APPENDIX 8.6
Landfill Gas Modeling

Appendix 8.6

LFG Generation Modeling

LFG generation estimates for the Mission Bay Landfill was developed using the EPA's LFG generation model (LANDGEM, Pelt et al, 1998) and actual methane gas concentrations reported from analytical data collected from the raw LFG samples taken from the Mission Bay Landfill.

Inputs for the EPA model included the estimates of in-place refuse amounts, which were placed during the operational period of the landfill (1952 to 1959), the ultimate methane generation potential ("Lo" value) of 170 m^3/Mg, and a refuse decay coefficient ("k" value) of 0.05. Refuse data was derived from previous investigations including a site assessment plan prepared for the City of San Diego by Woodward-Clyde Consultants on August 22, 1983, historical data review, as well as information collected by SCS. Default "Lo" and "k" values were derived from the EPA's Compilation of Air Pollutant Emission Factors (AP-42), Section 2.4 on landfills and/or from SCS' own database of factors derived from empirical studies of LFG recovery data of over 300 landfills, including over 75 landfills in Southern California. Landfill gas generation estimates were used in the exposure assessment portion of the health risk assessment. The results of the model indicate that the LFG generation rate for 2005 is 105 cubic feet per minute (cfm). The results of the LFG generation model can be found in Table 8.6.1.

Based on OEHHA comments dated May 14, 2004, detected concentrations of toxic air contaminants (TAC) in Summa canisters were multiplied by the number of composite samples taken into each canister. This is based on the possibility that all contaminants in the composite sample were collected from a single location, and were diluted with sample from other locations that had no detectable contaminants. Resulting concentrations of TAC in landfill gas are shown in Table 8.6.2. Total estimated LFG emissions were calculated in tons/year (tons per year) assuming a landfill gas total flow from the landfill of 105 cfm and a methane content of 50%. Total estimated LFG emissions are also shown on Table 8.6.2.

Maximum surface emissions of the landfill were then estimated using the total estimated LFG emissions, assuming a landfill surface area of 115 acres. Maximum surface emissions from the landfill site are presented on Table 8.6.3. The resulting maximum surface emissions were then used in a "box model" to determine on-site airborne concentrations of LFG.

Calculation of On-Site Airborne Concentrations of LFG (LFG EPC)

To calculate on-site airborne concentrations of LFG, a "box" model was utilized as recommended by the California Air Resources Board (DaMassa, 1992). A box model is a simple mass-balance equation that uses the concept of a theoretically enclosed space (i.e., box) over the impacted area. The model assumes that emissions of contaminants into a box, with their removal based on wind speed.

Airborne concentrations of LFG within the box were calculated and used as on-site EPCs for contaminant concentrations for on-site receptors. The LFG EPC calculated within the box is calculated by the following equation:

$$B = QA/(u)(h)(l) \times CF$$

Where:

B	=	Box concentration, EPC (ug/m^3)
Q	=	Emission flux (g/cm^2-sec)
A	=	Emitting area of the site (cm^2)
u	=	Wind speed (cm^2/sec)
h	=	Height of box (cm)
l	=	Length of box (cm)
CF	=	Conversion factor, 10^{12} ($ug\text{-}cm^3/g\text{-}m^3$)

The results of the box model calculations are presented in Table 8.6.4.

TABLE 8.6.1.
LANDFILL GAS GENERATION MODEL
PROJECTED LFG AND NMOC GENERATION RATES
MISSION BAY LANDFILL, SAN DIEGO, CALIFORNIA

Year	Disposal Rate (tons/yr)	Refuse In-Place (tons)	Disposal Rate (Mg/yr)	Refuse In-Place (Mg)	Methane Generation Rates (m^3/yr)	LFG Generation Rates (cfm)	LFG Generation Rates (Million ft^3/yr)	NMOC Generation Rates (tons/yr)	NMOC Generation Rates (Mg/yr)
1952	75,000	0	68,039	0	0.000E+00	0	0	0	0
1953	150,000	75,000	136,078	68,039	5.783E+05	78	41	18	16
1954	150,000	225,000	136,078	204,117	1.707E+06	229	121	53	48
1955	150,000	375,000	136,078	340,194	2.780E+06	374	196	86	78
1956	150,000	525,000	136,078	476,272	3.801E+06	511	268	118	107
1957	150,000	675,000	136,078	612,350	4.773E+06	641	337	148	135
1958	150,000	825,000	136,078	748,427	5.696E+06	765	402	177	161
1959	150,000	975,000	136,078	884,505	6.575E+06	884	464	204	185
1960	0	1,125,000	0	1,020,583	7.411E+06	996	523	230	209
1961	0	1,125,000	0	1,020,583	7.050E+06	947	498	219	199
1962	0	1,125,000	0	1,020,583	6.706E+06	901	474	208	189
1963	0	1,125,000	0	1,020,583	6.379E+06	857	451	198	180
1964	0	1,125,000	0	1,020,583	6.068E+06	815	429	189	171
1965	0	1,125,000	0	1,020,583	5.772E+06	776	408	179	163
1966	0	1,125,000	0	1,020,583	5.490E+06	738	388	171	155
1967	0	1,125,000	0	1,020,583	5.223E+06	702	369	162	147
1968	0	1,125,000	0	1,020,583	4.968E+06	668	351	154	140
1969	0	1,125,000	0	1,020,583	4.726E+06	635	334	147	133
1970	0	1,125,000	0	1,020,583	4.495E+06	604	317	140	127
1971	0	1,125,000	0	1,020,583	4.276E+06	575	302	133	121
1972	0	1,125,000	0	1,020,583	4.067E+06	547	287	126	115
1973	0	1,125,000	0	1,020,583	3.869E+06	520	273	120	109
1974	0	1,125,000	0	1,020,583	3.680E+06	495	260	114	104
1975	0	1,125,000	0	1,020,583	3.501E+06	470	247	109	99
1976	0	1,125,000	0	1,020,583	3.330E+06	447	235	104	94
1977	0	1,125,000	0	1,020,583	3.168E+06	426	224	98	89
1978	0	1,125,000	0	1,020,583	3.013E+06	405	213	94	85
1979	0	1,125,000	0	1,020,583	2.866E+06	385	202	89	81
1980	0	1,125,000	0	1,020,583	2.726E+06	366	193	85	77
1981	0	1,125,000	0	1,020,583	2.593E+06	349	183	81	73
1982	0	1,125,000	0	1,020,583	2.467E+06	332	174	77	70
1983	0	1,125,000	0	1,020,583	2.347E+06	315	166	73	66
1984	0	1,125,000	0	1,020,583	2.232E+06	300	158	69	63
1985	0	1,125,000	0	1,020,583	2.123E+06	285	150	66	60
1986	0	1,125,000	0	1,020,583	2.020E+06	271	143	63	57
1987	0	1,125,000	0	1,020,583	1.921E+06	258	136	60	54
1988	0	1,125,000	0	1,020,583	1.828E+06	246	129	57	52
1989	0	1,125,000	0	1,020,583	1.738E+06	234	123	54	49
1990	0	1,125,000	0	1,020,583	1.654E+06	222	117	51	47
1991	0	1,125,000	0	1,020,583	1.573E+06	211	111	49	44
1992	0	1,125,000	0	1,020,583	1.496E+06	201	106	47	42
1993	0	1,125,000	0	1,020,583	1.423E+06	191	101	44	40
1994	0	1,125,000	0	1,020,583	1.354E+06	182	96	42	38
1995	0	1,125,000	0	1,020,583	1.288E+06	173	91	40	36
1996	0	1,125,000	0	1,020,583	1.225E+06	165	87	38	35
1997	0	1,125,000	0	1,020,583	1.165E+06	157	82	36	33
1998	0	1,125,000	0	1,020,583	1.108E+06	149	78	34	31
1999	0	1,125,000	0	1,020,583	1.054E+06	142	74	33	30
2000	0	1,125,000	0	1,020,583	1.003E+06	135	71	31	28
2001	0	1,125,000	0	1,020,583	9.541E+05	128	67	30	27
2002	0	1,125,000	0	1,020,583	9.076E+05	122	64	28	26
2003	0	1,125,000	0	1,020,583	8.633E+05	116	61	27	24
2004	0	1,125,000	0	1,020,583	8.212E+05	110	58	26	23
2005	0	1,125,000	0	1,020,583	7.811E+05	105	55	24	22
2006	0	1,125,000	0	1,020,583	7.430E+05	100	52	23	21
2007	0	1,125,000	0	1,020,583	7.068E+05	95	50	22	20
2008	0	1,125,000	0	1,020,583	6.723E+05	90	47	21	19
2009	0	1,125,000	0	1,020,583	6.395E+05	86	45	20	18
2010	0	1,125,000	0	1,020,583	6.084E+05	82	43	19	17
2011	0	1,125,000	0	1,020,583	5.787E+05	78	41	18	16
2012	0	1,125,000	0	1,020,583	5.505E+05	74	39	17	16

ESTIMATED NMOC CONCENTRATION IN LFG:	4000	ppmv
ASSUMED METHANE CONTENT OF LFG:	50%	
SELECTED DECAY RATE CONSTANT:	0.05	
SELECTED ULTIMATE METHANE RECOVERY RAT	5,446	ft3/ton
METRIC EQUIVALENT:	170	cu m/Mg

TABLE 8.6.2.
EMISSIONS FROM LANDFILL GAS
MISSION BAY LANDFILL
SEA WORLD DRIVE
SAN DIEGO, CALIFORNIA

Toxic Air Contaminant (TAC)[1]	Molecular Weight	Concentration of TAC Found in LFG[2]	Total Estimated LFG Emissions[3]
	g/Mol	ppmv	tons/yr
Hydrogen sulfide	34.1	100	0.244341
Total Non-Methane Hydrocarbons as Methane	16.0	4600	5.286927
1,2-Dichlorobenzene	147.0	0.145	0.001527
1,4-Dichlorobenzene	147.0	0.8	0.008427
2-Butanone (MEK)	72.1	0.2	0.001033
Acetone	58.1	0.6	0.002498
Chlorobenzene	112.6	0.18	0.001452
Chlorodifluoromethane	86.5	1.15	0.007128
Chloroethane (Ethyl Chloride)	64.5	0.043	0.000196
Dichlorodifluoromethane (Freon 12)	120.9	0.95	0.008230
Dichlorofluoromethane (Freon 21)	102.9	0.055	0.000406
Ethylbenzene	106.2	4.05	0.030819
n-Butane	58.1	24	0.099949
n-Hexane	86.2	2.35	0.014515
Pentane	72.1	7.5	0.038747
Propane	44.1	55	0.173758
Trichloroethene	131.4	0.0455	0.000428
Vinyl chloride	62.5	0.30	0.001344
Total Xylenes	106.2	0.73	0.005553
TOTAL		**4,798**	**5.6829**

NOTES:
(1) Toxic air contaminants include volatile organic compounds identified from TO-15 analysis of landfill gas samples collected from Mission Bay Landfill
(2) Concentrations are taken from samples collected from Mission Bay Landfill. Based on OEHHA comments (May, 14, 2005), highest concentration of each detected contaminant should be multiplied by the number of composite landfill gas samples (5 samples).
(3) Based on concentrations of TAC found in LFG and an estimated LFG generation rate of 105 cfm (see Table 1).

INPUT MODEL VARIABLES

Landfill Gas Total Flow from LF (See Table C-1, 2005):	105 cfm
Methane content of LFG	50%

TABLE 8.6.3.
MAXIMUM SURFACE EMISSIONS FROM SITE
MISSION BAY LANDFILL
SEA WORLD DRIVE
SAN DIEGO, CALIFORNIA

Toxic Air Contaminants (TAC)[1]	Existing Surface Emissions from Site[2]	Maximum Surface Emissions from Site[3]		Maximum Surface Emissions from Site[4]	
	lb/year		tons/yr	g/sec	g/cm^2-sec of landfill surface
Hydrogen sulfide	489	489	0.244341	7.03E-03	1.51E-12
Total Non-Methane Hydrocarbons as Methane	10,574	10,574	5.28693	1.52E-01	3.27E-11
1,2-Dichlorobenzene	3.1	3.1	0.00153	4.39E-05	9.44E-15
1,4-Dichlorobenzene	16.9	16.85	0.00843	2.42E-04	5.21E-14
2-Butanone (Methyl Ethyl Ketone)	2.1	2.1	0.00103	2.97E-05	6.39E-15
Acetone	5.0	5.0	0.00250	7.19E-05	1.54E-14
Chlorobenzene	2.9	2.9	0.00145	4.18E-05	8.98E-15
Chlorodifluoromethane	14.3	14.3	0.00713	2.05E-04	4.41E-14
Chloroethane (Ethyl Chloride)	0.4	0.393	0.00020	5.65E-06	1.21E-15
Dichlorodifluoromethane (Freon 12)	16.5	16.5	0.00823	2.37E-04	5.09E-14
Dichlorofluoromethane (Freon 21)	0.8	0.8	0.00041	1.17E-05	2.51E-15
Ethylbenzene	61.6	61.6	0.03082	8.87E-04	1.91E-13
n-Butane	200	200	0.09995	2.88E-03	6.18E-13
n-Hexane	29	29	0.01451	4.18E-04	8.97E-14
Pentane	77.5	77.5	0.03875	1.11E-03	2.40E-13
Propane	348	348	0.17376	5.00E-03	1.07E-12
Trichloroethene	0.86	0.86	0.00043	1.23E-05	2.65E-15
Vinyl chloride	2.7	2.7	0.00134	3.86E-05	8.30E-15
Xylenes	11.1	11.1	0.00555	1.60E-04	3.43E-14

NOTES:
(1) Toxic air contaminants include volatile organic compounds identified from TO-15 analysis of landfill gas samples collected from Mission Bay Landfill.
(2) Current surface emission levels (See Table C-2, Total Estimated LFG Emissions).
(3) Converted using factors listed below.

Conversion factors:

Landfill surface area =	115	acres
=	5,009,400	ft^2
=	465,373	m^2
since:	1 acre = 43,560 ft^2	
and	1 ft^2 = 0.0929 m^2	
1 g =	1E-06	metric tons
1 metric ton =	1.1023	short tons
1 year =	31,536,000	seconds

TABLE 8.6.4.
COMPUTATIONS FOR LANDFILL GAS (BOX MODEL)
MISSION BAY LANDFILL
SEA WORLD DRIVE
SAN DIEGO, CALIFORNIA

Chemical	Emission Flux	Emitting Area[1]	Wind Speed[2]	Box Height[3]	Length of Site[1]	Conversion Factor	On-Site Concentration
	g/cm^2-sec	cm^2	cm/s	cm	cm	$\mu g\text{-}cm^3/g\text{-}m^3$	$\mu g/m^3$
VOCs							
Hydrogen sulfide	1.51E-12	4.52E+09	313	150	153,924	1.00E+12	9.45E-01
Total Non-Methane Hydrocarbons as Methane	3.27E-11	4.52E+09	313	150	153,924	1.00E+12	2.04E+01
1,2-Dichlorobenzene	9.44E-15	4.52E+09	313	150	153,924	1.00E+12	5.90E-03
1,4-Dichlorobenzene	5.21E-14	4.52E+09	313	150	153,924	1.00E+12	3.26E-02
2-Butanone (Methyl Ethyl Ketone)	6.39E-15	4.52E+09	313	150	153,924	1.00E+12	3.99E-03
Acetone	1.54E-14	4.52E+09	313	150	153,924	1.00E+12	9.66E-03
Chlorobenzene	8.98E-15	4.52E+09	313	150	153,924	1.00E+12	5.61E-03
Chlorodifluoromethane	4.41E-14	4.52E+09	313	150	153,924	1.00E+12	2.76E-02
Chloroethane (Ethyl Chloride)	1.21E-15	4.52E+09	313	150	153,924	1.00E+12	7.59E-04
Dichlorodifluoromethane (Freon 12)	5.09E-14	4.52E+09	313	150	153,924	1.00E+12	3.18E-02
Dichlorofluoromethane (Freon 21)	2.51E-15	4.52E+09	313	150	153,924	1.00E+12	1.57E-03
Ethylbenzene	1.91E-13	4.52E+09	313	150	153,924	1.00E+12	1.19E-01
n-Butane	6.18E-13	4.52E+09	313	150	153,924	1.00E+12	3.86E-01
n-Hexane	8.97E-14	4.52E+09	313	150	153,924	1.00E+12	5.61E-02
Pentane	2.40E-13	4.52E+09	313	150	153,924	1.00E+12	1.50E-01
Propane	1.07E-12	4.52E+09	313	150	153,924	1.00E+12	6.72E-01
Trichloroethene	2.65E-15	4.52E+09	313	150	153,924	1.00E+12	1.66E-03
Vinyl chloride	8.30E-15	4.52E+09	313	150	153,924	1.00E+12	5.19E-03
Xylenes	3.43E-14	4.52E+09	313	150	153,924	1.00E+12	2.15E-02

Notes:

[1] Emitting Area (Dimensions) of the site are estimated from Figure 2.1 from Review Draft Workplan for Mission Bay Landfill Site Assessment (SCS, 200

[2] Wind speed is average reported by National Oceanic and Atmospheric Administration (NOAA) for San Diego, California (7 miles per hour [mph]).

[3] The height at which the nose and mouth of the average person are located.