Draft Preliminary Site Evaluation

Santa Susana Field Laboratory (SSFL)
Ventura County, California
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Executive Summary

The Santa Susana Field Laboratory site is in the Simi Hills area of Ventura County, California. Located on approximately 2,668 acres, the site has been used as a rocket engine testing facility since 1948. At that time, few people resided in the area, but in the 1980s and 1990s there was a large increase in population. Approximately 3,100 people reside within one mile of the site boundary, based on spatial analysis of 1990 census data.

In response to a petition request, ATSDR held public availability sessions at three different locations in the area in the fall of 1999 to gather information on the health concerns of community members. More than 250 community members attended those meetings, and other community members have presented ATSDR with written comments and concerns. This report addresses the concerns of the community and is a preliminary assessment of the potential for adverse human health effects from past, present, and future activities at the Santa Susana Field Laboratory site based on currently available information.

ATSDR has also reviewed five epidemiologic studies from the Santa Susana site. Two were detailed health studies of workers at the site, and three were brief evaluations of community cancer registry data conducted in response to concerns that community members expressed about cancer occurrences in the area.

Process operations and activities at the Santa Susana site have resulted in the release of chemicals and radionuclides to the environment. The release of hazardous substances does not necessarily result in harm to humans. There must be human contact with these substances at levels of health concern before there is a potential for exposure-related health effects. Human contact of hazardous substances may occur through the air, soil, water, or food chain. ATSDR has evaluated these pathways relative to chemical and radioactive releases from the Santa Susana Field Laboratory.

This is a preliminary evaluation of the potential exposure pathways and associated health studies which ATSDR has reviewed for the Santa Susana site. Based on currently available data:

- The preliminary results of the exposure pathway analyses for air, ground water and surface water, and soil and sediment indicate that it is unlikely that people living in communities near the site have been exposed to substances from the site at levels that would have resulted in adverse health effects.
- Although chemicals and radionuclides were released from the site, the likelihood of those releases resulting in human exposure is limited by a number of factors, including; 1) the distance from the release sources to the offsite residential areas that results in rapid dispersion and degradation of oxidants and solvents in air; 2) the predominant wind patterns that normally blow away from the nearest residential areas; 3) other meteorological conditions at the site such as the atmospheric mixing height; and 4) drawdowns in ground water levels that reduce the rates of contaminant migration. Considering these factors, it is unlikely that residents living near the site are, or were exposed to SSFL-related chemicals and radionuclides at levels that would result in adverse human health effects. Changes in site operations, such as reduced frequency of rocket engine testing, discontinuation of trichloroethylene use, and shut down of nuclear operations make it unlikely that future exposures to the offsite community will occur.
- A more in-depth evaluation of exposure pathways that addresses past, current, and future exposure to chemicals and radionuclides from the SSFL should be conducted to improve the assessment of potential offsite exposures and public health implications associated with this site. Such an assessment must be facilitated through community outreach and participation and must include health education activities. We further recommend that this assessment address the following related issues:
- More in-depth evaluation of airborne chemical releases from SSFL operations, including air dispersion modeling of past accidents and disposal activities, and compilation and use of a consistent, site-specific meteorological data set to improve the assessment of past exposures to these substances.
  - Development of a regional hydrogeological flow model and additional monitoring at down-gradient springs or seeps in Simi Valley and Santa Susana Knolls to evaluate the potential for deep fracture flow and potential future exposure. Also, even though it may not be related to SSFL, additional source characterization of the perchlorate detection in Simi Valley should be conducted.

- Additional radiological characterization of Area IV with more sensitive instrumentation and appropriate grid spacing to assure a lower detection limit.

- A re-analysis of the cancer registry data including additional years of newly available cancer data and updated demographic information should be conducted to see if the apparent increase in the incidence rates of bladder and lung cancers persist. A more in-depth evaluation of cancer data should be conducted that addresses environmental exposures from the SSFL, possible confounding exposures from other nearby contaminant release sources, and residential histories.

Agency for Toxic Substances and Disease Registry

Santa Susan Field Laboratory

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Introduction

Scope of Report

The Agency for Toxic Substances and Disease Registry (ATSDR) received a petition to conduct a public health assessment of the Santa Susana Field Laboratory (SSFL) site in Ventura, California. To determine whether ATSDR would accept the petition request the agency assembled a team of environmental health professionals to visit the SSFL site and review and evaluate the available environmental and health information. In addition, the National Aeronautics and Space Administration (NASA) has requested that ATSDR conduct a public health consultation regarding ground water contamination at the SSFL site.

ATSDR visited the SSFL site from October 3 to 8, 1999. The purpose of the visit was to see thesite operations first-hand, meet with members of the surrounding community, and interview siteand regulatory agency personnel. The site team also conducted three public availability sessions tocollect information from the community about their health and environmental concerns.Specifically, this report includes (1) observations from the site visit, (2) a preliminary evaluationof available information related to chemicals and radionuclides released from the SSFL site, andan evaluation of the environmental pathways by which the surrounding community may beexposed to these substances, (3) a summary of the health and environmental concerns of thesurrounding community, and (4) a preliminary evaluation of the public health implications of theSSFL site on the surrounding community.

This report is comprised of five sections. This introductory section outlines the scope of thisreport, provides a brief overview of the SSFL site operations and history, and describes thedemographic characteristics of the community living adjacent to the SSFL facility. TheCommunity Concerns and Health Studies Section presents a summary of the community's healthand environmental concerns that were collected by the ATSDR site team, and a review of healthstudies that have been conducted for SSFL workers and the surrounding community.

The Exposure Pathways Analyses discusses the chemicals and radionuclides released to air,ground water and surface water, and soil and sediment from the SSFL. It also describes theadequacy or limitations of the data available for evaluating each pathway and the potential forcommunity exposure to contaminants via these pathways. In the Public Health Implicationssection, ATSDR considers the results of the exposure pathways analyses together with thecommunity concerns and available health studies to determine the potential for health impact tocommunities surrounding the SSFL. The Conclusions and Recommendations summarize thefindings of this preliminary evaluation including the potential for public health hazard posed bythe SSFL as well as gaps in the available health or environmental data and information. It alsomakes specific recommendations for follow-up activities to address the health issues or data gapsidentified in this report.

Site Operations and History

The Santa Susana Field Laboratory (SSFL) site consists of four administrative areas used for research, development, and test operations and buffer areas on the southern and northwestern boundaries of the facility. The 2,668 acre site is located in the Simi Hills area of Ventura County and is approximately 30 miles northwest of downtown Los Angeles. SSFL is situated on an east-west trending ridge, between 1640 and 2250 feet (above sea level), overlooking Simi Valley to the north and northwest and the San Fernando Valley to the southeast [Robinson, 1998].

The SSFL is jointly owned by Boeing and the National Aeronautics and Space Administration (NASA), and is operated by the Rocketdyne Propulsion and Power Division of Boeing. A small portion of the Rocketdyne-owned property is leased to the U.S. Department of Energy (DOE). The site is divided into four administrative areas (I, II, III, and IV) and undeveloped buffer properties to the northwest and south, as shown in Figure 1 [Robinson, 1998; Ogden, 1998b].

- *Area I* consists of 671 acres owned by Rocketdyne and 42 acres owned by NASA (formerly owned by U.S. Air Force) in the northeast portion of the site. Area I contains administrative and laboratory facilities and was formerly used for rocket engine testing. Area I also includes the former Area I Thermal Treatment Facility and three rocket engine test areas, the Bowl, Canyon, and Advanced Propulsion Test Facility (APTF) areas.
- *Area II* consists of 410 acres in the north-central portion of the site and is owned by NASA and operated by Rocketdyne. Area II contains two formerly-used rocket test firing facilities and two currently operating rocket test firing facilities. Area II includes the Alfa, Bravo, Coca, and Delta rocket engine test areas (Figure 2).
- *Area III* consists of 114 acres in the northwest portion of the site and is owned and operated by Rocketdyne. Area III includes systems test area (STL-IV) and associated laboratories.
- *Area IV* consists of 290 acres owned and operated by Rocketdyne and 90 acres leased by the DOE. DOE and its contractors operated several nuclear reactors and associated fuel facilities and laboratories within this area. This area also includes five surface water discharge outfalls monitored under the National Pollutant Discharge Elimination System (NPDES).
- The northwestern and southern *buffer areas* consist of 175 and 1140 acres, respectively. Industrial activities have never occurred on these naturally vegetated areas. Two NPDES discharge outfalls and drainage channels are located within the southern boundary area. The northern boundary area was recently purchased by Rocketdyne from the adjoining Brandeis-Bardin Institute [GRC, 1999].

Figure 1. Facility Areas and Communities around Santa Susana Field Laboratory

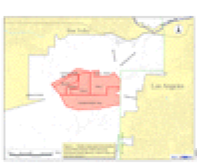 .

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Figure 2. Area II rocket test stands and surrounding terrain.

SSFL has been used as a rocket engine testing facility since 1948. The principal activity has beentesting of large rocket engines and engine components. Other operations include testing smallrocket motors; testing and developing water pumps, lasers, liquid metal heat exchangercomponents, and nuclear reactor research and associated activities. Processes that releasedsubstances to the environment at the SSFL can be grouped into four general categories:

- Accidental spills and releases of solvents, rocket fuels, and oxidizers related to rocketengine testing.
- Emissions resulting from the combustion of rocket propellants.
- Volatilization of solvents; Very large volumes of trichloroethylene (TCE) were used toclean rocket engine components before and after testing.
- Accidental releases of radioactive isotopes; Nuclear reactor operations and associatedfacilities, and reactor accidents resulted in the release of various radioactive isotopes.

Areas I, II, and III. History of Rocket Test Operations

Many thousands of rocket engine tests have been performed at the SSFL over the almost fifty years of operation. The predominant types of propellants used at the SSFL are liquid fuels and associated oxidizers. The primary propellants used at the SSFL are (1) hydrazine-based fuels (including hydrazine, monomethyl hydrazine, and unsymmetrical dimethyl hydrazine) and nitrogen tetroxide (oxidizer), (2) kerosene-based fuels (RP-1 and JP-4) and liquid oxygen (oxidizer), and (3) liquid hydrogen fuel and liquid oxygen (oxidizer). At present, hydrazine- and kerosene-based fuels are being used at the SSFL [CH2M Hill, 1993; Rocketdyne, 1999b]. Table 1 presents an overview of the engine testing programs at the SSFL including the types of fuels and oxidizers used, as well as the duration and location of each program.

During the 1960s, the SSFL also conducted research on solid rocket fuels, many of whichcontained beryllium. Solid fuels were used on a much smaller scale than the liquid fuels. Verylimited information is currently available concerning the historic solid rocket fuel testingconducted at the SSFL. The specific release sources and chemical emissions are presented in thefollowing section on Exposure Pathways Analyses.

Area IV. History of Nuclear Research Operations and Incidents

Area IV was the location of nuclear power development activities from the 1950s until the late1980s. Facilities utilizing radioactive materials made up less than 5% of the total land area withinArea IV. The site has had an ongoing program to monitor and cleanup radiological contaminationsince operations began.

Radioactivity at the SSFL has resulted from: The operation of ten reactors and seven criticality test facilities, fuel fabrication, reactor and used fuel disassembly activities, small scale laboratory work, and onsite storage of nuclear material. Nine of the ten reactors operated at power levels below one megawatt (1 MW). The ten reactors and criticality test facilities have all been dismantled and removed from the SSFL [Oldenkamp and Mills, 1991].
There have been nine radiological incidents at the SSFL. The August 16, 1959 tetralin explosion, was a non-radiological, chemical explosion in the Sodium Laboratory. Table 2 presents a chronological list of the radiological incidents in Area IV of the SSFL.

Table 1. Overview of Rocket Engine Testing Programs at the SSFL

Program	Fuel	Oxidizer	Duration	Test Area
RS-27 Delta	Kerosene	LOx	1971 - present	Alfa
Atlas	Kerosene	LOx	1954 - present	Alfa, Bravo, Bowl,Coca, and Delta
Navaho	Kerosene	LOx	1949-57	Alfa, Bravo, Bowl
Jupiter	Kerosene	LOx	1958-63	Alfa, Delta,Canyon
Thor	Kerosene	LOx	1956-79	Alfa, Delta,Canyon, andBravo
3.5 inch injectors	Kerosene	LOx	1978-79	APTF
5.7 inch injectors	Kerosene	LOx	1989-91	APTF
AdvancedExperimentalThrust Program	MMH	NTO	1967	APTF
HHC Hit withAzine	Kerosene	LOx	1991	APTF
Liquid flybackbooster	Kerosene	LOx	1998	APTF
MK-51Turbopump	MMH	NTO	1984-85	APTF
OMS	Ethanol	LOx	1998	APTF
Pulse engine	MMH	NTO	early 1980s	APTF
RS-44	Hydrogen	LOx	1984-89	APTF
RS-68 gasgenerator	Hydrogen	LOx	1997	APTF
Static PulseEngine	MMH	NTO	1983-86	APTF
XLR-132	MMH	NTO	1989-91	APTF
Lance	UDMH	IRFNA	1962-70	APTF, Delta
Redstone	Ethanol	LOx	1951-59	Bowl
F-1 Saturn Vcomponents	Kerosene	LOx	1959-71	Bravo
H-1 Saturn 1B	Kerosene	LOx	1958-68	Canyon
J-2 Saturn V	Hydrogen	LOx	1960-71	Coca and Delta
SSME	Hydrogen	LOx	1971-88	Coca
X-1 AND X-4	Kerosene	LOx	1956-61	Delta
E-1 (pre F-1)	Kerosene	LOx	1956-60	Delta and Bravo
Apollo reentry	Hydrazine*	NTO	1962-69	STL IV
Beech	Hydrazine*	NTO	1959-66	STL IV
Condor (RS-19)	Hydrazine*	CTF	1967-70	STL IV
EXO	MMH	NTO	1978	STL IV

Gemi	Hydrazine*	NTO	1953-54	STL IV
HOE	MMH	NTO	1979	STL IV
KEW	MMH	NTO	1993 - present	STL IV
LE3	Hydrazine*	NTO*	1973-76	STL IV
LEM	Hydrazine*	NTO*	1967-70	STL IV
Liquid aircraftrockets	Hydrazine*	NTO	1955-58	STL IV
MKV	MMH	NTO	1979	STL IV
MX Peacekeeper	MMH	NTO	1978-94	STL IV
OEM-6K	Hydrazine*	NTO*	1973	STL IV
RCS-600	Hydrazine*	NTO*	1973	STL IV
RS-14 Minuteman	Hydrazine*	NTO*	1968-77	STL IV
RS21	Hydrazine*	NTO*	1975	STL IV
SE5	Hydrazine*	NTO	1960-68	STL IV
Transtage	Hydrazine*	NTO	1953	STL IV
X70	MMH	NTO	1977-78	STL IV

Key: LOx = liquid oxygen; NTO = nitrogen tetroxide; MMH = monomethyl hydrazine; UDMH =unsymmetrical dimethyl hydrazine
APFT - advanced propellants test facility. LETF - Laser engineering test facility. STL - System testlaboratory

* Other types of fuels and oxidizers, such as pentaborane, have been used at the SSFL

Table 2. Chronological List of Radiological Incidents in Area IV of the SSFL.

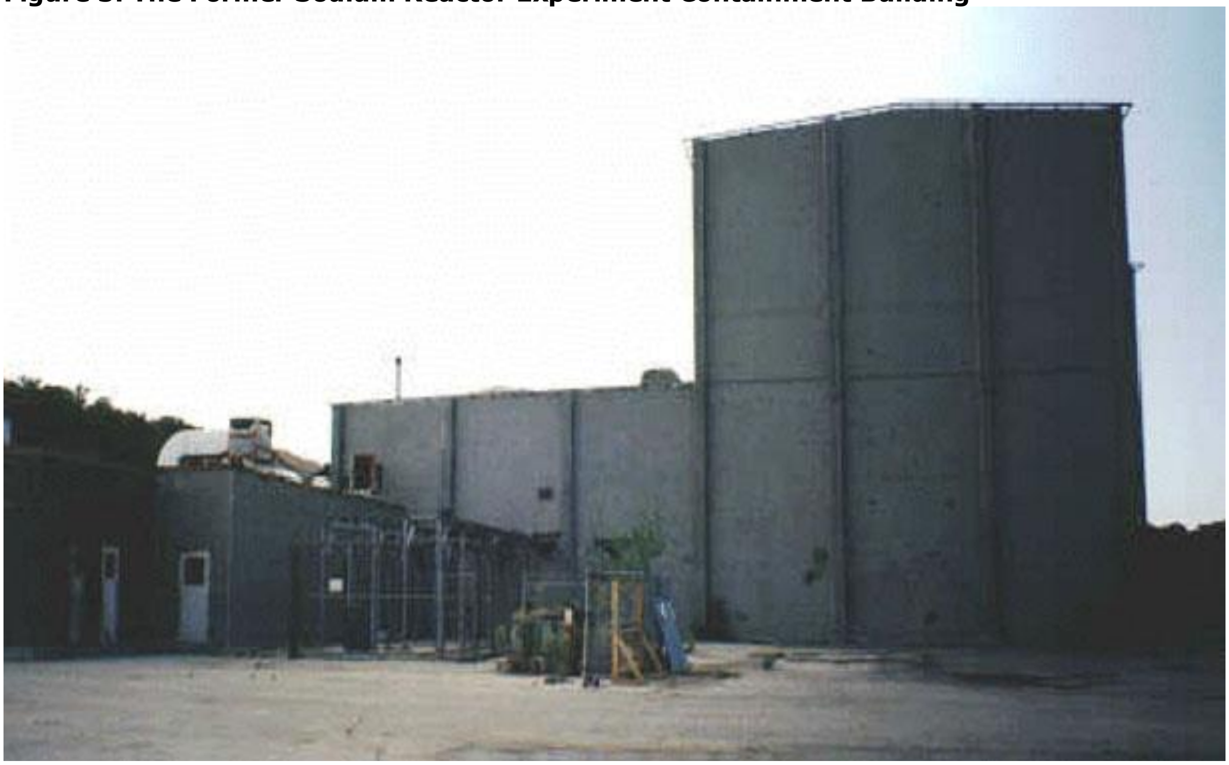
Date	**Description of Incident**
March 25, 1959	AE-6 Power Doubling Excursion
June 4, 1959	SRE Wash Cell Explosion
July 13, 1959	SRE Power Excursion
July 26, 1959	SRE Fuel Damage "Meltdown"
March 19, 1960	SRE Steam Cleaning Pad Contamination
1964	SNAP 8 (S8ER) Fuel Element Failures
1969	SNAP 8 (S8DR) Fuel Element Failures
May 19, 1971	Hot Lab NaK Fire in the Hot Lab DecontaminationRoom
November 3, 1976	Radioactive Material Disposal Facility LeachfieldContamination

Notes:

AE-6 was a 2 kilowatt, low power research reactor with a solution of uranyl sulfate in a spherical tank andused as a neutron source.
SRE (Sodium Reactor Experiment) was part of a program with the Atomic Energy Commission todemonstrate the feasibility of a high-temperature, sodium cooled power reactor for civilian application.
SNAP 8 was a small sodium cooled reactor for space applications.
Of all these incidents, only the Sodium Reactor Experiment (SRE) Fuel Damage incident, commonly known as "The Meltdown," resulted in a measurable release of radioactive material into the environment. The SRE was a graphite moderated, liquid sodium metal cooled, 20 MW power reactor (Figure 3). In 1959, a clogged coolant channel resulted in localized melting of 30% of the fuel elements in the reactor core. The fuel elements fell to the bottom of the primary sodium containment vessel and the reactor was shut down. Most of the radioactive fission products were trapped in the sodium coolant or attached to metal components. Only the noble gas fission products made it to the helium cover gas and were held for decay before being vented to the atmosphere [Hart, 1962].

These operations and the resulting releases of chemicals and radionuclides into the environment are discussed in the following section, Exposure Pathways Analyses.

Figure 3. The Former Sodium Reactor Experiment Containment Building



Area Demographics

Figure 4 summarizes the demographic characteristics of the community surrounding the SSFL within a distance of one mile from the facility boundary. Population estimates in Figure 1 are based on census tracts and population data from the 1990 census. As of 1990, there were 1,089 housing units within one mile of the site boundary. The total population was estimated to be 3,062 based on an area-proportional spatial analysis technique. The population is comprised predominantly of Whites (87%), with smaller proportions of Asian/Pacific Islanders (9%), Blacks (2%), and other races (2%). Approximately 10% of the total population was children aged 6 years or younger while less than 7% of the population was adults 65 years or older.

The rapid population increase of the SSFL area during the 1980's and 1990's is documented in Table 3. This table, based on Ventura County census tract 75.03, shows a total population of 3,597 in 1980 which increases to an estimated total of 5,755 in 1998. The location of census tract 75.03 is shown inFigure 4. It encompasses most of the one mile area surrounding the SSFL, except for a small portion to the east of the site, which is in Los Angeles County. Census tract 75.03 also includes a larger portion of the Santa Susana Knolls and Simi Valley areas than the one mile buffer area, and consequently includes a larger total population than the one mile buffer area of Figure 4.

Table 3 also shows that most of the houses in this census tract were built after 1970; the area was very sparsely populated before 1970. Maps created by the U.S. Geological Survey [USGS, 1952; 1967] indicate that fewer than six buildings were present in the area directly bordering the SSFL before 1967. If each of these buildings is assumed to be a residence, the total population adjacent to the SSFL before 1967 was probably less than 20 individuals. Currently, residents live directly adjacent to the eastern and southern site boundaries, and two mobile home parks are located east of the site on Woolsey Canyon Road. According to the maps and observations by the ATSDR site team, there are no schools, nursing homes, or other facilities within one mile of the site boundary that would indicate the presence of persons who may have increased sensitivity to chemicals and radionuclides.

Figure 4. Population Characteristics in One Mile Area Surrounding the SSFL and Location of Ventura County, CA Census Tract 75.03.

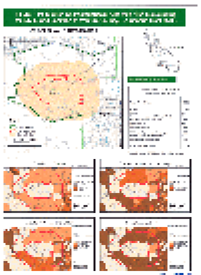


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Table 3. Demographic Statistics for Census Tract 75.03, Ventura County, CA			
Variable	1980	1990	1998
Total Population	3,597	5,118	5,755
Race White	3,358 (93%)	4,593 (90%)	5,234 (91%)
Black	36 (1%)	213 (4%)	108 (2%)
Other	203 (6%)	312 (6%)	413 (7%)
Hispanic Origin	235 (7%)	326 (6%)	720 (13%)
Children 5 years of age or younger	317 (9%)	481 (9%)	516 (9%)
Persons 65 years of age or older	162 (4%)	290 (6%)	413 (7%)
Females 15 to 44 years of age	956 (27%)	1,325 (26%)	1,271 (22%)
Total Housing Units	1,211	1,834	1,982
Occupied Housing Units	1,145	1,716	1,867
Total Housing Units Built In: 1985-98	---		561 (28%)
1985-3/90	---	368 (20%)	---
1980-84	---	235 (13%)	226 (11%)
1979-80	133 (10%)	403 (22%)	385 (19%)
1975-78	133 (10%)		
1970-74	149 (12%)		
1960-69	459 (36%)	413 (23%)	482 (24%)
1950-59	145 (12%)	82 (4%)	
1940-49	101 (8%)	96 (5%)	328 (17%)
Before 1940	152 (12%)	237 (13%)	
Householder Moved Into Housing Unit:			
0-5 years ago (1993-1998)	---	---	1,024 (55%)
6-10 years ago (1988-1992)	---	---	300 (16%)
11 or more years ago (Before 1988)	---	---	543 (29%)

Data are from 1980 and 1990 census tables. The 1998 data are estimates produced by extrapolation of1990 data.

Community Concerns and Health Studies

Community Concerns

On October 5 and 6, and November 3, 1999, ATSDR staff held public availability sessions tomeet with members of the SSFL community in order to discuss their health concerns. Thesemeetings, in Chatsworth, Simi Valley, and the West

Hills area, California, were preceded by mail-outs of the meeting announcements and ATSDR fact sheets to more than 1700 members of theSSFL community. To further assist in informing the public about the availability sessions, pressreleases and media press kits were mailed to 36 media outlets.

At the public sessions, ATSDR made a brief statement about ATSDR responsibilities and thepurpose of these sessions. Following the introductory remarks and public questions, communitymembers had individual discussions with ATSDR site team members. No personal identifierswere collected unless the community members requested follow-up information or indicated thatthey wished to be placed on the mailing list. More than 250 community members attended thesessions and provided the site team with the comments. Comment cards were also distributed tomeeting attendees for written submission of comments and concerns.

The concerns obtained at the public availability sessions and comment cards are summarized in Tables 4 and 5. These concerns fall into two basic groups; health and medical concerns (Table 4) and environmental or exposure concerns (Table 5). These categories are further broken into subcategories based on the relative frequency with which each concern was repeated. It should be noted that for the week preceding the public availability sessions, a local television station ran a series of reports on SSFL activities and community health concerns.
The most commonly expressed health concerns were related to the perceived frequency of severaltypes of cancer, specifically, breast, bladder, lung, and prostate cancers. These concerns werefrequently expressed as comments concerning the number of cancers in their neighborhood. Several comments about health concerns were related to the communities adjacent to theBoeing/Rocketdyne Canoga Park and DeSoto facilities. Several comments also addressed thehealth concerns of former Rocketdyne employees or contractors.

Table 4. Community Health Concerns Related to the Santa Susanna Field Laboratory	
Many people expressed concerns about	• the number of cancer cases in the surrounding communities, most notably, breast, bladder, lung, and prostate cancer. • the number of asthma cases. • the number of immune system disorders. • is my/my family's health adversely impacted by living near the site?
Some people expressed concerns about	• leukemia • neurological disorders • thyroid cancer • skin cancer
A few people expressed concerns about	• liver cancer • birth defects

The most commonly expressed environmental concerns related to property values and whether itis safe to construct or buy homes in the areas surrounding the SSFL site. Other commonenvironmental concerns were about the potential for migration of contaminated ground water orsurface water from the SSFL site. There were also reports from community members that theywere distrustful of the data and results produced from Rocketdyne, and have a general distrust ofthe government agencies overseeing or regulating environmental operations at the SSFL.

Table 5. Community Environmental Concerns and Observations

Many people expressed concerns about:	• safety of drinking water supplies • runoff of potentially contaminated surface water • radiation exposure • desire for environmental sampling of air, water, and soil on their property
A few people expressed concerns about:	• noise from rocket engine testing • is the site being cleaned up properly? • deformities in wildlife and domestic animals

Health Studies

ATSDR reviewed five epidemiologic investigations previously completed in the SSFL area. Ofthe five investigations, three were brief reviews of cancer registry data conducted in response tocommunity concerns about cancer occurrence surrounding the SSFL. The remaining two wereoccupational health studies of the SSFL workers. ATSDR has reviewed the methodologies andfindings of these reports for two main purposes, (1) as a measure of the health status of thecommunities surrounding the SSFL, and (2) to determine whether future activities should beconsidered to address any health issues in these communities.

Community Health Studies

The first of the community-based epidemiological investigations evaluated cancer incidence rates in five Los Angeles County census tracts within a five-mile radius of the SSFL [CDHS, 1990]. The SSFL is located in eastern Ventura County adjacent to Los Angeles County. However, Ventura County was not included in this investigation because the cancer registry had not been established at that time.

The age-adjusted cancer incidence rates in five Los Angeles census tracts were compared to therates for Los Angeles County as a whole. Two time periods were examined, 1978-82 and 1983-1987. Specific cancers examined included lung, bone, bladder, thyroid, Hodgkin's and non-Hodgkin's lymphomas, and leukemia (including acute lymphatic leukemia, acute non-lymphaticleukemia, chronic lymphatic leukemia, and chronic myelogenous leukemia). The report concludedthat a significant increase was observed in bladder cancer during 1983-1987 for one census tract(tract 1132). This census tract adjoins the SSFL site, however it also extends more than five milesto the east, such the individual cases may not be close to the site.

This study has several limitations; most of them inherent to this type of investigation. The accuracy of the population estimates at the census tract level is not known. Although standardized rates are useful as a summary measure, the rates are affected by random variation. Because multiple comparisons were made, the probability of finding a significant association by chance is increased even if there is no association at all. No information was available on actual exposures to contaminants from the SSFL sites: a five-mile radius within the SSFL site is a weak surrogate for exposures and no information is available regarding how long the residents lived in the area. No information was available on any other risk factors. This investigation serves the purpose of generating and refining questions on cancer incidence and cannot assess the cause and effect relationship of potential SSFL exposures.

The second community health study was conducted as a follow-up in response to recommendations made in the 1990 investigation described above [CDHS, 1992]. In this investigation, the 1990 study data were re-analyzed after including a more homogeneous study population (i.e., cases of invasive cancers among non-Hispanic whites only, stratified by sex). Standardized Incidence Ratios (SIR) were calculated adding one more year of newly available cancer incidence data (i.e., 1978-1988). This study also analyzed the cancer data for census tracts where population estimates were not available. Proportional Incidence Ratios (PIRs) were computed using an odds ratio (OR) for Ventura County and other Los Angeles County census tracts at least partially within a five-mile radius of the SSFL site for 1988 and 1989. Comparison groups were the rest of Los Angeles County residents for Los Angeles County and the rest of Ventura County residents for Ventura County. Cancer sites were grouped based on the evidence for radiogenic causes because of radiation exposure concerns. No increase was found in the "very radiosensitive" cancer group (cancers of the thyroid and bone, and all the leukemias except for chronic lymphocytic leukemia). The bladder cancer rate was elevated (SIR:132.6, 95%CI:100.5-171.9) among Los Angeles men living near SSFL during 1983-1988. The odds of having lung cancer among all cancers diagnosed was higher among Ventura men living near SSFL compared to that among the rest of Ventura men (OR:1.66, 95%CI: 1.17-2.37).

The study methodology is generally sound, given the limited data and lack of exposure information. Most of the limitations of the 1990 study also apply to this study and they are acknowledged appropriately. The interpretation of the findings is reasonably cautious because lung and bladder cancers are "strongly associated with other risk factors (smoking and non-radiation occupational exposures), it is important to consider alternative explanations" [CDHS, 1992].

The third community study was a follow-up to the 1990 and 1992 studies. It involved an analysis of the newly available cancer registry data for the years 1988-1995 for the Ventura census tracts that were included in the 1992 study [Tri-Counties Regional Cancer Registry, 1997]. This study calculated SIRs by using the 1990 census data. The Tri-Counties region population served as a comparison group. This preliminary analysis reported a significant decrease in the leukemia incidence in women. A significant increase in lung cancer was also reported for the combined group of men and women. However, this increase was small (SIR:117, 99%CI:100.6-135.6 [Nasseri, 1999]), and lung cancer was not significantly increased in men or women separately. The report acknowledged the lack of appropriate census tract level population estimates. If estimates of the base population are too low, the population-based number of expected cancer cases is also too low, which would lead to an overestimation of SIRs.

Occupational Health Studies

ATSDR reviewed two occupational studies of SSFL workers [Morganstern, *et.al*., 1997; 1999]. The first of these was a retrospective cohort study to determine whether workers at the SSFL nuclear sites experienced excessive mortality from specific cancers, total cancers, or other causes as a result of their work-related exposures to radiation. The cohort consisted of the SSFL workers enrolled in the Health Physics Radiation Monitoring Program, for external (4,563 workers) and internal (2,289 workers) radiation exposures. The internally monitored group was mostly a subset of the externally monitored group. A fairly long follow-up period is included, extending from 1950 to 1993. The study estimated radiation effects by employing internal comparisons of monitored workers according to level of cumulative radiation doses. Conditional logistic regression was used to examine the dose-response relationships by controlling for potential confounders and effect modifiers. Variables controlled for were (1) the other type of radiation exposure, (2) age at risk, (3) time since first radiation monitoring, (4) pay type, and (5) exposures to asbestos and hydrazine. External comparisons were also conducted by using two external reference populations to describe the mortality experience of the study population. The study found that mortality rates of the study cohort were lower for all causes, all cancers, and heart disease compared to the rates of the general U.S. population. Compared with NIOSH cohort members of similar pay type, the monitored workers experienced lower mortality rates for all causes and heart disease, but similar rates for total cancers. Although none of the 95% confidence intervals exclude the null value, there appear to be some excess mortality from leukemias in the monitored workers compared with either reference population. In the dose-response analyses of monitored workers, external-radiation dose was positively associated with the mortality rate for hemato-lymphopoietic cancers and for lung cancer. For dose levels greater than 200 mSv, the mortality rates for both types were particularly elevated. Increasing trends in mortality rates were found with internal-radiation dose for upper aerodigestive tract cancers and for hemato-lymphopoietic cancers.

This study is well designed and the data analysis is rigorous. The major strength of the study is theability to examine the dose-response relationships by reconstructing internal and external dosesreceived by the individual workers in the past. The choice of the study cohort and availability ofthe radiation monitoring records at the SSFL benefitted the study; however, they also pose someproblems because of incomplete records. In particular, for internal radiation doses, uncertainty ofthe estimates appears to be high. The study measured cumulative SSFL exposures, howeverexposures received before employment at SSFL could not be accounted for because ofinconsistency in the recording practice. Although the study attempted to control for the effect ofother chemical exposures (i.e., hydrazine and asbestos), misclassification of the chemicalexposures is highly likely. The use of the upper aerodigestive tract cancers group is somewhatunusual, although it is meant to take consideration the properties of internally depositedradionuclides. Another problem of the study is the small number of cancer deaths, particularly inthe high dose group (e.g., >200 mSv). Most of these limitations are acknowledged appropriatelyin the report. Given the limitations, the most consistent and biologically plausible finding of thestudy is the hemato-lymphopoietic cancers. The observed positive relationship between externalradiation and lung cancer mortality has not been reported consistently in other studies of nuclearworkers.

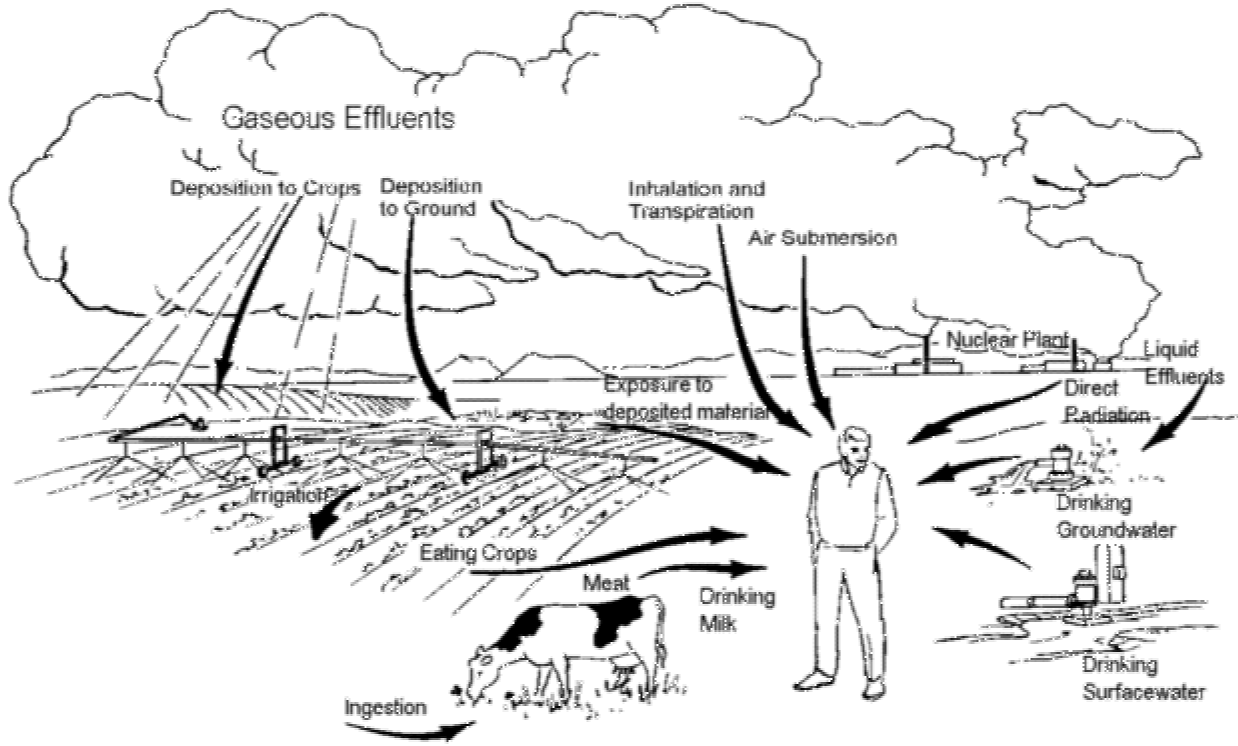
The second occupational study is part of the 1997 study described above [Morganstern, *et.al.*, 1999]. This addendum report focused on the chemical exposure portion, and included a cohort based on presumed exposure to the hydrazine (6,107 workers with 176,886 person-years) and a cohort with presumed exposure to asbestos (4,563 workers with 118,749 person-years). Employing an internal comparison method described in the 1997 report, this study reported the observed positive association between presumptive exposures to hydrazine and the rates of dying from cancers of the lung.
The weakness of this study mainly stems from the unavailability of adequate information on past exposures for individual workers. Even though the study was able to identify work locations with a high probability of exposure to hydrazine and asbestos at the SSFL site, information was not sufficient to link individual workers with job locations. As a result, the exposure classification was based on job titles. In addition to the possible exposure misclassification, bias may also have been introduced by confounding. Exposure information on other risk factors, such as exposure to other chemicals (e.g., trichloroethylene and nitrosamines) or personal characteristics is not available for the study. There is also a possibility that the radiation exposures are misclassified, hindering the ability to control for confounding by radiation exposures. Despite the limitations, the observed increase in the lung cancer risk associated with presumptive hydrazine exposure is noteworthy**.** The direction of the bias caused by the exposure misclassification may be toward the null value, because individual subject's exposure classification did not depend on the subject's disease status. This increase is observed after taking into account the effects of other potential confounding factors on which the relevant data were available. The increase is consistent across two hydrazine compounds. Given the uncertainties, the authors' recommendation that the worker group should be followed further is reasonable since the result shows a positive association, and health effects of exposure to these chemicals in humans are not well understood.

Exposure Pathways Analyses
A release of a chemical or radionuclide into the environment does not always result in humanexposure. People may be exposed by eating, breathing, or contacting these substances when theyare present in environmental media such as air, drinking water, or soil. Unlike chemicals,radionuclides that are present at high enough concentrations in the environment can result inirradiation exposures to persons who are sufficiently close to the material.

For exposure to occur, an *exposure pathway* must exist. The following section discusses thevarious pathways of exposure to persons in the community surrounding the SSFL site. The fiveelements of an exposure pathway are (1) a source of chemical or radiological contamination,

(2) an environmental medium (e.g., ground water, surface water, or air) through which the contaminants are transported from the site to the community, (3) a place or process where human exposure is likely to occur, (4) a route of human exposure (e.g., eating, breathing, skin contact), and (5) an exposed population in the surrounding community. Figure 5 illustrates the necessary components of an exposure pathway.

Figure 5:



For example, chemicals or radionuclides may be released from a facility onto the ground (soil) during routine operations or an accident (the *contaminantsource*). These substances may then dissolve in rainwater that percolates down through the soil to the underlying ground water (the *environmental media*). If the contaminated ground water is used as a drinking water source (the *point of exposure*), then people (the *exposed population*) may be drinking and bathing (the *routes of exposure*) in water that contains these substances. All elements of the pathway must be present before the pathway is complete.

With regard to chemicals and radionuclides, not all exposures result in adverse health effects. Several factors determine whether exposure to a chemical or radionuclide has the potential to cause harm. These factors include the contaminant concentration, the exposure duration and frequency, the route of exposure, the toxicity or radioactivity of the substances, and the way the substance is handled by the body following exposure. In addition, factors related to a person's overall health and nutritional status, as well as genetic and lifestyle factors (e.g., smoking and alcohol consumption, diet, level of physical activity), may affect whether exposure to a chemical or radionuclide results in adverse health effects. Therefore, ATSDR evaluates exposure pathways, and considers community concerns and population characteristics, when determining whether adverse health effects are likely to occur in a community.

It is important to remember that **EXPOSURE** to chemicals and radionuclides in the environment **must** occur before any exposure-related health effects are possible. Also, not all exposures result in exposure related health effects.

Special Consideration of Women and Children

Women and children may sometimes be affected differently from the general population bycontaminants in the environment. Both are smaller than the population average and are affected bysmaller quantities of the contaminants. The effect of hormonal variations, pregnancy, and lactationcan change the way a woman's body responds to some substances. Exposure during pregnancyand lactation can expose the fetus or infant if contaminants cross the placenta or get into themother's milk. Depending upon the stage of pregnancy, exposure of the fetus could result in death(miscarriage or stillbirth) or birth defects. If the mother is exposed during lactation, her milk mayconcentrate certain contaminants, increasing the exposure to her infant.

ATSDR's Child Health Initiative recognizes that unique vulnerabilities are inherent in thedeveloping young, whether fetus, infant, or child. For example, some exposures would affectchildren more than adults because of their reduced body weight and higher ingestion rate,resulting in an increased dose or amount taken into the body compared to their body weight. Achild's shorter height results in a breathing zone closer to the ground; thus, closer to soilcontaminants and low-lying layers in the air. Children's behavioral characteristics include morehand-to-mouth behavior, increasing the ingestion of soil or dust contaminants.

In addition to physical and behavioral differences, children's metabolic pathways, especially in thefirst months after birth, are less developed than those of adults which can affect the uptake ortoxicological response to hazardous substances. In some instances, children's bodies are betterable to deal with environmental toxins, but in others, they are less able and more vulnerable.Some chemicals that are not toxic to adults are highly toxic to infants.

Children are rapidly growing and developing in the first months and years of life. Some organsystems, especially the nervous and respiratory systems, may experience permanent damage ifexposed to high concentrations of certain contaminants during this period. Because of rapidgrowth and development, a child's genetic material (DNA) is more likely to be exposed than laterin life making it more vulnerable to damage.

Children have more future years than adults, giving more time for the development of illnesses that require many years to progress from the earliest initiation to the manifestation of the disease. Finally, young children have less ability to avoid hazards because of their lack of knowledge and their dependence on adults for decisions.
In the following sections of this report, we will indicate whether people, including women and children, were, are, or may be exposed to contaminants of concern and discuss the possible health concerns related to these exposures.

Air Pathway

Background

Process operations and waste disposal activities at SSFL have resulted in the airborne release ofnumerous chemicals and radionuclides. This section reviews the meteorological conditions at thesite, identifies the release processes, and discusses the information available or needed forestimating or documenting those releases. Finally, within the limitations of the availablemeteorological and environmental data, we discuss the potential for human exposure to chemicalsand radionuclides from the SSFL.

The Los Angeles basin is a semi-arid region with the climate controlled primarily by the semi-permanent Pacific high pressure cell. Changes in the position of this cell control seasonal weather patterns. During the summer months, the high pressure cell covers the Los Angeles area which results in mostly clear skies with little precipitation. During the winter months, the high pressure cell is displaced southward which allows Pacific frontal systems to move into the area producing light to moderate precipitation [Rutherford, 1999].

During the summer, a shallow inversion layer covers most of the Los Angeles basin. The base and top of this inversion are lower than the elevation of the SSFL site [Rutherford, 1999]. Air releases from SSFL during the summer are likely to disperse above the inversion layer before diffusing downward into the Simi or San Fernando Valleys. In the winter season, surface airflow is dominated by easterly moving fronts accompanied by rainfall. Generally, a light southwesterly wind precedes the storms producing an onshore flow of marine air and an unstable vertical profile. Wind speeds increase as the frontal systems approach. Average wind speeds range from 0 to 9.8 mph [Rutherford, 1999].

A meteorology station has been in intermittent operation at SSFL. ATSDR has received hourly meteorological data for the years 1994-97, summary data for 1960-61, and hourly data for the first 10 months of 1999 [PEC, 1999]. Rocketdyne has indicated that the 1994-97 data set was collected or recorded in error, however, they have provided documentation of the correction factors [PEC, 1999]. The general wind direction pattern from these data sets is predominantly diurnal with north-northwest winds blowing from the ocean during the day, and reversing to the east-southeast during the night. A wind rose diagram for the years 1960-61 also indicates a strong bi-modal wind pattern with similar wind directions.

Local wind directions are strongly affected by the orientation of canyons and ridges such thatwind directions at the SSFL meteorological station are different than those of stations in the Simior San Fernando Valleys and may be different for specific areas within SSFL. It is imperative thata consistent and representative meteorological data set be compiled and used for evaluating thepotential emission source areas within the SSFL site.

There are several processes or operations at SSFL that release chemicals and radionuclides to the atmosphere. These include rocket engine testing, waste treatment and disposal, and accidental releases or spills.

Rocket Testing

The test firing of rocket engines over the operating history of the facility routinely released particulates (soot) and by-products of propellent combustion into the atmosphere. As indicated previously, rocket engine tests at SSFL utilized a variety of fuels; however, the predominant fuels were combinations of kerosene and liquid oxygen. Solid fuel rocket engine testing occurred on a limited basis at the SSFL during the 1960s [CH2M Hill, 1993; Ogden, 1998b; Rocketdyne, 1999b].

Routine rocket engine testing at the SSFL released combustion products into the atmosphere (Figure 6). The majority of these releases were products of complete and partial combustion of hydrocarbon fuels, and include carbon dioxide, carbon monoxide, hydrogen gas, hydrogen chloride, nitrogen gas, nitrous oxide, chlorine, metallic oxide particulates (e.g., aluminum oxide), soot, and organic compounds (e.g., polyaromatic hydrocarbons, [PAHs], Volatile organic compounds, [VOCs]).

In addition to combustion products, air releases were likely to have occurred during routine operations, accidents, and spills of rocket propellants. Liquid fuels containing hydrazines may volatilize from, or sorb to, soils following release. Hydrazines degrade fairly rapidly in most environmental media, including air, water, or soil. Oxidation is the dominant fate, but biodegradation occurs in both water and soil. The half-life of hydrazine in air ranges from less than ten minutes to several hours, depending on atmospheric ozone and hydroxyl radical concentrations. The half-life in water and soil ranges from several minutes to several weeks, depending on several factors such as the presence of certain metal ions, ionic strength, pH buffer, temperature, presence of bacteria, and amount of dissolved oxygen [ATSDR, 1997a]. Oxidizers are reactive and have a very short half-life in air or soil; therefore, they would rapidly disappear from soil and sediment following an accidental spill or release.

After firing, the tested engines were cleaned with large volumes of liquid solvent trichloroethylene (TCE) that was allowed to volatilize into air or was burned from open retention and skim ponds that received surface runoff from the test engine stands. Spills and accidents involving TCE releases also have occurred during rocket testing operations at the SSFL [CH2M Hill, 1993; ICF Kaiser, 1993]. TCE readily volatilizes from soil or surface water into air. Therefore, concentrations of TCE in soil or surface water would rapidly diminish after an accidental release or spill.

Figure 6. Test firing of an Atlas Rocket Engine, September 7, 1999. Note that most of the exhaust plume is steam from evaporation of the quench water used to cool the test stand

Waste Treatment and Disposal

Chemicals and radionuclides may have been released to air during waste handling, storage, treatment, and disposal operations. Both excess rocket fuels and solvents (such as TCE) may have been burned from the skim ponds following test firings. Hydrocarbon disposal by open burning was prohibited by Ventura County Air Pollution Control District in 1969. Mixtures of fuels, solvents, water, and other materials were also routinely burned at the Area I Thermal Treatment Facility (TTF) [Rockwell International, 1992; GRC, 1993; Rocketdyne unpublished letters, various dates]. Incomplete disposal records indicate that the burning or venting of waste materials at the TTF was conducted by the SSFL fire department and that disposal protocols were developed and observed [Rocketdyne unpublished letters, various dates].

Accidental Releases and Spills

Accident reports indicate that tank ruptures of gaseous materials and spills of liquid materials have resulted in airborne emissions. Historical accident reports are maintained by Rocketdyne, however, with the exception of TCE releases [CH2M Hill, 1993] these records have not been compiled and no evaluation of concentrations or dispersion to offsite areas has been conducted to date [Lafflam, 1989; ICF Kaiser, 1993]. Releases of radionuclides also occurred during incidents that occurred in Area IV from 1959 to 1976 (Table 2) and are evaluated later in this section.

Environmental Data

There are very few quantitative measurements of airborne chemicals from SSFL operations. Some meteorological data for the period of operation are available, however, there does not appear to be a long-term consistent record of when or what types of meteorological data have been collected. Current air emissions are regulated through permits by the Ventura County Air Control Board. These permits are based on estimates of materials usage and do not require ongoing air monitoring. Emissions from rocket engine tests were measured over a six-month period to quantify releases from liquid fuel engine tests [ABB Environmental Services, 1992]. Results from these measurements, a three-dimensional model of exhaust plume characteristics [Melvold, 1992], and associated fuel consumption rates are used to produce annual emission estimates.

With respect to disposal of chemicals at the Area I Thermal Treatment Facility (TTF), Rocketdyne kept some records on the types and volumes of material that were burned. A partial list of chemicals burned includes hydrazine and hydrazine compounds, sodium, pentaborane, kerosene-based fuels (e.g., RP-1, JP-4), lithium powder, nitrogen tetroxide, waste oils, TCE, chlorine trifluoride, and alcohol mixtures [Rocketdyne unpublished letters, various dates; Rockwell International, 1992; GRC, 1993]. The TTF was operational from 1958 to 1990 for the destruction of explosive, reactive, and ignitable wastes by open burning.

Although no air monitoring information is available for the TTF, soil sampling data provide important information concerning the dispersion and deposition of airborne chemicals. This is especially true for chemicals such as polyaromatic hydrocarbons (PAHs) that are not rapidly degraded (and thus persist) in soil for long periods. Soil sampling was conducted at the TTF in 1981, 1982, 1990, and 1993 [reviewed by ICF Kaiser, 1993]. Analyses were conducted for a variety of organic chemicals, anions (fluoride, chloride, nitrate, and sulfate), and metals. Overall, there is no indication that any of the chemicals in soils and sediment at the TTF have migrated to offsite areas [Appendix A].

Chemicals

As mentioned previously, the categories of chemicals evaluated as airborne releases are rocketfuels, oxidizers, and solvents. The types and quantities of airborne releases from the SSFL havevaried over time. ATSDR does not have quantitative measurements of offsite concentrations ofthese substances. Although future monitoring data cannot recreate historic concentrations, airdispersion modeling could be used to estimate past concentrations.

Radionuclides

Of all the radiological incidents that are known to have occurred at the SSFL (shown in Table 2), only the Sodium Reactor Experiment (SRE) Fuel Damage incident, commonly known as "The Meltdown," resulted in a measurable release of radioactive material into the environment [Oldenkamp and Mills, 1991]. The SRE was a graphite moderated, liquid sodium cooled, 20 MW power reactor. In the Summer of 1959 a coolant channel became clogged, which resulted in localized melting of 30% of the fuel elements. The fuel elements fell to the bottom of the primary sodium containment vessel and the reactor was shut down. Most of the radioactive fission products were trapped in the sodium coolant or attached to metal components. Only the noble gas fission products made it to the helium cover gas and were held for decay before being vented to the atmosphere [Hart, 1962].

Potential for Human Exposure

ATSDR reviewed the available environmental data and site-specific information to evaluatepotential human exposure to chemicals and radionuclides in the community surrounding theSSFL. There are very few quantitative measurements of airborne chemicals and radionuclides*offsite* of the SSFL. Available information indicates that these substances were released *onsite*during rocket engine testing, waste treatment and disposal, and accidental releases or spills. Releases were probably much higher in the past than at present, due to increased awareness aboutenvironmental processes (release, transport, fate) and more stringent environmental regulations. Several factors must be considered when evaluating the potential for any *onsite* releases to migrate*offsite* and be a potential source of exposure to nearby communities.

First, many of the active areas at the SSFL are located within valleys surrounded by rugged, hillyterrain that separates the active areas from nearby communities. Airborne releases from SSFLsources would be dispersed during transport over these hills to offsite areas. The nearest offsiteresidences are currently located more than one half mile from any of the facility sources. Giventhe distance of the nearby populations to the source areas, it is likely that airborne contaminantconcentrations would be substantially reduced before reaching offsite communities. During thepeak operations at the facility in the 1950s and 1960s, very few residents lived near the SSFL.Although air releases may have been higher in the past, the potentially exposed population wasquite distant from the source areas. In addition to the dispersion of air pollutants that occursduring transport, the oxidizers used at SSFL have a very short half-life in the atmosphere andwould be degraded to non-toxic compounds and elements before reaching offsite areas.

Second, a shallow inversion layer covers most of the Los Angeles basin during the summer months [Rutherford, 1999]. Because of this inversion, any airborne emissions from the SSFL are released *above* the inversion layer and are dispersed in the atmosphere high above ground level where human exposure could not occur. This means that during the summer months, there is no direct way for airborne releases from the SSFL to be transported to nearby communities before being substantially reduced by dispersion and degradation.

Finally, although there are no wind direction data for specific release incidents, the prevailingwind directions at SSFL blow from the source release areas towards uninhabited areas aroundSSFL. The residences nearest to the site boundaries are not downwind for the strongly prevailingwind directions. Thus, during prevailing wind conditions that have occurred for more than 70% ofthe recorded hourly wind measurements, the closest potentially exposed populations are more thanone mile from the nearest source areas.

ATSDR used the available environmental data, incident reports, and computer modeling toestimate possible radionuclide exposures to the offsite community from the SRE meltdownincident that occurred in 1959. Making a conservative assumption that all of the radioactive noblegases were released instantaneously in the incident, ATSDR used CAP88-PC, a software packagefrom the U.S. Environmental Protection Agency, to estimate doses from air release of radiologicalmaterial. We estimated that the maximally exposed individual could receive up to 0.005millirem. The current exposure limit for members of the public is 100 millirem in one year. Dueto residential locations and meteorological conditions, it is unlikely that anyone received themaximum estimated dose of 0.005 millirem dose.

Based on the distance from the onsite release sources to offsite residential areas, the predominantwind directions, the meteorological conditions at the site, and the rapid dispersion and degradationof oxidants in air, *it is unlikely that offsite residents have been, or currently are being exposed tochemicals and radionuclides at concentrations that would result in adverse human health effects*.However, because there has been no monitoring of past airborne releases, air dispersion modelingof past releases using site-specific meteorological data would improve the current assessment ofpotential past exposures.

Groundwater and Surface Water Pathway

Background

Ground water in the SSFL area occurs within two distinct hydrogeological units. These units are identified as the Shallow Zone and the Chatsworth Formation. The Shallow Zone occurs within the thin (0 to 20 ft.), discontinuous surficial alluvium found along canyon drainages and in isolated level areas. The principal ground water aquifer occurs within the Chatsworth Formation, which is composed of fractured sandstones with siltstone and claystone interbeds. Almost all water flow occurs within fractures and the unfractured portions are virtually impermeable [GRC, 1999].

Because of the overall low precipitation in this area, there are no continuous streams draining thesite. However, ground water elevations under the SSFL site are significantly higher than Simi andSan Fernando Valleys such that ground water emerges at a number of springs and seeps in thecanyons leading from the site into the valleys. Similarly, surface water impoundments within thesite boundary directly recharge the ground water flow system. Because of these linkages betweenthe surface water and ground water flow systems, and the intermittent nature of surface waterflows, the ground water and surface water system will be evaluated as an integrated exposurepathway.

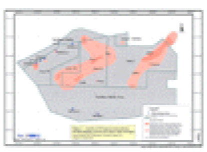
Ground water beneath the SSFL was found to be contaminated with trichloroethylene (TCE) in the early 1980's [GRC, 1999]. The presumed source for most of the TCE contamination was downward flow from the series of surface water impoundments that drain the rocket engine test areas of the site. Historically, TCE was used to wash the rocket engines between tests [CH2M Hill, 1993]. Following the discovery of TCE in ground water, the facility installed a network of 214 monitor wells to define the distribution of the contaminants. These 214 monitor wells, plus 13 facility supply wells and 16 private wells and springs are sampled quarterly or annually for more than 100 different chemicals, radioactive isotopes, or trace metals.

Plumes of TCE-contaminated ground water have migrated offsite along the northeast and northwest boundaries of SSFL (Figure 7). The facility purchased the property overlying the northwest TCE plume from the Brandeis-Bardin Institute such that this area is now onsite and comprises the northwest buffer area.

Since 1987, the SSFL has operated a network of ground water remediation and treatment wells and eight contaminant treatment systems. More than 1.4 billion gallons of contaminated water have been treated since initiation of the treatment system. The treatment system includes six packed tower aeration systems, and two ultraviolet/hydrogen peroxide units with air emissions regulated by permit from the Ventura County Air Control Board [GRC, 1999].

Water level data from the monitor, remediation, and supply wells indicates that long term water levels underlying SSFL have declined as much as 200 feet [GRC, 1999]. This decline in water elevations creates ground water flows towards the central portion of the SSFL facility and has likely reduced offsite migration of ground water contaminants.

Figure 7. Location of TCE ground water plumes, NPDES sampling stations and surface water drainages.



(Click on Thumbnail for larger view)

Environmental Data

Groundwater Resource Consultants has provided ATSDR with a comprehensive data base containing most of the monitoring data collected (electronic data sets listed in Appendix C). This data base has records for 256 locations, with more than 120 different analytes (including volatile organic compounds, metals, acid and base/neutral organics, and common ions). Perchlorate and radionuclide analyses were provided to ATSDR in separate data bases and tables. ATSDR also reviewed written documentation and reports on ground water investigations conducted at the site (shown in Appendix B). Overall, the available data provides good documentation of the distribution of chemicals and radionuclides underlying the SSFL facility, and areas surrounding the site that are most likely to be affected by site releases. However, the possibility of deep fracture flow presents the potential for substances in ground water to migrate long distances and emerge at springs and seeps along the margins of Simi Valley.

Surface flow at the SSFL drains to the north, northeast, south, or east and is very intermittent. Surface water drainages are regularly monitored as National Pollutant Discharge Elimination System (NPDES) outfalls at seven locations (Figure 7), five in Meier Canyon (in the northwestern portion of the site), and two in Bell Canyon (in the

southwestern portion of the site). An additional station, located in Woolsey Canyon, has been measured only once due to infrequent surface water flow and the lack of source areas within that drainage system.
The facility monitors various parameters at the NPDES outfalls, including physical parameters(e.g., rainfall, flow, temperature), common ions (e.g., nitrate and nitrite, chlorine, fluoride, sulfate,boron), oil and grease, radioactive parameters (e.g., gross alpha and beta, radium 226/228, tritium,and strontium-90), heavy metals (e.g., arsenic, beryllium, chromium, lead), and other substancesrelated to site operations. Several stations are also monitored for organic compounds, includingpolychlorinated biphenyls (PCBs), ethylbenzene, toluene, and xylenes. Volatile organiccompounds (VOCs) such as trichloroethylene (TCE) and its degradation products are monitoredonly at the two NPDES outfalls (01 and 02) located in Bell Canyon. These substances are notmonitored at other NPDES stations because the substances are no longer being used at the site. With the exception of the OS-14 station located in the undeveloped area of the SSFL facility asdescribed below, existing monitoring of surface water runoff appears adequate for detection andmonitoring of surface water contaminants from current facility operations.

Chemicals
Table 6 lists the offsite surface water and ground water sampling stations that may be impacted bychemicals and radionuclides migrating in ground water and surface water from the SSFL. Thetable also includes the sampling points or wells where these substances were found.

Chemical concentrations in surface water samples routinely collected at the NPDES outfalls havegenerally been below regulatory limits. Two VOCs, chloroform and TCE, have been detected atotal of three times in samples collected at the outfalls; the concentrations did not exceedregulatory limits. Chloroform was detected on two occasions at concentrations of 4 Âµg/L (in 1992)and 1.6 Âµg/L (in 1995); TCE was found on one occasion at a concentration of 4.3 Âµg/L (at outfall#02, in 1995).

Metals, such as cadmium, chromium, nickel, lead, and zinc have frequently been detected atNPDES outfalls but levels are similar to background concentrations in most samples. Chromiumwas measured at outfall #02 at a concentration of 75 Âµg/L (in 1993), which exceeded theregulatory limit of 50 Âµg/L. Zinc was detected at outfalls #03, #04, and #06 on several occasions;the maximum concentration detected was 640 Âµg/L, which is well below the NPDES regulatorylimit of 5000 Âµg/L. PCB (Aroclor 1254) was detected at outfalls #05 and #06 on several occasionsat a maximum concentration of 120 Âµg/L in 1994.

Sample location OS-14 is located in the undeveloped southern buffer zone of the SSFL facilityand is in the drainage leading to Bell Creek. This station was sampled on only one occasion in1985. The contaminants detected were: TCE (100 ug/l), vinyl chloride (8 Âµg/l), and trans-1,2-dichloroethylene (1,2-DCE; 230 Âµg/L). Although NPDES outfalls are downstream of the OS-14location, and have routinely been found to contain low or non-detectable concentrations of VOCs,the finding of chemical contamination at OS-14 suggests possible migration of chemicals infracture flow from the SSFL. Additional sampling at OS-14 is warranted to better characterizeoffsite concentrations and possible migration of chemicals in deep fracture flow from the SSFL.

Table 7 lists the chemicals that were commonly detected in onsite ground water wells. Of thetwenty-one chemicals listed in Table 7, eighteen were detected in offsite wells or springs, and fiveof the these were detected on only one to three occasions. The only routinely occurring chemicalsin offsite ground water samples are TCE and its degradation products, 1,1-dichloroethylene (1.1-DCE) and 1,2-dichloroethylene (1,2-DCE). TCE was found at a maximum offsite concentration of670 Âµg/L at well RD-38A (in 1994). Maximum TCE concentrations currently found offsite havedecreased to 330 Âµg/L (in 1999). Well RD-56A, which was previously considered an offsitesample location but is currently part of the onsite property (within the northern buffer area), had amaximum TCE concentration of 810 Âµg/L (in 1999).

Two other offsite wells located within the boundaries of the eastern TCE plume have shown significant decreases in concentrations of TCE, and its degradation products, over time. Forexample, TCE concentrations in Well RD-36B decreased from 320 Âµg/L (in 1994) to 24 Âµg/L (in1999); concentrations in well RD-36C decreased from 310 Âµg/L to 78 Âµg/L during this same timeperiod. The declining concentrations of TCE and its degradation products over time indicate theeffectiveness of the ongoing ground water remediation program at the SSFL. No chemicals havebeen detected in the two offsite wells known to be used as drinking water sources.

Perchlorate has been detected in only one of the offsite monitor wells routinely sampled by the SSFL facility (Table 7). It was also detected at a concentration or 4.6 Âµg/L in a ground water well that discharges into the storm drains in the City of Simi Valley [CDHS, 1999]. This concentration is below public health standards proposed by the U.S. Environmental Protection Agency and the State of California [EPA, 1998, 1999; CDHS, 1999]. In addition, this well is located more than three miles northwest of the SSFL. Ground water in this area is currently not being used as a drinking water supply. Although perchlorate has been found in soil and water samples collected from SSFL Area I, ATSDR has no information indicating that the perchlorate found in this discharge well is related to the SSFL. However, the potential for deep fracture flow from the SSFL exists and has not been fully characterized.
Perchlorate contamination has been detected in a number of water sources throughout much of California and the United States, indicating that there may be other sources of perchlorate contamination for the Simi Valley well [CDHS, 1999]. Additional perchlorate characterization and monitoring of ground water in Simi Valley is warranted to identify possible sources of contamination and to better characterize deep fracture flow from the SSFL.

Table 6. Surface Water and Ground Water Sampling Stations Offsite of the SSFL Facility

Direction	**NW**	**N**	**NE, E, SE**	**S, SW**
Location	Brandeis Barden Institute	Santa Monica Mountains Conservancy	Private Lands Woolsey, DaytonCanyons	Bell Canyon Area
Ground water wells	OS-1 to10 RD-59ABC RD-68AB	OS-24-27 RD-36ABCD RD-38AB,71 RD-39AB,66	OS-15-**17**, 19, 20, **27** RD-32, 43	OS-21
Surface Water Stations	NPDES 03-07 OS-8	no surfacewater drainageinto this area	NPDES NearWell 13, OS-12, 13	Bell Creek NPDES # 01,02 OS-14
Note: Wells OS-17 and OS-27 are drinking water supply wells. No contaminants have been detected in those wells.				

Table 7. Offsite Distribution of Chemicals Commonly Found in SSFL Monitoring Wells

Contaminant	**Number ofOffsiteDetections**	**Number ofOffsite Analyses**	**MaximumConc. Âµg/L or ppb**	**Location ofMax. Conc.(Well ID)**	**Date ofMaximumConc.**
Benzene	2	895	3.8	RD-38A	11/94

Carbon Tetrachloride	2	895	4.5	RD-59A	02/95
Chloroform	9	895	10	OS-2	10/89
1,1-DCA	34	895	6.5	RD-38A	11/96
1,2-DCA	2	895	0.6	RD-38A	05/98
1,1-DCE	40	895	19	RD-38A	05/96
Cis-1,2-DCE	46	895	27	RD-38A	11/96
Trans-1,2-DCE	12	895	38	RD-56A*	05/96
Methylene chloride	16	860	6	OS-8	06/92
PCE	23	895	13	RD38A	08/98
1,1,1-TCA	10	895	3.3	RD-36C	05/95
TCE	137	895	670	RD-38A	08/94
Vinyl Chloride	8	895	64	RD-56A*	03/94
N-Nitrosodimethylamine	-	47	ND	-	-
Nitrobenzene	-	47	ND	-	-
Perchlorate	1	67	5	RD-59A	08/98
Arsenic	2	57	7.1	RD-37	03/94
Lead	17	57	50	RD-43A	12/94
Manganese	18	57	390	RD-32	3/94
Silver	-	57	ND	-	-
Zinc	11	57	810	RD-38B	02/99

Key:
1,1-DCA = 1,1,-dichloroethane; 1,2-DCA = 1,2-dichloroethane; 1,1-DCE = 1,1-dichloroethylene; cis-1,2-DCE andtrans-1,2-DCE = cis/trans-1,2-dichloroethylene; PCE = tetrachloroethylene; 1,1,1-TCA = 1,1,1-trichloroethane; TCE= trichloroethylene.

ND = not detected above analytical reporting limits

Note: Wells OS-17 and OS-27 are used for drinking water supply. No contaminants have been detected in thesewells. [*RD-56AB, RD-34ABC, RD-57, and RD-33ABC are currently considered to be onsite but were considered part of the offsite area until Rocketdyne acquired the northern buffer area]

Radionuclides

Offsite areas have had limited sampling and radiological characterization of surface water because of the intermittent flow from the SSFL. Surface water sampling has been sufficient to find limited radionuclide migration. Sampling in the Bell Canyon area found only background concentrations of naturally occurring radionuclides. Multi-media sampling at the Brandeis-Bardin Institute and the Santa Monica Mountains Conservancy revealed that radionuclides have washed down from the Radioactive Material Disposal Facility (RMDF) at the SSFL onto what was part of the Brandeis-Bardin property, located north of Area IV [McLaren/Hart,1993; 1995]. This area has been purchased by Rocketdyne and is now part of the SSFL buffer zone. Strontium-90 and tritium were detected at concentrations slightly above background levels in these areas. Concentrations of radionuclides in ground water and surface water offsite of the SSFL are presented in Table 8 (below).

Table 8. Concentrations of Radionuclides in Ground Water and Surface Water Offsite of the SSFL

Radionuclide	Maximum Concentration	Location
Cesium-137	ND	Brandeis-Bardin or

		Bell Canyon
Iodine-131	ND	Bell Canyon
Strontium-90	7.79 pCi/L	RMDF Watershed on Brandeis-Bardin
Tritium	1500 pCi/L	RMDF Watershed on Brandeis-Bardin

Key : ND = not detected above analytical reporting limits
pCi/L = picocuries per liter

Potential for Human Exposure

Rocket testing operations and waste disposal activities at the SSFL have resulted in the contamination of ground water and surface water underlying and immediately adjacent to the SSFL facility (Figure 7). Well surveys conducted by Groundwater Resource Consultants indicate that there are 42 privately-owned water wells located within one mile of the SSFL [GRC, 1995; 1998]. Most of these wells are used for livestock watering; only seven of these wells are known to have been used, or are currently being used, for drinking water purposes. No contaminants have been detected in any of the wells used for drinking water.

There are dozens of other privately-owned water wells located more than one mile from the SSFL. Most of these wells are located in the Santa Susana Knolls community and the unincorporated areas outside the City of Simi Valley. Because well usage for most of these wells is not specified in the Off-Site Well Inventory [GRC, 1995], it is assumed that all of these wells are used for drinking water supply. Based on available information, ATSDR has no indication that privately-owned wells in the Santa Susana Knolls and Simi Valley areas have been affected by chemicals from the SSFL.

Available monitoring data indicates that there is limited offsite migration of chemicals in groundwater at the SSFL. It is likely that water level drawdowns created by SSFL water supply wellshave reduced ground water flow from the site and limited chemical migration to the surroundingcommunities.

There are no known municipal water supply wells located within two miles of the SSFL facility. Most of the municipal water provided to residents near the SSFL is supplied by various resellers of water imported by the Metropolitan Water District of Southern California [GRC, 1995]. Although several of the local water purveyors operate ground water wells to supplement imported water supplied to local residents, none of these wells are located within two miles of the SSFL boundary. ATSDR has no information indicating that any of these municipal wells has been contaminated by chemicals from the SSFL or any other source.

The SSFL has constructed 13 water supply wells onsite; however, these wells are currently beingused only for industrial supply. Several of these wells are routed through the site remediationfacilities for VOC extraction and treatment prior to any use. ATSDR has no information aboutwhether any of these wells were ever used for drinking water at the SSFL.

Based on our review of ground water monitoring data and well inventories, there is no indicationthat residents living near the SSFL have been exposed, or are currently being exposed tochemicals or radionuclides in ground water offsite of the SSFL. Chemicals in ground water at theSSFL have not migrated to offsite privately-owned wells or to municipal water supplies. As aresult of the ongoing ground water remediation at the SSFL site, it is unlikely that there will befuture exposure to contaminated ground water. However, because the potential for deep fractureflow from the site has not been adequately characterized, there is a potential for substances inground water to discharge at springs or downgradient water wells along the margins of SimiValley. Development of a regional hydrogeological flow model and additional monitoring atdowngradient springs or seeps in Simi Valley and Santa Susana Knolls would provide additionalcharacterization of potential future exposure via ground water and surface water pathways.

Surface water samples collected at the NPDES outfalls (located in the undeveloped area south ofthe SSFL) have been found to contain volatile organic compounds (chloroform, TCE), metals(chromium), and PCBs on a few isolated occasions. However, the concentrations detected aregenerally below regulatory discharge limits and are not at levels that would result in adversehuman effects if people came into contact with this surface water.

Surface water runoff from the SSFL is not used for drinking water purposes either at the SSFL orin nearby communities. These NPDES outfalls are located upstream of the residential area of BellCanyon (and Bell Creek) and have not been shown to be contain chemical contamination. Basedon the available data, there is no indication that chemicals and radionuclides have migrated, or arecurrently migrating in surface water from the SSFL to Bell Canyon. This is confirmed by the factthat these substances have not been detected in soil and sediment samples collected in BellCanyon and along Bell Creek. These data are discussed in the Soil and Sediment Pathway.

Based on our preliminary review of the available data, there is no indication that residents livingnear the SSFL have been exposed, or are currently being exposed to chemicals or radionuclidesin ground water or surface water at levels that would result in adverse human health effects. Based on the discontinuation of TCE use and the effectiveness of the ground water treatmentsystem, it is unlikely that future exposure to chemicals or radionuclides will occur. However, dueto the potential for deep fracture flow to offsite areas, additional monitoring of offsite springs andmodeling of regional ground water flow is recommended to improve the assessment of potentialfuture exposures.

Soil and Sediment Pathway *Background*

ATSDR reviewed the available environmental sampling data, information on the potential foroffsite migration of soil and sediment (e.g., surface water flow and wind patterns), and populationcharacteristics to determine whether chemical and radionuclide releases from the SSFL havemigrated, or are currently migrating to offsite areas where they may be a source of potentialhuman exposure. Soil and sediment at the SSFL site have been shown to be contaminated by avariety of chemicals and radionuclides. Migration to *offsite* areas may result from (1) release ofchemicals and radionuclides to air during rocket testing or waste storage, treatment, or disposal;transport in air; and then deposition onto surface soil and sediment in offsite areas, and(2)accidental spills and leaks of chemicals and radionuclides onto onsite soil and sediment withsubsequent resuspension and transport via surface water or air to offsite areas.

As discussed previously for the Air Pathway, air releases at the SSFL site are not likely to have impacted offsite areas. Therefore, the predominant pathway for chemicals and radionuclides to be transported offsite areas is via sediment resuspension and surface water flow. The SSFL site is located in hilly terrain that controls surface flow patterns at the site (Figure 2). Surface water flow onsite is directed through a series of surface impoundments that drain the active areas of the site and ultimately discharge through several NPDES permitted outfalls near the northern and southern site boundaries. Approximately 90% of the surface water flows from the site into Bell Creek through the Bell Canyon residential community located directly south of the SSFL property. These two onsite drainage channels join to form the headwaters of Bell Creek in the southern buffer zone of the SSFL. The remaining surface flow from the site (10%) discharges via drainage channels flowing in a northerly direction from Area 4 to Meier Canyon in Simi Valley [Rocketdyne, 1999a].

Environmental Data

ATSDR evaluated environmental data from soil and sediment sampling conducted in three main areas surrounding the SSFL. These include (1) the Brandeis-Bardin Institute [McLaren/Hart, 1993; 1995], (2) the Santa Monica Mountains Conservancy (McLaren/Hart, 1993; 1995), and
(3) Bell Canyon, including Bell Canyon Creek [Ogden, 1998a]. These areas are downgradient of SSFL and therefore are most likely to be impacted by any chemicals and radionuclides migrating from the site [McLaren/Hart, 1993; 1995; Ogden, 1995]. In addition, ATSDR evaluated sampling data for the Former Sodium Disposal Facility located in Area IV (onsite) because chemicals from this source have migrated to nearby offsite areas. Samples from these all of these areas were analyzed for a variety of chemicals and radionuclides [ICF Kaiser, 1995; ITC, 1999].
The Area IV Radiological Characterization Survey, dated August 6, 1996, found limited cesium-137 contamination on the SSFL site [Rocketdyne, 1996]. The Environmental Protection Agency in Las Vegas, Nevada, identified problems with the sampling techniques used in the Area IV characterization survey. They identified specific problems related to survey instrument calibration procedures and too large of a grid spacing. They also suggested that using improper techniques used could have resulted in an under-reporting of possible contamination [Dempsey, 1997]. The DOE Oakland Office and EPA's Las Vegas Laboratory are currently negotiating an Interagency Agreement to conduct a revised radiological survey of the Area IV at SSFL.
Maximum concentrations of chemicals and radionculides found in samples at these offsite locations is presented in Tables 9 and 10 (chemicals) and Table 11 (radionuclides), below.

Chemicals

Bell Canyon

Soil and sediment samples were collected in areas of Bell Canyon that are most likely to be impacted by surface flow from the SSFL site. These areas include the surface drainages leading from SSFL to Bell Canyon, Bell Creek, and the yards of three residents who requested sampling [Ogden, 1998]. Background samples were collected in undeveloped portions of Bell Canyon representing areas that are not likely to be impacted by the SSFL.
Sample analyses were conducted for a wide range of chemicals and radionuclides. Because perchlorate and dioxin (and dioxin-like compounds) have been found in soil and sediment samples collected on the SSFL, analyses were also conducted for these analytes. There were no procedures established by the EPA for analyzing perchlorate in soil and sediment samples at the time that these analyses for Bell Canyon were conducted. Concentrations of dioxin and dioxin-like compounds were reported in units of TCDD-Total Equivalents (TCDD-TEQs) which reflects the sum of all dioxin and dioxin-like congeners in a sample [Ogden, 1998a].
As presented in Table 9, concentrations of total TCDD-TEQ and several metals (arsenic, barium, beryllium, chromium, and lead) were above analytical reporting limits in soil and sediment samples collected in Bell Canyon. However, the maximum concentrations in these samples were similar to levels in background samples. Two organic compounds, pyrene and N'-nitrosodiphenylamine were detected above analytical reporting limits (at a maximum concentration of 39 Âµg/kg and 36 Âµg/kg, respectively) *only* in background samples, and *not* in samples collected along drainage channels leading from the SSFL to Bell Canyon. Collectively, these data indicate that chemicals in soils and sediment at the SSFL are not migrating to Bell Canyon.

Brandeis-Bardin Institute and Santa Monica Mountains Conservancy

Soil and sediment samples were collected in the Brandeis-Bardin Institute and Santa Monica Mountains Conservancy. The areas sampled were ravines nearest the SSFL (and most likely to have received surface runoff from the site), and nearby playgrounds, campgrounds, and parking lots. Background samples were collected from areas 1.5 to 12.5 miles away from the SSFL representing areas that are not likely to be impacted by the SSFL [McLaren/Hart, 1993;1995].
Sample analyses were conducted for a wide range of chemicals and radionuclides. Maximum concentrations of chemicals in soil and sediment at the Brandeis-Bardin Institute and Santa Monica Mountains Conservancy are presented in Table 10. Two metals, mercury and lead, were found in samples from the Brandeis-Bardin Institute and Santa Monica Mountains Conservancy at concentrations significantly above background levels. Mercury was detected

in a single sample (at a concentration of 0.35 mg/kg) collected along the drainage leading from the former Sodium Disposal Facility, located in Area IV, to the Brandeis-Bardin Institute. Contamination in this sample most likely resulted from past activities at the Sodium Disposal Facility because mercury was not found in background samples or in samples from other offsite locations. The SSFL facility has removed the mercury-contaminated soils from this area. Lead was also found at concentrations significantly above background levels in a single sample atthe former Rocketdyne Shooting Range near the Santa Monica Mountains Conservancy. Othersamples collected in the Brandeis-Bardin Institute and Santa Monica Mountains Conservancy didnot have elevated lead concentrations. The isolated distribution of the soil lead at the formerShooting Range is due to lead ammunition used at the shooting range and does not indicate offsitemigration of SSFL contamination.

Several organic compounds, including bis(2-ethylhexyl)phthalate, 4,4'-DDE, 4-methylphenol, andmethylene chloride, were found in *single* samples collected in the Brandeis-Bardin Institute andnot in any background samples. Because these were single detections, there is no indication thatthere is widespread contamination at the Brandeis-Bardin Institute and the Santa MonicaMountains Conservancy. Methylene chloride and toluene were also detected in samples collectedat the Conservancy, and not in background samples.

Former Sodium Disposal Facility

ATSDR evaluated environmental data from several *onsite* areas where chemicals have been released into the environment and have the potential to migrate to offsite areas. These include the Area I Thermal Treatment Facility [Rockwell International, 1992; GRC, 1993], the Former Sodium Disposal Facility [ICF Kaiser, 1995; ITC, 1999], Sodium Burn Pit, and Happy Valley [Ogden, 1999]. ATSDR also evaluated environmental data pertaining to a number of accidental releases of chemicals and radionuclides to soil and sediment to determine whether these releases could have resulted in contamination of offsite areas [Lafflam, 1989; ICF Kaiser, 1993; Rockwell International, 1994]. Based on the information reviewed, chemicals from the Former Sodium Disposal Facility have migrated to offsite areas. The Disposal Facility is located on the western boundary of Area IV and is comprised primarily of an upper pond, lower pond, and adjacent areas. Approximately 12,000 cubic yards of soil have been removed from this area to an offsite landfill. Currently, up to six feet of overburden remains in the upper pond (Figure 8). In the lower pond, all soils have been removed down to bedrock [ITC, 1999].

Figure 8. Site of former Sodium Disposal Facility. The view is looking northwest towards Brandeis-Bardin Institute and Simi Valley.

During periods of rainfall, surface flow from the Disposal Facility flows primarily in a northerly direction via two channels that ultimately discharge at NPDES-permitted outfalls at the northwest property boundary. In 1995, contractors for the SSFL facility collected soil and sediment samples along these surface drainages. The samples were analyzed for several types of organic compounds, including polychlorinated biphenyls (PCBs), dioxin and dioxin-like compounds (reported as TCDD-TEQs), volatile and semi-volatile organic compounds, and metals [ITC., 1999]. Sampling data indicate that PCBs, TCDD-TEQ, and mercury had migrated in drainages from the Disposal Facility to offsite areas. Maximum concentrations were found in offsite samples collected a short distance downstream of the upper and lower ponds; concentrations decreased with increasing distance from the ponds.

Offsite concentrations of PCBs ranged from 22 to 3800 Âµg/kg. The maximum concentration wasfound in a sample collected just north of the facility boundary; the lowest concentration was foundin a sample collected at a distance of 4000 feet from the Disposal Facility.

Offsite concentrations of TCDD-TEQ ranged from 0.00018 to 0.00672 Âµg/kg, which is equivalentto 0.18 to 6.72 parts per trillion (ppt) for TCDD -TEQs; concentrations of mercury ranged fromnot detected to 0.00052 Âµg/kg. The maximum concentration of TCDD-TEQ and mercury werefound in samples collected just north of the facility boundary. The lowest concentration of TCDD-TEQ was in a sample collected at a distance of 4000 feet from the Disposal Facility. Mercury wasnot detected in samples collected just offsite of the SSFL boundary; therefore additional samplingat more distant areas from the source was not conducted.

Radionuclides

The U.S. Department of Energy's Remote Sensing Laboratory and EG & G Energy Measurement Group from Las Vegas performed aerial radiological surveys of all nuclear facilities in the late 1970s [EG&G, 1979]. In June and July of 1978, they performed surveys of the Rockwell International Facilities in Canoga Park and at the SSFL. The report states that radiation on the Rockwell properties could not be detected from the property boundary lines. The survey of SSFL detected no gamma emitters (e.g., cesium-137, cobalt-60) above background levels in drainage channels at the site. Offsite areas have had limited sampling and radiological characterization, but sufficient to find limited radionuclide migration. The Bell Canyon sampling found only background concentrations of naturally-occurring radionuclides [Ogden, 1998a]. Multi-media sampling at the Brandeis-Bardin Institute and the Santa Monica Mountains Conservancy found that radionuclides have washed down from the Radioactive Material Disposal Facility (RMDF) onto what was part of the Brandeis-Bardin property, North of Area IV [McLaren/Hart, 1993;1995]. Cesium-137, strontium-90, and tritium were detected at levels above background.

Table 9. Maximum Contaminant Concentrations in Surface (0 to 0.5') and Subsurface (0.5 - 1') Soil and Sediment Samples in and near Bell Canyon

Contaminant	Surface Soil(SS) Bell Canyon Âµg/kg or ppb	Surface Soil(SS) BackgroundÂµg/kg or ppb	SubsurfaceSoil (BS) Bell Canyon Âµg/kg or ppb	Subsurface Soil(BS)Background Âµg/kg or ppb	Comments
PCBs	<110-150(RL)	<100-110 (RL)	<120-160 (RL)	<120 (RL)	No samples abovereporting limits forAroclor 1016-1260
PAHs	<32-46 (RL)	<31(RL)-39	<34-48 (RL)	<36 (RL)	Only 1 bkgrdBCSS09 with PAHconc. abovereporting limit, forpyrene (39 ppb)
Total TCDD-TEQ	0-0.00013	0-0.000046	0.00001-0.00055	0	See text fordiscussion of TotalTCDD-TEQ
Perchlorate	<43-260 (RL)	<41-230 (RL)	<46-210 (RL)	<49 (RL)	No samples abovereporting limits forperchlorate
N'-Nitrosodi-methylamine(NDMA)	<2-3 (RL)	<2 (RL)	<2-3 (RL)	<2 (RL)	No samples abovereporting limits forNMDA
N'-Nitrosodi-phenylamine(NDPA)	<32-46 (RL)	<31-34 (RL)	<34-48 (RL)	<36	No samples abovereporting limits forNDPA
As (ppm)	<5(RL)-14	<5(RL)-16	<6(RL)-8	14	
Ba (ppm)	31-170	36-97	22-63	140	
Be (ppm)	0.5(RL)-1.0	0.5(RL)-1.1	NA	1.1	Analyses forberyllium wasconducted for 4 of15 samples (SS andBS) collected fromBell Canyon
Cr-total (ppm)	5-30	9-26	6-15	29	
Pb (ppm)	6(RL)-27	7-26	6(RL)-9	29	

Key:
RL = Analytical Reporting Limits

ppb = parts per billion; ppm = parts per million

PCBs = polychlorinated biphenyls; PAHs = polyaromatic hydrocarbons; TCDD-TEQ = TCDD-toxicequivalency; As = arsenic, Ba = barium, Be = beryllium; Cr-total = total chromium; Pb = lead

[Source: Ogden, 1998]

Table 10. Maximum Contaminant Concentrations in Soil and Sediment at Brandeis-BardinInstitute and Santa Monica Mountains Conservancy from Sampling Conducted in 1992[McLaren/Hart, 1993; 1995]

Contaminant	Background Concentration (mg/kg or ppm) and sample with maximum concentration	Concentration at BBI (mg/kg or ppm) and sample with maximum concentration	Concentration at SMMC (mg/kg or ppm) and sample with maximum concentration	Comments
As	14 (BG-03)	24 (BB-18)	8.2 (SM-01)	
Be	1.00 (BG-03)	0.99 (BB-13)	1.20 (SM-01)	
Cd	7.3 (BG-03)	1.1 (BB-06)	ND (<0.50)	BB-06 detection reported by EPA
Cr-total	96 (BG-03)	27 (BB-09)	24 (SM-01)	
Hg		0.35 (BB-18)		Only offsite sample with positive detection in drainage from the former Sodium Burn Pit; EPA split sample reported a concentration of 0.4 ppm; contaminated soils have been excavated from this area
Pb	22.8 (BG-02)	53 (BB-12)	26 (SM-01); 280 (SM-03)	SM-03 is near the former Rocketdyne Employee Shooting Range
Zn	120 (BG-03)	78 (BB-12)	76 (SM-01)	
Bis(2-ethylhexyl)-phthalate		8.5 (BB-07)		Only offsite sample with positivedetection
4,4'-DDE	---	0.360 (BB-11)	---	Only offsite sample with positive detection
4-Methylphenol	---	0.670 (BB-02)	---	Only offsite sample with positive detection
Acetone	0.012 (BG-02)	0.030 (BB-19)	---	
MethyleneChloride	---	0.017 (BB-15)	0.007 (SM-01)	
Toluene	---	---	0.009 (SM-01)	

Key: BBI = Brandeis-Bardin Institute
SMMC = Santa Monica Mountains Conservancy

ND = Laboratory analysis indicating that the concentration is below specified reporting limit

-- = Laboratory analysis indicating that the concentration is below reporting limits

mg/kg = milligrams per kilogram; ppm = parts per million

As = arsenic; Be = beryllium; Cd = cadmium; Cr-total = total chromium; Hg = mercury, 4,4'-DDE = 4,4'-dichloro-bis(p-chlorophenyl)ethylene

EPA = Environmental Protection Agency

Table 11. Maximum Offsite Radionuclide Concentrations in Surface Soils and Sediments

Radionuclide	Maximum Concentration	Sampling Location
Cesium-137	0.60 pCi/g	RMDF watershed on Brandeis-Bardin
Iodine-131	ND	Bell Canyon
Plutonium-238	ND	Bell Canyon
Potassium-40	25 pCi/g	Bell Canyon
Radium-226	1.5 pCi/g	Bell Canyon
Strontium-90	0.15 pCi/g	Orange Grove on Brandeis-Bardin
Thorium-228	1.8 pCi/g	Bell Canyon
Thorium-230	1.4 pCi/g	Bell Canyon
Thorium-232	1.5 pCi/g	Bell Canyon
Tritium	0.36 pCi/g	Bell Canyon
Uranium-233/234	1 pCi/g	Bell Canyon
Uranium-235	0.07 pCi/g	Bell Canyon
Uranium-238	1.1pCi/g	Bell Canyon

Potential for Human Exposure

ATSDR used the available sampling data and other information about the site and surroundingcommunity to determine whether persons in the community may have been exposed, or becurrently exposed, to chemicals or radionuclides released to soil and sediment from the SSFL.

Chemicals and radionuclides have migrated by sediment transport in surface water runoff from the SSFL to offsite areas. In general, maximum concentrations have been detected *just outside* the SSFL property boundary; concentrations decrease rapidly with increasing distance from the facility. The area surrounding the SSFL is rugged and hilly and not easily accessible to persons in the nearby community. There is a limited likelihood that persons in the community would come into contact with chemicals and radionuclides in soils and sediment just offsite of the SSFL. In addition, maximum concentrations of chemicals and radionuclides at these offsite areas are not at levels that would result in adverse human health effects if human exposure were to occur [DeRosa, 1997; ATSDR, 1997b, 1998]. Chemicals and radionuclides have not been found in samples collected in *more distant*residential or recreational areas surrounding the SSFL, including Bell Canyon, Brandeis-Bardin Institute, and Santa Monica Mountains Conservancy, at levels that would result in adverse human health effects if any human exposure were to occur in these offsite areas. As mentioned previously for Bell Canyon sampling data, there were no established procedures for analyzing perchlorate in soil and sediment samples at the time the Bell Canyon investigation was conducted. Therefore, ATSDR evaluated the potential for adverse health effects to occur if persons were exposed to soil and sediment containing perchlorate at the maximum reporting limit used for Bell Canyon, which was 260 Âµg/kg.
The U.S. EPA recently published a comprehensive review of toxicity data for perchlorate [EPA, 1998, 1999]. In this review, the EPA considers the most sensitive effect of perchlorate exposure to be developmental effects on the thyroid of newborn rats (exposed in the womb or *in utero*). Based on these animal studies, they reported that human exposure to perchlorate at a dose of 0.0009 mg/kg/day or less does not pose a health hazard for thyroid toxicity or cancer. We used this reference dose established by the EPA to determine whether potential exposure to persons in the

Bell Canyon would pose a health hazard. To do this, we assumed that a small child living in Bell Canyon ingests contaminated soil (at a maximum concentration of 260 Âµg/kg for perchlorate) while playing. We assumed exposure to a small child because children are potentially more sensitive to the toxic effects of chemicals because of their immature and developing biological systems. We determined that even if a small child ingests 200 milligrams of soil containing 260 ppb of perchlorate daily for several years, adverse health effects on the thyroid are not likely. In fact, a small child would have to ingest more than 300 times this concentration in soil to exceed the dose that the EPA considers to be protective for thyroid toxicity. Therefore ATSDR considers the reporting limit used in the Bell Canyon sampling to be protective of public health.

Based on our preliminary review of the available data, ATSDR has no indication that persons inthe community surrounding the SSFL have been, or are currently being exposed to chemicals orradionuclides in soil or sediment from the SSFL at levels that would result in adverse humanhealth effects .

Public Health Implications

In this section, ATSDR considers the results of the exposure pathways analyses together with thecommunity concerns and available health studies to determine the potential for health impact tocommunities surrounding the SSFL.

The results of the exposure pathways analyses for air, surface water and ground water, and soiland sediment indicate that human exposure to chemicals and radionuclides from the SSFL is notlikely to have occurred, or be occurring, in the communities surrounding the SSFL at levels thatwould result in adverse human health effects. Chemicals and radionuclides have been released tothe environment at the SSFL site. Based on the available data, ATSDR has no indication thatsignificant concentrations of chemicals and radionuclides have migrated from the site to offsiteareas where human exposure could occur. Because we have no indication of human exposure atlevels of health concern in offsite communities, there is also no indication that adverse humanhealth effects are likely to occur in these communities.

The findings of the health studies for the SSFL area do not provide conclusive answers regardingwhether members of the community surrounding the SSFL site experienced adverse health effectsfrom potential exposure to chemicals and radionuclides released from the SSFL. While thecommunity expressed concern about potential exposure to radionuclides from the SSFL, thecommunity studies do not show any increase in cancers considered to be "very radiosensitive",such as leukemia.

Interpretation of the bladder and lung cancer findings for the community cancer registry studies isdifficult because the increases were not consistent across sex or the surrounding geographic area(Ventura vs. Los Angeles County). In addition, the studies provide no information about potentialenvironmental or lifestyle exposures that may have contributed to these observed increases. Forbladder cancer, there was no evidence of increased mortality among the SSFL workers; site-related exposures should have been higher for the SSFL workers than for the communitymembers, thus health effects of the exposures would more likely be found in the worker studies.The worker studies did show an increase in lung cancer mortality in workers with presumedexposure to external radiation or hydrazine, however confounding effects due to smoking, lifestylefactors, and other unmeasured chemical exposures, could not be ruled out. The uncontrolledconfounding effects can introduce either positive or negative bias into the expected mortalityfrequencies.

The community identified a number of specific health concerns in addition to the incidence ofbladder and lung cancers. In the absence of documented exposures to SSFL chemicals andradionuclides, it is very unlikely that the diseases underlying those health concerns are related toenvironmental releases from the SSFL. Specific community environmental concerns included thesafety of drinking water supplies, surface water runoff, radiation exposure, and the desire foradditional environmental sampling. Currently no drinking water supply wells have been affectedby SSFL-related contaminants. Due to water recycling processes at the SSFL and the aridconditions in this area there is very limited potential for surface water runoff. Surface watermonitoring indicates that chemicals and radionuclides are rarely detected and well below levels ofhealth concern. Extensive monitoring also indicates that radiation in areas of potential offsiteexposure has not been detected above background levels. Concerns related to additionalenvironmental sampling are addressed in the Exposure Pathways Analyses and Conclusions andRecommendations sections.

Conclusions and Recommendations

In this preliminary evaluation of available data and information, *ATSDR has not identified an apparent public health hazard to the surrounding communities because people have not been, and are currently not being exposed to chemicals and radionuclides from the site at levels that are likely to result in adverse health effects.*

Air Pathway

Available environmental data indicate that chemicals and radionuclides have been released to air during rocket engine testing and waste handling and disposal activities at the SSFL. Quantitative air monitoring data and verified site-specific meteorological data are not available. Releases in the past were probably higher than at present. Given that the nearest communities are located more than one half mile from any onsite release sources, it appears unlikely that onsite releases would migrate to offsite areas at levels that would pose a health hazard to the surrounding community.

Ground and Surface Water Pathway

Ground water under the site is contaminated by trichloroethylene (TCE) that has migrated offsite of the northwestern and northeastern facility boundaries. Contamination was first recognized in the 1980s and concentrations of TCE, and its degradation products, have declined over time. The majority of the local water supply is provided by purveyors who obtain water from surface water sources distant from the SSFL. These purveyors have supplemental water supply wells that are located more than two miles from the SSFL. Some privately-owned water wells are located in the Santa Susana Knolls and unincorporated areas of Simi Valley. Available data and information provide no indication that municipal and privately-owned water wells have been adversely impacted by chemicals or radionuclides from the SSFL. As a result of the ongoing ground water remediation at the SSFL site, it is unlikely that there will be future exposure to contaminated ground water. Because the potential for deep fracture flow from the site has not been adequately characterized, there is a potential for substances in ground water to discharge at springs or down-gradient water wells along the margins of Simi and San Fernando Valleys.

Soil and Sediment Pathway

Available data and information indicate that chemical and radionuclide releases to soil and sediment have occurred at the SSFL. One important source of releases is the Former Sodium Disposal Facility located in Area IV. There has been limited soil and sediment migration of chemicals and radionuclides from the Disposal Area to offsite areas north of the facility boundary. Concentrations are highest close to the facility boundary and decrease rapidly with increasing distance from the property boundary. Because the area surrounding the SSFL is hilly and rugged, it is not easily accessible to persons in the nearby community. Any human exposure to these maximum offsite concentrations is not likely to result in adverse human health effects. Based on available data and information, there is no indication that offsite residential areas, including the Brandeis-Bardin Institute, Santa Monica Mountains Conservancy, and Bell Canyon, have been adversely impacted by chemicals and radionculides from the SSFL. Therefore, there is no apparent likelihood for human exposure to chemicals and radionuclides in soil and sediment in these offsite areas. In response to comments made by the Las Vegas EPA office on the sampling techniques used to characterize radionuclides in Area

IV of the facility, further characterization of Area IV radionuclides is being proposed by EPA and the Department of Energy.

Recommendations

ATSDR acknowledges that this report is a *preliminary* assessment of the potential for human exposure and public health hazard posed by the SSFL. On the basis of our preliminary conclusions, we make the following recommendations:

- A more in-depth evaluation of exposure pathways that addresses past, current, and future exposure to chemicals and radionuclides from the SSFL should be conducted to improve the assessment of potential offsite exposures and public health implications associated with this site. Such an assessment must be facilitated through community outreach and participation and must include health education activities. We further recommend that this assessment address the following related issues:
    - More in-depth evaluation of airborne chemical releases from SSFL operations, including air dispersion modeling of past accidents and disposal activities, and compilation and use of a consistent, site-specific meteorological data set to improve the assessment of past exposures to these substances.
    - Development of a regional hydrogeological flow model and additional monitoring at down-gradient springs or seeps in Simi Valley and Santa Susana Knolls to evaluate the potential for deep fracture flow and potential future exposure. Also, even though it may not be related to SSFL, additional source characterization of the perchlorate detection in Simi Valley should be conducted.
    - Additional radiological characterization of Area IV with more sensitive instrumentation and appropriate grid spacing to assure a lower detection limit.

- A re-analysis of the cancer registry data including additional years of newly available cancer data and updated demographic information should be conducted to see if the apparent increase in the incidence rates of bladder and lung cancers persist. A more in-depth evaluation of cancer data should be conducted that addresses environmental exposures from the SSFL, possible confounding exposures from other nearby contaminant release sources, and residential histories.

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