north of U.S. 64 is underlain by fine-grained facies of the Nacimiento Formation. In some cases, such as with BLM-16 (Appendix L; cross section C-C′ Plate 6b), coarse-grained facies are found immediately below the alluvium, but these in turn are underlain by fine-grained facies. Claystone, siltstone, and sandstone intertongue in many of the deep boreholes. However, the deepest claystone/siltstone is consistently found at an elevation (above sea level) of 5,365 ft to 5,375 ft. Below this elevation, claystone/siltstone layers are limited to rare beds of less than 1 ft thick. Cross sections A-A′ and B-B′ show this relationship (Plate 6a). The claystone/siltstone beds that underlie the landfill are thinned to the west by the paleotopographic surface. This is observable in section H-H′, where interbedded sandstones, siltstones, and claystones are 45 ft thick in the easternmost well (BLM-35). At this location, the lowest claystone/siltstone subcrops at an elevation of 5,366 ft. Further west, BLM-19 has less than 1 ft of claystone/siltstone at an elevation of 5,373 ft. The 7-ft variation in the elevation of the base of the claystone/siltstone bed is due either to the eastern regional dip of bedrock or to an uneven depositional contact.

The depositional environment during the Tertiary is responsible for the geometry of the sandstone and claystone/siltstone seen in the subsurface. The lenticular shape of sandstone and claystone/sandstone bodies and the channeling of these deposits can be seen in cross sections C-C′ and F-F′ in the form of intertongued lithologies (Plate 6b). Other effects of the environment of deposition can be seen in the grain size, sedimentary structures, coal deposits, and cementation of the bedrock.

Sedimentary structures are abundant in the bedrock core. In addition to the nearly horizontal bedding surfaces, there are gradational contacts, high- and low-angle crossbeds, interformational conglomerates (claystone/siltstone clasts within sandstone channels), sand-filled vertical burrows in the claystone/siltstone layers, rootcasts, soft-sediment deformation features (flame structures), and compaction features (drape folding). A few boreholes logs describe slickensides in the claystones. Slickensides are structures usually associated with tectonic features, but these are probably artifacts of the drilling operations.

Coal intervals and carbonaceous shales have been described in many of the boreholes (e.g., BLM-41, BLM-44, and BLM-59; Appendix L). Coal and carbonaceous shales are often interbedded and most commonly occur at the stratigraphically lowest claystone/siltstone-sandstone contact. BLM-41 contains the thickest coal interval, with up to 3 ft of coal and carbonaceous shales. However, most coal intervals are usually 1/10 to a few tenths of a foot thick. Coal-filled rootcasts have been observed in the sandstone below the coal and carbonaceous shales (e.g., in BLM-35).

Cementation of the Nacimiento Formation was influenced not only by the depositional environment but by diagenetic history of the sediments. A detailed petrographic study was not conducted on the Nacimiento Formation in the study area, so a chronology of cementation is not available. Cement identified in hand samples includes (in order of frequency of occurrence), gypsum/anhydrite, calcite, limonite, authigenic clays, and pyrite. The limonite and pyrite cement is usually limited to nodules, with the pyrite often associated with coal seams and carbonaceous shales.

South of U.S. 64, the bedrock lithology is all sandstone, except for an undetermined thickness of claystone (at least 1.5 ft thick) in BLM-37, and a 0.2-ft thick layer of claystone in BLM-32 (see cross section C-C′ Plate 6b). The boreholes south of the U.S. 64 are stratigraphically the deepest in the study area. Sandstone subcrops at these deepest levels, at an elevation of 5,274 ft (BLM-26; Appendix L). It is not known if extensive claystone/siltstone beds subcrop below this elevation; however, it is apparent that thick, areally extensive, fine-grained facies do not underlie the Nacimiento Formation (subsection 4.1.2).

4.1.7. Physical Characteristics of Subsurface Materials

Representative samples of alluvium as well as fine- and coarse-grained facies of the bedrock were collected for geotechnical testing. Grain size distribution curves are presented in Appendix J. Results of the grain size analysis are summarized in Table 4-1. Alluvium samples range from sandy silt to silty sand with 10 to 18 percent clay, 12 to 53 percent silt, and 29 to 78 percent sand and gravel. Bedrock samples range from poorly graded to well-graded siltstone and sandstone. Samples identified in the field as claystone (Sample IDs 32098, 36443, and 51613; Appendix J) were determined by laboratory analysis to be siltstone (Table 4-1). The sandstone samples contained as much as 25 percent clay (Sample ID 50614; Table 4-1), which may be due to poorly sorted sediments at time of deposition, or development of authigenic clays during diagenesis.

4.2. HYDROGEOLOGY

The physical characteristics of local aquifers and groundwater behavior found within the Lee Acres Landfill Study Area are presented in following subsections. Groundwater flow direction and velocity, aquifer characteristics, and hydrostratigraphic relationships are described, and estimates of the travel time for a mobile groundwater plume to travel from the former Lee Acres Landfill to specified downgradient locations are provided. Section 6 presents the results of the groundwater sampling and analysis program and defines the horizontal and vertical extent of groundwater contamination in the alluvial and bedrock aquifer systems. Section 7 presents the results of a groundwater modeling study that examined the behavior of a retarded groundwater contaminant plume.

4.2.1. Regional Groundwater Characteristics and Use

Because of the arid climate and limited availability of surface water in the San Juan Basin, most domestic, municipal, and agricultural water comes from wells completed in Quaternary surficial valley deposits or underlying sandstones of Tertiary, Cretaceous, Jurrassic, and Triassic Age (Stone et al. 1983). The community of Bloomfield obtains municipal drinking water from the San Juan River and from a single well completed in the San Juan River valley fill aquifer. In March 1987, Lee Acres Subdivision residents were transferred from private domestic well supply to Bloomfield municipal supplies through the Lee Acres Water Users Association. This action was implemented by the BLM in response to measured contamination in domestic wells and an agreement with the NMEID (WESTON 1989l).

The Tertiary Nacimiento Formation and Ojo Alamo Sandstone are the primary regional bedrock aquifers in the Farmington-Bloomfield area (Stone et al. 1983). Nacimiento Formation sandstone aquifers are often confined and may yield from 35 to over 200 gallons per minute (gpm); transmissivities range from 50 to 250 ft^2/day (FCGS 1973). Water quality in the Nacimiento sandstones varies considerably in the San Juan Basin. Chloride concentrations range from 1.2 mg/L to 754 mg/L; sulfate ranges up to 6,700 mg/L (Stone et al. 1983). The Nacimiento Formation is the uppermost bedrock unit at the Lee Acres Study Area underlying the unnamed arroyo alluvial aquifer system.

The Ojo Alamo Sandstone is the lowest Tertiary rock in the San Juan Basin. It underlies the Nacimiento Formation and outcrops approximately 1 mile east of the study area (Stone et al. 1983). This aquifer unit is widely used as a source of domestic and stock water in the San Juan Basin; it interfingers with the Nacimiento Formation approximately 130 ft below ground surface at the study area.

Regional bedrock aquifers in the San Juan Basin are generally confined. Recharge to bedrock aquifers is from topographically high outcrop areas toward lower outcrop areas (Stone et al. 1983). In the New Mexico portion of the San Juan Basin, recharge occurs on the flanks of the Zuni, Chuska, Cebolleta, and San Juan mountains to the north. The San Juan River serves as one of the main discharge areas for the basin. Numerous ephemeral stream channels filled with alluvium are the principal sources for groundwater recharge in some areas and discharge in others. Leakage between major bedrock aquifers, driven by vertical hydraulic gradients, also provide a flow mechanism.

4.2.2. Groundwater Occurrence at the Lee Acres Landfill Study Area

Two hydraulically connected aquifers are of primary importance at the Lee Acres Landfill Study Area. The uppermost unconfined alluvial aquifer consists of Quaternary alluvial deposits found in the unnamed arroyo adjacent and west of the former Lee Acres Landfill (Plate 1). The thickness of alluvium in the arroyo channel, from ground surface to bedrock, ranges from approximately 30 to 60 ft. This aquifer is bounded by the incised bedrock channel on both sides of the unnamed arroyo, and ranges in saturated thickness from approximately 20 to 30 ft within the approximate center of the arroyo channel (Plate 5). Saturated alluvium is thickest beneath the active unnamed arroyo channel and thins laterally toward the bedrock slopes to the east and west. The extent of saturated alluvium shown on Plate 5 corresponds well with that shown on the seismic refraction profiles in Appendix E-2. Figures 4-6 through 4-10 show potentiometric levels for the alluvial aquifer and illustrate the approximate alluvial-bedrock contact that defines boundaries of the alluvial aquifer and unnamed arroyo channel. Figure 4-11 shows the potentiometric surface of the bedrock aquifer within the area of the landfill for July 1991. Appendix S contains groundwater level data for both BLM and Giant-Bloomfield Refinery monitoring wells.

The Quaternary alluvium that comprises the unconfined aquifer is described in subsection 4.1 as poorly to moderately sorted, fined-grained to coarse-grained sands, with some gravels and cobbles. Unconsolidated silt and clay lenses are common. Boulders and cobbles are found occasionally. South of U.S. 64, unnamed arroyo channel alluvium mixes and interfingers with San Juan River terrace deposits. Saturated alluvium south of U.S. 64 is also wider and thicker than saturated alluvium north of U.S. 64 (Plate 5).

Groundwater in the unnamed arroyo alluvial aquifer flows from north to south toward the San Juan River within the bedrock channel defined by the arroyo. Flow direction locally responds to irregular bedrock topography. Recharge is derived from unidentified upstream alluvial aquifer flow, periodic late-summer arroyo runoff events, ponding and downward movement of water in the landfill lagoons, and discontinuous recharge from the underlying Nacimiento Formation. Fire water storage ponds located southeast of the landfill have contributed to alluvial aquifer recharge in the past (USGS 1987). A hydrograph constructed for well GBR-18, located southwest of the ponds, indicates that water levels have decreased in this well since January 1988, when the ponds were emptied and abandoned (Appendix S). Discharge from the alluvial aquifer is south to the San Juan River and to the underlying bedrock aquifer.

The second aquifer of importance is the Nacimiento Formation bedrock aquifer. Flow in this aquifer is generally to the southwest (Figure 4-11). In some well clusters or pairs the water level in bedrock is higher than the water level in the alluvium, while in other well clusters or pairs the water level configuration between alluvium and bedrock is reversed (see subsection 4.2.5). Generally, vertical hydraulic gradients between the unconfined alluvial aquifer and the bedrock aquifer are upward on the eastern side of the arroyo and downward on the western side of the arroyo. Subsection 4.2.5 presents estimates of vertical hydraulic gradients for selected well clusters and pairs at the study area. Unnamed arroyo channel incisement has eroded portions of the claystone, exposing underlying sandstone units that have a stronger hydraulic communication with alluvium than the claystone.

4.2.3. Hydrostratigraphy

Cross sections A-A′ through G-G′ on Plates 6a and 6b show the stratigraphic relationships between the alluvial aquifer, the landfill, the groundwater monitoring well screens, and the lithology. Plate 4 shows cross section locations. Cross sections A-A′, B-B′, and E-E′ are west to east and transverse to alluvial aquifer flow. Cross section I-I′ is located through the landfill, cross section H-H′ is located along the southern landfill boundary, and cross section E-E′ is located through well GBR-32, approximately 250 ft south of the landfill property boundary (Plate 4).

Stratigraphy at the study area consists of alternating layers of Nacimiento sandstones and claystones overlain by sandy alluvium in the incised unnamed arroyo channel (Plate 6a). Occasional clay lenses appear within the alluvium. All cross sections show that the alluvium-bedrock contact consists of an alluvium-claystone or alluvium-sandstone contact.

4.2.4. Seasonal Fluctuation in Water Level Elevation

Eighteen hydrographs were generated for selected well clusters and pairs and are presented in Appendix S. Individual well hydrographs were also generated for BLM monitoring wells. The hydrographs were generated to observe any seasonal trends and to estimate vertical hydraulic gradients. Locations for the hydrographs were selected based on the availability of data and geographical distribution. Listed below are well clusters used to generate hydrographs according to study subareas. Hydrographs and supporting data are presented in Appendix S. Well locations and study subareas are shown on Plate 1.

Study Subarea	Hydrograph Well Cluster (BLM Monitoring Wells)
Background, Subarea 1	14, 15, 16
Site 1, Subarea 2	17, 18, 19
Site 1, Subarea 2	20, 21, 22
Site 2	24, 25, 26
Site 2	27, 28, 29
Site 2	30, 31, 32
Site 1, Subarea 2	23, 33, 34
Background, Subarea 1	39, 40
Site 1, Subarea 2	41, 42, 43
Site 1, Subarea 2	44, 45, 46
Site 1, Subarea 2	47, 48, 49
Site 1, Subarea 2	50, 51, 52
Site 1, Subarea 2	54, 55
Site 1, Subarea 2	56, 58
Site 1, Subarea 2	59, 60
Site 1, Subarea 3	61, 62
Site 1, Subarea 3	67, 78
Site 1, Subarea 3	75, 79

Inspection of these 18 hydrographs reveals no significant evidence of periodic seasonal trends or yearly cycles. However, fluctuation of groundwater elevation is expected in response to rare and sporadic late summer thunderstorm runoff and recharge events. Groundwater elevation data shown on hydrographs for wells BLM-14, BLM-15, and BLM-16 depict water levels that may have responded to precipitation events (BLM-14 in July 88 and BLM-16 in June 1988). However, this response to possible precipitation is not seen on any of the other nested hydrographs.

During the first week of August 1989, a major thunderstorm occurred at the Lee Acres Landfill Study Area (WESTON 1990h). This storm was described as a 500-year event and resulted in approximately 3 ft of channel flow in the unnamed arroyo. Damage from erosion prompted the installation of erosion protection measures that included the placement of gabions at two locations on the east side of the landfill (subsection 4.3). Water level elevations measured in BLM wells in early September 1989 do not reveal any observable response to this storm event (Appendix S). Therefore, any measurable response to periodic late summer thunderstorms is considered short-lived.

Hydraulic relationships between alluvial and bedrock well screens are generally stable over time at each well cluster. For example, the bedrock screen of well BLM-29 in well cluster BLM-27, BLM-28, and BLM-29, shows that the upward vertical hydraulic gradient from the bedrock to the alluvial aquifer is constant over time. All other well cluster hydrographs presented in Appendix S reveal the same general trend. This observation suggests that the upward hydraulic gradient is natural, and no man-induced aquifer stresses have affected either system to an extent that would cause gradient reversal.

A subtle decrease in groundwater elevation was observed at the study area from late 1987 to mid 1991. This trend was observed in the upgradient well cluster hydrographs for BLM-17, BLM-18, and BLM-19 and the downgradient well cluster hydrography for BLM-27, BLM-28, and BLM-29, especially over the past two years. A possible explanation for this subtle decreasing trend is decreasing upgradient recharge due to the lesser amount of rainfall within the drainage basin.

Comparison of two well clusters located south of U.S. 64 reveals a common trend in response to periodic aquifer fluctuation. Clusters BLM-27, BLM-28, and BLM-29 and BLM-24, BLM-25, and BLM-26 mimic each other in terms of subtle increases and decreases in groundwater elevation in all well screens over time.

4.2.5. Horizontal and Vertical Hydraulic Flow

Tables 4-2 and 4-3 show estimated horizontal and vertical gradients, respectively, for selected locations at the Lee Acres Landfill Study Area. Horizontal gradients range from 0.004 ft/ft to 0.022 ft/ft. Higher horizontal gradients are found in both the alluvial and bedrock aquifer systems closer to the former landfill;

horizontal gradients generally decrease to the south. Geologic cross section C-C′ (Plate 6a) shows the alluvial and bedrock aquifer potentiometric surface along the unnamed arroyo.

Vertical hydraulic gradients shown on Table 4-3 reveal alternating upward and downward hydraulic gradients. Monitoring wells located on the eastern side of the arroyo channel generally show upward vertical gradients; wells on the western side of the arroyo channel generally show downward vertical gradients.

Well cluster hydrographs presented in Appendix S illustrate relative upward and downward hydraulic gradients over time. Estimated hydraulic gradients shown on Table 4-3 can be compared to the relative position of alluvial and bedrock aquifer water level data shown on hydrographs to observe both upward and downward trends.

4.2.6. Aquifer Characteristics

Aquifer characteristics are parameters that describe the ability of an aquifer to transmit and store water. This subsection provides estimates, based on both past and current data, of hydraulic conductivity (K), transmissivity (T), and storativity (S) for the alluvial unconfined aquifer and the semi-confined bedrock aquifer. Aquifer tests were conducted at the Lee Acres Landfill Study Area in 1987 by Geoscience Consultants, Ltd. (GCL) for the Giant-Bloomfield Refinery (GCL 1987). A series of slug tests were conducted during the RI in both aquifer systems in February 1988, March 1990, and June 1991. The discussion below presents an analysis of these data sets, resulting in approximate ranges of K, T, and S for the alluvial and bedrock aquifer systems.

GCL analyzed aquifer test data for pumping wells GBR-25, GBR-27, and GBR-14 (GCL 1988). Drawdown was corrected to account for product thickness and for borehole and casing storage effects. The results of a modeling study conducted to duplicate the effects of a planned groundwater recovery system was also reported by GCL. Model calibration was performed to compare model results with field conditions, and the simulated steady-state head distribution was compared with the observed water table.

A total of 27 slug tests were completed during the RI in the alluvial and bedrock aquifer systems of the study area. Bouwer and Rice's method for calculating hydraulic conductivity for unconfined aquifers was employed (Bouwer and Rice 1976). Procedures given in SOP 3.2 for the collection of data and determination of saturated hydraulic conductivity by the slug test method of analysis were followed in the field (WESTON 1988a). This SOP includes technical procedures, decontamination procedures, and documentation instructions. The hydraulic conductivity of the alluvial aquifer was determined from the rate of rise of the water level in a well after a volume or "slug" was removed from or introduced to the well.

Instantaneous change of water level in each well was achieved by submerging a decontaminated cylinder in the water. For injection tests, the slug was positioned directly above the static water level. As the slug was quickly lowered into the well, subsequent rise and fall in water level was recorded with a pressure transducer and data logger. Withdrawal tests were performed when the water level had equilibrated with the submersed slug. The slug was then removed. Water level data were again recorded by the pressure transducer and data logger, as was any subsequent rise or fall in water level.

Table 4-4 summarizes slug test results for 19 alluvial aquifer wells and eight bedrock aquifer wells. Well locations are shown on Plate 1. Elapsed time versus residual drawdown graphs and calculations for all 27 tests are presented in Appendix T. An examination of the results shows a distinction between K measured in alluvial and bedrock aquifer wells. K for the alluvial aquifer ranged from 0.3 to 245.3 gallons per day per square foot (gpd/ft^2); bedrock aquifer K values ranged from 0.7 to 17.9 gpd/ft^2. K values reported in Table 4-4 for the alluvial aquifer fall within ranges given in Freeze and Cherry (1979) for the upper hydraulic range of a silty sand and the lower hydraulic range of a clean sand. Bedrock aquifer K values reported in Table 4-4 fall within the upper range given by Freeze and Cherry (1979) for a sandstone.

K values reported by GCL (1988) for the Nacimiento Formation sandstone range from 0.4 to 6.2 gpd/ft^2. This range compares well with the 0.7 to 14.2 gpd/ft^2 range reported in Table 4-4. K values for the alluvial aquifer derived from tests completed at well GBR-14 were reported to range from 0.5 to 3.0 gpd/ft^2 (GCL 1988). These K values seem low compared to those of the sandstone; an explanation was given by GCL that these low K values are the result of clays found within the alluvial sands at this location. K values presented by GCL were calculated by dividing T by saturated aquifer thickness. It is possible that overestimated thicknesses or the presence of clay within the alluvium may be responsible for the low K values reported by GCL. A K range from 6.0 to 85.3 gpd/ft^2, reported in Table 4-4, seems more representative of an unconsolidated alluvial aquifer than the value reported by GCL.

S values reported by GCL for the bedrock aquifer range from 0.00016 to 0.0045 (GCL 1988). This range falls within a range considered normal for a confined aquifer (Freeze and Cherry 1979). Unconfined S for the alluvial aquifer is reported as 0.051 in the southern portion of the Giant-Bloomfield Refinery area, which is in the normal range for a water-table aquifer system.

T values reported in Table 4-4 are also dependent upon estimated saturated aquifer thicknesses. Thicknesses shown in Table 4-4 were derived from examination of the well logs provided in Appendix L. They were estimated according to the thickness of a particular unique geologic unit adjacent to each well screen. In some cases, it is possible that these thicknesses were overestimated, as it is difficult to select an aquifer thickness that is in active hydraulic communication with the well screen during each test. However, the T ranges for the alluvial aquifer shown on Table 4-4 are considered acceptable for the purpose of estimating response to aquifer stress and groundwater flow velocities in subsequent sections of this report. T values for the alluvial aquifer range from 6.0 to 2,050.7 gallons per day per foot (gpd/ft). The following section presents an analysis of groundwater flow in the alluvial aquifer; subsection 4.8 presents simulations of contaminant transport in the alluvial aquifer.

4.2.7. Groundwater Flow

North of U.S. 64, groundwater flow in the unconfined alluvial aquifer system generally follows the north-to-south direction of the unnamed arroyo channel (Figures 4-6 through 4-10). South of U.S. 64, the unnamed arroyo alluvium interfingers with San Juan River terrace and floodplain deposits, producing a condition where alluvial groundwater is no longer contained within the incised unnamed arroyo channel. Within this area, unnamed arroyo alluvial groundwater discharges to and mixes with San Juan River groundwater. Bedrock groundwater flow direction is based on local gradients and is generally to the south-southwest (Figure 4-11).

Presented below is an estimated range of the time required for groundwater to travel under a normal alluvial aquifer gradient from the Lee Acres Landfill to the San Juan River. Ranges of aquifer characteristics presented in the previous subsection are used to evaluate the sensitivity of estimated groundwater flow velocities and travel times to changes in porosity and hydraulic conductivity. Groundwater flow in the alluvial aquifer is contained within saturated alluvium within the incised bedrock channel formed by the unnamed arroyo (Plate 5). Groundwater flow velocity is calculated according to Darcy's equation as:

$$v = Ki/n$$

where

v is groundwater flow velocity in ft/day,

K is saturated hydraulic conductivity in ft/day,

i is the hydraulic gradient in ft/ft, and

n is average effective porosity expressed as a fraction.

A constant hydraulic gradient of 0.015 ft/ft is estimated from Table 4-2 as a representative gradient from the landfill to the San Juan River. Effective porosity (n) is estimated as a range of 0.15 for a poorly sorted sand to 0.35 for a well-sorted sand (Freeze and Cherry 1979). Table 4-5 presents groundwater velocities calculated using Darcy's equation and with K varying within the ranges reported in Table 4-4, and n varying from 0.2 and 0.3.

Estimated groundwater velocities in the alluvial aquifer range between 0.033 and 1.003 ft/day (Table 4-5). However, the lower range of values are only representative of short range microscopic scale flow. Macroscopic scale flow moves preferentially through the more conductive sediments. Therefore, estimated travel times are based on macroscopic scale flow. Groundwater modeling input parameters presented in Section 7 include an average groundwater velocity of 0.6 ft/day. Given the estimated groundwater velocity of 0.6 ft/day, groundwater would move from the former liquid waste lagoons to the southern landfill boundary in approximately 5 years, to U.S. 64 in approximately 15 years, and to the San Juan River in approximately 36 years. These travel time estimates are considered reasonable for normal conditions and do not take into account infrequent groundwater pulses that may be created by seasonal late-summer storms. Section 7 presents results of solute transport simulations that consider dispersion and contaminant retardation. Aquifer characteristics used for solute transport simulation are taken from the analyses presented in subsection 4.2.

4.3. FLOODPLAIN ANALYSIS

The Lee Acres Landfill Study Area lies within the drainage area identified for this report as the unnamed arroyo alluvial basin. The major perennial streams in the area, which exist within entrenched narrow valleys, are the San Juan River and its two main tributaries, the Animas and La Plata rivers. The San Juan River is the southern boundary of the study area. The surface runoff within the unnamed arroyo alluvial basin flows ultimately to the San Juan River. Surface water within the unnamed arroyo alluvial basin exists as ephemeral streams that flow only after a significant rainfall event. A description of the geomorphology of the unnamed arroyo alluvial basin is presented in subsection 4.1.3 of this report.

A flood event occurred in the unnamed arroyo in August 1989. This event was estimated to have resulted from a 500-year storm and reached a depth in the arroyo of approximately 3 ft. The former landfill was eroded at one location; therefore, corrective action was necessary to prevent further damage to the landfill and potential contaminant releases via the surface water. Erosion protection measures in the form of gabions (rock-filled wire encasements) were constructed along the northwestern and southwestern corners of the landfill during January and February 1990. The gabion walls were designed to protect the landfill from storms of the magnitude of a 500-year storm. Design descriptions and methods are documented in the "Lee Acres Landfill Erosion Protection, San Juan County, New Mexico, Invitation for Bid, Subcontract Documents and Final Design for Construction" (WESTON 1990i). The final action and as-built drawings are detailed in the "Lee Acres Landfill Erosion Protection, Final Summary Report" (WESTON 1990h).

To characterize the floodplain within the Lee Acres Landfill Study Area, flood events were simulated to determine their effect on the two gabion walls at the former Lee Acres Landfill. Hydrologic and hydraulic analyses were performed to characterize the impact of flood events upon the gabion walls and the former landfill. The data that influence the amount and rate of runoff, and therefore, flooding, within the Lee Acres Landfill Study Area include drainage basin characteristics, the type and extent of vegetation or cultivation, and the amount of precipitation expected in the geographical area. Two computer modeling packages, HEC-1 and HEC-2, were used to estimate peak flows for the 100- and 500-year frequency storms and water surface elevations in the arroyo resulting from these storms, respectively. The methodology and results of the floodplain analyses are presented in the following subsections.

4.3.1. Methodology

The HEC-1 computer model was used to estimate the amount of flow in the unnamed arroyo from storms of various intensity. HEC-1 is a flood hydrograph computer modeling package developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center at Davis, California (COE 1981). The HEC-1 model simulates the surface runoff response of a drainage basin to precipitation. The large drainage area is divided into subbasins that are represented as an interconnected system of hydrologic and hydraulic components. HEC-1 combines the subbasin runoff components and routes the runoff to the final analysis point for peak flow estimates.

The unnamed arroyo alluvial basin, shown in Figure 4-12, was delineated using the USGS Horn Canyon and Flora Vista Quadrangle topographic maps (USGS 1979a,b). The unnamed arroyo alluvial basin covers an area of approximately 5.8 square miles and cuts into Crouch Mesa, which separates the Animas River drainage to the north from the San Juan River drainage to the south. The basin ranges in elevation from 5,385 to 5,930 ft and extends 5.4 stream miles northeast of U.S. 64. After the delineation of the unnamed arroyo alluvial basin, it was then subdivided into 12 subbasins (Figure 4-12). Each subbasin represents an area of the watershed that on the average has similar hydraulic and hydrologic properties.

Four parameters are required for the HEC-1 model. Two parameters, the time of concentration (T_C) and the lag time, are specific to each subbasin. These subbasin characteristics are presented in Table 4-6. The remaining two parameters, soil cover and precipitation amounts, are specific to the entire drainage basin and Lee Acres Landfill Study Area. Methods used for obtaining these parameters are summarized below.

The T_C is the time required for runoff from the most remote part of a subbasin to reach the next subbasin. The height of the most remote point above the outlet and the maximum length of travel were measured for each subbasin (Figure 4-12) and are listed in Table 4-6. Times of concentration were then estimated for each subbasin using the Kirpich nomograph (AISI 1971). For five of the subbasins, it was necessary to follow a path that had two distinct changes in slope, and therefore, two path lengths. This resulted in two T_C values, which were then added together. After the T_C value was obtained for each subbasin, the lag time was calculated. Lag time is defined as the time in hours from the midpoint of excess rainfall to the time of peak discharge. Lag time is equal to 0.6 times T_C (DOI 1977). T_C and lag time values were also estimated for additional paths used to route the flow of surface runoff from subbasin to subbasin (Table 4-6).

The type of soil and cover existing in the drainage basin had to be determined in order to estimate the amount of runoff that will result from a given amount of precipitation. From the RI field work, the soil and cover in the drainage basin was determined to be poor pasture or range land that has plant cover on less than 50 percent of the area, is sparsely covered with sage, and has an understory of grass. The U.S. Soil Conservation Service (SCS) has developed runoff curve numbers for specific hydrologic soil cover conditions (DOI 1977). With the cover defined as poor sage-grass, the SCS curve number selected ranges from 64 to 78 (DOI 1977). The higher the SCS curve number, the less the infiltration that occurs and the larger the amount of surface runoff. The curve number of 78 was selected to represent the worst-case scenario for the Lee Acres Landfill Study Area.

Precipitation data are needed to estimate the peak flow for a given storm event. These data were obtained from the National Oceanic and Atmospheric Administration (NOAA) Precipitation-Frequency Atlas, Volume IV for New Mexico (NOAA 1973). Precipitation values were obtained for the 10-, 50-, and 100-year storm frequencies that could occur within the Lee Acres Landfill Study Area. The amounts of precipitation for a 6-hour storm for the three storm frequencies were then distributed according to the Hydrometeorological Report No. 49, "Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages" (NOAA 1977). Little information is known about the time sequence of incremental 1-hour rainfalls from intense local storms. However, Hydrometeorological Report No. 49 states that for a 6-hour storm in the Southwest, the maximum intensities of rainfall occur in the middle of the storm period. The distributed precipitation amounts for 10-, 50-, and 100-year, 6-hour storms, in 15-minute increments, are provided in Table 4-7.

Additionally, in order to determine the flow of the probable maximum flood (PMF), the probable maximum precipitation (PMP) resulting from a local-area storm was required. The PMP was estimated using Hydrometeorological Report No. 49 (NOAA 1977). The distributed precipitation amounts for the PMP are presented in Table 4-7.

The HEC-1 computer model, with the above data, computed the peak flows for the 10-, 50-, and 100-year storms, and for the PMF. After the flows for the 10-, 50- and 100-year storms were calculated, the peak flow for a 500-year storm was extrapolated from the three storm flowrates. This was performed by plotting the flow versus the time increment for each storm (Figure 4-13). As precipitation data are unavailable for a 500-year storm, the flowrate for such a storm had to be extrapolated instead of being calculated using the HEC-1 model.

Next, the flowrates for the 100-year and 500-year storms and the PMF were used as inputs for HEC-2, a computer model also developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center (COE 1982). HEC-2 calculates water surface profiles for steady, gradually varied flow in natural or man-made channels. The objective of using HEC-2 is to compute water surface elevations at all locations of interest for given flowrates. The data needed to perform these computations include flow regime, starting water surface elevation, and the physical characteristics of the channel such as channel profile and roughness.

The flow regime and starting water surface elevation were determined from the flowrates calculated by HEC-1. HEC-2 calculates a water surface elevation at any specified point along the channel. Five sections along the landfill were identified as points of interest:

- Section 1: the first point of contact with the gabion wall;
- Section 2: the edge of the former landfill that juts into the arroyo;
- Sections 3 and 4: points where erosion had occurred; and
- Section 5: the southwest gabion wall (Figure 4-14).

HEC-2 allows the floodplain for each storm event to be determined. Results of the surface water characterization are presented in the following subsection.

4.3.2. Results

Two computer models, HEC-1 and HEC-2, were used to estimate the peak flows in the unnamed arroyo due to a 100-year and 500-year flood. The peak flows and the estimated water surface elevations that would occur in the arroyo due to these floods are discussed below. In addition, the PMF was also modeled to characterize the impact of this worst-case scenario upon the gabion walls and the former Lee Acres Landfill. The resultant flow from the PMF and its effect in comparison to the 500-year flood are also presented below.

Initially, HEC-1 was used to determine the amount of the surface runoff in the unnamed arroyo resulting from precipitation due to the 10-, 50-, and 100-year storms. HEC-1 estimated that peak flows of approximately 300, 880, and 1110 cubic feet per second (cfs) could be expected in the unnamed arroyo for the 10-, 50-, and 100-year storms, respectively. The peak flow from a 500-year storm was also considered to be important. This was due to the fact that the flood that occurred during August 1989 was estimated to be the result of a storm approximately equal to a 500-year storm. Precipitation data were unavailable for a 500-year storm; however, the peak flow for this storm frequency was extrapolated from the peak flows for the three storms mentioned above and was estimated to be approximately 1660 cfs (Figure 4-13). The extrapolation of the 500-year flow was used as a conservative but appropriate approach in estimating the amount of flow for an event that is believed to have occurred in the unnamed arroyo.

The peak flows for the 100- and 500-year storms and physical data regarding the arroyo were used as the inputs into HEC-2 (COE 1982). The objective of HEC-2 is to compute water surface elevations at any location of interest for given flowrates. Water surface depths and elevations were computed by the HEC-2 model at five sections of the arroyo next to the landfill (Figure 4-14). Table 4-8 presents the HEC-2 results. Due to the low flowrates for the 10- and 50-year storms, only water surface elevations for the 100- and 500-year storms were computed. The depths of water at each cross section range from 0.8 to 2.6 ft the 100-year storm and from 1.1 to 3.1 ft for the 500-year storm. Water surface elevations vary by less than 0.5 ft between the two storm frequencies at each cross section; therefore, only the 500-year floodplain elevations are shown in Figure 4-14.

The resultant flow from a 500-year storm spreads out beyond the main arroyo channel. In Figure 4-14, the shaded area shows that the flow from a 500-year storm exceeds the widths of the main arroyo channel. The gabion wall prevents flow from encroaching on the former landfill. The highest water elevation, 5,439.1 ft, occurs at Section 1 (Figure 4-14). The gabion wall elevation is 5,442 ft at Section 1, which is approximately 3 ft higher than the estimated 500-year flood depth. The gabion wall elevation is 5,417 ft at Section 5 and the flood elevation is 5,415.6 ft. Therefore, the gabion wall at both the northwestern and southwestern corners is of sufficient height to protect the former landfill from a 500-year flood.

In addition to determining the impact of a 500-year flood upon the gabion walls, the HEC-1 and HEC-2 models were used to estimate the flowrate and depth of water that could occur in the unnamed arroyo under the worst-case scenario of a PMF. The PMF in the unnamed arroyo is considered in order to compare the effects of the worst-case scenario upon the gabion walls and landfill against those of the design 500-year flood event.

The PMF flowrate was calculated by the HEC-1 model to be approximately 19,700 cfs. The depth of water in the unnamed arroyo from the PMF ranges from 4.9 to 8.5 ft (Table 4-8). The resultant flood elevation is 5,444.5 ft at Section 1, which is approximately 2 ft above the gabion wall elevation. The PMF elevation is 5,419.1 ft at Section 5, which is also approximately 2 ft above the gabion wall elevation. Therefore, the floodwaters from the PMF will encroach slightly upon the former Lee Acres Landfill, as shown in Figure 4-14. At Section 1, the PMF encroaches less than 50 ft into the western edge of the landfill. The PMF continues to follow a path along the gabion wall to Section 2. The floodplain still encroaches slightly upon the landfill, approximately following the fence line from Section 2 to Section 4. As the flood reaches the southwestern gabion wall, it may encroach approximately 100 ft into the former landfill (Figure 4-14).

The occurrence of the PMF takes place in a relatively short span of time. The peak flow for the PMF occurs at 3 hours, 15 minutes into the estimated 6-hour storm (Table 4-9). Flow does not occur until 2 hours and 15 minutes into the storm. The flowrate at this time is approximately 1,375 cfs, which is less than the flowrate of the 500-year flood. At 3 hours, flow is approximately 12,500 cfs, and it peaks at 19,700 cfs 15 minutes later (Table 4-9). By 5 hours, 30 minutes, the flow has decreased to less than 1,500 cfs, which is below the flowrate of a 500-year flood (Table 4-9).

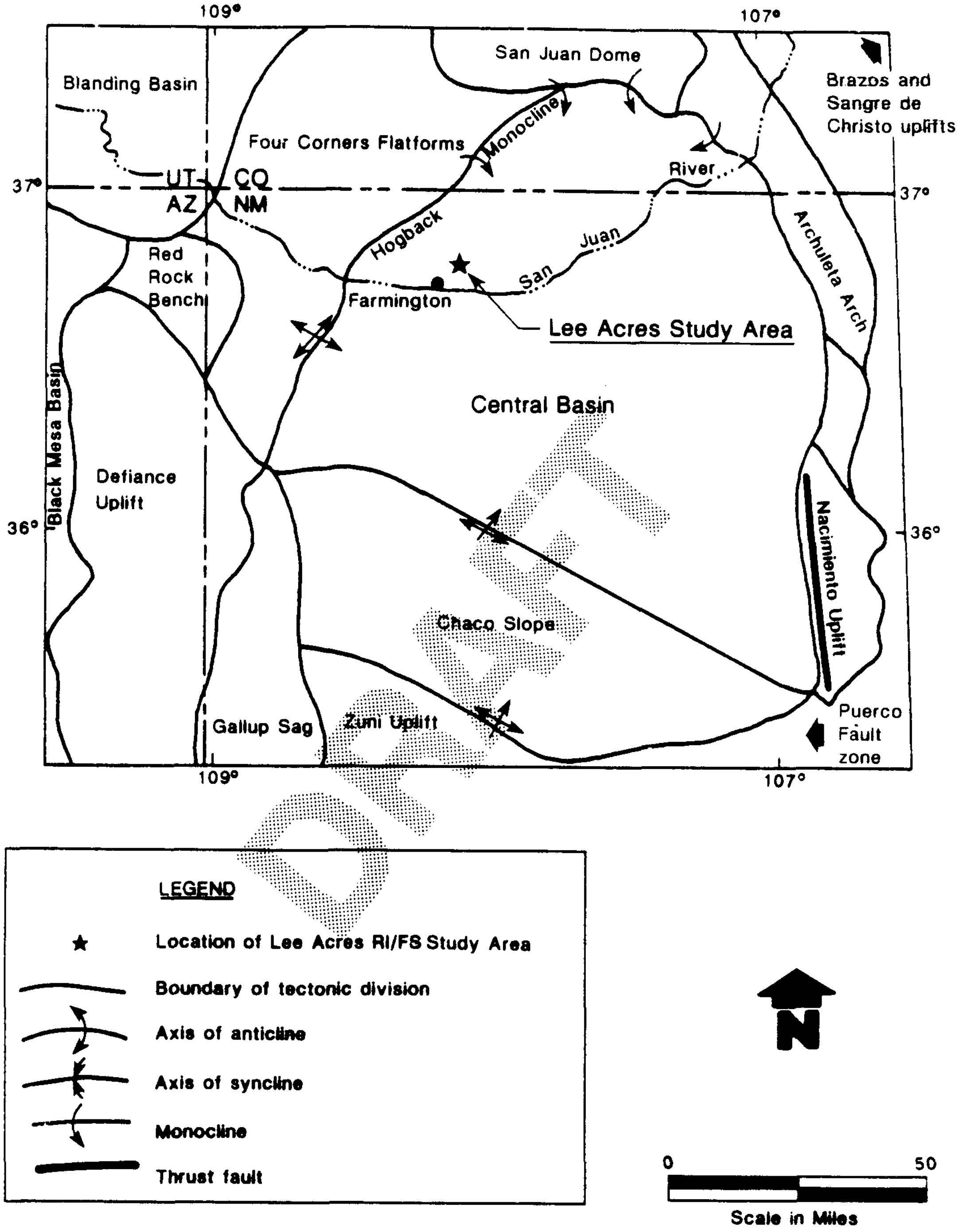
The gabion walls at the northwestern and southwestern corners of the former Lee Acres Landfill were designed to withstand and protect the landfill from a 500-year flood. Should this flood occur, the integrity of the walls will remain intact. However, the gabion walls were not designed to withstand a flow from a PMF of 19,700 cfs. However, should a PMF occur, the gabion walls will protect the integrity of the landfill. The encroachment of the floodwaters upon the western edge of the landfill is less than 100 ft. However, due to the velocity of the water in the arroyo, undercutting below the gabion walls will occur. The velocity of the water in the main channel of the arroyo is higher than the velocity at the edges of the arroyo. Table 4-8 presents the average velocities in the main channel and the velocities at the edge of the arroyo, next to the landfill, for each section. The main channel velocities range from approximately 16 to 31 feet per second (ft/s). The velocities of the water near the landfill edges are less than 10 ft/s. The main channel velocities will cause erosion to occur beneath the gabion walls. The walls will then sag into the eroded areas. However, the walls will still remain in place to protect the former landfill. The gabion walls do not have to withstand the peak 19,700 cfs flow for a long period of time. This peak flow would last for less than 30 minutes, and would decrease rapidly within the following 2 hours. The gabion walls would therefore protect the integrity of the landfill. The damage to the gabion walls from a PMF would require repair and maintenance in order to ensure the continued protection of the former landfill.

4.3.3. Summary

Gabion walls constructed along the northwestern and southwestern corners of the landfill provide protection from a 500-year flood event as the walls are above the estimated flood levels that could occur in the adjacent arroyo. The gabion wall at the northwestern corner is approximately 3 ft higher than the 500-year flood level of 5,439.1 ft. The gabion wall at the southwestern corner is approximately 1.5 ft higher than the 500-year flood level of 5,415.6 ft. The gabion wall at each location is set two feet below the ground surface to prevent underscouring and undercutting.

The gabion walls were not designed to withstand a PMF. The gabion walls will, however, protect the integrity of the former Lee Acres Landfill from a PMF. The velocities that occur during a PMF will cause undercutting beneath the gabions. However, the gabion wall design provides for sagging should undercutting occur. Therefore, the walls would sag into the eroded area and still provide protection of the landfill. Some erosion of the surface of the former landfill may occur along the western edge as the PMF would encroach less than 100 ft into the landfill (Figure 4-14). The velocities of the PMF flood waters decrease along the edges of the arroyo to less than 10 ft/s (Table 4-8). Underscouring and undercutting by the flood waters would occur in the main channel and at the gabion walls. The lower velocities at the western edge of the former landfill would cause some slight erosion.

Should a PMF occur, the integrity of the former Lee Acres Landfill is expected to remain intact; however, the gabion walls would probably require repair and maintenance. Should a 500-year flood occur in the unnamed arroyo, the gabion walls would withstand the event with little maintenance and would continue to ensure the integrity of the former Lee Acres Landfill after such an event.



Adapted from Kelley and Clinton 1960, in Woodward and Callender 1977.

Figure 4-1. Tectonic map of San Juan Basin and adjacent areas.

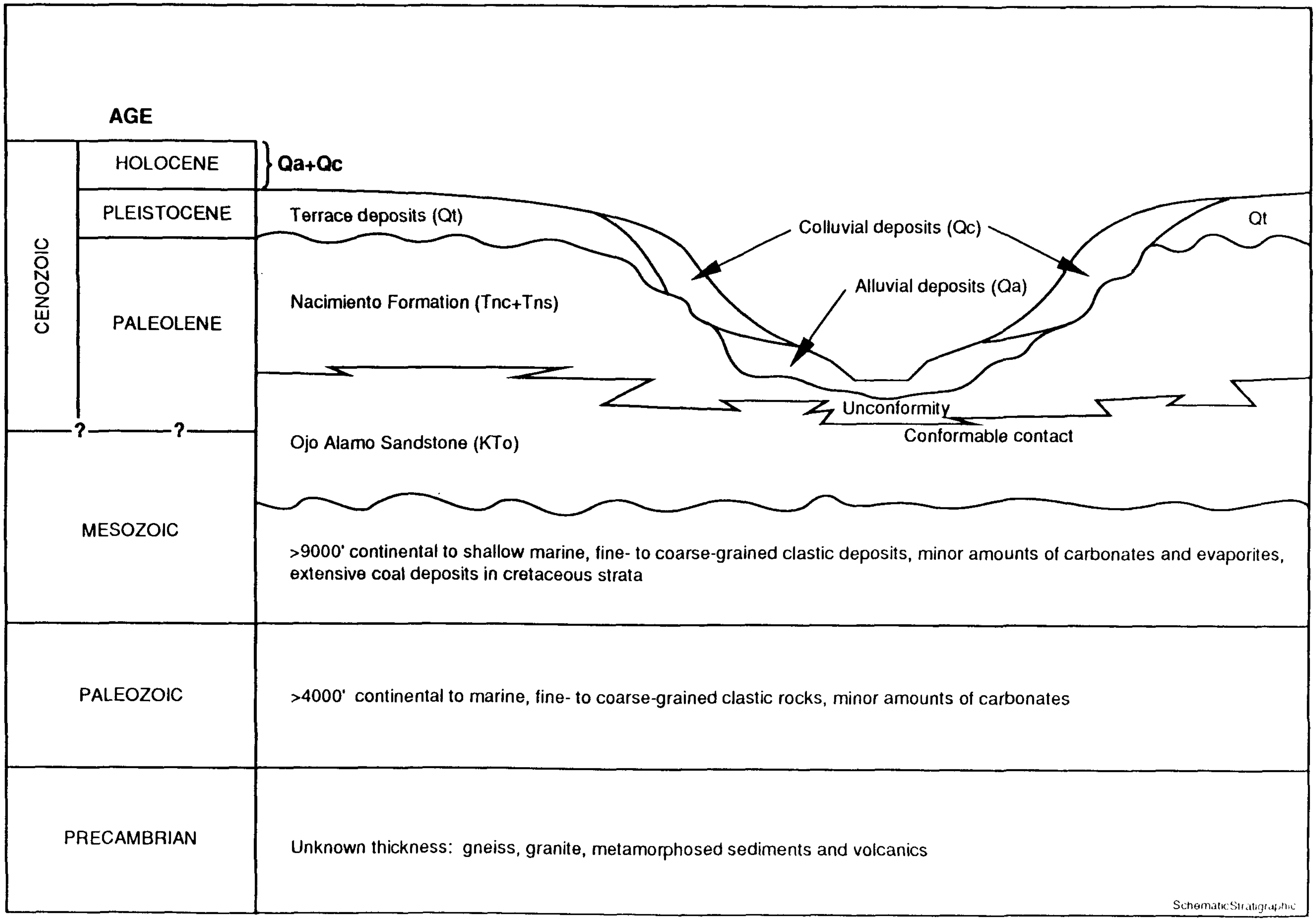


Figure 4 2 Schematic stratigraphic column of deposits exposed and underlying the study area.

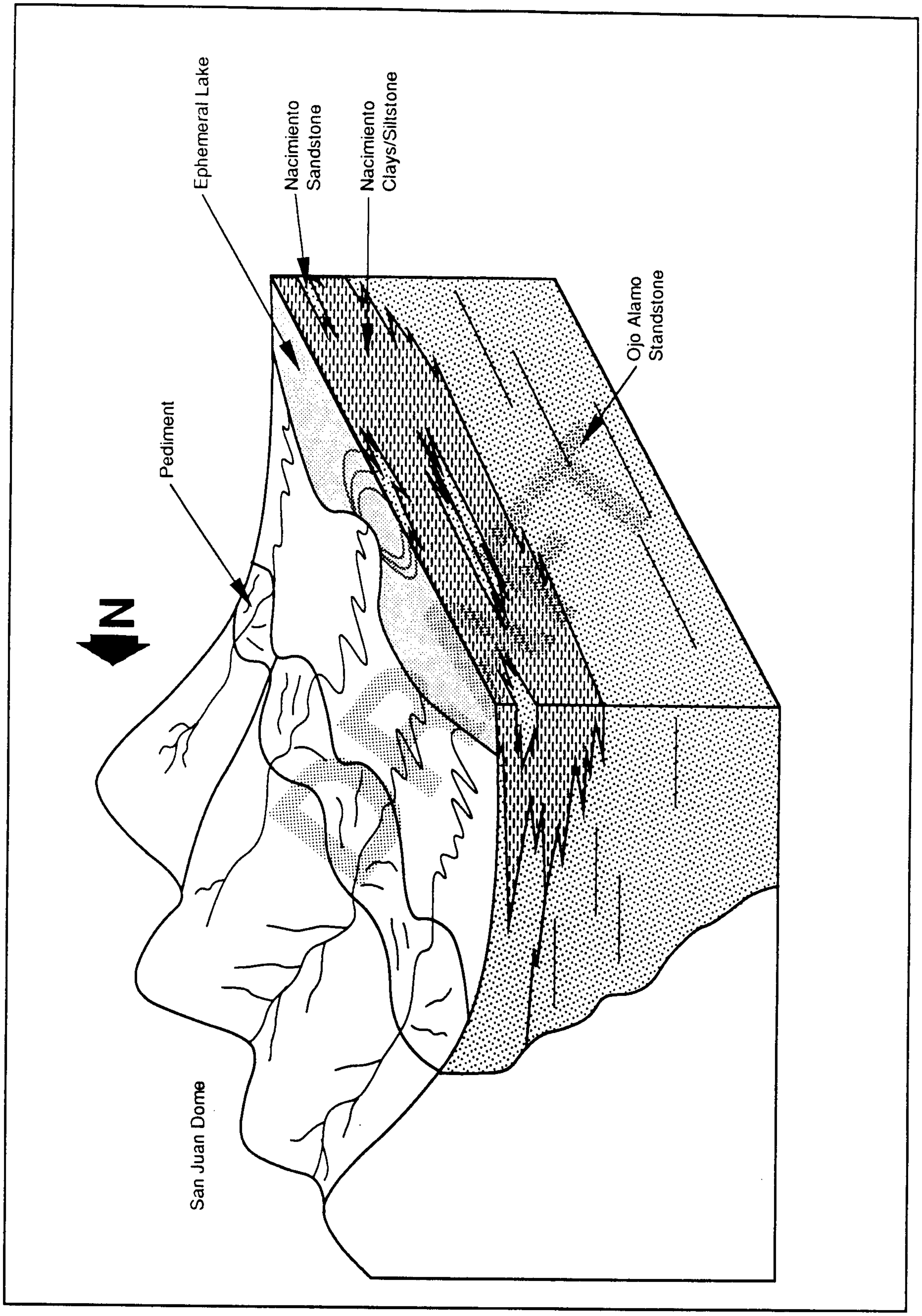


Figure 4-3. Hypothetical depositional environment during the Paleocene.

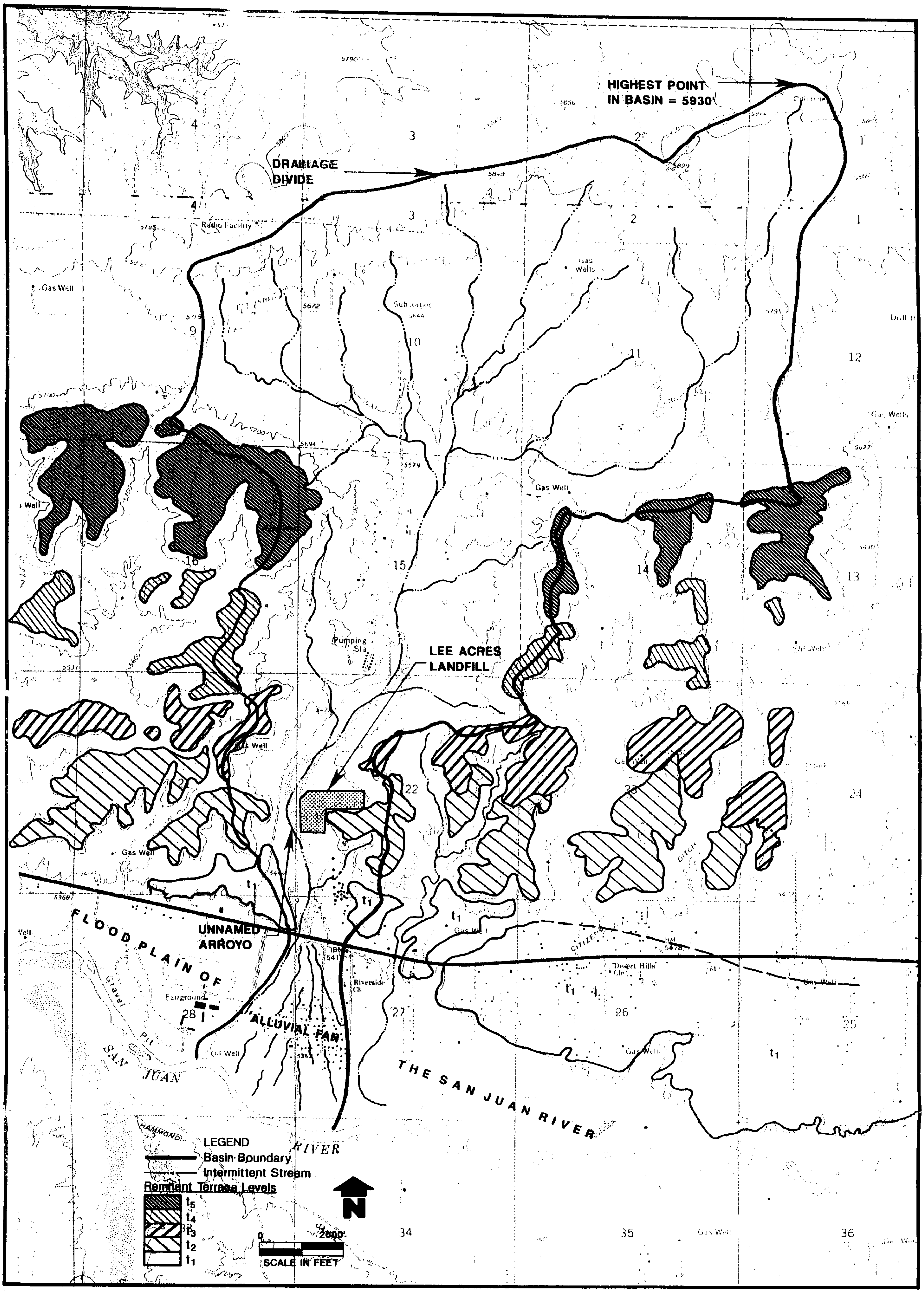
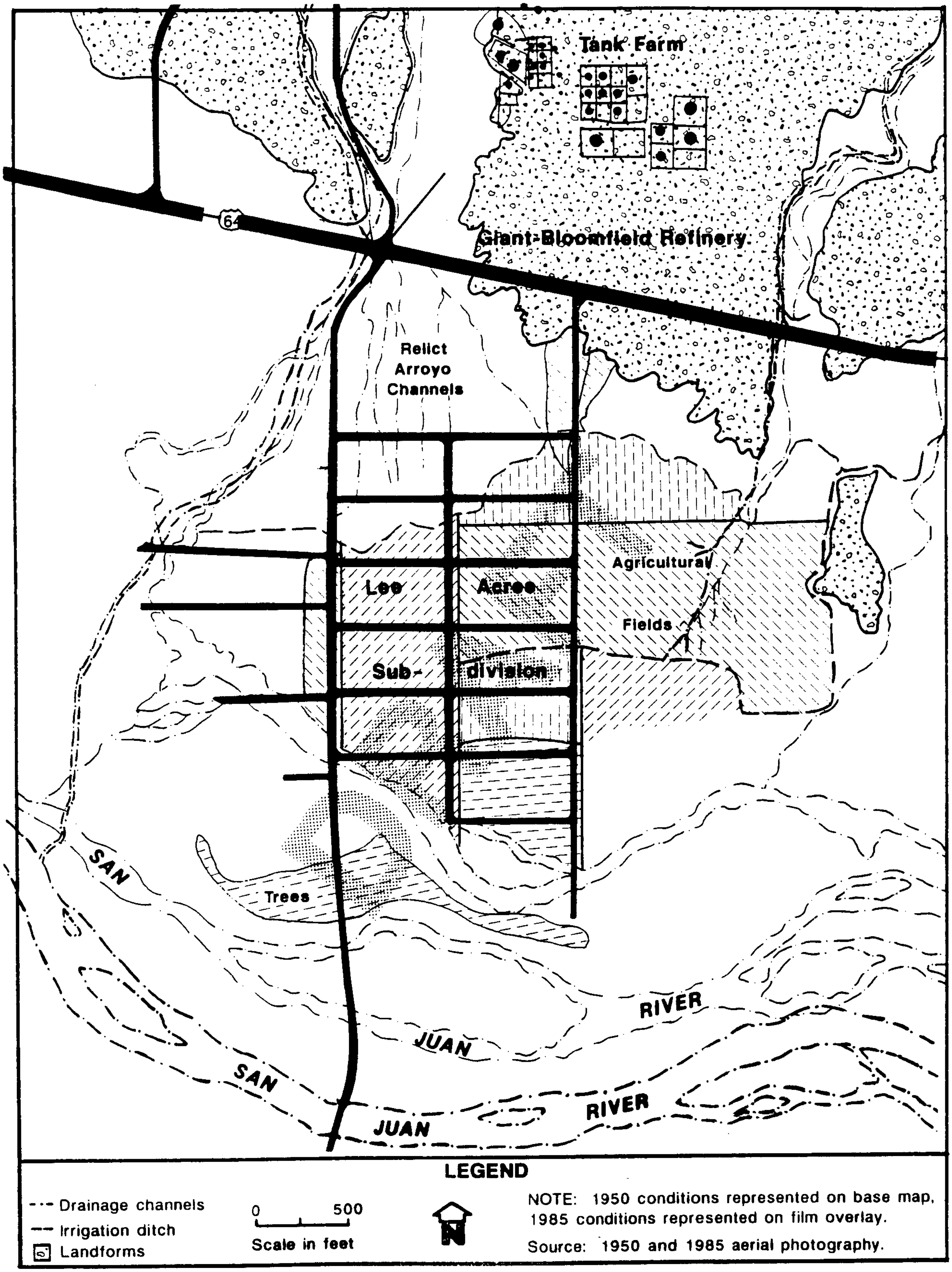


Figure 4-4. Geomorphic features in the vicinity of the study area (from USGS 7.5 quadrangle).



NOTE: 1950 conditions represented on base map, 1985 conditions represented on film overlay.

Source: 1950 and 1985 aerial photography.

Figure 4-5. Air photo interpretation showing changes in alluvial fan and San Juan River floodplain/channels from 1950-1985.

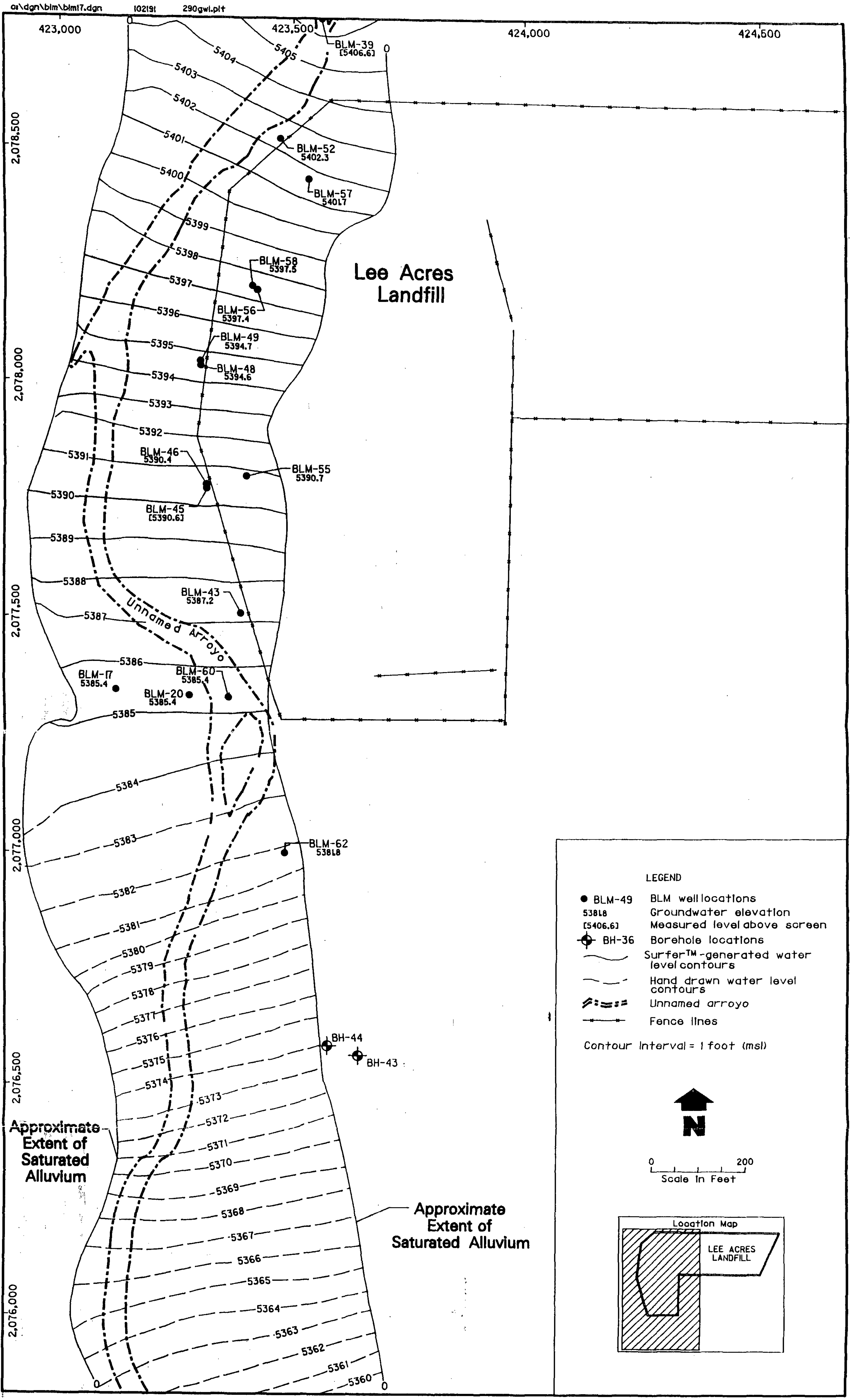


Figure 4-6. Water table map for the alluvial aquifer, February 1990.

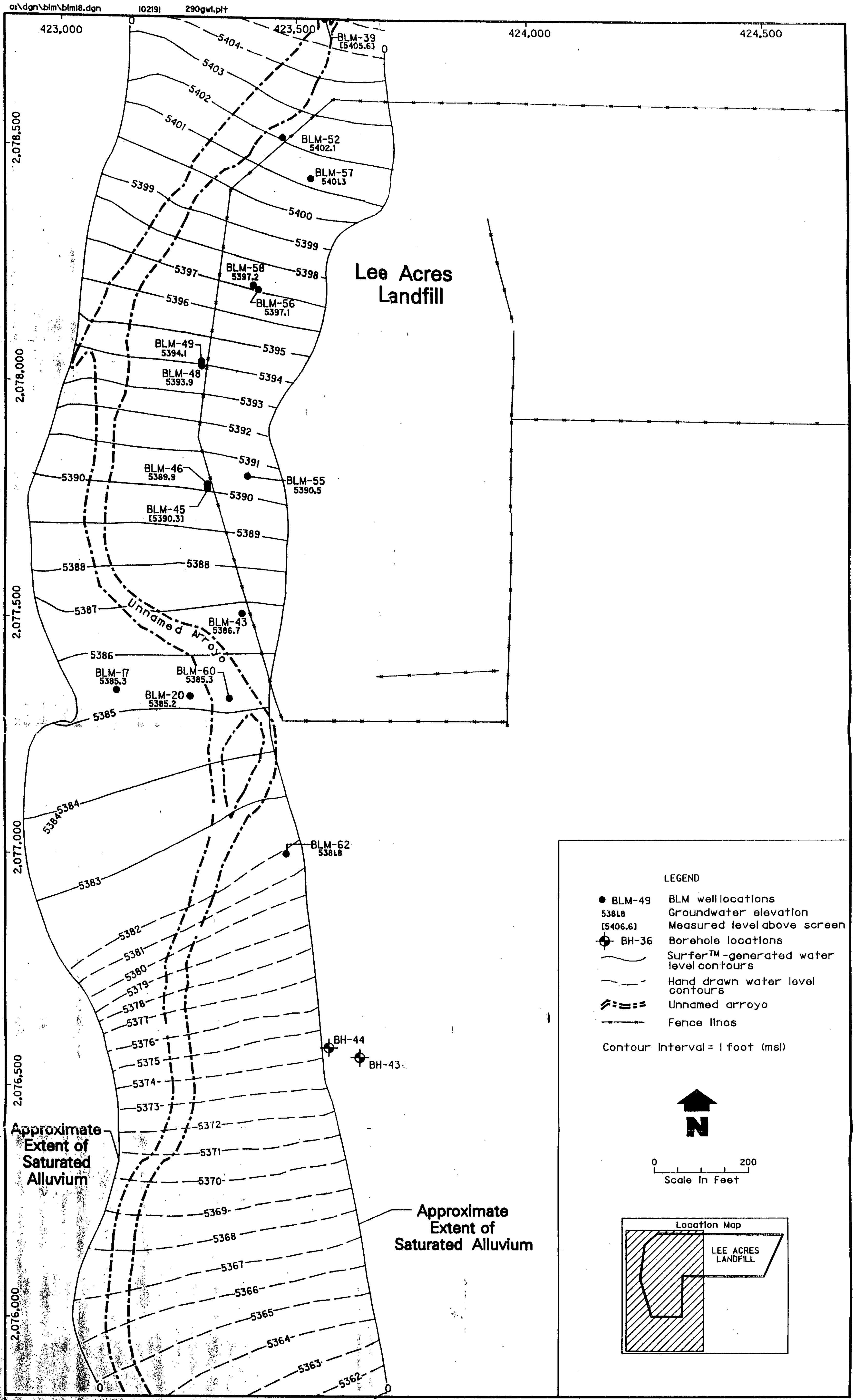


Figure 4-7. Water table map for the alluvial aquifer, May 1990.

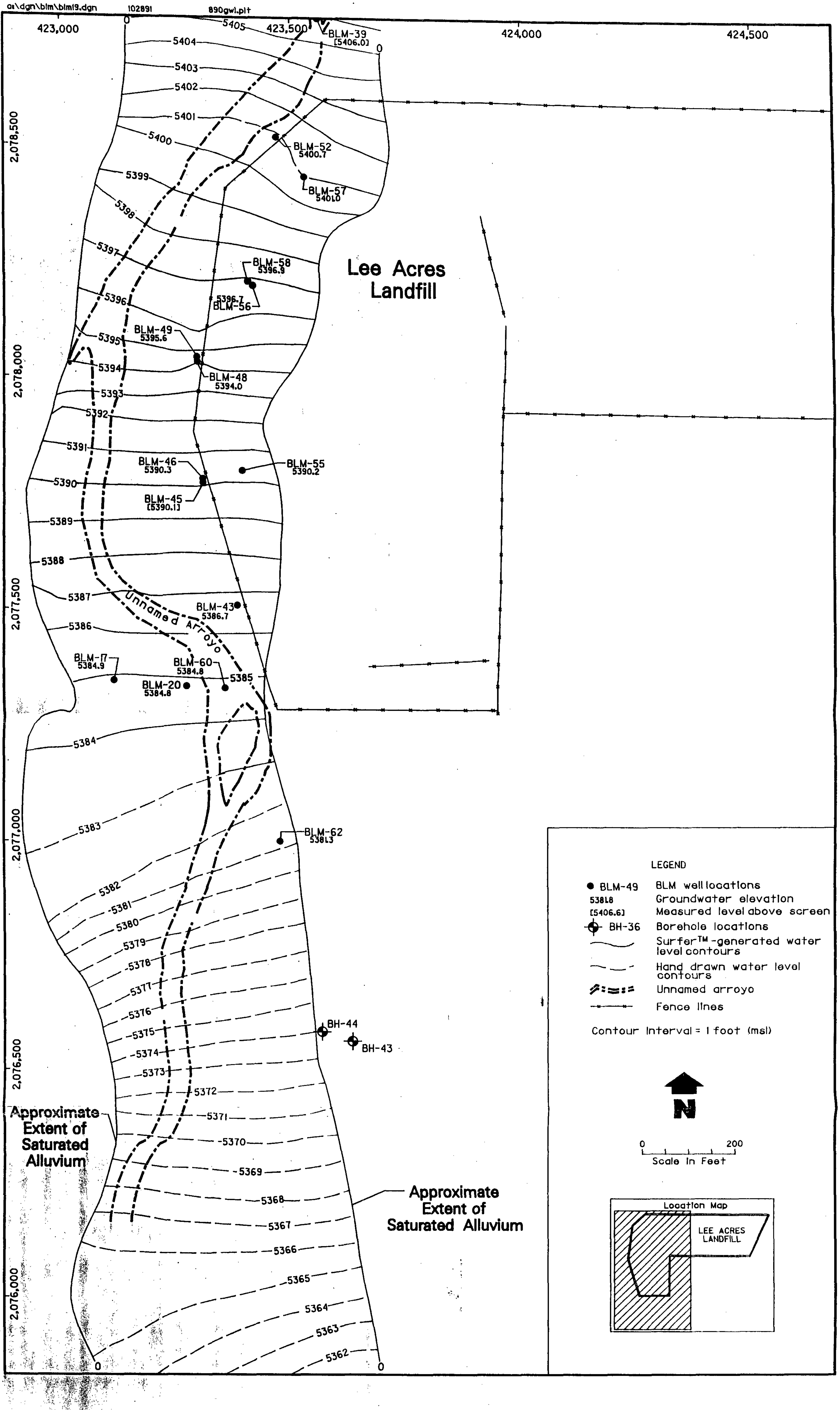


Figure 4-8. Water table map for the alluvial aquifer, August 1990.

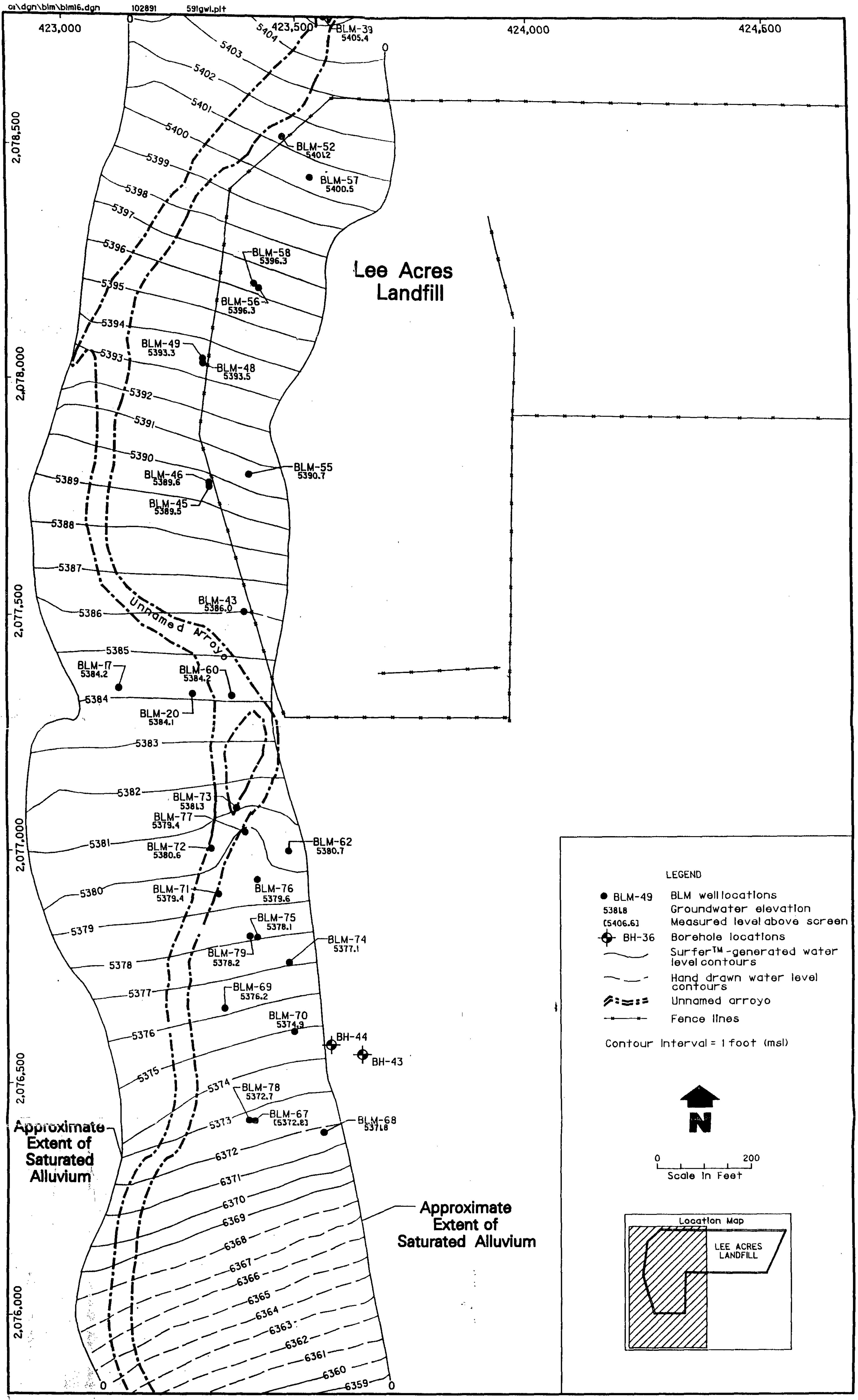


Figure 4-9. Water table map for the alluvial aquifer, May 1991.

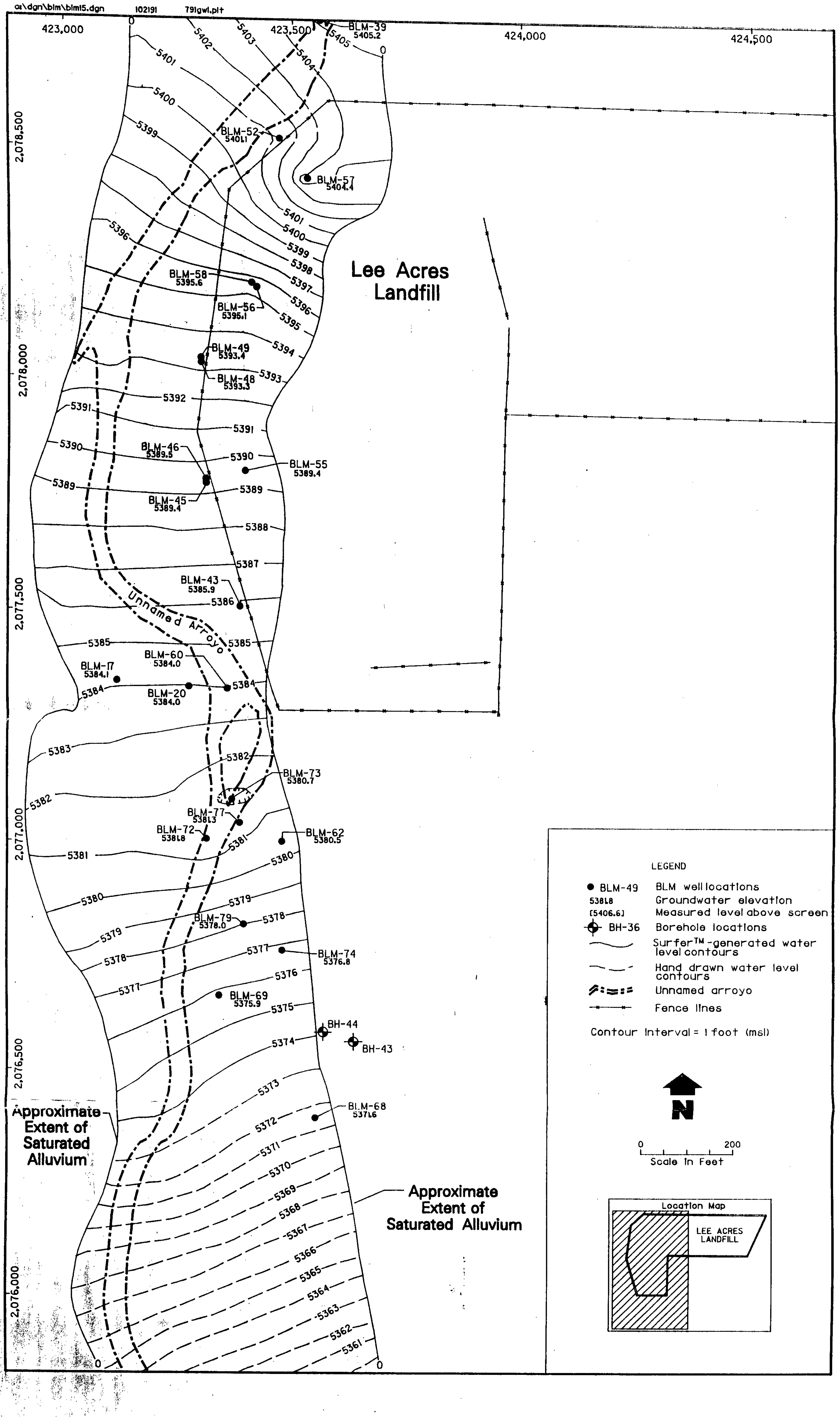


Figure 4-10. Water table map for the alluvial aquifer, July 1991.

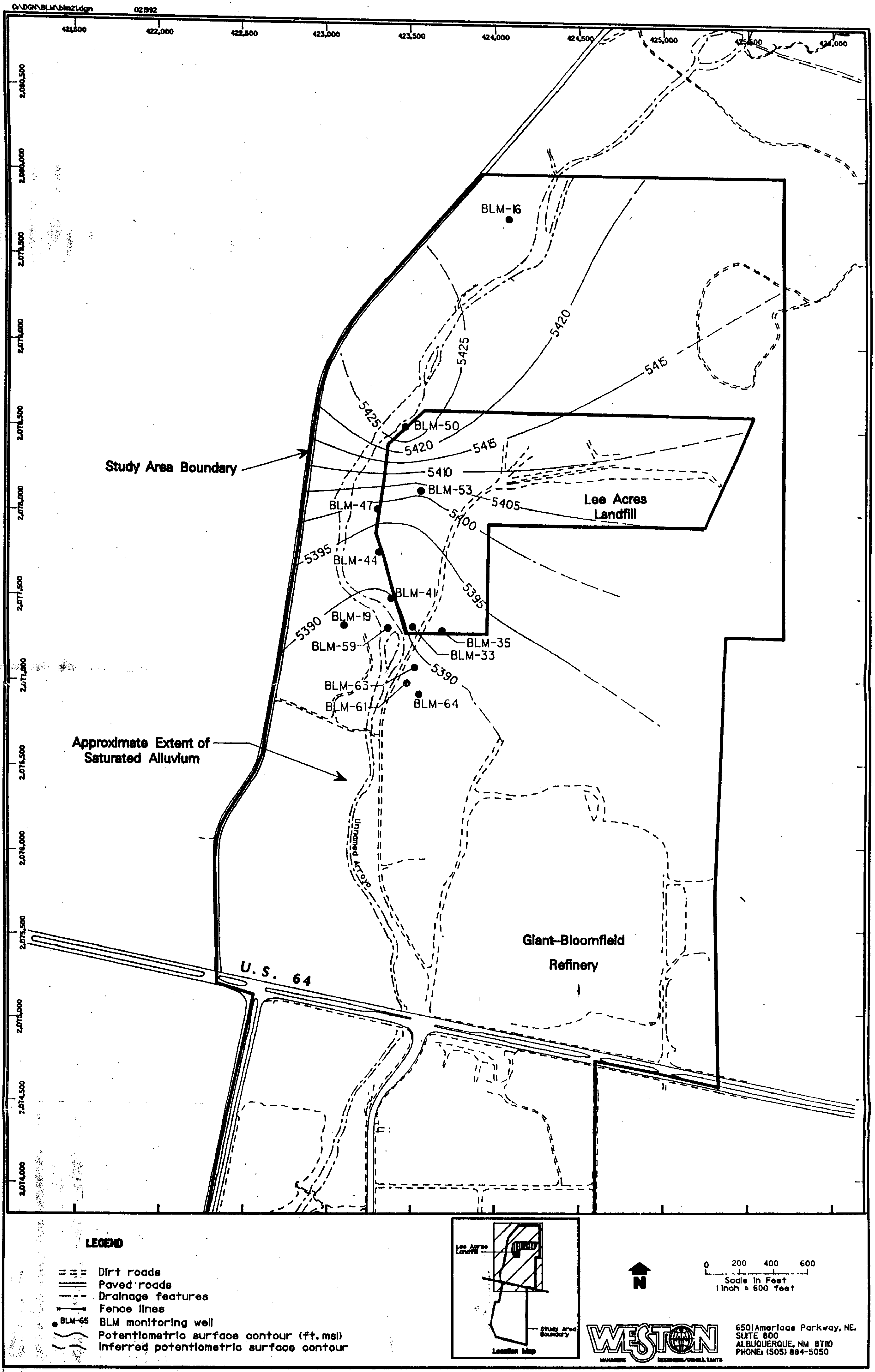


Figure 4-11. Potentiometric map for the bedrock aquifer, July 1991

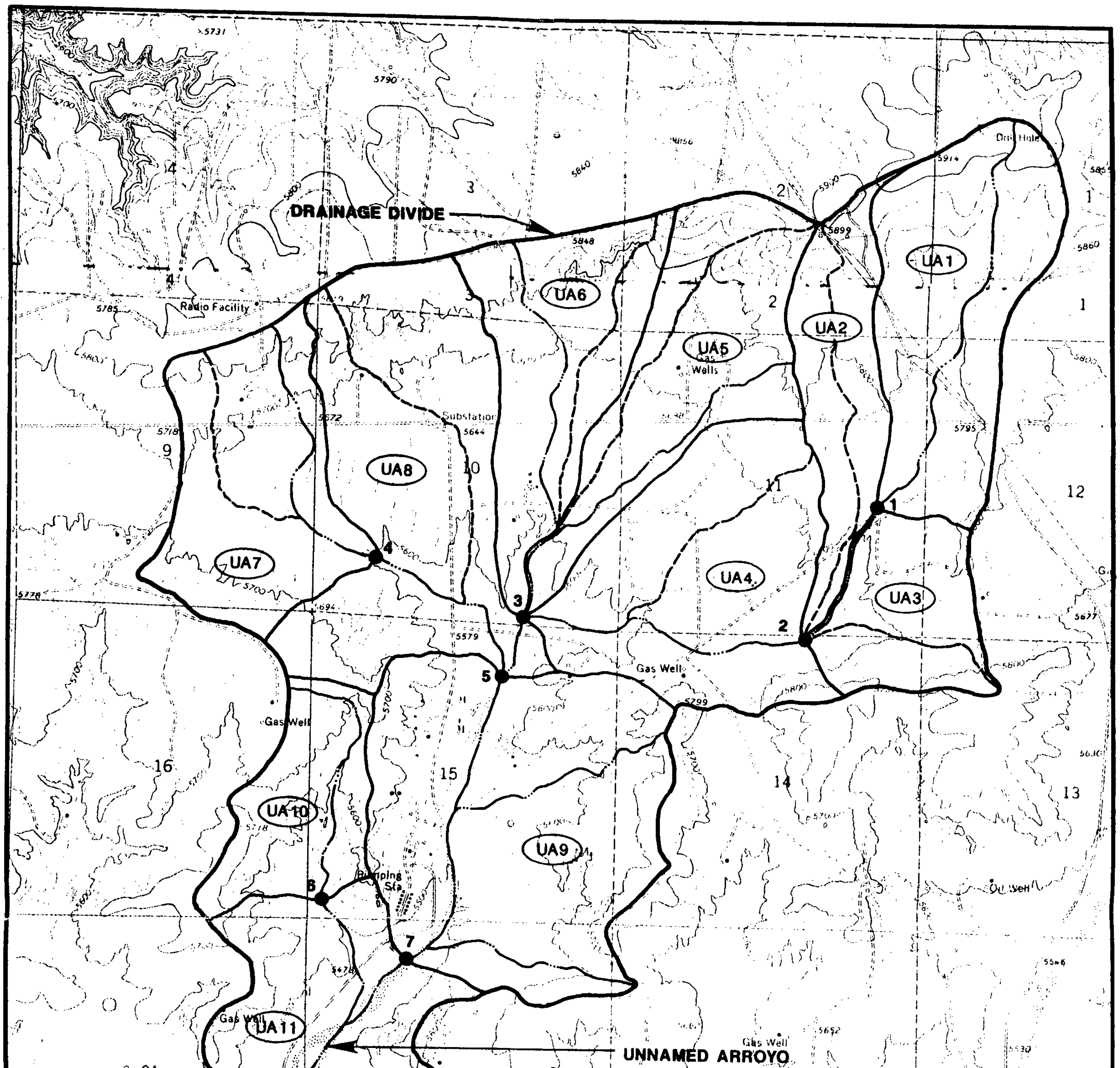


Figure 4-12. Unnamed arroyo alluvial basin (UA) and subbasins.

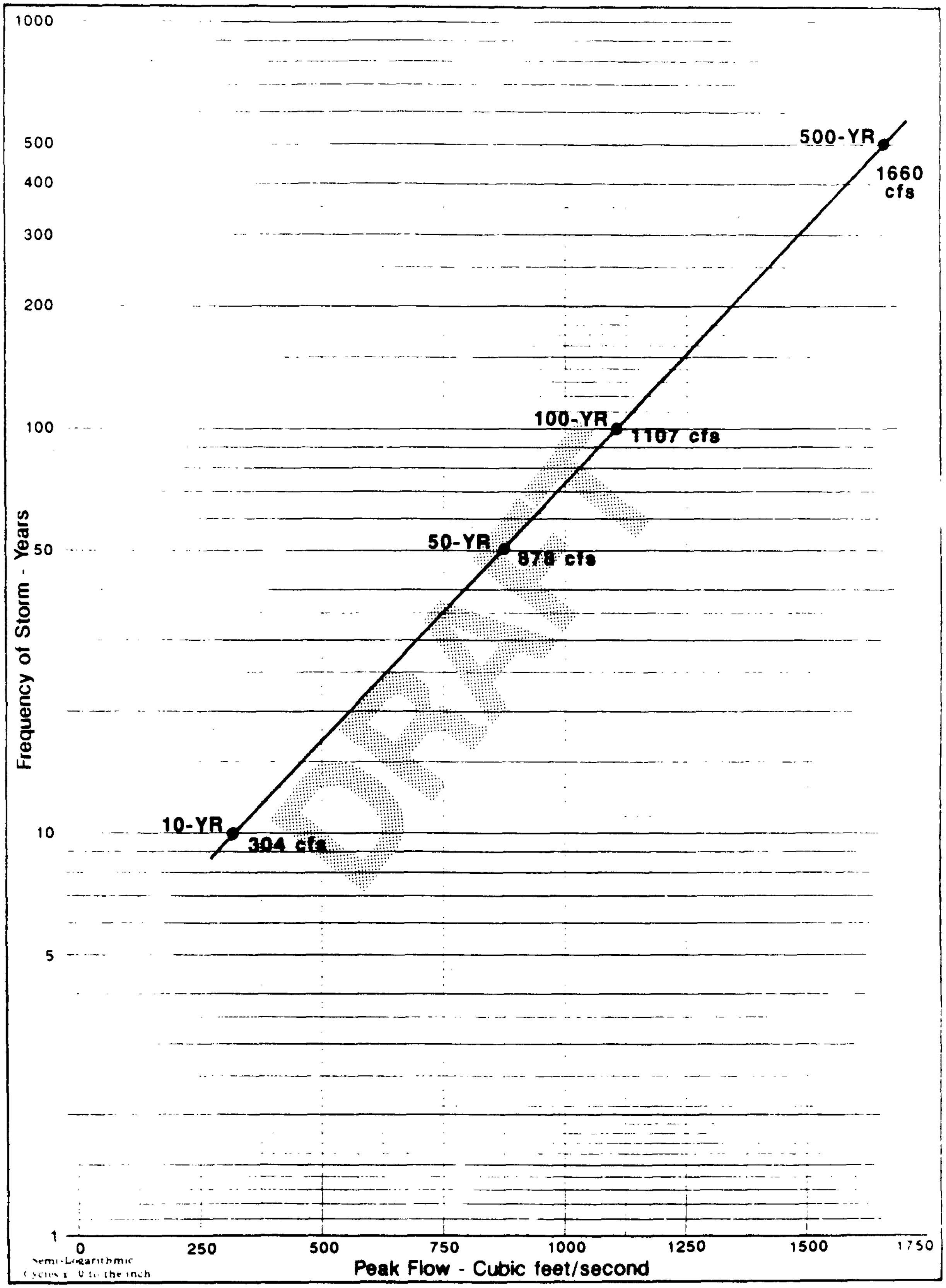
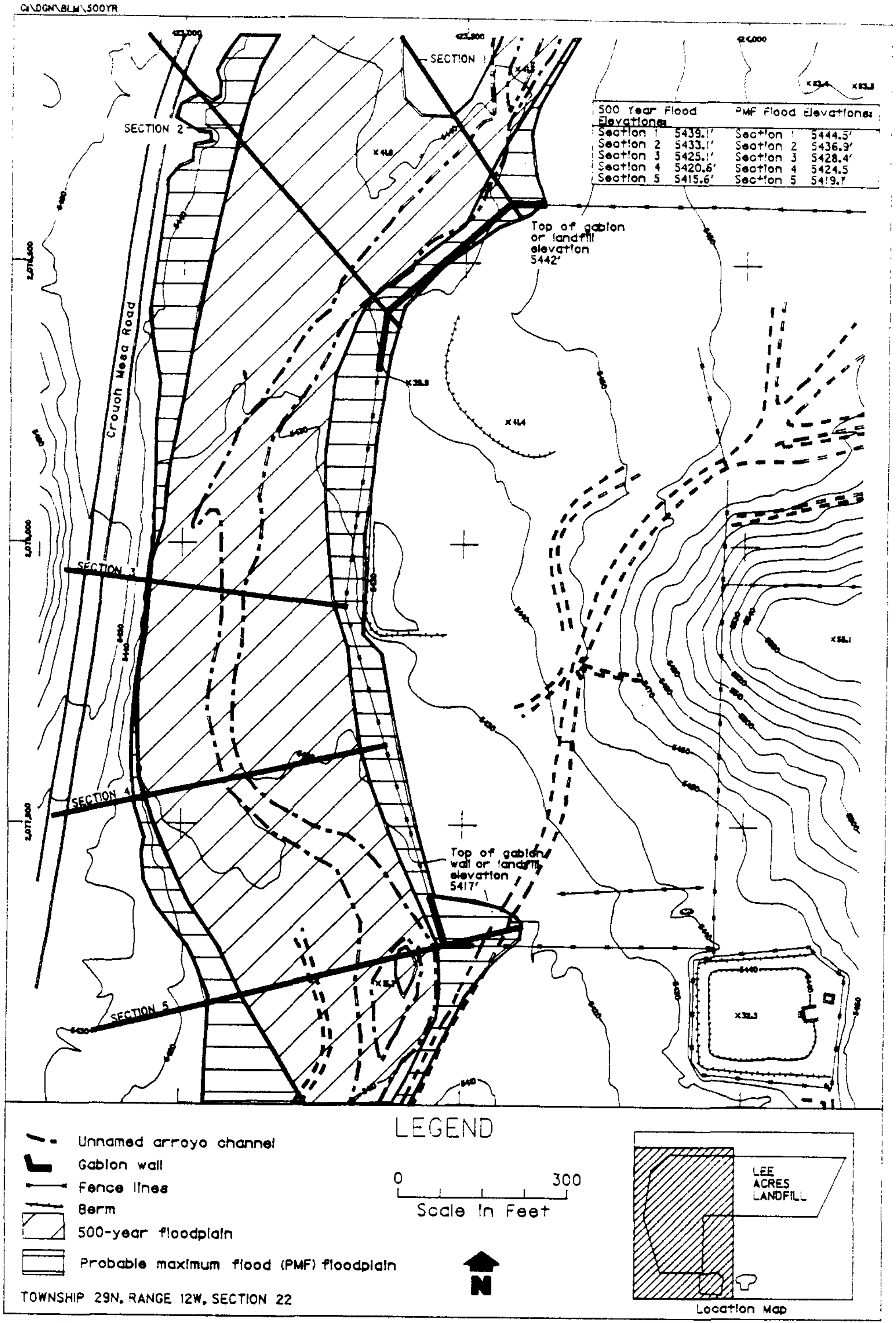


Figure 4-13. Extrapolation of the unnamed arroyo peak flow for the 500-year flood.



500 Year Flood Elevations		PMF Flood Elevations	
Section 1	5439.1'	Section 1	5444.5'
Section 2	5433.1'	Section 2	5436.9'
Section 3	5425.1'	Section 3	5428.4'
Section 4	5420.6'	Section 4	5424.5
Section 5	5415.6'	Section 5	5419.1'

Figure 4-14. The 500-year and probable maximum flood floodplains of the unnamed arroyo adjacent to the Lee Acres Landfill.

Table 4-1. Results of Grain Size Analysis from Alluvium and Bedrock Samples

Borehole or Monitoring Well ID[a]	Sample Depth Interval[b] (ft)	Sample Classification	% Clay[c] (<0.0039 mm)	% Very Fine To Medium Silt[c] (0.0039 to 0.031 mm)	% Coarse Silt[c] (0.031 to 0.074 mm)	% Sand and Gravel[c] (>0.074 mm)	Chain of Custody Sample ID
Alluvium Samples:							
BLM-68	32.2 - 32.7	Silty Sand	10	6	6	78	B068-0001
BLM-71	29.4 - 29.5	Sandy Silt	18	32	21	29	B076-0001
BLM-76	29.0 - 30.0	Silty Sand	18	18	14	50	B076-0001
Bedrock Samples:							
BH-32	9.3 - 9.8	Siltstone	29	22	46	3	G32098
BH-36	43.8 - 44.3	Siltstone	20	21	24	35	G36443
BH-36	44.7 - 45.0	Sandstone	20	8	4	68	G36450
BH-39	40.0 - 40.2	Sandstone	12	7	4	77	G39402
BLM-50	61.0 - 61.4	Sandstone	25	12	6	57	G50614
BLM-50	66.0 - 66.8	Sandstone	16	14	5	65	G50668
BLM-50	71.9 - 72.5	Sandstone	21	14	6	59	G50725
BLM-50	77.0 - 77.4	Sandstone	8	4	1	87	G50774
BLM-50	82.9 - 83.3	Sandstone	9	3	1	87	G50833
BLM-50	87.5 - 88.2	Sandstone	7	3	1	89	G50882
BLM-51	60.8 - 61.3	Siltstone	35	52	9	4	G51613
BLM-61	43.1 - 43.6	Sandstone	17	11	2	70	G61436
BLM-61	46.5 - 47.1	Sandstone	10	6	1	83	G61471
BLM-61	50.0 - 50.7	Sandstone	7	1	0	92	G61507

Geotechnical Analytical Results presented in Appendix J.

[a] Sample locations shown on Plate 1.

[b] Depth below ground surface.

[c] Based on Wentworth size class (Pettijohn, Potter, and Siever 1972).

Table 4-2. Horizontal Hydraulic Groundwater Gradients at the Lee Acres Landfill Study Area

Aquifer	Locations	Estimated Distance	Groundwater Elevation	Elevation Differential	Horizontal Gradient (ft/ft)
SA	BLM-49 BLM-20	725	5,393.41 5,383.96	9.45	0.013
SA	BLM-20 BLM-27	2,800	5,383.96 5,335.90	48.06	0.017
SA	BLM-27 BLM-65	1,525	5,335.90 5,327.10	8.80	0.006
SA	BLM-65 BLM-66	1,025	5,327.10 5,323.28	3.82	.004
SA	BLM-49 San Juan River	6,750	5,393.41 5,325.00	68.41	0.010
SA	BLM-57 San Juan River	8,050	5,404.43 5,325.00	79.43	0.010
BR	BLM-47 BLM-22	725	5,396.33 5,379.76	16.24	0.022
BR	BLM-22 BLM-29	2,800	5,379.76 5,339.42	40.34	0.014

Groundwater elevation data used to calculate gradients was collected during July 1991 and is presented in Appendix S.
SA: Shallow alluvial aquifer
BR: Bedrock aquifer

Table 4-3. Vertical Hydraulic Groundwater Gradients at the Lee Acres Landfill Study Area

Study Area	Well ID	Aquifer	Screen Bottom Elevation	Screen Differential	Groundwater Elevation	Elevation Differential	Vertical Gradient	Flow Direction
Site 1, subarea 1	BLM-14	SA	5419.51	59.52	5421.30	-0.80	-0.01	Up
	BLM-16	BR	5359.99		5422.10			
Site 1, subarea 2	BLM-46	SA	5385.92	35.33	5389.52	-1.99	-0.06	Up
	BLM-44	BR	5350.59		5391.51			
Site 1, subarea 2	BLM-49	SA	5390.95	37.72	5393.41	-2.92	-0.08	Up
	BLM-47	BR	5353.23		5396.33			
Site 1, subarea 2	BLM-20	SA	5379.01	61.77	5383.96	4.20	0.07	Down
	BLM-22	BR	5317.24		5379.76			
Site 1, subarea 3	BLM-62	SA	5354.69	22.07	5380.51	-6.75	-0.31	Up
	BLM-61	BR	5376.76		5387.26			
Site 2	BLM-24	SA	5327.72	54.61	5331.76	-5.73	-0.11	Up
	BLM-26	BR	5273.11		5337.49			
Site 2	BLM-27	SA	5333.92	56.86	5335.90	-3.52	-0.06	Up
	BLM-29	BR	5277.06		5339.42			
Site 2	BLM-30	SA	5333.17	65.07	5336.49	4.22	0.06	Down
	BLM-32	BR	5268.10		5332.27			
Site 1, subarea 2	BLM-17	SA	5380.81	62.96	5384.11	7.25	0.12	Down
	BLM-19	BR	5317.85		5376.86			
Site 1, subarea 2	BLM-23	BR(L)	5328.07	30.49	5386.67	3.74	0.12	Down
	BLM-33	BR(U)	5358.56		5390.41			

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Table 4-3. (page 2 of 2)

Study Area	Well ID	Aquifer	Screen Bottom Elevation	Screen Differential	Groundwater Elevation	Elevation Differential	Vertical Gradient	Flow Direction
Site 1, subarea 1	BLM-39	SA	5392.12	30.22	5405.19	-24.05	-0.80	Up
	BLM-40	BR	5361.90		5429.24			
Site 1, subarea 2	BLM-41	BR	5355.46	22.60	5389.56	-3.65	-0.16	Up
	BLM-43	SA	5378.06		5385.91			
Site 1, subarea 2	BLM-50	BR	5351.36	44.86	5429.91	-28.83	-0.64	Up
	BLM-52	SA	5396.22		5401.08			
Site 1, subarea 2	BLM-54	BR	5344.10	42.92	5392.05	-2.64	-0.06	Up
	BLM-55	SA	5387.02		5389.41			
Site 1, subarea 2	BLM-56	DA	5388.20	4.21	5395.05	0.58	0.14	Down
	BLM-58	SA	5392.41		5395.63			
Site 1, subarea 2	BLM-59	BR	5354.92	22.47	5387.89	-3.89	-0.17	Up
	BLM-60	DA	5377.39		5384.00			
Site 1, subarea 3	BLM-67	DA	5361.74	5.34	5367.39	0.05	0.01	Down
	BLM-78	SA	5367.08		5367.44			
Site 1, subarea 3	BLM-75	DA	5369.27	3.04	5372.88	5.1	1.68	Down
	BLM-79	SA	5372.31		5377.98			

Note: Groundwater elevation data used to calculate gradients were collected during July 1991, and are presented in Appendix S.
DA: Deep alluvial aquifer
SA: Shallow alluvial aquifer
BR: Bedrock aquifer
L: Lower
U: Upper

Table 4-4. Lee Acres Landfill Slug Test Data Summary

Well ID	Date	Aquifer Type	Aquifer Thickness	Slug Test Type	Hydraulic Conductivity		Transmissivity	
					K (gpd/ft^2)	K (ft/day)	T (gpd/ft)	T (ft^2/day)
BLM-15	Feb 88	Alluvial	22.3	I	23.2	3.1	517.4	69.1
BLM-21	Feb 88	Alluvial	11.0	I	13.5	1.8	148.5	19.8
BLM-25	Feb 88	Alluvial	18.1	I	64.3	8.6	1163.8	155.7
BLM-28	Feb 88	Alluvial	30.6	I	4.9	0.6	149.9	18.3
BLM-31	Feb 88	Alluvial	7.3	I	68.8 to 14.2	9.2 to 1.9	502.2 to 103.7	67.2 to 3.9
BLM-46	Mar 90	Alluvial	13.87	W	8.2	1.1	113.7	15.3
BLM-48	Mar 90	Alluvial	13.67	W	12.7	1.7	173.6	23.2
BLM-51	Mar 90	Alluvial	21.81	W	65.1	8.7	1419.8	189.7
BLM-67	Jun 91	Alluvial	10.73	I	1.5	0.2	16.1	2.1
BLM-67	Jun 91	Alluvial	10.73	W	1.5 to 0.3	0.2 to 0.04	16.1 to 3.2	2.1 to 0.4
BLM-68	Jun 91	Alluvial	5.01	W	65.1	8.7	326.2	43.6
BLM-69	Jun 91	Alluvial	8.41	W	3.0	0.4.	25.2	3.4
BLM-71	Jun 91	Alluvial	8.63	W	1.5 to 0.7	0.2 to 0.1	12.9 to 6.0	1.7 to 0.9
BLM-72	Jun 91	Alluvial	8.13	W	3.74	0.5	30.4	4.1
BLM-73	Jun 91	Alluvial	8.36	W	245.3	32.8	2050.7	274.2
BLM-75	Jun 91	Alluvial	8.57	W	9.7	1.3	83.1	11.
BLM-76	Jun 91	Alluvial	7.58	W	4.5 to 1.5	0.6 to 0.2	34.1 to 11.4	4.5 to 1.5
BLM-77	Jun 91	Alluvial	7.98	W	67.3	9.0	537.1	71.8
BLM-78	Jun 91	Alluvial	9.97	W	5.2	0.7	51.8	7.0

Table 4-4. (page 2 of 2)

Well ID	Date	Aquifer Type	Aquifer Thickness	Slug Test Type	Hydraulic Conductivity K (gpd/ft^2)	Hydraulic Conductivity K (ft/day)	Transmissivity T (gpd/ft)	Transmissivity T (ft^2/day)
BLM-79	Jun 91	Alluvial	8.42	W	22.4	3.0	188.6	25.3
BLM-16	Feb 88	Bedrock	123.0	W	0.7	0.1	86.1	12.3
BLM-19	Feb 88	Bedrock	110	I	4.5 to 0.7	0.6 to 0.1	495.0 to 77.0	66 to 11
BLM-22	Feb 88	Bedrock	107.2	I	0.7	0.1	75.0	10.7
BLM-23	Feb 88	Bedrock	120	I	2.2	0.3	264.0	36
BLM-29	Feb 88	Bedrock	134.3	I	17.9	2.4	2404.0	322.3
BLM-32	Feb 88	Bedrock	117	I	12.0	1.6	1404	187.2
BLM-47	Mar 90	Bedrock	109.38	W	12.7 to 1.5	1.7 to 0.2	1389.1 to 164.1	185.9 to 21.9
BLM-50	Mar 90	Bedrock	111.29	W	12.7 to 2.2	1.7 to 0.3	1413.4 to 244.8	189.2 to 33.38

Table 4-5. Estimated Groundwater Velocities and Travel Times for the Alluvial Aquifer System at the Lee Acres Landfill Study Area

Estimated Alluvial Aquifer Groundwater Velocities (ft/day):

Porosity Range (n)	Hydraulic Conductivity Range K (gpd/ft^2)				
	5	25	50	75	100
0.2	0.050	0.251	0.501	0.752	1.003
0.25	0.040	0.201	0.401	0.602	0.802
0.3	0.033	0.167	0.334	0.501	0.668

Estimated Alluvial Aquifer Groundwater Travel Times from BLM-57 to the Southern Lee Acres Landfill Boundary (years):

Porosity Range (n)	Hydraulic Conductivity Range K (gpd/ft^2)				
	5	25	50	75	100
0.2	62.8	12.6	6.3	4.2	3.1
0.25	78.6	15.7	7.9	5.2	3.9
0.3	94.3	18.9	9.4	6.3	4.7

Estimated Alluvial Aquifer Groundwater Travel Times from BLM-57 to the San Juan River (years):

Porosity Range (n)	Hydraulic Conductivity Range K (gpd/ft^2)				
	5	25	50	75	100
0.2	439.9	88.0	44.0	29.3	22.0
0.25	549.9	110.0	55.0	36.7	27.5
0.3	659.9	132.0	66.0	44.0	33.0

Table 4-6. Unnamed Arroyo Alluvial Basin Drainage Characteristics

Subbasin[a]	Subbasin Area (sq. mi.)	Change in Elevation[b] (ft)	Length of Travel[c] (ft)	Time of Concentration, T_c[d] (min)	Lag Time, L[e] (hr)
UA1	0.55	5,930 - 5,710 = 220	7,650	30	0.30
UA2	0.28	5,895 - 5,556 = 339	7,700	29	0.29
UA3	0.26	5,825 - 5,656 = 169	3,900	15	0.15
UA4	0.64	5,770 - 5,560 = 210	6,750	26.5	0.27
UA5	0.47	5,890 - 5,595 = 295 5,595 - 5,560 = 35	7,000 1,800	24 11.5	0.36
UA6	0.43	5,920 - 5,595 = 325 5,595 - 5,560 = 35	5,900 1,800	19 11.5	0.31
UA7	0.49	5,808 - 5,595 = 213	5,700	22	0.22
UA8	0.74	5,825 - 5,570 = 255 5,570 - 5,545 = 25	6,700 1,600	25 11.5	0.37
UA9	0.92	5,799 - 5,512 = 287 5,512 - 5,470 = 42	4,500 3,000	14 19	0.33
UA10	0.28	5,790 - 5,522 = 268	4,800	16	0.16
UA11	0.46	5,522 - 5,450 = 72 5,450 - 5,425 = 25	2,600 1,850	13 13	0.26
UA12	0.29	5,425 - 5,385 = 40	3,000	19.5	0.20
Subbasin Route:					
Point 1 to 2	N/A	5,710 - 5,656 = 54	2,650	15	0.15
Point 3 to 5	N/A	5,560 - 5,545 = 15	1,100	9	0.09
Point 4 to 3	N/A	5,595 - 5,545 = 50	3,250	20	0.20
Point 7 to 8	N/A	5,470 - 5,425 = 45	3,400	20.5	0.21
Point 5 to 7	N/A	5,545 - 5,470 = 75	5,400	29	0.29
Total Basin Area = 5.8 sq. mi.					

[a] UA: Unnamed arroyo alluvial basin, Figure 4-12.

[b] Change in elevation is the height above the drainage outlet.

[c] Length of drainage path.

[d] Estimated from Kirpich Nomograph (AISI 1971).

[e] Lag time: 0.6 x T_c (DOI 1977).

Table 4-7. Distributed Precipitation Amounts for the Unnamed Arroyo Alluvial Basin

	Precipitation Amount (inches) For Time Increments			
Hour	**15-min**	**30-min**	**45-min**	**1-hr**
10-Year Period[a]				
1-hr	0.02	0.02	0.02	0.02
2-hr	0.57	0.22	0.11	0.1
3-hr	0.03	0.03	0.03	0.03
				Total Precipitation = 1.20 inches
50-Year Period[a]				
1-hr	0.01	0.01	0.01	0.01
2-hr	0.86	0.33	0.16	0.15
3-hr	0.05	0.05	0.05	0.05
				Total Precipitation = 1.75 inches
100-Year Period[a]				
1-hr	0.01	0.01	0.01	0.02
2-hr	0.97	0.37	0.19	0.17
3-hr	0.03	0.03	0.02	0.02
				Total Precipitation = 1.85 inches
PMP				
1-hr	0.07	0.07	0.07	0.07
2-hr	5	5	5	5
3-hr	0.12	0.12	0.12	0.12
4-hr	5	5	5	5
5-hr	5.2	1.3	0.6	0.5
6-hr	0.25	0.25	0.25	0.25
	0.07	0.07	0.07	0.07
	5	5	5	5
	0.05	0.05	0.05	0.05
				Total Precipitation = 9.9 inches

Ref: NOAA 1973

[a]Precipitation amounts for the 4-, 5-, 6-hour periods are insignificant for distribution.

PMP: probable maximum precipitation

Table 4-8. Estimated Flood Elevations and Velocities at the Former Lee Acres Landfill

100-Year Flood Peak Flow = 1110 cfs				
Section Number	Depth (ft)	Water Surface Elevation (ft)	Main Arroyo Channel Velocity (ft/s)	Landfill Edge Velocity (ft/s)
1	2.6	5438.6	9.6	1.8
2	0.8	5432.8	0.8	0.2
3	1.8	5424.8	0.3	0.1
4	2.3	5420.3	0.2	0.1
5	1.2	5415.2	0.1	0.1

500-Year Flood Peak Flow = 1660 cfs				
Section Number	Depth (ft)	Water Surface Elevation (ft)	Main Arroyo Channel Velocity (ft/s)	Landfill Edge Velocity (ft/s)
1	3.1	5439.1	10.9	2.6
2	1.1	5433.1	22.3	22.3[a]
3	2.1	5425.1	10.4	4.9
4	2.6	5420.6	7.8	1.4
5	1.6	5415.6	11.8	5.3

Probable Maximum Flood (PMF) Peak Flow = 19,700 cfs				
Section Number	Depth (ft)	Water Surface Elevation (ft)	Main Arroyo Channel Velocity (ft/s)	Landfill Edge Velocity (ft/s)
1	8.5	5444.5	18.7	7.4
2	4.9	5436.9	31.3	4.9
3	5.4	5428.4	25	8.5
4	6.5	5424.5	16.5	4.6
5	5.1	5419.1	20.3	10

[a] Velocity is at the edge of gabion wall and not at landfill edge.

Table 4-9. Probable Maximum Flood Times of Peak Flow Occurrence

Time		Flow Rate (cfs)
Hours	Minutes	
0	0	0
0	15	0
0	30	0
0	45	0
1	0	0
1	15	0
1	30	0
1	45	2
2	0	9
2	15	1,375
2	30	2,963
2	45	6,763
3	0	12,562
3	15	19,717
3	30	17,747
3	45	13,002
4	0	8,764
4	15	5,924
4	30	4,412
4	45	3,502
5	0	2,789
5	15	1,985
5	30	1,463
5	45	1,169

5. SOURCE CHARACTERIZATION

An extensive drilling and sampling program was performed at the former Lee Acres Landfill during the RI. Three areas were investigated under this program and include the former Lee Acres Landfill, the adjacent unnamed arroyo, and the southern area of Site 1. This section presents, in detail, the contaminants and concentrations detected in each borehole and wellbore soil sample to identify COCs. Subsections 5.1.3, 5.2.3 and 5.3.3 summarize the COCs for the former solid waste disposal areas, the former liquid waste lagoons, and the arroyo adjacent to the landfill, respectively. Subsection 5.6 summarizes the COCs for OU 1, the former Lee Acres Landfill, and subsection 5.7.5 presents the COCs for the southern area of Site 1 (Plate 1). Summary tables in this section present contaminants and concentration ranges, and identify COCs based on regulatory exceedance or due to the lack of any promulgated or proposed soil regulatory standard. Sixty COCs have been identified for OU 1; however, only 11 of the 60 COCs exceed regulatory standards.

The purpose of the drilling and sampling program was to characterize the nature and extent of contamination present in OU 1 (see subsection 1.5) and in the southern area of Site 1 (Plate 1), and to define any potential source areas for contaminant migration from the landfill to soils in the surrounding areas or into the underlying groundwater. OU 1 includes solid waste and soil within the boundaries of the Lee Acres Landfill. The southern area of Site 1 includes soil in the area north of well GBR-17 and west of the Giant-Bloomfield Refinery.

The nature and extent of contamination present within the boundaries of the former Lee Acres Landfill was characterized by sampling soils from 29 boreholes (BH-01 through BH-29) and 12 wellbores (BLM-33 through BLM-35, BLM-41, BLM-44, BLM-47, BLM-50, BLM-53, BLM-54, BLM-56, BLM-57, and BLM-59) drilled within the landfill (including the two former liquid waste lagoons). Additional characterization of vadose zone moisture was conducted through sampling four lysimeters (LS-3, LS-5 through LS-7) installed within the two former liquid waste lagoons. In addition, results from the 1985 sampling of the northern liquid waste lagoon by the New Mexico Oil Conservation District (NMOCD) and the NMEID are presented and discussed in subsection 5.2.1.

Six boreholes (BH-48 through BH-53) were drilled to bedrock in the unnamed arroyo adjacent to the former Lee Acres Landfill and sampled to determine if contaminants had been washed into the arroyo by erosion and subsequently transported by surface water, or whether contaminants were migrating from the landfill with surface water or infiltrated water into the arroyo. The results of the investigation are presented in subsection 5.3.

A determination of the materials of concern boundaries and volumes is presented in subsection 5.4, based upon the soil analytical results and borehole and wellbore logs obtained from the landfill soil characterization discussed above. Two scenarios are considered: the conservative volume scenario and the worst-case volume scenario. Also presented in this section are the results of an extensive air monitoring and soil gas monitoring program (subsection 5.5).

Thirteen boreholes (BH-30 through BH-33 and BH-39 through BH-47) and 17 wellbores (BLM-61 through BLM-64 and BLM-67 through BLM-79) were drilled and sampled in the southern area of Site 1 to characterize any soil contamination. The nature and extent of contamination is discussed in subsection 5.7.

5.1. FORMER SOLID WASTE DISPOSAL AREAS

Areas at the former Lee Acres Landfill considered to be former solid waste disposal areas are those in which trenches or pits existed. Information regarding these areas were compiled through the review of inspection reports obtained from the NMEID, air photos dating back to 1950, and a comprehensive site investigation. A detailed site history and air photo analysis is provided in Appendix B. A chronology of events pertaining to the operational history of the former solid waste disposal areas is presented in subsection 1.2 and Table 1-1.

5.1.1. Physical Nature of Solid Waste

During the period of landfill operation, no records of waste disposal were maintained. A trench study was conducted during the RI to examine contents and subsurface conditions within landfill waste cells. Three trenches were excavated in the former landfill. The results of the trench study are presented in subsection 2.5.2. Figures 2-19, 2-20, and 2-21 show cross sections of the excavated trenches and illustrate the waste material types encountered. Information obtained from the trench study, air photos, air monitoring data, and borehole logs was integrated for the purpose of estimating the geographic distribution of solid waste within the former landfill.

The following four general waste categories were identified in the landfill:

- Household trash: plastic containers, garbage bags, newspapers, books, clothing, cans, toys, appliance parts, glass, carpet, and tires;
- Construction and demolition debris: drywall, wire, concrete, steel reinforcement, and wood;
- Lagoonal sediments: oily or stained soils within former liquid waste lagoon boundaries; and

- Dead animal pit: three small pits located in the north-central portion of the former landfill.

Figure 5-1 illustrates the estimated physical distribution of these four types of solid waste materials at the former landfill as determined from the integration of information discussed above. All four waste types appear as either single units or, in most cases, as a combination of several waste types within the landfill boundary. Household trash and construction and demolition debris are characteristically found intermixed, whereas lagoonal sediments and the contents of the dead animal pits occur mostly as single units. The physical and chemical nature of the lagoonal sediments is presented in subsection 5.2. Solid waste volume estimates for the former Lee Acres Landfill are given in subsection 5.4.

During the RI, no evidence of hazardous waste containers were encountered during the trench study or during drilling activities. Air monitoring instruments were used during the RI as part of specified health and safety procedures and to provide information regarding the presence of bulk hazardous materials or leaking tanks or drums. Some materials encountered were charred, but the absence of charred soils indicates that these materials were probably burned before they were disposed of at the landfill. Gases encountered within the landfill subsurface during the RI are considered a potential contaminant source. The nature and extent of these gases is presented in subsection 5.5.

5.1.2. Chemical Nature of Solid Waste

The chemical nature of the solid waste contained in the landfill was assessed by interpreting analytical data from soil samples taken from boreholes (BH-01 through BH-29) and wellbores (BLM-33, BLM-34, BLM-35, BLM-41, BLM-44, BLM-47, BLM-50, BLM-53, BLM-54, BLM-56, BLM-57, and BLM-59) installed within and along the perimeter of the landfill during the RI. Subsections 2.4 and 2.8 present the technical rationale for the borehole and wellbore sampling programs, respectively. Borehole and wellbore locations were selected on the basis of 1) geophysical information from magnetometer and terrain conductivity surveys, 2) air photo information, 3) existing data gaps, and 4) CPT profiles. Locations of all boreholes and monitoring wells installed within and outside of the former Lee Acres Landfill are shown on Plate 1. Tables 2-8 and 2-16 summarize the borehole and wellbore sampling and analytical program. Generally, the analytical program consisted of analyses for VOCs according to EPA Methods 8010 and 8020; semivolatile organic compounds (BNAs) according to EPA Method 8270; pesticides and PCBs according to EPA Method 8080; and EP Toxicity metals, total metals, chloride, and sulfate. Chemical data results for soil are presented in Appendix I-1. Regulations for the TCLP were issued after the initial stage of the RI, and therefore, TCLP analyses were not performed on soil samples taken within or along the perimeter of the landfill.

Because CERCLA provides no standards for soil that can be used to decide whether an FS is necessary, RI soil data are compared with the proposed RCRA Corrective Action Rule action levels (55 FR 30865). Any contaminants present in soil above the proposed RCRA action levels have been identified as COCs. In addition, any contaminants detected in soil that do not have a proposed action level will also be identified as COCs. The proposed RCRA action levels discussed above are not proposed as soil cleanup standards. Cleanup standards will be established as part of the FS process.

5.1.2.1. Volatile Organic Constituents

Table 5-1 summarizes the RI soil data for VOCs, shows the sampling location, the concentration range for each contaminant detected, and also provides the proposed RCRA action levels for each of the detected contaminants. COCs are also identified. Appendix I-1 presents the laboratory analytical results for all soil samples. Borehole and wellbore logs are shown in Appendixes H and L, respectively.

5.1.2.1.1. Petroleum Hydrocarbons (BTEX)

The areal distribution of the concentrations of the petroleum hydrocarbons benzene, toluene, ethylbenzene, and xylene (collectively known as BTEX) within the landfill is shown in Figure 5-2. The maximum depth of contamination as well as the concentration of total BTEX encountered within each borehole and wellbore are shown.

Various combinations of BTEX were detected in boreholes throughout the landfill. Toluene was the most prevalent component of BTEX encountered. A number of BTEX concentrations were measured above detection limits along the western border of the landfill. In addition, BTEX was detected in several boreholes located within the former liquid waste lagoon areas; their association with liquid waste lagoon chemistry is discussed in subsections 5.2.2.2 and 5.2.2.3. Benzene was detected in four boreholes, ethylbenzene in eight boreholes, xylene in 13 boreholes, and toluene in 16 boreholes and three wellbores (Figure 5-2). All four components of BTEX were detected in only two boreholes, BH-12 and BH-23 (Figure 5-2).

The highest concentrations of BTEX were found in BH-23. Benzene was detected at 1,600 µg/kg, ethylbenzene at 41,000 µg/kg, toluene at 20,000 µg/kg, and xylene at 190,000 µg/kg (Table 5-1). Benzene concentrations in other soil samples ranged from 2.4 µg/kg in BH-19 to 16 µg/kg in BH-12; concentrations of ethylbenzene ranged from 2.1 µg/kg in BH-05 to 75 µg/kg in BH-12; and xylene concentrations ranged from 1.3 µg/kg in BH-22 to 71 µg/kg in BH-12. Ethylbenzene concentrations were detected in boreholes and wellbores in concentrations ranging from 1.0 µg/kg at BLM-47 to 14 µg/kg at BH-11. All detected concentrations of toluene, ethylbenzene, and xylene were below proposed RCRA action levels, and are therefore not considered to be COCs. Because benzene does not have a proposed RCRA action level for soil, it is retained as a COC (Table 5-1).

Figure 5-3 shows two cross section lines, H-H′ and I-I′, that were located across the former landfill to show the distribution of VOCs in the landfill soils with depth. The locations of the two cross section lines were chosen so that the greatest number of borehole and wellbore locations could be projected onto the lines. Cross section H-H′ is approximately 170 ft in length and trends west-east across the landfill. Cross section I-I′ is approximately 81 ft long and trends northeast-southwest across the landfill. Figures 5-4 and 5-5 show the distribution of BTEX and other VOCs with depth in the landfill subsurface in the boreholes and wellbores that were projected onto the two cross section lines.

In general, the areal distribution of BTEX in soils seems to be limited to two areas within the former landfill. The majority of the BTEX detected was present in soils in the western portion of the landfill in the vicinity of the two former liquid waste lagoons, as well as the area in between the lagoons. The other area of BTEX contamination is located in the center of the eastern portion of the former landfill (Figure 5-2).

The distribution of BTEX contamination with depth shows no apparent trends; however, it does appear to decrease in frequency eastward along cross section line H-H′ and southward along cross section line I-I′ (Figures 5-4 and 5-5). BTEX contamination in boreholes along cross section line H-H′ was not detected below 21 ft, with the exception of BH-23 where BTEX contamination was found to a depth of 51 ft. Cross section I-I′ shows BTEX contamination to be randomly present in boreholes and wellbores from 4 to 56 ft.

Boreholes and wellbores located within the former liquid waste lagoons (BH-10, BH-12, BH-22, BH-23, BH-26, and BLM-47) do not show BTEX concentrations in excess of those found in boreholes and wellbores not located in the former lagoons, with one exception. Borehole BH-23 shows the highest concentrations of all four components of BTEX found anywhere in the landfill.

Proposed RCRA action levels for toluene, ethylbenzene, and xylene (55 FR 30865) were not exceeded in soils within the former landfill. Benzene was identified as a COC because no proposed RCRA action level exists. Only two boreholes, BH-12 and BH-23, contained concentrations of all four BTEX components. These two boreholes are located in the former northern liquid waste lagoon area. Borehole BH-23 is generally more contaminated than other landfill boreholes and wellbores; therefore, it follows that the former northern liquid waste lagoon may have served as a primary contaminant source to groundwater. In addition, any potential source for future benzene contamination in groundwater may be limited to the former liquid waste lagoon areas, as these areas are the only locations in which benzene was detected. Toluene, ethylbenzene, and xylene contamination in soils occurs over a larger area than benzene, thereby providing a broader source area for groundwater contamination. Potential source areas are the former liquid waste lagoons, and the area of soil contamination located in the center of the eastern portion of the former landfill.

A detailed discussion of the occurrence of BTEX in the landfill subsurface detected in boreholes and wellbores along cross section lines H-H′ and I-I′ is presented in the remainder of this subsection. The contaminants detected, their depths of occurrence, and the concentrations present in sampled soils are discussed in depth for each borehole and wellbore along the two cross section lines. The summary above is, in part, a discussion of these results.

Benzene was detected in BH-23 and BH-12 along cross section H-H′ at depths of 6 to 7 ft and 13-14 ft, respectively. The concentrations of benzene in these two boreholes ranged from 16 µg/kg to 1,600 µg/kg (Figure 5-4). Two boreholes along cross section I-I′ showed benzene concentrations above laboratory detection limits at depths of 4 to 5 ft in BH-18 and 43 to 44 ft in BH-19. Benzene concentrations ranged from 2.4 µg/kg to 2.7 µg/kg (Figure 5-5).

Toluene was detected in six boreholes along cross section H-H′. Toluene was detected in BH-12 from 1 to 2 ft (5.8 µg/kg) and from 13 to 14 ft (7.4 µg/kg), in BH-23 from 6 to 7 ft (20,000 µg/kg), from 41 to 42 ft (2.2 µg/kg), from 45 to 46 ft (1.8 µg/kg), and from 50 to 51 ft (1.8 µg/kg), in BH-10 from 3 to 4 ft (1.2 µg/kg), in BH-11 from 20 to 21 ft (14 µg/kg), in BH-05 from 6 to 7 ft (1.6 µg/kg) and from 21 to 22 ft (1.9 µg/kg), and in BH-03 from 7 to 8 ft (9.5 µg/kg) (Figure 5-4). Six boreholes and three wellbores showed detectable concentrations of toluene along cross section I-I′. Toluene was measured in BH-22 from 55 to 56 ft (2.4 µg/kg), in BH-24 from 5 to 6 ft (1.5 µg/kg), in BH-21 from 18 to 19 ft (1.8 µg/kg), in BH-19 from 43 to 44 ft (3.8 µg/kg), in BH-18 from 4 to 5 ft (12 µg/kg), in BLM-53 from 30 to 31 ft (1.2 µg/kg) and from 38 to 39 ft (1.7 µg/kg), in BLM-47 from 40 to 41 ft (1 µg/kg), in BH-26 from 1 to 2 ft (1.6 µg/kg), in BLM-44 from 45 to 46 ft (1.9 µg/kg) (Figure 5-5).

Ethylbenzene was detected in six boreholes along cross section H-H′. It was found present in BH-12 from 1 to 2 ft (22 µg/kg), from 4 to 5 ft (4.2 µg/kg), from 13 to 14 ft (75 µg/kg), and from 19 to 20 ft (3.3 µg/kg), in BH-23 from 6 to 7 ft (41,000 µg/kg), in BH-10 from 3 to 4 ft (6.1 µg/kg), in BH-11 from 20 to 21 ft (12 µg/kg), in BH-05 from 6 to 7 ft (2.1 µg/kg), and in BH-03 from 7 to 8 ft (6 µg/kg) (Figure 5-4). No ethylbenzene was detected in any of the boreholes or wellbores along cross section I-I′.

Total xylenes were detected in six boreholes along cross section H-H′. Xylenes were measured in BH-12 from 1 to 2 ft (49 µg/kg), from 4 to 5 ft (13 µg/kg), and from 13 to 14 ft (71 µg/kg), in BH-23 from 6 to 7 ft (190,000 µg/kg), in BH-10 from 3 to 4 ft (17 µg/kg), in BH-11 from 20 to 21 ft (25 µg/kg), in BH-05 from 6 to 7 ft (5.1 µg/kg), and in BH-03 from 7 to 8 ft (15 µg/kg) (Figure 5-4). Along cross section I-I', xylenes were found present in five boreholes. Total xylenes were detected in BH-22 from 55 to 56 ft (1.3 µg/kg), in BH-24 from 5 to 6 ft (1.9 µg/kg), in BH-21 from 18 to 19 ft (1.6 µg/kg), in BH-19 from 43 to 44 ft (1.7 µg/kg), and in BH-18 from 4 to 5 ft (3.5 µg/kg) (Figure 5-5).

In addition, four other boreholes not located in close proximity to the two cross section lines showed concentrations of BTEX above laboratory detection limits. Two of the boreholes, BH-04 and BH-06, are located in the center of the eastern portion of the landfill. The other two, BH-27 and BH-13, are located in the western portion of the landfill (Figure 5-2).

Benzene was not detected in any of the four boreholes; however, toluene, ethylbenzene, and xylene were detected in the boreholes either individually or in some combination. Ethylbenzene was detected in BH-04 from 23 to 24 ft (5.9 µg/kg), and in BH-13 from 4 to 5 ft (3.8 µg/kg). Toluene was detected in BH-04 from 23 to 24 ft (8 µg/kg), in BH-06 from 14 to 15 ft (5.1 µg/kg), in BH-13 from 4 to 5 ft (4.4 µg/kg) and from 33 to 34 ft (2 µg/kg), and in BH-27 from 3 to 4 ft (1.4 µg/kg) and from 8 to 9 ft (1.5 µg/kg). Xylene was found present in BH-04 from 23 to 24 ft (19 µg/kg), and in BH-06 from 14 to 15 ft (23 µg/kg) and from 20 to 21 ft (3 µg/kg) (Appendix I-1).

5.1.2.1.2. <u>Chlorinated and Non-Chlorinated Volatile Organic Compounds</u>

Several different chlorinated and non-chlorinated VOCs were detected in subsurface landfill soils in boreholes and wellbores along cross section lines H-H′ and I-I′ (Figures 5-4 and 5-5). Chlorinated VOCs were detected in a number of boreholes and wellbores, whereas non-chlorinated VOCs were detected in only two wellbores (BLM-33 and BLM-35). It is not known why non-chlorinated VOCs were detected at only two locations in the former landfill. Both of the wellbores where these compounds were detected are located in the far southwestern portion of the former landfill near the entrance (Figure 5-3).

Chlorinated VOCs, unlike the non-chlorinated VOCs and the BTEX compounds discussed previously, are distributed throughout the former landfill in subsurface soils. Their nature of occurrence, being generally low in concentration and unevenly distributed vertically through the landfill soils (Figures 5-4 and 5-5), would seem to indicate typical landfill disposal practices.

The occurrence of these compounds seems not to be dependent upon the former liquid waste lagoons as a source, as was BTEX. Borehole BH-23, located in the former northern liquid waste lagoon, and BH-26, located in the former southern liquid waste lagoon, do contain a number of chlorinated VOCs, but the other boreholes and wellbores located in the former northern and southern lagoons (BH-10, BH-12, BH-22, and BLM-47) show no chlorinated or non-chlorinated VOCs to be present in soils.

A detailed discussion of the occurrence of chlorinated and non-chlorinated VOCs in the landfill subsurface along cross section lines H-H′ and I-I′ is presented in the remainder of this subsection. The contaminants detected, their depths of occurrence, and the concentrations present in sampled soils are discussed in depth for each borehole and wellbore along the two cross section lines. The summary above is a discussion of these results.

Chlorinated Volatile Organic Compounds

Dichloromethane was present above laboratory detection limits in BH-23 and BH-20 along cross section line H-H′. It was detected at four different sampling depths in BH-23 (6 to 7 ft, 41 to 42 ft, 45 to 46 ft, and 50 to 51 ft), and was the only contaminant found in BH-20 soils (4 to 5 ft, 10 to 11 ft, and 18 to 19 ft). The only occurrence of dichloromethane detected along cross section line I-I′ was found in wellbore BLM-44 from 41 to 42 ft. It was also the greatest concentration of dichloromethane found in the former landfill (130 µg/kg) (Figure 5-5). The concentrations found in boreholes BH-20 and BH-23 ranged from 4.1. µg/kg to 8.6 µg/kg, both in BH-20 (Figure 5-4). Dichloromethane was also found in other boreholes and wellbores not on cross section lines H-H′ and I-I′. These included BH-06, BLM-33, BLM-35, and BLM-41. Concentrations ranged from 11 µg/kg in BLM-33 to 21 µg/kg in BLM-35 (Table 5-1).

Trichloroethene (TCE) was detected in BH-26 from 1 to 2 ft and in BH-16 from 4 to 5 ft, both in boreholes along cross section I-I′. Concentrations ranged from 3.2 µg/kg in BH-26 to 5.4 µg/kg in BH-16 (Figure 5-5). Borehole BH-23, along cross section line H-H′, showed TCE to be present at 14 µg/kg from 6 to 7 ft (Figure 5-4). TCE was also detected in BH-04 at 1.8 µg/kg and BH-14 at 1.4 µg/kg (Table 5-1).

1,1,1-Trichloroethane (1,1,1-TCA) was present in soils at BH-03 from 2 to 3 ft and from 7 to 8 ft, and in BH-09 from 4 to 5 ft along cross section H-H′ (Figure 5-4). It was also detected in BH-24 along the I-I′ cross section line from 5 to 6 ft (Figure 5-5). Concentrations in these three boreholes ranged from 1.2 µg/kg in BH-09 to 5.4 µg/kg in BH-24. 1,1,1-TCA was also found in soils at BH-06 and BLM-35 in concentrations ranging from 2.6 µg/kg to 3 µg/kg, respectively (Table 5-1).

Soils from BH-11 and BH-23 along cross section line H-H′ showed concentrations of tetrachloroethene (PCE) above laboratory detection limits. PCE was present in BH-23 from 6 to 7 ft and from 20 to 21 ft in BH-11 (Figure 5-4). Concentrations in the two boreholes ranged from 1.6 µg/kg in BH-11 to 19 µg/kg in BH-23. PCE was also detected in soils at BH-16 and BH-18 along cross section line I-I′ from 4 to 5 ft, and in BH-24 from 5 to 6 ft (Figure 5-5). PCE concentrations ranged from 1.2 µg/kg in BH-18 to 31 µg/kg in BH-16. PCE was also found in BH-13, BH-15, and BH-16 in concentrations ranging from 1.5 µg/kg to 4 µg/kg (Table 5-1).

1,1,2,2-Tetrachloroethane was found present in only one borehole, BH-06, at 5.5 µg/kg (Table 5-1) 1,2-*trans*-Dichloroethene (1,2-*trans*-DCE) also was detected in only one borehole, BH-16. It was present from 4 to 5 ft at 8.5 µg/kg (Figure 5-5). 1,1-Dichloroethane (1,1-DCA) was detected in BH-23 from 6 to 7 ft

(Figure 5-4), and in BH-24 from 5 to 6 ft (Figure 5-5). Concentrations ranged from 1.6 µg/kg in BH-24 to 18 µg/kg in BH-23. In addition, 1,1,-DCE was also found to be present in BH-23 from 6 to 7 ft at 4.7 µg/kg.

Trichloromethane was detected in one wellbore and one borehole along cross section line I-I′. Trichloromethane was found in soils from 1 to 2 ft and 14 to 15 ft in BH-26, and from 30 to 31 ft and 38 to 39 ft in BLM-53 (Figure 5-5). Concentrations ranged from 1.6 µg/kg in BH-26 to 2 µg/kg in BLM-53. Borehole BH-23, along the H-H′ cross section line, showed trichloromethane contamination ranging from 1.5 µg/kg to 1.9 µg/kg. Contamination was detected in soils at 41 to 42 ft, 45 to 46 ft, and 50 to 51 ft (Figure 5-4).

Trichlorofluoromethane was detected in BH-23 along the H-H′ cross section line, and in BH-24, along the I-I′ cross section line (Figures 5-4 and 5-5). Contamination was found from 5 to 6 ft in BH-24 and from 6 to 7 ft in BH-23. Concentrations ranged from 5.2 µg/kg to 6.4 µg/kg in the two boreholes, respectively.

Chloroethane, chloromethane, and vinyl chloride were detected wellbore BLM-33. This wellbore is not shown on either cross section line because of its location (the very southwest corner of the western portion of the former landfill). All three compounds were detected in soil from 29 to 30 ft. The concentration of all three compounds in sampled soils was 10 µg/kg (Table 5-1 and Appendix I-1).

Non-Chlorinated Volatile Organic Compounds

The remaining VOCs not falling under petroleum hydrocarbons or chlorinated VOCs were all detected in wellbore BLM-33. Acetone was present from 9 to 10 ft (3 µg/kg), 29 to 30 ft (2 µg/kg), and 39 to 40 ft (8 µg/kg). Bromomethane was present from 29 to 30 ft (10 µg/kg), and carbon disulfide was present from 29 to 30 ft (5 µg/kg) (Table 5-1 and Appendix I-1).

Acetone was also detected in wellbore BLM-35 from 9 to 10 ft, 19 to 20 ft, 29 to 30 ft, 39 to 40 ft, and 49 to 50 ft. Concentrations at these depths ranged from 9 µg/kg to 170 µg/kg (Table 5-1 and Appendix I-1).

5.1.2.2. Semivolatile Organic Constituents

Table 5-2 summarizes the RI soil data for semivolatile organic compounds. The table shows the sampling location, the concentration range for each contaminant detected, and also provides the proposed RCRA Corrective Action Rule action levels for each of the detected contaminants. COCs are identified in the table. Appendix I-1 presents the laboratory analytical results. Borehole and wellbore logs are presented in Appendixes H and L.

Figures 5-6 and 5-7 show the distribution of semivolatile organic compounds in the landfill subsurface with depth in boreholes and wellbores along the two cross section lines, H-H' and I-I' (Figure 5-3). Presented below is a summary of the distribution of semivolatile organic compounds detected in soils sampled in the subsurface at the former Lee Acres Landfill. A total of thirty-four semivolatile organic compounds were detected in boreholes and wellbores within the boundaries of the landfill (Table 5-2).

The distribution of semivolatile organic compounds within the former landfill is site wide. There is no apparent trend or pattern to the distribution of these contaminants in the subsurface (Figure 5-6 and 5-7). Semivolatile compounds were detected in almost every borehole and wellbore drilled in the former landfill, and at varying depths. Their occurrence does not seem to be concentrated in any one or two specific areas of the landfill.

Boreholes BH-04, BH-06, BH-26, and BH-27 contained the greatest number of semivolatile organic compounds. Wellbores BLM-41 and BLM-47 contained the greatest number of semivolatile organics detected in the wellbores within the former landfill.

Borehole BH-26 and wellbore BLM-47 are located in the former southern liquid waste lagoon. Table 5-3 presents a condensed list of constituents developed by the Office of Solid Waste for identifying contaminants associated with petroleum refinery wastes. The original list of 89 hazardous constituents is similar to the list used for refinery delisting actions (EPA 1984). Borehole BH-26 soils contained 16 semivolatile organic compounds that have been identified as being potentially present in refinery wastes; wellbore BLM-47 contained six (Tables 5-2 and 5-3).

Boreholes BH-12 and BH-23, located in the former northern liquid waste lagoon, also contained a number of semivolatile organic compounds. Out of the eight semivolatile compounds detected in BH-12, six are identified as being potentially present in refinery wastes. Of the five semivolatile compounds detected in BH-23, all five are identified as being potentially present in refinery wastes (Tables 5-2 and 5-3).

The occurrence of semivolatile organic compounds in these soils may be linked to the lagoonal sediments; however, the distribution of these compounds throughout the landfill, particularly in areas where liquid waste lagoons did not exist, does not support this assumption. For example, borehole BH-27 contains 13 semivolatile organic compounds; 11 are identified as being potentially present in refinery wastes. BH-27 is not located in or adjacent to a former liquid waste lagoon. Borehole BH-04 also contains a large number of semivolatile organic compounds. Of the 11 semivolatiles detected, six are identified as being potentially present in refinery wastes.

In addition, boreholes BH-10 and BH-22 contained no semivolatile organic compounds in the sampled soils. Both of these boreholes are located within the boundaries of the former northern liquid waste lagoon.

It should be noted that although many of the detected semivolatile organic compounds may be potentially present in refinery wastes, many of them may also be present in household waste (e.g., *bis*(2-ethylhexyl) phthalate, di-n-butyl phthalate, and naphthalene). The presence of phthalates in soils sampled from the landfill subsurface may be attributed to the presence of plastics in the solid waste.

A detailed discussion of the occurrence of semivolatile organic compounds in the landfill subsurface along cross section lines H-H′ and I-I′ is presented in the remainder of this subsection. The contaminants detected, their depths of occurrence, and the concentrations present in sampled soils are discussed in depth for each borehole and wellbore along the two cross section lines. The summary above is a discussion of these results.

5.1.2.2.1. Boreholes Along Cross Section Line H-H′

Borehole BH-01 showed three semivolatile organic compounds to be present in the soils (Figure 5-6). 1,4-Dichlorobenzene was detected from 3 to 4 ft at 9,500 µg/kg, benzoic acid was detected from 8 to 9 ft at 110 µg/kg, and phenol was present from 3 to 4 ft at a concentration of 57 µg/kg. Borehole BH-02 showed only diethyl phthalate to be present in soils from 3 to 4 ft at a concentration of 50 µg/kg.

Borehole BH-03 showed four semivolatile organic compounds to be present in soils (Figure 5-6). Methyphenol was detected from 7 to 8 ft at 570 µg/kg, benzoic acid was found present from 7 to 8 ft at 1,600 µg/kg and from 25 to 26 ft at 160 µg/kg, chrysene was detected from 7 to 8 ft at 54 µg/kg, and phenanthrene was detected in soils from 7 to 8 ft at 140 µg/kg.

Six semivolatile organic compounds were detected in BH-05 (Figure 5-6). 1,4-Dichlorobenzene was present from 6 to 7 ft at 5,100 µg/kg, 2-methylnaphthalene was found in soils from 16 to 17 ft at 41 µg/kg, 4-methylphenol was detected in soils from 6 to 7 ft at a concentration of 130 µg/kg, benzoic acid was measured at 900 µg/kg from 16 to 17 ft, diethyl phthalate was detected at 340 µg/kg in soils from 16 to 17 ft, and phenol was found in soils from 6 to 7 ft at 110 µg/kg and from 21 to 22 ft at 49 µg/kg.

Five contaminants were detected in BH-11 (Figure 5-6). 2-Methylnaphthalene was detected in soils from 20 to 21 ft at 600 µg/kg, 4-methylphenol was present at the same depth in a concentration of 1,200 µg/kg, *bis*(2-ethylhexyl) phthalate was detected in soils from the same depth as the previous two at 2,100 µg/kg, napthalene and phenol were also found present in soils from 20 to 21 ft in concentrations of 270 µg/kg and 600 µg/kg, respectively.

Borehole BH-12 showed eight semivolatile organic compounds to be present in soils (Figure 5-6). 2-Methylnaphthalene was detected from 13 to 14 ft at 410 µg/kg, benzoic acid was found present from 4 to 5 ft at 250 µg/kg, *bis*(2-ethylhexyl) phthalate was detected in soils from 1 to 2 ft (180 µg/kg), 4 to 5 ft (47 µg/kg), 13 to 14 ft (540 µg/kg), 19 to 20 ft (62 µg/kg), 25 to 26 ft (46 µg/kg), and 41 to 42 ft (96 µg/kg), butyl benzyl phthalate was detected in soils from 13 to 14 ft at 92 µg/kg, chrysene was found present from 1 to 2 ft at 150 µg/kg, di-n-butyl phthalate was detected in soils from 1 to 2 ft (160 µg/kg), 4 to 5 ft (230 µg/kg), 13 to 14 ft (100 µg/kg), 19 to 20 ft (88 µg/kg), 25 to 26 ft (48 µg/kg), 41 to 42 ft (52 µg/kg), and 49 to 50 ft (70 µg/kg), diethyl phthalate was detected in soils from 4 to 5 ft at 48 µg/kg, and naphthalene was found in soils from 13 to 14 ft at a concentration of 500 µg/kg.

Five semivolatile compounds were detected in borehole BH-23 (Figure 5-6). 1,2-Dichlorobenzene and 1,4-dichlorobenzene were detected from 6 to 7 ft at concentrations of 1.4 µg/kg and 3.1 µg/kg, respectively. *Bis*(2-Ethylhexyl) phthalate, fluoranthene, and pyrene were also detected in soils from 6 to 7 ft. The concentrations of these compounds were 180 µg/kg, 54 µg/kg, and 78 µg/kg, respectively.

5.1.2.2.2. Boreholes and Wellbores Along Cross Section Line I-I'

Borehole BH-16 showed two semivolatile organic compounds to be present in soils (Figure 5-7). *Bis*(2-Ethylhexyl) phthalate was detected from 4 to 5 ft at 65 µg/kg, and di-n-butyl phthalate was found present in soils from 14 to 15 ft at 49 µg/kg and from 24 to 25 ft at 41 µg/kg (Figure 5-7). Borehole BH-17 showed only 2-chlorophenol to be present in soils from 13 to 14 ft at a concentration of 42 µg/kg. Borehole BH-18 showed two semivolatile compounds to be present in soils (Figure 5-7). *Bis*(2-Ethylhexyl) phthalate and di-n-butyl phthalate were found present in soils from 4 to 5 ft at concentrations of 360 µg/kg and 50 µg/kg. respectively. Only one semivolatile organic was found in BH-21 (Figure 5-7). Di-N-butyl phthalate was detected in soils from 9 to 10 ft, 18 to 19 ft, and 30 to 31 ft. Concentrations ranged from 44 µg/kg to 56 µg/kg. Four compounds were detected in borehole BH-24 (Figure 5-7). Benzoic acid, fluoranthene, phenanthrene, and pyrene were all detected in soils from 16 to 17 ft. The concentrations detected were 370 µg/kg, 54 µg/kg, 62 µg/kg, and 63 µg/kg, respectively.

Borehole BH-26 showed 17 semivolatile organic compounds to be present in soils sampled from the borehole (Figure 5-7). 1,2,4-Trichlorobenzene was detected in soils from 29 to 30 ft at 69 µg/kg, 2-methylnaphthalene was detected from 1 to 2 ft at 80 µg/kg, and *bis*(2-ethylhexyl) phthalate was found present in soils from 1 to 2 ft at 72 µg/kg. Acenaphthene (100 µg/kg), anthracene (250 µg/kg), benzo(a)anthracene (550 µg/kg), benzo(a)pyrene (400 µg/kg), benzo(b)fluoranthene (370 µg/kg), benzo(g,h,i)perylene (200 µg/kg), benzo(k)fluoranthene (410 µg/kg), chrysene (520 µg/kg), di-n-butyl phthalate (3,900 µg/kg), fluoranthene (1,500 µg/kg), fluorene (77 µg/kg), indeno (1,2,3-CD) pyrene (230 µg/kg), phenanthrene (1,100 µg/kg), and pyrene (980 µg/kg) were all detected in soils from 14 to 15 ft.

One semivolatile organic compound, *bis*(2-ethylhexyl) phthalate, was detected in borehole BH-29 (Figure 5-7) from 14 to 15 ft at 71 µg/kg, from 28 to 29 ft at 44 µg/kg, and from 40 to 41 ft at a concentration of 43 µg/kg. Wellbore BLM-44 showed the presence of two semivolatile compounds in sampled soils. Di-N-butyl phthalate was detected from 12 to 13 ft at 140 µg/kg, 28 to 29 ft at 64 µg/kg, and from 45 to 46 ft at 66 µg/kg (Figure 5-7).

Wellbore BLM-47 showed seven semivolatile compounds to be present in sampled soils (Figure 5-7). 1,2-Dichlorobenzene (2.3 µg/kg), 1,3-dichlorobenzene (1.4 µg/kg), 1,4-dichlorobenzene (1.7 µg/kg), di-n-butyl phthalate (380 µg/kg), and benzoic acid (110 µg/kg) were all detected in soils from 30 to 31 ft. *Bis*(2-Ethylhexyl) phthalate was found present in soils from 20 to 21 ft at 41 µg/kg and pyrene was detected at 39 µg/kg in soils from 40 to 41 ft. Di-N-butyl phthalate, in addition to the sample referred to above, was detected in soils from 15 to 16 ft (58 µg/kg), 20 to 21 ft (330 µg/kg), and 40 to 41 ft (51 µg/kg).

Wellbore BLM-53 showed only one semivolatile compound to be present in sampled soils from 20 to 21 ft at a concentration of 1.4 µg/kg. Wellbore BLM-54 showed only *bis*(2-ethylhexyl) phthalate to be present in soils from 28 to 29 ft. Two samples were taken at this depth showing concentrations of 63 µg/kg and 120 µg/kg. The final wellbore along cross section I-I', BLM-56, showed n-nitrosodiphenylamine to be present in soils from 6 to 7 ft at a concentration of 43 µg/kg (Figure 5-7).

Some of the remaining boreholes and wellbores not included in cross sections H-H' and I-I', because of location, showed concentrations of semivolatile organic compounds above laboratory detection limits (Table 5-2 and Appendix I-1). Boreholes showing semivolatile compounds in soils were BH-04, BH-06, BH-13, BH-14, BH-27, and BH-28. Wellbores showing detectable concentrations of semivolatile organics were: BLM-33, BLM-35, BLM-41, BLM-57, and BLM-59.

Borehole BH-04, located in the eastern portion of the landfill, showed 11 semivolatile organic compounds to be present in sampled soils. Borehole BH-06, located in the same area of the former landfill as BH-04, showed 19 semivolatile compounds to be present in sampled soils (Figure 5-2 and Table 5-2). Boreholes BH-27 and BH-28, located in the western portion of the former landfill, showed 13 and 6 semivolatile organic compounds to be present, respectively (Figure 5-2 and Table 5-2). Wellbore BLM-41, located in the southwestern portion of the former landfill, had 10 semivolatile organic compounds detected in sampled soils. The semivolatile organic compounds detected in each of these boreholes and wellbores are presented in Table 5-2. The depth at which the contaminants were detected are presented in Appendix I-1.

5.1.2.3. Pesticide/PCB Constituents

Table 5-4 summaries the RI soil data for pesticides/PCBs. The table shows the sampling location, the concentration range for each contaminant detected, and also provides the proposed RCRA action levels for each of the detected contaminants. COCs are also identified in the table. Appendix I-1 presents the laboratory analytical results. Borehole and wellbore logs are presented in Appendices H and L, respectively.

Figures 5-8 and 5-9 show the distribution of contaminants in the landfill subsurface with depth in boreholes and wellbores along the two cross section lines, H-H′ and I-I′ (Figure 5-3). Presented below is a summary of the distribution of pesticides in soils sampled at the former Lee Acres Landfill. No PCB compounds were detected in any of the boreholes or wellbores drilled within the landfill boundaries.

Eight different pesticides were detected in borehole and wellbore soils sampled from the landfill subsurface. 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, dieldrin, heptachlor, heptachlor epoxide, and delta-BHC were found in measurable concentrations. 4,4'-DDT was the most frequently detected pesticide (13 times). Heptachlor, heptachlor epoxide, and aldrin were detected only once in the landfill soils.

The occurrence and distribution of pesticides is widespread in both areal and vertical extent. 4,4'-DDT was found in the former landfill as far east as BH-07, and as far southwest as BLM-44. Depths at which pesticides were detected in soils ranged from 1 ft to 42 ft below ground surface. No apparent trends or patterns have been identified in pesticide occurrence within the former landfill.

A detailed discussion of the occurrence of pesticide compounds in the landfill subsurface along cross section lines H-H′ and I-I′ is presented in the remainder of this subsection. The pesticides detected, their depths of occurrence, and the concentrations present in sampled soils are discussed in depth for each borehole and wellbore along the two cross section lines. The summary above is a discussion of these results.

5.1.2.3.1. <u>Boreholes Along Cross Section Line H-H′</u>

Boreholes BH-01 and BH-02 showed 4,4'-DDD to be present from 3 to 4 ft (Figure 5-8). The concentrations detected were 3.8 µg/kg and 2.2 µg/kg, respectively. Borehole BH-05 showed 4,4'-DDD to be present from 6 to 7 ft at 2.3 µg/kg. 4,4'-DDE was also detected in the borehole from 3 to 4 ft (25 µg/kg), 6 to 7 ft (3 µg/kg), and from 21 to 22 ft (4 µg/kg) (Figure 5-8). Borehole BH-07 showed only one pesticide to be present in sampled soils. 4,4'-DDT was detected from 1 to 2 ft at a concentration of 13 µg/kg (Figure 5-8). Boreholes BH-10 and BH-11 showed 4,4'-DDE to be present in soils from 3 to 4 ft. The concentrations detected were 5.2 µg/kg and 7.1 µg/kg, respectively (Figure 5-8). 4,4'-DDE was also detected in BH-11 from 20 to 21 ft (14 µg/kg) and 28 to 29 ft (3.7 µg/kg). Heptachlor epoxide was detected at 1.5 µg/kg in soils from 20 to 21 ft (Figure 5-8). Three pesticides were detected in borehole BH-12. 4,4'-DDE was found to be present in soils from 40 to 41 ft at a concentration of 9.8 µg/kg. 4,4'-DDT was detected in samples from 4 to 5 ft (2.4 µg/kg), 13 to 14 ft (6.5 µg/kg), 19 to 20 ft (4.8 µg/kg), 25 to 26 ft (4 µg/kg), 40 to 41 ft (7.1 µg/kg), and from 41 to 42 ft (2.7 µg/kg). Dieldrin was also detected in soils from 13 to 14 ft at a concentration of 5.7 µg/kg (Figure 5-8). 4,4'-DDE and 4,4'-DDT were detected in soils from borehole BH-20 at a depth of 4 to 5 ft. The concentrations were 9.4 µg/kg and 10 µg/kg, respectively. Dieldrin was detected in borehole BH-23 from 6 to 7 ft. It was present in sampled soils at a concentration of 48 µg/kg (Figure 5-8). No pesticides were detected in boreholes BH-03, BH-08, or BH-09.

5.1.2.3.2. Boreholes and Wellbores Along Cross Section Line I-I'

Borehole BH-16 contained 4,4'-DDE in soils from 4 to 5 ft (5.1 µg/kg), 14 to 15 ft (2 µg/kg), 24 to 25 ft (2.8 µg/kg), and from 37 to 38 ft (2.8 µg/kg) (Figure 5-9). Borehole BH-17 showed 4,4'-DDT to be present in soils from 13 to 14 ft at a concentration of 3.6 µg/kg. Borehole BH-19 soils contained 4,4'-DDE from 9 to 10 ft at a concentration of 4.1 µg/kg. Both 4,4'-DDE and 4,4'-DDT were detected in borehole BH-22 from 9 to 10 ft (Figure 5-9). 4,4'-DDE was detected at 1.4 µg/kg and 4,4'-DDT was present at a concentration of 2.7 µg/kg. Borehole BH-25 showed 4,4'-DDT to be present in soils from 18 to 19 ft a concentration of 3.8 µg/kg (Figure 5-9). Borehole BH-26 contained 4,4'-DDE in soils from 1 to 2 ft at a concentration of 2.3 µg/kg. Wellbores BLM-44 and BLM-47 both contained measurable concentrations of 4,4'-DDT. BLM-44 showed contamination to be present in soils from 28 to 29 ft (15 µg/kg) and from 41 to 42 ft (5.1 µg/kg). BLM-47 contained contaminated soils from 30 to 31 ft at a concentration of 4.2 µg/kg. Wellbore BLM-54 showed delta-BHC to be present in soils from 18 to 19 ft at a concentration of 15 µg/kg (Figure 5-9). No pesticides were detected in boreholes BH-18, BH-21, BH-24, or BH-29, nor were any detected in wellbores BLM-53 and BLM-56.

Other boreholes and wellbores not shown on cross sections H-H' and I-I' that contained measurable concentrations of pesticides were BH-04, BH-06, BH-13, BH-14, BH-15, BH-27, and BLM-41. Borehole BH-04 showed dieldrin to be present in sampled soils. No other pesticides were detected. Borehole BH-06 contained heptachlor, in addition to 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT. BH-13 showed dieldrin and aldrin to be present along with 4,4'-DDE and 4,4'-DDT. BH-14 and BH-15 showed measurable concentrations of 4,4'-DDT and dieldrin. BH-27 showed 4,4'-DDE to be present, and BLM-41 contained measurable concentrations of 4,4'-DDD and 4,4'-DDT (Table 5-4).

5.1.2.4. Inorganic Constituents

Soil samples collected from the former landfill during the RI were analyzed for chloride, sulfate, EP Toxicity metals, and total metals. Concentration ranges for inorganics, EP Toxicity metals, and total metals are presented in Table 5-5. Laboratory analytical results are presented in Appendix I-1. Borehole and wellbore logs are presented in Appendices H and L, respectively.

Proposed RCRA soil action levels do not exist for inorganics or metals in soil. However, the EP Toxicity metal concentrations were compared with the TCLP regulatory levels. The new TCLP rule promulgated by the EPA in March 1990 (55 FR 11798) is a replacement for the EP Toxicity test. These methods are not identical, but comparison allows for an assessment of general contaminant conditions. Presently, there are no state of New Mexico standards for metals in soil, so the total metal concentrations derived from the RI were not compared with any regulatory standards.

Five EP Toxicity metals were detected in the landfill soils above laboratory detection limits. Barium was detected in one soil sample from BH-26 at a concentration of 1.15 mg/L. The TCLP regulatory level barium is 100 mg/L. Mercury was detected in soil samples from boreholes BH-08. BH-11, BH-29, and from wellbore BLM-57. Concentrations ranged from 0.00025 mg/L in BH-11 to 0.0004 mg/L in BLM-57. The TCLP regulatory level for mercury is 0.2 mg/L. Tin and selenium were detected in only one soil sample from the former landfill. Tin was detected in soil from BH-06 at 0.113 mg/L and selenium was found present in soil from BH-23 at 0.103 mg/L. Strontium was detected in 31 boreholes and wellbores within the former landfill. Concentrations ranged from 0.636 mg/L in BH-24 to 20 mg/L in BH-06 (Table 5-5). No TCLP regulatory levels exist for tin, selenium, and strontium in soil.

Total metal analyses were performed on soil samples collected during the installation of monitoring wells BLM-33. BLM-34, and BLM-35. As discussed previously, no proposed RCRA action levels or state regulatory levels exist for metals in soil. Wellbore BLM-35 showed concentrations of arsenic in soil ranging from 2.5 to 4.8 mg/kg, barium ranging from 6.2 to 77.4 mg/kg, chromium ranging from 3.9 to 12.2 mg/kg, and lead ranging from 2.3 to 21.4 mg/kg. Wellbore BLM-34 showed concentrations of arsenic in soil ranging from 2.2 to 2.3 mg/kg, chromium ranging from 5.6 to 8.2 mg/kg, lead ranging from 3.7 to 3.9 mg/kg, selenium at 1.1 mg/kg, and silver at 2.4 mg/kg. Wellbore BLM-35 showed concentrations of arsenic in soil ranging from 0.34 to 2.1 mg/kg, selenium ranging from 1.4 to 10.7 mg/kg, and lead ranging from 2.3 to 32.9 mg/kg (Table 5-5).

The inorganic analyses for chloride and sulfate on landfill soils showed concentrations of chloride ranging from 11 mg/kg in BLM-57 to 8,330 mg/kg in BH-05, and sulfate concentrations ranging from 13.5 mg/kg in

BLM-59 to 20,600 mg/kg in BH-13. No proposed RCRA action levels or state regulatory levels exist for chloride and sulfate in soil (Table 5-5).

The distribution of metals in landfill soils, other than strontium, appears to be limited. Only six boreholes and four wellbores showed metals other than strontium to be present in sampled soils. Mercury was detected in three boreholes (BH-08, BH-11, and BH-29) and one wellbore (BLM-57), tin was detected in one borehole (BH-06), selenium was detected in one borehole (BH-23), and barium was detected in one borehole (BH-26). Two of the three remaining wellbores (BLM-33 and BLM-34) showed arsenic, barium, chromium, lead, selenium, and silver to be present in soils. The third remaining wellbore (BLM-35) showed arsenic, selenium, and lead to be present. Barium and mercury did not exceed the TCLP regulatory standards. Tin, selenium, and strontium were identified as COCs because no TCLP standard exits for these metals. The total metals detected in wellbores BLM-33, BLM-34, or BLM-35 were not compared with any regulatory standard and, therefore, are identified as COCs.

The southernmost portion of the former landfill appears to be an area where metals contamination is present within the subsurface soils. As discussed above, all three wellbores (BLM-33, BLM-34, and BLM-35) located in this area showed soil contaminated with a number of metals (Table 5-5).

Three boreholes (BH-23, BH-26, and BH-29) and one wellbore (BLM-57) are located in the vicinity of the former northern and southern liquid waste lagoons. Mercury was detected in soil from BH-29 and BLM-57, selenium was detected in BH-23, and barium was detected in BH-26. Three boreholes (BH-06, BH-08, and BH-11) located in the eastern portion of the landfill showed concentrations of mercury and tin to be present in soils. The occurrence of strontium in landfill soils is site wide. Strontium was detected in 23 boreholes and eight wellbores within the landfill boundaries.

The distribution of chloride and sulfate in landfill soils is site wide. Sulfate was detected in all boreholes and wellbores that were drilled within the boundaries of the landfill. Chloride was detected in all wellbores and in all boreholes, except BH-07. The concentrations of chloride and sulfate are randomly distributed throughout landfill soils. No apparent trends or patterns were identified in the distribution of chloride and sulfate.

5.1.3. Contaminants of Concern

5.1.3.1. Volatile Organic Constituents

Six VOCs were identified as COCs within the landfill (Table 5-1). Benzene was detected in soils at boreholes BH-12, BH-18, BH-19, and BH-23. 1,2-*trans*-DCE was detected in borehole BH-16. 1,1-DCA was detected in boreholes BH-23 and BH-24. Chloroethane, chloromethane, and vinyl chloride were found present in soils at wellbore BLM-33. The contaminants listed above were identified as COCs because RCRA action levels are not specified for these compounds.

5.1.3.2. Semivolatile Organic Constituents

Twenty-five semivolatile organic compounds were identified as COCs within the former landfill. The semivolatile organic compounds shown in Table 5-6 were identified as COCs because RCRA action levels are not specified for these compounds.

5.1.3.3. Pesticides/PCB Constituents

No PCB compounds were detected in landfill soils. Two pesticides compounds have been listed as COCs within the former landfill (Table 5-4). Dieldrin was detected in two soil samples from boreholes BH-13 and BH-23. The concentration of dieldrin detected in two soil samples exceeded the proposed RCRA action level of 40 µg/kg (55 FR 30865). Soils from borehole BH-13 showed a concentration of 63 µg/kg, and soils from borehole BH-23 showed a concentration of 48 µg/kg.

The second pesticide, delta-BHC, was detected in wellbore BLM-57. It was identified as a COC because no proposed RCRA action level exists.

5.1.3.4. Inorganic Constituents

EP Toxicity metals results showed strontium, tin, mercury, selenium, and barium to be present in landfill soils. Strontium was detected site wide, whereas tin, mercury, selenium, and barium were found at only one or two locations in the landfill. Only two metals were identified as COCs (Table 5-5). Mercury was detected in boreholes BH-08, BH-11, BH-29, and in wellbore BLM-57. All concentrations were below TCLP regulatory standards. Barium was detected in borehole BH-26. The concentration detected was below TCLP regulatory standards. Selenium was detected in borehole BH-23. The concentration detected was below TCLP regulatory standards (Table 5-5). Strontium and tin were identified as COCs in landfill soils because no TCLP regulatory standards exist for these two metals.

Total metal results for soils sampled from wellbores BLM-33, BLM-34, and BLM-35, showed arsenic, barium, chromium, lead, selenium, and silver to be present. The lack of a regulatory standard for total metals results in these six metals being COCs.

Chloride and sulfate were identified as COCs in soils within the landfill boundaries. Chloride was detected in all wellbores drilled within the landfill boundaries. Chloride was detected in all wellbores drilled within the former landfill and in all boreholes, except BH-07. Sulfate was detected in every borehole and wellbore drilled in the landfill. Both chloride and sulfate were identified as COCs because no proposed RCRA action levels exist (Table 5-5).

5.2. FORMER LIQUID WASTE LAGOONS

Figure 5-10 shows the approximate locations of the two former liquid waste lagoons at the former Lee Acres Landfill. Information pertaining to the history and locations of the two lagoons were compiled from NMEID inspection reports (subsection 1.2), from air photos (Appendix B), and from the RI geophysical surveys discussed in subsection 2.1. Additionally, the results of historical and RI analytical data were used to characterize the chemical composition of the wastes in the lagoons, and to determine the COCs associated with the two former liquid waste lagoons.

A detailed site history and an air photo analysis are presented in Appendix B. Information specific to the operational history of the two former liquid waste lagoons is presented in subsection 1.2. A chronology of historical events regarding the operation of the two former liquid waste lagoons is summarized in Table 1-2.

Analytical data available for characterization of the chemical nature of the lagoonal sediments and for identification of COCs include 1) selected results of sampling conducted by the NMOCD and NMEID in 1985 presented in published report form (McQuillan and Longmire 1986); 2) all of the results of the sampling conducted by the NMOCD and NMEID in 1985; 3) the RI borehole sampling and analytical program and; 4) the RI lysimeter sampling and analytical program. Subsections 2.4 and 2.6 present the technical rationales and methodologies for the borehole sampling and analytical program and the lysimeter sampling and analytical program, respectively.

5.2.1. Physical Description

The northern and southern liquid waste lagoons were present at the landfill from approximately 1979 to April 1985 (Figure 5-10). The two lagoons once covered an estimated combined area of approximately 95,000 square ft. The estimation of the areal extent of the two lagoons was based upon air photos and the geophysical data shown in Figure 2-7.

The northern lagoon was the larger of the two (approximately 70,000 square ft) and was located in the northwest corner of the landfill. The southern lagoon was approximately 25,000 square ft and was located near the center of the western boundary of the landfill.

Estimation of the volumes of liquid waste disposed of at the northern and southern lagoons between 1979 and 1986 was not possible because of the lack of records and unmetered dumping. In 1986, liquid waste disposal was terminated (NMEID, 1986a) and the two lagoons were abandoned and covered with soil.

5.2.2. Chemical Nature of the Liquid Waste Lagoon Contents

In January and February 1985, the NMOCD took three samples of the contents of the northern liquid waste lagoon. The February sampling included two locations, the east and west sides of the lagoon. In May, the NMEID received notice that the northern liquid waste lagoon at the Lee Acres Landfill had breached. The NMEID reported that hydrogen sulfide gas was also released from the northern lagoon during this occurrence. Ferric chloride was added to the lagoon during this time to chemically neutralize the lagoon contents (NMEID 1985a). In April, the NMEID collected a fourth sample of the lagoon contents from the south side of the lagoon.

The four samples (three collected in January and February 1985 by the NMOCD and one in April 1985 collected by the NMEID) were analyzed for pH, specific conductivity, total dissolved solids, metals, major inorganic ions, and other organic constituents. The analytical results of the 1985 northern liquid waste lagoon sampling were subsequently published by the NMEID in 1986 (McQuillan and Longmire 1986). The published results are presented in Table 5-7.

During the RI borehole sampling and analytical program, five boreholes were drilled in the areas of the two former liquid waste lagoons. Four of the boreholes (BH-10, BH-12, BH-22 and BH-23) were located in the area of the northern lagoon. The fifth borehole (BH-26) was located in the area of the southern lagoon (Figure 5-10). During the drilling of borehole BH-13 in the southern portion of the former landfill, hydrocarbon-stained soil was encountered that appeared to be similar to the lagoonal-type sediments (sand and sludge mix) found in and immediately around the two lagoons during drilling. The exact lateral extent of this layer and its relationship to the two former liquid waste disposal lagoons, however, is not known. Descriptions of the lagoonal-type sediments can be found in the borehole logs in Appendix H.

Vadose zone moisture in the unsaturated alluvium beneath the former Lee Acres Landfill is part of OU 1, as defined in subsection 1.5. Six lysimeters (LS-1, LS-3 through LS-7) were installed during the RI. Four of these lysimeters (LS-3, LS-5, LS-6, and LS-7) were subsequently used to collect vadose zone moisture for chemical analysis. Figure 5-10 shows the locations of the lysimeters within the former northern and southern liquid waste lagoon areas. The lysimeters were installed to 1) detect and characterize any remnant vadose zone contamination associated with the two former liquid waste lagoons, and 2) to assess the potential for future leaching of contaminants from the landfill to groundwater. The locations were based on a combination of geophysical data, air photos, borehole date, and groundwater monitoring well data.

5.2.2.1. 1985 Liquid Waste Lagoon Sampling

Table 5-8 presents all of the results of the 1985 sampling conducted and disseminated by the NMOCD and NMEID for the northern liquid waste lagoon. Some of these data appear in Table 5-7 as published information in the NMEID report (McQuillan and Longmire, 1986). For the purposes of describing the chemical composition of the liquid in the waste lagoon as it appeared in 1985, the published data was used. Subsection 5.2.3, which discusses the COCs, was based on all data disseminated by the NMOCD and the NMEID (Table 5-8).

5.2.2.1.1. Volatile Organic Constituents

The VOCs detected in the northern liquid waste lagoon samples are divided into two major groups: petroleum hydrocarbons (BTEX) and chlorinated VOCs, as indicated in Table 5-7. Petroleum hydrocarbons (BTEX) were detected in all four of the liquid waste lagoon samples. The total BTEX concentrations ranged from 0.68 mg/L to 4.38 mg/L. Benzene concentrations ranged from 0.12 mg/L to 1.03 mg/L, toluene concentrations ranged from 0.33 mg/L to 1.98 mg/L, ethylbenzene concentrations ranged from 0.025 mg/L to 0.17 mg/L, and xylene concentrations ranged from 0.205 mg/L to 1.34 mg/L.

The highest concentrations of BTEX were detected in the February samples from the east and west sides of the northern lagoon. The concentrations detected in the February samples are approximately two times higher than the concentrations found in the January 1985 samples. The BTEX concentrations in the May 1985 samples, after the addition of ferric chloride to the lagoon contents, decreased considerably from the previous two sampling events (Table 5-7).

Four chlorinated VOCs were detected in the northern liquid waste lagoon samples. 1,1,1-TCA, dichloromethane, TCE, and PCE were present in the samples. The total chlorinated VOCs ranged from 0.01 mg/L to 2.404 mg/L. 1,1,1-TCA was the only chlorinated volatile organic detected in all four samples, with concentrations ranging from 0.01 mg/L to 0.4 mg/L. Dichloromethane was detected in the January and February samples only, ranging from 0.18 mg/L to 2.00 mg/L. PCE was detected only in the February 1985 samples; the concentration detected in the sample from the west side of the lagoon (0.016 mg/L) being almost twice the concentration detected in the sample from the east side (0.007 mg/L). TCE was detected only in the January 1985 sample at a concentration of 0.004 mg/L (Table 5-7).

5.2.2.1.2. Inorganic Contaminants

Samples from the northern liquid waste lagoon contained high concentrations of chloride (2,251 mg/L to 4,474 mg/L), sodium (1,263 mg/L to 1,833 mg/L), and TDS (5,268 mg/L to 9,018 mg/L). High concentrations of TDS yielded conductivities as high 13,500 µmhos/cm. Sulfate concentrations were slightly elevated in the lagoon samples, with concentrations ranging from 40.2 mg/L to 1,881 mg/L (Table 5-7). However, higher sulfate concentrations were found to be characteristic of groundwater samples collected throughout the study area. Based on the concentrations of the above-mentioned constituents in the northern lagoon, it appears that chloride, sodium, and TDS may provide tracers for plume identification and definition. The use of the constituents to define groundwater plumes is discussed in subsection 6.2.

The following total metals were detected in the northern liquid waste lagoon samples: aluminum, arsenic, barium, boron, chromium, iron, manganese, selenium, silicon, strontium and zinc. Concentration ranges and frequency of detection for each metal vary only slightly with three exceptions. Arsenic and selenium were not detected in the February samples. Iron increased an order of magnitude in concentration between the February and May sampling (Table 5-7). The increase in the iron concentration detected in the May lagoon sample was most likely due to the addition of ferric chloride to the lagoon contents after the breach incident in April. The reason for the absence of arsenic and selenium in the February lagoon samples is not known.

5.2.2.1.3. Overview of Results

Petroleum hydrocarbons (BTEX) were detected in all four samples collected from the northern lagoon in 1985. The highest concentrations were detected in the February samples and decreased in concentration after the addition of ferric chloride to the lagoon contents in April 1985.

Four chlorinated VOCs were detected in the northern liquid waste lagoon samples in 1985. 1,1,1-TCA was detected in all four lagoon samples. The other three chlorinated VOCs were not consistently detected. Dichloromethane was detected in the January and February samples, TCE was detected only in the January sample, and PCE was detected only in the February samples.

Elevated concentrations of chloride, sodium, and TDS were detected in the northern lagoon samples from 1985. However, elevated concentrations of these three inorganics seemed to be characteristic of groundwater samples collected throughout the former landfill area (see subsection 6.2).

Eleven total metals were detected in the northern lagoon samples in 1985. Concentration ranges varied only slightly between all the detected metals, with three exceptions. Arsenic and selenium were not detected in lagoon samples during the February sampling event, and the concentration of iron in lagoon samples increased an order of magnitude between the February and May sampling events. This has been attributed to the addition of ferric chloride to the northern lagoon after the breach incident in April 1985.

5.2.2.2. Borehole Analytical Data

Table 2-8 summarizes the RI borehole sampling and analytical program. The soil samples collected during this program were analyzed for VOCs (EPA Methods 8010 and 8020); semivolatile organic compounds (EPA Method 8270); pesticides/PCBs (EPA Method 8080); and EP Toxicity metals, chloride, and sulfate.

Results obtained from the chemical analyses of hydrocarbon-stained soils sampled from boreholes provide a quantitative assessment of the contaminants in soils in the former lagoon areas, and are the closest approximation to the original lagoon chemistry that can be derived from data collected during the RI. The analytical data also provide information about the chemical nature of the remaining contaminants in the former lagoon areas that may be a potential source for future contaminant leaching and subsequent groundwater contamination.

Four boreholes (BH-10, BH-12, BH-22 and BH-23) were drilled in the area of the former northern liquid waste lagoon as shown in Figure 5-10. Hydrocarbon residues were encountered in each of the four boreholes at depths ranging from 2 to 8.3 ft. One borehole was drilled in the area of the former southern liquid waste lagoon (BH-26). Hydrocarbon-stained sediments were encountered and sampled in the borehole at depths of from 1.2 to 1.9 ft. Hydrocarbon-stained sediments were encountered and sampled in one borehole in the southern part of the landfill (BH-13) from 5 to 7.5 ft. Borehole logs for each of the above-mentioned boreholes are presented in Appendix H.

Contaminants detected in the hydrocarbon-stained sediments included chlorinated VOCs as well as petroleum hydrocarbons (BTEX). Table 5-9 presents contaminant concentrations found in the hydrocarbon-stained soil samples for each borehole.

EP Toxicity metal analyses were performed on the soil samples collected from each of the five boreholes located in the two former liquid waste lagoons, as well as soils from BH-13. Strontium was detected in all six of the boreholes. No TCLP regulatory level for strontium exists. In addition, selenium was detected in BH-23 and barium was detected in BH-26 (Table 5-5).

5.2.2.2.1. Former Northern Liquid Waste Lagoon

Hydrocarbon residues and stained soil were encountered in the four boreholes drilled in the area of the former northern liquid waste lagoon (Appendix H). Petroleum hydrocarbons, chlorinated VOCs, and inorganics were detected in the soil samples collected from these boreholes (Table 5-9).

Hydrocarbon-stained soils were encountered in BH-10 from 2.6 to 3.7 ft, and a soil sample was collected at a depth interval from 3 to 4 ft. Ethylbenzene, toluene, and xylene were detected in this sample at concentrations ranging from 1.2 μg/kg to 17 μg/kg, as shown in Table 5-9. In BH-12, hydrocarbon-stained soil was found at depths from 2 to 5 ft, and samples were collected at two depth intervals in the stained soil: 1 to 2 ft, and 4 to 5 ft. Ethylbenzene, toluene, and xylene were detected in concentrations ranging from 4.2 μg/kg to 49 μg/kg. Borehole BH-22 showed hydrocarbon-stained soils to be present from 4.4 to 4.9 ft; however, no petroleum hydrocarbons were detected in the sample from this interval. Hydrocarbon residue was encountered in BH-23 from 5.7 to 8.3 ft, and a sample was collected at a depth interval of 6 to 7 ft in the stained soils. BTEX was detected in this sample in concentrations ranging from 1,600 μg/kg (benzene) to 190,000 (xylene) μg/kg. The concentrations of BTEX in soils sampled from this borehole were higher than those detected in any of the other soil samples collected (Table 5-9). Borehole BH-26 showed hydrocarbon-stained soils to be present from 1.2 to 1.9 ft. Soils sampled from 1 to 2 ft in the stained soils showed toluene to be present at a concentration of 1.6 μg/kg. No other components of BTEX were detected. Toluene, ethylbenzene, and xylene did not exceed the proposed RCRA action levels (55 FR 30865) in any of the samples taken from the five boreholes located within the two former liquid waste lagoons, nor the sample taken from BH-13. No proposed RCRA action level exists for benzene in soil.

Chlorinated VOCs were detected in one soil sample from BH-23. The chlorinated VOCs detected in the sample from BH-23 (6 to 7 ft) were 1,1,-DCA, 1,1-DCE, dichloromethane, PCE, TCE, and trichlorofluoromethane. Concentrations ranged from 3.2 μg/kg to 19 μg/kg as indicated in Table 5-9, and do not exceed proposed RCRA soil action levels (55 FR 30865). 1,1-DCA and 1,1-DCE do not have proposed RCRA action levels specified.

The chlorinated semivolatile organic compounds detected were 1,2-dichlorobenzene (1.4 μg/kg) and 1,4-dichlorobenzene (3.1 μg/kg), both present in soils in BH-23 (Table 5-9). Neither of these contaminants have a proposed RCRA action level specified. Chloride and sulfate were detected in concentrations ranging from 76.7 mg/kg to 513 mg/kg and 253 mg/kg to 3,940 mg/kg, respectively (Table 5-9).

5.2.2.2.2. Former Southern Liquid Waste Lagoon

Hydrocarbon-stained soils were encountered in BH-26, located in the former southern liquid waste lagoon, from 1.2 to 1.9 ft. A sample was collected at a depth interval of 1 to 2 ft. One petroleum hydrocarbon, toluene, was detected at a concentration of 1.6 μg/kg. Two chlorinated VOCs were detected. Trichloromethane was detected at a concentration of 1.7 μg/kg and TCE was detected at a concentration of 3.2 μg/kg (Table 5-9). No proposed RCRA action levels (55 FR 30865) were exceeded in soils sampled in BH-26 at the southern liquid waste lagoon. Chloride was detected at a concentration of 124 mg/kg. Sulfate was detected at 453 mg/kg (Table 5-9).

5.2.2.2.3. Borehole BH-13

BH-13 is located outside of any known lagoon area in the southern portion of the former landfill. During the drilling of the borehole, hydrocarbon residue was encountered at depths from 5 to 7.5 ft. This may indicate the presence of a small liquid waste disposal area that was not previously identified. A sample was collected in the hydrocarbon-stained soils at a depth of 4 to 5 ft. Two petroleum hydrocarbons, ethylbenzene and toluene, were detected in this sample at concentrations of 3.8 μg/kg and 4.4 μg/kg, respectively. In addition, a chlorinated VOC, PCE, was also detected at 3.2 μg/kg in this sample (Table 5-9). The concentrations of these contaminants are well below the proposed RCRA action levels (55 FR 30865). Chloride and sulfate were also detected at concentrations of 506 mg/kg and 20,000 mg/kg, respectively (Table 5-9).

5.2.2.3. Chemical Nature of Vadose Zone Moisture

Lysimeter sampling was conducted in early and later April, May, June, and August 1990. The lysimeter sample volumes collected during each sampling period are presented in Table 5-10. Because there are low moisture levels in the vadose zone soils at the former landfill, sufficient quantities of water required for VOA (EPA Methods 8010 and 8020) were only collected in four lysimeters, LS-3, LS-5, LS-6 and LS-7. Lysimeter LS-3 is located in the former southern liquid waste lagoon, while LS-5, LS-6 and LS-7 are located in the former northern liquid waste lagoon, as shown in Figure 5-10.

Data indicate that relatively low levels of contamination are present in the vadose zone moisture below the former liquid waste lagoon areas. Table 5-11 shows the concentration ranges for the organic contaminants detected in the lysimeter samples. Petroleum hydrocarbons, specifically BTEX, are present in concentrations ranging from 1.5 μg/L to 7.4 μg/L. Benzene did exceed the SDWA MCL of 5 μg/L in lysimeter LS-5, but did not exceed the NM HHS level of 10 μg/L. Nine chlorinated VOCs are present in concentrations ranging from 0.64 μg/L to 8.9 μg/L. None of these concentrations, however, exceeds promulgated or proposed SDWA MCLs. 1,3-*cis*-Dichloropropene and dichlorofluoromethane do not have proposed or promulgated MCLs, nor do they have a state specified regulatory level.

Table 5-12 presents the results of the inorganic analyses that were performed on the lysimeter samples. Bicarbonate, bromide, chloride, and sulfate were detected in samples from lysimeter LS-5. No metals analyses were performed on lysimeter samples because of the limited volume of fluid available.

Lysimeter data show that vadose zone moisture in the former liquid waste lagoon areas contain some remnant contamination. Therefore, the sediments in these areas may provide a source for future, low-level groundwater contamination in the event that additional moisture is provided to the system in sufficient quantity to induce contaminant migration.

In general, petroleum hydrocarbons, chlorinated VOCs, and chlorinated semivolatile organics were detected in the soils sampled from the five boreholes (BH-10, BH-12, BH-22, BH-23, and BH-26) located in the former northern and southern liquid waste lagoons. Samples from hydrocarbon residue and stained soil showed BTEX, eight chlorinated VOCs, and two chlorinated semivolatile organic compounds to be present in soils. Benzene was only detected in soils in borehole BH-23, located in the former northern liquid waste lagoon. Toluene, ethylbenzene, and xylene were detected in soils in boreholes BH-10, BH-12, and BH-23. Borehole BH-22 showed toluene and ethylbenzene to be present in soils. Borehole BH-23 was determined to be the most contaminated borehole of the five located within two former liquid waste lagoons, with BTEX concentrations ranging from 1,600 μg/kg (benzene) to 190,000 μg/kg (xylene).

Soils sampled from the southern lagoon were generally not as contaminated as the northern lagoon sediments. Only one petroleum hydrocarbon, toluene, was found to be present in soils sampled from the stained area at 1.2 to 1.9 ft below ground surface. Two chlorinated VOCs were detected. No chlorinated semivolatile organic compounds were detected in the stained area.

Borehole BH-13, located in the southern part of the former landfill, also contained hydrocarbon residue. The occurrence of the residue indicated the possible presence of a small liquid waste disposal area that has not been previously identified. Air photos and inspection reports do not indicate or mention liquid waste disposal in that portion of the landfill.

Sources for the petroleum hydrocarbons in the lagoons were probably produced waters from formations containing oil or natural gas. Historical data indicate that disposal of produced waters in the lagoons was prevalent from 1980 to 1985 during landfill operations (Appendix B). Chlorinated VOCs may have been introduced from a number of sources including industrial, household, and agricultural waste or drilling operations. In addition, 1,4-dichlorobenzene, detected in BH-23, is used as an insecticide/germicide (Sax and Lewis 1987). The presence of these contaminants in groundwater and their affect on water quality are discussed in Section 6. In addition, these data characterize the remaining source at the former Lee Acres Landfill.

In addition to organic constituents, Table 5-9 lists the inorganic results from hydrocarbon-stained sediments sampled from boreholes. By comparison, these chloride concentrations are considerably lower than those measured in the 1985 lagoon sampling. This may be explained by the fact that chloride is a conservative element, and should travel with the groundwater without being adsorbed on sediments or being chemically bound. Sulfate concentrations are also low, relative to lagoon and groundwater samples. EP Toxicity metals were found to be generally low in concentration and limited in occurrence. Strontium was detected in all five boreholes located in the two former liquid waste lagoons. Other than strontium, only selenium (BH-23) and barium (BH-26) were detected in the boreholes.

5.2.3. Contaminants of Concern

COCs have been identified in two ways. Concentrations of contaminants detected in soil samples have been compared to proposed RCRA soil action levels (55 FR 30865), and concentrations of contaminants detected in lagoon and lysimeter samples have been compared to New Mexico HHSs (Section 3-103.4) or proposed/promulgated SDWA MCLs (40 CFR 141). If any contaminants were found to exceed the levels specified under RCRA, SDWA, or the state, they were identified as COCs. Secondly, if the contaminants were found to have no specified levels under RCRA, SDWA, or the state, they were also identified as COCs.

5.2.3.1 1985 Liquid Waste Lagoon Sampling

Twelve VOCs were identified as COCs (Table 5-13). Six of these contaminants were identified on the basis of regulatory exceedance. The other six were identified because they did not have SDWA MCLs or state regulatory levels specified. The sampling locations referred to below were all located in the former northern liquid waste lagoon. The locations described were those given by the NMOCD and the NMEID during the 1985 lagoon sampling events.

2-Propanol, 2-pentene, acetone, methylcyclohexane, hexamethylcyclotrisiloxane, and octamethylcyclotetrasiloxane were all detected in liquid samples from the Waste Disposal Pit. None of these contaminants are regulated under the SDWA or the state. 1,1,1-TCA and dichloromethane were detected in liquid samples from Lagoon Pit, East Side Lagoon, and West Side Lagoon. Benzene was detected in samples from Lagoon Pit, East Side Lagoon, West Side Lagoon, Waste Disposal Pit, and Lagoon-South Pump. PCE and m-xylene were detected in samples from West Side Lagoon and East Side

Lagoon. Toluene as detected in samples from Lagoon Pit, East Side Lagoon, West Side Lagoon, and Waste Disposal Pit. These contaminants were found to exceed specified MCLs or state regulatory levels at one or more of the sampling locations (Table 5-13). No semivolatile organic compounds, pesticides, or PCBs have been identified as COCs from the 1985 northern liquid waste lagoon sampling events.

Eight total metals have been identified as COCs (Table 5-14). Boron and selenium were detected in samples from Lagoon-South Pump. Iron and manganese were also present in samples from Lagoon-South Pump and south Pond in concentrations that exceed secondary MCLs. Chromium, iron, and manganese were detected in samples from Lagoon Pit, East Side Lagoon, and West Side Lagoon. Lead was detected in samples from East Side Lagoon and West Side Lagoon. Selenium was also detected in samples from Lagoon Pit, East Side Lagoon, West Side Lagoon, and Lagoon-South Pump. These six metals were present in concentrations above specified MCLs or state regulatory levels at one or more of the sampling locations. Silicon and strontium were detected in samples from Lagoon Pit, East Side Lagoon, West Side Lagoon, Lagoon-South Pump, and South Pond (Table 5-14). Neither of these metals are regulated under SDWA or the state.

Bicarbonate, chloride, and sulfate were detected at all lagoon sampling locations. Bicarbonate concentrations ranged from 54 mg/L to 476.1 mg/L, chloride concentrations ranged from 540.3 mg/L to 4,474.5 mg/L, and sulfate concentrations ranged from 40.2 mg/L to 1,881 mg/L (Table 5-14). Chloride and sulfate concentrations present in samples from all lagoon sample locations were below state water quality standards and SDWA MCLs. Bicarbonate was identified as a COC because no state or SDWA standard exists.

5.2.3.2. Lysimeter Sampling

Three VOCs were identified as COCs (Table 5-11). Benzene was detected in lysimeter LS-5. It was present at a concentration above the SDWA MCL, but below the New Mexico HHS regulatory level. 1,3-*cis*-Dichloropropene and dichlorodifluoromethane were detected in samples from lysimeter LS-5. In addition, dichlorodifluoromethane was also detected in lysimeter LS-7. Neither of these contaminants are regulated under SDWA or the state. No semivolatile organic compounds, pesticides, or PCBs were detected in any of the samples from the lysimeters. Metal analyses were not performed on lysimeter samples.

Bicarbonate, bromide, chloride, and sulfate were detected in samples from lysimeter LS-5 (Table 5-12) Chloride and sulfate concentrations were below state and SDWA standards. Bicarbonate and bromide however, were identified as COCs because no state or SDWA standards exist for these two inorganics

5.2.3.3. Borehole Sampling Program

COCs identified from soils sampled in the five boreholes located in the two former liquid waste lagoons (BH-10, BH-12, BH-22, BH-23, and BH-26) are discussed in subsection 5.1.3. COCs in soils sampled from borehole BH-13 are discussed in the same subsection.

5.3. ARROYO ADJACENT TO LANDFILL

In May 1991, six boreholes (BH-48 through BH-53) were drilled to bedrock in the unnamed arroyo west of the former landfill (Figure 5-11). The purpose of the boreholes was to determine if the arroyo has acted as a transport pathway for contaminants. The boreholes were placed along the entire length of the western portion of the landfill, 300 ft apart. Subsection 2.4 presents the technical rationale, methodology, and frequency of the RI borehole sampling program. Subsurface lithologies for the six boreholes are presented in Appendix H.

5.3.1. Physical Description

The unnamed arroyo lies adjacent to the former Lee Acres Landfill on the west side (Figure 5-11). It trends north-south and roughly parallels the western fenceline of the landfill. The arroyo originates in the high mesa (locally referred to as Crouch Mesa) and terminates just south of U.S. 64 where deposits from the arroyo have formed an alluvial fan at the San Juan River, a distance of 5.4 stream miles (see subsection 4.1.3). The arroyo drains approximately 3,800 acres (WESTON 1990i). Surface water within the unnamed arroyo exists as ephemeral streams that flow only after a significant rainfall event. The surface runoff within the unnamed arroyo flows ultimately to the San Juan River, its point of termination.

A flood event occurred in the unnamed arroyo in August 1989. The former landfill was eroded at one location; therefore, corrective action was necessary to prevent further damage to the landfill and potential releases via the surface water. Erosion protection measures in the form of gabions were constructed along the northwestern and southwestern corners of the former landfill (Figure 4-14). It was not known whether contaminants from the landfill had been washed into the arroyo by erosion and subsequently transported by surface water, or whether contaminants were migrating from the landfill with surface water into the arroyo. Therefore, the six boreholes discussed above were drilled in the unnamed arroyo to determine whether contamination was present. The results of the investigation are discussed below.

5.3.2. Chemical Nature of Arroyo Soils

Samples from the six arroyo boreholes were analyzed for VOCs (EPA Methods 8010 and 8020), semivolatile organics (EPA Method 8270), pesticides/PCBs (EPA Method 8080), TCLP metals, chloride, and sulfate. The soil borehole analytical program is discussed in detail in subsection 2.4. The analytical results are presented in Appendix I-1 and in subsection 5.3.2.1 below. In addition to the soil samples from the six boreholes, a surface sample was taken from a crusted, black-layer located beneath an old car that had been exposed by erosion at the northwest corner of the former landfill.

5.3.2.1. Volatile Organic Constituents

Dichloromethane and toluene were the only two VOCs detected in the six boreholes. Borehole BH-48 showed dichloromethane and toluene to be present in soils from 5 to 5.5 ft at 23 µg/kg and 1 µg/kg, respectively (Appendix I-1 and Table 5-15). Dichloromethane was detected in BH-49 in the ten samples collected approximately every 5 ft from 1 to 45.8 ft at concentrations ranging from 9.3 µg/kg to 52 µg/kg. Toluene was detected in soils from 26.5 to 27 ft, and 31 to 31.5 ft at concentrations ranging from 1.2 µg/kg to 1.6 µg/kg (Appendix I-1 and Table 5-15). Dichloromethane was detected in BH-50 soils in ten samples collected from 1.5 to 46 ft. Concentrations ranged from 13 µg/kg to 56 µg/kg (Appendix I-1 and Table 5-15). Borehole BH-51 showed dichloromethane to be present from 48 to 48.5 ft and 44 µg/kg. Borehole BH-52 showed dichloromethane to be present from 31.5 to 32.5 ft, 37 to 37.5 ft, and 44 to 44.5 ft. Concentrations at these depths ranged from 17 µg/kg to 30 µg/kg. Toluene was detected at 18.5 to 19 ft, 22.5 to 23 ft, and 29 to 29.5 ft. Concentrations ranged from 1.5 µg/kg to 2.1 µg/kg (Appendix I-1 and Table 5-15). Borehole BH-53 showed dichloromethane to be present in soils from 2 to 2.5 ft, 6.5 to 7 ft, 12.5 to 13 ft, 18.5 to 19 ft, 21 to 21.5 ft, 45 to 45.5 ft, and 48.5 to 49 ft. Concentrations at these depths ranged from 7.6 µg/kg to 28 µg/kg (Appendix I-1 and Table 5-15). None of the VOCs detected were present in sufficient concentrations to exceed proposed RCRA soil action levels.

5.3.2.2. Semivolatile Organic Constituents

No semivolatile organic compounds were detected in soils from the six boreholes in the arroyo (BH-48 and BH-53). Semivolatile organics were detected in the surface soil sample (0 to 0.1 ft) collected from beneath the old car. The sample showed 2-methylaphtalene to be present at 3,900 µg/kg, anthracene at 2,700 µg/kg, chrysene at 2,600 µg/kg, and phenanthrene at 7,200 µg/kg (Table 5-16). No proposed RCRA soil action levels exist for these four contaminants.

5.3.2.3. Pesticides/PCBs

No pesticides or PCBs were detected in soils from the six boreholes in the arroyo (BH-48 through BH-53). One pesticide was detected in the surface soil sample (0 to 0.1 ft) collected from beneath the old car. Beta-BHC was found to be present at 1,200 µg/kg (Table 5-16). No proposed RCRA soil action level exists for this contaminant.

5.3.2.4. Inorganic Constituents

Sulfate was detected in all six of the boreholes located in the unnamed arroyo. Concentrations ranged from 28.7 µg/kg in BH-51 to 436 µg/kg in BH-50. Chloride was detected in only one borehole, BH-52, at a concentration of 35.2 µg/kg (Table 5-17). No proposed RCRA action levels exist for either sulfate or chloride in soils.

TCLP metal analyses showed barium and strontium to be present in soil samples from all six boreholes (BH-48 through BH-53). Mercury was also detected in BH-51. Table 5-17 presents a summary of the TCLP metal results.

Barium concentrations in the six boreholes ranged from 0.201 mg/L in BH-50 to 2.01 mg/L in BH-48. Strontium concentrations in the six boreholes ranged from 0.357 mg/L in BH-49 to 3.74 mg/L in BH-50. Mercury was present in BH-51 at concentrations ranging from 0.00022 mg/L to 0.00037 mg/L. The TCLP regulatory levels for barium and mercury are 100 mg/L and 0.2 mg/L, respectively. No TCLP regulatory level for strontium exists (Table 5-17).

5.3.3. Contaminants of Concern

Two VOCs were detected in the six boreholes (BH-48 through BH-53) located in the unnamed arroyo west of the landfill. Dichloromethane was detected in all six of the boreholes and toluene was detected in three of the boreholes (BH-48, BH-49, and BH-52) (Table 5-15). The highest concentration of dichloromethane detected was 56 µg/kg, more than three orders of magnitude less than the proposed RCRA action level of 90,000 µg/kg (55 FR 30865). The highest concentration of toluene detected, 2.1 µg/kg, is about seven orders of magnitude less than the proposed RCRA action level of 20,000,000 µg/kg (55 FR 30865). It is apparent that neither of these compounds approach proposed RCRA action levels and, therefore, are not considered to be COCs (Table 5-15).

The four semivolatile compounds (2-methynaphthalene, anthracene, chrysene, and phenanthrene) and the pesticide (Beta-BHC) detected in the surface sample taken from beneath the old car have been listed as COCs because no proposed RCRA action level exists for these five compounds (Table 5-16).

Barium, which was detected in all six of the arroyo boreholes (BH-48 through BH-53), and mercury, which was detected in BH-51, are not listed as COCs because neither metal exceeds the TCLP regulatory level. The highest concentration of barium detected was 2.01 mg/L. The TCLP regulatory level for barium is 100 mg/L, about two orders of magnitude greater than the highest barium concentration detected. The concentration of mercury detected in BH-51 soils (0.00037 mg/L) was three orders of magnitude less than the TCLP regulatory level of 0.2 mg/L (Table 5-17). Strontium, detected in all six of the arroyo boreholes (BH-48 through BH-53), has been listed as a COC because no TCLP regulatory level exists for this metal (Table 5-17).

Both chloride and sulfate were identified as COCs because no RCRA action levels exist for these two inorganics (Table 5-17). Sulfate was detected in all six of the boreholes sampled in the unnamed arroyo. Chloride was detected in only one of the six boreholes sampled in the arroyo.

5.4. MATERIALS OF CONCERN BOUNDARIES AND VOLUMES

5.4.1. Discussion of Parameters

The materials of concern within the former Lee Acres Landfill are separated into two types: solid waste and contaminated soil and waste. Solid waste is considered to be solid material hauled to the landfill as waste. Examples of solid waste materials are paper, plastics, glass, metal objects, and building materials. Some of the solid waste may be contaminated, but soil was included as solid waste only if soil was mixed with solid waste or covered solid waste. Contaminated soil and waste is defined as soil and solid waste contaminated by any of the COCs identified in subsections 5.1 through 5.3 and summarized in subsection 5.6. Soil contamination was determined by analysis of the results of geochemical tests conducted on soil samples collected from boreholes and wellbores identified in subsection 2.4. Analytical results are presented in Appendix I-1.

Two scenarios have been developed that provide preliminary estimates of the volumes of materials of concern. For the conservative scenario, a positive result above laboratory detection limits results in the assumption that contaminated soil or solid wastes have been found. The second scenario incorporates concentrations identified as present below laboratory detection limits ("J" values). The inclusion of these "J" values in determining volumes of contaminated soil and solid wastes results in the development of a worst-case scenario. An estimate of any volume of material that may be removed as part of a selected remedial action will be based upon the final soil ARARs and will be completed as part of the FS.

The estimates of the volumes of solid waste and contaminated soil and waste are dependent upon borehole logs (Appendix H), well logs (Appendix L), subsurface geology profiles (Plates 6a and 6b), positive results of organic analysis (Appendix I-1), and air photo and geophysical data analyses (Figure 2-7). The lateral and vertical extents of solid waste and contaminated soil and waste are estimated in this section as accurately as possible, given available data. By careful examination of existing data, solid waste is geographically distributed according to similar waste types. The distribution of waste at the former Lee Acres Landfill was neither mapped nor recorded at the time of placement, so volumes are estimated from areas and depths of solid waste determined by analysis of data from the sources mentioned above.

5.4.2. Method of Volume Calculation

The solid waste and contaminated soil and waste volume estimates involve identification of geographic areas and maximum depths of solid waste and contamination within the soil matrix of the former Lee Acres Landfill. Three steps used in this process are as follows:

1) Examine the primary quantitative data.
    - a) Borehole logs
    - b) Well logs
    - c) Geochemical data

These data are used to determine the maximum depth of solid waste and contaminated soil and waste at known locations. Also, these data are used as support data for step 2.

2) Examine secondary qualitative data.
    - a) Air photo data
    - b) Geophysical data

The geographic distribution of solid waste and soil contamination is estimated from analysis of data listed above.

3) Examine qualitative and all other remaining data to determine relationships between depths and areas of solid waste and contaminated soil and waste. Also, identify areas where contaminated materials and solid wastes were not found.
    - a) Subsurface geology profiles

Borehole logs, well logs, and geochemical data are considered primary quantitative data because exact locations of boreholes and wells are surveyed and exact depths of soil samples and lithology are recorded. Air photos are considered secondary data because of a lack of available air photos over the entire operational history of the landfill. Geophysical data are considered less defined because of the less descriptive nature of a conductive anomaly as opposed to a borehole log or geochemical sample in identifying solid waste or a chemical contaminant. While the air photo and geophysical data are less defined, on a large-scale examination the data proved valuable to the process of estimating the distribution of post-1962 solid waste placement.

The areas used to define contaminated soil and waste and solid waste volumes are divided into simple polygons to simplify area and volume estimation. An average depth is then determined for each polygon, based on available data within and around each polygon. The average depth for solid waste polygons is determined by polygon proximity to boreholes where solid waste depths are known from borehole logs. The average depth for contaminated soil and waste polygons is also determined by polygon proximity to boreholes and wells where geochemical samples were taken. The deepest positive value based on laboratory geochemical data at a wellbore or borehole is assumed to be the maximum depth of contamination at that location for the conservative contaminated soil or solid waste volume scenario. For the worst-case contaminated soil or solid waste volume scenario, all laboratory geochemical data is considered. The depth of contamination for this scenario will be determined by the deepest geochemical value encountered at a borehole or wellbore location, whether it be a value above laboratory detection limits (positive result) or an estimated value below detection limits ("J"). All material above the deepest detected contaminant will be assumed to be contaminated for both scenarios. The depths used for volume estimates are extended one ft to ensure that the estimates include all solid waste placed at the former Lee Acres Landfill.

5.4.3. Results

5.4.3.1. Conservative Volume Scenario

The estimated geographic distributions of areas of contaminated soil and solid waste are shown on Figures 5-12 and 5-13, respectively. Subsections used to estimate polygon volumes are shown on Figures 5-13 and 5-14. Table 5-18 lists solid waste depths, bedrock depths, contaminated soil depths for each borehole in the former landfill, and depths used for each volume calculation. Table 5-19 shows volume calculation details for all contaminated soil and waste subsections. Table 5-20 shows volume calculation details for all solid waste subsections.

The volume of contaminated soil and waste is estimated to be 600,000 cubic yards. Figure 5-12 shows five different areas of the contaminated material: Areas A, B, C, D, and E. Each area exhibits data patterns that are considered unique to that area. A discussion of each area is give below.

Area A contains boreholes BH-13, BH-14, BH-15, and BH-16. Assumptions used in Area A, the southernmost area on Figure 5-12, are as follows:

1) The surface layer of artificial fill is contaminated material.
2) An estimated 40,000 square-foot area, located around BH-13, is contaminated to bedrock depth.

Assumption 1 is justified because of a number of chlorinated VOCs were present above detection limits in the alluvial cover at each borehole site. At BH-14 and BH-15, the fill contains solid waste, so the extent of the contaminated material is considered to be the bottom of solid waste. Assumption 2 is justified because BH-13 shows chlorinated VOCs to 34 ft, which is 11 ft below the top of bedrock. Figure 2-7 shows a conductive anomaly at BH-13, and it is assumed that the anomaly approximates the extent of the deep contamination. Since bedrock is not included in the volume calculations, depth to bedrock is used.

Area B, which contains boreholes BH-18 and BH-26 (Figure 5-12), includes the former southern liquid waste lagoon area. Generally, Area B contamination occurs at less than 16 ft below ground surface. However, BH-18 has a lithology similar to BH-19 in Area C, and BH-19 shows contamination at 44 ft. Drilling at BH-18 was terminated at 10 ft due to an unpassable wire mass. To maintain continuity of depth in the volume calculation, the depth of contamination at BH-18 is assumed to be at the top of bedrock at 47 ft.

Area C includes boreholes BH-10, BH-12, BH-19, BH-21, BH-22, BH-23, and BH-24, and BLM-53 and BLM-57. Area C includes the former northern liquid waste lagoon and berm area. BH-10, BH-12, BH-22, and BH-23 are located in the north lagoon area, and BH-19 and BH-24 and BLM-53 and BLM-57 are located in the berm area to the south of the lagoon. The assumptions used for Area C are as follows:

1) All positive results of BTEX are related.
2) The excavated area noted in Figure 1-5 is cleared of all contaminated material.

The former northern liquid waste lagoon was sampled in 1985 before the liquid evaporated or was covered and BTEX contaminants were found in the samples (see subsection 5.2.2). Boreholes BH-24 and -21 are located at previous berm breach areas. Boreholes BH-19 and BLM-53 show BTEX concentrations that suggest migration of BTEX from the lagoon area. Therefore, assumption 1 is justified. Assumption 2 is justified because geochemical samples from boreholes BH-17 and -28 did not show positive results, and air photos taken between 1981 and 1986 show an excavated area where BH-17 and BH-28 are located (Figure 1-5).

Area D, located in the northeast area of the former landfill (Figure 5-12), contains boreholes BH-3, BH-4, BH-5, BH-6, BH-9, and BH-11. Assumptions used in area D are as follows:

1) Area D is contaminated to bedrock.

2) The geophysical anomalies noted on Figure 2-7 in the northeast area of the landfill indicate the lateral extent of the contaminated material.

3) Trenches in areas shown on Figure 1-5 were constructed 12-ft deep (the depth specified in the 1980 development and operational plan [SJC 1980]).

Boreholes BH-3, BH-4, BH-5, BH-6, and BH-11 show contamination in solid waste, and the bottom of solid waste depth in each hole is down to bedrock. BH-9 reveals contamination at the bedrock alluvium contact. The conductive anomalies in this area indicate solid waste or contaminated material at all borehole locations except BH-9. The southern and northern boundaries of this area are located at bedrock. The northern boundary is placed at BH-9 where contamination is measured, so a depth of contaminated soil and waste can be assumed. The southern boundary does not show contamination. All waste trenches in Area D are cut into bedrock and are assumed to be 12 ft deep, as specified in the 1980 development and operational plan (SJC 1980). Therefore, the vertical boundary for Area D is assumed to be bedrock.

Area E includes BH-27, east of the excavated area shown on Figure 1-5. Toluene and PCE were measured to 9 ft in BH-27. Since the contaminated soil appears to be mixed with solid waste at BH-27, and the solid waste extends vertically to bedrock depth at 12 ft below the ground surface, the depth of contamination is assumed to be at the top of bedrock. Figure 2-7 shows a conductive anomaly that is representative of the lateral extent of the contamination.

The total volume of solid waste at the former Lee Acres Landfill is estimated at 390,000 cubic yards. All of the solid waste is considered contaminated except an estimated 10,000 cubic yards of uncontaminated solid waste found in isolated locations at the former landfill. Therefore, the contaminated solid waste volume is estimated at 380,000 cubic yards. Figure 5-14 shows the areas used for the volume calculation, and Table 5-20 shows the depth to the bottom of solid waste at each borehole. The calculation method was the same method used for the contaminated soil and waste, consisting of area polygons of an average depth added together for a total volume.

The total volume of the materials of concern is the sum of the contaminated soil and waste and the uncontaminated solid waste. The estimated volume of the contaminated soil and waste is 600,000 cubic yards. This total includes the contaminated solid waste volume (approximately 380,000 cubic yards) and the contaminated soil volume (approximately 220,000 cubic yards). The uncontaminated solid waste volume is estimated at 10,000 cubic yards. Therefore, the sum total of the volumes of the materials of concern at the former Lee Acres Landfill for the conservative scenario is estimated to be 610,000 cubic yards.

5.4.3.2. Worst-Case Volume Scenario

The estimated geographic distributions of areas of contaminated soil and solid waste are shown on Figures 5-15 and 5-13, respectively. Subsections used to estimate polygon volumes are shown on Figures 5-13 and 5-16. Table 5-21 lists solid waste depths, bedrock depths, contaminated soil depths for each borehole in the former landfill, and depths used for each volume calculation. Table 5-22 shows volume calculation details for all contaminated soil and waste subsections. Table 5-20 shows volume calculation details for all solid waste subsections.

The volume of contaminated soil and waste is estimated to be 800,000 cubic yards. Figure 5-15 shows six different areas of contaminated materials: Areas A, B, C, D, E, and F. Areas A through E were also identified in the conservative volume scenario. In addition to the five areas of contaminated materials identified in the conservative volume scenario, a sixth area of contaminated material has been identified in the worst-case scenario based on estimated concentrations of contaminants that were present below detection limits. Area F is located in the far northeastern portion of the former landfill and contains boreholes BH-01, BH-02, and BH-07 (Figure 5-15).

Boreholes BH-01, BH-02, and BH-07 show contamination extending into bedrock in Area F, as determined by geochemical analyses of soil samples taken from each of the boreholes (Table 5-21). Since bedrock is not included in the volume calculations, depth to bedrock is used. No solid waste was encountered in any of the three boreholes. No conductive waste anomalies were identified in Area F (Figure 2-7); however, EM-31 and magnetometer geophysical surveys showed metal debris to be spread throughout the area (Figure 2-1). Borehole BH-01 showed benzoic acid to be present at a depth of nine ft. 4,4'-DDT and diethyl phthalate were present in BH-02 at 4 ft, and 4,4'-DDT was detected in BH-07 at a depth of 2 ft (Appendix I-1). The depth to bedrock in each of these boreholes ranges from zero to 1.8 ft (Table 5-21). Several differences in maximum contaminant depth from the conservative volume scenario have been noted in the worst-case volume scenario. Boreholes BH-15 and BH-16 in Area A; borehole BH-26 in Area B; boreholes BH-12, BH-21, and BH-24 in Area C; borehole BH-11 in Area D; and boreholes BH-17, BH-20, BH-25, BH-27, BH-28, and BH-29 in Area E showed increased depths of contaminants in the subsurface (Table 5-21). The increased depths, as discussed previously, are the result of consideration of contaminants present in soils and waste at concentrations less than the detection limit. These contaminants are denoted in

Appendix I-1 with a "J". The assumptions detailed in the conservative volume scenario for Areas A, C, and D are also justified in the worst-case scenario.

The total volume of the materials of concern is the sum of the contaminated soil and waste and the uncontaminated solid waste. The estimated volume of the contaminated soil and waste is 800,000 cubic yards. This total includes the contaminated solid waste volume (approximately 380,000 cubic yards) and the contaminated soil volume (approximately 420,000 cubic yards). The uncontaminated solid waste volume is estimated at 10,000 cubic yards. Therefore, the sum total of the volumes of the materials of concern at the former Lee Acres Landfill for the worst-case scenario is estimated to be 810,000 cubic yards.

5.4.4. Summary

Two scenarios were developed for the determination of the volumes of the materials of concern at the former Lee Acres Landfill. The conservative scenario included only concentrations of contaminants at depth that were at or above laboratory detection limits for volume determination. The worst-case scenario included all geochemical data. The greatest depth at which contamination was encountered, whether a concentration above detection limits or an estimated concentration ("J") below detection limits, was used for volume determination.

The conservative scenario provided a total of 610,000 cubic yards of contaminated soil and waste, and the worst-case scenario provided a total of 810,000 cubic yards of contaminated soil and waste.

The volume of solid waste is estimated to be 35 percent less than the volume of contaminated soil and waste because:

- The solid waste placed in the southern area of the former landfill is assumed to be covered and mixed with contaminated soil that is spread over a larger area than that in which the solid waste was placed. The solid waste is not considered contaminated.

- The excavated area shown in Figure 1-5 is completely free of solid waste, and no solid waste was identified during the drilling of BLM-53.

- The area of geophysical conductive anomalies that indicates solid waste in Area D is smaller than the area of anomalies that indicates contaminated soil.

- The solid waste depth is shallow compared to the depth of contaminants in all areas of the former landfill except for the following two isolated locations: 1) the dead animal pit along the north edge of the landfill, and 2) an area where solid waste and septic material were excavated out of the unnamed arroyo and placed near the BH-12 location.

The volume of the uncontaminated solid waste at the dead animal pit north of BH-9 is estimated to be 10,000 cubic yards. The volumes of solid waste, contaminated soil and waste, and materials of concern at the former Lee Acres Landfill are all estimated values. The uncertainty in the calculations results from the unplanned, non-uniform distribution of the solid waste. RI activities presented in Section 2 provide data to determine the lateral and vertical extents of the solid waste boundaries. The error acceptable by data collection standards leads to the uncertainty in the volume calculations.

5.5. NATURE AND EXTENT OF SUBSURFACE LANDFILL GASES

During the RI at the former Lee Acres Landfill, an extensive air sampling program was performed within the boundaries of the landfill. Results of the air monitoring program show that the quantities of subsurface landfill gases currently being released do not approach regulatory standards. However, during RI drilling activities, a number of gases were detected in the landfill subsurface using hand-held field instruments. This section provides an assessment of the nature and extent of these gases, as well as the vapor distribution, and the chemical nature of the gases within the landfill.

5.5.1. Physical Occurrence of Subsurface Landfill Gases

Figure 5-17 shows the estimated distribution of positive vapor readings detected within the landfill boundaries measured during the RI investigation. Three instruments were used to monitor subsurface landfill gases during intrusive RI activities: 1) an organic vapor analyzer (OVA), 2) a combustible gas indicator (CGI), and 3) an HNu meter. A hydrogen sulfide (H_2S) meter was also used during all intrusive activities; however, no positive readings were recorded. Each of the instruments mentioned above is unique to the type of vapor it detects. The OVA is a flame ionizer used for detection of total organic vapors (lower chain hydrocarbons) and methane. The CGI is used to monitor percent of the lower explosive limit and percent oxygen. The HNu is a photoionizer used for detection of total organic vapors (higher chain hydrocarbons), and the H_2S meter is used specifically for detection of hydrogen sulfide.

The readings obtained from each of the four instruments are not exact. Factors either limiting or affecting instrument readings are:

- The instruments are not chemical specific (except for the H_2S meter).
- Friction within the borehole, resulting from drilling, produces heat that may volatilize contaminants present in the soil.
- The vapor density for a chemical may be heavier than air and may not migrate to the surface where they can be detected.

- Residual contamination may remain in the auger string from shallower depths resulting in false readings at greater depths.

Although the primary function of these screening instruments was for establishing levels of protection for personnel, they did provide information on the general distribution of gases encountered within the landfill subsurface.

During drilling activities, measurements were taken with each of the four instruments at five foot intervals in the breathing zone, at the surface of the borehole, and inside the auger string. Table 5-23 shows the results of instrument readings with depth for each borehole and wellbore drilled within the boundaries of the landfill. Subsurface soil samples were also screened to identify trapped gases within the soil matrix. These combined techniques allowed for the general determination of contaminated subsurface soils and soil gases within the former landfill.

5.5.2. Chemical Nature of Subsurface Landfill Gases

Three gases, methane, solvent vapor, and hydrogen sulfide, were identified in subsurface soils within the landfill boundaries during intrusive activities under the RI. The methane, solvent vapor, and hydrogen sulfide profiles for boreholes and wellbores within the landfill boundaries are shown in Appendix U. Methane ("marsh gas," CH_4) was detected in soils in boreholes BH-03, BH-05, BH-06, BH-11, BH-12, BH-13, BH-15, BH-16, BH-18, BH-22, BH-23, BH-24, BH-29, and in wellbore BLM-57. Depths at which methane was detected in these boreholes ranged from 6 to 53 ft (Appendix U). Solvent vapor was detected in boreholes BH-12, BH-17, BH-18, BH-20, BH-23, BH-24, and BH-26 at depths ranging from 0 to 32 ft (Appendix U). Hydrogen sulfide was detected in only one borehole, BH-19, from 14 to 47 ft (Appendix U). The estimated areal distribution of methane, solvent vapor, and hydrogen sulfide detected in soils within the landfill boundaries is shown in Figure 5-18. The vertical distribution of methane, solvent vapor, and hydrogen sulfide in soils at boreholes and wellbores located within the former landfill is shown in Appendix U.

The areal distribution of methane is broad (Figure 5-18). It was detected in a majority of the boreholes in the western half of the western portion of the landfill. In addition, it was present in soils in the vicinity of the former northern liquid waste lagoon as well as in the soils in the center of the eastern portion of the former landfill.

The areal distribution of solvent vapor is much more limited in extent within the landfill boundaries than methane (Figure 5-18). Solvent vapors appear to be limited to soils directly in and immediately around the former northern and southern liquid waste lagoons.

Hydrogen sulfide was detected in only one borehole, BH-19, within the landfill boundaries. The borehole is located just north of the former southern liquid waste lagoon, which might account for the presence of hydrogen sulfide; however, none of the other boreholes located either directly in or adjacent to the two former liquid waste lagoons showed any presence of hydrogen sulfide in soils during intrusive activities.

In summary, the following boreholes and wellbores showed no detectable concentrations of gases to be present in subsurface landfill soils, as determined by the OVA, CGI, HNu, and the H_2S meter during RI intrusive activities: BH-01, BH-02, BH-04, BH-07, BH-08, BH-09, BH-14, BH-21, BH-25, BH-27, B-28, BLM-54, BLM-56, BLM-53.

In general, the areal extent of methane gas in the landfill subsurface is broadly distributed. It was detected in 13 boreholes and one wellbore during drilling. Methane is produced from the degradation of organic domestic wastes, and its occurrence in subsurface landfill soils has been attributed to this type of degradation. Overall, methane was found to be present in soils where bulk solid waste cells were generally located (Figures 1-3, 1-4, and 1-5).

Solvent vapors in subsurface landfill soils were determined to be less extensive than methane, and were generally present in soils either directly in or adjacent to the former northern and southern liquid waste lagoons. Boreholes located directly in the former liquid waste lagoons showed lagoonal sediments (sand and sludge mix) containing elevated vapor readings believed to consist mainly of lighter chain hydrocarbons (solvents vapors). Soils from boreholes adjacent to the former liquid waste lagoons showed solvent vapors to be present as well. These vapors have been generally attributed to remnant contamination from the former lagoons.

Hydrogen sulfide was detected in only one borehole. Its occurrence at this one location may be attributed to the former southern liquid waste lagoon since it is located just to the north. This seems to be unlikely, though, because none of the other boreholes or wellbores located directly in or immediately around the two former liquid waste lagoons show hydrogen sulfide to be present in subsurface soils.

Because gases are most frequency released from the landfill when the subsurface is disturbed, any remedial actions that involve the excavation or removal of landfill soils and wastes will consider all risks associated with the release of these gases from the subsurface.

5.6. SUMMARY OF CONTAMINANTS OF CONCERN FOR OPERABLE UNIT 1

The data used to identify COCs for OU 1 include RI soil boring data from 29 boreholes drilled in the former landfill (BH-01 through BH-29) and six boreholes drilled in the unnamed arroyo adjacent to the landfill (BH-48 through BH-53), from soil samples from 11 wellbores installed within and along the western landfill fenceline (BLM-33 through BLM-35, BLM-41, BLM-44, BLM-47, BLM-50, BLM-53, BLM-54, BLM-56, and BLM-57) and one wellbore drilled in the unnamed arroyo adjacent to the former landfill (BLM-59), and from four lysimeters installed within the landfill (LS-3, LS-5, LS-6, and LS-7) (Figure 5-11). The contents of the northern liquid waste lagoon were sampled in 1985 by the NMOCD and the NMEID. In addition, four boreholes were drilled in and adjacent to the unnamed arroyo (BH-35 through BH-38). These boreholes were not sampled, but were used to define stratigraphy. Geophysics and CPTs were also performed in the former landfill and in the unnamed arroyo adjacent to the landfill. COCs were not identified based on CPTs or geophysics because these methods are not intended for that purpose.

Soil and lagoon sediment samples collected from the former landfill were analyzed in the laboratory for VOCs, semivolatile organics, pesticides, PCBs, inorganics (chloride and sulfate), total metals, and EP Toxicity metals. In addition, vadose zone moisture was sampled in the landfill from lysimeters located within the former northern and southern liquid waste lagoons (Figures 5-10 and 5-11). Samples obtained from the lysimeters were analyzed for VOCs, semivolatile organics, and inorganics. Samples taken from the northern liquid waste lagoon in 1985 by the NMOCD and the NMEID were analyzed for pH, specific conductivity, TDS, metals, major inorganic ions and other organic constituents. Soil samples from the unnamed arroyo adjacent to the former landfill were analyzed for VOCs, semivolatile organics, pesticides, PCBs, inorganics (sulfate and chloride), and TCLP metals. The criteria used for identification of COCs depended upon the type of laboratory analysis being performed and the sample matrix.

For soils, COCs were identified on the basis of a comparison of the laboratory analytical results with proposed RCRA action levels (55 FR 30865). Any contaminants detected in soil samples that were present above proposed RCRA action levels were identified as COCs.

For EP Toxicity metals and TCLP metals in soils, COCs were identified on the basis of a comparison of the laboratory analytical results with TCLP regulatory standards (55 FR 26986-26988). Any contaminants detected above the TCLP regulatory standards were identified as COCs.

For the northern liquid waste lagoon samples collected in 1985 (McQuillan and Longmire 1986 and NMEID 1985a) and vadose zone moisture samples collected from lysimeters, COCs were identified on the basis of a comparison of the laboratory analytical results with promulgated or proposed federal standards (SDWA MCLs) (40 CFR 141) and the New Mexico HHS (Section 3-103.A). Comparison was first based on the New

Mexico state regulations. If no New Mexico standard existed, then a comparison with the SDWA MCLs was made. Any contaminants that were detected above New Mexico standards or SDWA MCLs were identified as COCs. It is questionable as to what standard should be used from comparison with 1985 liquid waste lagoon sample results. It was determined that since the 1985 samples from the northern waste lagoon were liquid, and were analyzed as liquid, they should be compared to liquid (or water) standards even though presently no liquid remains in the lagoon. Infiltration of the liquid waste into the soil underlying the lagoon and any resulting soil contamination is addressed in subsection 5.1.

If no proposed RCRA Corrective Action Rule action level (55 FR 30865), proposed or promulgated SDWA MCL (40 CFR 141), TCLP regulatory standard (55 FR 26986-26988), or New Mexico regulatory standard existed for a particular contaminant or contaminants, they were also identified as COCs.

Table 5-24 shows the COCs that have been identified from soil samples, lagoon samples, and lysimeter samples for OU 1. The contaminants shown on the table that are denoted with an "a" are those that have been identified as COCs based on regulatory exceedance.

5.6.1. Soils (Boreholes and Wellbores)

Six VOCs have been identified as COCs in soils from boreholes and wellbores located within the former landfill boundaries (Table 5-24). They were identified as COCs because none of them have proposed RCRA action levels specified. No VOCs were identified as COCs in soils from the six boreholes that were sampled in the unnamed arroyo adjacent to the former landfill.

Twenty-five semivolatile organic compounds were identified as COCs (Table 5-24). Four semivolatile organic compounds that have been identified as COCs were detected in the surface soil sample taken from beneath an old car that was exposed by erosion in the northwest corner of the landfill (see subsection 5.3). Soils from 17 boreholes (BH-01, BH-03 through BH-06, BH-11 through BH-14, BH-16, BH-18, BH-21, BH-23, BH-24, and BH-26 through BH-28) and five wellbores (BLM-35, BLM-41, BLM-44, BLM-47, and BLM-53) located within the landfill boundaries contained semivolatile organic compounds that have been identified as COCs. All twenty-five semivolatile organic compounds were identified as COCs because they do not have proposed RCRA action levels specified.

Three pesticide compounds were identified as COCs (Table 5-24). Two of the compounds (beta-BHC and delta-BHC) do not have proposed RCRA action levels specified. The third pesticide (dieldrin) was detected in two boreholes, BH-13 and BH-23, and in both cases its concentrations in the sampled soils exceeded the proposed RCRA action level.

Eight metals were identified as COCs (Table 5-24). EP Toxicity data showed strontium and tin to be present in sampled soils from boreholes located within the former landfill boundaries. TCLP data showed strontium to be present in all six of the boreholes located in the unnamed arroyo. These two metals were identified as COCs because they do not have TCLP standards specified. The total metals arsenic, barium, chromium, lead, selenium, and silver were identified as COCs because current regulatory standards do not exist for total metals in soil.

Chloride and sulfate were identified as COCs in landfill soils as well as in soils sampled from the unnamed arroyo adjacent to the former landfill (Table 5-24). Both chloride and sulfate were identified as COCs because no RCRA action levels exist for these two inorganics.

5.6.2. Former Liquid Waste Lagoons and Lysimeters

Twelve VOCs were identified as COCs from the 1985 NMOCD and NMEID lagoon sampling (Table 5-24). No semivolatile organic compounds, pesticides, or PCBs were detected in the samples. Eight metals were identified as COCs based on total metals data (Table 5-24). Six of the twelve VOCs and two of the metals were identified as COCs because they do not have specified state standards or SDWA MCLs. The remaining six VOCs and six metals were identified on the basis of regulatory exceedance.

Three VOCs were identified as COCs from lysimeter sample analysis (Table 5-24). Benzene was identified on the basis of regulatory exceedance. Dichlorodifluoromethane was identified because it does not have a specified state standard or SDWA MCL. No semivolatile organics, pesticides, or PCBs were detected in the samples. No metal analyses were performed on samples from the lysimeters.

Bicarbonate, chloride, and sulfate were detected at all of the northern liquid waste lagoon sampling locations in 1985. Chloride and sulfate concentrations in all of the lagoon samples were below state standards and SDWA MCLs. Bicarbonate was identified as a COC because no state standard or SDWA MCL exists (Table 5-24).

Bicarbonate, bromide, chloride, and sulfate were detected in samples from lysimeter LS-5. Chloride and sulfate concentrations were below state standards and SDWA MCLs. Bicarbonate and bromide, however, were identified as COCs because no state standards or SDWA MCLs exist (Table 5-24).

A total of 60 COCs have thus been identified for OU 1 (Table 5-24). Only 13 of these contaminants were identified on the basis of regulatory exceedance. The remaining 43 were identified because they do not have regulatory standards specified. The risks of the COCs identified for OU 1 are assessed in Section 10.

5.7. SITE 1 - SOUTHERN AREA SOIL CHARACTERIZATION

Thirteen boreholes (BH-30 through BH-33 and BH-39 through BH-47) and 17 wellbores (BLM-61 through BLM-64 and BLM-67 through BLM-79) were drilled in the southern area of Site 1 during the RI (Figures 5-19 and 5-20).

The boreholes were drilled for the purpose of general soil characterization, and to identify any contaminants that may be present in the southern area soils. More specifically, boreholes BH-30 through BH-33 were drilled to identify any contaminants present in soils that may have migrated from the former Giant-Bloomfield refinery firewater storage ponds (Figure 5-19). Boreholes BH-40 through BH-42 were drilled adjacent to three monitoring wells installed by the former Giant-Bloomfield Refinery: GBR-32, GBR-48, and GBR-49. Borehole BH-40 was drilled approximately 15 ft south of GBR-48, BH-41 was drilled approximately 15 ft north of GBR-49, and BH-42 was drilled approximately 15 ft north of GBR-32 (Figures 5-19 and 5-20). The purpose of these three boreholes was to identify possible localized contamination sources in the vicinity of these three Giant-Bloomfield Refinery wells. The groundwater in these three Giant-Bloomfield Refinery wells was found to be contaminated (see subsection 6.4). Boreholes BH-45 through BH-47 were drilled in the unnamed arroyo south of the landfill (Figure 5-19). The purpose of these boreholes was to determine if the arroyo had acted as a transport pathway for contaminants migrating from the southern boundary of the former landfill or from the area east of the arroyo with surface runoff or with infiltrated surface water. Borehole BH-39 located west of the arroyo was used to determine stratigraphy, and was not sampled (Figure 5-19).

Borehole BH-43 was initially meant to be an alluvial monitoring well; however, groundwater was not found in the wellbore. As a result, borehole BH-44 was drilled 75 ft northwest of BH-43, again for the purpose of establishing an alluvial monitoring well; again groundwater was not found. Both wellbores were grouted and designated as boreholes. During drilling, areas of elevated HNu readings were detected in both boreholes at various depths and soil samples were taken (Appendix H). The two boreholes were ultimately used to help determine the extent of saturated alluvium as well as to characterize soil contamination in the area.

The 17 wellbores were drilled to establish monitoring wells for the purpose of groundwater sampling, and to sample soils at the soil-water interface to identify any contaminants that may have migrated downward from soil into groundwater. Wellbores BLM-78 and BLM-79 were drilled but not sampled because they are located in close proximity to two other wellbores that were sampled (BLM-67 and BLM-75). The boreholes and wellbore logs are presented in Appendices H and L, respectively. The laboratory analytical results for the sampled soils are shown in Appendix I-1. Presented below is a summary of the contaminants detected in soils sampled from the southern area of Site 1.

5.7.1. Boreholes Located in the Unnamed Arroyo

The boreholes drilled in the unnamed arroyo are shown on Figure 5-19. They include boreholes BH-45, BH-46, and BH-47. A summary of the results of laboratory analyses performed on soils taken from these boreholes is given below.

5.7.1.1. Volatile Organic Constituents

Boreholes BH-45, BH-46, and BH-47 showed only two VOCs to be present in sampled soils (Table 5-25). Dichloromethane was detected in concentrations ranging from 4.3 g/kg in BH-46 (20 to 20.5 ft) to 53 µg/kg in BH-47 (7 to 7.5 ft). Toluene was detected only in soil sampled from BH-47. Concentrations ranged from 1.1 µg/kg at 16 to 16.5 ft to 1.9 µg/kg at 22 to 22.5 ft.

5.7.1.2. Semivolatile Organic and Pesticide/PCB Constituents

No semivolatile organic compounds, pesticides, or PCBs were detected in any of the soils sampled from boreholes BH-45, BH-46, or BH-47.

5.7.1.3. Inorganic Constituents

Sulfate was detected in soils sampled from all three boreholes (BH-45, BH-46, and BH-47). Concentrations ranged from 35.3 µg/kg at 10 to 10.5 ft in BH-46 to 3,440 µg/kg at 25 to 25.5 ft in BH-45. Chloride was found only in soils sampled from BH-45. The sample from 15 to 15.5 ft showed chloride to be present at a concentration of 34.6 µg/kg (Table 5-26).

TCLP metals results showed barium and strontium to be present in soils at all three of the boreholes. Barium was detected in soils at concentrations ranging from 206 µg/L in BH-45 to 2,010 µg/L in BH-46. Strontium was detected in concentrations ranging from 377 µg/L to 5,990 µg/L, both in BH-45. In addition, lead was detected in soils sampled from BH-45 at a concentration of 1,570 µg/L (Table 5-27).

5.7.2. Boreholes Located East of the Unnamed Arroyo

The boreholes located in the area east of the unnamed arroyo are shown on Figure 5-19. They include boreholes BH-30, BH-31, BH-32, BH-33, BH-40, BH-41, BH-42, BH-43, and BH-44. A summary of the results of laboratory analyses performed on soil samples taken from these boreholes is given below.

5.7.2.1. Volatile Organic Constituents

Total xylenes were detected in soils from 3 to 4 ft in BH-33 at a concentration of 2 μg/kg. Toluene was detected in two boreholes, BH-40 and BH-41. Concentrations ranged from 1.6 μg/kg in BH-40 (29 to 29.4 ft) to 1.8 μg/kg in BH-41 (5 to 5.5 ft). 1,2-*trans*-DCE was present in soils at two boreholes. Concentrations ranged from 2.6 μg/kg in BH-42 (37.5 to 37.9 ft) to 7.5 μg/kg in BH-41 (35.6 to 35.8 ft). Trichloromethane was detected in two boreholes, BH-43 and BH-44. Concentrations of trichloromethane in soils from these two boreholes ranged from 1.4 μg/kg in BH-43 (17.4 to 17.8 ft) to 1.5 μg/kg detected in both boreholes (BH-43: 3.6 to 3.9 ft; BH-44: 8.6 to 9 ft) (Table 5-26).

5.7.2.2. Semivolatile Organic and Pesticide/PCB Constituents

No semivolatile organic compounds, pesticides, or PCBs were detected in soils sampled from any of the boreholes (BH-30 through BH-33 and BH-40 through BH-44) located in the area east of the unnamed arroyo.

5.7.2.3. Inorganic Constituents

Chloride and sulfate were detected in all of the boreholes located in the area east of the unnamed arroyo, except BH-44 where neither were detected. Concentrations of sulfate ranged from 13.2 mg/kg in BH-40 (14.5 to 15 ft) to 2,030 mg/kg in BH-33 (3 to 4 ft). Chloride concentrations ranged from 6.7 mg/kg in BH-32 (7 to 8 ft) to 498 mg/kg in BH-31 (3 to 4 ft) (Table 5-26).

EP Toxicity metals results showed strontium to be present in soils at boreholes BH-30 through BH-33. Concentrations ranged from 647 μg/L in BH-32 to 3,180 μg/L in BH-33. In addition, EP Toxicity metals results showed mercury to be present in soils sampled from BH-30 at a concentration of 0.28 μg/L (Table 5-27).

TCLP metals results showed strontium to be present in soils sampled from boreholes BH-40 through BH-44. Concentrations detected in samples from these boreholes ranged from 501 μg/L to 2,460 μg/L, both in BH-41. Barium was also detected in soils sampled from boreholes BH-40 through BH-44. Barium concentrations ranged from 323 μg/L in BH-42 to 1,620 μg/L in BH-44. TCLP results also showed cadmium to be present in soils sampled from BH-40 at concentrations ranging from 14.7 μg/L to 19.2 μg/L (Table 5-27).

5.7.3. Wellbores Located in and Adjacent to the Unnamed Arroyo

The wellbores drilled in and adjacent to the unnamed arroyo are shown on Figure 5-20. They include wellbores BLM-71, BLM-72, BLM-73, and BLM-77. A summary of the results of laboratory analyses performed on samples taken from the soil-water interface in each of these wellbores is given below.

5.7.3.1. Volatile Organic Constituents

Trichloromethane was detected in one sample at the soil-water interface (29.4 to 29.9 ft) in wellbore BLM-71. It was detected in concentrations ranging from 1.6 μg/kg (duplicate sample) to 1.8 μg/kg. Toluene was also detected in a sample from the soil-water interface (27.7 to 28.3 ft) in BLM-73 at a concentration of 1.4 μg/kg. Dichloromethane was detected at the soil-water interface (28.6 to 29.2 ft) in BLM-77 at a concentration of 3.4 μg/kg (Table 5-25).

5.7.3.2. Semivolatile Organic and Pesticide/PCB Constituents

No semivolatile organic compounds, pesticides, or PCBs were detected at the soil-water interface in wellbores BLM-71, BLM-72, BLM-73, or BLM-77 located in and adjacent to the unnamed arroyo.

5.7.3.3. Inorganic Constituents

Sulfate was detected in soils sampled at the soil-water interface in all of the wellbores located in and adjacent to the unnamed arroyo (BLM-71 through BLM-73 and BLM-77). Concentrations ranged from 99.6 mg/kg in BLM-73 to 222 mg/kg in BLM-72. Chloride was not detected in any of the wellbores listed above (Table 5-26).

TCLP metals analyses performed on samples from the soil-water interface showed barium present in all four wellbores located in and adjacent to the unnamed arroyo. Concentrations ranged from 243 μg/L in BLM-71 to 508 μg/L in BLM-73. A duplicate sample was taken in wellbore BLM-71. The concentration of barium detected was 224 μg/L. Strontium was detected in all wellbores, except BLM-73. Concentrations of strontium at the soil-water interface ranged from 1,060 μg/L in BLM-77 to 2,370 μg/L in BLM-71. The duplicate sample taken in BLM-71 showed strontium to be present at a concentration of 1,820 μg/L (Table 5-27).

5.7.4. Wellbores Located in the Area East of the Unnamed Arroyo

The locations of the wellbores in the area east of the unnamed arroyo are shown on Figure 5-20. They include wellbores BLM-61, BLM-63, BLM-64, BLM-67, BLM-68, BLM-69, BLM-70, BLM-74, BLM-75, and BLM-76. A summary of the results of laboratory analyses performed on samples taken from the soil-water interface in each of these wellbores is given below.

5.7.4.1. Volatile Organic Constituents

Dichloromethane was detected in three wellbores in the area east of the unnamed arroyo. BLM-68 showed dichloromethane present at the soil-water interface (32.2 to 32.7 ft) at a concentration of 5.2 μg/kg. BLM-70 showed dichloromethane present at the soil-water interface (31.4 to 31.8 ft) at a concentration of 5 μg/kg, and BLM-76 showed dichloromethane present at a concentration of 4.5 μg/kg at the soil-water interface (29 to 30 ft). Trichloromethane was detected at the soil-water interface in wellbores BLM-69 and BLM-70 at depths of 35 to 35.5 ft and 31.4 to 31.8 ft, respectively. Concentrations ranged from 1.8 μg/kg in BLM-70 to 1.9 μg/kg in BLM-69 (Table 5-25).

5.7.4.2. Semivolatile Organic and Pesticide/PCB Constituents

Benzoic acid was detected at the soil-water interface in wellbores BLM-61 and BLM-63. It was detected at 23 to 24 ft in BLM-61 at a concentration of 200 μg/kg, and was detected in BLM-61 from 14 to 15 ft at a concentration of 290 μg/kg (Table 5-25).

5.7.4.3. Inorganic Constituents

Sulfate was detected in all of the wellbores located in the area east of the unnamed arroyo (BLM-61, BLM-63, BLM-64, BLM-67, BLM-68, BLM-69, BLM-70, BLM-74, BLM-75, and BLM-76). Concentrations ranged from 7.7 mg/kg in BLM-61 (14 to 15 ft) to 325 mg/kg in BLM-63. Chloride was only detected at the soil-water interface in wellbores BLM-61, BLM-70, and BLM-76. Concentrations ranged from 57.5 mg/kg (a duplicate sample) in BLM-76 (29 to 30 ft) to 102 mg/kg in BLM-61 (39 to 40 ft). In addition, sulfide was detected in BLM-61 at the soil-water interface (39 to 40 ft) at a concentration of 24.2 mg/kg (Table 5-26).

TCLP metals analyses showed strontium present at the soil-water interface in wellbores BLM-67, BLM-68, BLM-69, BLM-70, BLM-75, and BLM-76. Concentrations ranged from 800 μg/L in BLM-68 to 3,280 μg/L in BLM-76. A duplicate sample was taken from BLM-76. The concentration of strontium detected in the duplicate sample was 2,840 μg/L. Barium was detected in soils at the soil-water interface in wellbores BLM-68, BLM-70, BLM-74, BLM-75, and BLM-76. Concentrations ranged from 261 μg/L in BLM-68 to

897 μg/L in BLM-76. The duplicate sample taken from BLM-76 showed a barium concentration of 849 μg/L. TCLP results also showed silver present at the soil-water interface in BLM-68 at a concentration of 10.1 μg/L (Table 5-27).

In summary, analytical results of soils sampled from boreholes and wellbores located in the southern area of Site 1 show only a small number of VOCs to be present. Dichloromethane was the most frequently detected VOC. It was present in soils sampled from three boreholes (BH-45, BH-46, and BH-47) and in soils sampled from the soil-water interface in four wellbores (BLM-68, BLM-70, BLM-76, and BLM-77). Trichloromethane was the next most frequent VOC detected in soils sampled from boreholes and wellbores located in the southern area of Site 1. It was found present in soils sampled from two boreholes (BH-43 and BH-44) and in soils sampled from the soil-water interface in three wellbores (BLM-69, BLM-70, and BLM-71).

Toluene was detected in three boreholes (BH-40, BH-41, and BH-47), and in soils sampled from the soil-water interface in one wellbore (BLM-73). 1,2-*trans*-DCE was detected in soils sampled from boreholes BH-41 and BH-42. Xylene was detected in only one borehole (BH-33). Only two semivolatile organic compounds were detected in soils sampled from two well-bores located in the southern area of Site 1. Benzoic acid was detected at the soil-water interface in BLM-61 and BLM-63 (Table 5-25).

Sulfate was detected in all wellbores and boreholes, except borehole BH-44. Chloride was detected in nine boreholes (BH-30 through BH-33, BH-40 through BH-43, and BH-45) and in three wellbores (BLM-61, BLM-70, and BLM-76). Three boreholes (BH-44, BH-46, and BH-47) and 11 wellbores (BLM-63 through BLM-64, BLM-67 through BLM-69, BLM-71 through BLM-75, and BLM-77) did not contain chloride. In addition, sulfide was detected in soils sampled from wellbore BLM-61 (Table 5-26).

Two EP Toxicity metals were detected in soils sampled from boreholes BH-30 through BH-33. Mercury and strontium were present in BH-30 soils, and strontium was detected in soils from BH-31, BH-32, and BH-33 (Table 5-27).

TCLP metals analysis showed five metals present in soils sampled from boreholes and wellbores located in the southern area of Site 1. Barium and strontium were the most frequently detected metals. Barium was detected in all boreholes and wellbores, except wellbores BLM-73 and BLM-74. Strontium was also detected in all boreholes and wellbores located in the southern area of Site 1, except wellbores BLM-67 and BLM-69. Cadmium, lead, and silver were detected in soils from boreholes BH-40, BH-45, and wellbore BLM-68, respectively (Table 5-27). No TCLP metals analyses were performed on soils sampled from wellbores BLM-61, BLM-63, or BLM-64. None of the five metals discussed above were detected in concentrations that exceeded TCLP standards. Only strontium was identified as a COC because no TCLP standard exists.

5.7.5. Contaminants of Concern

COCs for soils in the southern area of Site 1 have been identified in two ways. Analytical results for VOCs, semivolatile organics, and inorganics (sulfate and chloride) have been compared to proposed RCRA action levels for soils (55 FR 30865). EP Toxicity metal results and TCLP metal results have been compared to TCLP regulatory standards (55 FR 26986-26988). Any contaminants present in soil samples in levels above proposed RCRA action levels or TCLP regulatory standards were identified as COCs. Secondly, if no proposed or promulgated standard exists for a particular contaminant or contaminants, then they were also identified as COCs.

Tables 5-25 through 5-27 show the COCs that have been identified in soils in the southern area of Site 1. All of the contaminants present in sampled soils did not exceed regulatory standards.

Six COCs have been identified because they did not have proposed RCRA Corrective Action Rule action levels or TCLP regulatory standards specified. 1,2-*trans*-DCE was detected in soils sampled from boreholes BH-41 and BH-42, benzoic acid was detected in soils sampled from wellbores BLM-61 and BLM-63, and strontium was detected in soils from all of the boreholes and wellbores located in the southern area of Site 1, except wellbores BLM-67 and BLM-69. Chloride was detected in nine boreholes (BH-30 through BH-33, BH-40 through BH-43, and BH-45) and in three wellbores (BLM-61, BLM-70, and BLM-76); sulfate was detected in all wellbores and boreholes, except borehole BH-44; and sulfide was detected in one wellbore, BLM-61.

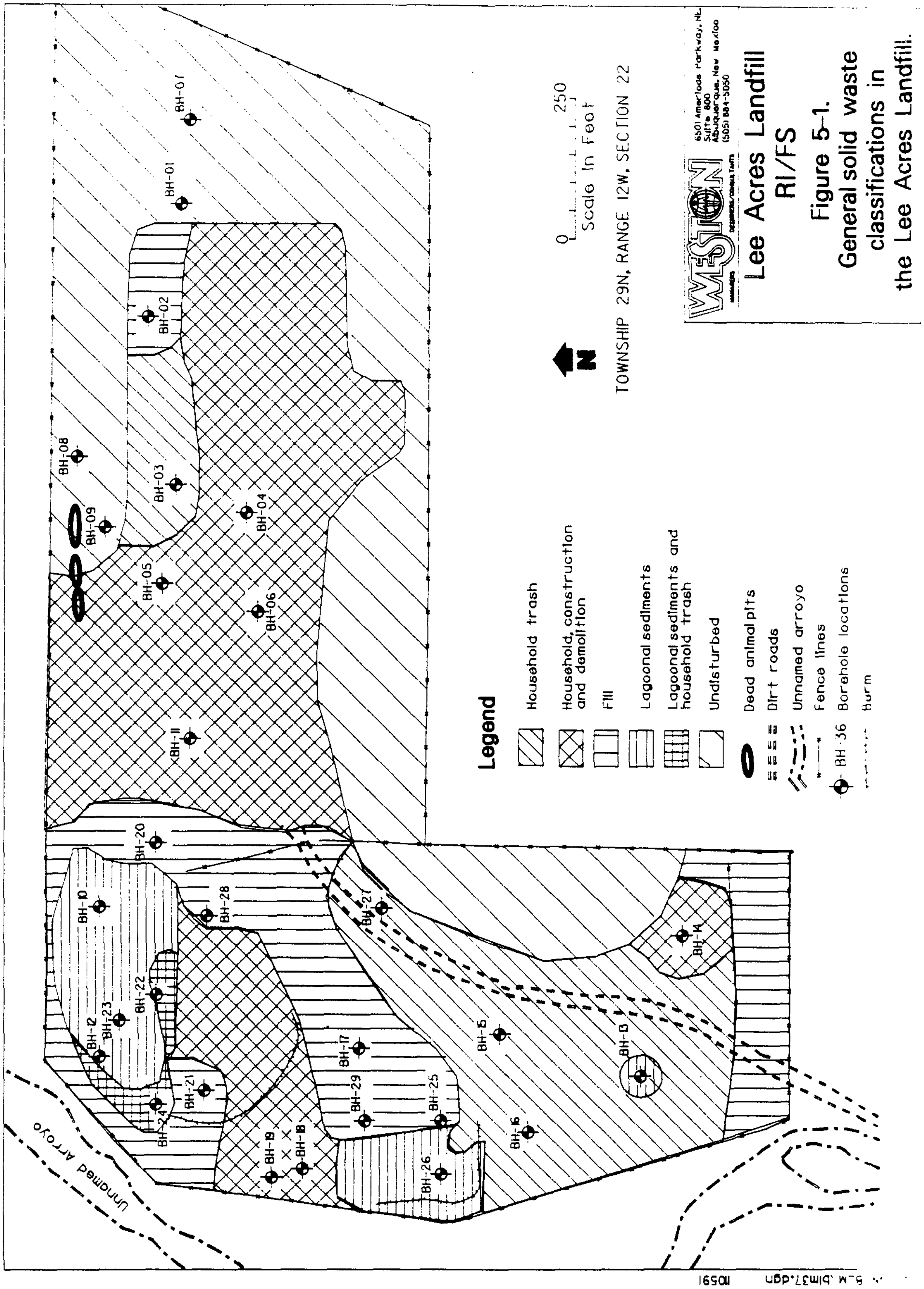


Figure 5-1.
General solid waste classifications in the Lee Acres Landfill.

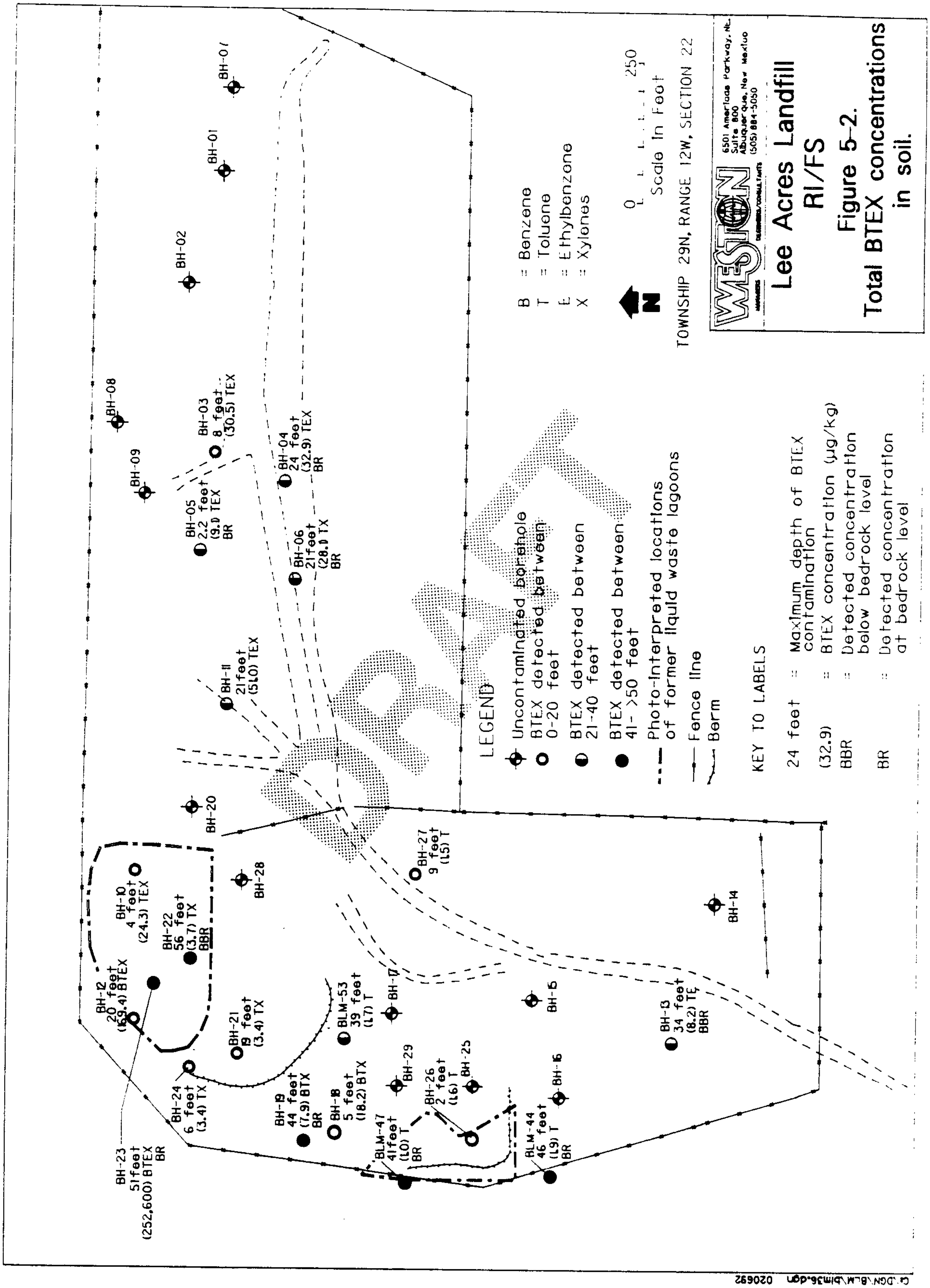


Figure 5-2.
Total BTEX concentrations in soil.

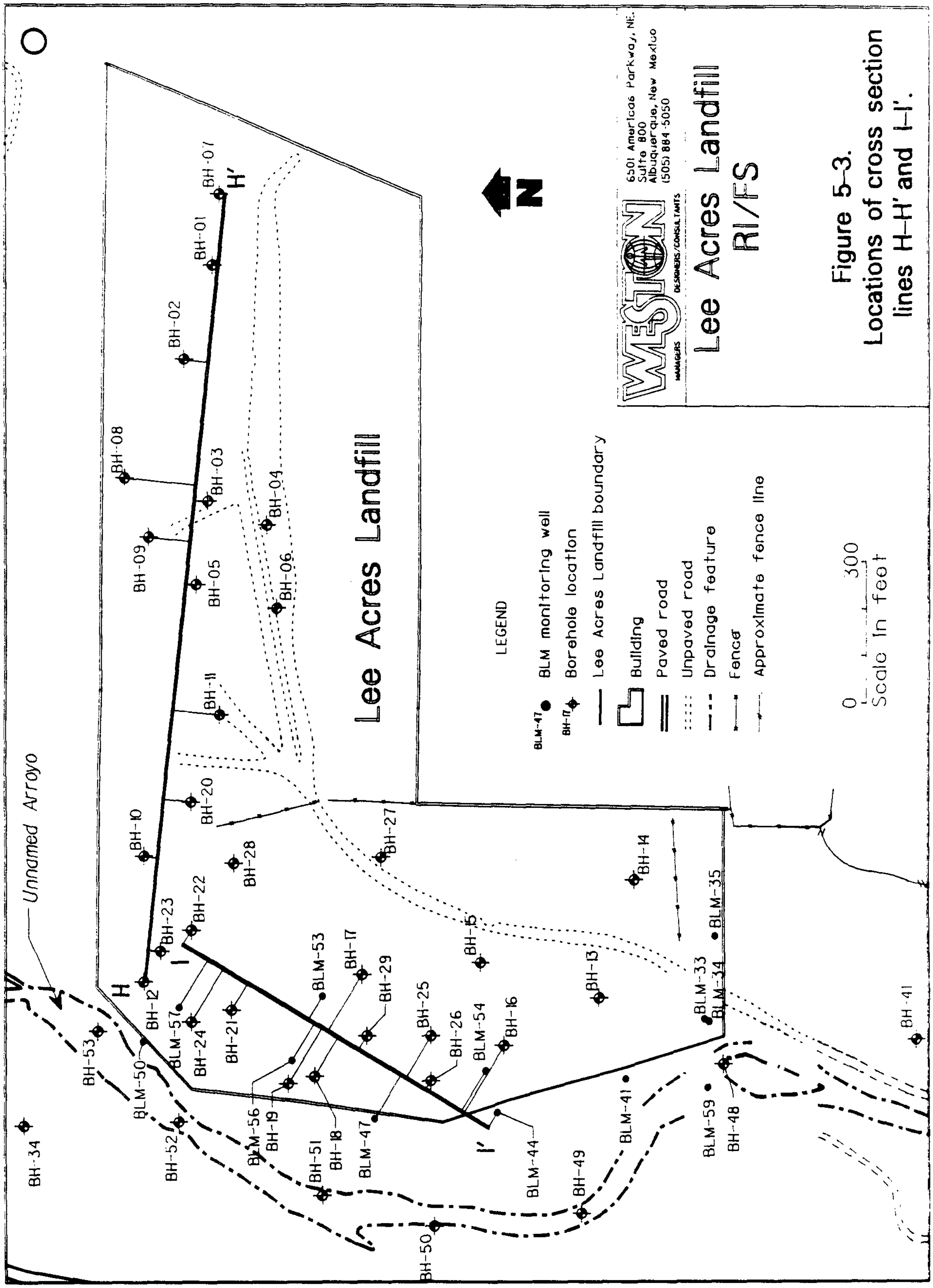


Figure 5-3.
Locations of cross section lines H-H' and I-I'.

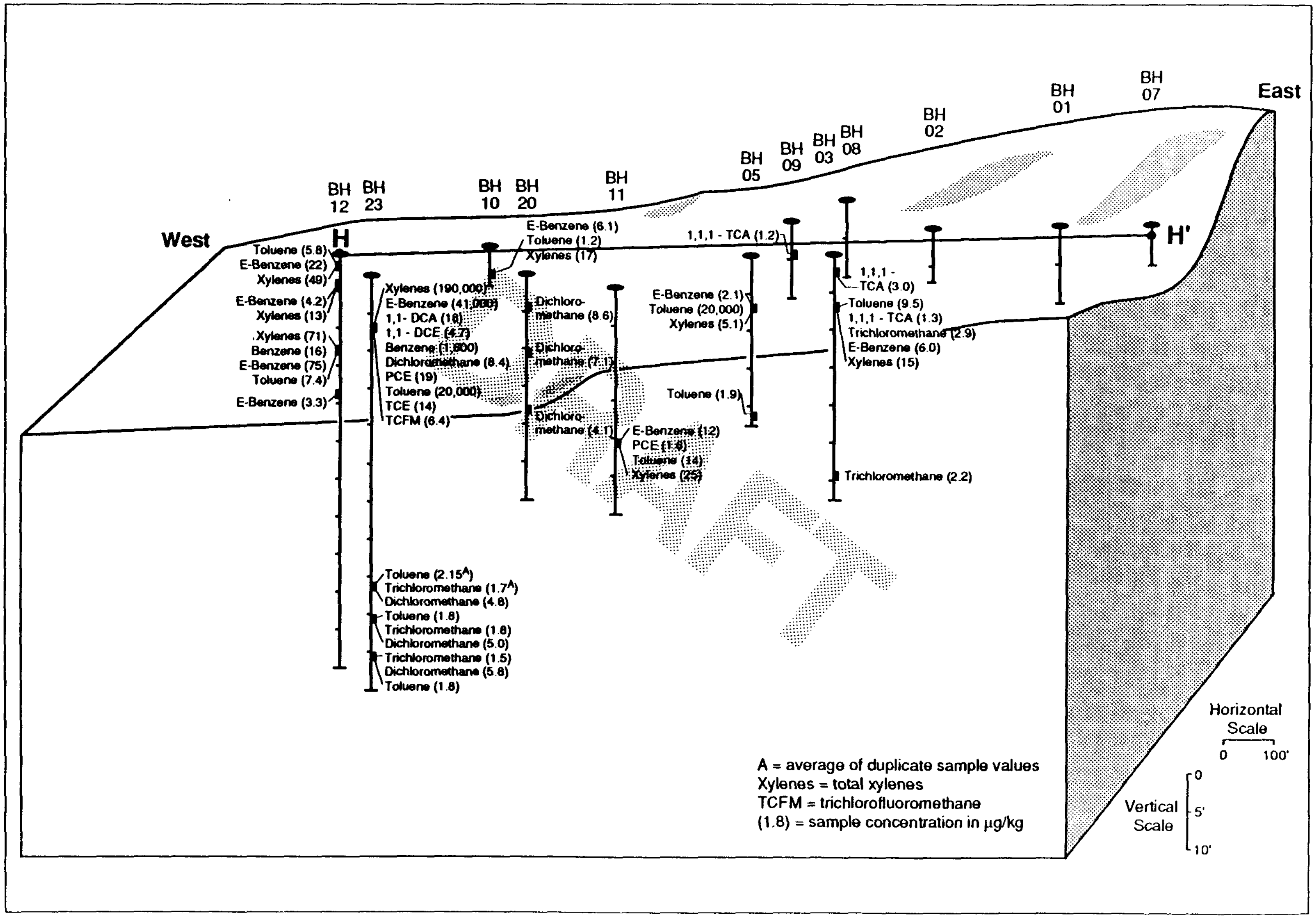


Figure 5-4. Cross section H - H' vertical distribution of volatile organic compounds in the landfill.

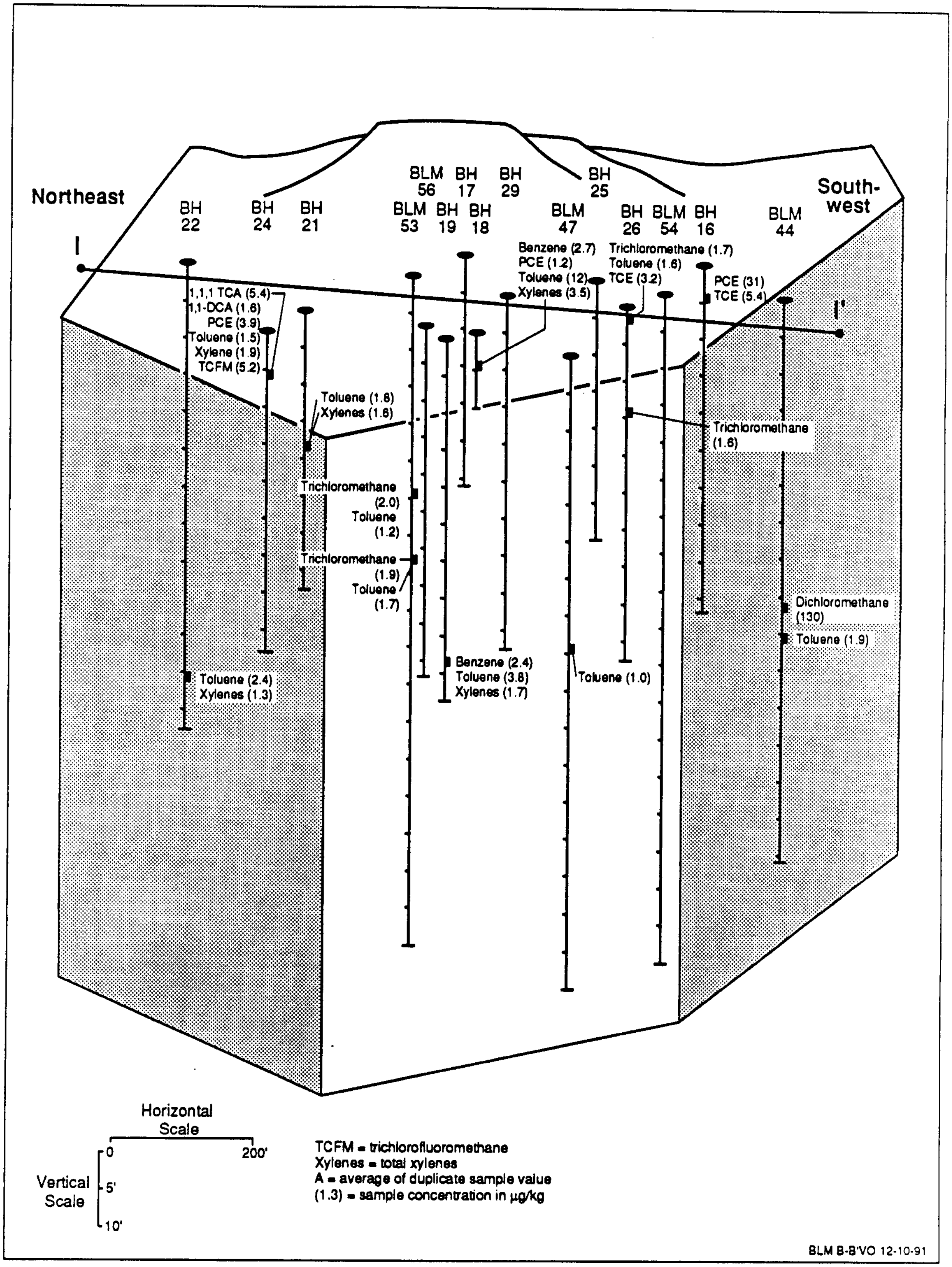
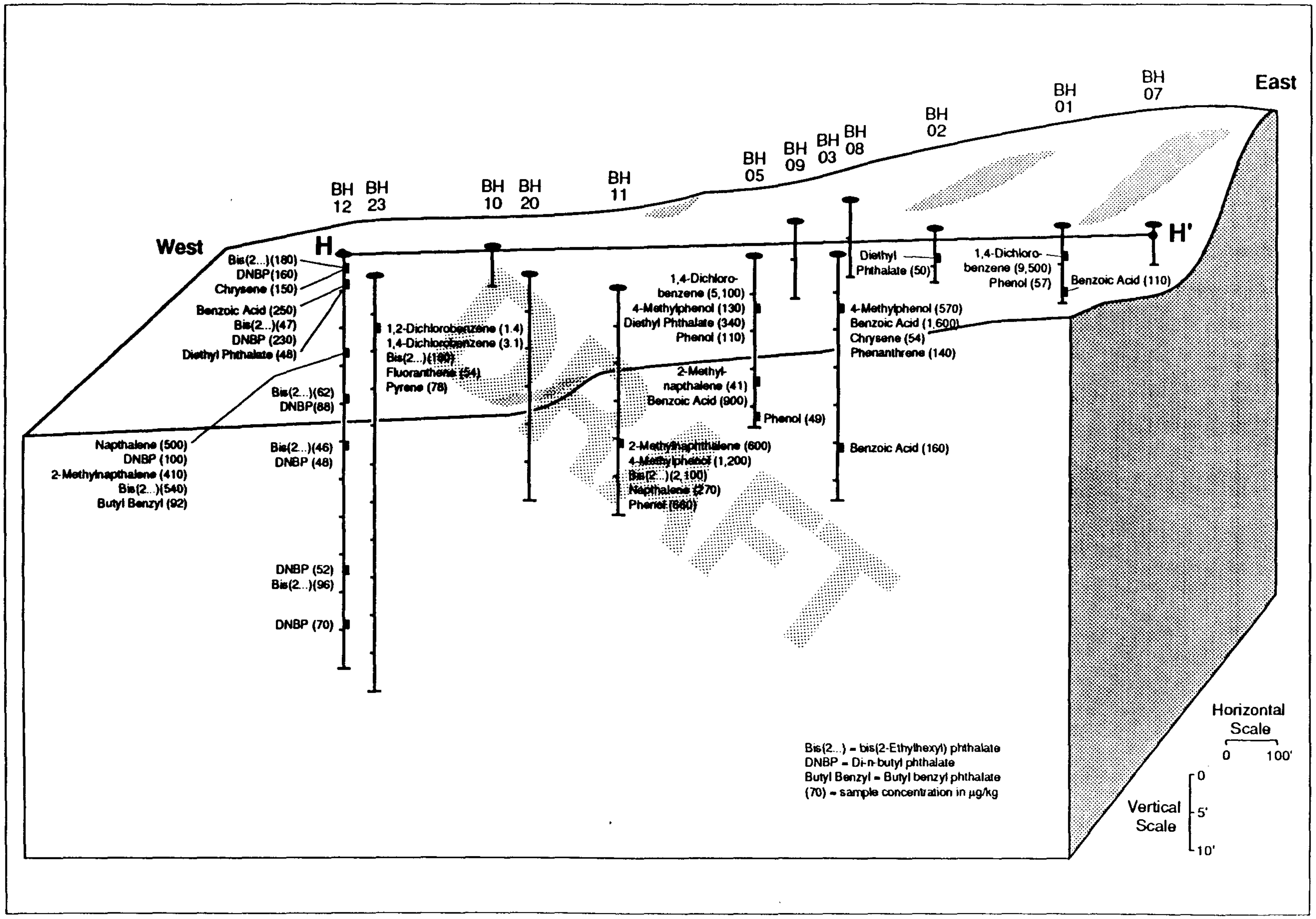
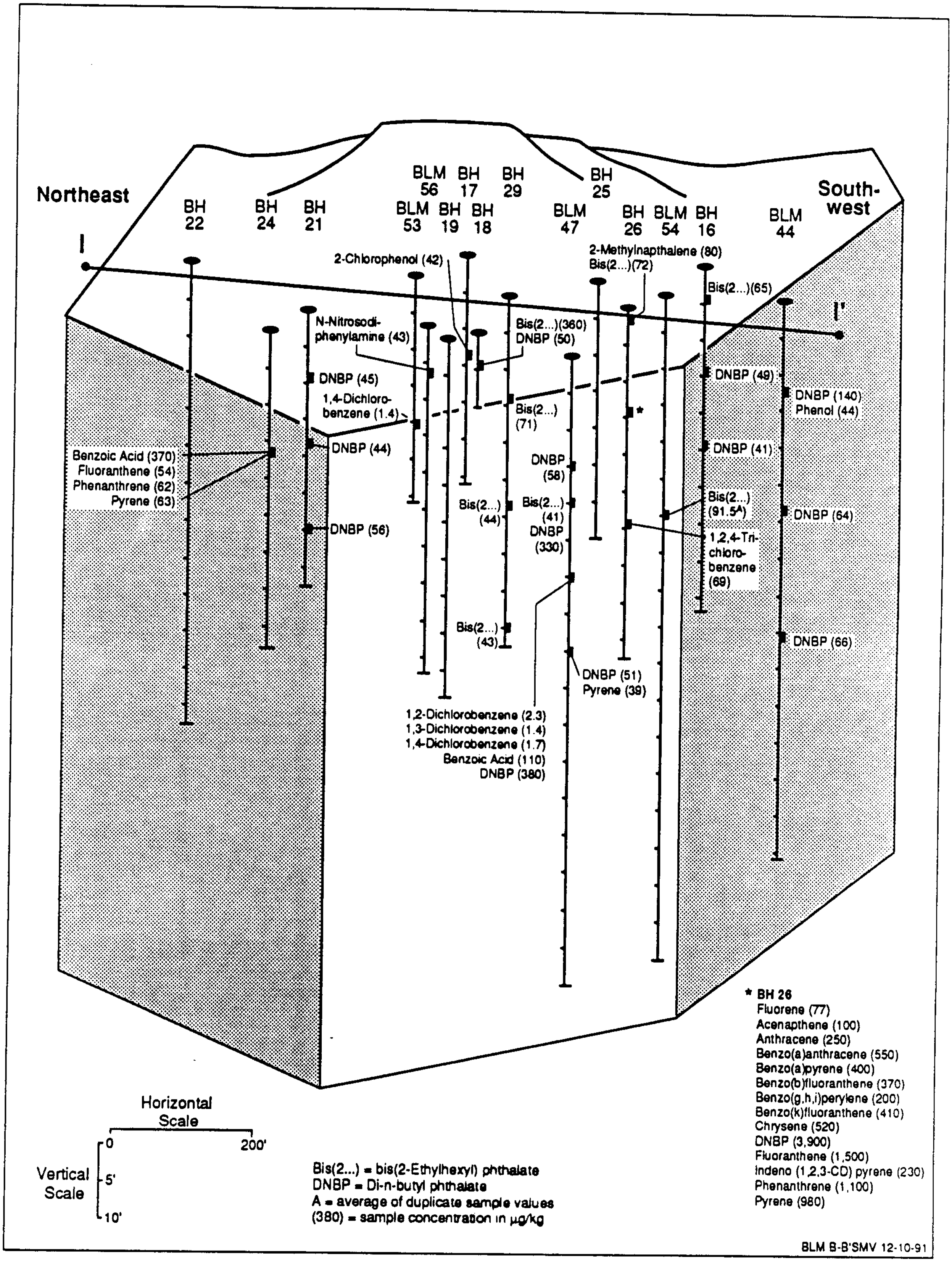


Figure 5-5. Cross section I - I' vertical distribution of volatile organic compounds in the landfill.



BLM A-A'SMV 12-10-91

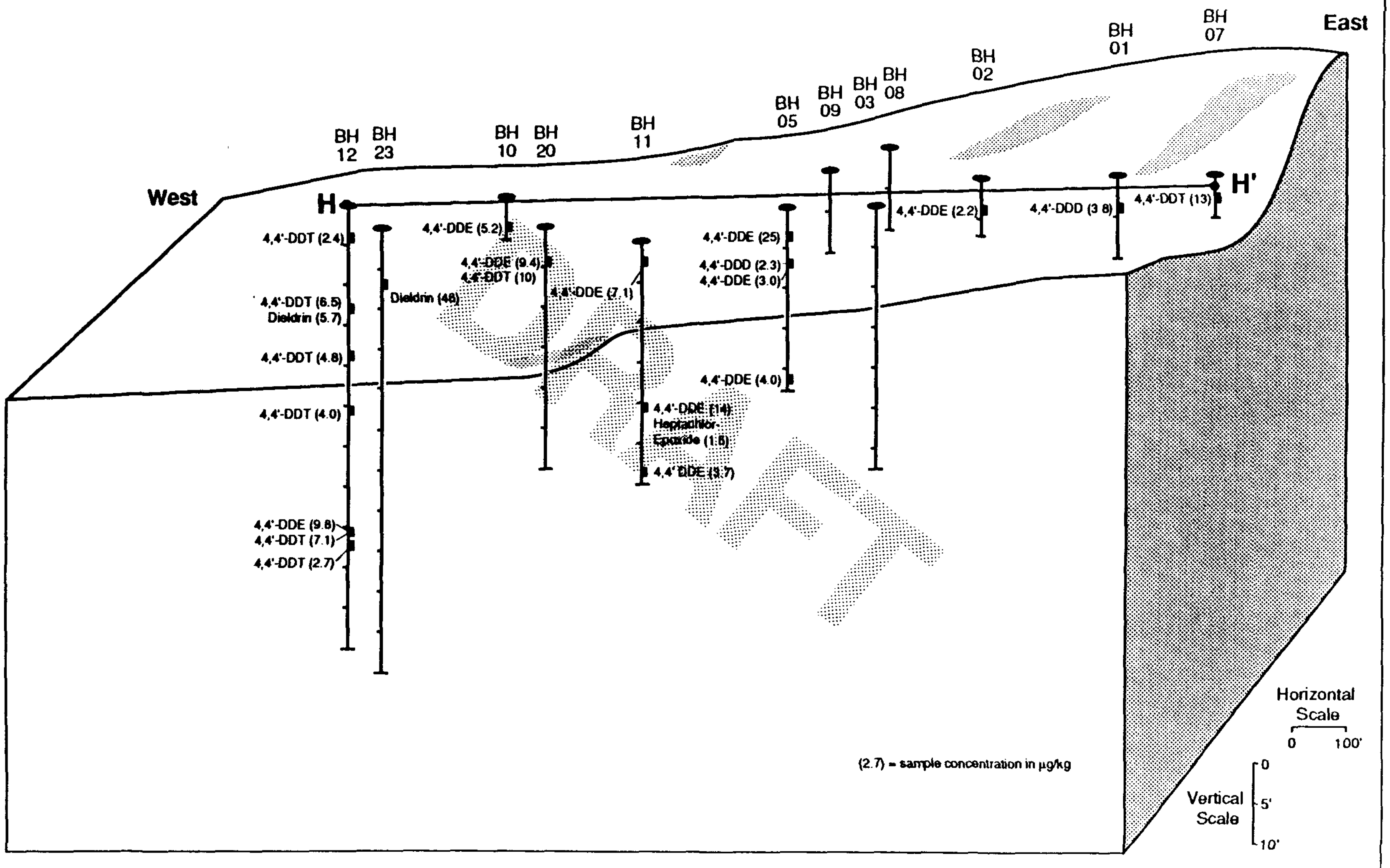
Figure 5-6. Cross section H - H' vertical distribution of semivolatile organic compounds in the landfill.



* BH 26
Fluorene (77)
Acenapthene (100)
Anthracene (250)
Benzo(a)anthracene (550)
Benzo(a)pyrene (400)
Benzo(b)fluoranthene (370)
Benzo(g,h,i)perylene (200)
Benzo(k)fluoranthene (410)
Chrysene (520)
DNBP (3,900)
Fluoranthene (1,500)
Indeno (1,2,3-CD) pyrene (230)
Phenanthrene (1,100)
Pyrene (980)

Bis(2...) = bis(2-Ethylhexyl) phthalate
DNBP = Di-n-butyl phthalate
A = average of duplicate sample values
(380) = sample concentration in µg/kg

Figure 5-7. Cross section I - I' vertical distribution of semivolatile organic compounds in the landfill.



BLM A-A'PST 12-10-91

Figure 5-8. Cross section H - H' vertical distribution of pesticides in the landfill.

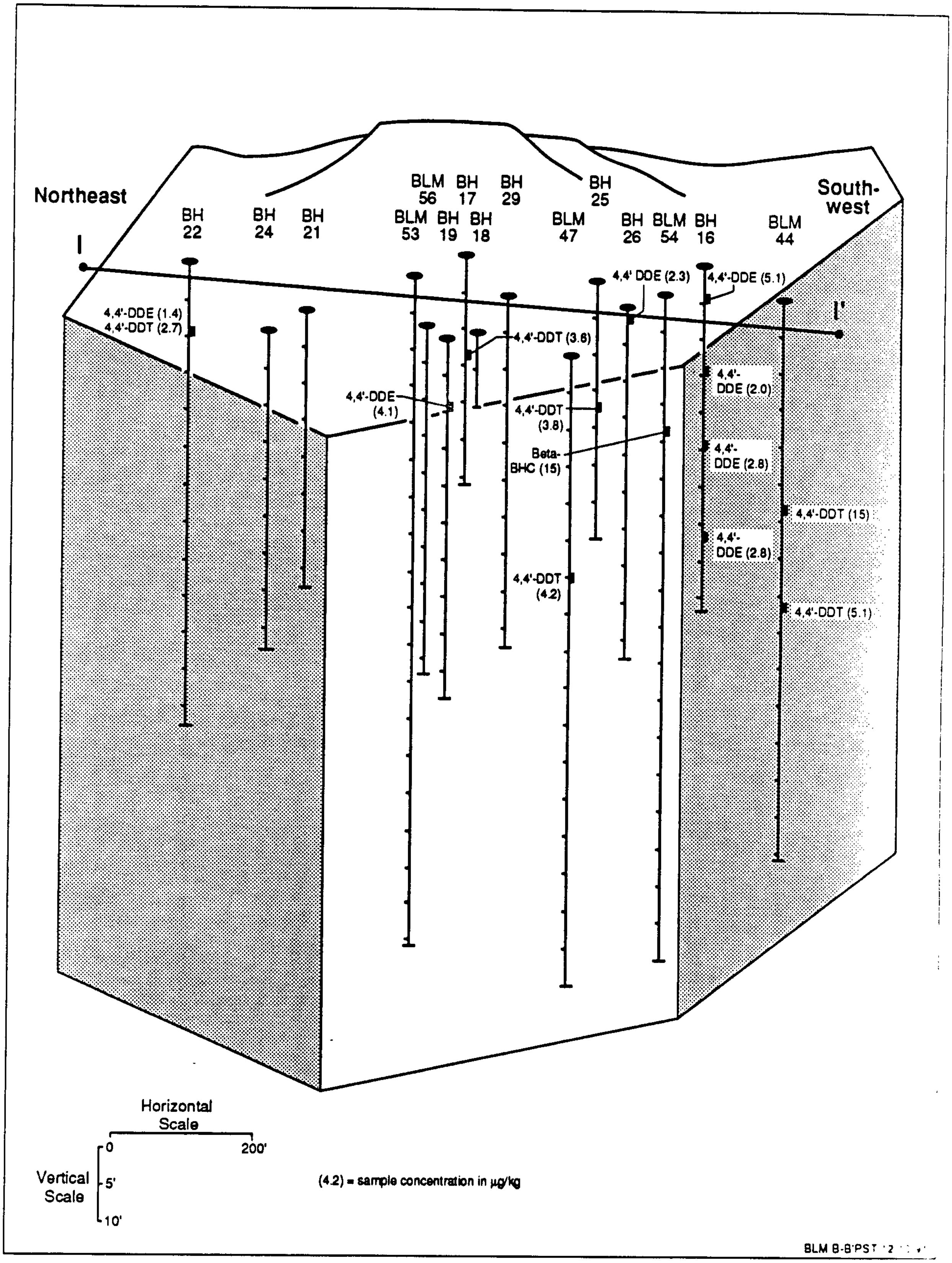


Figure 5-9. Cross section I - I' vertical distribution of pesticides in the landfill.

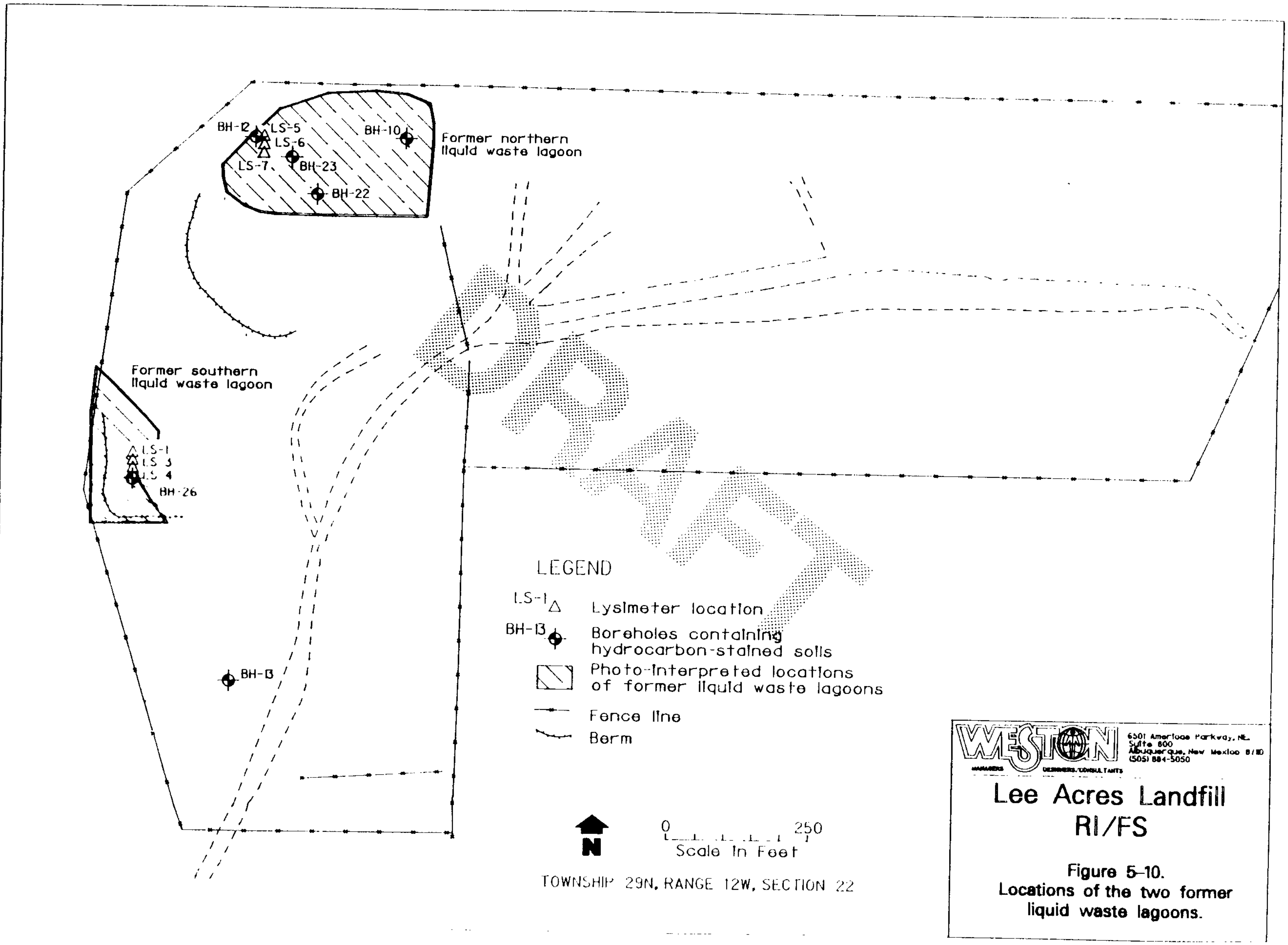


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Figure 5-10.
Locations of the two former liquid waste lagoons.

c:\DGN\BLM\blm34.dgn 020692

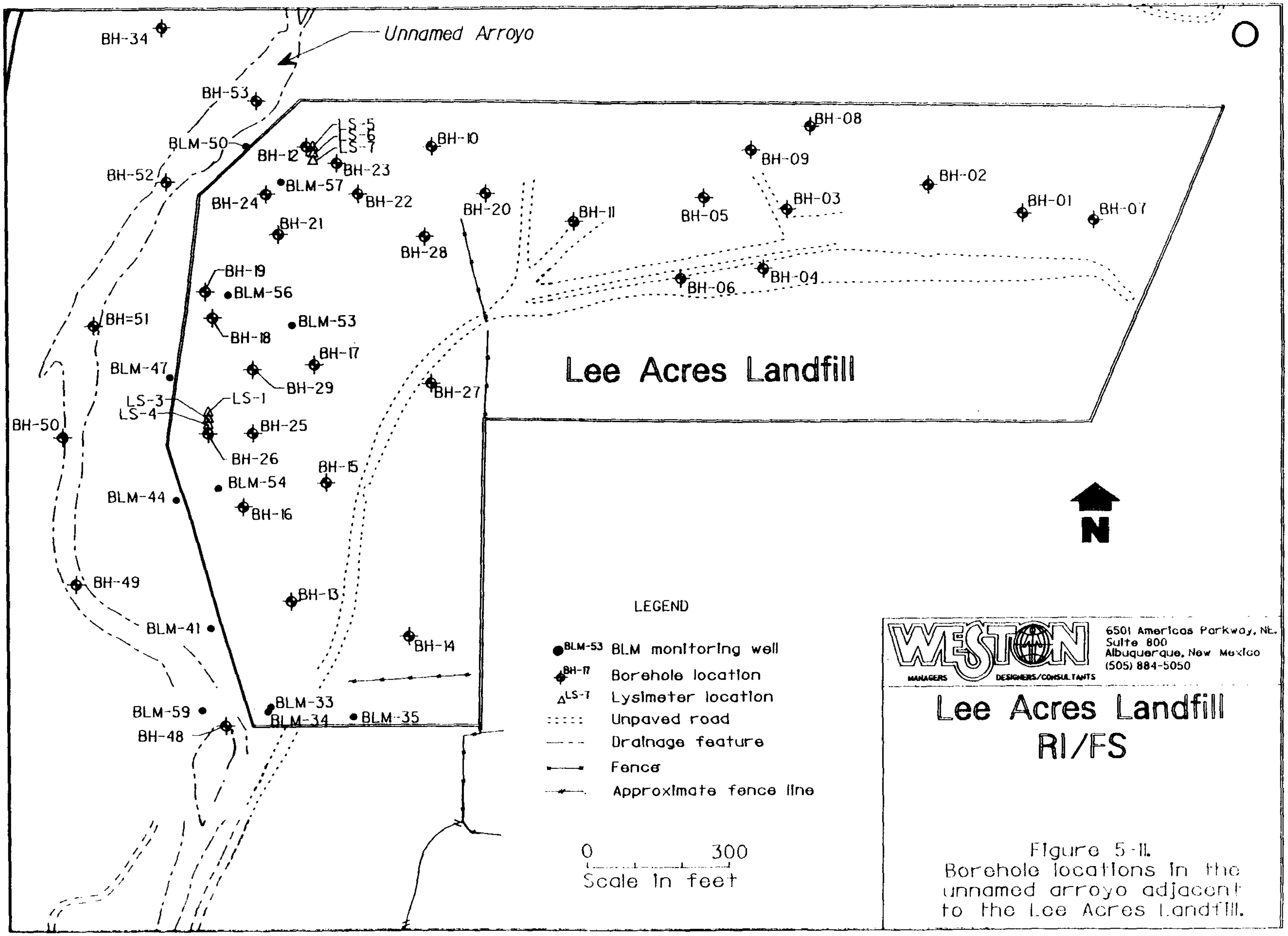

Figure 5-11.
Borehole locations in the unnamed arroyo adjacent to the Lee Acres Landfill.

C:\DGN\BLM\BLM32.DGN 121091

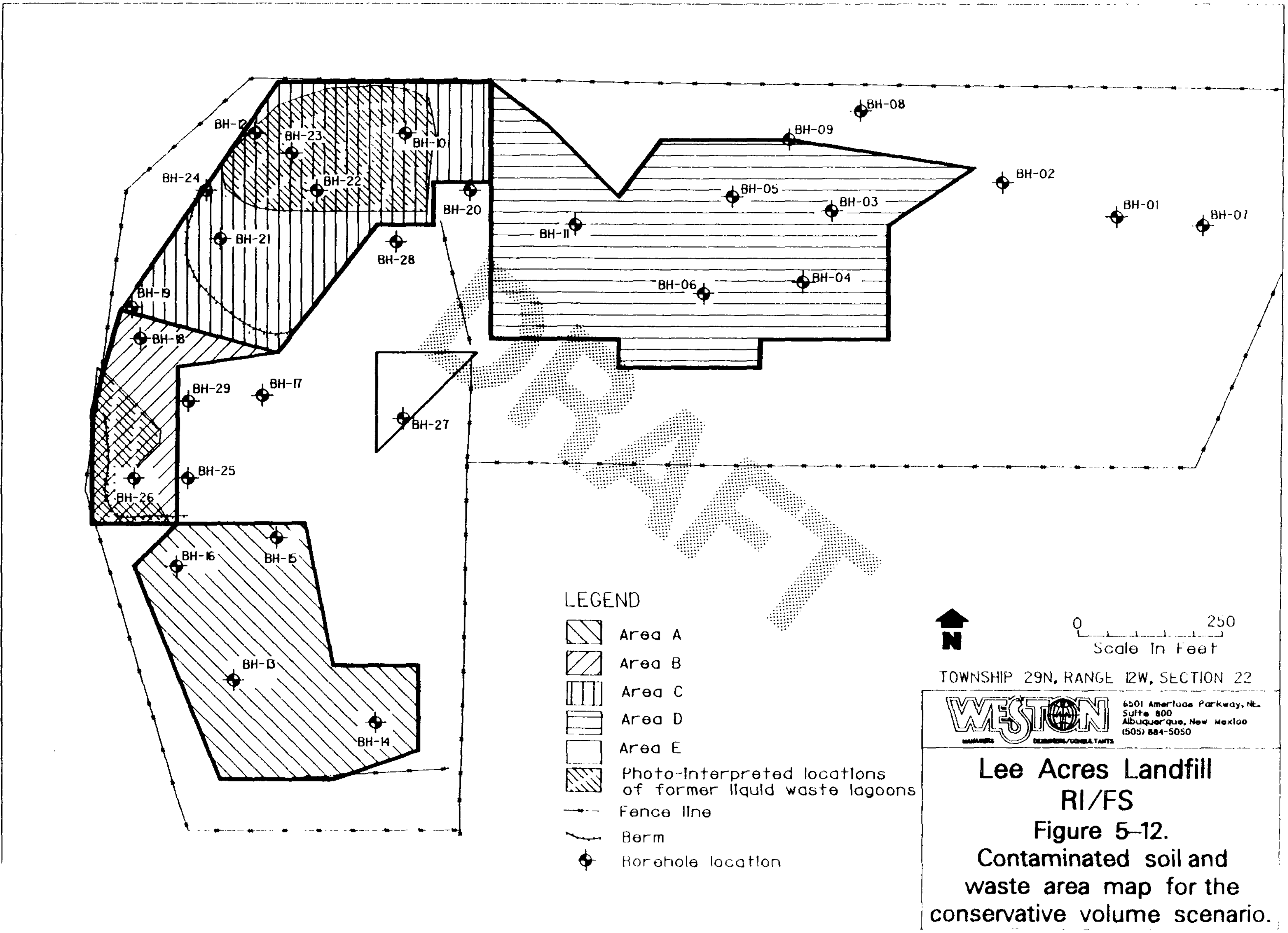

Figure 5-12.
Contaminated soil and waste area map for the conservative volume scenario.

020692 blm38.dgn

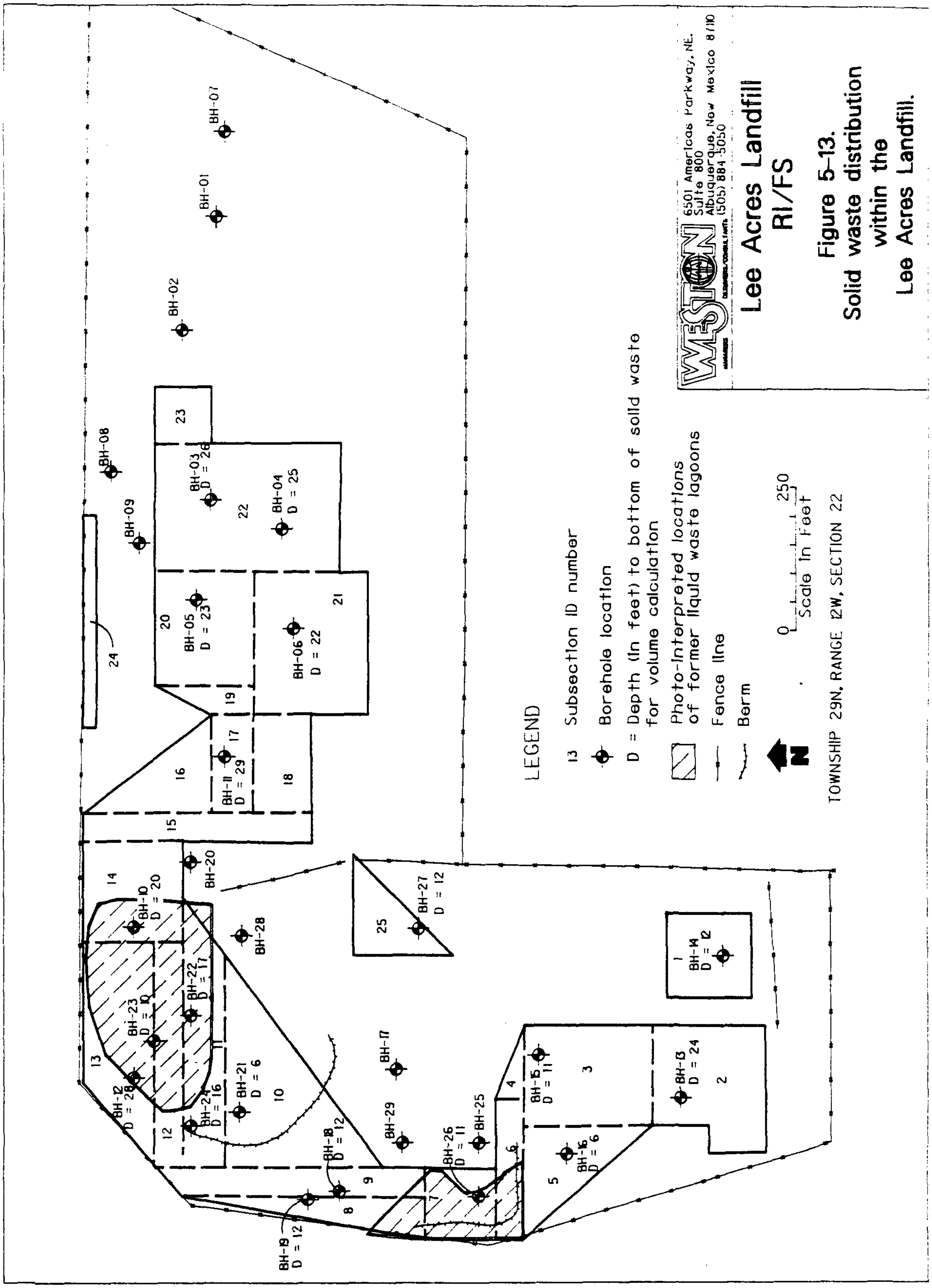

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Figure 5-13.
Solid waste distribution within the Lee Acres Landfill.

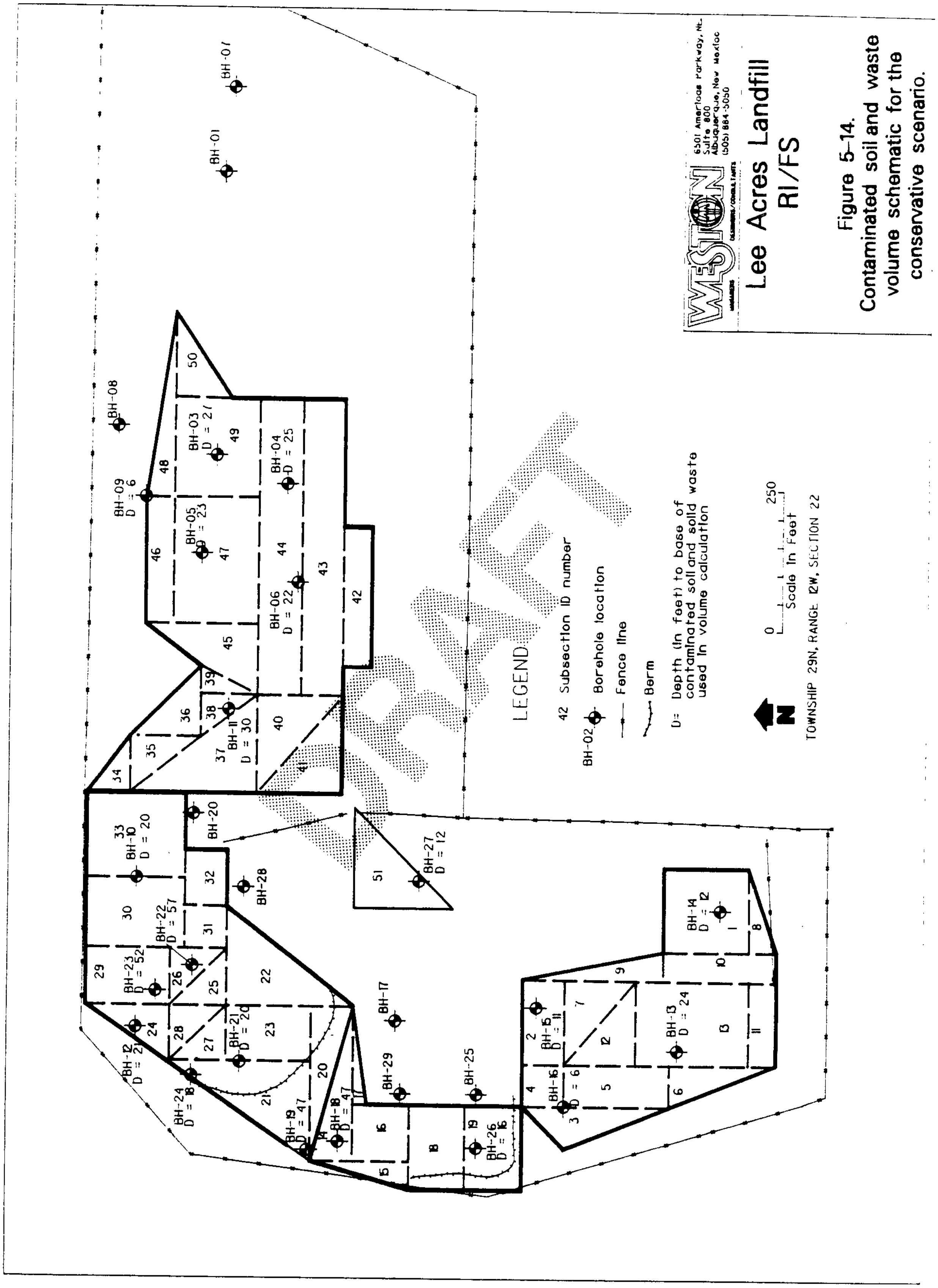

Figure 5-14.
Contaminated soil and waste volume schematic for the conservative scenario.

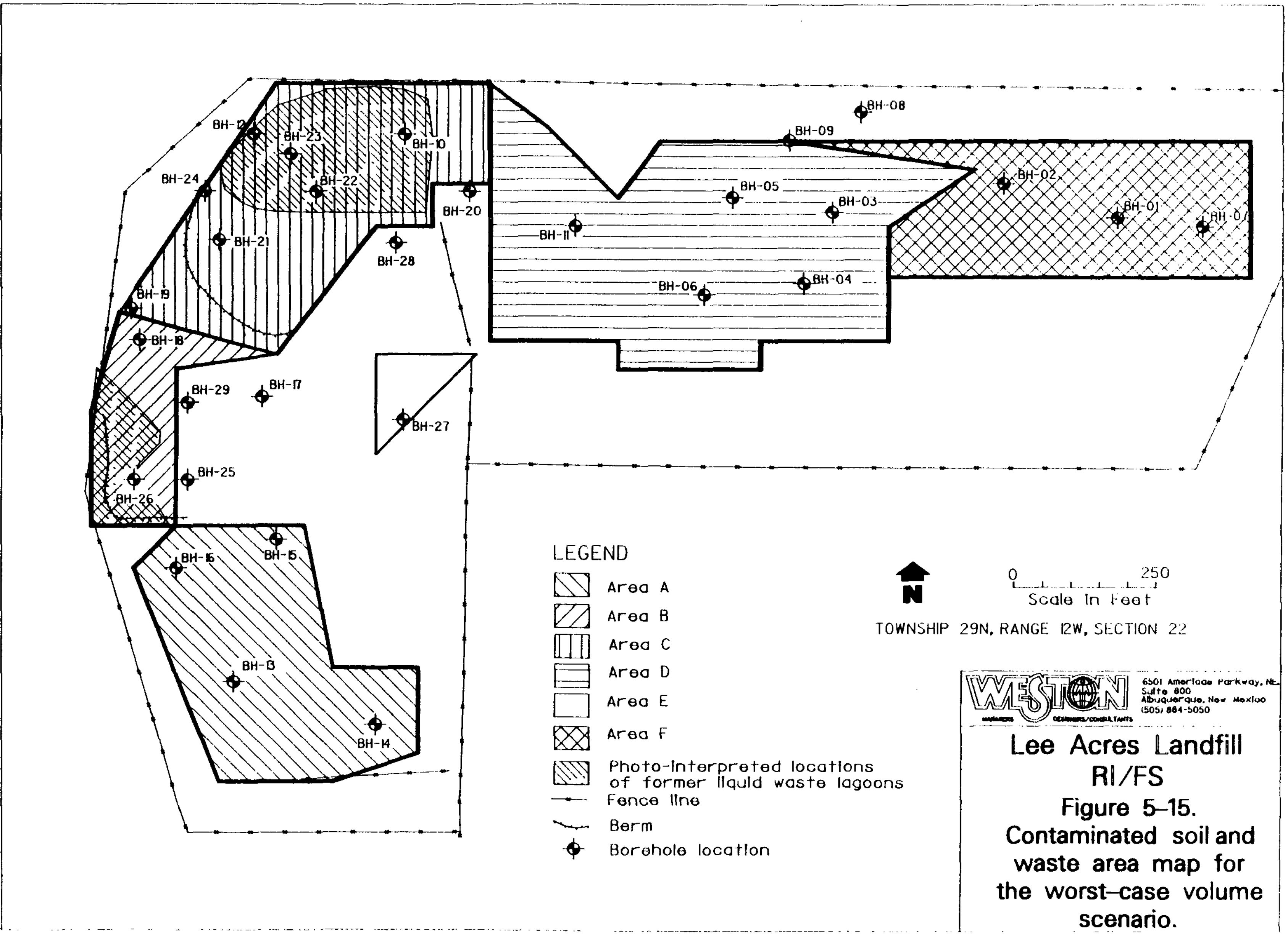

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Figure 5-15. Contaminated soil and waste area map for the worst-case volume scenario.

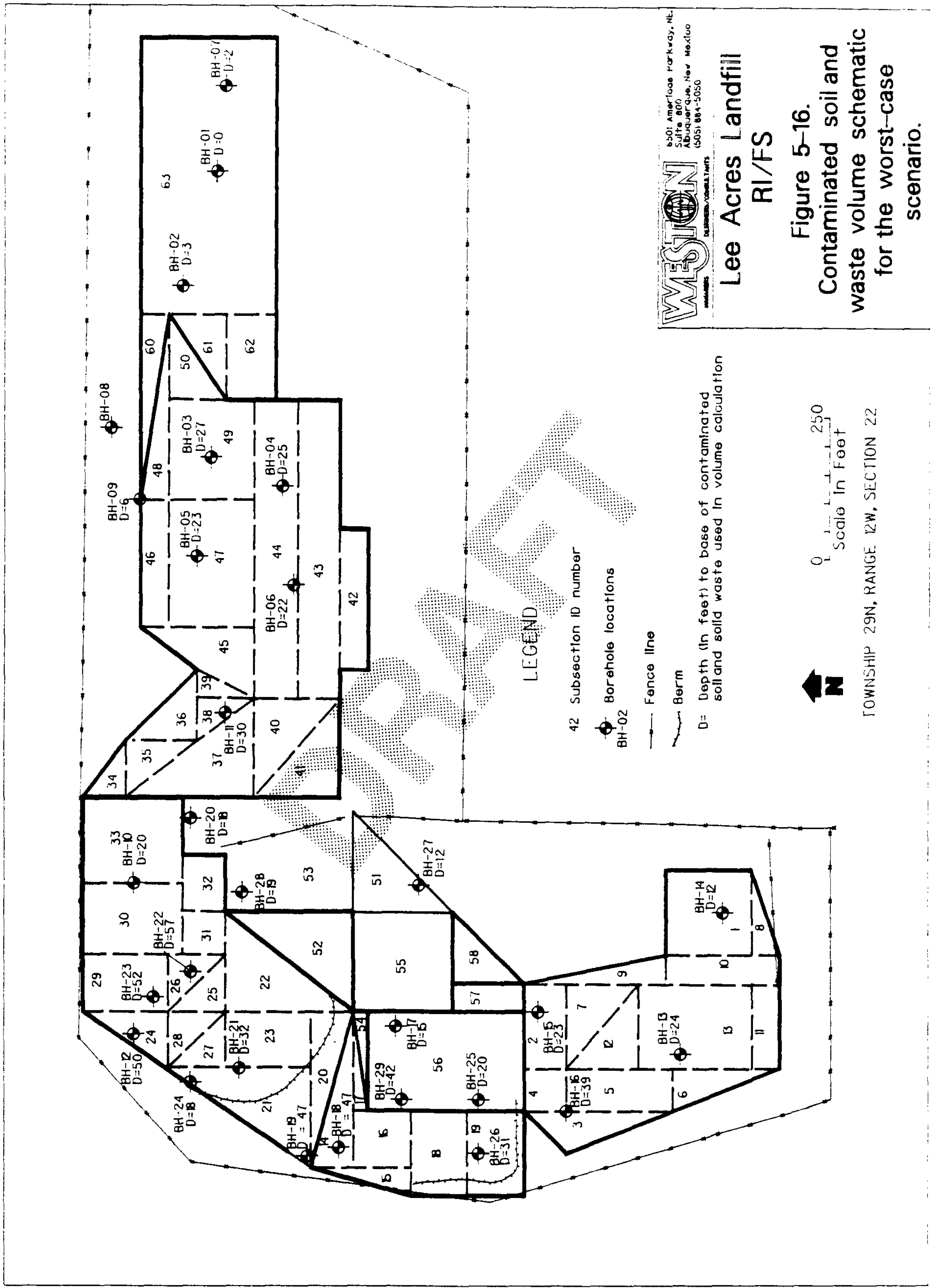

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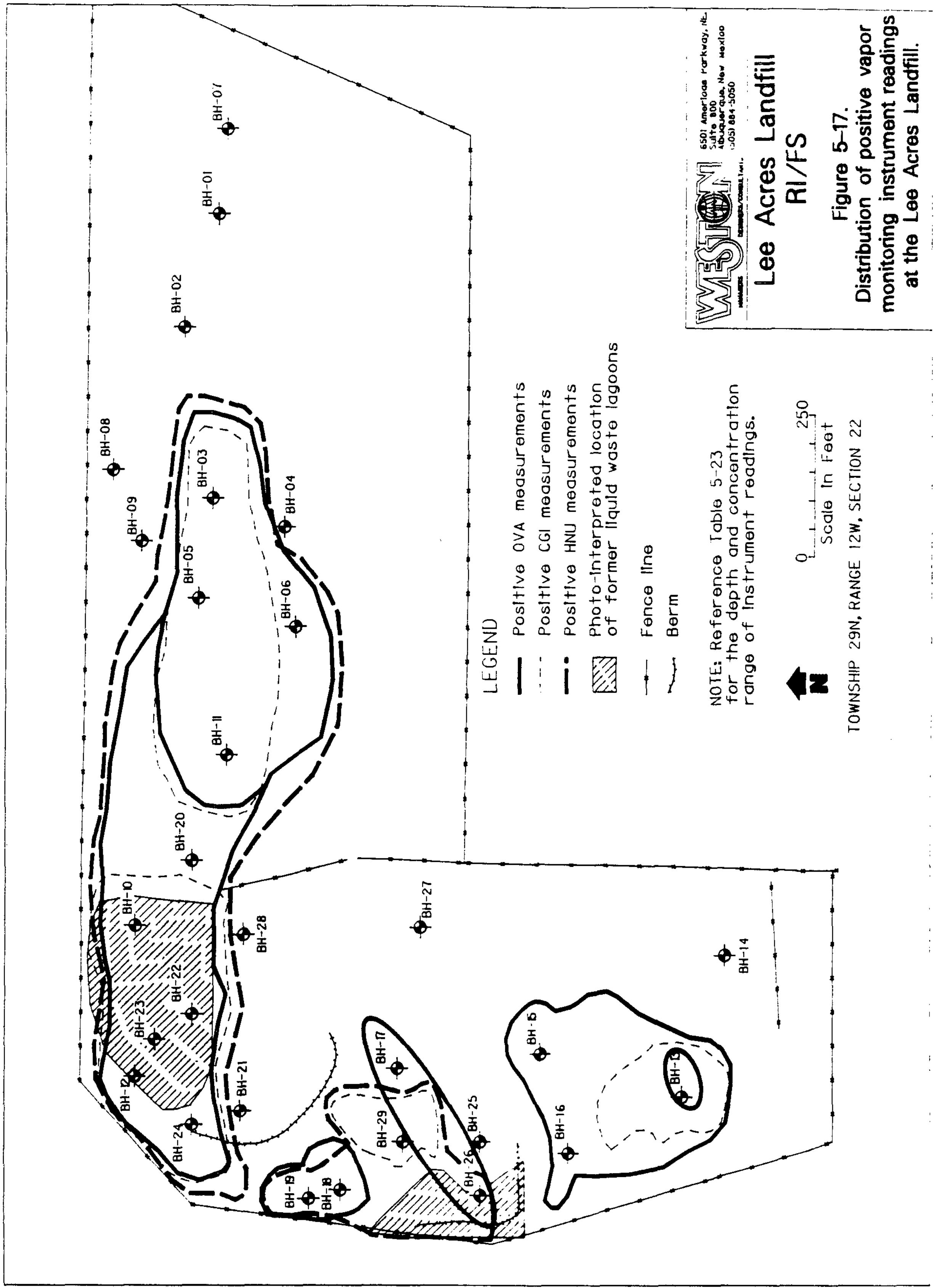
Figure 5-16.
Contaminated soil and waste volume schematic for the worst-case scenario.



NOTE: Reference Table 5-23 for the depth and concentration range of instrument readings.

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Figure 5-17.
Distribution of positive vapor monitoring instrument readings at the Lee Acres Landfill.

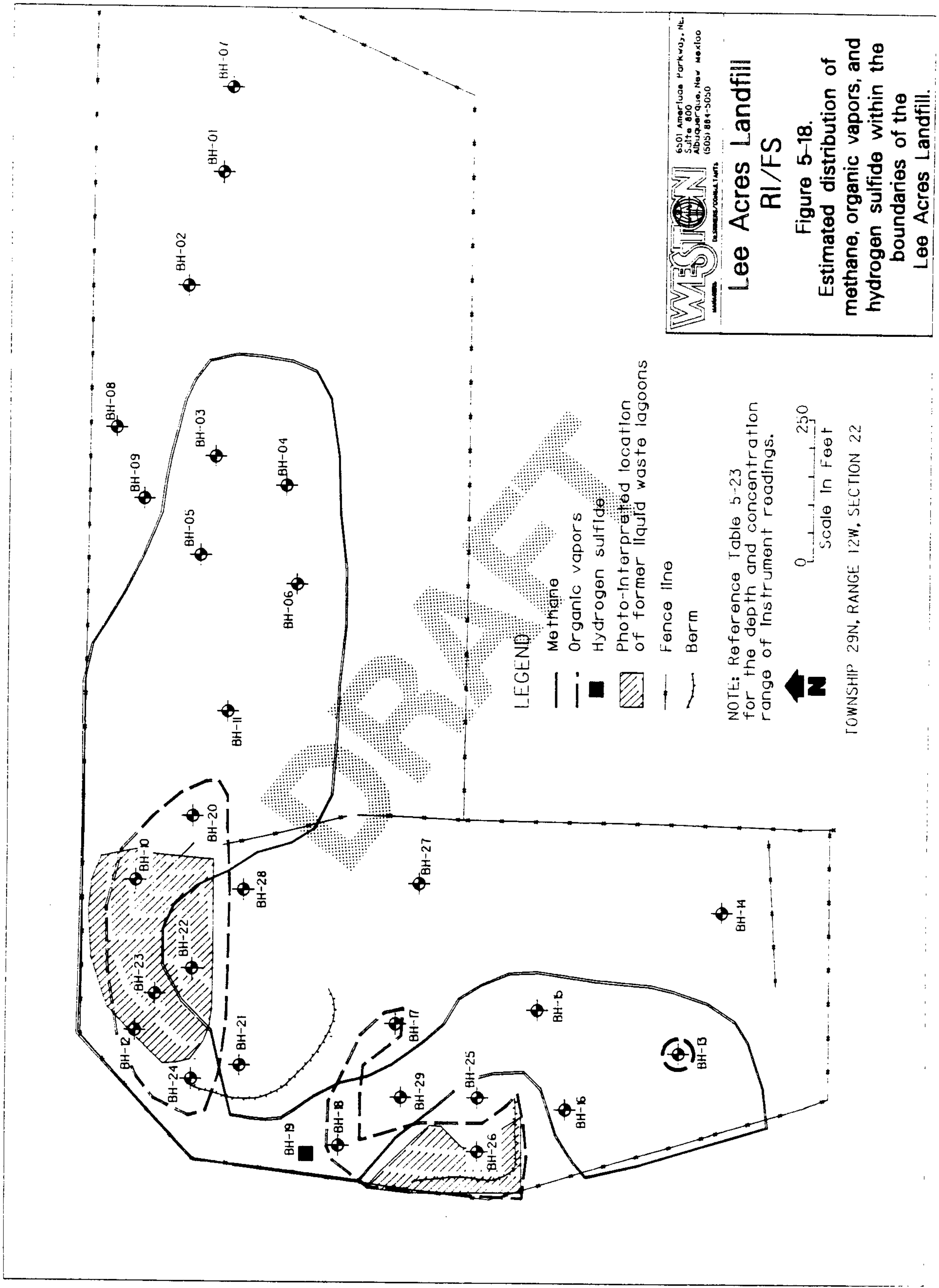

Figure 5-18. Estimated distribution of methane, organic vapors, and hydrogen sulfide within the boundaries of the Lee Acres Landfill.

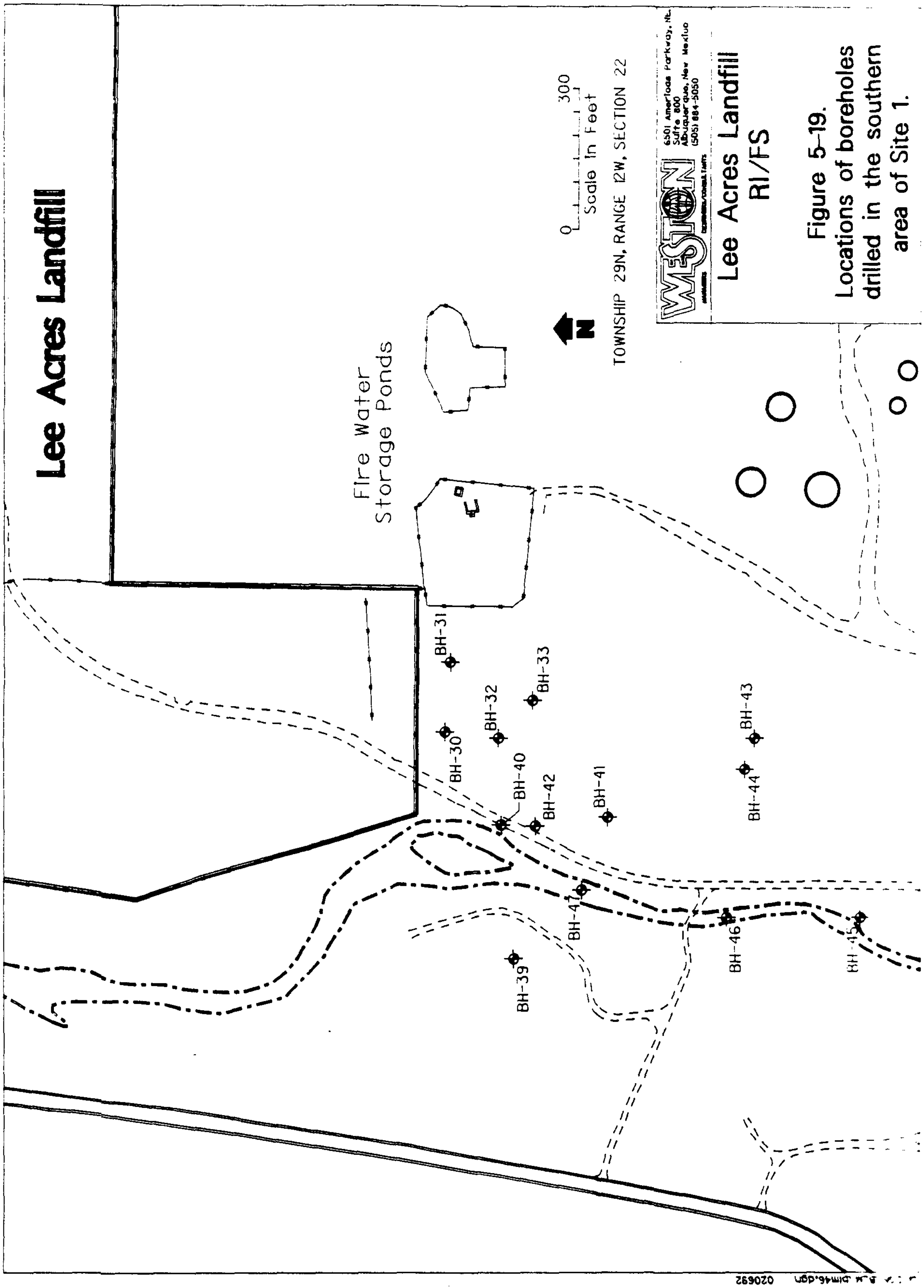

Figure 5-19. Locations of boreholes drilled in the southern area of Site 1.

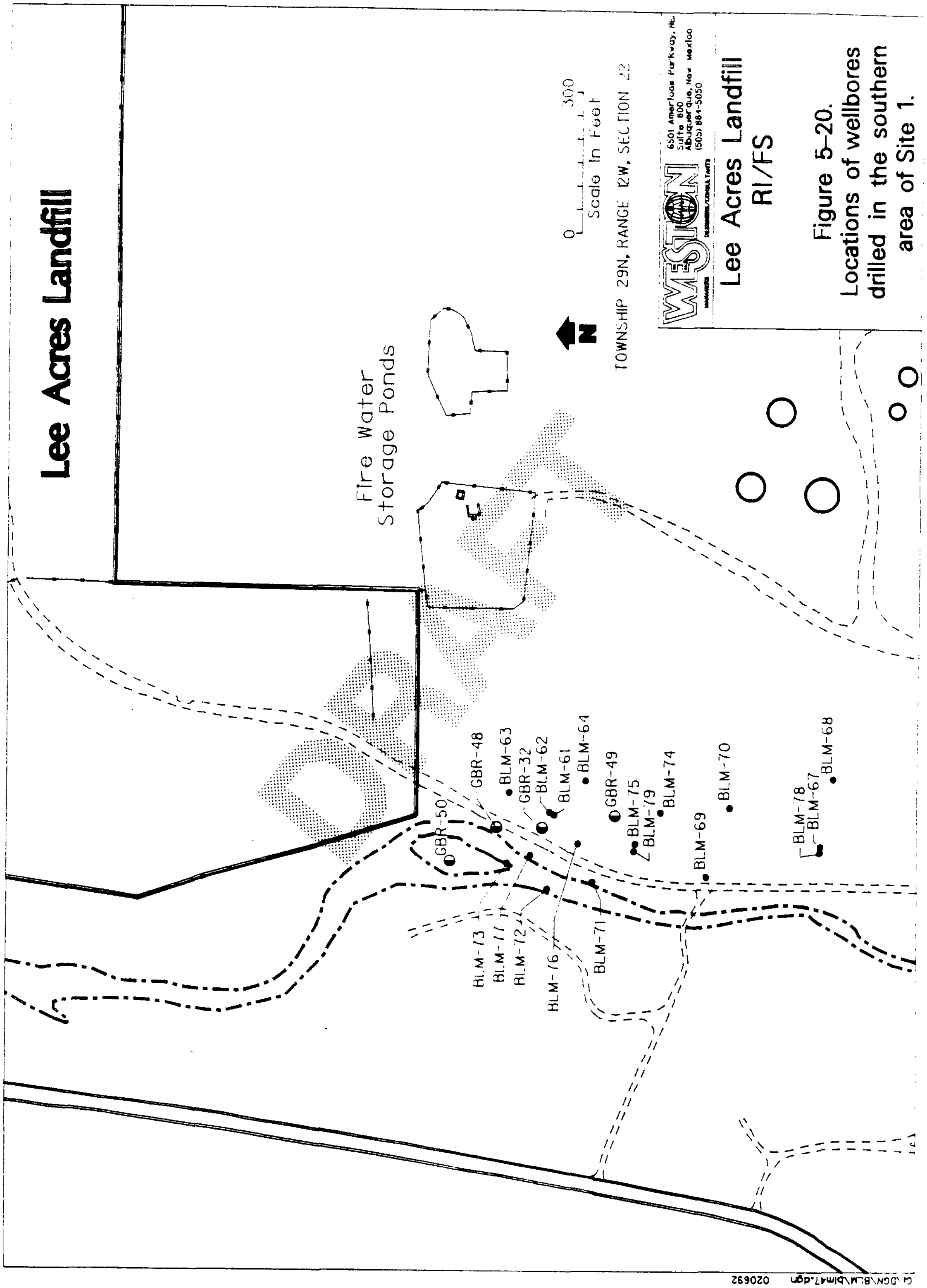

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Figure 5-20.
Locations of wellbores drilled in the southern area of Site 1.

Table 5-1. Volatile Organic Compounds Detected in Operable Unit 1 - Lee Acres Landfill Soils

Sampling Location	Concentration Range		Contaminant	RCRA Action Level^a (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
Volatile Organics (µg/kg):					
BH-03	1.3	3	1,1,1-Trichloroethane	7,000,000	
	2.2	2.9	Chloroform	100,000	
	6	6	Ethylbenzene	8,000,000	
	9.5	9.5	Toluene	20,000,000	
	15	15	Total xylenes	200,000,000	
BH-04	5.9	5.9	Ethylbenzene	8,000,000	
	1.8	1.8	Tetrachloroethene	10,000	
	8	8	Toluene	20,000,000	
	19	19	Total xylenes	200,000,000	
BH-05	2.1	2.1	Ethylbenzene	8,000,000	
	1.6	1.9	Toluene	20,000,000	
	5.1	5.1	Total xylenes	200,000,000	
BH-06	2.6	2.6	1,1,1-Trichloroethane	7,000,000	
	5.5	5.5	1,1,2,2-Tetrachloroethane	40,000	
	16	16	Methylene chloride	90,000	
	5.1	5.1	Toluene	20,000,000	
	3	23	Total xylenes	200,000,000	
BH-09	1.2	1.2	1,1,1-Trichloroethane	7,000,000	
BH-10	6.1	6.1	Ethylbenzene	8,000,000	
	1.2	1.2	Toluene	20,000,000	
	17	17	Total xylenes	200,000,000	
BH-11	12	12	Ethylbenzene	8,000,000	
	1.6	1.6	Tetrachloroethene	10,000	
	14	14	Toluene	20,000,000	
	25	25	Total xylenes	200,000,000	
BH-12	16	16	Benzene	-	C^b
	3.3	75	Ethylbenzene	8,000,000	
	5.8	7.4	Toluene	20,000,000	
	13	71	Total xylenes	200,000,000	
BH-13	3.8	3.8	Ethylbenzene	8,000,000	
	3.2	3.2	Tetrachloroethene	10,000	
	2	4.4	Toluene	20,000,000	
BH-14	1.4	1.4	Trichloroethene	60,000	
BH-15	4	4	Tetrachloroethene	10,000	

Table 5-1. (page 2 of 3)

Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
BH-16	8.5	8.5	1,2-*trans*-Dichloroethene	-	C[b]
	31	31	Tetrachloroethene	10,000	
	5.4	5.4	Trichloroethene	60,000	
BH-18	2.7	2.7	Benzene	-	C[b]
	1.2	1.2	Tetrachloroethene	10,000	
	12	12	Toluene	20,000,000	
	3.5	3.5	Total xylenes	200,000,000	
BH-19	2.4	2.4	Benzene	-	C[b]
	3.8	3.8	Toluene	20,000,000	
	1.7	1.7	Total xylenes	200,000,000	
BH-20	4.1	8.6	Methylene chloride	90,000	
BH-21	1.8	1.8	Toluene	20,000,000	
	1.6	1.6	Total xylenes	200,000,000	
BH-22	2.4	2.4	Toluene	20,000,000	
	1.3	1.3	Total xylenes	200,000,000	
BH-23	18	18	1,1-Dichloroethane	-	C[b]
	4.7	4.7	1,1-Dichloroethene	10,000	
	1,600	1,600	Benzene	-	C[b]
	1.5	1.9	Chloroform	100,000	
	4.4	8.4	Methylene chloride	90,000	
	41,000	41,000	Ethylbenzene	8,000,000	
	19	19	Tetrachloroethene	10,000	
	1.8	20,000	Toluene	20,000,000	
	190,000	190,000	Total xylenes	200,000,000	
	14	14	Trichloroethene	60,000	
	6.4	6.4	Trichlorofluoromethane	20,000,000	
BH-24	5.4	5.4	1,1,1-Trichloroethane	7,000,000	
	1.6	1.6	1,1-Dichloroethane	-	C[b]
	3.9	3.9	Tetrachloroethene	10,000	
	1.5	1.5	Toluene	20,000,000	
	1.9	1.9	Total xylenes	200,000,000	
	5.2	5.2	Trichlorofluoromethane	20,000,000	
BH-26	1.6	1.7	Chloroform	100,000	
	1.6	1.6	Toluene	20,000,000	
	3.2	3.2	Trichloroethene	60,000	

Table 5-1. (page 3 of 3)

Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
BH-27	1.4	1.5	Tetrachloroethene	10,000	
	1.4	1.5	Toluene	20,000,000	
BLM-33	2	8	Acetone	8,000,000	
	10	10	Bromomethane	100,000	
	5	5	Carbon disulfide	8,000,000	
	10	10	Chloroethane	-	C[b]
	10	10	Chloromethane	-	C[b]
	7	11	Methylene chloride	90,000	
	10	10	Vinyl chloride	-	C[b]
BLM-35	3	3	1,1,1-Trichloroethane	7,000,000	
	9	170	Acetone	8,000,000	
	7	21	Methylene chloride	90,000	
BLM-41	4.8	15	Methylene chloride	90,000	
BLM-44	130	130	Methylene chloride	90,000	
	1.9	1.9	Toluene	20,000,000	
BLM-47	1	1	Toluene	20,000,000	
BLM-53	1.9	2	Chloroform	100,000	
	1.2	1.7	Toluene	20,000,000	

µg/kg: micrograms per kilogram

[a] Proposed RCRA action levels for soils (55 FR 30865).

[b] For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.

BH-01: designates a borehole

BLM-33: designates a monitoring well

C: indicates the chemical is identified as a contaminant of concern

-: no action level proposed

Table 5-2. Semivolatile Organic Compounds Detected in Operable Unit 1 - Lee Acres Landfill Soils

Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
Semivolatile Organics (µg/kg):					
BH-01	9,500	9,500	1,4-Dichlorobenzene	-	C[b]
	110	110	Benzoic acid	-	C[b]
	57	57	Phenol	50,000,000	
BH-02	50	50	Diethyl phthalate	60,000,000	
BH-03	570	570	4-Methylphenol	-	C[b]
	160	1,600	Benzoic acid	-	C[b]
	54	54	Chrysene	-	C[b]
	140	140	Phenanthrene	-	C[b]
BH-04	100	100	1,2,4-Trichlorobenzene	2,000,000	
	4,400	4,400	1,4-Dichlorobenzene	-	C[b]
	91	91	2-Methylnaphthalene	-	C[b]
	930	930	Benzoic acid	-	C[b]
	43	1,500	*bis*(2-Ethylhexyl) phthalate	50,000	
	49	49	Chrysene	-	C[b]
	51	51	Fluorene	-	C[b]
	65	65	Naphthalene	-	C[b]
	150	150	Phenanthrene	-	C[b]
	41	110	Phenol	50,000,000	
	40	40	Pyrene	-	C[b]
BH-05	5,100	5,100	1,4-Dichlorobenzene	-	C[b]
	41	41	2-Methylnaphthalene	-	C[b]
	130	130	4-Methylphenol	-	C[b]
	900	900	Benzoic acid	-	C[b]
	340	340	Diethyl phthalate	60,000,000	
	49	110	Phenol	50,000,000	
BH-06	1,600	1,600	1,4-Dichlorobenzene	-	C[b]
	1,100	1,100	2,4-Dimethylphenol	-	C[b]
	45	3,700	2-Methylnapthalene	-	C[b]

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Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
BH-06 (continued)	670	670	2-Methylphenol	-	C[b]
	2,500	2,500	4-Methylphenol	-	C[b]
	370	370	Acenaphethene	-	C[b]
	240	240	Benzo(a)anthracene	-	C[b]
	10,000	10,000	Benzoic acid	-	C[b]
	740	910	*bis*(2-Ethylhexyl) phthalate	50,000	
	410	410	Chrysene	-	C[b]
	2,500	2,500	Di-n-butyl phthalate	-	C[b]
	160	160	Di-n-octyl phthalate	-	C[b]
	190	190	Dibenzofuran	-	C[b]
	310	310	Fluoranthene	-	C[b]
	680	680	Fluorene	-	C[b]
	2,400	2,400	Naphthalene	-	C[b]
	2,000	2,000	Phenanthrene	-	C[b]
	4,600	4,600	Phenol	50,000,000	
	510	510	Pyrene	-	C[b]
BH-11	600	600	2-Methylnaphthalene	-	C[b]
	1,200	1,200	4-Methylphenol	-	C[b]
	2,100	2,100	*bis*(2-Ethylhexyl) phthalate	50,000	
	270	270	Naphthalene	-	C[b]
	660	660	Phenol	50,000,000	
BH-12	410	410	2-Methylnaphthalene	-	C[b]
	250	250	Benzoic acid	-	C[b]
	46	540	*bis*(2-Ethylhexyl) phthalate	50,000	
	92	92	Butyl benzyl phthalate	20,000,000	
	150	150	Chrysene	-	C[b]
	48	230	Di-n-butyl phthalate	-	C[b]
	48	48	Diethyl phthalate	60,000,000	
	500	500	Naphthalene	-	C[b]
BH-13	790	790	Benzoic acid	-	C[b]
	87	87	*bis*(2-Ethylhexyl) phthalate	50,000	
	3,200	3,200	Di-n-butyl phthalate	-	C[b]
BH-14	59	59	Di-n-butyl phthalate	-	C[b]
BH-16	65	65	*bis*(2-Ethylhexyl) phthalate	50,000	
	41	49	Di-n-butyl phthalate	-	C[b]
BH-17	42	42	2-Chlorophenol	400,000	

Table 5-2. (page 3 of 5)

Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
BH-18	360	360	*bis*(2-Ethylhexyl) phthalate	50,000	
	50	50	Di-n-butyl phthalate	-	C[b]
BH-21	44	56	Di-n-butyl phthalate	-	C[b]
BH-23	1.4	1.4	1,2-Dichlorobenzene	-	C[b]
	3.1	3.1	1,4-Dichlorobenzene	-	C[b]
	180	180	*bis*(2-Ethylhexyl) phthalate	50,000	
	54	54	Fluoranthene	-	C[b]
	78	78	Pyrene	-	C[b]
BH-24	370	370	Benzoic acid	-	C[b]
	54	54	Fluoranthene	-	C[b]
	62	62	Phenanthrene	-	C[b]
	63	63	Pyrene	-	C[b]
BH-26	69	69	1,2,4-Trichlorobenzene	2,000,000	
	80	80	2-Methylnaphthalene	-	C[b]
	100	100	Acenaphthene	-	C[b]
	250	250	Anthracene	-	C[b]
	550	550	Benzo(a)anthracene	-	C[b]
	400	400	Benzo(a)pyrene	-	C[b]
	370	370	Benzo(b)fluoranthene	-	C[b]
	200	200	Benzo(g,h,i)perylene	-	C[b]
	410	410	Benzo(k)fluoranthene	-	C[b]
	72	72	*bis*(2-Ethylhexyl) phthalate	50,000	
	520	520	Chrysene	-	C[b]
	3,900	3,900	Di-n-butyl phthalate	-	C[b]
	1,500	1,500	Fluoranthene	-	C[b]
	77	77	Fluorene	-	C[b]
	230	230	Indeno(1,2,3-cd)pyrene	-	C[b]
	1,100	1,100	Phenanthrene	-	C[b]
	980	980	Pyrene	-	C[b]

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Table 5-2. (page 4 of 5)

Sampling Location	Concentration Range		Contaminant	RCRA Action Level^a (μg/kg)	Contaminant of Concern
	Minimum	Maximum			
BH-27	270	270	1,4-Dichlorobenzene	-	C^b
	46	46	2-Methylnaphthalene	-	C^b
	120	120	Benzo(a)anthracene	-	C^b
	93	93	Benzo(a)pyrene	-	C^b
	110	110	Benzo(b)fluoranthene	-	C^b
	110	110	Benzo(g,h,i)perylene	-	C^b
	92	92	Benzo(k)fluoranthene	-	C^b
	61	4,400	*bis*(2-Ethylhexyl) phthalate	50,000	
	210	210	Chrysene	-	C^b
	270	270	Fluoranthene	-	C^b
	62	62	Naphthalene	-	C^b
	230	230	Phenanthrene	-	C^b
	300	300	Pyrene	-	C^b
BH-28	140	140	1,2,4-Trichlorobenzene	2,000,000	
	54	54	1,2-Dichlorobenzene	-	C^b
	74	74	1,4-Dichlorobenzene	-	C^b
	410	410	*bis*(2-Ethylhexyl) phthalate	50,000	
	46	46	Fluoranthene	-	C^b
	39	39	Pyrene	-	C^b
BH-29	43	71	*bis*(2-Ethylhexyl) phthalate	50,000	
BLM-33	76	270	*bis*(2-Ethylhexyl) phthalate	50,000	
BLM-35	1,700	1,700	*bis*(2-Ethylhexyl) phthalate	50,000	
	100	100	Di-n-octyl phthalate	-	C^b
BLM-41	97	97	2,4,6-Trichlorophenol	40,000	
	54	54	2,4-Dichlorophenol	200,000	
	160	160	Anthracene	-	C^b
	140	140	Benzo(a)anthracene	-	C^b
	810	810	Benzo(a)pyrene	-	C^b
	150	150	*bis*(2-Ethylhexyl) phthalate	50,000	
	100	100	Chrysene	-	C^b
	51	51	Fluoranthene	-	C^b
	58	58	Fluorene	-	C^b
	230	230	Pyrene	-	C^b
BLM-44	64	140	Di-n-butyl phthalate	-	C^b
	44	44	Phenol	50,000,000	

Table 5-2. (page 5 of 5)

Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
BLM-47	2.3	2.3	1,2-Dichlorobenzene	-	C[b]
	1.4	1.4	1,3-Dichlorobenzene	-	C[b]
	1.7	1.7	1,4-Dichlorobenzene	-	C[b]
	110	110	Benzoic acid	-	C[b]
	41	41	*bis*(2-Ethylhexyl) phthalate	50,000	
	51	380	Di-n-butyl phthalate	-	C[b]
	39	39	Pyrene	-	C[b]
BLM-53	1.4	1.4	1,4-Dichlorobenzene	-	C[b]
BLM-54	63	120	*bis*(2-Ethylhexyl) phthalate	50,000	
BLM-56	43	43	N-Nitrosodiphenylamine	100,000	
BLM-57	130	330	*bis*(2-Ethylhexyl) phthalate	50,000	
BLM-59	36	41	*bis*(2-Ethylhexyl) phthalate	50,000	

µg/kg: micrograms per kilogram
- : no action level proposed
[a] Proposed RCRA action levels for soils (55 FR 30865).
[b] For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.
BH-01: designates a borehole
BLM-33: designates a monitoring well
C: indicates the chemical is identified as a contaminant of concern

Table 5-3. Constituents Identified as Potentially Present in Petroleum Refining Wastes

Semivolatile Acid-Extractable Organics

Benzenethiol
Cresols
2,4-Dimethylphenol
2,4-Dinitrophenol
4-Nitrophenol
Phenol

Metals

Antimony
Arsenic
Barium
Beryllium
Cadmium
Chromium
Cobalt
Lead
Mercury
Nickel
Selenium
Vanadium

Volatile Organics

Benzene
Carbon disulfide
Chlorobenzene
Chloroform
1,2-Dichloroethane
1,4-Dioxane
Ethyl benzene
Ethylene dibromide
Methyl ethyl ketone
Styrene
Toluene
Xylene

Semivolatile Base/Neutral Extractable Organics

Anthracene
Benzo(a)anthrancene
Benzo(b)fluoranthene
Benzo(k)fluoroanthene
Benzo(a)pyrene
bis(2-Ethylhexyl) phthalate
Butyl benzyl phthalate
Chrysene
Dibenzo(a,j)acridine
Dibenzo(a,h)anthracene
Dichlorobenzenes
Diethyl phthalate
7,12-Dimethylbenzo(a)anthracene
Dimethyl phthalate
Di-n-butyl phthalate
Di-n-octyl phthalate
Fluoroanthene
Indene
Methylchrysene
1-Methylnaphthalene
Naphthalene
Phenanthrene
Pyrene
Pyridine
Quinoline

Ref: EPA 1984

Table 5-4. Pesticides/PCBs Detected in Operable Unit 1 - Lee Acres Landfill Soils

Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
Pesticides/PCBs (µg/kg):					
BH-01	3.8	3.8	4,4'-DDD	3,000	
BH-02	2.2	2.2	4,4'-DDD	3,000	
BH-04	13	13	Dieldrin	40	
BH-05	2.3 3	2.3 25	4,4'-DDD 4,4'-DDE	3,000 2,000	
BH-06	2.8 65 120 2.8	3.6 65 220 2.8	4,4'-DDD 4,4'-DDE 4,4'-DDT Heptachlor	3,000 2,000 2,000 200	
BH-07	13	13	4,4'-DDT	2,000	
BH-10	5.2	5.2	4,4'-DDE	2,000	
BH-11	3.7 1.5	14 1.5	4,4'-DDE Heptachlor Epoxide	2,000 80	
BH-12	9.8 2.4 5.7	9.8 7.1 5.7	4,4'-DDE 4,4'-DDT Dieldrin	2,000 2,000 40	
BH-13	3.8 120 7.6 63	11 120 7.6 63	4,4'-DDE 4,4'-DDT Aldrin Dieldrin	2,000 2,000 40 40	 C
BH-14	8.6 5.7	8.6 5.7	4,4'-DDT Dieldrin	2,000 40	
BH-15	14 2.1	16 4.5	4,4'-DDT Dieldrin	2,000 40	
BH-16	2	5.1	4,4'-DDE	2,000	
BH-17	3.6	3.6	4,4'-DDT	2,000	
BH-19	4.1	4.1	4,4'-DDE	2,000	
BH-20	9.4 10	9.4 10	4,4'-DDE 4,4'-DDT	2,000 2,000	
BH-22	1.4 2.7	1.4 2.7	4,4'-DDE 4,4'-DDT	2,000 2,000	

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Table 5-4. (page 2 of 2)

Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
BH-23	48	48	Dieldrin	40	C
BH-25	3.8	3.8	4,4'-DDT	2,000	
BH-26	2.3	2.3	4,4'-DDE	2,000	
BH-27	12	12	4,4'-DDE	2,000	
BLM-41	2.7 3.6	2.7 52	4,4'-DDD 4,4'-DDT	3,000 2,000	
BLM-44	5.1	15	4,4'-DDT	2,000	
BLM-47.	4.2	4.2	4.4'-DDT	2,000	
BLM-54	15	15	Delta-BHC	-	C[b]

µg/kg: micrograms per kilogram

[a] Proposed RCRA action levels for soils (55 FR 30865).

[b] For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.

BH-01: designates a borehole

BLM-33: designates a monitoring well

C: indicates the chemical is identified as a contaminant of concern

- : no action level proposed

Table 5-5. Inorganic Compounds Detected in Operable Unit 1 - Lee Acres Landfill Soils

Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
Inorganics (µg/kg):					
BH-01	156 6,800	156 8,280	Chloride Sulfate	- -	C[c] C[c]
BH-02	114 198	114 198	Chloride Sulfate	- -	C[c] C[c]
BH-03	134 221	336 12,600	Chloride Sulfate	- -	C[c] C[c]
BH-04	151 6,670	311 18,600	Chloride Sulfate	- -	C[c] C[c]
BH-05	113 4,710	8,330 15,400	Chloride Sulfate	- -	C[c] C[c]
BH-06	84 3,150	329 16,300	Chloride Sulfate	- -	C[c] C[c]
BH-07	1,500	1,500	Sulfate	-	C[c]
BH-08	98.2 11,700	133 20,100	Chloride Sulfate	- -	C[c] C[c]
BH-09	53.4 14,600	53.4 14,600	Chloride Sulfate	- -	C[c] C[c]
BH-10	76.7 2,530	76.7 2,530	Chloride Sulfate	- -	C[c] C[c]
BH-11	108 378	473 6,970	Chloride Sulfate	- -	C[c] C[c]
BH-12	112 241	1,060 7,570	Chloride Sulfate	- -	C[c] C[c]
BH-13	32 402	506 20,600	Chloride Sulfate	- -	C[c] C[c]
BH-14	134 6,950	134 6,950	Chloride Sulfate	- -	C[c] C[c]
BH-15	59.8 184	96 6,720	Chloride Sulfate	- -	C[c] C[c]
BH-16	286 62.3	286 294	Chloride Sulfate	- -	C[c] C[c]
BH-17	334 363	340 1,070	Chloride Sulfate	- -	C[c] C[c]
BH-18	1,530 5,860	1,530 5,860	Chloride Sulfate	- -	C[c] C[c]
BH-19	45.8 45.5	45.8 213	Chloride Sulfate	- -	C[c] C[c]
BH-20	66.1 57	66.1 977	Chloride Sulfate	- -	C[c] C[c]

Table 5-5. (page 2 of 4)

Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
BH-21	169	169	Chloride	-	C[c]
	60.7	1,280	Sulfate	-	C[c]
BH-22	141	681	Chloride	-	C[c]
	386	9,620	Sulfate	-	C[c]
BH-23	69	744	Chloride	-	C[c]
	86.4	11,100	Sulfate	-	C[c]
BH-24	26.6	26.6	Chloride	-	C[c]
	210	340	Sulfate	-	C[c]
BH-25	142	426	Chloride	-	C[c]
	528	2,340	Sulfate	-	C[c]
BH-26	90.7	732	Chloride	-	C[c]
	57.3	453	Sulfate	-	C[c]
BH-27	86.7	672	Chloride	-	C[c]
	314	5,650	Sulfate	-	C[c]
BH-28	181	181	Chloride	-	C[c]
	120	1,010	Sulfate	-	C[c]
BH-29	66	567	Chloride	-	C[c]
	256	1,630	Sulfate	-	C[c]
BLM-41	50.9	74.6	Chloride	-	C[c]
	32.5	594	Sulfate	-	C[c]
BLM-44	44.2	49.9	Chloride	-	C[c]
	71.9	1,280	Sulfate	-	C[c]
BLM-47	109	315	Chloride	-	C[c]
	99.2	634	Sulfate	-	C[c]
BLM-50	12.8	45.8	Chloride	-	C[c]
	47.9	346	Sulfate	-	C[c]
BLM-53	66.8	182	Chloride	-	C[c]
	212	1,520	Sulfate	-	C[c]
BLM-54	12.6	150	Chloride	-	C[c]
	23	335	Sulfate	-	C[c]
BLM-56	17.3	1,070	Chloride	-	C[c]
	33.5	3,080	Sulfate	-	C[c]
BLM-57	11	298	Chloride	-	C[c]
	106	412	Sulfate	-	C[c]
BLM-59	21.3	21.3	Chloride	-	C[c]
	13.5	180	Sulfate	-	C[c]

Table 5-5. (page 3 of 4)

Sampling Location	Concentration Range		Contaminant	TCLP^b (μg/L)	Contaminant of Concern
	Minimum	Maximum			
EP Toxicity Metals (μg/L):					
BH-6	2.97 0.113	20.0 0.113	Strontium Tin	- -	C^c C^c
BH-7	3.09	3.09	Strontium	-	C^c
BH-8	0.0003 1.81	0.0003 6.72	Mercury Strontium	0.2 -	 C^c
BH-9	3.50	3.50	Strontium	-	C^c
BH-10	2.48	2.48	Strontium	-	C^c
BH-11	0.00025 1.7	0.00025 2.48	Mercury Strontium	0.2 -	 C^c
BH-12	0.807	4.40	Strontium	-	C^c
BH-13	2.10	4.12	Strontium	-	C^c
BH-14	2.15	2.15	Strontium	-	C^c
BH-15	0.835	4.02	Strontium	-	C^c
BH-16	0.669	1.31	Strontium	-	C^c
BH-17	1.43	1.53	Strontium	-	C^c
BH-18	1.20	1.20	Strontium	-	C^c
BH-20	1.38	2.03	Strontium	-	C^c
BH-21	0.651	1.85	Strontium	-	C^c
BH-22	0.799	5.71	Strontium	-	C^c
BH-23	0.103 1.04	0.103 5.86	Selenium Strontium	1.0 -	 C^c
BH-24	0.583	0.636	Strontium	-	C^c
BH-25	1.46	3.06	Strontium	-	C^c
BH-26	1.15 0.527	1.15 1.14	Barium Strontium	100 -	 C^c
BH-27	1.49	2.61	Strontium	-	C^c
BH-28	0.762	2.72	Strontium	-	C^c
BH-29	0.00032 0.64	0.00032 2.37	Mercury Strontium	0.2 -	 C^c
BLM-41	0.566	1.13	Strontium	-	C^c
BLM-44	0.859	0.932	Strontium	-	C^c
BLM-47	0.59	0.646	Strontium	-	C^c
BLM-50	0.542	1.380	Strontium	-	C^c

Table 5-5. (page 4 of 4)

Sampling Location	Concentration Range		Contaminant	TCLP[b] (μg/L)	Contaminant of Concern
	Minimum	Maximum			
BLM-53	1.07	1.85	Strontium	-	C[c]
BLM-54	0.697	0.697	Strontium	-	C[c]
BLM-56	1.07	4.32	Strontium	-	C[c]
BLM-57	0.0004	0.0004	Mercury	0.2	
	0.547	3.77	Strontium	-	C[c]
Total Metals (mg/kg):					
BLM-33	2.5	4.8	Arsenic, total	-	C[c]
	6.2	77.4	Barium, total	-	C[c]
	3.9	12.2	Chromium, total	-	C[c]
	2.3	21.4	Lead, total	-	C[c]
BLM-34	2.2	2.3	Arsenic, total	-	C[c]
	5.6	8.2	Chromium, total	-	C[c]
	3.7	3.9	Lead, total	-	C[c]
	1.1	1.1 B	Selenium, total	-	C[c]
	2.4	2.4	Silver, total	-	C[c]
BLM-35	0.34 B	2.1	Arsenic, total	-	C[c]
	1.4 B	10.7	Selenium, total	-	C[c]
	2.3	32.9	Lead, total	-	C[c]

[a] Proposed RCRA action levels for soils (55 FR 30865).

[b] TCLP: maximum concentration of contaminants using Toxicity Characteristic Leachate Procedure.

[c] For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.

C: indicates the chemical is identified as a contaminant of concern

-: no action level proposed

Table 5-6. Semivolatile Organic Compounds Listed as Contaminants of Concern

Contaminant	Sampling Location[a]
2-Methylnaphthalene	BH-04, BH-05, BH-11, BH-12, BH-27, BH-27
2-Methylphenol	BH-06
4-Methylphenol	BH-03, BH-05, BH-06, BH-11
1,2-Dichlorobenzene	BH-23, BH-28, BLM-47
1,3-Dichlorobenzene	BLM-47
1,4-Dichlorobenzene	BH-01, BH-04, BH-05, BH-06, BH-23, BH-27, BH-28, BLM-47, BLM-53
2,4-Dimethylphenol	BH-06
Acenaphthene	BH-06, BH-26
Anthracene	BH-26, BLM-41
Benzo(a)anthracene	BH-06, BH-26, BH-27, BLM-41
Benzo(a)pyrene	BH-26, BH-27, BLM-41
Benzo(b)fluoranthene	BH-26, BH-27
Benzo(g,h,i)perylene	BH-26, BH-27
Benzo(k)fluoranthene	BH-26, BH-27
Benzoic acid	BH-01, BH-03, BH-04, BH-05, BH-06, BH-12, BH-13, BH-14, BLM-47
Chrysene	BH-03, BH-04, BH-06, BH-12, BH-26, BH-27, BLM-41
Di-n-butyl phthalate	BH-06, BH-12, BH-13, BH-14, BH-16, BH-18, BH-21, BH-26, BLM-44, BLM-47
Di-n-octyl phthalate	BH-06, BLM-35
Dibenzofuran	BH-06
Fluoranthene	BH-06, BH-23, BH-24, BH-26, BH-27, BH-28, BLM-41
Fluorene	BH-04, BH-06, BH-26, BLM-41
Indeno(1,2,3-cd)pyrene	BH-26
Napthalene	BH-04, BH-06, BH-11, BH-12, BH-27
Phenanthrene	BH-03, BH-04, BH-06, BH-24, BH-26, BH-27
Pyrene	BH-04, BH-06, BH-23, BH-24, BH-26, BH-27, BH-28, BLM-41, BLM-47

[a] Boreholes and monitoring wells are shown on Figure 5-3.

Table 5-7. 1985 NMOCD and NMEID Liquid Waste Lagoon Sampling Results

Chemical Constituent	NMOCD January 11, 1985 Sampling (mg/L)	NMOCD February 27, 1985		NMEID May 2, 1985 South Side[a] (mg/L)
		West Side (mg/L)	East Side (mg/L)	
Inorganics:				
Calcium	204/170	267/230	234/200	224/240
Magnesium	26.8/19	18.7/19	18.5/16	36.6/25
Sodium	1,507	1,833	1,263	1,790
Potassium	885	848	548	390
Bicarbonate	---	417	625	476
Sulfate	430	1,881	1,086	40.2
Chloride	2,759	3,577	2,251	4,474
Phosphate	---	---	---	0.92
Nitrate-N	---	---	---	<0.01
Ammonia-N	---	---	---	6.8
Total Kjeldahl Nitrogen	---	---	---	11.1
TDS	6,308	7,695	5,268	9,018
pH	7.14	8.08	7.64	6.14
Metals:				
Aluminum	2.3	1.8	1.5	0.30
Arsenic	0.022	---	---	0.009
Barium	0.74	0.60	0.37	0.5
Beryllium	<0.10	<0.10	<0.10	<0.1
Boron	0.61	0.58	0.48	1.6
Cadmium	<0.10	<0.10	<0.10	<0.10
Chromium	0.28	0.23	0.15	<0.10
Cobalt	<0.10	<0.10	<0.10	<0.10
Copper	<0.10	<0.10	<0.10	<0.10
Iron	6.9	7.8	6.8	75
Lead	<0.10	0.21	0.10	<0.10
Manganese	1.5	0.83	0.80	2.1
Mercury	---	---	---	---
Molybdenum	<0.10	<0.10	<0.10	<0.10
Nickel	<0.10	<0.10	<0.10	<0.10

Table 5-7. (page 2 of 2)

Chemical Constituent	NMOCD January 11, 1985 Sampling (mg/L)	NMOCD February 27, 1985		NMEID May 2, 1985 South Side[a] (mg/L)
		West Side (mg/L)	East Side (mg/L)	
Selenium	0.026	---	---	0.025
Silicon	1.2	2.0	2.0	1.40
Silver	<0.10	<0.10	<0.10	<0.10
Strontium	4.4	6.0	4.5	7.3
Tin	<0.10	<0.10	<0.10	<0.10
Vanadium	<0.10	<0.10	<0.10	<0.10
Yttrium	<0.10	<0.10	<0.10	<0.10
Zinc	0.29	0.24	0.54	<0.10
Organics:				
Benzene	0.44	1.03	0.89	0.120
Toluene	0.95	1.98	1.94	0.330
Ethylbenzene	0.1	0.16	0.17	0.025
Xylenes	0.71	1.21	1.34	0.205
Methylene Chloride	2.0	0.18	0.21	---
1,1,1-Trichloroethane	0.4	0.19	0.23	0.010
Trichloroethene	0.004	---	---	---
Tetrachloroethene	---	0.016	0.007	---
Acetone	---	---	---	---
2-Propanol	---	---	---	---

Ref: McQuillan and Longmire 1986.

[a] After the addition of ferric chloride.

---: not measured above detection

NMEID: New Mexico Environmental Improvement Division

NMOCD: New Mexico Oil Conservation District

Table 5-8. 1985 Northern Liquid Waste Lagoon Sampling Analytical Results Disseminated by the NMOCD and the NMEID

Location:		Lagoon	East Side Lagoon Near Disposal Area	West Side Lagoon	Waste Disposal Pit	Lee Acres Landfill South Pump	Lee Acres Landfill South Pond
Date:		01/11/85	02/27/85	02/27/85	04/18/85	05/02/85	09/12/85
Sample Collected/Analyzed:		NMOCD/SLD	NMOCD/SLD	NMOCD/SLD	NMEID/SLD	NMEID/SLD	NMOCD/SLD
Temperature:		NA	55°F	55°F	UNK	23°C	35°C
Volatile Organics:							
2-Propanol	μg/L	NA	NA	NA	[10]	NA	NA
2-Pentene	μg/L	NA	NA	NA	[5]	NA	NA
1,1,1-Trichloroethane	μg/L	[400]	230	190	38	10	NA
Acetone	μg/L	NA	NA	NA	[100]	NA	NA
Aromatic purgeables	μg/L	NA	6 UNKs	10 UNKs	NA	10 UNKs	NA
Benzene	μg/L	440	890	1030	360	120	TR 5
Dichloromethane	μg/L	[2,000]	210	180	NA	NA	NA
Ethylbenzene	μg/L	100	170	160	[200]	25	NA
Halogenated purgeables	μg/L	NA	NA	NA	NA	2 compounds	<10.0
Hexamethylcyclotrisiloxane	μg/L	NA	NA	NA	>1,000	NA	NA
m-Xylene	μg/L	380	770	690	NA	120	NA
Methylcyclohexane	μg/L	NA	NA	NA	[20]	NA	NA
o-Xylene	μg/L	200	360	320	NA	55	NA
p-Xylene	μg/L	130	210	200	NA	30	NA
Tetrachloroethene	μg/L	NA	7	16	NA	NA	NA
Toluene	μg/L	950	1,940	1,980	1,380	330	TR 10
Total xylenes	μg/L	NA	NA	NA	[500]	NA	NA
Trichloroethene	μg/L	TR [4]	NA	NA	NA	NA	NA

Table 5-8. (page 2 of 4)

Location: Date: Sample Collected/Analyzed: Temperature:		Lagoon 01/11/85 NMOCD/SLD NA	East Side Lagoon Near Disposal Area 02/27/85 NMOCD/SLD 55°F	West Side Lagoon 02/27/85 NMOCD/SLD 55°F	Waste Disposal Pit 04/18/85 NMEID/SLD UNK	Lee Acres Landfill South Pump 05/02/85 NMEID/SLD 23°C	Lee Acres Landfill South Pond 09/12/85 NMOCD/SLD 35°C
Metals:							
Silver	mg/L	-0.1	-0.1	-0.1	NA	-0.1	-0.1
Aluminum	mg/L	2.3	1.5	1.8	NA	0.3	0.2
Arsenic	mg/L	0.022	0.046	0.024	NA	0.009	NA
Boron	mg/L	0.61	0.48	0.58	NA	1.6	-0.1
Barium	mg/L	0.74	0.37	0.6	NA	0.5	0.2
Beryllium	mg/L	-0.1	-0.1	-0.1	NA	-0.1	-0.1
Calcium	mg/L	170.0	200.0	230.0	NA	240.0	140.0
Cadmium	mg/L	-0.1	-0.1	-0.1	NA	-0.1	-0.1
Cobalt	mg/L	-0.1	-0.1	-0.1	NA	-0.1	-0.1
Chromium	mg/L	0.28	0.15	0.23	NA	-0.1	-0.1
Copper	mg/L	-0.1	-0.1	-0.1	NA	-0.1	-0.1
Iron	mg/L	6.9	6.8	7.8	NA	75.0	0.8
Magnesium	mg/L	19.0	16.0	19.0	NA	25.0	15.0
Manganese	mg/L	1.5	0.8	0.83	NA	2.1	0.68
Molybdenum	mg/L	-0.1	-0.1	-0.1	NA	-0.1	-0.1
Nickel	mg/L	-0.1	-0.1	-0.1	NA	-0.1	-0.1
Lead	mg/L	-0.1	0.1	0.21	NA	-0.1	-0.1
Selenium	mg/L	0.026	0.011	0.025	NA	0.25	NA
Silicon	mg/L	1.2	2.0	2.0	NA	14.0	4.3

Table 5-8. (page 3 of 4)

Location:		Lagoon	East Side Lagoon Near Disposal Area	West Side Lagoon	Waste Disposal Pit	Lee Acres Landfill South Pump	Lee Acres Landfill South Pond
Date:		01/11/85	02/27/85	02/27/85	04/18/85	05/02/85	09/12/85
Sample Collected/Analyzed:		NMOCD/SLD	NMOCD/SLD	NMOCD/SLD	NMEID/SLD	NMEID/SLD	NMOCD/SLD
Temperature:		NA	55°F	55°F	UNK	23°C	35°C
Metals (continued):							
Strontium	mg/L	4.4	4.5	6.0	NA	7.3	2.3
Tin	mg/L	-0.1	-0.1	-0.1	NA	-0.1	-0.1
Vanadium	mg/L	-0.1	-0.1	-0.1	NA	-0.1	-0.1
Yttrium	mg/L	-0.1	-0.1	-0.1	NA	-0.1	-0.1
Zinc	mg/L	0.29	0.54	0.24	NA	-0.1	-0.1
Ions:							
Ammonia as N	mg/L	NA	19.78	10.8	NA	6.8	1.3
Bicarbonate	mg/L	661.5	624.8	416.6	NA	476.1	54.0
Calcium	mg/L	204.0	234.0	267.0	NA	224.0	136.0
Chloride	mg/L	2,758.9	2,251.4	3,576.8	NA	4,474.5	540.3
Conductivity	µmhos/cm	10,154.0	7,500.0	10,020.0	UNK	13,500.0	2,200.0
Fluoride	mg/L	3.58	2.19	2.08	NA	0.94	0.48
Magnesium	mg/L	26.8	18.5	18.7	NA	36.6	24.4
Nitrate-nitrite, nitrogen	mg/L	NA	5.23	0.94	NA	-0.01	0.58
pH		7.14	7.64	8.08	UNK	6.14	NA
Phosphate	mg/L	NA	NA	NA	NA	0.92	NA
Potassium	mg/L	885.0	548.0	848.0	NA	390.0	44.5
Sodium	mg/L	1,507.0	1,263.0	1,833.0	NA	1,790.0	259.9
Sulfate	mg/L	430.0	1,086.0	1,881.0	NA	40.2	416.3

Table 5-8. (page 4 of 4)

Location:		Lagoon	East Side Lagoon Near Disposal Area	West Side Lagoon	Waste Disposal Pit	Lee Acres Landfill South Pump	Lee Acres Landfill South Pond
Date:		01/11/85	02/27/85	02/27/85	04/18/85	05/02/85	09/12/85
Sample Collected/Analyzed:		NMOCD/SLD	NMOCD/SLD	NMOCD/SLD	NMEID/SLD	NMEID/SLD	NMOCD/SLD
Temperature:		NA	55°F	55°F	UNK	23°C	35°C
Ions (continued):							
Total dissolved solids	mg/L	6,308.0	5,268.0	7,695.0	NA	9,018.0	1,638.0
Total K. nitrogen	mg/L	NA	24.7	21.4	NA	11.1	1.67

µmhos/cm: micromhos per centimeter
µg/L: micrograms per liter
mg/L: milligrams per liter
NA: not analyzed
NMEID: New Mexico Environmental Improvement Division
NMOCD: New Mexico Oil Conservation Division
SLD: New Mexico Scientific Laboratory Division
TR: trace below detection limit
UNK: unknown
[]: approximate

Table 5-9. Constituents Detected in Stained Areas within Boreholes

Analyte	Former Northern Liquid Waste Lagoon				Former Southern Lagoon	Hydrocarbon Residue
	BH-10 (µg/kg)	BH-12^a (µg/kg)	BH-12^b (µg/kg)	BH-23 (µg/kg)	BH-26 (µg/kg)	BH-13 (µg/kg)
Petroleum Hydrocarbons (BTEX):						
Benzene	ND	ND	ND	1,600	ND	ND
Toluene	1.2	5.8	ND	20,000	1.6	4.4
Ethylbenzene	6.1	22	4.2	41,000	ND	3.8
Xylene	17	49	13	190,000	ND	ND
Chlorinated Hydrocarbons:						
1,1-Dichloroethane	ND	ND	ND	18	ND	ND
1,1-Dichloroethene	ND	ND	ND	4.7	ND	ND
1,2-Dichlorobenzene	ND	ND	ND	1.4	ND	ND
1,4-Dichlorobenzene	ND	ND	ND	3.1	ND	ND
Dichloromethane	ND	ND	ND	8.4	ND	ND
Tetrachloroethene	ND	ND	ND	19	ND	3.2
Trichloroethene	ND	ND	ND	14	3.2	ND
Trichlorofluoromethane	ND	ND	ND	6.4	ND	ND
Trichloromethane	ND	ND	ND	ND	1.7	ND
Inorganics:	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Chloride(IC)	76.7	112	218	513	124	506
Sulfate	2,530	253	2,050	3,940	453	20,600

[a] Sample depth interval = 1 to 2 ft.
[b] Sample depth interval = 4 to 5 ft.
Note: Phase I RI soil boring analytical results are in Appendix I-1.
BH: borehole
mg/kg: milligrams per kilogram
ND: not detected

Table 5-10. Lysimeter Sample Volumes

Lysimeter Location	Lysimeter Sample Volumes and Sample Dates					Total Sample Volume Collected (mL)
	April 4 - 5, 1990	April 24 - 27, 1990	May 18, 1990	June 26, 1990	August 21, 1990	
LS-1	0	0	0	0	0	0
LS-3	0	65	0	30	0	95
LS-4	0	0	0	0	0	0
LS-5	360	0	38	0	0	398
LS-6	55	0	20	0	0	75
LS-7	85	0	105	35	0	225

mL: milliliters

BLRIPD11.510 02/17/92

Table 5-11. Organic Compounds Detected in Lysimeter Samples

Sampling Location	Concentration Range		Contaminant	SDWA MCL[a] (μg/L)	NM WQCC[b] (μg/L)	Contaminant of Concern
	Minimum	Maximum				
Volatile Organics (μg/L):						
LS-5 (Shallow)	1.2	1.2	1,1-Dichloroethane	L	25	
	1.5	1.5	1,3-*cis*-Dichloropropene	L	-	C[c]
	7.4	7.4	Benzene	5	10	C
	4.9	4.9	Dichlorodifluoromethane	-	-	C[c]
	0.64	0.64	Dichloromethane	-	100	
	1.6	1.6	Ethylbenzene	700(P)	750	
	2.2	2.2	Toluene	2,000(P)	750	
	5	5	Total xylenes	10,000(P)	620	
	2.3	2.3	Trichloromethane	L	100	
LS-6 (Intermediate)	7.2	7.2	Dichloromethane	-	100	
LS-7 (Deep)	7.3	7.3	1,1-Dichloroethane	L	25	
	1.2	1.2	1,1-Dichloroethene	7	5	
	1.5	1.5	Benzene	5	10	
	4.1	4.1	Dichlorodifluoromethane	-	-	C[c]
	0.72	0.72	Methylene chloride	-	100	
	1.8	1.8	Toluene	2,000(P)	750	
	3.1	3.1	Trichloroethene	5	100	
Semivolatile Organics (μg/L):						
LS-3	0.78	8.9	1,2-Dichlorobenzene	75	-	
	1.7	1.7	1,4-Dichlorobenzene	600(P)	-	

μg/L: micrograms per liter

[a] SDWA MCL = Safe Drinking Water Act maximum contaminant levels.

[b] NM WQCC = New Mexico State Water Quality Control Commission regulations (Section 3-103.A).

[c] For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.

C: indicates the chemical is identified as a contaminant of concern

L: listed for regulation but MCL is currently unproposed

LS-5: designates a lysimeter

P: proposed Safe Drinking Water Act MCL

-: no state water quality standard or SDWA MCL specified

Table 5-12. Inorganic Compounds Detected in Lysimeter Samples

Sampling Location	Concentration Range		Contaminant	SDWA MCL[a] (µg/L)	NM WQCC[b] (µg/L)	Contaminant of Concern
	Minimum	Maximum				
Inorganics (µg/L):						
LS-5 (Shallow)	400	400	Bicarbonate	-	-	C[c]
	1.6	1.6	Bromide	-	-	C[c]
	295	295	Chloride	-	250,000	
	729	729	Sulfate	400,000/ 500,000(P)	600,000	

µg/L: micrograms per liter

[a] SDWA MCL = Safe Drinking Water Act maximum contaminant level.

[b] NM WQCC = New Mexico State Water Quality Control Commission regulations (Section 3-103.A).

[c] For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.

C: indicates the chemical is identified as a contaminant of concern.

LS-5: designates a lysimeter

-: no state water quality standard or SDWA MCL specified

Table 5-13. Volatile Organic Compounds Detected in Liquid Waste Lagoon Samples Collected in 1985

Sampling Location	Concentration Range		Contaminant	SDWA MCL^a (µg/L)	NM WQCC^b (µg/L)	Contaminant of Concern
	Minimum	Maximum				
Volatile Organics (µg/L):						
Lagoon Pit	400	400	1,1,1-Trichloroethane	200	60	C
	440	440	Benzene	5	10	C
	2,000	2,000	Dichloromethene	-	100	C
	100	100	Ethylbenzene	700(P)	750	
	950	950	Toluene	2,000(P)	750	C
	380	380	m-Xylene	10,000(P)^c	620	
	200	200	o-Xylene	10,000(P)^c	620	
	130	130	p-Xylene	10,000(P)^c	620	
	4	4	Trichloroethene	5	100	
East Side Lagoon	230	230	1,1,1-Trichloroethane	200	60	C
	890	890	Benzene	5	10	C
	210	210	Dichloromethane	-	100	C
	170	170	Ethylbenzene	700(P)	750	
	7	7	Tetrachloroethene	5(P)	-	C
	1,940	1,940	Toluene	2,000(P)	750	C
	770	770	m-Xylene	10,000(P)^c	620	C
	360	360	o-Xylene	10,000(P)^c	620	
	210	210	p-Xylene	10,000(P)^c	620	
West Side Lagoon	190	190	1,1,1-Trichloroethane	200	60	C
	1,030	1,030	Benzene	5	10	C
	180	180	Dichloromethane	-	100	C
	160	160	Ethylbenzene	700(P)	750	
	16	16	Tetrachloroethene	5(P)	-	C
	1,980	1,980	Toluene	2,000(P)	750	C
	690	690	m-Xylene	10,000(P)^c	620	C
	320	320	o-Xylene	10,000(P)^c	620	
	200	200	p-Xylene	10,000(P)^c	620	

Table 5-13. (page 2 of 2)

Sampling Location	Concentration Range		Contaminant	SDWA MCL^a (µg/L)	NM WQCC^b (µg/L)	Contaminant of Concern
	Minimum	Maximum				
Waste Disposal Pit	38	38	1,1,1-Trichloroethane	200	60	
	360	360	Benzene	5	10	C
	200	200	Ethylbenzene	700(P)	750	
	1,380	1,380	Toluene	2,000(P)	750	C
	100	100	Acetone	-	-	C^d
	500	500	Total xylenes	10,000(P)	620	
	10	10	2-Propanol	-	-	C^d
	5	5	2-Pentene	-	-	C^d
	20	20	Methylcyclohexane	-	-	C^d
	>1,000	>1,000	Hexamethylcyclotrisiloxane	-	-	C^d
	>1,000	>1,000	Octamethylcyclotetrasiloxane	-	-	C^d
Lagoon - South Pump	10	10	1,1,1-Trichloroethane	200	60	
	120	120	Benzene	5	10	C
	25	25	Ethylbenzene	700(P)	750	
	330	330	Toluene	2,000(P)	750	
	120	120	m-Xylene	10,000(P)^c	620	
	55	55	o-Xylene	10,000(P)^c	620	
	30	30	p-Xylene	10,000(P)^c	620	
South Pond	<5	<5	Benzene	5	10	
	<10	<10	Toluene	2,000(P)	750	

µg/L: micrograms per liter

^{a}SDWA MCL = Safe Drinking Water Act maximum contaminant levels.

^{b}NM WQCC = New Mexico State Water Quality Control Commission regulations (Section 3-103.A).

^{c}SDWA MCL for total xylenes was also used for m-xylene, o-xylene, and p-xylene.

^{d}For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.

C: indicates the chemical is identified as a contaminant of concern

P: proposed SDWA MCL

-: no state water quality standard or SDWA MCL specified

Table 5-14. Inorganic Compounds Detected in Liquid Waste Lagoon Samples Collected in 1985

Sampling Location	Concentration Range		Contaminant	SDWA MCL^a (mg/L)	NM WQCC^b (mg/L)	Contaminant of Concern
	Minimum	Maximum				
Inorganics (mg/L):						
Lagoon Pit	661.5	661.5	Bicarbonate	-	-	C^c
	2,758.9	2,758.9	Chloride	-	250,000	
	430	430	Sulfate	400,000/ 500,000(P)	600,000	
East Side Lagoon	624.8	624.8	Bicarbonate	-	-	C^c
	2,251.4	2,251.4	Chloride	-	250,000	
	1,086	1,086	Sulfate	400,000/ 500,000(P)	600,000	
West Side Lagoon	416.6	416.6	Bicarbonate	-	-	C^c
	3,576.4	3,576.4	Chloride	-	250,000	
	1,881	1,881	Sulfate	400,000/ 500,000(P)	600,000	
Lagoon - South Pump	476.1	476.1	Bicarbonate	-	-	
	4,474.5	4,474.5	Chloride	-	250,000	
	40.2	40.2	Sulfate	400,000/ 500,000(P)	600,000	
South Pond	54	54	Bicarbonate	-	-	C^c
	540.3	540.3	Chloride	-	250,000	
	416.3	416.3	Sulfate	400,000/ 500,000(P)	600,000	
Total Metals (mg/L):						
Lagoon Pit	0.74	0.74	Barium	1.0	1.0	
	0.61	0.61	Boron	L	0.75	
	0.28	0.28	Chromium	0.05	0.05	C
	6.9	6.9	Iron	0.3(S)	1.0	C
	1.5	1.5	Manganese	0.05(S)	0.2	C
	1.2	1.2	Silicon	-	-	C^c
	4.4	4.4	Strontium	L	-	C^c
	0.29	0.29	Zinc	5(S)	10	
	0.022	0.022	Arsenic	0.05	0.1	
	0.026	0.026	Selenium	0.01	0.05	C
East Side Lagoon	0.37	0.37	Barium	1.0	1.0	
	0.48	0.48	Boron	L	0.75	
	0.15	0.15	Chromium	0.05	0.05	C
	6.8	6.8	Iron	0.3(S)	1.0	C
	0.1	0.1	Lead	0.05	0.05	C

Table 5-14. (page 2 of 2)

Sampling Location	Concentration Range		Contaminant	SDWA MCL[a] (mg/L)	NM WQCC[b] (mg/L)	Contaminant of Concern
	Minimum	Maximum				
East Side Lagoon (continued)	0.8	0.8	Manganese	0.05(S)	0.2	C
	2.0	2.0	Silicon	-	-	C[c]
	4.5	4.5	Strontium	L	-	C[c]
	0.54	0.54	Zinc	5(S)	10	
	0.046	0.046	Arsenic	0.05	0.1	
	0.011	0.011	Selenium	0.01	0.05	C
West Side Lagoon	0.6	0.6	Barium	1.0	1.0	
	0.58	0.58	Boron	L	0.75	
	0.23	0.23	Chromium	0.05	0.05	C
	7.8	7.8	Iron	0.3(S)	1.0	C
	0.21	0.21	Lead	0.05	0.05	C
	0.83	0.83	Manganese	0.05(S)	0.2	C
	2.0	2.0	Silicon	-	-	C[c]
	6.0	6.0	Strontium	L	-	C[c]
	0.24	0.24	Zinc	5(S)	10	
	0.024	0.024	Arsenic	0.05	0.1	
	0.025	0.025	Selenium	0.01	0.05	C
Lagoon - South Pump	0.5	0.5	Barium	1.0	1.0	
	1.6	1.6	Boron	L	0.75	C
	75.0	75.0	Iron	0.3(S)	1.0	C
	2.1	2.1	Manganese	0.05(S)	0.2	C
	14.0	14.0	Silicon	-	-	C[c]
	7.3	7.3	Strontium	L	-	C[c]
	0.0090.25	0.009	Arsenic	0.05	0.1	
		0.25	Selenium	0.01	0.05	C
South Pond	0.2	0.2	Barium	1.0	1.0	
	0.8	0.8	Iron	0.3(S)	1.0	C
	0.68	0.68	Manganese	0.05(S)	0.2	C
	4.3	4.3	Silicon	-	-	C[c]
	2.3	2.3	Strontium	L	-	C[c]

mg/L: milligrams per liter

[a] SDWA MCL: Safe Drinking Water Act maximum contaminant level.

[b] NM WQCC: New Mexico State Water Quality Control Commission regulations (Section 3-103.A).

[c] For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.

C: indicates the chemical is identified as a contaminant of concern

L: listed for regulation but MCL is currently unproposed

P: proposed SDWA MCL

S: Secondary SDWA MCL

-: no state water quality standard or SDWA MCL specified

Table 5-15. Volatile Organic Compounds Detected in Arroyo Soils Adjacent to the Former Lee Acres Landfill

Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
Volatile Organics (µg/kg):					
BH-48	23 1	23 1	Dichloromethane Toluene	90,000 20,000,000	
BH-49	9.3 1.2	52 1.6	Dichloromethane Toluene	90,000 20,000,000	
BH-50	13	56	Dichloromethane	90,000	
BH-51	44	44	Dichloromethane	90,000	
BH-52	17 1.5	30 2.1	Dichloromethane Toluene	90,000 20,000,000	
BH-53	7.6	28	Dichloromethane	90,000	

µg/kg: micrograms per kilograms

[a] Proposed RCRA action levels for soils (55 FR 30865).

BH-48: designates a borehole

Note: Because these compounds did not exceed RCRA action levels, they are not identified as contaminants of concern.

Table 5-16. Semivolatile Organic Compounds Detected in Arroyo Soils Adjacent to the Former Lee Acres Landfill

Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (μg/kg)	Contaminant of Concern
	Minimum	Maximum			
Semivolatile Organics (μg/kg):					
Soil near car in arroyo	3,900	3,900	2-Methlnaphthalene	-	C[b]
	2,700	2,700	Anthracene	-	C[b]
	2,600	2,600	Chrysene	-	C[b]
	7,200	7,200	Phenanthrene	-	C[b]
Pesticides/PCBs (μg/kg):					
Soil near car in arroyo	1,200	1,200	Beta-BHC	-	C[b]

μg/kg: micrograms per kilogram

[a] There are no proposed RCRA action levels for these compounds (55 FR 30865).

[b] For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.

C: indicates the chemical is identified as a contaminant of concern

Table 5-17. Inorganic Compounds and Metals Detected in Arroyo Soils Adjacent to the Former Lee Acres Landfill

Sampling Location	Concentration Range		Contaminant	RCRA Action Level[a] (µg/kg)	Contaminant of Concern
	Minimum	Maximum			
Inorganics (µg/kg):					
BH-48	84.6	309	Sulfate	-	C[c]
BH-49	39.4	309	Sulfate	-	C[c]
BH-50	31	436	Sulfate	-	C[c]
BH-51	28.7	371	Sulfate	-	C[c]
BH-52	35.2 211	35.2 314	Chloride Sulfate	- -	C[c] C[c]
BH-53	49	295	Sulfate	-	C[c]
TCLP Metals (mg/L):					
BH-48	0.266 0.559	2.01 2.69	Barium Strontium	100 -	 C[c]
BH-49	0.217 0.357	1.77 2.92	Barium Strontium	100 -	 C[c]
BH-50	0.201 0.462	0.909 3.74	Barium Strontium	100 -	 C[c]
BH-51	0.43 0.00022 0.443	1.33 0.99937 1.44	Barium Mercury Strontium	100 0.2 -	 C[c]
BH-52	0.299 0.44	1.13 2.08	Barium Strontium	100 -	 C[c]
BH-53	0.259 0.535	1.02 2.86	Barium Strontium	100 -	 C[c]

µg/kg: micrograms per kilogram
mg/L: milligrams per liter
[a] Proposed RCRA action levels for soils (55 FR 30865).
[b] TCLP = Maximum concentration of contaminants using toxicity characteristic leachate procedure.
[c] For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.
BH-48: designates a borehole
C: indicates the chemical is identified as a contaminant of concern
-: no RCRA action level or TCLP standard is proposed

Table 5-18. Depths of Solid Waste, Contaminated Material, and Bedrock at Borehole Locations - Conservative Scenario

Borehole	Bottom of Solid Waste[a]	Depth of Solid Waste[b]	Depth to Bedrock[a]	Depth of Deepest Contamination[c]	Depth of Contaminated Soil and Waste[b]
BH-01	0	0	0	0	0
BH-02	0	0	1.5	0	0
BH-03	25.0	26	26.4	30	27
BH-04	23.2	25	23.2	24	25
BH-05	22.1	23	22.1	22	23
BH-06	20.9	22	20.9	21	22
BH-07	0	0	1.8	0	0
BH-08	0	0	0	0	0
BH-09	0	0	5.0	5	6
BH-10	>5	20	26.0[d]	4	20
BH-11	28.1	29	28.1	21	30
BH-12	26.5	28	52.7	20	21
BH-13	23.1	24	23.1	34	24
BH-14	10.8	12	12.0[d]	4	12
BH-15	10.0	11	22.4	6	11
BH-16	5.2	6	45.0	5	6
BH-17	0	0	31.0	0	0
BH-18	>10	12	46.0[d]	5	47
BH-19	10.0	12	46.8	44	47
BH-20	0	0	17.0	0	0
BH-21	4.5	6	35.9	19	20
BH-22	16.0	17	55.0	56	57
BH-23	8.3	10	50.9	51	52
BH-24	15.0	16	50.0[d]	6	18

Table 5-18. (page 2 of 2)

Borehole	Bottom of Solid Waste[a]	Depth of Solid Waste[b]	Depth to Bedrock[a]	Depth of Deepest Contamination[c]	Depth of Contaminated Soil and Waste[b]
BH-25	0	0	28.3	0	0
BH-26	10.0	11	40.7	15	16
BH-27	10.5	12	10.5	9	12
BH-28	0	0	21.6	0	0
BH-29	0	0	40.9	0	0

[a] Taken from borehole logs presented in Appendix H.

[b] Approximately 1 foot of depth added to the measured bottom of solid waste and deepest positive contaminant result.

[c] Taken from soil boring analytical results presented in Appendix I-1.

[d] Estimates of bedrock depth taken from bedrock geology shown on Plate 5.

Table 5-19. Contaminated Soil and Waste Volume Calculations - Conservative Scenario

Subsection[a]	Area (sq ft)	Average Depth (ft)	Volume (cu ft)	Volume (cu yd)
AREA A:				
1	22,500	12	270,000	10,000
2	11,250	11	123,750	4,583
3	9,375	6	56,250	2,083
4	5,625	9	47,813	1,771
5	13,125	15	196,875	7,292
6	7,500	15	112,500	4,167
7	9,375	18	168,750	6,250
8	3,750	12	45,000	1,667
9	6,250	12	75,000	2,778
10	10,000	18	180,000	6,667
11	7,500	18	135,000	5,000
12	9,375	24	225,000	8,333
13	30,000	24	720,000	26,667
Area A Total	145,625		2,355,938	87,257
AREA B:				
14	10,313	44	448,594	16,615
15	4,375	40	175,000	6,481
16	10,000	40	400,000	14,815
17	938	43	40,313	1,493
18	15,000	24	360,000	13,333
19	15,000	16	240,000	8,889
Area B Total	55,625		1,663,906	61,626
AREA C:				
20	10,313	42	433,125	16,042
21	21,875	34	743,750	27,546
22	19,688	45	885,938	32,813
23	15,000	32	480,000	17,778
24	7,500	35	262,500	9,722
25	5,000	45	225,000	8,333
26	5,000	57	285,000	10,556

Table 5-19. (page 2 of 3)

Subsection[a]	Area (sq ft)	Average Depth (ft)	Volume (cu ft)	Volume (cu yd)
AREA C: (continued)				
27	5,000	26	130,000	4,815
28	5,000	35	175,000	6,481
29	15,000	53	795,000	29,444
30	21,875	40	875,000	32,407
31	5,625	55	309,375	11,458
32	7,500	35	262,500	9,722
33	26,250	20	525,000	19,444
Area C Total	170,625		6,387,188	236,563
AREA D:				
34	3,750	20	75,000	2,778
35	6,250	24	150,000	5,556
36	7,813	26	203,125	7,523
37	19,688	23	452,813	16,771
38	3,750	27	101,250	3,750
39	2,500	24	60,000	2,222
40	13,125	20	262,500	9,722
41	13,125	12	157,500	5,833
42	12,500	12	150,000	5,556
43	39,375	17	669,375	24,792
44	39,375	26	1023,750	37,917
45	10,000	20	200,000	7,407
46	12,500	13	162,500	6,019
47	37,500	25	937,500	34,722
48	8,125	12	97,500	3,611
49	26,250	25	656,250	24,306
50	7,500	20	150,000	5,556
Area D Total	263,125		5,509,063	204,039

Table 5-19. (page 3 of 3)

Subsection[a]	Area (sq ft)	Average Depth (ft)	Volume (cu ft)	Volume (cu yd)
AREA E:				
51	15,313	12	183,750	6,806
LANDFILL:				
Total	650,313		16,099,844	596,291

[a] Subsections and areas are show on Figures 5-12 and 5-14.

Table 5-20. Solid Waste Volume Calculations

Subsection[a]	Area (sq ft)	Average Depth (ft)	Volume (cu ft)	Volume (cu yd)
1	22500	12	270000	10000
2	40000	24	960000	35556
3	39375	11	433125	16042
4	3125	11	34375	1273
5	22500	6	135000	5000
6	12500	11	137500	5093
7	15625	11	171875	6366
8	15938	12	191250	7083
9	22500	12	270000	10000
10	51563	6	309375	11458
11	31875	16	510000	18889
12	20000	10	200000	7407
13	46875	15	703125	26042
14	30625	20	612500	22685
15	20000	12	240000	8889
16	19688	20	393750	14583
17	13125	30	393750	14583
18	17500	15	262500	9722
19	6250	20	125000	4630
20	35000	20	700000	25926
21	50000	18	900000	33333
22	73125	26	1901250	70417
23	10000	15	150000	5556
24	18650	12	223800	8289
25	15313	12	183750	6806
TOTAL	653650		10411925	385627

[a] Subsection locations are shown on Figure 5-13.

Table 5-21. Depths of Solid Waste, Contaminated Material, and Bedrock at Borehole Locations - Worst-Case Scenario

Borehole	Bottom of Solid Waste[a]	Depth of Solid Waste[b]	Depth to Bedrock[a]	Depth of Deepest Contamination[c]	Depth of Contaminated Soil and Waste[b]
BH-01	0	0	0	9	0
BH-02	0	0	1.5	4	3
BH-03	25.0	26	26.4	30	27
BH-04	23.2	25	23.2	24	25
BH-05	22.1	23	22.1	22	23
BH-06	20.9	22	20.9	21	22
BH-07	0	0	1.8	2	2
BH-08	0	0	0	0	0
BH-09	0	0	5.0	5	50
BH-10	>5	20	26.0[d]	4	20
BH-11	28.1	29	28.1	29	30
BH-12	26.5	28	52.7	50	50
BH-13	23.1	24	23.1	34	24
BH-14	10.8	12	12.0[d]	4	12
BH-15	10.0	11	22.4	23	23
BH-16	5.2	6	45.0	38	39
BH-17	0	0	31.0	14	15
BH-18	>10	12	46.0[d]	5	47
BH-19	10.0	12	46.8	44	47
BH-20	0	0	17.0	19	18
BH-21	4.5	6	35.9	31	32
BH-22	16.0	17	55.0	56	57
BH-23	8.3	10	50.9	51	52
BH-24	15.0	16	50.0[d]	17	18
BH-25	0	0	28.3	19	20
BH-26	10.0	11	40.7	30	31
BH-27	10.5	12	10.5	14	12
BH-28	0	0	21.6	18	19
BH-29	0	0	40.9	41	42

[a] Taken from borehole logs presented in Appendix H.

[b] Approximately 1 foot of depth added to the measured bottom of solid waste and deepest positive contaminant result.

[c] Taken from soil boring analytical results presented in Appendix I-1.

[d] Estimates of bedrock depth taken from bedrock geology shown on Plate 5.

Table 5-22. Contaminated Soil and Waste Volume Calculations - Worst-Case Scenario

Subsection[a]	Area (sq ft)	Average Depth (ft)	Volume (cu ft)	Volume (cu yd)
AREA A:				
1	22,500	12	270,000	10,000
2	11,250	23	258,741	9,583
3	9,375	39	365,134	13,542
4	5,625	31	174,366	1,458
5	13,125	32	419,985	15,555
6	7,500	23	345,006	12,778
7	9,375	29	271,863	10,069
8	3,750	12	45,000	1,667
9	6,250	18	111,996	4,148
10	10,000	18	180,000	6,667
11	7,500	18	135,000	5,000
12	9,375	29	271,863	10,069
13	30,000	24	720,000	26,667
Area A Total	145,625		3,569,484	132,203
AREA B:				
14	10,313	44	448,594	16,615
15	4,375	45	196,884	7,292
16	10,000	45	450,009	16,667
17	938	43	40,313	1,493
18	15,000	31	464,994	17,222
19	15,000	32	480,006	17,778
Area B Total	55,625		2,080,810	77,067
AREA C:				
20	10,313	42	433,125	16,042
21	21,875	34	743,750	27,546
22	19,688	45	885,938	32,813
23	15,000	32	480,000	17,778
24	7,500	40	299,997	11,111
25	5,000	45	225,000	8,333

Table 5-22. (page 2 of 3)

Subsection[a]	Area (sq ft)	Average Depth (ft)	Volume (cu ft)	Volume (cu yd)
AREA C: (continued)				
26	5,000	57	285,000	10,556
27	5,000	26	130,000	4,815
28	5,000	35	175,000	6,481
29	15,000	53	795,000	29,444
30	21,875	40	875,000	32,407
31	5,625	55	309,375	11,458
32	7,500	35	262,500	9,722
33	26,250	20	525,000	19,444
Area C Total	170,625		6,424,705	237,952
AREA D:				
34	3,750	20	75,000	2,778
35	6,250	24	150,000	5,556
36	7,813	26	203,125	7,523
37	19,688	23	452,813	16,771
38	3,750	27	101,250	3,750
39	2,500	24	60,000	2,222
40	13,125	20	262,500	9,722
41	13,125	12	157,500	5,833
42	12,500	12	150,000	5,556
43	39,375	17	669,375	24,792
44	39,375	26	1023,750	37,917
45	10,000	20	200,000	7,407
46	12,500	13	162,500	6,019
47	37,500	25	937,500	34,722
48	8,125	12	97,500	3,611
49	26,250	25	656,250	24,306
50	7,500	20	150,000	5,556
Area D Total	263,125		5,509,063	204,039

Table 5-22. (page 3 of 3)

Subsection[a]	Area (sq ft)	Average Depth (ft)	Volume (cu ft)	Volume (cu yd)
AREA E:				
51	15,313	12	183,750	6,806
52	15,936	17	278,904	10,033
53	42,800	17	727,600	26,948
54	2,394	30	71,820	2,660
55	24,241	15	438,615	16,245
56	43,947	30	1,318,410	48,830
57	6,498	20	129,960	4,813
58	6,498	20	129,960	4,813
59	7,100	18	127,800	4,733
Area E Total	169,727		3,398,819	125,881
AREA F:				
60	6,751	5	33,755	1,534
61	6,149	20	122,980	4,555
62	12,298	20	245,960	9,110
63	107,859	2	215,718	7,990
Area F Total	133,057		626,103	23,189
LANDFILL:				
Total	937,784		21,608,984	800,331

[a] Subsections and areas are show on Figures 5-15 and 5-16.

Table 5-23. Vapor Monitoring Instrument Measurements at the Former Lee Acres Landfill

Borehole or Wellbore Number	Depth (Ft)	Photoionization Detector		Flame Ionization Detector		CGI % LEL	Oxygen Content (%)	Comments
		Downhole Reading (ppm)	Core Reading (ppm)	Downhole Reading	Core Reading			
BH-01								No vapors detected
	10.0							Total depth
BH-02								No vapors detected
	7.5							Total depth
BH-03	15.0	1.4				2.0	20.5	
	20.0					1.0	20.0	
	25.0	1.0				5.0	20.0	
	31.5							Total depth
BH-04								No vapors detected
	23.6							Total depth
BH-05	15.0					1.5	20.5	
	20.0					50.0	18.0	
	22.5							Total depth
BH-06	20.0					1.0	20.0	
	21.2							Total depth
BH-07								No vapors detected
	5.0							Total depth
BH-08								No vapors detected
	10.0							Total depth
BH 09								No vapors detected
	10 0							Total depth

Table 5-23. (page 2 of 6)

Borehole or Wellbore Number	Depth (Ft)	Photoionization Detector		Flame Ionization Detector		CGI % LEL	Oxygen Content (%)	Comments
		Downhole Reading (ppm)	Core Reading (ppm)	Downhole Reading	Core Reading			
BH-10	5.0					100.0	15.0	Total depth
BH-11	10.0	15.3				80.0	5.0	
	25.0					10.0	0.0	
	29.6					100.0	0.0	Total depth
BH-12	5,0	1.0	1.0					
	10.0	38.5	4.5			38.0		
	13.0					100.0		Vented overnight
	15.0	2.5	8.5			3.0		
	20.0	3.5		500.0		5.0		
	25.0			>1,000.0		100.0		
	30.0				100.0	100.0	6.0	
	35.0					2.0		
	54.8							Total depth
BH-13	10.0	1.0		3.0		1.0		
	17.5	1.0			600.0	25.0		
	20.0	1.9		>1,000.0	600.0	25.0		
	25.0	2.0		420.0	10.0	5.0		
	30.0		4.2	300.0	45.0	60.0		
	35.0	4.0	3.2	520.0	10.0	40.0		Total depth
BH-14								No vapors detected
	11.0							Total depth

Table 5-23. (page 3 of 6)

Borehole or Wellbore Number	Depth (Ft)	Photoionization Detector		Flame Ionization Detector		CGI % LEL	Oxygen Content (%)	Comments
		Downhole Reading (ppm)	Core Reading (ppm)	Downhole Reading	Core Reading			
BH-15	20.0			0.8	1.0			
	25.0							Total depth
BH-16	10.0				0.3			
	15.0				1.1			Could be
	20.0				0.2			fluctuation in
	25.0				0.3			background
	40.0				0.2			
	46.0							Total depth
BH-17	25.0	0.2	0.6					
	30.0		1.2					
	31.0							Total depth
BH-18	10.0	3.4		17.5				Total depth
BH-19	15.0		3.1					
	20.0		3.2					Background may
	22.5		3.3					have increased
	25.0		2.6					during drilling
	27.5		3.4					at this
	37.5		2.6					borehole
	46.8		0.6					
	50.0							Total depth

Table 5-23. (page 4 of 6)

Borehole or Wellbore Number	Depth (Ft)	Photoionization Detector		Flame Ionization Detector		CGI % LEL	Oxygen Content (%)	Comments
		Downhole Reading (ppm)	Core Reading (ppm)	Downhole Reading	Core Reading			
BH-20	7.5		0.4					
	25.0				3.2			
	30.0				0.9			Total depth
BH-21								No vapors detected
	37.5							Total depth
BH-22	5.0	3.6		258.6		3.0		
	10.0			8.6				
	30.0				10.0			
	58.0							Total depth
BH-23	7.5	7.4		6.0				
	10.0	2.0		7.0				
	15.0	7.4		520.0		5.0	20.0	
	17.5	6.6		560.0		4.0	19.0	
	20.0	2.8		200.0				
	22.5	2.0		28.0		20.0		
	25.0			150.0				
	30.0			160.0				
	32.0				200.0			
	35.0	0.4		1.9				
	45.0			2.6	120.0			

Table 5-23. (page 5 of 6)

Borehole or Wellbore Number	Depth (Ft)	Photoionization Detector		Flame Ionization Detector		CGI % LEL	Oxygen Content (%)	Comments
		Downhole Reading (ppm)	Core Reading (ppm)	Downhole Reading	Core Reading			
BH-23 (continued)	47.5				5.8			
	50.0			2.0	1.0			
	55.0							Total depth
BH-24	5.0	0.3	3.7	0.6	6.0			
	35.0			0.8		5.0	19.5	
	40.0			1.2		2.0	19.5	
	42.5							Total depth
BH-25								No vapors detected
	35.0							Total depth
BH-26	0.0	4.2		3.8				Surface contamination
	5.0	0.2		1.0				caused high background
	47.0							Total depth
BH-27								No vapors detected
	15.0							Total depth
BH-28								*No vapors detected*
	26.0							Total depth
BH-29	40.0			0.6		2.0		
	45.0							Total depth
BLM-53								No vapors detected
	91.9							Total depth
BLM-54								*No vapors detected*
	89.5							Total depth

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Borehole or Wellbore Number	Depth (Ft)	Photoionization Detector		Flame Ionization Detector		CGI % LEL	Oxygen Content (%)	Comments
		Downhole Reading (ppm)	Core Reading (ppm)	Downhole Reading	Core Reading			
BLM-56								No vapors detected
	47.5							Total depth
BLM-57	30.0			1.2	0.2			
	35.0			1.2				
	40.0			1.4				
	45.0			1.4				
	53.0			79.6				
	53.5							Total depth

ppm: parts per million
CGI: combustible gas indicator
LEL: lower explosive limit

Table 5-24. Contaminants of Concern Identified for Operable Unit 1

Contaminant Analytical Group	Contaminant of Concern	Location of Contaminant	Number of Contaminants of Concern
Soils (Boreholes and Wellbores):			
Volatile organics	1,1-Dichloroethane	BH-23, -24	6
	1,2-*trans*-Dichloroethene	BH-16	
	Benzene	BH-12, -18, -19, -23	
	Chloroethane	BLM-33	
	Chloromethane	BLM-33	
	Vinyl chloride	BLM-33	
Semivolatile organics	2-Methylnaphthalene	BH-04, -05, -06, -11, -12, -26, -27; soil near car in arroyo	25
	2-Methylphenol	BH-06	
	4-Methylphenol	BH-03, -05, -06, -11	
	1,2-Dichlorobenzene	BH-23, -28; BLM-47	
	1,3-Dichlorobenzene	BLM-47	
	1,4-Dichlorobenzene	BH-01, -04, -05, -06, -23, -27, -28; BLM-47, -53	
	2,4-Dimethylphenol	BH-06	
	Acenaphthene	BH-06, -26	
	Anthracene	BH-26; BLM-41; soil near car in arroyo	
	Benzo(a)anthracene	BH-06, -26, -27; BLM-41	
	Benzo(a)pyrene	BH-26, -27; BLM-41	
	Benzo(b)fluoranthene	BH-26, -27	
	Benzo(g,h,i)perylene	BH-26, -27	
	Benzo(k)fluoranthene	BH-26, -27	
	Benzoic acid	BH-01, -03, -04, -05, -06, -12, -13 -24; BLM-47	
	Chrysene	BH-03, -04, -06, -12, -26, -27; BLM-41; soil near car in arroyo	
	Dibenzofuran	BH-06	
	Di-n-butyl phthalate	BH-06, -12, -13, -14, -16, -18, -21, -26; BLM-44, -47	
	Di-n-octyl phthalate	BH-06; BLM-35	
	Fluoranthene	BH-06, -23, -24, -26, -27, -28; BLM-41	
	Fluorene	BH-04, -06, -26; BLM-41	
	Indeno(1,2,3-cd)pyrene	BH-26	
	Naphthalene	BH-04, -06, -11, -12, -27	
	Phenanthrene	BH-03, -04, -06, -24, -26, -27; soil near car in arroyo	
	Pyrene	BH-04, -06, -23, -24, -26, -27, -28; BLM-41, -47	
Pesticides	Dieldrin[a]	BH-13, -23	3
	Beta-BHC	Soil near car in arroyo	
	Delta-BHC	BLM-54	

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Contaminant Analytical Group	Contaminant of Concern	Location of Contaminant	Number of Contaminants of Concern
Metals (EP Toxicity)	Strontium Tin	BH-06, -07, -08, -09, -10, -11, -12, -13, -14, -15, -16, -17, -18, -20, -21, -22, -23, -24, -25, -26, -27, -28, -29; BLM-41, -44, -47, -50, -53, -54, -56, -57 BH-06	2
Metals (TCLP)	Strontium	BH-48, -49, -50, -51, -52, -53	1
Metals (Total)	Arsenic, total Barium, total Chromium, total Lead, total Selenium, total Silver, total	BLM-33, -34, -35 BLM-33 BLM-33,-34 BLM-33, -34, -35 BLM-34, -35 BLM-34	6
Inorganics	Sulfate Chloride	BH-01, -02, -03, -04, -05, -06, -07, -08, -09, -10, -11, -12, -13, -14, -15, -16, -17, -18, -19, -20, -21, -22, -23, -24, -25, -26, -27, -28, -29, -48, -49, -50, -51, -52, -53; BLM-41, -44, -47, 50, -53, -54, -56, -57, -59 BH-01, -02, -03, -04, -05, -06, -08, -09, -10, -11, -12, -13, -14, -15, -16, -17, -18, -19, -20, -21, -22, -23, -24, -25, -26, -27, -28, -29, -52; BLM-41, -44, -47, -50, -53, -54, -56, -57, -59	2
Lagoons:			
Volatile organics	2-Propanol 2-Pentene 1,1,1-Trichloroethane[a] Acentone Benzene[a] Dichloromethane Hexamethylcyclotrisiloxane Methylcyclohexane m-Xylene[a] Toluene[a] Octamethylcyclotetrasiloxane Tetrachloroethene[a]	Waste disposal pit Waste disposal pit Lagoon pit, east side lagoon, west side lagoon Waste disposal pit Lagoon pit, east side lagoon, west side lagoon, waste disposal pit, lagoon-south pump Lagoon pit, east side lagoon, west side lagoon Waste disposal pit Waste disposal pit East side lagoon, west side lagoon Lagoon pit, east side lagoon, west side lagoon, waste disposal pit Waste disposal pit East side lagoon, west side lagoon	12

Table 5-24. (page 3 of 3)

Contaminant Analytical Group	Contaminant of Concern	Location of Contaminant	Number of Contaminants of Concern
Metals (Total)	Boron[a]	Lagoon-south pump	8
	Chromium[a]	Lagoon pit, east side lagoon, west side lagoon	
	Selenium[a]	Lagoon pit, east side lagoon, west side lagoon, lagoon-south pump	
	Iron[a]	Lagoon pit, east side lagoon, west side lagoon, lagoon-south pump, south pond	
	Lead[a]	East side lagoon, west side lagoon	
	Manganese[a]	Lagoon pit, east side lagoon, west side lagoon, lagoon-south pump, south pond	
	Silicon	Lagoon pit, east side lagoon, west side lagoon, lagoon-south pump, south pond	
	Strontium	Lagoon pit, east side lagoon, west side lagoon, lagoon-south pump, south pond	
Inorganics	Bicarbonate	Lagoon pit, east side lagoon, west side lagoon, lagoon-south pump, south pond	1
Lysimeters:			
Volatile organics	1,3-*cis*-Dichloropropene	LS-5 (shallow)	3
	Benzene[a]	LS-5 (shallow)	
	Dichlorodifluoromethane	LS-5 (shallow), LS-7 (deep)	
Inorganics	Bicarbonate	LS-5 (shallow)	2
	Bromide	LS-5 (shallow)	

[a] Identified as contaminants of concern based on regulatory exeedance.

Note: A total of 60 contaminants of concern have been identified for Operable Unit 1. A total of 85 contaminants of concern are shown on the table; however, several are listed more than once.

Table 5-25. Volatile Organic Compounds Detected in Site 1, Southern Area Soils

Sampling Location	Depth Range (ft)	Concentration Range		Contaminant	RCRA Action Level[a]	Contaminant of Concern
		Minimum	Maximum			
Volatile Organics (µg/kg):						
BH-33	3 - 4	2	2	Total xylenes	200,000,000	
BH-40	29 - 29.4	1.6	1.6	Toluene	20,000,000	
BH-41	34.5 - 35	3.2	3.2	1,2-*trans*-Dichloroethene	-	C[b]
	35.6 - 35.8	7.5	7.5	1,2-*trans*-Dichloroethene	-	C[b]
	5 - 5.5	1.8	1.8	Toluene	20,000,000	
BH-42	34 - 35	4.9	4.9	1,2-*trans*-Dichloroethene	-	C[b]
	37.5 - 37.9	2.6	2.6	1,2-*trans*-Dichloroethene	-	C[b]
BH-43	3.6 - 3.9	1.5	1.5	Trichloromethane	100,000	
	17.4 - 17.8	1.4	1.4	Trichloromethane	100,000	
BH-44	8.6 - 9	1.5	1.5	Trichloromethane	100,000	
BH-45	1 - 1.5	5.5	5.5	Dichloromethane	90,000	
BH-46	1 - 1.5	11	11	Dichloromethane	90,000	
	5 - 5.5	5.2	5.2	Dichloromethane	90,000	
	10 - 10.5	4.6	4.6	Dichloromethane	90,000	
	15 - 15.5	4.4	4.4	Dichloromethane	90,000	
	20 - 20.5	4.3	4.3	Dichloromethane	90,000	
	25 - 25.5	5.9	5.9	Dichloromethane	90,000	
	32.5 - 33	7.3	7.3	Dichloromethane	90,000	
BH-47	7 - 7.5	53	53	Dichloromethane	90,000	
	13 - 13.5	35	35	Dichloromethane	90,000	
	16 - 16.5	31	31	Dichloromethane	90,000	
	22 - 22.5	40	40	Dichloromethane	90,000	
	27.5 - 28	28	28	Dichloromethane	90,000	
	7 - 7.5	1.4	1.4	Toluene	20,000,000	
	13 - 13.5	1.3	1.3	Toluene	20,000,000	
	16 - 16.5	1.1	1.1	Toluene	20,000,000	
	22 - 22.5	1.9	1.9	Toluene	20,000,000	
	27.5 - 28	1.2	1.2	Toluene	20,000,000	

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Sampling Location	Depth Range (ft)	Concentration Range		Contaminant	RCRA Action Level[a]	Contaminant of Concern
		Minimum	Maximum			
BLM-68	32.2 - 32.7	5.2	5.2	Dichloromethane	90,000	
BLM-69	35 - 35.5	1.9	1.9	Trichloromethane	100,000	
BLM-70	31.4 - 31.8 31.4 - 31.8	5 1.8	5 1.8	Dichloromethane Trichlormethane	90,000 100,000	
BLM-71	29.4 - 29.9 29.4 - 29.9[c]	1.8 1.6	1.8 1.6	Trichloromethane Trichloromethane	100,000 100,000	
BLM-73	27.7 - 28.3	1.4	1.4	Toluene	20,000,000	
BLM-76	29 - 30	4.5	4.5	Dichloromethane	90,000	
BLM-77	28.6 - 29.2	3.4	3.4	Dichlormethane	90,000	
Semivolatile Organics (μg/kg)					RCRA Action Level[a]	
BLM-61	23 - 24	200	200	Benzoic acid	-	C[b]
BLM-63	14 - 15	290	290	Benzoic acid	-	C[b]

[a] Proposed RCRA action levels for soils (55 FR 30865).

[b] For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.

[c] Designates duplicate sample

μg/kg: micrograms per kilogram

BH: designates a borehole

BLM: designates a wellbore

C: indicates the chemical is identified as a contaminant of concern

-: no action level proposed

Table 5-26. Inorganic Compounds Detected in Site 1, Southern Area Soils

Sampling Location	Depth Range (ft)	Concentration Range		Contaminant	RCRA Action Level[a]	Contaminant of Concern
		Minimum	Maximum			
Inorganics (µg/kg):						
BH-30	5 - 6	420		Sulfate	-	C^b
	15 - 16	522		Sulfate	-	C^b
	5 - 6	40.9		Chloride	-	C^b
	15 - 16	23.9		Chloride	-	C^b
BH-31	3 - 4	1,160		Sulfate	-	C^b
	3 - 4	498		Chloride	-	C^b
BH-32	7 - 8	63.1		Sulfate	-	C^b
	7 - 8	6.7		Chloride	-	C^b
BH-33	3 - 4	2,030		Sulfate	-	C^b
	3 - 4	342		Chloride	-	C^b
BH-40	9.5 - 10	114		Sulfate	-	C^b
	14.5 - 15	13.2		Sulfate	-	C^b
	24.5 - 25	80		Sulfate	-	C^b
	38.4 - 38.7	315		Sulfate	-	C^b
	38.4 - 38.7	129		Chloride	-	C^b
BH-41	5 - 5.5	52.2		Sulfate	-	C^b
	29.2 - 29.7	309		Sulfate	-	C^b
	34.5 - 35	301		Sulfate	-	C^b
	35.6 - 35.8	396		Sulfate	-	C^b
	29.2 - 29.7	75.1		Chloride	-	C^b
	34.5 - 35	40		Chloride	-	C^b
	35.6 - 35.8	104		Chloride	-	C^b
BH-42	4.4 - 4.8	88.4		Sulfate	-	C^b
	14 - 15	29	31.3	Sulfate	-	C^b
	19.5 - 20	48.7		Sulfate	-	C^b
	25.2 - 25.7	76.1		Sulfate	-	C^b
	29.5 - 30	51.4		Sulfate	-	C^b
	34 - 35	382		Sulfate	-	C^b
	37.5 - 37.9	294		Sulfate	-	C^b
	32.5 - 33	33.2		Chloride	-	C^b
	34 - 35	67.1		Chloride	-	C^b
	37.5 - 37.9	74.5		Chloride	-	C^b

Table 5-26. (page 2 of 3)

Sampling Location	Depth Range (ft)	Concentration Range		Contaminant	RCRA Action Level[a]	Contaminant of Concern
		Minimum	Maximum			
BH-43	17.4 - 17.8	101		Sulfate	-	C^b
	17.4 - 17.8	121		Chloride	-	C^b
BH-45	10 - 10.5	52.2		Sulfate	-	C^b
	15 - 15.5	386		Sulfate	-	C^b
	20 - 20.5	338		Sulfate	-	C^b
	25 - 25.5	3,440		Sulfate	-	C^b
	30 - 30.5	435		Sulfate	-	C^b
	15 - 15.5	34.6		Chloride	-	C^b
BH-46	10 - 10.5	35.3		Sulfate	-	C^b
	15 - 15.5	45.5		Sulfate	-	C^b
	25 - 25.5	257		Sulfate	-	C^b
	32.5 - 33	219		Sulfate	-	C^b
BH-47	22 - 22.5	57.9		Sulfate	-	C^b
	27.5 - 28	184		Sulfate	-	C^b
BLM-61	14 - 15	7.7		Sulfate	-	C^b
	23 - 24	56.2		Sulfate	-	C^b
	39 - 40	263		Sulfate	-	C^b
	39 - 40	102		Chloride	-	C^b
	39 - 40	24.2		Sulfide	-	C^b
BLM-63	14 - 15	321	325	Sulfate	-	C^b
BLM-64	12 - 13	57.5	68.9	Sulfate	-	C^b
BLM-67	29.4 - 29.7	134		Sulfate	-	C^b
BLM-68	32.2 - 32.7	107	127	Sulfate	-	C^b
BLM-70	31.4 - 31.8	248		Sulfate	-	C^b
	31.4 - 31.8	63.1		Chloride	-	C^b
BLM-71	29.4 - 29.7	198	204	Sulfate	-	C^b
BLM-72	29.5 - 30	222		Sulfate	-	C^b
BLM-73	27.7 - 28.3	99.6		Sulfate	-	C^b

Table 5-26. (page 3 of 3)

Sampling Location	Depth Range (ft)	Concentration Range		Contaminant	RCRA Action Level[a]	Contaminant of Concern
		Minimum	Maximum			
BLM-74	30.6 - 31.5	95.4		Sulfate	-	C[b]
BLM-75	29 - 30.5	178		Sulfate	-	C[b]
BLM-76	29 - 30 29 - 30	115 57.5	206 77.1	Sulfate Chloride	- -	C[b] C[b]
BLM-77	28.6 - 29.2	106		Sulfate	-	C[b]

[a] Proposed RCRA action levels for soils (55 FR 30865).

[b] For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.

µg/kg: micrograms per kilogram
BH: designates a borehole
BLM: designates a wellbore
C: indicates the chemical is identified as a contaminant of concern
Note: For inorganics with a minimum and maximum concentration specified, this indicates that a duplicate sample was taken.
-: no action level proposed

Table 5-27. Metals Detected in Site 1 - Southern Area Soils

Sampling Location	Concentration Range		Contaminant	TCLP[a]	Contaminant of Concern
	Minimum	Maximum			
EP Toxicity Metals (μg/L):					
BH-30	0.28 739	0.28 2,160	Mercury Strontium	200 -	 C[b]
BH-31	2,550	2,550	Strontium	-	C[b]
BH-32	647	647	Strontium	-	C[b]
BH-33	3,180	3,180	Strontium	-	C[b]
TCLP Metals (μg/L):					
BH-40	389 14.7 583	1,360 19.2 2,010	Barium Cadmium Strontium	100,000 1,000 -	 C[b]
BH-41	501	2,460	Strontium	-	C[b]
BH-42	323 562	1,280 2,120	Barium Strontium	100,000 -	 C[b]
BH-43	461 764	986 764	Barium Strontium	100,000 -	 C[b]
BH-44	1,620 721	1,620 721	Barium Strontium	100,000 -	 C[b]
BH-45	206 1,570 377	1,330 1,570 5,990	Barium Lead Strontium	100,000 5,000 -	 C[b]
BH-46	239 474	2,010 2,040	Barium Strontium	100,000 -	 C[b]
BH-47	456	2,250	Strontium	-	C[b]
BLM-67	1,550	1,550	Strontium	-	C[b]
BLM-68	261 10.1 800	311 10.1 932	Barium Silver Strontium	100,000 5,000 -	 C[b]
BLM-69	2,890	2,890	Strontium	-	C[b]
BLM-70	305 1,040	305 1,040	Barium Strontium	100,000 -	 C[b]

Table 5-27. (page 2 of 2)

Sampling Location	Concentration Range		Contaminant	TCLP[a]	Contaminant of Concern
	Minimum	Maximum			
BLM-71	224 1,820	243 2,370	Barium Strontium	100,000 -	 C[b]
BLM-72	483 1,730	483 1,730	Barium Strontium	100,000 -	 C[b]
BLM-73	508	508	Barium	100,000	
BLM-74	804	804	Barium	100,000	
BLM-75	433 1,010	433 1,010	Barium Strontium	100,000 -	 C[b]
BLM-76	849 2,840	897 3,280	Barium Strontium	100,000 -	 C[b]
BLM-77	462 1,060	462 1,060	Barium Strontium	100,000 -	 C[b]

[a] Maximum concentration of contaminants using toxicity characteristic leachate procedure.

[b] For contaminants with no proposed or promulgated standards, the chemical will be considered a contaminant of concern.

µg/L: micrograms per liter
BH: designates a borehole
BLM: designates a wellbore
C: indicates the chemical is identified as a contaminant of concern
EP: Extraction Procedure
-: no TCLP standard specified

6. GROUNDWATER CHARACTERIZATION

Subsection 1.5 defines OU 2 as any response action implemented to reduce groundwater contamination beneath and immediately south of the former landfill. In order to determine the effects of the former Lee Acres Landfill on the groundwater quality within the study area, it is necessary to closely examine and compare the background groundwater chemistry, the groundwater chemistry adjacent to and beneath the landfill, and the groundwater chemistry in downgradient areas. This section presents, in detail, the characterization of groundwater within the Lee Acres Landfill Study Area, including the types and distribution of contaminants and their concentration ranges. Subsections 6.1.3, 6.2.3, and 6.7 summarize the details presented in this section regarding the nature and extent of groundwater contamination in the Lee Acres Landfill Study Area.

Background groundwater quality is defined as upgradient groundwater that has not been affected by practices at the former landfill. The five monitoring wells in subarea 1 (Plate 1), north of the landfill, represent the background chemical characteristics of groundwater in the Lee Acres Landfill Study Area. The groundwater chemistry beneath, adjacent to, and downgradient of the former landfill to monitoring well BLM-68 is defined as Site 1, OU 2, and is represented by the 51 monitoring wells located in subareas 2 and 3. Within Site 1, two areas of groundwater contamination have been identified and are defined as the northern and southern areas of contamination of OU 2. The Site 1, OU 2, northern area of contamination is defined by 30 monitoring wells located within and adjacent to the landfill in subarea 2. The Site 1, OU 2, southern area of contamination is defined by the 21 monitoring wells located south of the landfill and north of well GBR-17 in subarea 3, including four GBR wells. The groundwater chemistry downgradient of the landfill south of well BLM-68 is defined as Site 2, and includes the former Giant-Bloomfield Refinery and properties south of U.S. 64 to the San Juan River (Plate 1). The Site 2 area of contamination is defined by the monitoring wells south of and including GBR-17 on Giant-Bloomfield Refinery property and the 12 BLM monitoring wells south of U.S. 64 to the San Juan River.

The chemical characteristics and differences in groundwater quality between alluvial and bedrock aquifers throughout the study area are presented in the following subsections. The nature and extent of groundwater contamination in the Lee Acres Landfill Study Area also include discussions of the distribution of primary groundwater constituents (subsection 6.2) and groundwater chemical fingerprinting (subsection 6.6). The nature or type of contamination is identified according to the COC criteria described in subsection 1.6. Appendix V presents the statistics calculations performed for the frequency analysis on the groundwater analytical results, by aquifer, for each subarea. Groundwater analytical results for each monitoring well are presented in Appendix N-1 and the results of the laboratory contamination evaluation is presented in Appendix N-2. Tables presented in Section 6 list background contaminants for upgradient wells and COCs for the remainder of the study area for both the alluvial and bedrock aquifer systems.

6.1. BACKGROUND GROUNDWATER QUALITY

In order to examine the effects of the former Lee Acres Landfill on groundwater quality, the background (upgradient) groundwater chemistry was determined. Background groundwater quality is defined as upgradient groundwater that has not been affected by practices at the former landfill. Any contaminants found in upgradient waters are of concern as they could potentially migrate downgradient to the area beneath and south of the former Lee Acres Landfill. The rationale presented in subsection 1.6.2 for identifying COCs is applicable to the definition of background groundwater quality.

The five monitoring wells in subarea 1 (Plate 1), north of the former landfill, represent the background chemical characteristics of groundwater in the Lee Acres Landfill Study Area. Monitoring wells BLM-14, BLM-15, and BLM-39 are screened in alluvial materials, and monitoring wells BLM-16 and BLM-40 are screened in the bedrock aquifer. The RI groundwater monitoring program is presented in subsection 2.9. Background groundwater quality is defined for the alluvial and bedrock aquifers in the following subsections.

6.1.1. Alluvial Aquifer Background Groundwater Quality

Three monitoring wells, BLM-14, BLM-15, and BLM-39, are completed in alluvial materials and are located upgradient from the Lee Acres Landfill. Monitoring wells BLM-14 and BLM-15 were installed in December 1987 as part of the PI. Monitoring well BLM-39 was installed during the RI. The frequency of sampling events varies from monthly sampling during the PI to quarterly sampling during the RI (Appendix M). The following laboratory analyses were performed on the groundwater samples: VOCs, semivolatile organics, pesticides, PCBs, inorganics, and soluble metals. In addition, total metals analyses were performed on the groundwater samples collected in May 1989 (wells BLM-14, and BLM-15 only). Sampling and analytical methods are described in detail in subsection 2.9 as well as in the SAPP (WESTON 1990d). Analytical results for all groundwater samples are presented in Appendix N-1. The discussion of the alluvial aquifer background groundwater quality is divided by contaminant group, inorganic and organic compounds, and is presented to identify any contaminants that may be present upgradient of the former Lee Acres Landfill.

6.1.1.1. Inorganic COCs

Inorganic compounds and metals are prevalent in groundwater. The comparison criteria described in subsection 1.6.2.1 are implemented to identify inorganic and metal background contaminants. Table 6-1 presents the protection standard, regional background concentrations, and study area alluvial background concentrations from BLM-14, BLM-15, and BLM-39 for inorganic compounds and metals. Background concentrations of inorganics are generally within regional background ranges. Chloride and sulfate concentrations exceed their New Mexico HHSs, although they are within the regional range that also exceeds the New Mexico HHSs. Thus, chloride and sulfate are not considered to be study area background contaminants.

Sulfide was detected at 1.2 mg/L in BLM-15 during one sampling event but was not detected in any other upgradient, alluvial groundwater samples. In addition, soluble iron was detected during only one sampling round where it was less than the detection limit. These factors indicate that conditions in the upgradient alluvial system are oxidizing.

Of the soluble metals detected in upgradient alluvial groundwater samples, only chromium exceeds the SDWA MCL concentration of 50 μg/L. This value was exceeded at 14 monitoring wells throughout the study area. Consistent and elevated chromium values in background monitoring wells indicate chromium is from upgradient sources and is identified as a background contaminant.

6.1.1.2. Organic Constituents

A total of 14 organic compounds were detected at various times in the three alluvial background monitoring wells. Dichloromethane (methylene chloride), toluene, acetone, and phthalate esters were all detected in groundwater samples from the upgradient alluvial aquifer. All of these constituents are common laboratory contaminants (EPA 1988c). In addition to these contaminants, benzene, chlorobenzene, trichloromethane, TCE, and trichlorofluoromethane were detected in alluvial background groundwater samples. Table 6-2 presents the organic compounds and the maximum concentrations detected in the alluvial background wells. Two organic compounds, ethylbenzene and 1,2-dichlorobenzene, are not presented on Table 6-2. These two compounds were detected once and were present in the laboratory blank. Through the lab blank evaluation (subsection 2.9.3), the concentrations for these two compounds are not considered positive results and, therefore, are not background contaminants.

Eleven of the remaining 12 organic compounds are not background contaminants based on the frequency criteria described in subsection 1.6.2.2. Table 6-2 also presents the number of detections per the total number of samples for each contaminant and the screening criteria. Nine of the 11 compounds are eliminated based on the frequency criteria of a one-time detection or one-time detection per well. The one-time detection per well criterion for a majority of the compounds is considered a valid elimination criterion as the concentrations are below detection limits and the compounds were not detected in subsequent samples.

The remaining two compounds, toluene and TCE, are also not background contaminants because of the frequency of detection and trends in the analytical results. Toluene was detected four times out of a total of 40 sampling events: three times in BLM-14 and once in BLM-15. However, the concentration detected in BLM-15 was identified as present below detection limits, and therefore is eliminated as a contaminant for BLM-15. Only two of the detections in BLM-14 are above detection limits (1.1 and 8 µg/L). The high concentration (8 µg/L) was detected in the first sample collected in December 1987. The concentration of 1.1 µg/L was detected in April 1990 (Appendix N-1). Because of the inconsistent detection of toluene, the three subsequent nondetections, and because it is a common laboratory contaminant (EPA 1988c), toluene is not considered to be a background contaminant.

TCE, based on a similar rationale used for the elimination of toluene, is also not a contaminant in the alluvial background groundwater. TCE was detected three times out of a total of 43 sampling events, once in BLM-14 and twice in BLM-15. However, two detections were identified as being below detection limits, therefore eliminating TCE as a contaminant from BLM-14. In December 1987, TCE was detected at 140 µg/L in BLM-15. This was the first sample collected after the installation of BLM-15 and the beginning of the PI monthly groundwater monitoring program. TCE was not detected in six subsequent samples from this well and, therefore, the 140 µg/L is considered an outlier value and not an accurate representation of contamination.

The only organic compound that is found in the alluvial background groundwater is dichloromethane. While dichloromethane is considered a common laboratory contaminant (EPA 1988c), the number of positive results after the lab blank evaluation is still significant. The detection of dichloromethane is confined to BLM-14 and BLM-15 located approximately 1,000 ft upgradient from BLM-39 (Plate 1). Dichloromethane was detected once in BLM-39 at a concentration of 0.84 µg/L in March 1990 (Appendix N-1), and there are at least three subsequent nondetections.

6.1.2. Bedrock Aquifer Background Groundwater Quality

Two monitoring wells, BLM-16 and BLM-40, are located in subarea 1, upgradient from the Lee Acres Landfill, and are completed in the bedrock formation. BLM-16 was installed as part of the PI and is approximately 1,000 ft north of BLM-40. BLM-40 was installed during the RI. Background bedrock water quality is defined in the following subsections according to inorganic and organic compounds using the analytical results from these two wells.

6.1.2.1. Inorganic COCs

Table 6-3 presents the protection standard, regional concentration range and the background bedrock concentrations detected for inorganics and metals. All of the inorganic constituents are within the regional concentration ranges. Generally, the water from the bedrock aquifer is higher in TDS, sulfate, potassium, and calcium than water from the alluvial aquifer.

Chromium was detected at 59.1 µg/L in February 1989 in a sample from well BLM-16. This is the same sampling round in which levels of chromium in excess of the SDWA MCL (50 µg/L) were detected in adjacent alluvial wells (BLM-14 and BLM-15). This result indicates that any chromium contamination detected adjacent to or downgradient from the former landfill may be the result of contamination from upgradient sources.

6.1.2.2. Organic Constituents

Seven organic compounds were detected during various sampling events in the two background bedrock wells. Table 6-4 presents six organic compounds and their maximum detected concentrations. The seventh compound, ethylbenzene, was eliminated during the lab blank evaluation (subsection 2.9.3).

Dichloromethane, toluene, acetone, and phthalate esters (*bis*[2-ethylhexyl] phthalate and di-n-butyl phthalate) are identified in the groundwater samples from the upgradient bedrock aquifer. All of these constituents are common laboratory contaminants (EPA 1988c), and all but dichloromethane and di-n-butyl phthalate were detected in laboratory blanks. All organics, with the exception of dichloromethane, are not background contaminants because they are eliminated according to the frequency of detection criteria described in subsection 1.6.2.2.

Acetone is not a background contaminant because it is common laboratory contaminant. The five detections of acetone occurred during the first five months of sampling during the PI. The remaining four detections were eliminated based on the lab blank evaluation. The four concentrations identified as present in the lab blank are within the range of the five detections. This indicates the possibility that all acetone detections are the result of laboratory contamination. Therefore, acetone is not identified as a background contaminant in the bedrock aquifer.

PCE was detected in September 1989 at 1.3 µg/L in a groundwater sample from well BLM-16. This was the only organic contaminant detected in the upgradient bedrock aquifer that is not a common laboratory contaminant. PCE was detected once in BLM-16, and there are at least five subsequent samples in which it was not detected. Therefore, PCE is not a background contaminant.

Dichloromethane is the only organic compound that is a background contaminant. Five detections occur in BLM-16 that cannot be attributed to laboratory contamination, although dichloromethane is a common lab contaminant. Therefore, dichloromethane is identified as a contaminant in the bedrock aquifer upgradient of the former Lee Acres Landfill. Because the majority of the dichloromethane was detected in BLM-16, there may be a localized source upgradient of BLM-16.

6.1.3. Summary

The groundwater analytical results for the background alluvial and bedrock wells indicate that there may be a source of chromium contamination upgradient of the landfill in both the alluvial and bedrock aquifer systems. Consistently elevated values of dissolved chromium were measured during several sampling events in all five upgradient wells.

The detection of TCE in upgradient alluvial groundwater, and the detection of a low concentration of PCE in the upgradient bedrock aquifer, may indicate some amount of chlorinated hydrocarbon contamination from upgradient sources. However, these contaminants were each only detected once in the wells that are the northernmost upgradient wells (Plate 1), were not detected in upgradient wells closer to the former landfill, and were not detected in subsequent samples. Chemical analyses of upgradient groundwater samples reveal no trend indicating that hydrocarbon contaminants are present in upgradient groundwater, with the exception of dichloromethane. For these reasons it is assumed that chlorinated hydrocarbon contamination from upgradient sources does not currently affect groundwater quality adjacent to or downgradient from the former landfill. It is not known if the detection of dichloromethane in both the alluvial and bedrock aquifers represents contamination or is only an artifact of laboratory analysis.

The major difference between the background (upgradient) alluvial aquifer and the background bedrock aquifer is that the bedrock waters have higher TDS and higher concentrations of most major dissolved ions. This is considered normal because bedrock waters tend to be closer to chemical equilibrium with surrounding materials. Lower hydraulic conductivities in the bedrock increase the residence time of groundwater in contact with the bedrock materials. In addition, the bedrock formation in the study area is primarily mudstones or poorly sorted sandstones that may introduce components of a variety of soluble minerals into the groundwater.

6.2. DISTRIBUTION OF PRIMARY GROUNDWATER CONSTITUENTS

In Section 5, the general chemical characteristics of former liquid waste lagoon contents, soils in the landfill, and vadose zone moisture (OU 1) are presented. Data derived from the 1985 liquid waste lagoon sampling and from chemical analyses of hydrocarbon-stained soils in former lagoon areas characterize the nature of liquid contamination that formerly existed in the landfill lagoons from 1979 to 1985 (subsections 5.1 and 5.2). Liquid wastes in the lagoons contained high concentrations of chloride, sodium, and TDS, as well as high concentrations of petroleum hydrocarbons (BTEX) and chlorinated hydrocarbons. However, the lagoons contained lower sulfate concentrations than those measured in groundwater samples collected throughout most of the study area (Table 5-14).

During the period of operation of the liquid waste lagoons (1979 to 1985), the hydraulic head produced by liquid waste disposal practices would likely have promoted leaching of contaminants through the vadose zone to the water table. In the alluvial aquifer, contaminants would move downgradient according to hydrologic conditions (subsection 4.2). It is possible that six years of liquid waste disposal in the lagoons would produce an area of contamination at a location downgradient of the former landfill. Thus, chloride, TDS, sodium, and sulfate were used as indicators to investigate downgradient contamination derived from former liquid waste lagoon sources. Table 6-5 presents the concentration ranges for these four constituents in the alluvial and bedrock aquifers within the four study subareas.

Chloride was selected as an ion to be used as an indicator because the original lagoon waters contained elevated chloride concentrations, and because chloride is one of the most conservative constituents in groundwater. The term "conservative" refers to ions that travel with groundwater and remain relatively unaffected by ongoing chemical processes.

TDS concentrations were used as indicators because the lagoon waters contained high TDS. TDS may not be conservative in groundwater because dissolved constituents may be chemically altered or adsorbed onto sediments. In addition, TDS values are consistently higher in the background (upgradient) bedrock aquifer than in the background alluvial aquifer. Therefore, at locations where the alluvial aquifer is recharged by bedrock groundwater, there may be an increase in TDS.

Sodium was also used as an indicator because high sodium concentrations were measured in lagoon samples. However, sodium will tend to adsorb onto clay particles and is therefore somewhat less conservative in groundwater than chloride. Because of this, sodium will be a good indicator only in areas where there is a high density of monitoring wells.

Sulfate was used as an indicator because relatively low levels of sulfate were detected in some of the lagoon samples. In fact, sulfate values in water samples from most wells exceeded values measured in the lagoon samples. The low sulfate values in the lagoon samples may have been caused by microbial reduction of sulfate to sulfide that left the system in a gas phase (hydrogen sulfide). Sulfate concentrations may be elevated in natural groundwater through oxidation of hydrogen sulfide derived from deeper sources where reducing conditions exist. This particularly applies in evaporite basins where formation waters contain high concentrations of organic compounds. Groundwater contamination originating from the former landfill lagoons should therefore have low sulfate concentrations and a reducing environment. A discussion of the four indicator ions, in the alluvial aquifer and bedrock aquifer, is provided below.

6.2.1. Distribution of Major Groundwater Constituents in the Alluvial Aquifer

6.2.1.1. Subarea 1

Background (upgradient) water samples from the alluvial aquifer taken from December 1987 to May 1990 have chloride values ranging from 6.4 to 76.8 mg/L (Table 6-5). The value of 404 mg/L reported for BLM-15 in February 1990 appears to be an outlier, as the 16 previous chloride concentrations from this well range from 6.4 to 54 mg/L. Chloride concentrations in the four most recent samples are below 50 mg/L (Appendix N-1). Therefore, the high value is not included in determining the background range.

TDS values in background alluvial wells from December 1987 to May 1990 range from 760 to 3,600 mg/L. Background sodium concentrations for this same period range from 173 to 452 mg/L for alluvial wells, and background alluvial aquifer concentrations of sulfate range from 420 to 2,120 mg/L (Table 4-39).

6.2.1.2. Subarea 2, Site 1 Northern Area of OU 2

In the vicinity of the former landfill (subarea 2), most chloride values are lower than 100 mg/L (Table 6-5). Notable exceptions occur in and adjacent to the former liquid waste lagoon areas. Well BLM-57 is completed in shallow alluvium in the former northern liquid waste lagoon area. The highest chloride concentration in groundwater samples from this well, 352 mg/L was measured in April 1990. Well BLM-46 is adjacent to the former southern liquid waste lagoon area. The chloride value from the April 1990 sampling of BLM-46 was 260 mg/L (Appendix N-1). High chloride concentrations have also been detected in BLM-56, just south of the northern former liquid waste lagoon, and in BLM-20 (Plate 1). The high concentration of 730 mg/L, shown on Table 6-5, occurred in well BLM-20 in August 1988. However, this concentration may be an outlier because the chloride concentration decreases to 98 mg/L in the September 1988 sample (Appendix N-1). No distinct chloride concentration gradient exists. Because concentrations in monitoring wells located in areas other than the former liquid waste lagoons have decreased over time, there is no indication that a source currently exists in study subarea 2.

TDS values in the alluvial aquifer in subarea 2 are relatively consistent. TDS values range from 943 to 6,560 mg/L in alluvial wells throughout this area (Table 6-5). Samples from wells BLM-46 and BLM-57 have the highest TDS values. However, concentrations only exceed background values in these two wells, and have decreased over time. No TDS concentration gradient exists that indicates a constant source migrating from either of the former liquid waste lagoon areas.

Sodium values in subarea 2 show a similar pattern to TDS and chloride values. In general, sodium concentrations were less than 500 mg/L in study subarea 2. The August 1990 sample from well BLM-57 showed a sodium concentration of 995 mg/L. Concentrations in the 600 mg/L range have also been measured in BLM-20 and BLM-21. However, sodium concentrations in other alluvial groundwater samples collected from monitoring wells in subarea 2 are close to background values (Table 6-5).

Sulfate concentrations range from 195 to 4,370 mg/L in subarea 2 alluvial groundwater and fall within the background concentration range (420 to 2,120 mg/L, Table 6-5). Only two alluvial monitoring wells (BLM-17 and BLM-21) at the southwest corner of the landfill exceed the maximum background (upgradient) concentration.

6.2.1.3. Subarea 3, Site 1 Southern Area of OU 2

In subarea 3, south of the former landfill and north of GBR-17, there are elevated chloride concentrations. An area containing high chloride groundwater is located south of the southern landfill boundary. Wells GBR-32, GBR-48, and GBR-49 have chloride concentrations of greater than 1,000 mg/L. BLM wells in close proximity to these three GBR wells show chloride concentrations that are close to background. The variation in groundwater quality between these GBR wells and BLM wells may be due to a number of factors that are discussed in subsection 6.4.

The available monitoring well data center the northern chloride concentrations around well GBR-48, south of the landfill boundary. The elevated chloride concentrations appear to be limited in size or sinuous in nature. This is evident as there is a high density of wells in the area, and samples from wells that are close to one another have markedly different chloride concentrations.

Concentrations of TDS south of the landfill boundary show trends similar to chloride. They indicate an areally confined zone of elevated TDS immediately south of the landfill boundary that is identified by wells GBR-32, GBR-48, and GBR-49. The wells have TDS concentrations that are nearly twice those of adjacent wells. This indicates that an area of contamination may exist at this location that is sinuous and stratigraphically controlled.

Similar trends can be seen in the sodium data for the alluvial aquifer in subarea 3. Wells GBR-32, GBR-48, and GBR-49 have sodium concentrations higher than concentrations in adjacent wells. The highest sodium concentrations (1,060 mg/L) reported in the study area occur in the March and May 1990 samples from GBR-48. Adjacent BLM wells had sodium concentrations near background values (173 to 452 mg/L, Table 6-5).

Sulfate concentrations show a trend opposite that of the three other major groundwater constituents considered. Sulfate concentrations in wells GBR-32, GBR-48, and GBR-49 are slightly lower than sulfate concentrations in adjacent wells. This is similar to the trend of these constituents in the former liquid waste lagoons. Low sulfate values may indicate that microbial reduction of sulfate is an ongoing process in subarea 3. This hypothesis will be further discussed in subsection 6.4, where contamination in the southern area of OU 2 is described, and in subsection 6.6.1, where stable sulfur isotope results are analyzed.

6.2.1.4. Site 2

There is also an area of contamination in Site 2 located at the former Giant-Bloomfield Refinery facility that is defined by chloride concentrations in groundwater samples from monitoring wells south of well GBR-17. This area of contamination appears to be more areally extensive in the alluvial aquifer than the southern area of OU 2. The highest chloride concentrations are found in alluvial wells just north of U.S. 64. The formation of completion of the GBR wells is not clear, but the screened intervals of all the wells discussed include sections in the alluvial aquifer. Chloride concentrations as high as 891 mg/L (GBR-47) were reported.

Elevated TDS concentrations are also present in wells south of GBR-17. The data available for this area, from the first quarter 1990, define a TDS plume that appears to extend across U.S. 64. Sodium values also are slightly higher in GBR wells south of GBR-17. Concentration gradients indicate that the highest sodium concentrations are located just north of U.S. 64. Sulfate concentrations are relatively consistent in alluvial wells south of well GBR-17. It does not appear that any trends in sulfate concentrations can be defined at Site 2.

Also, in Site 2, south of U.S. 64, elevated chloride concentrations are evident in the alluvial aquifer. Well BLM-37 was completed in shallow alluvium and a chloride concentration of 535 mg/L was measured in September 1989. Immediately downgradient of well BLM-37 are two well clusters, BLM-27 through BLM-29 and BLM-30 through BLM-32, each containing two alluvial wells (Plate 1). For each well cluster, the shallow alluvial aquifer contains higher chloride concentrations than the deep alluvial aquifer. This trend is not found in other well clusters in the study area, except for the well cluster located in subarea 2 adjacent to the former southern lagoon (BLM-44, BLM-45, BLM-46). As chloride is a conservative ion and is controlled only by dispersion over time and distance from the source, it should achieve a relatively constant concentration with depth in a given aquifer. The fact that chloride concentrations decrease with depth in the well clusters to the south (downgradient) of well BLM-37 indicates a shallow, proximal source for chloride in the alluvial system with a short residence time. This leads to the conclusion that the elevated chloride concentrations in the alluvial system to the south of U.S. 64 are not derived from sources at the former Lee Acres Landfill.

TDS concentrations identify two distinct areas of contamination in Site 2, one of which may extend south of U.S. 64. As TDS is a composite of many ions and complexes, it does not behave conservatively in groundwater. Thus, concentration variations in the alluvial aquifer with depth are not solely controlled by mechanical dispersion. In general, TDS values increase with depth in the alluvial aquifer within the study area.

Sodium values are slightly higher in the southern part of Site 2. However, the highest sodium concentrations occur in the area north of U.S. 64 in Site 2.

6.2.2. Distribution of Major Groundwater Constituents in the Bedrock Aquifer

Chloride concentrations in the bedrock aquifer are quite consistent and are generally less than 40 mg/L (Table 6-5). It does not appear that any sources of chloride have affected the chemical composition of bedrock aquifer waters. Variations in chloride values do not identify a contaminant plume in the bedrock aquifer. However, BLM-26 south of U.S. 64 has a high chloride concentration possibly indicating that alluvial contamination in the vicinity of this well has moved into the bedrock aquifer. An analysis of other constituents and contaminant distribution is necessary to form any firm conclusions.

Concentrations of TDS in the bedrock aquifer are generally higher than concentrations in the alluvial aquifer; excluding those alluvial wells located in the former liquid waste lagoons. TDS concentrations in the bedrock aquifer are also quite consistent. Variation in TDS values do not indicate contamination of the bedrock aquifer in the study area.

Concentrations of sodium in the bedrock aquifer are consistent and tend to be higher than concentrations in the alluvial aquifer. There is no evidence sodium concentrations in the bedrock aquifer are related to contamination. Sodium concentrations in the bedrock aquifer do not exceed background (upgradient) bedrock aquifer concentrations except in isolated cases in subarea 2.

No obvious trends are present in the sulfate concentration data for the bedrock aquifer. Although some concentrations in BLM-54 (located in the southern former liquid waste lagoon) and BLM-64 (located in subarea 3) exceed the range of background bedrock aquifer concentrations (Table 6-5), the concentrations are less than two times background levels and are not considered of concern.

6.2.3. Summary of the Distribution of Primary Groundwater Constituents

The distribution of major groundwater constituents (TDS, chloride, sodium, and sulfate) in the alluvial aquifer system identifies two separate areas of contamination in the alluvial aquifer within the Lee Acres Landfill Study Area. These areas of contamination are located in subareas 3 and 4 and are referred to as the southern area of OU 2 and Site 2.

The OU 2 southern area is defined by wells to the north of well GBR-17, and the Site 2 area of contamination is defined by wells south of and including well GBR-17. The distributions of major groundwater constituents do not indicate whether the two areas are connected, overlap, or are derived from the same source. The fact that chloride values are distributed with depth in Site 2 indicates the two areas of contamination are not connected.

Based on the distribution of major dissolved constituents in the bedrock aquifer, there is little exchange between alluvial and bedrock aquifer systems. Poor hydraulic connection of the aquifers is expected since the bedrock in the study area is composed of poorly-sorted sandstones and mudstones that have inherently low hydraulic conductivities (subsection 4.2.6). The hydrologic gradients in the study area do not generally favor mixing of alluvial groundwater and bedrock groundwater. It, therefore, appears unlikely that there are any areas of contamination in the bedrock aquifer.

6.3. SITE 1, OU 2 NORTHERN AREA GROUNDWATER CHARACTERIZATION

The northern area of OU 2 is identified as the groundwater beneath the former Lee Acres Landfill (Site 1). A total of 30 groundwater monitoring wells have been installed in and adjacent to the landfill, of which 17 are alluvial wells and 13 are bedrock wells. The contaminants found in the alluvial and bedrock aquifer are described below.

6.3.1. Contamination in the Site 1, OU 2 Alluvial Aquifer (Subarea 2)

The alluvial aquifer beneath the landfill is characterized by the analytical results from the groundwater samples collected from the 17 alluvial wells in subarea 2: BLM-17, BLM-18, BLM-20, BLM-21, BLM-42, BLM-43, BLM-45, BLM-46, BLM-48, BLM-49, BLM-51, BLM-52, BLM-55, BLM-56, BLM-57, BLM-58, and BLM-60 (Plate 1). Groundwater samples were analyzed for VOCs and semivolatile organic compounds, pesticides, PCBs, metals, and inorganics. Pesticides and PCBs were not detected in any alluvial groundwater samples. The nature of contamination in the alluvial groundwater beneath the landfill is composed of both inorganic and organic compounds and is described below.

6.3.1.1. Inorganic COCs

In general, all the inorganic compounds are below the protection standard and within regional and study area background ranges as shown in Table 6-6. Exceptions are chloride and sulfate. Chloride ranges from 8.8 to 730 mg/L and exceeds the New Mexico HHS of 250 mg/L; however, it is within the regional background range of 34,000 mg/L (Table 6-6). Chloride is not considered a COC for this OU, as the high concentrations have decreased over time and are within the regional range. Sulfate ranges from 195 to 4,370 mg/L and exceeds the New Mexico HHS of 600 mg/L. However, the concentrations are within the regional and study area background ranges of 1.9 to 14,000 mg/L and 420 to 2,120 mg/L, respectively. Therefore, sulfate is not a COC. Subsection 6.2.1 discusses the distribution of chloride and sulfate concentrations throughout the study area.

Manganese is the only metal identified as a COC. Manganese exceeds the protection standard and the study area background range (Table 6-6). Manganese concentrations in the Lee Acres Landfill Study Area were measured by two methods: soluble and total. Total metals and soluble metals were not measured during the same sampling events. Therefore, a direct comparison of the total and soluble concentrations is not possible. However, in general, both soluble and total measurements were in the same range and thus were used interchangeably in the data analysis.

Soluble metals analysis is performed on groundwater samples that have been filtered during the sample collection process. The usual size of filter used is 0.45 microns, which is small enough to remove some of the clay, iron hydroxide, silica, and carbonate colloidal materials from the groundwater sample. Colloidal materials, which are very soluble, are retained on the filter and not counted in the soluble metals analysis.

Most free metal ions are retarded by cation exchange as they move through the aquifer. But, if a metal is part of a colloid, it will most likely move close to the same speed as the groundwater, since the sites available for ion exchange in the aquifer materials are not large enough to adsorb these colloids. Additionally, under oxidizing conditions, it is common for metals to combine with oxygen and form oxyanions. Oxyanions are not readily sorbed onto the aquifer materials because the available sorption sites are for cations.

Alluvial groundwater with chromium concentrations that exceed the SDWA MCL of 50 μg/L can be found throughout subarea 1, OU 2, and Site 2. However, chromium is not identified as a COC because it is a background contaminant. One upgradient well in subarea 1 (BLM-14) had an average chromium concentration of 54.7 μg/L, slightly exceeding the SDWA MCL.

In February 1989, the total chromium measurements were higher than during any other sampling period. The explanation for this is unclear; however, one explanation may be that more silt than usual remained in the wellbore because the wells had not been sampled for five months. The total and soluble manganese values for all other sampling events are in the same range, indicating that colloidal transport of metal ions is not a factor.

In OU 2, chromium concentrations inside the landfill range from nondetect to an average of 17 µg/L in BLM-58. However, outside the landfill fence, average chromium concentrations exceed SDWA MCL at three locations: BLM-51 (54.3 µg/L), BLM-17 (53.6 µg/L), and BLM-20 (78.6 µg/L). In subarea 2, the chromium concentrations in groundwater from the shallow alluvial wells are consistently greater than those found in the adjacent deep alluvial wells.

In the OU 2 southern area of contamination, all the BLM wells had chromium concentrations less than the SDWA MCL. However, the GBR wells had levels greater than 50 µg/L, including GBR-32 (70 µg/L) and GBR-49 (60 µg/L). In Site 2, six wells had average chromium concentrations greater than 50 µg/L, including BLM-24 (75.1 µg/L), BLM-25 (59 µg/L), BLM-27 (78.7 µg/L), BLM-28 (67.6 µg/L), BLM-30 (78.1 µg/L), and BLM-31 (83.4 µg/L). Two of the three well clusters (BLM-24, BLM-25, BLM-27, and BLM-28) have chromium concentrations in groundwater from the shallow alluvial well greater than concentrations found in the adjacent deep alluvial well.

Throughout the study area, there is no apparent trend in chromium concentrations decreasing or increasing over time. Because chromium is detected in the alluvial background wells (subarea 1) and is detected in monitoring wells outside the landfill, it is suspected that the chromium contamination in the Site 1 alluvial aquifer is from an upgradient source.

The higher chromium values along the arroyo may indicate the arroyo groundwater system is oxidizing and chromium oxyanions (soluble ions) are formed. These oxyanions are readily transported. Because the total chromium measurements are in the same numerical range as the soluble chromium values, there is no evidence of the presence of colloids in the groundwater system. In addition, chromium concentrations are low in the landfill and higher in the arroyo outside the landfill. This also indicates the source of chromium is associated with the arroyo rather than the landfill.

The distribution of manganese is different than the chromium distribution and is mainly confined to Site 1 monitoring wells within the landfill and along its western edge. Almost all concentrations in subarea 2 wells exceed the New Mexico HHS of 200 µg/L, with the exception of concentrations found in BLM-51 and BLM-52, located at the northwest corner of the landfill. Manganese concentrations in these two wells range from not detected to 73.4 µg/L and are below the New Mexico HHS. Concentrations in the four alluvial landfill monitoring wells range from 421 to 8,620 μg/L. The lowest concentrations (421 to 2,460 μg/L) in the landfill wells are found in BLM-56 located between the two former liquid waste lagoons, and the highest concentrations (7,260 to 8,620 μg/L) are found in BLM-57 located in the former northern liquid waste lagoon. Concentrations in monitoring wells along the edge of the landfill (BLM-42 through BLM-49), with the exception of BLM-43, range from 1,090 to 2,490 μg/L, with an average concentration of approximately 1,600 μg/L. BLM-43 exceeds this range by approximately three times. Manganese concentrations in BLM-43 range from 4,350 to 6,700 μg/L.

In addition, manganese was also detected in monitoring well BLM-60, located in the unnamed arroyo west of the southwest corner of the landfill (Figure 6-1). Concentrations in BLM-60 range from 3,930 to 4,720 μg/L. Manganese concentrations in the other alluvial wells located west of BLM-60 are an order of magnitude lower in concentration and range from 16.1 to 149 μg/L.

6.3.1.2. Organic COCs

Twenty-three organic compounds were detected in OU 2 alluvial groundwater samples. Table 6-7 presents 22 organic compounds and their maximum concentrations. One compound, 2-methylnaphthalene, was eliminated as a positive result during the lab blank evaluation (Appendix N-2). Thirteen of the 22 organic compounds, with the exception of acetone, are eliminated as COCs based on the two frequency criteria of one-time detection and one detection per well.

Acetone is eliminated as a COC because in most cases acetone was detected in the first sampling events after well construction. A majority of the acetone detections are eliminated due to the lab blank evaluation (Appendix N-2) and the remaining detections are, therefore, also considered artifacts of laboratory analysis. Two high concentrations (18,000 and 340 μg/L, Table 6-7) are considered outliers and products of laboratory error because in three subsequent monthly samples acetone was not detected.

The following organic compounds are identified as COCs for the northern area of the OU 2 alluvial aquifer: 1,1-DCA, 1,2-DCE (*cis* and *trans* isomers), benzene, trichloromethane, dichloromethane, PCE, TCE, and vinyl chloride (Table 6-7). Table 6-8 presents the concentrations and locations of the detected organic compounds. With the exception of dichloromethane, the extent of contamination is confined to ten monitoring wells, shown on Figure 6-1: BLM-17, BLM-21, BLM-42, BLM-43, BLM-49, BLM-52, BLM-55, BLM-56, BLM-57, and BLM-60. However, the majority of the contamination is chlorinated hydrocarbons and is found in three wells located in the Lee Acres Landfill: BLM-55, BLM-56, and BLM-57 (Figure 6-1).

Well BLM-55 is located in the area of the former southern liquid waste lagoon (Figure 6-1) and has concentrations of 1,1-DCA, 1,2-DCE, trichloromethane, PCE, and TCE. However, 1,1-DCA and trichloromethane were detected only in the May 1991 sample (Table 6-8). PCE (1.4 to 3 µg/L); 1,2-DCE (2.9 to 8.9 µg/L); and TCE (1 to 3.2 µg/L) are more frequently detected in this well at six, three, and two times, respectively.

Well BLM-56 is located between BLM-55 and BLM-57 and between the two former liquid waste lagoons (Figure 6-1). 1,1-DCA is the most commonly detected COC for this well (3 out of 7 times) and ranges in concentration from 1.3 to 3.3 µg/L. Trichloromethane and benzene were also detected once in samples collected in March 1990 and August 1990, respectively (Table 6-8), but were not detected in subsequent sampling events.

Well BLM-57 is located in the area of the former northern liquid waste lagoon (Figure 6-1). Concentrations of 1,1-DCA, 1,2-*trans*-DCE, TCE, and vinyl chloride are present. 1,2-*trans*-DCE is detected in the three samples collected in 1991 and ranges in concentration from 1.5 to 2.3 µg/L. TCE and vinyl chloride were not detected in the 1991 samples.

The seven other alluvial wells in subarea 2 with contamination are located outside the former landfill. The contamination is limited to one-time detections in each well. In BLM-17, PCE was detected at 9 µg/L in December 1987. Trichloromethane was detected in BLM-21 and BLM-60 at 1.2 and 19 µg/L, respectively. Benzene was detected once in the March 1990 samples from BLM-42, BLM-43, and BLM-52 at 0.13, 0.2, and 0.61 µg/L, respectively (Table 6-8). Trichloromethane was also detected in BLM-43 ranging from 1.9 to 2.9 µg/L; however, it was not detected in three subsequent samples.

The final monitoring well with suspected contamination is BLM-49, located outside the former landfill (Figure 6-1). 1,1-DCA, benzene, PCE and TCE were detected in the April 1990 sample for this well. However, samples collected before and after this sampling event indicate nondetections for these contaminants (Table 6-9). It is suspected that the April 1990 VOC samples were mislabeled with the samples collected from monitoring well GBR-49 located in subarea 3, south of the landfill (Plate 1). Table 6-9 presents the analytical results from five sampling events for 1,1-DCA, benzene, PCE, and TCE for both BLM-49 and GBR-49. The only contaminants detected in BLM-49 occur in the April 1990 sample and the concentrations follow the trend shown in the other sample events for GBR-49. Since April 1990, subsequent samples from BLM-49 have been clean. Based on this comparison, it is assumed that there is no contamination in well BLM-49.

Of the COCs identified in Table 6-7, dichloromethane is the only COC that is detected in all of the northern area OU 2 alluvial aquifer monitoring wells. Concentrations for dichloromethane range from 1 to 36 µg/L and it was detected in several wells in nearly all of the RI sampling events. Dichloromethane is a common laboratory contaminant (EPA 1988c). The lab blank evaluation described in subsection 2.9.3 was performed for dichloromethane, however, a majority of the results are not identified as present in the blank and therefore, cannot be eliminated. Dichloromethane is also present in the background alluvial wells and may either be from an upgradient source or an artifact of laboratory analysis. It cannot be determined whether the detection of dichloromethane identifies laboratory contamination; therefore, dichloromethane is identified as a COC for the northern area OU 2 alluvial wells.

All concentrations of the COCs detected in the northern area of OU 2 are below regulatory standards except for vinyl chloride. Vinyl chloride was only detected in BLM-57 at a frequency of three out of seven times at concentrations ranging from 1.6 to 6.7 μg/L (Table 6-8). Two of three detections exceed the SDWA MCL of 2 μg/L. However, vinyl chloride has not been detected since August 1990. Three other COCs, benzene, PCE, and TCE, exceed the regulatory standards, as shown in Table 6-7. However, the maximum values that exceed the standards are from the BLM-49/GBR-49 sample (Table 6-7, Table 6-9). All other concentrations for these three COCs are below regulatory standards.

Only the three wells within the former Lee Acres Landfill are considered contaminated with chlorinated hydrocarbons, possibly from the former liquid waste lagoons. 1,1-DCA is the most common COC, with the exception of dichloromethane. 1,1-DCA is found in all three wells within the former landfill and in all samples collected from BLM-57 at a concentration range of 1.3 to 4.4 μg/L (Table 6-8).

6.3.2. Contamination in the Site 1, OU 2 Northern Area Bedrock Aquifer

Thirteen wells characterize the groundwater in the bedrock aquifer beneath the former Lee Acres Landfill: BLM-19, BLM-22, BLM-23, BLM-33 through BLM-35, BLM-41, BLM-44, BLM-47, BLM-50, BLM-53, BLM-54, and BLM-59. Six of the 13 monitoring wells are located inside the landfill fenceline (BLM-23, BLM-33, BLM-34, BLM-35, BLM-53, and BLM-54). Contamination in the northern area OU 2 bedrock aquifer is identified according to inorganic and organic COCs in the following subsections.

6.3.2.1. Inorganic COCs

Table 6-10 presents the subarea 2 bedrock aquifer concentration ranges for inorganics and metals. Chromium is the only COC identified. The SDWA MCL for chromium is 50 μg/L and the chromium concentration ranges from 57.7 to 68.5 μg/L. The distribution of chromium in the bedrock aquifer is confined to wells BLM-23, BLM-33, BLM-34, and BLM-35 located in the southwest part of the landfill and those wells west of the southwest corner, BLM-19 and BLM-22. Chromium is also identified as a background contaminant in the background bedrock aquifer (subsection 6.1.2.1). Therefore, the chromium contamination detected in the subarea 2 bedrock aquifer is considered to be from an upgradient source and is not identified as a COC.

6.3.2.2. Organic COCs

Eighteen organic compounds including three pesticides were detected in the bedrock groundwater samples. Two compounds, phenol and diethyl phthalate, are eliminated on the basis of the lab blank evaluation (Appendix N-2). Table 6-11 presents the 16 organics detected in subarea 2 bedrock groundwater samples. Of the 16 organics compounds, only two are identified as COCs for the northern area bedrock groundwater: dichloromethane and *bis*(2-ethylhexyl) phthalate. Fourteen organic compounds are eliminated as COCs based on the frequency criterion of one-time detections or one-time detections per well. The three pesticides detected are one-time detections in well BLM-47 and confirmation sampling was performed in May 1991, at which time they were not detected. Therefore, pesticides are not identified as COCs.

Dichloromethane and *bis*(2-ethylhexyl) phthalate are common laboratory contaminants; however, they could not be eliminated as COCs in the lab blank evaluation. The majority of *bis*(2-ethylhexyl) phthalate was detected in monitoring wells BLM-19, BLM-22, BLM-33, BLM-34, and BLM-35, and in early PI and RI samples, only with several subsequent nondetections. Concentrations range from 1 to 71 µg/L. *Bis*(2-ethylhexyl) phthalate is retained as a COC for risk assessment purposes only.

Dichloromethane ranges in concentration from 0.51 to 21 µg/L and is present in at least one sample from all bedrock monitoring wells. The majority of the dichloromethane detections occurred in early 1988 and 1989 samples collected from BLM-19, BLM-22, BLM-23, BLM-33 through BLM-35. One-time detections occurred in the other seven bedrock monitoring wells. Twelve of the 30 detections exceed the proposed regulatory standard of 5 µg/L. Dichloromethane is a common laboratory contaminant; however, it is unknown whether the dichloromethane detected in the bedrock aquifer is due to laboratory contamination or is a true COC. Therefore, it will be retained as a COC for the baseline risk assessment (Section 10).

6.4. SITE 1, OU 2 SOUTHERN AREA GROUNDWATER CHARACTERIZATION

The southern area of OU 2 is defined by 21 monitoring wells located south of the landfill boundary and north of well GBR-17 on Giant-Bloomfield Refinery property (Plate 1). Three wells are completed in the bedrock formation and 18 wells are completed in alluvial materials, four of which are Giant-Bloomfield Refinery wells. Table 6-12 presents the well completion information for all OU 2 southern area wells.

An objective of monitoring well installation and sampling during the RI was to identify and define the nature and extent of the contamination in the southern area of OU 2. Groundwater analytical results for the OU 2 southern area of contamination are discussed in the following subsections to determine the nature and extent of groundwater contamination primarily consisting of chlorinated hydrocarbons and metals in the alluvial and bedrock aquifers and assess the impact of the former Lee Acres Landfill on groundwater quality.

6.4.1. Contamination in the Site 1, OU 2 Southern Area Alluvial Aquifer

In the initial stage of the RI, groundwater contamination was identified in samples collected from three GBR monitoring wells located on Giant-Bloomfield Refinery property immediately south of the former landfill: GBR-32, GBR-48, and GBR-49. One alluvial monitoring well, BLM-62 was installed adjacent to GBR-32 and was sampled in 1990. However, contamination was not detected in the groundwater samples from this well, prompting the second stage of the RI conducted in 1991 (WESTON 1991). The objectives and work plan for the second stage of the RI are presented in the RI Briefing Document (WESTON 1991), and resulted in the installation of 13 additional monitoring wells in the area between the southern boundary of the landfill fence and north of monitoring well GBR-17 (Plate 1). Eighteen monitoring wells, BLM-62, BLM-67 through BLM-79, GBR-32, and GBR-48 through GBR-50, characterize the alluvial groundwater in the southern area of OU 2. The review of the groundwater analytical results for the determination of the frequency of detection for these wells includes only the groundwater samples collected during the RI. Additional data are available for the four GBR wells, as they are part of the Giant-Bloomfield Refinery quarterly groundwater monitoring program. However, only positive detections from the quarterly monitoring program are incorporated into the RI groundwater analytical results database. The GBR data substantiated the trends in contaminant distribution and concentrations identified in the RI. The following subsections describe the inorganic and organic COCs identified in the OU 2 southern area.

6.4.1.1. Inorganic COCs

Table 6-13 presents the inorganic compounds and metals concentrations for the southern area of Site 1 The compounds that are identified as COCs are chloride, cobalt, manganese, nickel and selenium.

Chloride concentrations range from 19 to 2,110 mg/L. The distribution of chloride in this area is discussed in subsection 6.2.1.3. Well GBR-48 has chloride concentrations greater than 1,000 mg/L. However, chloride concentrations in the other 18 wells range from 19 to 471 mg/L, which is similar to study area background concentrations (Table 6-13).

Cobalt concentrations range from 50.3 to 110 µg/L and exceed the New Mexico HHS of 50 µg/L. Cobalt is present in three BLM wells in the area: in BLM-68 from 56.1 to 60.7 µg/L, in BLM-70 from 74.8 to 86.5 µg/L, and in BLM-76 from 55.7 to 62.5 µg/L. Cobalt is also detected in three GBR wells: in GBR-32 from not detected to 52.8 µg/L, in GBR-48 from not detected to 110 µg/L, and in GBR-49 from 54.8 to 110 µg/L.

Manganese in the OU 2 southern area of contamination ranges in concentration from 21.4 to 4,230 µg/L. Concentrations follow two trends: concentrations are less than 225 µg/L or are greater than 500 µg/L. Five wells, BLM-68, BLM-69, BLM-75, BLM-78, and BLM-79, have concentrations that range from 21.4 to 225 µg/L. The concentrations in the other 12 alluvial wells range from 646 to 4,230 µg/L. However, of these 12 wells, eight wells have consistent concentrations of manganese greater than 1,000 µg/L: BLM-71, BLM-72, BLM-76, BLM-77, GBR-32, GBR-48, GBR-49, and GBR-50.

Elevated nickel concentrations that exceed the New Mexico HHS of 200 µg/L occur in two Giant-Bloomfield Refinery wells: GBR-48 and GBR-49. The elevated selenium concentrations that exceed the SDWA MCL of 10 µg/L occur in GBR-48 as well. The southeasternmost BLM well, BLM-68, also has a one-time concentration of 11.6 µg/L, which exceeds the SDWA MCL.

6.4.1.2. Organic COCs

The groundwater contamination identified in the southern area of OU 2 is composed primarily of chlorinated hydrocarbons. There were no pesticides encountered above detection limits in any alluvial groundwater samples in the OU 2 southern area of contamination. Twenty-three organic compounds are identified in the groundwater samples collected from the 19 monitoring wells. Acetone is eliminated as one of the 23 COCs because all detected concentrations are eliminated as laboratory contamination. The maximum detected concentrations for the remaining 22 organic compounds are presented in Table 6-14. Of these 22 compounds, 13 are eliminated based on the frequency criterion of one-time detection, resulting in the identification of nine organic COCs for the OU 2 southern area alluvial aquifer.

The organic contamination is composed of the following VOCs: 1,1,1-TCA, 1,1-DCA, 1,2-DCE (both *cis* and *trans* isomers), benzene, trichloromethane, dichloromethane, PCE, and TCE. 1,1,1-TCA, 1,1-DCA, 1,2-DCE, PCE, and TCE are commonly referred to as chlorinated hydrocarbons and are the main contaminants in the southern area of the OU 2 alluvial aquifer. The distribution of chlorinated hydrocarbons and their degradation process and the distribution of benzene, trichloromethane, and dichloromethane in the OU 2 southern area alluvial aquifer are described in the following paragraphs.

6.4.1.2.1. Chlorinated Hydrocarbon Contamination in the OU 2 Southern Area Alluvial Aquifer

Figure 6-2 shows the approximate extent of chlorinated hydrocarbon contamination. Chlorinated hydrocarbons are detected in 10 of the 18 alluvial monitoring wells: BLM-68, BLM-70, BLM-72, BLM-74, BLM-76, BLM-77, GBR-32, GBR-48, GBR-49, and GBR-50. Table 6-15 presents the concentrations of chlorinated hydrocarbons and the other four organic compounds detected in the OU 2 southern area alluvial wells. Table 6-15 presents the northernmost to southernmost monitoring wells with chlorinated hydrocarbon contamination and the monitoring wells outside the area of chlorinated hydrocarbon contamination.

Two wells, BLM-67 and BLM-71, are free of any organic contamination. The distribution of chlorinated hydrocarbon contamination in the 10 southern area monitoring wells is varied (Figure 6-2, Table 6-15). Giant-Bloomfield Refinery wells GBR-32 and GBR-48 are the most contaminated wells as all five chlorinated hydrocarbons, trichloromethane, and dichloromethane have been detected. Benzene has also been detected in these wells and will be discussed separately.

The next two most contaminated wells are GBR-49 and BLM-68. Four chlorinated hydrocarbons, 1,1-DCA, 1,2-DCE, PCE, and TCE, are present in these two wells. However, BLM-68 is the southernmost well and approximately 500 ft south of GBR-49. The monitoring wells between GBR-49 and BLM-68 have chlorinated hydrocarbon concentrations an order of magnitude lower (Table 6-15) and only three chlorinated hydrocarbons, 1,2-DCE, PCE, and TCE, are present in wells BLM-70, BLM-74, and BLM-76.

The final three wells with chlorinated hydrocarbon contamination are BLM-73, BLM-77, and GBR-50. These wells are located at the western and northern extent of contamination. 1,2-DCE and PCE are present in BLM-73; only 1,2-DCE is present in BLM-77; and 1,1-DCA and 1,2-DCE are present in GBR-50. Concentrations for all chlorinated hydrocarbons are presented in Table 6-15.

Of the five chlorinated hydrocarbons detected in the OU 2 southern area of contamination, 1,2-DCE is the most commonly detected with concentrations ranging from 1.1 to 200 μg/L. However, in four monitoring wells, GBR-48, GBR-32, GBR-49, and BLM-68, the 1,2-DCE concentrations are greater than 50 μg/L.

It should be noted that 1,2-DCE exists as two distinct isomers: 1,2-*cis*-DCE and 1,2-*trans*-DCE. VOCs, including 1,2-DCE, are analyzed by gas chromatography, using either a packed column or a capillary column. Because of its higher efficiency, the capillary column provides separation of both 1,2-DCE isomers. This allows both quantitative and qualitative information to be obtained. The packed column is unable to provide sufficient resolution to separate both isomers. It provides a quantitative result, but does not give specific qualitative information. The analytical result obtained using a packed column may actually be due to either the *cis* or the *trans* isomer, or a combination of both. The packed column was used in a majority of the RI VOAs and concentrations for 1,2-DCE were reported as the *trans* isomer, although the result could be either isomer or a combination. In some cases during the RI, the laboratory ran a confirmation analysis using the capillary column to separate both, thus reporting both isomers, with the major concentration contributed by the *cis* isomer. Since the majority of the RI analytical results for 1,2-DCE are reported as the *trans* isomer, the confirmation analytical results are combined and also reported under the *trans* isomer. Therefore, it should be noted that in the discussions of 1,2-DCE, the actual concentration could be either isomer or a combination.

In addition to 1,2-DCE, PCE and TCE are the next most commonly detected chlorinated hydrocarbons in the southern area of the OU 2 alluvial aquifer contamination. Chlorinated hydrocarbons are known in organic chemistry as chlorinated aliphatic hydrocarbons because of their chemical structure. The following subsection describes the potential degradation or breakdown process of chlorinated hydrocarbons.

6.4.1.2.2. Degradation of Chlorinated Aliphatic Hydrocarbons

The fate of organic compounds in the subsurface environment is dependent of a variety of chemical and biological reactions, the chemical structure of the compound, and the environmental conditions surrounding the chemical. The environmental conditions of concern to chlorinated aliphatic hydrocarbons include oxygen excess or deficiency, the heterogeneity of the aquifer, local substrate availability, and the acclimatization of microbial populations.

Reactions involved in the chemical transformations of organic compounds include hydrolysis, oxidation, reduction, and dehydrohalogenation. Hydrolysis is the reaction of the organic compound with water. A typical reaction between a halogenated aliphatic hydrocarbon and water would result in the formation of an alcohol and the loss of a halide group. As an example, chloroethane and water would result in the formation of an alcohol and the loss of a halide group. Oxidation reactions involve the addition of oxygen to the contaminant. The result of a complete oxidation reaction is mineralization--the conversion of organic compounds to carbon dioxide and water. Oxidation reactions are a primary method of breakdown for aromatic hydrocarbons. Reduction reactions utilize a transfer of electrons to an alkane or alkene of interest, with the simultaneous loss of a hydrogen and/or halide group. This results in the generation of a less halogenated compound. An example would be the formation of vinyl chloride from the DCE isomers. Reduction reactions can occur under aerobic, anaerobic, or abiotic conditions. Dehydrohalogenation is an elimination reaction resulting in the creation of a less halogenated alkene from a halogenated alkane. This is a primary transformation route of chlorinated aliphatic hydrocarbons, particularly in an anaerobic or abiotic environment. This process would form the 1,2-DCE isomers from 1,1,1-TCA.

Biological degradation of organic contaminants can be accomplished through reduction dehydrogenation caused by microorganisms. These biotransformations are associated with cometabolism. Cometabolism is the biological degradation of a chemical in the presence of other organic material, which serves as a primary energy source. Through this process chlorinated alkanes and alkenes are transformed into less halogenated intermediate products. As an example, TCE would degrade into the two 1,2-DCE isomers. The production of the *cis* isomer can be 20 to 30 times that of the *trans* isomer.

The alluvial aquifer in the southern area of OU 2 may contain low amounts of dissolved oxygen, and therefore, be subject to anaerobic conditions. Using the reactions discussed above, the degradation of the chlorinated hydrocarbon contaminants detected in this aquifer would proceed through a complex combination of chemical (reduction, dehydrohalogenation) and biological (reduction dehydrogenation) reactions. Figure 6-3 represents the mineralization process of polychlorinated ethanes and ethenes. These processes favor an anaerobic environment. Degradation rates are influenced by chemical compound structure, the degree of halogenation, the surrounding environmental properties, and the level of microbial activity. Table 6-16 presents the potential degradation products resulting from the chlorinated hydrocarbons detected in the southern area of the OU 2 alluvial aquifer. As the degradation process proceeds for the chlorinated hydrocarbons (1,1-DCA; 1,2-DCE; TCE; and PCE) detected in the southern area of OU 2, vinyl chloride and chloroethane are the potential degradation products that are expected, and in potentially higher concentrations (Table 6-16). Dichloromethane and trichloromethane probably will not degrade significantly and will be essentially unchanged.

6.4.1.2.3. Benzene

Benzene has been detected in the three northernmost GBR wells, GBR-32, GBR-48, and GBR-49, ranging in concentration from 0.24 to 110 µg/L. However, all detections of benzene in these wells occurred only in the 1989 and 1990 sampling events conducted for the RI and by Giant-Bloomfield Refinery. Table 6-17 presents the benzene concentrations for all OU 2 southern area alluvial wells. As indicated in Table 6-17, benzene suddenly decreased from 100 µg/L in GBR-32 in September 1990 to not detected in all the samples collected in 1991. The same trend occurs in GBR-48 and GBR-49. Benzene was not detected in any of the monitoring wells installed in the second stage of the RI (wells BLM-67 through BLM-79).

The detection of benzene and then its disappearance eight months later cannot be explained. If benzene migrated downgradient, concentrations should be detected in the downgradient wells and have a noticeable decrease in concentration in the wells in which it was originally detected. Two different analytical laboratories were used during the RI; however, both are CLP laboratories and follow CLP protocol. Review of the chromatographs did not reveal any unmarked peaks that could be identified as benzene. In addition, several samples from the May 1991 RI groundwater sampling event were split with the NMED. Analytical results for the two data sets matched almost identically and benzene was not detected.

6.4.1.2.4. Trichloromethane and Dichloromethane

Trichloromethane is present in seven wells in the southern area of OU 2 contamination as shown in Table 6-15 and ranges in concentration from not detected to 6.3 µg/L. It is the only contaminant detected in

BLM-78 and was detected only once. Trichloromethane and dichloromethane were the only contaminants detected in BLM-79. The other occurrences of trichloromethane were in the chlorinated hydrocarbon contaminated wells (Table 6-15).

The distribution of dichloromethane, shown on Figure 6-2, does not follow the same area of contamination as the chlorinated hydrocarbon contamination. Concentration ranges for each well are presented on Table 6-15. The general range of dichloromethane concentration is 0.68 to 15 µg/L.

6.4.2. Summary of the OU 2, Southern Area Alluvial Aquifer Contamination

In OU 2 southern area wells, levels of chlorinated hydrocarbons, benzene, trichloromethane, and dichloromethane were encountered that exceed the SDWA MCLs and New Mexico HHSs (Table 6-14). Ten monitoring wells identify an area of contamination consisting mainly of chlorinated hydrocarbons, although cobalt, manganese, nickel and selenium also were detected above standards in several of these wells. Analytical results indicate that there is no petroleum hydrocarbon contamination between wells GBR-49 and BLM-68, and concentration gradients indicate that the OU 2 southern area of contamination is centered somewhere near GBR-48 and GBR-32 and decreases in concentration downgradient. However, concentrations of chlorinated hydrocarbons increase dramatically in well BLM-68, the southernmost RI monitoring well. Subsection 6.5.3 and Figure 6-4 provide possible sources for contamination found in well BLM-68.

The highest levels of chlorinated hydrocarbon contamination were found in wells GBR-32, GBR-48, and GBR-49, with concentrations of 1,2-DCE ranging from 1.2 to 200 µg/L. Adjacent BLM wells contained only low concentrations of chlorinated hydrocarbons. Hydrocone samples collected to the south of GBR-49 did not show any chlorinated hydrocarbon contamination. However, these samples were taken in shallow alluvium, and because most chlorinated hydrocarbons sink in water and have low solubilities, these data are inconclusive. Concentration gradients indicate that the southern area of OU 2 contamination, as defined by chlorinated hydrocarbons, is centered near well GBR-48.

Chromium concentrations in the OU 2 southern area alluvial wells did not exceed the SDWA MCL or New Mexico HHS. However, elevated chromium concentrations were reported in upgradient wells in subareas 1 and 2. This may indicate that the contamination from the upgradient chromium source has not yet reached the southern area of OU 2.

Elevated cobalt values above the New Mexico HHS of 50 µg/L were also reported in wells GBR-32, GBR-48, and GBR-49. These are the same wells that showed elevated TDS, chloride, sodium, chlorinated hydrocarbons, and low sulfate values.

6.4.3. Contamination in the OU 2 Southern Area Bedrock Aquifer

The bedrock aquifer in the southern area of OU 2 is characterized by three bedrock wells: BLM-61, BLM-63, and BLM-64. Contaminant concentrations in the bedrock aquifer in this area are almost negligible compared to those in the alluvial aquifer. Table 6-18 presents the concentration ranges for the inorganics and metals detected in the bedrock aquifer. All inorganics and metals are below regulatory standards or are within the study area and regional concentration ranges. Therefore, no inorganics or metals are identified as COCs for the OU 2 southern bedrock aquifer.

The only COC identified for the OU 2 southern area bedrock aquifer is dichloromethane as shown on Table 6-19. A common laboratory contaminant, dichloromethane, may be attributed to lab contamination as the concentration range is 0.34 to 5.6 μg/L, which is quite low. In addition, detections of dichloromethane occurred only in March 1990 and July 1991 sampling events, with nondetections occurring in the intervening events. However, the concentrations are not identified as present in the lab blank, and therefore, must be considered valid results. Therefore, dichloromethane is identified as a COC and will be retained for the baseline risk assessment (Section 10).

The lack of chlorinated hydrocarbon contamination in the bedrock aquifer, in conjunction with hydrostratigraphic data and distribution of major groundwater constituents, indicates that there is little mixing of alluvial waters with bedrock waters in the OU 2 southern area or in study subareas 1 and 2. Hydrologic data also indicate that there is a prevalent upward hydraulic gradient in the vicinity of the southern area of contamination (subsection 4.2.5).

A complication arises in the discussion of contamination in the bedrock aquifer in the OU 2 southern area of contamination when the fire water storage ponds to the east of the wells in question are considered (Plate 1). Bedrock monitoring well GBR-18, located in the northeastern portion of subarea 3, is not used to identify contaminants of concern for OU 2. GBR-18 is a bedrock well located west of any potential source of contamination from the landfill. Although the ponds were drained in early 1988, the presence of the ponds may have impacted the migration of contaminants. While the fire water ponds were full, they may have provided a hydrologic barrier, through the formation of a groundwater mound in alluvial materials. The hydrograph for well GBR-18 shows a significant decrease in groundwater elevation around January 1989, several months after the ponds were abandoned (Appendix S), indicating GBR-18 may be hydraulically connected to the fire water ponds located approximately 100 ft to the northeast. Therefore, constituents measured in this well are not used in the identification of contaminants for the OU 2 southern area bedrock aquifer.

6.5. SITE 2 GROUNDWATER CHARACTERIZATION

The Site 2 area of contamination is identified as the groundwater contamination currently being investigated and remediated by the Giant-Bloomfield Refinery on their property and on property immediately south of U.S. 64. The discussion of groundwater contamination presented in this section includes the area from monitoring well GBR-17 on the north, to the San Juan River (Plate 1). The discussion will group contaminants as petroleum hydrocarbons composed of benzene, toluene, ethylbenzene and xylene (BTEX), chlorinated hydrocarbons, metals, and pesticides.

Information on the nature and extent of groundwater contamination related to the Site 2 area of contamination is presented for groundwater in the alluvial and bedrock aquifers. The major emphasis is with groundwater quality in the alluvial aquifer. An understanding of the nature and extent of groundwater contamination in Site 2 requires a presentation of the present situation and a review of historical information to establish trends to identify changes that may occur in the future.

Table 6-20 presents historical and recent analyses of groundwater samples from selected wells in the Site 2 area of contamination for discrete COCs. Table 6-21 and Table 6-22 present the COCs for inorganics and metals and organic compounds, respectively for the RI monitoring wells, excluding BLM-37.

6.5.1. Groundwater Quality in the Site 2 Alluvial Aquifer

6.5.1.1. BTEX Constituents in the Alluvial Aquifer

Releases at the former Giant-Bloomfield Refinery are considered to have produced floating product at 19 monitoring wells in Site 2, including monitoring well BLM-37 located south of U.S. 64. Figure 6-5 identifies monitoring wells where the presence of floating product has been documented. Floating product in the alluvial aquifer is reported over a large area located westward of the refinery to the unnamed arroyo and southward to beyond U.S. 64. An additional investigation is currently being conducted by Giant-Bloomfield Refinery to identify its floating product plume south of U.S. 64 (GCL 1990).

Figure 6-6 shows the combined concentration of BTEX measured in groundwater samples collected in November 1986 from monitoring wells and groundwater recovery wells installed by Giant-Bloomfield Refinery. Total BTEX concentrations range from undetected to 14,400 µg/L. The highest concentrations are located southwest of the refinery within 200 ft of U.S. 64.

Figure 6-7 shows the combined concentration of BTEX measured in groundwater samples collected from monitoring wells in the first quarter 1990. Total BTEX concentrations vary from not detected to

14,610 µg/L, with the highest concentrations measured at monitoring well BLM-37 located south of U.S. 64 in Site 2. The monitoring wells with the highest concentrations of BTEX are located in the northern part of Site 2 on the refinery facility itself. BTEX constituents have never been detected at monitoring well GBR-17 located north of the refinery in subarea 3.

As shown in Figure 6-7, monitoring wells in Site 2, located south of U.S. 64, also have high concentrations of BTEX: SHS-1, BLM-37, and SHS-2. The only other BLM monitoring wells in Site 2 where BTEX constituents were measured, all had isolated detections of total xylenes at levels less than 1.5 µg/L and are not considered part of the plume. Table 6-20 presents BTEX constituents measured in selected wells in Site 2.

In summary, BTEX contamination of groundwater in the alluvial aquifer occurs over a large part of Site 2. Floating product has been reported at many wells in Site 2 and at well BLM-37. Groundwater elevation data presented in a February 23, 1990, report by Geoscience Consultants, Ltd. (GCL 1990), predict that BTEX-contaminated groundwater has the potential to migrate southward in Site 2 in the future.

6.5.1.2. Chlorinated Hydrocarbon Constituents in the Site 2 Alluvial Aquifer

Figure 6-8 presents total chlorinated hydrocarbon concentrations measured in groundwater samples collected in November 1986 from monitoring wells in Site 2 installed by the Giant-Bloomfield Refinery. Concentrations range from undetected to 170 µg/L. The highest concentrations were reported in wells located north of U.S. 64, with the exception of GBR-17.

Monitoring well GBR-17 is the northernmost alluvial well in Site 2 and was installed by Giant-Bloomfield Refinery in 1986. The available analytical data on groundwater quality at monitoring well GBR-17 include 15 samples collected from June 5, 1986, to April 3, 1990 (NMOCD 1990). Chlorinated hydrocarbons were detected in 14 of the 15 samples, with total concentrations decreasing over time from 52 µg/L on June 5, 1986, to 7.4 µg/L on November 12, 1987, to 4.4 µg/L on April 20, 1988, to 1.0 µg/L on December 12, 1989, and 1.7 µg/L on April 30, 1990. The decline in total concentration of chlorinated hydrocarbons is accompanied by a decline in chloride concentration from 1,005 mg/L on June 5, 1986, to 111 mg/L on April 3, 1990. Chlorinated hydrocarbon constituents detected in groundwater samples collected from GBR-17 on June 5, 1986, and April 3, 1990, are reported in Appendix N-1. The two constituents present in the September 3, 1990, groundwater samples were 1,1,1-TCA at a concentration of 1.7 µg/L and PCE at a concentration of 0.37 µg/L. TCA was reported in the June 3, 1986, analysis at a concentration of 14 µg/L, and PCE was reported at a concentration of 1 µg/L. Other constituents reported in the June 5, 1986, analyses were 1,1-DCA (20 µg/L), dichloromethane (15 µg/L), and TCE at 1 µg/L. The available data indicate that groundwater quality at monitoring well GBR-17 has improved over time since 1986 (Appendix N-1).

Figure 6-9 presents total chlorinated hydrocarbon concentrations at monitoring well locations for groundwater samples collected in first quarter 1990 during the RI. Table 6-22 presents the organic compounds detected in the RI groundwater monitoring program, excluding BLM-37 because of the floating product in this well. Chlorinated hydrocarbons were detected in many monitoring wells located between the former refinery and U.S. 64 and between the former refinery and the unnamed arroyo. The highest concentrations were measured in the area near U.S. 64. Chlorinated hydrocarbon concentrations measured at monitoring wells SHS-1 and BLM-37, located north of U.S. 64, are 23.8 µg/L and 100 µg/L, respectively.

Table 6-20 presents information on the chlorinated hydrocarbon constituents detected in groundwater samples from selected monitoring wells located in Site 2. The available data indicate that concentrations of chlorinated hydrocarbons are present in groundwater in the alluvial aquifer over much of Site 2, including wells with floating product at concentrations as high as those found in subarea 3.

Figure 6-9 presents information on total chlorinated hydrocarbon concentrations measured in groundwater from monitoring wells and from hydrocone samples at locations in Site 2, south of U.S. 64. Current data show that chlorinated hydrocarbon concentrations decrease rapidly south of monitoring wells SHS-1, BLM-37, and SHS-2. For groundwater samples collected in March 1990, chlorinated hydrocarbons were only detected at monitoring wells BLM-65 and hydrocone samples HP-23, HP-24, and HP-40. Total concentrations (the summation of all chlorinated hydrocarbon concentrations for each well) in the four groundwater samples ranged from 9.7 to 68 µg/L, with the highest concentrations (>60 µg/L) measured at the location of hydrocone samples HP-24 and HP-40. The discrete constituents measured in the groundwater samples are listed in Table 6-20. 1,2-*trans*-DCE is a major constituent in the three hydrocone samples. However, the contaminant has not been detected at monitoring well BLM-65. The major constituent at BLM-65 is 1,2-DCA. This contaminant was also detected in the HP-24 and HP-40 samples. The other chlorinated hydrocarbons measured at BLM-65 are 1,1,1-TCA and 1,1-DCA. The concentration of 1,1-DCA detected in May 1991 is 3.4 µg/L. The only other chlorinated hydrocarbon detected in BLM-65 in May 1991 is 1,2-DCA at 3.6 µg/L (Appendix N-1).

An understanding of the nature and extent of contamination of groundwater in the alluvial aquifer for chlorinated hydrocarbons requires an analysis of samples taken over time at monitoring wells. A narrative review is presented below for monitoring wells BLM-27, BLM-30, BLM-65, and BLM-66. The locations of the wells are shown on Plate 1.

Seventeen groundwater sampling events have been conducted from monitoring well BLM-27, with the first sample collected on December 16, 1987. Chlorinated hydrocarbons were present in five sequential groundwater samples collected from December 16, 1987, to April 21, 1988, with total concentrations ranging between 54 µg/L on December 16, 1987, and 13 µg/L on April 21, 1988. No chlorinated hydrocarbons were detected in subsequent samples collected from May 17, 1988, to May 20, 1990 (Appendix N-1). Chloride concentrations measured in the sequence of groundwater samples show a decreasing trend in concentration over time from values around 400 mg/L in samples collected from January to May 1988. Samples collected from June 1980 to May 1990 show a decline in chloride values to 126 mg/L on May 20, 1990. Generally, chloride concentrations greater than 300 mg/L were measured in groundwater samples that contained the chlorinated hydrocarbons. The data indicate an area of contaminated groundwater that contained chlorinated hydrocarbons had migrated through the alluvial aquifer in the vicinity of monitoring well BLM-27. Chlorinated hydrocarbon constituents were detected in groundwater samples from monitoring well BLM-27 are 1,2-DCA at concentrations ranging from 10 to 12 µg/L; 1,1-DCA at concentrations ranging from 6 to 9 µg/L, and dichloromethane at concentrations ranging from 7 to 44 µg/L (Appendix N-1). Chlorinated hydrocarbon constituents could reappear in this well even though they were not detected from May 17, 1988, to May 20, 1990. BLM-27 is located downgradient in the alluvial aquifer groundwater flow system from monitoring wells SHS-1 and BLM-37, according to an interpretation map of the flow system prepared in February 1990 by Geoscience Consultants, Ltd (GCL 1990). A chlorinated hydrocarbon concentration of 486 µg/L and a chloride concentration of 783 mg/L were reported for groundwater samples collected from SHS-1 on December 12, 1989 (Figure 6-9 and Table 6-20). The available information indicates that a plume of high chloride groundwater containing chlorinated hydrocarbon constituents is migrating downgradient toward well BLM-27.

Monitoring well BLM-30 is completed in the upper part of the alluvial aquifer. Seventeen groundwater samples have been collected from this well over the time period from December 16, 1987, to May 20, 1990. The only chlorinated hydrocarbon contaminant detected in this well is dichloromethane measured at concentrations from 0.74 to 16 µg/L in four groundwater samples collected over the time interval from February 6, 1989, to March 4, 1990 (Appendix N). Earlier and later groundwater samples have not detected dichloromethane. Dichloromethane is a common laboratory contaminant, and the values detected in the four groundwater samples may be due to laboratory contamination. Of interest, with regard to the groundwater samples collected from monitoring well BLM-30, is that chloride concentrations show a regular increase over time from 117 mg/L on December 16, 1987, to 281 mg/L on May 20, 1990. The increase in chloride concentrations may indicate that a plume of different groundwater quality is migrating through the shallow alluvial aquifer in the vicinity of the well.

Monitoring wells BLM-65 and BLM-66 are located in the channel of the unnamed arroyo at distances of approximately 1,750 ft and 2,800 ft south of U.S. 64, respectively. The locations of the wells are shown on Plate 1. The two wells were installed to investigate the alluvium in the arroyo channel as a preferred migration pathway for contaminated groundwater from upgradient sources. Both wells have screened intervals through a major part of the saturated alluvium. The wells were installed in March 1990, and groundwater quality information is limited to five sampling periods from March to August 1990, and May 1991. With regard to contaminants of concern for the Site 2 area of contamination, no BTEX constituents or pesticides have been detected in either BLM-65 or BLM-66 (Appendix N-1).

The analysis of three groundwater samples taken from BLM-66 had a single positive chlorinated hydrocarbon result. Trichloromethane was detected at 1.1 µg/L (Appendix N-1), but this result may be a product of residual contamination from water used during well drilling and installation. However, there is evidence that the groundwater quality is changing in the vicinity of monitoring well BLM-66, because chloride concentration levels rise from 17.9 mg/L on March 20, 1990, to 59.3 mg/L on May 18, 1990.

In summary, chlorinated hydrocarbon constituents are present in groundwater samples collected from many GBR monitoring wells in Site 2. The highest concentrations were measured in monitoring wells located southwest of the refinery, north of U.S. 64. High concentrations have been present since monitoring wells were installed and sampled in 1986. The variation in concentration of major dissolved ions (chloride, sulfate, TDS, and chlorinated hydrocarbon constituents) occurring in groundwater samples collected over time at discrete wells indicates that there may be multiple areas of contaminated groundwater in the shallow alluvial groundwater system in Site 2.

6.5.1.3. Inorganic COCs in the Alluvial Aquifer

Chloride, nitrate, sulfate, and sulfide are the inorganic COCs in Site 2, south of U.S. 64. Since contamination of BLM-37 with petroleum product is well documented, it is not included in the following general discussion of contaminants in Site 2. The main inorganic contaminants in BLM-37 are aluminum, iron, lead, and nitrate. A summary of inorganic and metal concentrations for all Site 2 alluvial wells excluding BLM-37 is given in Table 6-21. The table also indicates if inorganics or metals are identified as COCs.

High chloride concentrations may indicate the presence of chlorinated hydrocarbons. The highest value measured in Site 2 was in BLM-28 (604 mg/L); but concentrations have decreased over time to background range (Table 6-21). Concentrations have also decreased in BLM-24 and BLM-27. Chloride concentrations are increasing in BLM-30 and BLM-31 and are in the 150 mg/L range in BLM-65 located approximately halfway between U.S. 64 and the San Juan River. High chloride concentrations are not evident in BLM-66. Chloride concentrations in BLM-66 range from 17.9 to 67.6 µg/L.

High nitrate values have been detected in wells BLM-27, BLM-30, and BLM-31. Concentrations in BLM-30 are consistently above 6 mg/L, although only one measurement exceeded the SDWA MCL of 10 mg/L. Sulfate is also of concern since it is consistently high in BLM-28. Sulfide concentrations greater than 600 mg/L have been detected twice in BLM-25. This well is located on the west side of the arroyo. The source of sulfide in the well may be different than the source of inorganic contamination in the other Site 2 wells to the east.

Metals contamination in Site 2 is generally found in the shallow alluvial wells BLM-27 and BLM-30. Aluminum, arsenic, barium, and iron were all detected above standard in the above two wells during 1989. Although it appears concentrations of the above metals may have decreased over time, there are insufficient samples to confirm the decrease.

Beryllium has been measured in BLM-24, BLM-27, and BLM-30. Chromium has been measured above the 50 µg/L standard in all the alluvial aquifer wells in Site 2 excluding BLM-65 and BLM-66. High levels have been detected more than once in both BLM-27 and BLM-30. Concentrations that exceed the standard for lead and cobalt are also found in the above two wells (Table 4-55). Selenium has been detected above the standard in the BLM-30 well cluster, but not in the BLM-27 well cluster that is further west.

6.5.2. Contamination in the Site 2 Bedrock Aquifer

The discussion of groundwater quality in the bedrock aquifer in Site 2 includes three BLM monitoring wells located south of U.S. 64. The three BLM wells (BLM-26, BLM-29, and BLM-32) are shown on Figures 6-7 and 6-9. Contamination of the bedrock aquifer in Site 2, from north of U.S. 64 to GBR-17, is not discussed because there is no available information to identify GBR monitoring wells that produce groundwater only from bedrock.

6.5.2.1. Inorganic COCs

Table 6-22 presents concentration ranges for inorganics and metals in the three bedrock wells in Site 2 The table also indicates if inorganics or metals are identified as COCs.

Sulfate was measured once in BLM-26, above the study area background level, at 4,460 mg/L. The sulfate concentration in this well has decreased over time. Sulfide was also detected in BLM-26. This is the same well cluster that has high concentrations of sulfide in the alluvial aquifer wells. The maximum concentration in the bedrock well was 110 mg/L.

Beryllium was measured once in BLM-29 but was not detected in the later sampling event or in any other wells. Chromium was detected above the 50 µg/L standard in all three wells in February of 1989, but was not confirmed during the May 1989 sampling period.

6.5.2.2. Organic COCs

Toluene is the only BTEX constituent that has been detected in monitoring wells BLM-26, BLM-29, and BLM-32. Measured concentrations occur as isolated events and do not reoccur over sequential sampling. Therefore, the presence of toluene in groundwater samples is considered to be the result of laboratory contamination rather than contamination of groundwater in the bedrock.

The only other BTEX constituent that has been detected in the three bedrock monitoring wells is a measured value of 0.74 µg/L for total xylenes in a groundwater sample collected from well BLM-32 on March 4, 1990 (Figure 6-7). Total xylenes were not detected in subsequent samples collected on April 25, 1990, and May 19, 1990.

As presented in Table 6-24, acetone and dichloromethane are the only other organic compounds detected in water samples collected from monitoring wells BLM-26, BLM-29, and BLM-32. The occurrence of these contaminants is not consistent between sampling events. The measured concentrations are believed to represent laboratory contamination rather than contamination present in the bedrock aquifer.

In summary, the results of analyses for BTEX in three bedrock monitoring wells located south of U.S. 64 indicate that the bedrock aquifer is not contaminated with BTEX constituents (Table 6-24). The results of analyses for groundwater samples collected from three bedrock monitoring wells located in Site 2 indicate that the bedrock is not contaminated with any of the chlorinated hydrocarbons identified in OU 2 monitoring wells.

6.5.3. Potential Site 2 Contaminant Sources

Previously identified potential sources of groundwater contaminants for the Site 2 area of contamination from the Giant-Bloomfield Refinery property are identified and briefly discussed in this section. Areas of contaminated soil on the Giant-Bloomfield Refinery property are discussed below.

- The Wastewater Retention Pond: The wastewater retention pond was used to accept all oily wastewaters from production operations between 1973 and 1978. When use of the wastewater retention pond was discontinued, sludges were left in place and covered (GCL 1987).
- The Evaporation Pond: The evaporation pond was used to retain oil/water separator effluent between 1978 and 1982 (GCL 1987).

- The Fire Fighting Drill Area: The fire fighting drill area was presumably in operation from the start of refinery operations until 1979, when the residues that remained from crude oil and gasoline training fires were left in place and covered (GCL 1987).
- The Storage Tank Water Drain Areas: The storage tank water drain areas were used to dispose of water/paraffin wastes that were drained from Tanks 1 and 2 between 1975 and 1982. This area was left intact and covered over (GCL 1987).
- The Storage Tank Bottom Containment Areas: The storage tank bottom containment areas were areas where unrecoverable tank bottom sludges were buried (GCL 1987).
- The Underground Catch Tank in the Truck Loading Area: The underground catch tank in the truck loading area was in operation between 1973 and 1975 to contain occasional spills from the truck loading dock (GCL 1987).
- The Storm Water Containment Areas: The storm water containment areas were natural, closed depressions that received storm water runoff from the refinery until they were filled in 1980 (GCL 1987).
- The Amoco Produced Water Pit: The Amoco produced water pit was used to accept produced waters from a natural gas well from 1973 until 1985. Amoco was operating a natural gas well at the northern end of the refinery property when Giant first purchased the refinery site. Prior to 1985, all produced waters were discharged to unlined pits. Undetermined amounts of produced waters were discharged to these pits. These pits were replaced sometime in 1985 with fiberglass tanks (GCL 1987).
- The Oil/Water Separator Area: The oil/water separator is a concrete vessel that contained sludge from past refinery operations (GCL 1987).

The wastewater retention pond, storage tank water drain areas, and the Amoco produced water pit were unlined pits, and the evaporation pond was lined with a synthetic material (GCL 1987). It is unclear whether any of the remaining storage/containment areas used synthetic or natural clay liners.

Soil and groundwater sampling data identify petroleum hydrocarbons, chlorinated hydrocarbons, polynuclear aromatic hydrocarbons inorganic constituents, and metals in some or all of these areas, and significant quantities of free-floating petroleum product were found in several groundwater monitoring wells (GCL 1987). Free-floating petroleum product is currently being recovered by pumping the petroleum product and some groundwater to aboveground storage tanks and then treating and discharging clean groundwater to a ground application system (GCL 1990).

In November 1986, a leak in a diesel fuel delivery system at the Giant-Bloomfield Refinery was discovered. Approximately 15,000 gallons of diesel were lost before this leak was repaired (GCL 1987). In addition, the Giant-Bloomfield Refinery laundry facilities discharged to a septic tank to the east of the fire fighting drill area (GCL 1987). Leachate from this septic tank may have flowed through the fire fighting drill area toward the southwest and existed as a seep (GCL 1987). Some water from the seep may have originated from a leaking underground fire line that ran north-south along the eastern edge of the fire fighting drill area.

Casing leaks associated with oil and gas wells are also possible sources (GCL 1987). Because oil and gas are generally produced under considerable pressure, a small leak can result in significant escape of hydrocarbons. Improperly sealed exploratory boreholes or abandoned wells could also be conduits for the introduction of hydrocarbons to the soil and groundwater. Remedial actions undertaken at some of the known areas of contamination at the former Giant-Bloomfield Refinery are focused in four main areas, including the diesel fuel spill area, the truck fueling area, the southern refinery, and the fire-fighting drill area.

Some of the disposal actions undertaken at the former Giant-Bloomfield Refinery may be considered to be potential Site 2 contaminant sources. Approximately 4,500 cubic yards of soil were removed from the storage tank waste drain areas, the storage tank bottom containment areas, and the underground catch tank in the truck loading area, and placed in two bermed areas on the northern edge of the eastern tank battery for onsite bioremediation (GCL 1987). It is unclear whether these bermed areas are lined with synthetic or natural clay material. It was proposed that soils in the remaining contaminated areas be left in place to degrade naturally over time. In the southern refinery area, groundwater recovery was proposed, along with controlled wetting of soils to aid contaminant flushing and subsequent capture by the recovery systems (GCL 1987).

As part of the groundwater remediation project, six large tanks were used to temporarily store produced water from the recovery wells before it was treated (if necessary) and discharged. These tanks include:

- Tank 23: 210,000 gallon capacity,
- Tank 24: 840,000 gallon capacity,
- Tank 27: 210,000 gallon capacity,
- Tank 32: 210,000 gallon capacity,
- Tank 37: 420,000 gallon capacity (GCL 1987), and
- Tank 34: 210,000 gallon capacity (GCL 1988).

Each tank was sampled and chemically analyzed after it was filled in order to determine the appropriate level of treatment of the produced water. Various concentrations of BTEX, polynuclear aromatic hydrocarbons, chlorinated hydrocarbons, inorganic constituents, and metals were detected in the process of sampling these tanks. The concentrations of contaminants varied over time from undetected levels to significantly elevated concentrations. The concentrations of some of these contaminants may have been influenced by the different analytical methods employed throughout the course of sampling. Positive chemical analytical results for chlorinated hydrocarbons from these and several other tanks from the Giant-Bloomfield Refinery are provided in Table 6-25. The proposed treatment for some of the contaminated groundwater was to sprinkle it onto the excavated soils at the northern edge of the eastern tank battery, where aeration and microbiological degradation could occur within a controlled bermed area (GCL 1987).

Several areas on the Giant-Bloomfield Refinery site are potential Site 2 contaminant sources. These include several retention and storage ponds or pits, a diesel fuel spill area, the truck refueling area, the storage tanks for the groundwater remediation system, excavated soils placed in the bermed area on the northern edge of the eastern tank battery, oil and gas production wells and their associated plumbing, the seep area associated with the fire-fighting training area, and the laundry septic tank.

6.6. GROUNDWATER CHEMICAL FINGERPRINTING

A number of analyses were performed on groundwater samples to identify and differentiate between alluvial groundwater in the northern and southern areas of OU 2. This comparison is referred to as chemical fingerprinting. Samples collected from all BLM monitoring wells, Giant-Bloomfield Refinery wells GBR-32, GBR-48, GBR-49, and GBR-50, and from the San Juan River during March 1990 were analyzed for stable sulfur isotopes. The thermodynamics of some samples were evaluated, and stable strontium isotopes were analyzed in six groundwater samples as well as two San Juan River water samples. In addition, the chemical characteristics of groundwater samples were plotted on trilinear diagrams for both the alluvial and bedrock aquifers, for samples where the charge balance (cation-anion) error was less than 10 percent. The following subsections discuss the results of these analyses and their effectiveness in differentiating between different water types within the Lee Acres Landfill Study Area.

Manganese has been identified as a COC for both the northern and southern areas of OU 2. The concentration gradients in OU 2 identify the former Lee Acres Landfill and the former liquid waste lagoons as the potential sources of the elevated concentrations of manganese. Subsection 6.6.5 presents the distribution of soluble manganese in the alluvial groundwater system in the former Lee Acres Landfill Study Area.

6.6.1. Stable Sulfur Isotopes

All groundwater samples collected during March 1990 were analyzed for stable sulfur isotopes. Sulfur isotope ratios for the alluvial and bedrock groundwater were used to determine if the former liquid waste lagoons at the landfill may have affected the isotopic signature of ambient groundwater. The isotopic characteristics of groundwater in the study area were not known prior to the RI sampling events. Sulfur has four stable isotopes whose approximate abundances are as follows: S^{32} = 95.02 percent, S^{33} = 0.75 percent, S^{34} = 4.2 percent, and S^{36} = 0.02 percent (Faure 1977). Ratios of the most abundant isotopes,

S^{32} and S^{34}, are used in the analysis. The S^{32}/S^{34} ratios, called delta S^{34}, were calculated for each sample. Values are expressed in parts-per-thousand (per mil) variances from the Troilite standard.

S^{32}/S^{34} ratios can be significantly altered by several methods. The biogenic fractionation of sulfate by sulfur-reducing bacteria in gas or oil brines is of interest since brines were disposed of in the Lee Acres Landfill lagoons. Light sulfur (S^{32}) is preferentially reduced because the sulfur^{32}-oxygen (S^{32}-O) bonds in sulfate are weaker than the S^{34}-O bonds. Sulfate is reduced to hydrogen sulfide gas that generally rises toward the surface until it encounters oxidizing conditions, whereupon it is oxidized to sulfate. The signature of the sulfate remaining in the brines tends to become more positive, i.e., contains a greater proportion of S^{34} than it did originally. Measured delta S^{34} values in petroleum (and associated brines) vary between -8 and +32 (Faure 1977). However, within the same sedimentary basin, the delta S^{34} values are similar. Groundwater in oxidizing environments, unaltered by man's actions, will contain sulfur isotope signatures that depend on the source of sulfate in the aquifer sediments. Additional information of sulfur isotope fractionation may be found in a number of sources (Faure 1977; Friedman and O'Neil 1977; and Kaplan and Rittenburg 1964).

The distribution of delta S^{34} values from the March 1990 sampling event is shown in Figure 6-10. These data are summarized by aquifer and area in Table 6-26. The following observations result from the sulfur isotopic data analysis:

- The bedrock groundwater delta S^{34} signature is distinctly positive.
- One well that may represent background alluvial water quality (well BLM-39) has a value of +0.3. One well, BLM-17, is geographically separated from other areas of known contamination and also has delta S^{34} signatures of +0.3 (Figure 6-10). This may be the expected background signature of unaltered alluvial water. Groundwater samples collected in, adjacent to, and southwest of the former southern liquid waste lagoon have very negative delta S^{34} signatures. Values in the alluvial aquifer near the former southern liquid waste lagoon range from -9.2 in BLM-45 (southwest of the lagoon) to -3.2 in BLM-21 (directly south of the former lagoon). Alluvial groundwater samples collected in the southern portion of OU 2 (directly south of the landfill) generally have positive delta S^{34} signatures. The average value in the southern area of OU 2 is +0.88. These observations indicate that
    - the alluvial groundwater flowpath from the southern former liquid waste lagoon defined by negative delta S^{34} signatures is narrow (low transverse dispersivity) and to the south-southwest;
    - a different source of recharge has affected the alluvial groundwater directly south of the landfill than at the former southern liquid waste lagoon; and
    - the positive delta S^{34} signature expected in the former liquid waste lagoons, caused by the dumping of produced water and brines, does not occur.

- Delta S^{34} signatures from samples collected in the northern part of subarea 1 (wells BLM-14 and BLM-16) are significantly different than the signatures in the rest of the samples and appear to be spurious or are possibly affected by an upgradient source of contamination.

The sulfur isotope analysis indicates that the background alluvial aquifer signature is slightly positive at 0.3. The signature of water derived from the former southern liquid waste lagoon is distinctly negative and this water has recharged a small area at the southwestern corner of the former landfill. The southern area of OU 2 has positive delta S^{34} signatures that are generally higher than background. It appears that there is a separate source of recharge to the alluvial aquifer in this area that is not from either background or the former southern liquid waste lagoon.

Although the delta S^{34} data may indicate possible flow paths in the vicinity of the former Lee Acres Landfill, the validity of these flow paths should be verified using other hydrologic and geochemical analyses.

6.6.2. Thermodynamic Modeling

In an evaluation by McQuillan and Longmire (1986), the lagoon water at the former Lee Acres Landfill and the alluvial groundwater in the vicinity of the landfill were characterized as high in sodium, high in chloride, and relatively low in sulfate concentrations. In contrast, the groundwater samples collected from well BLM-37, located south of U.S. 64, are higher in sulfate and lower in chloride and sodium than groundwater in the vicinity of the landfill. The evaluation included a hypothesis that the chemical characteristics of a contaminated groundwater plume (high sodium and high chloride), released from the lagoons, enhanced gypsum solubility. Therefore, the chemical composition of the groundwater in the alluvial aquifer changed as the contamination moved downgradient forming sulfate-rich groundwater by the time the contamination reached the residential area located south of U.S. 64 and well BLM-37 (McQuillan and Longmire 1986).

To test this hypothesis, the computer program WATEQF was used to calculate mineral saturations in samples from various wells in the study area. If the observed downgradient increase in sulfate concentration in the alluvial groundwater was due to dissolution of gypsum or anhydrite, then the saturation of the samples should increase significantly from upgradient wells to downgradient wells.

Table 6-27 presents a summary of the WATEQF results. The wells are listed from northern locations to southern locations (upgradient to downgradient). The lagoon samples were collected in 1985 from the lagoon waters rather than from groundwater. The redox potential was not measured. For each sample, the redox potential was calculated with an assumed dissolved oxygen value of 5 mg/L. The sample from well BLM-20 was used to test the sensitivity of the results to this assumption. The redox potential was also calculated with two other assumptions:

- using an assumed dissolved oxygen value of 8 mg/L, and
- using the ratio of sulfate to sulfide.

Table 6-27 shows that the change to the results using the three different assumptions for calculating the redox potential is negligible.

The cation/anion ratios are listed to indicate the reliability of the analytical results. Generally, ratios between 0.90 and 1.10 are considered acceptable. Based on this criterion, the sample results for wells BLM-20, GBR-32, and BLM-30 would be considered acceptable; the reliability of the results for the other samples should be considered questionable.

The indicator used to evaluate the mineral saturation is the log(IAP/KT), where IAP is the ion activity product and KT is the solubility constant. If log(IAP/KT) is less than zero, then the solution is undersaturated in respect to the given species. If log(IAP/KT) is zero, then the solution is saturated in respect to the species. If log(IAP/KT) is greater than zero, then the solution is supersaturated in respect to the species.

The thermodynamic analyses indicate that gypsum and anhydrite were slightly undersaturated in wells upgradient of the landfill, adjacent to the landfill, and between the landfill and U.S. 64. Log(IAP/KT) for gypsum was approximately -0.2, and the value was relatively consistent for all wells north of U.S. 64. Log(IAP/KT) for anhydrite was approximately -0.5, and the value was also relatively consistent for the wells north of U.S. 64. It appears that the chemical nature of the hypothetical contamination did not transform through the dissolution of gypsum as it migrated down the saturated alluvium of the arroyo. Rather, it appears that the chemical composition and distribution of major constituents in the hypothetical contamination remained relatively consistent.

In well BLM-30, south of U.S. 64, gypsum is slightly oversaturated, with a log(IAP/KT) value of +0.054. However, this value, along with all other values calculated for the wells in the study area is quite close to equilibrium. It is also evident, as discussed in subsection 6.2, that there is no clear gradient for sulfate concentrations in the alluvial groundwater aquifer. In addition, sulfate may be dissolved from abundant natural sources in the sediments and bedrock and is therefore variable in concentration throughout the study area. Therefore, the available data and the thermodynamic evaluation do not indicate that contaminated groundwater was released from the lagoons, enhancing gypsum solubility.

6.6.3. Stable Strontium Isotopes

Because strontium was detected in most water samples and is often associated with production waters and oil field brines, $Sr^{87/86}$ ratios were calculated for six selected groundwater samples and two San Juan

River samples. Stable Sr^{87} increases through decay of unstable rubidium-87. Water that has been in contact with ancient rocks high in rubidium should have an isotopically heavy signature. The results of the strontium isotope analyses are presented in Table 6-28.

In general, the $Sr^{87/86}$ ratios are lower in the alluvial groundwaters of the study area than in the San Juan River. Values tend to become lower downgradient. Because all values are negative, the data indicate, although not conclusively, that the alluvial water is relatively young and, therefore, probably not associated with brine waters.

6.6.4. Piper Trilinear Diagrams

Figure 6-11 shows the chemical composition of bedrock waters plotted on a trilinear (Piper) diagram. The samples were collected in March 1990. The GBR wells to the north of U.S. 64 are not plotted because their formations of completion are unclear, and they likely represent composites of bedrock and alluvial aquifer waters. In addition, samples in which charge balance errors exceeded 10 percent are omitted from the plot. Table 6-29 lists the wells used in this analysis. The plot shows that groundwater quality in the bedrock aquifer in the study area is remarkably consistent in chemical composition.

Figure 6-12 shows a trilinear diagram for the alluvial wells for samples collected in March 1990, where the charge balance error was less than 10 percent. Table 6-30 lists the wells used in this analysis. Although there is a greater variation than for the bedrock aquifer, there are no obvious trends, and most waters plot close together in chemical composition. Notable exceptions are wells BLM-37, and GBR-48, both of which are contaminated. Well GBR-48 is lower in sulfate and higher in chloride than the other alluvial wells. Of the contaminated wells in the northern plume, only GBR-48 had a charge balance error of less than 10 percent. Well BLM-37 also plots outside the main cluster of alluvial wells on the chloride-sulfate plot. However, the sample from this well is higher in sulfate and lower in chloride than the sample from GBR-48.

Figure 6-13 shows a trilinear diagram for the alluvial well samples collected in May 1991, where the charge balance error was less than 10 percent. Table 6-31 lists the wells that were used in this analysis. The results are very similar to those shown in Figure 6-12. The main clusters for the March 1990 water quality data and the main clusters for the May 1991 water quality data are nearly identical.

The trilinear diagrams do not illustrate spatial trends in groundwater quality in the study area, nor do they define two or more distinct water types. In no area do the alluvial and the bedrock groundwaters have a distinctive chemical "fingerprint". Significant mixing of two or more distinctive groundwater types is not apparent. However, the contaminated wells in the alluvial aquifer (GBR-48 and BLM-37) do represent a different water type than the uncontaminated samples, and the samples from these two wells are chemically distinct.

6.6.5. Soluble Manganese in the Alluvial Groundwater System

Manganese has been identified as a COC in the study area as discussed in subsections 6.3 and 6.4. The chemical properties of manganese affect its mobility in the natural environment. In most cases, manganese will exist as a free metal ion (Mn^{+2}) in groundwater. Like iron, it forms a solid when oxidized. The pH of groundwater in the Lee Acres Landfill Study Area is neutral or slightly variable (6 to 8), indicating slightly reducing conditions; therefore, manganese does not precipitate out as an oxide or hydroxide.

Manganese is more stable as a free metal ion than other transition metals, and may travel at a similar flow rate as groundwater. It will not be absorbed onto aquifer materials when other transition metals are present. Manganese will disperse in groundwater, like chloride and calcium, rather than absorb, sink, or float, depending on the longitudinal transpersivity of the aquifer.

Manganese analytical results have been reported as total and soluble concentrations, depending on whether samples were filtered or unfiltered. The available data indicate there is no difference between the total and soluble manganese analyses because manganese is less stable than the other transition metals when complexed with other ions or compounds; therefore, it will not be attached to the complexes that are filtered out during sample collection. The analytical results discussed below are concentrations of soluble manganese, which is the most complete data set.

6.6.5.1. Subarea 1 (Background)

Soluble manganese concentrations in subarea 1 ranged from nondetect (wells BLM-14 and BLM-15) to 423 µg/L (well BLM-39; Figure 6-14). The average value of 334 µg/L in BLM-39 is considered to be the background concentration for the study area although it is almost twice the standard (200 µg/L) established by the State of New Mexico (subsection 1.7).

6.6.5.2. Site 1, Northern Area of OU 2 Groundwater

The northern area of OU 2 (subarea 2) contains the highest concentrations of soluble manganese in the study area with a concentration greater than 8,600 µg/L detected in BLM-57 and an average concentration of 7,905 µg/L (Figure 6-14). In contrast, the alluvial wells immediately west of BLM-57 have average concentrations of nondetect to less than 50 µg/L in wells BLM-52 and BLM-51, respectively. The high concentrations found at BLM-57 may be due to its location in the former northern liquid waste lagoon.

Southwest of BLM-57, wells BLM-56 and BLM-58 have lower concentrations of manganese with an average of 1,000 to 2,000 µg/L (Figure 6-14). Like BLM-57, well BLM-55 (immediately downgradient of the former southern liquid waste lagoon) has high manganese concentrations with an average of greater than 4,100 µg/L.

Wells outside the western fenceline of the former Lee Acres Landfill show a dramatic increase in manganese concentrations from north to south with less than 50 µg/L at BLM-51, increasing to approximately 1,100 µg/L at BLM-48 and to more than 5,300 µg/L in BLM-43 (Figure 6-14). The line of wells trending east-west at the southern boundary of the landfill fenceline shows an equally dramatic increase from west to east. Concentrations range from less than 30 µg/L at wells BLM-17 and BLM-18, increasing to approximately 100 µg/L at wells BLM-20 and BLM-21 and to greater than 4,400 µg/L at well BLM-60.

Ten of the 14 wells with detectable concentrations of manganese in subarea 2 show general trends of decreasing concentrations over time. There is no apparent trend in concentration between shallow and deep alluvial wells within any well cluster.

6.6.5.3. Site 1, Southern Area of OU 2 Groundwater

Based on manganese concentrations, the Site 1, southern area of OU 2 (subarea 3) can be divided into two sections, either north or south of an east-west line north of the well cluster BLM-75 and BLM-79 (Figure 6-14). North of this line, manganese concentrations have a maximum average concentration of greater than 2,800 µg/L at BLM-72, and generally have a concentration greater than 1,000 µg/L with the exceptions of BLM-73 (872 µg/L) and BLM-62 (721 µg/L). For a majority of the wells south of this line, average concentrations are less than 1,000 µg/L and generally decrease toward the south. Manganese concentrations are very low at the southernmost well in subarea 3 (BLM-68), ranging from nondetect to 21.4 µg/L.

In contrast with the northern area of OU 2, there is no apparent difference in east-west distribution of manganese; the manganese concentrations in the western part of the arroyo may be greater or less than concentrations in the eastern part of the arroyo. Furthermore, although less data are generally available, there is no apparent trend in the concentrations over time.

6.6.5.4. Site 2 Groundwater

The east-west line of BLM wells south of U.S. 64 have manganese concentrations less than 500 µg/L except BLM-37 (the well with petroleum product) that has a concentration of 2,980 µg/L (Figure 6-14)

Further downgradient, the concentrations increase in wells BLM-65 and BLM-66 and range from approximately 2,000 to 3,000 µg/L. There is no apparent trend in concentrations over time. The manganese in BLM-65 and BLM-66 is potentially from a separate source, immediately north of BLM-65, at the San Juan County Fairgrounds.

6.6.5.5. Summary of the Distribution of Soluble Manganese

The wells upgradient of the landfill had soluble manganese concentrations ranging from nondetect to 423 µg/L. Nearest the landfill source, the highest concentrations are found along the east side of the arroyo with apparent source areas within the landfill at or near wells BLM-57 and BLM-55. Oil field brines and production waters that were disposed of in the former liquid waste lagoons, may be a source of the manganese (NMEID 1981d and Boyer 1986). For example, the Dakota Sandstone is a common oil-bearing stratigraphic unit in the San Juan Basin. Produced water from the Dakota Sandstone can have manganese concentrations up to 2,800 µg/L (Boyer 1986). Manganese data are not available for all oil and gas stratigraphic horizons in the San Juan Basin, and it is not known from which stratigraphic unit or units the produced water that was disposed of in the former liquid waste lagoons originated. However, produced waters possibly contain manganese concentrations that exceed the New Mexico HHS of 200 µg/L.

Samples of the liquid waste in the lagoons were collected by NMOCD and NMEID in 1985 (subsection 5.2.2.1) and were analyzed for metals as well as VOCs. The analytical results presented in Section 5, Table 5-8 of this report, indicate total manganese was detected in concentrations ranging from 0.68 to 2.1 mg/L (680 to 2,100 µg/L).

Whatever the original source, the soils in this area may also contain a source of manganese. Borehole descriptions from locations within the landfill or in the adjacent arroyo indicate the presence of a black "sooty" mineral in blebs or as grain coatings just above or within the water table. This black substance is often described as carbonaceous material (see borehole logs for BLM-57, BH-22, BH-37, and BH-50; Appendixes H and L) but may in fact be a manganese-bearing mineral, either an oxide (pyrolusite--MnO_2) or one of two hydroxides (manganite--MnO(OH), or psilomelane (Ba, Mn) = $(O,OH)_6Mn_8O_{16}$). Any of these three minerals fit the vague descriptions found in the borehole logs; without definitive mineralogical identification techniques (through x-ray diffraction), it is not possible to identify the black substance. Soil samples collected in the landfill were analyzed for EP Toxicity metals, which does not include an analysis for manganese. The potential presence of these manganese minerals indicates a local oxidizing environment. Recent regional studies of soil geochemistry by the USGS indicate the soils in the northwestern corner of New Mexico may have manganese concentrations ranging from 2 to 700 ppm (USGS 1984). If there is a slight change in redox or pH conditions, thereby causing reducing conditions, the manganese in these minerals may become soluble and move into the groundwater.

Further downgradient (just south of the landfill fence in subarea 3), there appears to be mixing of manganese-rich waters emanating from the former landfill and "fresh" water from the western edge of the alluvial aquifer, with lower manganese concentrations in the western and eastern parts of the alluvial aquifer. Mixing continues downgradient until concentrations progressively decrease to below background levels at BLM-68. At locations south of U.S. 64, manganese concentrations are near background levels immediately south of the highway, except for BLM-37. The high concentrations at BLM-37 suggest another local source related to, or affected by, the product plume emanating from the former Giant-Bloomfield Refinery. Furthest downgradient, wells BLM-65 and BLM-66 show increasing concentrations toward the river, which suggests another local source north of BLM-65.

6.7. SUMMARY OF THE GROUNDWATER CHARACTERIZATION

The previous sections established an understanding of the nature and extent of the groundwater contamination in the Lee Acres Landfill Study Area. Table 6-32 summarizes background contaminants and COCs identified in the alluvial and bedrock aquifers within the study area. Groundwater analytical results from background (upgradient) wells established that no chlorinated hydrocarbon contamination is present upgradient of the former Lee Acres Landfill, although dichloromethane is present in both the alluvial and bedrock background monitoring wells (Table 6-32). Chromium contamination is also present in the alluvial and bedrock aquifers upgradient of the landfill. The source of the chromium cannot be identified based on the available RI data. However, it is most likely derived from a source upgradient of the monitoring well cluster of wells BLM-14, BLM-15, and BLM-16.

The effect of the former Lee Acres Landfill on the groundwater quality within the study area was examined through the identification of the groundwater chemistry adjacent to and beneath the former landfill (northern area of OU 2), and the groundwater chemistry in downgradient areas (southern area of OU 2 and Site 2 contamination). Volatile and semivolatile organic compounds, pesticides, PCBs, metals, and inorganic compounds were part of the RI analytical program. Pesticides and PCBs are not identified as COCs for any groundwater within the Lee Acres Landfill Study Area.

The organic groundwater contamination identified beneath the former landfill in the alluvial aquifer (northern area of OU 2) is confined to three wells: BLM-55, BLM-56, and BLM-57 (Figure 6-1). Eight organic COCs and two metals were identified in the northern area of OU 2 alluvial aquifer; however, the major COCs within the three landfill wells are the chlorinated hydrocarbons 1,1-DCA; 1,2-DCE; PCE; TCE; and vinyl chloride (Table 6-32). Concentrations of these constituents are low concentrations (<10 μg/L) and, with the exception of vinyl chloride, do not exceed regulatory standards. Vinyl chloride was detected three out of seven times; in the four most recent samples, vinyl chloride was not detected. Additional contamination identified in the northern area of OU 2 consists of single detections of COCs, with nondetections in subsequent sampling events, and is located in monitoring wells along the western landfill edge. Dichloromethane contamination is prevalent throughout the northern area of OU 2. However, the majority of the organic contamination in the groundwater beneath the landfill in the alluvial aquifer is confined to the three wells located within and between the former liquid waste lagoons.

Manganese has been identified as a COC for the OU 2 alluvial aquifer. The distribution of chromium concentrations that exceed the SDWA MCL of 50 µg/L is confined to three wells: BLM-17, BLM-20, and BLM-52. Chromium is not identified as a COC for OU 2 because the background alluvial wells also have elevated concentrations of chromium. The distribution of the manganese concentrations is mainly confined to monitoring wells within the former landfill and along its western edge. Highest manganese concentrations (>8,000 µg/L) are found in the monitoring well located in the former northern liquid waste lagoon. Concentrations in monitoring wells along the western edge range from 1,090 to 2,490 µg/L and exceed the New Mexico HHS of 200 µg/L.

Groundwater contamination in the bedrock aquifer beneath the former Lee Acres Landfill is limited to dichloromethane, *bis*(2-ethylhexyl) phthalate and chromium (Table 6-32). Dichloromethane and *bis*(2-ethylhexyl) phthalate, are common laboratory contaminants; however, they could not be eliminated as COCs based on the frequency-of-detection criterion. The majority of the detections occurred in early PI and RI sampling events. These two compounds are retained for the toxicity screening performed in the baseline risk assessment (Section 10). The chromium concentrations in the bedrock aquifer beneath the landfill range from 57.7 to 68.5 µg/L and the distribution is confined to the southwest part of the landfill. Because chromium is also identified in the background bedrock wells, chromium detected in the OU 2 bedrock aquifer is not identified as a contaminant of concern.

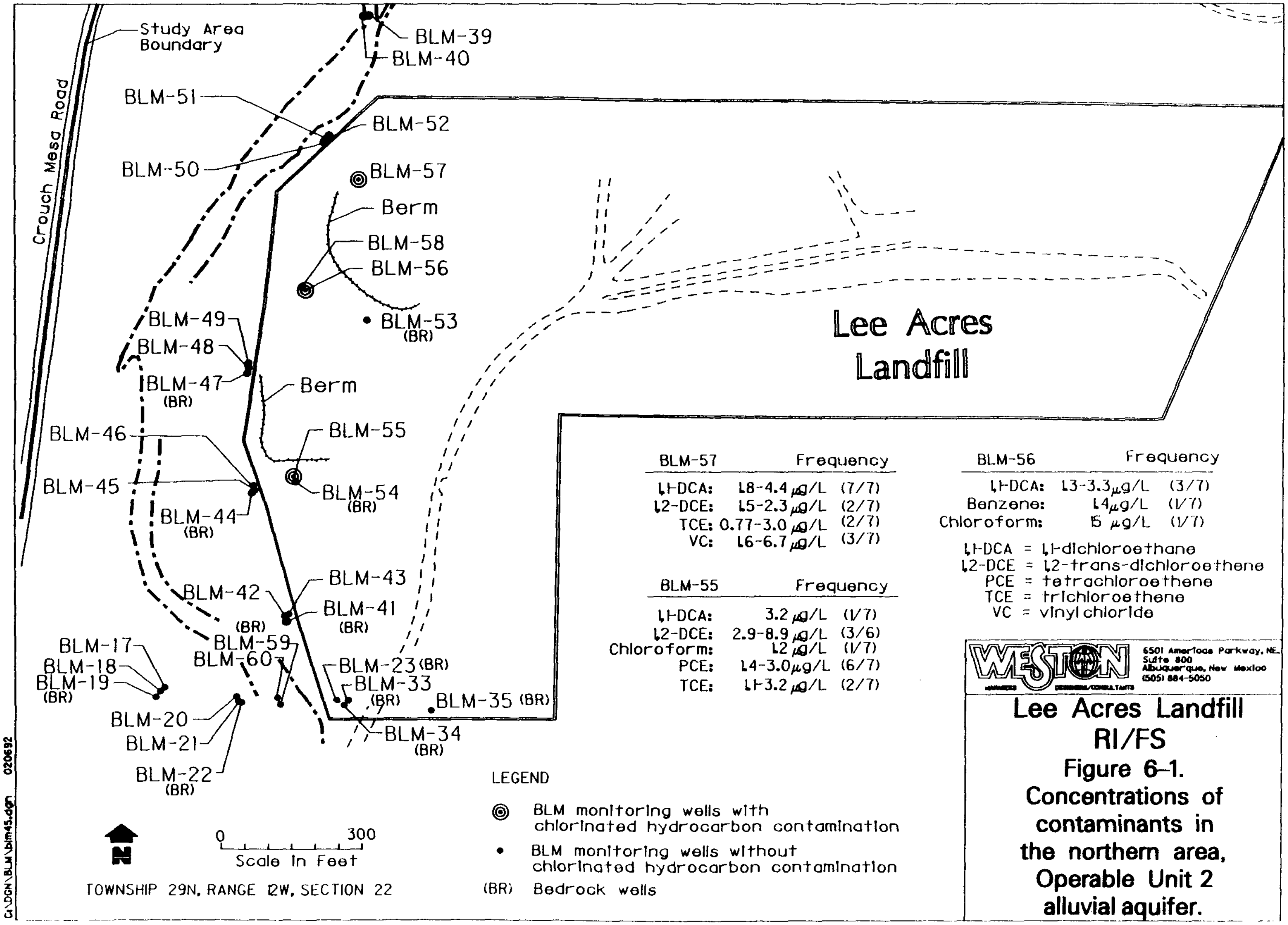
The distribution of major groundwater constituents (TDS, chloride, sodium, and sulfate) in the alluvial aquifer system identifies two separate areas of contamination in the alluvial aquifer within the Lee Acres Landfill Study Area. These areas of contamination are located in subareas 3 and 4 and are referred to as the Site 1 southern area of OU 2, and Site 2.

The southern area of OU 2 is defined by wells to the north of well GBR-17, and Site 2 is defined by wells south of and including well GBR-17, south to the San Juan River. The distributions of major groundwater constituents do not indicate whether the two areas of contamination are connected or overlap. The fact that chloride values are distributed with depth in Site 2 may indicate that the two areas of contamination are not connected.

Contamination in the alluvial aquifer in the southern area of OU 2 consists of chlorinated hydrocarbons and manganese (Table 6-32) and is confined to 10 monitoring wells (Figure 6-2). However, the distribution of the chlorinated hydrocarbon contamination is centered near Giant-Bloomfield Refinery monitoring wells GBR-32 and GBR-48 and decreases in concentration downgradient. However, concentrations increase in the southernmost RI well, BLM-68. The highest levels of chlorinated hydrocarbon contamination were found in wells GBR-32, GBR-48, and GBR-49, with concentrations of 1,2-DCE ranging from 1.2 to 200 µg/L. Adjacent BLM monitoring wells contain low concentrations (<10 µg/L) of chlorinated hydrocarbons. Chloride, cobalt, manganese, nickel, and selenium are also identified as OU 2 southern area COCs. The high concentrations of these inorganic and metal COCs are generally centered in the vicinity of the three GBR wells (GBR-32, GBR-48, and GBR-49).

Table 6-33 summarizes and compares groundwater conditions observed at Sites 1 and 2. Contaminant distribution, chloride distribution, and potential sources are compared. Site 1 northern area organic contamination is confined to wells located within former liquid waste lagoons. Wells located adjacent and west of the former landfill, and wells located on the southern landfill boundary, are free of organic contamination. Site 1 manganese contamination is continuous from the former landfill to well BLM-68 where it decreases in concentration. Site 1 southern area organic contamination is discontinuous; no northward and increasing concentration gradient exists.

Site 2 contamination at and south of the former Giant-Bloomfield Refinery is derived from past refinery operations. Therefore, potential hazard and risk associated with this contaminant mass are not addressed as part of the RI/FS.



BLM-57		Frequency
1,1-DCA:	1.8-4.4 µg/L	(7/7)
1,2-DCE:	1.5-2.3 µg/L	(2/7)
TCE:	0.77-3.0 µg/L	(2/7)
VC:	1.6-6.7 µg/L	(3/7)

BLM-55		Frequency
1,1-DCA:	3.2 µg/L	(1/7)
1,2-DCE:	2.9-8.9 µg/L	(3/6)
Chloroform:	1.2 µg/L	(1/7)
PCE:	1.4-3.0µg/L	(6/7)
TCE:	1.1-3.2 µg/L	(2/7)

BLM-56		Frequency
1,1-DCA:	1.3-3.3µg/L	(3/7)
Benzene:	1.4µg/L	(1/7)
Chloroform:	15 µg/L	(1/7)

1,1-DCA = 1,1-dichloroethane
1,2-DCE = 1,2-trans-dichloroethene
PCE = tetrachloroethene
TCE = trichloroethene
VC = vinyl chloride

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◎	BLM monitoring wells with chlorinated hydrocarbon contamination
•	BLM monitoring wells without chlorinated hydrocarbon contamination
(BR)	Bedrock wells

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Figure 6-1.
Concentrations of contaminants in the northern area, Operable Unit 2 alluvial aquifer.

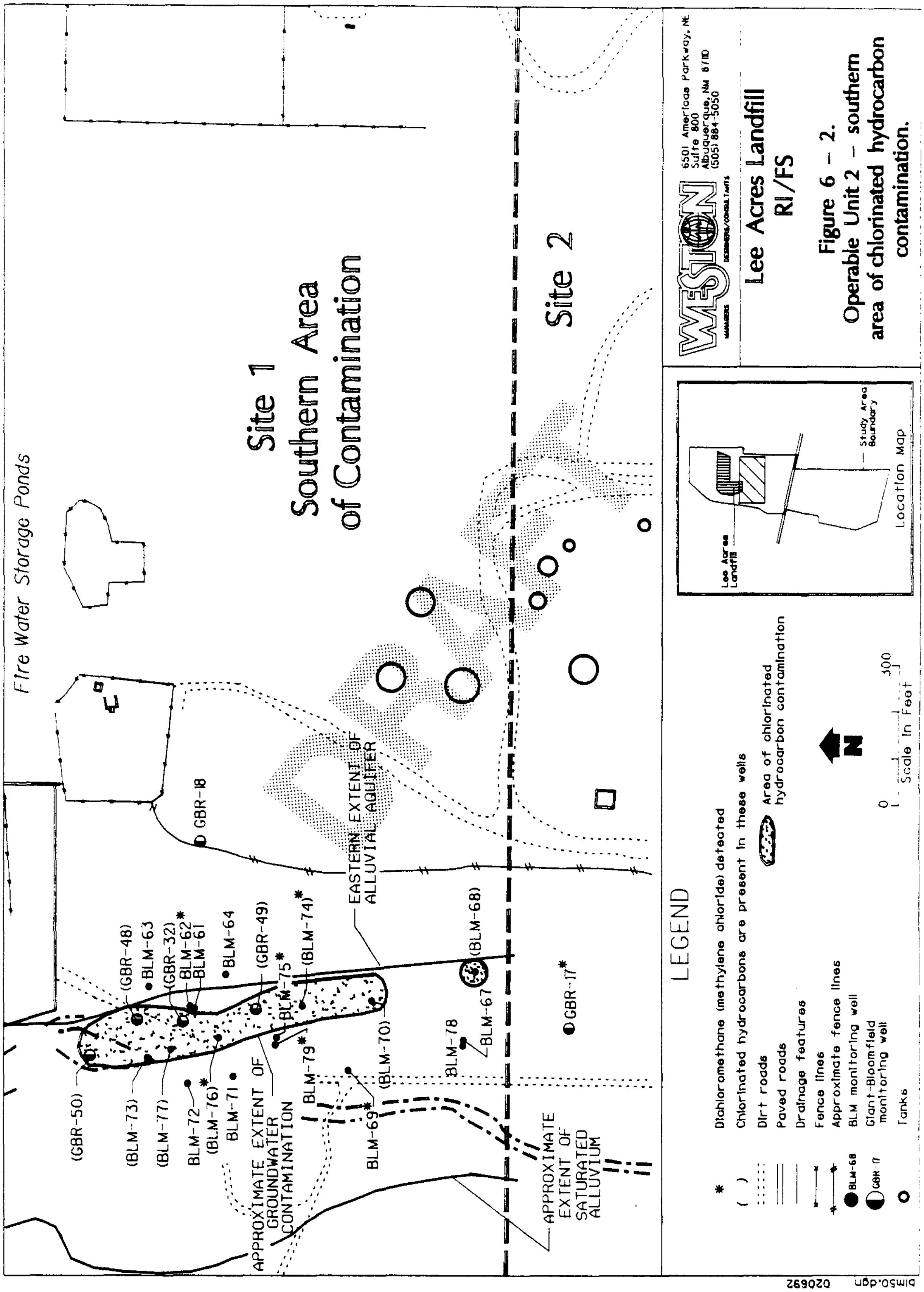
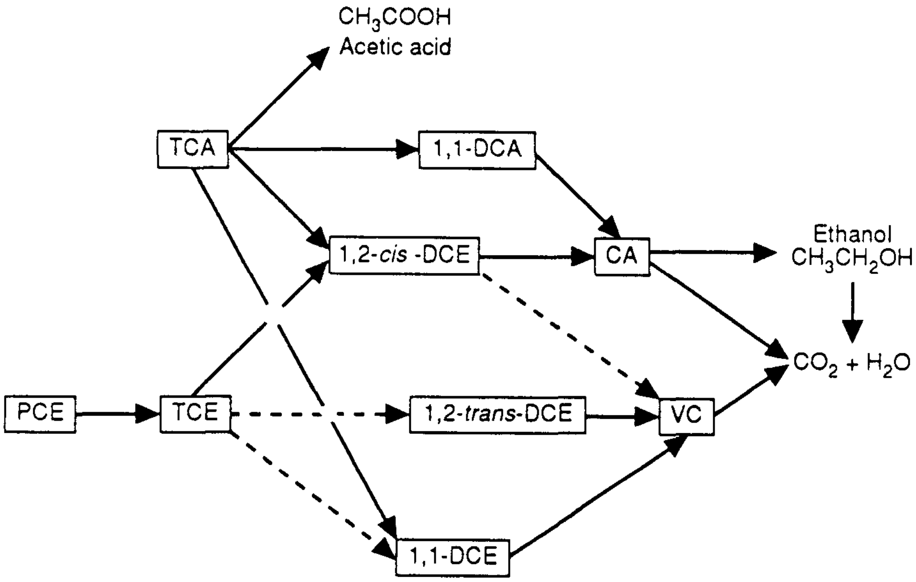


Figure 6 – 2.
Operable Unit 2 – southern area of chlorinated hydrocarbon contamination.



Footnotes

→ Major pathway
⇢ Minor pathway

1,1,1–TCA = 1,1,1–Trichloroethane
1,1–DCA = 1,1–Dichloroethane
1,2–*cis*–DCE = 1,2–*cis*–Dichloroethene
CA = Chloroethane
PCE = Tetrachloroethene
TCE = Trichloroethene
1,2–*trans*–DCE = 1,1–*trans*–Dichloroethene
VC = Vinyl chloride
1,1–DCE = 1,1–Dichloroethene

Modified from HMC July/August 1990.

BLM/chem break/R1

Figure 6-3. Chemical breakdown products of selected chlorinated hydrocarbons.

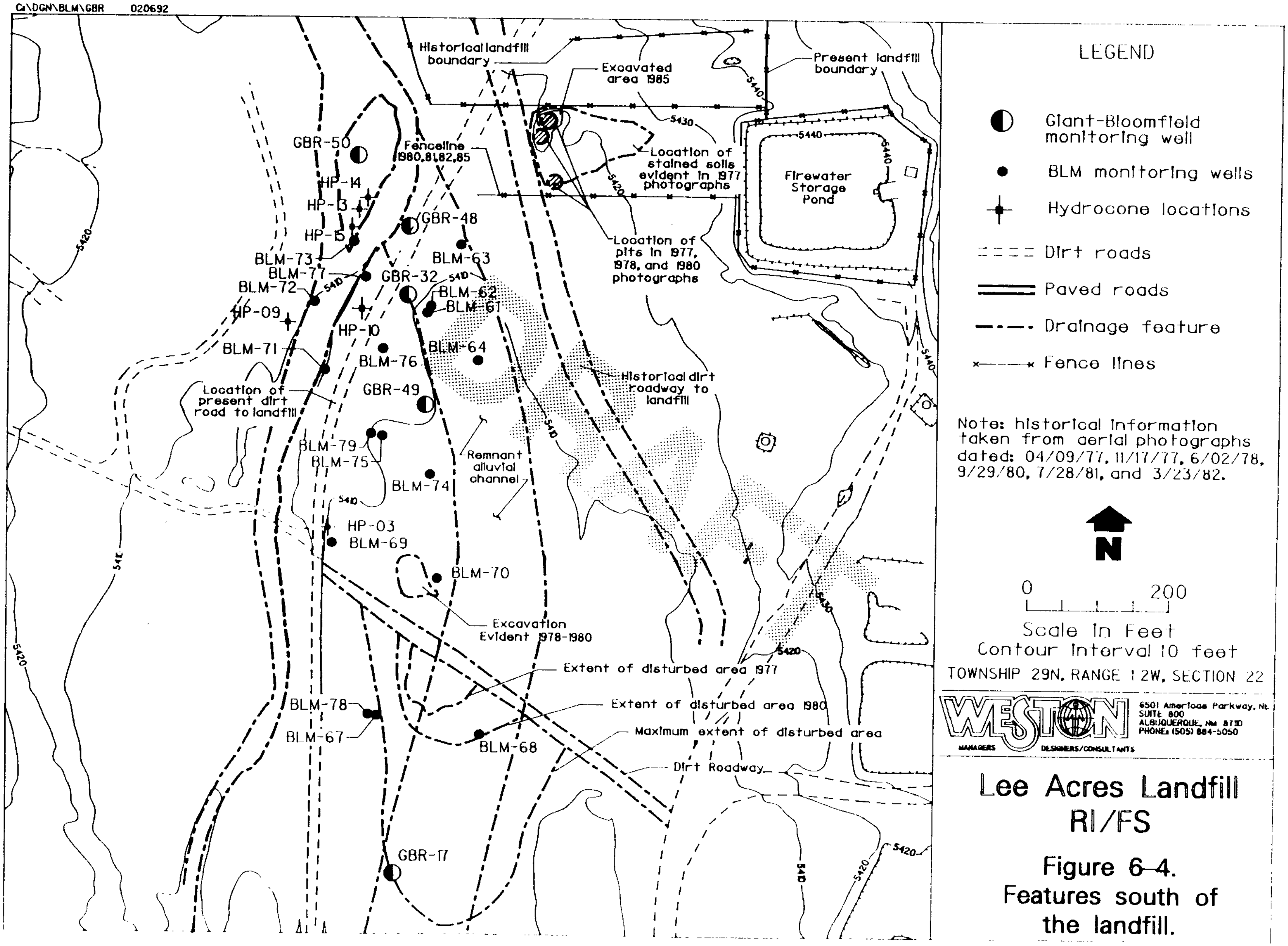


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Figure 6-4. Features south of the landfill.

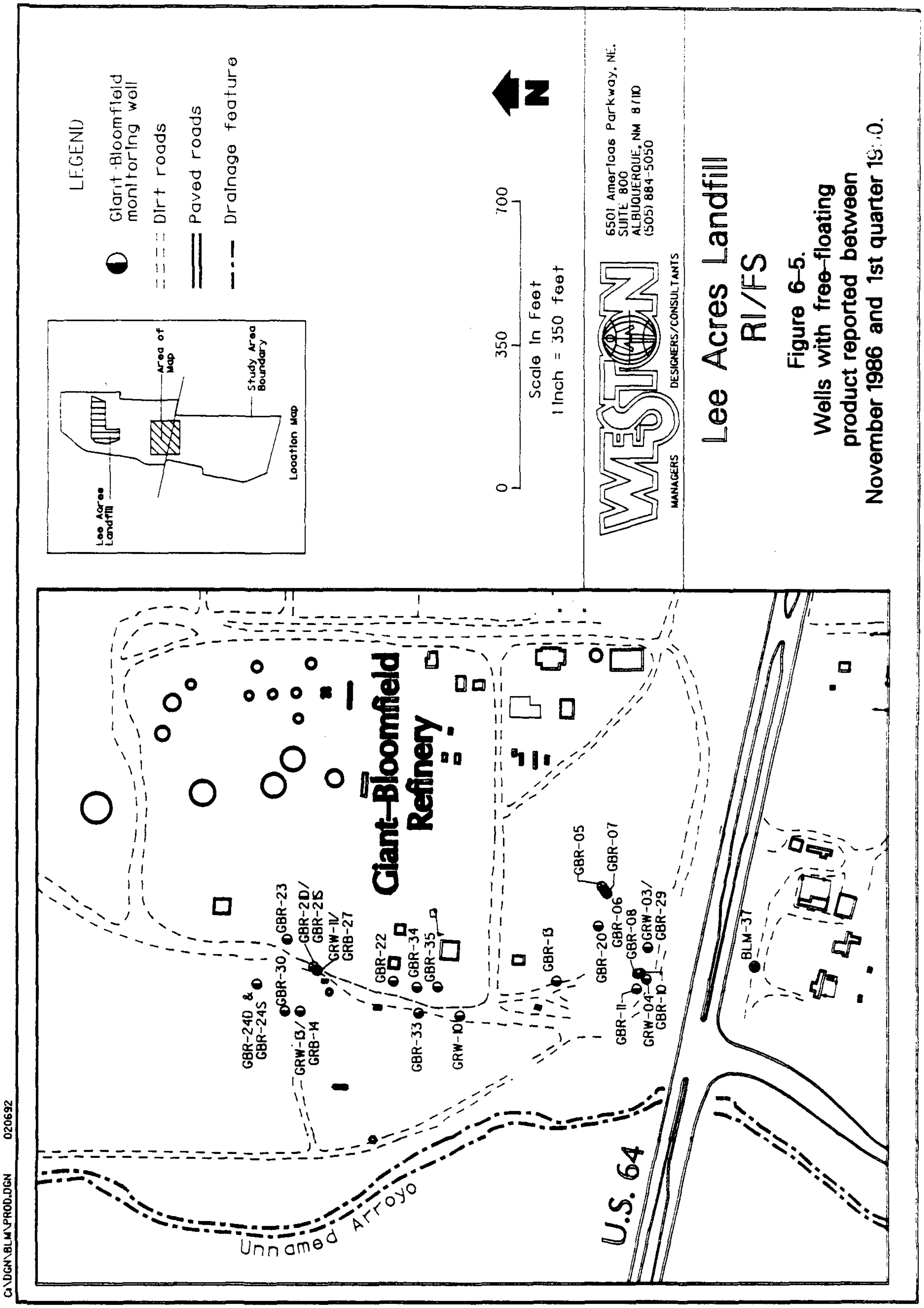

Figure 6-5.
Wells with free-floating product reported between November 1986 and 1st quarter 1990.

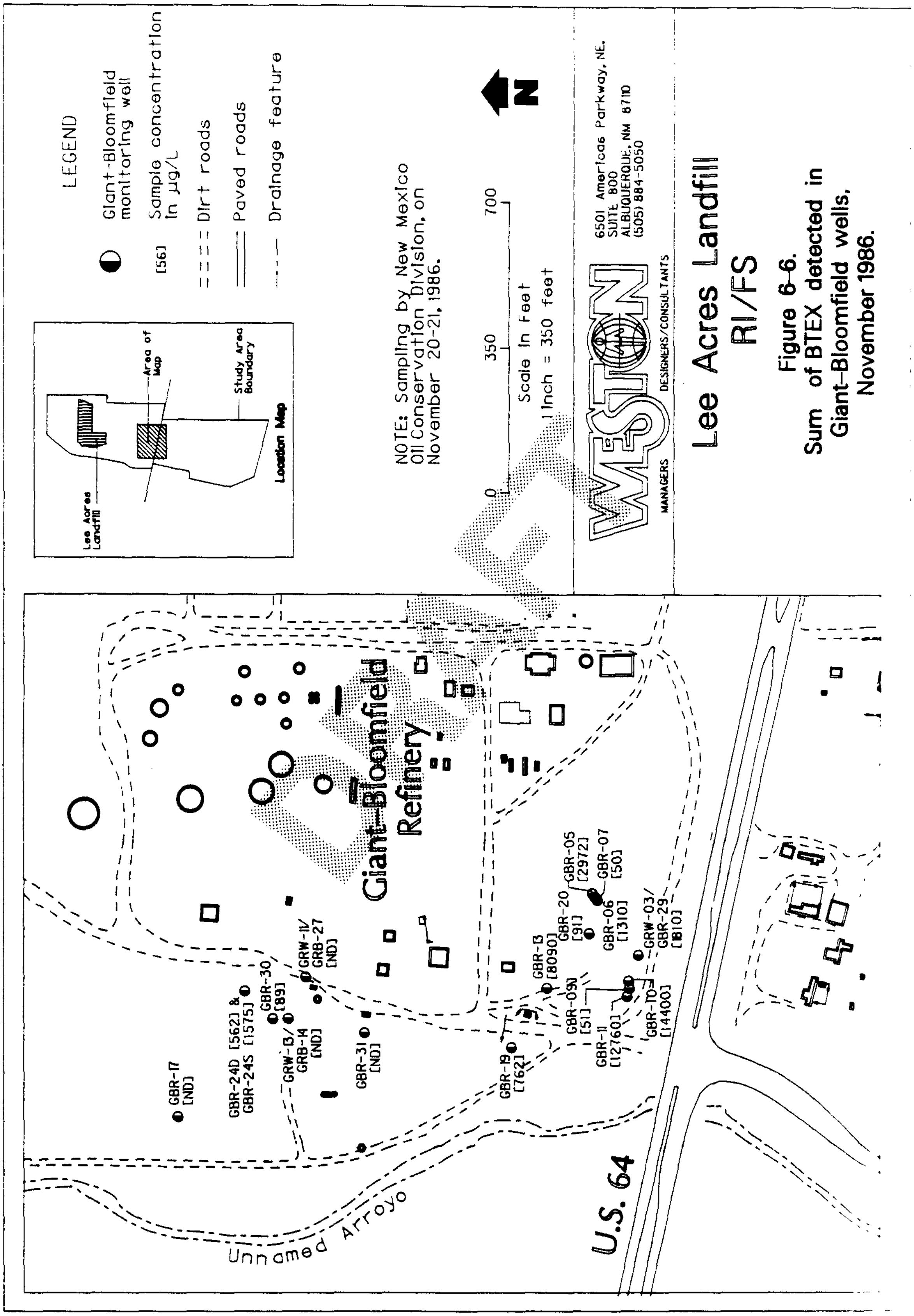

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Figure 6-6.
Sum of BTEX detected in
Giant-Bloomfield wells,
November 1986.

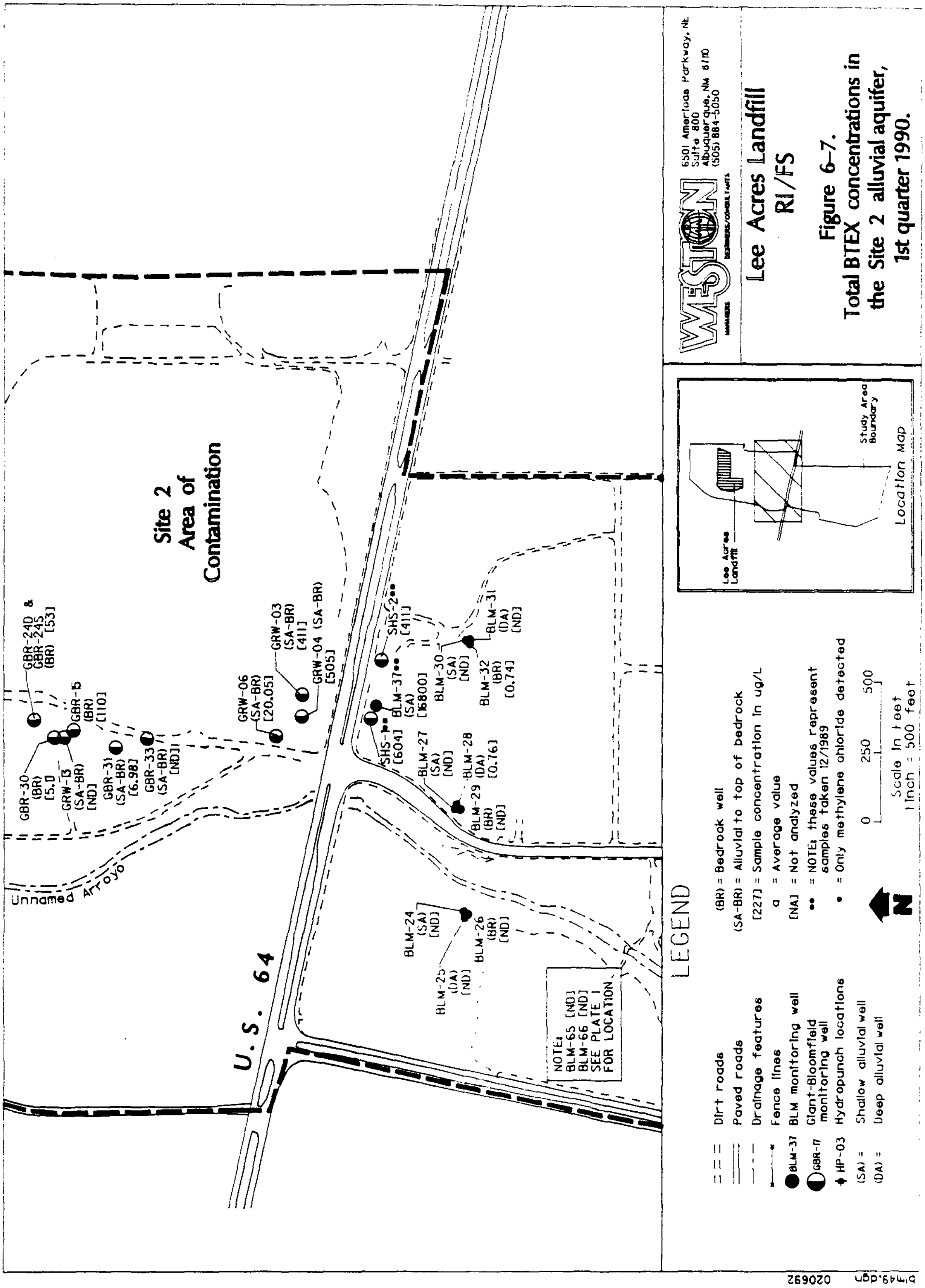
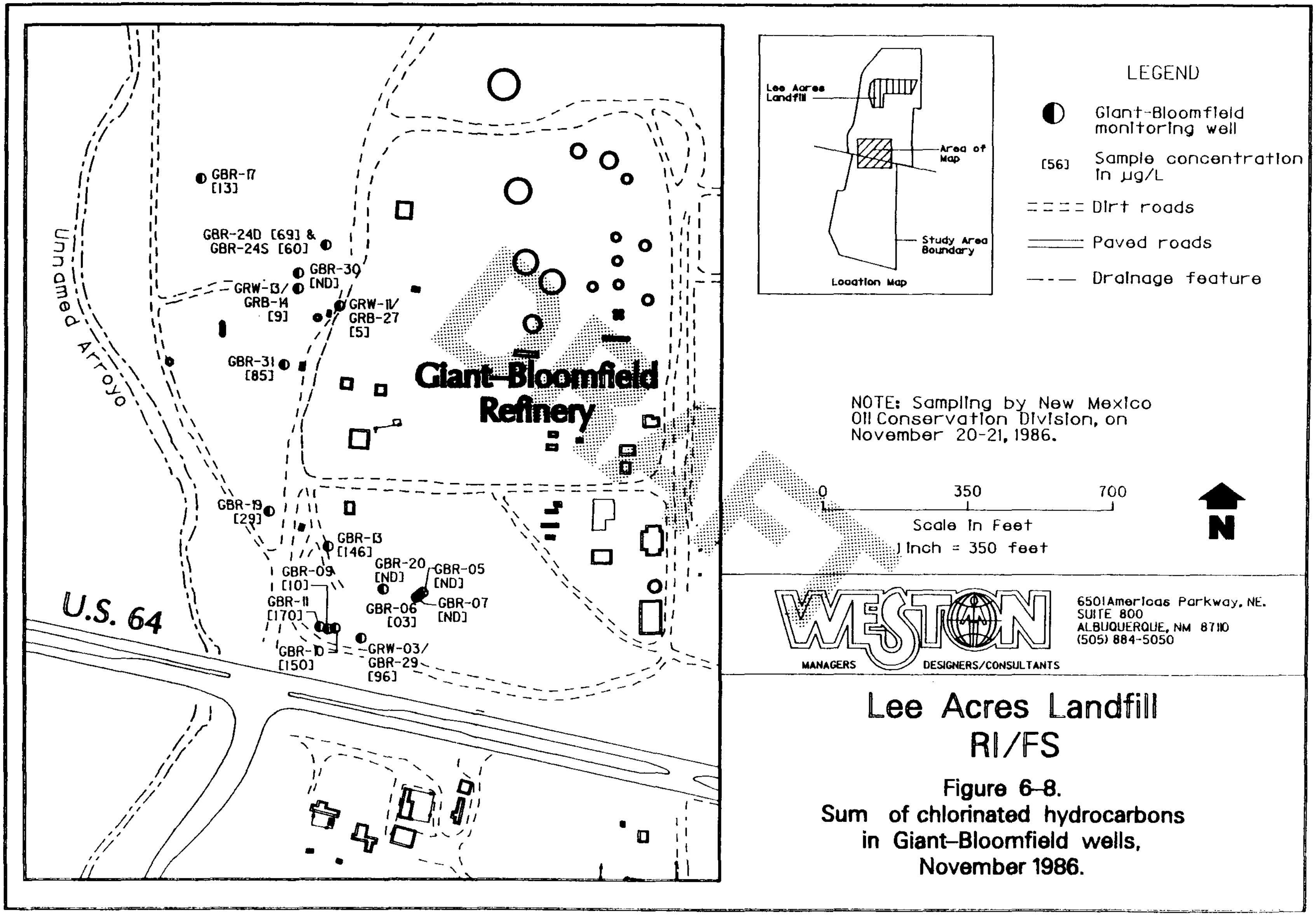


Figure 6-7. Total BTEX concentrations in the Site 2 alluvial aquifer, 1st quarter 1990.

C:\DGN\BLM\GBRCL.DGN 020692



NOTE: Sampling by New Mexico Oil Conservation Division, on November 20-21, 1986.

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Figure 6-8.
Sum of chlorinated hydrocarbons in Giant-Bloomfield wells, November 1986.

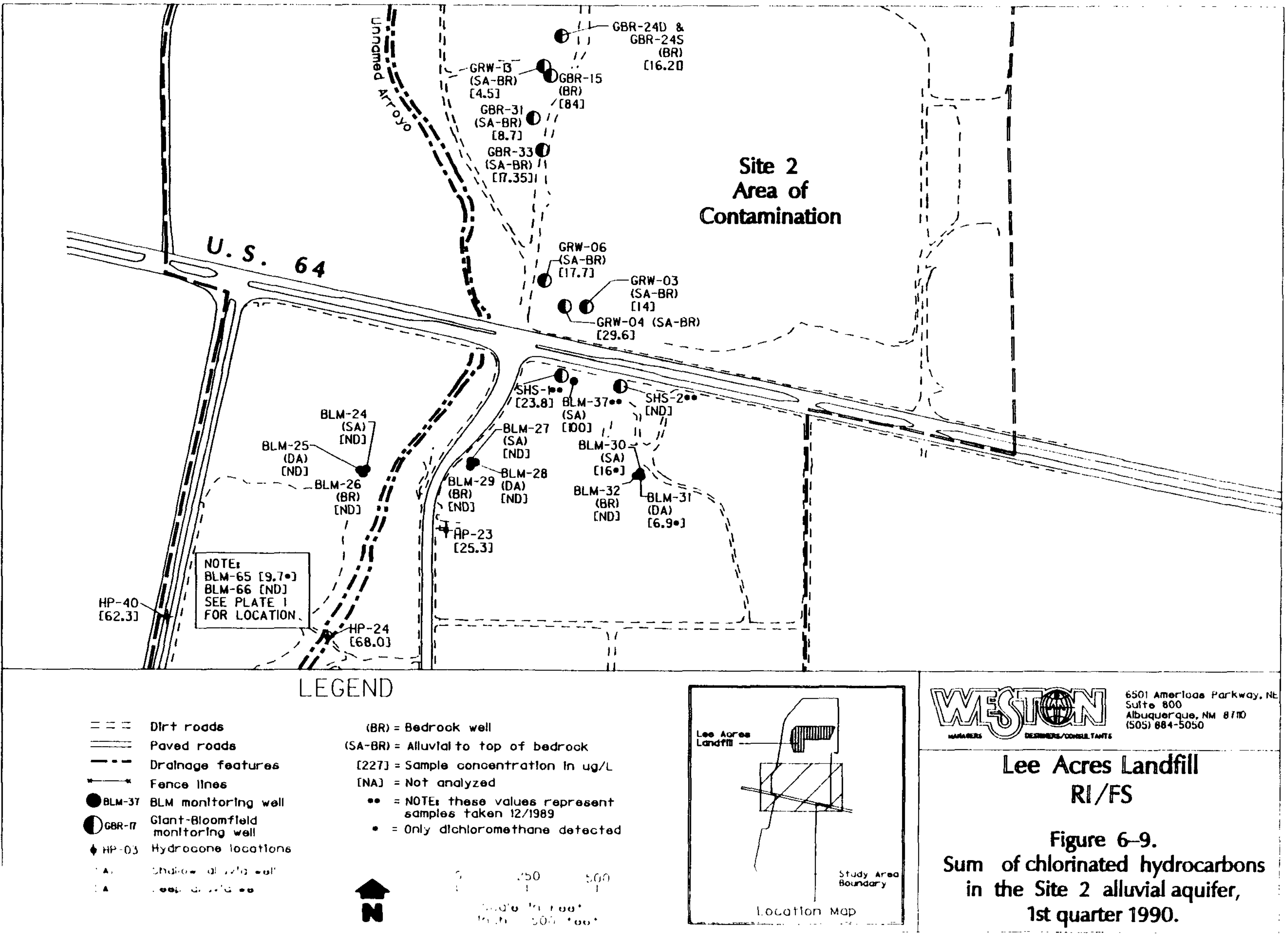

Figure 6-9.
Sum of chlorinated hydrocarbons in the Site 2 alluvial aquifer, 1st quarter 1990.

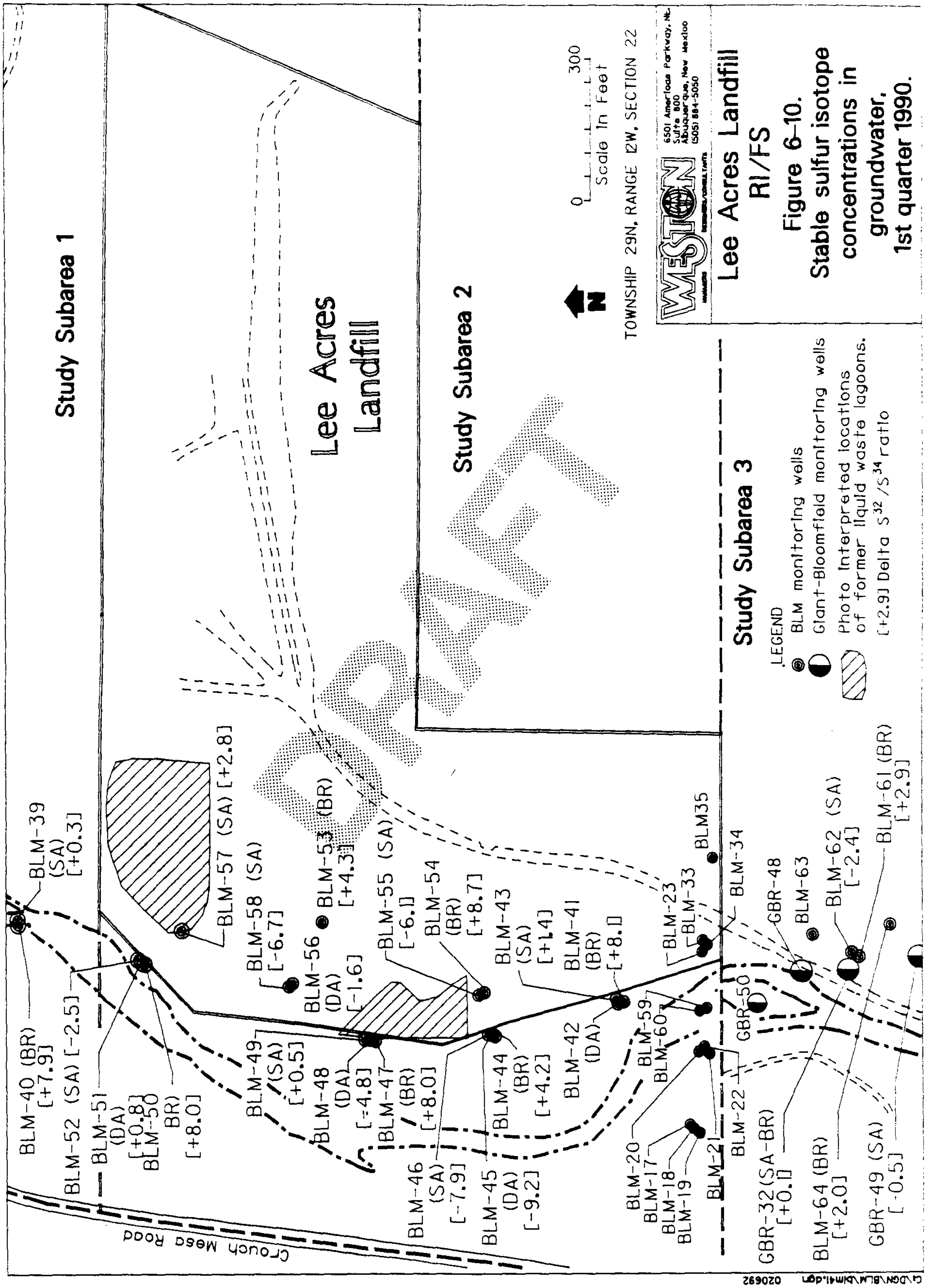

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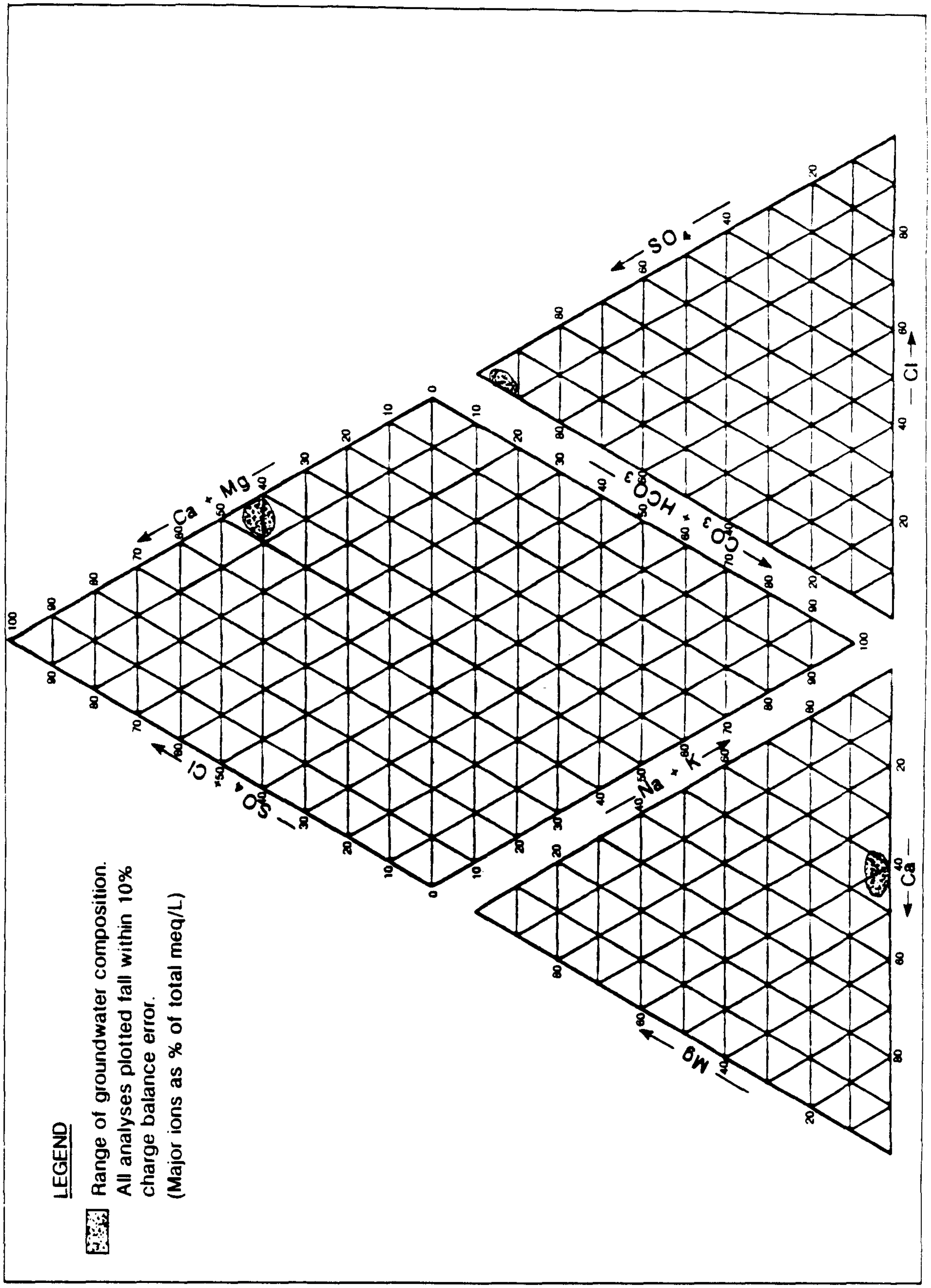
Figure 6-10.
Stable sulfur isotope concentrations in groundwater, 1st quarter 1990.



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▨ Range of groundwater composition.
All analyses plotted fall within 10% charge balance error.
(Major ions as % of total meq/L)

Figure 6-11. Trilinear diagram for bedrock groundwater.

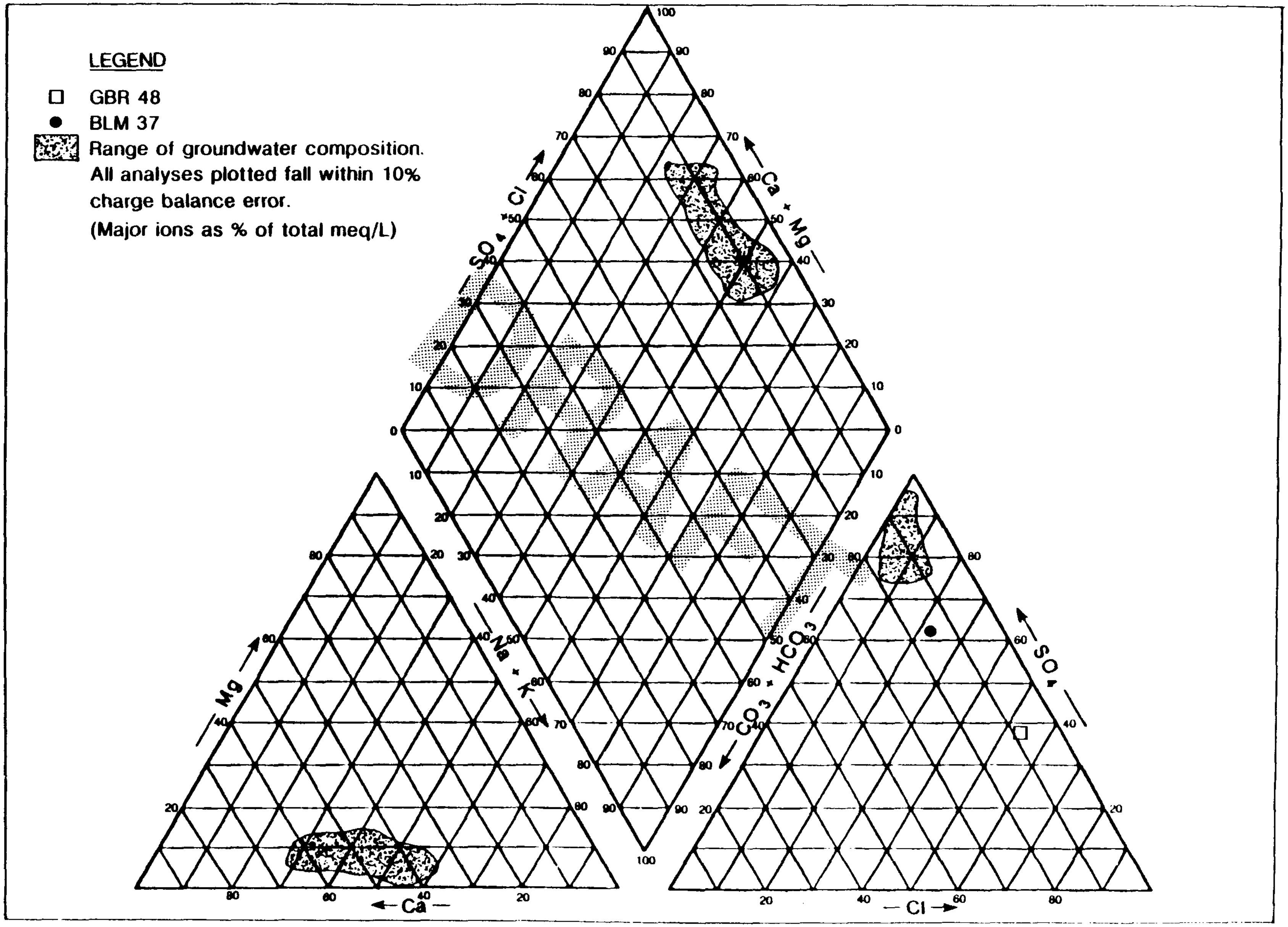


Figure 6-12. Trilinear diagram for alluvial groundwater.

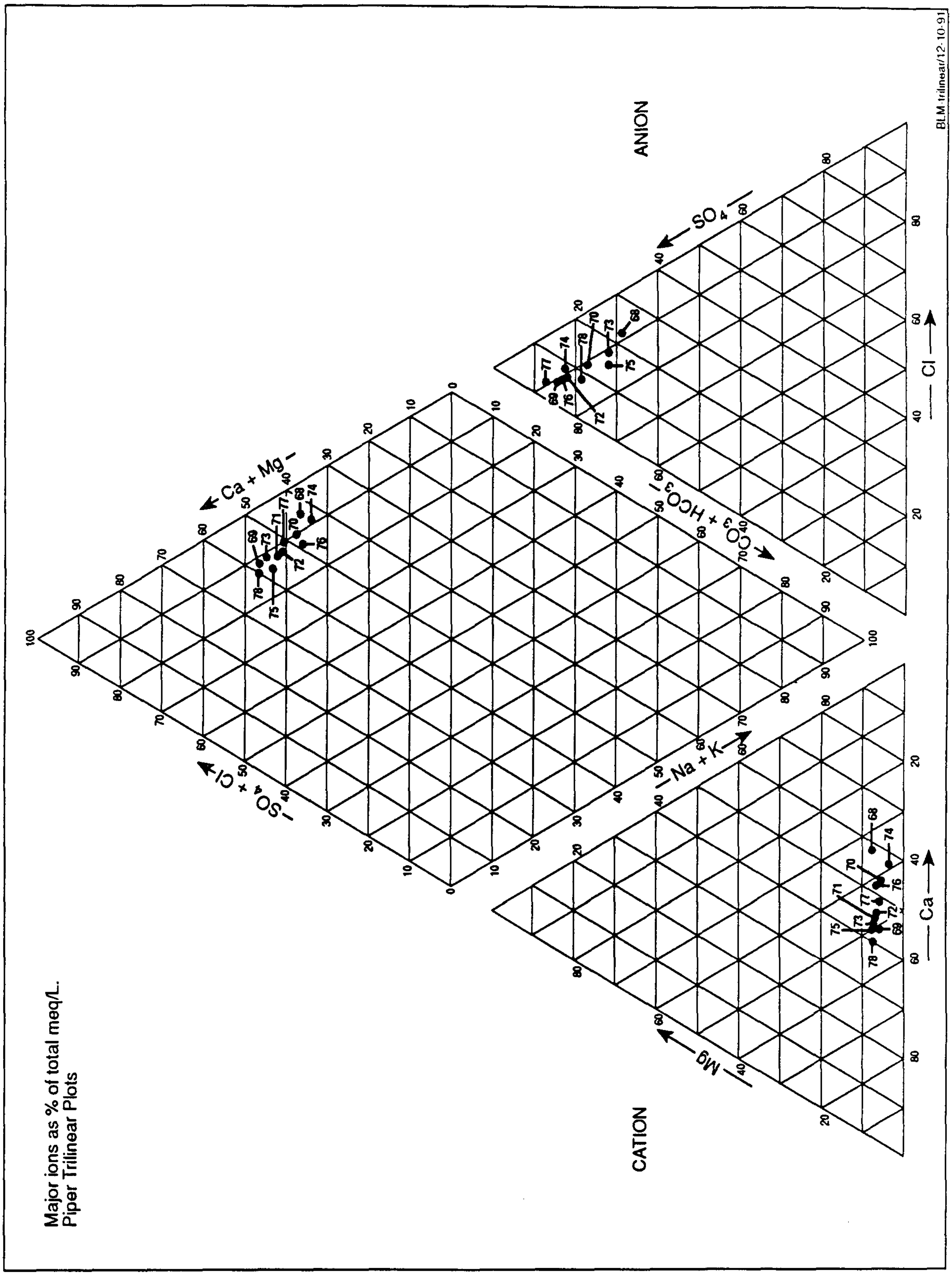
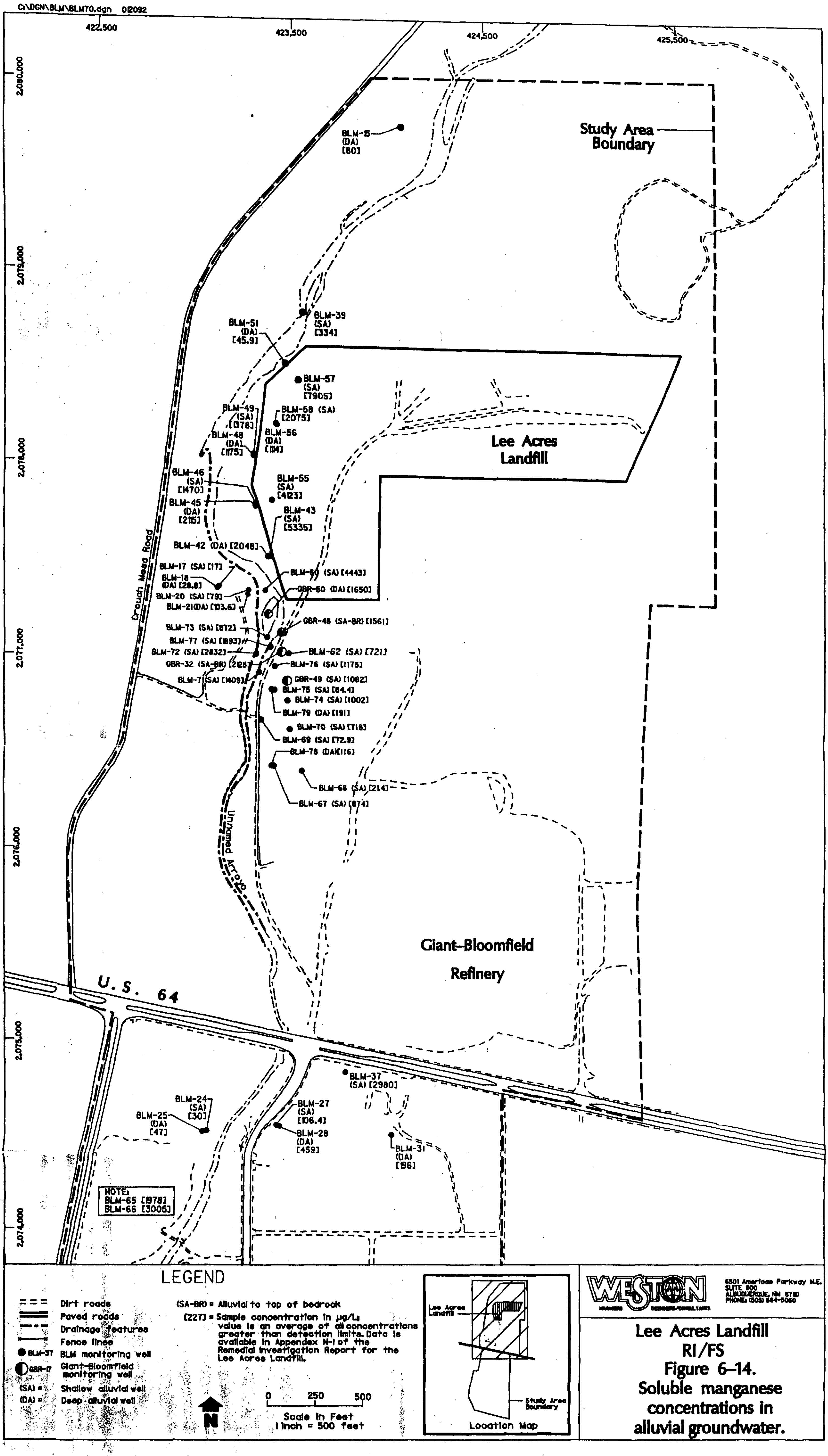


Figure 6-13. Trilinear diagram for alluvial groundwater samples, May 1991.



(SA-BR) = Alluvial to top of bedrock

[227] = Sample concentration in µg/L; value is an average of all concentrations greater than detection limits. Data is available in Appendix N-1 of the Remedial Investigation Report for the Lee Acres Landfill.

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Figure 6-14.
Soluble manganese concentrations in alluvial groundwater.

Table 6-1. Inorganic Compounds and Metals Detected in the Background Alluvial Aquifer

Parameter Name	Protection Standard[a]	Regional Background Concentration Range[b]	Study Area Alluvial Aquifer Background Concentration Range[c]	Identified as a Background Contaminant
Inorganics: (mg/L)				
Bicarbonate	N/A	36 - 2,830	99 - 291	No (1)
Bromide	N/A	N/A	0.26 - 1.2	No (1)
Calcium	N/A	4 - 2,200	228 - 473	No (1)
Carbonate	N/A	0 -73	U	No (1)
Chloride	250 (NM)[e]	2 - 34,000	6.4 - 404	No (2)
Magnesium	N/A	1 - 880	19 - 50.9	No (3)
Nitrate-nitrite, nitrogen	10	0.10 - 1,640[f]	1.2 - 4.9	No (1)
Potassium	N/A	1 - 19,000	1.13 - 6.99	No (1)
Sodium	N/A	6.2 - 16,000	173 - 452	No (1)
Sulfate	400/500p (SDWA)	1.9 - 14,000	420 - 2,120	No (2)
Sulfide	N/A	N/A	U - 1.2	No (1)
Total dissolved solids	10,000	N/A	760 - 3,600	No (3)
Metals: (μg/L)				
Aluminum	50s (SDWA)	30 - 1,100	U - 1,280	No (3)
Arsenic	50 (SDWA)[g]	N/A	U	No (3)
Barium	1,000 (SDWA)	0 - 3,400	U	No (3)
Beryllium	0.008 (RCRA)[h]	N/A	U	No (3)
Boron	750 (NM)	20 - 7,500	247 - 294	No (3)
Cadmium	10 (SDWA)	1 - 18	U	No (3)
Chromium	50 (SDWA)	1 - 60	14.4 - 113	Yes
Cobalt	50 (NM)	1 - 6	U	No (3)
Copper	1,000 (NM)	1 - 12	U - 63.5	No (3)
Iron	300s (SDWA)	10 - 16,000	U - 1,480	No (2)
Lead	50 (NM)	0 - 55	U	No (3)
Manganese	200 (NM)	0 - 2,600	16.1 - 423	No (2)
Mercury	2 (SDWA)	N/A	U	No (3)
Molybdenum	1,000 (NM)	N/A	U	No (3)
Nickel	100p (SDWA)	N/A	U	No (3)
Selenium	10 (SDWA)	2 - 40	8 - 9.5	No (3)
Silicon	N/A	N/A	5,010 - 6,010	No (1)
Silver	50 (SDWA)	N/A	27.3 - 30.9	No (3)
Strontium	N/A	N/A	3,600 - 8,670	No (1)
Tin	N/A	N/A	U	No (1)
Vanadium	N/A	0 - 63	U	No (1)
Zinc	10,000 (NM)	10 - 5,000	22.4 - 642	No (3)

Table 6-1. (page 2 of 2)

[a] Lowest applicable protection standard between New Mexico human health standard and Safe Drinking Water Act maximum contaminant level is presented.

[b] From Stone et al. 1983.

[c] Groundwater analytical results for monitoring wells BLM-14, BLM-15, and BLM-39; results are also presented in Appendix N.

[d] Groundwater analytical results are presented in Appendix N. Table 2-11 identifies formation of completion for alluvial wells (SA and DA). Monitoring wells within study subarea 2 are shown on Plate 1.

[e] NM: New Mexico human health standard, section 3-103 (NMWQCC 1988).

[f] Nitrate only.

[g] SDWA: Safe Drinking Water Act maximum contaminant level.

[h] proposed RCRA action level (55 FR 30865).

(1) No protection standard.

(2) Concentration range exceeds protection standard; however, range is within regional and/or study area background concentrations that also exceed protection standard.

(3) Concentration range is below protection standard.

N/A: not available
p: proposed Safe Drinking Water Act maximum contaminant level
s: secondary Safe Drinking Water Act maximum contaminant level
U: less than detection limit

Table 6-2. Organic Compounds Detected in the Background Alluvial Aquifer

Parameter Name	Number of Detections	Maximum Concentration (µg/l)	Lowest Regulatory Standard (µg/l)	Screening Criteria		
				Eliminated Based on Frequency	Identified as a Background Contaminant	Comments
Volatile Organic Compounds:						
Acetone	2/20	32	4,000[a]	x		One detection per well
Benzene	3/40	2	5[b]	x		One detection per well
Chlorobenzene	2/43	2	700[a]	x		One detection per well
Dichloromethane (methylene chloride)	13/43	63	5[b] p		Y	
Toluene	4/40	8	750[c]	x		High in 1987, undetected since
Trichloroethene	3/43	140	5[b]	x		High in 1987, undetected since
Trichlorofluoromethane	1/23	3.5	N/A	x		Only one time detection
Trichloromethane (chloroform)	1/43	1.9	100[c]	x		One detection per well
Xylenes	2/40	2.9	620[c]	x		One detection per well
Semivolatile Organic Compounds:						
bis(2-Ethylhexyl) phthalate	1/17	40	3[a]	x		Only one time detection
Butyl benzl phthalate	1/17	5	4p[b]	x		Only one time detection
Di-n-butyl phthalate	1/17	0.6	N/A	x		Only one time detection

[a] proposed RCRA action level (55 FR 30865).

[b] Safe Drinking Water Act maximum contaminant level.

[c] New Mexico human health standard, Section 3-103 (NMWQCC 1988).

N/A: not available

p: proposed Safe Drinking Water Act maximum contaminant level

Y: identified as a contaminant of concern

x: contaminant is eliminated as a contaminant of concern

Table 6-3. Inorganic Compounds and Metals Detected in the Background Bedrock Aquifer

Parameter Name	Protection Standard^{a}	Regional Background Concentration Range^{b}	Study Area Bedrock Aquifer Background Concentration Range^{c}	Identified as a Background Contaminant
Inorganics: (mg/L)				
Bicarbonate	N/A	36 - 2,830	42 - 169	No (1)
Bromide	N/A	N/A	0.26 - 2.4	No (1)
Calcium	N/A	4 - 2,200	312 - 543	No (1)
Carbonate	N/A	0 -73	U	No (1)
Chloride	250 (NM)^{e}	2 - 34,000	10.8 - 26.1	No (2)
Magnesium	N/A	1 - 880	14.8 - 33.2	No (1)
Nitrate-nitrite, nitrogen	10	0.10 - 1,640^{f}	0.7 - 9.8	No (1)
Potassium	N/A	1 - 19,000	5.31 - 24.8	No (1)
Sodium	N/A	6.2 - 16,000	56 - 791	No (1)
Sulfate	400/500p (SDWA)	1.9 - 14,000	370 - 3,030	No (3)
Sulfide	N/A	N/A	U	No (1)
Total dissolved solids	10,000	N/A	3,500 - 11,800	No (4)
Metals: (μg/L)				
Aluminum	50s (SDWA)	30 - 1,100	U - 434	No (2)
Arsenic	50 (SDWA)^{g}	N/A	U	No (2)
Barium	1,000 (SDWA)	0 - 3,400	U	No (2)
Beryllium	0.008 (RCRA)^{h}	N/A	U	No (2)
Boron	750 (NM)	20 - 7,500	368 - 394	No (2)
Cadmium	10 (SDWA)	1 - 18	U	No (2)
Chromium	50 (SDWA)	1 - 60	U - 59.1	Yes
Cobalt	50 (NM)	1 - 6	U	No (2)
Copper	1,000 (NM)	1 - 12	U - 149	No (2)
Iron	300s (SDWA)	10 - 16,000	220 - 993	No (2)
Lead	50 (NM)	0 - 55	U	No (2)
Lithium	N/A	N/A	U	No (1)
Manganese	200 (NM)	0 - 2,600	149 - 504	No (3)
Mercury	2 (SDWA)	N/A	U - 0.22	No (2)
Molybdenum	1,000 (NM)	N/A	N/A	No (2)
Nickel	100p (SDWA)	N/A	U	No (2)
Selenium	10 (SDWA)	2 - 40	U	No (2)
Silicon	N/A	N/A	6,030 - 6,410	No (1)
Silver	50 (SDWA)	N/A	U - 28.6	No (2)
Strontium	N/A	N/A	U - 8,560	No (1)
Tin	N/A	N/A	U	No (1)
Vanadium	N/A	0 - 63	U	No (1)
Zinc	10,000 (NM)	10 - 5,000	21 - 394	No (2)

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Table 6-3. (page 2 of 2)

[a] Lowest applicable protection standard between New Mexico human health standard and Safe Drinking Water Act maximum contaminant level is presented.
[b] From Stone et al. 1983.
[c] Groundwater analytical results for monitoring wells BLM-16 and BLM-40; results are also presented in Appendix N.
[d] Groundwater analytical results presented in Appendix N. Monitoring wells within study subarea 2 are shown on Plate 1.
[e] NM = New Mexico human health standard, Section 3-103 (NMWQCC 1988).
[f] Nitrate only.
[g] SDWA = Safe Drinking Water Act maximum contaminant level.
[h] Proposed RCRA action level (55 FR 30865).
(1) No protection standards.
(2) Concentration range is below protection standard.
(3) Concentration range exceeds protection standard; however, range is within regional and/or study area background concentrations that also exceed protection standard.
(4) Maximum concentration detected once; all other concentrations are within background ranges and below protection standard
N/A: not available
p: proposed Safe Drinking Water Act maximum contaminant level
s: secondary Safe Drinking Water Act maximum contaminant level
U: less than detection limit

Table 6-4. Organic Compounds Detected in the Background Bedrock Aquifer

Parameter Name	Number of Detections	Maximum Concentration (µg/l)	Lowest Regulatory Standard (µg/l)	Screening Criteria		
				Eliminated Based on Frequency	Identified as a Background Contaminant	Comments
Volatile Organic Compounds:						
Acetone	5/9	110.0	4,000[a]	x		BLM-16 only, common lab contaminant
Dichloromethane (methylene chloride)	6/20	59.0	5[b] p		Y	
Tetrachloroethene (PCE)	1/20	1.3	5[b] p	x		One detection per well
Toluene	2/18	6.0	750[c]	x		Detected in BLM-16 six months apart
Semivolatile Organic Compounds:						
bis(2-Ethylhexyl) phthalate	2/10	74	3[a]	x		Not detected since 1988
Di-n-butyl phthalate	1/10	17	N/A	x		Only one time detection

[a] Proposed RCRA action level (55 FR 30865).

[b] Safe Drinking Water Act maximum contaminant level.

[c] New Mexico human health standard, Section 3-103 (NMWQCC 1988).

N/A: not available

p: proposed Safe Drinking Water Act maximum contaminant level

Y: identified as a contaminant of concern

x: contaminant is eliminated as a contaminant of concern

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Table 6-5. Concentrations of Primary Groundwater Constituents in the Lee Acres Landfill Study Area

	Primary Groundwater Constituents			
Lee Acres Landfill Study Subareas	**Chloride (mg/L)**	**Sulfate (mg/L)**	**Sodium (mg/L)**	**TDS (mg/L)**
Subarea 1, Background - Alluvial Aquifer	6.4 - 76.8	420 - 2,120	173 - 452	760 - 3,600
Subarea 2, OU 2 - Alluvial Aquifer	8.8 - 730	195 - 4,370	127 - 995	943 - 6,560
Subarea 3, OU 2 - Southern Area - Alluvial Aquifer	19 - 2,110	830 - 2,610	234 - 1,060	622 - 5,300
Site 2 - Alluvial Aquifer	3.5 - 891.04	310 - 3,220	142 - 754	616 - 6,370
Subarea 1, Background - Bedrock Aquifer	10.8 - 26.1	370 - 3,030	56 - 791	3,500 - 11,800
Subarea 2, OU 2 - Bedrock Aquifer	8 - 35	507 - 6,030	255 - 5,471	1,170 - 4,130
Subarea 3, OU 2 - Southern Area - Bedrock Aquifer	14.7 - 25.7	1,950 - 5830	538 - 704	1,600 - 4,210
Site 2 - Bedrock Aquifer	15.1 - 448	304 - 4,460	393 - 836	2,770 - 4,710

Study subareas are shown on Plate 1.
Groundwater analytical results are presented in Appendix N-1.
OU: operable unit
TDS: total dissolved solids

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Table 6-6. Inorganic Compounds and Metals Detected in Site 1, Operable Unit 2 Alluvial Aquifer (Subarea 2)

Parameter Name	Protection Standard^a	Regional Background Concentration Range^b	Study Area Alluvial Aquifer Background Concentration Range^c	Alluvial Aquifer (Study Subarea 2) Concentration Range^d	Identified as a Contaminant of Concern
Inorganics: (mg/L)					
Bicarbonate	N/A	36 - 2,830	99 - 291	26 - 326	No (1)
Bromide	N/A	N/A	0.26 - 1.2	0.26 - 4.2	No (1)
Calcium	N/A	4 - 2,200	228 - 473	234 - 523	No (1)
Carbonate	N/A	0 -73	U	U - 5	No (1)
Chloride	250 (NM)^e	2 - 34,000	6.4 - 404	8.8 - 730	No (2)
Magnesium	N/A	1 - 880	19 - 50.9	16.5 - 39.9	No (3)
Nitrate-nitrite, nitrogen	10	0.10 - 1,640^f	1.2 - 4.9	0.5 - 20.3	No (2)
Potassium	N/A	1 - 19,000	1.13 - 6.99	1.2 - 11.6	No (1)
Sodium	N/A	6.2 - 16,000	173 - 452	127 - 995	No (2)
Sulfate	400/500p (SWDA)	1.9 - 14,000	420 - 2,120	195 - 4,370	No (4)
Sulfide	N/A	N/A	U - 1.2	2.18 - 166	No (1)
Total dissolved solids	10,000	N/A	760 - 3,600	943 - 6,560	No (5)
Metals: (µg/L)					
Aluminum	50s (SDWA)	30 - 1,100	U - 1,280	U - 3,370	No (5)
Arsenic	50 (SDWA)^g	N/A	U	U	No (5)
Barium	1,000 (SDWA)	0 - 3,400	U	U	No (5)
Beryllium	0.008 (RCRA)^h	N/A	U	U	No (5)
Boron	750 (NM)	20 - 7,500	247 - 294	221 - 284	No (5)
Cadmium	10 (SDWA)	1 - 18	U	U - 6.4	No (5)
Chromium	50 (SDWA)	1 - 60	14.4 - 113	10.8 - 124	No (6)
Cobalt	50 (NM)	1 - 6	U	U	No (5)
Copper	1,000 (NM)	1 - 12	U - 63.5	U - 92.1	No (5)
Iron	300s (SDWA)	10 - 16,000	U - 1,480	118 - 1,710	No (7)
Lead	50 (NM)	0 - 55	U	3.4 - 11.5	No (5)
Manganese	200 (NM)	0 - 2,600	16.1 - 423	16.1 - 8,620	Yes

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Table 6-6. (page 2 of 2)

Parameter Name	Protection Standard[a]	Regional Background Concentration Range[b]	Study Area Alluvial Aquifer Background Concentration Range[c]	Alluvial Aquifer (Study Subarea 2) Concentration Range[d]	Identified as a Contaminant of Concern
Mercury	2 (SDWA)	N/A	U	0.21 - 0.56	No (5)
Molybdenum	1,000 (NM)	N/A	U	U - 10.5	No (5)
Nickel	100p (SDWA)	N/A	U	47.5 - 146	No (5)
Selenium	10 (SDWA)	2 - 40	8 - 9.5	5 - 30	No (8)
Silicon	N/A	N/A	5,010 - 6,010	5,260 - 6,100	No (3)
Silver	50 (SDWA)	N/A	27.3 - 30.9	U - 139	No (8)
Strontium	N/A	N/A	3,600 - 8,670	4,210 - 13,300	No (4)
Tin	N/A	N/A	U	U	No (1)
Vanadium	N/A	0 - 63	U	U	No (1)
Zinc	10,000 (NM)	10 - 5,000	22.4 - 642	20 - 387	No (5)

[a] Lowest applicable protection standard between New Mexico human health standard and Safe Drinking Water Act maximum contaminant level is presented.

[b] From Stone et al. 1983.

[c] Groundwater analytical results for monitoring wells BLM-14, BLM-15, and BLM-39; results are also presented in Appendix N.

[d] Groundwater analytical results are presented in Appendix N. Table 2-11 identifies formation of completion for alluvial wells (SA and DA). Monitoring wells within study subarea 2 are shown on Plate 1.

[e] NM = New Mexico human health standard, Section 3-103 (NMWQCC 1988).

[f] Nitrate only.

[g] SDWA = Safe Drinking Water Act maximum contaminant level.

[h] Proposed RCRA action level (55 FR 30865).

(1) No protection standard.

(2) Several concentrations exceed standard and study area background concentrations; however, range is within the regional range and high concentrations have decreased over time.

(3) Concentrations range is within study area and regional concentration ranges.

(4) Maximum detected once; all other values are within study area and/or regional background concentration ranges.

(5) Concentration range is below protection standard.

(6) Concentrations are detected in upgradient wells, therefore, this contaminant is not considered a contaminant of concern for the Lee Acres Landfill.

(7) Concentration range exceeds protection standard; however, range is within regional and/or study area background concentrations that also exceed protection standard.

(8) Maximum concentration detected once; all other concentrations are within background ranges and below protection standard.

N/A: not available

p: proposed Safe Drinking Water Act maximum contaminant level

s: secondary Safe Drinking Water Act maximum contaminant level

U: less than detection limit

Table 6-7. Organic Compounds Detected in the Site 1, Operable Unit 2 Alluvial Aquifer (Subarea 2)

Parameter Name	Number of Detections	Maximum Concentration	Lowest Regulatory Standard	Eliminated Based on Frequency	Identified as a Contaminant of Concern	Comments
Volatile Organic Compounds						
1,1-Dichloroethane	12/158	4.4^a	25^b		Y	
1,2-*cis*-Dichloroethene^c	1/42	20	70^d p		Y	One time detection
1,2-*trans*-Dichloroethene	5/116	8.9	100^d p		Y	
2-Butanone	1/42	1	N/A	x		One time detection
Acetone	5/42	18,000	$4{,}000^e$	x		One detection per well with outlier
Benzene	5/151	1.4^a	5^d		Y?	One detection per well: sample mislabeled
Bromodichloromethane	1/158	2.5	0.03^e	x		Only one time detection
Dichlorodifluoromethane	1/116	7.6	$7{,}000^e$	x		Only one time detection
Dichloromethane (methylene chloride)	44/158	36	5^d p		Y	
Ethylbenzene	2/151	1.3	700^d p	x		One detection per well
Tetrachloroethene (PCE)	8/158	9^a	5^d p		Y	
Toluene	8/151	2.3	750^b	x		One detection per well
Trichloroethene (TCE)	5/158	3.2^a	5^d		Y	
Trichloromethane (chloroform)	6/158	19	100^b		Y	
Vinyl chloride	3/158	6.7	1^b		Y	
Xylene (total)	7/151	3.1	620^b	x		Only one detection/well: Only one since 3/90
Semivolatile Organic Compounds						
1,3-Dichlorobenzene	1/147	14	600^dp	x		Only one time detection
Benzoic Acid	1/71	5	N/A	x		Only one time detection
bis(2-Ethylhexyl) phthalate	5/72	39	3^e	x		One detection per well
Di-n-butyl phthalate	2/72	2	N/A	x		One detection per well
Di-n-octyl phthalate	5/72	7	N/A	x		One detection per well
N-Nitrosodiphenylamine	1/72	5	7^e	x		One detection per well

[a] Maximum concentrations excluding the April 1990 results from BLM-49, see subsection 6.3.1.2.

[b] New Mexico human health standard, Section 3-103 (NMWQCC 1988).

[c] 1,2-*cis*-dichloroethene coelutes with 1,2-*trans*-dichloroethene and therefore, in most cases was reported as the *trans* isomer. Both isomers are considered in the discussions of contaminants of concern.

[d] Safe Drinking Water Act, maximum contaminant level.

[e] Proposed RCRA action level (55 FR 30865).

p proposed Safe Drinking Water Act maximum contaminant level

Y identified as a contaminant of concern

Y? may not be a contaminant of concern since the high value occurs in a sample suspected of being mislabeled. All others are only one time detections.

x contaminant is eliminated as a contaminant of concern

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Table 6-8. Summary of Organic Compounds Detected in the Northern Area of the Operable Unit 2 Alluvial Aquifer
SITE: BLM01 BLM (Lee Acres)
12/15/87 TO 07/19/91
REPORT DATE: 12/10/91

PARAMETER NAME	LOCATION ID	LOG DATE	SAMPLE ID	FORM COMP	FLOW REL.	UNITS OF MEASURE	PVI	PARAMETER VALUE	DETECTION LIMIT	LAB CODE	DILUTION FACTOR
1,1-DICHLOROETHANE	B049	04/26/90	0022	SA	2	UG/L		0.96	0.50	RWS	-
	B055	05/23/91	0001	SA	2	UG/L		3.2	1.0	RWL	1.00
	B056	03/06/90	0002	DA	2	UG/L	J	2	5	RWS	-
	B056	05/23/91	0001	DA	2	UG/L		3.3	1.0	RWL	1.00
	B056	06/22/91	0001	DA	2	UG/L		1.3	1.0	RWL	1.00
	B057	03/21/90	0006	SA	2	UG/L		3.3	0.50	RWS	-
	B057	04/29/90	0021	SA	2	UG/L		2.9	0.50	RWS	-
	B057	05/22/90	0007	SA	2	UG/L		2.2	0.50	RWS	-
	B057	08/24/90	0005	SA	2	UG/L		1.8	0.50	RWS	-
	B057	05/23/91	0001	SA	2	UG/L		4.4	1.0	RWL	1.00
	B057	05/23/91	0002	SA	2	UG/L		4.4	1.0	RWL	1.00
	B057	06/22/91	0001	SA	2	UG/L		1.8	1.0	RWL	1.00
	B057	07/19/91	0001	SA	2	UG/L		2.4	1.0	RWL	1.00
1,2-CIS-DICHLOROETHENE	B055	03/04/90	0002	SA	2	UG/L		20	5	RWS	-
1,2-TRANS-DICHLOROETHENE	B055	05/23/91	0001	SA	2	UG/L		2.9	1.0	RWL	1.00
	B055	06/21/91	0001	SA	2	UG/L		8.0	1.0	RWL	1.00
	B055	07/17/91	0001	SA	2	UG/L		8.9	1.0	RWL	1.00
	B057	05/23/91	0001	SA	2	UG/L		2.3	1.0	RWL	1.00
	B057	05/23/91	0002	SA	2	UG/L		2.3	1.0	RWL	1.00
	B057	07/19/91	0001	SA	2	UG/L		1.5	1.0	RWL	1.00
1,3-DICHLOROBENZENE	B021	02/12/88	0001	DA	2	UG/L		14	-	RWG	-
2-BUTANONE	B056	03/06/90	0002	DA	2	UG/L	JB	1	10	RWS	-
2-METHYLNAPHTHALENE	B045	05/17/90	0001	DA	2	UG/L	JB*	1	10	RWS	-
ACETONE	B017	12/15/87	0013	SA	2	UG/L		94	10	RWS	-
	B017	05/16/88	0025	SA	2	UG/L	B*	11	10	RWS	-
	B017	08/24/88	0004	SA	2	UG/L	JB*	7.00	10	RWS	-
	B018	12/15/87	0017	DA	2	UG/L		18000	10	RWS	-
	B018	01/18/88	0021	DA	2	UG/L		340	-	RWS	-
	B018	05/16/88	0029	DA	2	UG/L	JB*	7.0	10	RWS	-

Table 6-8. Summary of Organic Compounds Detected in the Northern Area of the Operable Unit 2 Alluvial Aquifer
SITE: BLM01 BLM (Lee Acres)
12/15/87 TO 07/19/91
REPORT DATE: 12/10/91

PARAMETER NAME	LOCATION ID	LOG DATE	SAMPLE ID	FORM COMP	FLOW REL.	UNITS OF MEASURE	PVI	PARAMETER VALUE	DETECTION LIMIT	LAB CODE	DILUTION FACTOR
ACETONE	B018	05/16/88	0033	DA	2	UG/L	JB*	3.0	10	RWS	-
	B018	06/27/88	0007	DA	2	UG/L	JB*	4.0	10	RWS	-
	B018	07/18/88	0007	DA	2	UG/L	B*	15	10	RWS	-
	B018	08/23/88	0001	DA	2	UG/L	B*	12	10	RWS	-
	B018	09/19/88	0007	DA	2	UG/L	JB*	7.0	10	RWS	-
	B018	09/19/88	0008	DA	2	UG/L	B*	16	10	RWS	-
	B020	05/16/88	0005	SA	2	UG/L	JB*	8.0	10	RWS	-
	B020	07/18/88	0009	SA	2	UG/L	JB*	8.0	10	RWS	-
	B020	08/24/88	0005	SA	2	UG/L	JB*	6.0	10	RWS	-
	B020	09/19/88	0010	SA	2	UG/L	B*	14	10	RWS	-
	B021	12/15/87	0005	DA	2	UG/L		33	10	RWS	-
	B021	05/16/88	0009	DA	2	UG/L	B*	13	10	RWS	-
	B021	07/18/88	0010	DA	2	UG/L	JB*	10	10	RWS	-
	B021	07/18/88	0011	DA	2	UG/L	JB*	9.0	10	RWS	-
	B021	08/23/88	0002	DA	2	UG/L	JB*	10	10	RWS	-
	B055	03/04/90	0002	SA	2	UG/L	JB	3	10	RWS	-
	B056	03/06/90	0002	DA	2	UG/L	B	19	10	RWS	-
BENZENE	B017	12/14/89	0002	SA	2	UG/L	B*	0.98	0.50	RWS	-
	B017	12/14/89	0002	SA	2	UG/L	B*	0.98	0.50	RWS	-
	B018	12/14/89	0003	DA	2	UG/L	B*	1.0	0.50	RWS	-
	B018	12/14/89	0003	DA	2	UG/L	B*	1.0	0.50	RWS	-
	B021	12/15/89	0002	DA	2	UG/L	B*	1.0	0.50	RWS	-
	B021	12/15/89	0002	DA	2	UG/L	B*	1.0	0.50	RWS	-
	B042	03/01/90	0005	DA	2	UG/L	J	0.13	0.50	RWS	-
	B043	03/01/90	0006	SA	2	UG/L	J	0.20	0.50	RWS	-
	B049	04/26/90	0022	SA	2	UG/L		61	0.50	RWS	-
	B052	03/20/90	0005	SA	2	UG/L		0.61	0.50	RWS	-
	B056	08/24/90	0011	DA	2	UG/L		1.4	0.50	RWS	-
BENZOIC ACID	B055	03/04/90	0002	SA	2	UG/L	J	5	50	RWS	-
BIS(2-ETHYLHEXYL)PHTHALATE	B017	02/12/88	0008	SA	2	UG/L	B*	28	-	RWG	-
	B018	01/18/88	0022	DA	2	UG/L		11	-	RWS	-
	B018	02/12/88	0009	DA	2	UG/L	B*	34	-	RWG	-

Table 6-8. Summary of Organic Compounds Detected in the Northern Area of the Operable Unit 2 Alluvial Aquifer
SITE: BLM01 BLM (Lee Acres)
12/15/87 TO 07/19/91
REPORT DATE: 12/10/91

PARAMETER NAME	LOCATION ID	LOG DATE	SAMPLE ID	FORM COMP	FLOW REL.	UNITS OF MEASURE	PVI	PARAMETER VALUE	DETECTION LIMIT	LAB*CODE	DILUTION FACTOR
BIS(2-ETHYLHEXYL)PHTHALATE	B020	01/18/88	0042	SA	2	UG/L		39	-	RWS	-
	B020	02/12/88	0010	SA	2	UG/L	B*	26	-	RWG	-
	B021	02/12/88	0001	DA	2	UG/L	B*	32	-	RWG	-
	B021	02/14/88	0003	DA	2	UG/L	B*	25	-	RWG	-
	B045	04/26/90	0013	DA	2	UG/L	JB*	2	10	RWS	-
	B045	04/26/90	A113	DA	2	UG/L	JB*	2	10	RWS	-
	B046	05/17/90	0002	SA	2	UG/L	JB*	1	10	RWS	-
	B048	04/26/90	0021	DA	2	UG/L	JB*	4	10	RWS	-
	B048	05/17/90	0018	DA	2	UG/L	JB*	2	10	RWS	-
	B048	05/17/90	A118	DA	2	UG/L	JB*	2	10	RWS	-
	B049	04/26/90	0022	SA	2	UG/L	JB*	1	10	RWS	-
	B051	04/26/90	0010	DA	2	UG/L	JB*	4	10	RWS	-
	B051	05/17/90	0010	DA	2	UG/L	JB*	1	10	RWS	-
	B052	04/26/90	0007	SA	2	UG/L	JB*	2	10	RWS	-
	B056	03/06/90	0002	DA	2	UG/L	B*	24	10	RWS	-
	B056	08/24/90	0004	DA	2	UG/L	JB*	2	10	RWS	-
	B057	03/21/90	0006	SA	2	UG/L	JB*	1	10	RWS	-
	B057	03/21/90	R106	SA	2	UG/L	JB*	1	10	RWS	-
	B057	05/22/90	R107	SA	2	UG/L	J	2	10	RWL	-
	B058	05/22/90	R108	SA	2	UG/L	J	2	11	RWL	-
BROMODICHLOROMETHANE	B060	07/19/91	0003	SA	2	UG/L		2.5	1.0	RWL	1.00
CHLOROFORM	B021	02/06/89	0001	DA	2	UG/L		1.20	0.5	RWS	-
	B043	03/01/90	0006	SA	2	UG/L		2.9	0.50	RWS	-
	B043	04/27/90	0004	SA	2	UG/L		1.9	0.50	RWS	-
	B055	05/23/91	0001	SA	2	UG/L		1.2	1.0	RWL	1.00
	B056	03/06/90	0002	DA	2	UG/L	J	1	5	RWS	-
	B060	07/19/91	0003	SA	2	UG/L		19.	1.0	RWL	1.00
DI-N-BUTYL PHTHALATE	B020	02/12/88	0010	SA	2	UG/L	J	1	-	RWG	-
	B048	05/17/90	0018	DA	2	UG/L	J	2	10	RWS	-
	B048	05/17/90	A118	DA	2	UG/L	J	2	10	RWS	-
DI-N-OCTYL PHTHALATE	B049	05/17/90	0019	SA	2	UG/L	J	3	10	RWS	-

Table 6-8. Summary of Organic Compounds Detected in the Northern Area of the Operable Unit 2 Alluvial Aquifer
SITE: BLM01 BLM (Lee Acres)
12/15/87 TO 07/19/91
REPORT DATE: 12/10/91

PARAMETER NAME	LOCATION ID	LOG DATE	SAMPLE ID	FORM COMP	FLOW REL.	UNITS OF MEASURE	PVI	PARAMETER VALUE	DETECTION LIMIT	LAB*CODE	DILUTION FACTOR
DI-N-OCTYL PHTHALATE	B049	05/17/90	A119	SA	2	UG/L	J	3	10	RWS	-
	B051	05/17/90	0010	DA	2	UG/L	J	7	10	RWS	-
	B056	08/24/90	0004	DA	2	UG/L	J	2	10	RWS	-
	B056	08/24/90	0011	DA	2	UG/L	J	1	10	RWS	-
	B058	04/29/90	0020	SA	2	UG/L	J	2	10	RWS	-
	B060	05/18/90	0008	SA	2	UG/L	J	1	10	RWS	-
DICHLORODIFLUOROMETHANE	B057	05/22/90	0007	SA	2	UG/L		7.6	0.50	RWS	-
DICHLOROMETHANE-METHYLENE CHLORIDE	B017	12/15/87	0013	SA	2	UG/L		36	5	RWS	-
	B017	05/16/88	0025	SA	2	UG/L	JB*	1.0	5	RWS	-
	B017	07/18/88	0006	SA	2	UG/L	B*	9.0	5	RWS	-
	B017	08/24/88	0004	SA	2	UG/L	B*	6.00	5	RWS	-
	B017	09/19/88	0006	SA	2	UG/L	J	3.0	5	RWS	-
	B017	02/06/89	0005	SA	2	UG/L		2.00	0.5	RWS	-
	B017	05/15/89	0006	SA	2	UG/L		3.80	0.5	RWS	-
	B017	09/08/89	0007	SA	2	UG/L		4.20	0.50	RWS	-
	B017	04/25/90	0001	SA	2	UG/L		4.4	0.50	RWS	-
	B018	07/18/88	0007	DA	2	UG/L	B*	20	5	RWS	-
	B018	08/23/88	0001	DA	2	UG/L	J	3.0	5	RWS	-
	B018	02/06/89	0006	DA	2	UG/L		1.3	0.5	RWS	-
	B018	02/06/89	0007	DA	2	UG/L		5.20	0.5	RWS	-
	B018	05/15/89	0007	DA	2	UG/L		3.50	0.5	RWS	-
	B018	09/08/89	0006	DA	2	UG/L		4.70	0.50	RWS	-
	B018	04/25/90	0002	DA	2	UG/L		4.9	0.50	RWS	-
	B018	06/21/91	0001	DA	2	UG/L	B*	9.9	4.0	RWL	1.00
	B020	07/18/88	0009	SA	2	UG/L	B*	7.0	5	RWS	-
	B020	08/24/88	0005	SA	2	UG/L	B*	5.0	5	RWS	-
	B020	02/06/89	0002	SA	2	UG/L		8.10	0.5	RWS	-
	B020	05/15/89	0009	SA	2	UG/L		1.80	0.5	RWS	-
	B020	04/25/90	0003	SA	2	UG/L		4.7	0.50	RWS	-
	B020	08/21/90	0004	SA	2	UG/L		3.6	0.50	RWS	-
	B020	06/21/91	0001	SA	2	UG/L	B*	9.8	4.0	RWL	1.00
	B020	07/17/91	0001	SA	2	UG/L		6.8	4.0	RWL	1.00
	B021	12/15/87	0005	DA	2	UG/L		12	5	RWS	-

Table 6-8. Summary of Organic Compounds Detected in the Northern Area of the Operable Unit 2 Alluvial Aquifer
SITE: BLM01 BLM (Lee Acres)
12/15/87 TO 07/19/91
REPORT DATE: 12/10/91

PARAMETER NAME	LOCATION ID	LOG DATE	SAMPLE ID	FORM COMP	FLOW REL.	UNITS OF MEASURE	PVI	PARAMETER VALUE	DETECTION LIMIT	LAB*CODE	DILUTION FACTOR
DICHLOROMETHANE-METHYLENE CHLORIDE	B021	03/09/88	0021	DA	2	UG/L		24	-	RWS	-
	B021	05/16/88	0009	DA	2	UG/L	J	1.0	5	RWS	-
	B021	07/18/88	0010	DA	2	UG/L	JB*	2.0	5	RWS	-
	B021	07/18/88	0011	DA	2	UG/L	B*	7.0	5	RWS	-
	B021	08/23/88	0002	DA	2	UG/L	J	3.0	5	RWS	-
	B021	05/15/89	0011	DA	2	UG/L		1.30	0.5	RWS	-
	B021	05/15/89	0012	DA	2	UG/L		1.30	0.5	RWS	-
	B021	09/09/89	0002	DA	2	UG/L		3.50	0.50	RWS	-
	B021	09/09/89	0003	DA	2	UG/L		2.60	0.50	RWS	-
	B021	02/26/90	0008	DA	2	UG/L		3.3	0.50	RWS	-
	B021	08/21/90	0005	DA	2	UG/L		10	0.50	RWS	-
	B021	06/20/91	0001	DA	2	UG/L	B*	19.	4.0	RWL	1.00
	B021	07/17/91	0001	DA	2	UG/L		6.5	4.0	RWL	1.00
	B042	03/01/90	0005	DA	2	UG/L		2.7	0.50	RWS	-
	B043	03/01/90	0006	SA	2	UG/L		1.5	0.50	RWS	-
	B045	03/02/90	0002	DA	2	UG/L		4.4	0.50	RWS	-
	B046	03/02/90	0003	SA	2	UG/L		4.6	0.50	RWS	-
	B048	05/17/90	0018	DA	2	UG/L		1.1	0.50	RWS	-
	B048	08/21/90	0002	DA	2	UG/L		6.7	0.50	RWS	-
	B049	05/17/90	0019	SA	2	UG/L		1.2	0.50	RWS	-
	B049	08/21/90	0003	SA	2	UG/L		5.8	0.50	RWS	-
	B051	03/20/90	0004	DA	2	UG/L	B*	1.7	0.50	RWS	-
	B051	05/20/91	0001	DA	2	UG/L	B*	5.3	4.0	RWL	1.00
	B051	05/20/91	0002	DA	2	UG/L	B*	13.	4.0	RWL	1.00
	B052	03/20/90	0005	SA	2	UG/L	B*	1.7	0.50	RWS	-
	B052	05/20/91	0001	SA	2	UG/L	B*	5.8	4.0	RWL	1.00
	B055	05/21/90	0004	SA	2	UG/L		1.7	0.50	RWS	-
	B055	05/23/91	0001	SA	2	UG/L		6.1	4.0	RWL	1.00
	B055	07/17/91	0001	SA	2	UG/L		4.4	4.0	RWL	1.00
	B056	03/06/90	0002	DA	2	UG/L	JB	2	5	RWS	-
	B056	04/29/90	0019	DA	2	UG/L	B*	1.0	0.50	RWS	-
	B056	05/22/90	0006	DA	2	UG/L		1.2	0.50	RWS	-
	B056	08/24/90	0011	DA	2	UG/L		4.6	0.50	RWS	-
	B057	04/29/90	0021	SA	2	UG/L	B*	2.0	0.50	RWS	-
	B057	05/22/90	0007	SA	2	UG/L		6.7	0.50	RWS	-

Table 6-8. Summary of Organic Compounds Detected in the Northern Area of the Operable Unit 2 Alluvial Aquifer
SITE: BLM01 BLM (Lee Acres)
12/15/87 TO 07/19/91
REPORT DATE: 12/10/91

PARAMETER NAME	LOCATION ID	LOG DATE	SAMPLE ID	FORM COMP	FLOW REL.	UNITS OF MEASURE	PVI	PARAMETER VALUE	DETECTION LIMIT	LAB*CODE	DILUTION FACTOR
DICHLOROMETHANE-METHYLENE CHLORIDE	B058	04/29/90	0020	SA	2	UG/L	B*	1.1	0.50	RWS	-
	B058	05/22/90	0008	SA	2	UG/L		14	0.50	RWS	-
	B058	05/23/91	0001	SA	2	UG/L		5.6	4.0	RWL	1.00
	B060	03/02/90	0005	SA	2	UG/L		5.3	0.50	RWS	-
	B060	07/19/91	0001	SA	2	UG/L		8.8	4.0	RWL	1.00
ETHYLBENZENE	B017	12/14/89	0002	SA	2	UG/L		1.3	0.50	RWS	-
	B017	12/14/89	0002	SA	2	UG/L		1.3	0.50	RWS	-
	B018	02/26/90	0005	DA	2	UG/L		0.72	0.50	RWS	-
N-NITROSODIPHENYLAMINE	B021	06/28/88	0003	DA	2	UG/L	J	5.0	10	RWS	-
TETRACHLOROETHENE	B017	12/15/87	0013	SA	2	UG/L		9	5	RWS	-
	B049	04/26/90	0022	SA	2	UG/L		12	0.50	RWS	-
	B055	03/04/90	0002	SA	2	UG/L	J	3	5	RWS	-
	B055	04/29/90	0017	SA	2	UG/L		2.0	0.50	RWS	-
	B055	05/21/90	0004	SA	2	UG/L		1.7	0.50	RWS	-
	B055	08/24/90	0003	SA	2	UG/L		1.5	0.50	RWS	-
	B055	06/21/91	0001	SA	2	UG/L		1.4	1.0	RWL	1.00
	B055	07/17/91	0001	SA	2	UG/L		1.9	1.0	RWL	1.00
TOLUENE	B017	12/14/89	0002	SA	2	UG/L	B*	1.2	0.50	RWS	-
	B017	12/14/89	0002	SA	2	UG/L	B*	1.2	0.50	RWS	-
	B017	02/27/90	0001	SA	2	UG/L	B*	0.82	0.50	RWS	-
	B018	12/14/89	0003	DA	2	UG/L	B*	1.2	0.50	RWS	-
	B018	12/14/89	0003	DA	2	UG/L	B*	1.2	0.50	RWS	-
	B018	02/26/90	0005	DA	2	UG/L		2.3	0.50	RWS	-
	B020	02/26/90	0007	SA	2	UG/L		0.66	0.50	RWS	-
	B020	08/21/90	0004	SA	2	UG/L	B	0.66	0.50	RWS	-
	B021	12/15/89	0002	DA	2	UG/L	B*	1.2	0.50	RWS	-
	B021	12/15/89	0002	DA	2	UG/L	B*	1.2	0.50	RWS	-
	B042	03/01/90	0005	DA	2	UG/L	B*	1.3	0.50	RWS	-
	B043	03/01/90	0006	SA	2	UG/L	B*	0.50	0.50	RWS	-
	B048	08/21/90	0002	DA	2	UG/L	B	0.59	0.50	RWS	-
	B051	03/20/90	0004	DA	2	UG/L		0.98	0.50	RWS	-

Table 6-8. Summary of Organic Compounds Detected in the Northern Area of the Operable Unit 2 Alluvial Aquifer
SITE: BLM01 BLM (Lee Acres)
12/15/87 TO 07/19/91
REPORT DATE: 12/10/91

PARAMETER NAME	LOCATION ID	LOG DATE	SAMPLE ID	FORM COMP	FLOW REL.	UNITS OF MEASURE	PVI	PARAMETER VALUE	DETECTION LIMIT	LAB*CODE	DILUTION FACTOR
TOLUENE	B052	03/20/90	0005	SA	2	UG/L		1.6	0.50	RWS	-
	B056	07/19/91	0001	DA	2	UG/L		1.4	1.0	RWL	1.00
	B060	03/02/90	0005	SA	2	UG/L		0.83	0.50	RWS	-
TOTAL XYLENES	B018	12/14/89	0003	DA	2	UG/L		2.8	0.50	RWS	-
	B018	12/14/89	0003	DA	2	UG/L		2.8	0.50	RWS	-
	B018	02/26/90	0005	DA	2	UG/L		2.6	0.50	RWS	-
	B021	12/15/89	0002	DA	2	UG/L		3.1	0.50	RWS	-
	B021	12/15/89	0002	DA	2	UG/L		3.1	0.50	RWS	-
	B042	03/01/90	0005	DA	2	UG/L		1.4	0.50	RWS	-
	B051	03/20/90	0004	DA	2	UG/L		1.4	0.50	RWS	-
	B052	03/20/90	0005	SA	2	UG/L		1.8	0.50	RWS	-
	B060	03/02/90	0005	SA	2	UG/L		0.94	0.50	RWS	-
TRICHLOROETHENE	B049	04/26/90	0022	SA	2	UG/L		9.8	0.50	RWS	-
	B055	03/04/90	0002	SA	2	UG/L	J	1	5	RWS	-
	B055	04/29/90	0017	SA	2	UG/L		3.2	0.50	RWS	-
	B057	03/21/90	0006	SA	2	UG/L		0.77	0.50	RWS	-
	B057	04/29/90	0021	SA	2	UG/L		3.0	0.50	RWS	-
VINYL CHLORIDE	B057	03/21/90	0006	SA	2	UG/L		6.7	0.50	RWS	-
	B057	04/29/90	0021	SA	2	UG/L		2.7	0.50	RWS	-
	B057	08/24/90	0005	SA	2	UG/L		1.6	0.50	RWS	-

* - ELIMINATED DURING LAB BLANK EVALUATION
J - PRESENT BELOW DETECTION LIMIT
JB - PRESENT IN BLANK BELOW DETECTION LIMIT
B - PRESENT IN BLANK

FORMATION OF COMPLETION CODE:
SA - SHALLOW ALLUVIAL AQUIFER
DA - DEEP ALLUVIAL AQUIFER

FLOW RELATIONSHIP CODE:
2 - SUBAREA 2

Note: "B" in the Location ID indicates a BLM monitoring well (i.e., B014 = BLM-14).

DATA FILE NAME: K:\DART\BLMX\BLM01\GWQ10102.DAT

Table 6-9. Comparison of BLM-49 and GBR-49 Volatile Organic Results

Parameter	BLM-49		GBR-49	
	Log Date	Parameter Value	Log Date	Parameter Value
1,1-Dichloroethane	03/03/90	U 0.50	03/22/90	0.53
	04/26/90	0.96[a]	04/26/90	U 0.50[a]
	05/17/90	U 0.50	05/15/90	1.4
	08/21/90	U 0.50	08/23/90	0.82
	05/20/91	U 1.0	05/23/91	4.6
Benzene	03/03/90	U 0.50	03/22/90	45
	04/26/90	61[a]	04/26/90	U 0.50[a]
	05/17/90	U 0.50	05/18/90	64
	08/21/90	U 0.50	08/23/90	U 0.50
	05/20/91	U 1.0	05/23/91	U 1.0
Tetrachloroethene	03/03/90	U 0.50	03/22/91	9.3
	04/26/90	12[a]	04/26/90	U 0.50[a]
	05/17/90	U 0.50	05/18/90	11
	08/21/90	U 0.50	08/23/90	9.8
	05/20/91	U 1.0	05/23/91	8.0
Trichloroethene	03/03/90	U 0.50	03/22/91	7.5
	04/26/90	9.8[a]	04/26/90	U 0.50[a]
	05/17/90	U 0.50	05/18/90	6.9
	08/21/90	U 0.50	08/23/90	6.0
	05/20/91	U 1.0	05/23/91	5.8

Analytical results presented in Appendix N-1. Monitoring wells shown on Plate 1.
[a] Sample event suspected of being switched.
U: not detected

Table 6-10. Inorganic Compounds and Metals Detected in the Site 1, Northern Area of the Operable Unit 2 Bedrock Aquifer

Parameter Name	Protection Standard[a]	Regional Background Concentration Range[b]	Study Area Bedrock Aquifer Background Concentration Range[c]	Bedrock Aquifer (Study Subarea 2) Concentration Range[d]	Identified as a Contaminant of Concern
Inorganics: (mg/L)					
Bicarbonate	N/A	36 - 2,830	42 - 169	10 - 180	No (1)
Bromide	N/A	N/A	0.26 - 2.4	0.25 - 1.3	No (1)
Calcium	N/A	4 - 2,200	312 - 543	256 - 667	No (1)
Carbonate	N/A	0 -73	U	U	No (1)
Chloride	250 (NM)[e]	2 - 34,000	10.8 - 26.1	8.0 - 35	No (2)
Magnesium	N/A	1 - 880	14.8 - 33.2	7.3 - 26.9	No (1)
Nitrate-nitrite, nitrogen	10	0.10 - 1,640[f]	0.7 - 9.8	0.05 - 6.3	No (2)
Potassium	N/A	1 - 19,000	5.31 - 24.8	3.12 - 41.2	No (1)
Sodium	N/A	6.2 - 16,000	56 - 791	255 - 5,471	No (1)
Sulfate	400/500p (SDWA)	1.9 - 14,000	370 - 3,030	507 - 6,030	No (3)
Sulfide	N/A	N/A	U	1.3 - 11	No (2)
Total dissolved solids	10,000	N/A	3,500 - 11,800	1,770 - 4,130	No (2)
Metals: (µg/L)					
Aluminum	50s (SDWA)	30 - 1,100	U - 434	U - 584	No (2)
Arsenic	50 (SDWA)[g]	N/A	U	U	No (2)
Barium	1,000 (SDWA)	0 - 3,400	U	U	No (2)
Beryllium	0.008 (RCRA)[h]	N/A	U	5.1 - 5.5	No (4)
Boron	750 (NM)	20 - 7,500	368 - 394	275 - 398	No (2)
Cadmium	10 (SDWA)	1 - 18	U	5.1 - 8.3	No (2)
Chromium	50 (SDWA)	1 - 60	U - 59.1	57.7 - 68.5	No (5)
Cobalt	50 (NM)	1 - 6	U	U	No (2)
Copper	1,000 (NM)	1 - 12	U - 149	26.6 - 337	No (2)
Iron	300s (SDWA)	10 - 16,000	220 - 993	103 - 1,920	No (6)
Lead	50 (NM)	0 - 55	U	U	No (2)
Lithium	N/A	N/A	U	108 - 121	No (1)

Table 6-10. (page 2 of 2)

Parameter Name	Protection Standard[a]	Regional Background Concentration Range[b]	Study Area Bedrock Aquifer Background Concentration Range[c]	Bedrock Aquifer (Study Subarea 2) Concentration Range[d]	Identified as a Contaminant of Concern
Manganese	200 (NM)	0 - 2,600	149 - 504	98 - 756	No (5)
Mercury	2 (SDWA)	N/A	U - 0.22	0.2 - 0.98	No (2)
Molybdenum	1,000 (NM)	N/A	N/A	15.9 - 81.5	No (2)
Nickel	100p (SDWA)	N/A	U	56.1 - 71.1	No (2)
Selenium	10 (SDWA)	2 - 40	U	U	No (2)
Silicon	N/A	N/A	6,030 - 6,410	5,070 - 7,990	No (1)
Silver	50 (SDWA)	N/A	U - 28.6	U - 35.3	No (2)
Strontium	N/A	N/A	U - 8,560	4,020 - 13,700	No (1)
Tin	N/A	N/A	U	U	No (1)
Vanadium	N/A	0 - 63	U	U	No (1)
Zinc	10,000 (NM)	10 - 5,000	21 - 394	20.4 - 489	No (2)

[a] Lowest applicable protection standard between New Mexico human health standard and Safe Drinking Water Act maximum contaminant level is presented.
[b] From Stone et al. 1983.
[c] Groundwater analytical results for monitoring wells BLM-16 and BLM-40; results are also presented in Appendix N.
[d] Groundwater analytical results are presented in Appendix N. Monitoring wells within study subarea 2 are shown on Plate 1.
[e] NM = New Mexico human health standard, Section 3-103 (NMWQCC 1988).
[f] Nitrate only.
[g] SDWA = Safe Drinking Water Act maximum contaminant level.
[h] Proposed RCRA action level (55 FR 30865).

(1) No protection standards.
(2) Concentration range is below protection standard.
(3) Maximum detected once; all other values are within study area and/or regional background concentration ranges.
(4) Considered outlier values, not confirmed in subsequent samples.
(5) Concentrations are detected in upgradient wells, therefore, this contaminant is not considered a contaminant of concern for the Lee Acres Landfill.
(6) Concentration range exceeds protection standard; however, range is within regional and/or study area background concentrations that also exceed protection standard.

N/A: not available
p: proposed Safe Drinking Water Act maximum contaminant level
s: secondary Safe Drinking Water Act maximum contaminant level
U: less than detection limit

Table 6-11. Organic Compounds Detected in the Site 1, Northern Area of the Operable Unit 2 Bedrock Aquifer

Parameter Name	Number of Detections	Maximum Concentration (µg/L)	Lowest Regulatory Standard (µg/L)	Screening Criteria		
				Eliminated Based on Frequency	Identified as a Contaminant of Concern	Comments
Volatile Organic Compounds						
Acetone	5/29	6,000.0	4,000[a]	x		Not detected after 4/88, high in 12/87
Benzene	3/98	1.4	5[b]	x		Only 1 detection per well
Dichloromethane (methylene chloride)	30/105	21.0	5p[b]		Y	
Ethylbenzene	1/98	0.5	700p[b]	x		Only 1 time detection
Toluene	9/98	12.0	750[c]	x		Only 1 detection per well
Trichloromethane (chloroform)	2/105	4.2	100[c]	x		Detected in BLM-53, clean since 4/90
Xylene (total)	9/98	2.7	620[c]	x		Only 1 detection per well
Semivolatile Organic Compounds						
Dichlorobenzene, 1,3-	1/98	0.75	600p[b]	x		Only 1 time detection
Benzo(a)pyrene	1/53	2	0.2p[b]	x		Only 1 time detection
Benzo(g,h,i)perylene	1/53	4	N/A	x		Only 1 time detection
bis(2-Ethylhexyl) phthalate	17/53	71	3[a]		Y RISK	
Di-n-butyl phthalate	1/53	1	N/A	x		Only 1 time detection
Di-n-octyl phthalate	5/53	9.0	N/A	x		Only 1 detection/well, below detection limit
Pesticides/PCBs						
4,4-DDT	1/43	0.12	0.1[a]	x		Only 1 time detection
Aldrin	1/43	0.06	0.002[a]	x		Only 1 time detection
Endrin	1/43	0.14	0.2[a]	x		Only 1 time detection

[a] Proposed RCRA action level (55 FR 30865).

[b] Safe Drinking Water Act maximum contaminant level.

[c] New Mexico human health standard, Section 3-103 (NMWQCC 1988).

N/A: not available

P: proposed Safe Drinking Water Act maximum contaminant level

Y: identified as a contaminant of concern

Y RISK: retained as a contaminant of concern for risk assessment purposes only

x: contaminant is eliminated as a contaminant of concern

Table 6-12. Site 1, Southern Area of Operable Unit 2
Monitoring Well Completion Information
SITE: BLM01 BLM (Lee Acres)
REPORT DATE: 12/10/91

LOCATION ID	NORTH COORDINATE (FT)	EAST COORDINATE (FT)	GROUND ELEVATION (FT MSL)	BOREHOLE DEPTH (FT) *	CASING STICKUP (FT)	CASING ELEVATION (FT MSL)	CASING DEPTH (FT) *	CASING + DIAMETER (INCHES)	SCREEN * BEGINNING DEPTH (FT)	SCREEN LENGTH (FT)	FLOW CODE	FORMATION OF COMPLETION
B061	2076990.54	423472.98	5409.6	55.6	2.84	5412.44	55.30	2.0	45.35	9.53	3	BR
B062	2076999.82	423478.33	5411.3	35.6	1.37	5412.67	35.00	2.0	25.04	9.54	3	SA
B063	2077086.74	423520.20	5411.3	56.1	2.62	5413.92	54.00	2.0	44.05	9.52	3	BR
B064	2076923.20	423546.11	5406.5	57.0	2.65	5409.15	54.45	2.0	44.49	9.54	3	BR
B067	2076418.41	423406.40	5403.4	42.3	3.01	5406.41	42.01	2.0	32.07	9.59	3	DA
B068	2076392.27	423552.50	5405.2	38.5	3.44	5408.64	37.82	2.0	27.86	9.61	3	DA
B069	2076663.31	423340.43	5407.3	40.7	3.22	5410.52	38.09	2.0	28.15	9.59	3	DA
B070	2076613.18	423489.79	5407.7	36.8	3.44	5411.14	36.66	2.0	26.71	9.60	3	DA
B071	2076908.19	423328.09	5408.8	40.0	4.50	5413.30	38.58	2.0	28.62	9.60	3	DA
B072	2077004.92	423312.76	5408.4	37.0	3.35	5411.75	36.59	2.0	26.63	9.6	3	SA
B073	2077090.31	423367.87	5409.6	37.7	3.16	5412.76	27.05	2.0	27.05	9.59	3	SA
B074	2076761.36	423478.98	5408.5	35.75	2.98	5411.48	33.58	5.25	23.21	9.97	3	SA
B075	2076815.53	423410.83	5408.6	40.0	1.90	5410.50	39.73	5.25	29.37	9.96	3	SA
B076	2076938.78	423410.88	5411.9	40.85	2.43	5414.33	39.49	5.25	29.10	9.99	3	SA
B077	2077039.90	423385.67	5411.0	37.0	3.33	5414.33	35.05	5.25	24.76	9.99	3	SA
B078	2076419.76	423393.94	5403.4	36.68	3.50	5406.90	36.68	2.0	26.72	9.60	3	SA
B079	2076818.3	423394.9	5409.1	37.5	2.73	5411.83	37.15	2.0	27.20	9.59	3	SA
G032	2077015.27	423444.62	5412.7	45.2	4.07	5416.77	45.00	2.0	25.00	15.00	3	SA
G048	2077112.31	423445.93	5416.6	44.00	2.49	5419.09	-	-	28.40	10.00	3	SA
G049	2076861.24	423467.25	5410.76	42.50	1.69	5412.45	-	-	25.90	10.40	3	SA
G050	2077212.01	423372.38	5413.13	43.00	3.46	5416.59	-	-	26.91	10.30	3	SA

* DEPTH GIVEN IN FEET BELOW GROUND SURFACE

\+ CASING DIAMETER = INSIDE DIAMETER

FORMATION OF COMPLETION CODE:
BR - BEDROCK AQUIFER
SA - SHALLOW ALLUVIAL AQUIFER
DA - DEEP ALLUVIAL AQUIFER

FLOW RELATIONSHIP CODE:
3 - SUBAREA 3

DATA FILE: K:\DART\BLMX\BLM01\MWI10008.DAT

FIELDS DISPLAYED WITH A DASH INDICATE THE DATA IS UNAVAILABLE

Table 6-13. Inorganic Compounds and Metals Detected in the Site 1, Southern Area of the Operable Unit 2 Alluvial Aquifer

Parameter Name	Protection Standard^a	Regional Background Concentration Range^b	Study Area Alluvial Aquifer Background Concentration Range^c	Alluvial Aquifer (Study Subarea 3) Concentration Range^d	Identified as a Contaminant of Concern
Inorganics: (mg/L)					
Bicarbonate	N/A	36 - 2,830	99 - 291	38 - 446	No (1)
Bromide	N/A	N/A	0.26 - 1.2	0.25 - 9.8	No (1)
Calcium	N/A	4 - 2,200	228 - 473	200 - 629	No (1)
Carbonate	N/A	0 -73	U	U	No (1)
Chloride	250 (NM)^e	2 - 34,000	6.4 - 404	19.0 - 2,110	Yes
Magnesium	N/A	1 - 880	19 - 50.9	19.7 - 63.1	No (1)
Nitrate-nitrite, nitrogen	10	0.10 - 1,640^f	1.2 - 4.9	0.67 - 7.3	No (2)
Potassium	N/A	1 - 19,000	1.13 - 6.99	3.03 - 6.9	No (1)
Sodium	N/A	6.2 - 16,000	173 - 452	234 - 1,060	No (1)
Sulfate	400/500p (SDWA)	1.9 - 14,000	420 - 2,120	830 - 2,610	No (3)
Sulfide	N/A	N/A	U - 1.2	4.3 - 12.2	No (2)
Total dissolved solids	10,000	N/A	760 - 3,600	622 - 5,300	No (2)
Metals: (μg/L)					
Aluminum	50s (SDWA)	30 - 1,100	U - 1,280	U	No (2)
Arsenic	50 (SDWA)^g	N/A	U	U	No (2)
Barium	1,000 (SDWA)	0 - 3,400	U	U	No (2)
Beryllium	0.008 (RCRA)^h	N/A	U	U	No (2)
Boron	750 (NM)	20 - 7,500	247 - 294	U	No (2)
Cadmium	10 (SDWA)	1 - 18	U	U	No (2)
Chromium	50 (SDWA)	1 - 60	14.4 - 113	14.5 - 40.6	No (2)
Cobalt	50 (NM)	1 - 6	U	50.3 - 110	Yes
Copper	1,000 (NM)	1 - 12	U - 63.5	U - 90.6	No (2)
Iron	300s (SDWA)	10 - 16,000	U - 1,480	148 - 23,900	No (4)
Lead	50 (NM)	0 - 55	U	U	No (2)
Manganese	200 (NM)	0 - 2,600	16.1 - 423	21.4 - 4,230	Yes

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Table 6-13. (page 2 of 2)

Parameter Name	Protection Standard[a]	Regional Background Concentration Range[b]	Study Area Alluvial Aquifer Background Concentration Range[c]	Alluvial Aquifer (Study Subarea 3) Concentration Range[d]	Identified as a Contaminant of Concern
Mercury	2 (SDWA)	N/A	U	U - 10	No (5)
Molybdenum	1,000 (NM)	N/A	U	U	No (2)
Nickel	100p (SDWA)	N/A	U	40.5 - 3,580	Yes
Selenium	10 (SDWA)	2 - 40	8 - 9.5	5.1 - 61.5	Yes
Silicon	N/A	N/A	5,010 - 6,010	4,440 - 7,850	No (1)
Silver	50 (SDWA)	N/A	27.3 - 30.9	U	No (2)
Strontium	N/A	N/A	3,600 - 8,670	3,800 - 11,400	No (1)
Tin	N/A	N/A	U	U	No (1)
Vanadium	N/A	0 - 63	U	U	No (1)
Zinc	10,000 (NM)	10 - 5,000	22.4 - 642	20 - 462	No (2)

[a] Lowest applicable protection standard between New Mexico human health standard and Safe Drinking Water Act maximum contaminant level is presented.

[b] From Stone et al. 1983.

[c] Groundwater analytical results for monitoring wells BLM-14, BLM-15, and BLM-39; results are also presented in Appendix N.

[d] Groundwater analytical results are presented in Appendix N. Table 2-11 identifies formation of completion for alluvial wells (SA and DA). Monitoring wells within study subarea 3 are shown on Plate 1.

[e] NM = New Mexico human health standard, Section 3-103 (NMWQCC 1988).

[f] Nitrate only.

[g] SDWA = Safe Drinking Water Act maximum contaminant level.

[h] Proposed RCRA action level (55 FR 30865).

(1) No protection standards.

(2) Concentration range is below protection standard.

(3) Concentration range exceeds protection standard; however, range is within regional and/or study area background concentrations that also exceed protection standard.

(4) Maximum detected once; all other values are within study area and/or regional background concentration ranges.

(5) Maximum concentration detected once; all other concentrations are within background ranges and below protection standard.

N/A: not available

p: proposed Safe Drinking Water Act maximum contaminant level

s: secondary Safe Drinking Waer Act maximum contaminant level

U: less than detection limit

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Table 6-14. Organic Compounds Detected in the Site 1, Southern Area of the Operable Unit 2 Alluvial Aquifer (Subarea 3)

Parameter Name	Number of Detections	Maximum Concentration (μg/l)	Lowest Regulatory Standard (μg/l)	Screening Criteria		
				Eliminated Based on Frequency	Identified as a Contaminant of Concern	Comments
Volatile Organic Compounds						
1,1,1-Trichloroethane	8/81	8.0	60^a		Y	
1,1-Dichloroethane	24/81	8.7	25^a		Y	
1,2-*cis*-Dichloroethene[b]	1/2	97	70^cp		Y	
1,2-*trans*-Dichloroethene	29/79	200.0	100^cp		Y	
1,3-*trans*-Dichloropropene	1/81	2.2	10^d	x		Only 1 time detection
Benzene	9/80	110.0	5^c		Y	
Dichlorodifluoromethane	3/79	10	$7,000^d$	x		Only 1 time detection per well/5 clean samples
Dichloromethane (methylene chloride)	23/81	47.0	5^cp		Y	
Ethylbenzene	1/80	0.7	700^cp	x		Only 1 time detection
Tetrachloroethene (PCE)	35/81	18.0	5^cp		Y	
Toluene	4/80	1.6	750^a	x		Only 1 detection per well
Trichloroethene	33/81	19.0	5^c		Y	
Trichloromethane (chloroform)	15/81	6.3	100^a		Y	
Vinyl chloride	1/81	3.6	1^a	x		Only 1 time detection/6 clean samples
Xylene (total)	4/80	1.6	620^a	x		Only 1 time detection/clean since 1990
Semivolatile Organic Compounds						
Methylnaphthalene, 2-	1/56	1	N/A	x		Only 1 time detection
bis(2-Ethylhexyl) phthalate	22/56	23	3^d	x		18 detections below limit
Di-n-butyl phthalate	2/56	3	N/A	x		Only 1 detection per well
Di-n-octyl phthalate	1/56	2.0	N/A	x		Only 1 time detection
Naphthalene	1/56	2	N/A	x		Only 1 time detection
N-Nitrosodiphenylamine	1/56	1	7^d	x		Only 1 time detection

Table 6-14. (page 2 of 2)

Parameter Name	Number of Detections	Maximum Concentration (µg/l)	Lowest Regulatory Standard (µg/l)	Screening Criteria		
				Eliminated Based on Frequency	Identified as a Contaminant of Concern	Comments
Pesticides/PCBs						
gamma-BHC (Lindane)	1/54	0.01	4[c]	x		Only 1 time detection

[a] New Mexico human health standard, Section 3-103 (NMWQCC 1988).

[b] 1,2-*cis*-Dichloroethene coelutes with 1,2-*trans*-dichloroethene and therefore, in most cases, was reported as the trans isomer. Both isomers are considered in the discussions of contaminants of concern.

[c] Safe Drinking Water Act maximum contaminant level.

[d] Proposed RCRA action level (55 FR 30865).

p: proposed Safe Drinking Water Act maximum contaminant level
Y: identified as a contaminant of concern
x: contaminant is eliminated as a contaminant of concern

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Table 6-15. Summary of Groundwater Analytical Results for the Site 1, Southern Area of the Operable Unit 2 Alluvial Aquifer - Organic Compounds

Monitoring Wells	Chlorinated Hydrocarbon Concentrations, µg/L						Other Organic Compounds Concentrations, µg/L		
Site 1 - Southern Area of Contamination[a]	1,1,1-Trichloroethane	1,1-Dichloroethane	1,2-Dichloroethene[b]	Tetrachloroethene	Trichloroethene	Vinyl Chloride	Trichloromethane	Dichloromethane	Benzene[c]
GBR-50	U	U - 3.1	U - 1.2	U	U	U	U	14 - 13	U - 66
GBR-48	1.1 - 8	2.9 - 8.7	81 - 200	9.6 - 18	7.5 - 19	U - 3.6	2.3 - 4.5	1.8 - 15	80 - 110
BLM-73	U	U	1.4 - 1.6	1.2 - 1.3	U	U	U	U	U
BLM-77	U	U	1.1 - 1.3	U	U	U	U	U	U
GBR-32	0.8 - 5.9	1.3 - 5.4	70 - 140	6 - 16	4.3 - 12	U	1.6 - 3.7	U - 2.3	68 - 100
BLM-76	U	U	8.9 - 10	2.5 - 3.4	1.2 - 1.7	U	U - 1.2	6.4 - 11	U
GBR-49	U	0.53 - 4.6	49 - 64	5.1 - 11	4 - 7.5	U	U - 3.1	0.68 - 13	45 - 64
BLM-74	U	U	7.5 - 15	2.3 - 3	1.4 - 2	U	U	5.3 - 5.6	U
BLM-70	U	U	11 - 11	2.8 - 3.3	1.3 - 1.8	U	U	U	U
BLM-68	U	3.6 - 5.4	96 - 150	9.7 - 14	6.1 - 9.4	U	1.4 - 1.8	U	U
Other Site 1 Southern Area Monitoring Wells[d]									
BLM-62	U	U	U	U	U	U	U	0.9 - 4.9	U
BLM-67	U	U	U	U	U	U	U	U	U
BLM-69	U	U	U	U	U	U	U	U - 14	U
BLM-71	U	U	U	U	U	U	U	U	U
BLM-72	U	U	U	U	U	U	U	5.4 - 6.6	U
BLM-75	U	U	U	U	U	U	U	12	U
BLM-78	U	U	U	U	U	U	U - 1.7	U	U
BLM-79	U	U	U	U	U	U	U - 6.3	5.7 - 12	U
GBR-17	U	U	U	U	U	U	U	5 - 5.8	U

[a] Wells with chlorinated hydrocarbon contamination are presented from northernmost to southernmost and are shown on Figure 6-2.
[b] Both isomers.
[c] Detection occurred in the 1990 sampling events only.
[d] Wells without chlorinated hydrocarbon contamination.

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Table 6-16. Potential Degradation Products for the Site 1, Southern Area of Operable Unit 2 Groundwater Contamination

Contaminant	Potential Degradation Product(s)
1,1-Dichloroethane	Chloroethane
1,1,1-Trichloroethane	1,2-*cis*-Dichloroethene 1,1-Dichloroethane 1,1-Dichloroethene
1,2-Dichloroethene (*cis/trans*)	Vinyl chloride and chloroethane
Dichloromethane (methylene chloride)	Essentially unchanged
Tetrachloroethene	Trichloroethene
Trichloroethene	1,2-*cis*-Dichloroethene (primary), and 1,2-*trans*-Dichloroethene
Trichloromethane	Essentially unchanged
Vinyl chloride	Carbon dioxide and water

Ref: Davis and Olsen 1990

Note: Dichloromethane and trichloromethane probably do not degrade significantly. These compounds may have been co-solvents or impurities in the initial chlorinated hydrocarbons.

Table 6-17. Summary of Benzene Concentrations in the Southern Area of the Operable Unit 2 Alluvial Aquifer
SITE: BLM01 BLM (Lee Acres)
08/24/88 TO 07/18/91
REPORT DATE: 12/10/91

PARAMETER NAME	LOCATION ID	LOG DATE	SAMPLE ID	FORM COMP	FLOW REL.	UNITS OF MEASURE	PVI	PARAMETER VALUE	DETECTION LIMIT	LAB CODE	DILUTION FACTOR
BENZENE	B062	03/21/90	0002	SA	3	UG/L	U	0.50	0.50	RWS	-
	B062	03/21/90	0003	SA	3	UG/L	U	0.50	0.50	RWS	-
	B062	04/27/90	0008	SA	3	UG/L	U	0.50	0.50	RWS	-
	B062	05/20/90	0005	SA	3	UG/L	U	0.50	0.50	RWS	-
	B062	05/20/90	0006	SA	3	UG/L	U	0.50	0.50	RWS	-
	B062	05/23/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B062	06/20/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B062	07/18/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B067	05/21/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B067	06/19/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B067	07/16/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B068	05/22/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B068	06/19/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B068	06/22/91	1111	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B068	07/16/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B068	07/16/91	1111	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B069	05/21/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B069	06/19/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B069	07/17/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B070	05/22/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B070	05/22/91	0002	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B070	06/19/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B070	07/16/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B070	07/16/91	1111	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B071	05/22/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B071	06/20/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B071	07/16/91	0001	DA	3	UG/L	U	1.0	1.0	RWL	1.00
	B072	05/22/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B072	06/20/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B072	07/17/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B072	07/17/91	0002	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B073	05/22/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B073	06/20/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B073	07/17/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B073	07/17/91	1111	SA	3	UG/L	U	1.0	1.0	RWL	1.00

Table 6-17. Summary of Benzene Concentrations in the
Southern Area of the Operable Unit 2 Alluvial Aquifer
SITE: BLM01 BLM (Lee Acres)
08/24/88 TO 07/18/91
REPORT DATE: 12/10/91

PARAMETER NAME	LOCATION ID	LOG DATE	SAMPLE ID	FORM COMP	FLOW REL.	UNITS OF MEASURE	PVI	PARAMETER VALUE	DETECTION LIMIT	LAB CODE	DILUTION FACTOR
BENZENE	B074	05/22/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B074	06/19/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B074	07/16/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B074	07/16/91	1111	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B075	05/21/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B075	06/19/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B075	06/19/91	0002	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B075	07/16/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B075	07/16/91	0002	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B076	05/21/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B076	06/20/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B076	06/20/91	0002	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B076	07/16/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B076	07/16/91	1111	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B077	05/22/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B077	06/20/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B077	07/17/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B077	07/17/91	1111	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B078	05/21/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B078	06/19/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B078	07/16/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B079	05/21/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B079	06/19/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	B079	07/16/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G017	08/24/88	0001	NR	3	UG/L	U	5	5	RWS	-
	G017	03/14/89	0001	NR	3	UG/L	U	0.2	0.2	INL	-
	G017	06/14/89	0001	NR	3	UG/L	U	0.2	0.2	INL	-
	G017	04/03/90	0001	NR	3	UG/L	U	0.20	0.20	RDC	-
	G017	08/23/90	0007	NR	3	UG/L	U	0.50	0.50	RWS	-
	G017	10/04/90	0001	NR	3	UG/L		4.6	2.0	RDC	10
	G017	05/23/91	0001	NR	3	UG/L	U	1.0	1.0	RWL	1.00
	G017	06/21/91	0001	NR	3	UG/L	U	1.0	1.0	RWL	1.00
	G017	06/21/91	1111	NR	3	UG/L	U	1.0	1.0	RWL	1.00
	G017	07/18/91	0001	NR	3	UG/L	U	1.0	1.0	RWL	1.00
	G017	07/18/91	1111	NR	3	UG/L	U	1.0	1.0	RWL	1.00

Table 6-17. Summary of Benzene Concentrations in the Southern Area of the Operable Unit 2 Alluvial Aquifer
SITE: BLM01 BLM (Lee Acres)
08/24/88 TO 07/18/91
REPORT DATE: 12/10/91

PARAMETER NAME	LOCATION ID	LOG DATE	SAMPLE ID	FORM COMP	FLOW REL.	UNITS OF MEASURE	PVI	PARAMETER VALUE	DETECTION LIMIT	LAB CODE	DILUTION FACTOR
BENZENE	G032	08/24/88	0003	SA	3	UG/L	U	5	5	RWS	-
	G032	03/14/89	0001	SA	3	UG/L		0.81	0.2	RDC	-
	G032	06/13/89	0001	SA	3	UG/L	U	0.2	0.2	INL	-
	G032	12/10/89	0001	SA	3	UG/L		96	0.20	RDC	-
	G032	12/12/89	0001	SA	3	UG/L		96	0.20	RDC	1
	G032	12/20/89	0001	SA	3	UG/L	U	0.20	0.20	RDC	-
	G032	03/22/90	0002	SA	3	UG/L		68	0.50	RWS	-
	G032	04/26/90	0017	SA	3	UG/L		94	0.50	RWS	-
	G032	05/18/90	0003	SA	3	UG/L		96	0.50	RWS	-
	G032	09/18/90	0001	SA	3	UG/L		100	0.50	RWS	-
	G032	05/23/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G032	06/21/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G032	06/21/91	1111	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G032	07/18/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G032	07/18/91	1111	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G048	03/14/89	0001	SA	3	UG/L		0.24	0.2	INL	-
	G048	06/13/89	0001	SA	3	UG/L	U	0.2	0.2	INL	-
	G048	03/22/90	0001	SA	3	UG/L		80	0.50	RWS	-
	G048	04/26/90	0016	SA	3	UG/L		110	0.50	RWS	-
	G048	05/18/90	0002	SA	3	UG/L		96	0.50	RWS	-
	G048	06/18/90	0001	SA	3	UG/L		5.7	5.0	RDC	25
	G048	06/18/90	0001	SA	3	UG/L		5.70	-	INL	-
	G048	08/23/90	0009	SA	3	UG/L	U	0.50	0.50	RWS	-
	G048	05/23/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G048	05/23/91	0002	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G048	06/21/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G048	06/21/91	0002	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G048	06/21/91	1111	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G048	07/18/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G048	07/18/91	0002	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G048	07/18/91	0004	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G048	07/18/91	1111	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G049	03/14/89	0001	SA	3	UG/L		0.63	0.2	INL	-
	G049	06/14/89	0001	SA	3	UG/L	U	0.2	0.2	INL	-
	G049	12/10/89	0001	SA	3	UG/L		74	0.20	RDC	-
	G049	12/12/89	0001	SA	3	UG/L		74	0.20	RDC	5

Table 6-17. Summary of Benzene Concentrations in the Southern Area of the Operable Unit 2 Alluvial Aquifer
SITE: BLM01 BLM (Lee Acres)
08/24/88 TO 07/18/91
REPORT DATE: 12/10/91

PARAMETER NAME	LOCATION ID	LOG DATE	SAMPLE ID	FORM COMP	FLOW REL.	UNITS OF MEASURE	PVI	PARAMETER VALUE	DETECTION LIMIT	LAB CODE	DILUTION FACTOR
BENZENE	G049	03/22/90	0003	SA	3	UG/L		45	0.50	RWS	-
	G049	04/26/90	0018	SA	3	UG/L	U	0.50	0.50	RWS	-
	G049	05/18/90	0004	SA	3	UG/L		64	0.50	RWS	-
	G049	08/23/90	0010	SA	3	UG/L	U	0.50	0.50	RWS	-
	G049	05/23/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G049	06/21/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G049	07/18/91	1111	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G050	03/22/90	0005	SA	3	UG/L		0.66	0.50	RWS	-
	G050	04/26/90	0015	SA	3	UG/L	U	0.50	0.50	RWS	-
	G050	05/18/90	0001	SA	3	UG/L	U	0.50	0.50	RWS	-
	G050	08/23/90	0012	SA	3	UG/L	U	0.50	0.50	RWS	-
	G050	05/23/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G050	06/21/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G050	06/21/91	1111	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G050	07/18/91	0001	SA	3	UG/L	U	1.0	1.0	RWL	1.00
	G050	07/18/91	1111	SA	3	UG/L	U	1.0	1.0	RWL	1.00

FORMATION OF COMPLETION CODE:
DA - DEEP ALLUVIAL AQUIFER
NR - NOT REPORTED
SA - SHALLOW ALLUVIAL AQUIFER

FLOW RELATIONSHIP CODE:
3 - SUBAREA 3

PARAMETER VALUE INDICATOR (PVI): U - LESS THAN DETECTION LIMIT

DATA FILE NAME: K:\DART\BLMX\BLM01\GWQ10011.DAT

Table 6-18. Inorganic Compounds and Metals Detected in the Site 1, Southern Area of the Operable Unit 2 Bedrock Aquifer

Parameter Name	Protection Standard[a]	Regional Background Concentration Range[b]	Study Area Bedrock Aquifer Background Concentration Range[c]	Bedrock Aquifer (Study Subarea 3) Concentration Range[d]	Identified as a Contaminant of Concern
Inorganics: (mg/L)					
Bicarbonate	N/A	36 - 2,830	42 - 169	76 - 136	No (1)
Bromide	N/A	N/A	0.26 - 2.4	U - 0.61	No (1)
Calcium	N/A	4 - 2,200	312 - 543	336 - 411	No (1)
Carbonate	N/A	0 -73	U	U	No (1)
Chloride	250 (NM)[e]	2 - 34,000	10.8 - 26.1	14.7 - 25.7	No (2,3)
Magnesium	N/A	1 - 880	14.8 - 33.2	17.3 - 23.4	No (1)
Nitrate-nitrite, nitrogen	10	0.10 - 1,640[f]	0.7 - 9.8	2.0 - 2.5	No (4)
Potassium	N/A	1 - 19,000	5.31 - 24.8	5.23 - 12.4	No (1)
Sodium	N/A	6.2 - 16,000	56 - 791	538 - 704	No (1)
Sulfate	400/500p (SDWA)	1.9 - 14,000	370 - 3,030	1,950 - 5,830	No (5)
Sulfide	N/A	N/A	U	U	No (4)
Total dissolved solids	10,000	N/A	3,500 - 11,800	1,600 - 4,210	No (4)
Metals: (μg/L)					
Aluminum	50s (SDWA)	30 - 1,100	U - 434	U - 544	No (4)
Arsenic	50 (SDWA)[g]	N/A	U	U - 30.5	No (4)
Barium	1,000 (SDWA)	0 - 3,400	U	U	No (4)
Beryllium	0.008 (RCRA)[h]	N/A	U	U	No (4)
Boron	750 (NM)	20 - 7,500	368 - 394	U	No (4)
Cadmium	10 (SDWA)	1 - 18	U	U	No (4)
Chromium	50 (SDWA)	1 - 60	U - 59.1	U	No (4)
Cobalt	50 (NM)	1 - 6	U	U	No (4)
Copper	1,000 (NM)	1 - 12	U - 149	U	No (4)
Iron	300s (SDWA)	10 - 16,000	220 - 993	125 - 1,220	No (5)
Lead	50 (NM)	0 - 55	U	U	No (6)
Manganese	200 (NM)	0 - 2,600	149 - 504	252 - 882	No (5)

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Parameter Name	Protection Standard[a]	Regional Background Concentration Range[b]	Study Area Bedrock Aquifer Background Concentration Range[c]	Bedrock Aquifer (Study Subarea 3) Concentration Range[d]	Identified as a Contaminant of Concern
Mercury	2 (SDWA)	N/A	U - 0.22	U	No (4)
Molybdenum	1,000 (NM)	N/A	N/A	U	No (4)
Nickel	100p (SDWA)	N/A	U	U	No (4)
Selenium	10 (SDWA)	2 - 40	U	U - 30.1	No (5)
Silicon	N/A	N/A	6,030 - 6,410	U	No (1)
Silver	50 (SDWA)	N/A	U - 28.6	U	No (4)
Strontium	N/A	N/A	U - 8,560	6,910 - 8,590	No (1)
Tin	N/A	N/A	U	U	No (1)
Vanadium	N/A	0 - 63	U	U	No (1)
Zinc	10,000 (NM)	10 - 5,000	21 - 394	23.3 - 191	No (4)

[a] Lowest applicable protection standard between New Mexico human health standard and Safe Drinking Water Act maximum contaminant level is presented.

[b] From Stone et al. 1983.

[c] Groundwater analytical results for monitoring wells BLM-16 and BLM-40; results are also presented in Apendix N.

[d] Groundwater analytical results are presented in Appendix N. Monitoring wells within study subarea 3 are shown on Plate 1.

[e] NM = New Mexico human health standard, Section 3-103 (NMWQCC 1988).

[f] Nitrate only.

[g] SDWA = Safe Drinking Water Act maximum contaminant level.

[h] Proposed RCRA action level (55 FR 30865).

(1) No protection standards.

(2) Several concentrations exceed standard and study area background concentrations; however, range is within the regional range and high concentrations have decreased over time.

(3) Maximum concentration detected once; all other concentrations are within background ranges and below protection standard.

(4) Concentration range is below protection standard.

(5) Maximum detected once; all other values are within study area and/or regional background concentration ranges.

(6) Concentration range exceeds protection standard; however, range is within regional and/or study area background concentrations that also exceed protection standard.

N/A: not available
p: proposed Safe Drinking Water Act maximum contaminant level
s: secondary Safe Drinking Water Act maximum contaminant level
U: less than detection limit

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Table 6-19. Organic Compounds Detected in the Site 1, Southern Area of the Operable Unit 2 Bedrock Aquifer

				Screening Criteria		
Parameter Name	Number of Detections	Maximum Concentration ($\mu g/L$)	Lowest Regulatory Standard[a] ($\mu g/L$)	Eliminated Based on Frequency	Identified as a Contaminant of Concern	Comments
Volatile Organic Compounds						
1,1,1-Trichloroethane	2/21	1.4	60[b]	x		Only 1 detection per well, 4 clean samples
Dichloromethane (methylene chloride)	7/21	5.6	5p[a]		Y	
Toluene	2/18	1.0	750[b]	x		Onle 1 detection per well
Trichloromethane (chloroform)	1/21	1.8	100[b]	x		Only 1 time detection
Xylene (total)	2/18	1.2	620[b]	x		Only 1 detection per well
Semivolatile Organic Compounds						
bis(2-Ethylhexyl) phthalate	1/9	1	3[c]	x		Only 1 time detection
Di-n-butyl phthalate	1/9	2	N/A	x		Only 1 time detection

[a] Safe Drinking Water Act maximum contaminant level.
[b] New Mexico human health standard, Section 3-103 (NMWQCC 1988).
[c] Proposed RCRA action level (55 FR 30865).
N/A: not available
p: proposed Safe Drinking Water Act maximum contaminant level
x: contaminant is eliminated as a contaminant of concern

Table 6-20. Dissolved Constituents from Selected Monitoring Wells in Site 2

Well	Sample Period	Inorganics			Petroleum Hydrocarbons (BTEX)				Chlorinated Hydrdocarbons [a]		
		Total Dissolved Solid (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	Total Xylenes (ug/L)	1,1,1-Trichloro-ethane (ug/L)	1,2-Dichloro-benzene (ug/L)	1,1-Dichloro-ethane (ug/L)
Giant-Bloomfield Refinery Wells [b] :											
GBR-6	11/86	3252	358	1293	70.0	U	U	1240	U	0.77	U
	12/89	2486	294.4	609	110	U	85.0	140	U	U	U
GBR-8	11/87	NA	NA	NA	6500	820	1200	3600	2.2	U	U
	01/90	3690	710	1220	U	U	U	130	U	U	1.3
GBR-10	11/86	3332	1149	463	9500	1100	670	3150	U	U	U
GBR-11	11/86	3460	1194	294	6500	2600	680	2780	5.5	U	U
GBR-14 (GRW-13)	04/90	3822	639.6	1274.4	U	U	U	U	U	U	U
	04/90	2442	262	1122	U	U	U	U	U	U	U
GBR-15	10/86	NA	NA	NA	334	52.0	209	772	U	U	U
	04/90	3746	355.4	2029.5	110	U	U	U	U	U	U
GBR-19	10/86	1884	547	401	112	105	111	306	U	U	12.0
	08/88	3070	438	1240	U	U	U	U	U	U	U
GBR-24D	11/86	2826	618	943	230	5.0	180	147	U	U	U
	04/90	3534	548.3	1381.1	31	2.3	13.0	6.7	U	U	U
GBR-29 (GRW-3)	11/86	8288	2819	1481	240	72.0	98.0	1400	8.0	U	34.0
	04/90	3186	416.3	1218	280	240	98.0	33.0	U	U	U
GBR-31	11/86	9672	2901	2249	U	U	U	U	12.0	U	22.0
	04/90	3310	568.6	1294.6	0.98	U	U	6.0	U	U	U
GBR-33	09/87	NA	NA	NA	764	188	1120	1393	U	1.1	1.0
	04/90	3488	599	1395.8	U	U	U	U	0.24	U	1.3
GBR-44 (GRW-6)	06/88	4012	633	1180	10.0	0.7	U	U	1.6	U	5.5
	04/90	3100	811.5	737.4	16.0	0.65	U	3.4	U	U	2.1
Wells sampled by WESTON [c] :											
BLM-27	04/90	2480	149	1380	U	U	U	U	U	U	U
	01/88	3280	375	1330	U	U	U	U	U	U	U
BLM-37	12/89	4420	417	1610	8700	1200	1500	5400	U	U	U
	05/89	4430	451	1950	9900	1600	2500	12000	U	U	U
BLM-65	03/90	3170	163	1710	U	U	U	U	U	U	U
	05/90	NA	NA	NA	U	U	U	U	U	U	1.5
	05/91	3150	22	1670	U	U	U	U	U	U	3.4
BLM-66	03/90	2960	17.9	1600	U	U	U	U	U	U	U
	05/90	3190	59.3	1840	U	U	U	U	U	U	U
HP-23 [d]	01/90	NA	520	1580	U	U	U	U	1.6	U	U
HP-24 [d]	01/90	NA	1800	563	U	U	U	U	6.9	U	10.0
HP-40 [d]	01/90	NA	27	1530	U	U	U	U	3.4	U	10.0
SHS-1	12/89	3360	783	1190	100	44.0	160	300	U	U	5.4
SHS-2	12/89	3140	361	1110	59.0	62	140	150	U	U	U

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Well	Sample Period	Chlorinated Hydrocarbons[a]								
		1,2-Dichloro-ethane (ug/L)	1,1-Dichloro-ethene (ug/L)	1,2-cis-Dichloro-ethene (ug/L)	1,2-trans-Dichloro-ethene (ug/L)	Chloroethane (ug/L)	Trichloromethane (ug/L)	Dichloromethane (ug/L)	Tetrachloro-ethene (ug/L)	Trichloro-ethene (ug/L)
Giant–Bloomfield Refinery Wells[b]:										
GBR-6	11/86	3.0	U	U	U	U	U	U	U	U
	12/89	1.2	U	U	U	U	U	U	U	U
GBR-8	11/87	32.0	U	U	U	U	12.0	U	U	U
	01/90	U	U	U	16.0	U	U	U	U	U
GBR-10	11/86	150	U	U	U	U	U	U	U	U
GBR-11	11/86	170	U	U	U	U	U	U	U	U
GBR-14 (GRW-13)	04/90	4.5	U	U	U	U	U	U	U	U
	04/90	9.0	U	U	U	U	U	U	U	U
GBR-15	10/86	78.0	U	U	U	U	U	U	U	U
	04/90	84.0	U	U	U	U	U	U	U	U
GBR-19	10/86	5.9	U	U	14.0	U	U	U	U	9.3
	08/88	U	U	U	U	U	U	U	U	U
GBR-24D	11/86	69.0	U	U	U	U	U	U	U	U
	04/90	16.0	U	U	U	U	U	U	U	U
GBR-29 (GRW-3)	11/86	28.0	U	14.0	U	U	U	U	U	12.0
	04/90	U	U	14.0	U	U	U	U	U	U
GBR-31	11/86	U	U	23.0	U	U	U	U	16.0	12.0
	04/90	1.0	U	6.2	U	U	U	U	0.64	0.86
GBR-33	09/87	22.8	U	U	3.4	0.4	U	U	0.4	0.4
	04/90	0.21	U	12.0	U	U	U	U	2.5	1.1
GBR-44 (GRW-6)	06/88	2.4	U	20.0	U	U	U	4.0	6.7	3.6
	04/90	7.9	U	U	U	U	U	1.1	2.7	2.3
Wells sampled by WESTON[c]:										
BLM-27	01/88	U	U	U	U	U	U	6.0	U	U
	04/90	U	U	U	U	U	U	U	U	U
BLM-37	05/89	81.0	U	U	U	U	U	U	U	U
	12/89	100	U	U	U	U	U	U	U	U
BLM-65	03/90	9.7	U	U	U	U	U	U	U	U
	05/90	8.5	U	U	U	U	U	U	U	U
	05/91	3.6	U	U	U	U	U	U	U	U
BLM-66	03/90	U	U	U	U	U	U	U	U	U
	05/90	U	U	U	U	U	U	U	U	U
HP-23	01/90	U	4.1	U	8.2	U	U	U	6.9	6.1
HP-24	01/90	29	U	U	13.0	U	U	U	7.0	9.0
HP-40	01/90	29	U	U	3.5	U	5.6	U	18.0	11.0
SHS-1	12/89	6.3	U	U	U	U	16	U	U	2.4
SHS-2	12/89	U	U	U	U	U	U	U	U	U

[a] The following chlorinated hydrocarbons were analyzed but not detected: 1,1,2-trichloroethane, 1,1,2,2-tetrachloroethane, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichloropropane, chlorobenzene, chloromethane, and vinyl chloride.

[b] Data obtained from NMOCD 1990.

[c] Data presented in Appendix N-1.

[d] Data presented in Appendix G.

NA: not analyzed
U: below detection limit

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Table 6-21. Inorganic Compounds and Metals Detected in the Site 2 Alluvial Aquifer

Parameter Name	Protection Standard[a]	Regional Background Concentration Range[b]	Study Area Alluvial Aquifer Background Concentration Range[c]	Alluvial Aquifer (Study Subarea 4) Concentration Range[d]	Identified as a Contaminant of Concern
Inorganics: (mg/L)					
Bicarbonate	N/A	36 - 2,830	99 - 291	56 - 590	No (1)
Bromide	N/A	N/A	0.26 - 1.2	0.26 - 3	No (1)
Calcium	N/A	4 - 2,200	228 - 473	167.73 - 795	No (1)
Carbonate	N/A	0 -73	U	U	No (1)
Chloride	250 (NM)[e]	2 - 34,000	6.4 - 404	3.5 - 604	Yes
Magnesium	N/A	1 - 880	19 - 50.9	5.5 - 189.03	No (1)
Nitrate-nitrite, nitrogen	10	0.10 - 1,640[f]	1.2 - 4.9	0.2 - 28	Yes
Potassium	N/A	1 - 19,000	1.13 - 6.99	1 - 18.9	No (1)
Sodium	N/A	6.2 - 16,000	173 - 452	142 - 754	No (1)
Sulfate	400/500p (SDWA)	1.9 - 14,000	420 - 2,120	310 - 3,220	Yes
Sulfide	N/A	N/A	U - 1.2	8 - 60,400	Yes
Total dissolved solids	10,000	N/A	760 - 3,600	616 - 6,370	No (2)
Metals: (μg/L)					
Aluminum	50s (SDWA)	30 - 1,100	U - 1,280	U - 68,900	Yes
Arsenic	50 (SDWA)[g]	N/A	U	U - 61	Yes
Barium	1,000 (SDWA)	0 - 3,400	U	750 - 1,400	Yes
Beryllium	0.008 (RCRA)[h]	N/A	U	U - 6.1	Yes
Boron	750 (NM)	20 - 7,500	247 - 294	234 - 346	No (2)
Cadmium	10 (SDWA)	1 - 18	U	U - 5.5	No (2)
Chromium	50 (SDWA)	1 - 60	14.4 - 113	43 - 110	Yes
Cobalt	50 (NM)	1 - 6	U	25.8 - 82.1	Yes
Copper	1,000 (NM)	1 - 12	U - 63.5	25.8 - 178	No (2)
Iron	300s (SDWA)	10 - 16,000	U - 1,480	74.9 - 64,100	Yes
Lead	50 (NM)	0 - 55	U	6.1 - 130	Yes
Manganese	200 (NM)	0 - 2,600	16.1 - 423	13.1 - 3,400	Yes

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Parameter Name	Protection Standard[a]	Regional Background Concentration Range[b]	Study Area Alluvial Aquifer Background Concentration Range[c]	Alluvial Aquifer (Study Subarea 4) Concentration Range[d]	Identified as a Contaminant of Concern
Mercury	2 (SDWA)	N/A	U - 10	0.20 - 0.93	No (2)
Molybdenum	1,000 (NM)	N/A	U	U	No (2)
Nickel	100p (SDWA)	N/A	U	40.7 - 70.3	No (2)
Selenium	10 (SDWA)	2 - 40	8 - 9.5	2.4 - 69	Yes
Silicon	N/A	N/A	5,010 - 6,010	5,620 - 9,620	No (1)
Silver	50 (SDWA)	N/A	27.3 - 30.9	U - 37.2	No (2)
Strontium	N/A	N/A	3,600 - 8,670	5,640 - 10,300	No (1)
Tin	N/A	N/A	U	103 - 111	No (1)
Vanadium	N/A	0 - 63	U	U - 129	No (1)
Zinc	10,000 (NM)	10 - 5,000	22.4 - 642	20 - 564	No (2)

[a] Lowest applicable protection standard between New Mexico human health standard and Safe Drinking Water Act maximum contaminant level is presented.

[b] From Stone et al. 1983.

[c] Groundwater analytical results for monitoring wells BLM-14, BLM-15, and BLM-39; results are also presented in Appendix N.

[d] Groundwater analytical results are presented in Appendix N. Table 2-11 identifies formation of completion for alluvial wells (SA and DA). Monitoring wells within study subarea 4 are shown on Plate 1.

[e] NM = New Mexico human health standard, Section 3-103 (NMWQCC 1988).

[f] Nitrate only.

[g] SDWA = Safe Drinking Water Act maximum contaminant level.

[h] Proposed RCRA action level (55 FR 30865).

(1) No protection standards.

(2) Concentration range is below protection standard.

N/A: not available

p: proposed Safe Drinking Water Act maximum contaminant level

s: secondary Safe Drinking Water Act maximum contaminant level

U: less than detection limit

Table 6-22. Organic Compounds Detected in the Site 2 Alluvial Aquifer

Parameter Name	Number of Detections	Maximum Concentration (µg/L)	Lowest Regulatory Standard (µg/L)	Screening Criteria		
				Eliminated Based on Frequency	Identified as a Contaminant of Concern	Comments
Volatile Organic Compounds						
1,1,1-Trichloroethane	3/120	3.4	60^{c}	x		Only 1 detection per well
1,1-Dichloroethane	8/120	12.0	25^{c}		Y	
1,2-*cis*-Dichloroethene	1/62	4	70p^{a}	x		Only 1 time detection
1,2-Dichloroethane	6/120	11	5^{a}		Y	
Acetone	9/60	910.0	4,000^{b}	x		Only 1 detection per well
Dichloromethane (methylene chloride)	32/120	46.0	5p^{a}		Y	
Ethylbenzene	2/119	1.4	700p^{a}	x		Only 1 detection per well
Tetrachloroethene (PCE)	1/119	2.0	5p^{a}	x		Only 1 time detection
Vinyl acetate	1/60	2	N/A	x		Only 1 time detection
Xylene (total)	8/119	1.5	620^{c}	x		Only 1 detection per well
Semivolatile Organic Compounds						
1,2-Dichlorobenzene	1/99	1.9	75^{a}	x		Only 1 time detection
bis(2-Ethylhexyl) phthalate	2/48	49 B	3^{b}	x		Only 1 detection per well
Di-n-butyl phthalate	1/48	0.6	N/A	x		Only 1 time detection
Di-n-octyl phthalate	2/48	2	N/A	x		Only 1 detection per well

[a] Safe Drinking Water Act maximum contaminant level.
[b] Proposed RCRA action level (55 FR 30865).
[c] New Mexico human health standard, Section 3-103 (NMWQCC 1988).
N/A: not available
p: proposed Safe Drinking Water Act maximum contaminant level
Y: identified as a contaminant of concern
x: contaminant is eliminated as a contaminant of concern

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Table 6-23. Inorganic Compounds and Metals Detected in the Site 2 Bedrock Aquifer

Parameter Name	Protection Standard[a]	Regional Background Concentration Range[b]	Study Area Bedrock Aquifer Background Concentration Range[c]	Bedrock Aquifer (Study Subarea 4) Concentration Range[d]	Identified as a Contaminant of Concern
Inorganics: (mg/L)					
Bicarbonate	N/A	36 - 2,830	42 - 169	25 - 465	No (1)
Bromide	N/A	N/A	0.26 - 2.4	U - 0.32	No (1)
Calcium	N/A	4 - 2,200	312 - 543	97.8 - 607	No (1)
Carbonate	N/A	0 - 73	U	42 - 3,300	No (1)
Chloride	250 (NM)[e]	2 - 34,000	10.8 - 26.1	15.1 - 448	No (2)
Magnesium	N/A	1 - 880	14.8 - 33.2	1.62 - 23.6	No (1)
Nitrate-nitrite, nitrogen	10	0.10 - 1,640[f]	0.7 - 9.8	0.05 - 0.43	No (3)
Potassium	N/A	1 - 19,000	5.31 - 24.8	2.4 - 272	No (1)
Sodium	N/A	6.2 - 16,000	56 - 791	393 - 836	No (1)
Sulfate	400/500p (SDWA)	1.9 - 14,000	370 - 3,030	304.4 - 4,460	No (4)
Sulfide	N/A	N/A	U	7.2 - 110	No (1)
Total dissolved solids	10,000	N/A	3,500 - 11,800	2,770 - 4,710	No (3)
Metals: (μg/L)					
Aluminum	50s (SDWA)	30 - 1,100	U - 434	U	No (3)
Arsenic	50 (SDWA)[g]	N/A	U	U	No (3)
Barium	1,000 (SDWA)	0 - 3,400	U	U	No (3)
Beryllium	0.008 (RCRA)[h]	N/A	U	U - 5.1	Yes
Boron	750 (NM)	20 - 7,500	368 - 394	293 - 382	No (3)
Cadmium	10 (SDWA)	1 - 18	U	U - 5.1	No (3)
Chromium	50 (SDWA)	1 - 60	U - 59.1	55.7 - 68.4	Yes
Cobalt	50 (NM)	1 - 6	U	U	No (3)
Copper	1,000 (NM)	1 - 12	U - 149	27.4 - 133	No (3)
Iron	300s (SDWA)	10 - 16,000	220 - 993	118 - 851	No (3)
Lead	50 (NM)	0 - 55	U	U	No (3)
Manganese	200 (NM)	0 - 2,600	149 - 504	89.5 - 419	No (4)
Mercury	2 (SDWA)	N/A	U - 0.22	0.21 - 0.51	No (3)

Table 6-23. (page 2 of 2)

Parameter Name	Protection Standard[a]	Regional Background Concentration Range[b]	Study Area Bedrock Aquifer Background Concentration Range[c]	Bedrock Aquifer (Study Subarea 4) Concentration Range[d]	Identified as a Contaminant of Concern
Molybdenum	1,000 (NM)	N/A	N/A	13.3 - 24.5	No (3)
Nickel	100p (SDWA)	N/A	U	U	No (3)
Selenium	10 (SDWA)	2 - 40	U	U	No (3)
Silicon	N/A	N/A	6,030 - 6,410	1,000 - 8,170	No (1)
Silver	50 (SDWA)	N/A	U - 28.6	27.9 - 33.9	No (3)
Strontium	N/A	N/A	U - 8,560	4,110 - 9,250	No (1)
Tin	N/A	N/A	U	U	No (1)
Vanadium	N/A	0 - 63	U	U	No (1)
Zinc	10,000 (NM)	10 - 5,000	21 - 394	21.9 - 399	No (3)

[a] Lowest applicable protection standard between New Mexico human health standard and Safe Drinking Water Act maximum contaminant level is presented.
[b] From Stone et al. 1983.
[c] Groundwater analytical results for monitoring wells BLM-16 and BLM-40; results are also presented in Appendix N.
[d] Groundwater analytical results are presented in Appendix N. Monitoring wells within study subarea 4 are shown on Plate 1.
[e] NM = New Mexico human health standard, Section 3-103 (NMWQCC 1988).
[f] Nitrate only.
[g] SDWA = Safe Drinking Water Act maximum contaminant level.
[h] Proposed RCRA action level (55 FR 30865).

(1) No protection standards.
(2) Several concentrations exceed standard and study area background concentrations; however, range is within the regional range and high concentrations have decreased over time.
(3) Concentration range is below protection standard.
(4) Concentration range is within study area and regional concentration ranges.

N/A: not available
p: proposed Safe Drinking Water Act maximum contaminant level
s: secondary Safe Drinking Water Act maximum contaminant level
U: less than detection limit

Table 6-24. Organic Compounds Detected in the Site 2 Bedrock Aquifer

Parameter Name	Number of Detections	Maximum Concentration (µg/L)	Lowest Regulatory Standard (µg/L)	Screening Criteria		
				Eliminated Based on Frequency	Identified as a Contaminant of Concern	Comments
Volatile Organic Compounds						
Acetone	11/30	1,100.0	4000[a]		Y	
Dichloromethane (methylene chloride)	18/52	44.0	5p[b]		Y	
Toluene	8/52	18.0	750[c]		Y	
Trichloromethane (chloroform)	2/52	7.0	100[c]	x		Only 1 detection per well
Xylene (total)	1/52	0.7	620[c]	x		Only 1 detection per well
Semivolatile Organic Compounds						
bis(2-Ethylhexyl) phthalate	9/22	260	3[a]		Y	

[a] Proposed RCRA action level (55 FR 30865).
[b] Safe Drinking Water Act maximum contaminant level.
[c] New Mexico human health standard, Section 3-103 (NMWQCC 1988).
p: proposed Safe Drinking Water Act maximum contaminant level
x: contaminant is eliminated as a contaminant of concern

Table 6-25. Analytical Results for Chlorinated Hydrocarbons from Groundwater Holding Tanks at Giant-Bloomfield Refinery

Parameter	N Tank	S Tank	Tank 22	Tank 24	Tank 27	Tank 32	Tank 37	Tank 106
1,1-Dichloroethane	U	9.9-14.5	4.4-10.0	8.0	5.7	12.0	2.0	2.9
1,1-Dichloroethene	U	U	0.32	0.61	U	0.51	U	U
1,2-Dichloroethane	6.3	5.9-7.0	4.5-7.4	130.0	8.3	10.0	7.0	U
1,2-*trans*-Dichloroethene	U	7.1-14.2	17.0	13.0	U	18.0	3.0	U
1,1,1-Trichloroethane	U	1.9-3.2	1.7	5.5	U	2.3	U	U
1,1,2-Trichloroethane	U	U	3.4	U	U	U	U	U
Tetrachloroethene	U	1.1-3.1	0.50	1.8	U	1.5	U	U
Trichloroethene	U	4.8-6.1	3.0-3.4	4.1	2.6	4.9	U	U
Trichloromethane	U	U	U	U	3.0	U	U	U

Ref: NMOCD 1990
U: not detected

Table 6-26. Summary Evaluation of Isotopic Sulfur and Sulfate Data

Description	Number of Samples	Isotopic Sulfur			Sulfate (mg/L)		
		Maximum	Average	Minimum	Maximum	Average	Minimum
All samples	56	13.90	1.47	-9.20	2,440	1,713	895
All alluvial wells	31	6.7	-1.32	-9.20	2,380	2,760	895
All bedrock wells	20	13.9	5.38	-8.10	2,440	2,655	1,240
Wells in Site 1, northern area	30	13.90	1.49	-9.20	2,400	1,689	895
Wells in Site 1, southern area	9	4.50	1.17	-2.40	2,230	1,739	1,180
Wells in Site 2	12	12.60	0.96	-7.60	2,440	1,806	1,260
Alluvial wells in Site 1, northern area	17	3.20	-2.45	-9.20	1,850	1,322	895
Alluvial wells in Site 1, southern area	5	2.90	0.88	-0.50	1,920	1,512	1,180
Alluvial wells in Site 2	9	6.70	-0.40	-7.60	2,380	1,642	1,260
Bedrock wells in Site 1, northern area	13	13.90	6.64	-8.10	2,400	2,169	1,240
Bedrock wells in Site 1, southern area	4	4.50	1.53	-2.40	2,230	2,023	1,760
Bedrock wells in Site 2	3	12.60	5.03	0.40	2,440	2,297	2,080

mg/L: milligrams per liter

Table 6-27. Summary of WATEQF Results

Location	Cation (meq/L)	Anion (meq/L)	Cation/Anion Ratio	Log (IAP/KT)		Comment
				Anhydrite	Gypsum	
Lagoon	110.79	141.61	0.78	-0.61	-0.28	DO = 5 mg/l
Lagoon	79.60	58.80	1.35	-0.95	-0.62	DO = 5 mg/l
BLM-14	21.39	17.80	1.20	-0.53	-0.15	DO = 5 mg/l
BLM-20	21.02	21.71	0.97	-0.51	-0.21	DO = 5 mg/l
BLM-20	21.02	22.14	0.95	-0.51	-0.21	S/S for Eh
BLM-20	21.02	22.09	0.95	-0.51	-0.21	DO = 8 mg/l
BLM-30	31.65	32.62	0.97	-0.27	0.04	DO = 5 mg/l
BLM-48	23.66	62.43	0.38	-0.56	-0.29	DO = 5 mg/l
BLM-49	27.49	22.92	1.20	-0.42	-0.13	DO = 5 mg/l
BLM-57	79.49	40.93	1.94	-0.40	-0.07	DO = 5 mg/l
GBR-32	42.96	44.00	0.98	-0.41	-0.12	DO = 5 mg/l

meq/L: milliequivalents/liter
DO: dissolved oxygen
IAP: ion activity product
KT: equilibrium constant
S/S: sulfate/sulfide
WATEQF: computer model for calculating mineral saturation

Table 6-28. Results of Strontium Isotope Analysis

Water Sample	Delta Strontium-87	Delta Strontium-87 Normalized to San Juan River Water (times 10^{-5})
BLM-15	0.70987	-35
BLM-28	0.70920	-102
BLM-37	0.70969	-53
BLM-60	0.71008	-14
GBR-32	0.70987	-35
SJR-1	0.71022	0
SJR-2	0.71022	0

SJR: San Juan River sample

Table 6-29. Cation/Anion Balances for Bedrock Wells - March 1990 Samples

Monitoring Well[a]	Aquifer Type	Cations (meq/L)	Anions (meq/L)	Cation/Anion Ratio
BLM-16	BR	48.9	46.87	1.04
BLM-19	BR	48.28	47.35	1.02
BLM-22	BR	48.64	47.87	1.02
BLM-23	BR	48.29	48.83	0.99
BLM-26	BR	50.13	47.26	1.06
BLM-29	BR	51.08	51.66	0.99
BLM-32	BR	47.84	53.39	0.9
BLM-33	BR	50.89	47.15	1.08
BLM-34	BR	50.81	47.89	1.06
BLM-35	BR	50.1	47.94	1.05
BLM-40	BR	48.93	48.4	1.01
BLM-41	BR	46.4	50.57	0.92
BLM-44	BR	49.88	50.94	0.98
BLM-47	BR	46.95	51.3	0.92
BLM-50	BR	54.04	52.63	1.03
BLM-53	BR	30.05	27.62	1.09
BLM-54	BR	46.79	47.13	0.99
BLM-59	BR	46.67	49.21	0.95
BLM-61	BR	45.83	46.99	0.96
BLM-63	BR	41.91	42.26	0.99
BLM-64	BR	45.01	48.55	0.93
GBR-15	BR	55.31	56.02	0.99
GBR-18	BR	62.7	45.02	1.39[b]
GBR-24D	BR	50.17	49.15	1.02
GBR-30	BR	50.28	50.11	1

[a] Monitoring wells are shown on Plate 1.
[b] Sample with balances out of acceptable range.
meq/L: milliequivalents per liter
BR: bedrock

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Table 6-30. Cation/Anion Balances for Alluvial Wells - March 1990 Samples

Monitoring Well[a]	Aquifer Type	Cations (meq/L)	Anions (meq/L)	Cation/Anion Ratio
BLM-14	SA	26.11	24.23	1.08
BLM-15	DA	31.17	39.2	0.8[b]
BLM-17	SA	23.33	23.36	1
BLM-18	DA	32.34	31.28	1.03
BLM-20	SA	25.58	26.76	0.96
BLM-21	DA	31.56	30.43	1.04
BLM-24	SA	34.34	34.67	0.99
BLM-25	DA	39.23	39.08	1
BLM-27	SA	31.33	34.38	0.91
BLM-28	DA	49.56	51.27	0.97
BLM-30	SA	39.95	40.99	0.97
BLM-31	DA	42.28	43.32	0.98
BLM-37	SA	60.7	58.07	1.05
BLM-39	SA	27.49	32.07	0.86[b]
BLM-42	DA	34.52	35.26	0.98
BLM-43	SA	36.46	39	0.94
BLM-45	DA	35.27	33.83	1.04
BLM-46	SA	29.72	35.05	0.85[b]
BLM-48	DA	29.56	32.84	0.9
BLM-49	SA	29.04	33.16	0.88[b]
BLM-51	DA	30.68	30.21	1.02
BLM-52	SA	25.81	24.22	1.07
BLM-55	SA	30.92	34.59	0.89[b]
BLM-56	DA	35.84	39.94	0.9
BLM-57	SA	53.22	52.07	1.02
BLM-58	SA	31.77	36.47	0.87[b]
BLM-60	SA	28.4	31.21	0.91
BLM-62	SA	46.03	42.8	1.08
BLM-65	SA	46.21	46.3	1
BLM-66	SA	37.68	38.14	0.99
GBR-17	SA	33.86	34.7	0.98
GBR-31	SA/BR	50.49	51.05	0.99
GBR-32	SA	46.58	41.02	1.14[b]
GBR-33 -	SA/BR	53.36	53.52	1
GBR-48	SA	82.61	76.3	1.08
GBR-49	SA	42.38	36.29	1.17[b]
GBR-50	SA	33.97	33.5	1.01

[a] Monitoring wells are shown on Plate 1.

[b] Samples with balances out of acceptable range.

meq/L: milliequivalents per liter

BR: bedrock

DA: deep alluvial

SA: shallow alluvial

Table 6-31. Cation/Anion Balances for Alluvial Wells - May 1991 Samples

Monitoring Well[a]	Aquifer Type	Cations (meq/L)	Anions (meq/L)	Cation/Anion Ratio
BLM-67	DA	47.02	30.82	1.53[b]
BLM-68	DA	58.32	57.65	1.01
BLM-69	DA	34.30	31.81	1.08
BLM-70	DA	39.63	36.56	1.08
BLM-71	DA	33.05	33.78	0.98
BLM-72	SA	28.57	31.17	0.92
BLM-73	SA	34.86	32.17	1.08
BLM-74	SA	39.47	38.49	1.03
BLM-75	SA	32.78	32.24	1.02
BLM-76	SA	34.71	34.45	1.01
BLM-77	SA	36.63	37.22	0.98
BLM-78	SA	28.37	27.85	1.02
BLM-79	SA	23.55	21.09	1.12[b]

[a] Monitoring wells are shown on Plate 1.
[b] Samples with balances out of acceptable range.
meq/L: milliequivalents per liter
DA: deep alluvial
SA: shallow alluvial

Table 6-32. Summary of the Contaminants of Concern Identified in the Lee Acres Landfill Study Area Alluvial and Bedrock Aquifers

	Background Contaminants		Identified as Contaminants of Concern					
			Northern Area of Operable Unit 2		Southern Area of Operable Unit 2		Site 2[a]	
Parameter Name	Alluvial	Bedrock	Alluvial	Bedrock	Alluvial	Bedrock	Alluvial	Bedrock
Volatile Organic Compounds								
1,1,1-Trichloroethane					Y			
1,1-Dichloroethane			Y		Y		Y	
1,2-Dichloroethane							Y	
1,2-*cis*-Dichloroethene[b]			Y		Y			
1,2-*trans*-Dichloroethene			Y		Y			
Acetone								Y
Benzene					Y			
Dichloromethane (methylene chloride)	Y	Y	Y	Y	Y	Y	Y	Y
Tetrachloroethene (PCE)			Y		Y			
Toluene								Y
Trichloromethene (TCE)			Y		Y			
Trichloroethane (chloroform)			Y		Y			
Vinyl chloride			Y		Y RISK			
Semivolatile Organic Compounds								
bis(2-Ethylhexyl) phthalate				Y RISK				Y
Inorganics								
Chloride					Y		Y	
Nitrate							Y	

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Table 6-32. (page 2 of 2)

			Identified as Contaminants of Concern					
	Background Contaminants		Northern Area of Operable Unit 2		Southern Area of Operable Unit 2		Site 2[a]	
Parameter Name	Alluvial	Bedrock	Alluvial	Bedrock	Alluvial	Bedrock	Alluvial	Bedrock
Inorganics (Continued)								
Sulfate							Y	
Sulfide							Y	
Metals								
Aluminum							Y	
Arsenic							Y	
Barium							Y	
Beryllium							Y	Y
Cobalt					Y		Y	
Chromium	Y RISK	Y RISK	Y RISK	Y RISK			Y	Y
Iron							Y	
Lead							Y	
Manganese			Y		Y			
Nickel					Y			
Selenium					Y		Y	

[a] Sampling locations include only Bureau of Land Management monitoring wells located south of U.S. 64; BLM-37 is excluded.

[b] 1,2-*cis*-Dichloroethene coelutes with 1,2-*trans*-dichloroethene and, therefore, in most cases, was reported as the *trans* isomer. Both isomers are considered in the discussions of contaminants of concern.

Y: identified as a contaminant of concern

Y RISK: retained as a contaminant for the risk assessment only

Table 6-33. Summary of Site 1 and Site 2 Groundwater Conditions

	Site 1	Site 2
Geographic distribution of contaminants	- Northern area contamination is limited to wells within former liquid waste lagoon locations (BLM-55, BLM-56, and BLM-57). - Organic contamination is absent from wells adjacent to and west of the former landfill (perimeter wells). - Southern area organic contamination is isolated from the landfill. - Manganese contamination is continuous from the former lagoon locations to the southern areas.	- A separate mass of organic contamination exists at and south of the former Giant-Bloomfield Refinery. - Various Site 2 wells contain floating petroleum product. - There is no increasing contaminant concentration gradient from Site 2 northward to Site 1. - Low levels of organic contamination were measured in wells BLM-65 and BLM-66 in the unnamed arroyo.
Chloride distribution	- No distinct chloride concentration gradient was observed within the landfill. - In the southern area, elevated chloride concentrations (> 1,000 mg/L) are found in wells GBR-32, GBR-48, and GBR-49.	- South of U.S. 64, a trend is observed where deeper alluvial wells cluster screens show relatively lower chloride concentrations compared to shallow screens. The fact that chloride concentrations decrease with depth indicates that there is a proximal source for chloride with a short residence time.
Potential sources	- Manganese contamination is derived from former liquid waste lagoon disposal operations (brine water disposal). - RI data provide no conclusive evidence for active southern area sources.	- The contaminant mass found at the former Giant-Bloomfield Refinery and south of U.S. 64 is derived from past refinery operations. - Contamination measured in wells BLM-65 and BLM-66 could be derived from former production wells located on adjacent San Juan County Fairground property.

7. CONTAMINANT FATE AND TRANSPORT

The COCs and the nature and extent of contamination measured within the Lee Acres Landfill Study Area were presented in Sections 5 and 6. Section 7 presents the technical approach and results of solute transport simulations. The fate and transport of contaminants in the alluvial groundwater system in the Lee Acres Landfill Study Area were evaluated using the Random-Walk Solute Transport computer model (Prickett et al. 1981). The areas considered include Site 1, OU 2 groundwater beneath and south of the landfill, and Site 1, OU 1 landfill soils. The fate and transport of contaminants in Site 2 groundwater were not evaluated because the source of contamination for Site 2 is unrelated to the former landfill. The objectives of the solute transport modeling were to predict

- the future movement of organic groundwater contamination presently in the southern area of OU 2 (as represented by 1,2-DCE), assuming no action is performed to contain or capture the contamination;
- the future movement of the manganese contamination presently in OU 2 groundwater, assuming no action is performed to contain or capture the contamination; and
- the future impact from contamination leaching from the landfill soils to groundwater quality and a hypothetical groundwater user, assuming a domestic drinking water well is placed within the OU 2 southern area of contamination.

Based on the groundwater analytical results for OU 2 (subsection 6.3 and 6.4), 1,2-DCE was chosen to represent organic groundwater contamination because it occurred in the most samples and in the highest concentrations. The current extent of organic contamination is centered around wells GBR-32, GBR-48, and GBR-49, as well as a separate area centered around well BLM-68. Simulation results indicated that the leading edge of Site 1 organic groundwater contamination located at well BLM-68, if allowed to migrate unabated, will reach the subdivision just south of U.S. 64 in approximately 10 years (from 1991) and will reach the San Juan River in approximately 50 years (Figures 7-1 and 7-2). U.S. 64 and the San Juan River are located south of BLM-68, approximately 1,375 ft and 4,750 ft, respectively. Although the maximum predicted groundwater concentration will decrease with time, simulated results show that the maximum concentration of 1,2-DCE will remain above the proposed regulatory standard of 70 μg/L during the plume's migration to the subdivision, and will attenuate to below the proposed standard before it reaches the San Juan River.

Simulation results also indicate that manganese groundwater contamination, if allowed to migrate, will reach the area just north of U.S. 64 in approximately 10 years and will reach an area 1,000 ft north of the San Juan River in approximately 50 years (from 1991)(Figures 7-3 and 7-4). The maximum concentration of manganese is currently above the regulatory standard and is expected to remain above the New Mexico regulatory standard of 200 μg/L throughout the plume's migration to the San Juan River.

In order to achieve the above objectives, a solute transport model was selected and calibrated before long-term contaminant migration could be modeled. The following subsections present model selection (subsection 7.1), model limitations and assumptions (subsection 7.2), calibration (subsection 7.3), and results (subsection 7.4) of the solute transport modeling. Subsection 7.5 presents the modeling of potential groundwater impact from landfill leachate.

7.1. MODEL SELECTION AND SETUP

A personal computer version of the Random-Walk Solute Transport Model (Prickett et al. 1981) was selected to simulate saturated flow and solute transport of 1,2-DCE and manganese in the alluvial aquifer system at the Lee Acres Landfill Study Area. This code was selected because of its demonstrated ability and numerical efficiency in simulating a large class of solute transport problems in groundwater. Selection criteria required that the model have an ability to

- simulate solute transport for a variety of chemical constituents having a wide range of mobilities in groundwater;
- include effects of advection, dispersion, and retardation or adsorption of chemical constituents;
- calculate chemical constituent concentrations at specified locations and times during simulation;
- simulate multiple contaminant sources that vary in concentration and time duration; and
- simulate the effects of plume mixing and dilution.

All these criteria were met by the Random-Walk Solute Transport Model in its original or modified version. Its use as a reliable tool for predicting solute chemical concentrations in saturated porous media is widely documented and accepted by the technical community. In addition, this code was selected because it is easy to use, easy to understand, and its use provided adequate calibrations and predictions.

The Random-Walk models solute as a set number of particles of equal mass. Particles are entered into the system to represent a contaminant source or sources. In this case 2,000 particles were used and were entered in rectangular source configurations. Each particle moves through the simulated flow field by advection and dispersion. The ambient advection is assumed to be linear but can be modified by the influence of discharge and recharge wells.

The effects of discharge and recharge wells are simulated with superposition of the Theis equation in a form that modifies the magnitude and direction of the velocity vectors depending on the distance of the particle from each well. The Theis equation was developed for confined conditions and may be inaccurate for unconfined conditions where the aquifer thickness changes significantly as a result of discharge or recharge. Conditions for the modeled Lee Acres Landfill site are considered unconfined. For the calibration and the evaluation of long-term impacts, no discharge wells or recharge wells were included. Therefore, for these simulations, the fact that the Random-Walk code assumes confined conditions and the modeled site is unconfined has no impact on the results. The third phase of the modeling, the evaluation of the potential impact from leachate, does include one pumping well. The effect of the false assumption of confined conditions on this simulation are discussed in subsection 7.5.

Groundwater flow is simulated by direct input of a single velocity vector with a component in the x direction and a component in the y direction. Given that groundwater flow is not modeled explicitly, hydraulic boundaries are not considered explicitly. The hydraulic boundaries are considered in the conceptual model and considered implicitly in the solute transport model, as discussed below.

- The eastern and western boundaries of the model grid represent the eastern and western margins of the alluvium surrounding the unnamed arroyo. These boundaries are considered to be no-flow boundaries. The width of the plume spreading is controlled by the transverse dispersivity. The "best fit" of measured concentrations to calculated concentrations in the calibration process resulted in a very low value of tranverse dispersivity. This low value matches the relatively narrow width of the saturated alluvium surrounding the unnamed arroyo and simulates these no-flow boundaries.

- Upgradient of the former landfill, no natural groundwater flow boundary occurs in the vicinity of the site. Therefore, a constant flux boundary along the northern edge of the model is assumed.

- Downgradient of the former landfill, the San Juan River serves as a constant head boundary for groundwater flow and a discharge boundary for solute.

- The upper and lower boundaries are assumed to be constant flux boundaries of equal and relatively small magnitude, (i.e., the percolation rate to the water table is equal to the leakage rate from the alluvium to the bedrock). Therefore, the net change of storage in the alluvial system is zero and the system for calibration and long-term predictions is assumed to be under steady-state conditions. Also, it is assumed that the vertical rate of groundwater flow is sufficiently small so that the vertical hydraulic gradients and vertical solute transport are inconsequential relative to the lateral hydraulic gradients and lateral solute transport (see subsection 4.2).

The longitudinal and transverse dispersivity are assumed to be random functions with statistically normal distributions, thus the name Random-Walk. For each move of each particle, the code calculates two normally distributed random numbers. One number is used in the calculation of the movement of the particle caused by the tranverse dispersivity. The other number is used in the calculation of the particle movement caused by the longitudinal dispersivity.

Each normally distributed random number is created by summing 12 uniformly distributed numbers with values between 0 and 1. A value of six is then subtracted from the normally distributed random number. The resulting distribution of normal random numbers has a range from -6 to 6, a mean of 0, and a standard deviation of 1.

If the seed number provided by the computer to generate the sequence of uniformly distributed random numbers was the same for each run, then the results for runs with the same input would be identical. However, the seed number is based on the time on the computer's clock. Therefore, a different solution is obtained for each simulation with identical input. The effect of randomness is further discussed and evaluated in subsection 7.3.

The rectangular grid used for the modeling is depicted in Figure 7-5. The grid spacing is 25 ft in the x direction (east to west) and 100 ft in the y direction (north to south). The total grid dimensions are 450 ft, east to west, by 8,200 ft, north to south. The version of the Random-Walk used in this study assumes linear (one dimensional) advection. Based on the RI groundwater level and groundwater contaminant concentration data, groundwater flow is north to south. However, along a length of approximately 700 ft, the flow tends to be offset from north to south by about 10 degrees. To best simulate groundwater flowpaths and match plume concentrations, this portion of the grid between $y=1{,}500$ ft and $y=2{,}200$ ft was bent at a 10 degree angle. By making this slight coordinate transfer in the grid, the need for a more complex and cumbersome modeling approach was prevented.

Due to low predicted percolation rates and lack of available moisture, any future leachate derived from the former landfill is predicted to be innocuous to alluvial aquifer groundwater quality. Existing concentrations measured in Site 1 groundwater are likely the result of percolation during the operation of liquid waste lagoons, which provided moisture and a driving force for downward migration of contaminants.

7.2. MODEL LIMITATIONS AND ASSUMPTIONS

Mathematical models may be used to predict future conditions at the Lee Acres Landfill Study Area provided that the operating limitations and assumptions are understood. These include statements that are generic to the mathematical expression of saturated flow in porous media and those that are specific to past or current conditions at the study area. Listed below are assumptions that apply to all model cases.

- Flow in the alluvial aquifer is considered linear, homogeneous, isotropic, laminar, and governed by Darcy's Law.

- Vertical flow components are considered negligible.
- Dispersivity is a random process and normally distributed.
- Chemical concentrations assigned to well locations are those measured in July 1991.
- The alluvial aquifer flow system at the study area is everywhere hydraulically connected, and no significant physical barriers to flow exist within the boundaries of the aquifer.
- Input parameters used for the model are reasonable estimates of actual field conditions.
- Eastern, western, upper, lower, upgradient, and downgradient hydraulic boundaries are reasonable estimates of actual field conditions.
- Future hydraulic conditions at the study area are likely to remain steady and comparable to those used in the model.
- Contamination measured in well BLM-37 is not within the capture zone defined by remedial action activities currently being performed by the Giant-Bloomfield Refinery.
- The distribution of contaminants in the alluvial aquifer is reasonably represented by a finite number of particles, each having a mass representing a fraction of the total mass of contamination.

Limitations of the model are those that accompany most quantitative estimates of physical phenomena and also those that are particular to the Random-Walk Model. These are

- error associated with spatial and temporal heterogeneity;
- common field measurement error;
- flow and transport are simulated in two dimensions; the vertical component is ignored;
- transport of a single species solute is considered; any chain reactions, aggregate effects, or decay products are ignored;
- solute transport considers one-dimensional advection and two-dimensional dispersion; and
- vapor phase transport is ignored.

These limitations are considered acceptable for the purposes of achieving modeling objectives. Any error introduced into model results due to these limitations will not affect interpretation of model results. It is important to understand that modeling results presented here are estimates that represent the complex natural processes of groundwater flow and mass transport in saturated porous media. Results are not exact solutions but are considered reliable for the intended applications.

7.3. SOLUTE TRANSPORT MODEL CALIBRATION

The calibration process used known site information and RI data regarding the source history, hydrogeologic and geochemical properties and conditions, and the groundwater contamination distribution to numerically reproduce measured contaminant concentrations at specified locations. Calibration results were a reasonable starting point for the simulation of future conditions and impacts.

Two contaminants were chosen for the calibration process: 1,2-DCE and manganese. 1,2-DCE was chosen as a primary indicator of organic compound behavior because it occurs in higher groundwater concentrations than other chlorinated hydrocarbon contaminants (subsection 6.4). The shape of its plume and its chemical characteristics are similar to other measured chlorinated hydrocarbon contaminants such as TCE, chloromethane, and PCE. All these organic contaminants principally occur in the southern area of OU 2. Manganese was chosen because there is a relatively continuous manganese plume throughout Site 1. The highest concentrations of manganese were in the former northern and southern liquid waste lagoons within the former landfill. Measured manganese concentrations steadily decrease in the downgradient (southern) direction (subsection 6.3.1.2).

For the calibration process, the methods and algorithms to move particles in the Random-Walk model were not modified. The input and output procedures and the method to determine the particle mass were altered. The Random-Walk code was revised to

- allow input of nodal locations, well identifiers, and measured concentrations at specified calibration nodes (Appendix W-1).
- allow input of multiple values of specified parameters. These parameters are
  - the x and y components of the linear velocity vector;
  - the longitudinal and transverse dispersivity;
  - the retardation factor; and
  - the source release scenarios, which include the duration and relative contribution of a set of source releases. Each source is modeled as a rectangle.
- produce simulations with every combination of input parameter values. The modeler can input a set of values for six parameters, as listed above. If two values were input for each of the six parameters, then 2^6, or 64 simulations would be produced. If three values were input for each of the six parameters, then 3^6, or 729 simulations would be produced.
- calculate the mass per contaminant particle rather than assign the mass per contaminant particle. The mass is calculated so that the sum of the measured concentrations at calibration points is equal to the sum of the calculated

concentrations at calibration points. The relative magnitude of calculated concentrations at calibration points is determined by the relative number of contaminant particles within the cell representing the calibration point. Selection of calibration points is a critical factor in the calibration process. For this modeling exercise, all monitoring wells within and bounding the extent of contamination were included as calibration points.

- compare the sum of the absolute differences between measured and calculated concentrations of the current run with the previous lowest value after each run. If the current run has a lower value than the previous lowest value, then that value is declared as the lowest value and its particle positions are saved in a file.
- produce two output sets. One output set contains a summary of information; examples of this form of output is included as Table 7-1. The second output compares the measured and calculated concentrations for each calibration point for each simulation (Table 7-2). Table 7-3 consolidates this output for the best calibration simulations for manganese and 1,2-DCE. Samples of the two output sets are presented in Appendix W-1.

Table 7-4 presents the input parameters for Random-Walk and the rationale for their selection. Single values were input for hydraulic conductivity, transmissivity, storage coefficient, and porosity. Multiple values were input for the y component of velocity, longitudinal dispersivity, transverse dispersivity, the retardation factors for both manganese and 1,2-DCE, and the source release scenario.

The source term percent and durations of release used in the modeling are based on a combination of Lee Acres Landfill site history and an effort to best match the relative magnitudes of concentration found in the set of monitoring wells. The source release history is the major unknown in the calibration process. 1,2-DCE was selected as the indicator and modeled parameter to represent the chlorinated hydrocarbons because it is found in the most samples and in the highest concentrations collected at monitoring wells. The 1,2-DCE plume perhaps could have been matched more closely than it was in the calibration if more pulses or slugs of contaminant release were simulated. However, the source release was modeled as a continuous source because the limited information on source deposition indicates that a more or less continuous release is reasonable. A series of many short pulses would be difficult to justify.

The calibration process is comprised of the following steps:

- The modeled area and ranges of input parameter values were determined based on hydrostratigraphic information, hydraulic testing, water level data, geotechnical data, and groundwater analytic results.
- The July 1991 groundwater analytical results were selected from RI groundwater samples to compare with concentrations calculated by the model.
- The model input sets to be used in numerous simulations were created with various parameter values within the possible range of values.

- The model output was evaluated, including tables showing the comparison of measured to calculated concentrations at specific locations.
- The ranges of input parameters were refined.
- The computer code was rerun with varying sets of input parameters (groundwater velocity, longitudinal and transverse dispersivity, retardation factor, and the spatial and temporal source term configuration).

The sets of input parameters that represent the closest match of measured contaminant concentrations to simulated contaminant concentrations in groundwater were chosen as the optimal calibration set.

The parameter values that produced the best-fit calibration and comparison of measured to simulated concentrations are presented in Table 7-5. Figures 7-6 and 7-7 are iso-concentration maps of predicted plumes for the two modeled contaminants for current conditions using July 1991 groundwater sampling results. 1,2-DCE concentrations were measured in μg/L and manganese concentrations were measured in mg/L. The posted values are the July 1991 concentrations measured in samples from specific wells and the contour lines represent concentrations predicted by the model. The model tends to produce continuous plumes.

The July 1991 groundwater analytical results suggest a noncontinuous plume for 1,2-DCE. Therefore, the model overestimated the extent and total mass of actual 1,2-DCE contamination. Because the manganese plume is relatively continuous, the extent and total mass of manganese contamination is probably better estimated by the model than for 1,2-DCE. As a point of reference, the plume configurations for 1985, when the lagoons were closed, were also simulated. The 1985 plume configurations for 1,2-DCE and manganese are shown in Figures 7-8 and 7-9, respectively. Both the simulated 1985 and 1991 plume configurations and the measured 1991 data suggest that

- the source of 1,2-DCE and other chlorinated hydrocarbons ceased in 1985;
- the chlorinated hydrocarbon source contaminated the alluvial aquifer during the early part of the operational life of the lagoons, from 1979 to 1986; and
- the source of manganese continued throughout the operational life of the liquid waste lagoons.

The results of Random-Walk simulations not only vary with values of input parameters, but they also vary because of the random nature of the dispersivity calculations. The only parameter that varies in the 1,2-DCE calibrations is the retardation factor. The retardation factor varies from 1.5 to 2.5 in increments of 0.1. The results presented in Table 7-6 show that identical input will not produce identical output. Fifteen simulations were produced for each value of the retardation factor (Table 7-6). With the same set of input parameters, the sum of the absolute differences between measured and calculated concentrations and the calculated source mass vary (Table 7-6). The lowest sum occurs with a retardation factor of 2.4, yet the lowest average sum occurs when the retardation factor equals 2.5 (Table 7-6).

The non-unique solutions are created by the Random-Walk model. For the modeling results presented in this section and for all "real world" cases, limitations, imprecision, and inaccuracy are caused by the general nature of the governing equations, numerical errors, limitations in the solution techniques, and the practical limitations of available data. There are no exact solutions to groundwater flow and solute transport in systems that are constantly changing in space and time and that are affected by phenomena not included in the governing equations or even understood. The Random-Walk model provides a more credible picture of the real world than other methods that "pretend" that there is a unique solution to a given set of input parameters.

In the particular case shown in Table 7-6, a retardation factor of 2.5 may be a better selection. However, the best single run was generated using a retardation factor of 2.4. That particular run (run number 54) produced a simulated plume whose shape and relative concentrations best matched the measured field data. In the view of the modeler, it represented the best starting point for predicting future conditions. Whether the chosen value for the retardation factor for 1,2-DCE in the calibrated process was 2.4 or 2.5, all the parameter values chosen in the calibration are reasonable based on field groundwater level data, slug test data, laboratory material testing results, groundwater analytical results, and a conceptual understanding of the groundwater flow system in the alluvial deposits within the unnamed arroyo.

7.4. GROUNDWATER MODELING RESULTS

The Random-Walk Model was also used to predict long-term impacts. The best calibration data sets, generated in the calibration modeling step, were used as the initial conditions for the long-term simulations. These data sets represent the conditions for July 1991. The plume migration was simulated assuming linear advection, two-dimensional dispersion, no additional source, and no interference by pumping wells.

A post-processor was created to convert the output format from the Random-Walk model into an input format for the Surfer™ program TOPO. The output values were not modified; only the format of the files was changed to fit the requirements of the TOPO program.

Long-term downgradient migration of the present groundwater contamination was simulated toward the subdivisions and the San Juan River to the south, assuming no action is taken to contain or capture the contaminated groundwater. On the model grid, the subdivisions begin at y=3,600 ft and the San Juan River is at y=8,200 ft (Figure 7-5). Figures 7-1 and 7-3 are iso-concentration maps that depict predicted concentrations in 10 years. From July 1991, it will take more than 10 years for manganese and 1,2-DCE to reach the subdivision area south of U.S. 64.

Figures 7-2 and 7-4 are simulated iso-concentration maps predicting when the plumes will reach the San Juan River. From July 1991, manganese and 1,2-DCE will reach the river in approximately 50 years. The retardation factor is 2.4 for 1,2-DCE compared with 2.5 for manganese. Both constituents move in the alluvial aquifer at an rate approximately 0.4 times the velocity of groundwater.

The center of mass of the 1,2-DCE plume is further downgradient than the center of mass of the manganese contamination. Although the contaminant masses are relatively nondispersive (transverse dispersivity = 0.075 ft), the concentrations tend to decrease with time. The highest predicted concentration for manganese decreased by 32 percent in 10 years of migration (from July 1991 to the year 2001) and decreased by 60 percent in 50 years of migration (from July 1991 to the year 2041) (Table 7-7). The highest predicted concentration within the 1,2-DCE plume decreased by 38 percent in 10 years of migration (from July 1991 to the year 2001) and decreased 71 percent in 50 years of migration (from July 1991 to the year 2041) (Table 7-7).

The former liquid waste lagoons operated from 1979 to 1985. Groundwater modeling results show that approximately 22 years would be required for the leading edge of an organic plume to migrate from the former liquid waste lagoons to the current Site 2 contaminant plume near U.S. 64. Twenty-two years ago, in 1969, the liquid waste lagoons were not yet in operation. This observation reveals that Site 2 groundwater contamination is unrelated to former landfill activities.

7.5. POTENTIAL GROUNDWATER IMPACT FROM LANDFILL LEACHATE

The final modeling task was to predict the potential effect of leachate generated from the former landfill. The source term to groundwater was not calculated with the Random-Walk model. Rather, the Hydrologic Evaluation of Landfill Performance (HELP) model was used to predict percolation rates and partition coefficients (K_ds) to estimate contaminant mobility in the unsaturated zone. Analytical results from soil samples collected from boreholes drilled in the landfill were reviewed. Eight constituents were chosen for further evaluation based on the data review. Four petroleum hydrocarbon compounds (benzene, toluene, ethyl benzene, and xylene) were chosen because they were detected in relatively high concentrations, particularly in borehole BH-23 located in the former northern liquid waste lagoon. Four chlorinated hydrocarbon compounds (chloromethane, TCE, PCE, and 1,2-DCE) were chosen because they were detected in several landfill soil samples and have been detected in OU 2 groundwater.

The assumptions used for the leachate simulation were as follows:

- The highest concentration detected in any soil sample is considered the source concentration for the eight potential contaminants (Table 7-8);
- The leachate concentrations generated in the unsaturated soil are controlled by the partition coefficient (K_d), (Table 7-8). The K_d represents the ratio of the mass of contaminant adsorbed onto the soil relative to the mass of contaminant dissolved in the pore water. The mobility of each contaminant (i.e., how much would move in the water relative to how much would stay in the soil) was estimated by dividing the maximum soil concentrations by the K_d plus 1.
- The source area is bounded by boreholes BH-10, BH-12, BH-20, BH-22, and BH-24 because these five boreholes surround borehole BH-23, which generally had samples with the highest concentrations. The assumed source area is approximately 43,000 ft^2 (1 acre).
- The driving force is the net percolation predicted by the HELP model. The predicted percolation rate for the present landfill cover is a continuous 0.002 inches/year. The predicted percolation rate for a new cover is 0.002 inches/year for five years, due to drainage, and then no further percolation. These calculations are documented in Appendixes W-2 and W-3.
- The "worst-case" receptor of the groundwater contamination is a domestic well placed in the southern area of OU 2, pumping at a rate of 500 gallons per minute.
- The parameters developed in the solute transport model calibration process (subsection 7.1) are appropriate for this modeling task.

The HELP computer code was used to estimate the soil water distribution in various cover conditions at the Lee Acres Landfill.

The HELP computer code was developed to provide rapid, economical estimation of the amounts of surface runoff, subsurface drainage, and leachate that may be expected to result from the operation of a wide variety of possible landfill designs. The computer code models the effects of hydrogeologic processes in two dimensions, including precipitation, surface storage, and lateral drainage.

For the HELP analysis, two different operating conditions were simulated: 1) existing conditions, and 2) final capped conditions. Existing conditions assumed a 30-ft-thick waste layer covered with a 2-ft layer of alluvial sand. The 30-ft waste layer was assumed to consist of 15 ft of solid waste material underlain by 15 ft of alluvial sands.

Final capped conditions assumed a multi-layer, RCRA-type, cover consisting of the following components in descending order: 1) 24-inch topsoil layer, 2) 12-inch drainage layer, 3) 24-inch low permeability layer with a flexible membrane liner, and 4) 6-inch gas vent layer.

The data used to represent the soil are shown in Appendix W-2. As no capillary moisture tests were performed on the alluvial sands, the Soil Water Retention Data (SWRDAT) computer code was used to derive an empirical relationship between pressure and water content. SWRDAT generates a capillary moisture curve, using material gradation and clay activity as the input parameters.

Default soil characteristics, describing typical municipal landfill waste and typical clay liners, were used for input into the HELP model. The default soil data were obtained from the HELP program users manual.

Daily values of precipitation, minimum and maximum temperature, and solar radiation were calculated by the HELP synthetic weather generation routine, using default statistical parameters for Albuquerque, New Mexico. The data set was improved by inputting mean monthly temperatures and mean monthly precipitation values for Farmington, New Mexico.

The results indicate that, due to low annual precipitation and the high rate of evapotranspiration, only 0.002 inches per year percolates from the base of the landfill under existing conditions. Infiltration through the cover is reduced to 0.0 inches when a RCRA-type cover is installed.

Model results, presented in Table 7-9, indicate that any future leachate derived from the former landfill will be innocuous to groundwater quality. The highest predicted concentration to the hypothetical domestic well, for any of the eight modeled constituents, is 1.1 μg/L for xylene. Most of the predicted concentrations are below quantification limits, and all predicted concentrations are well below applicable regulatory standards for drinking water.

The calculated drawdown caused by pumping the well at 500 gallons per minute for 1,000 days is 0.7 ft at 10 ft from the well and 0.4 ft at 100 ft from the wells. These calculations were performed with the Theis equation and indicate the inaccuracy, caused by assuming confined conditions, should affect the results minimally. The validity of the conclusions is not affected.

The main reason for the lack of simulated groundwater impact is the extremely low calculated percolation rate. Percolation rates during former liquid waste lagoon operation are likely to have been significantly greater than current rates. However, the lack of current discharged fluid (water and brine) to the liquid waste lagoons has greatly reduced the potential percolation rate. The former lagoon area has also been filled and regraded to inhibit ponding or infiltration. The predicted low percolation rate is supported by the fact that the soil concentrations of BTEX are relatively high in some soil samples (subsection 5.6), yet low or undetected in groundwater samples from wells adjacent or immediately downgradient from the former lagoon area (subsection 6.3). In addition, lysimeters installed within the former liquid waste lagoon areas (subsection 5.2) collected minimal pore water that decreased over time.

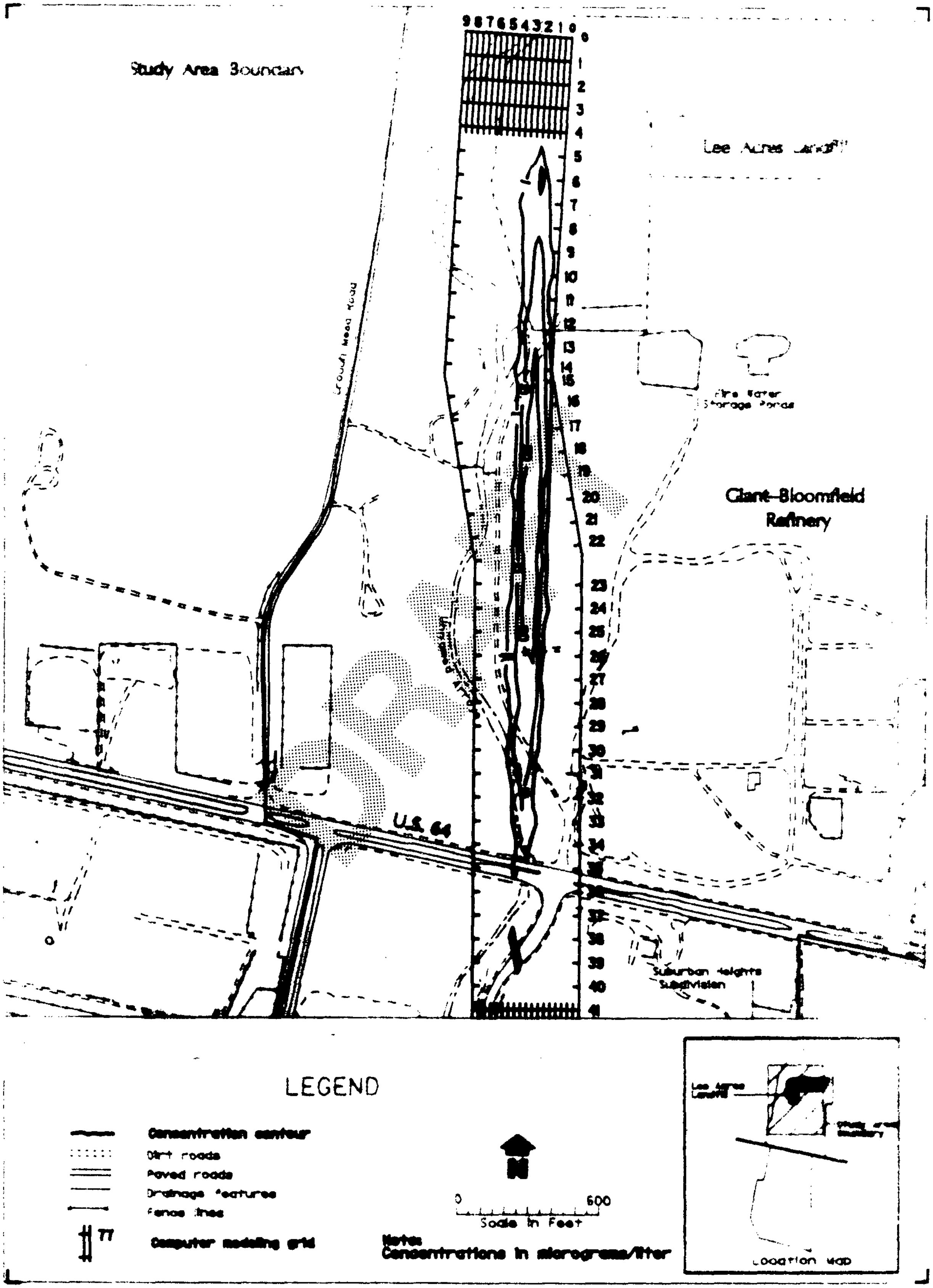

Figure 7-1. Predicted 1,2-dichloroethene plume in 10 years.

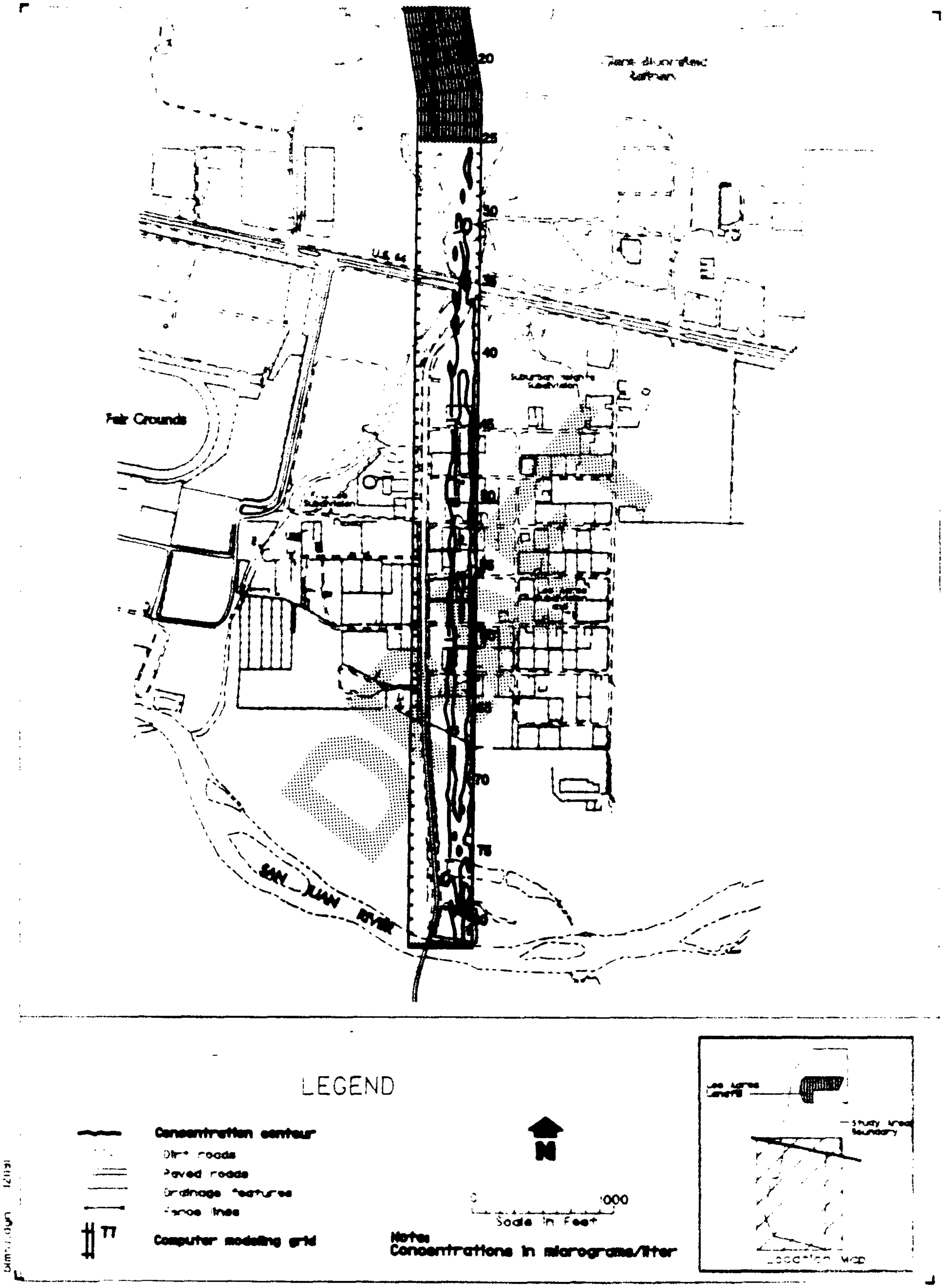

Figure 7-2. **Predicted 1,2-dichloroethene plume in 50 years.**

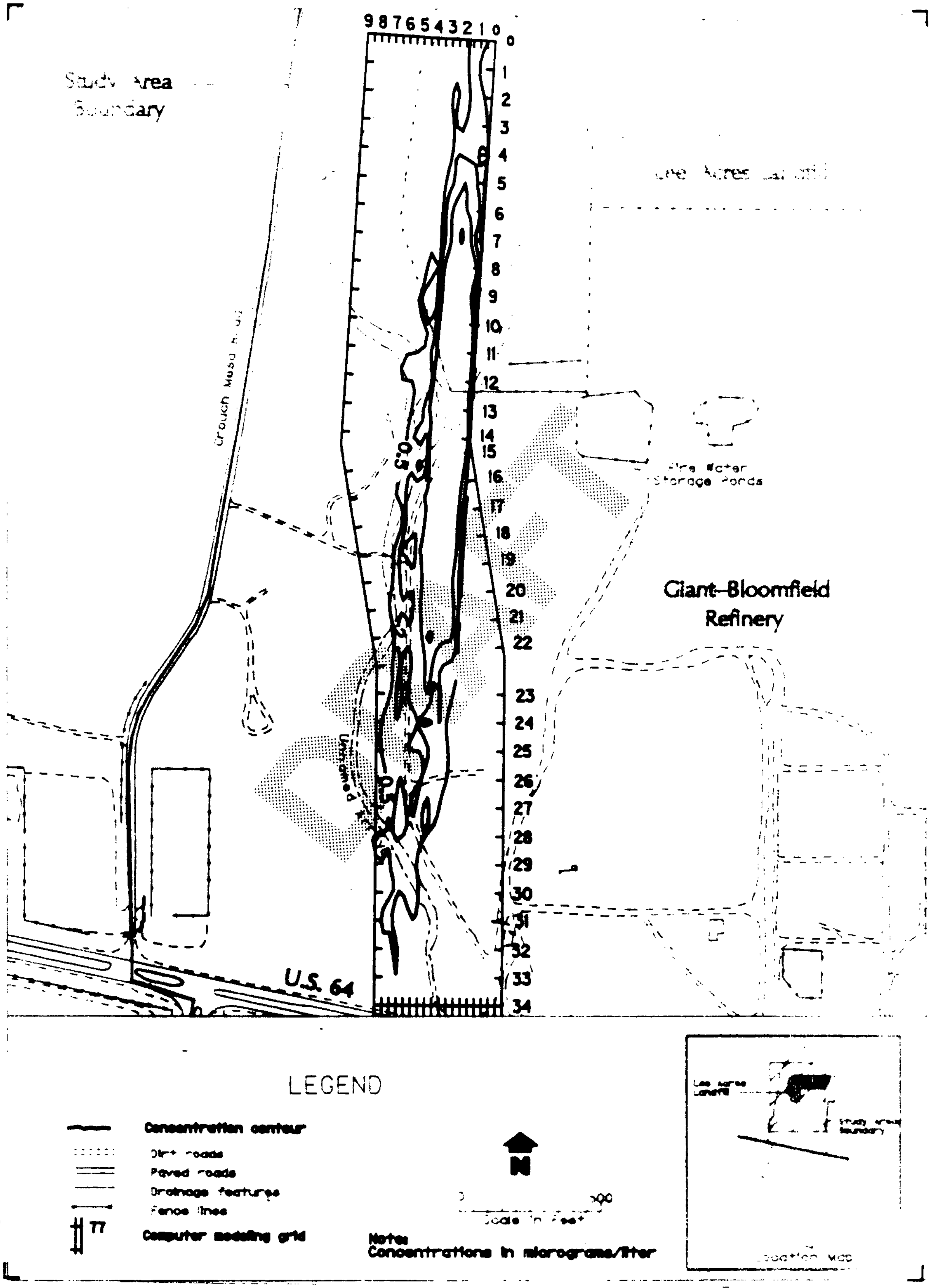

Figure 7-3. Predicted manganese plume in 10 years.

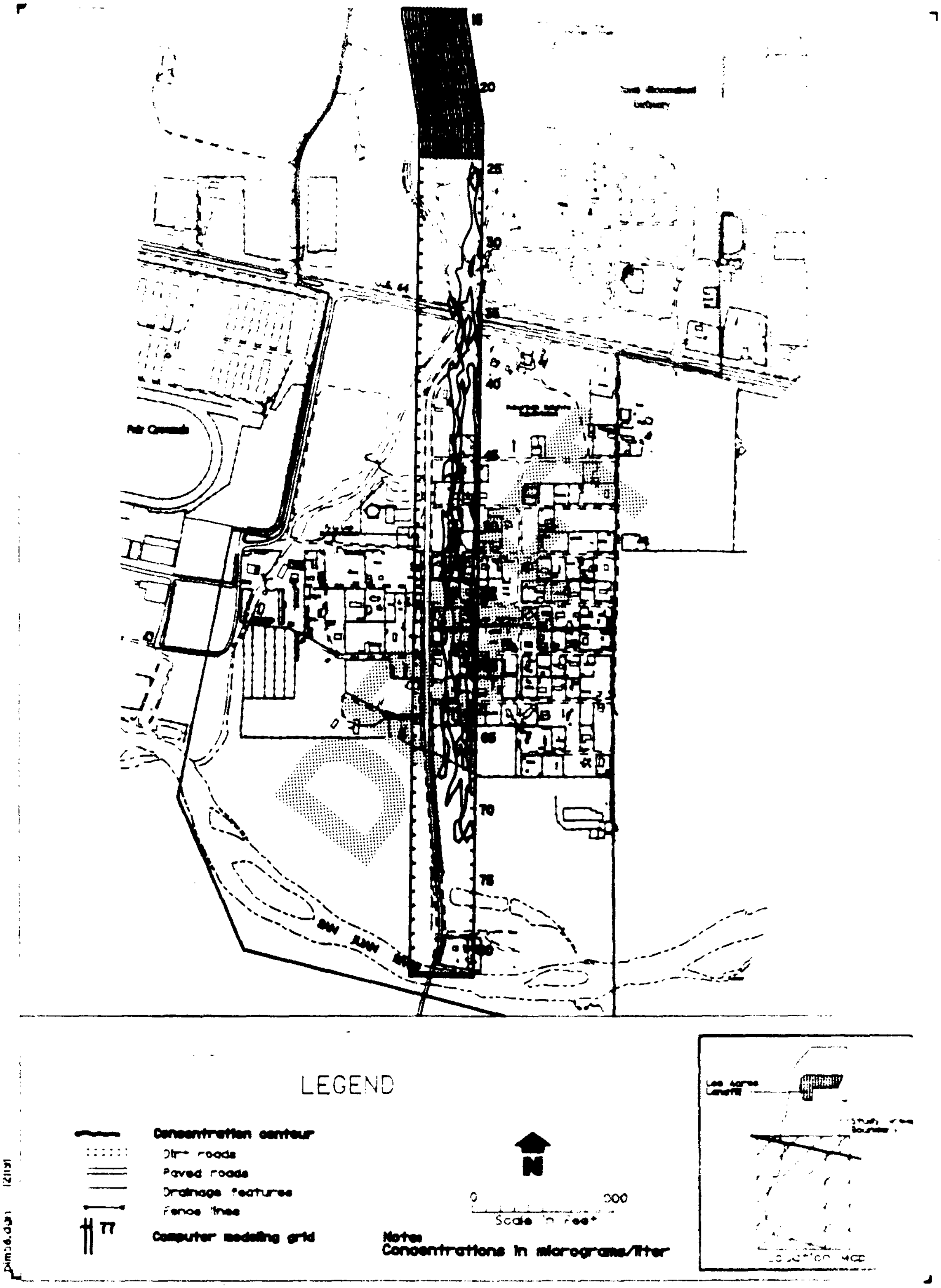

Figure 7-4. Predicted manganese plume in 50 years.

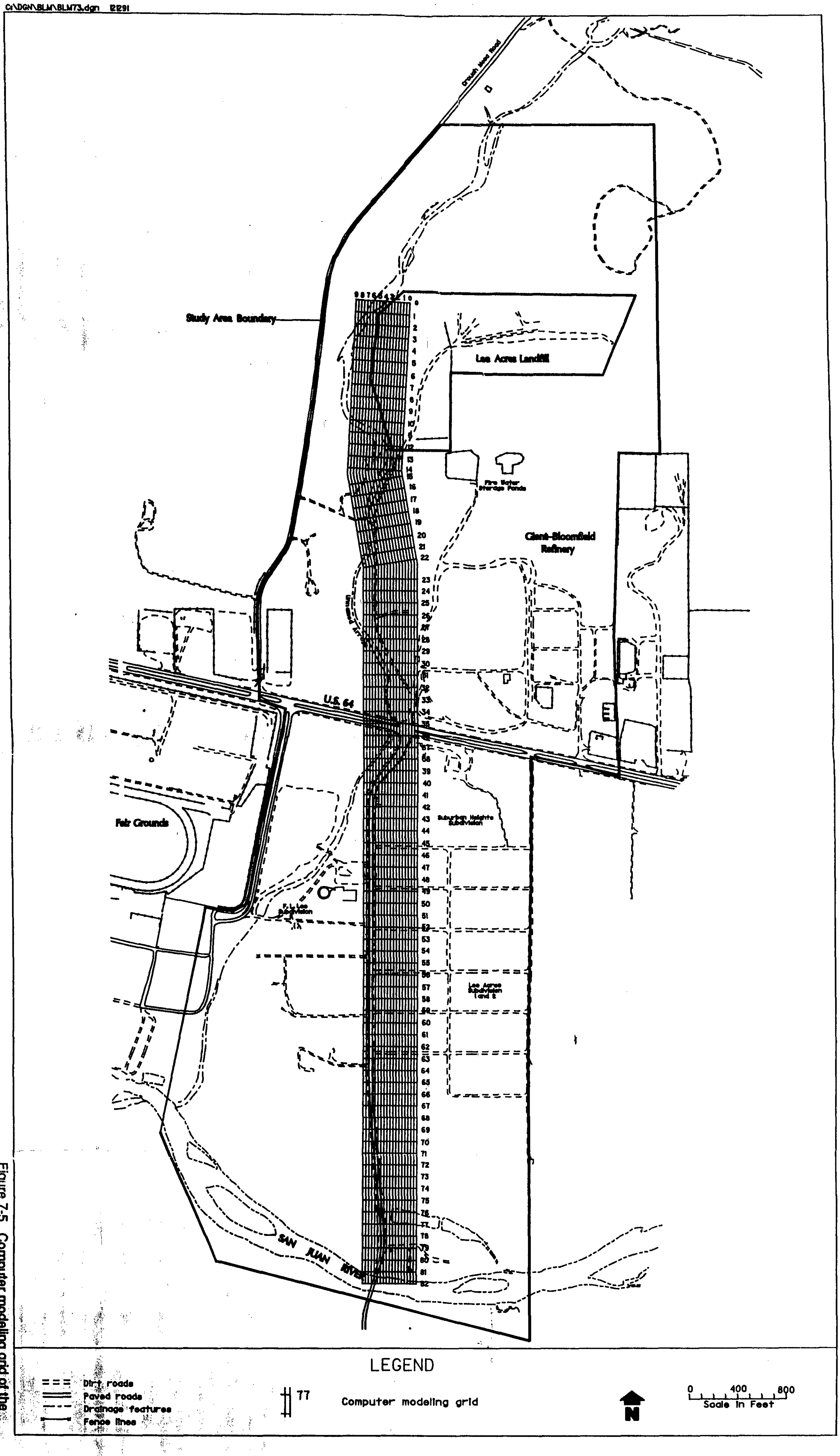

Figure 7-5. Computer modeling grid of the Lee Acres Landfill study area.

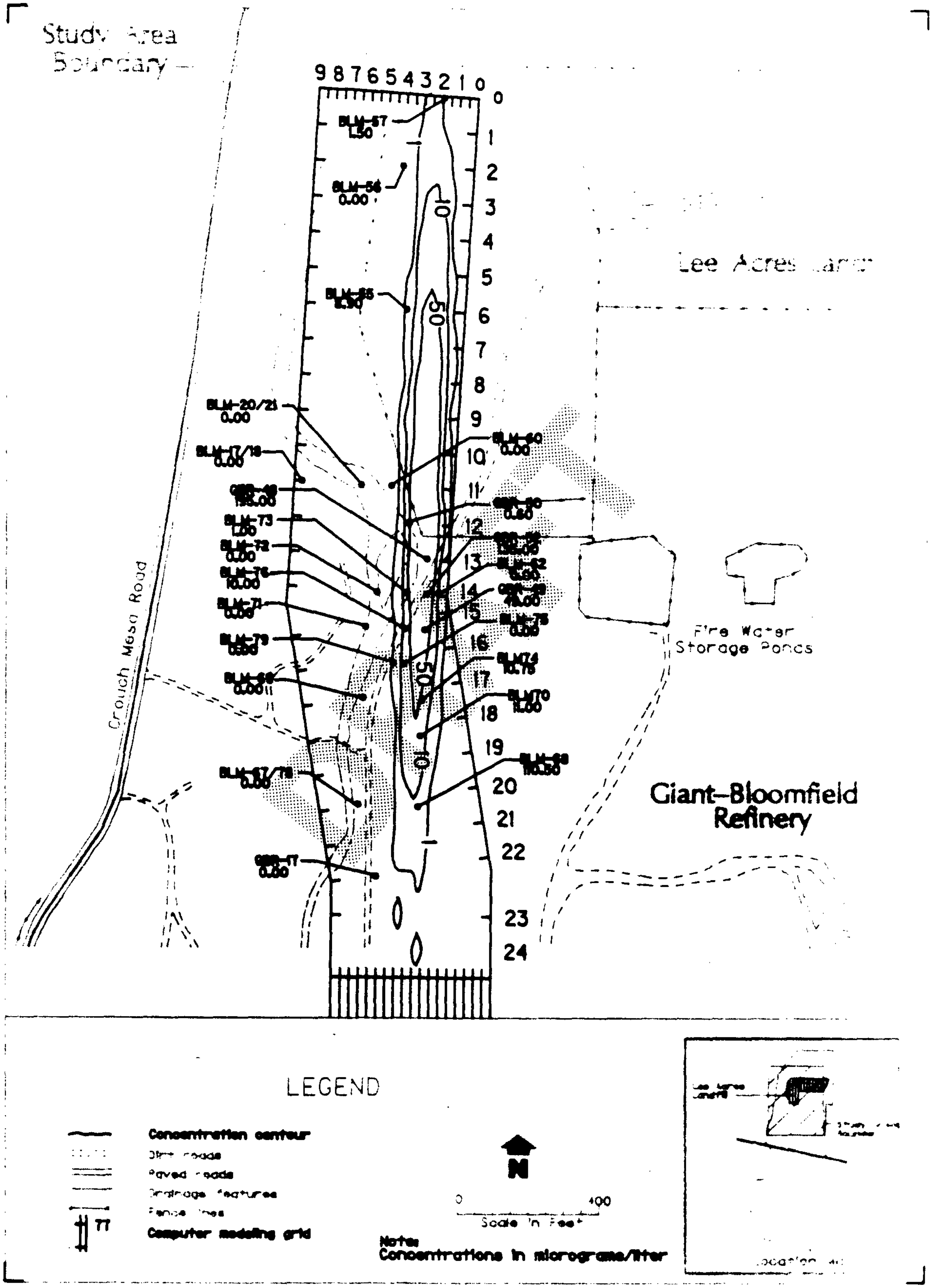

Figure 7-6. Calibration of 1991 conditions for 1,2-dichloroethene.

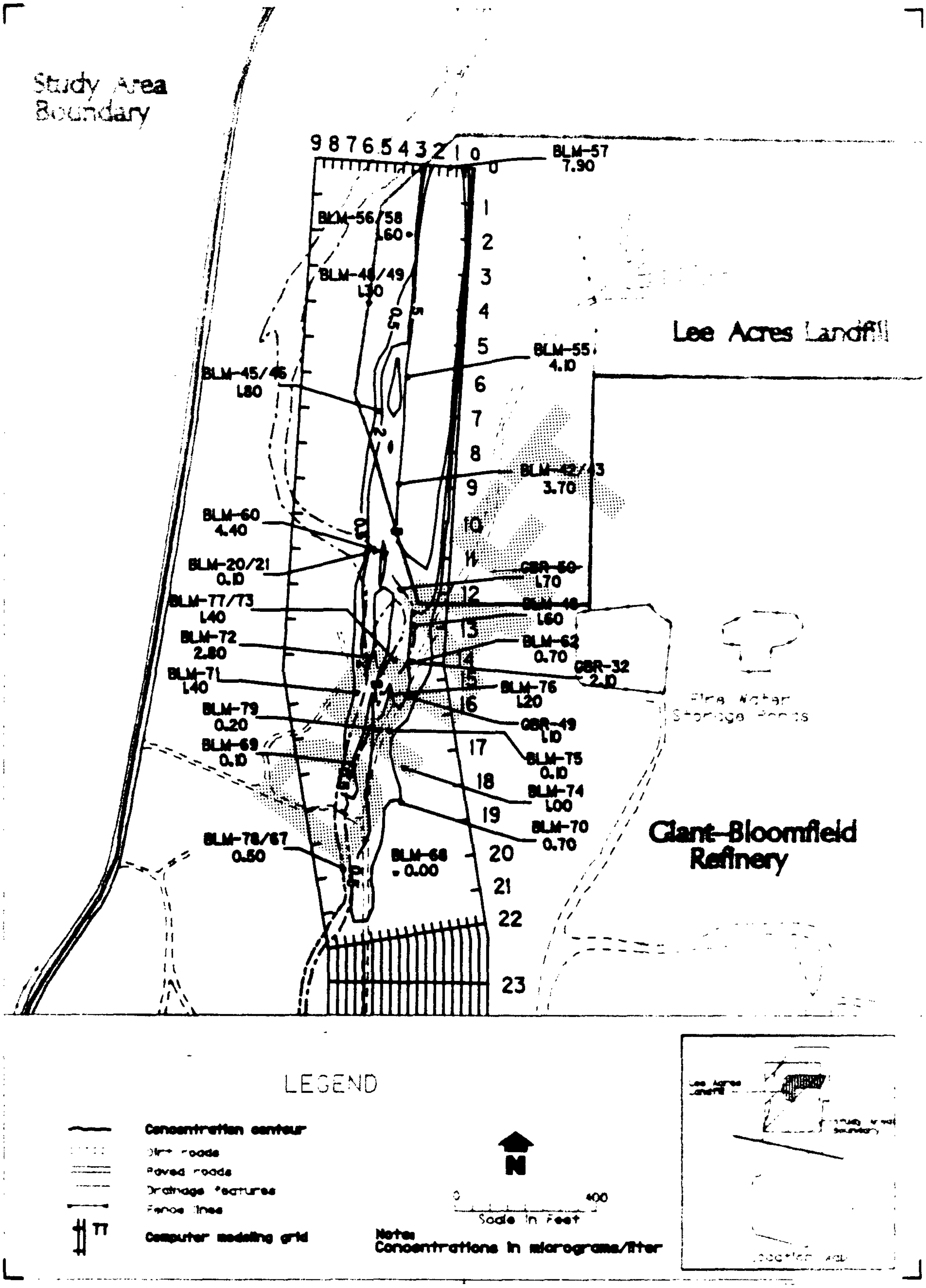

Figure 7-7. Calibration of 1991 conditions for manganese.

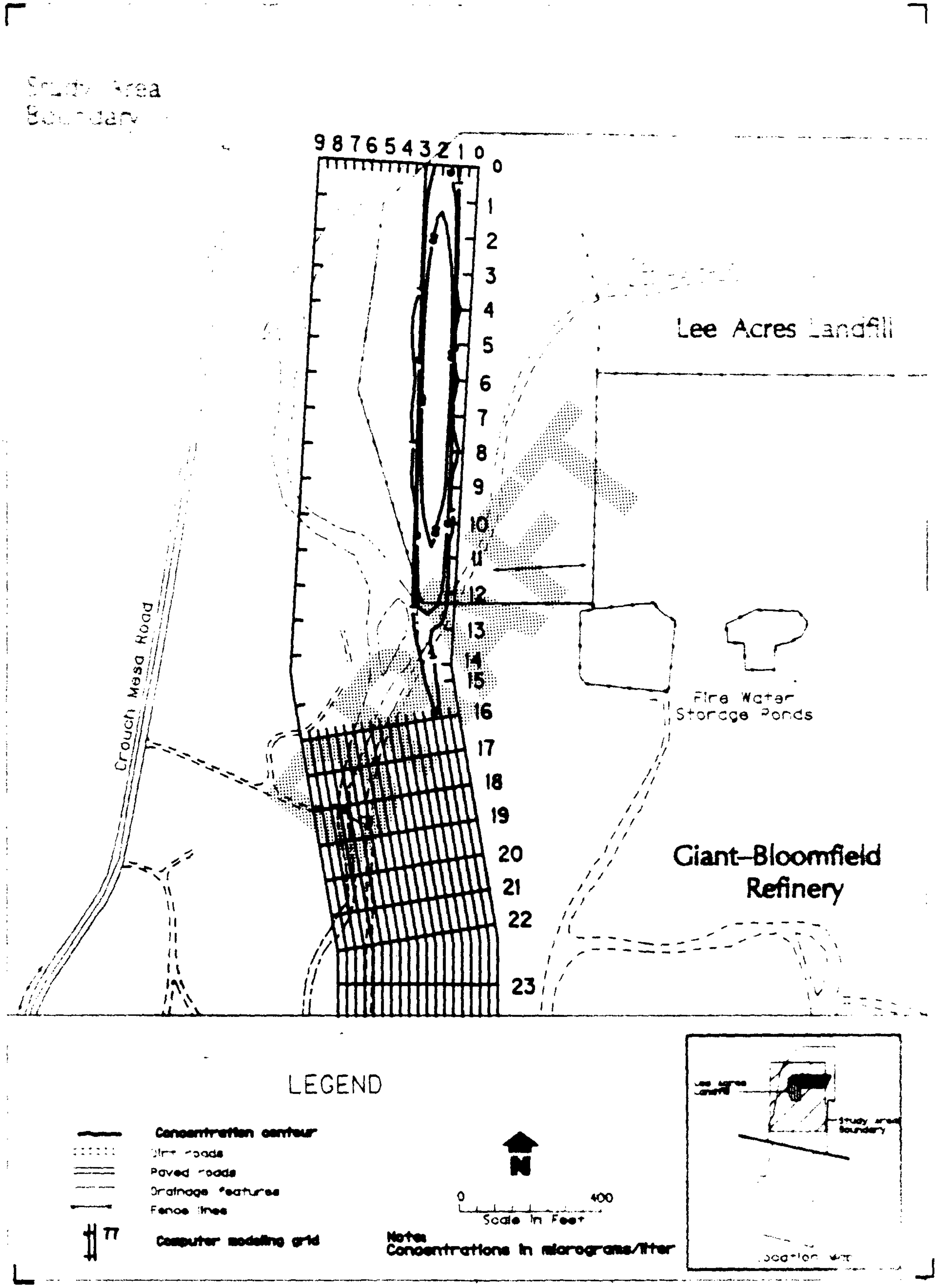

Figure 7-8. Simulated 1985 1,2-dichloroethene conditions.

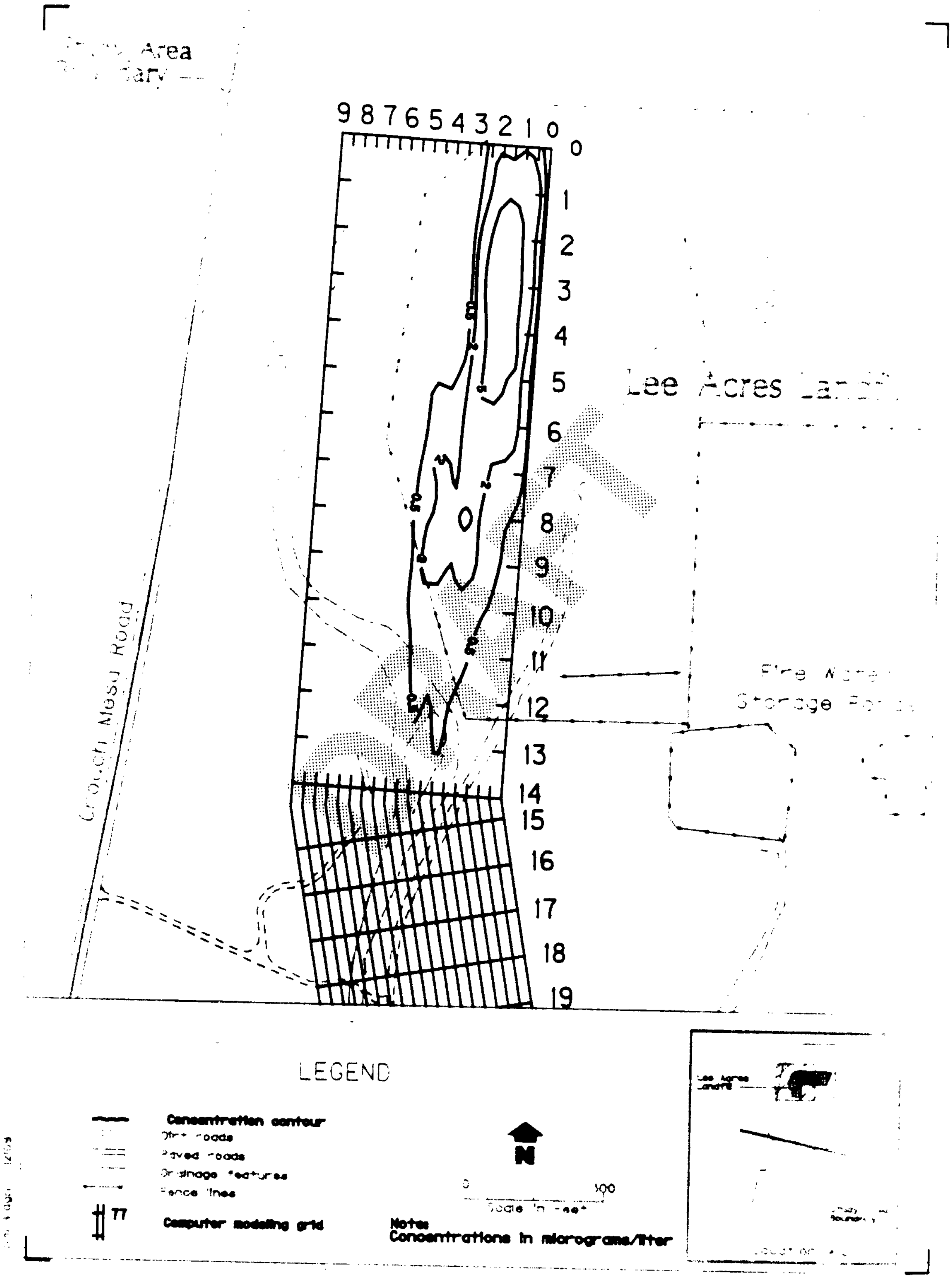

Figure 7-9. Simulated 1985 manganese conditions.

Table 7-1. Output from Final Manganese Calibration Run

Run Number	X Velocity ft/day	Y Velocity ft/day	Longitudinal Dispersity (ft)	Transverse Dispersity (ft)	Retardation Factor	Source Mass (Pounds)	Sum of Absolute Differences
1	0.0	0.6	70	0.075	2.4	500	21,000
2	0.0	0.6	70	0.075	2.5	440	32,000
3	0.0	0.6	70	0.075	2.5	400	29,000
4	0.0	0.6	70	0.075	2.5	400	33,000
5	0.0	0.6	70	0.075	2.6	440	26,000
6	0.0	0.6	75	0.075	2.4	380	29,000
7	0.0	0.6	75	0.075	2.5	340	31,000
8	0.0	0.6	75	0.075	2.5	340	26,000
9	0.0	0.6	75	0.075	2.5	420	33,000
10	0.0	0.6	75	0.075	2.6	460	24,000
11	0.0	0.6	80	0.075	2.4	400	34,000
12	0.0	0.6	80	0.075	2.5	360	32,000
13	0.0	0.6	80	0.075	2.5	400	26,000
14	0.0	0.6	80	0.075	2.5	360	30,000
15	0.0	0.6	80	0.075	2.6	340	26,000
16	0.0	0.6	70	0.075	2.4	400	30,000
17	0.0	0.6	70	0.075	2.5	360	35,000
18	0.0	0.6	70	0.075	2.5	380	27,000
19	0.0	0.6	70	0.075	2.5	380	29,000
20	0.0	0.6	70	0.075	2.6	520	25,000
21	0.0	0.6	75	0.075	2.4	340	31,000
22	0.0	0.6	75	0.075	2.5	360	31,000
23	0.0	0.6	75	0.075	2.5	380	20,000
24	0.0	0.6	75	0.075	2.5	460	26,000
25	0.0	0.6	75	0.075	2.6	520	29,000
26	0.0	0.6	80	0.075	2.4	380	28,000
27	0.0	0.6	80	0.075	2.5	400	24,000
28	0.0	0.6	80	0.075	2.5	360	22,000
29	0.0	0.6	80	0.075	2.5	380	24,000
30	0.0	0.6	80	0.075	2.6	380	21,000

The chosen run number is 23
The chosen source term configuration is 1
The chosen velocity in the x direction is 0
The chosen velocity in the y direction is 0.6
The chosen longitudinal dispersivity is 75
The chosen transverse dispersivity is 0.075
For Mn: The chosen retardation coefficient is 2.5

Table 7-2. Output from Final 1,2-DCE Calibration Run

Run Number	X Velocity ft/day	Y Velocity ft/day	Longitudinal Dispersity (ft)	Transverse Dispersity (ft)	Retardation Factor	Source Mass (Pounds)	Sum of Absolute Differences
1	0	0.6	75	0.075	1.5	1.14	610
2	0	0.6	75	0.075	1.6	1.10	570
3	0	0.6	75	0.075	1.7	1.02	630
4	0	0.6	75	0.075	1.8	0.96	620
5	0	0.6	75	0.075	1.9	0.94	610
6	0	0.6	75	0.075	2.0	1.00	590
7	0	0.6	75	0.075	2.1	1.12	570
8	0	0.6	75	0.075	2.2	1.14	620
9	0	0.6	75	0.075	2.3	1.20	590
10	0	0.6	75	0.075	2.4	1.22	600
11	0	0.6	75	0.075	2.5	1.50	600
12	0	0.6	75	0.075	1.5	1.14	620
13	0	0.6	75	0.075	1.6	1.04	640
14	0	0.6	75	0.075	1.7	1.00	650
15	0	0.6	75	0.075	1.8	0.98	610
16	0	0.6	75	0.075	1.9	1.02	590
17	0	0.6	75	0.075	2.0	1.04	650
18	0	0.6	75	0.075	2.1	1.10	620
19	0	0.6	75	0.075	2.2	1.06	570
20	0	0.6	75	0.075	2.3	1.16	550
21	0	0.6	75	0.075	2.4	1.26	600
22	0	0.6	75	0.075	2.5	1.34	600
23	0	0.6	75	0.075	1.5	1.10	650
24	0	0.6	75	0.075	1.6	1.06	620
25	0	0.6	75	0.075	1.7	1.02	660
26	0	0.6	75	0.075	1.8	1.02	630
27	0	0.6	75	0.075	1.9	1.04	630
28	0	0.6	75	0.075	2.0	1.00	630
29	0	0.6	75	0.075	2.1	1.02	620
30	0	0.6	75	0.075	2.2	1.10	640
31	0	0.6	75	0.075	2.3	1.18	610
32	0	0.6	75	0.075	2.4	1.20	570

Table 7-2. (page 2 of 6)

Run Number	X Velocity ft/day	Y Velocity ft/day	Longitudinal Dispersity (ft)	Transverse Dispersity (ft)	Retardation Factor	Source Mass (Pounds)	Sum of Absolute Differences
33	0	0.6	75	0.075	2.5	1.38	590
34	0	0.6	75	0.075	1.5	1.18	630
35	0	0.6	75	0.075	1.6	0.94	610
36	0	0.6	75	0.075	1.7	1.06	680
37	0	0.6	75	0.075	1.8	1.02	640
38	0	0.6	75	0.075	1.9	1.04	580
39	0	0.6	75	0.075	2.0	1.04	600
40	0	0.6	75	0.075	2.1	1.04	590
41	0	0.6	75	0.075	2.2	1.08	600
42	0	0.6	75	0.075	2.3	1.16	560
43	0	0.6	75	0.075	2.4	1.32	610
44	0	0.6	75	0.075	2.5	1.48	540
45	0	0.6	75	0.075	1.5	1.18	650
46	0	0.6	75	0.075	1.6	1.10	620
47	0	0.6	75	0.075	1.7	1.14	610
48	0	0.6	75	0.075	1.8	0.90	610
49	0	0.6	75	0.075	1.9	0.96	630
50	0	0.6	75	0.075	2.0	1.02	610
51	0	0.6	75	0.075	2.1	1.00	600
52	0	0.6	75	0.075	2.2	1.16	570
53	0	0.6	75	0.075	2.3	1.18	600
54	0	0.6	75	0.075	2.4	1.26	500
55	0	0.6	75	0.075	2.5	1.32	550
56	0	0.6	75	0.075	1.5	1.22	600
57	0	0.6	75	0.075	1.6	1.02	600
58	0	0.6	75	0.075	1.7	0.94	610
59	0	0.6	75	0.075	1.8	1.06	580
60	0	0.6	75	0.075	1.9	1.00	580
61	0	0.6	75	0.075	2.0	0.98	590
62	0	0.6	75	0.075	2.1	1.08	640
63	0	0.6	75	0.075	2.2	1.14	580
64	0	0.6	75	0.075	2.3	1.20	590

Table 7-2. (page 3 of 6)

Run Number	X Velocity ft/day	Y Velocity ft/day	Longitudinal Dispersity (ft)	Transverse Dispersity (ft)	Retardation Factor	Source Mass (Pounds)	Sum of Absolute Differences
65	0	0.6	75	0.075	2.4	1.40	570
66	0	0.6	75	0.075	2.5	1.30	550
67	0	0.6	75	0.075	1.5	1.02	640
68	0	0.6	75	0.075	1.6	1.00	640
69	0	0.6	75	0.075	1.7	1.00	610
70	0	0.6	75	0.075	1.8	1.00	620
71	0	0.6	75	0.075	1.9	1.00	630
72	0	0.6	75	0.075	2.0	1.04	640
73	0	0.6	75	0.075	2.1	1.06	580
74	0	0.6	75	0.075	2.2	1.26	630
75	0	0.6	75	0.075	2.3	1.16	590
76	0	0.6	75	0.075	2.4	1.32	610
77	0	0.6	75	0.075	2.5	1.38	590
78	0	0.6	75	0.075	1.5	1.18	560
79	0	0.6	75	0.075	1.6	1.00	610
80	0	0.6	75	0.075	1.7	1.04	630
81	0	0.6	75	0.075	1.8	1.02	580
82	0	0.6	75	0.075	1.9	1.04	610
83	0	0.6	75	0.075	2.0	0.96	590
84	0	0.6	75	0.075	2.1	0.98	600
85	0	0.6	75	0.075	2.2	1.10	590
86	0	0.6	75	0.075	2.3	1.16	610
87	0	0.6	75	0.075	2.4	1.38	620
88	0	0.6	75	0.075	2.5	1.54	580
89	0	0.6	75	0.075	1.5	1.06	650
90	0	0.6	75	0.075	1.6	1.10	640
91	0	0.6	75	0.075	1.7	0.96	590
92	0	0.6	75	0.075	1.8	0.98	620
93	0	0.6	75	0.075	1.9	0.94	630
94	0	0.6	75	0.075	2.0	0.98	600
95	0	0.6	75	0.075	2.1	1.04	620
96	0	0.6	75	0.075	2.2	1.10	560

Table 7-2. (page 4 of 6)

Run Number	X Velocity ft/day	Y Velocity ft/day	Longitudinal Dispersity (ft)	Transverse Dispersity (ft)	Retardation Factor	Source Mass (Pounds)	Sum of Absolute Differences
97	0	0.6	75	0.075	2.3	1.14	590
98	0	0.6	75	0.075	2.4	1.26	620
99	0	0.6	75	0.075	2.5	1.42	530
100	0	0.6	75	0.075	1.5	1.14	670
101	0	0.6	75	0.075	1.6	1.00	590
102	0	0.6	75	0.075	1.7	1.06	590
103	0	0.6	75	0.075	1.8	0.96	590
104	0	0.6	75	0.075	1.9	1.00	580
105	0	0.6	75	0.075	2.0	0.96	590
106	0	0.6	75	0.075	2.1	1.00	580
107	0	0.6	75	0.075	2.2	1.08	600
108	0	0.6	75	0.075	2.3	1.30	550
109	0	0.6	75	0.075	2.4	1.26	610
110	0	0.6	75	0.075	2.5	1.48	550
111	0	0.6	75	0.075	1.5	1.08	620
112	0	0.6	75	0.075	1.6	0.92	620
113	0	0.6	75	0.075	1.7	0.94	610
114	0	0.6	75	0.075	1.8	0.96	590
115	0	0.6	75	0.075	1.9	0.96	610
116	0	0.6	75	0.075	2.0	0.96	660
117	0	0.6	75	0.075	2.1	1.08	590
118	0	0.6	75	0.075	2.2	1.10	570
119	0	0.6	75	0.075	2.3	1.20	620
120	0	0.6	75	0.075	2.4	1.28	580
121	0	0.6	75	0.075	2.5	1.46	580
122	0	0.6	75	0.075	1.5	1.12	620
123	0	0.6	75	0.075	1.6	1.06	600
124	0	0.6	75	0.075	1.7	0.98	630
125	0	0.6	75	0.075	1.8	1.02	600
126	0	0.6	75	0.075	1.9	0.94	620
127	0	0.6	75	0.075	2.0	1.02	660
128	0	0.6	75	0.075	2.1	1.04	630

Table 7-2. (page 5 of 6)

Run Number	X Velocity ft/day	Y Velocity ft/day	Longitudinal Dispersity (ft)	Transverse Dispersity (ft)	Retardation Factor	Source Mass (Pounds)	Sum of Absolute Differences
129	0	0.6	75	0.075	2.2	1.08	580
130	0	0.6	75	0.075	2.3	1.24	560
131	0	0.6	75	0.075	2.4	1.28	650
132	0	0.6	75	0.075	2.5	1.48	600
133	0	0.6	75	0.075	1.5	1.14	600
134	0	0.6	75	0.075	1.6	1.00	600
135	0	0.6	75	0.075	1.7	1.00	600
136	0	0.6	75	0.075	1.8	0.98	600
137	0	0.6	75	0.075	1.9	1.06	600
138	0	0.6	75	0.075	2.0	1.06	610
139	0	0.6	75	0.075	2.1	1.08	560
140	0	0.6	75	0.075	2.2	1.10	610
141	0	0.6	75	0.075	2.3	1.16	600
142	0	0.6	75	0.075	2.4	1.40	580
143	0	0.6	75	0.075	2.5	1.42	570
144	0	0.6	75	0.075	1.5	1.04	650
145	0	0.6	75	0.075	1.6	1.00	640
146	0	0.6	75	0.075	1.7	1.02	580
147	0	0.6	75	0.075	1.8	0.96	600
148	0	0.6	75	0.075	1.9	0.96	640
149	0	0.6	75	0.075	2.0	0.96	590
150	0	0.6	75	0.075	2.1	1.10	630
151	0	0.6	75	0.075	2.2	1.08	650
152	0	0.6	75	0.075	2.3	1.32	590
153	0	0.6	75	0.075	2.4	1.26	600
154	0	0.6	75	0.075	2.5	1.56	580
155	0	0.6	75	0.075	1.5	1.12	610
156	0	0.6	75	0.075	1.6	1.00	610
157	0	0.6	75	0.075	1.7	1.10	600
158	0	0.6	75	0.075	1.8	0.98	620
159	0	0.6	75	0.075	1.9	1.04	600
160	0	0.6	75	0.075	2.0	1.10	590

Table 7-2. (page 6 of 6)

Run Number	X Velocity ft/day	Y Velocity ft/day	Longitudinal Dispersity (ft)	Transverse Dispersity (ft)	Retardation Factor	Source Mass (Pounds)	Sum of Absolute Differences
161	0	0.6	75	0.075	2.1	1.10	580
162	0	0.6	75	0.075	2.2	1.16	620
163	0	0.6	75	0.075	2.3	1.18	590
164	0	0.6	75	0.075	2.4	1.18	550
165	0	0.6	75	0.075	2.5	1.44	550

The chosen run number is 54.
The chosen source term configuration is 1.
The chosen velocity in the x direction is 0.
The chosen velocity in the y direction is 0.6.
The chosen longitudinal dispersivity is 75.
The chosen transverse dispersivity is 0.075.
For DCE the chosen retardation coefficient is 2.4.

Table 7-3. Solute Transport Model Calibration Results

Monitoring Well ID	X Node	Y Node	Manganese (mg/L)		1,2-Dichloroethene (μg/L)	
			Measured	Calculated	Measured	Calculated
BLM-57	4	1	7.91	8.70	1.50	0.00
BLM56/BLM-58	8	3	1.60	0.00	0.00	0.00
BLM-48/BLM-49	12	5	1.28	0.00	NA	NA
BLM-55	7	7	4.12	4.10	8.90	3.36
BLM-45/BLM-46	10	8	1.79	0.51	NA	NA
BLM-42/BLM-43	7	10	3.69	4.10	NA	NA
BLM-60	8	12	4.44	1.54	0.00	0.00
BLM-20/BLM-21	10	12	0.09	0.00	NA	NA
BLM-20/BLM-21	11	12	NA	NA	0.00	0.00
BLM-17/BLM-18	18	12	0.02	0.00	0.00	0.00
GBR-50	6	13	1.65	3.07	0.60	85.79
BLM-48	4	14	1.56	1.54	195.00	112.71
BLM-62	3	15	0.72	0.51	0.00	5.05
GBR-32	4	15	2.13	1.54	135.00	79.06
BLM-77/BLM-75	6	15	1.38	3.58	1.00	65.60
BLM-72	9	15	2.83	3.58	0.00	0.00
GBR-49	4	16	1.08	2.05	49.00	52.15
BLM-76	6	16	1.18	1.54	10.00	47.10
BLM-71	10	16	1.41	0.51	0.00	0.00
BLM-75	6	17	0.08	1.54	0.00	38.69
BLM-79	7	17	0.19	1.02	0.00	1.68
BLM-74	4	18	1.00	0.00	10.75	23.55
BLM-69	10	18	0.07	1.02	0.00	0.00
BLM-70	4	19	0.72	0.51	11.00	13.46
BLM-68	4	21	0.02	0.00	110.50	5.05
BLM-67/BLM-78	10	21	0.50	0.51	0.00	0.00
GBR-17	8	23	NA	NA	0.00	0.00

Constituent	Retardation factor	Mass (lbs)
Manganese	2.50	380.00
1,2-Dichloroethene	2.40	1.26

Velocity: 0.6 ft/day in y direction
Longitudinal dispersivity: 75.00 ft
Transverse dispersivity: 0.075 ft

Table 7-4. Random-Walk Input Parameters for the Lee Acres Landfill

Parameter	Value	Selection Rationale
Hydraulic Conductivity	60.0 gal/day/ft^2 (8.0 ft/day)	Representative of range provided by slug test calculations, (see subsection 4.2), and consistent with the value of velocity chosen in the calibration process. This parameter is involved only in simulations with discharging or recharging wells.
Transmissivity	480.0 gal/day/ft (64.0 ft^2/day)	Derived by multiplying representative hydraulic conductivity of 25 gal/day/ft^2 by a representative saturated thickness of 8 ft. This parameter is involved only in simulations with discharging or recharging wells.
Storage Coefficient	0.2	A representative value of the alluvial material type under unconfined conditions found at the site. This parameter only is involved only in simulations with discharging or recharging wells.
Porosity	0.3	A representative value of the alluvial material type at the site. This parameter is involved only in simulations with discharging or recharging wells.
Velocity	0.25 to 0.60 ft/day	Calculated by Darcy's Law, assuming a storage coefficient of 0.2, a hydraulic gradient of 0.015 ft/ft and hydraulic conductivity ranging from 3.3 to 8.0 ft/day. The velocity is in the y direction, i.e., the x component of velocity is zero.
Longitudinal Dispersivity	0.10 to 80.0 ft	The values for longitudinal and transverse dispersivity are parameters used to tune the calibration to best match the shape and distribution of measured groundwater concentrations. The greater the longitudinal dispersivity, the more diffuse the distribution of contamination, particularly along the leading edge of the plume. The same effect can be achieved by increasing the duration of source release while maintaining the same total mass of source.
Transverse Dispersivity	0.01 to 10.0 ft	The long and narrow shape of the manganese plume indicates that a low value for transverse dispersivity will best simulate the shape of the plume. The transverse dispersivity is the only parameter that directly effects the thickness of the plume.
Retardation Factor (Manganese)	1.0 to 5.0	Representative range expected for manganese given the site conditions, the range of velocity, and time for the manganese to migrate from the source to monitor wells detecting it.
Retardation Factor (1,2-DCE)	1.0 to 2.4	Representative range, given the geochemical site conditions (see Table 7-5).

gal/day/ft^2: gallons per day per square foot
ft/day: feet per day
gal/day/ft: gallons per day per foot
ft^2/day: square foot per day
1,2-DCE: 1,2-dichloroethene

Table 7-5. Parameter Ranges and Chosen Values

Parameters with the same range and value for both contaminants

Parameter	Low Value	High Value	Chosen Value	Units
Velocity	0.25	0.60	0.60	ft/day
Longitudinal Dispersivity	0.10	80.00	75.00	ft
Transverse Dispersivity	0.01	10.00	0.075	ft

The retardation factor, number of sources, source location, and release of source to the groundwater as a function of time are different for 1,2-dichloroethene and managanese.

For 1,2-Dichloroethene

	Low Value	High Value	Chosen Value
Retardation Factor	1.00	2.50	2.40
Number of sources	1		

Rectangular source area defined by two corners[a]

Lower left corner	(75 ft,100 ft)
Upper right corner	(125 ft ,200 ft)

Source temporal distribution determined by number of particles released during consective time periods

Length of Time Period in Days	Number of Particles Released	Percentage of Particles Released
10	300	15%
30	699	35%
30	600	30 %
10	400	20%
3900	0	0%

For Manganese

	Low Value	High Value	Chosen Value
Retardation factor	1.00	5.00	2.50
Number of sources	2		

Rectangular sources defined by two corners[a]

Source 1	
Lower left corner	(25 ft,75 ft)
Upper right corner	(125 ft,175 ft)

Table 7-5. (page 2 of 2)

Source 2	
Lower left corner	(100 ft,550 ft)
Upper right corner	(220 ft,650 ft)

Source temporal distribution determined by number of particles released during consecutive time periods

For Source 1 - Length of Time Period in Days	Number of Particles Released	Percentage of Particles Released
1200	200	10%
2815	1500	75%
For Source 2 - Length of Time Period in Days	Number of Particles Released	Percentage of Particles Released
1200	100	5%
2815	200	10%

[a]Refer to Figure 7-1 in the main text of the Remedial Investigation Report for Lee Acres Landfill.

Table 7-6. Comparison of Output from Final 1,2-DCE Calibration Run

Retardation Factor		1.5	Retardation Factor		1.6	Retardation Factor		1.7
Run Number	Source Mass (Pounds)	Sum of Absolute Differences	Run Number	Source Mass (Pounds)	Sum of Absolute Differences	Run Number	Source Mass (Pounds)	Sum of Absolute Differences
1	1.14	610	2	1.10	570	3	1.02	630
12	1.14	620	13	1.04	640	14	1.00	650
23	1.10	650	24	1.06	620	25	1.02	660
34	1.18	630	35	0.94	610	36	1.06	680
45	1.18	650	46	1.10	620	47	1.14	610
56	1.22	600	57	1.02	600	58	0.94	610
67	1.02	640	68	1.00	640	69	1.00	610
78	1.18	560	79	1.00	610	80	1.04	630
89	1.06	650	90	1.10	640	91	0.96	590
100	1.14	670	101	1.00	590	102	1.06	590
111	1.08	620	112	0.92	620	113	0.94	610
122	1.12	620	123	1.06	600	124	0.98	630
133	1.14	600	134	1.00	600	135	1.00	600
144	1.04	650	145	1.00	640	146	1.02	580
155	1.12	610	156	1.00	610	157	1.10	600
Avg	1.12	625	Avg	1.02	614	Avg	1.02	619
Std	0.05	27	Std	0.05	20	Std	0.05	27
Max	1.22	670	Max	1.10	640	Max	1.14	680
Min	1.02	560	Min	0.92	570	Min	0.94	580

Table 7-6. (page 2 of 4)

Retardation Factor		1.8	Retardation Factor		1.9	Retardation Factor		2.0
Run Number	Source Mass (Pounds)	Sum of Absolute Differences	Run Number	Source Mass (Pounds)	Sum of Absolute Differences	Run Number	Source Mass (Pounds)	Sum of Absolute Differences
4	0.96	620	5	0.94	610	6	1.00	590
15	0.98	610	16	1.02	590	17	1.04	650
26	1.02	630	27	1.04	630	28	1.00	630
37	1.02	640	38	1.04	580	39	1.04	600
48	0.90	610	49	0.96	630	50	1.02	610
59	1.06	580	60	1.00	580	61	0.98	590
70	1.00	620	71	1.00	630	72	1.04	640
81	1.02	580	82	1.04	610	83	0.96	590
92	0.98	620	93	0.94	630	94	0.98	600
103	0.96	590	104	1.00	580	105	0.96	590
114	0.96	590	115	0.96	610	116	0.96	660
125	1.02	600	126	0.94	620	127	1.02	660
136	0.98	600	137	1.06	600	138	1.06	610
147	0.96	600	148	0.96	640	149	0.96	590
158	0.98	620	159	1.04	600	160	1.10	590
Avg	0.99	607	Avg	1.00	609	Avg	1.01	613
Std	0.04	17	Std	0.04	20	Std	0.04	26
Max	1.06	640	Max	1.06	640	Max	1.10	660
Min	0.90	580	Min	0.94	580	Min	0.96	590

Table 7-6. (page 3 of 4)

Retardation Factor		2.1	Retardation Factor		2.2	Retardation Factor		2.3
Run Number	Source Mass (Pounds)	Sum of Absolute Differences	Run Number	Source Mass (Pounds)	Sum of Absolute Differences	Run Number	Source Mass (Pounds)	Sum of Absolute Differences
7	1.12	570	8	1.14	620	9	1.20	590
18	1.10	620	19	1.06	570	20	1.16	550
29	1.02	620	30	1.10	640	31	1.18	610
40	1.04	590	41	1.08	600	42	1.16	560
51	1.00	600	52	1.16	570	53	1.18	600
62	1.08	640	63	1.14	580	64	1.20	590
73	1.06	580	74	1.26	630	75	1.16	590
84	0.98	600	85	1.10	590	86	1.16	610
95	1.04	620	96	1.10	560	97	1.14	590
106	1.00	580	107	1.08	600	108	1.30	550
117	1.08	590	118	1.10	570	119	1.20	620
128	1.04	630	129	1.08	580	130	1.24	560
139	1.08	560	140	1.10	610	141	1.16	600
150	1.10	630	151	1.08	650	152	1.32	590
161	1.10	580	162	1.16	620	163	1.18	590
Avg	1.06	601	Avg	1.12	599	Avg	1.20	587
Std	0.04	24	Std	0.05	27	Std	0.05	21
Max	1.12	640	Max	1.26	650	Max	1.32	620
Min	0.98	560	Min	1.06	560	Min	1.14	550

Table 7-6. (page 4 of 4)

Retardation Factor		2.4	Retardation Factor		2.5
Run Number	Source Mass (Pounds)	Sum of Absolute Differences	Run Number	Source Mass (Pounds)	Sum of Absolute Differences
10	1.22	600	11	1.50	600
21	1.26	600	22	1.34	600
32	1.20	570	33	1.38	590
43	1.32	610	44	1.48	540
54	1.26	500	55	1.32	550
65	1.40	570	66	1.30	550
76	1.32	610	77	1.38	590
87	1.38	620	88	1.54	580
98	1.26	620	99	1.42	530
109	1.26	610	110	1.48	550
120	1.28	580	121	1.46	580
131	1.28	650	132	1.48	600
142	1.40	580	143	1.42	570
153	1.26	600	154	1.56	580
164	1.18	550	165	1.44	550
Avg	1.29	591	Avg	1.43	571
Std	0.07	34	Std	0.08	23
Max	1.40	650	Max	1.56	600
Min	1.18	500	Min	1.30	530

Avg is average
Std is standard deviation
Max is the maximum value
Min is the minimum value

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Table 7-7. Predicted Manganese and 1,2-DCE Arrival Times

Plume Location	Manganese			1,2-DCE		
	Arrival Year	Travel Time (Years)	Maximum Concentration[a] (mg/L)	Arrival Year	Travel Time (Years)	Maximum Concentration[a] (µg/L)
Suburban Heights Subdivision	2018	27	5.9	2004	13	57.1
San Juan River	2066	75	4.4	2051	60	17.1
Regulatory Standards	NMHHS = 0.2 mg/L			SDWA proposed MCL = 70 µg/L		

[a] Maximum concentrations are maximum predicted plume concentrations, not plume front concentrations.

1,2-DCE: 1,2-dichloroethene
SDWA: Safe Drinking Water Act
NMHHS: New Mexico human health standard
MCL: maximum contaminant level
mg/L: milligrams per liter
µg/L: micrograms per liter

Table 7-8. Calculation of K_ds and Predicted Source Concentrations to Groundwater

Constituent	Log(K_{ow})	K_d (mL/g)	K_d (gals/lb)	R_d	Concentration in soil (μg/kg)	Predicted Concentration in water (μg/L)	Annual Input to Groundwater (μg)	Annual Input to Groundwater (lbs)
TCE	2.29	0.10	0.01	1.59	14.00	12.68	2.57E+03	5.66E-06
PCE	2.6	0.20	0.02	2.12	31.00	25.86	5.25E+03	1.15E-05
1,1-DCE	2.13	0.07	0.01	1.42	4.70	4.38	8.87E+02	1.95E-06
MC	1.3	0.01	0.00	1.07	130.00	128.32	2.60E+04	5.73E-05
B	2.11	0.07	0.01	1.40	1,600.00	1,493.65	3.03E+05	6.66E-04
T	2.69	0.24	0.03	2.36	20,000.00	16,132.65	3.27E+06	7.20E-03
E	3.15	0.63	0.08	4.55	41,000.00	25,186.76	5.11E+06	1.12E-02
X	3	0.46	0.05	3.60	190,000.00	130,255.82	2.64E+07	5.81E-02

Fraction organic content = 0.00086
bulk density = 106 lbs/ft^3 = 14.17112 lbs/gal
porosity = 0.3
Source area = 43,000 ft^2
Percolation rate = 0.000167 ft/yr
Volume of annual percolation = 7.166667 ft^3/yr = 202.81666667 L/yr

B: benzene
1,2-DCE: 1,2-dichloroethene
E: ethylbenzene
K_{ow}: octanol/water partition coefficient
K_d: soil/water partition coefficient
MC: methylene chloride
Mn: manganese
PCE: tetrachloroethene
R_d: retardation factor
T: toluene
TCE: trichloroethene
μg/kg: micrograms per kilograms
μg/L: micrograms per liter
X: xylene

Note: 2.57E+03 indicates a value equal to 2,570, and 5.66E-06 indicates a value equal to 0.0000566.

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Table 7-9. Calculated Concentrations Resulting from Landfill Leachate

Years	Trichloroethene	Tetrachloroethene	1,2-dichloroethene	Methylene Chloride	Benzene	Toluene	Ethyl Benzene	Xylene
1	1.2E-04	2.5E-04	4.2E-05	1.2E-03	1.5E-02	1.3E-01	1.5E-01	9.5E-01
2	5.6E-05	1.1E-04	1.9E-05	5.6E-04	9.8E-03	1.3E-01	1.1E-01	4.8E-01
3	6.5E-05	1.3E-04	2.2E-05	6.6E-04	1.4E-02	9.5E-02	7.4E-02	9.5E-01
4	1.1E-04	2.3E-04	3.8E-05	1.1E-03	1.2E-02	7.1E-02	1.5E-01	7.6E-01
5	6.5E-05	1.3E-04	2.2E-05	6.6E-04	1.4E-02	1.3E-01	1.7E-01	1.0E+00
6	1.5E-04	3.0E-04	5.1E-05	1.5E-03	1.2E-02	1.3E-01	1.8E-01	1.1E+00
7	8.4E-05	1.7E-04	2.9E-05	8.5E-04	1.6E-02	4.7E-02	7.4E-02	8.6E-01
8	5.6E-05	1.1E-04	1.9E-05	5.6E-04	9.8E-03	1.1E-01	9.2E-02	2.9E-01
9	1.2E-04	2.5E-04	4.2E-05	1.2E-03	8.7E-03	8.3E-02	1.3E-01	1.1E+00
10	9.3E-05	1.9E-04	3.2E-05	9.4E-04	1.3E-02	1.5E-01	9.2E-02	4.8E-01
11	9.3E-05	1.9E-04	3.2E-05	9.4E-04	2.0E-02	1.5E-01	7.4E-02	3.8E-01
12	1.3E-04	2.6E-04	4.5E-05	1.3E-03	1.7E-02	1.1E-01	1.1E-01	7.6E-01
13	1.1E-04	2.3E-04	3.8E-05	1.1E-03	1.5E-02	2.4E-02	7.4E-02	4.8E-01
14	9.3E-05	1.9E-04	3.2E-05	9.4E-04	9.8E-03	1.1E-01	9.2E-02	5.7E-01
15	1.0E-04	2.1E-04	3.5E-05	1.0E-03	1.4E-02	9.5E-02	1.3E-01	4.8E-01
16	1.5E-04	3.0E-04	5.1E-05	1.5E-03	1.9E-02	1.7E-01	9.2E-02	8.6E-01
17	8.4E-05	1.7E-04	2.9E-05	8.5E-04	1.5E-02	4.7E-02	1.3E-01	8.6E-01
18	1.0E-04	2.1E-04	3.5E-05	1.0E-03	1.1E-02	1.4E-01	5.5E-02	7.6E-01
19	1.4E-04	2.8E-04	4.8E-05	1.4E-03	9.8E-03	9.5E-02	5.5E-02	7.6E-01
20	1.1E-04	2.3E-04	3.8E-05	1.1E-03	1.5E-02	7.1E-02	5.5E-02	8.6E-01

Note: All concentrations in μg/L. 1.2E-04 indicates a value equal to 0.00012.

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8. PATHWAY ANALYSIS

This qualitative pathway analysis evaluates the potential threat to human health and the environment in the absence of any remedial action. This analysis is the first step of the risk assessment process, which identifies COCs; assesses exposure and toxicity; and characterizes and quantifies, to the extent possible, actual risk. The procedures used in this process are outlined in the following guidance documents:

- Endangerment Assessment Handbook (EPA 1986c);
- Guidelines for the Evaluation of Risks for Carcinogens, Mutagens, Mixtures, Developmental Toxicants, and Exposures (EPA 1986e);
- Superfund Exposure Assessment Manual (EPA 1988e).

At the former Lee Acres Landfill, the migration of contaminants through air, surface water, soils, sediments, groundwater, and biota is considered. This section presents a qualitative screening of all potential exposure pathways for each OU in Site 1, and identifies those pathways that are, in the absence of any remedial action, currently considered a potential risk to public health or the environment. This screening analysis is conducted to provide an initial qualitative assessment of contaminant transport and to provide organization and direction for subsequent in-depth analyses and risk estimation. The next step of this analysis is the development of the site conceptual model (Section 9). A pathway analysis for Site 2 is not performed because contaminant sources are unrelated to the landfill.

Identified potential exposure pathways are considered further in Section 10, which describes the results of a baseline risk assessment. Section 10 discusses contaminant toxicity, exposure estimates, and risk to exposed populations for each potential exposure pathway selected as part of this qualitative exposure assessment. The baseline risk assessment is completed under the assumption that no remedial actions will occur, and contaminant levels for all media are based on RI data or predicted concentrations.

This section provides the rationale used to justify the elimination of pathways identified as having insignificant potential risk. Those pathways screened out from the list of potential pathways are not addressed in the baseline risk assessment (Section 10). The general purpose of this qualitative evaluation is to consider all pathways and identify those likely to result in any possible future exposure risk in order to complete a quantitative evaluation of exposure risk.

Qualitative exposure pathway screening is generally based on decision networks for air, surface water, soils, groundwater, and biota, shown in Figures 8-1 through 8-5. These decision networks are specific to the Lee Acres Landfill Study Area and are modeled after generic networks given in the Superfund Exposure Assessment Manual (EPA 1988e). The decision network for each pathway illustrates a series of decisions specific to the Lee Acres Landfill Study Area and results in the selection or rejection of a particular pathway as an identified active pathway. The subsections below discuss the rationale used to justify the selection of potential exposure pathways for the Lee Acres Landfill Study Area.

8.1. AIR PATHWAY SCREENING

Figure 8-1 is an air pathway decision network that illustrates possible atmospheric exposure pathways identified for the former Lee Acres Landfill. Results of the RI air sampling program presented in subsection 3.1 show that no organic, particulate, or metal emissions were measured above any regulatory standards. The air pathway decision network illustrates this finding by selecting the negative response to the question: Do RI air quality data indicate that landfill contaminants are released to air? In the absence of remedial action, the assumption is valid that future activities at the former Lee Acres Landfill will not include intrusive activities or activities that will disturb the landfill surface (Figure 8-1). Therefore, no future air emissions are expected, and the air pathway is rejected as a potential exposure pathway.

Subsection 5.5 documents the presence of subsurface gases below the landfill surface primarily consisting of organic gases (methane) derived from landfill waste decomposition. If selecting a final remedial action includes landfill excavation, surface disturbance, or other activities that may result in a potential release of these gases, the release will be considered part of the FS process. In this case, subsequent decisions shown on Figure 8-1 below the initial two decisions will be reconsidered and an air pathway risk assessment may be included in the FS.

8.2. SURFACE WATER PATHWAY SCREENING

The surface water pathway (Figure 8-2) is eliminated as a potential exposure pathway in the unnamed arroyo at the former Lee Acres Landfill for two reasons. First, surface flow rarely occurs in the unnamed arroyo. During the initial 5 months of RI data collection activities, no flow occurred. This documents the general rarity of storm events capable of producing runoff. However, during a week in August 1989, an estimated 500-year flood event produced erosion damage that threatened the integrity of the landfill (WESTON 1990h). As a result, BLM installed gabion walls at the west side of the landfill designed to sufficiently protect the landfill from a 500-year flood event. This provides the second reason for elimination of the surface water pathway; namely, the gabion walls provide a measure of protection that is considered permanent. Subsection 4.3 presents a floodplain analysis that compares the predicted 100-year and 500-year floodwater elevations with the gabion wall elevations.

8.3. SOIL PATHWAY SCREENING

The decision network for the soil pathway (Figure 8-3) illustrates several important findings. Ingestion, inhalation, or contact with contaminated soils within the landfill boundary is not considered a potential exposure pathway. The waste cells and landfill trenches are covered with approximately 2 to 10 ft of soil. Workers participating in RI data collection activities are protected according to procedures required by their health and safety plan, and are excluded as potential receptors (WESTON 1990c). Future ingestion, inhalation, or contact with contaminated landfill soil is prevented by restricting access to the site with a chain-link and barbed-wire fence and locked gate.

Well logs and geologic cross sections (Plate 6a) show that alluvial aquifer groundwater is below the limits of excavation within the former landfill. But, contaminants have been detected in wells below the landfill former liquid waste lagoons and just west of the western boundary. For example, groundwater samples collected from well screens installed beneath the landfill in BLM-55 and BLM-57 show levels of chlorinated hydrocarbons in the low parts-per-billion range (subsection 6.3 and Appendix N-1). Analytical results from OU 1 borehole soil samples show measurable levels of volatile and semivolatile contaminants (subsection 5.1 and Appendix I-1). These results indicate that in the past landfill contaminants may have leached through vadose zone soils to the alluvial aquifer system beneath the landfill.

RI data show there is no currently active or significant leaching process beneath the landfill that would move landfill contaminants through the vadose zone to alluvial aquifer groundwater. Although there is no evidence that the pathway is active or that wells were not contaminated by landfill soils, this pathway cannot be classified as inactive or dormant because an increase in available moisture to the landfill may result in a subsequent activation of the vadose zone leaching process. Contaminant leaching from the landfill to alluvial groundwater is, therefore, classified as a potential contaminant pathway.

8.4. GROUNDWATER PATHWAY SCREENING

The alluvial aquifer groundwater results, presented in section 6, also document contamination in OU 2 (northern and southern areas). The organic contamination in the southern area of OU 2 may or may not be a result of past leaching of contaminants from former liquid waste lagoons or from possible isolated areas of waste disposal separate from the Lee Acres Landfill. Downgradient migration of contamination in alluvial groundwater is considered a potential groundwater contaminant pathway. The groundwater pathway decision network is presented in Figure 8-4.

8.5. BIOTIC PATHWAY

No potential biotic exposure is identified through air, soil, or groundwater. Figure 8-5 shows the biotic pathway decision network. The possibility that fish caught in the San Juan River may pose a risk to humans when ingested is insignificant. Human exposure to the San Juan River was not included in the analysis as the river is located in Site 2.

8.6. EXPOSURE PATHWAY SCREENING SUMMARY

A qualitative analysis of all possible pathways resulted in the selection of two potential exposure pathways for the Lee Acres Landfill site. The two pathways are

- potential leaching of contaminants from the landfill to the alluvial aquifer, and
- ingestion or dermal contact with contaminated groundwater from Site 1, OU 2 groundwater.

All other air and biotic pathways are rejected as potential pathways. Section 10 presents the assumptions used to identify potentially exposed populations and estimate doses and risk associated with each of the pathways listed above.

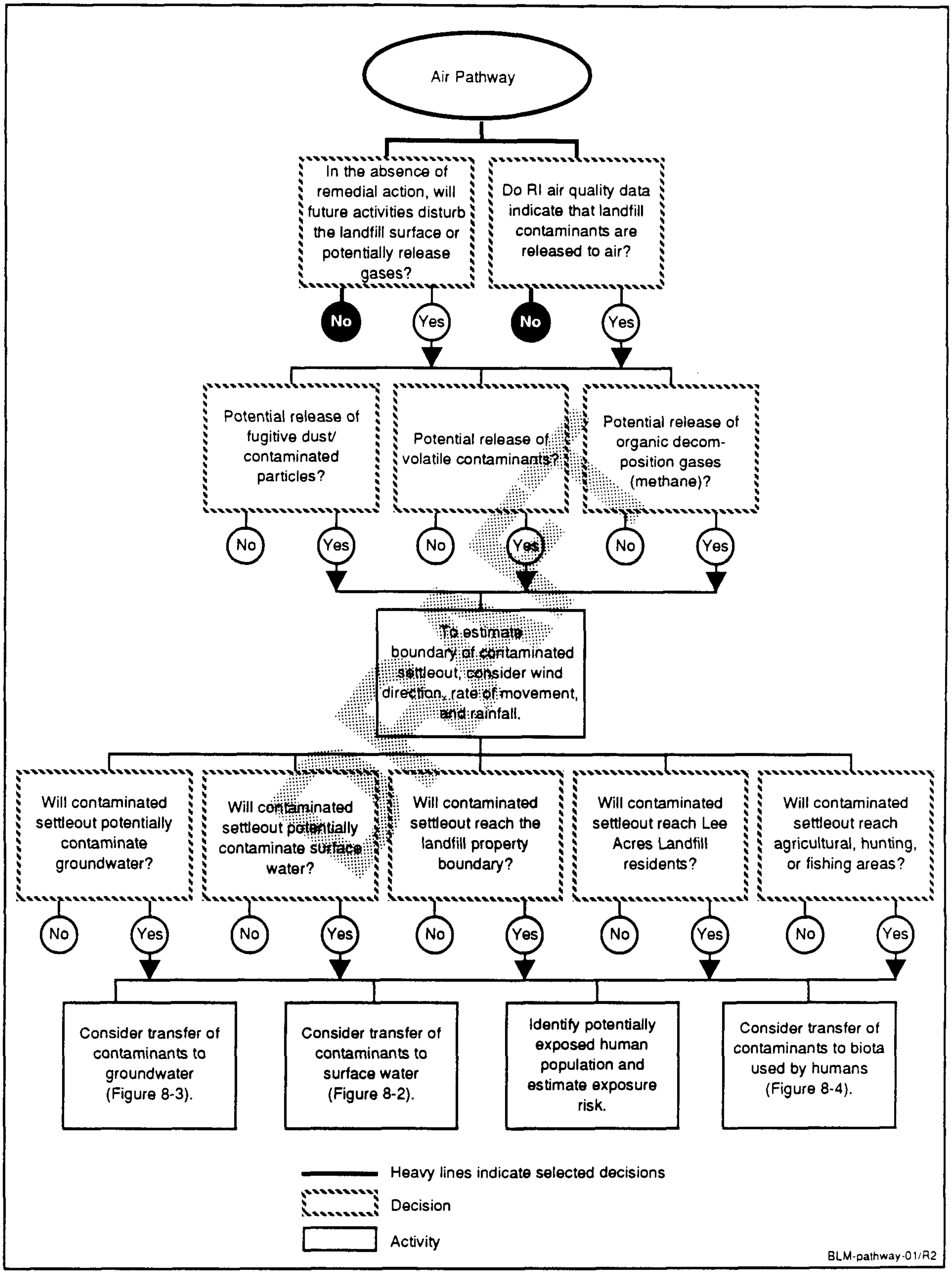


Figure 8-1. Air pathway decision network.

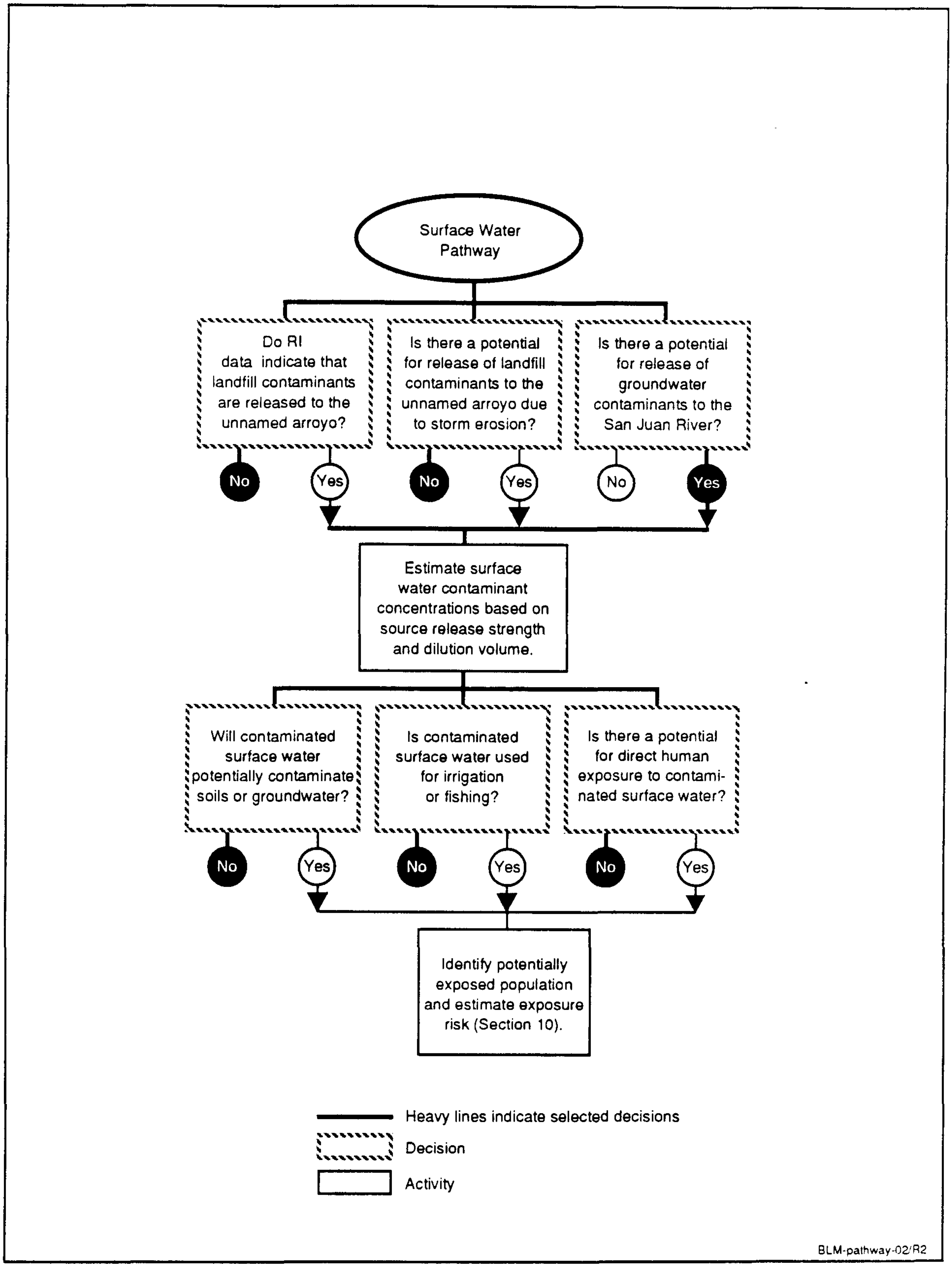


Figure 8-2. Surface water pathway decision network.

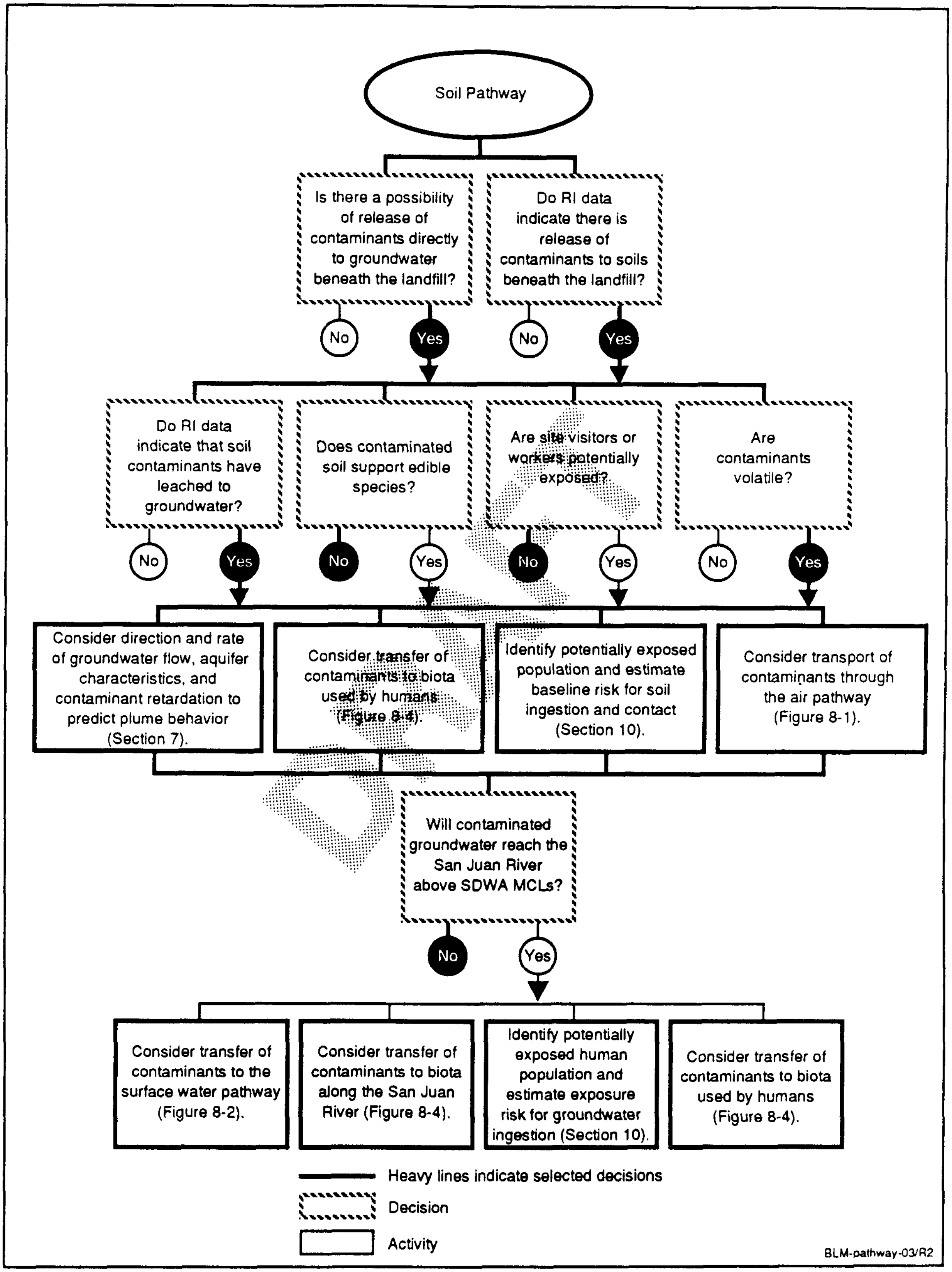
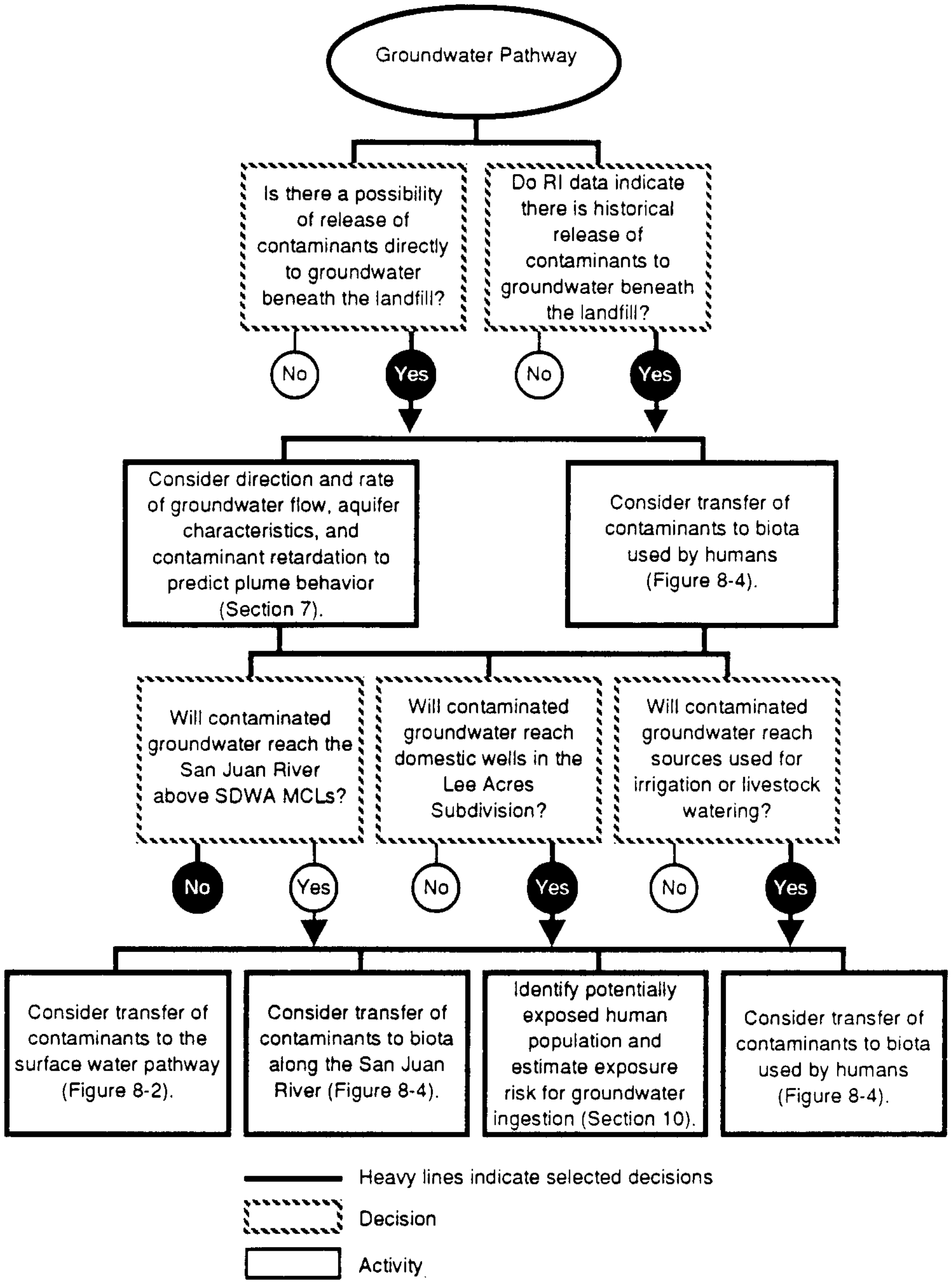


Figure 8-3. Soil pathway decision network.



BLM-pathway-04.R2

Figure 8-4. Groundwater pathway decision network.

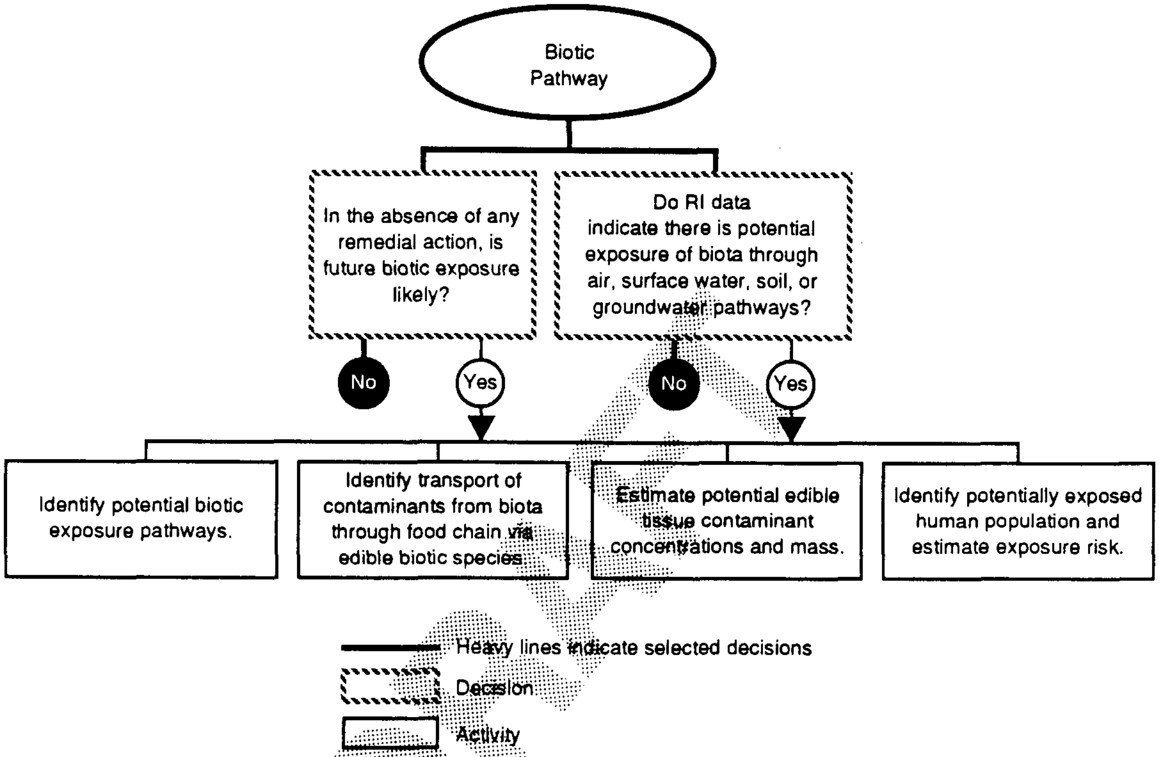


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Figure 8-5. Biotic pathway decision network.

9. CONCEPTUAL SITE MODEL

This section presents a conceptual understanding of the former Lee Acres Landfill in terms of contaminant sources, pathways, and receptors. This conceptual site model is based on past studies and RI data and is detailed enough to present the types and amounts of contaminants, affected media, rates and routes of migration, and receptors. A conceptual site model has not been developed for Site 2 because contaminant sources are unrelated to the former landfill. Figures 9-1 and 9-2 illustrate the Lee Acres Landfill site conceptual model, showing potential and dormant pathways. A description of how the site operates is provided below.

The former Lee Acres Landfill lies within a tributary drainage feature east of an ephemeral unnamed arroyo (Plate 1). Solid waste disposal was conducted by San Juan County from the 1960s to April 1986. However, disposal activity was minimal until 1970. Approximately 390,000 cubic yards of solid waste were disposed of in the landfill during this period (subsection 5.4). Liquid waste disposal, conducted from approximately 1979 to April 1985, generally consisted of the disposal of oil and gas well field brines. At no time was hazardous waste disposal approved or recorded in any inspection reports.

An extensive air monitoring program was completed during the RI to evaluate the potential for contaminated vapor release from the landfill. Under current site conditions, the potential for contaminant release into the atmosphere is considered dormant. RI data presented in subsection 3.1 show no release of any measurable amount of contaminated vapors. Gases released from the former liquid waste lagoons during the lagoon breach in April 1985 no longer pose a threat to human health or the environment because the lagoons have since evaporated, and been treated, abandoned, and filled with native material. These gases were not tested analytically in 1985 but were suspected of being primarily composed of hydrogen sulfide. The only gases encountered during the RI were found in the subsurface in boreholes. RI data show that these gases are not being released to the atmosphere, and pose no threat to human health or the environment. Therefore, the air pathway is shown on Figure 9-1 as a dormant pathway.

Direct contact with or ingestion of contaminated soil at the former Lee Acres Landfill is identified as a dormant pathway (Figure 9-1). The entire landfill has been regraded and covered with approximately 2 to 10 ft of native soil. The landfill boundary has a 6-ft chain link fence with barbed wire on top, all gates are locked, and highly visible signs written in three languages warn potential visitors against unauthorized entry. The above controls were designed to eliminate any possibility of exposure to contaminated soil or waste at the landfill.

Surface runoff in the unnamed arroyo is characterized as a dormant contaminant pathway because the landfill is protected from erosion by gabion walls (subsection 8.2). Any surface runoff in the unnamed arroyo has no contact with landfill contents. Precipitation is low and late summer storm events are rarely intense enough to produce surface water flow. The estimated equivalent of a 500-year flood event did occur in August 1989, resulting in erosion damage to the western edge of the landfill. No waste cells were damaged and no waste was released. This event prompted the design and construction of the gabion walls. The gabion walls are considered permanent and sufficient to protect the landfill from erosion damage in the unnamed arroyo. Figure 9-1 shows the surface water pathway as a dormant pathway.

Leaching of contaminants from the former landfill may have been an active process during the period of liquid waste disposal, which lasted from approximately 1979 to April 1985. The former liquid waste lagoons provided a flow mechanism in the form of a differential hydraulic head that induced contaminant leaching to groundwater beneath the landfill. There is currently no mechanism or available moisture to induce contaminant leaching from the former landfill to groundwater. Moisture in the solid waste cells may be present in small amounts, but little contaminant leaching is expected because of low precipitation and lack of available moisture. However, the possibility that contaminant leaching may be reactivated cannot be eliminated. Any increase in available moisture may result in the leaching of contaminants to groundwater. Therefore, vadose zone contaminant leaching from the former landfill is presented as a potential pathway on Figure 9-1.

Because the leaching process that occurred when the lagoons were operating has been reduced to a minimal level, little or no contamination is currently being introduced to the alluvial aquifer by vadose zone leaching. With increased precipitation, it is likely this pathway will become active. Therefore, the contaminant leaching to groundwater pathway is shown as a potential pathway on in Figure 9-1.

Migration of contaminants from the northern and southern areas of OU 2 groundwater contamination is considered the major pathway of contaminant migration at the former Lee Acres Landfill. During the RI, the highest elevated levels of VOCs were measured in wells GBR-32, GBR-48, and GBR-49 at the area designated as the Site 1 southern area (Plate 1 and Section 6). The rate of contaminant migration varies with the ability of each chemical to adsorb, but is generally considered equivalent to the velocity of groundwater flow. For the purpose of simulating solute transport, a groundwater flow velocity of approximately 0.6 ft/day was used (Section 7).

Although there is currently no domestic groundwater use immediately downgradient from the former landfill, the Site 1 southern area of contamination is considered a potential threat to human health and the environment. Exposure risk is estimated for this pathway in Section 10; this estimate is made assuming that no remedial action is implemented.

In subsection 6.5, substantial evidence is provided demonstrating that the Site 2 contaminant sources are separate from the former landfill, and that landfill contaminants have not contributed to the Site 2 area of contamination. In addition, landfill contaminants have not yet reached the Site 2 location. Although Site 2 sources are not associated with the former landfill, Figure 9-2 shows that the migration of contaminants from the Site 2 area is a potential contaminant pathway.

This conceptual model provides a basis on which to develop preliminary remedial objectives. Final remedial objectives may include action to cover the landfill to eliminate, by inhibiting infiltration, any secondary leaching process within the landfill. Remedial action objectives are likely to include steps that involve containment, treatment, or other alternatives to eliminate downgradient migration of northern groundwater plume contamination. Several technical rationales are presented in subsection 6.5 suggesting that the Site 2 area of contamination is associated with sources other than the former Lee Acres Landfill. Therefore, final remedial objectives will not include objectives designed to address Site 2.

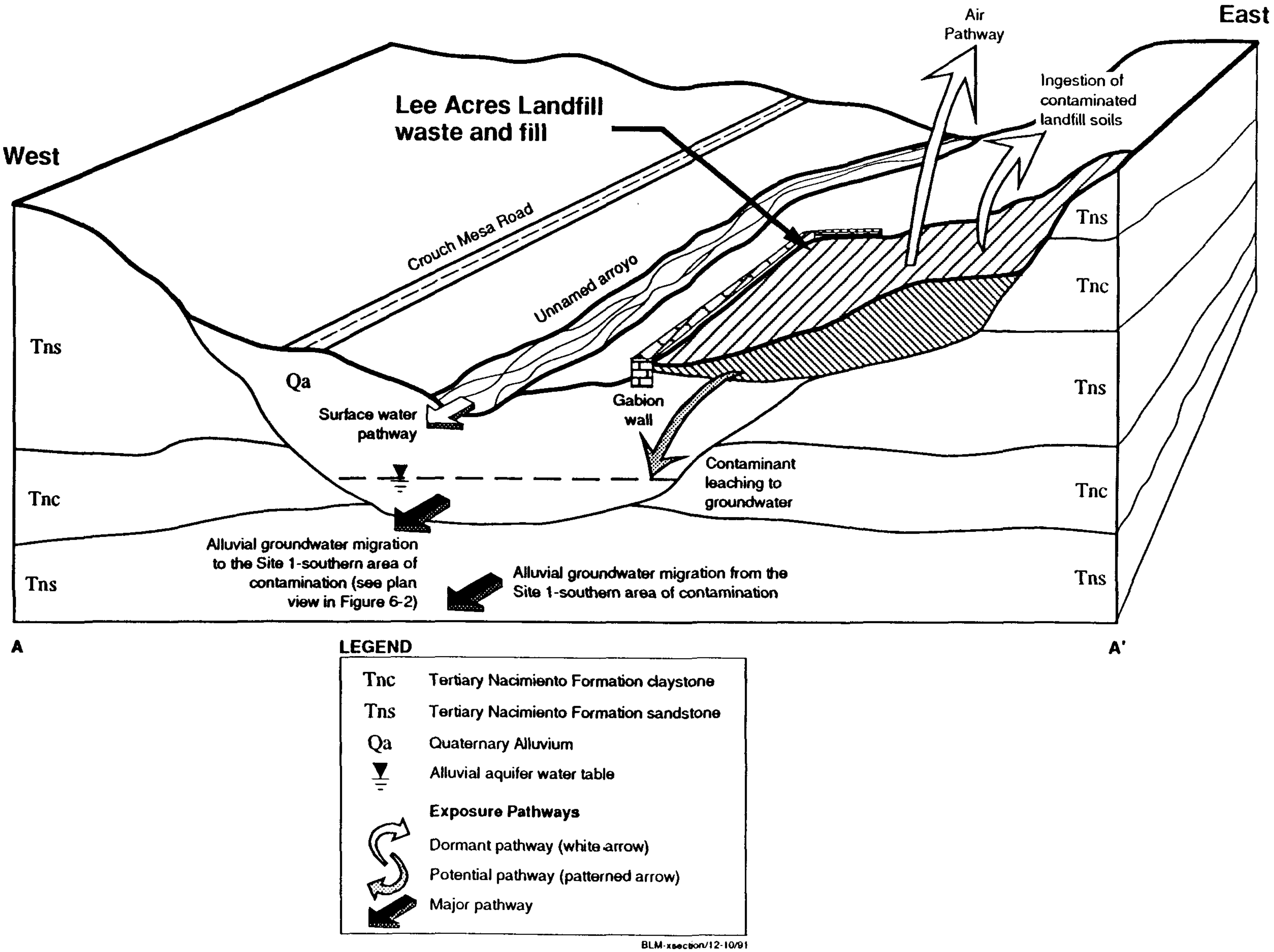

Figure 9-1. Illustrated conceptual site model, cross-sectional view looking north.

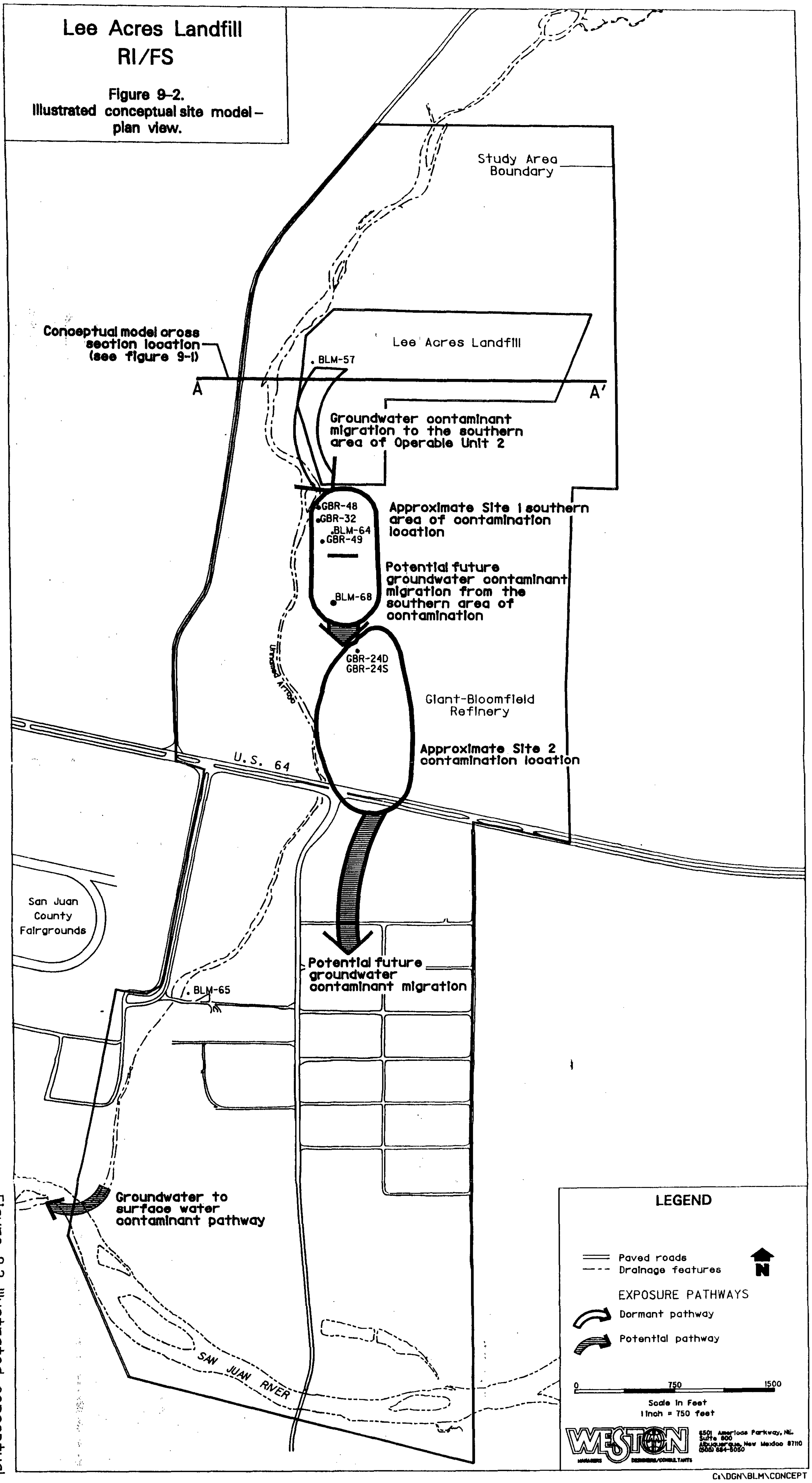

Figure 9.2. Illustrated conceptual site model - plan view.

10. BASELINE RISK ASSESSMENT

CERCLA established a national program for responding to releases of hazardous substances into the environment (EPA 1990a). The mandate of CERCLA is to protect human health and the environment from current and potential threats posed by uncontrolled hazardous substance releases. To help meet this mandate, a human health evaluation process, or baseline risk assessment, has been developed as part of the remedial response program (EPA 1989b). Because the former Lee Acres Landfill is listed on the NPL, the baseline risk assessment process at the Lee Acres Landfill has been conducted according to CERCLA guidance. The approach and results of this risk assessment will be reviewed and modified in response to EPA comments.

The baseline risk assessment for the former Lee Acres Landfill site addresses future public health risks that may someday exist, assuming that no remedial actions will be performed. Therefore, the assessment serves as a baseline case that can be used to compare the relative effectiveness of alternative remedial strategies in reducing public health risks. This baseline risk assessment focuses on exposure to hypothetical future residents from groundwater beneath Site 1, OU 2, northern and southern areas of contamination. Subarea 1 is considered to be background. Previous sections discuss that contamination within Site 2 (Plate 1) is the result of sources and releases separate and unrelated to the Lee Acres Landfill. Therefore, no risk assessment is performed to address future subarea 1 or Site 2 exposure.

The baseline risk assessment estimates risk associated with nine potential pathways identified by the qualitative pathway analysis (Section 8) and by the conceptual site model (Section 9). It also identifies pathways that exceed acceptable risk, so that the FS process is focused on pathways that present a threat to human health and environment. Any risk associated with a selected remedial action, such as landfill excavation, is not addressed as part of the baseline risk assessment. Releases and associated exposure risk that may occur as part of a remedial action will be addressed under adverse impacts in the Phase III FS.

Pertinent information on the content and preparation of health assessments at Superfund sites is contained in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988a), and *Risk Assessment Guidance for Superfund* (EPA 1989b). The primary components of the baseline risk assessment are identified in Figure 10-1 and include the identification of COCs, the exposure assessment, the toxicity assessment, and the risk characterization.

10.1. CONTAMINANTS OF CONCERN

Subsection 1.6 presents the rationale for identifying the COCs for the two sites and two OUs. Chemicals of potential concern are defined as those chemicals present at the former Lee Acres Landfill because of past activities, and include only those chemicals detected above reportable levels or at concentrations above naturally occurring levels that have been determined not to be sampling or laboratory artifacts. Laboratory artifacts could include common laboratory contaminants such as acetone, 2-butanone, dichloromethane, toluene, and phthalate esters. Figures 10-2 and 10-3 present the decision process used to identify COCs in soil (OU 1) and groundwater (OU 2), respectively.

This subsection will be used to refine the list of COCs established in previous sections using, as a basis, each contaminant's intrinsic toxicological properties, the quantities of the contaminant present, its potential critical exposure routes, and its utility as an indicator chemical.

10.1.1. <u>Subarea 1 Groundwater</u>

Subarea 1 groundwater, north of the former Lee Acres Landfill, is not considered to be a potential critical exposure pathway through ingestion or dermal contact. This area is north of, and upgradient from, the Lee Acres Landfill and is considered to be background.

Organic chemicals were identified in background samples from subarea 1, including acetone, phthalate esters, benzene, chlorobenzene, dichloromethane (methylene chloride), PCE, toluene, TCE, trichlorofluoromethane, trichloromethane (chloroform), and xylenes (Tables 10-1 and 10-2). The concentrations of acetone, benzene, phthalate esters, chlorobenzene, PCE, toluene, trichloromethane (chloroform), trichlorofluoromethane, and xylenes are in the low part-per-billion range, and are also found in some sample blanks. Dichloromethane and trichloromethane were identified in decontamination water during well installation. PCE, TCE, trichlorofluoromethane, and xylenes were identified in one or two rounds of early sampling, but have not been confirmed in subsequent sampling. All analytes mentioned above except dichloromethane are not considered to be contaminants in subarea 1, but are considered to be artifacts of the sampling program. Concentrations of inorganic constituents were within the regional concentration range, with the exception of chromium (Tables 10-1 and 10-2). Chromium is attributed to upgradient sources.

No quantitative risk assessment will be performed on subarea 1. However, the contribution to the total risk from dichloromethane and chromium from background water to OU 2 downgradient will be identified. This will allow an assessment of risk with and without the contribution from background.

10.1.2. Site 1 Soils and Groundwater

10.1.2.1. Site 1, OU 1 Soils

Site 1, OU 1 soils within the former Lee Acres Landfill may be considered to be a potential critical exposure pathway through ingestion, inhalation, or dermal contact (subsection 8.3 and Figure 8-3). However, the former Lee Acres Landfill is closed to dumping, is fenced and locked, is surrounded by warning signs written in three languages, and access is restricted. Contaminated soils and waste trenches are covered with 2 to 10 feet of soils. Also, public access to the site is unlikely in the near or foreseeable future.

Organic chemicals were identified in the upper 2 feet of soil from Site 1, OU 1 soils, including 4,4'-DDT, 1,4-dichlorobenzene, dichloromethane, dieldrin, ethylbenzene, toluene, 1,1,1-TCA, TCE, trichloromethane, and xylenes. The concentrations of all organic constituents except 1,1,1-TCA, which was also found in blanks, were in the low parts per million range. The concentrations of all organic constituents, except dieldrin, were below proposed RCRA action levels (55 FR 30865). Therefore, all analytes except dieldrin are not considered to be COCs in Site 1, OU 1. The concentrations of inorganic constituents were all below detection limit except for barium and strontium, which are within regional background levels. As a result no quantitative baseline risk assessment will be performed for inhalation, ingestion, or direct contact with landfill soils.

Subsection 8.3 presents the rationale for including the leaching of contaminants through vadose zone soils from the landfill as a potential migration pathway. Although the pathway is currently dormant, the possibility that future leaching will occur cannot be eliminated. Past leaching is attributed to the transport of contaminants from former liquid waste lagoons. The lagoons no longer exist, but any future addition of significant moisture to the landfill may provide a transport mechanism capable of inducing the migration of contaminants from landfill waste cells.

The receptor for the leaching pathway is groundwater. The FS will consider possible remedial actions to eliminate the leaching pathway, or reduce its potential risk within an acceptable health-based risk standard. Remedial actions to be considered will eliminate the introduction of moisture to the landfill or remove and treat landfill sources.

10.1.2.2. Site 1, Northern Area of OU 2 Groundwater

The northern area of OU 2, in Site 1, is defined as the groundwater beneath and adjacent to the former Lee Acres Landfill (subarea 2) and is considered to be an important exposure pathway (Figures 9-1 and 9-2). The former Lee Acres Landfill is closed to dumping, is fenced, is surrounded by posted warnings, access to it is restricted, and free access to the site in the future is unlikely. However, restricted access to the former Lee Acres Landfill may not be maintained forever. Groundwater from the northern area of OU 2 may be considered to be available as a drinking water source. Therefore, a quantitative baseline risk assessment is performed for groundwater in the northern area of OU 2 (Site 1).

Organic chemicals identified in groundwater samples from the northern area of OU 2 include aldrin, acetone, phthalate esters, benzene, benzoic acid, benzo-a-pyrene, benzo(g,h,i)perylene, bromodichloromethane, 2-butanone, 4,4'-DDT, 1,3-dichlorobenzene, dichloromethane, 1,1-DCA, 1,2-*cis*-DCE, 1,2-*trans*-DCE, dichlorofluoromethane, endrin, ethylbenzene, n-nitrosodiphenylamine, PCE, toluene, TCE, trichloromethane, vinyl chloride, and xylenes (Tables 10-3 and 10-4). The concentrations of acetone, phthalate esters, dichloromethane, and toluene are in the low part-per-billion range, and are also found in sample blanks. Dichloromethane and trichloromethane were identified in decontamination water during well installation. Aldrin, benzo-a-pyrene, benzo(g,h,i)perylene, 4,4'-DDT, endrin, n-nitrosodiphenylamine, PCE, TCE, and xylenes were identified in one or two rounds of early sampling, but have not been confirmed in subsequent sampling. The concentrations of inorganic constituents were within the regional concentration range, with the exception of chromium and manganese, (Tables 10-3 and 10-4). These contaminants from the northern area of OU 2 groundwater will be evaluated in terms of the risk posed by these chemicals in a baseline risk assessment.

A further reduction in the number of chemicals of concern for the northern area of OU 2 groundwater was necessary because identification of COCs must include an assessment of relative toxicity and risk. Carrying large numbers of chemicals through a quantitative risk assessment can be complex and difficult to understand and can distract from the dominant risks presented by the site (EPA 1988a). To achieve this reduction, quantitative screening of all potential COCs was used to prepare the final list of COCs. Quantitative screening determines the contribution of a chemical in relation to the contributions of all chemicals together. Using the maximum concentration of the contaminant and the carcinogenic slope factor or the noncarcinogenic reference concentration (RfC) or reference dose (RfD) from the EPA Integrated Risk Information System (IRIS) computerized data base (EPA 1990b), the relative contribution of that chemical to the contributions of all chemicals together is determined. The maximum concentration of each contaminant was multiplied by a carcinogenic slope factor or divided by a reference dose for that contaminant. If the total relative contribution for a chemical was 1 percent or less, it was screened out from further quantitative risk assessment.

Organic analytes from the northern area of OU 2 groundwater that were eliminated from quantitative risk assessment using frequency-of-detection evaluation and quantitative screening included all semivolatile compounds and pesticides, acetone, 2-butanone, bromo-dichloromethane, 1,1-DCA, 1,2-*cis*-DCE, 1,2-*trans*-DCE, 1,3-dichlorobenzene, dichlorodifluoromethane, ethylbenzene, toluene, and xylenes

(Tables 10-3 and 10-4). No inorganic analytes from the northern area of OU 2 were eliminated from quantitative risk assessment.

10.1.3. Site 1, Southern Area of OU 2 Groundwater

The southern area of OU 2 (Site 1) groundwater, located south of the landfill and north of GBR-17 (subarea 3), is considered to be an important exposure pathway (Figures 9-1 and 9-2). Access to subarea 3 is not restricted, and groundwater contamination has been documented. The chemicals of potential concern for the southern area of OU 2 are identified in Tables 10-5 and 10-6. A further reduction in the number of chemicals of concern for the southern area of OU 2 groundwater south of the former Lee Acres Landfill was performed (EPA 1988a) by using an evaluation of the frequency-of-detection evaluation and quantitative screening of all potential COCs.

Organic analytes from subarea 3 groundwater that were eliminated from quantitative risk assessment using frequency-of-detection evaluation and quantitative screening included all semivolatile compounds and pesticides, 1,1,1-TCA, 1,1-DCA, 1,3-*cis*-DCE, 1,2-*trans*-DCE, 1,3-*trans*-dichloropropene, dichlorodifluoromethane, ethylbenzene, toluene, vinyl chloride, and xylenes (Table 10-5 and 10-6). Inorganic analytes from subarea 3 groundwater that were eliminated from quantitative risk assessment using frequency-of-detection evaluation and quantitative screening included chloride and cobalt. Tables 10-5 and 10-6 also identify the remaining COCs for the southern area of OU 2 groundwater used in the quantitative risk assessment.

10.1.4. Site 2 Groundwater

Groundwater samples have also been collected from Site 2 (Figures 9-1 and 9-2). Site 2 is south of the former Lee Acres Landfill and includes GBR-17, approximately 1,000 ft south of the landfill, and extends southward to the San Juan River. Previous sections of this RIR show that Site 2 contamination is a result of sources and releases separate and unrelated to the former Lee Acres Landfill. Tables 10-7 and 10-8 identify chemicals of potential concern for Site 2 groundwater. Site 2 groundwater may be considered to be an important exposure pathway but is beyond the scope of this document. Therefore, no quantitative risk assessment will be performed.

10.2. EXPOSURE ASSESSMENT

The objective of the exposure assessment is to estimate the type and magnitude of hypothetical exposures to chemicals of potential concern that are present at or migrating from the former Lee Acres Landfill (EPA 1989b). There are currently no active or actual exposure pathways. The exposure pathway is the unique mechanism by which an individual or population is exposed to chemicals or physical agents at or originating from a site. Each exposure pathway requires a source or release from a source, an exposure route, and an exposure point.

The potential chemical release sources at the former Lee Acres Landfill are presented in Table 10-9. The only quantifiable contamination is from surface or buried waste and contaminated soils, and the migration of contaminants (leaching) through vadose zone soils to groundwater. Additionally there is an area of contamination south of the landfill on Site 2. Therefore, the primary exposure points are from Site 1, OU 2 northern and southern areas groundwater.

The exposure route involves the contact of an organism with a chemical or physical agent. The magnitude of exposure is determined by measuring or estimating the amount of that agent available at exchange boundaries from inhalation, ingestion, or direct contact (i.e., contact on the surface of the skin). The frequency and duration of exposure is estimated. Only hypothetical current and future scenarios that pose the greatest potential for exposure and risk were considered.

10.2.1. Detailed Characterization of Exposure Pathways

The exposure setting, which includes the Lee Acres Landfill's climate, vegetation, groundwater hydrology, and surface water, is described in Sections 3 and 4. Potentially exposed populations are present approximately 2,500 ft south of the former Lee Acres Landfill and include the Suburban Heights subdivision, the F. L. Lee subdivision, Lee Acres subdivisions No. 1 and No. 2, the Cottonwood Acres subdivisions, and several county and private plots. The estimated population within the study area is 486 persons. Contamination in residential areas directly attributable to the Lee Acres Landfill has not been demonstrated or verified.

Current population activity patterns are presented in Section 3. The majority of land in the study area is used as open rangeland for wildlife and livestock, with industrial, residential, and recreational uses also occurring in the immediate area. A more detailed description of land use and demographics is also found in subsection 3.3.2.

Exposure to a chemical is a function of the environmental migration pathway of that chemical. The migration, or fate and transport, of chemicals in the environment is influenced by site characteristics, characteristics of the source areas, and the physical and chemical properties of chemicals. Hydrogeologic models are often used to provide the most realistic understanding of the fate and transport of chemicals in the environment. Groundwater mass transport modeling was performed to evaluate the fate and transport of selected chemicals at the former Lee Acres Landfill; the results of this modeling are presented in

Section 7. Additional discussion of the physicochemical properties of chemicals of potential concern is presented below.

The chemicals of potential concern can be classified under the following general categories according to their similarity in chemical structure or in properties that affect fate and transport in the environment:

- simple nonchlorinated aromatics (i. e., benzene);
- chlorinated aliphatics (i.e., dichloromethane, PCE, TCE, trichloromethane, and vinyl chloride);
- phthalates (i.e., *bis*(2-ethylhexyl) phthalate); and
- inorganics (i.e., chromium, manganese, nickel, and selenium).

Table 10-10 provides a summary of the physicochemical properties of contaminants, along with an explanation of the parameters identified. Physicochemical properties of inorganic contaminants are provided; however, migration of inorganic chemicals is greatly dependent on many external factors. Some of these factors and there interaction are difficult to calculate or measure in the field and were therefore not evaluated. These parameters include the identity of other ions that may influence transport or mobility via chemical complexation reactions; the pH of groundwater; the presence of humic materials in soil; the presence of hydrous oxides in soil; the presence of silicates in soil; the presence of carbonate minerals in soil; oxidizing and reducing conditions; and the presence of microorganisms.

Chlorinated aliphatic chemicals have been found to undergo biological reduction-dechlorination reactions (Bouwer et al. 1981; Kobayashi and Rittman 1982). Degradation of chlorinated aliphatic hydrocarbons is discussed in detail in subsection 6.4.1.2.2. For example, PCE can be converted to TCA and 1,1,1-TCA (Cooper 1987; Parsons et al. 1984). Dichloromethane can be converted to methylchloride. TCE can be converted to 1,2-*trans*-DCE, and eventually to vinyl chloride. The chemicals detected in groundwater beneath and downgradient from the former Lee Acres Landfill may or may not be degradation products; the distribution and change in relative concentrations or the area and concentration of the initial source due to chemical degradation processes will not be fully characterized, although expected degradation products are identified in Section 6.

Transformation processes such as those previously discussed would result in reduced concentrations of the parent chemicals as they migrate from the former Lee Acres Landfill. Dispersion and dilution processes can also reduce the concentrations of both parent and degradation products as they migrate.

Section 8 is a qualitative exposure pathway analysis for the former Lee Acres Landfill. Two potential, but hypothetical, exposure pathways were selected as potential exposure pathways. These include exposure to future residents through groundwater pathways from Site 1, northern and southern areas of OU 2. Air exposure pathways, sediment and surface water runoff exposure pathways, and biotic pathways were rejected. The basic exposure pathways are listed in Table 10-11. These scenarios will be evaluated for potential health risks on the basis of specific pathways including inhalation, ingestion, and dermal exposure to contaminated groundwater. No current resident exposure scenarios are presented because modeling in Section 7 indicates that contaminants from the southern area of OU 2 will not reach subdivision residents for 10 years from 1991 (subsection 7.4).

For the scenario in which risk results from exposure to Site 1, northern area of OU 2 groundwater, the future resident is assumed to live within the present confines of the former Lee Acres Landfill (Figure 9-2). This location for a dwelling is unlikely because it is fenced, is surrounded by warning signs written in three languages, and access to it is restricted. This location will be used as the baseline case for a private dwelling by which the location of a dwelling in the southern area of OU 2 is compared. It is assumed that future residents will remain at that location over a 30-year period, which is a reasonable upper bound estimate for living in any one given location (EPA 1991b). Exposure to the future resident would come from groundwater pathways. A drinking water and domestic use well would be installed at the dwelling, and water for all domestic uses would come from this well. This exposure scenario is conservative and provides a baseline scenario.

For the scenario in which risk results from exposure to the southern area of OU 2 groundwater, the future resident is assumed to live immediately downgradient of the current position of the area of contamination (Figure 9-2). This location for a dwelling is unlikely because this land is on the site of the former Giant-Bloomfield Refinery, but will be used as the closest possible worst-case location for a private dwelling. It is assumed that future residents will remain at that location over a 30-year period, which is a reasonable upper bound estimate for living in any one given location (EPA 1991b). Exposure to the future resident would come from groundwater pathways. A drinking water and domestic use well would be installed at the dwelling, and water for all domestic uses would come from this well. This exposure scenario is conservative, and provides a worst-case scenario.

10.2.2. Quantification of Exposure

This subsection presents the mathematical models that were used to calculate the estimated daily intakes for the human exposure routes identified in Table 10-11. Estimated daily intake is the exposure expressed as mass of a contaminant contacted per unit body weight per day. The models are presented in tabular form, and each table includes the definitions and assumptions used. Each estimated daily intake model is approximate and is only as valid as the assumptions used. Estimated daily intakes were calculated using the geometric average and maximum exposure concentrations presented in Tables 10-1 through 10-8.

intakes were computed for both an adult and a child (age 1 to 6 years). The intakes calculated for each exposure route are presented following the applicable tabulated exposure model.

10.2.3. Drinking Water Ingestion

Drinking water ingestion is a potential route of exposure for the future resident located south of the northern area of contamination. The equation and assumptions used in calculating the estimated daily intakes of contaminants through drinking water ingestion are presented in Table 10-12. Daily intakes of contaminants through drinking water ingestion are presented for future residents in Tables 10-13 and 10-14.

10.2.4. Inhalation and Dermal Absorption

It has been estimated that the amount of VOCs absorbed by an adult through the inhalation of enclosed shower air could be equivalent to that absorbed through ingestion of drinking water (Cothern et al. 1986; NRC 1986). The combination of elevated temperatures and the spray from the shower head could result in high vapor concentrations, particularly in confined areas such as an enclosed shower. The elevated temperatures would also be expected to facilitate dermal absorption. Dermal absorption while showering in contaminated water is also potential exposure route for future residents. Therefore, it is assumed that inhalation and dermal absorption of contaminants together result in exposure equivalent of one liter/per day (child) and 2 liter per day (adult). The equation and assumptions used in calculating the estimated daily intake of contaminants through inhalation and dermal absorption while showering is presented in Table 10-15. The calculated daily intake through this pathway is also included in Tables 10-13 and 10-14.

10.2.5. Uncertainties for Exposure Assessment

Uncertainties exist in the exposure assessment. Assumptions were made regarding all modes of exposure, and each assumption has its own associated uncertainties. The uncertainties for the exposure assessment are provided in Table 10-16. Uncertainties include whether or not sufficient samples have been collected to characterize the media being evaluated, or whether systematic or random errors in chemical analyses yield erroneous data. In addition, there are uncertainties in standard parameters, including average human body weight, period exposed, amount of media intake, lifetime exposure duration, and amount of groundwater used. These uncertainties and assumptions could be over estimated or underestimated, and the relative potential for over or under estimation is identified. This qualitative evaluation of the uncertainties can provide an evaluation of whether the exposure estimates are the maximum exposures that can be reasonably expected to occur. A more detailed discussion of uncertainties for the entire risk assessment is provided in subsection 10.7.

10.3. TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to weigh available evidence regarding the potential for particular contaminants to cause adverse effects in exposed individuals and to provide an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects (EPA 1989b). This test includes the preparation of toxicity and fate profiles for each of the chemicals and the identification of human health criteria. This section addresses human health criteria. The toxicity and fate profiles for contaminants used in the risk assessment are presented in Appendix X.

Toxicity is the expression (usually determined through human or animal testing) of the dose of a chemical and the response elicited in an organism (dose-response evaluation) that is used in risk assessment. Toxicity assessment also includes hazard assessment. Hazard assessment is the process of determining whether exposure to an agent can cause an increase in the incidence of a particular adverse health effect such as cancer or birth defects. Dose-response evaluation is the process of quantitatively evaluating the toxicity information, and then characterizing the relationship between the dose of the contaminant administered or received and the incidence of adverse health effects in the exposed population.

Carcinogenic risks are evaluated using carcinogenic slope factors. Slope factors are plausible upper-bound estimates of the probability of a response (cancer) per unit intake of a chemical over an individual's lifetime. In dealing with carcinogenesis, it is believed that there is essentially no level of exposure to a carcinogen that does not pose some finite probability, however small, of generating a cancer. Therefore, in evaluating cancer risks, an effect threshold cannot be estimated. Each substance is assigned a weight-of-evidence classification (Table 10-17), and slope factors are then calculated. Nine of the contaminants of concern have been categorized as carcinogens (classified in Groups A, B, or C) by the EPA including benzene, trichloromethane, dichloromethane, PCE, TCE, vinyl chloride, *bis*(2-ethylhexyl) phthalate, chromium, and nickel. An explanation of these classifications is also provided in Table 10-17. Toxicity values and types of cancer for the COCs are provided in Table 10-18.

Noncarcinogenic risks are classified as chronic or subchronic. The RfC or RfD are concepts used in evaluating noncarcinogenic effects resulting from chemical exposures. The chronic RfC and RfD are estimates (with an uncertainty spanning perhaps an order of magnitude or greater) of daily exposure levels for the human population that are likely to be without an appreciable risk of deleterious effects during a lifetime. The chronic RfC and RfD were developed in order to analyze the effects of long-term exposure to a compound. The subchronic RfC and RfD are useful for shorter-term exposures of from 1 week to 7 years. Unlike carcinogenic effects, noncarcinogenic effects are believed to be manifested only after some protective mechanisms are overcome. As a result, a range of exposures from zero to some finite value, or threshold value, can be tolerated by an organism with essentially no chance of expression of adverse effects. Toxicity values and critical effects for chronic and subchronic noncarcinogenic effects for the contaminants of concern are provided in Tables 10-19 and 10-20, respectively.

Oral or inhalation chronic RfCs and RfDs were available for all contaminants except vinyl chloride. A chronic oral RfD was calculated for vinyl chloride based on a reported no-observed-adverse-effect level of 0.13 mg/kg/day from a chronic oral study in rats (ATSDR 1988a) by incorporating an uncertainty factor of 100 in accordance with EPA guidelines (10 for extrapolation from animals to humans, 10 for human variation) (EPA 1985). By this method the chronic RfD for a human for vinyl chloride is estimated to be 0.0013 mg/kg/day. Subchronic oral or inhalation RfDs were available for all of the contaminants except benzene, vinyl chloride, and TCE. Subchronic RfCs and RfDs were derived for vinyl chloride from an adult longer-term health advisory of 46 μg/L (EPA 1987a), assuming an average adult body weight of 70 kg and the consumption of 2 L of drinking water per day. In the absence of data on which to base a subchronic RfD for benzene and TCE, the chronic oral RfD was used. RfD values for benzene and TCE were derived similarly (ATSDR 1987 and ATSDR 1988b, respectively).

10.4. RISK CHARACTERIZATION

In this subsection, toxicity and exposure assessments are summarized and integrated into quantitative and qualitative expressions of risk. Both noncarcinogenic and carcinogenic effects are evaluated. Of the 10 COCs, seven chemicals are evaluated for carcinogenic risk. All COCs are assessed for potential noncarcinogenic effects. A qualitative assessment and comparison of estimated risk to future residents and nonresidents is provided in subsection 10.8.

10.4.1. Carcinogenic Risk Characterization

Carcinogenic risk depends on three factors: the dose, the carcinogenic potency of the chemical, and the exposure duration. Residents are assumed to be exposed for a total of 30 years of their adult lives (EPA 1991b). To calculate carcinogenic risk, the product of the individual chemical exposures and carcinogenic slope factors were taken and then summed to provide the estimated risk to the current and future resident and nonresident. Table 10-21 provides the geometric average and maximum carcinogenic risk to the future resident of Site 1, northern area of OU 2 groundwater. Table 10-22 provides the geometric average and maximum carcinogenic risk to the future nonresident.

10.4.2. Noncarcinogenic Risk Characterization

Noncarcinogenic risk was evaluated by calculating the hazard quotient, which is the ratio of the estimated daily exposure of each contaminant to the applicable subchronic or chronic RfC or RfD for that contaminant. The hazard quotients were then summed to derive a hazard index (HI) for each exposure route and for all exposure routes combined. The potential concern level is 1.0 and greater. A HI of greater than 1.0 at any time during an individual's lifetime indicates there may be a potential for noncarcinogenic effects. Table 10-23 provides the average and maximum chronic HIs for future residents, Site 1, northern area of OU 2 groundwater. Table 10-24 provides the average and maximum chronic hazard indices for future residents, Site 1, southern area of OU 2 groundwater. Table 10-25 provides the average and maximum subchronic hazard indices for future nonresidents, Site 1, northern area of OU 2 groundwater. Table 10-26 provides the average and maximum subchronic hazard indices for future nonresidents, Site 1, southern area of OU 2 groundwater. Results are discussed in subsections 10.6 and 10.8.

10.5. ENVIRONMENTAL EVALUATION

Environmental and human health evaluation are parallel activities in the evaluation of the Lee Acres Landfill. The environmental evaluation, or more precisely the ecological assessment, is a qualitative or quantitative appraisal of the actual or potential effects of a hazardous waste site on plants and animals other than people and domesticated species (EPA 1989b). The NCP (EPA 1990a) calls for identification and mitigation of the environmental impacts of hazardous waste sites and the selection of alternatives that are protective of environmental organisms and ecosystems. Compliance with certain ARARs may also require evaluation of a site's effects on the ecology and the measures needed to mitigate those effects. Much of the data and analyses relating to the nature, fate, and transport of contaminants is used for both evaluations, although certain contaminants and exposure pathways may be more important for the environmental evaluation than for the health evaluation.

The objective of the environmental evaluation at the Lee Acres Landfill was to determine if the contaminants present are resulting in an adverse ecological impact. The data collected were used in conjunction with toxicity information to assess impacts. A more complete description of the flora, fauna, and ecology of the Lee Acres Landfill Study Area is presented in Section 3.

Effects on ecosystems were assessed qualitatively. Based on visual assessments, there have been no known reductions in the size of populations, no known changes in community structure, and no known changes in ecosystem structure and function within the study area. The native vegetation has been removed from significant portions of the study area due to past landfill operations. The density and diversity of wildlife are already low due to arid conditions and the physically disturbed nature of the study area.

Calculated concentrations of dichloromethane, TCE, PCE, and 1,1-DCA in the San Juan River were compared to data on the aquatic toxicity of these compounds to fish. The lowest effective concentration for aquatic organisms (LEC--the lowest concentration for which a toxic effect is observed) for dichloromethane, TCE, PCE, and 1,1-DCA are presented in Table 10-27 and range from 0.84 to 224 μg/L. The estimated future concentrations of these contaminants in the San Juan River range from 0.003 to 0.0003 μg/L, based on a San Juan River flow rate of 1.179M acre ft/yr (Table 10-27). Estimated future concentrations for these constituents in the San Juan River are significantly lower than SDWA MCLs for both compounds (Table 10-27).

10.6. DISCUSSION OF RESULTS

This subsection presents an overview of the risk characterization and discusses the potential contributions of the chemicals and exposure pathways to carcinogenic and noncarcinogenic risk for future residents and future nonresidents located downgradient from the northern groundwater plume.

10.6.1. Carcinogenic Risk

10.6.1.1. Future Residents - Site 1, Northern Area of OU 2 Groundwater

Table 10-21 summarizes the potential average and maximum carcinogenic risk to future residents through the drinking water pathway. Total average and maximum risk from all chemicals and pathways is 5E-5 (0.00005) and 4E-4 (0.0004), respectively. These risk levels are of potential concern because they represent incremental cancer risks on the order of one excess cancer observed in a population of 100,000 and 10,000 persons exposed, respectively. Vinyl chloride contributes approximately 90 and 84 percent of the total average and maximum risk, respectively. The remaining chemicals each contributed approximately five percent or less to the total average or maximum risk.

The ingestion pathway contributes approximately 75 percent to the total average and maximum risk. Inhalation contributes less than 5 percent to the total average and maximum risk. The direct contact during showering pathway contributes less than 20 percent to the total average and maximum risk, respectively.

The contributions to the total carcinogenic risk from TCE and vinyl chloride in background groundwater were 4E-05 (0.000041) geometric average and 3.2E-04 (0.00032) maximum. The contributions from the remaining chemicals are less than one percent of the totals for subarea 1 groundwater and are not considered to significantly add to the total carcinogenic risk.

10.6.1.2. Future Residents - Site 1, Southern Area of OU 2 Groundwater

Table 10-22 summarizes the average and maximum carcinogenic risk to future residents through the drinking water pathway. Total average and maximum risk from all chemicals and pathways is 5E-06 (0.000005) and 2E-04 (0.0002), respectively. These risk levels are of potential concern because they represent incremental cancer risk on the order of one excess cancer observed in a population of 1,000,000 and 10,000 persons exposed, respectively. Benzene contributes approximately 17 and 67 percent of the total average and maximum risk, respectively. Dichloromethane contributes 9 and 6 percent of the total average and maximum risk, respectively. PCE contributes 53 and 19 percent of the total average and maximum risk, respectively. TCE contributes 11 and 5 percent of the total average and maximum risk, respectively. Trichloromethane contributes 10 and 3 percent of the total average and maximum risk, respectively.

The ingestion pathway contributes approximately 40 and 50 percent to the total average and maximum risk, respectively. The inhalation pathway contributes approximately 40 and 25 percent to the total average and maximum risk, respectively. The direct contact during showering pathway contributes approximately 20 and 25 percent to the total average and maximum risk, respectively.

10.6.2. Noncarcinogenic Risks

10.6.2.1. Future Residents (Chronic) - Site 1, Northern Area of OU 2 Groundwater

Table 10-23 summarizes the average maximum chronic HI values for future residents of subarea 2, OU 2 groundwater. Only the average and maximum inhalation, average ingestion, and average dermal pathways had HI levels below 1.0. All other pathways with HI levels above 1.0 indicate potential concern for these pathways. The organic chemicals with the most significant influence on the total average and maximum HI values are benzene (15 and 2 percent, respectively) and vinyl chloride (11 and 5 percent, respectively). The inorganic chemicals with the most significant influence on HI values included chromium VI and manganese. In summary, HI values for the future resident show that ingestion of, and direct contact (showering) with, the maximum contaminant concentrations of Site 1, OU 2 groundwater are of potential concern.

The contributions to the total noncarcinogenic chronic hazard indices, from dichloromethane and chromium in background water totaled 0.6. The noncarcinogenic contributions from these chemicals may be significant for subarea 1 groundwater. This represents a high percentage of the total risk of subarea 1 groundwater or from upgradient background water.

10.6.2.2. Future Residents (Chronic) - Site 1, Southern Area of OU 2 Groundwater

Table 10-24 summarizes the average and maximum chronic HI values for future residents of Site 2, subarea 3 groundwater. Only the average inhalation, ingestion, and dermal pathways had HI values below 1.0. All other pathways with HI levels above 1.0 indicate potential concern for these pathways. The organic chemical with the most significant influence on the total average and maximum HI values is benzene (15 and 46 percent, respectively) and the inorganic chemicals manganese, nickel, and selenium.

10.6.2.3. Future Residents (Subchronic) - Site 1, Northern Area of OU 2 Groundwater

Table 10-25 summarizes the average and maximum subchronic HI values for future residents of Site 1, OU 2 groundwater. The trends of contribution by exposure pathway, and by chemical, are very similar to those of the future resident (chronic) scenario presented above.

10.6.2.4. Future Resident (Subchronic) - Site 1, Southern Area of OU 2 Groundwater

Table 10-26 summarizes the average and maximum subchronic HI values for future residents of Site 1, subarea 3 groundwater. The trends of contribution by exposure pathway and by chemical are very similar to that of the future resident (subchronic) scenario presented above.

10.6.3. Environmental Evaluation

All available sources of information indicate there have been no known reductions in the size of populations, no known changes in community structure, and no known changes in ecosystem structure and function as a result of contamination from the former Lee Acres Landfill. Any changes in ecosystem structure are a direct result of landfill operation, not contaminant releases. Therefore, the former Lee Acres Landfill appears to pose no current threat to terrestrial ecosystems within the study area.

Mass transport modeling results give predicted containment plume concentrations for 1,1-DCA and manganese at the San Juan River. After mixing with San Juan River waters, these concentrations are diluted below SDWA MCLs, and are considered to be insignificant. Therefore, future contamination from subarea 3 contamination at the San Juan River is expected to pose no threat to aquatic organisms in the San Juan River.

10.7. UNCERTAINTIES AND ASSUMPTIONS

The primary objective of this risk assessment is to determine potential current or future risks to human health and the environment posed by groundwater contamination resulting from previous disposal activities at the former Lee Acres Landfill. In assessing risk, as outlined in EPA guidelines, a number of conservative assumptions are made such that the relative risks calculated are likely to overstate the true (absolute) risk. Erring on the conservative side provides most effectively for safeguarding the public health and for emphasizing the most prominent sources of health risk that will influence the remedial process.

These conservative assumptions made throughout the risk assessment process are primarily due to uncertainties in scientific data and methodologies required to assess the risk of adverse health effects posed by chemical contaminants and uncertainties about the characteristics of the contaminated sites and chemicals, the surrounding environment, and the potentially exposed populations. The remainder of this section summarizes these uncertainties and assumptions, including uncertainties inherent in all risk assessments, uncertainties and assumptions that may overestimate risk at the former Lee Acres Landfill and uncertainties and assumptions that may underestimate risk at the former Lee Acres Landfill. Some assumptions cannot be easily assessed as to their impact on the conservatism of the results. These are also discussed.

10.7.1. Uncertainties Inherent in All Risk Assessments

- The extrapolation methods used in the development of the RfD by the EPA (extrapolation of high dose to low dose; extrapolation of animal data to humans) require uncertainty factors of up to 1000 or greater to be incorporated into the calculation. A large margin of safety is thus built into the development of the RfD.

- The use of the EPA model (linear, multistage) for developing carcinogenic slope factors overestimates cancer risk because the statistical upper 95 percent confidence limit for cancer risk, produced by a lifetime exposure, is used. Because of the difficulty in determining whether carcinogens have threshold doses, it is conservatively assumed that there are no thresholds, and that even a single molecule of a carcinogen can induce cancer.

10.7.2. Uncertainties and Assumptions that May Overestimate Risk at the Lee Acres Landfill (Site 1)

- It is assumed that all COCs detected in wells over the course of sampling are simultaneously present in the water to which individuals are exposed. This assumption is extremely conservative.

- It is assumed that there will be no decline in chemical concentrations in the groundwater during resident exposure over the 30-year periods used in the exposure calculations. This assumption is also extremely conservative.

- Because no dermal RfDs or carcinogenic slope factors have been derived, the more conservative of the oral or inhalation RfDs or slope factors available for a chemical were used in assessing risk through dermal absorption.
- Subchronic RfD for vinyl chloride was derived from longer-term health advisories.
- Benzene and TCE subchronic RfDs could not be derived; therefore, more conservative chronic RfDs were substituted.
- Future residents are assumed to live downgradient from the current position of the northern groundwater plume for 30 years.

10.7.3. Uncertainties and Assumptions that May Underestimate Risk at the Lee Acres Landfill (Site 1)

- Certain noncarcinogens were excluded from consideration based on the fact that they were only detected once in downgradient wells or they were below the detection limit.
- Exposure, by way of vegetable ingestion, was omitted because of the likelihood that the VOCs would volatilize from irrigation spraying, soil contact, or transpiration from the vegetables.
- Exposure through the inhalation of VOCs from surface waters was not considered.
- Synergism or potentiation of carcinogenic and noncarcinogenic effects cannot be predicted with any certainty, although animal studies indicate such effects are possible.

10.7.4. Additional Uncertainties and Assumptions

- In the future resident scenarios, it was assumed that during showering, an equivalent of 2 liters per day (adult) or 1 liter per day (child) would be absorbed through inhalation and dermal contact together, in addition to the standard assumption of ingestion of 2 liters per day of drinking water (1 liter per day for a child).
- Chemical concentration data were averaged from samples taken several years apart. These create some uncertainty as to the actual concentrations to which human receptors would be exposed over long periods of time.
- No chronic RfDs (oral or inhalation) were available for vinyl chloride; an RfD was derived from a no-observed-adverse-effect level using an uncertainty factor of 100.

In conclusion, the uncertainties and assumptions discussed above must be considered in interpreting the results of this risk assessment, particularly in relation to the remedial actions proposed. The EPA has taken into consideration many uncertainties in order to develop risk assessment methods that adequately provide a margin of safety in the calculation of relative risk. The guidelines allow for flexibility in judgment on the part of the risk assessor. In this risk assessment, a number of assumptions have been made that are consistent with a conservative estimate of risk in view of site-specific characteristics. The limitations of the results of this assessment are discussed in the next section.

10.8. CONCLUSIONS

The risk assessment performed for the Lee Acres Landfill Study Area as provided estimates of average and maximum potential relative risk for current and future residents resulting from future exposure to Site 1, northern and southern areas of OU 2 groundwater contamination. The scenarios that were developed are conservative and hypothetical, and the relative risks determined for these can be interpreted more flexibly by examining the assumptions and conservatism inherent in the calculations. The actual risks may be somewhere between average and maximum values.

For future hypothetical residents living above Site 1, northern area of OU 2 groundwater, inhalation while showering, direct contact while showering, and ingestion of groundwater are all pathways that exceed a 1-in-100,000 and 1-in-10,000 incremental average and maximum cancer risk, respectively (Table 10-21). The total average and maximum carcinogenic risk to the future resident are 5E-05 (0.00005) and 4E-04 (0.0004), respectively; the major contribution is from ingestion of drinking water at an estimated carcinogenic risk of 3E-04 (0.0003). For future hypothetical residents living immediately downgradient from Site 1, southern area of OU 2 groundwater, inhalation while showering, direct contact while showering, and ingestion of groundwater are all pathways that exceed a 1-in-1,000,000 and 1-in-10,000 incremental average and maximum cancer risk, respectively, and are very similar to those from Site 1, the northern area of OU 2 groundwater (Table 10-22). The total average and maximum carcinogenic risk to the future resident are 5E-06 (0.000005) and 2E-04 (0.0002), respectively; the major contribution is from ingestion of drinking water at an estimated carcinogenic risk of 8E-05 (0.00008).

Noncarcinogenic chronic and subchronic hazards to future residents are shown to be congruent with carcinogenic risk. Inhalation while showering in, direct contact with, and ingestion of contaminated Site 1 southern area of OU 2 groundwater present HIs above unity for maximum contaminant concentrations (Tables 10-19 through 10-22).

The contributions to the total carcinogenic risk, and to the total noncarcinogenic chronic hazard indices, from dichloromethane and chromium in background water were evaluated. These compounds may not contribute greater than 1 percent to total carcinogenic risk, but may contribute a significant percentage to noncarcinogenic risk at subarea 1.

As for the environmental evaluation, all available sources of information indicate there have been no known reductions in the size of population, no known changes in community structure, and no known changes in ecosystem structure and function as a result of contamination from the former Lee Acres Landfill. The former Lee Acres Landfill (Site 1) appears to pose no current threat to terrestrial or aquatic ecosystems within the study area.

This baseline risk assessment is considered to be conservative and provides baseline "worst-case" scenarios in the absence of any remedial action. The general conclusion of the baseline risk assessment is that Site 1, northern area of OU 2 groundwater contamination represents unacceptable risk to future hypothetical residents who may reside on the Lee Acres Landfill site. In addition, Site 2, southern area of OU 2 groundwater contamination also represents an unacceptable risk to future hypothetical residents who may reside immediately downgradient from the southern area of contamination. The differences between the two subareas is slight, although different chemicals contribute slight differences to the overall risk. The model used assumes that these residents use groundwater for showering and domestic drinking water supply. RI data indicate that leaching of contaminants from the former landfill may be a dormant process, although active leaching occurred between 1979 and 1985, when the liquid waste lagoons were active. At that time, available moisture in the lagoons acted as the primary mechanism of contaminant migration, and contributed to contamination of Site 1, northern area of OU 2 groundwater.

This baseline risk assessment addresses the risk associated with hypothetical future residents. There is no current risk because there are no residents living on the former Lee Acres Landfill, or within an area where subarea 2 or 3 groundwater is available. Any real risk is hypothetical and unlikely because it is unlikely that future residents will establish households on the former Lee Acres Landfill or in subarea 3, or will use groundwater for all domestic purposes. However, the primary finding that groundwater contaminants pose unacceptable risk to hypothetical future residents directs the focus of the feasibility study to address remedial objectives that will eliminate or significantly reduce potential exposure through these pathways.

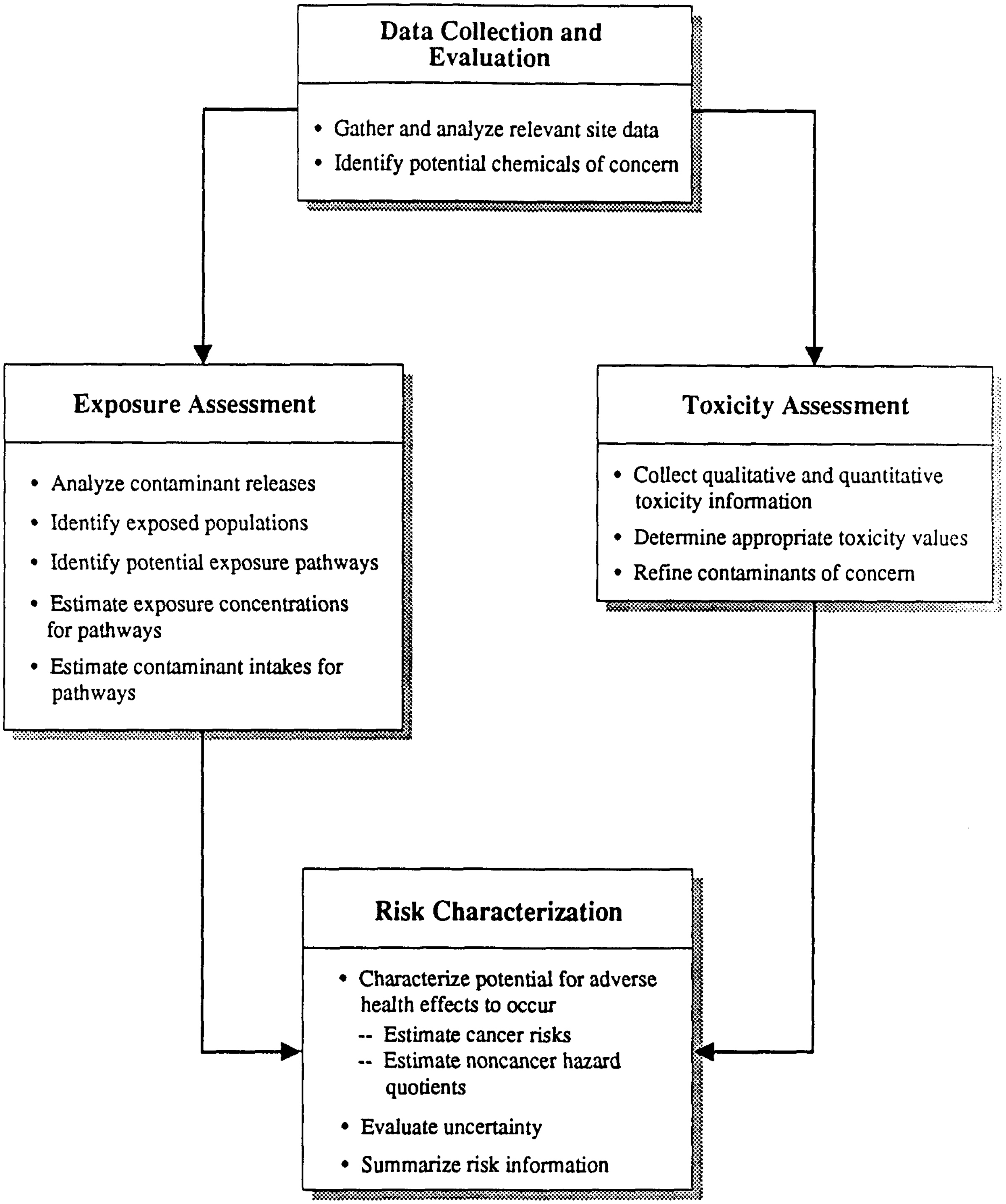

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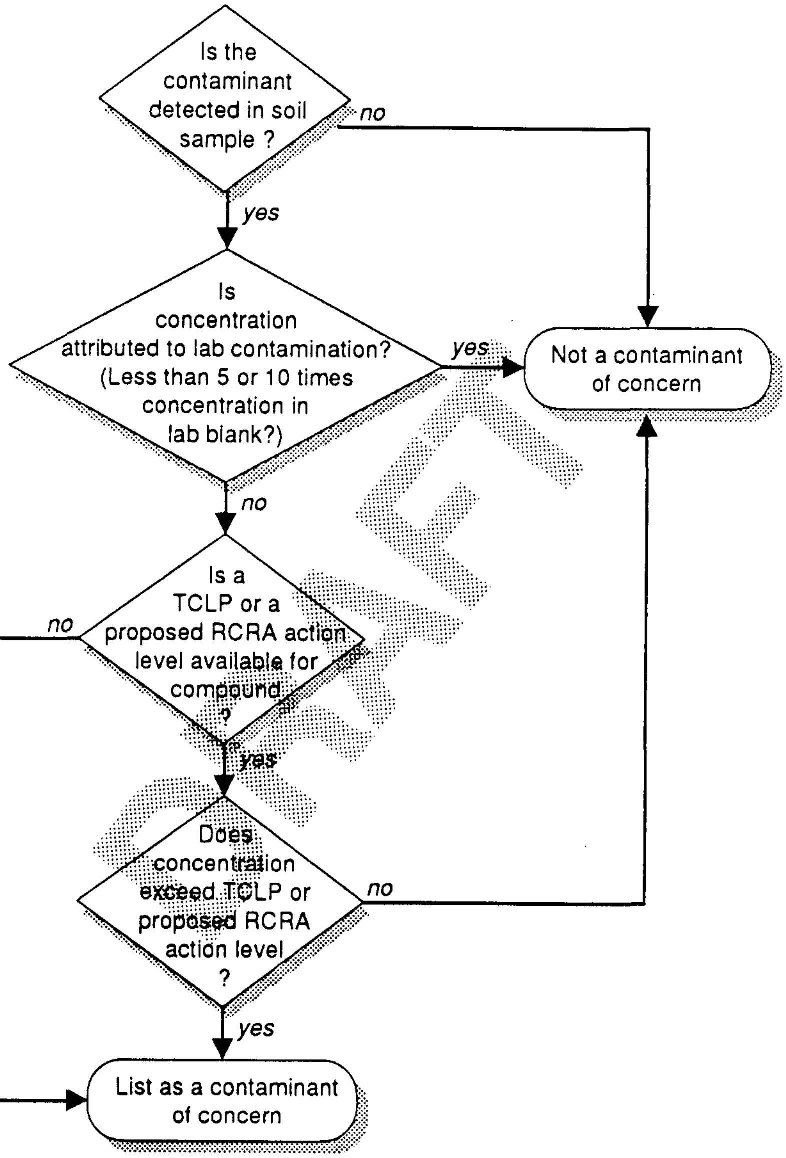
Figure 10-1. Baseline risk assessment.



BLM-decision tree-03/R1

Figure 10-2. Decision tree for identifying contaminants of concern in soil.

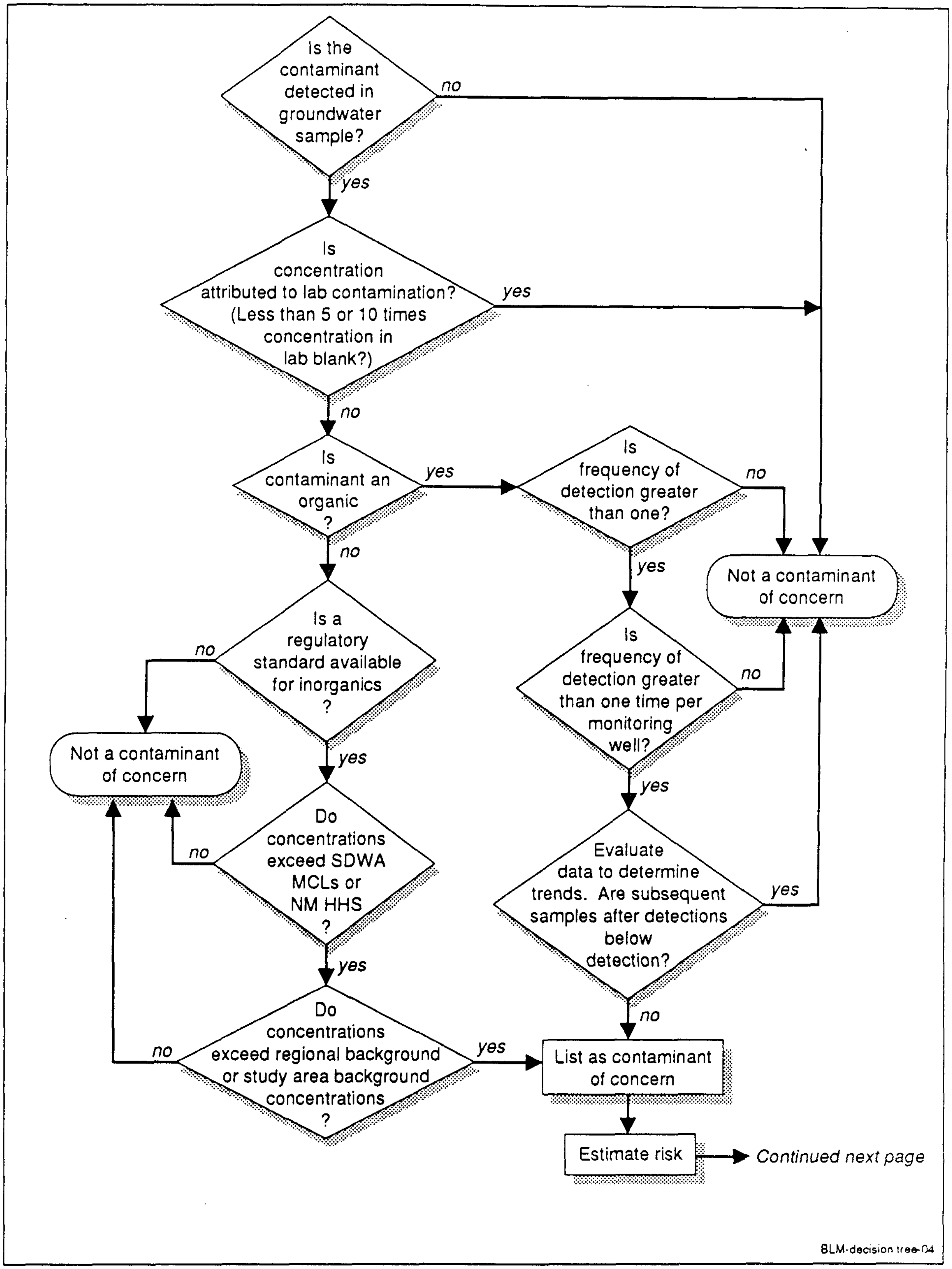
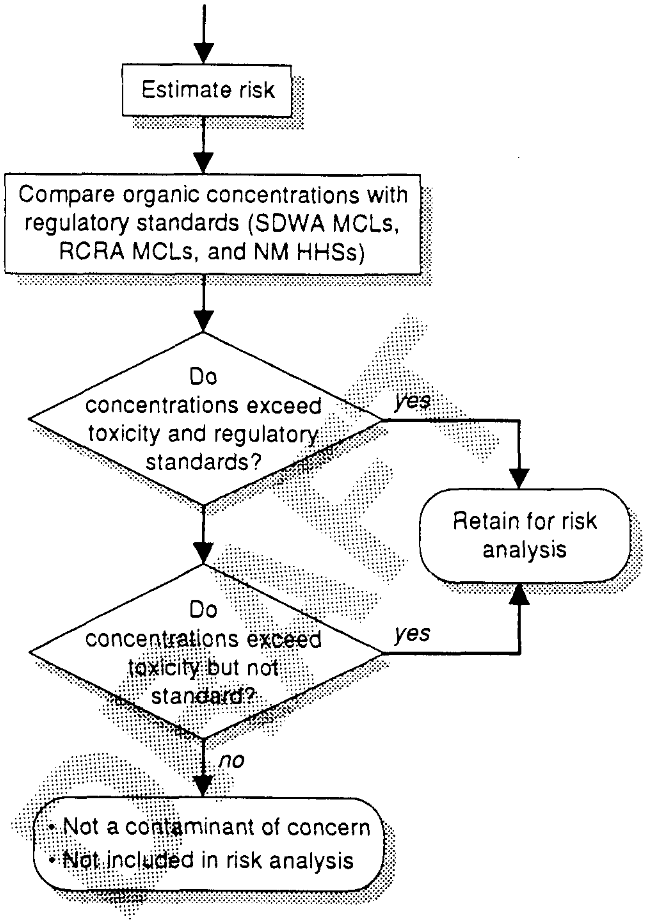


Figure 10-3. Decision tree for identifying contaminants of concern in groundwater.



BLM-decision tree-01-R1

Figure 10-3. Decision tree for identifying contaminants of concern in groundwater (page 2 of 2).

Table 10-1. Screening and Identification of Contaminants in the Background Alluvial Aquifer

Parameter Name	Number of Detections	Maximum Concentration (μg/l)	Lowest Regulatory Standard (μg/l)	Screening Criteria: Eliminated Based on Frequency[a]	Screening Criteria: Eliminated Based on Standard	Screening Criteria: Eliminated Based on Toxicity	Screening Criteria: Identified as a Contaminant of Concern
Volatile Organic Compounds:							
Acetone	2/20	32	4,000^b	x	-	-	No
Benzene	3/40	2	5^c	x	-	-	No
Chlorobenzene	2/43	2	700^b	x	-	-	No
Dichloromethane (methylene chloride)	13/43	63	5^c p	R	R	R	Yes
Toluene	4/40	8	750^d	x	-	-	No
Trichloroethene	3/43	140	5^c	x	-	-	No
Trichlorofluoromethane	1/23	3.5	N/A	x	-	-	No
Trichloromethane (chloroform)	1/43	1.9	100^d	x	-	-	No
Xylenes	2/40	2.9	620^d	x	-	-	No
Semivolatile Organic Compounds:							
bis(2-Ethylhexyl) phthalate	1/17	40	3^b	x	-	-	No
Butyl-benzyl-phthalate	1/17	5	4^c p	x	-	-	No
Di-n-butylphthalate	1/17	0.6	N/A	x	-	-	No
Metals:							
Chromium	18/20	113	50^c	R	R	R	Yes

[a] Frequency screening includes the number of times the contaminant was detected, whether compounds were found in blanks or below detection limit, and the isolated and sporadic nature of contaminants found. Refer to Section 6, Tables 6-1 and 6-2, for frequency screening criteria.

[b] Proposed RCRA action level (55 FR 30865).

[c] Safe Drinking Water Act maximum contaminant level.

[d] New Mexico human health standard, Section 3-103 (NMWQCC 1988).

p: proposed standard
N/A: not available
R: retained
x: eliminated
-: screening criteria not applied because contaminant was eliminated based on frequency

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Table 10-2. Screening and Identification of Contaminants in the Background Bedrock Aquifer

Parameter Name	Number of Detections	Maximum Concentration (μg/l)	Lowest Regulatory Standard (μg/l)	Screening Criteria: Eliminated Based on Frequency[a]	Screening Criteria: Eliminated Based on Standard	Screening Criteria: Eliminated Based on Toxicity	Screening Criteria: Identified as a Contaminant of Concern
Volatile Organic Compounds:							
Acetone	5/9	110	4,000[b]	x	-	-	No
Dichloromethane (methylene chloride)	6/20	59	5[c] p	R	R	R	Yes
Tetrachloroethene (PCE)	1/20	1.3	5[c] p	x	-	-	No
Toluene	2/18	6	750[d]	x	-	-	No
Semivolatile Organic Compounds:							
bis(2-Ethylhexyl) phthalate	2/10	74	3[b]	x	-	-	No
Di-n-butylphthalate	1/10	17	N/A	x	-	-	No
Metals:							
Chromium	1/2	59.1	50[c]	R	R	R	Yes

[a] Frequency screening includes the number of times the contaminant was detected, whether compounds were found in blanks or below detection limit, and the isolated and sporadic nature of contaminants found. Refer to Section 6, Tables 6-3 and 6-4, for frequency screening criteria.

[b] Proposed RCRA action level (55 FR 30865).

[c] Safe Drinking Water Act maximum contaminant level.

[d] New Mexico human health standard, Section 3-103 (NMWQCC 1988).

p: proposed standard
N/A: not available
R: retained
x: eliminated
-: screening criteria not applied because contaminant was eliminated based on frequency

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Table 10-3. Screening and Identification of Contaminants in the Site 1, Northern Area of Operable Unit 2 Alluvial Aquifer

Parameter Name	Number of Detections	Maximum Concentration (μg/l)	Lowest Regulatory Standard (μg/l)	Screening Criteria			
				Eliminated Based on Frequency[a]	Eliminated Based on Standard	Eliminated Based on Toxicity	Identified as a Contaminant of Concern
Volatile Organic Compounds:							
1,1-Dichloroethane	12/158	4.4	25[f]	R	x	x	No
1,2-*cis*-Dichloroethene[c]	1/42	20	70[b] p	R	x	x	No
1,2-*trans*-Dichloroethene	5/116	8.9	100[b] p	R	x	x	No
2-Butanone	1/42	1	N/A	x	-	-	No
Acetone	5/42	18,000	4,000[d]	x	-	-	No
Benzene	5/151	1.4[e]	5[b]	R	x	R	Yes
Bromodichloromethane	1/158	2.5	0.03[d]	x	-	-	No
Dichlorodifluoromethane	1/116	7.6	7,000[d]	x	-	-	No
Dichloromethane (methylene chloride)	44/158	36	5[b] p	R	R	R	Yes
Ethylbenzene	2/151	1.3	700[b] p	x	-	-	No
Tetrachloroethene (PCE)	8/158	9[e]	5[b] p	R	R	R	Yes
Toluene	8/151	2.3	750[f]	x	-	-	No
Trichloroethene (TCE)	5/158	3.2[e]	5[b]	R	x	R	Yes
Trichloromethane (chloroform)	6/158	19	100[f]	R	x	R	Yes
Vinyl chloride	3/158	6.7	1[f]	R	R	R	Yes
Xylene (total)	7/151	3.1	620[f]	x	-	-	No

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Table 10-3. (page 2 of 2)

Parameter Name	Number of Detections	Maximum Concentration (µg/l)	Lowest Regulatory Standard (µg/l)	Screening Criteria			
				Eliminated Based on Frequency[a]	Eliminated Based on Standard	Eliminated Based on Toxicity	Identified as a Contaminant of Concern
Semivolatile Organic Compounds:							
1,3-Dichlorobenzene	1/147	14	600[b] p	x	-	-	No
Benzoic Acid	1/71	5	N/A	x	-	-	No
bis(2-Ethylhexyl) phthalate	5/72	39	3[d]	x	-	-	No
Di-n-butylphthalate	2/72	2	N/A	x	-	-	No
Di-n-octylphthalate	5/72	7	N/A	x	-	-	No
N-Nitrosodiphenylamine	1/72	5	7[d]	x	-	-	No
Metals:							
Chromium	44/83	124	50[b]	R	R	R	Yes
Manganese	64/87	8,620	200[f]	R	R	R	Yes

[a] Frequency screening includes the number of times the contaminant was detected, whether compounds were found in blanks or below detection limit, and the isolated and sporadic nature of contaminants found. Refer to Section 6, Tables 6-6 and 6-7 for frequency screening criteria.

[b] Safe Drinking Water Act maximum contaminant level.

[c] 1,2-*cis*-Dichloroethene coelutes with 1,2-*trans*-dichloroethene and therefore, in most cases was reported as the *trans* isomer. Both isomers are considered in the discussions of contaminants of concern.

[d] Proposed RCRA action level (55 FR 30865).

[e] Maximum concentrations excluding the April 1990 results from BLM-49, see subsection 6.3.1.2.

[f] New Mexico human health standard, Section 3-103 (NMWQCC 1988).

N/A: not available

R: retained

x: eliminated

-: screening criteria not applied because contaminant was eliminated based on frequency

Table 10-4. Screening and Identification of Contaminants in the Site 1, Northern Area of Operable Unit 2 Bedrock Aquifer

Parameter Name	Number of Detections	Maximum Concentration (μg/l)	Lowest Regulatory Standard (μg/l)	Screening Criteria			
				Eliminated Based on Frequency[a]	Eliminated Based on Standard	Eliminated Based on Toxicity	Identified as a Contaminant of Concern
Volatile Organic Compounds:							
Acetone	5/29	6,000	4,000^b	x	-	-	No
Benzene	3/98	1.4	5^c	x	-	-	No
Dichloromethane (methylene chloride)	30/105	21	5^c p	R	R	R	Yes
Ethylbenzene	1/98	0.5	700^c p	x	-	-	No
Toluene	9/98	12	750^d	x	-	-	No
Trichloromethane (chloroform)	2/105	4.2	100^d	x	-	-	No
Xylene (total)	9/98	2.7	620^d	x	-	-	No
Semivolatile Organic Compounds:							
1,3-Dichlorobenzene	1/98	0.75	600^c p	x	-	-	No
Benzo(a)pyrene	1/53	2	0.2^c p	x	-	-	No
Benzo(g,h,i)perylene	1/53	4	N/A	x	-	-	No
bis(2-Ethylhexyl)phthalate	17/53	71	3^b	R	R	R	Yes
Di-n-butylphthalate	1/53	1	N/A	x	-	-	No
Di-n-octylphthalate	5/53	9	N/A	x	-	-	No
Pesticides/PCBs:							
4,4-DDT	1/43	0.14	0.1^b	x	-	-	No
Aldrin	1/43	0.06	0.002^b	x	-	-	No
Endrin	1/43	0.14	0.2^b	x	-	-	No

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Table 10-4. (page 2 of 2)

Parameter Name	Number of Detections	Maximum Concentration (µg/l)	Lowest Regulatory Standard (µg/l)	Screening Criteria			
				Eliminated Based on Frequency[a]	Eliminated Based on Standard	Eliminated Based on Toxicity	Identified as a Contaminant of Concern
Metals:							
Chromium	6/12	68.5	50[b]	R	R	R	Yes

[a] Frequency screening includes the number of times the contaminant was detected, whether compounds were found in blanks or below detection limit, and the isolated and sporadic nature of contaminants found. Refer to Section 6, Tables 6-10 and 6-11, for frequency screening criteria.

[b] Proposed RCRA action level (55 FR 30865).

[c] Safe Drinking Water Act maximum contaminant level.

[d] New Mexico human health standard, Section 3-103 (NMWQCC 1988).

p: proposed standard
N/A: not available
R: retained
x: eliminated
-: screening criteria not applied because contaminant was eliminated based on frequency

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Table 10-5. Screening and Identification of Contaminants in the Site 1, Southern Area of Operable Unit 2 Alluvial Aquifer

Parameter Name	Number of Detections	Maximum Concentration (µg/l)	Lowest Regulatory Standard (µg/l)	Screening Criteria			
				Eliminated Based on Frequency[a]	Eliminated Based on Standard	Eliminated Based on Toxicity	Identified as a Contaminant of Concern
Volatile Organic Compounds:							
1,1,1-Trichloroethane	8/81	8	60[b]	R	x	x	No
1,1-Dichloroethane	24/81	8.7	25[b]	R	x	x	No
1,2-*cis*-Dichloroethene[c]	1/2	97	70[d] p	R	R	x	No
1,2-*trans*-Dichloroethene	29/79	200	100[d] p	R	R	x	No
1,3-*trans*-Dichloropropene	1/81	2.2	10[e]	x	-	-	No
Benzene	9/80	110	5[d]	R	R	R	Yes
Dichlorodifluoromethane	3/79	10	7,000[e]	x	-	-	No
Dichloromethane (methylene chloride)	23/81	47	5[d] p	R	R	R	Yes
Ethylbenzene	1/80	0.7	700[d] p	x	-	-	No
Tetrachloroethene (PCE)	35/81	18	5[d] p	R	R	R	Yes
Toluene	4/80	1.6	750[b]	x	-	-	No
Trichloroethene	33/81	19	5[d]	R	R	R	Yes
Trichloromethane (chloroform)	15/81	6.3	100[b]	R	x	R	Yes
Vinyl chloride	1/81	3.6	1[b]	x	-	-	No
Xylene (total)	4/80	1.6	620[b]	x	-	-	No
Semivolatile Organic Compounds:							
2-Methylnaphthalene	1/56	1	N/A	x	-	-	No
bis(2-Ethylhexyl) phthalate	22/56[f]	23	3[e]	x	-	-	No
Di-n-butylphthalate	2/56	3	N/A	x	-	-	No

Table 10-5. (page 2 of 2)

Parameter Name	Number of Detections	Maximum Concentration (µg/l)	Lowest Regulatory Standard (µg/l)	Screening Criteria			
				Eliminated Based on Frequency[a]	Eliminated Based on Standard	Eliminated Based on Toxicity	Identified as a Contaminant of Concern
Di-n-octylphthalate	1/56	2	N/A	x	-	-	No
Naphthalene	1/56	2	N/A	x	-	-	No
N-Nitrosodiphenylamine	1/56	1	7[e]	x	-	-	No
Pesticides/PCBs:							
gamma-BHC(Lindane)	1/54	0.01	4[d]	x	-	-	No
Inorganics:							
Chloride	79/79	2,110,000	250,000[b]	R	R	x	No
Metals:							
Cobalt	19/60	110	50[b]	R	R	x	No
Manganese	57/60	4,230	200[b]	R	R	R	Yes
Nickel	26/60	3,580	100[d] p	R	R	R	Yes
Selenium	10/60	61.5	10[d]	R	R	R	Yes

[a] Frequency screening includes the number of times the contaminant was detected, whether compounds were found in blanks or below detection limit, and the isolated and sporadic nature of contaminants found. Refer to Section 6, Tables 6-13 and 6-14, for frequency screening criteria.

[b] New Mexico human health standard, Section 3-103 (NMWQCC 1988).

[c] 1,2-*cis*-Dichloroethene coelutes with 1,2-*trans*-Dichloroethene and therefore, in most cases was reported as the *trans* isomer. Both isomers are considered in the discussions of contaminants of concern.

[d] Safe Drinking Water Act maximum contaminant level.

[e] Proposed RCRA action level (55 FR 30865).

[f] 18 of 22 detected below detection limit. See Table 6-14.

p: proposed standard
N/A: not available
R: retained
x: eliminated
-: screening criteria not applied because contaminant was eliminated based on frequency

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Table 10-6. Screening and Identification of Contaminants in the Site 1, Southern Area of Operable Unit 2 Bedrock Aquifer

Parameter Name	Number of Detections	Maximum Concentration (µg/l)	Lowest Regulatory Standard (µg/l)	Screening Criteria			
				Eliminated Based on Frequency[a]	Eliminated Based on Standard	Eliminated Based on Toxicity	Identified as a Contaminant of Concern
Volatile Organic Compounds:							
1,1,1-Trichloroethane	2/21	1.4	60[b]	x	-	-	No
Dichloromethane (methylene chloride)	7/21	5.6	5[c] p	R	R	R	Yes
Toluene	2/18	1	750[b]	x	-	-	No
Trichloromethane (chloroform)	1/21	1.8	100[b]	x	-	-	No
Xylene (total)	2/18	1.2	620[b]	x	-	-	No
Semivolatile Organic Compounds:							
bis(2-Ethylhexyl) phthalate	1/9	1	3[d]	x	-	-	No
Di-n-butylphthalate	1/9	2	N/A	x	-	-	No

[a] Frequency screening includes the number of times the contaminant was detected, whether compounds were found in blanks or below detection limit, and the isolated and sporadic nature of contaminants found. Refer to Section 6, Tables 6-18 and 6-19, for frequency screening criteria.

[b] New Mexico human health standard, Section 3-103 (NMWQCC 1988).

[c] Safe Drinking Water Act maximum contaminant level.

[d] Proposed RCRA action level (55 FR 30865).

p: proposed standard
N/A: not available
R: retained
x: eliminated
-: screening criteria not applied because contaminant was eliminated based on frequency

Table 10-7. Screening and Identification of Contaminants in the Site 2 Alluvial Aquifer

Parameter Name	Number of Detections	Maximum Concentration ($\mu g/l$)	Lowest Regulatory Standard ($\mu g/l$)	Screening Criteria			
				Eliminated Based on Frequency[a]	Eliminated Based on Standard	Eliminated Based on Toxicity	Identified as a Contaminant of Concern
Volatile Organic Compounds:							
1,1,1-Trichloroethane	3/120	3.4	60[b]	x	-	-	No
1,1,-Dichloroethane	8/120	12	25[b]	R	x	x	No
1,2,-*cis*-Dichloroethene	1/62	4	70[c] p	x	-	-	No
1,2-Dichloroethane	6/120	11	5[c]	R	R	R	Yes
Acetone	9/60	910	4,000[d]	x	-	-	No
Dichloromethane (methylene chloride)	32/120	46	5[c] p	R	R	R	Yes
Ethylbenzene	2/119	1.4	700[c] p	x	-	-	No
Tetrachloroethene (PCE)	1/119	2	5[c] p	x	-	-	No
Vinyl acetate	1/60	2	N/A	x	-	-	No
Xylene (total)	8/119	1.5	620[b]	x	-	-	No
Semivolatile Organic Compounds:							
1,2-Dichlorobenzene	1/99	1.9	75[c]	x	-	-	No
bis(2-Ethylhexyl) phthalate	1/48	13	3[d]	x	-	-	No
Di-n-butylphthalate	1/48	0.6	N/A	x	-	-	No
Di-n-octylphthalate	2/48	2	N/A	x	-	-	No
Inorganics:							
Chloride	106/106	604,000	250,000[b]	R	R	x	No
Nitrate	20/28	28,000	10,000[c]	R	R	x	No
Sulfate	103/104	3,220,000	400,000/ 500,000[c] p	R	R	x	No
Sulfide	17/76	60,400,000	N/A	R	N/A	x	No

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Parameter Name	Number of Detections	Maximum Concentration (µg/l)	Lowest Regulatory Standard (µg/l)	Screening Criteria: Eliminated Based on Frequency[a]	Screening Criteria: Eliminated Based on Standard	Screening Criteria: Eliminated Based on Toxicity	Screening Criteria: Identified as a Contaminant of Concern
Metals:							
Aluminum	5/54	68,900	50[c] s	R	R	x	No
Arsenic	3/56	61	50[c]	R	R	R	Yes
Barium	4/5	1,400	1,000[c]	R	R	R	Yes
Beryllium	4/54	6.1	0.008[d]	R	R	R	Yes
Chromium	12/56	110	50[c]	R	R	R	Yes
Cobalt	4/54	82.1	50[b]	R	R	x	No
Iron	15/60	64,100	300[c] s	R	R	x	No
Lead	7/56	130	50[c]	R	R	R	Yes
Selenium	12/56	69	10[c]	R	R	R	Yes

[a] Frequency screening includes the number of times the contaminant was detected, whether compounds were found in blanks or below detection limit, and the isolated and sporadic nature of contaminants found. Refer to Section 6, Tables 6-21 and 6-22, for frequency screening criteria.

[b] New Mexico human health standard, Section 3-103 (NMWQCC 1988).

[c] Safe Drinking Water Act maximum contaminant level.

[d] Proposed RCRA action level (55 FR 30865).

p: proposed standard
N/A: not available
R: retained
S: secondary standard
x: eliminated
-: screening criteria not applied because contaminant was eliminated based on frequency

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Table 10-8. Screening and Identification of Contaminants in the Site 2 Bedrock Aquifer

Parameter Name	Number of Detections	Maximum Concentration (μg/l)	Lowest Regulatory Standard (μg/l)	Screening Criteria			
				Eliminated Based on Frequency[a]	Eliminated Based on Standard	Eliminated Based on Toxicity	Identified as a Contaminant of Concern
Volatile Organic Compounds:							
Acetone	11/30	1,100	4,000[b]	R	x	R	Yes
Dichloromethane (methylene chloride)	18/52	44	5[d] p	R	R	R	Yes
Toluene	8/52	18	750[c]	R	x	x	No
Trichloromethane (chloroform)	2/52	7	100[c]	x	-	-	No
Xylene (total)	1/52	0.7	620[c]	x	-	-	No
Semivolatile Organic Compounds:							
bis(2-Ethylhexyl) phthalate	9/22	260	3[b]	R	R	R	Yes
Metals:							
Beryllium	1/6	5.1	0.008[b]	x	-	-	No
Chromium	3/6	68.4	50[d]	R	R	R	Yes

[a] Frequency screening includes the number of times the contaminant was detected, whether compounds were found in blanks or below detection limit, and the isolated and sporadic nature of contaminants found. Refer to Section 6, Tables 6-23 and 6-24, for frequency screening criteria.

[b] Proposed RCRA action level (55 FR 30865).

[c] New Mexico Human health standard, Section 3-103 (NMWQCC 1988).

[d] Safe Drinking Water Act maximum contaminant level.

p: proposed standard
R: retained
x: eliminated
-: screening criteria not applied because contaminant was eliminated based on frequency

Table 10-9. Potential Chemical Release Sources at the Former Lee Acres Landfill in the Absence of Remedial Action

Receiving Medium	Release Mechanism	Release Source	Relative Release Potential
Air	Volatilization	Surface wastes, including lagoons, pits, and spills	Low
	Fugitive dust generation	Contaminated surface soil	Low
		Waste piles	Low
Surface Water	Surface runoff/infiltration	Contaminated surface soil	NA
	Groundwater seepage	Contaminated groundwater	NA
Groundwater	Leaching	Buried waste	Moderate
		Contaminated soil	Moderate
Soil	Leaching	Buried waste	Moderate
		Contaminated soil	Moderate
	Surface runoff	Contaminated surface soil	NA
	Fugitive dust generation/deposition	Contaminated surface soil	Low
	Tracking mud and soil and depositing off-site	Contaminated surface soil	NA
Arroyo Sediment	Surface runoff	Contaminated surface soil	NA
	Groundwater seepage	Contaminated groundwater	NA
	Leaching	Contaminated soil	NA
Biota	Uptake (direct contact, ingestion, inhalation)	Contaminated soil, surface water, groundwater or air	NA
		Other biota	NA

Modified from EPA 1989c.
NA: not applicable, or not quantifiable

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Table 10-10. Physiochemical Properties of Contaminants

Chemical	Aqueous Solubility (mg/l)	Specific Gravity	Viscosity (centipoise)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm/m3/mole)	Log Octanol/ Water Partition Coefficient	Molecular Weight (g/mole)	Melting Point (C)	Boiling Point (C)	Vapor Density	CAS Number
Volatile Organic Compounds											
Benzene	1750.00	0.88	0.60	95.20	5.59E-03	2.12	78.12	5.50	80.10	2.77	71-43-2
Dichloromethane (methylene chloride)	20000.00	1.33	0.45	362.00	2.03E-03	1.30	85.00	-96.70	40.00	2.93	75-09-2
Tetrachloroethene (PCE)	200.00	1.63	1.93	17.80	2.59E-02	2.60	166.00	-22.70	121.40	5.83	127-18-4
Trichloroethene	1100.00	1.47	0.57	57.90	9.10E-03	2.24	132.00	-87.00	86.70	4.54	79-01-6
Trichloromethane (chloroform)	8200.00	1.49	0.60	151.00	2.87E-03	1.97	119.00	-63.50	61.70	4.12	67-66-3
Vinyl chloride	2670.00	0.91	NA	2660.00	8.19E-02	1.38	63.00	-153.80	-13.40	2.24	75-01-4
Semivolatile Organic Compounds											
bis(2-Ethylhexyl) phthalate	0.29	0.98	81.40	2.00E-07	3.61E-07	3.98	391.00	-50.00	230.00	NA	117-81-7
Metals/Inorganics											
Chromium: assume 90% split Cr6 +	soluble	7.20	NA	NA	NA	NA	52.00	1857.00	2672.00	NA	7440-47-3
Chromium: assume 10% split Cr3 +	insignificant	7.20	NA	NA	NA	NA	52.00	1857.00	2672.00	NA	7440-47-3
Manganese	pH/complex specific	7.20	NA	NA	NA	NA	55.00	1245.00	1962.00	NA	7439-96-5
Nickel	in salts	8.90	NA	0.00	NA	NA	59.00	1453.00	2732.00	NA	7440-02-0
Selenium	at high pH	4.26-4.81	NA	0.00	NA	NA	79.00	217.00	684.90	NA	7782-49-2

Sources:
Basics of Pump-and-Treat Groundwater Remediation Technology, Appendices A-2 and A-3 (EPA/600/8-90/003)
Chemical, Physical, and Biological Properties of Compounds Present at Hazardous Waste Sites (Clement Assoc. 1985)
Handbook of Environmental Data on Organic Chemicals (Verschueren 1983)
RREL Database (EPA 1991b)
Note: 8.19E-02 indicates a value equal to 0.0819.

Table 10-11. Human Exposure Scenarios - Potential Exposure Scenarios

Future Resident

Site 1, Northern Area of OU 2 Groundwater	Site 1, Southern Area of OU 2 Groundwater
Inhalation during showering	Inhalation during showering
Ingestion of well water	Ingestion of well water
Dermal contact during showering	Dermal contact during showering

Table 10-12. Model for Estimating Contaminant Intake through Drinking Water Ingestion

$$\text{DWID} = \frac{C_{GW} \times \text{DWIR}}{\text{BW}};$$

where

DWID = drinking water ingestion dose (mg/kg/day),
C_{GW} = current or estimated future contaminant concentration in the groundwater (mg/L),
DWIR = drinking water ingestion rate (L/day), and
BW = body weight (kg).

Modified from EPA 1989d
Assumptions:

(1) The current and estimated future contaminant concentrations in groundwater (C_{GW}) are the geometric average and maximum concentrations presented in Tables 10-1 through 10-4.
(2) The drinking water ingestion rate from current and future resident wells is 2 L/day for the adult resident and 1 L/day for the future child resident (EPA 1989d). Both subchronic and chronic dose indices are adjusted for absorption.
(3) The average body weight (BW) for a child aged 1-6 years is 10 kg; an average adult weighs 70 kg (EPA 1989d).

Table 10-13. Estimated Average and Maximum Daily Intake through Inhalation, Ingestion, and Direct Contact With Well Water for Future Residents - Site 1, Northern Area of Operable Unit 2 Groundwater

			Inhalation (mg/kg/day)				Ingestion (mg/kg/day)				Direct Contact (mg/kg/day)			
			Geometric Average		Maximum		Geometric Average		Maximum		Geometric Average		Maximum	
Chemical	Geometric Average (μg/L)	Maximum Concentration (μg/L)	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Volatile Organic Compounds														
Benzene	0.6	1.4	3.1E-06	2.1E-06	7.1E-06	5.0E-06	6.1E-06	4.3E-06	1.4E-05	1.0E-05	3.1E-06	2.1E-06	7.1E-06	5.0E-06
Dichloromethane (methylene chloride)	1.5	36.0	7.7E-06	5.4E-06	1.8E-04	1.3E-04	1.5E-05	1.1E-05	3.7E-04	2.6E-04	7.7E-06	5.4E-06	1.8E-04	1.3E-04
Tetrachloroethene (PCE)	0.6	9.0	3.1E-06	2.1E-06	4.6E-05	3.2E-05	6.1E-06	4.3E-06	9.2E-05	6.4E-05	3.1E-06	2.1E-06	4.6E-05	3.2E-05
Trichloroethene (TCE)	0.6	3.2	3.1E-06	2.1E-06	1.6E-05	1.1E-05	6.1E-06	4.3E-06	3.3E-05	2.3E-04	3.1E-06	2.1E-06	1.6E-05	1.1E-05
Trichloromethane (chloroform)	0.6	19.0	3.1E-06	2.1E-06	9.7E-06	6.8E-05	6.1E-06	4.3E-06	1.9E-04	1.4E-04	3.1E-06	2.1E-06	9.7E-06	6.8E-05
Vinyl chloride	0.8	6.7	4.1E-06	2.9E-06	3.4E-05	2.4E-05	8.2E-06	5.7E-06	6.8E-05	4.8E-05	4.1E-06	2.9E-06	3.4E-05	2.4E-05
Semivolatile Organic Compounds														
bis(2-Ethylhexyl) phthalate	5.3	71.0	2.7E-05	1.9E-05	3.6E-04	2.5E-04	5.4E-05	3.8E-05	7.2E-04	5.1E-04	2.7E-05	1.9E-05	3.6E-04	2.5E-04
Metals														
Chromium: assume 90% split Cr6 +	10.8	111.6	5.5E-05	3.9E-05	5.7E-04	4.0E-04	1.1E-04	7.7E-05	1.1E-03	8.0E-04	5.5E-05	3.9E-05	5.7E-04	4.0E-04
Chromium: assume 10% split Cr3 +	1.2	12.4	6.1E-06	4.3E-06	6.3E-05	4.4E-05	1.2E-05	8.6E-06	1.3E-04	8.9E-05	6.1E-06	4.3E-06	6.3E-05	4.4E-05
Manganese	278.2	8,620.0	1.4E-03	9.9E-04	4.4E-02	3.1E-02	2.8E-03	2.0E-03	8.8E-02	6.2E-02	1.4E-03	9.9E-04	4.4E-02	3.1E-02

Note: 1.7E-05 indicates a value equal to 0.000017.

Table 10-14. Estimated Average and Maximum Daily Intake Through Inhalation, Ingestion, and Direct Contact With Well Water for Future Residents - Site 1, Southern Area of Operable Unit 2 Groundwater

Chemical	Geometric Average (µg/L)	Maximum Concentration (µg/L)	Inhalation (mg/kg/day)				Ingestion (mg/kg/day)				Direct Contact (mg/kg/day)			
			Geometric Average		Maximum		Geometric Average		Maximum		Geometric Average		Maximum	
			Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Volatile Organic Compounds														
Benzene	0.9	110.0	4.3E-06	3.0E-06	5.6E-04	3.9E-04	8.7E-06	6.1E-06	1.1E-03	7.9E-04	4.3E-06	3.0E-06	5.6E-04	3.9E-04
Dichloromethane (methylene chloride)	2.1	47.0	1.1E-05	7.5E-06	2.4E-04	1.7E-04	2.2E-05	1.5E-05	4.8E-04	3.4E-04	1.1E-05	7.5E-06	2.4E-04	1.7E-04
Tetrachloroethene (PCE)	1.5	18.0	7.8E-06	5.4E-06	9.2E-05	6.4E-05	1.6E-05	1.1E-05	1.8E-04	1.3E-04	7.8E-06	5.4E-06	9.2E-05	6.4E-05
Trichloroethene (TCE)	1.3	19.0	6.4E-06	4.5E-06	9.7E-05	6.8E-05	1.3E-05	9.0E-06	1.9E-04	1.4E-04	6.4E-06	4.5E-06	9.7E-05	6.8E-05
Trichloromethane (chloroform)	0.6	6.3	3.0E-06	2.1E-06	3.2E-05	2.2E-05	6.0E-06	4.2E-06	6.4E-05	4.5E-05	3.0E-06	2.1E-06	3.2E-05	2.2E-05
Metals														
Manganese	529.3	4,230.0	2.7E-03	1.9E-03	2.2E-02	1.5E-02	5.4E-03	3.8E-03	4.3E-02	3.0E-02	2.7E-03	1.9E-03	2.2E-02	1.5E-02
Nickel	43.6	3,580.0	2.2E-04	1.6E-04	1.8E-02	1.3E-02	4.4E-04	3.1E-04	3.7E-03	2.6E-02	2.2E-04	1.6E-04	1.8E-02	1.3E-02
Selenium	4.5	61.5	2.3E-05	1.6E-05	3.1E-04	2.2E-04	4.6E-04	3.2E-05	6.3E-04	4.4E-04	2.3E-05	1.6E-05	3.1E-04	2.2E-04

Note: 2.4E-05 indicates a value equal to 0.000024.

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Table 10-15. Model for Estimating Contaminant Intake through Inhalation and Dermal Absorption while Showering

$$\text{NIUD} = \frac{C_{GW} \times \text{NIEE}}{\text{BW}};$$

where

NIUD = noningestion water use dose (mg/kg/day),
C_{GW} = current or estimated future contaminant concentration in the groundwater (mg/L),
NIEE = noningestion exposure equivalent (L/day), and
BW = body weight (kg).

Modified from EPA 1989d.
Assumptions:

(1) The current and estimated future contaminant concentrations in groundwater (C_{GW}) are the geometric average and maximum concentrations presented in Tables 10-1 through 10-4.
(2) The inhalation and dermal exposure equivalents through household water uses are 1 L/day for the child resident and 2 L/day for the adult resident.
(3) The average body weight (BW) for a child aged 1-6 years is 10 kg; an average adult weighs 70 kg (EPA 1989d).

Table 10-16. Uncertainties for Exposure Assessment

Assumption	Effect on Exposure[a]		
	Potential Magnitude for Over-estimation of Exposure	Potential Magnitude For Under-estimation of Exposure	Potential Magnitude for Over- or Under-estimation of Exposure
Environmental Sampling and Analysis			
Sufficient samples may not have been taken to characterize the media being evaluated.			Moderate
Systematic or random errors in the chemical analyses may yield erroneous data.			Low
Exposure Parameter Estimation			
The standard assumptions regarding body weight, period exposed, life expectancy, population characteristics, and lifestyles may not be representative of any actual exposure situation.			Moderate
The amount of media intake is assumed to be constant and representative of the exposed population.	Moderate		
Assumption of daily lifetime exposure for residents.	Moderate to High		
Use of maximum concentrations in groundwater data for upper-bound lifetime exposure	Moderate to High		

---

[a] As general guidelines, assumptions marked as "low" may affect estimates of exposure by less than 1 order of magnitude; assumptions marked "moderate" may affect estimates of exposure by between 1 and 2 orders of magnitude; and assumptions marked "high" may affect estimates of exposure by more than 2 orders of magnitude.

Table 10-17. EPA Categorizations of Carcinogens Based on Human and Animal Evidence

EPA Categorization of Carcinogens[a]

	Animal Evidence				
Human evidence	Sufficient	Limited	Inadequate	No Data	No Evidence
Sufficient	A	A	A	A	A
Limited	B1	B1	B1	B1	B1
Inadequate	B2	C	D	D	D
No data	B2	C	D	D	E
No evidence	B2	C	D	D	E

Key:

Group A -	Human carcinogen (sufficient evidence from epidemiological studies).
Group B1 -	Probable human carcinogen (at least limited evidence of carcinogenicity to humans).
Group B2 -	Probable human carcinogen (a combination of sufficient evidence in animals and inadequate data in humans).
Group C -	Possible human carcinogen (limited evidence in animals in the absence of human data).
Group D -	Not classified (inadequate animal and human data).
Group E -	No evidence for carcinogenicity (no evidence for carcinogenicity in at least two adequate animal tests in different species or in both epidemiological and animal studies).

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[a] EPA 1989b

Table 10-18. Toxicity Values - Potential Carcinogenic Effects

Chemical	Oral Slope Factor (mg/kg/day)$^{-1}$	Weight of Evidence Classification	Type of Cancer	Slope Factor Basis/ Slope Factor Source
Benzene	2.9E-02	A	Leukemia	Oral/EPA 1990b
bis(2-Ethylhexyl) phthalate	1.4E-02	B2	Liver	Oral/EPA 1990b
Chromium VI	4.1E+1[a]	A	Lung	HEAST (EPA 1991a)
Dichloromethane (methylene chloride)	7.5E-03	B2	Liver	Oral/EPA 1990b
Nickel	1.7E+0[a]	A	Respiratory Tract	HEAST (EPA 1991a)
Tetrachloroethene (PCE)	5.1E-02	B2	Liver	Oral/EPA 1990b
Trichloroethene (TCE)	1.1E-02	B2	Liver	Oral/EPA 1990b
Trichloromethane (chloroform)	6.1E-03	B2	Kidney	Oral/EPA 1990b
Vinyl chloride	1.9E-00	A	Lung	HEAST (EPA 1991a)

[a] inhalation slope factor

Note: 2.9E-02 indicates a value equal to 0.029.

Table 10-19. Toxicity Values - Potential Chronic Noncarcinogenic Effects

Chemical	Reference Dose (RfD) (mg/kg/day)		Confidence Level	Critical Effect	RfD Basis/ RfD Source	Uncertainty Factors
	Inhalation	Ingestion				
Aromatics						
Benzene	7.0E-04[a]	7.0E-04[a]	ND	ND	Oral/IRIS/EPA 1990b	ND
Chlorinated hydrocarbons						
Dichloromethane (methylene chloride)	3.0E+00[b]	6.0E-02	Medium	Liver toxicity	Oral/EPA 1990b	100
Tetrachloroethene (PCE)	ND	1.0E-02	Medium	Hepatotoxicity	Oral/EPA 1990b	1,000
Trichloromethane (chloroform)	ND	1.0E-02	Medium	Liver lesions	Oral/EPA 1990b	1,000
Trichloroethene (TCE)	7.35E-03[c]	7.35E-03[c]	ND	ND	Oral/IRIS/EPA 1990b	ND
Vinyl chloride	1.30E-03[d]	1.30E-03[d]	ND	ND	Derived/ATSDR 1988	ND
Phthalates						
bis(2-Ethylhexyl) phthalate	ND	2.0E-02	Medium	Increased relative liver weight	Oral/EPA 1990b	1,000
Inorganics						
Chromium III	2E-5	1E+0	ND	Nasal mucosa atrophy	HEAST (EPA 1991a)	1,000/300
Chromium IV	2E-6	5E-3	ND	Nasal mucosa atrophy	HEAST (EPA 1991a)	500/300
Manganese	4E-4	1.0E-01	ND	CNS disruptions and degeneration	HEAST (EPA 1991a)	900
Nickel	ND	2.0E-02	ND	Reduced body and organ weight	Oral/EPA 1990b	300
Selenium	ND	3.0E-03	ND	Hair and nail loss; dermatitis	Oral/EPA 1990b	15

Notes: Confidence levels from IRIS are low, medium, or high.
7.0E-04 indicates a value equal to 0.0007.

[a] RfD for benzene from ATSDR 1987

[b] mg/m^3

[c] RfD for TCE from ATSDR 1988b

[d] RfD for vinyl chloride derived from no observed adverse effect level of 0.13 mg/kg/day (ATSDR 1988a) by incorporating an uncertainty factor of 100 (EPA 1989b).

CNS: central nervous system
HEAST: Health Effects Assessment Summary Tables (EPA 1991a)
IRIS: Integrated Risk Information System (EPA 1990b)
ND: not determined

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Table 10-20. Toxicity Values - Potential Subchronic Noncarcinogenic Effects

Chemical	Reference Dose (RfD) (mg/kg/day)		Confidence Level	Critical Effect	RfD Basis/ RfD Source	Uncertainty Factors
	Inhalation	Ingestion				
Aromatics						
Benzene	7.0E-04[a]	7.0E-04[a]	ND	ND	Oral/IRIS/EPA 1990b	ND
Chlorinated hydrocarbons						
Dichloromethane (methylene chloride)	3.0E+00[b]	6.0E-02	Medium	Liver toxicity	Oral/EPA 1990b	100
Tetrachloroethene (PCE)	ND	1.0E-01	Medium	Hepatotoxicity	HEAST (EPA 1991a)	100
Trichloromethane (chloroform)	ND	1.0E-02	Medium	Liver lesions	Oral/EPA 1990b	1,000
Trichloroethene (TCE)	7.35E-03[c]	7.35E-03[c]	ND	ND	Oral Derived/ATSDR 1988	ND
Vinyl chloride	1.30E-03[d]	1.30E-03[d]	ND	ND	Derived/ATSDR 1988	ND
Phthalates						
bis(2-Ethylhexyl) phthalate	ND	2.0E-02	Medium	Increased relative liver weight	Oral/EPA 1990b	1,000
Inorganics						
Chromium III	2E-5	1E+1	ND	Nasal mucosa atrophy	HEAST (EPA 1991a)	100/30
Chromium IV	2E-5	2E-2	ND	Nasal mucosa atrophy	HEAST (EPA 1991a)	100/30
Manganese	1E-1	5.0E-01	ND	CNS disruptions	HEAST (EPA 1991a)	900
Nickel	ND	2.0E-02	ND	Reduced body and organ weight	Oral/EPA 1990b	300
Selenium	ND	3.0E-03	ND	Hair and nail loss; dermatitis	Oral/EPA 1990b	15

Notes: Confidence levels from IRIS are low, medium, or high.
7.0E-04 indicates a value equal to 0.0007.

[a] RfD for benzene from ATSDR 1987

[b] mg/m^3

[c] RfD for TCE from ATSDR 1988b

[d] RfD for vinyl chloride dervied from no observed adverse effect level of 0.13 mg/kg/day (ATSDR 1988a) by incorporating an uncertainity factor of 100 (EPA 1989b).

CNS: central nervous system
HEAST: Health Effects Assessment Summary Tables (EPA, 1991a)
IRIS: Integrated Risk Information System (EPA 1990b)
ND: not determined

Table 10-21. Average and Maximum Carcinogenic Risk for Future Residents - Site 1, Northern Area of Operable Unit 2 Groundwater

Chemical	Geometric Average (µg/L)	Maximum Concentration (µg/L)	Carcinogenic Risk						Total	
			Inhalation		Ingestion		Dermal Contact			
			Geometric Average	Maximum	Geometric Average	Maximum	Geometric Average	Maximum	Geometric Average	Maximum
Volatile Organic Compounds:										
Benzene	0.6	1.4	1.5E-07	3.5E-07	3.0E-07	7.0E-07	1.5E-07	3.5E-07	6E-07	1E-06
Dichloromethane (methylene chloride)	1.5	36.0	2.1E-08	5.1E-07	2.0E-07	4.7E-06	9.8E-08	2.3E-06	3E-07	8E-06
Tetrachloroethene (PCE)	0.6	9.0	2.7E-08	4.0E-07	5.3E-07	8.0E-06	2.7E-07	4.0E-06	1E-06	2E-05
Trichloroethene (TCE)	0.6	3.2	8.8E-08	4.7E-07	1.1E-07	6.1E-07	5.7E-08	3.1E-07	3E-07	1E-06
Trichloromethane (chloroform)	0.6	19.0	4.2E-07	1.3E-05	6.3E-08	2.0E-06	3.2E-08	1.0E-06	5E-07	2E-05
Vinyl chloride	0.8	6.7	2.0E-06	1.7E-05	2.6E-05	2.2E-04	1.3E-05	1.1E-04	4E-05	3E-04
Semivolatile Organic Compounds:										
bis(2-Ethylhexyl) phthalate	5.3	71.0	ND	ND	1.3E-06	1.7E-05	6.4E-07	8.6E-06	2E-06	3E-05
Metals/Inorganics:										
Chromium: assume 90% split Cr6 +	10.8	111.6	NA	NA	NA	NA	ND	ND	-	-
Chromium: assume 10% split Cr3 +	1.2	12.4	NA	NA	NA	NA	NA	NA	-	-
Manganese	278.2	8,620.0	NA	NA	NA	NA	NA	NA	-	-
Total			3E-6	4E-5	3E-5	3E-4	1E-5	1E-4	5E-5	4E-4

NA: not applicable
ND: not determined
Note: 2E-06 indicates a value equal to 0.000002.

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Table 10-22. Average and Maximum Carcinogenic Risk for Future Residents - Site 1, Southern Area of Operable Unit 2 Groundwater

			Carcinogenic Risk							
			Inhalation		Ingestion		Dermal Contact		Total	
Chemical	Geometric Average (µg/L)	Maximum Concentration (µg/L)	Geometric Average	Maximum	Geometric Average	Maximum	Geometric Average	Maximum	Geometric Average	Maximum
Volatile Organic Compounds:										
Benzene	0.9	110.0	2.1E-07	2.8E-05	4.3E-07	5.5E-05	2.1E-07	2.8E-05	9E-07	1E-04
Dichloromethane (methylene chloride)	2.1	47.0	3.0E-08	6.7E-07	2.7E-07	6.1E-06	1.4E-07	3.1E-06	4E-07	1E-05
Tetrachloroethene (PCE)	1.5	18.0	6.7E-07	8.0E-06	1.3E-06	1.6E-05	6.7E-07	8.0E-06	3E-06	3E-05
Trichloroethene (TCE)	1.3	19.0	1.9E-07	2.8E-06	2.4E-07	3.6E-06	1.2E-07	1.8E-06	5E-07	8E-06
Trichloromethane (chloroform)	0.6	6.3	4.1E-07	4.4E-06	6.2E-08	6.7E-07	3.1E-08	3.3E-07	5E-07	5E-06
Metals/Inorganics:										
Manganese	529.3	4,230.0	NA	NA	NA	NA	NA	NA	-	-
Nickel	43.6	3,580.0	NA	NA	NA	NA	NA	NA	-	-
Selenium	4.5	61.5	NA	NA	NA	NA	NA	NA	-	-
Total			2E-6	4E-5	2E-6	8E-5	1E-6	4E-5	5E-6	2E-4

NA: not applicable
Note: 3E-06 indicates a value equal to 0.000003.

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Table 10-23. Average and Maximum Chronic Hazard Index for Future Residents - Site 1, Northern Area of Operable Unit 2 Groundwater

Chemical	Inhalation		Ingestion		Dermal		Total	
	Geometric Average	Maximum	Geometric Average	Maximum	Geometric Average	Maximum	Geometric Average	Maximum
Volatile Organic Compounds								
Benzene	7.4E-03	1.7E-02	1.5E-02	3.5E-02	7.4E-03	1.7E-02	0.0	0.1
Dichloromethane (methylene chloride)	1.5E-05	3.6E-04	4.3E-04	1.0E-02	2.2E-04	5.2E-03	0.0	0.0
Tetrachloroethene (PCE)			1.0E-03	1.6E-02	5.2E-04	7.8E-03	0.0	0.0
Trichloroethene (TCE)	7.1E-04	3.8E-03	1.4E-03	7.6E-03	7.1E-04	3.8E-03	0.0	0.0
Trichloromethane (chloroform)			1.0E-03	3.3E-02	5.2E-04	1.6E-02	0.0	0.0
Vinyl chloride	5.3E-03	4.5E-02	1.1E-02	8.9E-02	5.3E-03	4.5E-02	0.0	0.2
Semivolatile Organic Compounds								
bis(2-Ethylhexyl) phthalate	ND	ND	4.6E-03	6.2E-02	2.3E-03	3.1E-02	0.0	0.1
Metals								
Chromium: assume 90% split Cr6 +	NA	NA	3.7E-02	3.9E-01	1.9E-02	1.9E-01	0.1	0.6
Chromium: assume 10% split Cr3 +	NA	NA	2.1E-05	2.2E-04	1.0E-05	1.1E-04	0.0	0.0
Manganese	NA	NA	4.8E-02	1.5E+00	2.4E-02	7.5E-01	0.1	2.2
Total	0.0	0.1	0.1	2.1	0.1	1.1	0.2	3.0

NA: not applicable
ND: not determined
Note: 1E-01 indicates a value equal to 0.1.

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Table 10-24. Average and Maximum Chronic Hazard Index for Future Residents - Site 1, Southern Area of Operable Unit 2 Groundwater

Chemical	Inhalation		Ingestion		Dermal		Total	
	Geometric Average	Maximum	Geometric Average	Maximum	Geometric Average	Maximum	Geometric Average	Maximum
Volatile Organic Compounds								
Benzene	1.1E-02	1.4E+00	2.1E-02	2.7E+00	1.1E-02	1.4E+00	0.0	5.5
Dichloromethane (methylene chloride)	2.1E-05	4.8E-04	6.1E-04	1.4E-02	3.0E-04	6.8E-03	0.0	0.0
Tetrachloroethene (PCE)	ND	ND	2.6E-03	3.1E-02	1.3E-03	1.6E-02	0.0	0.0
Trichloroethene (TCE)	1.5E-03	2.2E-02	3.0E-03	4.5E-02	1.5E-03	2.2E-02	0.0	0.1
Trichloromethane (chloroform)	ND	ND	1.0E-03	1.1E-02	5.1E-04	5.5E-03	0.0	0.0
Metals								
Manganese	NA	NA	9.2E-02	7.3E-01	4.6E-02	3.7E-01	0.1	1.1
Nickel	NA	NA	3.8E-02	3.1E+00	1.9E-02	1.6E+00	0.1	4.7
Selenium	NA	NA	2.6E-02	3.6E-01	1.3E-02	1.8E-01	0.0	0.5
Total	0.0	1.4	0.2	7.0	0.1	3.5	0.3	10.0

NA: not applicable
ND: not determined
Note: 2E-01 indicates a value equal to 0.2.

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Table 10-25. Average and Maximum Subchronic Hazard Index for Future Residents - Site 1, Northern Area of Operable Unit 2 Groundwater

	Inhalation		Ingestion		Dermal		Total	
Chemical	**Geometric Average**	**Maximum**	**Geometric Average**	**Maximum**	**Geometric Average**	**Maximum**	**Geometric Average**	**Maximum**
Volatile Organic Compounds								
Benzene	7.4E-03	1.7E-02	1.5E-02	3.5E-02	7.4E-03	1.7E-02	0.0	0.1
Dichloromethane (methylene chloride)	1.5E-05	3.6E-04	4.3E-04	1.0E-02	2.2E-04	5.2E-03	0.0	0.0
Tetrachloroethene (PCE)	ND	ND	1.0E-04	1.6E-03	5.2E-05	7.8E-04	0.0	0.0
Trichloroethene (TCE)	7.1E-04	3.8E-03	1.4E-03	7.6E-03	7.1E-04	3.8E-03	0.0	0.0
Trichloromethane (chloroform)	ND	ND	1.0E-03	3.3E-02	5.2E-04	1.6E-02	0.0	0.0
Vinyl chloride	5.3E-03	4.5E-02	1.1E-02	8.9E-02	5.3E-03	4.5E-02	0.0	0.2
Semivolatile Organic Compounds								
bis(2-Ethylhexyl) phthalate	ND	ND	4.6E-03	6.2E-02	2.3E-03	3.1E-02	0.0	0.1
Metals								
Chromium: assume 90% split Cr6 +	NA	NA	9.4E-03	9.7E-02	4.7E-03	4.8E-02	0.0	0.1
Chromium: assume 10% split Cr3 +	NA	NA	2.1E-06	2.2E-05	1.0E-06	1.1E-05	0.0	0.0
Manganese	NA	NA	4.8E-02	1.5E+00	2.4E-02	7.5E-01	0.1	2.2
Total	0.0	0.1	0.1	1.8	0.0	0.9	0.1	3

NA: not applicable
ND: not determined
Note: 1E-01 indicates a value equal to 0.1.

Table 10-26. Average and Maximum Subchronic Hazard Index for Future Residents - Site 1, Southern Area of Operable Unit 2 Groundwater

Chemical	Inhalation		Ingestion		Dermal		Total	
	Geometric Average	Maximum	Geometric Average	Maximum	Geometric Average	Maximum	Geometric Average	Maximum
Volatile Organic Compounds								
Benzene	1.1E-02	1.4E+00	2.1E-02	2.7E+00	1.1E-02	1.4E+00	0.0	5.5
Dichloromethane (methylene chloride)	2.1E-05	4.8E-04	6.1E-04	1.4E-02	3.0E-04	6.8E-03	0.0	0.0
Tetrachloroethene (PCE)	ND	ND	2.6E-04	3.1E-03	1.3E-04	1.6E-03	0.0	0.0
Trichloroethene (TCE)	1.5E-03	2.2E-02	3.0E-03	4.5E-02	1.5E-03	2.2E-02	0.0	0.1
Trichloromethane (chloroform)	ND	ND	1.0E-03	1.1E-02	5.1E-04	5.5E-03	0.0	0.0
Metals								
Manganese	NA	NA	9.2E-02	7.3E-01	4.6E-02	3.7E-01	0.1	1.1
Nickel	NA	NA	3.8E-02	3.1E+00	1.9E-02	1.6E+00	0.1	4.7
Selenium	NA	NA	2.6E-02	3.6E-01	1.3E-02	1.8E-01	0.0	0.5
Total	0.0	1.4	0.2	7.0	0.1	3.5	0.3	10.0

NA: not applicable
ND: not determined
Note: 2E-01 indicates a value equal to 0.2.

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Table 10-27. Comparison of Estimated Contaminant Concentrations in Fish and the San Juan River

Contaminant	Lowest Effective Concentration for Aquatic Organisms μg/L[a]	Estimated Future Concentrations in the San Juan River[b] μg/L	Regulatory Standard[c] μg/L
1,1-Dichloroethane	11.6	0.003	25 (NM HHS)
Dichloromethane	224	0.0003	5p (SDWA MCL)
Tetrachloroethene	0.84	0.0003	5p (SDWA MCL)
Trichloroethene	8.4	0.0002	100 (NM HHS)

[a] Lowest effective concentration for which a toxic effect is observed (EPA 1990b).
[b] Based on a San Juan River flow rate of 1.179M acre ft/yr.
[c] New Mexico human health standard is presented where an SDWA MCL does not exist.
NM HHS: New Mexico promulgated human health standard
p: proposed
SDWA MCL: Safe Drinking Water Act maximum contaminant level

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11. SUMMARY AND CONCLUSIONS

This section provides an overview of results and an interpretation of RI data collected at the Lee Acres Landfill Study Area. Important findings and conclusions are presented with a list of preliminary remedial objectives.

11.1. RI PROGRAM SUMMARY

This RIR presents the data, results, and integrated analyses of a comprehensive RI program designed to characterize all media and potential contaminant migration pathways at the Lee Acres Landfill Study Area. The primary goals of the RI program were to determine the extent and magnitude of contamination at and resulting from the former landfill and to provide the information needed to select a preferred remedial action that will eliminate or significantly reduce any threat to human health and the environment. Subsection 1.1.4 presents details of all other RI/FS goals.

The characterization program began in October 1989 and ended in July 1991. This program was extensive and included the following activities:

- air photo interpretation,
- geophysical surveys,
- cone penetrometer tests,
- hydrocone groundwater sampling,
- soil boring installation and sampling,
- waste trench studies,
- well installations,
- hydrogeologic investigations,
- groundwater sampling and analyses,
- fire water pond sediment sampling, and
- air quality investigation.

Air photo interpretation played an important role in establishing landfill operational history (Appendix B). Seismic refraction, magnetometer, and terrain conductivity surveys were completed at the study area and were used to guide the placement of soil borings and wells. Approximately 139 CPTs were completed at the study area to establish subsurface control on saturated alluvium and to help define waste boundaries and subsurface conditions (subsection 2.3). CPTs were followed by a groundwater hydrocone sampling program. Thirty-nine hydrocone samples were collected and analyzed at an onsite mobile laboratory (subsection 2.4). These data were used to establish trends in the distribution of contaminated groundwater within the study area and to design the permanent groundwater monitoring well network.

The soil boring and sampling program (subsection 2.5) and the trench study (subsection 2.6) were the primary data sets used to estimate the volumes and physical distributions, which are presented in subsection 5.4, of contaminated soil and waste in the landfill. Fifty-three boreholes were drilled and sampled within, adjacent to, and south of the landfill. Three trenches were excavated to determine waste cell distribution and waste types.

As part of the RI, 64 wells were installed and sampled during various stages at the Lee Acres Landfill Study Area. A staged approach was employed so that all previous data could be used to design subsequent sampling programs. The last stage of the RI included the installation and sampling of 13 wells south of the landfill in the OU 2 Site 1 southern area of contamination. The laboratory analytical program consisted of EPA methods for volatiles (8010 and 8020), semivolatiles (8270), pesticides/PCBs (8080), metals (total, soluble, and EP Toxicity), general water chemistry parameters, and isotopic sulfur and strontium. EPA CLP quality assurance, quality control, and reporting requirements were followed during the groundwater sampling and analyses program. All monitoring wells were sampled a minimum of three times. However, many of the older BLM wells have data dating back to late 1987 and have been sampled as many as 17 times.

The technical rationale, strategy, and raw data for these data collection activities are presented in Sections 2 and 3. Results are compared and integrated in Sections 4, 5, 6, 7, and 8, which present detailed analyses of study area hydrogeology, groundwater characterization, source characterization, and contaminant migration pathways. A description and analysis of potential migration pathways is presented and integrated into the conceptual site model (Section 9). Baseline risk is estimated and presented in Section 10 for pathways identified to be of potential concern.

11.2. NATURE AND EXTENT OF CONTAMINATION

11.2.1. Site 1, OU 1, Soils

The results of the excavation of three trenches within the former landfill area are presented in subsections 5.1 and 5.4. Based on trench study results and borehole sample analyses, the landfill is estimated to contain between approximately 600,000 and 800,000 cubic yards of contaminated soil and waste. Waste types encountered within the landfill generally consist of common household waste and various types of construction debris. The physical distribution of various waste types found within the landfill are presented in Figure 5-1.

Subsection 5.1 presents the results of analyses of soil samples collected from 53 boreholes and various wellbores within and adjacent to the landfill. These results are compared with proposed RCRA soil action levels concentrations (Table 5-1). Six VOCs and 25 semivolatile compounds were identified as COCs in landfill soil samples. Proposed RCRA action levels for many of these COCs do not exist. Both chlorinated hydrocarbons and BTEX are found within the landfill subsurface. VOCs include benzene, 1,2-*trans*-DCE, 1,1-DCA, chloroethane, chloromethane, and vinyl chloride. The major portion of BTEX was detected in boreholes in the former northern liquid waste lagoon. Samples from borehole BH-23, located beneath the former northern liquid waste lagoon, were the most contaminated at the Lee Acres Landfill. Benzene was measured in BH-23 samples up to 1,600 µg/kg (Table 5-1).

Low levels of the pesticides 4,4'-DDT, 4,4'-DDE, delta-BHC, and dieldrin were detected in landfill soils at concentrations of up to 120 µg/kg (Table 5-4). Only dieldrin exceeded the proposed RCRA action level of 40 µg/kg in samples from BH-23 and BH-13 at concentrations of 48 and 63 µg/kg, respectively. No PCBs were detected in any landfill soil samples. Two metals, mercury and barium, were identified as COCs in landfill soils (Table 5-5). Mercury was measured in samples collected from BH-08, BH-11, BH-29, and wellbore BLM-57. Barium was detected in samples collected from BH-26.

Six lysimeters were installed in the former northern and southern liquid waste lagoons within the landfill to examine the potential for vadose zone contamination. Four of the lysimeters collected sufficient moisture to allow analysis for VOCs. Results in subsection 5.2 show that vadose zone moisture beneath the former northern liquid waste lagoon contains BTEX ranging from 1.5 to 7.4 µg/L. Nine chlorinated hydrocarbons range from 0.78 to 8.9 µg/L in concentration. These levels are low but document the past migration of lagoon leachate from the landfill during liquid disposal activity from 1979 to April 1985. Because soil samples collected within former lagoons were the highest measured within the landfill and lysimeter samples below former lagoons reveal remnants of past leachate migration, the former lagoons are considered to have acted as the primary source for past groundwater contamination. During landfill operational history, no other significant moisture input was available to any other portions of the landfill.

11.2.2. Site 1, OU 2, Groundwater

Upgradient alluvial and bedrock aquifer water quality shows that elevated chromium concentrations are background because elevated values of dissolved chromium were consistently measured during several sampling events in all five upgradient wells (see subsection 6.1). Dichloromethane identified in only 13 of 43 sampling events indicates it may be a laboratory contaminant (see subsection 6.1.1.2). Semivolatile organic compounds and pesticide/PCBs were not identified as COCs for upgradient alluvial or bedrock groundwater.

Results from groundwater samples collected from alluvial aquifer wells within and adjacent to the landfill (Site 1, OU 2) revealed 23 organic compounds above detection (Table 6-7). Eight of these compounds were identified as COCs: 1,1-DCA, 1,2-DCE, benzene, trichloromethane, dichloromethane, PCE, TCE, and vinyl chloride. The remaining 15 compounds were rejected as COCs because of one-time detection frequency criteria or by the laboratory blank evaluation (see subsection 6.3.1.2). The extent of measured contamination beneath the landfill is generally limited to the 10 wells shown on Figure 6-1. However, the majority of organic contamination measured within the landfill is found in three wells: BLM-55, BLM-56, and BLM-57. With the exception of vinyl chloride, all concentrations measured during the RI within the landfill boundaries were detected below regulatory standards (Table 6-8). Vinyl chloride was detected in only one well (BLM-57) for three of seven sampling events at concentrations ranging from 1.6 to 6.7 µg/L (Table 6-8). The general lack of organic contamination measured beneath and adjacent to the landfill during the RI indicates there is currently no significant organic contaminant leaching process operating beneath the landfill and leaching is a dormant pathway.

Results for manganese in groundwater show that this metal forms a plume in groundwater at the Lee Acres Landfill (subsections 6.3.1 and 6.6.5). Upgradient background manganese concentrations range up to 423 µg/L, which is about twice the New Mexico HHS of 200 µg/L. An elevated plume of manganese is within and south of the landfill. Well BLM-57 is within the area of the former northern liquid waste lagoon. At well BLM-57, an average manganese concentration of 7,905 µg/L indicates that manganese has been introduced into the alluvial aquifer as a result of past landfill operations. The current maximum manganese concentration is above regulatory standard. Groundwater modeling results presented in Section 7 indicate that manganese will continue to exceed the regulatory standard as it reaches the San Juan River. Figure 6-14 shows that the manganese plume decreases in concentration to the south at wells BLM-75, BLM-79, and BLM-74, where concentrations are less than 1,000 µg/L. Further to the south, at wells BLM-78, BLM-67, and BLM-68, the manganese plume is generally measured within and below the upgradient background concentration range.

The manganese plume is attributed to past disposal of liquid petroleum byproduct (brine waters) in the former liquid waste lagoons. The manganese source is most likely to have been added to the lagoons for an extended period during liquid waste lagoon operation.

As part of the RI, 13 bedrock wells were located and sampled within Site 1 boundaries. Two compounds, dichloromethane and *bis*(2-ethylhexyl) phthalate, were identified as COCs. Dichloromethane was detected at concentrations ranging from undetected to 21 µg/L. It is also listed as a COC for upgradient alluvial aquifer groundwater. Detections for dichloromethane from 12 of 30 bedrock well samples exceeded the proposed SDWA standard of 5 μg/L.

11.2.3. Site 1, Operable Unit 2, Southern Area of Contamination

During the initial stages of the RI, groundwater contamination was identified in existing wells GBR-32, GBR-48, and GBR-49. These wells are on Giant-Bloomfield Refinery property approximately 250 ft south of the landfill (Plate 1 and Figure 6-2). This area was identified within the study area as the Site 1, OU 2, southern area of contamination. To investigate the extent and nature of contamination in the southern area, a total of 17 wells were installed and sampled during the RI (Plate 1).

Figure 6-2 shows the approximate extent of measured southern area chlorinated hydrocarbon contamination. This contaminant mass does not extend northward into the former landfill. Measured contamination found in southern area wells defines a thin sinuous area of contamination generally centered around wells GBR-32 and GBR-48 and decreasing southward to well BLM-68. Chlorinated hydrocarbons were detected in 10 of the 18 southern area alluvial aquifer wells, but most of the contamination was found in the southern area in wells GBR-32, GBR-48, and GBR-49 (Table 6-15). BLM wells installed adjacent to and downgradient from the Giant-Bloomfield Refinery wells are free of contamination or relatively low in measured contamination compared with the Giant-Bloomfield Refinery wells. RI data show that this mass of contamination is disconnected from the former landfill. Well clusters located at the southern perimeter of the former landfill and between the former liquid waste lagoons and the Site 1 southern area are free of organic contamination. The lack of a continuous plume indicates that there is currently no active migration of organic contaminants from the landfill to the Site 1 southern area.

Nine volatile organic compounds were identified as COCs for the Site 1 southern area (Table 6-14). With the exception of benzene, these consist of chlorinated hydrocarbons. 1,2-DCE is the most commonly detected compound ranging up to 200 μg/L. 1,2-DCE, benzene, dichloromethane, PCE, and TCE levels exceed regulatory standards. No semivolatile organic compounds were identified as COCs for the southern area. The area of contamination does not extend northward into the landfill.

Manganese concentrations in the southern area range up to 4,230 μg/L (Table 6-18). As described in the previous subsection, the observed manganese plume within the southern area consists of the southern extent of a continuous plume originating beneath the former northern liquid waste lagoon near well BLM-57. Figure 6-14 shows that this manganese plume decreases in concentration to the south at wells BLM-74, BLM-75, and BLM-79, where concentrations are less than 1,000 μg/L. Further south, at wells BLM-67, BLM-68, and BLM-78, the manganese plume is generally within or below background concentrations.

Cobalt, nickel, and selenium concentrations were also measured above regulatory standards within the southern area (Table 6-18).

An examination of the products that are expected as a result of any degradation of organic compounds in the southern area groundwater plume revealed that vinyl chloride and chloroethane are likely to be measured in higher quantities in the future (Figure 6-3). During the RI, groundwater samples collected from bedrock wells within the southern area were found to be generally free of contamination and within regulatory standards.

11.2.4. <u>Site 2 Groundwater Contamination</u>

Site 2 is defined as the area south of Site 1 to the San Juan River including the Giant-Bloomfield Refinery, the subdivisions, and other private property. Currently, two plumes are being investigated and remediated by the Giant-Bloomfield Refinery on Giant property and property south of U.S. 64 to the San Juan River (Plate 1). This area is generally defined by the area south of well BLM-68. On Giant property, floating petroleum product was found in 19 monitoring wells (Figure 6-5). An investigation is being conducted by the Giant-Bloomfield Refinery to further define this plume.

The primary COCs within the two Giant-Bloomfield Refinery Site 2 plumes are BTEX (Table 6-20). Chlorinated hydrocarbons are measured in various wells within the southern plume, but are not distributed according to a pattern that would indicate any single source (Figures 6-8 and 6-9). With the exception of wells BLM-37, BLM-65, and BLM-66, manganese levels in Site 2 wells are significantly lower than those in the landfill and in the Site 1 southern area of groundwater contamination (Figure 6-14). Manganese levels in well BLM-37 range up to 2,980 μg/L. Wells BLM-65 and BLM-66 show levels of manganese contamination relatively higher in concentration than those measured in other Site 2 wells. This difference may be explained by an alternate local source, such as former petroleum production wells located immediately north on adjacent San Juan County fairground property.

11.3. POTENTIAL CONTAMINANT MIGRATION

Section 8 provides the technical rationale for eliminating the air, surface water, and biotic pathways as potential pathways of concern because there is no actual or potential for future exposure through these pathways. Ingestion, inhalation, or contact with contaminated soil or waste within the former landfill are eliminated as potential pathways because 2 to 10 ft of fill material cover former waste cells and landfill access is restricted. The primary pathways of concern at the Lee Acres Landfill are:

- potential future leaching of contaminants through the vadose zone to the alluvial aquifer that may occur as a result of increased moisture availability, and

- ingestion, inhalation, or dermal contact with contaminated groundwater measured at the Site 1 southern area of contamination (study subarea 3).

Section 10 of this RIR presents the assumptions used to identify potentially exposed populations and the risk estimates associated with each of these pathways. Bloomfield's municipal well is located hydraulically upgradient of the valley fill area affected by the former Lee Acres Landfill. Therefore, it is unlikely that contamination emanating from the landfill would have any adverse effect on this water supply. The city of Farmington obtains municipal drinking water from the Animas River and contamination emanating from the former Lee Acres Landfill would have no adverse effect on this water supply.

RI data show that the former northern liquid waste lagoon provided the moisture needed for the downward migration and leaching of lagoon contaminants into alluvial aquifer groundwater. In Section 7, the leaching of contaminants through the vadose zone was simulated to estimate the effects of future movement of contaminants, given current conditions. Mass transport simulation results show that contaminants will have no detectable effect on alluvial aquifer groundwater quality because of the lack of moisture available to produce the percolation rates needed to move water through the vadose zone. Although moisture has been removed from the lagoons and there is no active release mechanism, the potential for leaching by the addition of moisture is not ignored. Therefore, in Section 8, contaminant leaching from the landfill to alluvial groundwater is classified as a potential migration pathway.

The conceptual site model presented in Section 9 summarizes current understanding of landfill contaminant sources, pathways, and receptors by illustrating and describing how the site currently operates in terms of contaminant migration. The model provides the basis to develop preliminary remedial objectives (Figure 9-1). All pathways are illustrated and identified as either dormant or active.

Section 7 presents the results of a transport simulation of contaminant mass in groundwater performed to estimate future Site 1 and Site 2 groundwater conditions in the absence of any remedial action. Retardation factors are an estimate of the rate at which chemical adsorption processes decrease the movement of constituents in groundwater. Due to chemical retardation, 1,2-DCE and manganese will move approximately 0.40 times the velocity of groundwater. Groundwater modeling results show that approximately 22 years would be required for the leading edge of the organic plume to migrate from the former landfill liquid waste lagoons to the area just south of U.S. 64. Twenty-two years ago in 1969, liquid waste lagoons were not in existence at the landfill, and solid waste disposal was not in an active phase until approximately 1975. Liquid waste lagoons came into existence in 1979 and were active until 1985. Simulation results indicate that Site 1 southern area contamination, if allowed to migrate unabated, will reach the subdivision just south of U.S. 64 in approximately 10 years (from 1991), and will reach the San Juan River in approximately 50 years (Figures 7-1 and 7-2).

Evidence is available that indicates that two Site 2 plumes are a result of past practices at the Giant-Bloomfield Refinery and not past disposal practices at the Lee Acres Landfill. In subsection 6.5, it is shown that a number of Site 2 sources may have contributed to the Site 2 plumes. These consist of containment areas, pits, concrete storage vessels, tanks, ponds, fire drill areas, and truck loading areas. Also, this section reviews the history of several documented leaks and spills. Currently, the Giant-Bloomfield Refinery is investigating and remediating two Site 2 groundwater plumes, one of which extends south into the Suburban Heights subdivision.

In 1969, no liquid waste lagoons existed at the landfill (they became operational in 1979), and solid waste disposal activities were not in an active phase until 1975. An inspection report issued in 1968 indicated that the landfill was in use at that time (BLM-DLM 1968). The bulk of solid waste disposal occurred between 1975 and 1985. There is no evidence that a contaminant mass left the landfill in 1969 and produced BTEX or chlorinated hydrocarbon concentrations 22 years later more than 3,500 ft downgradient within or adjacent to the Site 2 areas of groundwater contamination.

There is no northward and increasing contaminant concentration gradient from the Site 2 areas of contamination to indicate that contaminants have migrated from the landfill to the Site 2 areas of contamination. Groundwater samples collected from well GBR-17 and hydrocone sampling stations south of the Site 1 plume show no significant groundwater contamination exists between Site 1 and Site 2 and that these plumes are two separate masses of contamination. The lack of a northward concentration gradient indicates contaminants found at Site 2 did not move from the landfill but are related to other sources.

The magnitude of contamination in Site 2 wells is generally two or three orders higher in concentration for chlorinated hydrocarbons and BTEX than that of Site 1 wells. For example, the highest reported concentration for benzene in Site 1 wells is 100 μg/L in well GBR-48; the highest reported concentration for benzene in the Site 2 plume is 24,000 μg/L in well BLM-37. This distinction indicates that Site 2 contamination is derived from separate sources unrelated to the Lee Acres Landfill. Well BLM-37 consistently shows a measurable amount of petroleum product on the groundwater surface. It is documented that petroleum product contamination is a result of releases from the Giant-Bloomfield Refinery.

11.4. BASELINE RISK

The baseline risk assessment presented in Section 10 generally results in the development of the remedial objective to eliminate or significantly reduce potential risk to a hypothetical future resident residing in subarea 3. Inhalation, direct contact, and ingestion of Site 1 southern area groundwater by hypothetical future residents all exceed a 1-in-10,000 maximum and a 1-in-10,000 average cancer risk (Table 10-22). There is currently no actual risk to any residents south of the landfill because no households use Site 1 groundwater for any purpose.

Section 10 also presents results of an environmental risk assessment. All information indicates there have been no known reductions in population size, no known changes in community structure, and no known changes in ecosystem structure and function as a result of contamination from the Lee Acres Landfill. The Lee Acres Landfill appears to pose no current threat to terrestrial or aquatic ecosystems within the study area. The general conclusion of the baseline risk assessment is that Site 1, OU 2 groundwater contamination represents unacceptable risk to future hypothetical residents who may inhale, have contact with, or ingest Site 1 groundwater.

11.5. PRELIMINARY REMEDIAL OBJECTIVES

The former liquid waste lagoons at the landfill could have provided moisture that acted as an active transport mechanism between approximately 1979 and 1985, when the lagoons were active. Since January 1986, the lagoons have been empty, and any measurable leaching process apparently has ceased because there is no northward and increasing organic contaminant concentration gradient in groundwater from the Site 1 southern area plume to the landfill. Results from modeling of the leaching process presented in Section 7 also support the statement that the landfill will not significantly affect alluvial aquifer quality in the future without the input of additional moisture.

Based on the analyses and integration of RI data, the pathway analysis, and results of the baseline risk assessment, remedial action objectives are developed and generally consist of the following:

- <u>OU 1</u> - elimination or significant reduction of any potential for future contaminant leaching as a result of increased moisture availability to the landfill.
- <u>OU 2</u> - elimination or significant reduction of any risk posed by potential downgradient contaminant migration in groundwater.

Any risk posed during implementation of remedial actions will be addressed as part of the Phase III FS under adverse impact.

Site 2 contamination is shown to be separate from and unrelated to the Site 1 groundwater plume and landfill sources. Therefore, no remedial objectives are defined for the Site 2 area.

Preliminary OU 1 remedial alternatives consist of a combination of institutional actions, containment, treatment, collection, and disposal actions. Preliminary remedial alternatives for OU 2 may include various combinations of groundwater containment, collection, treatment, and disposal actions. These alternatives will be screened further and an assessment will be made at that time if bench scale treatability testing of an alternative is required prior to the Phase III FS. In the Phase III FS, retained alternatives will undergo a detailed analysis according to nine EPA-recommended criteria, resulting in the selection of a preferred remedial alternative for each OU.

This RIR presents a comprehensive overview of RI data and conditions at the Lee Acres Landfill Study Area. Two contaminant migration pathways are identified that require selection of a preferred remedial action. The primary recommendation is to perform the detailed analysis of remedial alternatives, complete the feasibility study process, and implement selected remedial actions.

No risks are currently posed by past or current releases from the Lee Acres Landfill to any humans by either of the two potential pathways; no residents currently use Site 1 southern area groundwater for any purpose. Contaminants found in domestic wells at the Lee Acres subdivision are derived from Site 2 sources, which are shown to be separate and unrelated to the Lee Acres Landfill.

The Site 1 southern area groundwater contamination is approximately 250 ft south of the southern landfill boundary. There is little or no likelihood that any future hypothetical residents will establish a household on this property, now owned and maintained by Giant Industries, Inc. Because southern area contaminants are located off BLM property, it is recommended that the remediation of Site 1 southern area groundwaters be established according to an aggressive schedule. This recommendation would ensure that contaminated groundwaters do not migrate any significant distance before final remedial actions are approved through the CERCLA process.

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13. GLOSSARY OF SCIENTIFIC AND RELATED TERMS

100-year frequency storm	A storm with a 1 percent chance of occurring in any one year.
500-year frequency storm	A storm with a 0.20 percent chance of occurring in any one year.
6-hour storm	A storm of 6 hours.
abiotic	A chemical reaction occurring without a biological catalyst.
acceptable risk	The risk that falls within the overall target range of 10^{-4} to 10^{-6} or one excess cancer in 10 thousand to one in 1 million.
acute	See subchronic.
adsorption	In groundwater, the chemical reaction of solutes with porous media. This process locks contamination in the soil matrix until it is desorbed and retards the contaminant transport process.
advection	The process by which solutes are transported through groundwater by the bulk motion of groundwater flow.
aerobic	A chemical reaction requiring oxygen to occur.
air stripper	A device used to treat groundwater and soils that employs a mass transfer process in which volatile contaminants are transferred from liquid to gas. (Air is pumped into contaminated soil or groundwater; the volatile contaminants are dispersed into the air, and the air is blown into the atmosphere.)
aliphatic	Any organic compound of hydrogen and carbon characterized by a straight chain of carbon atoms.
alkalinity	The measure of a solution's capacity to neutralize acids. The alkalinity of natural waters is primarily due to the salts of weak acids, although weak or strong bases may also contribute. Bicarbonates represent the major form of alkalinity because they are formed in considerable amounts from the action of carbon dioxide on basic materials in the soil.
alkane	A member of a series of saturated aliphatic hydrocarbons.
alkene	One of a class of unsaturated aliphatic hydrocarbons containing one or more carbon-to-carbon double bonds.
alluvial (alluvium)	All sedimentary deposits resulting from the operations of modern rivers.
alluvial aquifer	Saturated unconsolidated strata above bedrock.
alluvial deposits	Unconsolidated sediments deposited by streams.

alluvial fan	Depositional feature formed by stream sediments.
alluviation	The deposition of mechanical sediments by rivers anywhere along their courses.
ambient magnetic field	Local background magnetic field.
ambient noise	Background noise related to natural or man-made causes.
anaerobic	A chemical reaction that occurs in the absence of oxygen.
analyte-free water	Reagent grade water where the analyte of concern is below the detection limit.
analytical sampling program	A selected group of sampling stations and analytical methods designed to accomplish remedial investigation objectives.
anastomosing	Branching, interlacing channels that produce a netlike or braided appearance.
angular	The edges of clasts, as opposed to rounded surfaces.
anhydrite	A mineral, $CaSO_4$.
anisotropic	Nonidentical physical properties in different directions.
annulus	The ringlike structure between the inside of a surrounding concentric circle and the outside of the enclosed, smaller concentric circle.
apparent conductivity	A composite value of conductivities (ability to carry an electrical current) of materials measured with an electromagnetic instrument.
aquifer	A stratigraphic layer sufficiently permeable to yield measurable quantities of groundwater.
aquifer characteristics	Parameters that describe the ability of an aquifer to store and transmit water. These include hydraulic conductivity (K), transmissivity (T), and storativity (S).
arch	An uplift with greatest uplift in the center and decreasing uplift along the flanks.
argillaceous	Consisting mostly of clay-sized particles.
aromatic volatile compound	A volatile organic compound characterized by the presence of at least one benzene ring.
arroyo	The channel of an ephemeral or intermittent stream.
as-built drawings	Engineering drawings representing a completed construction project.

Atterberg limits	A classification system for the state of a very fine-grained soil. For clays, the usual classification is derived from their engineering properties under varying conditions of moisture. Consistency is a term frequently used to describe the degree of firmness (e.g., soft, medium, firm, or hard). The Atterburg limits are an empirically developed but widely used procedure for establishing and describing the consistency of soil.
auger	A rotary drilling device that mechanically and continuously removes the cuttings during the drilling operation without the use of fluids.
auger string	The casing, tubing, or pipe of one size used in an augered well.
authigenic	Forming in place.
badlands	A region lacking vegetation in which soft bedrock is carved into narrow ravines and sharp crests and pinnacles.
Banded Iron Formation	A rock type consisting of alternate layers of silica and iron oxide minerals.
baseline risk assessment	"An evaluation of the potential threat to human health and the environment in the absence of any remedial action." (EPA 1988a).
basement	Complex, generally igneous or metamorphic rocks that are unconformably overlain by sedimentary rocks.
Basin and Range Province	Extensional tectonic province that extends across New Mexico, Arizona, Nevada, California, Utah, and Oregon.
bedding surface	In rocks, the division surface that separates the individual layers.
bedrock	Any solid rock exposed at the surface of the earth or overlain by unconsolidated material.
bedrock channel	In the case of the Lee Acres Landfill, a channel incised into bedrock that has since filled with alluvial material.
bench-test treatability study	A study performed in a laboratory where comparatively small volumes of waste are tested to determine the characteristics of a treatment technology (EPA 1988a).
bentonitic	Rock formed from the alteration of volcanic ash which is used commercially in drilling fluids.
berm	An earthen embankment used to contain liquids in an impoundment.
biogenic fractionation	The separation of isotopes through the preferential biological use of those isotopes in compounds.

biological degradation	Breakdown of compounds, eventually into carbon dioxide and water, through biological processes.
borehole	A hole drilled into the ground for soil sample collection.
borehole log	A description of the materials encountered at specific depths during the drilling of a borehole.
braided stream	A stream with many divided and reunited channels.
breakthrough concentration	The highest contaminant concentration observed or predicted at a specified location.
breathing zone	An area, approximately from the waist to the top of the head, from which a worker breathes.
brine	A highly saline solution containing appreciable amounts of sodium chloride (NaCi) and other salts.
BTEX	Benzene, toluene, ethylbenzene, and xylene.
buffered groundwater	Groundwater containing a concentration of a buffer that can accept changes in hydrogen ion concentrations with little or no change in pH.
bulk density	Characteristic of a material that is the weight of material divided by the total volume of material including pore space.
burrows	Sediments disturbed by animals tunneling through.
butte	A conspicuous isolated hill or mountain.
C_1 - C_8 aromatic hydrocarbons	Hydrocarbons with one to eight carbon atoms in each molecule.
calcite	A mineral, $CaCO_3$.
calibration	In mass transport modeling, it is desirable to calibrate modeling results with measured concentrations of groundwater.
calibration blank	Triple-distilled, deionized water assumed to be analyte-free used to calibrate lab equipment to zero.
calibration verification sample	A material of known composition analyzed concurrently with test samples to evaluate a measurement process.
caliche	Gravel, sand, or desert debris cemented by intergranular calcium carbonate.
capillary column	A column of sufficiently small diameter that capillary attraction of a liquid into the column is significant.
carbonaceous	Containing an abundance of carbon or organic matter.

carbonate	Sedimentary rocks that contain a high percentage of calcium carbonate minerals.

	Group*	Description
carcinogenic classification for chemicals	A	Human carcinogen
	B1 or B2	Probable human carcinogen B1 indicates that limited human data are available B2 indicates sufficient evidence in animals and inadequate or no evidence in humans
	C	Possible human carcinogen
	D	Not classifiable as to human carcinogenicity
	E	Evidence of noncarcinogenicity for humans

*Based on EPA weight-of-evidence

carcinogenic slope factor	A plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen.
casing	A special steel tube lowered into a wellbore to prevent entry of loose rock into the wellbore.
cation exchange	A chemical reaction in which hydrated cations of a solid are exchanged, equivalent for equivalent, for cations of a like charge in solution.
cementation	The process of precipitating a binding material around grains or minerals in rocks.
Cenozoic	The latest of the four eras into which geologic time is divided, including the present. The Cenozoic Era includes the Tertiary and Quaternary periods.
chain of custody	A record of the people who retained possession of samples from the time of sample collection through laboratory analysis.
charge balance	The requirement that the sum charge of positive and negative ions in solution be zero.
chelating metal	Metal involved in the chelation process.
chelation	Formation of a chemical compound having an organic compound that includes a metal ion in its structure without rigidly binding the metal ion. The metal ion can be stripped from or added to the organic compound without destroying the overall structure of the compound.
chemical fingerprinting	The use of chemical properties (breakdown products, isotopic ratio, sorption potential) to distinguish separate groundwaters.
chemical of concern	See contaminant of concern.

chemical reactions	Reactions that may include, but are not necessarily limited to, degradation, hydrolysis, oxidation, reduction, dehydrohalogenation volatilization, adsorption, and biodegradation.
chert	A mineral, SiO_2, finer-grained than quartz.
chloride analysis	Analysis to identify chloride ion concentration and distribution.
chlorinated ethene, ethane	Part of the chlorinated hydrocarbon family.
chlorinated hydrocarbon	A family of chemical compounds in which chlorine atoms replace hydrogen atoms at one or more locations in hydrocarbon molecules.
chronic	Long-term noncarcinogenic effects.
chronic daily intake	Exposure expressed as mass of a substance contacted per unit body weight per unit time, averaged over a long period of time (as a Superfund program guideline, seven years to a lifetime).
chronic reference dose	An estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Chronic reference doses are specifically developed to be protective for long-term exposure to a compound (as a Superfund program guideline, seven years to lifetime).
clast	An individual constituent of sediment or rock produced by the physical disintegration of a larger mass.
clastic	Consisting of fragments of rocks moved individually from their place of origin.
clay	A mineral group, and a clast size category of particles with diameters less than 1/256 mm.
clay matrix	Clay as the cementing material between coarser grains of a sedimentary deposit.
claystone	An indurated clay; a rock of clay-sized particles.
clean quartz sandstone	A clastic sedimentary deposit of sand-sized quartz grains with little to no silt or clay included in the consolidated nature.
coliform bacteria	Bacilli bacteria, or forms that resemble or are related to them.
colluvial	Geomorphic processes dominated by gravity.
colluvium	Loose deposits usually at the foot of a slope or cliff, brought there mainly by gravity.
Colorado Plateau	A physiographic high tectonic province centered in the Four Corners area of the U.S.

combustible gas indicator	A gas meter that defines the concentration of a combustible gas to a percentage of its lower explosive limit concentration.
cometabolism	Two or more chemical substances used together by a living organism.
common laboratory contaminants	Certain organic chemicals (considered by EPA to be acetone, 2-butanone, methylene chloride, toluene, and the phthalate esters) that are commonly used in the laboratory and thus may be introduced into a sample from laboratory cross-contamination, and not necessarily from the site.
compaction features	Changes in original layering of sediments during burial by younger sediments.
compressional seismic wave	A disturbance traveling through an elastic medium, characterized by changes in volume and particle motion parallel to the direction of wave movement.
conductivity	The measure of a solution's ability to carry an electrical current (varies both with the number and type of ions in the solution).
conductivity anomaly	A change in the conductivity of a mass, such as soil, indicating a change in the components of the mass.
cone penetrometer	A soil property sensing device. Detail is presented in subsection 2.3.1.
confined aquifer	An aquifer in which the water is under hydrostatic pressure because the aquifer is bounded above and below by impermeable or semipermeable beds.
conformable	Sedimentary deposits occurring in sequence without major breaks in time between the deposition of layers.
conglomerate	Clastic sedimentary deposit containing gravel-sized particles.
conservative ions	An ion not easily adsorbed onto aquifer materials and, therefore, tending to travel at the same speed as groundwater flow.
contact rate	Amount of medium (e.g., groundwater, soil) contacted per unit item or event (e.g., liters of water ingested per day).
containment	The isolation of waste from human and environmental (air, water, soil) systems.
contaminant	Any element, substance, compound, or mixture that after release into the environment and assimilation through food chains may cause death, disease, etc.
contaminant mobility	In groundwater, the ability of a particular contaminant to move with groundwater flow. Constituents that adsorb in porous media compared with others are considered less mobile.

contaminant of concern	A potentially site-related chemical whose data are of sufficient magnitude for use in the quantitative risk assessment.
contaminant plume	A mass of dissolved contamination in groundwater identified by measured contamination in specified monitoring wells.
contaminant slug	A mass of contamination in groundwater released in the past that no longer has an active source component.
contaminant transport	The migration of contaminants through various media induced by a transport mechanism. (Groundwater flow is a primary mechanism of contaminant transport in groundwater.)
contaminated soil and waste	Soil and solid waste contaminated by any contaminant of concern.
contaminated source	Solid, liquid, hazardous, or mixed waste that is the origin of contaminated soil or water.
continental crust	The type of rocks underlying the continents, thicker and less dense than oceanic crust.
continental deposits	Sedimentary rocks formed by deposition on a landmass rather than in a water body.
Contract Laboratory Program	A national EPA program for analyzing organic and inorganic parameters which is characterized by specific analytical and contractual requirements, documented QA/QC requirements, stringent data packages, documented data review, and validation protocols.
craton	Tectonically stable portion of the continent.
Cretaceous	The third and latest of the periods of the Mesozoic Era.
cross section	A profile portraying an interpretation of a vertical section of the earth.
crossbedding	The arrangement of laminations of strata transverse or oblique to the main planes of stratification.
cuesta	A sloping plain terminated on one side by a steep slope.
decontamination	Thorough cleaning of sampling equipment.
decontamination water	Final water rinse used in decontamination which is analyzed to determine effectiveness of the cleaning.
dehydrohalogenation	Removal of hydrogen and a halogen from a compound.
dendritic	A drainage pattern in which the streams branch randomly in all directions, resembling the branching pattern of trees.
diagenesis	Processes involving physical and chemical changes in sediment after deposition converts it to rock.

diagenetic changes	Physical and chemical changes in sediments that turn them into rocks.
diffusivity	The movement of a molecule in a liquid or gas medium as a result of differences in concentration. It is used to calculate the dispersive component of chemical transport. The higher the diffusivity, the more likely a chemical will move in response to concentration gradients.
dilution	In groundwater, the reduction of contaminant concentration by the addition of water. Dilution is usually a result of mechanical dispersion processes.
dipole	Any object or system oppositely charged at two ends, such as a magnet.
discharge	In groundwater, the process of underground flow becoming surface flow, such as a stream or spring.
dispersion	The hydrodynamic spreading process caused by mechanical mixing during fluid advection. Dispersion is expressed as longitudinal or transverse to groundwater flow.
dissected	Cut by erosion, particularly stream erosion.
dissolved oxygen	The measure of oxygen dissolved in or available to groundwater systems. Low oxygen content may indicate pollution of a high soil organic content.
distal	Located away from the point of origin or attachment.
dormant pathway	An inactive exposure pathway that may be activated later.
dose	The amount of a substance penetrating the exchange boundaries of an organism after contact via inhalation, ingestion, or direct contact. Absorbed dose is calculated from the intake and the absorption efficiency. Dose is usually expressed as mass of a substance absorbed into the body per unit body weight per unit time (e.g., mg/kg/day).
dose-response evaluation	The process of quantitatively evaluating toxicity information and characterizing the relationship between the dose of a contaminant administered or received and the incidence of adverse health effects in the exposed population. From the quantitative dose-response relationship, toxicity values are derived that are used in the risk characterization step to estimate the likelihood of adverse effects occurring in humans at different exposure levels.
double-blind spike	A sample prepared with known concentrations of selected analytes by a third party laboratory and then submitted with field samples to the contract laboratory for analysis. Analytical results from the contract laboratory are compared with the results from the third party laboratory to determine the accuracy of the contract laboratory analytical procedures.

down section	In geology, the direction of increasing age in a rock formation.
downgradient well network	System of groundwater monitoring wells used to track contaminants downstream from potential sources.
drainage area or basin	An area in which all surface runoff collects and is carried by one drainage system, such as a river and its tributaries.
drape folding	A fold produced in layered rocks by movement of an underlying brittle block at high angles to the layering.
drilling fluids	Fluids used during the drilling phase of the construction of certain types of wells, including water, gas, and oil wells.
dry density	The density of dry soil.
duplicate sample	A sample split sent to the laboratory to verify the accuracy of the analysis.
electrolyte	A chemical compound that will conduct an electric current when dissolved in water.
electromagnetic terrain conductivity survey	An electronic survey of a given area to detect differences in the terrain.
empirical observation	Observation based on measurement or experience rather than theory.
Eolian deposits	Sediments deposited by wind.
Eolian processes	Processes dominated by wind.
EP Toxicity metals	The list of metals analyzed by the EPA Extraction Procedure Toxicity Method. This analytical method has been replaced with the Toxicity Characteristic Leaching Procedure.
ephemeral flow	Intermittent flow of surface water in direct response to precipitation runoff, usually associated with a rainy season.
ephemeral lake	A lake that exists only seasonally and dries up during a drought or dry season.
ephemeral stream	A stream channel that carries water only during and immediately after periods of rainfall or snowmelt.
epicenter	The point on the earth's surface directly above the focus of an earthquake.
evaporites	Sedimentary rocks and minerals that form by the evaporation of sea or lake water.
exhumation	Exposure of a feature by the removal of the material that covered it.

exposure	Contact of an organism with a chemical or physical agent. Exposure is quantified as the amount of the agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut) and available for absorption.
exposure assessment	The determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, and route of exposure.
exposure event	An incident of contact with a chemical or physical agent. An exposure event can be defined by time (e.g., day, hour) or by the incident (e.g., eating a single meal of contaminated fish).
exposure pathway	The course a chemical or physical agent takes from a source to an exposed organism. An exposure pathway describes a unique mechanism by which an individual or population is exposed to chemicals or physical agents at or originating from a site. Each exposure pathway includes a source or release from a source, an exposure point, and an exposure route. If the exposure point differs from the source, a transport/exposure medium (e.g., air) or media (in cases of intermedia transfer) is included.
exposure point	The point of contact between an organism and a chemical or physical agent.
exposure route	The way a chemical or physical agent comes in contact with an organism (e.g., by ingestion, inhalation, dermal contact).
extensional stress field	Stress field caused by tensional tectonic processes.
extrapolate	To estimate a point that is larger than or smaller than all the points at which the value is known.
facies	General appearance or nature of one part of a rock body as contrasted with other parts.
faults	Fractures in rock or strata accompanied by displacement in any direction.
ferric chloride	An easily dissolved salt, $FeCl_3$, used in sewage treatment.
ferricrete	A cement in sedimentary rocks composed of hydrous iron oxides.
field blank	Usually an organic or aqueous solution that is as free of analyte as possible and is transferred from one vessel to another at the sampling site and preserved with the appropriate reagents. This serves as a check on reagent and environmental contamination. One field blank should be analyzed with each analytical batch or every 20 samples, whichever is greater.
field duplicate	A second aliquot of a sample taken in the field which is treated the same as the original sample to determine the precision of the method.

firewater storage ponds	Dry, abandoned ponds south of the Lee Acres Landfill on Giant-Bloomfield Refinery property, formerly used for water storage.
first break picks	The selection of times of the first arrival of energy at geophones.
fissile	A rock fabric that allows it to split easily along closely spaced parallel planes.
flame structure	A sedimentary structure showing evidence of differential settling and horizontal slip.
floating product	Petroleum or gas floating on the water surface in a well.
floodplain	The position of a stream's water surface during a particular flood.
flow rate	Time required for a given quantity to flow a measured distance.
flow regime	A range of streamflows having similar bed forms, flow resistances, and means of transporting sediments.
fluvial	Pertaining to a stream environment.
fold	A bend in strata or any planar structure.
formation	A primary unit of rock with certain distinctive or a combination of distinctive lithic features.
fracture	Breaks in rocks caused by intense folding or faulting.
frequency of detection evaluation	An analysis of the number of times a contaminant is detected in a well.
gabion or gabion wall	A rock-filled wire encasement used in the support of steep slopes, usually installed to protect against erosion.
gas chromatograph	An instrument used in gas chromatography to detect volatile organic compounds. The instrument operates by a separation technique involving the passage of a gaseous moving phase through a column containing a fixed adsorbent phase.
geochemistry	The study of the chemical composition of the various phases of the earth and the physical and chemical processes that produced the observed distribution of the elements and nuclides in these phases.
geology	The study of the earth, its history, and its life as recorded in the rocks.
geomorphology	The study of the origin of topographic features carved by erosion and built up from erosional debris.
geophone	Means by which seismic waves can be detected.

glaciation	A time of glacier ice accumulation dominated by erosion and deposition of glacially derived sediments.
gneiss	Metamorphic rock type.
gradational contacts	Changes from one rock unit occurring without a major distinction in grain size of the sediments.
grain-size distribution	A soil classification based on the determination of particle size and size distribution. Most often it is accomplished by using sieve analysis for the coarse fraction (sizes greater than 200 mesh sieve) and by sedimentation methods for the fine fraction (e.g., hydrometer).
granite	Igneous rock type.
gravel	Rock grains or fragments with diameters of 4.76 mm to 76 mm.
groundwater	Water in a saturated zone or stratum beneath the surface of land or water.
groundwater elevation	The height of the top of the saturated zone above a datum; usually sea level.
groundwater modeling	The analytical or numerical simulation of groundwater flow and/or solute transport.
groundwater plume	A geographical description of a foreign material that has propagated through groundwater from a single source or series of sources.
gypsum	A mineral, $CaSO_4$-$2H_2O$.
H_2S	Hydrogen sulfide, which forms in environments with low oxygen content (vs. sulfate).
halocarbon	A compound of carbon and a halogen.
halogen	A family of elements that includes fluorine, chlorine, bromine, iodine, and astatine.
halogenated aromatic	An aromatic hydrocarbon with selective replacement of hydrogen atoms with any of the halogens.
halogenated organic compound	A volatile or semivolatile organic compound with some selective replacement of hydrogen with halogens (fluorine, chlorine, bromine, iodine, and astatine).
hazard identification	The process of determining whether exposure to an agent can cause an increase in the incidence of a particular adverse health effect (e.g., cancer, birth defect) and whether the adverse health effect is likely to occur in humans.

hazard index	The sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. The hazard index is calculated separately for chronic, subchronic, and shorter-duration exposures.
hazard quotient	The ratio of a single substance exposure level over a specified time period (e.g., subchronic) to a reference dose for that substance derived from a similar exposure period.
hematite	A mineral, Fe_2O_3.
Henry's Law constant	Provides a measure of the extent of chemical partitioning between air and water at equilibrium. The higher the Henry's Law constant, the more likely a chemical is to volatilize than to remain in the water.
HNu	A photoionization detector used to determine the relative concentrations of air contaminants up to 2000 ppm.
hogback	Sharp-crested ridge formed by a hard bed of rock that dips steeply.
Holocene	Recent; the period of time since the last ice age.
humus	The amorphous, ordinarily dark-colored colloidal matter in soil; a complex of the fractions of organic matter of plant, animal, and microbial origin that are most resistant to decomposition.
hydraulic analysis	Analytical technique applied to fluids in motion.
hydraulic conductivity	The measure of permeability of porous medium (K).
hydraulic gradient	Pressure gradient; as applied to an aquifer, it is the rate of change of pressure head per unit of distance of flow.
hydraulic head	See hydraulic gradient.
hydrocarbons	A family of chemical compounds containing carbon and hydrogen in their molecules in addition to other possible elements.
hydrocone	A groundwater sampling device.
hydrocone sample	A groundwater sample collected using a hydrocone water sampling device. Detail is presented in subsection 2.4.1.
hydrograph	A graphical representation of a characteristic of water (flow or groundwater elevation) at a given point as a function of time.
hydrologic analysis	An analytical technique applied to the waters of the earth, regarding their occurrence, circulation, distribution, and chemical and physical properties.

hydrologic boundary	A boundary that defines a difference in hydrologic characteristics between two stratigraphic layers or other boundary.
hydrologic system	Related hydrologic units and their man-related aspects such as the use, treatment, reuse, and disposal of water.
hydrologic unit	See hydrostratigraphy.
hydrology	A science that deals with the relationship between water and the earth.
hydrolysis	Decomposition or alteration of a chemical substance by water.
hydrometer	Material finer than the openings of a No. 200 mesh sieve (openings of 0.075 mm) is generally analyzed by a method of sedimentation. The most common test, the hydrometer test, is based on the principle that grains of different sizes fall through a liquid at different velocities.
hydrostatic pore pressure	The pressure exhibited in the pores of a saturated soil when a stress is placed upon the soil.
hydrostratigraphy	A classification of rocks based on their hydrologic properties (permeability, porosity) rather than their lithologic characteristics.
in-phase component of the EM-31	Component of the electromagnetometer that is sensitive to metal.
in situ	In place.
in situ density	The "in place" density of a soil.
infiltration	Movement of water through the soil surface into the ground.
injection test	A measure of an aquifer's properties through addition of water in order to observe the recovery in a well.
inorganic	A substance that does not contain carbon.
intake	A measure of exposure expressed as the mass of a substance in contact with the exchange boundary per unit body weight per unit time (e.g., mg chemical/kg body weight/day).
integrated risk information system	An EPA computerized data base containing verified reference doses and slope factors and up-to-date health risk and EPA regulatory information for numerous chemicals. IRIS is EPA's preferred source for toxicity information for Superfund.
intercoil spacings	The distance between the transmitting and receiving coils of an electromagnetic instrument.
interfluvial ridge	The high ground between adjacent streams flowing in the same general direction.

interglaciation	Period of time between glaciations.
intraformational conglomerate	A conglomerate with clasts derived from the formation of which the conglomerate is part.
intrinsic toxicity properties	See toxicity.
ion activity product	A measure of the effective concentration of ions in solution.
isomer	A chemical substance with the same elementary percentage composition and molecular weight as one or more other chemical substances, but with a different molecular structure and different properties.
isopach	A line on a map drawn through points of equal thickness of a lithologic unit.
isostatic	Characterized by the equilibrium in the earth's crust which is maintained by a yielding flow of rock beneath the surface under gravitational stress.
isostatic pressure	Subject to equal pressure from either side.
isostatic rebound	The adjustment of the earth's rocks to maintain equilibrium among units of varying mass and density; excess mass above is balanced by a deficit of density below.
isotope	Elements having the same atomic number (number of protons) but different atomic weights (number of neutrons).
isotopic signature	The consistent ratio of two isotopes found when the source of a chemical compound is the same.
isotropic	Identical physical properties in all directions.
J values	An estimated value of an analyte below the detection limit.
Jurassic	The middle of the three periods that form the Mesozoic Era.
knickpoint	Points of abrupt change in the longitudinal profile of stream valleys.
lab blank	A sample with known compounds sent to the laboratory for analysis to verify the calibration of laboratory instruments.
lacustrine	A lake environment.
Laramide	A time of deformation, typically recorded in the eastern Rocky Mountains, that occurred in the late Cretaceous.
leaching	The process wherein contaminants migrate from a source on the land surface or shallow subsurface through the vadose zone.

leakage	Significant conduction of water out of a confined aquifer through the confining beds.
lenticular	Shaped in three dimensions like a lens.
limonite	A mineral, hydrous iron oxide.
linear conductivity anomaly	A trend in geophysical conductivity characteristics that is recognizably linear.
lithology	The description of rock based on color, structure, mineral content, and grain size.
local-area storm	A storm with unusually heavy rains occurring in 3 hours or less that are reasonably isolated from surrounding rains. This storm may or may not include thunder. For the Southwest, a local storm has a timespan of 1 to 2 hours, occasionally as long as 3 hours, and generally a precipitation of up to 1.5 inches.
loess	A homogeneous, non-stratified deposit of silt.
lysimeter	A tube or pipe placed vertically in the ground to collect moisture from the nonsaturated soil (see subsection 2.7).
magnetic vertical gradient	The difference between the magnetic field simultaneously measured over the same point at two different heights.
magnetite	A mineral, $FeFe_2O_4$.
magnetometer	An instrument used for measuring the vertical magnetic intensity.
magnitude	A quantity characteristic of the total energy released by an earthquake.
marine deposits	Sedimentary rocks formed by deposition in the oceans.
mass spectrometry	A technique used to identify the chemical nature of a substance.
material of concern	See contaminant of concern.
matrix	Portion of a rock with smaller grain size.
matrix spike	Spiking the material tested for analytes with a known concentration of a known analyte in order to check laboratory equipment.
mesa	A flat-topped mountain or other elevation bounded on at least one side by a steep cliff.
Mesozoic	One of the four large divisions of geologic time.
metasediment	Partly metamorphosed sedimentary rock.

metavolcanic	Partly metamorphosed volcanic rock.
method (laboratory) blank	An analytical control, consisting of all reagents, internal standards, and surrogate standards, that is carried through the entire analytical procedure. The method blank is used to define the level of laboratory background contamination.
mg/L	Milligrams per liter; equivalent to parts per million.
micaceous	Containing an abundance of mica minerals.
microbial reduction	The reduction of an element through reaction with a microorganism.
migration pathway	A route of exposure from a source to a receptor; usually considered in terms of media such as air, groundwater, or soils.
mg/kg	Milligrams per kilogram; equivalent to parts per million.
moisture content	The quantity of water in a mass of soil, expressed in percentage by weight of water in the mass.
monitoring well	A well used only to collect groundwater samples.
monocline	A one-limbed flexure that often has flat-lying strata on either side.
moraine	A deposit of glacially derived sediments.
mudstone	A blocky, fine-grained sedimentary rock in which the proportions of clay and silt are approximately equal.
nodules	Small, usually rounded body somewhat harder than the surrounding sediment.
nomograph	A chart that represents an equation containing three variables by means of three scales. A straight line will cut the three scales at values, for the three variables, that satisfy the equation.
nonferrous metal	Any metal that does not contain iron in its chemical makeup (e.g., copper, brass, aluminum).
octanol-water partition coefficient (K_{ow})	Provides a measure of the extent of chemical partitioning between water and octanol at equilibrium. The greater the K_{ow} the more likely a chemical is to partition to octanol than to remain in water. Octanol is used as a surrogate for lipids or fat and K_{ow} can be used to predict bioconcentration in aquatic organisms.
organic carbon partition coefficient (Koc)	The measure of a chemical's ability to adsorb to organic carbon, specifically organic carbon in soils.

organic vapor analyzer	A device that detects organic gas vapors in the air at a test location.
orogeny	Period of mountain building due to tectonic forces.
outcrop	The exposure of bedrock projecting through the overlying cover of detritus and soil.
outwash	Sediments deposited by glacier meltwater streams.
oxidize	The process of combining with oxygen to change an element from lower to higher positive valence.
packed column	A column used in gas chromatography to separate different chemical compounds for quantitative measurements.
paleocurrent	The flow direction of water or air during the deposition of sediments.
paleotopographic	A historical topographic surface usually buried by younger sediments.
Paleozoic	One of the four large divisions of geologic time.
parting	A small joint in rock.
pathway analysis	An assessment of the ability of a migration pathway to transport contaminants.
peak discharge	Maximum flow rate of a river for a given storm; expressed as volume per unit of time.
peak flow	See peak discharge.
pediment	Erosional surface carved into bedrock.
peneplain	A land surface eroded to a nearly flat plain.
Pennsylvanian	The sixth of seven periods in the Paleozoic Era.
perennial	Characterized by flow of surface water year-round.
perennial stream	A stream flowing throughout the year and from source to mouth.
permeability	Capacity of a medium for transmitting a fluid.
pesticide	A chemical agent that destroys pests; also known as a biocide.
pH	Used to express the intensity of the acid or alkaline condition of a solution including the hydrogen-ion concentration, or more precisely, the hydrogen-ion activity.
photoionization	A technique used to detect organic gas vapors in the air at test locations.

phthalate ester	Any of a group of plastics plasticizers; generally characterized by moderate cost, good stability, and good general properties. Di-n-butyl phthalate is commonly used as a buffer in standard laboratory solutions.
physiochemical	The inherent physical and chemical properties of a compound.
physiographic province	Regions of similar structure and climate with a unified geomorphic history.
piezometer	A tube or pipe placed vertically in the ground to measure the groundwater potential.
piezometric surface	The level of the surface or elevation of groundwater measured in a piezometer.
piezometric surface contour map	A map showing the elevation of the water table or potentiometric surface by contours on a base map.
pilot-scale treatability study	A study intended to simulate the physical and chemical characteristics of a full-scale treatment process. It is used to bridge the gap between bench tests and a full-scale operation (EPA 1988a).
Pleistocene	The earlier of the two epochs that form the Quaternary period.
plume	An elongated, mobile, feather-shaped body of water or smoke.
plume mixing	In groundwater, the physical and chemical interaction of two distinct plumes; usually considered to represent two sources that released contaminants at a separate time and location.
polychlorinated biphenyls	A family of chlorinated hydrocarbons.
porosity	The ratio of pore volume versus the total volume of a given soil or rock.
potential critical exposure routes	Actual mechanism of exposure by inhalation, ingestion, or direct (dermal) contact.
potentiometric surface	Surface to which water would rise by hydrostatic pressure.
Precambrian	All rocks formed before the Paleozoic Era.
pressure transducer	An instrument component that detects a fluid pressure and produces an electrical signal related to the pressure.
probable maximum flood	The theoretically worst-case flood event that could occur in a drainage area. The probable maximum flood is normally several times larger than the largest flood of record and is derived from the probable maximum precipitation amount.
probable maximum precipitation	The theoretically greatest depth of precipitation for a given duration that is physically possible over a particular drainage area at a certain time of year.

produced waters	Water recovered with the petroleum or gas from an oil field well.
product	In the petroleum industry, the petroleum or gas that has been recovered from a well or has been through the refining process.
pyrite	A mineral, FeS_2.
pyrrhotite	A mineral, FeS.
quadrature component of the EM 31	Component that measures terrain conductivity.
quartz	A mineral, SiO_2 (silicon dioxide).
Quaternary	The younger of the two periods in the Cenozoic Era.
radiating distributary channel	A channel stemming from a single trunk stream in which flowing water is dissipated.
RCRA action levels	RCRA action levels are concentration levels for water, soil, and air presented in the proposed Corrective Action Rule (55 FR 30798) that are intended to be used as thresholds indicating a need to examine risks posed by media that exceed them. Proposed RCRA action levels are not intended to be used as cleanup goals.
receptor	A receptor is a biotic, human, or environmental endpoint of contaminant migration through a particular pathway.
recharge	The process by which water is added to the saturated zone of an aquifer.
recovery well	A well used to extract contaminated groundwater.
redox potential	The ability of a natural environment to activate any oxidation or reduction process. Specifically, it is the measure of the ability of an environment to supply electrons to an oxidizing agent or to take up electrons from a reducing agent.
reduction	The process of removing oxygen from a compound or decreasing the positive valence of an atom.
reference dose	The EPA's preferred toxicity value for evaluating noncarcinogenic effects resulting from exposures at Superfund sites. See specific entries for chronic reference dose and subchronic reference dose. The acronym RfD, when used without other modifiers, either refers generically to all types of reference doses or specifically to chronic reference doses; it never refers specifically to subchronic or developmental reference doses.
relic arroyo	A portion of an arroyo that has remained somewhat intact after the major portion has been removed by erosion.

remnant channel	A channel left standing above the general land surface after erosion has reduced the surrounding area.
replicate spike	Spiking the material tested for analytes with a known concentration of a known analyte in order to check laboratory equipment.
residence time	The average length of time a compound or ion spends in a system.
residuum	Soil formed in place by the decomposition of bedrock.
retardation	In solute transport, the reduction of contaminant concentrations in groundwater due to chemical reaction or adsorption.
Richter scale	An assigned logarithmic scale of numerical values of earthquake magnitude.
rinsate blank	Rinsing fluid tested for analytes to ensure that the rinsing process of field equipment was adequate.
Rio Grande rift	Extensional tectonic feature that stretches from Colorado to Mexico.
rip-up clasts	Gravel-sized clasts of fine-grained sediments removed from their original location of deposition and redeposited in coarse-grained sediments.
risk characterization	Combination of exposure and toxicity assessments to determine whether current or future levels at or near the site are of potential concern.
rootcasts	Relict root structures preserved in sediments.
San Jose Formation	Unconformable Eocene sedimentary formation above the Naciamento.
sand	Detrital material of the size range 1/16 mm to 2 mm.
sandstone	Clastic sedimentary deposit of sand-sized particles.
sanitary landfill	A landfill with restrictions on the type of solid waste accepted. More detailed information about the nature of the Lee Acres Landfill is available in "The Lee Acres Sanitary Landfill Development and Operation Plan" (SJC 1980) in the section titled "Types and Quantities of Solid Waste Disposal."
saturated solution	A solution that contains enough of a dissolved solid, liquid, or gas to ensure that no more will dissolve into the solution at a given temperature and pressure.
saturated zone	A subsurface zone in which all rock pore space is filled with water.

scarp	A cliff or steep slope of some extent along the margin of a mesa or terrace.
screen	A section of well casing with regularly spaced holes or slits that allows the flow of water, but not large granular material, into a well.
secondary standard	A concentration limit for an element based on aesthetics rather than toxicity criteria.
sediment load	The solid material transported by a stream.
sedimentary facies	A stratigraphic body as distinguished from other bodies of different appearance or composition.
sedimentary structure	Any structure in a sedimentary rock such as a crossbed.
seismic	Pertaining to earthquake or earth vibrations.
seismic lines	A line across a map of a given area where a seismic survey was conducted.
seismic refraction survey	A test used to determine subsurface layers of soil and bedrock.
semivolatile organic compound	An organic compound, determined by specific EPA methods in a laboratory, that generally has a boiling temperature greater than 140° C at normal atmospheric pressure (@ 1 atm).
shale	A laminated sedimentary rock consisting of mostly clay-sized particles.
shot point	The position (or place) where energy is generated for the collection of seismic data.
silica	A compound, SiO_2.
silt	A clastic sediment, most of the particles of which are between 1/16 mm and 1/256 mm.
siltstone	A very fine-grained rock composed primarily of silt-sized particles.
sinuous	Of a serpentine or wavy form; winding.
slickensides	Shiny and scratched surface that results from friction along a plane.
slope factor	A plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen.
sludge	Any semisolid waste from a chemical process.

slug test	An aquifer test in which aquifer parameters are evaluated based on the length of time required for the well to return to its original level after a slug of water is injected or withdrawn.
soft-sediment deformation	Changes in original layering of sediments prior to becoming lithified.
soil gas isoconcentration map	A map that shows gas in soil concentration levels.
soil/sediment distribution coefficient (K_d)	Provides a soil or sediment-specific measure of the extent of chemical partitioning between soil or sediment and water, unadjusted for dependence upon organic carbon. This factor can be adjusted for the fraction of organic carbon present in soil or sediment. The higher the K_d, the more likely a chemical is to bind to soil or sediment than to remain in water.
soil/water interface	Location at the water table from which soil samples are collected.
solid waste	Solid material hauled to the landfill as waste.
solubility	An upper limit on a chemical's dissolved concentration in water at a specified temperature. Aqueous concentrations in excess of solubility may indicate sorption onto sediments, the presence of solubilizing chemicals such as solvents, or the presence of a non-aqueous phase liquid.
solubility constant	A simplified equilibrium constant defined for and useful for equilibria between solids and their respective ions in solution.
soluble	A substance that can form a solution with another substance.
solute	The substance dissolved in a solvent.
solute transport simulation	In groundwater modeling, solute transport simulations predict future solute concentrations given known chemical and hydraulic conditions of an aquifer system.
specific conductance	The measure of the capacity of solution to carry an electrical current, which in turn is related to the concentration of ionized substances in the solution.
specific gravity	A material characteristic that is the ratio of a given volume of a given material versus the same volume of water.
spike	An aliquot of a matrix (water or soil) fortified (spiked) with known quantities of specific compounds and subjected to the entire analytical procedure to indicate the appropriateness of the method for the matrix by measuring recovery.
stable isotope	An isotope that does not spontaneously undergo radioactive decay.
stacked	Repeated seismic shots added together to increase signal amplitude and decrease the amplitude of random noise.

static water level	The level of water measured in a well when the water level has stabilized after activity at or around the well has ceased.
steady state	A body or system is in steady state when the conditions at each point do not change with time.
storativity	A quantitative term that describes the net available volume of water in an aquifer.
stratigraphic control	The apparent control of deposition or flow by stratigraphic features.
stratigraphic markers	A distinct layer of rock, such as a coal seam, used to correlate locations in a rock formation.
stratigraphy	Study of the formation, composition, sequence, and correlation of stratified rocks.
subchronic	Short-term noncarcinogenic effects.
subchronic daily intake	Exposure expressed as mass of a substance contacted per unit body weight per unit time, averaged over a portion of a lifetime (as a Superfund program guideline, two weeks to seven years).
subchronic reference dose	An estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a portion of a lifetime (as a Superfund program guideline, two weeks to seven years).
subcrop	Rock unit found in subsurface boreholes.
subduction	The process by which one of the earth's crustal blocks descends beneath another.
subtraction cone	A device used in cone penetrometer testing (see subsection 2.3).
sulfate	A common ion in groundwater, H_2SO_4.
sulfate analysis	Analysis of sulfate ion isotopic ratios, concentration, and distribution.
supersaturated	A solution containing more of the solute than is normally present at equilibrium.
surface runoff	Water traveling over the ground surface to a channel.
surface water	All bodies of water on the earth's surface.
surrogate spike	An analyte of a known concentration is added to the sample to be tested as a check of laboratory equipment.

SW-846 methods	"Test Methods for Evaluating Solid Waste, Physical/Chemical Methods" (EPA November 1986). These test methods provide the test procedures and guidance recommended for use in conducting the evaluations and measurements needed to comply with RCRA.
synorogenic	Occurring at the same time as an orogeny.
tank bottoms	The liquid material in a tank below the level of the outlet pipe; often a mixture of the stored liquid with rust, heavy metals, and other sediment.
technical database system	Interactive software package used to store, analyze, verify, and report laboratory sample data.
tectonic pulse	Period of tectonic activity; a part of an orogeny.
tectonics	Study of large-scale deformation of the earth's crust.
terraces	Relatively flat surfaces bounded by a steeper ascending slope on one side and by a steeper descending slope on the opposite side usually formed by river systems.
terrestrial	Consisting of or pertaining to land.
Tertiary	The older of the two geologic units that form the Cenozoic Era.
Tertiary bedrock	Bedrock between 2 and 65 million years old. All bedrock in the Lee Acres Landfill area is Tertiary.
thermodynamic equilibrium	Property of a system in mechanical, chemical, and thermal equilibrium.
thermodynamics	The mathematical treatment of the relation of heat to mechanical and other forms of energy.
till	Nonsorted, nonstratified sediment carried or deposited by a glacier.
topographic contour map	A map showing in detail the position, size, and shape of the physical features of a given area. The topography (representation of relief) is shown by contours on a base map, which serves to fix the geographic locations.
topography	The general configuration of a land surface in a given area.
total dissolved solids	The total mass of ions dissolved in water.
Toxic Characteristic Leaching Procedure	A laboratory procedure that leaches contaminants from soil to the extent thought possible in natural systems.

toxicity	The numerical expression of a substance's dose-response relationship which is used in risk assessment. This include reference concentrations, reference doses, and carcinogenic slope factors.
toxicity assessment	The weighting of available evidence regarding the potential for particular contaminants to cause adverse effects in exposed individuals. Also, to provide an estimate of the relationship between the extent of exposure to a contaminant and the increases, likelihood, and/or severity of adverse effects.
toxicity value	A numerical expression of a substance's dose-response relationship that is used in risk assessments. The most common toxicity values used in Superfund program risk assessments are reference doses (for noncarcinogenic effects) and slope factors (for carcinogen effects).
transmissivity	An aquifer characteristic that is the product of the thickness of the aquifer and the hydraulic conductivity, which represents the ability of the aquifer to transmit water.
transpiration	The passage of a gas or liquid (in the form of vapor) through the skin, a membrane, or other tissue.
transport pathway	The path along which contaminants can travel, such as through soil or with water.
Triassic	The earliest of the three periods of the Mesozoic Era.
tributary	Any stream or channel that contributes its flow to another stream or channel.
trilinear diagram	A triangular diagram with three axes often used to plot groundwater cations and anions.
trip blank	An organic or aqueous solution as free of analyte as possible, transported to the sampling site, and returned to the laboratory without being opened. This serves as a check on sample contamination originating from sample transport, shipping, and the site conditions.
trough-crossbedded	A structure formed by the deposition of clasts in a dune or ripple.
unconfined (alluvial) aquifer	A (water table alluvial) aquifer without nonpermeable strata above it; its piezometer pressure is atmospheric.
unconformity	A break in sedimentary deposits.
unconsolidated sediment	A sediment loosely arranged or whose particles are not cemented together.
undercutting	The erosion of material at the base of a steep slope, cliff, or other exposed rock.

underscouring	The erosion of material in the stream channel.
upgradient	In groundwater, the direction against flow from a lower to higher piezometer elevation.
uplift	Upward deformation of one tectonic region in comparison with adjacent areas.
vadose zone	The vadose zone consists of the zone above the saturated zone between the capillary fringe and ground surface. It may be free of moisture or partially saturated.
vapor pressure	The pressure exerted by a chemical vapor in equilibrium with its solid or liquid form at any given temperature. Vapor pressure is used to calculate the rate of volatilization of a pure substance from a surface or in estimating a Henry's Law constant for chemicals with low water solubility. The higher the vapor pressure, the more likely a chemical is to exist in a gaseous state.
velocity	The time rate of change of position of a body.
vertical coils	The position of the transmitting and receiving coils (hoops) of the electromagnetic instrument when they are perpendicular to the ground (horizontal dipole).
VOA analysis	Analysis of the data from laboratory methods used to identify volatile organic compounds.
volatile organic compound	An organic compound, determined by specific EPA methods in a laboratory, that generally has a boiling temperature less than 140° C at normal atmospheric pressure (@ 1 atm).
volcanic	Igneous rocks that flow or explode onto the earth's surface.
waste cell	An excavated trench or pit in which solid waste is disposed. When the excavated trench or pit is full, it is backfilled.
water table	The planar surface between the saturated zone and the vadose zone; the term usually applies only to an unconfined aquifer.
watershed	The drainage area of a stream.
weight-of-evidence classification	An EPA classification system for characterizing the extent to which the available data indicate that an agent is a human carcinogen. Recently, the EPA developed weight-of-evidence classification systems for some other kinds of toxic effects, such as developmental effects.
well completion materials	The material used to fill the annulus between the casing and the wellbore; usually a clay or cement grout.
wellbore	A hole drilled for water sampling as well as sediment sampling.

wellhead protection	A cover over the top of a well casing used to keep out possible contaminants.
Wisconsin	The last of the four classical glacial stages in North America.
µg/L	Micrograms per liter; equivalent to parts per billion.
µg/kg	Micrograms per kilogram; equivalent to parts per billion.