First Five-Year Review Report for

Fresno Sanitary Landfill Superfund Site Fresno County, California

Submitted to

U.S. Environmental Protection Agency Region 9

September 2005

CH2MHILL

FIRST FIVE-YEAR REVIEW REPORT

FOR
FRESNO SANITARY LANDFILL SUPERFUND SITE
FRESNO COUNTY, CALIFORNIA

September 2005

Prepared for
Contract No. 68-W-98-225/WA NO. 052-TBTA-09DM
U.S. Environmental Protection Agency
Region 9
75 Hawthorne Street
San Francisco, California 94105

Approved by: Date:

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USEPA, Region 9

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Contents

Tables

Figures

Appendices

Acronyms and Abbreviations

µg/L	micrograms per liter
ARARs	applicable or relevant and appropriate requirements
bgs	below ground surface
CCR	California Code of Regulations
CDM	Camp Dresser and McKee
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
City	City of Fresno, California
COC	constituent of concern
DCA	dichloroethane
DCB	dichlorobenzene
DCE	dichloroethene
DOHS	California Department of Health Services
DTSC	Department of Toxic Substances Control
ESD	Explanation of Significant Difference
FSL	Fresno Sanitary Landfill (Site)
gpm	gallons per minute
HDPE	high-density polyethylene
LFG	landfill gas
MCL	maximum contaminant level
mg/L	milligrams per liter
O&M	operation and maintenance
OU	operable unit
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
POTW	publicly-owned treatment works
ppbv	parts per billion by volume
ppmv	parts per million by volume

PTA	packed tower aerator
ROD	Record of Decision
RPM	Remedial Project Manager
RWQCB	Regional Water Quality Control Board
SCADA	Supervisory Control and Data Acquisition
SJVAPD	San Joaquin Valley Air Pollution Control District
SOW	Scope of Work
TBC	To Be Considered
TCA	trichloroethane
TCE	trichloroethene
TDS	total dissolved solids
THM	trihalomethane
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

Five-Year Review Summary Form

SITE IDENTIFICATION

Site name : Fresno Municipal Sanitary Landfill Superfund Site

EPA ID: 09H7 **CERCLIS ID :** CAD980636914

Region: 9 **State:** CA **City/County:** Fresno/Fresno

SITE STATUS

NPL status: ☒ Final ☐ Deleted ☐ Other (specify) _____

Remediation status (choose all that apply): ☒ Operating ☐ Complete

Multiple OUs? ☒ YES ☐ NO **Construction completion date:** January 2008

OU1: Source Control Operable Unit and OU2: Groundwater Operable Unit

Has site been put into reuse? ☒ YES ☐ NO

REVIEW STATUS

Reviewing agency: ☒ EPA ☐ State ☐ Tribe ☐ Other Federal Agency _____

Author name: Lisa Hanusiak

Author title: Remedial Project Manager **Author affiliation:** EPA Region 9

Review period: February – September 2005

Date(s) of site inspection: March 9th – 10th 2005

Type of review: ☒ Statutory

☐ Policy ☐ Post-SARA ☐ Pre-SARA ☐ NPL-Removal only

☐ Non-NPL Remedial Action Site ☐ NPL State/Tribe-lead

☐ Regional Discretion)

Review number: ☒ 1 (first) ☐ 2 (second) ☐ 3 (third) ☐ Other (specify)

Triggering action:

☒ Actual RA Onsite Construction at OU-1

☐ Actual RA at OU #1

☐ Previous Five-Year Review Report 1998

☐ Construction Completion

☐ Other (specify) _____

Triggering action date: June 2000

Due date (five years after triggering action date): June 2005

Issues and Recommendations

Issues Related to OU-1 and OU-2

Issue

An institutional control needs to be in place to prohibit well installation and construction in the area around the Fresno Sanitary Landfill that could cause contamination of that well or adversely affect the containment of the plume by the extraction wells. An institutional control also needs to be put in place to restrict certain uses of the site itself and protect the landfill cap.

Recommendation

USEPA recommends that an Explanation of Significant Difference (ESD) be prepared for the site. The ESD will include the following recommendations with regard to institutional controls for the site. The OU-1 Record of Decision (ROD) relied on the State Water Resources Control Board and Integrated Waste Management Board regulations for closure and post-closure maintenance requirements to ensure integrity of the landfill cap and protect public health and safety by preventing public contact with the waste. However, the State Water Resources Control Board and the Integrated Waste Management Board regulations cited in the Landfill ROD (Title 22, Chapter 15 and Title 14, Division 7, respectively) have been superseded and replaced by Title 27. Thus, the ESD will cite to the Title 27 regulations that pertain to closure and post-closure maintenance requirements. The ESD will also recommend that the City of Fresno execute and record a restrictive covenant for the property that would bind current and future owners and restrict certain uses of the site itself, including residential use, and prohibit use of the groundwater underneath the site.

Issues Related to the Landfill (OU-1)

Issue

During the first compliance testing, the flare did not achieve 98 percent destruction efficiency. The second compliance testing occurred in April 2005, but the report will not be available for this Five-Year Review.

Recommendation

The second compliance testing report will not be available for this Five-Year Review. Therefore, the second compliance testing Report will include how to address any problems identified with the performance of the flare. Additionally, resolutions will be identified for all outstanding recommendations included in the First Compliance Testing Report Fresno Sanitary Landfill Jensen Avenue Fresno California (July 2004).

This includes evaluating data collected as part of the second compliance testing to determine the mass of VOCs in the exhaust air from the groundwater treatment packed tower aerator (PTA) to account for all VOC sources. Because of the correlation between the VOC concentrations in groundwater and the potential VOC emissions in the exhaust air from the PTA, future scheduled compliance tests should include review and discussion of the total VOC influent groundwater concentrations. This review should include verification that no significant increases in total VOCs have occurred over time. Only if significant changes are found, would retesting the PTA exhaust air emissions be necessary.

Issue

The absence of dioxin testing of the flare has been an issue raised in the past.

Recommendation

Perform modeling to evaluate what dioxin emissions level from the flare stack would result in a 10^{-6} excess cancer risk to the maximally-exposed individual (probably a worker at the adjacent sports complex or a neighbor). If the level of emissions necessary for a 10^{-6} increase in cancer risk is much higher than expected from the landfill flare, then dioxin testing may not be called for at this time.

Consider reviewing data (when available) from a similar landfill site where dioxin testing has been performed recently. These data may assist in drawing further conclusions about the potential need for testing at Fresno Sanitary Landfill.

Perform sampling if analysis above indicates flare stack emissions level may exceed health protective standards (10^{-6}

excess cancer risk or 200 pg/m^3).

Additional recommendation: In evaluating the performance of the flare, consideration should be given to modifying the stack so that dioxin testing could be easily accomplished in the future, particularly if system re-engineering already will be necessary to bring the flare into compliance.

Issue

There has not been an ecological risk assessment conducted at the site. A review of ecological reports for the site found that a screening-level ecological risk assessment should have been conducted. (USEPA 2003a) The squirrel bait currently dispensed around the landfill and the heat of the flare that kills birds and bees could both be a threat to endangered species in the area.

Recommendation

Conduct a screening-level ecological risk assessment or an acceptable alternative assessment that evaluates the protectiveness of the remedy (i.e., ensure there are no exposure pathways connecting landfill contaminants and ecological receptors) and identifies any current adverse impacts of the remedy on the environment.

Issue

Debris and water were found in some of the gas monitoring wells (MMW4 at depths of 5 feet, 25 feet, and 45 feet and MMW3 at 5 feet) Also, one of the wells (MMW5 at 25 feet deep) detected methane at 13.4 percent by volume.

Recommendation

Maintenance should be conducted on the gas monitoring wells. MMW5 is located close to the waste and not near the property line. If the methane levels do not decrease, the City of Fresno may need to install an additional well between MMW5 and the property line along Jensen Avenue.

Issues Related to the Groundwater (OU-2)

Issue

The vertical migration of constituents appears to be increasing the concentration of tetrachloroethene in the C-Aquifer.

Recommendation

Continue to monitor the concentration changes in well clusters.

Use the groundwater model to predict how vertical migration of constituents of concern can be reduced, and consider the results of this analysis in evaluating the effectiveness of the Phase 1 remedial action for groundwater cleanup as appropriate.

Issue

The extraction wells have been operating at lower flow rates than designed. This leads to issues such as incomplete containment of the plume and non-functioning flow meters.

Recommendation

Replace flow meters.

Review flow rate data after the extraction well rehabilitation activities. Semi-annual or annual well rehabilitation activities may be necessary if the data are found to result in improved flow rates.

Review groundwater elevation data since the decommissioning of the agricultural wells.

The Phase 1 evaluation should assess the implications of the low extraction rates.

Protectiveness Statement

A protectiveness determination of the remedies for both OU-1 and OU-2 cannot be made at this time until further information is obtained and actions are completed. The information and actions required for OU-1 include demonstration that the flare performs adequately to prevent/eliminate emission levels that are unsafe, resolution of the potential dioxin emissions issue (i.e., perform modeling or sampling and/or review data from similar landfill site), and completion of a screening-level ecological risk assessment. It is expected that these actions will take no more than 6 months to complete.

The information and actions required for OU-2 include demonstration of adequate capture and migration control of the contamination plume through capture-zone analysis. The Phase I evaluation will assess the overall efficacy and protectiveness of the remedy. This evaluation will provide recommendations for any further modifications and is anticipated to be complete in early 2006.

The action required for both operable units relates to institutional controls. For the remedy to be protective in the long-term, institutional controls such as execution and recordation of a restrictive covenant for the property that would bind current and future owners and restrict certain uses of the site itself, including residential use and prohibit use of the groundwater underneath the site, need to be implemented. It is anticipated that this action would be completed by 2007.

As the required information is obtained and actions are completed at each of the operable units, the protectiveness determination will be made.

Executive Summary

A Five-Year Review of the Fresno Sanitary Landfill (FSL) Superfund Site (the site) in Fresno County, California was completed in September 2005. The Five-Year Review was required by statute and performed because hazardous substances, pollutants, or constituents remain at the site at concentrations above levels that would allow for unrestricted use and unlimited exposure. The triggering action for this review was mobilization for onsite construction, which occurred in June 2000.

From 1935 to 1987, the 145-acre site was used as a landfill for a variety of municipal wastes (USEPA 1993a). The landfill footprint is approximately 4,200 feet long and 1,250 feet wide, with an average height of 45 feet. It is in a primarily agricultural area; however, there are several residences nearby. In June of 1984, the California Department of Health, now the Department of Toxic Substances Control, conducted a preliminary inspection in response to complaints from nearby residents. Offsite migration of methane and volatile organic compounds (VOCs) was found in the groundwater. Numerous investigations were conducted and, in October of 1989, the FSL was listed on the National Priorities List.

Additional investigations were conducted, and a methane barrier was constructed after the site was listed on the National Priorities List. As part of the initial response in 1991, a vacuum was added to the methane barrier. An in-home landfill gas (LFG) assessment was performed to assess the potential for migration of LFG into homes. Based on this work, vapor intrusion of LFG constituents was determined not to be a problem. Therefore, the vacuum system on the LFG barrier was discontinued. In the early 1990s, the City of Fresno (City) began providing bottled drinking water and installing and maintaining wellhead treatment systems for some nearby residences. Currently, 13 residences north and south of the FSL receive bottled water. The City also purchased four homes along the southwest boundary of the site (Slater 2005). A portion of the site has been redeveloped into a regional park and sports complex including soccer and softball fields as well as picnic facilities (CDM 2003a).

In 1993, the first Record of Decision (ROD) was signed. The 1993 ROD called for an interim remedy, Operable Unit No. 1 (OU-1). This included the landfill cover, storm water management, and LFG collection and treatment, as well as migration monitoring.

The second ROD was signed on September 30, 1996 (USEPA 1996). It pertains to OU-2, which includes a groundwater monitoring system, a landfill perimeter groundwater containment system, a plume perimeter containment system, and an aquifer restoration system. The ROD specifies a phased implementation approach starting with the perimeter extraction and, ultimately, restoration of the aquifer to beneficial use. In September of 1997, a Consent Decree was signed whereby the City agreed to initiate a groundwater monitoring program, begin construction of OU-1, and design and construct OU-2.

In an effort to initiate control of VOC-impacted groundwater prior to construction and startup of the Phase 1 groundwater remediation system, the City implemented the early groundwater remedial action (Early Action). The Early Action program consisted of

installing groundwater extraction wells (planned for use as part of the Phase 1 groundwater remedial action), modular wellhead treatment systems (hydraulic venturi air strippers), and conveyance and discharge piping. Design and implementation of the Early Action was performed with oversight of the United States Environmental Protection Agency, but not required in the Consent Decree. Early Action system startup occurred in May of 1999 (CDM 2003b).

OU-1 was constructed from June 2000 to September 2001. The final cover included the installation of the foundation layer, the LFG collection system, the LFG treatment system, the high-density polyethylene geomembrane, drainage geocomposite, filter and cushion geotextile, vegetative soil layer, and the landfill access road. The final cover is in good condition. The LFG gathered in the gas collection system is conveyed via piping to the flare to be burned.

Startup on OU-2 occurred in September 2001. Currently, Phase 1 (landfill perimeter containment) is in progress. There are 31 monitoring wells in the A-Aquifer, 27 in the B-Aquifer, and 13 in the C-Aquifer. Five extraction wells (PW-1 through PW-5) operate along the western downgradient edge of the landfill in the A-Aquifer. The extracted groundwater is treated with a packed tower aerator. The treated water is sent to the detention basins onsite, where some of the water is used for irrigation of the park. The VOC-contaminated air is conveyed to the flare, where it is burned along with the LFG.

The groundwater treatment plant effluent discharge has been meeting the effluent discharge limits as set forth in the Clean Water Act, Title 33, Code of Federal Regulations, Parts 301 and 302 for the time that it has been operational. There have been occasions during this time when the treatment system was not operating due mainly to power failure and/or routine maintenance. The extraction wells that are part of the treatment system are currently operating at an 80 to 90 percent capacity. The downtime for the extraction wells is primarily due to a lowered water table and the subsequent inability to maintain appropriate flows. The lowered water table is due to regional-scale municipal and agricultural well pumping.

Analysis of groundwater monitoring has been focused on the main constituents of concern: trichloroethene, tetrachloroethene, and vinyl chloride. Plume maps and concentration trends are included in semi-annual monitoring reports. While concentrations in general are stable, the data seem to indicate an upward trend in cis-1,2-dichloroethene concentrations in a number of the monitoring wells. There is possible vertical migration carrying tetrachloroethene downward to the C-Aquifer. These issues are currently under investigation by the City and will be addressed in the Phase 1 evaluation report to be completed in early 2006.

A protectiveness determination of the remedies for both OU-1 and OU-2 cannot be made at this time until further information is obtained and actions are completed. The information and actions required for OU-1 include demonstration of adequate flare performance, resolution of the potential dioxin emissions issue (i.e., perform modeling or sampling and/or review data from similar landfill site), and completion of a screening-level ecological risk assessment. It is expected that these actions will take no more than 6 months to complete.

The information and action required for OU-2 includes demonstration of adequate capture and migration control of the contamination plume through capture-zone analysis. The Phase 1 evaluation will assess the overall efficacy and protectiveness of the remedy. This evaluation will provide recommendations for any further modifications and is anticipated to be completed in early 2006.

The action required for both operable units relates to institutional controls and would include execution and recordation of a restrictive covenant for the property that would bind current and future owners and restrict certain uses of the site itself, including residential use, and prohibit use of the groundwater underneath the site. It is anticipated that this action would be completed by 2007.

As the required information is obtained and actions are completed at each of the operable units, the protectiveness determination will be made.

SECTION 1.0

Introduction

The United States Environmental Protection Agency (USEPA) conducted a Five-Year Review of the remedial actions implemented at the Fresno Sanitary Landfill (FSL) Superfund Site (the site) in Fresno County, California (Figure 1-1). This review was conducted from February to June 2005. To assist USEPA, CH2M HILL has prepared this report documenting the results of the Five-Year Review. This report has been prepared in accordance with USEPA's guidance document, *Comprehensive Five-Year Review Guidance* (USEPA 2001).

The purpose of the Five-Year Review process is to evaluate whether the remedy at the site is protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in Five-Year Review Reports. In addition, Five-Year Review Reports identify any deficiencies found during the review and provide recommendations for addressing these deficiencies.

This review is required by federal statue. USEPA must implement Five-Year Reviews consistent with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). CERCLA Section 121(c), as amended, states:

> If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the Site, the President shall review such remedial action no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented.

Consequently, this Five-Year Review Report has been completed because hazardous substances, pollutants, or constituents remain at the site above levels that allow for unrestricted use and unlimited exposure.

This is the first Five-Year Review Report for the FSL. The triggering action for this review was the mobilization for onsite construction in June of 2000 (USEPA 2004). This report evaluates the FSL remedial objectives, as stated in the two Records of Decision (RODs).

The FSL Superfund Site consists of approximately 145 acres and is divided into two operable units (OUs). The source area, or landfill itself, defines OU-1. Onsite and offsite contaminated groundwater comprise OU-2.

This report covers both OU-1 and OU-2. It is organized into sections that describe the history and setting of the site, remedial action decisions and implementation, and an evaluation of remedial actions. These sections are:

- Section 2.0 - Chronology of site events.
- Section 3.0 - Land use, site setting, the history of contamination, and initial response.

- Section 4.0 - The remedial action implemented at the FSL, current status of the remedy, and treatment system operations and maintenance (O&M) activities and cost.
- Section 5.0 - Activities performed during the Five-Year Review process.
- Section 6.0 - Technical assessment of the remedial action implemented at the site.
- Section 7.0 - Issues at the site are identified and recommendations are provided.
- Section 8.0 - Protectiveness statement for the FSL.
- Section 9.0 – Next Five-Year Review
- Section 10.0 - List of works cited during the preparation of this document.

FIGURE 1-1
SITE LOCATION MAP
FRESNO SANITARY LANDFILL
FIRST FIVE-YEAR REVIEW REPORT
FRESNO, CA

Source: CDM, 2004.

SECTION 2.0

Site Chronology

Table 2-1 provides a chronology of events at the site.

TABLE 2-1
Chronology of Site Events
First Five-Year Review Report for Fresno Municipal Sanitary Landfill Superfund Site, Fresno County, California

Event	Date
Unlined landfill accepted waste.	1935 - 1987
City filed a CERCLA Section 103(c) notification.	May 1981
City began process of closing FSL by filing a Negative Declaration with RWQCB.	August 1981
City tested and found the presence of VOCs at concentrations greater than MCL in groundwater around the perimeter of the landfill. DOHS (DTSC) conducted preliminary inspection in response to complaints from nearby residents. Found offsite migration of methane and reviewed the documentation of VOCs in groundwater.	1983/1984
Environmental Impact Report for landfill closure, closure, and post-closure maintenance plan and a grading and drainage plan report prepared.	1989
Site listed on National Priorities List.	October 1989
Unilateral Order No. 90-19 issued to the City to apply an active vacuum system to the methane barriers and to install a landfill gas extraction system.	September 19, 1990
USEPA and City signed Administrative Consent Order No. 90-22 where City agreed to conduct RI/FS.	September 21,1990
Administrative Consent Order No. 90-23 issued by USEPA to modify 90-19 to still develop a vacuum system for the methane barriers and to implement a monitoring program to ensure that residents near the landfill were not exposed to vinyl chloride in their homes.	February 1991
Feasibility study conducted for source control OU.	January 1993
ROD for OU-1 signed. USEPA selected cleanup for OU-1 (capping, constructing gas collection system, building stormwater management system and, if necessary, a leachate collection system.	September 1993
Administrative Consent Order (90-22) between City and USEPA amended (94-07) to include design of landfill cap and other components of system.	December 1993
Remedial investigation for OU-2 completed.	May 1994
Risk assessment completed.	September 1994
Feasibility study completed, as required by 1990 Consent Order; it provided alternatives for OU-2.	July 1996
ROD for OU-2 signed. USEPA selected remedy for groundwater: three-phased containment and remediation.	September 1996

TABLE 2-1
Chronology of Site Events
First Five-Year Review Report for Fresno Municipal Sanitary Landfill Superfund Site, Fresno County, California

Event	Date
Consent Decree signed. It included agreements to initiate groundwater monitoring program and early groundwater remedial action, including constructing OU-1, developing remedial design, and constructing and conducting cleanup for OU-2.	September 1997
Remedial design for OU-2 approved.	November 1998
Operation of Early Action system.	May 1999 – September 2001
Construction of the OU-2 groundwater treatment facility began.	July 1999.
Final elements of Phase 1 groundwater monitoring network in place.	
Construction of landfill cap, gas control wells, and water treatment system began.	June 2000
Final Cover (OU-1) remedial action completed.	September 2001
OU-2 Phase 1 treatment system startup.	September 2001
Regional Park and Sports Complex constructed.	2001
Final Inspection of OU-1 by USEPA and DTSC.	December 2002
Remedial Action Report submitted. OU-1 complete closure occurred in May 2003.	June 2003
OU -2 Phase 1 Groundwater Remedial Action Evaluation Report completed.	December 2003
First Compliance testing reported – 98 percent destruction was not achieved by the flare.	July 2004
Quarterly groundwater monitoring. Currently, Phase 1 monitoring includes measuring water levels and water quality analysis of wells in the A-, B-, and C-Aquifers and extraction wells. Water quality is also measured at residential wells.	On-going quarterly

Notes:

CDHS	California Department of Health Services.
City	City of Fresno.
DTSC	Department of Toxic Substances Control.
MCL	maximum contaminant level.
RI/FS	remedial investigation/feasibility study.
RWQCB	Regional Water Quality Control Board.
VOC	volatile organic compound.

SECTION 3.0

Site Background

The FSL is located in Fresno County, California. Figure 1-1 presents a map showing the location of the site. This section provides site background including the land and resource use, the physical setting, the history of contamination, and the initial response to cleanup the contamination.

3.1 Land and Resource Use

From 1935 to 1987, the site was used as a landfill for a variety of municipal wastes (USEPA 1993a). Since then, the landfill has been closed and is undergoing remedial actions. Recently, part of the site has been redeveloped into a Regional Park and Sports Complex. The complex includes soccer and softball fields. The landfill itself has been covered and is revegetated. Land to the west, east, and south of the landfill contains stormwater detention ponds. An administrative building lies just west of the landfill and is used by City of Fresno (City) employees who maintain the site.

The land within 1 mile of the site has been used in the past for farming, rural habitation, industrial uses, and some commercial uses (CDM 1994). Land use in the vicinity of the FSL is currently primarily agricultural, with several residences nearby (USEPA 1993a). Western Elementary School is 0.5 mile east of the site, and Fresno Wastewater Treatment Plant is 3 miles west of the site (CDM 1994). According to the City, there are no plans to change the land use either at the site or in the surrounding vicinity in the future.

Historically, groundwater was used residentially. There were eight municipal wells within 3 miles of the site at the time of 1993 ROD. Over 350,000 people received water from a blended supply that included water from those wells (USEPA 1993a).

The Fresno Colony Canal, an unlined irrigation supply, runs along the eastern side of the landfill. The canal used to extend through what is now the FSL. After the landfill expansion in 1945, the canal was replaced by an 18-inch concrete pipeline. The water supply pipeline was used to carry water from the Fresno Colony Canal to fields west of the landfill (CDM 1994). The pipeline was eventually relocated to the south end of the landfill in 1996. The pipeline under the landfill was plugged and abandoned (CDM 2001a). Water from the canal is used for local irrigation. The water from George's Lake, a detention pond west of the landfill, is also used for irrigation when the canal is low on water (Slater 2005).

In December 1991, the United States Fish and Wildlife Service compiled a list of potential site endangered and threatened species. The endangered Fresno kangaroo rat was the only listed species that lives in the area. The spotted bat was the only candidate species listed, meaning the bat is a candidate to be listed as an endangered or threatened species, but substantial biological information was not available at the time to confirm a listing (USDOI 1991).

3.2 Physical Setting

The FSL sits at 265 feet above sea level in the eastern part of the San Joaquin Valley. It is approximately 10 miles south of the San Joaquin River and 20 miles southwest of the Sierra Nevada Mountains. The natural topography of the area is low relief.

The FSL is located in a sunny region that experiences hot, dry summers and moderate winters. Temperatures range throughout the year from 37 to 98 degrees F. The wind is predominantly in a northwest direction. Annual precipitation is approximately 10.5 inches; the wet season is from November to April.

The approximately 145-acre FSL is located 4 miles southwest of the City of Fresno in Fresno County, California. It is in a primarily agricultural area; however, there are several residences to the north and one residence to the south. Three roads border FSL: Jensen Avenue to the north, West Avenue to the East, and North Avenue to the south. Agricultural fields border the site to the west, and Marks Avenue lies beyond the fields.

The landfill itself is a 4,200 feet long by 1,250 feet wide rectangle. The side slope gradients range from 2 feet horizontal to 1 foot vertical (2:1) on the west side to a more gradual 10:1 slope on the east side (CDM 1994). The landfill rises to an average height of 45 feet, and the surrounding grade is essentially flat.

3.2.1 Geology/Hydrogeology

The FSL is located in the San Joaquin Valley. The San Joaquin Valley is the southern portion of the Central Valley (the northern part is called the Sacramento Valley and the middle section is the Sacramento – San Joaquin Delta). The Central Valley is known for its flat terrain. The Central Valley is composed of alluvial plains, flood plains, and dissected uplands. The majority of the groundwater originates as runoff from the surrounding mountains: the Coast Ranges to the west and the Cascades and Sierra Nevadas to the east.

The Central Valley is in a structural trough approximately 400 miles long and from 20 to 70 miles wide and comprises more than 20,000 square miles. The trough is filled to great depths by marine and continental sediments, which are the result of millions of years of inundation by the ocean and erosion of the rocks that form the surrounding mountains.

The geology under the FSL consists of interbedded layers and lenses of clay, silt, sand, and gravels. These layers, which are considered Older Alluvium of Quaternary age (Qoa), extend to around 500 feet below ground surface (bgs). Continental and marine sedimentary rock from the Cretaceous and Tertiary periods forms the next layer. At about 4,500 feet bgs, there is a composite of granitic and metamorphic rocks of the Sierra Nevada foothills. Sparser amounts of Younger Alluvium (Qya), flood-basin deposits, and sand dunes also exist on the surface of the valley floor. Quaternary sand dunes (Qsd) are abundant south of Fresno (CDM 1994).

The A-Aquifer is found at approximately 50 to 95 feet bgs. The A-Aquifer is mostly fine- to medium-grained, poorly-graded sand with interbedded layers of both coarse-grained sands and very fine-grained stiff clayey silts. The ponds associated with the Fresno Regional Wastewater Facilities, located northeast of the site, have created a water table high or recharged mound. Regional hydraulic conductivity has been calculated from 1 to 3 feet per

day. Local flow rates based on groundwater monitoring data are approximately 1 foot per year. Below the A-Aquifer is an aquitard composed of red-brown sandy clay, gray clayey silt and brown-gray clayey silt. According to the American Geological Institute, an aquitard is a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer. The B-Aquifer spans from approximately 110 to 150 feet bgs. The B-Aquifer is composed of thick, inter-layers of stiff clayey silt and poorly-graded, very fine to medium-grained sand that contains coarse-grained mica flakes. The aquitard below the B-Aquifer is composed of thick clayey silt layers like those in the B-Aquifer. The C-Aquifer is from approximately 200 to 240 feet bgs. The C-Aquifer is composed of inter-layered well- and poorly-graded sand and clayey silt. The sand grains include up to large gravel-sized volcanic pumice (pyroclastic) material (CDM 2001b; CDM 1999c).

The regional groundwater flow direction in this area is from east to west. There are some localized influences as a result of both pumping and man-made ponds. Due to the dry weather conditions in this mostly agricultural area, the available groundwater has been pumped out for irrigation purposes. Shallow groundwater levels have dropped; however, groundwater in the area of the site remains abundant. This has caused a cone of depression within the City of Fresno, including the landfill area. To the west of the landfill, the ponds associated with the Fresno Regional Wastewater Facilities have created a water table high or recharge mound. Regional hydraulic conductivity has been calculated from 1 to 3 feet per day (CDM 1994).

3.3 History of Contamination

The FSL, owned and operated by the City of Fresno from 1935 to 1987, was the "oldest compartmentalized landfill in the Western United States" (USEPA 1993a). The state of California designated the FSL as a Class III landfill (a municipal landfill that accepts non-hazardous solid waste) (California Code of Regulations [CCR] Title 27, Division 2, Subdivision 1, Chapter 3, Subchapter 2, Article 3, Section 20260). The unlined landfill was filled with municipal trash and some liquid waste (USEPA 1993a). The landfill was initially only located north of Annadale Avenue. In 1945, it was expanded south of Annadale Avenue.

An average of 16,500 tons of solid waste was disposed of at the FSL per month. The total amount of waste has been calculated to be about 4.7 million tons or 7.9 million cubic yards. In addition to municipal solid waste, 1,600-gallon tanker trucks disposed of battery acid in to the FSL twice a week from the late 1950s to the mid-1960s (CDM 1994).

In 1984, nearby residents wrote complaint letters to the California Department of Health Services (DOHS), now the California Department of Toxic Substances Control (DTSC). In June 1984, the DOHS conducted a preliminary inspection of the site in response to those letters (USEPA 1993a).

Numerous studies, described in Section 3.4, characterized the contamination. The studies showed that the highest volatile organic compound (VOC) concentrations in groundwater were downgradient (west side) of the landfill. The VOC concentrations were higher in the shallow (less than 70 feet bgs) and intermediate wells (70 to 110 feet bgs) than in the deep wells (greater than 110 feet bgs). VOCs, including vinyl chloride, trichloroethene (TCE), tetrachloroethene (PCE), 1,1-dichloroethene (DCE), 1,1-dichloroethane (DCA),

dichloropropane, dichloropropene, trichlorofluoromethane (Freon-11), and methylene chloride, were all detected in the groundwater. Purgeable aromatic compounds, including benzene, chlorobenzene, 1,2-dichlorobenzene (DCB), and 1,4-DCB, were also detected. Nitrate was the only inorganic compound detected above maximum contaminant levels (MCLs). Previous investigations attributed the high nitrate to the nitrogen-based fertilizers used for agriculture. No polychlorinated biphenyl (PCB) compounds or pesticides were detected in the groundwater (CDM 1994).

3.4 Initial Response

The City hired consultants to conduct numerous studies to further understand the physical characteristics of the site and the extent of the contaminant plume between 1983 and the startup of remedial actions at OU-2 in 2001. In 1983, the City initiated an assessment of groundwater contamination and landfill gas (LFG) migration. These results, along with additional testing that determined that hazardous constituents were disposed of in the landfill, were reported in 1986. The next year, additional sampling led to the conclusion that contamination had moved vertically downward beneath the landfill to as deep as 100 to 150 feet bgs. This vertical contamination occurred because the A-Aquifer is relatively thick and the first aquitard is not encountered until an approximate depth of 95 feet bgs. According to Section 3.2.1, there is an aquitard beneath the A-Aquifer at a depth of about 95 feet and is about 15 feet thick since the B-Aquifer starts at about 110 feet. The studies also show that LFG extended 150 feet laterally from the landfill edge.

The City discontinued accepting waste at the landfill in 1987. In preparation for the closure, an Air Quality Solid Waste Assessment Test report was prepared in 1988. The Solid Waste Assessment Test findings were that ambient air contained benzene, methylene chloride, PCE, carbon tetrachloride, trichloroethane (TCA), and TCE. The concentrations ranged from.07 to 2.6 parts per billion volume (ppbv). TCA, TCE, and PCE were also detected in the surface air of the landfill (2 to 3 inches above the landfill) (CDM 1994). The study also found VOCs above the detection limit in interior gas wells.

Also in 1988, the City installed two methane barriers to protect residences to the north and the south. The barriers were constructed by digging 26-foot deep trenches. The trenches were backfilled with gravel and a membrane liner on the landfill side of the barrier. The trenches had two perforated horizontal collection pipes at 12 and 19 feet bgs. These perforated pipes were tied into vertical pipes to allow for passive venting of landfill gases to the surface (USEPA 1993a). The City also retained Laidlaw Gas Recovery Systems to design a landfill gas extraction and recovery system. In 1990, a soil-gas survey found elevated methane and vinyl chloride just outside the methane gas barriers. Therefore, it was believed that the methane gas was migrating below or around the methane gas barriers. The City began removal of migrating landfill gas (VOCs) by placing a vacuum on an existing gas migration barrier. It was found that the vacuum was not effective in stopping the landfill gases from migrating past the barriers because the methane barriers were not designed for a vacuum extraction system (USEPA 1996).

The understanding of the lateral and vertical extent of groundwater contamination was expanded in 1989. An environmental impact report for landfill closure, a grading and drainage plan report, and a closure and post-closure maintenance plan were completed, and

a feasibility study was conducted. In October 1989, USEPA placed the landfill on the National Priorities List.

The remedial investigation showed that the groundwater was contaminated largely by VOCs. The highest concentrations of which were trans-1,2-DCE, methylene chloride, TCE, PCE, and vinyl chloride.

In the early 1990s, the City began providing bottled drinking water and installing and maintaining wellhead treatment systems for some nearby residences. In 1992, the City was providing bottled water and wellhead treatment systems to 15 nearby residences on North Avenue, West Avenue, and Jensen Avenue. One resident elected to only receive the City's bottled water. Five residences either refused or did not request bottled water or filtration (City of Fresno 1992). The City also purchased four homes along the southwest boundary of the site (Slater 2005). The City currently provides purified water to seven residences and filtration to seven residences.

The City was proactive in conducting an Early Action for groundwater cleanup. The Early Action was under the oversight of USEPA but not required in the Consent Decree. The startup began in May of 1999. It included pumping and treating groundwater. The objective of the Early Action was to get an immediate start on controlling and reducing the offsite contaminant plume. The data that the Early Action provided were also valuable in refining the design of the Phase 1 groundwater system for OU-2 (CDM 2000). The Early Action system included the installation and operation of three extraction wells (PW-1A, PW-2A, and PW-3A). In addition, the City continued monitoring 45 existing wells and installed six additional monitoring wells. The Early Action treatment unit included two modular hydraulic venturi air strippers. The north stripper treated groundwater from PW-1A and PW-2A. The south stripper treated groundwater from PW-3A. The treated effluent was conveyed to the South Detention Basin via newly-constructed transmission piping (CDM 1999).

3.5 Basis for Taking Action

The USEPA and the City signed an Administrative Consent Order in September of 1990, where the City agreed to conduct a remedial investigation/feasibility study.

The remedial investigation focused on the contamination of PCE, TCE, and vinyl chloride because the USEPA had stated, in a verbal disclosure, that those chemicals were the site preliminary constituents of concern (COCs). Groundwater and soil gas were found to be impacted by the COCs. It was determined that the ambient air and soil were not significantly contaminated. Based on the investigation, it appears the liquid wastes that were disposed were more of a contributor to the groundwater contamination than the leachate generated from percolation of water through the landfill waste.

VOC contamination of groundwater (above MCLs) existed downgradient of the landfill. Five COCs had a maximum detection exceeding 10 times their federal MCL value: PCE, TCE, trans-1,2-DCE, vinyl chloride, and methylene chloride. Benzene, 1,1-DCA, and 1,2-DCA all exceeded their federal MCLs as well. 1,2-DCA exceeded the California MCL (CDM 1994). Nitrate was the only inorganic constituent detected above MCLs. The presence of nitrate has been attributed to the nitrogen-based fertilizers used for agricultural purposes. Irrigation well

pumping in the vicinity of the site is thought to be the cause of downward vertical migration of constituents from the A-Aquifer into the B-Aquifer. Trans-1,2-DCE, cis-1,2-DCE, and vinyl chloride are likely the anaerobic biodegradation compounds of PCE and TCE.

The remedial investigation showed the soil-gas was contaminated around 1,000 feet from the perimeter of the landfill. Methane was found around 500 feet from the perimeter. There were no consistent trends of the vertical distribution of the VOCs and methane in soil gas. PCE, TCE, vinyl chloride, TCA, Freon-12, and methane were the only VOCs that were consistently found in soil-gas (CDM 1994).

The human health risk assessment (ICF 1994) found that, at the time of the report, there were no receptors present at the site. It was assumed that in the future: (1) the perimeter of the area would be fenced off, (2) access to the site would be controlled, (3) the site would be capped, (4) nothing would be built directly on top of the landfill because of potential subsidence, and (5) a worker would be present for 8 hours per day on the site after remediation. Therefore, potential receptors were determined to be adult and child offsite residents, offsite workers, onsite workers, and onsite trespassers. The mechanisms by which these receptors could be exposed include direct contact with contaminated soil, volatilization into the ambient air, fugitive dust generation via wind erosion, leaching by compression and percolation to groundwater supplies, and volatilization into soil-gas with subsequent transport through soil.

The constituents of potential concern were based on the most recent data available at the time. The risk assessment concluded that the constituents in indoor and outdoor air may pose potential carcinogenic risks to current residents in the Fresno area. For future risks, constituents in indoor air and groundwater may pose a potential carcinogenic risk to residents in the Fresno area. It was also concluded that residential receptors may experience adverse non-carcinogenic effects under the 1994 land-use conditions and future conditions (ICF 1994). Because of the determination that these potential risks existed, USEPA determined that remedial action was necessary.

SECTION 4.0

Remedial Actions

The following section summarizes the remedial actions selected and implemented at the FSL, as well as the operations and maintenance of the remedies. The RODs for the FSL were signed in 1993 and 1996. They address OU-1 (the source control operable unit) and OU-2 (the groundwater operable unit).

4.1 Remedial Action Selection and Implementation

Because the contamination at the FSL is complex and varied, USEPA organized the work into two operable units. The first of two RODs was signed on September 30, 1993 and pertains to OU-1, including the landfill cover, stormwater, and gas monitoring. The second ROD was signed on September 30, 1996 and pertains to OU-2, which includes a groundwater monitoring system, a landfill perimeter groundwater containment system, a plume perimeter containment system, and an aquifer restoration system.

An Administrative Consent Order was signed in 1990 and amended in 1993. The amendment to the Consent Order, signed December 1993, pertains to OU-1 and includes the scope of work, as well as a list of the reports that the City must submit to USEPA. A Consent Decree was recorded in official records on August 6, 1998. This Consent Decree outlines the most up-to-date requirements for OU-1 and OU-2, including producing monthly progress reports. Based on an approval from USEPA (letter dated April 16, 2004), the project update report submittals are now required on a quarterly basis rather than a monthly basis (Nyznyk 2005). The Consent Decree is a legal document that binds the City of Fresno, its assigns, and the United States. The City must give a copy of the Consent Decree to each contractor it hires to perform the work in the Consent Decree.

4.1.1 OU-1 Selection and Implementation

4.1.1.1 Selection

The primary objective for OU-1, outlined in the 1993 ROD, is to contain the contamination within the landfill. This involves minimizing the volume of leachate formed due to stormwater infiltration, as well as collection and offsite treatment of any generated leachate. It also includes controlling releases through the surface and subsurface and collection and treatment of the LFG. Managing stormwater, controlling oxygen intrusion into the landfill, and controlling erosion and offsite transport of contaminated soils are the other required remedial activities.

To obtain these objectives, a number of components were to be implemented at the FSL. Collectively, these components make up OU-1 and include:

- A landfill cover with a series of functional layers (including a synthetic membrane) that minimize the infiltration of water into the underlying refuse, provide erosion control,

and provide a barrier to fugitive surface emissions and to ambient air entering the waste pile under vacuum conditions.

- A LFG migration monitoring system consisting of monitoring probes along the landfill perimeter.
- A LFG collection and conveyance system that includes interior gas extraction wells, perimeter gas extraction wells, a blower system, and a piping system to move the gas to the treatment system.
- A LFG treatment system that is a flare to combust LFG onsite.
- A gas condensate collection system to manage any condensate that would form during the conveyance of the gas.
- A contingency leachate collection system that includes liquid extraction pumps at the bottoms of the gas extraction wells and a network of piping to move the leachate to a location where it would then be trucked offsite for treatment. This would only be installed if the leachate liquid found in the gas wells was determined to be a threat to groundwater.
- Stormwater management, which includes perimeter drains, retention basins, and other associated structures.

4.1.1.2 Implementation

Construction of OU-1 components occurred between June 2000 and September 2001, with construction quality assurance monitoring by GeoSyntec, the City of Fresno, and BSK construction quality assurance personnel. The final cover included the installation of the foundation layer, the LFG collection system, the LFG treatment system, the high-density polyethylene (HDPE) geomembrane, drainage geocomposite, filter and cushion geotextile, vegetative soil layer, and the landfill access road.

To construct the foundation layer, the landfill surface was cleared, grubbed, and stripped, and some wastes were excavated and relocated. The soil cover was from onsite borrow (previously piled when the sports complex was formed) and from biosolids from the Fresno/Clovis wastewater treatment plant. The cover was placed, compacted, and graded.

The LFG extraction wells were installed to the bottom of the waste after the foundation layer was complete. The treatment system was constructed, and the startup of the flare and condensate pumping system was monitored. The final cover system including the 60-mil (1.5 mm)-thick, double-sided textured and single-sided textured HDPE geomembrane was also installed and tested with seam testing. The double-sided and single-sided geocomposite for the final liner system was then installed and tested. The vegetative soil layer was placed and compacted to a minimum thickness of 33 inches (840 mm) (GeoSyntec 2001). The components of OU-1 were constructed in a manner consistent with standard construction industry practice. (Kleinfelder/Geosyntec 2003a).

A few minor design modifications occurred during construction, which were documented as construction memoranda and included in the remedial action completion report prepared by GeoSyntec Consultants in September 2001. These include the following:

- The landfill top surface settled from the initial topography (1994) to the time of construction (2000). Therefore, the final elevation was lower than originally designed.
- The grading of the north access road was modified.
- The slope of the perimeter road was reduced from 4 percent to 2 percent toward the trapezoidal ditch.
- Instead of the continuous layer of granular drainage material, a PVC-lined, V-shaped conduit was filled with gravel, and discharge laterals extended from it every 100 feet.
- The perimeter road alignment had to be altered because irrigation structures obstructed the path. These were supposed to be removed before the construction but were not removed until after. The perimeter road location was not changed after the irrigation structures were removed.
- The grades of the south- and west-side discharge system would not allow gravity to carry the flow. Therefore, a subdrain piping network to carry the flow was designed and constructed.
- Additional borrow material was necessary for the construction of the cover. Therefore, the East Pond was lengthened and deepened. Because, the East Pond was now larger, the stormwater from the northeast area was rerouted to the East Pond, and a 30-inch-diameter pipeline to the South Pond was eliminated.
- A 12-inch irrigation line obstructed the path for stormwater to flow in the pipeline from the trapezoidal ditch to the perimeter outside the cover to the ponds. Therefore, the irrigation line was modified to route water over the stormwater pipeline.
- The perimeter fence was needed to accommodate the park corporation yard area north of the landfill. Therefore, modifications were made in gate access locations.
- The existing gas monitoring wells were repaired.
- A vapor injection manifold was installed; the control panel was redesigned to allow communication with the packed tower aerator (PTA); a shut-off valve on the 12-inch PTA line was installed; and the stack was extended by 5 feet to provide additional residence time.
- Sump CS-1 was outside of the waste footprint. Therefore, it was modified to be a double-walled unit. (GeoSyntec 2001).

Also, the 1993 ROD called for a leachate collection system, if necessary. A leachate collection system was not designed or constructed because of the small quantity of leachate reported in the 1994 remedial investigation report (CDM 1994). Borings drilled through the refuse at the FSL showed no signs of saturated waste. Refuse leachate was not found, and the distribution of inorganic water quality parameters in the groundwater suggested that municipal refuse leachate was not a significant source of groundwater contamination at the site. The groundwater table is at least 25 feet below the base of the landfill (approximately 50 feet bgs) (CDM 1994).

The most recent progress report does not note any issues with OU-1 (City of Fresno 2005).

4.1.1.3 Reporting Deliverables

Per the 1998 Consent Decree, the remedial action report for OU-1, construction completion report for the entire site, yearly status reports, and monthly progress reports are the required deliverables for OU-1. A Scope of Work (SOW) for OU-1 was included in the amendment to Administrative Consent Order U.S. Docket No. 90-22 (December 1993). This was then revised and included as an attachment to the 1998 Consent Decree. This showed the specific reporting requirements for construction planning, construction, compliance testing, and O&M. The City of Fresno hired Kleinfelder and GeoSyntec to help meet these reporting requirements and oversee OU-1. Based on an approval from USEPA (letter dated April 16, 2004), the project update report submittals are now required on a quarterly basis rather than a monthly basis (Nyznyk 2005).

4.1.2 OU-2 Selection and Implementation

4.1.2.1 Selection

The objective of OU-2 is to restore the aquifer to beneficial use in a timely and cost-effective manner. Beneficial use is defined here as when levels are at or below MCLs. The 1994 remedial investigation had only identified PCE, TCE, and vinyl chloride as COCs, but the 1996 ROD identified 16 COCs. These are: PCE, TCE, vinyl chloride, 1,1-DCE, 1,2-DCA, trans-1,2 DCE, cis-1,2 DCE, 1,2-dichloropropane, 1,2-DCB, 1,4-DCB, benzene, chlorobenzene, chloroform, 1,1-DCA, trichlorofluoromethane, and toluene.

To obtain these objectives, a number of components were to be implemented at the FSL. Collectively, these components make up OU-2 and include:

- Phased installation of the groundwater extraction system.
- Installation and operation of Phase 1 groundwater extraction wells (landfill perimeter containment).
- Installation and operation of Phase 2 groundwater extraction wells (plume containment).
- Installation and operation of Phase 3 groundwater extraction wells (aquifer restoration).
- Analysis of each phase of the groundwater remedy.
- Treatment system for the extracted groundwater and all necessary piping.
- A groundwater monitoring system.
- Decommission certain wells, specifically agricultural wells affecting area water level elevations.
- Institutional control during remediation.

The remedy was to be implemented in three phases to optimize the design elements including the number of wells, location of wells, and pumping rates.

4.1.2.2 Implementation

The Phase 1 (landfill perimeter containment) groundwater remediation activities are currently ongoing. Thirty-four A-Aquifer monitoring wells, 24 B-Aquifer monitoring wells,

and 13 C-Aquifer monitoring wells (CDM 2000) were installed from 1986 to 2001 (CDM 2005a). Five extraction wells were installed along the western downgradient edge of the landfill (wells PW-1 through PW-5). Figure 4-1 shows the locations of the extraction wells and other groundwater remedial action components. Table 4-1 shows the extraction well information.

TABLE 4-1
Extraction Well Information
First Five-Year Review Report for Fresno Municipal Sanitary Landfill Superfund Site, Fresno County, California

Extraction Well	Aquifer	Date of Installation	Total Depth of Boring (feet bgs)	PVC Screen Interval (feet bgs)	Well Diameter (inches)	Top of Casing Elevation (feet above msl)
PW-1A	A	11/26/97	89	57-87	6	266.32
PW-2A	A	12/16/98	89	57-87	8	267.36
PW-3A	A	12/11/98	89	56 ½ - 86 ½	8	263.31
PW-4A	A	12/7/99	93 1/2	58-88	8	264.55
PW-5A*	A	6/15/01	86	54-84	8	259.69

Source: CDM 2000.
* CDM 2003a.

The extracted groundwater travels via the underground conveyance pipes to the groundwater treatment PTA. The anti-scalent and oxidant are added to the water stream. The contaminated water enters the tower from the top and runs down due to gravity flow. The water runs over a medium that converts the stream into tiny droplets (thereby increasing the surface area of the water). The PTA blower forces air past the water. The VOCs, which prefer to be in air over water, transfer to the air. The air is then sent to the LFG flare for combustion. The treated water ends up in the junction box, which then distributes the water for irrigation of the park complex. It is either sent to the South Detention Basin for infiltration or the lake to be used as irrigation water, depending on the lake level. Figure 4-2 shows the steps of the treatment plant process.

Some design changes did occur. These included changes during the bidding period and during construction. During the bidding period, changes were minor, including alternative lining for piping, additional valves or other ancillary equipment, and concrete-encased buried steel piping in the groundwater treatment plant yard. The changes made during construction that required engineering analysis are described below.

- Change Order 1 – Electrical modifications associated with the addition of two groundwater extraction wells.
- Change Order 2 – Modification to the instrumentation control loop tying together the groundwater treatment plant and the flare station operation.
- Change Order 3 – Modifications to the structural supports for the equipment yard canopy.
- Change Order 4 – Installation of intrinsic safety barriers for instruments location in the extraction well vaults.

- Change Order 5 – Revised electrical control schematics for the sump pump operation.
- Change Order 6 – Installation of a chemical feed system to provide hypochlorite to the influent to the PTA (CDM 2001a).

The Phase 1 groundwater remediation activities are currently ongoing. In early 2006, a Phase 1 evaluation report will be completed which will assess the effectiveness of the Phase 1 groundwater remedial action relative to the objectives of each phase of groundwater remediation (including Phases 2 and 3). Based on the results of the evaluation, a decision will be made either to proceed to Phase 2 or to refine and continue with Phase 1 remedial actions.

At the time of the remedial action completion report, three private agriculture wells (I-3, I-4, and I-5) located to the west still required decommissioning. A well decommissioning report was released by the City in June 2005. Beginning in October of 2004, the City began decommissioning the wells. This included pulling the well pumps and performing down-hole video and geophysical logging. The well casing for I-3, I-4, and I-5 were perforated and I-4 and I-5 were grouted. The agricultural well decommissioning was completed in April 2005. A technical report documenting the decommissioning was submitted in April 2005 (City of Fresno 2005).

The main institutional controls identified include prohibiting the use of nearby wells and preventing the installation of new wells in the area to ensure that their hydrologic effect will not adversely impact the goal of containing the contaminant plume during operations. The City has worked with neighbors to decommission the agricultural wells. Figure 4-3 shows the locations of the decommissioned agricultural wells and their replacements. (CDM 2003a). Institutional control activities are discussed in more detail in Section 4.1.3.

Reporting Deliverables

Per the 1998 Consent Decree, the remedial action/design report for each phase, a construction completion report for the entire site, evaluations of each phase, and yearly status reports are the required deliverables for OU-2. An SOW for OU-2 was included as an attachment to the 1998 Consent Decree. It included specific reporting requirements for design planning, design, evaluation, construction, and O&M of OU-2. The City of Fresno hired CDM to help meet these reporting requirements and oversee OU-2. OU-2 is currently in Phase 1.

4.1.3 Institutional Controls

Institutional controls are non-engineering methods by which access to contaminated environmental media is restricted. In order to comply with the requirements relating to institutional controls, as outlined in the 1996 Final ROD, the City of Fresno prepared the *Final Fresno Sanitary Landfill Technical Memorandum – institutional controls* (CDM 2003c) outlining the proposed approach to implementation. The institutional controls anticipated for FSL in the ROD were restriction of installation of water supply wells in the impacted aquifer and limiting site access. In addition, controls on the use of the groundwater pumped from existing wells in the contaminated aquifer were to be considered. The ROD states that implementation of these controls can be enforced by the county governmental agency or by zoning and deed restrictions.

According to the technical memorandum, two capture zones were identified on the perimeter of the site where well usage could cause adverse impacts on the treatment system and have the potential for exposing well users to constituents. The delineated zones presented in the 2003 memo applied only for Phase 1 operation of the FSL groundwater remediation system. The memo stated that "the presented evaluation of institutional controls no longer applied if the remediation system were expanded to include Phase 2 extraction wells."

A well's impact on the remediation system was defined as a function of its pumping rate, completion depth, and location. Therefore, the City determined that new water supply well installation should be restricted in these areas, and existing wells should be evaluated for impact on the treatment system.

The City of Fresno's approach for implementing the institutional controls addressed well construction and water supply well use in the vicinity of the FSL. The City selected restrictions or denial of well permits and evaluation of existing production wells by the Fresno County Health Services Agency (the enforcing agency) in the two identified capture zones on the perimeter of the FSL. The prescribed restrictions or denial and evaluation of existing wells were selected based on the results of technical studies using Phase 1 data from the pump-and-treat system.

The first zone, referred to as the Well Prohibition Zone, includes the landfill footprint and the areal extent of the offsite VOC plume that exceeds USEPA action levels. The City determined that any wells located in this area have a significant likelihood for exposing wells users to constituents and for compromising the effectiveness of the remediation system. Therefore, the City proposed no new water supply wells be allowed in this zone. At the time the institutional controls technical memorandum was issued, existing wells located in this zone had either been decommissioned or were in the process of being decommissioned.

The second zone is referred to as the Well Assessment Zone. It delineates an area where wells could have an adverse effect on the groundwater plume and remediation system. The institutional controls would require that all well permit applications for new or modified wells located in this zone be evaluated for potential impacts on the plume and the remediation system prior to approval of the well permit. The well evaluation would result in the approval of the well permit or would offer conditions for approval that would revise the well location, completion depth, or pumping rate.

The evaluation process for existing water supply wells presented in the 2003 memo calls for the identification and evaluation of existing wells within the Well Assessment Zone. The purpose of the evaluation is to identify if the potential exists for their operation to adversely impact the groundwater treatment system. Evaluation of the well impacts will be performed through modeling. Consistent with the present well decommissioning program, well permits could be rescinded and the wells could be decommissioned and replaced with wells that would not result in adverse impacts.

The technical memorandum also recommended that the following institutional controls be implemented to further restrict access:

- Install perimeter fencing around the landfill footprint with signs indicating that the site is a closed solid waste disposal facility.
- Attach a deed notification to the 145-acre landfill parcel. Restrictions on the deed should include prohibitions on excavations and construction.

As part of this Five-Year Review, a determination of the status of the institutional controls was made. An outstanding issue remains relating to the institutional controls:

No deed notification with restrictive covenants has been attached to the landfill parcel title. The USEPA recommends that an Explanation of Significant Difference (ESD) be created that will instruct the City to execute and record a restrictive covenant for the property that would bind current and future owners and restrict certain uses of the site itself, including residential use, and prohibit use of the groundwater underneath the site.

4.2 Operation and Maintenance

4.2.1 OU-1

The three aspects of O&M for OU-1 are landfill closure inspection and maintenance, LFG collection and treatment system operations, and the Compliance Testing Program.

The final O&M plan includes details about inspecting, maintaining, and operating the landfill final cover systems, the LFG collection and treatment, and surface water management. The O&M manuals for LFG control systems are in a separate volume. The O&M for the irrigation system were not submitted as of June 2003 and were not required until the 2-year landscaping establishment period. This would have been due in late 2003. These documents were not available for review.

The final O&M plan was developed according to the SOW included in the Consent Decree. The landfill control systems that are to receive post-closure care and frequency of this care are included in Table 4-2.

TABLE 4-2
OU-1 Operations and Maintenance Activities
First Five-Year Review Report for Fresno Municipal Sanitary Landfill Superfund Site, Fresno County, California

System	Sub-system	Activity Type	Frequency
Final Landfill Cover	Vegetation	Visual inspection for bare spots and poorly performing vegetation. Re-seed and mulch as necessary. See Section 02970 of Specifications.	Semi-annually
		Visual inspection for unwanted deep rooted plants, weeds or saplings. Remove as necessary.	Semi-annually
		Trimming/mowing of vegetation during fall and spring (or as necessary).	Semi-annually

TABLE 4-2
OU-1 Operations and Maintenance Activities
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System	Sub-system	Activity Type	Frequency
	Topsoil	Visual inspection for erosion or surface cracking. Replace topsoil, reseed and mulch as necessary. See Sections 02970 and 02930 of Specifications. Monitor areas with significant erosion or large cracks for additional erosion or movement of cover materials.	Semi-annually
		Visual inspection for settlement or subsidence. Monitor settlement to determine if repair is required.	Semi-annually
		Visual inspection for burrowing animals. Remove/trap animals and fill in holes. Use fine sand to fill holes. Mark and monitor holes for settling of sand.	Quarterly
Site Security Fence	Fence	Visual inspection of entire perimeter for breaches or damage. Repair or replace fence sections as necessary	Semi-annually
		Visual inspection of entire perimeter for under fence erosion. Repair erosion or extend fence as necessary.	Semi-annually
	Gates	Check for tampering/damage to locks. Repair or replace as necessary.	Semi-annually
		Check for proper gate lock function. Repair or replace as necessary.	Semi-annually
	Warning Signs	Check for presence of warning signs. Repair or replace as necessary	Semi-annually
		Check for damage to warning signs. Repair or replace as necessary.	Semi-annually
Surface Water Management System	Sideslopes	Visual inspection for erosion damage or cleaning. Repair erosion damage (replace topsoil, reseed and mulch per Appendix A). Maintain slopes (remove excess soil, weeds, etc.) as necessary.	Semi-annually or after 100-year rainfall event
	Culverts/Letdown Structures	Visual inspection for erosion damage or cleaning. Repair erosion damage (maintain riprap aprons). Maintain letdown structures (remove weeds and other debris or clogging materials) as necessary.	Semi-annually or after 100-year rainfall event
	Riprap	Visual inspection for erosion damage or cleaning. Replace or clean out riprap as necessary.	Semi-annually or after 100-year rainfall event

TABLE 4-2
OU-1 Operations and Maintenance Activities
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System	Sub-system	Activity Type	Frequency
	Cover Swales	Visual inspection for erosion damage or cleaning. Repair erosion damage (replace riprap, separator geotextile, etc.). Maintain drainage ways (remove excess soil, weeds, etc.) as necessary.	Semi-annually or after 100-year rainfall event
	Perimeter drainage ditch	Visual inspection for erosion damage or cleaning. Repair erosion damage (replace riprap, ditch liner, etc.). Maintain drainage ways (remove excess soil, weeds, etc.) as necessary.	Semi-annually or after 100-year rainfall event
	Detention basins	Visual inspection for erosion damage or cleaning. Repair erosion damage (replace or clean out riprap and reseed and mulch per Appendix A). Remove sediment from basin bottom and stockpile in appropriate areas. Maintain embankment (remove weeds) as necessary.	Semi-annually or after 100-year rainfall event
Gas Control, Treatment and Monitoring Systems	Gas Extraction wells	Visual inspection for damage. Monitor for gas constituents, flow rate, well pressure and adjust as necessary.	Weekly
	Gas header	Visual inspection for damage and low spot formation.	Monthly
	Condensate header	Visual inspection for damage, low spot formation and wet areas indicating a break in the condensate force main piping.	Monthly
	Condensate sumps	Visual inspection for damage. Adjust air pressure as necessary. Check liquid levels to ensure the pump is operating.	Monthly
	Blower	Check for proper lubrication, v-belt tension, inlet and outlet valve adjustments, and operating amperage.	Weekly
	Flare Station	Check for proper flare temperature, automatic control sequences for operation, system shutdowns, propane levels, chart recorder paper/pens, and air compressor operation.	Weekly
	Monitoring Wells	Sampling for presence of landfill gas.	Quarterly
		Sounding and/or visual inspection for presence of leachate in well.	Quarterly
Seep Monitoring and Collection System	Discolored Liquid	Visual inspection of the aerial extent and location of all seeps. Record the status of the seep (continual flow, relatively dry, etc.) and photograph.	Quarterly
		Collect liquid samples from the leachate	As necessary

TABLE 4-2
OU-1 Operations and Maintenance Activities
First Five-Year Review Report for Fresno Municipal Sanitary Landfill Superfund Site, Fresno County, California

System	Sub-system	Activity Type	Frequency
		seeps, for laboratory analysis.	
Access Roads	Ponding	Visual inspection for water ponding; repair as necessary.	Semi-annually
	Vegetation	Visual inspection for vegetative growth; removal as necessary.	Semi-annually
	Aggregate	Visual inspection for erosion, ruts or washed-out areas; addition of new aggregate to fill as necessary.	Semi-annually
Irrigation System	Sprinklers	Visual inspection for damage or malfunction; repair as necessary.	Bi-monthly
	Pumps	Visual inspection for damage or malfunction; repair as necessary.	Bi-monthly
	Satellite Controllers	Visual inspection for damage or malfunction; repair as necessary.	Monthly
	Central Control	System test and diagnostic; repair as necessary.	Quarterly

Source: Kleinfelder/GeoSyntec 2003b.

During the site inspection, a potential issue was identified. The lids on the soil-gas monitoring wells are about 200 pounds each. These are too heavy to be lifted by one person and are left open. As a replacement for the existing heavy lids, the City has chosen to place a plywood lid with a hinged opening on each of the monitoring well vaults.

The compliance testing plan adequately outlines requirements for compliance testing based on San Joaquin Valley Air Pollution Control District (SJVAPCD) Rule 4642. However, the PTA should be considered in the final compliance testing plan, especially as it is a contributor to the mass inlet emission rate of VOCs (GeoSyntec 2002, 2003).

4.2.2 OU-2

The four primary components of the groundwater remediation system are the groundwater extraction and monitoring, groundwater treatment (PTA), chemical addition (an anti-scalent buildup prevention precipitates and sodium hypochlorite for bacterial growth prevention within the PTA), and off-gas treatment (LFG flare station). Operation and maintenance is necessary to ensure all the components are functioning properly.

There are currently five extraction wells located on the western side of the landfill to intercept the VOC-contaminated groundwater as it flows in the westerly direction. These are the perimeter extraction wells that pump from both the A- and B-Aquifers. The well pumps have a hands-off remote switch for remote operation, as well as local and central alarms. There are numerous monitoring wells located around the site to measure the extent of movement of the downgradient edge of the VOC plume, the groundwater gradient, and

the extent that the groundwater is being intercepted at the landfill boundary. There is quarterly monitoring of a select number of these wells (CDM 2003d).

The PTA blower is operated automatically from the control system. The air-to-water ratio is maintained by the photoionization detector algorithm. Alarms enable automatic complete treatment plant shutdown for numerous unsafe conditions, such as low water level in a PTA reservoir.

The chemical system components of the groundwater treatment include chemical storage tanks, metering pumps, piping and valving, and mounted electrical and instrumentation and control components. The pump speeds are set manually on the local pump speed controller.

Quarterly monitoring of the influent and effluent from the treatment plant occurs to determine if the design treatment goal is reached. The goal is for the treated effluent to have VOC concentrations below one-half of the MCLs (CDM 2003d).

The off-gas from the top of the PTA is sent to the LFG flare. The condensate is collected in a sump and routed back to the PTA for treatment. When the flare is offline, the extraction system and treatment system will shut down. If the flare needs to be shut down for 1 to 3 days for maintenance, the system can resume without loss of hydraulic control. If the system is shut down long term because of low supply of LFG, propane gas can be used to keep the flare operating. Also, a granular-activated carbon system can be purchased and put online to treat the off-gas from the groundwater treatment system if the flare is shut down long term.

Currently, there is an onsite manager of the FSL. A daily printout of O&M activities provides a schedule of activities. Table 4-3 describes the routine O&M activities on OU-2.

TABLE 4-3
OU-2 Operations and Maintenance Activities
First Five-Year Review Report for Fresno Municipal Sanitary Landfill Superfund Site, Fresno County, California

System	Sub-system	Activity Type	Frequency
Groundwater Treatment System	Packed Tower Aerator	Routine inspection including: • Inspection of packing to determine the extent of fouling. • Removal and clean packing of PTA with chemical acid baths, high-pressure hosing, or combination of both procedures, as required.	Every 6 months
	Packed Tower Aerator Blower	Routine fan maintenance Including: • Check fan wheel for wear and corrosion • Check fan wheel for buildup of material leading to unbalancing. Clean as required. • Check the V-belt drive for proper alignment and tension. • Check all setscrews and bolts for tightness.	Every 3 months
		Fan-bearing Lubrication	Every 2 to 4 months
		Motor-bearing Lubrication	Every 3 months
	Blower Silencer/Muffler	Routine maintenance including: • Check the inlet screens for blockage. • Check the air paths between acoustic baffles for obstructions. • Check the perforated acoustic baffles for clogging. • Clean with cloth dampened in mild cleaning solution not containing any acid or caustic base.	Every 6 months
Hypochlorite feed system	Chemical Feed Pump	Routine inspection including: • Tighten leaking fittings. • Check pump oil level using sight glass on the back side of the gearbox. • Torque lead bolts.	Weekly
		• Check motor/pump flexible coupling. • Change gearbox oil. • Wetted end disassembly, inspect, and replace if needed.	First 100-200 hours of operation
		• Check pump capacity via calibration run. • Disassemble/inspect motor/pump flexible coupling.	Every 5,000 hours or every 12 months

TABLE 4-3
OU-2 Operations and Maintenance Activities
First Five-Year Review Report for Fresno Municipal Sanitary Landfill Superfund Site, Fresno County, California

System	Sub-system	Activity Type	Frequency
Anti-Scalent Feed System	Chemical Feed Pump	Routine tune-up Including: • Replace the check valves, diaphragm, and relief valve poppets.	Every 12 months
		Oil change: • Drain oil in the main housing and replace. Schedule oil changes to correspond with summer and winter seasons to allow for appropriate lubricant grade.	Every 6 months
Sump Pumps	Treatment Area Drainage Sump	Routine inspection including: • Check the oil level in the seal cavity. • Check the motor lubrication level when the pressure relief valve is activated.	Every month
		Lubrication schedule: • Replace the oil.	Every 12 months
	Off-gas Condensate Pump	Routine inspection including: • Check oil level with dip stick. The level should be 3/4 –inch below the top of the motor housing.	Every month
		Lubrication schedule: • Replace the oil.	Every 12 months

Source: CDM 2003d.

The quarterly progress reports document any issues regarding O&M. The most recent issues are documented in the first quarter 2005 report. The low-flow conditions have had a negative effect on the flow meters in that the flows are too low to be measured. New flow meters are to be installed within the next six months.

Recently, the City prepared a letter to USEPA requesting modifications to the groundwater monitoring program including reducing sampling frequency for certain wells. The USEPA responded by requesting more information to support these changes. In addition, the EPA has approved the City's request to use the City's wastewater analytical laboratory for performing inorganic analysis of groundwater samples. Also, EPA approved the City's request to continue groundwater treatment program operations while the landfill gas flare is not operating for maintenance purposes. (City of Fresno 2005).

Other current issues were identified during the site inspection and interviews. The throttle valves on the extraction wells were not optimally designed. The City plans to replace them with a better design, although they have not specified when this will occur. Higher frequency of well rehabilitation activities has been necessary lately because the performance of the extraction wells has decreased. Extraction well rehabilitation activities may become semi-annual or annual. The perimeter road also gets muddy during the rainy season; graveling or paving the road could be a good improvement.

An O&M issue in the past includes the unacceptable destruction efficiency on the flares, as identified during compliance testing. Also, the Supervisory Control and Data Acquisition (SCADA) system had small issues, and the City improved the computer system.

Optimization of O&M has occurred in numerous ways. The computerized O&M schedule produces work orders to help ensure efficient and thorough maintenance. The overall cost of O&M has been optimized, as the City took over groundwater sampling but retains Camp Dresser and McKee (CDM) for quality assurance oversight. The City has also developed a more efficient groundwater sampling route in that they have modified the sequence in which they sample the wells. The City was granted its request to perform its own analysis of inorganics and perform a reduced amount of sampling for organics (CDM 2005).

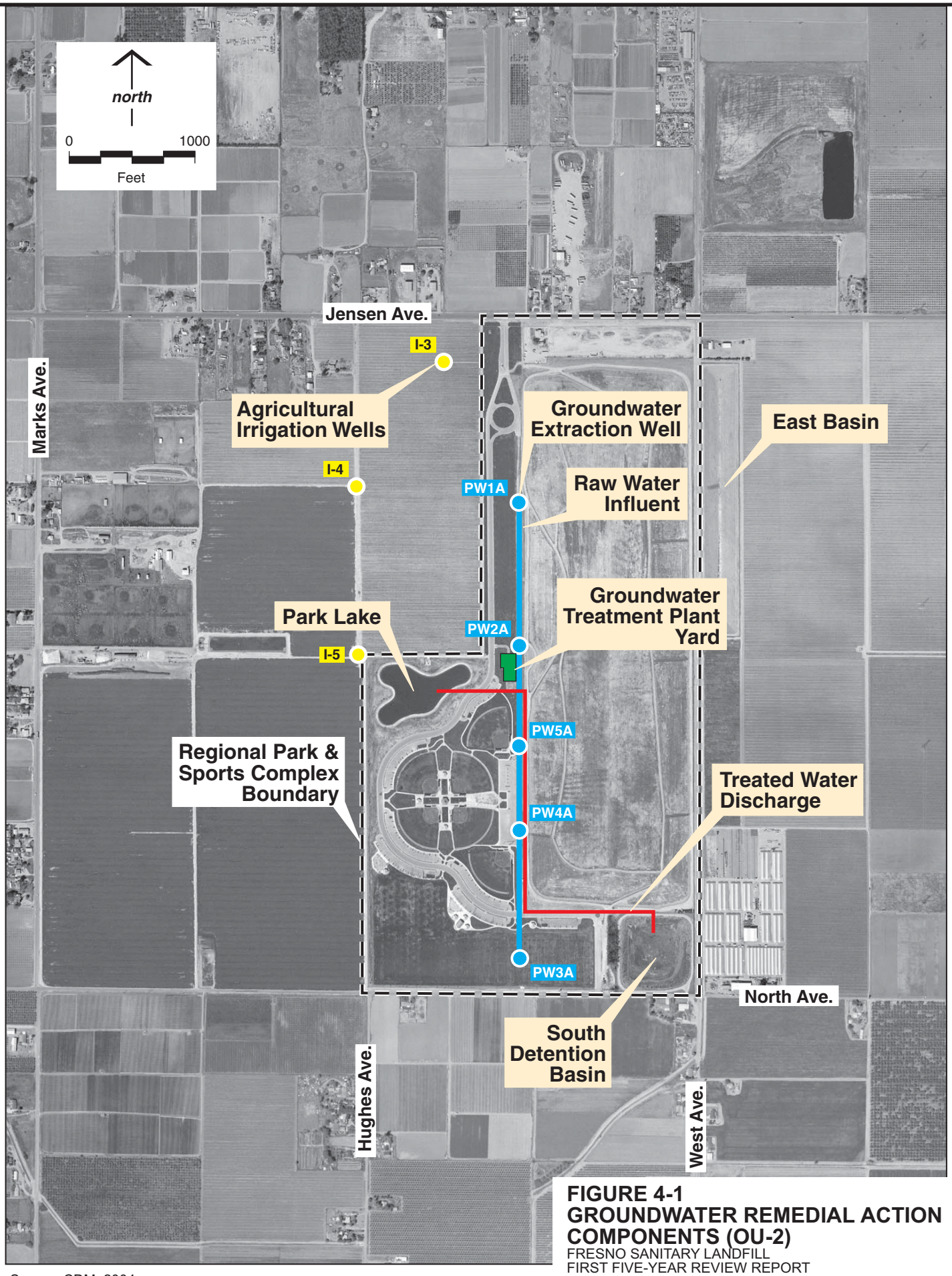
4.2.3 Operations and Maintenance Costs

Table 4-4 presents both the ROD-estimated costs and the actual dollars spent for the systems. The information for Kleinfelder was obtained from Table 8-1 in the Final RA Report (Kleinfelder/GeoSyntec 2003a). During the site inspection, George Slater, Project Coordinator for the City of Fresno, provided the City's annual O&M expenses. All of the annual O&M costs are well below the ROD-projected costs. This is mostly attributed to the fact that a leachate system was not needed due to an insignificant volume of leachate and the landfill gas condensate is disposed to the sanitary sewer (Kleinfelder/GeoSyntec 2003a). The budget for O&M in 2005-2006 is significantly higher than previous years because the City is preparing for potential additional costs associated with actions that will be taken according to the recommendations from the Phase 1 Evaluation Report. There do not appear to be any unusually high O&M costs.

TABLE 4-4
OU-1 and OU-2 Operations and Maintenance Costs
First Five-Year Review Report for Fresno Municipal Sanitary Landfill Superfund Site, Fresno County, California

			Annual O&M Cost						
UO	**$$**	**Capital Cost**	**99'- '00**	**'00 – '01**	**'01 – '02**	**'02 – '03**	**'03 – '04**	**'04 – '05**	**'05 – '06**
OU-1 (Kleinfelder)	Spent	$13,160,000[d]					$212,600[a]		
	ROD Estimate	$15,569,000[d]					$432,700		
	% Difference Between ROD Estimate and Spent	- 15.5 %					- 50.9 %		
OU-2 (CDM)	Spent						$338,708[e]		
	ROD Estimate	$3,714,000[b] (Phase 1) $6,375,000[b] (Phase 2) $7,948,000[b] (Phase 3)	$453,000[b] (Phase 1) $598,000[b] (Phase 2) $624,000[b] (Phase 3)						
Total (City)	Spent		$220,400	$188,625	$126,450	$337,600	$551,308	$787,100[c]	O&M: 1,075,200[c] Phase 2: $660,000[c]
	Estimate								

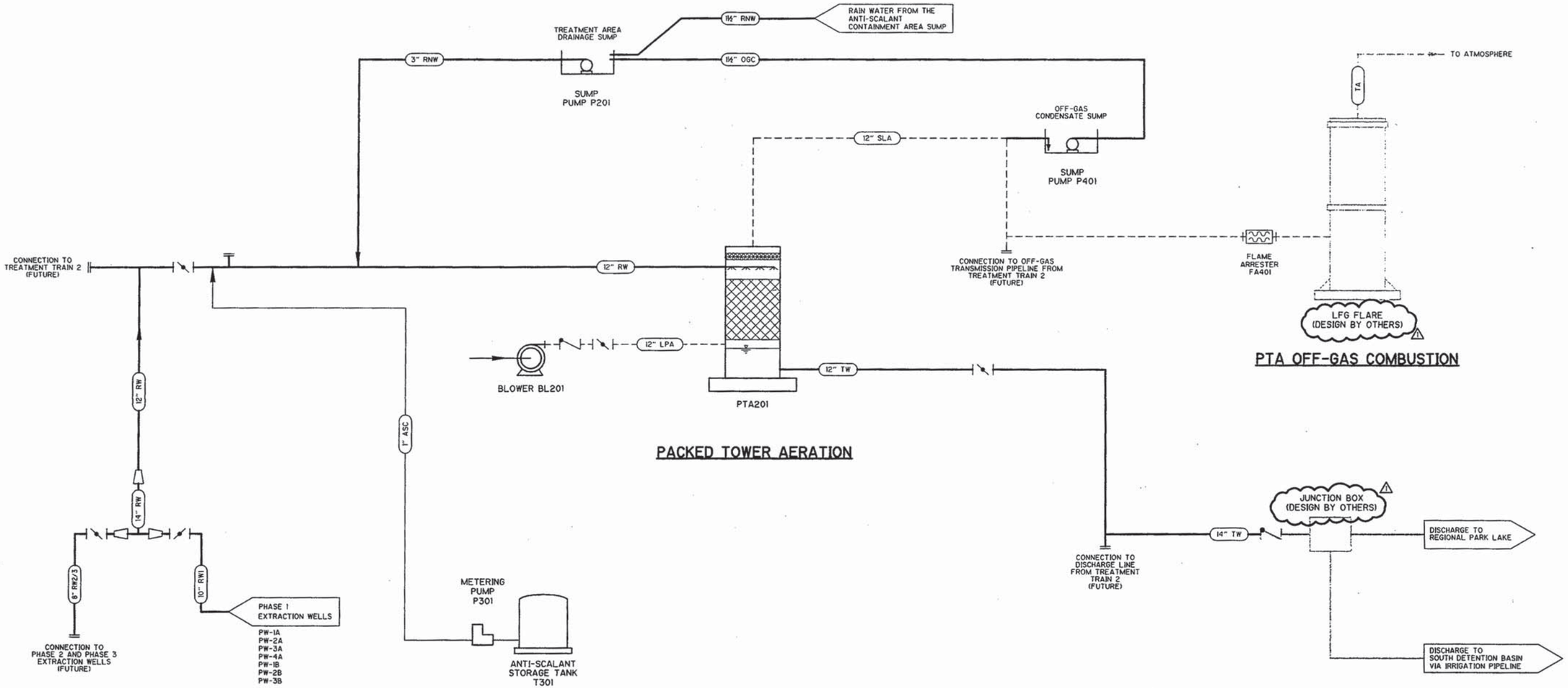
Notes:
[a] Estimated for that year.
[b] Estimates in 1996 dollars.
[c] Budgeted for that year.
[d] Estimates in 2003 dollars.
[e] Total O&M for City minus O&M for OU-1.



Source: CDM, 2004.

FIGURE 4-1
GROUNDWATER REMEDIAL ACTION COMPONENTS (OU-2)
FRESNO SANITARY LANDFILL
FIRST FIVE-YEAR REVIEW REPORT
FRESNO, CA

CH2MHILL



GROUNDWATER INFLUENT AND EFFLUENT CONCENTRATIONS AND VOC CONSTITUENT MASS BALANCE

COMPOUND	RAW GROUNDWATER CONCENTRATION (UG/L)	DESIGN EFFLUENT CONCENTRATION (UG/L)	PERCENT REMOVAL	MODELED EFFLUENT CONCENTRATION (UG/L)	RAW WATER (LB/DAY)	TREATED WATER (LB/DAY)	SOLVENT LADEN AIR (LB/DAY)
BENZENE	ND	0.5	--	--	--	--	--
CHLOROBENZENE	2.4	35	--	0.4	0.0288	0.0048	0.0240
CHLOROFORM	4.7	50	--	0.5	0.0564	0.0060	0.0504
1,2-DICHLOROBENZENE	ND	300	--	--	--	--	--
1,4-DICHLOROBENZENE	2.9	2.5	13.8%	0.6	0.0348	0.0072	0.0276
1,1-DICHLOROETHANE	5.4	2.5	53.7%	0.3	0.0648	0.0036	0.0612
1,2-DICHLOROETHANE	ND	0.25	--	--	--	--	--
1,1-DICHLOROETHENE	ND	3	--	--	--	--	--
CIS-1,2-DICHLOROETHENE	110	3	97.3%	3	1.3191	0.0360	1.2832
TRANS-1,2-DICHLOROETHENE	4.3	5	--	0.2	0.0516	0.0024	0.0492
1,2-DICHLOROPROPANE	1.2	2.5	--	0.3	0.0144	0.0036	0.0108
TETRACHLOROETHENE	45	2.5	94.4%	0.5	0.5396	0.0060	0.5337
TOLUENE	ND	75	--	--	--	--	--
TRICHLOROETHENE	25	2.5	90.0%	0.4	0.2998	0.0048	0.2950
TRICHLOROFLUOROMETHANE	ND	75	--	--	--	--	--
VINYL CHLORIDE	10	0.25	97.5%	0.0	0.1199	0.0000	0.1199

NOTES:
1. DESIGN GROUNDWATER FLOW RATE IS 1,000 GALLONS PER MINUTE.
2. DESIGN AIR-TO-WATER RATIO IS 10:1.

PIPE LEGEND

ASC	ANTI-SCALANT CHEMICAL	SLA	SOLVENT LADEN AIR
OGC	OFF-GAS CONDENSATE	TW	TREATED WATER
LPA	LOW PRESSURE AIR	TA	TREATED AIR
RNW	RAIN WATER		
RW	RAW WATER		
RW1	RAW WATER FROM PHASE 1 WELLS		
RW2/3	RAW WATER FROM PHASE 2/3 WELLS		

MAIN PROCESS STREAM
AIR STREAM
PROCESS STREAM PIPE (DESIGN BY OTHERS)
AIR STREAM DUCT (DESIGN BY OTHERS)

NOTES:
1. THE PHASE 1 DESIGN CONSISTS OF 1 TREATMENT TRAIN. AN ADDITIONAL TREATMENT TRAIN MAY BE ADDED TO ACCOMMODATE AN INCREASE IN RAW GROUNDWATER FLOWS FOLLOWING INSTALLATION OF THE PHASE 2 AND PHASE 3 EXTRACTION WELLS.
2. THE OFF-GAS TRANSMISSION PIPELINE SHALL BE CONNECTED TO A LANDFILL GAS FLARE (DESIGNED AND TO BE CONSTRUCTED AS AN ELEMENT OF THIS CONTRACT).
3. THE PTA DISCHARGE SHALL FLOW BY GRAVITY TO A JUNCTION BOX (DESIGNED BY OTHERS) FOR DISCHARGE TO EITHER THE REGIONAL PARK LAKE (DESIGNED BY OTHERS) OR THE IRRIGATION PIPELINE FOR TRANSMISSION TO THE SOUTH DETENTION BASIN (EXISTING).

Source: CDM, 2000.

FIGURE 4-2
GROUNDWATER TREATMENT SYSTEM PROCESS FLOW DIAGRAM
FRESNO SANITARY LANDFILL
FIRST FIVE-YEAR REVIEW REPORT
FRESNO, CA

CH2MHILL

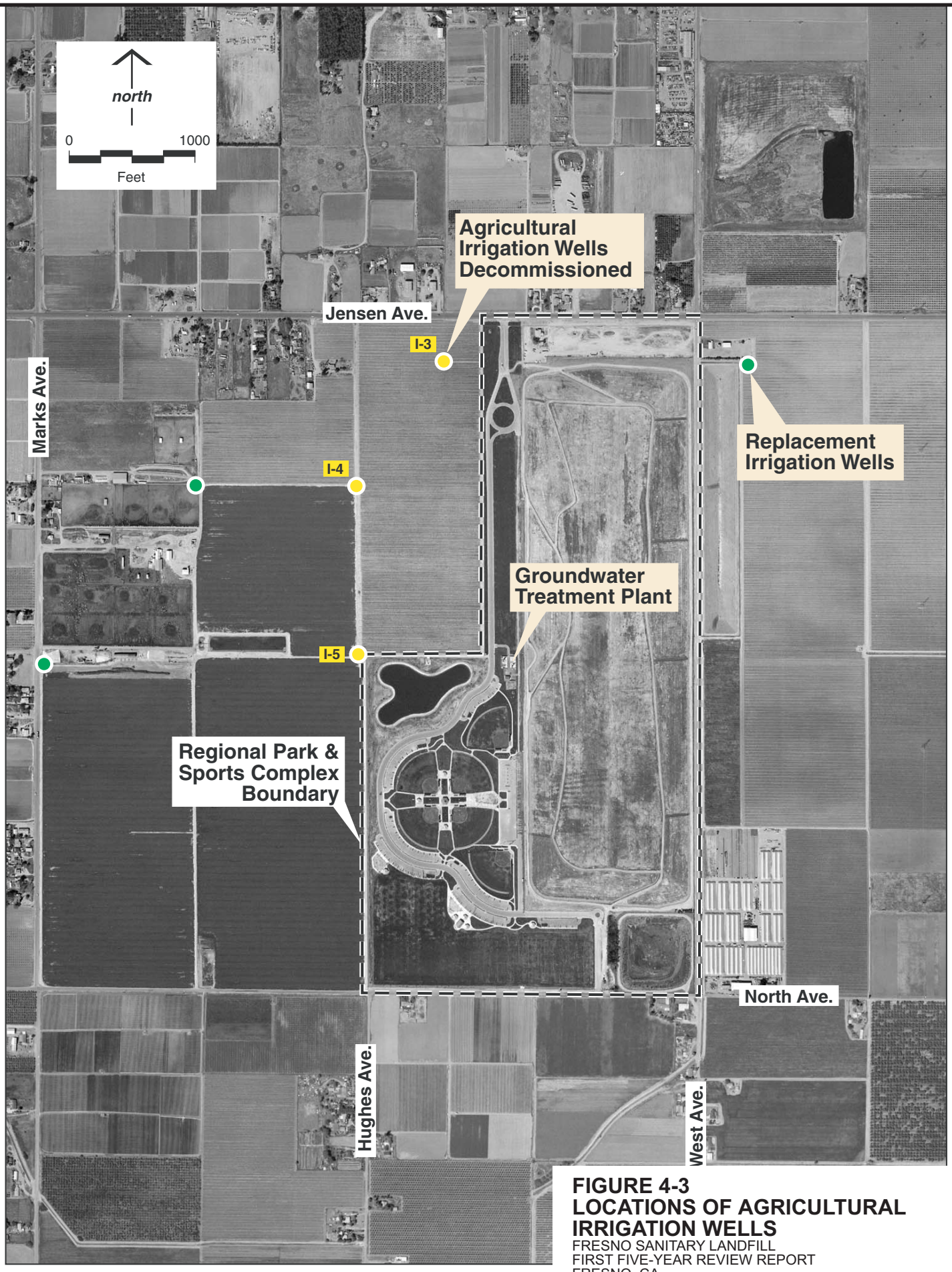


FIGURE 4-3
LOCATIONS OF AGRICULTURAL IRRIGATION WELLS
FRESNO SANITARY LANDFILL
FIRST FIVE-YEAR REVIEW REPORT
FRESNO, CA

Source: CDM, 2005.