NAS7.010099
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FOSTER WHEELER
ENVIRONMENTAL
CORPORATION

FINAL

FEASIBILITY STUDY REPORT FOR OPERABLE UNIT 2: POTENTIAL ON-SITE CONTAMINANT SOURCE AREAS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JET PROPULSION LABORATORY
4800 Oak Grove Drive
Pasadena, California 91109

July 2000

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4800 Oak Grove Drive
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July 2000

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ABBREVIATIONS AND ACRONYMS

Ag	Silver
ARARs	Applicable or Relevant and Appropriate Requirements
As	Arsenic
ATSDR	Agency for Toxic Substances and Disease Registry
Ba	Barium
BACT	Best available control technology
Be	Berylium
bgs	Below ground surface
CAA	Clean Air Act
Caltech	California Institute of Technology
Cc	Cubic centimeter
CCl_4	Carbon tetrachloride
CCR	California Code of Regulations
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
CN^-	Cyanide
Co	Cobalt
COPC	Constituent of potential concern
Cr	Chromium
Cr(VI)	Hexavalent chromium
Cu	Copper
CWA	Clean Water Act
DAF	Dilution-attenuation factor
°C	Degrees Celsius
°F	Degrees Fahrenheit
1,1-DCE	1,1-Dichloroethene
DTSC	California State Department of Toxic Substances Control
EPA	U.S. Environmental Protection Agency
ERA	Ecological risk assessment
FS	Feasibility study
ft, ft^2, ft^3	Foot or feet, square feet, cubic feet
g	Gram or grams
GAC	Granular activated carbon
GP	Sandy gravel
gpm	Gallons per minute
GRA	General response action
HCl	Hydrochloric acid

ABBREVIATIONS AND ACRONYMS
(Continued)

Hg	Mercury
HHRA	Human health risk assessment
JPL	Jet Propulsion Laboratory
kg	Kilogram
L	Liter
lb	Pound or pounds
m^3	Cubic meter
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
mg/kg	Milligrams per kilogram
ML	Silt
mm	Millimeter
MNA	Monitored natural attenuation
Mo	Molybdenum
mol	Mole
NASA	National Aeronautics and Space Administration
NCP	National Contingency Plan
Ni	Nickel
NO_3^-	Nitrate
NPL	National Priorities List
O&M	Operation and maintenance
OU-1	Operable Unit - 1 (On-site Groundwater Investigation)
OU-2	Operable Unit - 2 (On-site Contaminant Source Investigation)
OU-3	Operable Unit - 3 (Off-site Groundwater Investigation)
PAH	Polycyclic aromatic hydrocarbon
Pb	Lead
PCB	Polychlorinated biphenyl
ppmv	Parts per million by volume
PRG	Preliminary remediation goal
RAO	Remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial investigation
RI/FS	Remedial investigation/feasibility study
ROD	Record of decision
ROI	Radius of influence
RORI	Radius of remedial influence
RWQCB	California Regional Water Quality Control Board, Los Angeles Region
SARA	Superfund Amendments and Reauthorization Act
Sb	Antimony

ABBREVIATIONS AND ACRONYMS
(Continued)

SCAQMD	South Coast Air Quality Management District
SCM	Site conceptual model
SDWA	Safe Drinking Water Act
Se	Selenium
SM	Silty sand
SP	Sand, poorly graded
SP-GP	Sand and gravel mixture
Sr	Strontium
SSL	Soil screening level
SVE	Soil vapor extraction
SVOC	Semi-volatile organic compound
T-BACT	Best available control technology for toxics
TBC	To be considered
TCE	Trichloroethene
Tl	Thallium
TP	Test pit
TPH	Total petroleum hydrocarbons
µg	Microgram
µg/kg	Micrograms per kilogram
V	Vanadium
VOC	Volatile organic compound
Zn	Zinc

EXECUTIVE SUMMARY

Presented in this report are the results of the Feasibility Study (FS) for Operable Unit 2 (OU-2) (on-site soil) at the Jet Propulsion Laboratory (JPL). The JPL is a National Aeronautics and Space Administration (NASA)-owned facility managed by the California Institute of Technology (CalTech). The term "JPL" is used throughout this document to refer to facilities located at the 4800 Oak Grove Drive, Pasadena, California. In October 1992, JPL was placed on the National Priorities List (NPL) and, therefore, is subject to the provisions of the Comprehensive Environmental Response, Compensation, and Liabilities Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 (hereafter jointly referred to as CERCLA). Pursuant to CERCLA requirements, this FS was completed to evaluate potential remedial options for contaminated vadose zone soil at JPL. This involved development and analysis of remedial action alternatives to address soil and soil-vapor contamination at JPL while fulfilling the following CERCLA criteria:

- Protect human health and the environment.
- Achieve Federal and state Applicable or Relevant and Appropriate Requirements (ARARs).
- Incorporate a cost-effective solution.
- Utilize permanent solutions and treatment technologies or resources recovery technologies to the maximum extent practical.
- Address remedies that permanently and significantly reduce the mobility, toxicity, or volume of hazardous substances.

During the RI, a total of seven soil-vapor sampling events and three soil sampling events were conducted between January 1994 and June 1998, and samples were analyzed for a wide variety of contaminants. Although no risks to human or ecological receptors were identified for constituents detected in JPL soils, four volatile organic compounds (VOCs) were frequently detected in soil-vapor samples at elevated concentrations. Other VOCs were also detected; however, the detections were generally sporadic and/or concentrations were very low. The four frequently detected VOCs are carbon tetrachloride (CCl_4), 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113), trichloroethene (TCE), and 1,1-dichloroethene (1,1-DCE). These compounds, as well as other, less frequently detected VOCs, were generally located beneath the north-central portion of the site, and were detected at depths extending to the water table, which ranges up to 200 feet or more below ground surface. Non-volatile constituents were not found at concentrations requiring remediation.

A soil vapor extraction (SVE) pilot test was initiated at JPL in April 1998 and conducted through June 1998, and based on the results, an extended test was initiated in November 1998, and is ongoing as of July 2000. The test involves extraction of soil-vapor from one SVE well, and measurement of parameters such as extracted flow rate, exerted vacuum, VOC levels in extracted

vapors, and vacuum responses in observation and extraction wells on a regular basis. The test indicates that SVE is a feasible option for remediation of VOC-impacted soils at OU-2.

The primary objective of the FS is to develop remedial alternatives by assembling combinations of technologies that address soil-vapor contamination throughout the site. The specific objectives were to:

- Identify ARARs.
- Define remedial action objectives (RAOs) and proposed remediation goals (PRGs) on the basis of chemical-specific ARARs.
- Provide a methodology for identifying, screening, evaluating, and selecting remedial technologies and process options that would reduce soil-vapor and soil contamination to acceptable levels.
- Assemble selected technologies into remedial alternatives that provide an effective remedy.
- Incorporate ongoing removal actions at the site into the remedial alternatives.
- Conduct detailed and comparative analysis of remedial alternatives and present relevant information needed to allow NASA and regulatory agencies to select a final remedial alternative.

The format for this document follows the EPA's guidance on presumptive remedies for CERCLA sites with VOC compounds in soils (EPA, 1993), and where applicable, the *Guidance for Conducting Remedial Investigations and Feasibility Studies (RI/FS) under CERCLA* (EPA, 1988). The presumptive remedy approach is a means of accelerating future cleanups at sites that fall under specific categories based on EPA's collective knowledge about site investigation and remedy selection.

The identification of ARARS is a key component of the planning, evaluation, and selection of remedial actions. Federal ARARs may include requirements under any federal environmental laws, and state ARARs may only include promulgated, legally enforceable environmental or facility-siting laws that are more stringent or broader in scope than federal requirements. Many State of California laws give enforcement authority to local agencies, and, as a result, some local regulations can also be ARARs. ARARs can generally be divided into three categories: chemical-specific, location-specific, and action-specific requirements. The potential remedial action alternatives were evaluated to determine compliance with identified ARARs.

Based on information from the OU-2 RI, the four VOCs listed above (CCl_4, Freon 113, TCE, and 1,1-DCE) in soil-vapor were designated as the only constituents of interest for the OU-2 FS. PRGs are target treatment levels for constituents of interest in the relevant medium, in this case vadose-zone soils. PRGs are defined for this FS as vadose zone VOC concentrations required to protect groundwater from further migration of VOCs. These will be determined based on Regional Water Quality Control Board protocols.

Based on the information regarding constituents of interest, exposure pathways, and PRGs, remedial action objectives (RAOs) for the site were considered. Development of RAOs to protect human health regarding exposure to soils is not needed since it was determined in the risk assessment that direct exposure to soils does not pose risks to humans. Therefore, development of RAOs focused on preventing further migration of VOCs into the groundwater.

The RAO for OU-2 is to prevent, to the extent possible, migration of VOCs to groundwater (under RWQCB's non-degradation policy) to protect an existing drinking water source.

The EPA has developed a list of remedies that are presumed to be the most effective for sites with VOC contamination in soil. These presumptive remedies are:

- Soil Vapor Extraction
- Excavation/Thermal Desorption
- Excavation/Incineration

Of the three presumptive remedies, SVE is the primary option. The historical data show that SVE has been selected most frequently to address VOC contamination at Superfund sites. It was concluded in this FS that SVE is capable of effectively removing VOCs from soil at JPL at a relatively low cost.

Based on this analysis, the general alternatives for OU-2 at JPL include:

- No Action
- In Situ Soil Vapor Extraction

These alternatives include soil-vapor monitoring via the quarterly monitoring program (currently in place) to assess the VOC concentration trends over time.

With SVE, vapors extracted from the well(s) will contain VOCs, and the vapor stream will require treatment prior to discharge to the atmosphere. Therefore, process options that are required for treatment of waste streams from SVE were also considered. Using the EPA remediation technologies screening matrix, the following technologies were identified as being appropriate for VOC removal from the off-gas stream:

- Thermal Oxidation
- Catalytic Oxidation
- Carbon Adsorption
- VOC Adsorbing Resins

These process options, in conjunction with SVE, were evaluated based on effectiveness, implementability, and cost, with the greatest emphasis placed on effectiveness. Carbon adsorption was determined to be the preferred treatment for VOC removal from the off-gas stream. Based on the evaluations described above, the following alternatives were evaluated in detail:

Alternative 1	No Action
Alternative 2c	In Situ SVE/GAC Off-Gas Treatment

Following detailed evaluation, Alternative 2c, In Situ SVE/GAC Off-Gas Treatment, is chosen as the preferred alternative for OU-2 at the JPL site.

1.0 INTRODUCTION

Presented in this report are the results of the Feasibility Study (FS) for Operable Unit 2 (OU-2) (on-site soil) at the Jet Propulsion Laboratory (JPL). The JPL is a National Aeronautics and Space Administration (NASA)-owned facility where the California Institute of Technology (Caltech) performs research and development tasks. The term "JPL" is used throughout this document to refer to facilities located at the 4800 Oak Grove Drive, Pasadena, California. A separate FS has been prepared to address groundwater contamination (OU-1 and OU-3) at JPL (Foster Wheeler, 1999a).

In October 1992, JPL was placed on the National Priorities List (NPL) and, therefore, is subject to the provisions of the Comprehensive Environmental Response, Compensation, and Liabilities Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 (hereafter jointly referred to as CERCLA). Pursuant to CERCLA requirements, this FS was completed to evaluate potential remedial options for contaminated subsurface soil at JPL.

The Final Remedial Investigation (RI) Report for OU-2 (Foster Wheeler, 1999b) was used as a major source of site background information included in this report. This report presents the findings of the RI at OU-2 (soil).

1.1 FEASIBILITY STUDY OBJECTIVES

The primary objective of this FS is to develop and analyze remedial action alternatives to address soil and soil-vapor contamination at JPL while fulfilling the following criteria established in CERCLA Section 121 (EPA, 1988a):

- Protect human health and the environment.
- Achieve compliance with Federal and state Applicable or Relevant and Appropriate Requirements (ARARs).
- Incorporate a cost-effective solution.
- Utilize permanent solutions and treatment technologies or resource recovery technologies to the maximum extent practical.
- Address remedies that permanently and significantly reduce the mobility, toxicity, or volume of hazardous substances.

Remedial alternatives were developed by assembling combinations of technologies that address soil-vapor and soil contamination throughout the site. The specific objectives of the FS are to:

- Identify ARARs.
- Define remedial action objectives and proposed remediation goals on the basis of chemical-specific ARARs.

- Develop general response actions that can address the remedial action objectives.
- Provide a methodology for identifying, screening, evaluating, and selecting remedial technologies and process options.
- Assemble selected technologies into remedial alternatives that provide an effective remedy.
- Incorporate ongoing removal actions at the site into the remedial alternatives.
- Conduct detailed and comparative analysis of remedial alternatives and present relevant information needed to allow NASA and regulatory agencies to select a final remedial alternative.

1.2 REPORT ORGANIZATION

The format for this document follows the EPA's guidance on presumptive remedies for CERCLA sites with VOC compounds in soils (EPA, 1993b), and where applicable, the *Guidance for Conducting Remedial Investigations and Feasibility Studies (RI/FS) under CERCLA* (EPA, 1988a). The presumptive remedy approach is a means of accelerating future cleanups at sites that fall under specific categories based on EPA's collective knowledge about site investigation and remedy selection. In cases where remedial action is planned, compliance with the nine criteria in the RI/FS guidance (EPA, 1988) is still required.

The OU-2 report consists of six sections. Section 1.0, Introduction, outlines the purpose and organization of the report, and provides a summary of the remedial investigation, including a discussion of the nature and extent of soil-vapor and soil contamination, contaminant fate and transport, and baseline risk assessment. Section 2.0, Identification of Potential Applicable or Relevant and Appropriate Requirements, presents ARARs that may govern the type and extent of remedial activities. The ARARs will be considered during development of potential remedial alternatives. Section 3.0, Identification, Screening, and Evaluation of Remedial Technologies and Process Options, identifies and evaluates remedial technologies (the presumptive remedies for VOC-impacted soil) that are applicable for site-specific conditions. Section 4.0, Development and Screening of Remedial Alternatives, develops remedial alternatives from the technologies identified in Section 3.0. Section 5.0, Detailed Analysis of Alternatives, presents a detailed analysis of preferred alternatives. Section 6.0, References, is a list of references used to prepare this report.

1.3 BACKGROUND INFORMATION

Provided in this section are brief discussions regarding background information relevant to the FS including a site description, a summary of site history, a list of investigations previously conducted at the site, brief descriptions of site geology and geohydrology, a discussion of the nature and extent of contamination, an assessment of contaminant fate and transport, and the estimated risks associated with impacted soils. More detailed discussions on these subjects are

presented in the RI reports for OU-2 (Foster Wheeler, 1999b) and OU-1/OU-3 (Foster Wheeler, 1999a).

1.3.1 Site Description

JPL is located between the city of La Canada-Flintridge and the unincorporated city of Altadena, California, northeast of the 210 Foothill Freeway (Figure 1-1). The site is situated on a south facing slope along the base of the southern edge of the east-west trending San Gabriel Mountains at the northern edge of the metropolitan Los Angeles area. The Arroyo Seco, an intermittent streambed, lies immediately to the east and southeast of the site. Within the Arroyo Seco east of JPL is a series of surface impoundments used as surface water collection and spreading basins for groundwater recharge. Residential development, an equestrian club (Flintridge Riding Club), and a Los Angeles County Fire Department Station borders the site along its southwestern and western boundaries. Residential development is also present to the east of JPL, along the eastern edge of the Arroyo Seco (Figure 1-1).

The JPL site is comprised of approximately 176 acres. Of this, approximately 156 acres are Federally owned, with the remaining land leased from the City of Pasadena and the Flintridge Riding Club for parking. The main developed area of JPL is located on the southern half of the site, which can be divided into two general areas: the northeastern early-developed area and the southwestern later-developed area. Most of the northern half of the site is not developed because of steeply sloping terrain.

Currently, the northeastern part of the site is used by JPL for project support, testing, and storage facilities, while the southwestern part houses most of the personnel, administrative, management, laboratory, and project functions of JPL. Further development of JPL is constrained because of steeply sloping terrain to the north, the Arroyo Seco wash to the south and east, and residential development to the west.

Located at the northern boundary of JPL is the Gould Mesa area (Figure 1-1). This area has widely separated small buildings and is used primarily by JPL for antenna testing. The distance between buildings is a result of the terrain and the need to isolate transmitting and receiving equipment. The relatively steep mountainside area between Gould Mesa and the well-developed area at JPL is unpopulated.

Presently, over 150 structures and buildings occupy the JPL site. Total usable building space is approximately 1,330,000 square feet, of which about 40,200 square feet is occupied by trailers and vans. A site facility map is included in Figure 1-2.

1.3.2 Site History

In 1936, Professor Theodore Von Karmen of Caltech and a group of students began testing liquid propellant rockets in the Arroyo Seco. Later, the testing became part of the activities of the Gugenheim Aeronautical Laboratory at the California Institute of Technology-GALCIT. In 1940,

the Army Air Corps provided funding for the first permanent structures built near the present-day site. By 1944, the site continued to grow and changed its name to the Jet Propulsion Laboratory, GALCIT. In 1945, the United States began purchasing the property. Ultimately, the site became known as the Jet Propulsion Laboratory, or JPL, and became a fully-owned Federal facility. In 1958, NASA took over control of JPL. Today, under a prime contract, Caltech performs research and development tasks at facilities provided by NASA which are located at the current site of JPL. Caltech also maintains the facilities as part of its contractual agreement with NASA.

For Caltech to accomplish the research and development tasks under its purview, various chemicals and materials have been utilized during the operational history of the site. The general types of materials used and produced include a variety of solvents, solid and liquid rocket propellants, cooling-tower chemicals, and chemical laboratory wastes. During the 1940s and 1950s, many buildings at JPL maintained a cesspool to dispose of liquid and solid sanitary wastes collected from drains and sinks within the building. These cesspools were designed to allow liquid wastes to seep into the surrounding soil. Present-day terminology for these subsurface disposal areas is "seepage pits." Some of the seepage pits may have received volatile organic compounds (VOCs) and other waste materials that are currently found in the groundwater. In the late 1950s and early 1960s, a sewer system was installed and the use of the cesspools for waste disposal was discontinued.

In 1980, analyses of groundwater from City of Pasadena (Pasadena) water-supply wells located in the Arroyo Seco, near JPL, revealed the presence of VOCs. Around the same time, VOCs were also detected in two Lincoln Avenue Water Company (Lincoln) water supply wells. Initially, the VOC concentrations were below state and Federal drinking water standards. Over time, however, VOC levels rose above drinking water standards. As a result, City of Pasadena and Lincoln Avenue wells near JPL were forced to stop pumping between 1985 and 1989 by the California Department of Health Services. In 1990, NASA funded the installation of a water-treatment plant in the Arroyo Seco so that the Pasadena wells could resume supplying water. By 1992, the Lincoln Avenue Water Company had funded and installed a water-treatment plant and had similarly restarted production.

In 1988, a Preliminary Assessment/Site Inspection was completed at JPL (Ebasco, 1988a and 1988b) indicating further site characterization work was warranted. In 1990, an Expanded Site Investigation was performed at JPL during which several groundwater monitoring wells were installed on-site (Ebasco, 1990a). VOCs were subsequently detected in on-site groundwater above drinking water standards and the site was ranked using the Federal Hazard Ranking System. In October 1992, the site was placed on EPA's National Priorities List (NPL) and became a CERCLA site. Since that time, a Remedial Investigation was completed characterizing the nature and extent of groundwater contamination (Foster Wheeler, 1999a).

During the groundwater investigation at JPL, a total of twenty-three groundwater monitoring wells were installed and routinely sampled within the study area. Eighteen (18) of the wells are located on the JPL site (OU-1) and another five (5) wells are located off-site (OU-3)

(see Figure 1-7). Of the twenty-three total wells, ten (10) are relatively shallow standpipe wells that have a single screened interval at the groundwater table. All of the shallow standpipe wells are located on the JPL site. The other thirteen (13) wells, including all of the off-site monitoring wells, are relatively deep, multi-port wells that contain five (5) screened intervals each and a Westbay® multi-port casing system to allow for the simultaneous compliance monitoring of each zone. The multi-port wells extend down to approximately 1,000 feet below grade and are used to identify the vertical extent of groundwater contamination and to evaluate the hydrogeological characteristics of the greater than 700-foot-thick aquifer.

1.3.3 Previous Investigations Related to the Soil and Soil Vapor at JPL

Previous investigations conducted at JPL prior to the RI are listed below, and complete discussions on these investigations are contained in the RI/FS Work Plan (Ebasco, 1993a) and the OU-2 RI report (Foster Wheeler, 1999b).

- LeRoy Crandall and Associates (1977a), *Report of Subsurface Investigation, Overall Investigation of Geology, Soils and Seismic Hazard, Seismic Safety Plan, Jet Propulsion Laboratory Site.*
- Agbabian Associates (1977), *Seismic Studies for the Jet Propulsion Laboratory Facilities, Parts I, II, and III.*
- LeRoy Crandall and Associates (1977b), *Report of Fault Hazard Study, Jet Propulsion Laboratory.*
- LeRoy Crandall and Associates (1981), *Dewatering Well System, Building 150, Jet Propulsion Laboratory, Pasadena, California.*
- Ebasco Services Incorporated (1988a and 1988b), *Preliminary Assessment Report for NASA-Jet Propulsion Laboratory and Site Inspection Report for NASA-Jet Propulsion Laboratory.*
- Richard C. Slade (1984), *Preliminary Hydrogeologic Assessment of Soil and Groundwater Monitoring, Jet Propulsion Laboratory, Pasadena, California.*
- Ebasco Environmental (1990a), *Expanded Site Inspection Report for NASA-Jet Propulsion Laboratory.*
- Ebasco Environmental (1990b), *Supplemental Information to the Expanded Site Inspection Report on the NASA-Jet Propulsion Laboratory.*
- Jet Propulsion Laboratory (1990), Untitled set of memoranda, laboratory analyses, notes, sketches, and other correspondence associated with the removal of storm drain catch basin and associated impacted soil.
- Ebasco Environmental (1991), *(Draft) Remedial Investigation/Feasibility Study Work Plan for NASA-Jet Propulsion Laboratory.*
- Maness Environmental Services, Inc. (1992), *Environmental Site Investigation and Soil Remediation, Jet Propulsion Laboratory, Pasadena, California.*

- Ebasco Environmental (1993b), *Contaminant Source Research (1990 to Present)* in *Work Plan for Performing a Remedial Investigation/Feasibility Study at the NASA–Jet Propulsion Laboratory.*
- Ebasco Environmental (1993c), *Pre-RI Investigation* in *Work Plan for Performing a Remedial Investigation/Feasibility Study at the NASA–Jet Propulsion Laboratory.*
- U.S. Environmental Protection Agency (1993a), *Aerial Photographic Analysis of the NASA Jet Propulsion Laboratory, Pasadena, California.*

1.3.4 Surface Features and Topography

JPL is located at the southern base of the San Gabriel Mountains. The northernmost portion of the site consists of Gould Mesa, a flat-topped southern promontory of the San Gabriel Mountains that rises 300 feet above the main area of the JPL complex. The remainder of the site is moderately sloped, and has been graded extensively throughout its development. The JPL facility varies in elevation from approximately 1,070 to 1,550 above mean sea level. A topographic map that includes JPL and surrounding areas is presented in Figure 1-3.

1.3.5 Geology

The JPL Thrust Fault (part of the San Gabriel Thrust Fault) runs east-west across the middle portion of the JPL boundaries (Figure 1-4). North of the JPL Thrust Fault, crystalline bedrock is encountered at approximately 2 to more than 100 feet below ground surface (bgs) (Crandall and Associates, 1981). South of the fault, the bedrock was encountered in groundwater monitoring wells at 550 feet and 725 feet bgs.

The local stratigraphy at JPL is characterized by unconsolidated alluvium sequences consisting of medium- to coarse-grained sand and gravel, interbedded with some fine sand and silt. The alluvium thickness north of the fault ranges from 2 to more than 100 feet above the crystalline bedrock and south of the fault the thickness could extend up to 1,100 feet above the bedrock (CH2MHill, 1989).

The average thickness of coarse sand intervals ranges from 15 to 20 feet, although beds thicker than 50 feet or more are common in some soil borings. Relatively thick intervals of gravelly sand (SP), sandy gravel (GP), and gravelly sand-sandy gravel (SP-GP) are also common beneath the site though they are slightly less abundant than the coarse sands. Average bedding thickness for these coarse-grained soil types ranges from 5 to 15 feet. Overall, the coarse-grained soil types (SP, GP, and SP-GP) constitute the thickest intervals of soil identified in the borings at JPL.

Fine-grained intervals of silt (ML) and silty sand (SM) are far less abundant in the soil borings than those composed of coarse sand and gravel. Beds of silt (ML) were identified in only a few borings throughout the site where they rarely exceeded 1.0 foot in thickness. Silty sand (SM) beds ranging from 0.5 to 10 feet in thickness are commonly interbedded with the coarser sand and gravel intervals in many locations, though they do not make up a large percentage of the total

thicknesses of the soil encountered during the OU-2 investigation. A generalized geological cross-section through the north central portion of JPL is presented in Figure 1-5.

Artificial fill materials were encountered at several locations where drilling and excavation activities were performed at JPL. These fill materials were typically observed immediately below asphalt pavements for roadways and parking lots, extending downward roughly 2 to 10 feet below ground surface. In some locations, it appears that the native soil was screened and re-graded to provide the fill materials. In other locations, the darker brown, greenish-brown, or reddish brown colors of the artificial fill contrasts with the colors of the native soil, indicating that the fill materials were imported.

1.3.6 Hydrogeology

The San Gabriel Valley contains distinct groundwater basins, including the Raymond Basin where JPL is located. The Raymond Basin is bordered on the north by the San Gabriel Mountains, on the west by the San Rafael Hills, and on the south and east by the Raymond Fault. The Raymond Basin provides an important source of potable groundwater for many communities in the area including Pasadena, La Canada-Flintridge, San Marino, Sierra Madre, Altadena, Alhambra, and Arcadia. JPL is located in the northwest portion of the Raymond (Groundwater) Basin.

North of the JPL Thrust Fault, groundwater primarily occurs in joints and fractures in the bedrock. Due to low porosity of the bedrock, it is considered non-water-bearing.

South of the JPL Thrust Fault, groundwater occurs in the alluvial deposits. For data presentation purposes, the aquifer beneath JPL has been divided into four "aquifer layers", which are separated by non-contiguous, low permeability silt layers. A conceptual model of the JPL aquifer layers is presented in Figure 1-6. It is noted that Figure 1-6 is only a conceptual representation of the site, and as such is not intended to be used as a basis of determining future actions at the site.

Aquifer Layer 1 constitutes the upper 75 feet to 100 feet of the saturated thickness. Aquifer Layer 2 underlies Layer 1 and is approximately 150 to 200 feet thick. Aquifer Layer 3 is approximately 200 to 300 feet thick and generally overlies on top of the crystalline basement complex beneath the study area. Layer 4 is present only at the far eastern end of the study area (Figure 1-6), is approximately 150 feet thick, and rests on crystalline basement rocks.

Depth to groundwater at JPL has ranged from 22 feet bgs to 270 feet bgs. This wide range of depth to water can be attributed to steep topography and also to seasonal groundwater recharge at nearby spreading grounds and the municipal production wells. The shallow groundwater is observed only in groundwater monitoring wells MW-1, MW-9, and MW-15 located near the mouth of the Arroyo Seco, where groundwater mounding is known to occur. The depth to groundwater in the area underlying the major portion of the site averages approximately 200 feet. Figures 1-7, 1-8, and 1-9 show groundwater elevation contours for Aquifer Layers 1, 2, and 3, respectively, during September 1996. The time frame of September 1996 was selected as this was

the only period for which water levels were available simultaneously for all the three Aquifer Layers with all nearby production wells operating. A monthly groundwater elevation monitoring program is currently underway at JPL for Aquifer Layer 1.

Detailed discussions of local and regional hydrogeology at JPL is presented in the OU-1/OU-3 RI report (Foster Wheeler, 1999a).

1.3.7 Sources, Nature, And Extent Of Soil Contamination

1.3.7.1 Potential Sources of Contamination

Chemicals and materials with a variety of contaminant properties have been utilized during the operational history of the site. The general types of materials used and produced include a variety of solvents, solid and liquid rocket propellants, cooling-tower chemicals, and chemical laboratory wastes. During the 1940s and 1950s, many buildings at JPL were constructed with a cesspool to dispose of liquid and solid sanitary wastes collected from drains and sinks within the building. These cesspools were designed to allow liquid wastes to seep into the surrounding soil. The present-day term for these subsurface disposal areas is "seepage pits." Some of the seepage pits may have received volatile organic compounds (VOCs) and other waste materials that are currently found in either the soil or the groundwater. In the late 1950s and early 1960s, a sanitary sewer system was installed and the use of the cesspools for waste disposal was discontinued.

Various "seepage pits" and other waste disposal areas were identified as possible locations of past chemical waste disposal during previous investigations. The locations of the seepage pits and other potential waste disposal areas are shown in Figure 1-10. Using the information from these prior investigations, an initial screening event was conducted in January 1994, consisting of soil-vapor probes installed at depths ranging from 6 to 20 feet (one depth per probe). Thirty-five soil borings (28 of which were subsequently converted to soil-vapor wells) were also drilled and sampled to characterize any contaminants that might be identified at potential source areas. Subsequent soil-vapor analyses were performed on samples collected from the soil-vapor wells to characterize the horizontal and vertical extent of soil-vapor contamination. Three test pits, located adjacent to surface water discharge points, were excavated and sampled in areas where surface contamination was suspected. Locations of the initial vapor probes are shown in Figure 1-11, and the soil boring and test pit locations are shown in Figure 1-12. Locations of the soil borings converted to soil-vapor wells are shown in Figure 1-13.

1.3.7.2 Nature and Extent of Contamination

Two types of data were collected during the RI: soil vapor data obtained from analysis of vapor drawn from the soil pore space, and data obtained from direct analyses of soil samples. Soil-vapor samples were analyzed for volatile organic compounds (VOCs), and soil samples were analyzed for a variety of elements and compounds as discussed in the following subsections. In this report, the terms "soil analysis", and "soil data" are used to refer to the direct analysis of soil

samples. Methodologies used in the remedial investigation are described in detail in the remedial investigation report (Foster Wheeler, 1990b), and are summarized below.

The general approach used in the investigation was to drill into the various waste disposal areas described in the previous section. The majority of the soil samples were collected during the drilling activities from multiple depths. Surface soils were not sampled for two main reasons. The primary reason is that large amounts of water were discharged into the waste disposal areas (along with other wastes) before the sewer system was installed. It is believed that contaminants were flushed into the deeper portions of the vadose zone (this has been confirmed, as the majority of soil contamination is present at depth). Secondly, the uppermost sampling depth was selected to correspond with the upper boundary of the original disposal area. Fill material used to cover the pits was not exposed to contaminants, and was not sampled. Surface soil samples were, however, collected from test pits located at the southeast edge of the site.

Most of the boreholes were subsequently converted to soil-vapor wells. During drilling, a field instrument [flame ionization detector (FID)] was used to detect VOC vapors in soil samples at 5-foot intervals for qualitative evidence of VOC vapors. The uppermost soil-vapor sampling probes were located to correspond with the estimated upper boundary of the original disposal area, and deeper probes were located at depths at which VOCs were detected using the FID during drilling.

It is noted here that, in accordance with the California Regional Water Quality Control Board, Los Angeles Region, guidances (RWQCB, 1992 and 1997) soil samples collected during drilling were not analyzed for VOCs because of disturbances to the sample caused by the air percussion drilling technique. However, the surface soil samples collected from the test pits were analyzed for VOCs.

Summarized in the following subsections are findings of the RI with regard to the nature and extent of contamination.

Soil Vapor Analysis

A total of seven soil vapor sampling events (including the initial soil-vapor survey) were conducted between January 1994 and June 1998. Quarterly soil-vapor sampling is currently underway at JPL as part of an ongoing soil vapor extraction (SVE) pilot test. All seven sampling events are discussed thoroughly in the OU-2 RI report (Foster Wheeler, 1999b). However, only the results for the seventh event (June 1998) are summarized here because that event is the most recent and, therefore, the most representative.

Volatile Organic Compounds (VOCs). During the course of the OU-2 RI, four VOCs were more frequently detected in soil-vapor samples at elevated concentrations. These four VOCs are carbon tetrachloride (CCl_4), trichloroethene (TCE), 1,1-dichloroethene (1,1-DCE), and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113).

Sampling results from Event 7 are presented in Table 1-1. The locations and total VOC concentrations are shown on Figure 1-14. Carbon tetrachloride, TCE, 1,1-DCE, and Freon 113 were the most frequently detected analytes in the soil vapor. While several other chlorofluorocarbons and chlorinated aliphatic compounds were sporadically detected, they were generally at lower concentrations. The locations and concentrations of analytes detected in soil vapor during Event 7 were consistent with sampling results from Event 6.

The estimated areal and vertical extents of soil-vapor contamination for CCl_4, Freon 113, TCE, and 1,1-DCE are shown in Figures 1-15 through 1-22, respectively. For the figures showing areal extents of contamination, results from Events 2 and 3 are also included. This information was provided because vapor wells sampled in Events 2 and 3 were not sampled during Event 7. Thus, the most complete and conservative estimates of areal extents of contamination are depicted. Horizontal and vertical distributions of total VOCs during Sampling Events 6 and 7, which are considered representative of current site conditions, are presented in Figures 1-23 through 1-25, respectively.

Soil Analysis

All soil sampling events consisted of collecting samples during the drilling and test-pit excavation events during the OU-2 RI, and each event is discussed thoroughly in the OU-2 RI report (Foster Wheeler, 1999b). The soil samples were analyzed for various parameters as discussed below. Locations and concentrations of organic compounds and cyanide detected in soil samples are shown in Figure 1-26.

Metals. Results from the analysis of metals are presented in Table 1-2. Where detected, metal concentrations were reasonably well correlated within the range of background levels measured for soils at JPL, and within the range measured for other California soils (Foster Wheeler, 1999b).

Arsenic (As) was detected in soil samples at concentrations slightly above the measured background values but well within the range measured for other California soils and are considered naturally occurring. Hexavalent chromium was detected at four locations and is generally considered not to occur naturally. However, there is no information indicating historic use of hexavalent chromium at JPL.

Semi-Volatile Organic Compounds (SVOCs). Only those SVOCs (not including PAHs) detected above the method detection limit (MDL) are summarized in Table 1-3. MDLs for all SVOC analytes are contained in Appendix F1 of the OU-2 RI report (Foster Wheeler, 1999b). Of the 73 samples analyzed for SVOCs, only the following four analytes were detected in JPL soils: bis(2-ethylhexyl)phthalate, butylbenzylphthalate, di-n-butylphthalate, and n-nitroso-di-N-dipropylamine. These compounds were detected only in near-surface soil samples from test pit Nos. 2 and 2A (TP-2 and TP-2A) with the exception of bis(2-ethylhexyl)phthalate, which was detected at depths of 30 feet or greater in seven soil borings. Contaminant n-nitroso-di-N-

propylamine was detected in one soil boring only [500 micrograms per kilogram (μg/kg) in soil boring No. 30 at a depth of 30 feet below ground surface (bgs)].

Bis(2-ethylhexyl)phthalate was detected in the seven soil borings at concentrations ranging from 86 to 1,900 μg/kg. In samples from TP-2, bis(2-ethylhexyl)phthalate was detected at a concentration of 440 μg/kg, and di-n-butylphthalate and butylbenzylphthalate were detected at concentrations of 250 μg/kg and 160 μg/kg, respectively. In samples from test pit No. 2A, butylbenzylphthalate was detected at a concentration of 75 μg/kg at a depth of 1 foot, and bis(2-ethylhexyl)phthalate was detected at concentrations of 480 μg/kg and 50 μg/kg at depths of 1 foot and 5 feet, respectively.

Polycyclic Aromatic Hydrocarbons (PAHs). PAHs were found in samples from two soil borings and three test pits along the southeast portion of the site that were located in areas suspected of prior waste disposal activities. Compounds detected included benzo(b)fluoranthene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, fluoranthene, indeno (1,2,3-cd)pyrene, phenanthrene, pyrene and, benzo(a)anthracene. The maximum PAH concentration measured in a soil sample was 110 μg/kg for fluoranthene in soil boring No. 12 at a depth of 10 feet. PAHs detected above the MDL collected from soil boring Nos. 12 and 30 and from test pit Nos. 2, 2A, and 3 (TP-2, TP-2A, and TP-3) are presented in Table 1-4.

Polychlorinated Biphenyls (PCBs). Two PCB congeners, Arochlor-1254 and Arochlor-1260, were detected only in samples from TP-2 at depths of 1 and 5 feet at concentrations of 270 to 21 μg/kg, respectively. An additional congener, Arochlor-1232, was detected at a depth of 5 feet in TP-2A. Analytical results for PCBs are summarized in Table 1-5.

Dioxins and Furans. Dioxin congener 1,2,3,4,6,7,8,9-OCDD was detected in TP-2 and TP-2A with concentrations of 9.2 and 5.8 μg/kg, respectively, at depths of 1 foot. Furans were not detected in any of the soil samples collected during the OU-2 RI field program. Analytical results for dioxins and furans are listed in Table 1-6.

Volatile Organic Compounds (VOCs) in Test Pits. Four VOCs (acetone, bromodichloromethane, chloroform, and methylene chloride) were detected in soil samples collected from the test pits. All concentrations reported were either equal to or less than the reporting limits, and the presence of these compounds are attributable to laboratory contamination or to runoff of facility irrigation water. The VOC analytical results are summarized in Table 1-7.

Total Petroleum Hydrocarbons (TPHs). TPHs believed to consist of lubricating or mineral oils were detected in 13 soil borings. The highest TPH concentration of 6,500 milligrams per kilogram (mg/kg) was from soil boring No. 1 at depth of 20 feet (tiny asphalt granules in the materials used to backfill a seepage pit); all other detects were at least one order of magnitude lower, and most were two or more orders of magnitude lower. These results are included in Table 1-8.

Tributytlin. Tributyltin was detected at the reporting limit of 1 μg/kg in both soil samples collected from test pit No. 2A at depths of 1 foot and 5 feet. Sampling results for tributylin are summarized in Table 1-8.

Cyanide and Nitrate. Results of cyanide (CN^-) and nitrate (NO_3^-) analyses are also presented in Table 1-8. Cyanide was detected in three samples from soil boring No. 30 at concentrations ranging from 74 μg/kg to 85 μg/kg. As shown in Table 1-8, NO_3^- was detected in virtually all soil borings. The widespread occurrence of NO_3^- in JPL soils can be attributed to the use of agricultural fertilizers in cropland plus equestrian activities prior to the establishment of JPL, fertilizer usage by JPL in landscaped areas, irrigation waters, as well as the historic use of cesspools on the site.

Perchlorate. Perchlorate (ClO_4^-), a non-volatile oxyanionic compound (salt), has been detected in groundwater beneath JPL, and is of major importance with regard to the groundwater (OU-1/OU-3) RI/FS. The identification of ClO_4^- as an environmental contaminant has occurred relatively recently due to refinements in analytical methodology for detection in groundwater. The discovery of ClO_4^- in the groundwater occurred after most of the OU-2 fieldwork was completed. Several of the deep soil-vapor wells (Nos. 32 through 39), which were the final wells constructed for the OU-2 investigation at the site, were drilled shortly after ClO_4^- was discovered in groundwater. However, during the drilling of these wells, there was no suitable method available for analysis of ClO_4^- in soils. Also, because all of the soil samples analyzed during the OU-2 RI were collected before ClO_4^- was known (or suspected) to occur at the site, or before there was a method for quantifying ClO_4^- in soils, soil samples were not analyzed for ClO_4^- during the OU-2 RI.

Finally, ClO_4^- is highly soluble, and is not believed to undergo appreciable adsorption in sands and gravels such as those present in the JPL vadose zone. ClO_4^- is therefore likely to be highly mobile in vadose zone soils at JPL. In addition, ClO_4^- concentrations in on-site groundwater monitoring wells MW-7 and MW-16 (the wells with the highest ClO_4^- concentrations) have undergone fairly wide fluctuations, but do not appear to be increasing with time (Foster Wheeler, 2000). Given the mobility of ClO_4^- in soils such as those present at JPL, the general lack of increase in ClO_4^- levels in on-site groundwater monitoring wells, and the fact that any potential releases probably occurred over 30 years ago, it is reasonable to assume that most, if not all, of ClO_4^- has been flushed through the vadose zone.

1.3.8 Contaminant Fate And Transport

The fate and transport characteristics of the constituents of interest identified in the soil and soil-vapor samples during the OU-2 RI included VOCs in soil-vapor samples, and various SVOCs (including PAHs), three PCB congeners, one dioxin congener, TPH, As, Cr(VI), tributyltin, NO_3^-, and CN^- in soil samples.

The VOCs were generally characterized as being volatile (from soil or from water), moderately soluble in water, and moderately adsorbing to soil organic carbon. Results from the OU-2 RI, as well as the OU-1/OU-3 RI (Foster Wheeler, 1999a), suggests that migration of VOCs to the ground surface and subsequent emission to the atmosphere is not likely. However, vertical downward transport of VOCs into groundwater has occurred, the extent and trends of which are well documented.

Semi-volatile organic compounds detected include PAHs, phthalates, and n-nitroso-di-n-propylamine. With regard to PAHs, volatilization is considered to be of minor concern. The PAHs detected in soil at JPL have low aqueous solubilities and relatively high Log(K_{ow}) values indicating that these compounds have a high potential to adsorb to the solid phase and are not expected to leach from soil into groundwater. Results from the OU-2 RI, as well as the OU-1/OU-3 RI, support this assertion since the majority of PAHs detects have been in samples collected from the upper 10 feet of soil and there is no significant evidence of their presence in groundwater.

Three phthalates and n-nitroso-di-n-propylamine were detected in soil samples collected near the surface in the vicinity of a suspected prior waste disposal area. In general, phthalates are characterized by low solubilities, low volatilities, and moderate to high partition coefficients and are considered relatively immobile in soil-water systems. The infrequency of detects in deeper soil intervals or groundwater at JPL reflects the immobility of these compounds. N-nitroso-di-n-propylamine was detected in only one soil sample. N-nitroso-di-n-propylamine has a lower affinity for the solid phase compared to the phthalates detected, but because it was detected only once and it has not been detected in groundwater, concerns regarding this compound are minimal.

Three PCB congeners were detected in soil samples collected from two test pits at JPL. Arochlor-1254 and Arochlor-1260 were both detected in two samples from TP-2 at depths of 1 foot and 5 feet. Arochlor-1232 was detected in one sample from TP-1A at a depth of 5 feet. PCBs are characterized by very low solubilities and high affinities for adsorption by soil, and they are, therefore, considered relatively immobile in soil-water systems. The absence of PCBs in deeper soil and groundwater at JPL reflects their immobility. Potential migration pathways for PCBs at JPL are most likely limited to eolian transport in soil or dust particulates.

One dioxin congener was detected in samples collected from TP-2 and TP-2A at depths of 1 foot. Dioxins were not detected in any other samples collected during the RI. The absence of this compound in deeper soils and groundwater at JPL may reflect its immobility in the JPL soil-water system. Potential migration pathways for this compound are considered insignificant, and are probably limited to airborne, or eolian, transport in soil or dust particulates.

Total petroleum hydrocarbons were detected in 14 soil borings at JPL. The types of petroleum compounds believed to be present in JPL soils are generally considered to be relatively insoluble and to adsorb strongly to soil particles, which limits their mobility in the soils. In addition, their tendency to volatilize is weak, and, therefore, transfer to the atmosphere would be negligible.

These compounds are potentially subject to biodegradation reactions, with the degradation rates varying based on conditions present in the soil.

Arsenic was detected in all but two soil samples collected at JPL, and its presence is believed to have resulted from naturally occurring minerals. Arsenic occurs naturally in soils in a variety of chemical forms, the behavior of which can vary based on soil conditions. Chromium was also detected in JPL soils. Two forms of chromium are found in the environment: the trivalent form, which is considered to be insoluble and immobile in soils, and the hexavalent form, which is much more soluble and can be mobilized in soils as water passes through. Hexavalent chromium, which is generally believed not to occur naturally, was detected at four locations at JPL.

Nitrate detected in JPL soils is believed to have resulted from agricultural and landscaping fertilizers, historic equestrian activities, irrigation waters, and cesspools on the site. Nitrate is readily soluble and mobile in most soil-water systems, as evidenced by its presence (at levels well below MCLs) in JPL groundwater (Foster Wheeler, 1999a). Nitrate can also be reduced biologically (by soil bacteria) under anaerobic conditions to form nitrogen gas, provided a suitable carbon source is available.

Tributyltin compounds are the main active ingredient in bactericides and fungicides used to control a broad spectrum of organisms in wood preservatives, marine paints, and in industrial water systems. In soil, tributyltin usually takes 1 to 3 months to degrade in aerobic conditions and more than 2 years to degrade in anaerobic conditions.

Cyanide was detected in soil samples from one borehole only. Cyanide forms a variety of complexes in environmental systems with metals and organic compounds, which vary widely in terms of their chemical properties.

The transport of VOCs to groundwater beneath JPL has been substantiated by the presence of VOC vapors at the vadose zone-groundwater interface. Migration of VOCs because of volatilization to air, or into basements and buildings is expected to be of little if any significance. Although the high vapor pressures favor volatilization, the vertical distribution of VOCs in the soil indicates that movement is in the downward direction. This is supported by OU-1/OU-3 RI groundwater data that show the presence of VOCs, but these data also suggest that this process is predictable and decreasing in significance. In addition, elevated VOC concentrations are found at depths greater than 20 feet.

Erosion and subsequent eolian transport of contaminants residing in surface soil and sediment [primarily SVOCs (including PAHs), PCBs, dioxin, and metals] are considered insignificant at JPL, because concentrations are generally low, and the affected area is very limited. In addition, migration of metals and organic contaminants in surface soils and sediments to deeper soil horizons is possible, although the data does not suggest that this is a significant means of transport.

The presence of contaminants in surface soil and sediment increase the probability of migration of surface runoff mechanisms to surrounding on- and off-site receptors, especially during periods of rapid rainfall and flash flooding. However, because concentrations are low, and the affected area is very limited, environmental impacts associated with surface run-off are expected to be insignificant. VOCs released at seepage pits and other source areas at JPL have migrated to groundwater. However, migration of other organic compounds detected at the site to the water table is considered improbable based on the data available from OU-2 and OU-1/OU-3.

Cr(VI) and As have also been detected in JPL groundwater. The presence of the Cr(VI) in groundwater is consistent with Cr(VI) in soil at the site, but occurrences in soil and groundwater are very localized. Arsenic was also detected in groundwater, but this has also occurred only in a very localized deep portion of the aquifer, and is believed to be naturally-occurring.

1.3.9 Risk Assessments

The baseline human health risk assessment (HHRA) and screening-level ecological risk assessment (ERA) were conducted in accordance with State of California Environmental Protection Agency Department of Toxic Substances Control (DTSC) guidance and standard U.S. Environmental Protection Agency (EPA) guidance on risk assessments as discussed in the OU-2 RI report (Foster Wheeler, 1999b). The purpose of the risk assessments was to focus the analytical results presented in the RI report on constituents of potential concern (COPCs), evaluate potential exposure pathways, and identify site areas potentially posing risk to human health and the environment.

1.3.9.1 Human Health Risk Assessment Results

The HHRA was conducted in accordance with DTSC and EPA published protocols (Foster Wheeler, 1999b). In addition, consultations with DTSC and EPA toxicologists were conducted during preparation of the HHRA, and this shaped and guided the development of the document. The HHRA presented analytical results for soil samples and soil-vapor samples collected from across the site, including areas of known or suspected contamination. Detailed results and methodologies used are presented in the OU-2 RI report (Foster Wheeler, 1999b).

Based on specific guidance from DTSC and EPA, the OU-2 HHRA assessed risks associated with exposure to surface soils, which represents the only direct exposure scenario. It is noted here that although groundwater contaminants originated in the soils, the OU-2 HHRA was not intended to assess risks associated with exposure to groundwater, which is thoroughly addressed in the OU-1/OU-3 HHRA (Foster Wheeler, 1999a). To assess risks associated with surface soils at JPL, contaminant concentrations measured in the upper 15 feet of soil for analytes detected in soil samples, and concentrations measured in the upper 30 feet for VOCs detected in soil-vapor samples were considered (Foster Wheeler, 1999b). Preliminary COPCs were identified as those organic chemicals detected within the specified depths at concentrations exceeding preliminary remediation goals (PRGs) for soils, and those inorganic chemicals detected within the specified depths at concentrations exceeding PRGs and background concentrations. Using this

methodology, Arochlor-1254, Arochlor-1260, arsenic, and hexavalent chromium were the only constituents identified as preliminary COPCs. Occurrences of these preliminary COPCs were localized in the following areas of concern: DP-2, DP-3, DP-4, WP-1/DP-1, and WP-4. Risk was then quantified for these five sites.

To ensure that human health is adequately protected, conservative concentrations, exposure parameters (commercial as well as residential land use scenarios), and toxicity assumptions were used in estimating potential risks in accordance with State of California and EPA guidance. Theoretical risks to human health predicted by this assessment are, therefore, likely to be an overestimation of actual risks. For each of the exposure populations, the HQ value or cancer risk for each chemical and exposure pathway (ingestion, inhalation, and dermal) was summed to produce total non-cancer risk HI values and cancer risks. The off-site resident population was excluded from the risk assessment. The negligible estimated risks for the on-site receptors support the exclusion of the off-site resident from the quantitative risk assessment because the relatively low exposure of the off-site resident to on-site soils will result in correspondingly lower risk estimates.

Based on the assumptions and methodologies used to conduct the risk assessment, it was concluded that no volatile chemicals detected in soil-vapor samples contributed to unacceptable risk to potential human receptors. The results of the analysis at each of the discharge points indicate that the non-carcinogenic and carcinogenic risks to potential on-site human receptors in these areas are negligible, therefore, no chemicals were designated as constituents of concern (COCs).

In summary, the OU-2 HHRA assessed risks associated with the upper 15 feet of soil at JPL. Arochlor-1254, Arochlor-1260, arsenic, and hexavalent chromium were the only constituents detected at concentrations above applicable PRGs, and potential risks were assessed for these constituents in accordance with State of California and EPA guidance. The results of the HHRA showed that the risks associated with JPL soils were negligible, and were within acceptable regulatory guidelines. It is stressed here that the OU-2 HHRA is not intended to assess risks associated with groundwater constituents. This was thoroughly addressed in the OU-1/OU-3 HHRA (Foster Wheeler, 1999a).

One additional minor point requires clarification. It is acknowledged that the PRG exceeds the detection limit for two dioxin congeners, 2,3,7,8-TCDD and all HxCDDs. However, at the time the analyses were conducted, the detection limits achieved were the lowest that could be achieved by the laboratory that specialized in dioxin and furan analyses. It is further noted that these dioxin congeners were not detected above the detection limit of 80 nanograms (ng)/kg in any of 41 soil samples analyzed. In addition, furans were not detected in any of 41 soil samples analyzed at a detection limit of 100 ng/kg. Finally, groundwater samples were analyzed for dioxins and furans during the OU-1/OU-3 RI, and these compounds have not been detected. Based on this information, it is not reasonable to expect that these compounds are present at the site.

1.3.9.2 Ecological Risk Assessment Results

Detailed results and methodologies used in the Ecological Risk Assessment are presented and discussed in the OU-2 RI report (Foster Wheeler, 1999b). Chemicals identified as COPCs include chromium, lead, mercury, vanadium, and zinc. All COPCs were quantitatively evaluated for the deer mouse and the American kestrel. Lead concentrations at WP-1/DP-1 had HQs exceeding 10 for both the deer mouse and the American kestrel. These species were used because they are relatively high on the food chain and, therefore, generally have the highest exposures to contaminants. This is because they consume other wildlife that bioaccumulate the contaminants.

These HQs are likely overestimated because of differences in the form of lead used to derive the toxicity values (organic lead) and the likely form of lead present on-site (inorganic lead). In general, organic lead is more toxic than inorganic forms. These HQs may also be overestimated because of the conservatism of the exposure parameters used in the risk assessment. For example, it is assumed that the lead concentration in the dietary intake of the deer mouse is equal to the concentration in soil. In nature, the diet of the deer mouse is largely composed of plants and seeds, which absorb lead from soils only in limited amounts. Animals with large home ranges, such as the American kestrel, are not likely to be at risk since they would potentially obtain only a small fraction of their diet from this location. Although the HQs are elevated at this location, it is important to note that lead concentrations are within the range of background values for Californian and the western U.S. soils. Thus, potential ecological risks are likely to be lower than indicated by the estimated HQ values.

All other COPC concentrations had HQs less than 1.0 for the American kestrel, or between 1.0 and 10 for the deer mouse. COPCs with HQs between 1.0 and 10 for the deer mouse included molybdenum and zinc at soil boring No. 23A and chromium and zinc at test pit Nos. 2 and 2A. Chemicals with HQs in this range are not expected to pose a risk to potential receptors due to the conservatism of the exposure parameters used and the uncertainties inherent in the ecological risk assessment (ERA). For example, the ERA assumes that the dietary COPC concentration for the deer mouse is equal to the maximum COPC concentration in soil and that all exposure and diet are from the location of the maximum COPC concentration. In reality, the dietary concentration would be much less because the receptor would be exposed to a variety of concentrations, ranging from non-detectable concentrations to the maximum. Therefore, no risk from exposure to the evaluated COPCs is expected at JPL and, thus, no chemical was designated as a COC.

1.4 CURRENT FIELD ACTIVITIES

A SVE pilot test was initiated at JPL in April 1998 and conducted through June 1998. The objectives of this test were as follows:

- Confirm the feasibility of using in situ SVE to remediate the VOC-impacted soils in OU-2.

- Obtain design parameters for implementation of a full-scale system (number of wells, well and screen depths, extraction flowrate/vacuum at each well, type and size of vapor treatment system).

The test consisted of applying a vacuum to a SVE well, and measuring various parameters including extraction vacuum, flowrate, vacuum responses at nearby soil vapor monitoring wells, and VOC trends in extracted vapors and monitoring wells. Initial results from the test indicated high vacuum responses at significant distances from the extraction well. To confirm these results, and to obtain additional information regarding the actual radius of influence, it was decided to extend the test for an additional 9 months, as discussed during the RPM meeting on July 16, 1998. This extended test started in November 1998, and is ongoing as of July 2000.

The SVE well is located at the approximate center of the area with the highest VOC levels. This well is screened at three discrete depths to allow for good vacuum distribution. Soil vapor is extracted with a skid-mounted extraction blower, and is treated using four carbon vessels (each containing 1,800 pounds of vapor phase granular activated carbon) in a series-parallel arrangement before discharging to the atmosphere.