Appendix T. Estimation of Receptor Air Concentrations and Doses

T-1. Introduction

Dispersion modeling using estimated emissions (Appendix S and Chapter 3) served to identify offsite locations where the inhalation dose ratios (Chapter 6) were above unity. Receptor locations identified in Figure T-1 were specifically addressed in the study. Inhalation dose ratios were derived for offsite area screening purposes only and do not necessarily represent realistic exposure levels for people residing near SSFL.

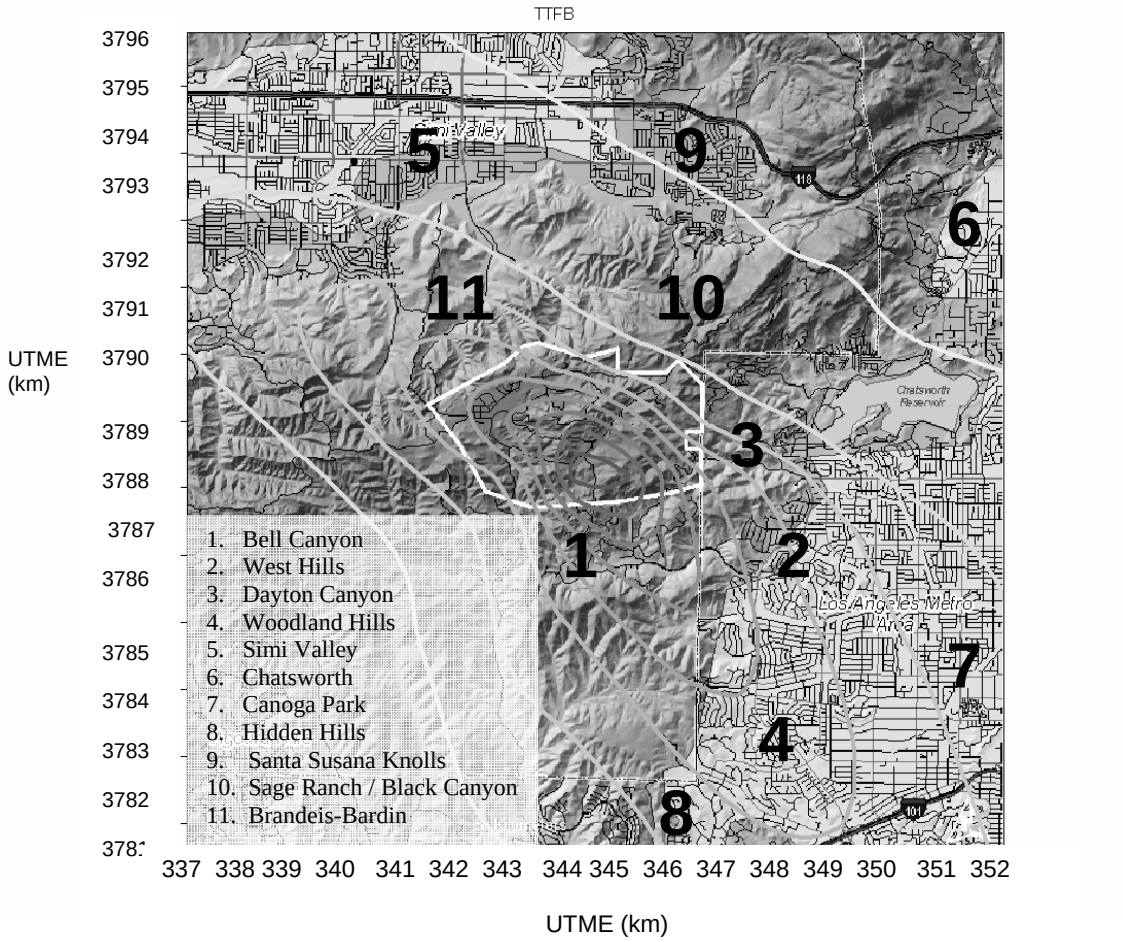

Figure T-1. Coordinates of Receptor Communities Used in Dose Analysis

The following communities were specifically addressed with respect to exposure linked to SSFL air emissions:

1. Bell Canyon (south/southwest): population ~3000. Covers 0.5 to 10 miles south and southeast of SSFL.

2. West Hills (southeast; includes Lakeside Park): population ~13,000. Covers ~0.5 to 4.0 miles to the east and southeast of SSFL.

3. Dayton Canyon (southeast): population ~2,000. Residential area ranging from 0.2 to 2 miles east of SSFL.

4. Woodland Hills (southeast): population ~45,000. Covers 5 to 10 miles southeast.

5. Simi Valley (northwest): population ~100,000. Covers areas 5 to 20 miles northwest.

6. Chatsworth (northeast): population ~50,000. Covers areas 5 to 10 miles northeast.

7. Canoga Park (southeast): population ~50,000. Covers areas 10 to 20 miles southeast.

8. Hidden Hills (south): population ~2,000. Covers areas 8 to 10 miles south.

9. Santa Susana Knolls (northeast): population ~20,000. Covers areas 3 to 5 miles northeast.

10. Sage Ranch/Black Canyon (northeast): population unknown~0 (recreational/residential). Covers areas 0.1 to 2 miles northeast.

11. Brandeis-Bardin Institute (northwest): population ~0 (recreational). Covers areas 0.1 to 2 miles northwest.

The protocol for identifying areas of exposure concern based on estimated maximum potential doses to communities from air contaminants originating from SSFL is outlined below.

- Maximum concentrations resulting from unit emission rates for each activity—rocket engine testing (RET), TCE solvent use during RET, activities at the Thermal Treatment Facility (TTF), and groundwater stripping of TCE in the stripping towers (ST)—were identified at various receptor locations (Chatsworth, Simi Valley, etc.) from all potential emission-specific sources (e.g., sources of kerosene-related emissions from RET included STL-IV, APTF, Bravo). (See Table T-1.) From this it could be ascertained for each activity (TCE use, for example) which source (in that case, APTF) contributed the greatest chemical-specific emissions (in that case, TCE) to each residential area (in that case, West Hills).

- Maximum emission rates for each activity, from emissions during years of similar activity levels (Appendix S), were identified. The information for chemicals which resulted in potential exposure doses within all potential exposure periods exceeding EPA-recommended doses are presented in Table T-2.

- Maximum chemical-specific concentrations ($\mu g/m^3$) were estimated from dispersion modeling of source-specific emissions for each activity (CALPUFF) (Table T-4).

- Maximum chemical- and activity-specific receptor doses (mg), D, were calculated (Table T-4) as follows:

  D = [receptor concentration (mg/m^3)] × [inhalation rate (m^3/yr)] × [activity time (yr)]

- Lifetime Average Daily Doses (LADDs in mg/kg-d) was derived by dividing maximum total lifetime inhalation doses (see Table T-4) by the average adult male weight (70 kg) and lifetime averaging period (70 years for carcinogens and the exposure duration for non-carcinogens).

- Dose ratios were derived by dividing the LADDs by the Acceptable Lifetime Average Daily Doses (ALADDs in mg/kg-d); see Table T-3.

Estimates of maximum doses in specific receptor locations were thus based on the maximum emission rates. Emission rates for chemicals which resulted in potential exposure exceeding EPA-recommended doses are presented in Table T-2; maximum potential concentrations for these chemicals are presented in Table T-4.[1] The reported relative doses (Table T-4) are conservative and represent the potential upper-limit lifetime maximum dose estimates with respect to estimated emission rates.

Table T-1. Coordinates of Approximate Maximum Concentration Resulting from Unit Emission Rates from the Indicated Sources

Emission Type	**Receptor Location**	**Receptor Coordinates**	**Maximum Concentrations Resulting from Unit Emission Rates at Receptor Locations from Indicated Source** ($\mu g/m^3$)
TCE volatilization from soil/ groundwater (area source, uniform emission)	Sage Ranch	(346, 3790)	2.91 (from APTF)
Rocket engine testing (area, daytime increasing emissions	Bell Canyon	(344, 3787)	$5.34x10^{-1}$ (from STL-IV)
	Canoga Park	(347, 3784)	$1.50x10^{-1}$ (from STL-IV)
	Chatsworth	(349, 3789)	$1.04x10^{-1}$ (from APTF)
	Simi Valley	(341, 3791)	$9.39x10^{-2}$ (from Alfa)
	Hidden Hills	(345, 3782)	$9.75x10^{-2}$ (from STL-IV)
	Santa Susana Knolls	(346, 3792)	$5.03x10^{-2}$ (from APTF)
	Woodland Hills	(347, 3783)	$1.57x10^{-1}$ (from Delta)

[1] For example, hydrazine was used in rocket engine testing from 1953 to 1977. There are no emission estimates for the years 1953 to 1954 and unreliable emission estimates for 1977, when testing activity was associated with the RS-14 Minutemen RET program. Therefore, the year of maximum recorded hydrazine emissions (1968), during the period in which there was RET using hydrazine fuels (1953–1977), was applied to all years associated with the activity under consideration. The maximum emission rate from a source was used to derive a potential exposure doses to offsite communities. This is a conservative approach, in that it assumes that the year of maximum emissions was indicative of activity levels for all relevant years. However, it must be acknowledged that doses presented in Table T-4 are used to represent potential exposure from an activity based on emissions from *only one source* (i.e., emissions from RET with hydrazine fuels were based on emissions from the STL-IV testing grounds only and do not take into account emissions from other testing grounds). As such, the doses presented here may under-represent potential lifetime exposure for residents residing near SSFL since 1953 with exposures to emissions from multiple RET areas (STL-IV, APTF, Alpha, etc.). The purpose of this analysis was not to represent community inhalation exposure doses, but rather to screen for offsite areas of potential exposure concern.

Emission Type	Receptor Location	Receptor Coordinates	Maximum Concentrations Resulting from Unit Emission Rates at Receptor Locations from Indicated Source ($\mu g/m^3$)
	Sage Ranch	(346, 3790)	$3.44x10^{-1}$ (from APTF)
	Brandeis-Bardin	(344, 3790)	$7.89x10^{-1}$ (from Alfa)
	West Hills	(347, 3787)	$4.16x10^{-1}$ (from APTF)
		(348, 3787)	$2.86x10^{-1}$ (from STL-IV)
	Dayton Canyon	(347, 3788)	$5.14x10^{-1}$ (from APTF)
TCE emissions from rocket testing (area, uniform)	Simi Valley	(341, 3791)	$5.43x10^{-1}$ (from STL-IV)
		(340, 3791)	$4.32x10^{-1}$ (from STL-IV)
		(342, 3791)	$6.47x10^{-1}$ (from Bravo)
	Woodland Hills	(347, 3783)	$1.31x10^{-1}$ (from Coca)
	Chatsworth	(349, 3790)	$2.07x10^{-1}$ (from APTF)
	Hidden Hills	(345, 3782)	$9.62x10^{-2}$ (from STL-IV)
	Dayton Canyon	(347, 3788)	$7.46x10^{-1}$ (from Canyon)
	Bell Canyon	(344, 3787)	$6.54x10^{-1}$ (from Coca)
		(344, 3787)	$5.98x10^{-1}$ (from Delta)
	Sage Ranch	(346, 3790)	$9.64x10^{-1}$ (from Canyon)
	Brandeis-Bardin	(344, 3790)	6.32 (from (Alfa)
	Santa Susana Knolls	(346, 3792)	$2.10x10^{-1}$ (from APTF)
	West Hills	(347, 3789)	$8.68x10^{-1}$ (from Canyon)
		(347, 3787)	$4.89x10^{-1}$ (from Canyon)
		(348, 3788)	$4.98x10^{-1}$ (from Canyon)
	Canoga Park	(348, 3784)	$1.80x10^{-1}$ (from Bowl)
		(348, 3785)	$2.02x10^{-1}$ (from Bowl)
Stripping towers (point, uniform)	West Hills	(347, 3787)	$3.68x10^{-1}$ (from Happy Valley)
		(348, 3788)	$3.58x10^{-1}$ (from Happy Valley)
		(347, 3789)	$6.66x10^{-1}$ (from Happy Valley)
			$5.85x10^{-1}$ (from Area I Road)
	Woodland Hills	(347, 3783)	$1.03x10^{-1}$ (from Delta)
	Sage Ranch	(346, 3790)	$1.07x10^{-1}$ (from Delta)
	Brandeis-Bardin	(344, 3790)	$9.62x10^{-1}$ (from Area I Road)
	Chatsworth	(349, 3790)	$1.10x10^{-1}$ (from Happy Valley)
	Hidden Hills	(345, 3782)	$7.92x10^{-2}$ (from Delta)
	Canoga Park	(349, 3785)	$1.33x10^{-1}$ (from Happy Valley)
	Dayton Canyon	(347, 3788)	$1.62x10^{-1}$ (from STL-IV)
			$5.13x10^{-1}$ (from Happy Valley)
	Santa Susana Knolls	(345, 3792)	$1.35x10^{-1}$ (from Happy Valley)
	Bell Canyon	(344, 3787)	$5.69x10^{-1}$ (from Delta)
	Simi Valley	(341, 3792)	$2.55x10^{-1}$ (from Bravo)
		(340, 3792)	$1.91x10^{-1}$ (from Delta)
			$1.44x10^{-1}$ (from Alfa)
		(341, 3792)	$1.40x10^{-1}$ (from Area I Road)
		(341, 3791)	$4.23x10^{-1}$ (from STL-IV)
Thermal Treatment Facility (TTF) (point, uniform)	West Hills	(347, 3785)	$1.97x10^{-1}$ (from Area I TTF)
	Simi Valley	(341, 3791)	$8.23x10^{-2}$ (from Area I TTF)
	Chatsworth	(349, 3790)	$2.00x10^{-2}$ (from Area I TTF)
	Santa Susana Knolls	(346, 3792)	$2.05x10^{-2}$ (from Area I TTF)
	Sage Ranch	(346, 3790)	$4.23x10^{-2}$ (from Area I TTF)
	Brandeis-Bardin	(344, 3790)	$6.86x10^{-2}$ (from Area I TTF)
	Hidden Hills	(345, 3782)	$6.25x10^{-2}$ (from Area I TTF)
	Woodland Hills	(347, 3784)	$1.69x10^{-1}$ (from Area I TTF)
	Canoga Park	(348, 3784)	$1.38x10^{-1}$ (from Area I TTF)
	Dayton Canyon	(347, 3788)	$1.15x10^{-1}$ (from Area I TTF)
	Bell Canyon	(346, 3786)	$3.19x10^{-1}$ (from Area I TTF)
		(345, 3787)	$5.97x10^{-1}$ (from Area I TTF)

Table T-2. Maximum Emission Rates[(a)] Assigned for Various Time Periods and SSFL Activities

Event	Release	Chemical	Emission Rate		
			Yr Max Emission Rate and Yrs Est. Exposure[(b)]	**Tons / Year**	**Grams / Second**
Rocket engine testing (RET)	Area/ daytime increasing	Hydrazine	1968 (STL-IV) (1955–1976; 20 yrs)	0.1	0.003
		UDMH	1955 (APTF/Delta) (1955–1976; 22 yrs)	0.15	0.004
TCE emissions from RET stands	Area/ uniform	TCE	1959 (1953–1966; 14 yrs)	387	11.15
			1967 (1967–1992; 26 yrs)*	43	1.24
Stripping Towers (ST)	Point/ uniform	TCE	1959 (1955–1967; 13 yrs)	91.8	2.64
			1968 (1968–1983; 16 yrs)	9.9	0.2
			1984 (1984–1989; 6 yrs)	18.9[†]	0.54
			1990 (1990–2004; 15 yrs)	3.1	8.9×10^{-2}
Thermal Treatment Facility (TTF)	Point/ daytime increasing	Hydrazine	All (1959–1994; 36 yrs)[‡]	0.66	1.9×10^{-2}

(a) The unit maximum emission rates at receptors from sources were derived from Appendix T, Table T-1, or other sources (as noted here) when conflicting reporting was encountered. Maximum emission rates reported in Appendix T (Table T-1) (tons per year) are averages of 4-year estimates (1994–1997). However, maximum emission rates were utilized in a conservative analysis within a given time period, particularly when there were either conflicting reporting or uncertain or lack of reporting. [†]For example, as noted in Appendix E,, there were no air permits for two stripping towers in 1988 and 1989, even though these were required. *Also, there are conflicting reports of annual TCE emissions from the RETs. Estimates derived from information supplied by Boeing were lower than those estimated by DOE (various years) as reported by ATSDR (1999). ATSDR (1999) reported that "estimated annual TCE emissions for the years 1988, 1989, 1990, 1991, 1992 were 2, 10.5, 7.5, 4.9, 42 tons per year (tpy), respectively (DOE, various years)." Given the lack of confidence in the reported emissions, the DOE-estimated value for 1967 was used for the 1967-1992 time period. [‡]Another example of conflicting information was with regards to TTF activity. The TTF was obligated to shut down in 1993 but did not actually terminate activity till 1994. This violation is cited in Appendix E.

(b) The exposure periods exclude years in which there were negligible emissions.

It is noted that atmospheric degradations were neglected in the dispersion analysis. This approximation has merit for most chemicals and generally results in a conservative estimation of receptor concentrations. Note also that the dispersion analysis did not consider toxic degradation byproducts (e.g., the formation of nitroso-amines). Such an analysis was beyond the scope of the present study, especially given the uncertainties in emissions and prevailing air quality during the emission periods. Furthermore, note that there are multiple sources (e.g. RET contaminants could disperse to Bell Canyon from the APTF, Delta, Coca, Bowl, Canyon, STL-IV, Bravo, and Alfa RET sites). Although concentration fields were obtained under various release scenarios, the present dose analysis based maximum receptor doses for each activity on the specific source contributing the greatest potential exposure to each receptor (Table T-1). For example, Table T-1 displays two sources for RET contaminants (STL-IV and APTF) at West Hills. The higher receptor unit emission rate (from APTF) was used, but there are other sources (Bowl, Alfa, TTF, stripping towers, etc.). Therefore, although the maximum source emission rate was used in dose estimations, the concentration at the receptor locations is likely to be underestimated if multiple sources were in operation.

Table T-3. Health-Based Standards for Chronic Exposure to Air Contaminants of Concern

Chemical	**Chronic Inhalation RfC,** (mg/m^3)	**Chronic Inhalation RfD** (mg/kg-d)	**Inhalation CPF** $(mg/kg\text{-}d)^{-1}$	**Inhalation Unit Risk** $(mg/m^3)^{-1}$	**ALADD** (mg/kg-d)
TCE	0.04	0.0114	**0.4**	0.114	$2.5x10^{-6}$
Hydrazine	—	—	**17.2**	4.9	$5.8x10^{-8}$
UDMH	—	—	**17.2**	4.9	$5.8x10^{-8}$

Notes: ALADD = Acceptable Lifetime Average Daily Dose for a 1×10^{-6} risk of disease; CPF = cancer potency factor; RfC = reference concentration; RfD = reference dose. (ALADDs were determined from RfDs for non-carcinogens (1,1,1-TCA, toluene, xylene, manganese, and mercury) and from CPFs for carcinogens.) Inhalation risk standards do not exist for copper, selenium, zinc and lead, so estimation of dose ratios was not possible for these contaminants. Lead was evaluated using LeadSpread (see Appendix R).

Table T-4 presents the receptor-specific concentrations derived from CALPUFF modeling of source-specific emissions, the maximum lifetime inhalation dose for each source-receptor, and the dose ratios for each activity specific to general location, chemical and activity. Only those contaminants with dose ratios above unity are presented in Table T-4. Where TCE is noted under RET, dose ratios are from use and dispersion of TCE during engine cleaning.

Table T-4. Maximum Estimated Inhalation Doses (mg) and Source-Specific Dose Ratios Exceeding Unity

Event	**Chemical**	**Receptor Locale**	**Yrs Exp. (T)**	**Receptor Max Concen. (C)** ($\mu g/m^3$)	**Maximum Total Lifetime Inhalation Dose (D)** (mg) (C/1000)×I×T×365 where I, inhalation rate= 20 m^3/d	**Dose Ratio (DR)** (dose > EPA acceptable dose by indicated factor)
Thermal Treatment Facility (TTF)	Hydrazine	Bell Canyon (345, 3787)	36	$1.13x10^{-2}$	2.98	29
		West Hills (347, 3785)		$3.74x10^{-3}$	0.98	9
		Canoga Park (348, 3784)		$2.62x10^{-3}$	0.69	7
		Dayton Canyon (347, 3788)		$2.19x10^{-3}$	0.57	6
		Simi Valley (341, 3791)		$1.56x10^{-3}$	0.41	4
		Hidden Hills (345, 3782)		$1.19x10^{-3}$	0.31	3
		Woodland (347, 3784)		$3.21x10^{-3}$	0.84	8
		Sage Ranch / Black Canyon (346, 3790)		$8.04x10^{-4}$	0.21	2
		Santa Susana Knolls (346, 3792)		$3.89x10^{-4}$	0.10	1
		Chatsworth (349, 3790)		$3.8x10^{-4}$	0.10	1
		Brandeis Bardin (344, 3790)		$1.30x10^{-3}$	0.34	3
Stripping Towers	TCE	West Hills (347, 3789)	13	1.76	167	47
			16	0.19	22	
			6	0.36	16	
			15	$5.93x10^{-2}$	6.5	
					211	
		Dayton Canyon (347, 3788)	13	1.35	129	36
			16	0.14	17	
			6	0.28	12	
			15	$4.56x10^{-2}$	5.0	
					163	
Stripping Tower continued		Santa Susana Knolls (345, 3792)	13	0.35	34	10
			16	$3.85x10^{-2}$	4.5	
			6	$7.34x10^{-2}$	3.2	
			15	$1.20x10^{-2}$	1.3	
					43	
	TCE	Bell Canyon (344, 3787)	13	1.50	143	40
			16	0.16	19	
			6	0.31	14	
			15	$5.06x10^{-2}$	5.5	
					181	
		Canoga Park (349, 3785)	13	0.35	33	10

Event	**Chemical**	**Receptor Locale**	**Yrs Exp. (T)**	**Receptor Max Concen. (C)** ($\mu g/m^3$)	**Maximum Total Lifetime Inhalation Dose (D)** (mg) $(C/1000)\times I\times T\times 365$ where I, inhalation rate= 20 m^3/d	**Dose Ratio (DR)** (dose > EPA acceptable dose by indicated factor)
			16	$3.79x10^{-2}$	4.4	
			6	$7.23x10^{-2}$	3.2	
			15	$1.18x10^{-2}$	1.3	
					42	
		Chatsworth (349, 3790)	13	0.29	28	8
			15	$3.13x10^{-2}$	3.6	
			6	$5.98x10^{-2}$	2.6	
			15	$9.79x10^{-3}$	1.1	
					35	
		Simi Valley (341, 3791)	13	1.12	106	30
			16	0.12	14	
			6	0.23	10	
			15	$3.76x10^{-2}$	4.1	
					134	
		Hidden Hills (345, 3782)	13	2.09	199	56
			16	0.22	26	
			6	0.43	19	
			15	$7.05x10^{-2}$	7.7	
					252	
		Woodland (347, 3783)	13	0.27	26	7
			16	$2.93x10^{-2}$	3.4	
			6	$5.60x10^{-2}$	2.4	
			15	$9.17x10^{-3}$	1.0	
					33	
		Sage Ranch / Black Canyon (346, 3790)	13	0.28	27	8
			16	$3.05x10^{-2}$	3.6	
			6	$5.82x10^{-2}$	2	
			15	$9.52x10^{-3}$	1	
					34	
		Brandeis Bardin Institute (344, 3790)	13	2.54	241	68
			16	0.27	32	
			6	0.52	23	
			15	$8.56x10^{-2}$	9.4	
					306	
Rocket Engine	TCE	West Hills (347, 3789)	14	9.67	989	267
			26	1.07	204	

Event	**Chemical**	**Receptor Locale**	**Yrs Exp. (T)**	**Receptor Max Concen. (C)** ($\mu g/m^3$)	**Maximum Total Lifetime Inhalation Dose (D)** (mg) (C/1000)×I×T×365 where I, inhalation rate= 20 m^3/d	**Dose Ratio (DR)** (dose > EPA acceptable dose by indicated factor)
Testing (RET)	TCE continued				1193	
		Bell Canyon (344, 3787)	14	7.29	745	201
			26	0.81	153	
					899	
		Dayton Canyon (347, 3788)	14	8.31	850	229
			26	0.92	175	
					1025	
Rocket Engine Testing (RET) continued		Canoga Park (348, 3785)	14	2.25	230	62
			26	0.25	47	
					277	
		Chatsworth (349, 3790)	14	2.31	236	64
			26	0.25	49	
					284	
		Simi Valley (342, 3791)	14	7.21	737	199
			26	0.80	152	
					889	
		Hidden Hills (345, 3782)	14	1.07	110	30
			26	0.12	23	
					132	
		Santa Susana Knolls (346, 3792)	14	2.34	239	65
			26	0.26	49	
					288	
		Woodland (347, 3783)	14	1.46	149	40
			26	0.16	31	
					180	
		Sage Ranch / Black Canyon (346, 3790)	14	10.74	1098	296
			26	1.19	226	
					1324	
		Brandeis Bardin Institute (344, 3790)	14	70.45	7200	1942
			26	7.82	1484	
					8684	
	UDMH	Bell Canyon (344, 3787)	22	2.14×10^{-3}	0.30	3
		West Hills (347, 3787)		1.66×10^{-3}	0.27	3
		Dayton Canyon (347, 3788)		2.06×10^{-3}	0.33	3
		Sage Ranch / Black Canyon (346, 3790)		1.37×10^{-3}	0.22	2

Event	Chemical	Receptor Locale	Yrs Exp. (T)	Receptor Max Concen. (C) ($\mu g/m^3$)	**Maximum Total Lifetime Inhalation Dose (D)** (mg) (C/1000)×I×T×365 where I, inhalation rate= 20 m^3/d	**Dose Ratio (DR)** (dose > EPA acceptable dose by indicated factor)
		Brandeis Bardin Institute (344, 3790)		$3.15x10^{-3}$	0.51	5
	Hydrazine	Bell Canyon (344, 3787)	20	$1.6x10^{-3}$	0.23	3
		Dayton Canyon (347, 3788)		$1.54x10^{-3}$	0.22	2
		West Hills (347, 3787)		$1.25x10^{-3}$	0.18	2
		Sage Ranch / Black Canyon (346, 3790)		$1.03x10^{-3}$	0.15	1
		Brandeis Bardin Institute (344, 3790)		$2.37x10^{-3}$	0.34	3