14.0 APPENDICES

Appendix A

Amundsen-Scott Station Wastewater Characteristics

Table A-1. Amundsen-Scott Station Sewage Testing Results

Constituent (mg/L)	24-Nov-94			7-Dec-94	14-Nov-95	15-Nov-95	17-Dec-95	25-Jan-96	21-Nov-96
Characteristic Pollutants									
Ammonia	4.8	12	4.8	73.5	NA	26.49	27.84	NA	26.80
Total Kjeldahl Nitrogen	ND	ND	ND	220	138	NA	NA	NA	NA
Nitrate + Nitrite	0.093	0.068	0.067	ND	0.378	NA	NA	NA	NA
Oil, Grease and Hydrocarbons	ND	ND	16	250	NA	2.6	55.2	170.2	ND
Orthophosphates	NA	NA	NA	NA	NA	9.94	14.23	NA	11.90
Total Recoverable Phenolics	NA	NA	NA	NA	0.192	NA	NA	NA	NA
Total Solids	1,310	1,780	600	1,645	NA	1,640	1,332	1,828	520
Total Suspended Solids	207	247	120	485	NA	274	184	210	520
Volatile Suspended Solids	200	240	87	485	NA	265	184	184	440
Biochemical Oxygen Demand	1,040	1,410	760	910	NA	966	596	1,420	966
Chemical Oxygen Demand	2,080	3,000	2,120	2,080	NA	1,800	1,360	2,270	3,000
Volatile and Semi-Volatile Organics									
Acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	ND	ND	ND	ND	ND	NA	NA	NA	NA
Benzoic Acid	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis-2(ethylhexyl)phthalate	NA	NA	NA	NA	0.024	NA	NA	NA	NA
Chloroform	ND	ND	ND	ND	ND	NA	NA	NA	NA
1,4-Dichlorobenzene	ND	ND	ND	ND	0.004	NA	NA	NA	NA
2,4-Dichlorophenol	ND	ND	ND	ND	ND	NA	NA	NA	NA
Diethylphthalate	NA	NA	NA	NA	0.004	NA	NA	NA	NA
Ethyl Benzene	ND	ND	ND	ND	0.005	NA	NA	NA	NA
4-Isopropyltoluene	NA	NA	NA	NA	NA	NA	NA	NA	NA
3,4-Methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	ND	ND	ND	0.005	0.002	NA	NA	NA	NA
m,p-Xylenes	ND	ND	ND	ND	ND	NA	NA	NA	NA
o-Xylenes	ND	ND	ND	ND	ND	NA	NA	NA	NA
Metals									

Table A-1. Amundsen-Scott Station Sewage Testing Results

Constituent (mg/L)	24-Nov-94			7-Dec-94	14-Nov-95	15-Nov-95	17-Dec-95	25-Jan-96	21-Nov-96
Cadmium	ND	ND	ND	0.0036	0.0003	NA	NA	NA	NA
Chromium	ND	ND	ND	ND	ND	NA	NA	NA	NA
Copper	2.3	1.7	1.7	4.6	1.9	NA	NA	NA	NA
Lead	ND	ND	ND	0.053	0.026	NA	NA	NA	NA
Mercury	ND	ND	ND	0.00024	0.0002	NA	NA	NA	NA
Nickel	NA	NA	NA	NA	0.011	NA	NA	NA	NA
Selenium	ND	ND	ND	0.0013	0.002	NA	NA	NA	NA
Silver	ND	ND	ND	0.0004	0.001	NA	NA	NA	NA
Thallium	NA	NA	NA	NA	0.001	NA	NA	NA	NA
Zinc	NA	NA	NA	NA	0.266	NA	NA	NA	NA

Table A-1. Amundsen-Scott Station Sewage Testing Results

Constituent (mg/L)	8-Jan-97	27-Jan-97	04-Dec-97	27-Dec-97	26-Jan-98	03-Dec-98	02-Dec-99	18-Jan-01	03-Jan-02	12-Feb-03
Characteristic Pollutants										
Ammonia	27.84	12.70	26.22	1.36	14.90	10	NA	NA	NA	NA
Total Kjeldahl Nitrogen	NA	NA	210	NA	NA	200	NA	NA	NA	NA
Nitrate + Nitrite	NA	0.23	0.80	NA	NA	0.33	NA	NA	NA	NA
Oil, Grease and Hydrocarbons	167	146	67	264	NA	58	NA	NA	NA	NA
Orthophosphates	14.23	11.76	23.63	1.10	15.30	1.6	NA	NA	NA	NA
Total Recoverable Phenolics	NA	1.6	ND	NA	NA	ND	NA	NA	NA	NA
Total Solids	930	1,244	2,240	2,808	1,724	917	NA	NA	NA	NA
Total Suspended Solids	186	238	486	418	723	153	NA	NA	NA	NA
Volatile Suspended Solids	180	220	478	400	646	147	NA	NA	NA	NA
Biochemical Oxygen Demand	588	615	842	1,681	1,108	470	NA	NA	NA	NA
Chemical Oxygen Demand	1,250	1,600	2,560	2,571	1,316	1,160	NA	NA	NA	NA
Volatile and Semi-Volatile Organics										
Acetone	NA	0.054	0.026	NA	NA	0.037	ND	ND	ND	ND
Benzene	NA	ND	ND	ND	ND	ND	ND	ND	ND	0.0006
Benzoic Acid	NA	ND	2.6	NA	NA	0.870	ND	ND	ND	ND
Bis-2(ethylhexyl)phthalate	NA	0.22	ND	NA	NA	ND	ND	4.4	0.018	0.018
Chloroform	NA	ND	ND	NA	NA	ND	ND	ND	ND	0.001
1,4-Dichlorobenzene	NA	0.0087	0.0041	NA	NA	ND	ND	ND	0.02	0.0071
2,4-Dichlorophenol	NA	ND	ND	NA	NA	ND	ND	ND	ND	0.047
Diethylphthalate	NA	ND	ND	NA	NA	ND	ND	ND	ND	0.002
Ethyl Benzene	NA	ND	0.0041	NA	NA	ND	ND	ND	ND	ND
4-Isopropyltoluene	NA	NA	NA	NA	NA	ND	ND	ND	ND	0.0005
3,4-Methylphenol	NA	NA	NA	NA	NA	ND	ND	ND	0.084	0.061
4-Methylphenol	NA	0.058	ND	NA	NA	0.040	ND	ND	ND	ND
Phenol	NA	ND	ND	NA	NA	ND	ND	ND	ND	0.05
Toluene	NA	ND	0.042	NA	NA	ND	ND	ND	ND	ND
m,p-Xylenes	NA	ND	0.017	NA	NA	ND	ND	ND	ND	ND
o-Xylenes	NA	ND	0.0039	NA	NA	ND	ND	ND	ND	ND
Metals										

Table A-1. Amundsen-Scott Station Sewage Testing Results

Constituent (mg/L)	8-Jan-97	27-Jan-97	04-Dec-97	27-Dec-97	26-Jan-98	03-Dec-98	02-Dec-99	18-Jan-01	03-Jan-02	12-Feb-03
Cadmium	NA	ND	ND	NA	NA	0.011	ND	0.005	0.001	0.0007
Chromium	NA	ND		NA	NA	NA	0.007	0.018	0.012	0.007
Copper	NA	1.15	8.5	NA	NA	ND	0.78	2.1	2.6	1.8
Lead	NA	0.011	0.073	NA	NA	ND	0.25	0.61	0.1	0.013
Mercury	NA	ND	ND	NA	NA	0.00047	0.0001	0.0008	ND	0.00016
Nickel	NA	0.024	0.03	NA	NA	ND	ND	0.02	0.012	0.036
Selenium	NA	0.0042	ND	NA	NA	ND	ND	ND	ND	ND
Silver	NA	0.022	ND	NA	NA	ND	ND	ND	ND	0.0004
Thallium	NA	0.0133	ND	NA	NA	ND	ND	ND	ND	ND
Zinc	NA	0.255	0.73	NA	NA	ND	0.1	1.3	0.37	0.178

Notes: NA = Not Analyzed; ND = Not detected

Table A-2. McMurdo Station Untreated Wastewater Testing Results for Total Suspended Solids

Week Ending	Population (person-days)	Flow (liters)	Total Suspended Solids (TSS)			
			Testing Results (mg/L)	Weekly Load (kg)	Loading Factor (g/1000L)	Loading Factor (g/person-day)
4/6/03	1,379	NR	NA	NA	NA	NA
4/13/03	1,379	NR	NA	NA	NA	NA
4/20/03	1,379	NR	NA	NA	NA	NA
4/27/03	1,379	384,226	200	76.8	200	55.7
5/4/03	1,379	408,489	256	104.6	256	75.8
5/11/03	1,379	408,489	288	117.6	288	85.3
5/18/03	1,379	405,420	476	193.0	476	139.9
5/25/03	1,379	380,627	220	83.7	220	60.7
6/1/03	1,379	379,225	264	100.1	264	72.6
6/8/03	1,379	368,932	220	81.2	220	58.9
6/15/03	1,379	407,696	200	81.5	200	59.1
6/22/03	1,379	385,337	156	60.1	156	43.6
6/29/03	1,379	354,432	216	76.6	216	55.5
7/6/03	1,379	391,555	152	59.5	152	43.2
7/13/03	1,379	420,370	128	53.8	128	39.0
7/20/03	1,379	399,705	148	59.2	148	42.9
7/27/03	1,379	351,812	260	91.5	260	66.3
8/3/03	1,379	337,841	240	81.1	240	58.8
8/10/03	1,379	399,149	280	111.8	280	81.0
8/17/03	1,379	409,998	296	121.4	296	88.0
8/24/03	1,747	460,510	208	95.8	208	54.8
8/31/03	2,667	542,377	284	154.0	284	57.8
9/7/03	2,667	587,174	280	164.4	280	61.6
9/14/03	2,667	755,010	504	380.5	504	142.7
9/21/03	2,667	773,747	620	479.7	620	179.9
9/28/03	2,667	863,862	540	466.5	540	174.9
10/5/03	3,460	889,661	192	170.8	192	49.4
10/12/03	5,018	1,071,725	304	325.8	304	64.9
10/19/03	5,447	1,105,918	202	223.4	202	41.0
10/26/03	6,620	1,191,203	186	221.6	186	33.5
11/2/03	6,730	1,344,761	256	344.3	256	51.2
11/9/03	6,755	1,315,153	290	381.4	290	56.5
11/16/03	NR	NR	NA	NA	NA	NA
11/23/03	6,898	1,498,479	232	347.6	232	50.4
11/30/03	6,969	1,463,529	269	393.7	269	56.5
12/7/03	7,025	1,494,759	398	594.9	398	84.7
12/14/03	6,885	1,547,948	177	274.0	177	39.8
12/21/03	6,723	1,428,522	277	395.7	277	58.9

Table A-2. McMurdo Station Untreated Wastewater Testing Results for Total Suspended Solids

Week Ending	Population (person-days)	Flow (liters)	Total Suspended Solids (TSS)			
			Testing Results (mg/L)	Weekly Load (kg)	Loading Factor (g/1000L)	Loading Factor (g/person-day)
12/28/03	6,446	1,411,830	254	358.6	254	55.6
1/4/04	6,751	1,245,015	217	270.2	217	40.0
1/11/04	6,957	1,420,804	228	323.9	228	46.6
1/18/04	NR	NR	193	NA	NA	NA
1/25/04	6,912	1,423,076	917	1,305	917	189
2/1/04	7,206	1,510,499	265	400	265	55.5
2/8/04	7,206	1,602,365	230	369	230	51.1
2/15/04	5,978	1,399,674	NA	NA	NA	NA
2/22/04	2,723	1,128,750	300	339	300	124
2/29/04	1,337	543,065	296	161	296	120
3/7/04	1,337	403,802	325	131	325	98
3/14/04	1,337	393,086	325	128	325	96
3/21/04	1,337	419,671	375	157	375	118
3/28/04	1,337	413,320	289	119	289	89
		Average	**286**	**240**	**288**	**75.4**
		Geometric Mean	**264**	**180**	**266**	**68.0**

Notes: NA = not analyzed; NR = not reported

Table A-2. McMurdo Station Untreated Wastewater Testing Results for Biochemical Oxygen Demand

Week Ending	Population (person-days)	Flow (liters)	5 Day Biochemical Oxygen Demand (BOD5)			
			Testing Results (mg/L)	Weekly Load (kg)	Loading Factor (g/1000L)	Loading Factor (g/person-day)
4/6/03	1,379	NR	NA	NA	NA	NA
4/13/03	1,379	NR	NA	NA	NA	NA
4/20/03	1,379	NR	NA	NA	NA	NA
4/27/03	1,379	384,226	531	204	531	148
5/4/03	1,379	408,489	470	192	470	139
5/11/03	1,379	408,489	700	286	700	207
5/18/03	1,379	405,420	847	343	847	249
5/25/03	1,379	380,627	477	182	477	132
6/1/03	1,379	379,225	566	215	566	156
6/8/03	1,379	368,932	NA	NA	NA	NA
6/15/03	1,379	407,696	319	130	319	94
6/22/03	1,379	385,337	421	162	421	118
6/29/03	1,379	354,432	501	178	501	129
7/6/03	1,379	391,555	632	247	632	179
7/13/03	1,379	420,370	220	92	220	67
7/20/03	1,379	399,705	570	228	570	165
7/27/03	1,379	351,812	616	217	616	157
8/3/03	1,379	337,841	813	275	813	199
8/10/03	1,379	399,149	365	146	365	106
8/17/03	1,379	409,998	420	172	420	125
8/24/03	1,747	460,510	881	406	881	232
8/31/03	2,667	542,377	830	450	830	169
9/7/03	2,667	587,174	336	197	336	74
9/14/03	2,667	755,010	409	309	409	116
9/21/03	2,667	773,747	473	366	473	137
9/28/03	2,667	863,862	483	417	483	156
10/5/03	3,460	889,661	332	295	332	85
10/12/03	5,018	1,071,725	301	323	301	64
10/19/03	5,447	1,105,918	274	303	274	56
10/26/03	6,620	1,191,203	417	497	417	75
11/2/03	6,730	1,344,761	501	674	501	100
11/9/03	6,755	1,315,153	290	381	290	56
11/16/03	NR	NR	NA	NA	NA	NA
11/23/03	6,898	1,498,479	219	328	219	48
11/30/03	6,969	1,463,529	324	474	324	68
12/7/03	7,025	1,494,759	343	513	343	73
12/14/03	6,885	1,547,948	251	389	251	56

Table A-2. McMurdo Station Untreated Wastewater Testing Results for Biochemical Oxygen Demand

Week Ending	Population (person-days)	Flow (liters)	5 Day Biochemical Oxygen Demand (BOD5)			
			Testing Results (mg/L)	Weekly Load (kg)	Loading Factor (g/1000L)	Loading Factor (g/person-day)
12/21/03	6,723	1,428,522	272	389	272	58
12/28/03	6,446	1,411,830	453	640	453	99
1/4/04	6,751	1,245,015	350	436	350	65
1/11/04	6,957	1,420,804	374	531	374	76
1/18/04	NR	NR	210	NA	NA	NA
1/25/04	6,912	1,423,076	203	289	203	42
2/1/04	7,206	1,510,499	338	511	338	71
2/8/04	7,206	1,602,365	251	402	251	56
2/15/04	5,978	1,399,674	NA	NA	NA	NA
2/22/04	2,723	1,128,750	345	389	345	143
2/29/04	1,337	543,065	260	141	260	106
3/7/04	1,337	403,802	300	121	300	91
3/14/04	1,337	393,086	296	116	296	87
3/21/04	1,337	419,671	350	147	350	110
3/28/04	1,337	413,320	325	134	325	100
		Average	**423**	**307**	**428**	**112**
		Geometric Mean	**392**	**273**	**398**	**101**

Notes: NA = not analyzed; NR = not reported

Table A-2. McMurdo Station Untreated Wastewater Testing Results for Total Phosphorous

Week Ending	Population (person-days)	Flow (liters)	Total Phosphorous			
			Testing Results (mg/L)	Weekly Load (kg)	Loading Factor (g/1000L)	Loading Factor (g/person-day)
4/6/03	1,379	NR	NA	NA	NA	NA
4/13/03	1,379	NR	NA	NA	NA	NA
4/20/03	1,379	NR	NA	NA	NA	NA
4/27/03	1,379	384,226	NA	NA	NA	NA
5/4/03	1,379	408,489	NA	NA	NA	NA
5/11/03	1,379	408,489	NA	NA	NA	NA
5/18/03	1,379	405,420	NA	NA	NA	NA
5/25/03	1,379	380,627	NA	NA	NA	NA
6/1/03	1,379	379,225	NA	NA	NA	NA
6/8/03	1,379	368,932	NA	NA	NA	NA
6/15/03	1,379	407,696	NA	NA	NA	NA
6/22/03	1,379	385,337	NA	NA	NA	NA
6/29/03	1,379	354,432	NA	NA	NA	NA
7/6/03	1,379	391,555	NA	NA	NA	NA
7/13/03	1,379	420,370	NA	NA	NA	NA
7/20/03	1,379	399,705	NA	NA	NA	NA
7/27/03	1,379	351,812	NA	NA	NA	NA
8/3/03	1,379	337,841	NA	NA	NA	NA
8/10/03	1,379	399,149	NA	NA	NA	NA
8/17/03	1,379	409,998	NA	NA	NA	NA
8/24/03	1,747	460,510	NA	NA	NA	NA
8/31/03	2,667	542,377	NA	NA	NA	NA
9/7/03	2,667	587,174	24.6	14	24.6	5.4
9/14/03	2,667	755,010	NA	NA	NA	NA
9/21/03	2,667	773,747	25.2	19	25.2	7.3
9/28/03	2,667	863,862	12.2	11	12.2	4.0
10/5/03	3,460	889,661	13.6	12	13.6	3.5
10/12/03	5,018	1,071,725	NA	NA	NA	NA
10/19/03	5,447	1,105,918	NA	NA	NA	NA
10/26/03	6,620	1,191,203	NA	NA	NA	NA
11/2/03	6,730	1,344,761	NA	NA	NA	NA
11/9/03	6,755	1,315,153	NA	NA	NA	NA
11/16/03	NR	NR	NA	NA	NA	NA
11/23/03	6,898	1,498,479	NA	NA	NA	NA
11/30/03	6,969	1,463,529	NA	NA	NA	NA
12/7/03	7,025	1,494,759	NA	NA	NA	NA
12/13/03 [1]	6,885	1,547,948	7.7	12	7.7	1.7

Table A-2. McMurdo Station Untreated Wastewater Testing Results for Total Phosphorous

Week Ending	Population (person-days)	Flow (liters)	Total Phosphorous			
			Testing Results (mg/L)	Weekly Load (kg)	Loading Factor (g/1000L)	Loading Factor (g/person-day)
12/14/03	6,885	1,547,948	NA	NA	NA	NA
12/21/03	6,723	1,428,522	NA	NA	NA	NA
12/28/03	6,446	1,411,830	NA	NA	NA	NA
1/4/04	6,751	1,245,015	NA	NA	NA	NA
1/11/04	6,957	1,420,804	NA	NA	NA	NA
1/18/04	NR	NR	NA	NA	NA	NA
1/24/04 [1]	6,912	1,423,076	10.8	15	11	2
1/25/04	6,912	1,423,076	NA	NA	NA	NA
2/1/04	7,206	1,510,499	170	257	170	36
2/8/04	7,206	1,602,365	215	345	215	48
2/15/04	5,978	1,399,674	NA	NA	NA	NA
2/22/04	2,723	1,128,750	45	51	45	19
2/29/04	1,337	543,065	32	17	32	13
3/7/04	1,337	403,802	35	14	35	11
3/14/04	1,337	393,086	30	12	30	8.8
3/21/04	1,337	419,671	35	15	35	11
3/28/04	1,337	413,320	38	16	38	12
		Average	**50**	**58**	**50**	**13**
		Geometric Mean	**31**	**24**	**31**	**8.5**

Notes: NA = not analyzed; NR = not reported
[1] Testing results for individual sample collected on date indicated; population and flow data for week used in loading factor calculation.

Table A-2. McMurdo Station Untreated Wastewater Testing Results (February 1999)

Grab Samples							
ID	**Date & Time**	**Station Population**	**Average Flow (Liters/Minute)**	**Settleable Solids (Ml/L)**	**Suspended Solids (Mg/L)**	**BOD (Mg/L)**	**Ammonia (Mg/L-N)**
G-1	2/2/1999 14:15	1,101	151		65	265	8.8
G-2	2/3/1999 10:40	1,046	148		88	249	12.3
G-3	2/4/1999 14:30	1,064	230	7.0	143	185	9.6
G-4	2/4/1999 18:30	1,064	202	3.5	136	281	7.6
G-5	2/4/1999 22:30	1,064	98	7.0	97	500	11.0
G-6	2/5/1999 2:30	1,040	44	4.0	167	180	19.0
G-7	2/5/1999 6:30	1,040	199	16.0	332	500	21.2
G-8	2/5/1999 10:30	1,040	167	15.0	348	500	10.9
G-9	2/5/1999 14:30	1,040	189	15.0	277	246	12.9
G-10	2/6/1999 14:30	1,061	177	10.0	117	281	11.6
G-11	2/7/1999 14:30	1,074	183	22.0	256	500	7.5
G-12	2/8/1999 14:30	962	154	5.0	151	320	10.6
Composite Samples							
ID	**Date & Time**	**Station Population**	**Flow (Liters/Day)**	**Settleable Solids (Ml/L)**	**Suspended Solids (Mg/L)**	**BOD (Mg/L)**	**Ammonia (Mg/L-N)**
C-1	2/2 - 2/3 (24 hrs)	1,101	273,656	N/A	188	405	14.4
C-2	2/3 - 2/4 (24 hrs)	1,046	269,114	N/A	239	373	16.2
C-3	2/4 - 2/5 (24 hrs)	1,064	259,273	N/A	257	500	17.3
C-4	2/5 - 2/6 (24 hrs)	1,040	275,170	N/A	68	250	19.5
C-5	2/6 - 2/7 (24 hrs)	1,061	251,703	N/A	140	382	27.9
C-6	2/7 - 2/8 (24 hrs)	962	250,189	N/A	228	475	36.4
	Maximum	1,101	275,170	N/A	257	500	36.4
	Minimum	962	250,189	N/A	68	250	14.4
	Average	1,046	263,184	N/A	187	398	21.9
	Standard Deviation	46	10,995	N/A	72	89	8.5
	Average per capita Pollutant Loading (g/person-day)	N/A	N/A	N/A	**47**	**100**	**5.5**

Appendix B

Air Emissions from Fuel Combustion Sources at the South Pole

TABLE B-1. ESTIMATED ANNUAL AIR EMISSIONS FROM FUEL COMBUSTION SOURCES AT THE AMUNDSEN-SCOTT STATION DURING YEAR 1 OF PROJECT ICE CUBE

Air Pollutant		Power & Water Production Fuel Usage: 1,209,600 L/yr		Heating Fuel Usage: 151,200 L/yr		Diesel-Powered Equipment Fuel Usage: 151,200 L/yr		Gasoline -Powered Equipment Fuel Usage: 15,000 L/yr		Total Emissions
Type	**Constituent**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**(kg/yr)**
Characteristic Air Pollutants	Sulfur Oxides	4.05E-04	4.89E+02	6.93E-03	1.05E+03	3.74E-03	5.65E+02	6.35E-04	9.52E+00	**2.11E+03**
	Nitrogen Oxides	4.65E-02	5.63E+04	2.41E-03	3.64E+02	4.43E-02	6.69E+03	1.15E-02	1.73E+02	**6.35E+04**
	Carbon Monoxide	1.72E-02	2.08E+04	6.01E-04	9.09E+01	1.85E-02	2.79E+03	4.76E-01	7.14E+03	**3.08E+04**
	Exhaust Hydrocarbons	5.05E-04	NCA	NCA	NCA	4.05E-03	6.13E+02	1.56E-02	2.34E+02	**8.47E+02**
	Particulate Matter	2.75E-04	3.33E+02	2.41E-04	3.64E+01	3.62E-03	5.47E+02	7.29E-04	1.09E+01	**9.27E+02**
	Carbon Dioxide	2.36E+00	2.86E+06	2.66E+00	4.03E+05	NCA	NCA	NCA	NCA	**3.26E+06**
	Aldehydes	1.02E-03	1.24E+03	NCA	NCA	8.15E-04	1.23E+02	5.34E-04	8.01E+00	**1.37E+03**
	Total Organic Carbon (TOC)	5.27E-03	6.37E+03	6.69E-05	1.01E+01	NCA	NCA	NCA	NCA	**6.38E+03**
	Non-methane TOC	NCA	NCA	4.09E-05	6.18E+00	NCA	NCA	NCA	NCA	**6.18E+00**
	Methane	NCA	NCA	2.60E-05	3.93E+00	NCA	NCA	NCA	NCA	**3.93E+00**
	Nitrous Oxide	NCA	NCA	1.32E-05	2.00E+00	NCA	NCA	NCA	NCA	**2.00E+00**
	Polycyclic Organic Matter (POM)	NCA	NCA	3.97E-07	6.00E-02	NCA	NCA	NCA	NCA	**6.00E-02**
Volatile Organics	Benzene	1.37E-05	1.65E+01	2.53E-08	3.82E-03	NCA	NCA	NCA	NCA	**1.65E+01**
	Ethylbenzene	NCA	NCA	7.65E-09	1.16E-03	NCA	NCA	NCA	NCA	**1.16E-03**
	Xylenes	4.17E-06	5.05E+00	NCA	1.98E-03	NCA	NCA	NCA	NCA	**5.05E+00**
	Toluene	5.99E-06	7.24E+00	7.46E-07	1.13E-01	NCA	NCA	NCA	NCA	**7.35E+00**
	1,1,1-Trichloroethane	NCA	NCA	2.84E-08	4.29E-03	NCA	NCA	NCA	NCA	**4.29E-03**
	Propylene	3.78E-05	4.57E+01	NCA	NCA	NCA	NCA	NCA	NCA	**4.57E+01**
	Formaldehyde	1.73E-05	2.09E+01	3.97E-06	6.00E-01	NCA	NCA	NCA	NCA	**2.15E+01**
Semi-Volatile Organics	Acetaldehyde	1.12E-05	1.36E+01	NCA	NCA	NCA	NCA	NCA	NCA	**1.36E+01**
	Naphthalene	1.24E-06	1.50E+00	1.36E-07	2.05E-02	NCA	NCA	NCA	NCA	**1.52E+00**
	Acenaphthene	NCA	NCA	2.54E-09	3.84E-04	NCA	NCA	NCA	NCA	**3.84E-04**
	Acenaphthylene	NCA	NCA	3.04E-11	4.60E-06	NCA	NCA	NCA	NCA	**4.60E-06**
	Anthracene	2.74E-08	3.31E-02	1.47E-10	2.22E-05	NCA	NCA	NCA	NCA	**3.31E-02**
	Benz(a)anthracene	2.46E-08	2.97E-02	4.82E-10	7.29E-05	NCA	NCA	NCA	NCA	**2.98E-02**
	Benzo(b,k)fluoranthene	NCA	NCA	1.78E-10	2.69E-05	NCA	NCA	NCA	NCA	**2.69E-05**
	Benzo(g,h,I)perylene	NCA	NCA	2.72E-10	4.11E-05	NCA	NCA	NCA	NCA	**4.11E-05**
	Chrysene	5.17E-09	6.25E-03	2.86E-10	4.33E-05	NCA	NCA	NCA	NCA	**6.29E-03**
	Dibenzo(a,h)anthracene	NCA	NCA	2.01E-10	3.04E-05	NCA	NCA	NCA	NCA	**3.04E-05**
	Fluoranthene	1.11E-07	1.35E-01	5.82E-10	8.80E-05	NCA	NCA	NCA	NCA	**1.35E-01**
	Fluorene	4.27E-07	5.17E-01	5.38E-10	8.13E-05	NCA	NCA	NCA	NCA	**5.17E-01**
	Indo(1,2,3-cd)pyrene	NCA	NCA	2.57E-10	3.89E-05	NCA	NCA	NCA	NCA	**3.89E-05**
	Octochloro-dibenzo-dioxin	NCA	NCA	3.73E-13	5.64E-08	NCA	NCA	NCA	NCA	**5.64E-08**
	Phenanthrene	4.30E-07	5.21E-01	1.26E-09	1.91E-04	NCA	NCA	NCA	NCA	**5.21E-01**
	Pyrene	7.00E-08	8.46E-02	5.11E-10	7.73E-05	NCA	NCA	NCA	NCA	**8.47E-02**
Metals	Arsenic	NCA	NCA	6.15E-08	9.30E-03	NCA	NCA	NCA	NCA	**9.30E-03**
	Beryllium	NCA	NCA	3.66E-08	5.53E-03	NCA	NCA	NCA	NCA	**5.53E-03**
	Cadmium	NCA	NCA	1.61E-07	2.43E-02	NCA	NCA	NCA	NCA	**2.43E-02**
	Chromium	NCA	NCA	8.42E-07	1.27E-01	NCA	NCA	NCA	NCA	**1.27E-01**
	Mercury	NCA	NCA	4.39E-08	6.64E-03	NCA	NCA	NCA	NCA	**6.64E-03**
	Manganese	NCA	NCA	2.05E-07	3.10E-02	NCA	NCA	NCA	NCA	**3.10E-02**
	Nickel	NCA	NCA	2.63E-07	3.98E-02	NCA	NCA	NCA	NCA	**3.98E-02**
	Lead	NCA	NCA	1.30E-07	1.97E-02	NCA	NCA	NCA	NCA	**1.97E-02**

NOTES: NCA = No characterization data available.

TABLE B-2. ESTIMATED ANNUAL AIR EMISSIONS FROM FUEL COMBUSTION SOURCES AT THE AMUNDSEN-SCOTT STATION DURING YEAR 2 AND BEYOND OF PROJECT ICE CUBE

Air Pollutant		Power & Water Production Fuel Usage: 1,360,800 L/yr		Heating Fuel Usage: 170,100 L/yr		Diesel-Powered Equipment Fuel Usage: 170,100 L/yr		Gasoline -Powered Equipment Fuel Usage: 15,000 L/yr		Total Emissions
Type	**Constituent**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**(kg/yr)**
Characteristic Air Pollutants	Sulfur Oxides	4.05E-04	5.51E+02	6.93E-03	1.18E+03	3.74E-03	6.36E+02	6.35E-04	9.52E+00	**2.37E+03**
	Nitrogen Oxides	4.65E-02	6.33E+04	2.41E-03	4.09E+02	4.43E-02	7.53E+03	1.15E-02	1.73E+02	**7.14E+04**
	Carbon Monoxide	1.72E-02	2.34E+04	6.01E-04	1.02E+02	1.85E-02	3.14E+03	4.76E-01	7.14E+03	**3.38E+04**
	Exhaust Hydrocarbons	5.05E-04	NCA	NCA	NCA	4.05E-03	6.89E+02	1.56E-02	2.34E+02	**9.24E+02**
	Particulate Matter	2.75E-04	3.75E+02	2.41E-04	4.09E+01	3.62E-03	6.16E+02	7.29E-04	1.09E+01	**1.04E+03**
	Carbon Dioxide	2.36E+00	3.22E+06	2.66E+00	4.53E+05	NCA	NCA	NCA	NCA	**3.67E+06**
	Aldehydes	1.02E-03	1.39E+03	NCA	NCA	8.15E-04	1.39E+02	5.34E-04	8.01E+00	**1.54E+03**
	Total Organic Carbon (TOC)	5.27E-03	7.17E+03	6.69E-05	1.14E+01	NCA	NCA	NCA	NCA	**7.18E+03**
	Non-methane TOC	NCA	NCA	4.09E-05	6.95E+00	NCA	NCA	NCA	NCA	**6.95E+00**
	Methane	NCA	NCA	2.60E-05	4.42E+00	NCA	NCA	NCA	NCA	**4.42E+00**
	Nitrous Oxide	NCA	NCA	1.32E-05	2.25E+00	NCA	NCA	NCA	NCA	**2.25E+00**
	Polycyclic Organic Matter (POM)	NCA	NCA	3.97E-07	6.75E-02	NCA	NCA	NCA	NCA	**6.75E-02**
Volatile Organics	Benzene	1.37E-05	1.86E+01	2.53E-08	4.30E-03	NCA	NCA	NCA	NCA	**1.86E+01**
	Ethylbenzene	NCA	NCA	7.65E-09	1.30E-03	NCA	NCA	NCA	NCA	**1.30E-03**
	Xylenes	4.17E-06	5.68E+00	NCA	2.23E-03	NCA	NCA	NCA	NCA	**5.68E+00**
	Toluene	5.99E-06	8.15E+00	7.46E-07	1.27E-01	NCA	NCA	NCA	NCA	**8.27E+00**
	1,1,1-Trichloroethane	NCA	NCA	2.84E-08	4.83E-03	NCA	NCA	NCA	NCA	**4.83E-03**
	Propylene	3.78E-05	5.14E+01	NCA	NCA	NCA	NCA	NCA	NCA	**5.14E+01**
	Formaldehyde	1.73E-05	2.35E+01	3.97E-06	6.75E-01	NCA	NCA	NCA	NCA	**2.42E+01**
Semi-Volatile Organics	Acetaldehyde	1.12E-05	1.53E+01	NCA	NCA	NCA	NCA	NCA	NCA	**1.53E+01**
	Naphthalene	1.24E-06	1.69E+00	1.36E-07	2.31E-02	NCA	NCA	NCA	NCA	**1.71E+00**
	Acenaphthene	NCA	NCA	2.54E-09	4.32E-04	NCA	NCA	NCA	NCA	**4.32E-04**
	Acenaphthylene	NCA	NCA	3.04E-11	5.18E-06	NCA	NCA	NCA	NCA	**5.18E-06**
	Anthracene	2.74E-08	3.72E-02	1.47E-10	2.50E-05	NCA	NCA	NCA	NCA	**3.73E-02**
	Benz(a)anthracene	2.46E-08	3.35E-02	4.82E-10	8.20E-05	NCA	NCA	NCA	NCA	**3.35E-02**
	Benzo(b,k)fluoranthene	NCA	NCA	1.78E-10	3.03E-05	NCA	NCA	NCA	NCA	**3.03E-05**
	Benzo(g,h,I)perylene	NCA	NCA	2.72E-10	4.62E-05	NCA	NCA	NCA	NCA	**4.62E-05**
	Chrysene	5.17E-09	7.03E-03	2.86E-10	4.87E-05	NCA	NCA	NCA	NCA	**7.08E-03**
	Dibenzo(a,h)anthracene	NCA	NCA	2.01E-10	3.42E-05	NCA	NCA	NCA	NCA	**3.42E-05**
	Fluoranthene	1.11E-07	1.52E-01	5.82E-10	9.90E-05	NCA	NCA	NCA	NCA	**1.52E-01**
	Fluorene	4.27E-07	5.82E-01	5.38E-10	9.14E-05	NCA	NCA	NCA	NCA	**5.82E-01**
	Indo(1,2,3-cd)pyrene	NCA	NCA	2.57E-10	4.38E-05	NCA	NCA	NCA	NCA	**4.38E-05**
	Octochloro-dibenzo-dioxin	NCA	NCA	3.73E-13	6.34E-08	NCA	NCA	NCA	NCA	**6.34E-08**
	Phenanthrene	4.30E-07	5.86E-01	1.26E-09	2.15E-04	NCA	NCA	NCA	NCA	**5.86E-01**
	Pyrene	7.00E-08	9.52E-02	5.11E-10	8.69E-05	NCA	NCA	NCA	NCA	**9.53E-02**
Metals	Arsenic	NCA	NCA	6.15E-08	1.05E-02	NCA	NCA	NCA	NCA	**1.05E-02**
	Beryllium	NCA	NCA	3.66E-08	6.22E-03	NCA	NCA	NCA	NCA	**6.22E-03**
	Cadmium	NCA	NCA	1.61E-07	2.74E-02	NCA	NCA	NCA	NCA	**2.74E-02**
	Chromium	NCA	NCA	8.42E-07	1.43E-01	NCA	NCA	NCA	NCA	**1.43E-01**
	Cobalt	NCA				NCA		NCA		**0.00E+00**
	Mercury	NCA	NCA	4.39E-08	7.47E-03	NCA	NCA	NCA	NCA	**7.47E-03**
	Manganese	NCA	NCA	2.05E-07	3.49E-02	NCA	NCA	NCA	NCA	**3.49E-02**
	Nickel	NCA	NCA	2.63E-07	4.48E-02	NCA	NCA	NCA	NCA	**4.48E-02**
	Lead	NCA	NCA	1.30E-07	2.22E-02	NCA	NCA	NCA	NCA	**2.22E-02**

NOTES: NCA = No characterization data available.

TABLE B-3 . ESTIMATED ANNUAL AIR EMISSIONS FROM FUEL COMBUSTION SOURCES OPERATED BY PROJECT ICE CUBE DURING YEAR 1 (0 holes drilled)

Air Pollutant		Power & Water Production Fuel Usage: 0 L/yr		Water Heating Fuel Usage: 0 L/yr		Space Heating Fuel Usage: 0 L/yr		Diesel-Powered Equipment Fuel Usage: 16,632 L/yr		Gasoline -Powered Equipment Fuel Usage: 1,000 L/yr		Total Emissions
Type	Constituent	Emissions Factor (kg/L)	Emissions (kg/yr)	Emissions Factor (kg/L) [1]	Emissions (kg/yr)	Emissions Factor (kg/L)	Emissions (kg/yr)	Emissions Factor (kg/L)	Emissions (kg/yr)	Emissions Factor (kg/L)	Emissions (kg/yr)	(kg/yr)
Characteristic Air Pollutants	Sulfur Oxides	4.25E-03	0.00E+00	6.93E-03	0.00E+00	6.93E-03	0.00E+00	3.74E-03	6.22E+01	6.35E-04	6.35E-01	**6.28E+01**
	Nitrogen Oxides	6.46E-02	0.00E+00	7.08E-04	0.00E+00	2.41E-03	0.00E+00	4.43E-02	7.36E+02	1.15E-02	1.15E+01	**7.48E+02**
	Carbon Monoxide	1.39E-02	0.00E+00	5.37E-04	0.00E+00	6.01E-04	0.00E+00	1.85E-02	3.07E+02	4.76E-01	4.76E+02	**7.83E+02**
	Exhaust Hydrocarbons	NCA	NCA	NCA	NCA	NCA	NCA	4.05E-03	6.74E+01	1.56E-02	1.56E+01	**8.30E+01**
	Particulate Matter	4.54E-03	0.00E+00	1.15E-04	0.00E+00	2.41E-04	0.00E+00	3.62E-03	6.02E+01	7.29E-04	7.29E-01	**6.09E+01**
	Carbon Dioxide	2.40E+00	0.00E+00	2.66E+00	0.00E+00	2.66E+00	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Aldehydes	1.02E-03	0.00E+00	NCA	NCA	NCA	NCA	8.15E-04	1.36E+01	5.34E-04	5.34E-01	**1.41E+01**
	Total Organic Carbon (TOC)	5.27E-03	0.00E+00	6.69E-05	0.00E+00	6.69E-05	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Non-methane TOC	NCA	NCA	4.09E-05	0.00E+00	4.09E-05	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Methane	NCA	NCA	2.60E-05	0.00E+00	2.60E-05	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Nitrous Oxide	NCA	NCA	1.32E-05	0.00E+00	1.32E-05	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Polycyclic Organic Matter (POM)	NCA	NCA	3.97E-07	0.00E+00	3.97E-07	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
Volatile Organics	Benzene	1.37E-05	0.00E+00	2.53E-08	0.00E+00	2.53E-08	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Ethylbenzene	NCA	NCA	7.65E-09	0.00E+00	7.65E-09	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Xylenes	4.17E-06	0.00E+00	NCA	NCA	1.31E-08	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Toluene	5.99E-06	0.00E+00	7.46E-07	0.00E+00	7.46E-07	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	1,1,1-Trichloroethane	NCA	NCA	2.84E-08	0.00E+00	2.84E-08	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Propylene	3.78E-05	0.00E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**0.00E+00**
	Formaldehyde	1.73E-05	0.00E+00	3.97E-06	0.00E+00	3.97E-06	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
Semi-Volatile Organics	Acetaldehyde	1.12E-05	0.00E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**0.00E+00**
	Naphthalene	1.24E-06	0.00E+00	1.36E-07	0.00E+00	1.36E-07	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Acenaphthene	NCA	NCA	2.54E-09	0.00E+00	2.54E-09	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Acenaphthylene	NCA	NCA	3.04E-11	0.00E+00	3.04E-11	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Anthracene	2.74E-08	0.00E+00	1.47E-10	0.00E+00	1.47E-10	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Benz(a)anthracene	2.46E-08	0.00E+00	4.82E-10	0.00E+00	4.82E-10	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Benzo(b,k)fluoranthene	NCA	NCA	1.78E-10	0.00E+00	1.78E-10	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Benzo(g,h,I)perylene	NCA	NCA	2.72E-10	0.00E+00	2.72E-10	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Chrysene	5.17E-09	0.00E+00	2.86E-10	0.00E+00	2.86E-10	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Dibenzo(a,h)anthracene	NCA	NCA	2.01E-10	0.00E+00	2.01E-10	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Fluoranthene	1.11E-07	0.00E+00	5.82E-10	0.00E+00	5.82E-10	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Fluorene	4.27E-07	0.00E+00	5.38E-10	0.00E+00	5.38E-10	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Indo(1,2,3-cd)pyrene	NCA	NCA	2.57E-10	0.00E+00	2.57E-10	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Octochloro-dibenzo-dioxin	NCA	NCA	3.73E-13	0.00E+00	3.73E-13	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Phenanthrene	4.30E-07	0.00E+00	1.26E-09	0.00E+00	1.26E-09	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Pyrene	7.00E-08	0.00E+00	5.11E-10	0.00E+00	5.11E-10	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
Metals	Arsenic	NCA	NCA	6.15E-08	0.00E+00	6.15E-08	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Beryllium	NCA	NCA	3.66E-08	0.00E+00	3.66E-08	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Cadmium	NCA	NCA	1.61E-07	0.00E+00	1.61E-07	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Chromium	NCA	NCA	8.42E-07	0.00E+00	8.42E-07	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Mercury	NCA	NCA	4.39E-08	0.00E+00	4.39E-08	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Manganese	NCA	NCA	2.05E-07	0.00E+00	2.05E-07	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Nickel	NCA	NCA	2.63E-07	0.00E+00	2.63E-07	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**
	Lead	NCA	NCA	1.30E-07	0.00E+00	1.30E-07	0.00E+00	NCA	NCA	NCA	NCA	**0.00E+00**

NOTES: NCA = No characterization data available.
[1] Emissions Factors for Nitrogen Oxides, Carbon Monoxide, Particulate Matter and Carbon Dioxide based on stacktesting data for Model 75 Water Heaters; emission factors for all other parameters derived from U.S. EPA Office of Air and Radiation, *Compilation of Air Pollutant Emission Factors. AP-42* , Volume II, Mobile Sources, Fourth Edition. September 1985.

TABLE B-4. ESTIMATED ANNUAL AIR EMISSIONS FROM FUEL COMBUSTION SOURCES OPERATED BY PROJECT ICE CUBE DURING YEAR 2 (4 holes drilled)

Air Pollutant		Power & Water Production Fuel Usage: 30,240 L/yr		Water Heating Fuel Usage: 66,528 L/yr		Space Heating Fuel Usage: 12,096 L/yr		Diesel-Powered Equipment Fuel Usage: 12,096 L/yr		Gasoline -Powered Equipment Fuel Usage: 2,000 L/yr		
Type	**Constituent**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Total Emissions (kg/yr)**
Characteristic Air Pollutants	Sulfur Oxides	4.25E-03	1.28E+02	6.93E-03	4.61E+02	6.93E-03	8.38E+01	3.74E-03	4.52E+01	6.35E-04	1.27E+00	**6.36E+02**
	Nitrogen Oxides	6.46E-02	1.95E+03	7.08E-04	4.71E+01	2.41E-03	2.91E+01	4.43E-02	5.35E+02	1.15E-02	2.30E+01	**2.56E+03**
	Carbon Monoxide	1.39E-02	4.21E+02	5.37E-04	3.57E+01	6.01E-04	7.27E+00	1.85E-02	2.23E+02	4.76E-01	9.52E+02	**1.63E+03**
	Exhaust Hydrocarbons	NCA	NCA	NCA	NCA	NCA	NCA	4.05E-03	4.90E+01	1.56E-02	3.13E+01	**8.03E+01**
	Particulate Matter	4.54E-03	1.37E+02	1.15E-04	7.63E+00	2.41E-04	2.91E+00	3.62E-03	4.38E+01	7.29E-04	1.46E+00	**1.90E+02**
	Carbon Dioxide	2.40E+00	7.26E+04	2.66E+00	1.77E+05	2.66E+00	3.22E+04	NCA	NCA	NCA	NCA	**2.50E+05**
	Aldehydes	1.02E-03	3.10E+01	NCA	NCA	NCA	NCA	8.15E-04	9.86E+00	5.34E-04	1.07E+00	**4.19E+01**
	Total Organic Carbon (TOC)	5.27E-03	1.59E+02	6.69E-05	4.45E+00	6.69E-05	8.09E-01	NCA	NCA	NCA	NCA	**1.64E+02**
	Non-methane TOC	NCA	NCA	4.09E-05	2.72E+00	4.09E-05	4.95E-01	NCA	NCA	NCA	NCA	**2.72E+00**
	Methane	NCA	NCA	2.60E-05	1.73E+00	2.60E-05	3.14E-01	NCA	NCA	NCA	NCA	**1.73E+00**
	Nitrous Oxide	NCA	NCA	1.32E-05	8.80E-01	1.32E-05	1.60E-01	NCA	NCA	NCA	NCA	**8.80E-01**
	Polycyclic Organic Matter (POM)	NCA	NCA	3.97E-07	2.64E-02	3.97E-07	4.80E-03	NCA	NCA	NCA	NCA	**2.64E-02**
Volatile Organics	Benzene	1.37E-05	4.13E-01	2.53E-08	1.68E-03	2.53E-08	1.68E-03	NCA	NCA	NCA	NCA	**4.15E-01**
	Ethylbenzene	NCA	NCA	7.65E-09	5.09E-04	7.65E-09	5.09E-04	NCA	NCA	NCA	NCA	**5.09E-04**
	Xylenes	4.17E-06	1.26E-01	1.31E-08	8.72E-04	1.31E-08	8.72E-04	NCA	NCA	NCA	NCA	**1.27E-01**
	Toluene	5.99E-06	1.81E-01	7.46E-07	4.96E-02	7.46E-07	4.96E-02	NCA	NCA	NCA	NCA	**2.31E-01**
	1,1,1-Trichloroethane	NCA	NCA	2.84E-08	1.89E-03	2.84E-08	1.89E-03	NCA	NCA	NCA	NCA	**1.89E-03**
	Propylene	3.78E-05	1.14E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**1.14E+00**
	Formaldehyde	1.73E-05	5.22E-01	3.97E-06	2.64E-01	3.97E-06	2.64E-01	NCA	NCA	NCA	NCA	**7.86E-01**
Semi-Volatile Organics	Acetaldehyde	1.12E-05	3.40E-01	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**3.40E-01**
	Naphthalene	1.24E-06	3.75E-02	1.36E-07	9.04E-03	1.36E-07	9.04E-03	NCA	NCA	NCA	NCA	**4.66E-02**
	Acenaphthene	NCA	NCA	2.54E-09	1.69E-04	2.54E-09	1.69E-04	NCA	NCA	NCA	NCA	**1.69E-04**
	Acenaphthylene	NCA	NCA	3.04E-11	2.02E-06	3.04E-11	2.02E-06	NCA	NCA	NCA	NCA	**2.02E-06**
	Anthracene	2.74E-08	8.28E-04	1.47E-10	9.76E-06	1.47E-10	9.76E-06	NCA	NCA	NCA	NCA	**8.38E-04**
	Benz(a)anthracene	2.46E-08	7.44E-04	4.82E-10	3.21E-05	4.82E-10	3.21E-05	NCA	NCA	NCA	NCA	**7.76E-04**
	Benzo(b,k)fluoranthene	NCA	NCA	1.78E-10	1.18E-05	1.78E-10	1.18E-05	NCA	NCA	NCA	NCA	**1.18E-05**
	Benzo(g,h,I)perylene	NCA	NCA	2.72E-10	1.81E-05	2.72E-10	1.81E-05	NCA	NCA	NCA	NCA	**1.81E-05**
	Chrysene	5.17E-09	1.56E-04	2.86E-10	1.90E-05	2.86E-10	1.90E-05	NCA	NCA	NCA	NCA	**1.75E-04**
	Dibenzo(a,h)anthracene	NCA	NCA	2.01E-10	1.34E-05	2.01E-10	1.34E-05	NCA	NCA	NCA	NCA	**1.34E-05**
	Fluoranthene	1.11E-07	3.37E-03	5.82E-10	3.87E-05	5.82E-10	3.87E-05	NCA	NCA	NCA	NCA	**3.41E-03**
	Fluorene	4.27E-07	1.29E-02	5.38E-10	3.58E-05	5.38E-10	3.58E-05	NCA	NCA	NCA	NCA	**1.30E-02**
	Indo(1,2,3-cd)pyrene	NCA	NCA	2.57E-10	1.71E-05	2.57E-10	1.71E-05	NCA	NCA	NCA	NCA	**1.71E-05**
	Octochloro-dibenzo-dioxin	NCA	NCA	3.73E-13	2.48E-08	3.73E-13	2.48E-08	NCA	NCA	NCA	NCA	**2.48E-08**
	Phenanthrene	4.30E-07	1.30E-02	1.26E-09	8.40E-05	1.26E-09	8.40E-05	NCA	NCA	NCA	NCA	**1.31E-02**
	Pyrene	7.00E-08	2.12E-03	5.11E-10	3.40E-05	5.11E-10	3.40E-05	NCA	NCA	NCA	NCA	**2.15E-03**
Metals	Arsenic	NCA	NCA	6.15E-08	4.09E-03	6.15E-08	4.09E-03	NCA	NCA	NCA	NCA	**4.09E-03**
	Beryllium	NCA	NCA	3.66E-08	2.43E-03	3.66E-08	2.43E-03	NCA	NCA	NCA	NCA	**2.43E-03**
	Cadmium	NCA	NCA	1.61E-07	1.07E-02	1.61E-07	1.07E-02	NCA	NCA	NCA	NCA	**1.07E-02**
	Chromium	NCA	NCA	8.42E-07	5.60E-02	8.42E-07	5.60E-02	NCA	NCA	NCA	NCA	**5.60E-02**
	Mercury	NCA	NCA	4.39E-08	2.92E-03	4.39E-08	2.92E-03	NCA	NCA	NCA	NCA	**2.92E-03**
	Manganese	NCA	NCA	2.05E-07	1.36E-02	2.05E-07	1.36E-02	NCA	NCA	NCA	NCA	**1.36E-02**
	Nickel	NCA	NCA	2.63E-07	1.75E-02	2.63E-07	1.75E-02	NCA	NCA	NCA	NCA	**1.75E-02**
	Lead	NCA	NCA	1.30E-07	8.67E-03	1.30E-07	8.67E-03	NCA	NCA	NCA	NCA	**8.67E-03**

NOTES: NCA = No characterization data available.
[1] Emissions Factors for Nitrogen Oxides, Carbon Monoxide, Particulate Matter and Carbon Dioxide based on stacktesting data for Model 75 Water Heaters; emission factors for all other parameters derived from U.S. EPA Office of Air and Radiation, *Compilation of Air Pollutant Emission Factors. AP-42* , Volume II, Mobile Sources, Fourth Edition. September 1985.

TABLE B-5 . ESTIMATED ANNUAL AIR EMISSIONS FROM FUEL COMBUSTION SOURCES OPERATED BY PROJECT ICE CUBE DURING YEAR 3 (12 holes drilled)

Air Pollutant		Power & Water Production Fuel Usage: 90,720 L		Water Heating Fuel Usage: 199,584 L		Space Heating Fuel Usage: 36,288 L/yr		Diesel-Powered Equipment Fuel Usage: 36,288 L		Gasoline -Powered Equipment Fuel Usage: 2,000 L		
Type	**Constituent**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Total Emissions (kg/yr)**
Characteristic Air Pollutants	Sulfur Oxides	4.25E-03	3.85E+02	6.93E-03	1.38E+03	6.93E-03	2.51E+02	3.74E-03	1.36E+02	6.35E-04	1.27E+00	**1.90E+03**
	Nitrogen Oxides	6.46E-02	5.86E+03	7.08E-04	1.41E+02	2.41E-03	8.73E+01	4.43E-02	1.61E+03	1.15E-02	2.30E+01	**7.63E+03**
	Carbon Monoxide	1.39E-02	1.26E+03	5.37E-04	1.07E+02	6.01E-04	2.18E+01	1.85E-02	6.70E+02	4.76E-01	9.52E+02	**2.99E+03**
	Exhaust Hydrocarbons	NCA	NCA	NCA	NCA	NCA	NCA	4.05E-03	1.47E+02	1.56E-02	3.13E+01	**1.78E+02**
	Particulate Matter	4.54E-03	4.12E+02	1.15E-04	2.29E+01	2.41E-04	8.73E+00	3.62E-03	1.31E+02	7.29E-04	1.46E+00	**5.67E+02**
	Carbon Dioxide	2.40E+00	2.18E+05	2.66E+00	5.31E+05	2.66E+00	9.66E+04	NCA	NCA	NCA	NCA	**7.49E+05**
	Aldehydes	1.02E-03	9.30E+01	NCA	NCA	NCA	NCA	8.15E-04	2.96E+01	5.34E-04	1.07E+00	**1.24E+02**
	Total Organic Carbon (TOC)	5.27E-03	4.78E+02	6.69E-05	1.33E+01	6.69E-05	2.43E+00	NCA	NCA	NCA	NCA	**4.91E+02**
	Non-methane TOC	NCA	NCA	4.09E-05	8.16E+00	4.09E-05	1.48E+00	NCA	NCA	NCA	NCA	**8.16E+00**
	Methane	NCA	NCA	2.60E-05	5.18E+00	2.60E-05	9.43E-01	NCA	NCA	NCA	NCA	**5.18E+00**
	Nitrous Oxide	NCA	NCA	1.32E-05	2.64E+00	1.32E-05	4.80E-01	NCA	NCA	NCA	NCA	**2.64E+00**
	Polycyclic Organic Matter (POM)	NCA	NCA	3.97E-07	7.92E-02	3.97E-07	1.44E-02	NCA	NCA	NCA	NCA	**7.92E-02**
Volatile Organics	Benzene	1.37E-05	1.24E+00	2.53E-08	5.04E-03	2.53E-08	5.04E-03	NCA	NCA	NCA	NCA	**1.24E+00**
	Ethylbenzene	NCA	NCA	7.65E-09	1.53E-03	7.65E-09	1.53E-03	NCA	NCA	NCA	NCA	**1.53E-03**
	Xylenes	4.17E-06	3.78E-01	NCA	2.62E-03	1.31E-08	2.62E-03	NCA	NCA	NCA	NCA	**3.81E-01**
	Toluene	5.99E-06	5.43E-01	7.46E-07	1.49E-01	7.46E-07	1.49E-01	NCA	NCA	NCA	NCA	**6.92E-01**
	1,1,1-Trichloroethane	NCA	NCA	2.84E-08	5.66E-03	2.84E-08	5.66E-03	NCA	NCA	NCA	NCA	**5.66E-03**
	Propylene	3.78E-05	3.43E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**3.43E+00**
	Formaldehyde	1.73E-05	1.57E+00	3.97E-06	7.92E-01	3.97E-06	7.92E-01	NCA	NCA	NCA	NCA	**2.36E+00**
Semi-Volatile Organics	Acetaldehyde	1.12E-05	1.02E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**1.02E+00**
	Naphthalene	1.24E-06	1.13E-01	1.36E-07	2.71E-02	1.36E-07	2.71E-02	NCA	NCA	NCA	NCA	**1.40E-01**
	Acenaphthene	NCA	NCA	2.54E-09	5.06E-04	2.54E-09	5.06E-04	NCA	NCA	NCA	NCA	**5.06E-04**
	Acenaphthylene	NCA	NCA	3.04E-11	6.07E-06	3.04E-11	6.07E-06	NCA	NCA	NCA	NCA	**6.07E-06**
	Anthracene	2.74E-08	2.48E-03	1.47E-10	2.93E-05	1.47E-10	2.93E-05	NCA	NCA	NCA	NCA	**2.51E-03**
	Benz(a)anthracene	2.46E-08	2.23E-03	4.82E-10	9.62E-05	4.82E-10	9.62E-05	NCA	NCA	NCA	NCA	**2.33E-03**
	Benzo(b,k)fluoranthene	NCA	NCA	1.78E-10	3.55E-05	1.78E-10	3.55E-05	NCA	NCA	NCA	NCA	**3.55E-05**
	Benzo(g,h,I)perylene	NCA	NCA	2.72E-10	5.42E-05	2.72E-10	5.42E-05	NCA	NCA	NCA	NCA	**5.42E-05**
	Chrysene	5.17E-09	4.69E-04	2.86E-10	5.71E-05	2.86E-10	5.71E-05	NCA	NCA	NCA	NCA	**5.26E-04**
	Dibenzo(a,h)anthracene	NCA	NCA	2.01E-10	4.01E-05	2.01E-10	4.01E-05	NCA	NCA	NCA	NCA	**4.01E-05**
	Fluoranthene	1.11E-07	1.01E-02	5.82E-10	1.16E-04	5.82E-10	1.16E-04	NCA	NCA	NCA	NCA	**1.02E-02**
	Fluorene	4.27E-07	3.88E-02	5.38E-10	1.07E-04	5.38E-10	1.07E-04	NCA	NCA	NCA	NCA	**3.89E-02**
	Indo(1,2,3-cd)pyrene	NCA	NCA	2.57E-10	5.14E-05	2.57E-10	5.14E-05	NCA	NCA	NCA	NCA	**5.14E-05**
	Octochloro-dibenzo-dioxin	NCA	NCA	3.73E-13	7.44E-08	3.73E-13	7.44E-08	NCA	NCA	NCA	NCA	**7.44E-08**
	Phenanthrene	4.30E-07	3.90E-02	1.26E-09	2.52E-04	1.26E-09	2.52E-04	NCA	NCA	NCA	NCA	**3.93E-02**
	Pyrene	7.00E-08	6.35E-03	5.11E-10	1.02E-04	5.11E-10	1.02E-04	NCA	NCA	NCA	NCA	**6.45E-03**
Metals	Arsenic	NCA	NCA	6.15E-08	1.23E-02	6.15E-08	1.23E-02	NCA	NCA	NCA	NCA	**1.23E-02**
	Beryllium	NCA	NCA	3.66E-08	7.30E-03	3.66E-08	7.30E-03	NCA	NCA	NCA	NCA	**7.30E-03**
	Cadmium	NCA	NCA	1.61E-07	3.21E-02	1.61E-07	3.21E-02	NCA	NCA	NCA	NCA	**3.21E-02**
	Chromium	NCA	NCA	8.42E-07	1.68E-01	8.42E-07	1.68E-01	NCA	NCA	NCA	NCA	**1.68E-01**
	Mercury	NCA	NCA	4.39E-08	8.76E-03	4.39E-08	8.76E-03	NCA	NCA	NCA	NCA	**8.76E-03**
	Manganese	NCA	NCA	2.05E-07	4.09E-02	2.05E-07	4.09E-02	NCA	NCA	NCA	NCA	**4.09E-02**
	Nickel	NCA	NCA	2.63E-07	5.26E-02	2.63E-07	5.26E-02	NCA	NCA	NCA	NCA	**5.26E-02**
	Lead	NCA	NCA	1.30E-07	2.60E-02	1.30E-07	2.60E-02	NCA	NCA	NCA	NCA	**2.60E-02**

NOTES: NCA = No characterization data available.
[1] Emissions Factors for Nitrogen Oxides, Carbon Monoxide, Particulate Matter and Carbon Dioxide based on stacktesting data for Model 75 Water Heaters; emission factors for all other parameters derived from U.S. EPA Office of Air and Radiation, *Compilation of Air Pollutant Emission Factors. AP-42* , Volume II, Mobile Sources, Fourth Edition. September 1985.

TABLE B-6. ESTIMATED ANNUAL AIR EMISSIONS FROM FUEL COMBUSTION SOURCES OPERATED BY PROJECT ICE CUBE DURING YEAR 4 (16 holes drilled)

Air Pollutant		Power & Water Production Fuel Usage: 120,960 L/yr		Water Heating Fuel Usage: 266,112 L/yr		Space Heating Fuel Usage: 48,384 L/yr		Diesel-Powered Equipment Fuel Usage: 48,384 L/yr		Gasoline -Powered Equipment Fuel Usage: 2,000 L/yr		
Type	**Constituent**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Total Emissions (kg/yr)**
Characteristic Air Pollutants	Sulfur Oxides	4.25E-03	5.13E+02	6.93E-03	1.84E+03	6.93E-03	3.35E+02	3.74E-03	1.81E+02	6.35E-04	1.27E+00	**2.54E+03**
	Nitrogen Oxides	6.46E-02	7.81E+03	7.08E-04	1.88E+02	2.41E-03	1.16E+02	4.43E-02	2.14E+03	1.15E-02	2.30E+01	**1.02E+04**
	Carbon Monoxide	1.39E-02	1.68E+03	5.37E-04	1.43E+02	6.01E-04	2.91E+01	1.85E-02	8.93E+02	4.76E-01	9.52E+02	**3.67E+03**
	Exhaust Hydrocarbons	NCA	NCA	NCA	NCA	NCA	NCA	4.05E-03	1.96E+02	1.56E-02	3.13E+01	**2.27E+02**
	Particulate Matter	4.54E-03	5.49E+02	1.15E-04	3.05E+01	2.41E-04	1.16E+01	3.62E-03	1.75E+02	7.29E-04	1.46E+00	**7.56E+02**
	Carbon Dioxide	2.40E+00	2.90E+05	2.66E+00	7.08E+05	2.66E+00	1.29E+05	NCA	NCA	NCA	NCA	**9.99E+05**
	Aldehydes	1.02E-03	1.24E+02	NCA	NCA	NCA	NCA	8.15E-04	3.94E+01	5.34E-04	1.07E+00	**1.64E+02**
	Total Organic Carbon (TOC)	5.27E-03	6.37E+02	6.69E-05	1.78E+01	6.69E-05	3.23E+00	NCA	NCA	NCA	NCA	**6.55E+02**
	Non-methane TOC	NCA	NCA	4.09E-05	1.09E+01	4.09E-05	1.98E+00	NCA	NCA	NCA	NCA	**1.09E+01**
	Methane	NCA	NCA	2.60E-05	6.91E+00	2.60E-05	1.26E+00	NCA	NCA	NCA	NCA	**6.91E+00**
	Nitrous Oxide	NCA	NCA	1.32E-05	3.52E+00	1.32E-05	6.40E-01	NCA	NCA	NCA	NCA	**3.52E+00**
	Polycyclic Organic Matter (POM)	NCA	NCA	3.97E-07	1.06E-01	3.97E-07	1.92E-02	NCA	NCA	NCA	NCA	**1.06E-01**
Volatile Organics	Benzene	1.37E-05	1.65E+00	2.53E-08	6.72E-03	2.53E-08	6.72E-03	NCA	NCA	NCA	NCA	**1.66E+00**
	Ethylbenzene	NCA	NCA	7.65E-09	2.04E-03	7.65E-09	2.04E-03	NCA	NCA	NCA	NCA	**2.04E-03**
	Xylenes	4.17E-06	5.05E-01	NCA	3.49E-03	1.31E-08	3.49E-03	NCA	NCA	NCA	NCA	**5.08E-01**
	Toluene	5.99E-06	7.24E-01	7.46E-07	1.98E-01	7.46E-07	1.98E-01	NCA	NCA	NCA	NCA	**9.23E-01**
	1,1,1-Trichloroethane	NCA	NCA	2.84E-08	7.55E-03	2.84E-08	7.55E-03	NCA	NCA	NCA	NCA	**7.55E-03**
	Propylene	3.78E-05	4.57E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**4.57E+00**
	Formaldehyde	1.73E-05	2.09E+00	3.97E-06	1.06E+00	3.97E-06	1.06E+00	NCA	NCA	NCA	NCA	**3.15E+00**
Semi-Volatile Organics	Acetaldehyde	1.12E-05	1.36E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**1.36E+00**
	Naphthalene	1.24E-06	1.50E-01	1.36E-07	3.62E-02	1.36E-07	3.62E-02	NCA	NCA	NCA	NCA	**1.86E-01**
	Acenaphthene	NCA	NCA	2.54E-09	6.75E-04	2.54E-09	6.75E-04	NCA	NCA	NCA	NCA	**6.75E-04**
	Acenaphthylene	NCA	NCA	3.04E-11	8.10E-06	3.04E-11	8.10E-06	NCA	NCA	NCA	NCA	**8.10E-06**
	Anthracene	2.74E-08	3.31E-03	1.47E-10	3.90E-05	1.47E-10	3.90E-05	NCA	NCA	NCA	NCA	**3.35E-03**
	Benz(a)anthracene	2.46E-08	2.97E-03	4.82E-10	1.28E-04	4.82E-10	1.28E-04	NCA	NCA	NCA	NCA	**3.10E-03**
	Benzo(b,k)fluoranthene	NCA	NCA	1.78E-10	4.74E-05	1.78E-10	4.74E-05	NCA	NCA	NCA	NCA	**4.74E-05**
	Benzo(g,h,I)perylene	NCA	NCA	2.72E-10	7.23E-05	2.72E-10	7.23E-05	NCA	NCA	NCA	NCA	**7.23E-05**
	Chrysene	5.17E-09	6.25E-04	2.86E-10	7.62E-05	2.86E-10	7.62E-05	NCA	NCA	NCA	NCA	**7.01E-04**
	Dibenzo(a,h)anthracene	NCA	NCA	2.01E-10	5.34E-05	2.01E-10	5.34E-05	NCA	NCA	NCA	NCA	**5.34E-05**
	Fluoranthene	1.11E-07	1.35E-02	5.82E-10	1.55E-04	5.82E-10	1.55E-04	NCA	NCA	NCA	NCA	**1.36E-02**
	Fluorene	4.27E-07	5.17E-02	5.38E-10	1.43E-04	5.38E-10	1.43E-04	NCA	NCA	NCA	NCA	**5.18E-02**
	Indo(1,2,3-cd)pyrene	NCA	NCA	2.57E-10	6.85E-05	2.57E-10	6.85E-05	NCA	NCA	NCA	NCA	**6.85E-05**
	Octochloro-dibenzo-dioxin	NCA	NCA	3.73E-13	9.92E-08	3.73E-13	9.92E-08	NCA	NCA	NCA	NCA	**9.92E-08**
	Phenanthrene	4.30E-07	5.21E-02	1.26E-09	3.36E-04	1.26E-09	3.36E-04	NCA	NCA	NCA	NCA	**5.24E-02**
	Pyrene	7.00E-08	8.46E-03	5.11E-10	1.36E-04	5.11E-10	1.36E-04	NCA	NCA	NCA	NCA	**8.60E-03**
Metals	Arsenic	NCA	NCA	6.15E-08	1.64E-02	6.15E-08	1.64E-02	NCA	NCA	NCA	NCA	**1.64E-02**
	Beryllium	NCA	NCA	3.66E-08	9.74E-03	3.66E-08	9.74E-03	NCA	NCA	NCA	NCA	**9.74E-03**
	Cadmium	NCA	NCA	1.61E-07	4.28E-02	1.61E-07	4.28E-02	NCA	NCA	NCA	NCA	**4.28E-02**
	Chromium	NCA	NCA	8.42E-07	2.24E-01	8.42E-07	2.24E-01	NCA	NCA	NCA	NCA	**2.24E-01**
	Mercury	NCA	NCA	4.39E-08	1.17E-02	4.39E-08	1.17E-02	NCA	NCA	NCA	NCA	**1.17E-02**
	Manganese	NCA	NCA	2.05E-07	5.45E-02	2.05E-07	5.45E-02	NCA	NCA	NCA	NCA	**5.45E-02**
	Nickel	NCA	NCA	2.63E-07	7.01E-02	2.63E-07	7.01E-02	NCA	NCA	NCA	NCA	**7.01E-02**
	Lead	NCA	NCA	1.30E-07	3.47E-02	1.30E-07	3.47E-02	NCA	NCA	NCA	NCA	**3.47E-02**

NOTES: NCA = No characterization data available.

[1] Emissions Factors for Nitrogen Oxides, Carbon Monoxide, Particulate Matter and Carbon Dioxide based on stacktesting data for Model 75 Water Heaters; emission factors for all other parameters derived from U.S. EPA Office of Air and Radiation, *Compilation of Air Pollutant Emission Factors. AP-42* , Volume II, Mobile Sources, Fourth Edition. September 1985.

TABLE B-7. ESTIMATED ANNUAL AIR EMISSIONS FROM FUEL COMBUSTION SOURCES OPERATED BY PROJECT ICE CUBE DURING YEAR 5 (16 holes drilled)

Air Pollutant		**Power & Water Production** Fuel Usage: 120,960 L/yr		**Water Heating** Fuel Usage: 266,112 L/yr		**Space Heating** Fuel Usage: 48,384 L/yr		**Diesel-Powered Equipment** Fuel Usage: 48,384 L/yr		**Gasoline -Powered Equipment** Fuel Usage: 2,000 L/yr		
Type	**Constituent**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Total Emissions (kg/yr)**
Characteristic Air Pollutants	Sulfur Oxides	4.25E-03	5.13E+02	6.93E-03	1.84E+03	6.93E-03	3.35E+02	3.74E-03	1.81E+02	6.35E-04	1.27E+00	**2.54E+03**
	Nitrogen Oxides	6.46E-02	7.81E+03	7.08E-04	1.88E+02	2.41E-03	1.16E+02	4.43E-02	2.14E+03	1.15E-02	2.30E+01	**1.02E+04**
	Carbon Monoxide	1.39E-02	1.68E+03	5.37E-04	1.43E+02	6.01E-04	2.91E+01	1.85E-02	8.93E+02	4.76E-01	9.52E+02	**3.67E+03**
	Exhaust Hydrocarbons	NCA	NCA	NCA	NCA	NCA	NCA	4.05E-03	1.96E+02	1.56E-02	3.13E+01	**2.27E+02**
	Particulate Matter	4.54E-03	5.49E+02	1.15E-04	3.05E+01	2.41E-04	1.16E+01	3.62E-03	1.75E+02	7.29E-04	1.46E+00	**7.56E+02**
	Carbon Dioxide	2.40E+00	2.90E+05	2.66E+00	7.08E+05	2.66E+00	1.29E+05	NCA	NCA	NCA	NCA	**9.99E+05**
	Aldehydes	1.02E-03	1.24E+02	NCA	NCA	NCA	NCA	8.15E-04	3.94E+01	5.34E-04	1.07E+00	**1.64E+02**
	Total Organic Carbon (TOC)	5.27E-03	6.37E+02	6.69E-05	1.78E+01	6.69E-05	3.23E+00	NCA	NCA	NCA	NCA	**6.55E+02**
	Non-methane TOC	NCA	NCA	4.09E-05	1.09E+01	4.09E-05	1.98E+00	NCA	NCA	NCA	NCA	**1.09E+01**
	Methane	NCA	NCA	2.60E-05	6.91E+00	2.60E-05	1.26E+00	NCA	NCA	NCA	NCA	**6.91E+00**
	Nitrous Oxide	NCA	NCA	1.32E-05	3.52E+00	1.32E-05	6.40E-01	NCA	NCA	NCA	NCA	**3.52E+00**
	Polycyclic Organic Matter (POM)	NCA	NCA	3.97E-07	1.06E-01	3.97E-07	1.92E-02	NCA	NCA	NCA	NCA	**1.06E-01**
Volatile Organics	Benzene	1.37E-05	1.65E+00	2.53E-08	6.72E-03	2.53E-08	1.22E-03	NCA	NCA	NCA	NCA	**1.66E+00**
	Ethylbenzene	NCA	NCA	7.65E-09	2.04E-03	7.65E-09	3.70E-04	NCA	NCA	NCA	NCA	**2.04E-03**
	Xylenes	4.17E-06	5.05E-01	NCA	3.49E-03	1.31E-08	6.34E-04	NCA	NCA	NCA	NCA	**5.08E-01**
	Toluene	5.99E-06	7.24E-01	7.46E-07	1.98E-01	7.46E-07	3.61E-02	NCA	NCA	NCA	NCA	**9.23E-01**
	1,1,1-Trichloroethane	NCA	NCA	2.84E-08	7.55E-03	2.84E-08	1.37E-03	NCA	NCA	NCA	NCA	**7.55E-03**
	Propylene	3.78E-05	4.57E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**4.57E+00**
	Formaldehyde	1.73E-05	2.09E+00	3.97E-06	1.06E+00	3.97E-06	1.92E-01	NCA	NCA	NCA	NCA	**3.15E+00**
Semi-Volatile Organics	Acetaldehyde	1.12E-05	1.36E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**1.36E+00**
	Naphthalene	1.24E-06	1.50E-01	1.36E-07	3.62E-02	1.36E-07	6.57E-03	NCA	NCA	NCA	NCA	**1.86E-01**
	Acenaphthene	NCA	NCA	2.54E-09	6.75E-04	2.54E-09	1.23E-04	NCA	NCA	NCA	NCA	**6.75E-04**
	Acenaphthylene	NCA	NCA	3.04E-11	8.10E-06	3.04E-11	1.47E-06	NCA	NCA	NCA	NCA	**8.10E-06**
	Anthracene	2.74E-08	3.31E-03	1.47E-10	3.90E-05	1.47E-10	7.10E-06	NCA	NCA	NCA	NCA	**3.35E-03**
	Benz(a)anthracene	2.46E-08	2.97E-03	4.82E-10	1.28E-04	4.82E-10	2.33E-05	NCA	NCA	NCA	NCA	**3.10E-03**
	Benzo(b,k)fluoranthene	NCA	NCA	1.78E-10	4.74E-05	1.78E-10	8.61E-06	NCA	NCA	NCA	NCA	**4.74E-05**
	Benzo(g,h,I)perylene	NCA	NCA	2.72E-10	7.23E-05	2.72E-10	1.31E-05	NCA	NCA	NCA	NCA	**7.23E-05**
	Chrysene	5.17E-09	6.25E-04	2.86E-10	7.62E-05	2.86E-10	1.38E-05	NCA	NCA	NCA	NCA	**7.01E-04**
	Dibenzo(a,h)anthracene	NCA	NCA	2.01E-10	5.34E-05	2.01E-10	9.72E-06	NCA	NCA	NCA	NCA	**5.34E-05**
	Fluoranthene	1.11E-07	1.35E-02	5.82E-10	1.55E-04	5.82E-10	2.82E-05	NCA	NCA	NCA	NCA	**1.36E-02**
	Fluorene	4.27E-07	5.17E-02	5.38E-10	1.43E-04	5.38E-10	2.60E-05	NCA	NCA	NCA	NCA	**5.18E-02**
	Indo(1,2,3-cd)pyrene	NCA	NCA	2.57E-10	6.85E-05	2.57E-10	1.25E-05	NCA	NCA	NCA	NCA	**6.85E-05**
	Octochloro-dibenzo-dioxin	NCA	NCA	3.73E-13	9.92E-08	3.73E-13	1.80E-08	NCA	NCA	NCA	NCA	**9.92E-08**
	Phenanthrene	4.30E-07	5.21E-02	1.26E-09	3.36E-04	1.26E-09	6.11E-05	NCA	NCA	NCA	NCA	**5.24E-02**
	Pyrene	7.00E-08	8.46E-03	5.11E-10	1.36E-04	5.11E-10	2.47E-05	NCA	NCA	NCA	NCA	**8.60E-03**
Metals	Arsenic	NCA	NCA	6.15E-08	1.64E-02	6.15E-08	2.97E-03	NCA	NCA	NCA	NCA	**1.64E-02**
	Beryllium	NCA	NCA	3.66E-08	9.74E-03	3.66E-08	1.77E-03	NCA	NCA	NCA	NCA	**9.74E-03**
	Cadmium	NCA	NCA	1.61E-07	4.28E-02	1.61E-07	7.79E-03	NCA	NCA	NCA	NCA	**4.28E-02**
	Chromium	NCA	NCA	8.42E-07	2.24E-01	8.42E-07	4.07E-02	NCA	NCA	NCA	NCA	**2.24E-01**
	Mercury	NCA	NCA	4.39E-08	1.17E-02	4.39E-08	2.12E-03	NCA	NCA	NCA	NCA	**1.17E-02**
	Manganese	NCA	NCA	2.05E-07	5.45E-02	2.05E-07	9.92E-03	NCA	NCA	NCA	NCA	**5.45E-02**
	Nickel	NCA	NCA	2.63E-07	7.01E-02	2.63E-07	1.27E-02	NCA	NCA	NCA	NCA	**7.01E-02**
	Lead	NCA	NCA	1.30E-07	3.47E-02	1.30E-07	6.30E-03	NCA	NCA	NCA	NCA	**3.47E-02**

NOTES: NCA = No characterization data available.

[1] Emissions Factors for Nitrogen Oxides, Carbon Monoxide, Particulate Matter and Carbon Dioxide based on stacktesting data for Model 75 Water Heaters; emission factors for all other parameters derived from U.S. EPA Office of Air and Radiation, *Compilation of Air Pollutant Emission Factors. AP-42* , Volume II, Mobile Sources, Fourth Edition. September 1985.

TABLE B-8. ESTIMATED ANNUAL AIR EMISSIONS FROM FUEL COMBUSTION SOURCES OPERATED BY PROJECT ICE CUBE DURING YEAR 6 (16 holes drilled)

Air Pollutant		Power & Water Production Fuel Usage: 120,960 L/yr		Water Heating Fuel Usage: 266,112 L/yr		Space Heating Fuel Usage: 48,384 L/yr		Diesel-Powered Equipment Fuel Usage: 48,384 L/yr		Gasoline -Powered Equipment Fuel Usage: 2,000 L/yr		
Type	**Constituent**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Total Emissions (kg/yr)**
Characteristic Air Pollutants	Sulfur Oxides	4.25E-03	5.13E+02	6.93E-03	1.84E+03	6.93E-03	3.35E+02	3.74E-03	1.81E+02	6.35E-04	1.27E+00	**2.54E+03**
	Nitrogen Oxides	6.46E-02	7.81E+03	7.08E-04	1.88E+02	2.41E-03	1.16E+02	4.43E-02	2.14E+03	1.15E-02	2.30E+01	**1.02E+04**
	Carbon Monoxide	1.39E-02	1.68E+03	5.37E-04	1.43E+02	6.01E-04	2.91E+01	1.85E-02	8.93E+02	4.76E-01	9.52E+02	**3.67E+03**
	Exhaust Hydrocarbons	NCA	NCA	NCA	NCA	NCA	NCA	4.05E-03	1.96E+02	1.56E-02	3.13E+01	**2.27E+02**
	Particulate Matter	4.54E-03	5.49E+02	1.15E-04	3.05E+01	2.41E-04	1.16E+01	3.62E-03	1.75E+02	7.29E-04	1.46E+00	**7.56E+02**
	Carbon Dioxide	2.40E+00	2.90E+05	2.66E+00	7.08E+05	2.66E+00	1.29E+05	NCA	NCA	NCA	NCA	**9.99E+05**
	Aldehydes	1.02E-03	1.24E+02	NCA	NCA	NCA	NCA	8.15E-04	3.94E+01	5.34E-04	1.07E+00	**1.64E+02**
	Total Organic Carbon (TOC)	5.27E-03	6.37E+02	6.69E-05	1.78E+01	6.69E-05	3.23E+00	NCA	NCA	NCA	NCA	**6.55E+02**
	Non-methane TOC	NCA	NCA	4.09E-05	1.09E+01	4.09E-05	1.98E+00	NCA	NCA	NCA	NCA	**1.09E+01**
	Methane	NCA	NCA	2.60E-05	6.91E+00	2.60E-05	1.26E+00	NCA	NCA	NCA	NCA	**6.91E+00**
	Nitrous Oxide	NCA	NCA	1.32E-05	3.52E+00	1.32E-05	6.40E-01	NCA	NCA	NCA	NCA	**3.52E+00**
	Polycyclic Organic Matter (POM)	NCA	NCA	3.97E-07	1.06E-01	3.97E-07	1.92E-02	NCA	NCA	NCA	NCA	**1.06E-01**
Volatile Organics	Benzene	1.37E-05	1.65E+00	2.53E-08	6.72E-03	2.53E-08	1.22E-03	NCA	NCA	NCA	NCA	**1.66E+00**
	Ethylbenzene	NCA	NCA	7.65E-09	2.04E-03	7.65E-09	3.70E-04	NCA	NCA	NCA	NCA	**2.04E-03**
	Xylenes	4.17E-06	5.05E-01	NCA	3.49E-03	1.31E-08	6.34E-04	NCA	NCA	NCA	NCA	**5.08E-01**
	Toluene	5.99E-06	7.24E-01	7.46E-07	1.98E-01	7.46E-07	3.61E-02	NCA	NCA	NCA	NCA	**9.23E-01**
	1,1,1-Trichloroethane	NCA	NCA	2.84E-08	7.55E-03	2.84E-08	1.37E-03	NCA	NCA	NCA	NCA	**7.55E-03**
	Propylene	3.78E-05	4.57E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**4.57E+00**
	Formaldehyde	1.73E-05	2.09E+00	3.97E-06	1.06E+00	3.97E-06	1.92E-01	NCA	NCA	NCA	NCA	**3.15E+00**
Semi-Volatile Organics	Acetaldehyde	1.12E-05	1.36E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**1.36E+00**
	Naphthalene	1.24E-06	1.50E-01	1.36E-07	3.62E-02	1.36E-07	6.57E-03	NCA	NCA	NCA	NCA	**1.86E-01**
	Acenaphthene	NCA	NCA	2.54E-09	6.75E-04	2.54E-09	1.23E-04	NCA	NCA	NCA	NCA	**6.75E-04**
	Acenaphthylene	NCA	NCA	3.04E-11	8.10E-06	3.04E-11	1.47E-06	NCA	NCA	NCA	NCA	**8.10E-06**
	Anthracene	2.74E-08	3.31E-03	1.47E-10	3.90E-05	1.47E-10	7.10E-06	NCA	NCA	NCA	NCA	**3.35E-03**
	Benz(a)anthracene	2.46E-08	2.97E-03	4.82E-10	1.28E-04	4.82E-10	2.33E-05	NCA	NCA	NCA	NCA	**3.10E-03**
	Benzo(b,k)fluoranthene	NCA	NCA	1.78E-10	4.74E-05	1.78E-10	8.61E-06	NCA	NCA	NCA	NCA	**4.74E-05**
	Benzo(g,h,I)perylene	NCA	NCA	2.72E-10	7.23E-05	2.72E-10	1.31E-05	NCA	NCA	NCA	NCA	**7.23E-05**
	Chrysene	5.17E-09	6.25E-04	2.86E-10	7.62E-05	2.86E-10	1.38E-05	NCA	NCA	NCA	NCA	**7.01E-04**
	Dibenzo(a,h)anthracene	NCA	NCA	2.01E-10	5.34E-05	2.01E-10	9.72E-06	NCA	NCA	NCA	NCA	**5.34E-05**
	Fluoranthene	1.11E-07	1.35E-02	5.82E-10	1.55E-04	5.82E-10	2.82E-05	NCA	NCA	NCA	NCA	**1.36E-02**
	Fluorene	4.27E-07	5.17E-02	5.38E-10	1.43E-04	5.38E-10	2.60E-05	NCA	NCA	NCA	NCA	**5.18E-02**
	Indo(1,2,3-cd)pyrene	NCA	NCA	2.57E-10	6.85E-05	2.57E-10	1.25E-05	NCA	NCA	NCA	NCA	**6.85E-05**
	Octochloro-dibenzo-dioxin	NCA	NCA	3.73E-13	9.92E-08	3.73E-13	1.80E-08	NCA	NCA	NCA	NCA	**9.92E-08**
	Phenanthrene	4.30E-07	5.21E-02	1.26E-09	3.36E-04	1.26E-09	6.11E-05	NCA	NCA	NCA	NCA	**5.24E-02**
	Pyrene	7.00E-08	8.46E-03	5.11E-10	1.36E-04	5.11E-10	2.47E-05	NCA	NCA	NCA	NCA	**8.60E-03**
Metals	Arsenic	NCA	NCA	6.15E-08	1.64E-02	6.15E-08	2.97E-03	NCA	NCA	NCA	NCA	**1.64E-02**
	Beryllium	NCA	NCA	3.66E-08	9.74E-03	3.66E-08	1.77E-03	NCA	NCA	NCA	NCA	**9.74E-03**
	Cadmium	NCA	NCA	1.61E-07	4.28E-02	1.61E-07	7.79E-03	NCA	NCA	NCA	NCA	**4.28E-02**
	Chromium	NCA	NCA	8.42E-07	2.24E-01	8.42E-07	4.07E-02	NCA	NCA	NCA	NCA	**2.24E-01**
	Mercury	NCA	NCA	4.39E-08	1.17E-02	4.39E-08	2.12E-03	NCA	NCA	NCA	NCA	**1.17E-02**
	Manganese	NCA	NCA	2.05E-07	5.45E-02	2.05E-07	9.92E-03	NCA	NCA	NCA	NCA	**5.45E-02**
	Nickel	NCA	NCA	2.63E-07	7.01E-02	2.63E-07	1.27E-02	NCA	NCA	NCA	NCA	**7.01E-02**
	Lead	NCA	NCA	1.30E-07	3.47E-02	1.30E-07	6.30E-03	NCA	NCA	NCA	NCA	**3.47E-02**

NOTES: NCA = No characterization data available.

[1] Emissions Factors for Nitrogen Oxides, Carbon Monoxide, Particulate Matter and Carbon Dioxide based on stacktesting data for Model 75 Water Heaters; emission factors for all other parameters derived from U.S. EPA Office of Air and Radiation, *Compilation of Air Pollutant Emission Factors. AP-42* , Volume II, Mobile Sources, Fourth Edition. September 1985.

TABLE B-9. ESTIMATED ANNUAL AIR EMISSIONS FROM FUEL COMBUSTION SOURCES OPERATED BY PROJECT ICE CUBE DURING YEAR 7 (16 holes drilled)

Air Pollutant		**Power & Water Production** Fuel Usage: 120,960 L/yr		**Water Heating** Fuel Usage: 266,112 L/yr		**Space Heating** Fuel Usage: 48,384 L/yr		**Diesel-Powered Equipment** Fuel Usage: 48,384 L/yr		**Gasoline -Powered Equipment** Fuel Usage: 2,000 L/yr		
Type	**Constituent**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Total Emissions (kg/yr)**
Characteristic Air Pollutants	Sulfur Oxides	4.25E-03	5.13E+02	6.93E-03	1.84E+03	6.93E-03	3.35E+02	3.74E-03	1.81E+02	6.35E-04	1.27E+00	**2.54E+03**
	Nitrogen Oxides	6.46E-02	7.81E+03	7.08E-04	1.88E+02	2.41E-03	1.16E+02	4.43E-02	2.14E+03	1.15E-02	2.30E+01	**1.02E+04**
	Carbon Monoxide	1.39E-02	1.68E+03	5.37E-04	1.43E+02	6.01E-04	2.91E+01	1.85E-02	8.93E+02	4.76E-01	9.52E+02	**3.67E+03**
	Exhaust Hydrocarbons	NCA	NCA	NCA	NCA	NCA	NCA	4.05E-03	1.96E+02	1.56E-02	3.13E+01	**2.27E+02**
	Particulate Matter	4.54E-03	5.49E+02	1.15E-04	3.05E+01	2.41E-04	1.16E+01	3.62E-03	1.75E+02	7.29E-04	1.46E+00	**7.56E+02**
	Carbon Dioxide	2.40E+00	2.90E+05	2.66E+00	7.08E+05	2.66E+00	1.29E+05	NCA	NCA	NCA	NCA	**9.99E+05**
	Aldehydes	1.02E-03	1.24E+02	NCA	NCA	NCA	NCA	8.15E-04	3.94E+01	5.34E-04	1.07E+00	**1.64E+02**
	Total Organic Carbon (TOC)	5.27E-03	6.37E+02	6.69E-05	1.78E+01	6.69E-05	3.23E+00	NCA	NCA	NCA	NCA	**6.55E+02**
	Non-methane TOC	NCA	NCA	4.09E-05	1.09E+01	4.09E-05	1.98E+00	NCA	NCA	NCA	NCA	**1.09E+01**
	Methane	NCA	NCA	2.60E-05	6.91E+00	2.60E-05	1.26E+00	NCA	NCA	NCA	NCA	**6.91E+00**
	Nitrous Oxide	NCA	NCA	1.32E-05	3.52E+00	1.32E-05	6.40E-01	NCA	NCA	NCA	NCA	**3.52E+00**
	Polycyclic Organic Matter (POM)	NCA	NCA	3.97E-07	1.06E-01	3.97E-07	1.92E-02	NCA	NCA	NCA	NCA	**1.06E-01**
Volatile Organics	Benzene	1.37E-05	1.65E+00	2.53E-08	6.72E-03	2.53E-08	1.22E-03	NCA	NCA	NCA	NCA	**1.66E+00**
	Ethylbenzene	NCA	NCA	7.65E-09	2.04E-03	7.65E-09	3.70E-04	NCA	NCA	NCA	NCA	**2.04E-03**
	Xylenes	4.17E-06	5.05E-01	NCA	3.49E-03	1.31E-08	6.34E-04	NCA	NCA	NCA	NCA	**5.08E-01**
	Toluene	5.99E-06	7.24E-01	7.46E-07	1.98E-01	7.46E-07	3.61E-02	NCA	NCA	NCA	NCA	**9.23E-01**
	1,1,1-Trichloroethane	NCA	NCA	2.84E-08	7.55E-03	2.84E-08	1.37E-03	NCA	NCA	NCA	NCA	**7.55E-03**
	Propylene	3.78E-05	4.57E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**4.57E+00**
	Formaldehyde	1.73E-05	2.09E+00	3.97E-06	1.06E+00	3.97E-06	1.92E-01	NCA	NCA	NCA	NCA	**3.15E+00**
Semi-Volatile Organics	Acetaldehyde	1.12E-05	1.36E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**1.36E+00**
	Naphthalene	1.24E-06	1.50E-01	1.36E-07	3.62E-02	1.36E-07	6.57E-03	NCA	NCA	NCA	NCA	**1.86E-01**
	Acenaphthene	NCA	NCA	2.54E-09	6.75E-04	2.54E-09	1.23E-04	NCA	NCA	NCA	NCA	**6.75E-04**
	Acenaphthylene	NCA	NCA	3.04E-11	8.10E-06	3.04E-11	1.47E-06	NCA	NCA	NCA	NCA	**8.10E-06**
	Anthracene	2.74E-08	3.31E-03	1.47E-10	3.90E-05	1.47E-10	7.10E-06	NCA	NCA	NCA	NCA	**3.35E-03**
	Benz(a)anthracene	2.46E-08	2.97E-03	4.82E-10	1.28E-04	4.82E-10	2.33E-05	NCA	NCA	NCA	NCA	**3.10E-03**
	Benzo(b,k)fluoranthene	NCA	NCA	1.78E-10	4.74E-05	1.78E-10	8.61E-06	NCA	NCA	NCA	NCA	**4.74E-05**
	Benzo(g,h,I)perylene	NCA	NCA	2.72E-10	7.23E-05	2.72E-10	1.31E-05	NCA	NCA	NCA	NCA	**7.23E-05**
	Chrysene	5.17E-09	6.25E-04	2.86E-10	7.62E-05	2.86E-10	1.38E-05	NCA	NCA	NCA	NCA	**7.01E-04**
	Dibenzo(a,h)anthracene	NCA	NCA	2.01E-10	5.34E-05	2.01E-10	9.72E-06	NCA	NCA	NCA	NCA	**5.34E-05**
	Fluoranthene	1.11E-07	1.35E-02	5.82E-10	1.55E-04	5.82E-10	2.82E-05	NCA	NCA	NCA	NCA	**1.36E-02**
	Fluorene	4.27E-07	5.17E-02	5.38E-10	1.43E-04	5.38E-10	2.60E-05	NCA	NCA	NCA	NCA	**5.18E-02**
	Indo(1,2,3-cd)pyrene	NCA	NCA	2.57E-10	6.85E-05	2.57E-10	1.25E-05	NCA	NCA	NCA	NCA	**6.85E-05**
	Octochloro-dibenzo-dioxin	NCA	NCA	3.73E-13	9.92E-08	3.73E-13	1.80E-08	NCA	NCA	NCA	NCA	**9.92E-08**
	Phenanthrene	4.30E-07	5.21E-02	1.26E-09	3.36E-04	1.26E-09	6.11E-05	NCA	NCA	NCA	NCA	**5.24E-02**
	Pyrene	7.00E-08	8.46E-03	5.11E-10	1.36E-04	5.11E-10	2.47E-05	NCA	NCA	NCA	NCA	**8.60E-03**
Metals	Arsenic	NCA	NCA	6.15E-08	1.64E-02	6.15E-08	2.97E-03	NCA	NCA	NCA	NCA	**1.64E-02**
	Beryllium	NCA	NCA	3.66E-08	9.74E-03	3.66E-08	1.77E-03	NCA	NCA	NCA	NCA	**9.74E-03**
	Cadmium	NCA	NCA	1.61E-07	4.28E-02	1.61E-07	7.79E-03	NCA	NCA	NCA	NCA	**4.28E-02**
	Chromium	NCA	NCA	8.42E-07	2.24E-01	8.42E-07	4.07E-02	NCA	NCA	NCA	NCA	**2.24E-01**
	Mercury	NCA	NCA	4.39E-08	1.17E-02	4.39E-08	2.12E-03	NCA	NCA	NCA	NCA	**1.17E-02**
	Manganese	NCA	NCA	2.05E-07	5.45E-02	2.05E-07	9.92E-03	NCA	NCA	NCA	NCA	**5.45E-02**
	Nickel	NCA	NCA	2.63E-07	7.01E-02	2.63E-07	1.27E-02	NCA	NCA	NCA	NCA	**7.01E-02**
	Lead	NCA	NCA	1.30E-07	3.47E-02	1.30E-07	6.30E-03	NCA	NCA	NCA	NCA	**3.47E-02**

NOTES: NCA = No characterization data available.
[1] Emissions Factors for Nitrogen Oxides, Carbon Monoxide, Particulate Matter and Carbon Dioxide based on stacktesting data for Model 75 Water Heaters; emission factors for all other parameters derived from U.S. EPA Office of Air and Radiation, *Compilation of Air Pollutant Emission Factors. AP-42* , Volume II, Mobile Sources, Fourth Edition. September 1985.

TABLE B-10. ESTIMATED ANNUAL AIR EMISSIONS FROM FUEL COMBUSTION SOURCES OPERATED BY PROJECT ICE CUBE DURING YEAR 8 AND BEYOND

Air Pollutant		Power & Water Production Fuel Usage: 0 L/yr		Water Heating Fuel Usage: 0 L/yr		Space Heating Fuel Usage: 11,340 L/yr		Diesel-Powered Equipment Fuel Usage: 1,134 L/yr		Gasoline -Powered Equipment Fuel Usage: 200 L/yr		
Type	**Constituent**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Emissions Factor (kg/L)**	**Emissions (kg/yr)**	**Total Emissions (kg/yr)**
Characteristic Air Pollutants	Sulfur Oxides	4.25E-03	0.00E+00	6.93E-03	0.00E+00	6.93E-03	7.85E+01	3.74E-03	4.24E+00	6.35E-04	1.27E-01	**4.37E+00**
	Nitrogen Oxides	6.46E-02	0.00E+00	7.08E-04	0.00E+00	2.41E-03	2.73E+01	4.43E-02	5.02E+01	1.15E-02	2.30E+00	**5.25E+01**
	Carbon Monoxide	1.39E-02	0.00E+00	5.37E-04	0.00E+00	6.01E-04	6.82E+00	1.85E-02	2.09E+01	4.76E-01	9.52E+01	**1.16E+02**
	Exhaust Hydrocarbons	NCA	NCA	NCA	NCA	NCA	NCA	4.05E-03	4.60E+00	1.56E-02	3.13E+00	**7.72E+00**
	Particulate Matter	4.54E-03	0.00E+00	1.15E-04	0.00E+00	2.41E-04	2.73E+00	3.62E-03	4.10E+00	7.29E-04	1.46E-01	**4.25E+00**
	Carbon Dioxide	2.40E+00	0.00E+00	2.66E+00	0.00E+00	2.66E+00	3.02E+04	NCA	NCA	NCA	NCA	**0.00E+00**
	Aldehydes	1.02E-03	0.00E+00	NCA	NCA	NCA	NCA	8.15E-04	9.25E-01	5.34E-04	1.07E-01	**1.03E+00**
	Total Organic Carbon (TOC)	5.27E-03	0.00E+00	6.69E-05	0.00E+00	6.69E-05	7.58E-01	NCA	NCA	NCA	NCA	**0.00E+00**
	Non-methane TOC	NCA	NCA	4.09E-05	0.00E+00	4.09E-05	4.64E-01	NCA	NCA	NCA	NCA	**0.00E+00**
	Methane	NCA	NCA	2.60E-05	0.00E+00	2.60E-05	2.95E-01	NCA	NCA	NCA	NCA	**0.00E+00**
	Nitrous Oxide	NCA	NCA	1.32E-05	0.00E+00	1.32E-05	1.50E-01	NCA	NCA	NCA	NCA	**0.00E+00**
	Polycyclic Organic Matter (POM)	NCA	NCA	3.97E-07	0.00E+00	3.97E-07	4.50E-03	NCA	NCA	NCA	NCA	**0.00E+00**
Volatile Organics	Benzene	1.37E-05	0.00E+00	2.53E-08	0.00E+00	2.53E-08	2.86E-04	NCA	NCA	NCA	NCA	**0.00E+00**
	Ethylbenzene	NCA	NCA	7.65E-09	0.00E+00	7.65E-09	8.67E-05	NCA	NCA	NCA	NCA	**0.00E+00**
	Xylenes	4.17E-06	0.00E+00	NCA	0.00E+00	1.31E-08	1.49E-04	NCA	NCA	NCA	NCA	**0.00E+00**
	Toluene	5.99E-06	0.00E+00	7.46E-07	0.00E+00	7.46E-07	8.45E-03	NCA	NCA	NCA	NCA	**0.00E+00**
	1,1,1-Trichloroethane	NCA	NCA	2.84E-08	0.00E+00	2.84E-08	3.22E-04	NCA	NCA	NCA	NCA	**0.00E+00**
	Propylene	3.78E-05	0.00E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**0.00E+00**
	Formaldehyde	1.73E-05	0.00E+00	3.97E-06	0.00E+00	3.97E-06	4.50E-02	NCA	NCA	NCA	NCA	**0.00E+00**
Semi-Volatile Organics	Acetaldehyde	1.12E-05	0.00E+00	NCA	NCA	NCA	NCA	NCA	NCA	NCA	NCA	**0.00E+00**
	Naphthalene	1.24E-06	0.00E+00	1.36E-07	0.00E+00	1.36E-07	1.54E-03	NCA	NCA	NCA	NCA	**0.00E+00**
	Acenaphthene	NCA	NCA	2.54E-09	0.00E+00	2.54E-09	2.88E-05	NCA	NCA	NCA	NCA	**0.00E+00**
	Acenaphthylene	NCA	NCA	3.04E-11	0.00E+00	3.04E-11	3.45E-07	NCA	NCA	NCA	NCA	**0.00E+00**
	Anthracene	2.74E-08	0.00E+00	1.47E-10	0.00E+00	1.47E-10	1.66E-06	NCA	NCA	NCA	NCA	**0.00E+00**
	Benz(a)anthracene	2.46E-08	0.00E+00	4.82E-10	0.00E+00	4.82E-10	5.47E-06	NCA	NCA	NCA	NCA	**0.00E+00**
	Benzo(b,k)fluoranthene	NCA	NCA	1.78E-10	0.00E+00	1.78E-10	2.02E-06	NCA	NCA	NCA	NCA	**0.00E+00**
	Benzo(g,h,I)perylene	NCA	NCA	2.72E-10	0.00E+00	2.72E-10	3.08E-06	NCA	NCA	NCA	NCA	**0.00E+00**
	Chrysene	5.17E-09	0.00E+00	2.86E-10	0.00E+00	2.86E-10	3.25E-06	NCA	NCA	NCA	NCA	**0.00E+00**
	Dibenzo(a,h)anthracene	NCA	NCA	2.01E-10	0.00E+00	2.01E-10	2.28E-06	NCA	NCA	NCA	NCA	**0.00E+00**
	Fluoranthene	1.11E-07	0.00E+00	5.82E-10	0.00E+00	5.82E-10	6.60E-06	NCA	NCA	NCA	NCA	**0.00E+00**
	Fluorene	4.27E-07	0.00E+00	5.38E-10	0.00E+00	5.38E-10	6.10E-06	NCA	NCA	NCA	NCA	**0.00E+00**
	Indo(1,2,3-cd)pyrene	NCA	NCA	2.57E-10	0.00E+00	2.57E-10	2.92E-06	NCA	NCA	NCA	NCA	**0.00E+00**
	Octochloro-dibenzo-dioxin	NCA	NCA	3.73E-13	0.00E+00	3.73E-13	4.23E-09	NCA	NCA	NCA	NCA	**0.00E+00**
	Phenanthrene	4.30E-07	0.00E+00	1.26E-09	0.00E+00	1.26E-09	1.43E-05	NCA	NCA	NCA	NCA	**0.00E+00**
	Pyrene	7.00E-08	0.00E+00	5.11E-10	0.00E+00	5.11E-10	5.80E-06	NCA	NCA	NCA	NCA	**0.00E+00**
Metals	Arsenic	NCA	NCA	6.15E-08	0.00E+00	6.15E-08	6.97E-04	NCA	NCA	NCA	NCA	**0.00E+00**
	Beryllium	NCA	NCA	3.66E-08	0.00E+00	3.66E-08	4.15E-04	NCA	NCA	NCA	NCA	**0.00E+00**
	Cadmium	NCA	NCA	1.61E-07	0.00E+00	1.61E-07	1.83E-03	NCA	NCA	NCA	NCA	**0.00E+00**
	Chromium	NCA	NCA	8.42E-07	0.00E+00	8.42E-07	9.54E-03	NCA	NCA	NCA	NCA	**0.00E+00**
	Mercury	NCA	NCA	4.39E-08	0.00E+00	4.39E-08	4.98E-04	NCA	NCA	NCA	NCA	**0.00E+00**
	Manganese	NCA	NCA	2.05E-07	0.00E+00	2.05E-07	2.32E-03	NCA	NCA	NCA	NCA	**0.00E+00**
	Nickel	NCA	NCA	2.63E-07	0.00E+00	2.63E-07	2.99E-03	NCA	NCA	NCA	NCA	**0.00E+00**
	Lead	NCA	NCA	1.30E-07	0.00E+00	1.30E-07	1.48E-03	NCA	NCA	NCA	NCA	**0.00E+00**

NOTES: NCA = No characterization data available.

[1] Emissions Factors for Nitrogen Oxides, Carbon Monoxide, Particulate Matter and Carbon Dioxide based on stacktesting data for Model 75 Water Heaters; emission factors for all other parameters derived from U.S. EPA Office of Air and Radiation, *Compilation of Air Pollutant Emission Factors. AP-42* , Volume II, Mobile Sources, Fourth Edition. September 1985.

Appendix C

Air Emissions from Fuel Evaporation at the South Pole

TABLE C-1. ESTIMATED ANNUAL FUEL EVAPORATIVE EMISSIONS FOR THE AMUNDSEN-SCOTT STATION DURING PROJECT ICE CUBE

Year	2004	2005	2006	2007	2008	2009	2010	2011
Project Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8+**
Activity Resulting in the Release of Petroleum Hydrocarbon Vapors to the Atmosphere								
Diesel Fuel Transfer to Equipment								
Annual Diesel Fuel Usage (liters/year)	1,512,000	1,701,000	1,701,000	1,701,000	1,701,000	1,701,000	1,701,000	1,701,000
Estimated Number of Diesel Fuel Transfers	4	4	4	4	4	4	4	4
Diesel Evaporative Emissions (kg/year) [1]	9.2	10.3	10.3	10.3	10.3	10.3	10.3	10.3
Gasoline Fuel Transfer to Equipment								
Annual Gasoline Usage (liters/year)	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Estimated Number of Gasoline Transfers	3	3	3	3	3	3	3	3
Gasoline Evaporative Emissions (kg/year)[2]	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
TOTAL WORKING LOSSES	29.2	30.4	30.4	30.4	30.4	30.4	30.4	30.4
ESTIMATED STANDING LOSSES [3]	29.2	30.4	30.4	30.4	30.4	30.4	30.4	30.4
TOTAL EVAPORATIVE EMISSIONS (kg/year)	58.5	60.8	60.8	60.8	60.8	60.8	60.8	60.8

[1] Evaporative Emissions Working Losses for Diesel Fuel = [1.52E-6]x[Annual Fuel Usage]x[Number of transfers]

[2] Evaporative Emissions Working Losses for Gasoline = [4.46E-4]x[Annual Fuel Usage]x[Number of transfers].

[3] Estimated standing losses are assumed to be equal to working losses.

TABLE C-2. ESTIMATED ANNUAL FUEL EVAPORATIVE EMISSIONS FOR PROJECT ICE CUBE

Project Year	1	2	3	4	5	6	7	8+
Activity Resulting in the Release of Petroleum Hydrocarbon Vapors to the Atmosphere								
Diesel Fuel Transfer to Equipment								
Annual Diesel Fuel Usage (liters/year)	16,632	120,960	362,880	483,840	483,840	483,840	483,840	12,474
Estimated Number of Diesel Fuel Transfers	4	4	4	4	4	4	4	4
Diesel Evaporative Emissions (kg/year) [1]	0.1	0.7	2.2	2.9	2.9	2.9	2.9	0.1
Gasoline Fuel Transfer to Equipment								
Annual Gasoline Usage (liters/year)	1,000	2,000	2,000	2,000	2,000	2,000	2,000	200
Estimated Number of Gasoline Transfers	3	3	3	3	3	3	3	3
Gasoline Evaporative Emissions (kg/year)[2]	1.3	2.7	2.7	2.7	2.7	2.7	2.7	0.3
TOTAL WORKING LOSSES	1.4	3.4	4.9	5.6	5.6	5.6	5.6	0.3
ESTIMATED STANDING LOSSES [3]	1.4	3.4	4.9	5.6	5.6	5.6	5.6	0.3
TOTAL EVAPORATIVE EMISSIONS (kg/year)	2.9	6.8	9.8	11.2	11.2	11.2	11.2	0.7

[1] Evaporative Emissions Working Losses for Diesel Fuel = [1.52E-6]x[Annual Fuel Usage]x[Number of transfers]
[2] Evaporative Emissions Working Losses for Gasoline = [4.46E-4]x[Annual Fuel Usage]x[Number of transfers].
[3] Estimated standing losses are assumed to be equal to working losses.

Appendix D

Air Emissions from Logistical Support Aircraft

TABLE D-1. DETAILED AIR EMISSIONS FROM AIRCRAFT USED FOR INTERCONTINENTAL MISSIONS SUPPORTING ACTIVITIES AT THE SOUTH POLE DURING YEARS 1 - 8 of PROJECT ICECUBE (Baseline Conditions)

Characteristic Pollutant	Intercontinental Flights: Number of Missions [1]	Intercontinental Flights: Flight Hours below 60°S [2]	Additional Idling Time (hr) [3]	Emission Rates [4]: LTO (kg/LTO)	Emission Rates [4]: Idling (kg/hr)	Emission Rates [4]: Flight (kg/hr)	Emissions (kg/year): LTO	Emissions (kg/year): Additional Idling	Emissions (kg/year): Cruise Flight	Emissions (kg/year): Total
Aircraft: LC-130 (4 Engine Turboprop, Engine Manufacturer: Detroit Diesel Allison Division of General Motors, Model T56)										
Sulfur Oxides	48	360	0	0.73	0.8	3	35	0	1,080	**1,115**
Nitrogen Oxides	48	360	0	4.35	4	24.6	209	0	8,856	**9,065**
Carbon Monoxide	48	360	0	14.68	31.6	7.4	705	0	2,664	**3,369**
Exhaust Hydrocarbons	48	360	0	9.2	20.8	1.2	442	0	432	**874**
Particulates	48	360	0	1.98	2.8	6.2	95	0	2,232	**2,327**
Aircraft: C-141 (4 Engine Turbofan, Engine Manufacturer: Pratt & Whitney, Model TF33)										
Sulfur Oxides	26	130	0	1.36	N/A	12.4	35	0	1,612	**1,647**
Nitrogen Oxides	26	130	0	11.59	N/A	124.8	301	0	16,224	**16,525**
Carbon Monoxide	26	130	0	64.71	N/A	42.8	1,682	0	5,564	**7,246**
Exhaust Hydrocarbons	26	130	0	63.4	N/A	15.8	1,648	0	2,054	**3,702**
Particulates	26	130	0	19.65	N/A	120.6	511	0	15,678	**16,189**
Aircraft: C-17 (2 Engine Turbofan, Engine Manufacturer: Pratt & Whitney, Model F117-PW-100)										
Sulfur Oxides	6	30	0	1.36	N/A	12.4	8	0	372	**380**
Nitrogen Oxides	6	30	0	40.1	N/A	472.4	241	0	14,172	**14,413**
Carbon Monoxide	6	30	0	25.64	N/A	12.0	154	0	360	**514**
Exhaust Hydrocarbons	6	30	0	2.3	N/A	0.96	14	0	29	**43**
Particulates	6	30	0	2.11	N/A	22.8	13	0	684	**697**

NOTES:
N/A = Not Applicable. NA = Not Available.
[1] Intercontinental missions comprise one round trip to Antarctica and have one landing/takeoff (LTO) cycle below 60°S.
[2] Intercontinental flight hours represent number of flight hours below 60°S; assumed to be 50 percent of the total flight hours.
[3] Represents extra aircraft idling at Antarctic field sites. Routine aircraft idling is included in LTO emissions.
[4] Presented in Table 4-10 of the *2002 Permit Amendments* (RPSC, 2002).

TABLE D-2. DETAILED ANNUAL AIR EMISSIONS FROM AIRCRAFT USED FOR INTRACONTINENTAL MISSIONS SUPPORTING ACTIVITIES AT THE SOUTH POLE DURING YEARS 1 - 8 of PROJECT ICECUBE (Baseline Conditions)

Characteristic Pollutant	Missions per year [1]	Flight Hours below 60^0S	Additional Idling Time (hr) [3]	Emission Rates [4]			Emissions (kg/year)			
				LTO (kg/LTO)	**Idling (kg/hr)**	**Flight (kg/hr)**	**LTO**	**Additional Idling**	**Cruise Flight**	**Total**
Aircraft: LC-130 (4 Engine Turboprop, Engine Manufacturer: Detroit Diesel Allison Division of General Motors, Model T56)										
Year 1										
Sulfur Oxides	300	1,725	300	0.73	0.8	3	438	240	5,175	**5,853**
Nitrogen Oxides	300	1,725	300	4.35	4	24.6	2,610	1,200	42,435	**46,245**
Carbon Monoxide	300	1,725	300	14.68	31.6	7.4	8,808	9,480	12,765	**31,053**
Exhaust Hydrocarbons	300	1,725	300	9.2	20.8	1.2	5,520	6,240	2,070	**13,830**
Particulates	300	1,725	300	1.98	2.8	6.2	1,188	840	10,695	**12,723**
Year 2										
Sulfur Oxides	250	1,438	250	0.73	0.8	3	365	200	4,313	**4,878**
Nitrogen Oxides	250	1,438	250	4.35	4	24.6	2,175	1,000	35,363	**38,538**
Carbon Monoxide	250	1,438	250	14.68	31.6	7.4	7,340	7,900	10,638	**25,878**
Exhaust Hydrocarbons	250	1,438	250	9.2	20.8	1.2	4,600	5,200	1,725	**11,525**
Particulates	250	1,438	250	1.98	2.8	6.2	990	700	8,913	**10,603**
Year 3										
Sulfur Oxides	241	1,386	241	0.73	0.8	3	352	193	4,157	**4,702**
Nitrogen Oxides	241	1,386	241	4.35	4	24.6	2,097	964	34,089	**37,150**
Carbon Monoxide	241	1,386	241	14.68	31.6	7.4	7,076	7,616	10,255	**24,946**
Exhaust Hydrocarbons	241	1,386	241	9.2	20.8	1.2	4,434	5,013	1,663	**11,110**
Particulates	241	1,386	241	1.98	2.8	6.2	954	675	8,592	**10,221**
Year 4										
Sulfur Oxides	235	1,351	235	0.73	0.8	3	343	188	4,054	**4,585**
Nitrogen Oxides	235	1,351	235	4.35	4	24.6	2,045	940	33,241	**36,225**
Carbon Monoxide	235	1,351	235	14.68	31.6	7.4	6,900	7,426	9,999	**24,325**
Exhaust Hydrocarbons	235	1,351	235	9.2	20.8	1.2	4,324	4,888	1,622	**10,834**
Particulates	235	1,351	235	1.98	2.8	6.2	931	658	8,378	**9,966**
Year 5										
Sulfur Oxides	228	1,311	228	0.73	0.8	3	333	182	3,933	**4,448**
Nitrogen Oxides	228	1,311	228	4.35	4	24.6	1,984	912	32,251	**35,146**
Carbon Monoxide	228	1,311	228	14.68	31.6	7.4	6,694	7,205	9,701	**23,600**
Exhaust Hydrocarbons	228	1,311	228	9.2	20.8	1.2	4,195	4,742	1,573	**10,511**
Particulates	228	1,311	228	1.98	2.8	6.2	903	638	8,128	**9,669**
Year 6										
Sulfur Oxides	219	1,259	219	0.73	0.8	3	320	175	3,778	**4,273**
Nitrogen Oxides	219	1,259	219	4.35	4	24.6	1,905	876	30,978	**33,759**
Carbon Monoxide	219	1,259	219	14.68	31.6	7.4	6,430	6,920	9,318	**22,669**
Exhaust Hydrocarbons	219	1,259	219	9.2	20.8	1.2	4,030	4,555	1,511	**10,096**
Particulates	219	1,259	219	1.98	2.8	6.2	867	613	7,807	**9,288**
Year 7										
Sulfur Oxides	227	1,305	227	0.73	0.8	3	331	182	3,916	**4,429**
Nitrogen Oxides	227	1,305	227	4.35	4	24.6	1,975	908	32,109	**34,992**
Carbon Monoxide	227	1,305	227	14.68	31.6	7.4	6,665	7,173	9,659	**23,497**
Exhaust Hydrocarbons	227	1,305	227	9.2	20.8	1.2	4,177	4,722	1,566	**10,465**
Particulates	227	1,305	227	1.98	2.8	6.2	899	636	8,093	**9,627**
Year 8										
Sulfur Oxides	186	1,070	186	0.73	0.8	3	272	149	3,209	**3,629**
Nitrogen Oxides	186	1,070	186	4.35	4	24.6	1,618	744	26,310	**28,672**
Carbon Monoxide	186	1,070	186	14.68	31.6	7.4	5,461	5,878	7,914	**19,253**
Exhaust Hydrocarbons	186	1,070	186	9.2	20.8	1.2	3,422	3,869	1,283	**8,575**
Particulates	186	1,070	186	1.98	2.8	6.2	737	521	6,631	**7,888**

NOTES:

N/A = Not Applicable. NA = Not Available.

[1] Intercontinental missions comprise one round trip to Antarctica and have one landing/takeoff (LTO) cycle below 6C^{o}S; Intracontinental flights have two LTO cycles below 60o

[2] Intercontinental flight hours represent number of flight hours below 60^oS; assumed to be 50 percent of the total flight hours.

[3] Represents extra aircraft idling at the South Pole, assumed to be 1.0 hours per mission. Routine aircraft idling is included in LTO emissions.

[4] Presented in Table 4-10 of the *2002 Permit Amendments* (RPSC, 2002).

TABLE D-3. DETAILED ANNUAL AIR EMISSIONS FROM AIRCRAFT USED FOR INTERCONTINENTAL MISSIONS SUPPORTING PROJECT ICECUBE (Years 1 - 8)

Characteristic Pollutant	Missions per year [1]	Flight Hours below 60^0S	Additional Idling Time (hr) [2]	Emission Rates [2] LTO (kg/LTO)	Idling (kg/hr)	Flight (kg/hr)	Emissions (kg/year) LTO	Additional Idling	Cruise Flight	Total
Aircraft: C-141 (4 Engine Turbofan, Engine Manufacturer: Pratt & Whitney, Model TF33) [3]										
Sulfur Oxides	13	65	0	1.36	N/A	12.4	18	0	806	**824**
Nitrogen Oxides	13	65	0	11.59	N/A	124.8	151	0	8,112	**8,263**
Carbon Monoxide	13	65	0	64.71	N/A	42.8	841	0	2,782	**3,623**
Exhaust Hydrocarbons	13	65	0	63.4	N/A	15.8	824	0	1,027	**1,851**
Particulates	13	65	0	19.65	N/A	120.6	255	0	7,839	**8,094**

NOTES:
N/A = Not Applicable. NA = Not Available.
[1] Intercontinental missions comprise one round trip to Antarctica and have one landing/takeoff (LTO) cycle below 60^oS; Intracontinental flights have two LTO cycles below 60^oS
[2] Presented in Table 4-10 of the *2002 Permit Amendments* (RPSC, 2002).
[3] All flights projected to occur in Year 1. Flights may be delayed and some cargo may be transported by C-17 aircraft, which have decreased emission rates (see Table D-1)

TABLE D-4. DETAILED ANNUAL AIR EMISSIONS FROM AIRCRAFT USED FOR INTRACONTINENTAL MISSIONS SUPPORTING PROJECT ICE CUBE (years 1 - 8)

Characteristic Pollutant	Missions per year [1]	Flight Hours below 60^0S	Additional Idling Time (hr) [3]	Emission Rates [4] LTO (kg/LTO)	Emission Rates [4] Idling (kg/hr)	Emission Rates [4] Flight (kg/hr)	Emissions (kg/year) LTO	Emissions (kg/year) Additional Idling	Emissions (kg/year) Cruise Flight	Emissions (kg/year) Total
Aircraft: LC-130 (4 Engine Turboprop, Engine Manufacturer: Detroit Diesel Allison Division of General Motors, Model T56)										
Year 1										
Sulfur Oxides	40	230	40	0.73	0.8	3	58	32	690	**780**
Nitrogen Oxides	40	230	40	4.35	4	24.6	348	160	5,658	**6,166**
Carbon Monoxide	40	230	40	14.68	31.6	7.4	1,174	1,264	1,702	**4,140**
Exhaust Hydrocarbons	40	230	40	9.2	20.8	1.2	736	832	276	**1,844**
Particulates	40	230	40	1.98	2.8	6.2	158	112	1,426	**1,696**
Year 2										
Sulfur Oxides	55	316	55	0.73	0.8	3	80	44	949	**1,073**
Nitrogen Oxides	55	316	55	4.35	4	24.6	479	220	7,780	**8,478**
Carbon Monoxide	55	316	55	14.68	31.6	7.4	1,615	1,738	2,340	**5,693**
Exhaust Hydrocarbons	55	316	55	9.2	20.8	1.2	1,012	1,144	380	**2,536**
Particulates	55	316	55	1.98	2.8	6.2	218	154	1,961	**2,333**
Year 3										
Sulfur Oxides	52	299	52	0.73	0.8	3	76	42	897	**1,015**
Nitrogen Oxides	52	299	52	4.35	4	24.6	452	208	7,355	**8,016**
Carbon Monoxide	52	299	52	14.68	31.6	7.4	1,527	1,643	2,213	**5,383**
Exhaust Hydrocarbons	52	299	52	9.2	20.8	1.2	957	1,082	359	**2,397**
Particulates	52	299	52	1.98	2.8	6.2	206	146	1,854	**2,205**
Year 4										
Sulfur Oxides	58	334	58	0.73	0.8	3	85	46	1,001	**1,132**
Nitrogen Oxides	58	334	58	4.35	4	24.6	505	232	8,204	**8,941**
Carbon Monoxide	58	334	58	14.68	31.6	7.4	1,703	1,833	2,468	**6,004**
Exhaust Hydrocarbons	58	334	58	9.2	20.8	1.2	1,067	1,206	400	**2,674**
Particulates	58	334	58	1.98	2.8	6.2	230	162	2,068	**2,460**
Year 5										
Sulfur Oxides	60	345	60	0.73	0.8	3	88	48	1,035	**1,171**
Nitrogen Oxides	60	345	60	4.35	4	24.6	522	240	8,487	**9,249**
Carbon Monoxide	60	345	60	14.68	31.6	7.4	1,762	1,896	2,553	**6,211**
Exhaust Hydrocarbons	60	345	60	9.2	20.8	1.2	1,104	1,248	414	**2,766**
Particulates	60	345	60	1.98	2.8	6.2	238	168	2,139	**2,545**
Year 6										
Sulfur Oxides	60	345	60	0.73	0.8	3	88	48	1,035	**1,171**
Nitrogen Oxides	60	345	60	4.35	4	24.6	522	240	8,487	**9,249**
Carbon Monoxide	60	345	60	14.68	31.6	7.4	1,762	1,896	2,553	**6,211**
Exhaust Hydrocarbons	60	345	60	9.2	20.8	1.2	1,104	1,248	414	**2,766**
Particulates	60	345	60	1.98	2.8	6.2	238	168	2,139	**2,545**
Year 7										
Sulfur Oxides	46	265	46	0.73	0.8	3	67	37	794	**897**
Nitrogen Oxides	46	265	46	4.35	4	24.6	400	184	6,507	**7,091**
Carbon Monoxide	46	265	46	14.68	31.6	7.4	1,351	1,454	1,957	**4,761**
Exhaust Hydrocarbons	46	265	46	9.2	20.8	1.2	846	957	317	**2,121**
Particulates	46	265	46	1.98	2.8	6.2	182	129	1,640	**1,951**
Year 8										
Sulfur Oxides	4	23	4	0.73	0.8	3	6	3	69	**78**
Nitrogen Oxides	4	23	4	4.35	4	24.6	35	16	566	**617**
Carbon Monoxide	4	23	4	14.68	31.6	7.4	117	126	170	**414**
Exhaust Hydrocarbons	4	23	4	9.2	20.8	1.2	74	83	28	**184**
Particulates	4	23	4	1.98	2.8	6.2	16	11	143	**170**

NOTES:
N/A = Not Applicable. NA = Not Available.
[1] Intercontinental missions comprise one round trip to Antarctica and have one landing/takeoff (LTO) cycle below 60^oS; Intracontinental flights have two LTO cycles below 60^oS
[2] Intercontinental flight hours represent number of flight hours below 60^oS; assumed to be 50 percent of the total flight hours.
[3] Represents extra aircraft idling at the South Pole, assumed to be 1.0 hours per mission. Routine aircraft idling is included in LTO emissions.
[4] Presented in Table 4-10 of the *2002 Permit Amendments* (RPSC, 2002).

APPENDIX E
PUBLIC COMMENTS FROM DRAFT COMPREHENSIVE ENVIRONMENTAL EVALUATION (CEE) and NSF RESPONSE TO COMMENTS

The Notice of Availability for public review of the draft CEE was published in the *Federal Register*. Via a website link, the draft CEE was made available for review and public comment. Comments received on the draft CEE and the responses to those comments are included in this appendix. The sections or pages of the final CEE that have been modified as a result of comments received are identified in the responses.

The respondents to the draft and the page on which their letter or comments appear are as follows:

Australian Antarctic Division

German Federal Environmental Agency

Antarctica New Zealand

Antarctic Treaty Consultative Meeting (ATCM)/Council on Environmental Protection (CEP)

Australian Comments on Draft CEE for Construction and Operation of Project Ice Cube in Antarctica

Dear Fabio

Australia has sought input from interested stakeholders in Australia on the draft CEE for the proposed construction and operation of the neutrino telescope (Project Ice Cube) at the South Pole station. I would like to pass on Australia's initial comments, prior to consideration of the draft CEE at ATCM XXVII/CEP VII.

Australia has no major concerns or comments on the draft CEE. A few minor points have been raised in discussions with interested stakeholders:

- the lack of contact name/address information [in accordance with Annex I Article 3(2)(l)];
- Noting the open-ended nature of the activity, the CEE could address a framework for progress reporting once the activity has commenced, as reflected in Resolution 2 (1997). The *Master Permit* reporting process, described in Section 7.3, could be an efficient basis for this;
- reference is made to the use of the *Permit Reporting Program*, the *USAP Master Permit*, and the *Waste Management Plan* for managing, mitigating and monitoring impacts but copies or synopses of these documents were not appended, nor links to them identified/provided;
- analysis of the reasons for choosing option A1 (supporting the project with resources from the Amundsen-Scott station during that Station's upgrade) and A2 (delaying the initiation of the traverse project until after completion of the new station) would be assisted by the inclusion of a more direct comparison of the resources needed for each option and their overall impacts (emissions, effect on logistics of other programs etc.); and

A copy of the proposal was made available to senior members of Australia's Antarctic astronomy community, who see the South Pole as providing a uniquely favourable environment for the construction of the experiment.

I am happy to discuss any of these issues with you prior to the CEP meeting in May.

Regards

Tom Maggs
A/g Manager, Environmental Policy and Protection Section
Australian Antarctic Division

Response to Comments from the Australian Antarctic Division (AAD)

AAD-1
Comment: the lack of contact name/address information [in accordance with Annex I Article 3(2)(l)]

Response: Contact Name and Address:

> Dr. Polly Penhale
> National Science Foundation, Office of Polar Programs
> 4201 Wilson Blvd., Suite 755S
> Arlington, VA 22230
> Telephone: 01 703 292 7420
> Email: ppenhale@nsf.gov

AAD-2
Comment: Noting the open-ended nature of the activity, the CEE could address a framework for progress reporting once the activity has commenced, as reflected in Resolution 2 (1997). The *Master Permit* reporting process, described in Section 7.3, could be an efficient basis for this

Response: The *Master Permit* reporting process will continue to be used to document conditions in the USAP governed by U.S. environmental regulations (45 CFR 671). In particular, the USAP will report annually on the management of Designated Pollutants (hazardous materials) stored and used at all facilities, the disposition of wastes, and the identification of all substances released to the Antarctic environment. The scope of the *Master Permitting* process is inclusive of all USAP facilities, operations, and research-related activities.

AAD-3
Comment: reference is made to the use of the *Permit Reporting Program*, the *USAP Master Permit*, and the *Waste Management Plan* for managing, mitigating and monitoring impacts but copies or synopses of these documents were not appended, nor links to them identified/provided

Response: The USAP will provide links to the documents which are available electronically such as the *USAP Master Permit*. Legacy documents such as the *Waste Management Plan* are only available in hard copy formats and will be converted into electronic versions when the documents become obsolete and require updating. In addition, many of the USAP environmental documents are extremely large. For example, the *USAP Master Permit* and *Annual Amendments* identify all USAP permitted activities and include listings of products and materials containing Designated Pollutant constituents (hazardous materials) which are stored and used in the USAP. The list of materials containing Designated Pollutants is over several hundred pages long.

AAD-4
Comment: analysis of the reasons for choosing option A1 (supporting the project with resources from the Amundsen-Scott station during that Station's upgrade) and A2 (delaying the initiation of the traverse project until after completion of the new station) would be assisted by the

inclusion of a more direct comparison of the resources needed for each option and their overall impacts (emissions, effect on logistics of other programs etc.);

Response: All activities associated with Options A1 and A2 are virtually identical except for the timing and sequence of some operations. It was deemed that Option A1 would represent a more rigorous environmental impact analysis since more of the activities associated with the proposed action would be occuring either simultaneously or in closely timed sequence. As a result, the CEE primarily focused on the identification and evaluation of potential impacts associated with Option A1 realizing that Option A2 impacts would either be the identical or slightly less severe than Option A1. In addition, it was determined that the overall conclusions of proposed action would be same for both options.

German Federal Environmental Agency

Comments on the Comprehensive Environmental Evaluation of “Project IceCube” of the National Science Foundation, USA

Current status
The National Science Foundation (NSF) plans to construct and operate a high-energy neutrino telescope in an area near the USA’s Amundsen-Scott Station at the Geographic South Pole. For this project, an environmental impact study was prepared for international participation in EIA pursuant to Article 8 of the Protocol of Environmental Protection to the Antarctic Treaty and Article 3, para. 3 of Annex I to this Protocol.

The [German] Federal Environmental Agency has made the study publicly accessible in accordance with Article 16, paras. 1 and 2 of the Act Implementing the Environmental Protection Protocol and forwards the following comments by Germany to the Parties:

Assessment
The environmental impact study is comprehensive and provides on the whole a clear description of the expected environmental impacts. The only problematic point is the proposed management of wastewater.

Management of wastewater
The wastewater is to be discharged into so-called “sewage bulbs” via heated collection piping (page 4-15). These bulbs utilize the cavities resulting from the Station’s water supply (page 4-8). A freshwater reservoir is created by circulating residual heat from the Station in a cavity referred to as a Rodriguez Well, some 100 metres below the ice surface. When empty, the cavity is filled with domestic wastewater (grey- and blackwater). The study states that these bulbs may accommodate up to 20 million litres of wastewater. This technique was first applied at the Amundsen-Scott Station in 2002/2003.

The second wastewater disposal variant mentioned in the study is the drilling of holes in the snow and using the intrinsic heat in the wastewater to melt the surrounding snow. The bulbs developed in this manner are stated to have a capacity of up to 7.6 million litres of wastewater. Regarding pollutants in domestic wastewater, guidelines have been implemented under the USAP (U.S. Antarctic Research Program) (page 4-16) to ensure that pollutants from non-domestic wastewater are not introduced to the wastewater that is discharged to the environment around the Station. Since 1994, the wastewater has been analysed for various pollutants as part of a monitoring programme.

From the Federal Environmental Agency’s point of view, it could be questionned whether the planned disposal in ice pits is still up-to-date. Article 2, para. 2, of Annex III to the Protocol of Environmental Protection to the Antarctic Treaty permits the disposal of sewage and liquid waste from stations (located inland on the grounded ice-sheet) in deep ice pits where this is the only practicable option. Given the diverse wastewater treatment and reprocessing technologies available today - at the German Neumayer winter station, for example, wastewater has been pre-treated for a number of years already – the proposed management of waste should be given further consideration.

Response to Comments from the German Federal Environmental Agency (GFEA)

GFEA-1

Comment: [reviewer provides a brief synopsis on the use of sewage bulbs at the Amundsen-Scott Station and the management of pollutants entering the domestic wastewater stream for subsequent discharge into the sewage bulbs]. From the Federal Environmental Agency's point of view, it could be questioned whether the planned disposal in ice pits is still up-to-date. Article 2, para. 2, of Annex III to the Protocol of Environmental Protection to the Antarctic Treaty permits the disposal of sewage and liquid waste from stations (located inland on the grounded ice-sheet) in deep ice pits where this is the only practicable option.

Response: In 1991, the NSF commissioned a detailed analysis of potential wastewater treatment systems for potential installation at the Amundsen-Scott Station. The treatment technologies evaluated included (1) conventional physical-chemical, (2) freeze/thaw, (3) evaporation/pyrolysis, (4) continuous micro-filtration, (5) supercritical water oxidation, (6) solar detoxification, and (7) biological treatment. Although all of these are proven technologies some of which are in use in polar climates, critical factors such as energy requirements, logistical support, and seasonal fluctuations in the population (wastewater flow) may limit the practical applicability of wastewater treatment at the Amundsen-Scott Station. The USAP is committed to reviewing the results of this engineering study and other relevant more recent research, operational and logistical factors at the Amundsen-Scott Station pertinent to wastewater treatment, experience gained through the design, construction, and operation of the McMurdo Station wastewater treatment plant, and information provided by other Treaty nations.

We [**Antarctica New Zealand**] have referred the two draft Comprehensive Environmental Evaluations (CEEs) prepared and circulated by the United States and to be considered at the seventh meeting of the Committee for Environmental Protection (CEP VII) to our environmental experts. A summary of the key comments and issues raised is provided below for your information in advance of the CEP meeting. Please note that more detailed technical comments will be provided by our CEP delegation during the course of the meeting next week.

1. Development and implementation of surface traverse capabilities in Antarctica

[Note: responses to these comments addressed in the Surface Traverse CEE] The nature and scale of the proposed activity fully justifies the preparation of a draft CEE, and the United States is to be complimented for commencing this process and completing a thorough and detailed document.

This draft CEE covers both the development of a general traverse capability in Antarctica and the surface re-supply of South Pole station. Our preference is for draft CEEs to relate to specific activities, rather than general concepts. This approach is foreseen in Annex I of the Protocol and allows the impacts associated with specific activities to be clearly defined and analysed. This has certainly been the case with all previous CEEs that have been forwarded to the CEP. The location of activities is an important component of the analysis of environmental impacts including assessing the nature of such of impacts. Every future traverse activity could potentially be different in nature, location, extent, duration and intensity. The reasoning behind producing a draft CEE for possibly unknown events is not immediately apparent.

The draft CEE provides detailed information on the likely direct, biophysical impacts and the value of the proposal (although, again, in a fairly generic and conceptual manner). Further consideration could be given to indirect and in particular cumulative impacts of the proposed activities. Given the types of locations that traverses are likely to occur in, consideration could be given to identifying and evaluating impacts on wilderness and aesthetic values.

2. Project Ice Cube

The United States is to be commended for producing a draft CEE for this project. This draft CEE is comprehensive in its description of the activity, as well as in its assessment of potential impacts and mitigating options. In our view the draft CEE is consistent with the requirements of Annex I to the Protocol and with the CEP's EIA Guidelines. It is a large project of long duration and we agree that a CEE is the appropriate level of EIA for this project. The draft CEE is of a very high standard.

We also agree with the general conclusion of the document that the potential scientific gain from the research far outweighs the significant but localised environmental impacts.

[Trevor Hughes, APU/ENV]

Response to Comments from Antarctica New Zealand (ANZ)

ANZ-1

Comment: The United States is to be commended for producing a draft CEE for this project. This draft CEE is comprehensive in its description of the activity, as well as in its assessment of potential impacts and mitigating options. In our view the draft CEE is consistent with the requirements of Annex I to the Protocol and with the CEP's EIA Guidelines. It is a large project of long duration and we agree that a CEE is the appropriate level of EIA for this project. The draft CEE is of a very high standard.

Response: No Response Required

ANZ-2

Comment: We also agree with the general conclusion of the document that the potential scientific gain from the research far outweighs the significant but localised environmental impacts.

Response: No Response Required

Response to Comments from the Antarctic Treaty Consultative Meeting (ATCM)/Council on Environmental Protection (CEP)

The following excerpts were derived from the **Council on Environmental Protection** (CEP) Report prepared during the Antarctic Treaty Consultative Meeting (ATCM) in Cape Town, South Africa (2004).

Comment: Argentina congratulated the U.S. on the CEE and enquired about the methodology used to weight the criteria used to assess the impact of the project.

Comment: New Zealand noted that the draft CEE states that the types and quantities of pollutants will be identified later, and suggested these be incorporated in the final CEE.

Comment: Germany suggested that some energy budget costing be done to indicate the relative advantage of advanced wastewater treatment.

Comment: CEP requested fuller information and clarification on the possibility of using advanced wastewater treatment technology on wastewater to be left in the ice.

Comment: CEP requested fuller information and clarification on efforts to be made to remove as much material as possible from the site after the completion of the project.

Comment: CEP requested fuller information and clarification on the quantity and type of pollutants that would be generated by the project.

Response to Comments from ATCM/CEP Organizations

IAA/CEP-1
Comment: Argentina (Instituto Antartico Argentino) congratulated the U.S. on the CEE and enquired about the methodology used to weight the criteria used to assess the impact of the project.

Response: It is assumed that the reviewer(s) are focusing on the information provided in Tables 6-8 and 6-9 of the CEE. The criteria were established in an attempt to define a broad range of potential impacts. On the low end of the scale, the criteria identified effects which would have a measurable or discernable impact but would be localized, relatively short duration, and reversible. On the other end of the scale, the criteria focused on effects which would have widespread impacts, occuring over long periods of time, essentially causing permanent change to the environment, and altering the behavior of potential receptors.

ANZ/CEP-1
Comment: New Zealand noted that the draft CEE states that the types and quantities of pollutants will be identified later, and suggested these be incorporated in the final CEE.

Response: It is unclear the context that the reviewer is referring to regarding the disclosure of the types and quantities of pollutants. The CEE identified all known or suspected substances that would be released to the environment as a result of the proposed action.

In regards to the management of pollutants, the Antarctic Conservation Act of 1978 (Public Law 95-541) which includes Part 671 – Waste Regulation, are the implementing requirements applicable to the United States Antarctic Program. These U.S. regulatory requirements are consistent with The Protocol on Environmental Protection to the Antarctic Treaty (1991). In compliance with these U.S. regulations and therefore the Protocol, the CEE repeatedly identifies the *USAP Master Permit* as a primary term of reference for environmental compliance in Antarctica. The Master Permit is consistent with and generally exceeds the obligations of Article 3 and Annex III and provides comprehensive detail describing all USAP actions involving the use and storage of Designated Pollutants (i.e., hazardous materials), the disposition of wastes, and the management of any substance intentional or accidentally released to the Antarctic environment.

Perhaps the reviewer was confused by the terminology used in the applicable United States regulation (45 CFR Part 671) pertaining to Designated Pollutants. As specified in 45 CFR §671.3:

> *Designated pollutant* means any substance designated as such by the Director pursuant to subpart E of this part; any pesticide, radioactive substance, or substance consisting of or containing any chemical listed by source, generic or chemical name at 40 CFR 61.01, Table 116.4A of 40 CFR 116.4; subpart D of 40 CFR part 261, 40 CFR 302.4, part 355, and part 372; and any substance which exhibits a hazardous waste characteristic as defined in subparts B and C of 40 CFR part 261; but shall not include any banned substance.

More simply stated a Designated Pollutant is a substance, product, or material which contains one or more hazardous material constituents. The term Designated Pollutant does not suggest that the material has been released to the environment but has the potential to become an environmental pollutant if released.

GFEA/CEP-1
Comment: Germany suggested that some energy budget costing be done to indicate the relative advantage of advanced wastewater treatment.

Response: See response to comment GFEA-1

CEP-1
Comment: CEP requested fuller information and clarification on the possibility of using advanced wastewater treatment technology on wastewater to be left in the ice.

Response: See response to comment GFEA-1

CEP-2
Comment: CEP requested fuller information and clarification on efforts to be made to remove as much material as possible from the site after the completion of the project.

Response: [US ACTM response #38; leaving in-place only refers to the detectors and buried cabling]

CEP-3
Comment: CEP requested fuller information and clarification on the quantity and type of pollutants that would be generated by the project.

Response: See response to comment ANZ-1