CHAPTER 6. EXPOSURE ANALYSIS

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6.0 EXPOSURE ANALYSIS

6.1 Overview

Various SSFL activites have resulted in the release of toxic chemicals toxics into the groundwater, toxics were also carried by surface water beyond the property, and air toxics were released into the atmosphere (Chapters 1-5). The environmental health risk associated with resulting offsite SSFL contamination is a function of the degree of human exposure to those contaminants. Offsite exposure to site-associated chemicals would occur if those chemicals have migrated via various transport pathways (air, water, and soil) from the SSFL to receptor locations where chemical intake can occur via various exposure routes (e.g., inhalation, ingestion, dermal contact).

Given that human receptors continually change their locations and activities, quantifying individuals' potential exposure to specific chemicals in a dynamic environment is generally infeasible. Assessing exposure requires accurate meteorological data, chemical emission source data, geographical data, and population activity patterns. In the present SSFL study, due to significant gaps in data on temporal and spatial chemical releases and concentration monitoring data on chemical concentrations, absolute exposures and health risks cannot be determined. Therefore, it is more meaningful to to establish a range of relative exposures for receptor locations surrounding the SSFL community.

In selecting exposure scenarios, the study team used the standard EPA methodology (EPA 1992) as a basis for potential dose ranges or highest doses. The various corresponding EPA-advised assumptions are summarized in Table 6-3. The pertinent potential exposures to air, water, and soil at receptor locations is discussed in Section 6.2, and details regarding contaminant sources are also provided in Appendix D. The conservative assumptions used to describe exposure scenarios are presented in Section 6.3. Section 6.4 presents the potential exposure doses at various receptor locations, relative to acceptable dose levels derived from EPA's acceptable cancer risks or non-cancer reference doses.

6.2 Exposure and Potential Receptors

This section discusses potential exposure to COCs at various relevant receptor locations surrounding the SSFL, and also evaluates the associated major exposure pathways. Potential exposure pathways were first identified and evaluated based on available information (Appendix O) and site inspections. An exposure pathway was considered as a plausible exposure route provided the following criteria were satisfied:

1. There is a contamination source.[6.1]

2. There is a potential for chemical transport from the source to offsite receptor locations.[6.2]

[6.1] The main sources of potential offsite contamination associated with SSFL include emissions from rocket engine testing and related activities (engine cleaning), open-pit burning at the Area I Thermal Treatment Facility, groundwater stripping towers, NPDES surface water runoff, and DOE-related nuclear research and development activities. Potential contamination sources from SSFL are outlined in Appendix D, as well as Sections 3.2 and 4.1.

3. There are potential receptors (e.g., residential communities) or exposure locations (e.g., specific groundwater wells).

To identify potential exposure pathways, the study team reviewed available records (see the reference section and Appendix O for a list of reviewed documents) and compiled a list of contaminants (onsite and offsite; see Appendix H) detected above health-based standards (Appendix N). Maximum detected concentrations were then run through EPA's Risk Assessment Information System's (RAIS) Human Health Risk Exposure Model[6.3] to eliminate contaminants of no concern from further consideration based on conservative EPA-based exposure assumptions. Moreover, within the context of the present worst case scenario analysis, only contaminants that were present at concentrations that would have resulted in exposure levels leading to dose above acceptable levels were examined further. The team also identified potential exposure locations based on site visits and review of SSFL-related reports and archived documents. For example, assessments of site-related exposure issues, with respect to direct or indirect exposures, were based (in part) on visits to SSFL.

West Hills and Bell Canyon are areas that exemplify potential exposure issues that were revealed by site visits. For example, Dayton Creek flows from SSFL through Orcutt Ranch in West Hills. Orcutt Ranch is used for community gardens that grow flowers, fruit, and vegetables; thus there is a potential for indirect exposure to contaminated crops (via ingestion) if contaminants have migrated through Dayton Creek. The team identified a number of other exposure issues during the site visits to West Hills and Bell Canyon, as documented in Figures 6-1 and 6-2 and the accompanying text.

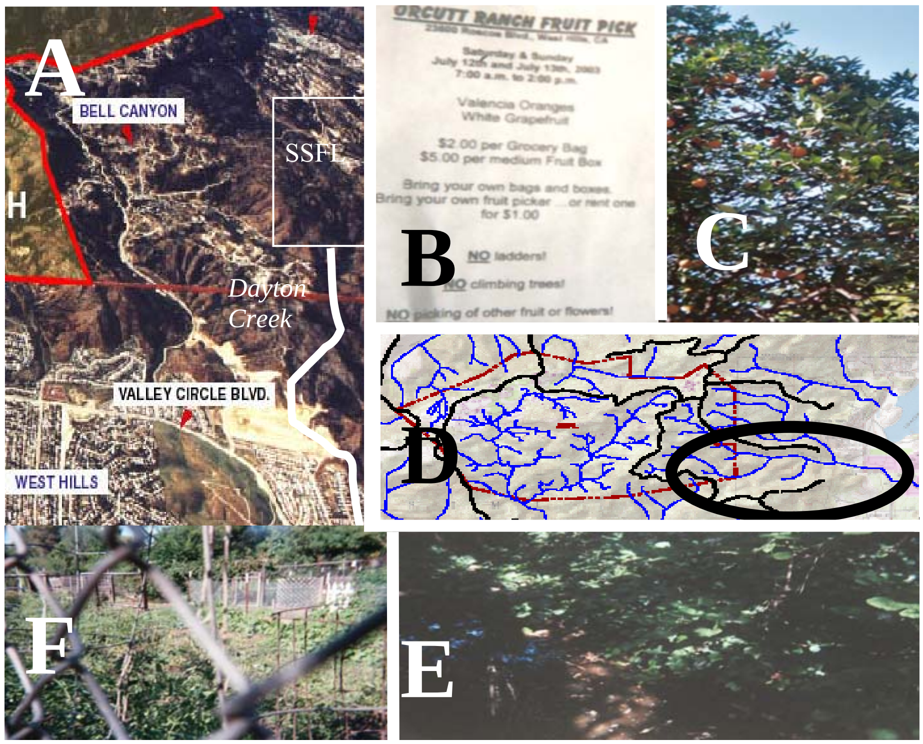
Contaminants found above health-based standards in Bell Canyon include beryllium, lead, and the manmade radionuclide thorium-228 (see Appendix H, Table H-4 and Table H-8). Each of these contaminants was also detected above health-based standards (Appendix N) at SSFL. Beryllium was used at SSFL from 1962 to 1967 and was found in air samples taken onsite from 1964 to 1969 (Appendix H, Table H-1). Lead was detected above health-based water standards in NPDES Outfall 001, which discharges into Bell Creek (Appendix H, Table H-4). Thorium-228, an alloying agent in certain metals used in the aerospace industry, has been detected onsite in Area IV groundwater around buildings T028 and 023 (at the ETEC) (DOE, 1997, 2004).

[6.2] The potential for contaminant transport via air, groundwater, surface water, and soil are discussed in Chapters 3, 4 and 5, respectively. Contaminants from SSFL were detected in offsite soil and groundwater. Areas in which contaminants were detected include the Brandeis-Bardin Institute, Sage Ranch, and Bell Canyon (McLaren Hart, 1993–1995; Ogden, 1998a; Appendix H). Monitoring data were not found for areas directly east of SSFL (Dayton Canyon, Lakeside Park, or West Hills). Contaminants potentially from SSFL (or other locations where Boeing-related activities were carried out) were detected in Simi Valley, Ahmanson Ranch, Chatsworth Reservoir and Canoga Park (MW, 2000, 2002; MWG, 2002; Klinefelder, 2000; Hughes, 1989; DWP, 2004; Lawrence Livermore, 1997). Other contracted sites where Rocketdyne-, Boeing-, and DOE-related operations were conducted include the De Soto site (which generated radioactive effluents; see Lawrence Livermore, 1997) and the Hughes facility in Canoga Park, south of Chatsworth Reservoir (soil and groundwater contaminated with VOCs and radioactivity; Hughes, 1989). The De Soto site's operations terminated in 1995, and Hughes operations terminated in 1976.

[6.3] The Risk Assessment Information System (RAIS) website is comprised of tools for conducting human and ecological risk assessments. The site was last viewed on Jan 17, 2006 at: http://risk.lsd.ornl.gov/homepage/rap_tool.shtml. Information from this website was sponsored by the U.S. Department of Energy (DOE), Office of Environmental Management, Oak Ridge Operations (ORO) Office and the DOE Center for Risk Excellence. The Human Health Risk Assessment tool is located on this site at: http://risk.lsd.ornl.gov/prg/for_sel_data.shtml.

Clearly, surface water transport and air dispersion from SSFL to the Bell Canyon area create the potential for exposure (Figure 6-2) to the above SSFL contaminants. Therefore the study team evaluated various hypothetical exposure scenarios to screen the range of plausible exposures.

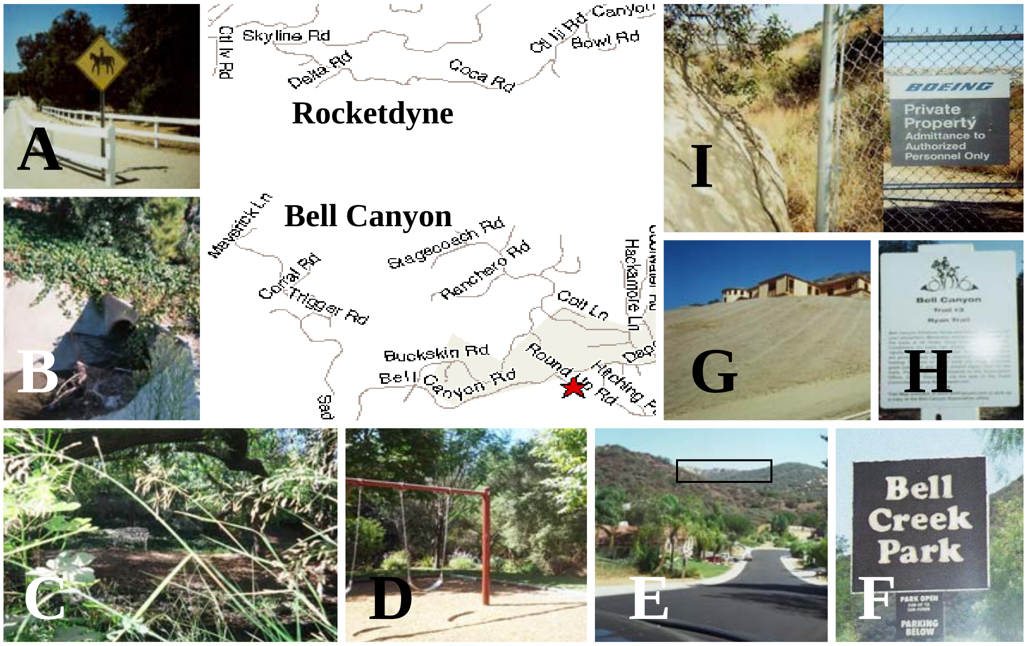
Figure 6-1. Exposure Issues in West Hills



The letter in each element corresponds to an issue described below:

A. Surface water from Area I (Happy Area) flows east via Dayton Creek into West Hills.Note that perchlorate (see Appendix H, Table H-1) has been found on site in Area I, which could potentially contaminate surface water runoff from this area. Note also that one of Dayton Creek's depositories is Orcutt Ranch (located at 23600 Roscoe Boulevard, West Hills, California), which has a community orchard and public-use garden.
B. The Orcutt Ranch Park supervisors organize seasonal fruit picks at Orcutt Ranch, as evidenced by this leaflet (collected by the UCLA study team) from the supervisors.
C. Fruit and vegetables grown at Orcutt Ranch—oranges, lemons, lettuce, etc.—could bioaccumulate certain contaminants. This suggests the need for monitoring.
D. Surface runoff and groundwater emanate from SSFL (Area I) and join to form the headwaters of Dayton Creek.
E. Dayton Creek runs through Orcutt Ranch in unlined channels.
F. Some of the land at Orcutt Ranch was allocated to the community for public-use gardens. Flowers, fruit, and vegetables are grown in these plots.

Figure 6-2. Exposure Issues in Bell Canyon



The letter in each element corresponds to an issue described below:

A. Bell Canyon is a dry canyon with many horse paths, both along Bell Creek and up into the hills where SSFL is located. Resuspension of soil due to horse movement could expose people to contaminants (if the soil is contaminated) via inhalation and ingestion. Note that soil contaminants were detected in this community (Ogden, 1998a; Section 5.1).

B. There are numerous surface runoff channels in the neighborhoods surrounding Bell Creek that are easily accessible to children. Surface water runoff of contaminants from SSFL to Bell Creek was detected in NPDES outfalls that run into Bell Creek (Appendix H). Moreover, it is estimated that about 90 percent of the NPDES treated waste flows (via Bell Creek) through Bell Canyon (Techlaw, 1990).

C. A summer camp sponsors softball activities near Bell Creek and children were observed wading through the creek, which is shallow enough for crossing, to obtain stray balls.

D. A playground is located within 10 feet of the creek. There are no warning signs about water quality in view.

E. Rocket engine testing areas are within 1 or 2 miles of Bell Canyon homes. Although the Delta and Coca, Area II, engine-testing areas are not presently operational, they have been a source of air emissions during past rocket testing activities in these areas.

F. Bell Creek Park is the site of various recreational activities: softball, picnics, summer camp, horse stable with riding trails, and hiking trails are located next to the creek.

G. Residential construction in the area could expose workers and residents to resuspended soil.

H. There are hiking trails and horseback riding in the hills between the community and SSFL where exposure to surface runoff or soil deposited during the rainy season may occur.

I. The SSFL site is not secure and children could easily enter it. This is evident by the unsecured gate between SSFL and Coolwater Road.

In summary, the primary contaminant transport routes associated with SSFL are surface water flows and runoff,[6.4] groundwater transport (Chapter 4),[6.5] and air dispersion (Chapter 3). Sections 6.2.1, 6.2.2, and 6.3 draw on the available data and information from site visits to discuss potential exposures with respect to groundwater wells in Simi and San Fernando Valleys, residences, recreational areas, and community gardens within 2 miles of SSFL.

6.2.1 Exposure to Contaminants in Groundwater and Surface Water

The groundwater and surface water pathways are highly interconnected, as discussed in Section 4.2. Therefore, this section discusses potential exposures associated with both of these media. Potential contaminant sources and associated migration pathways away from SSFL are discussed in Sections 4.1 and 4.2.

6.2.1.1 Groundwater Exposure

Information on the presence and usage of wells in the communities surrounding SSFL is paramount to assessing the potential contribution of the groundwater pathways to exposure to various chemicals associated with SSFL. Contaminated wells could impact both primary exposure via water drinking and secondary exposure linked to crop irrigation wells or livestock wells. Wells surrounding SSFL have been used for drinking water, various household purposes (e.g., showering and garden irrigation), and livestock, agricultural, industrial, or commercial (i.e., potable water distribution) purposes.

Quantitative assessment of exposure to contaminants via groundwater and surface water exposure pathways must consider source releases (e.g., NPDES discharges), onsite and offsite contamination, groundwater well distribution and use, population distribution, recreational facilities and activities, and development- and construction-related activities. Unfortunately, detailed data for the above are lacking for the constantly changing SSFL and its surroundings. Nonetheless, in order to evaluate the potential for exposure via potable water use, it is essential to review available information regarding potable wells in the SSFL area.

Contaminants have been detected offsite (at groundwater wells and NPDES Outfalls 005 and 006; see Appendix H, as well as Sections 4.2, 4.3, 5.1, and 5.2), which suggests that contaminants may have migrated from SSFL to offsite wells. Unfortunately, surveys of drinking water and irrigation wells could not be found and not all responsible agencies have cooperated in providing such pertinent information to the UCLA review team.[6.6] The limited available information indicates that wells have existed within 1 mile of SSFL (Techlaw, 1990). It has been reported that wells were used in areas north, northwest, northeast, and east of SSFL for livestock, irrigation, and/or domestic purposes (Table 6-1; Techlaw, 1990), and groundwater in San Fernando and Simi Valleys is also extensively used as a source of drinking water.

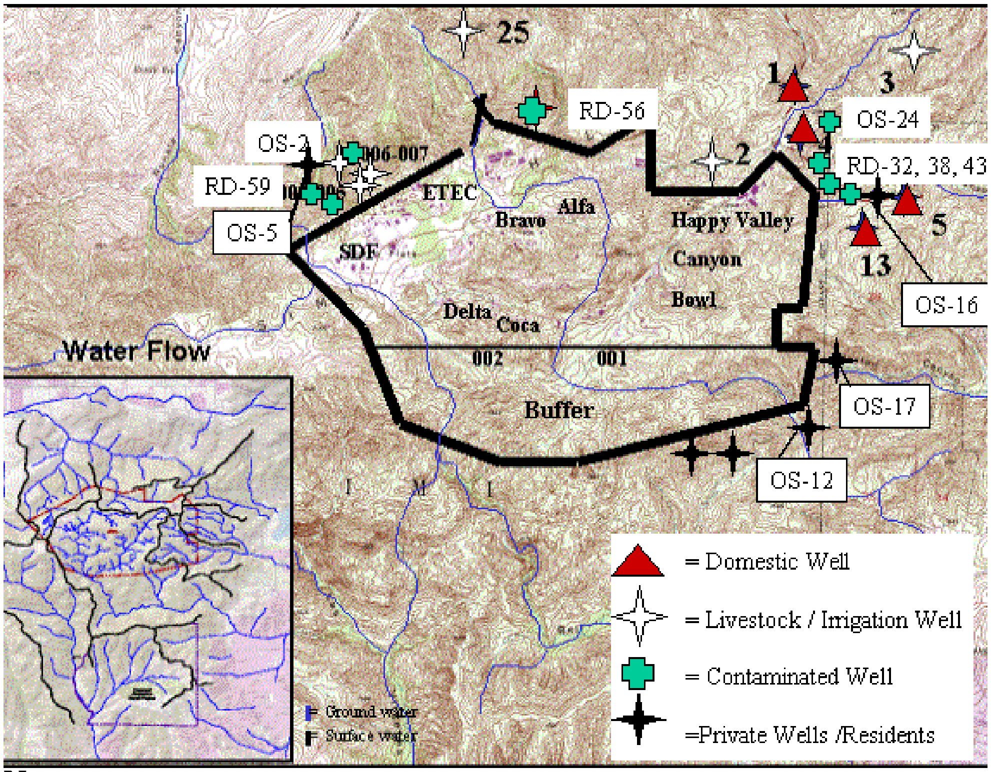
[6.4] Surface water from SSFL (Areas I, II, III, and IV) runs off at multiple locations, including the NPDES outfalls and Dayton, Woolsey, Bell, Meier, Runckle, Black, and Box Canyons.
[6.5] This analysis treats groundwater and surface water as an interconnected pathway (see Section 4). Surface water to groundwater paths exist, as do groundwater to surface water pathways—for example, artesian wells 2,000 feet north of SSFL (Bathtub 1 listed in Table 4-2 is one such artesian well; note that not all potential artesian sources have been adequately characterized).
[6.6] See Appendix J for correspondence regarding identification of potable water and irrigation wells.

The extent of groundwater contamination in West Hills, Canoga Park, and Chatsworth is difficult to determine due to the typically low groundwater level in the wells the above areas. Over a decade ago it was suggested that if any of these wells are contaminated they may serve as another potential source of contaminated groundwater for human receptors (ERC, 1990b). However, the transport routes (groundwater and surface water) between these valleys and SSFL must first be clearly identified to establish if there is indeed a connection between contaminants in these offsite wells and contaminants found at SSFL.

The present use and water quality of private wells is unknown and not all offsite wells could be located based on the available information. A list of offsite wells sampled by Rocketdyne (Boeing) and found to be contaminated is provided in Table 6-1. Wells are indicated in Figure 6-3. Wells denoted as 'RD' are Rocketdyne monitoring wells and do not pose exposure risks as the only identified purpose of these wells is to monitor subterranean groundwater flow for potential offsite contaminant migration. Other offsite wells (OS) are domestic, irrigation/livestock, and/or private/residential wells. If contaminants were detected within these wells or in nearby RD wells, exposures to the identified contaminants may have occurred. The closest boundary wells or springs associated with offsite residents are identified in Figure 6-3 (Techlaw, 1990; ERC, 1990b). These include OS-2 and OS-5 (private livestock wells) about 1,000 feet from the northwest boundary of the site), OS-16 (a domestic well about 500 feet east of RD-32 and 800 feet from the northeast boundary [Area I], south of Woolsey Canyon), OS-17 (a domestic well about 200 feet east of the SSFL boundary in an undeveloped buffer below Area I), and OS-12 (a spring southeast of the site). Note that OS-16 and OS-17 have been used for domestic purposes but it is unknown if they are currently in use (ERC, 1990b).

Having reviewed monitoring data, information on groundwater wells, and information from visits to the SSFL and surrounding communities, the study team concluded that exposure to contaminated groundwater should be considered in a conservative exposure analysis. (That is, an analysis that considers exposure to contaminated groundwater even if the affected population is small unless there is clear evidence that wells surrounding SSFL have not been used for drinking, irrigation, or other activities that could lead to direct or indirect contact with contaminated groundwater.) Accordingly, exposures via ingestion, inhalation, and dermal contact—as well as secondary exposure by vegetable ingestion—were considered for various exposure scenarios (residential, occupational, and recreational), as detailed in Sections 6.3 and 6.4. Maximum contaminant concentrations detected in offsite groundwater were used in the exposure analysis. Some of the primary contaminants considered are TCE and its degradation byproducts (1,1-DCE, 1,1-DCA, cis-1,2-DCE, and vinyl chloride), trans-1,2-DCE, perchlorate, carbon tetrachloride, PCBs, benzene, chloromethane, manganese, TCDD-TEQ, lead, arsenic, tritium, thorium-228, radium-226, and cesium-137. The contaminants considered in the analysis (see Appendix H for a complete list) are known to have been produced or used at SSFL (Section 1.2). Potential receptor areas considered in the exposure evaluation include residential areas served by Southern California Water Company and residential locations with private wells within 1 mile of SSFL.

Figure 6-3. Proximity of Private/Residential, Domestic and Livestock/Irrigation Wells to SSFL



Note: Residential / private wells are identified with boxed ID well numbers that correspond to the Well IDs in Table 6-1.

Table 6-1. Locations of Contaminated Offsite Groundwater Wells

Well ID	Direction from Site	Location	Comments	Contaminant(s)
OS-2	NW	BBI; Tapo Canyon and Walnut St.; 1,750 feet from NW boundary	Private well: livestock	Fluoride
OS-5	NW	BBI; Los Angeles Ave. and Stow St.; 1,100 feet from NW boundary	Private well: livestock	Chloromethane
OS-24	NE	~750 feet NE of SSFL; closest to RD-38A	Furthest observed offsite TCE migration; Chatsworth Formation well	TCE
RD-32	NE	Sage Ranch		Manganese
RD-38	NE	Sage Ranch near main gate, NE of Area I		1,1-DCE, TCE, 1,1-DCA, cis-1,2-DCE, benzene
RD-43	NE	Woolsey and Canyon Rd., near NE Area I		Lead
RD-56	N	BBI boundary, north of Areas II and III	Currently in undeveloped BBI buffer	TCE, trans-1,2-DCE, cis-1,2-DCE, vinyl chloride
Bathtub well #1	N	BBI	Well closed in 2003; listed as domestic (otherwise reported as livestock)	Perchlorate
RD-59	NW	West of Area IV		Perchlorate, carbon tetrachloride

Note: BBI=Brandeis Bardin Institute

6.2.1.2 Surface Water Exposure

Surface water flow from SSFL (Areas I, II, III, and IV) is known to exist at multiple locations, including the NPDES outfalls as well as Dayton, Woolsey, Bell, Meier, Runckle, and Black Canyons (primarily during heavy rainfall events). Only one major offsite monitoring study of surface water was available at the time of the UCLA study (McLaren Hart, 1992–1995). The McLaren-Hart study assessed surface water and sediments for radionuclides, organic compounds, and priority pollutant metals in two areas north of SSFL: BBI and SMMC.

Surface water runoff can transport contaminants offsite. For example, Dayton Canyon Creek flows from SSFL into Orcutt Ranch and thus represents a concern with respect to contamination of fruit and vegetables grown in the area. The potential impact of NPDES runoff into Bell Canyon Creek also merits consideration with respect to dermal exposure (see Figures 6-1 and 6-3). Surface water from the Area I TTF discharged into the Perimeter Pond, which is part of SSFL's reclaimed water system (Rockwell International, 1992). During rainfall events, the Perimeter Pond can overflow into NPDES Outfalls 001 and 002 to the south of the facility, which in turn discharge into Bell Canyon Creek (Rockwell International, 1992). Any contaminants carried with the NPDES outfall streams could then drain into southern Bell Creek as well as northwestern Meier and Runckle Creeks, which drain into the Arroyo Simi in Simi Valley. Surface water runoff can flow, during heavy rainfall events, from Dayton and Woolsey Canyons (east of SSFL) and Black Canyon (northeast of SSFL).

It is eported that there is some surface water drainage through residential communities (east, northeast, northwest, and south of SSFL) and summer camps in BBI and Bell Canyon. Unfortunately, surface water runoff from ephemeral sources (i.e., rainfall) has not been adequately monitored. The McLaren-Hart study reported that decreasing levels of PCBs, TCDD-TEQ, asbestos, and mercury in samples collected further from SSFL suggested that the above contaminants may have migrated via drainages from the Sodium Disposal Facility (SDF) to offsite areas (McLaren Hart, 1993). However, monitoring for that study was not done in areas downstream of the Sodium Reactor Experiment complex (SRE) and the RD-51 watershed where soil samples were found with radiation levels significantly above background (cesium-137 and plutonium-238). Also, surface water samples were not taken north of NPDES Outfalls 005–007 or the area of Meier Creek downstream of these NPDES outfalls. The study team found no surface water monitoring for Bell Creek and rainfall runoffs.

Given the lack of surface water monitoring data, the study team used data from NPDES outfalls—which have been regularly monitored—in conjunction with the McLaren-Hart study results to assess various scenarios of direct and indirect exposures via surface water (e.g., ingestion, inhalation, and/or dermal exposures), as described in Sections 6.3 and 6.4. The study team considered the following contaminants, detected at NPDES outfalls above health-based standards: chromium, lead, and heptachlor to the south (Appendix H, Table H-4) and chloride, DEHP, PCB-1254, lead, beryllium, chromium, benzene, nickel, cadmium, zinc, perchlorate, radium-225 and -228, and strontium-90 to the northwest (Appendix H, Tables H-6 and H-9).

6.2.2 Exposure to Contaminants in Soil

This section discusses the potential for offsite exposures to contaminated soil. People can be exposed to soil contaminants through dermal contact, inhalation, and incidental ingestion of soil particles. Exposure can also occur via secondary pathways—edible crops that have taken up contaminants. The study team considered various exposure scenarios for offsite soil contamination, as detailed in this section and Section 6.3. (Potential sources of soil contamination are discussed in Chapter 5; the primary routes of transport, air and water, are discussed in Chapters 3 and 4.)

Two offsite monitoring studies reported offsite soil contamination in areas south and north of SSFL (Ogden, 1998a; McLaren-Hart, 1993, 1995). Contaminants detected above health-based standards in these studies included beryllium, arsenic, lead, potassium-40, thorium-228 and -232, tritium, cesium-137, plutonium-238, radium-226 and -228, and strontium-90. Offsite surface soil contamination above health-based standards (residential soil screening levels) was detected northwest of SSFL at BBI (arsenic), and southeast and south (arsenic[6.7] and beryllium[6.8]) of the facility in Bell Canyon. Monitoring data for areas to the west and east were requested but not provided to the UCLA study team.

Exposure to contaminated soil via inhalation, ingestion, and dermal contact could occur when soil is resuspended during residential construction, hiking, horseback riding, gardening, and secondary exposure from exposed livestock and crops. For example, the 1997 Boeing (Rockedyne) NPDES Annual Report noted that livestock had entered the SSFL grounds. As the report states:

> *"It was discovered that livestock from the neighboring property had been entering the RD facility through a break in the fence located by the sampling basin for outfall 006 (northwest). This situation existed for approximately 3 weeks."*

It was also observed by these reviewers that avocado and orange groves exist northwest of SSFL at BBI and that many residents south of SSFL at Bell Canyon have private gardens. Site visits to Bell Canyon also identified alternate routes of exposure to these contaminants. Both of these areas have summer camps (Alonim at BBI and Bell Canyon Summer Camp in Bell Canyon), so consideration of susceptible populations (children) and their outdoor activities is warranted.

6.2.3 Exposure to Contaminants in Air

People can be exposed to air contaminants associated with SSFL if those contaminants, once emitted, are dispersed to certain locations. Unfortunately, ambient monitoring data on hazardous air pollutants associated with SSFL are lacking. Therefore, the study team developed emissions

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[6.7] All soil contains some arsenic. Naturally occurring arsenic is commonly found in southern California soils at levels of 5 to 20 mg/kg (AEHS, 2003). Levels found off site of SSFL are between 1 and 14 mg/kg (south) and 8 and 24 mg/kg (north). Onsite levels vary from 1 to 21 mg/kg. See Appendix H for details.

[6.8] It is important to note that arsenic and beryllium are listed among the EPA's 53 priority PBT chemicals. PBT pollutants are chemicals that are persistent, can bioaccumulate, and are toxic in the environment, and thus pose risks to human health and ecosystems.

estimates for specific COCs. Different emission sources (Appendix S) were considered, including rocket engine testing (RET), TCE emissions from rocket engine cleaning (RET-TCE), thermal treatment facilities (TTF), and air stripping towers (ST). The team estimated chemical-specific emission rates based on information on site activities, reported chemical usage, TRI-reported emissions, rocket engine testing and cleaning, air stripping, open pit burning, and emissions from contaminated soil.

This study's air exposure analysis (Sections 6.2 and 6.3; see also Chapter 3) is a conservative assessment of a range of potential inhalation exposure scenarios. Highly conservative asssumptions were used in these scenarios in order to bracket the upper exposure range and provide a relative ranking of potential doses for various receptor locations of concern. While it would be of great interest to determine each individual's exposure in the SSFL region, lack of monitoring data, emission data, population dynamics and activity patterns makes such an anlysis infeasible.

To be conservative, the present study considered worst-case scenarios based on the maximum emission rates. Air dispersion modeling was performed (see Chapter 3 and Appendix I) and maximum estimated annual emission rates for periods of similar activity were used to estimate contaminant air concentrations at different receptor locations to identify areas of potential exposure concern. The air dispersion analysis considered the impact of emission periods, emission source locations, area topology, and meteorology. The team assessed the maximum contaminant concentrations for potential receptor communities within 50 kilometers, among them Simi Valley, Brandeis Bardin Institute (BBI), Sage Ranch (SR), Santa Susana Knolls, Dayton Canyon, West Hills, Chatsworth, Bell Canyon, Canoga Park, Woodland Hills, and Hidden Hills (Table 6-2; see Appendix T for a complete list of locations and estimation of relative exposure levels for the contaminants of concern presented here).

Table 6-2. Partial List of Potential Air Contaminants and Receptor Locations of Concern

	Contact Location	**Time**	**Chemical**	**Exposure**
1	West Hills, Bell Canyon, Simi Valley, Dayton Canyon, Woodland Hills, Chatsworth, Hidden Hills, Santa Susana Knolls	1959–2004	TCE	Inhalation
2	West Hills, Bell Canyon, Simi Valley, Dayton Canyon, Woodland Hills, Chatsworth, Hidden Hills, Santa Susana Knolls	1959–1994	Hydrazine	Inhalation
4	West Hills, Bell Canyon, Simi Valley, Dayton Canyon, Woodland Hills, Chatsworth, Hidden Hills, Santa Susana Knolls	1955–1976	UDMH	Inhalation
5	Dayton Canyon, West Hills, Bell Canyon, Woodland Hills	1963–2004	MMH	Inhalation

6.3 Exposure Scenarios

An exposure scenario is a set of parameters and assumptions that specify how exposure of a receptor population or an individual takes place. The outcome from assessing an exposure scenario is an estimate of potential lifetime-average exposure dose for the target contaminant, typically in units of mg/kg/day. An exposure scenario generally includes facts, data, assumptions, and inferences pertaining to exposure settings, the exposed population, and intake and uptake routes. In the present analysis, three specific conservative scenarios were established: residential (people living in the SSFL area), occupational (people working in the SSFL area) and recreational (people using recreational facilities in the SSFL area). The various scenarios (Table 6-3) were based on either site-specific conditions when available or the standard EPA-suggested assumptions. The study team used highly conservative assumptions in these scenarios in order to establish the upper exposure range and provide a relative ranking of potential doses for various receptor locations of concern.

All potential exposure pathways were assessed for each of the three scenarios (i.e., residential, recreational, and occupational). For example, residential exposure to TCE was evaluated from all media (soil, water and air) and for each potential exposure route (inhalation, ingestion, dermal, secondary exposure via vegetable ingestion) (Table 6-3). In the most conservative estimate, maximum concentrations found in water, soil, and sediment in each area (north, northeast, northwest, south, southeast, southwest, and east of SSFL) were assumed to be the prevailing concentrations over the period of exposure. In assessing exposure to air contaminants emitted from SSFL, the study team considered the change in concentrations over the years in relation to emissions from SSFL (Appendices R and T). However, the inhalation exposure estimates are conservative in that the highest annual emission rate from a given source was used to represent emissions over periods of similar activity[6.9]. For example, the maximum annual emission rate for hydrazine released during RET at the STL-IV site between 1953 and 1977 was during 1968. This annual hydrazime emission rate from this site was then applied for each year with comparable activity levels (in this case during the entire 1953-1977 period).

Extensive development of the areas surrounding SSFL did not occur until the late 1960s and early 1970s. USGS maps (USGS, 1952, 1967) indicate that fewer than six buildings were present in the areas directly bordering SSFL before 1967, with an approximate near-border population of 20 individuals. Given the above, a 30-year exposure period was assumed to be a reasonably representative period of exposure to soil and groundwater contaminants in communities surrounding SSFL. The exposure period for air contaminants was taken to be the duration for which air emissions were reported. For carcinogens, the average daily exposure was calculated using the standard 70-year lifetime averaging period. For non-carcinogens, the average daily exposure was determined over a 30-year period for soil and water contaminants and the actual reported emission period for air contaminants.

[6.9] Additional details wer provided in Appendix T. Maximum concentrations resulting from unit emission rates for each activity were identified at various receptor locations from all potential emission-specific sources (STL-IV, APTF, Bravo, etc.; see Appendix T, Table T-1.) The above information was then utilized to ascertain, for each activity (e.g. TCE use), which source had the greatest contribution to chemical-specific emissions associated with the exposures for the selected receptor locations. Maximum emission rates for each activity, from emissions during years of similar activity levels (Appendix S), were then identified (Tables T-2) and applied as stated above.

Table 6-3. Scenario Assumptions

Pathways Assessed	Scenario		
	Recreational	**Occupational**	**Residential**
Soil ingestion	Exposure frequency = 75 day/yr Exposure time = 1 hr/day Ingestion rate = 0.0001 kg/day	Exposure frequency = 225 day/yr Exposure time = 1 hr/day Ingestion rate = 0.0001 kg/day	Exposure frequency = 75 day/yr Exposure time = 1 hr/day Ingestion rate = 0.2 kg/day
Vegetable ingestion	—	—	Exposure frequency = 350 d/yr Ingestion rate = 0.2 kg/day
Groundwater ingestion from private wells	Exposure frequency = 45 day/yr Exposure time = 1 hr/day Ingestion rate = 0.05 L/day	Exposure frequency = 225 day/yr Ingestion rate = 0.8 L/day	Exposure frequency = 350 d/yr Ingestion rate = 2 L/day
Groundwater dermal contact from showering	—	—	Exposure frequency = 350 d/yr Exposure time = 0.24 hr/day
Groundwater inhalation during household use	—	—	Exposure frequency = 350 d/yr Inhalation rate = 20 m^3/day
Surface water dermal contact	Exposure frequency = 45 day/yr Exposure time = 1 hr/day	—	Exposure frequency = 45 d/yr Exposure time = 1 hr/day
Air inhalation	—	—	Exposure frequency = 365d/yr Exposure time = 24 hr/day Inhalation rate = 20 m^3/day

Note: An adult receptor (body weight 70 kg) was assumed for all scenarios and pathways to systematize the exposure methodology for comparison and exposure ranking purposes. A 30-year exposure to maximum detected concentrations was assumed for exposure to water and soil contaminants to enable comparative analysis of receptor locations and exposure pathways. This exposure duration is appropriate because major development of the area surrounding SSFL did not begin until the late 1960s and activities such as rocket engine testing declined significantly during the early 1990s. Exposure to air contaminants was estimated over the duration of the emission period for each chemical.

6.4 Dose Estimation and Dose Ratios

6.4.1 Exposure Doses

A conservative estimate of the average daily dose can be obtained as follows (USEPA, 1989):

$$ADD\ (Average\ Daily\ Dose; mg/kg/day) = \frac{\sum_{i=1}^{N}\left(C_j I_j F_E t_E\right)_i}{M_B t_T} \qquad (6.1)$$

in which C_j is the concentration of chemical j in the medium of concern (e.g., mg/m^3 air or mg/L water), I_j is the intake rate of the medium phase (e.g., m^3 air/day or liter water/day), F_E is the frequency of exposure (number of exposure events/year), t_E is the event exposure period (e.g., days) to concentration C_j for the specific exposure event, subscript i designates the exposure year and N is the total number of exposure years, M_B is the total body mass, and t_T is the total time period (measured in days) over which the average daily dose is sought (e.g., lifetime). The lifetime average daily dose (LADD) was calculated from Equation 6.1, applied over the various exposure periods over the number of exposure years and then setting the averaging time period (t_T) to the default EPA standard lifetime assumption of 70 years. In the present analysis, the exposure period for offsite soil and water contaminants was assumed to be 30 years, while the exposure period for air contaminants was taken to be the actual period of emissions as ascertained from reviewing site activities (Chapter 3 and Section 6.3). Three primary routes of exposure to contaminants were considered: inhalation, drinking water, and skin absorption. Exposure via these routes can result from contact with contaminated air, soil, sediment, groundwater, and surface water and from ingestion of contaminated food.

In order to rank potential exposure sites and contaminants of concern, this report presents the dose ratio, DR,

$$DR = LADD / ALADD \tag{6.2}$$

in which ALADD is the acceptable lifetime average daily dose. The ALADD was determined based on the standard assumption of an acceptable disease (e.g., cancer) risk of 1×10^{-6} (see Appendix R, Table -4 and Appendix T, Table T-4). For carcinogens, the ALADD was calculated as the 1×10^{-6} risk divided by EPA's reported cancer slope factor. For non-carcinogens, the ALADD was taken to be EPA's chronic RfD for non-carcinogens. When comparing receptor locations and/or chemicals in terms of the DR, one should note that there are uncertainties with respect to the dose estimate. Thus, such comparisons are only useful as a qualitative means for ranking locations of concern and identifying areas of exposure concern. Note also that DR values are not additive across chemicals or locations.

Dose estimates were based on monitored and estimated offsite concentrations and standard default exposure parameters (see Appendix V). Given that monitoring data were inadequate for the purposes of a quantitative risk analysis, a highly conservative approach was undertaken: the maximum detected point concentrations and the maximum air emission rates for periods of similar emissions activity were assumed to be accurate for the entire exposure period. Doses for residential, recreational, and occupational scenarios were calculated for ingestion, inhalation, and dermal exposures (with EPA-default assumptions as in Table 6-3 above and as discussed in Appendix R).

In the above approach, if a DR falls below 1, one can be reasonably assured that the potential health impacts associated with the specific chemical and receptor location would be of little concern. DRs greater than 1 would suggest that there may be reason for concern and thus for a more detailed investigation to either confirm or rule out the potential for health impacts for the specific chemical and location of concern. Such an investigation would have to consider population dynamics and possibly involve additional field monitoring and retrospective studies. Because the population around the SSFL has changed continually since the facility was established, and because of the lack of adequate continuous offsite contaminant monitoring data, it is not feasible to conduct quantitative site-specific exposure and risk assessments to assess the actual health impact of the SSFL on the surrounding communities. One can, however, assess the potential exposure for various hypothetical scenarios to capture worst cases and to provide a dose-based ranking of chemicals of concern in locations of potential exposure cocnern.

The maximum detected concentrations of specific chemicals in soil and water monitoring data, collected over the lifetime of the facility, were used in dose calculations for the various receptor locations (Appendix H). DRs for soil and water contaminants are relevant for the areas surrounding detection locations, but the study team assumed that maximum detected concentrations were present for 30 years at all detection locations that were accessible to the public. Receptor locations for exposure-based ranking were identified based on the levels of contaminants detected in water and soil at locations of potential exposure concern, the time period of contaminant detections in soil and water, potential exposure routes, and estimates of the size of the potentially affected population (Table 6-4).

Receptor air concentrations were estimated (Chapter 3 and Appendix T) based on air dispersion simulations (Appendix I) using onsite meteorological data (Appendix I) and emission estimates for 1953 through 2004 (Appendix S). Concentrations of air contaminants were estimated at various receptor locations (Table 6-6 and Appendix T) for different emission sources (RET, RET-TCE-associated emissions, TTF, and air stripping towers).[6.] The study team took a conservative approach in which the highest emission rates (g/s) to be used for each source/receptor combination (Appendix S) were first identified[10]. The team then selected the maximum concentrations (μg/m^3) associated with each source for various receptors around SSFL, considering the release scenarios detailed in Appendix I.

The contaminants considered in the analysis are presented in the following Appendices: H (monitoring data), S (air emissions), T (inhalation dose calculations), and R (soil and water dose calculations). The specific locations considered in the comparative (ranking) exposure analysis for soil and water contaminants are marked in Table 6-4 and Figure 6-4. Receptor coordinates for the assessment of the air inhalation pathway are identified using the grid shown in Figure 6-5.

Table 6-4. Potential Pathways of Exposure to Soil and Water Contaminants with Dose Ratios Greater than One for Communities Surrounding SSFL[a]

Exposure or Detection Location[b]	**Year Detected**	**Chemical**	**Potential Media of Exposure**	**Potential Exposure Pathways[c]**	**Toxicity[d]**
Brandeis-Bardin Institute (1)	1992	Arsenic (8–24 mg/kg)	- Air - Soil -Vegetables/fruit	- Inhalation - Incidental soil ingestion - *Crop ingestion*	Carcinogen, cardiovascular, skin, bladder
Northeast of facility (2)	1994	TCE (10–900 μg/L)	- Air - Water wells - Vegetables/fruit	- *Inhalation* - Contact - Water ingestion - Crop ingestion	Carcinogen, liver, kidney, central nervous system
Northeast of facility (2)	1996	1,1-DCE (19 μg/L)	- Air - Water wells - Vegetables/fruit	- *Inhalation* - Water ingestion - Crop ingestion	Carcinogen, liver, kidney, lung
Northeast of facility (2)	1994	Vinyl chloride (64 μg/L)	- Air - Water wells - Vegetables/fruit	- Inhalation - Water ingestion - *Crop ingestion*	Carcinogen, liver, central nervous system
Bell Canyon (3)	1998	Arsenic (1–14 mg/kg)	- Air - Soil - Vegetables/fruit	- Inhalation - Incidental soil ingestion - *Crop ingestion*	Carcinogen, cardiovascular, skin, bladder

[a] Population estimates from Ventura County 75.03 Census Tract at a distance of about 1 mile surrounding SSFL. See Chapter 1 for additional details regarding population density.
[b] Well locations are identified by numbers (in parentheses) corresponding to the locations marked in Figure 6-4.
[c] Dominant potential exposure pathways are indicated in italics. The individual dose ratios for the intake pathways are provided in Appendix R, Table R-5.
[d] "Toxicity" represents the primary target organ of the chemical. It is based on toxicity summaries from ATSDR (2000–2003) and IRIS (EPA, 2004; see Appendix F).

[6.10] Maximum emission rates for each chemical (tons/year) were identified for each source (e.g., RET) from emission inventories (1953–2004) (Appendix T, Table T-2). Maximum emission rates were selected for worst-case scenario analysis.

Specific contaminants and exposure locations of concern at which the DRs were estimated to be above 1 are summarized in Tables 6-5 and 6-6 (analyses details are provided in Appendices R and T). DRs for exposure to soil and groundwater contaminated with TCE, vinyl chloride, and 1,1-DCE were significantly above 1 in the northeast area for the residential exposure scenario (Table 6-5). DRs above 1 were also determined for inhalation exposure to TCE and hydrazine and its derivatives in multiple receptor locations around the SSFL (Table 6-6).

DRs above 1 were also obtained for exposure to arsenic. Arsenic was detected at significant levels at Santa Monica Conservancy, Brandeis-Bardin and Las Virgenes Creek above health-based standards in soil samples (detections: 1-24 mg/kg; RSSL=0.39 mg/kg). This is 2-62 times in excess of health-based residential soil screening limits. However, it is unclear if these arsenic levels were above natural area background levels. Arsenic is naturally occurring in soil and groundwater as a result of releases from erosion of natural minerals deposits,, though human activities can also lead to arsenic contamination (ATSDR, 1990). Background concentrations of arsenic in California can be as high as 2.3 to 11 mg/kg, according to 1986 California soil samples (surface to about 2.5 feet below surface; Hunter, 2002). Unfortunately, the determination of background samplescollected from areas between Bell Canyon and SSFL in the McLaren/Hart studies (1993; 1995) was inadequate. Therefore, it is not possible with the present monitoring data to determine if the present levels of arsenic are indeed above expected background and/or to identify any specific sources of offsite arsenic.

Note also that DRs for perchlorate from contaminated groundwater in Simi Valley were generally low (up to DR=2 for direct groundwater ingestion; Appendix R, Table R-5), even assuming 30 years of exposure at maximum detected levels. However, recent offsite monitoring has detected perchlorate on the eastern side of SSFL (Allwest Remediation, 2005). On June 18 and 20th, plant debris and plant leaves from plants with new growth were collected along side Dayton Canyon Creek (Allwest Remediation, 2005). The results of these analyses demonstrated high levels of perchlorate ranging from 32 to 42 mg/kg on plant leaves, and from 42 to 57 mg/kg in plant debris (Appendix R, Table R-5; Allwest, 2005). If this vegetation had been edible it would have resulted in DRs ranging from 13 to 24 for chronic ingestion. This is of concern as this area has never been adequately characterized, despite the fact that runoff from Happy Valley where perchlorate was used and has since been detected, runs into Dayton and Woolsey Canyons. See Appendices H and R for offsite levels of perchlorate used in the analysis and the resulting DRs (Table R-5).

The range of DR values reflects the uncertainty in the estimates given the variability of the assumed exposure scenarios and associated parameters (see Tables 6-5 and 6-6). For example, in some scenarios it is assumed that residents drink local groundwater. This may be true for a select community east and north of the facility, but not for residents of Bell Canyon, where there are no known potable water wells. Similarly, exposure via ingestion of vegetables only applies to residents growing fruit and vegetables and eating them, whereas incidental ingestion of soil could affect all residents. It is also important to recognize that the DR values are for long-term exposure of residents (>30 years; Table 6-5) in the communities surrounding SSFL, and are based on maximum area-specific concentrations of offsite contaminant contaminants. Thus these DRs may not reflect realistic exposures for all residents. They were estimated for screening purposes and are presented here for the purpose of identification and ranking of areas of potential exposure concern.

Offsite DRs greater than unity suggest the potential for past or continuing community exposure, based on worst-case scenarios, and thus potential for adverse health impacts. Specific chemicals, potential exposure routes, and locations of such concern include:

1. Long-term (>30 years) residential exposure to TCE, vinyl chloride, and 1,1-DCE within SSFL's offsite TCE plume bounds, via extended use of private water wells north and northeast of the facility, soil vapor intrusion and inhalation, or from chronic area-grown crop ingestion.

2. Long-term residential exposure (>30 years) to arsenic (source unknown) via chronic area-grown crop ingestion in Bell Canyon, Brandeis-Bardin, and potentially all areas north and east of SSFL, including Simi Valley, Dayton Canyon, West Hills, and Canoga Park.

3. Long-term (>40 years) residential exposure to TCE via inhalation of emissions from SSFL in West Hills, Black Canyon, Dayton Canyon, Bell Canyon, Simi Valley, Hidden Hills, Santa Susana Knolls, Woodland Hills, Canoga Park and Chatsworth..

4. Long-term (>30 years) residential exposure to hydrazine and its derivatives via inhalation of emissions from SSFL in West Hills, Black Canyon, Dayton Canyon, Bell Canyon, Simi Valley, Hidden Hills, Woodland Hills and Canoga Park.

5. Residential exposure of children to lead (source unknown) via incidental soil ingestion / inhalation, or from chronic area-grown crop ingestion in Bell Canyon and areas east of the facility; as well as extended use of private water wells or habitual home-grown crop ingestion in areas east of the facility.

6. Potential residential exposure to perchlorate (source suspected to be SSFL) via chronic ingestion of groundwater or area-grown crops in areas east of SSFL (Dayton Canyon, West Hills, Woolsey Canyon).

Figure 6-4. Potential Soil and Water Contamination Exposure Points

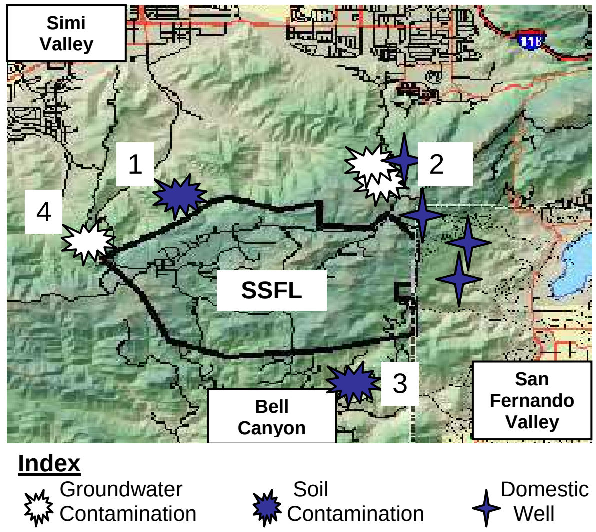
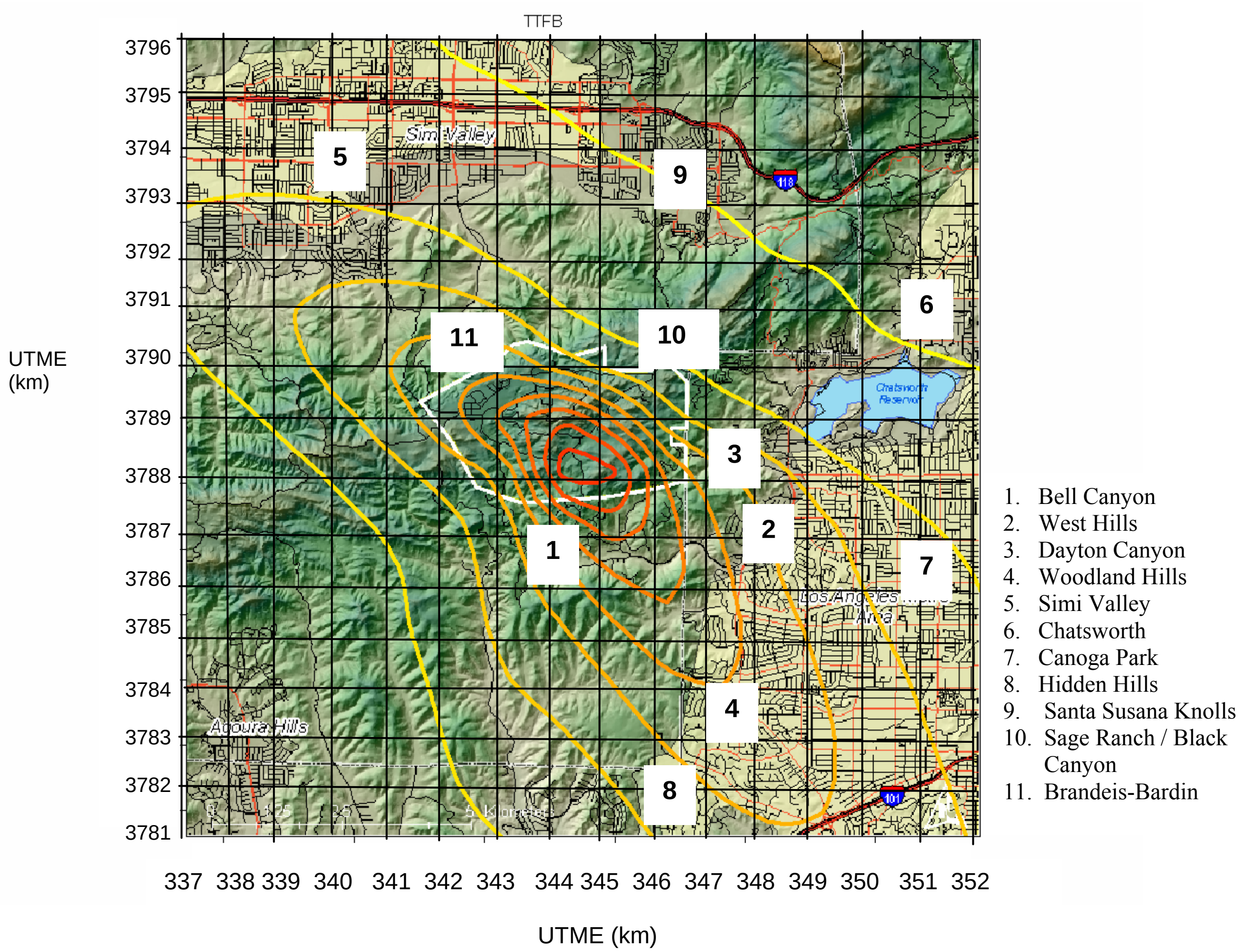


Figure 6-5. Coordinates of Receptor Communities Surrounding SSFL Used in Inhalation Dose Analysis



Note: The SSFL area is bounded by the white border.

Ranking of receptor sites based on the available monitoring data, modeling of available emission data, and the estimated Dose Ratio values (DRs), identified two areas of potential exposure concern (Tablel 6-5): (1) drinking water wells north and east of the facility and (2) soil in neighborhoods south (Bell Canyon), north, and east of the facility. With respect to wells north and east of the facility, note that previous SSFL studies (ATSDR, 2000; EE, 1989; ERC, 1990b; GRC, 1988a, 1988b) have assumed that there are no functioning wells in this location, but no recent well surveys in these areas have been conducted. Therefore, there is merit to conducting a comprehensive water well survey to enable quantitative exposure and risk assessments for these populations. It is important to recognize that due to the lack of monitoring data for areas east of SSFL, there is much uncertainty about exposure analysis for those areas. For a better assessment of exposure to the east of SSFL, there is a need for contaminant monitoring in the outfalls, streams, and soil.

The DRs determined for the air contaminants TCE and hydrazine were derived from a conservative analysis based on estimated emissions and dispersion modeling (Appendices S and I). Table 6-6 presents the range of potential long-term inhalation DRs (30-50 years of exposure) to contaminants from single sources to multiple sources (i.e. lowest DR for hydrazine exposure from rocket engine testing (RET) alone; highest DR for hydrazine exposure from RET and open pit burning (TTF) combined). Clearly, there is uncertainty in the analysis since the concentrations are derived from estimates based on available data. However, it is important to recognize that DR values are for *long-term* exposure of residents in the communities surrounding SSFL (Table 6-6). Such high DR values suggest that there is merit in more detailed investigation of the health impact of emissions of TCE and hydrazine and its derivatives. Ranking of the various receptor sites based on modeled emission estimates, and the estimated Dose Ratios (DRs), identified as areas of potential exposure concern those with DR values above unity (Table 6-6). For TCE exposure these areas include the Brandeis Bardin Institute, West Hills, Black Canyon, Dayton Canyon, Bell Canyon, Simi Valley, Sage Ranch, Hidden Hills, Woodland Hills, Canoga Park, and Chatsworth. The DR ratios for hydrazine were significantly lower compared to TCE. However, DR ratios above unity were encountered for the same areas as for TCE with the exception of Santa Susana Knolls and Chatsworth for which the DR values were consistently below unity. Additional information regarding receptor locations and contaminants of concern is provided in Chapters 8 and 9.

Table 6-5. Exposures of Concern Due to SSFL Activities (Dose Ratios[a] >1) Based on Offsite Monitored Soil, Groundwater and Vegetation Concentrations

Contaminant	Exposure Location with Respect to SSFL	Medium	Pathway	Scenario		
				Recreational	Occupational	Residential
TCE	Northeast (0.01–0.9 mg/L)	Groundwater	Ingestion	0–14	12–1,100	48–4,200
			Inhalation	—	—	230–21,000
			Dermal	—	—	12–1,000
			Veg. ing.	—	—	44–4,000
Vinyl chloride	Northeast (0.064 mg/L)	Groundwater	Ingestion	3	270	1,100
			Inhalation	—	—	120
			Dermal	—	—	29
			Veg. ing.	—	—	2400
1,1-DCE (vinylidene chloride)	North (0.019 mg/L)	Groundwater	Ingestion	—	23	89
			Inhalation	—	—	200
			Dermal	—	—	5
			Veg. ing.	—	—	20
Perchlorate	East (32-57 mg/kg)	Vegetation [b.]	Veg. Ing.	—	—	13-24

[a] Dose ratio is the ratio of daily lifetime average daily dose (LADD) to acceptable lifetime daily dose (ALADD =1x10^{-6} / Cancer Potentcy Factor (CPF) for 1 × 10^{-6} risk of cancer or ALADD= chronic Reference Dose (RfD) for non-carcinogens). [b.] Vegetation sampled here was not edible. This exposure scenario assumes similar levels could exist in areas along Dayton Creek; residents who grow and chronically eat vegetables in this area may be at risk.

Table 6-6. Lifetime Inhalation Exposures of Concern Due to SSFL Activities Based on Single- and Multiple-Source Inhalation Dose Ratios[a] (DRs) Derived from Air Dispersion Modeling and Air Emission Estimates

Location	TCE	Location	Hydrazine Derivatives[b]
Brandeis Bardin Institute[c]	17-503	Bell Canyon	3–35
West Hills	47-314	West Hills	2-14
Black Canyon	8-304	Dayton Canyon	2-11
Dayton Canyon	36-265	Woodland Hills	0–8
Bell Canyon	40-241	Canoga Park	0–7
Simi Valley	30-229	Black Canyon	1-5
Sage Ranch[c]	2-87	Simi Valley	0–4
Hidden Hills	30-86	Brandeis Bardin Institute[c]	1-3
Santa Susana Knolls	10-75	Hidden Hills	0–3
Woodland Hills	7-74	Sage Ranch [c]	0-2
Canoga Park	10-72	Chatsworth	≤1
Chatsworth	8-72	Santa Susana Knolls	<0

(a) Dose ratio (DR) = lifetime average daily dose/acceptable lifetime daily dose (ALADD). The ALADD is determined based on 1 × 10^{-6} risk of cancer as determined by EPA's Cancer Slope Factor. DRs were estimated based on maximum reported (or estimated) annual source emissions from 1953–2004 (Appendix S) and are representative of maximum receptor-specific modeled concentrations estimated from air dispersion analysis (Appendix I). Inhalation DR calculations are presented in Appendix T. The reported range of dR values includes both DRs from single and multiple source emissions. Dose ratios from multiple emission sources were obtained by adding the doses due to exposure from these multiple sources.
(b) Hydrazine derivatives include hydrazine, and UDMH (asymetrical dimethyl hydrazine).
(c) DRs presented in Appendix T for Brandeis Bardin Institute were multiplied by 0.25 to reflect summer only residency. DRs presented in Appendix T for Sage Ranch were multiplied by 2/7 to reflect weekend use only.