

# 4.0 GROUNDWATER AND SURFACE WATER PATHWAYS

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## 4.0 GROUNDWATER AND SURFACE WATER PATHWAYS

### 4.1 Overview

The groundwater system and surface water streams in the SSFL area and its immediate vicinity are a linked integrated system. The movement of groundwater is affected by the rate of recharge through precipitation, subsurface fracture systems, and groundwater pumpage by onsite water supply and remediation wells. Groundwater elevations at the SSFL site are significantly higher than elevations at Simi and San Fernando Valleys, with groundwater emerging from a number of springs and seeps in the canyons leading from the site into the valleys (GRC, 1987).

Groundwater monitoring studies have revealed significant groundwater contamination at the SSFL site, above health-based standards and regulatory levels (Appendix H; CHDS, 1999) McLaren/Hart, 1993, 1995; GRC, 1990a, 2000; Rocketdyne, 1958-1960, 1959-1989). There is also concern that chemicals and radionuclides have migrated away from SSFL via both groundwater and surface water pathways.<sup>4.1</sup> In order to identify groundwater and surface water contaminant migration pathways, as well as water COPCs (Appendix C), the study team reviewed NPDES releases, disposal and leakage from surface impoundments, site hydrogeology, groundwater pumping, and the extent of migration of subsurface contaminants.

#### 4.1.1 NPDES Releases

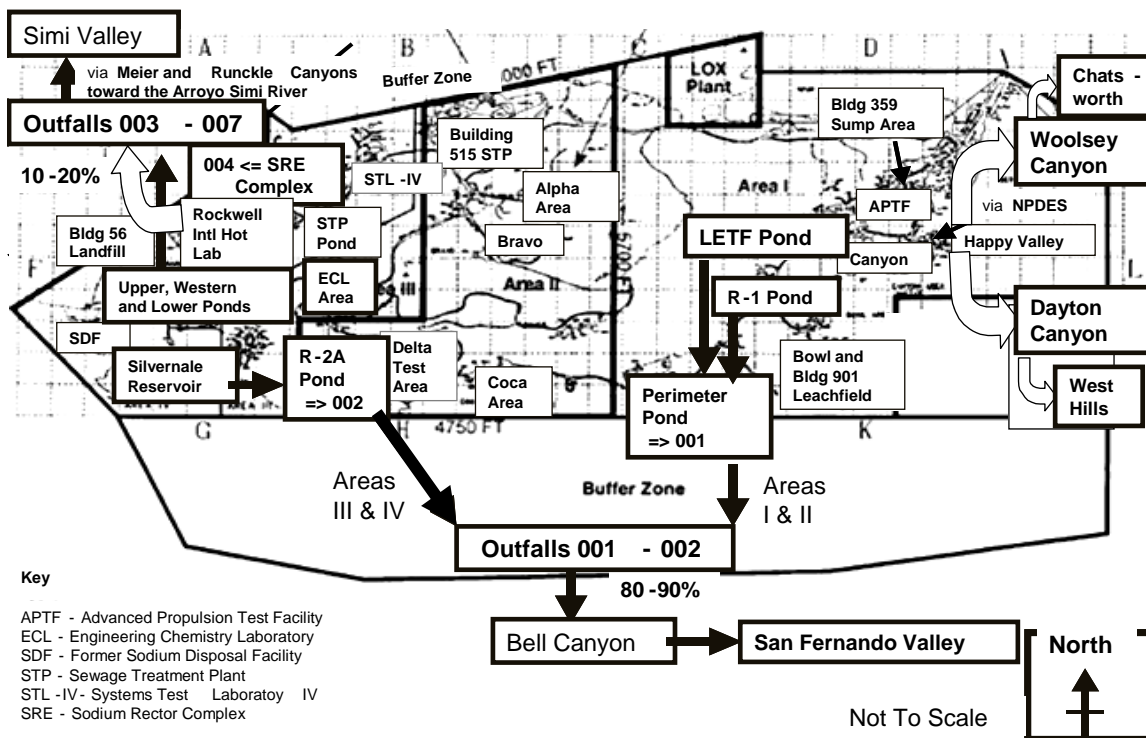
SSFL has a National Pollutant Discharge Elimination System (NPDES) permit<sup>4.2</sup> allowing it to discharge up to 160 million gallons of treated water per year (about 90% of the facility's surface water discharge). There are two NPDES outfalls (Figure 4-1): NPDES 001 (Perimeter Pond) and NPDES 002 (R2A) located near the undeveloped area south of SSFL and upstream (north) of the residential area of Bell Canyon (and Bell Creek) (Rockwell International, 1987; Boeing, 2003). These two onsite drainage channels join to form the headwaters of Bell Creek in the southern buffer zone of SSFL. Land south of SSFL is borderland and gated but easily accessible (see Chapter 6). South of this gated border zone is the Bell Canyon neighborhood, which extends essentially to the fence line. Chemical contamination above health-based standards has been reported in the Bell Creek headwaters (Table 4-1). The remaining 10 percent of treated water flows from Area IV into Outfalls 003 through 007 and drains north into the Simi Valley via Runckle and Meier Canyons.

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<sup>4.1</sup> Techlaw consultants (1990) reported that "a number of ponds were not lined and are situated in a drainage eroded along a fracture or fault" (Techlaw, 1990). See Figure 4-1 for pond locations.

<sup>4.2</sup> NPDES Permit No. CA0001309 (Rockwell International, 1987; Boeing, 2003).

Figure 4-1. Locations of NPDES Drainage



#### 4.1.2 Disposal and Leakage from Surface Impoundments

The SSFL water reclamation and contamination control system is formed by a series of surface impoundments (about 28 between 1963 and 1988) designed to collect cooling water, rinse water, stormwater runoff, and accidental spills. Waste collected in these impoundments consisted primarily of organic solvents, hydrazine fuels, oxidizers, and kerosene-based fuels (GRC, 1986). According to the Hydrogeologic Assessment Report by GRC (1987), approximately 870 tons of wastes were deposited in the impoundments from 1963 to 1988. It has been reported that a significant number of impoundments had either inadequate linings or no linings. The concrete linings in the older ponds were inadequately maintained, and cracking was reported (GRC, 1988a). Note that leachate recovery systems were not installed at the impoundments before 1988 (GRC, 1988a).

In 1991, the RWQCB sent a letter (RWQCB, 1991) to Rockwell International regarding the results of the 1990 GRC study, in which it was stated that: “Based on the analyses of disposal data at the facility and water elevation data [e.g., groundwater level is about 100–300 feet below surface in the vicinity of the SDF pond], it is apparent that hazardous waste constituents have migrated from the unlined pond at the Sodium Disposal Facility (SDF) to the vadose zone, Shallow Zone, and Chatsworth Formation groundwater system. It is also possible that migration is likely to continue.” The above early evaluation and evidence of groundwater contamination (Appendix H) beneath the SSFL site (GRC, 1990) suggest that there is a high likelihood that migration of contaminants, from leaky surface impoundments, has contributed to groundwater contamination (Table 4-1).

## 4.2 Hydrogeology

Groundwater and surface water flows determine the migration and dispersion of contaminants from SSFL via the water pathway. Therefore, it is instructive to review the hydrogeology at SSFL. Groundwater at SSFL is found in two systems: the shallow zone and the Chatsworth Formation. The shallow zone alluvium overlies the Chatsworth Formation, which is a Cretaceous marine turbidite sequence of sandstone interbedded with siltstone/mudstone and conglomerate lenses (Colburn et al., 1981). Zones of weakness, some of which have eroded to canyons infilled with alluvium, are formed by fractures, faults, or siltstone/claystone outcrops. Runoff from precipitation events flows in canyon bottoms and infiltrates in channels eroded along these zones of rock weakness (fractures and faults) (Techlaw, 1990).

General groundwater and surface water flow patterns are shown in Figure 4-2. Surface water and groundwater flow towards lower elevations in the north (Simi Valley), east (San Fernando Valley), and south (Bell Canyon) (GRC, 1987). Surface flows at SSFL drain to the north, northeast, south, southwest and east. Water level contours indicate a west to northwesterly component of groundwater flow in the northwestern portion of the facility and a southerly component of groundwater flow in the southwest portion of the facility (Rocketdyne, 1988). Connectivity of groundwater and surface water flows is hampered by low precipitation in the region. The mean annual precipitation from 1960 to 1986 (from the Simi-Hills/Burro Flats station) was reported to be in the range of 18.6 to 21.5 inches (Techlaw, 1990). A mean annual precipitation of 22.5 inches was reported for the period of 1978 to 1985 (GRC, 1987). Because of the low precipitation level in the region, there are only intermittent surface water runoff flows downhill from SSFL; this has resulted in limited offsite runoff water sampling, thereby preventing sufficiently detailed chemical and radiological characterization of surface water runoff.



The shallow groundwater zone occurs within the thin (0 to 20-foot), discontinuous superficial alluvium found along canyon drainages and in underlying zones of weathered sandstone and siltstone (Techlaw, 1990). It comprises a heterogeneous mixture of gravel, sand, silt, and clay and is estimated to have a hydraulic conductivity of 0.001 to 0.1 gpd (gallons per day)/ft<sup>2</sup> (Techlaw, 1990). This zone is distributed primarily in the Burro Flats area (Area IV) and along ephemeral drainage features (Techlaw, 1990). The shallow zone may be saturated along ephemeral drainages and in the southern part of Burro Flats (Techlaw, 1990). Some portions of the shallow alluvium are saturated only during and immediately following the wet season. Groundwater in

**Figure 4-2.** Surface Water (Light Lines) and Groundwater Flows (Bold Lines)

this zone flows under unconfined conditions. The thickness of the saturated portion of the shallow zone ranges from less than 1 foot to as much as 10 feet. The surface of the saturated portion of the shallow alluvium is a subdued expression of the topographic surface. Water in the shallow zone may move laterally to an area of discharge or downward into the underlying Chatsworth Formation via connecting fractures (Techlaw, 1990).

The principal groundwater aquifer is within the Chatsworth Formation (Techlaw, 1990). The Chatsworth Formation may be as thick as 6,000 feet at the facility, and is overlain in places by the Martinez Formation and by Quaternary alluvium. Fractures occurring in the Chatsworth Formation may be associated with bedding planes, jointing,<sup>4.3</sup> and faulting.<sup>4.4</sup> A number of faults are present at the site. These have two general orientations: the North, Coca, Burro Flats, Woolsey Canyon and Happy Valley Faults generally strike east/west, while the Shear Zone and Skyline Fault generally strike northeast/southwest. All faults appear to dip nearly vertically. There is disagreement as to whether the unfractured portions are permeable. Montgomery-Watson presented a model in which the “fracture network is interconnected, and groundwater flow is compartmentalized by the presence of lower permeability shale units and faults” (Montgomery Watson, 2000a). A report from Groundwater Resources Consultants (GRC) suggested that almost all water flow is in zones of fractures and that the unfractured portions are virtually impermeable (GRC, 1999). However, a 1999 letter from Ventura DHS to Rocketdyne warned that “The term virtually impermeable is misleading and wells constructed in unfractured areas still produce groundwater” (DHS, 1999).

The fracture subsurface system in the SSFL area makes it difficult to predict groundwater movement. Multiple methods have been used to derive estimates of the bulk hydraulic conductivity of the Chatsworth Formation. These methods show that the overall bulk hydraulic conductivity is likely to be in the range of  $1 \times 10^{-5}$  cm/s to  $5 \times 10^{-5}$  cm/s (MWG, 2003). Permeabilities in this fractured formation range from approximately 0.01 to 1,000 gpd/ft<sup>2</sup>; this wide range in permeability can be attributed to the fractured nature of the formation. The inflow into the groundwater system was estimated to be approximately 2 inches per year (MWG, 2003). Outflows from the groundwater system include discharges through springs and seeps, groundwater extraction for interim remedial measures, and discharge to the surrounding groundwater system (MWG, 2003).

To summarize, it appears that in some areas of SSFL the two groundwater systems are connected hydrologically. In others, the shallow zone aquifer is separate and distinct from the Chatsworth Formation groundwater, as evidenced by vastly different groundwater elevations and contaminant concentrations. Even in those areas, though, it is likely that the shallow zone transmits groundwater and contaminants to the underlying fractured Chatsworth Formation (GRC, 1986).

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<sup>4.3</sup> A joint is a divisional plane or surface that divides a rock along which there has been no visible movement parallel to the plane or surface.

<sup>4.4</sup> A fault is a fracture or fracture zone along which the two sides have been displaced relative to one another, parallel to the fracture.

#### **4.2.1 Groundwater Pumpage**

Onsite groundwater withdrawals, which commenced in October 1948, have reduced water levels at wells northeast of the facility (on and off site) (Rocketdyne, 1988). This has caused partial groundwater stagnation in certain areas around SSFL. As early as 1957, heavy pumping around the northeast corner of SSFL induced groundwater to migrate toward that quarter of the facility; pumping there was conducted primarily because that quadrant had the best yielding wells (Rocketdyne, 1988). This practice of heavy pumping in the northeast quadrant has continued from the 1950s to the present time. Since at least the early 1980s, groundwater extractions have been limited exclusively to that quadrant (Rocketdyne, 1988). It has been suggested that pumping at offsite wells northeast of the facility (i.e., wells RD-38A and OS-24) may have been responsible for the TCE plume's migration off site along the northeast boundaries of SSFL (ERD, 1992). The offsite wells appear to be located along major interconnected fracture systems (Rocketdyne, 1988). In recent years, substantial additional characterization efforts have focused on the above area (Montgomery Watson Harza, 2003a).

Because the pumping has lowered the groundwater table at SSFL overall (not just in the northeast), several existing wells were deepened and recycling and reuse of industrial water had to be implemented (Rocketdyne, 1988). As pumpage volumes continued to increase with time (from 1964 to 1988) and groundwater levels decreased, Rocketdyne was required to turn to imported water from Callegas Municipal Water District to supplement onsite drinking water (Rocketdyne, 1988). The ratio of imported water to water from well extractions, since 1984, has been approximately 2:3 (Rocketdyne, 1988).

#### **4.2.2 Extent and Migration of Subsurface Contamination**

In various offsite locations, groundwater contaminants have been detected at levels above health-based standards (see Table 4-1 and Figure 4-3). The detection of contaminants associated with SSFL off site, within 1 to 2 miles, suggests that—if these contaminants have originated from SSFL—migration pathways must exist. These pathways include surface water runoff (controlled and natural) in the northwest and south, as well as migration via groundwater in the northeast and northwest. Migration via surface water away from the site is associated primarily with manmade channels (e.g., NPDES outfalls), although natural surface flow can also take place during periods of heavy rainfall.

**Table 4-1. Offsite Water Contaminants Detected Above Health-Based Standards**

Chemical	Concentration (µg/L)		Date Detected	Location/Sample Identification	Sample Location, Sample Type, Factor by Which Detected Levels Are Above Standards or Comments	Ref
	Monitored Level <sup>a</sup>	Regulatory Standard <sup>b and c</sup>				
Chromium	75	50 <sup>b</sup>	1/28/93	NPDES Outfall 002	South	2
Nickel	130	100 <sup>b</sup>	12/6/94	NPDES Outfall 002	South	2
Lead	40	12 <sup>b</sup>	1/9/95	NPDES Outfall 001	South	2
Chromium	390	50 <sup>b</sup>	3/94	RD-32	Northeast (Sage Ranch)	3
Lead	50	12 <sup>b</sup>	12/94	RD-43	East (Woolsey Canyon)	3
Chloromethane	19	1.5 <sup>c</sup>	4/10/86	OS-5	12x > TWSL; livestock well	2
Bis(2-ethylhexyl) phthalate (DEHP)	66	6 <sup>b</sup>	1/13/90	SBP1	Surface water	2
Bis(2-ethylhexyl) phthalate (DEHP)	109	6 <sup>b</sup>	1/13/90	SBP2	Surface water; EPA priority analysis	2
Bis(2-ethylhexyl) phthalate (DEHP)	170	6 <sup>b</sup>	1/17/90	SBP1	Surface water	2
Fluoride	4,600–5,400	2,000 <sup>b</sup>	1/90-2/90	OS-2	Livestock well	1
Bis(2-ethylhexyl) phthalate (DEHP)	70	6 <sup>b</sup>	2/17/90	SBP1	Surface water	1
Bis(2-ethylhexyl) phthalate (DEHP)	97	6 <sup>b</sup>	2/17/90	SBP2	Surface water; EPA priority analysis	1
TCE	10	5 <sup>b</sup>	3/11/92	SMMC: well by gate	Groundwater	1
PCB-1254	120	0.5 <sup>b</sup>	2/4/94	Outfall 005	240x > MCL	7
PCB-1254	92	0.5 <sup>b</sup>	2/4/94	Outfall 006	184x > MCL	7
Lead	210	12 <sup>b</sup>	2/17/94	Outfall 003	14x > MCL	3
Vinyl chloride	64	0.5 <sup>b</sup>	3/94	RD-56A	128x > MCL	6
TCE	670	5 <sup>b</sup>	8/94	RD-38A	134x > MCL	6
Benzene	3.8	1 <sup>b</sup>	11/94	RD-38A	Groundwater	6
Carbon tetrachloride	4.5	0.5 <sup>b</sup>	2/95	RD-59A	> 9x MCL; northwest (west of Area IV RMDF)	6
Lead	30	12 <sup>b</sup>	1/3/95	Outfall 006	Northwest	5
Beryllium	8	4 <sup>b</sup>	5/15/95	Outfall 006	Northwest	5
Chromium (total)	240	100 <sup>b</sup>	5/15/95	Outfall 006	Northwest	5
Lead	45	12 <sup>b</sup>	5/15/95	Outfall 005	Northwest	5
Benzene	5.6	1 <sup>b</sup>	5/15/95	Outfall 005	Northwest	5
Lead	16	12 <sup>b</sup>	5/15/95	Outfall 003	Northwest	5
Lead	45	12 <sup>b</sup>	5/15/95	Outfall 003	Northwest	5
Lead	75	12 <sup>b</sup>	5/15/95	Outfall 006	Northwest	5
Nickel	170	170 <sup>b</sup>	5/15/95	Outfall 006	Northwest	5
Beryllium	5	4 <sup>b</sup>	1/31/96	Outfall 006	Northwest	5
Lead	47	12 <sup>b</sup>	1/31/96	Outfall 006	Northwest	5
Cadmium	5	3.7 <sup>b</sup>	1/31/96	Outfall 006	Northwest	5
Zinc	420	110 <sup>b</sup>	1/31/96	Outfall 006	Northwest	5

Chemical	Concentration (µg/L)		Date Detected	Location/Sample Identification	Sample Location, Sample Type, Factor by Which Detected Levels Are Above Standards or Comments	Ref
	Monitored Level <sup>a</sup>	Regulatory Standard <sup>b and c</sup>				
1,1-DCE	19	6 <sup>b</sup>	5/96	RD-38A	Groundwater	6
Trans-1,2-DCE	38	10 <sup>b</sup>	5/96	RD-56A	Groundwater	6
1,1-DCA	6.5	5 <sup>b</sup>	11/96	RD-38A	Groundwater	6
Cis-1,2-DCE	27	6 <sup>b</sup>	11/96	RD-38A	Groundwater	6
TCE	250–570	5 <sup>b</sup>	8/9/95– 2/2/97	RD-38A (NE of Area I off site, Sage Ranch)	9 samples	4
Perchlorate	5	2-4 <sup>b</sup>	8/98	RD-59A	Northwest (west of Area IV RMDF)	6
Perchlorate	4.26	2-4 <sup>b</sup>	5/5/98	Outfall 006	Northwest	6
TCE	130–570	5 <sup>b</sup>	8/7/97– 8/18/99	RD-38A (NE of Area I off site, Sage Ranch)	6 samples	4
Cis-1,2-DCE	75–630	6 <sup>b</sup>	3/18/84– 2/4/99	RD 56 A N of Area III	19 samples	4
Trans-1,2-DCE	22–82	10 <sup>b</sup>	3/18/84– 2/4/99	RD 56 A N of Area III	18 samples	4
TCE	330–900	5 <sup>b</sup>	3/18/84– 2/4/99	RD 56 A N of Area III	19 samples	4

<sup>a</sup> Concentrations represent single reported values (unless a range is given) from measurements (not averages) taken in the indicated locations; they represent all contaminant detections above health-based standards.

<sup>b</sup> MCL = U.S. EPA Maximum Contaminant Levels allowed in drinking water. Note: there is a debate regarding the standard for perchlorate.

<sup>c</sup> TWSL = Region 9 Tap Water Screening Level.

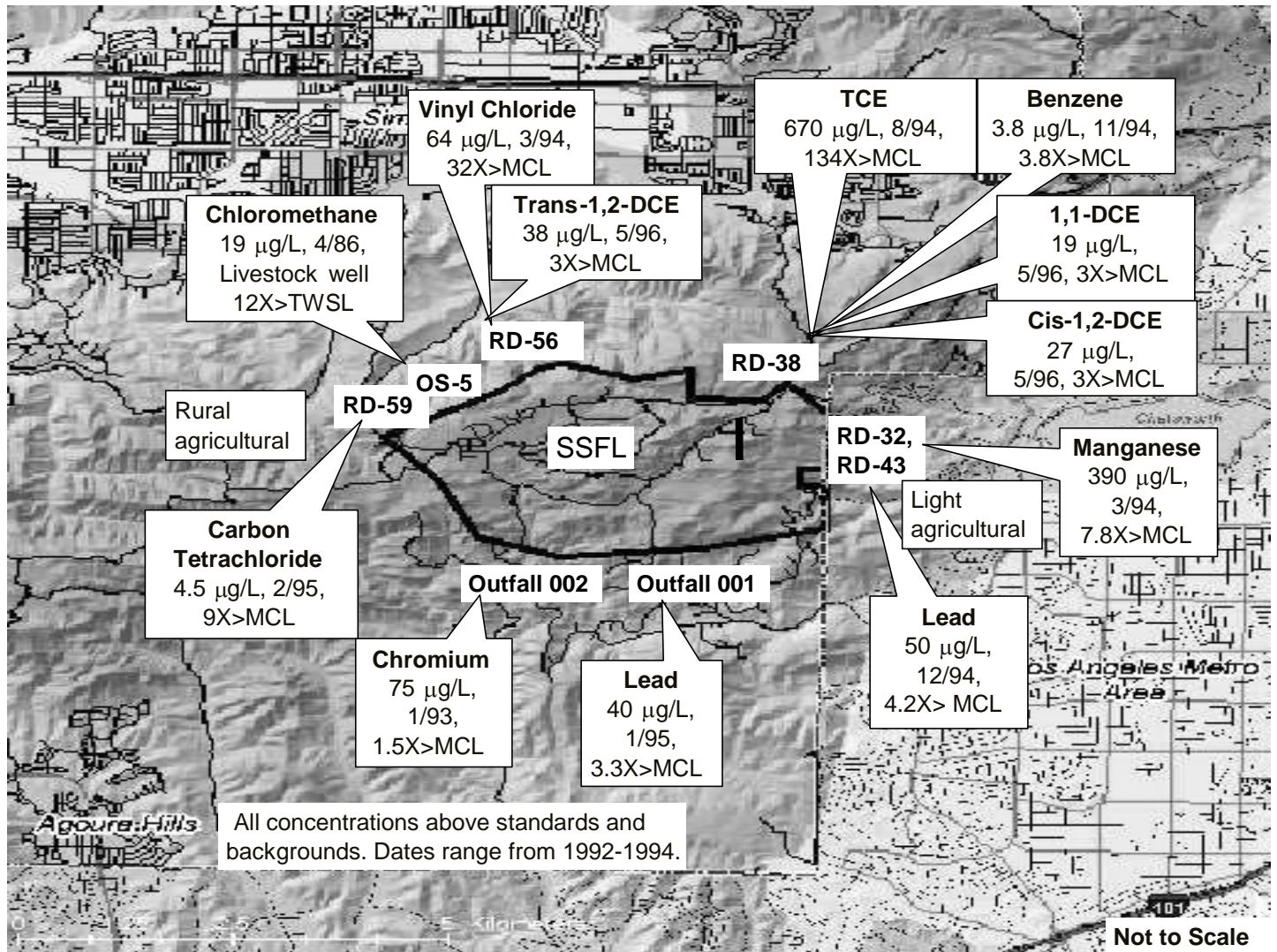
**Notes:**

**Abbreviations:** IDM = insensitive detection method; DEHP = bis(2-ethylhexyl)phthalate; SMMC = Santa Monica Mountain Conservancy; BBI = Brandeis-Bardin Institute

**Wells:** RD-32 and 43= Sage Ranch and Woolsey Canyon Wells, respectively; OS-2 and -5 = offsite wells used for livestock NW of SSFL at BBI; RD56A and RD-38A = SSMC wells; RD-59A= deep well located on BBI property.

**References:** 1. McLaren/Hart, 1993. 2. Boeing, 1990–2003. 3. CHDS, 1999. 4. GRC, 2000. 5. Rocketdyne, 1959–1989. 6. Boeing, 2002. 7. Rocketdyne, 1995.





**Figure 4-3.** Offsite Locations of Selected Groundwater Contaminants of Concern Detected at Levels Above Health-Based Standards. All offsite water contaminants (surface water and groundwater) were compared to MCLs, or Maximum Contaminant Levels (EPA-suggested drinking water standards). The identified contaminants are listed with their offsite detection levels, their dates of sampling, and the factors by which their concentrations were found to be above the MCLs. Contaminants were detected above health-based standards in groundwater northeast, northwest, and east of the facility, as well as in NPDES outfalls on the northeast and south borders of the facility.

## **4.3 Groundwater and Surface Water Exposure Issues**

### **4.3.1 Private and Public Wells**

The presence of contaminants in groundwater can pose a health risk if there is direct or indirect exposure to the contaminated water and if these contaminants are or may have been present above levels of health concern. Indeed, community concerns have been expressed regarding potential exposure to contaminants in private wells (ATSDR, 2000; Appendix G). Accordingly, the potential for community exposure to contaminated groundwater (via groundwater well use) and surface water is discussed in Chapter 6.

Exposure to groundwater can take place if groundwater is used for irrigation of edible crops, or as a source of drinking water for people or livestock. Therefore, it is essential to evaluate the locations of groundwater wells and groundwater use around SSFL. Table 4-2 provides a partial listing of offsite domestic and irrigation wells in the SSFL area, identifying the wells' locations, use, and detected contamination. The locations of selected wells in the immediate vicinity of SSFL are also indicated in Figure 4-3. An expanded discussion of potential exposures to contaminants in groundwater wells is provided in Chapter 6, and a brief account of well usage in the SSFL area is provided below,

An early assessment in 1988 identified 400 private domestic wells and one municipal well within 3 miles of the SSFL facility (GRC, 1988 a and b). Most of the private domestic wells are located in the Santa Susana Knolls community and the unincorporated areas outside the city of Simi Valley. It is unknown if privately owned wells in Santa Susana Knolls and Simi Valley have been affected by chemicals from SSFL. Note, however, that three domestic wells were identified within 2,000 feet to 1 mile of Area II (towards Santa Susana Knolls), serving an estimated population of 12 (GRC, 1988b). Between 1 and 2 miles from Area II, there are approximately 100 domestic wells serving an estimated population of 400; between 2 to 3 miles of Area II, there are approximately 300 wells and one municipal well serving an estimated population of 5000 to 10,000 (GRC, 1988b). Information could not be obtained regarding the water quality of this single municipal well, despite attempts to procure such information from the Southern California Water Company (Appendix J). Other entities contacted for well information included the Los Angeles County and Ventura County public works agencies and water resources departments (see Appendix J).

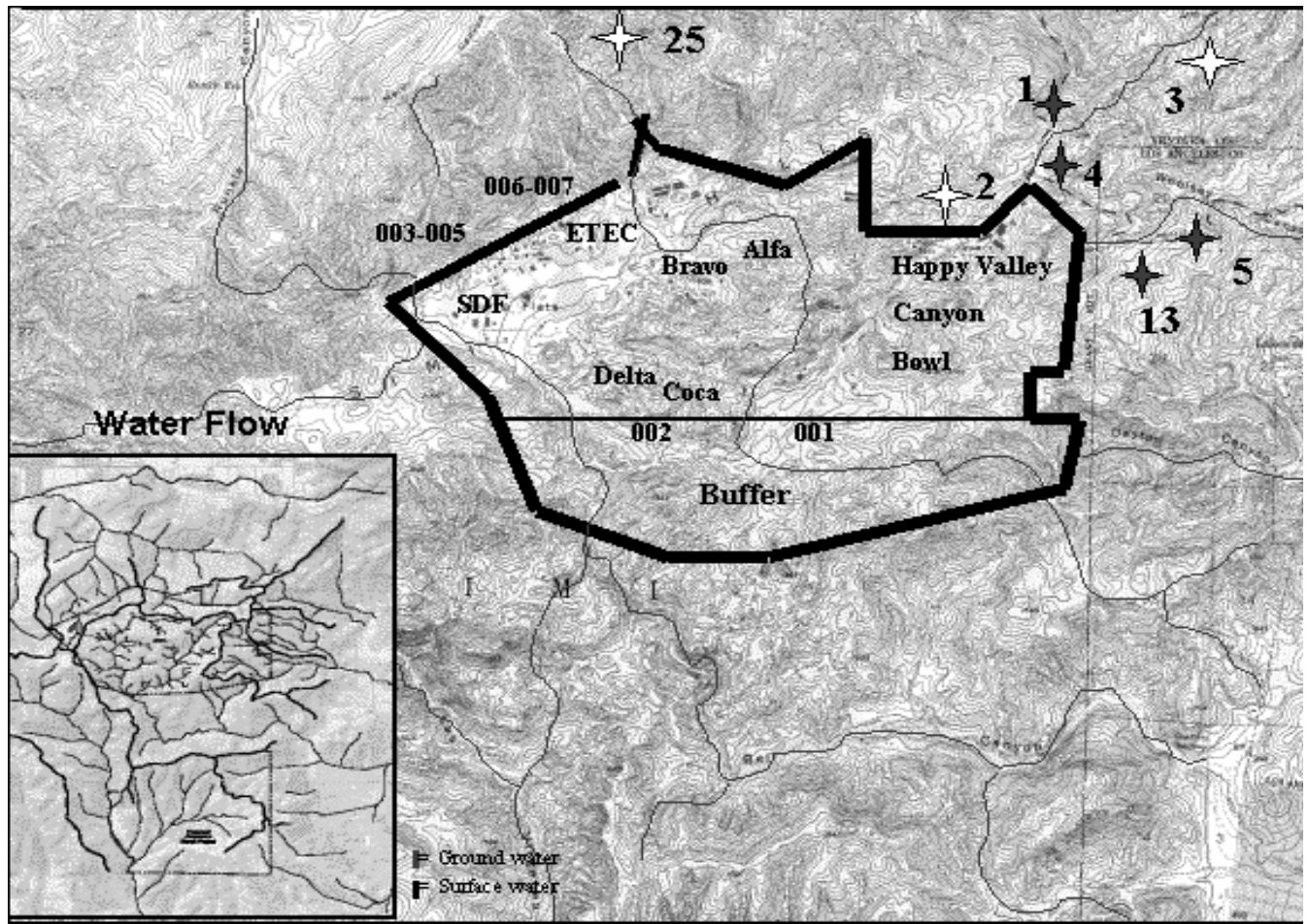
Groundwater wells beneath SSFL were used as potable water sources from the 1940s to the 1970s (Steve Lafflam, 2004). SSFL has 17 water supply wells that were constructed prior to 1960. These wells provided about 58 million gallons of water per year for sanitary, cooling, and other industrial uses. The local potable water supply was supplemented with bottled water after the late 1960s because of a "bad taste" (Lafflam, S., 1993 and 2004).

**Table 4-2.** Examples of currently or previously active offsite groundwater wells<sup>(#)</sup>

Well ID	Well Location <sup>a</sup>	Well Use	Contamination	Comment	Time Used	Vicinity
1	2N/17W-20H1	Domestic/irrigation	“Chemical analysis shows basin water is contaminated with solvents.” (6/89)		11/87-? Permit ends 2006	On Black Canyon Rd. by Woolsey Canyon
2	2N/17W-20P1	Irrigation	NA		NA	NA
3	2N/17W-21H1	Irrigation (orchards)	NA	477 ft. depth	5/16/54-?	By Sage Ranch Box Canyon Motorway mobile home park
4	2N/17W-21L1	Domestic/irrigation	“Chemical analysis shows basin water is contaminated with solvents.” (1989)  “Severe levels of iron—11 mg/L.” (10/95)	40 ft. depth	12/2/87-?	0.22 mi. NE of SSFL, #1 Black Canyon Rd.
5	2N/17W-21R2	Domestic	Manganese: 35 ppm	Owner: Chatsworth Mutual Water Co.	5/18/61-?	On road to SSFL
13	2N/17W-28B1	Domestic	“chemical analysis was not available”		5/18/60-?	On road to SSFL
25	2N/18W-20S1	Domestic	Perchlorate: 82 µg/L (2/12/03), <i>debated</i> ; 140–150 µg/L (5/1/03)	Bathtub well #1; Listed as domestic (reported in other sources as livestock)	NA	Brandeis-Bardin Institute

<sup>a</sup> **Source:** Ventura Public Works Agency, Water Resources and Development Division. The well location identifications were derived from US Geological Survey (USGS) topological maps which the Public Works Agency uses to identify well locations. Latitude and longitude are N and W respectively and the dashed notations identify the map quadrant where the wells are located. This agency does not have records on many private wells and older wells. This table’s survey of wells in the area is incomplete because of the lack of official information on the location and use of wells.

# - locations correspond to those indicated in Figure 4-4.  
NA – information not available



**Legend:** = Domestic Well    = Livestock /Agriculture/ or Irrigation Well

**Figure 4-4.** Example of Locations of Domestic and Irrigation Wells in the SSFL Area. These wells were identified from the files of the Ventura Public Work Agency's Water Resources and Development Division. Well locations are shown in relation to SSFL surface water pathways. Additional information for the wells in the figure is provided according to the wells' numbers in Table 4-2. An expanded list of offsite well contaminants detected above health-based standards and relevant concentrations is provided in Appendix H. **Note:** The three wells whose present status is unknown, OS-16, OS-17, and OS-18, were identified as domestic wells (ERC, 1990b) on the Los Angeles County side of SSFL (east) near the border.