APPENDIXES

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APPENDIX 4.3.1

MAXIMUM AND MINIMUM LOADS IN 1993

APPENDIX 4.3.1 MAXIMUM AND MINIMUM LOADS IN 1993

Table 4.3.1 (a) Muscat System - Maximum Loads (MW) in 1993

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1.	282	297	329	358	570	673	697	820	679	619	440	366
2.	318	302	339	358	580	713	738	805	645	653	446	358
3.	314	304	329	300	623	730	811	785	647	648	428	326
4.	322	310	340	382	665	716	791	769	688	639	417	375
5.	323	298	322	371	683	738	778	735	718	640	419	375
6.	321	304	351	379	674	721	733	683	729	614	448	374
7.	304	290	349	374	677	736	765	688	703	578	445	362
8.	282	296	344	383	702	771	747	730	681	554	449	357
9.	325	295	357	407	678	782	732	752	653	551	418	346
10.	323	303	374	459	617	747	767	780	690	533	426	305
11.	315	301	345	475	625	737	763	787	720	498	421	342
12.	314	282	313	485	681	791	786	771	736	480	394	341
13.	321	317	319	476	694	816	780	717	716	457	419	355
14.	265	331	328	398	656	795	803	703	720	441	416	352
15.	242	328	326	383	640	787	784	709	672	476	413	350
16.	279	325	333	417	632	759	741	707	631	480	427	335
17.	284	319	325	408	662	706	803	674	636	479	415	303
18.	288	307	335	532	673	718	791	683	633	447	386	350
19.	280	284	317	455	690	783	749	676	626	443	349	345
20.	270	330	369	492	697	790	747	739	638	430	391	349
21.	278	340	399	509	724	796	773	786	651	413	387	348
22.	260	337	360	444	753	826	783	779	644	386	380	351
23.	299	355	322	601	758	804	747	785	646	425	367	335
24.	295	318	264	639	736	781	760	799	651	421	364	314
25.	291	306	267	618	751	732	754	762	654	421	352	345
26.	297	288	273	614	762	780	774	732	660	412	308	340
27.	291	315	336	540	758	766	791	699	658	413	325	340
28.	282	317	327	587	746	778	782	705	662	418	338	338
29.	255		349	550	791	767	766	699	652	416	369	336
30.	293		347	548	733	765	749	673	637	445	370	332
31.	297		357		674		820	694		443		302
MONTH	325	355	399	639	791	826	820	820	736	653	449	375

Note: Peak demand on June 22 was recorded at 1,427 hrs (Load shed 20 MW)

Table 4.3.1(b) Muscat System - Minimum Loads (MW) in 1993

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1.	195	158	208	251	354	456	530	594	463	430	310	223
2.	193	160	224	262	350	480	517	572	449	414	309	220
3.	187	168	224	276	383	490	559	571	438	421	310	217
4.	189	177	228	296	388	495	549	548	457	403	299	216
5.	195	197	224	278	403	481	541	516	471	420	281	218
6.	191	194	241	273	437	496	536	472	472	411	303	228
7.	193	175	252	270	443	492	514	483	472	394	321	210
8.	189	157	243	383	459	505	500	469	448	366	304	207
9.	185	158	240	275	457	503	522	492	445	375	324	210
10.	188	157	244	308	395	541	535	523	454	367	309	205
11.	182	163	255	320	689	505	465	504	456	339	308	195
12.	190	170	222	320	407	535	507	536	470	318	285	199
13.	191	175	242	320	452	572	529	476	447	317	288	196
14.	173	189	212	287	436	554	550	482	466	304	284	199
15.	144	194	211	271	412	530	552	473	454	298	271	192
16.	137	200	222	278	395	537	531	482	436	337	286	195
17.	148	195	225	300	409	488	536	454	431	332	319	193
18.	152	188	212	282	433	471	531	445	425	330	286	194
19.	148	184	227	296	441	500	522	438	388	313	269	196
20.	152	186	241	315	438	533	498	465	383	307	267	191
21.	155	191	266	315	481	557	508	514	396	298	248	192
22.	154	212	278	346	487	537	541	521	409	283	245	194
23.	156	228	232	366	486	559	496	513	411	288	230	202
24.	163	239	209	386	470	545	515	513	427	304	222	202
25.	158	209	186	400	483	525	526	542	424	293	210	202
26.	162	194	193	381	493	503	519	521	398	289	212	204
27.	163	199	212	385	519	501	531	470	417	284	205	196
28.	155	202	239	367	510	518	547	475	412	295	211	195
29.	153		206	357	534	530	533	458	414	290	214	187
30.	147		243	362	511	533	515	457	428	298	217	191
31.	157		249		425		565	467		309		191
MONTH	137	157	186	251	350	456	465	438	383	283	205	187

Table 4.3.1 (c) Wadi Jizzi System - Maximum Load (MW) in 1993

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1.	73.5	79.7	78.7	85.5	133.0	193.7	210.0	216.6	196.0	172.4	100.7	85.6
2.	74.6	79.0	79.0	80.5	139.7	194.6	214.8	211.0	194.6	174.0	99.8	83.0
3.	73.9	79.3	78.7	86.9	155.8	193.8	209.0	211.0	191.0	168.6	99.5	82.0
4.	73.2	79.7	79.7	84.2	165.5	188.6	203.3	211.0	186.2	169.0	103.3	85.9
5.	78.2	77.5	79.1	85.0	175.0	177.4	205.5	210.0	193.8	165.0	108.0	84.5
6.	78.0	79.5	81.4	85.8	173.2	183.7	203.8	205.7	195.0	166.5	109.6	85.0
7.	77.2	80.9	76.8	84.2	171.0	189.6	202.5	200.3	192.7	164.2	105.4	84.9
8.	73.1	82.3	81.6	85.3	168.2	194.7	210.0	197.7	189.8	161.3	98.0	83.8
9.	77.7	82.0	83.8	104.8	149.3	204.3	218.2	202.6	188.6	146.0	97.7	85.0
10.	76.9	81.0	85.2	109.6	149.6	205.0	210.0	211.4	190.3	134.0	97.5	81.4
11.	77.5	78.9	80.8	117.4	161.3	205.5	207.3	215.0	194.7	128.5	100.0	84.8
12.	78.6	74.9	75.7	113.7	172.5	212.4	208.5	210.8	199.0	133.2	96.4	84.5
13.	79.1	78.0	72.3	106.6	170.2	207.7	206.5	207.6	194.6	126.7	86.3	78.9
14.	79.2	77.1	79.7	85.2	169.1	204.6	210.0	196.0	191.8	124.0	86.8	83.4
15.	79.6	75.1	80.2	87.2	163.1	202.3	211.5	199.7	189.2	122.0	85.9	77.5
16.	82.0	71.4	79.2	99.5	162.5	197.8	215.5	202.8	186.3	125.0	91.0	81.0
17.	81.4	79.2	79.5	101.2	169.2	196.5	215.6	200.0	185.0	120.7	91.5	78.5
18.	82.8	78.3	83.9	106.0	175.0	205.5	210.8	203.6	178.5	111.6	90.3	84.4
19.	83.5	75.7	84.1	118.5	182.6	206.8	212.4	207.0	171.5	104.3	85.7	80.0
20.	81.7	78.2	89.3	122.5	186.2	209.5	215.6	208.8	169.7	100.4	88.3	83.8
21.	80.7	78.6	90.2	131.5	190.2	202.0	218.3	212.3	171.6	97.0	85.6	84.9
22.	78.6	79.5	79.6	139.5	182.3	203.5	217.6	207.6	170.6	99.0	84.8	85.4
23.	82.8	81.0	80.7	147.2	177.5	210.4	217.0	209.5	177.0	92.7	84.3	84.5
24.	83.0	78.4	79.7	151.6	185.1	206.6	209.3	206.8	174.0	99.0	85.0	81.3
25.	82.6	78.4	73.4	151.6	188.6	209.6	194.8	204.6	169.0	96.5	85.0	75.0
26.	82.8	78.9	74.4	151.0	203.3	206.0	204.3	202.6	169.8	97.2	78.7	81.3
27.	83.3	76.4	81.0	150.8	200.4	198.6	206.8	199.4	171.3	94.0	82.0	82.0
28.	82.2	78.9	76.8	147.0	204.9	200.0	211.3	195.6	170.3	100.8	84.0	81.4
29.	78.0	78.9	81.9	145.4	203.4	203.6	210.0	192.0	174.0	102.8	84.9	83.7
30.	81.4		81.2	142.8	198.2	210.0	216.3	192.5	172.8	108.0	86.0	81.8
31.	81.2		82.5		196.3		217.6	195.4		105.6		80.0
MONTH	83.5	82.3	90.2	151.6	204.9	212.4	218.3	216.6	199.0	174.0	109.6	85.9

Table 4.3.1(d) Wadi Jizzi System - Minimum Load (MW) in 1993

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1.	37.0	34.0	43.1	52.4	64.0	90.9	100.4	113.2	99.8	85.0	62.3	46.9
2.	37.5	36.0	44.1	50.0	58.6	99.6	105.0	103.2	100.0	82.0	60.4	46.0
3.	34.8	37.2	43.5	48.7	65.0	95.6	107.0	110.0	95.3	80.6	62.9	47.0
4.	32.0	38.7	46.0	50.0	72.5	94.0	106.5	107.0	93.0	78.2	64.2	46.0
5.	36.1	33.5	46.0	50.5	78.8	85.7	106.7	101.0	95.8	77.2	63.4	46.3
6.	39.3	33.6	46.6	56.7	81.8	89.0	106.5	100.5	96.0	81.0	65.0	46.0
7.	39.1	36.3	46.8	56.7	85.4	94.2	103.4	101.3	99.4	80.6	65.9	43.0
8.	39.0	38.0	44.4	57.4	75.2	97.0	104.5	98.8	97.4	83.0	66.7	44.3
9.	38.7	39.4	48.3	58.7	69.8	99.0	106.5	101.7	95.0	77.2	63.8	43.8
10.	38.1	39.0	48.6	61.8	68.0	98.7	106.5	104.4	95.6	70.3	64.2	45.0
11.	39.7	38.8	47.4	62.8	69.9	100.0	97.3	107.0	90.7	59.5	67.3	43.4
12.	39.8	37.7	43.3	67.6	76.1	100.6	106.0	109.7	95.7	69.3	37.3	42.2
13.	39.9	36.0	41.6	63.3	81.7	102.7	102.5	102.5	94.0	71.2	63.5	37.9
14.	39.5	38.8	39.8	61.0	82.5	100.4	106.6	103.0	92.6	67.0	52.6	40.6
15.	37.2	39.0	45.5	57.4	71.8	95.3	110.0	91.0	92.0	67.5	55.3	37.6
16.	38.1	32.8	40.5	58.2	73.3	98.5	106.5	104.6	96.0	67.2	56.6	37.6
17.	37.8	36.8	44.7	60.6	75.7	100.6	113.0	101.0	88.4	64.8	55.8	41.9
18.	34.4	38.9	48.4	61.0	81.2	101.3	108.0	106.0	84.0	66.0	59.3	40.0
19.	38.9	35.4	49.2	61.7	81.9	99.0	105.4	105.0	80.5	65.0	55.8	40.5
20.	38.3	38.0	49.7	63.8	84.4	100.0	111.0	107.0	77.5	60.6	53.7	41.5
21.	39.0	37.8	53.3	65.0	88.9	101.3	111.0	109.3	77.6	60.5	51.3	41.2
22.	37.7	43.5	54.8	67.8	82.4	102.3	113.0	103.0	79.5	60.4	46.3	40.3
23.	37.8	44.8	47.4	72.8	80.5	94.2	109.2	97.0	83.4	60.2	43.8	40.7
24.	37.4	47.0	44.6	71.0	85.1	98.2	101.6	96.3	85.4	65.0	46.3	43.2
25.	37.8	44.7	40.4	71.5	87.5	100.6	101.6	108.6	75.3	64.0	46.6	37.8
26.	38.0	45.3	43.8	70.0	89.6	94.5	103.0	103.0	77.3	65.3	46.8	39.0
27.	38.4	38.8	44.5	68.3	92.9	95.7	101.5	93.5	75.5	62.6	45.5	41.4
28.	38.2	43.5	40.9	67.0	99.5	94.0	105.0	102.0	79.7	61.9	45.8	41.2
29.	36.9		46.8	66.8	94.3	94.2	105.5	97.0	80.8	65.0	46.8	39.7
30.	36.7		48.2	70.2	98.8	100.4	105.2	99.0	84.0	64.8	46.8	41.0
31.	30.0		50.0	46.8	79.9		114.0	102.3		66.2		41.4
MONTH	30.0	32.8	39.8	46.8	58.6	85.7	97.3	91.0	75.3	59.5	37.3	37.6

Appendix 4.5.1 Parameters

Year	GDP at current prices* (million O.R.)	GDP deflator (1978=100)	GDP at 1978 constant prices (million O.R.)										Gov't capital formation at market prices (million O.R.)	Change (%)	Gov't capital formation at 1978 prices (million O.R.)	Change (%)
			Petro.	Change (%)	Non-petro. Primary	Non-petro. Industry	Non-petro. Services	Non-petro. Total	Non-petro. Change(%)	Bank charges (-)	GDP Total	Change (%)				
1971													20.00	-		
1972													29.90	49.5		
1973													29.90	0.0		
1974													142.80	377.6		
1975													208.00	45.7		
1976	879.80												259.80	24.9		
1977	942.20												218.90	-15.7		
1978	942.30	100.00	493.02	-	31.52	90.37	341.60	463.49	-	-14.22	942.29	-	186.10	-15.0	119.70	-
1979	1,282.90	130.71	460.34	-6.63	41.27	99.02	399.22	539.51	16.4	-18.40	981.45	4.2	215.70	15.9	165.02	37.9
1980	2,054.90	197.43	437.55	-4.95	49.83	120.61	454.31	624.75	15.8	-21.50	1,040.80	6.0	305.80	41.8	154.89	-6.1
1981	2,479.20	203.64	499.61	14.18	51.68	146.04	552.30	750.02	20.1	-32.20	1,217.43	17.0	389.60	27.4	191.32	23.5
1982	2,598.90	191.64	501.74	0.43	57.65	198.81	633.21	889.67	18.6	-35.30	1,356.11	11.4	482.20	23.8	251.61	31.5
1983	2,718.20	172.14	593.30	18.25	70.70	252.37	703.37	1,026.44	15.4	-40.70	1,579.04	16.4	529.90	9.9	307.83	22.3
1984	3,015.00	164.07	635.99	7.20	79.85	333.64	840.99	1,254.48	22.2	-52.80	1,837.67	16.4	652.50	23.1	397.70	29.2
1985	3,415.50	163.62	764.70	20.24	93.38	371.78	915.37	1,380.53	10.0	-57.82	2,087.41	13.6	701.70	7.5	428.85	7.8
1986	2,763.40	128.45	868.51	13.58	91.48	394.40	857.08	1,342.96	-2.7	-60.10	2,151.37	3.1	651.90	-7.1	507.52	18.3
1987	2,975.70	143.12	925.52	6.56	93.36	324.20	793.99	1,211.55	-9.8	-57.85	2,079.22	-3.4	399.70	-36.7	279.26	-45.0
1988	2,896.30	131.66	995.20	7.53	111.30	325.40	826.00	1,262.70	4.2	-58.10	2,199.80	5.8	353.40	-11.6	268.41	-3.9
1989	3,201.20	140.86	1,022.60	2.75	104.50	329.30	882.70	1,316.50	4.3	-66.50	2,272.60	3.3	291.90	-17.4	207.23	-22.8
1990	4,017.80	164.44	1,093.40	6.92	104.80	372.60	972.80	1,450.20	10.2	-100.30	2,443.30	7.5	308.30	5.6	187.48	-9.5
1991	3,877.90	145.49	1,124.60	2.85	114.90	429.90	1,073.40	1,618.20	11.6	-77.40	2,665.40	9.1	410.30	33.1	282.01	50.4
1992	4,369.60	153.64	1,193.50	6.13	111.90	459.00	1,157.10	1,728.00	6.8	-77.50	2,844.00	6.7	501.70	22.3	326.54	15.8

Note: All the GDP figures are at producer's values.

Appendix 4.5.1

Gov't total at 1978 prices (million O.R.)	Change (%)	Private capital formation at market prices (million O.R.)	Change (%)	Private capital formation at1978 prices (million O.R.)	Change (%)	Private final consumption at market prices (million O.R.)	Change (%)	Private final consumption at 1978 prices (million O.R.)	Change (%)	Private total at 1978 prices (milion O.R.)	Change (%)
		15.6				21.40	-		-		
		12.1				35.10					
		14.5				40.60					
		31.3				49.60					
		50.0				122.60					
		57.3				181.60					
		70.6				246.20					
392.0		87.4		87.4		310.30	-	310.30	-	397.7	
436.4	11.3	119.7	37.0	91.6	4.8	337.40	8.7	441.03	42.1	532.6	
407.7	-6.6	159.9	33.6	81.0	-11.6	576.80	71.0	1,138.80	158.2	1,219.8	
513.6	26.0	193.9	21.3	95.2	17.6	590.60	2.4	1,202.71	5.6	1,297.9	
624.8	21.6	224.5	15.8	117.1	23.0	794.70	34.6	1,522.99	26.6	1,640.1	
760.8	21.8	207.0	-7.8	120.2	2.7	802.20	0.9	1,380.93	-9.3	1,501.2	
890.2	17.0	260.7	25.9	158.9	32.1	938.50	17.0	1,539.76	11.5	1,698.7	
1,002.2	12.6	251.4	-3.6	153.6	-3.3	1,125.60	19.9	1,841.75	19.6	1,995.4	
1,230.8	22.8	246.5	-1.9	191.9	24.9	1,020.00	-9.4	1,310.17	-28.9	1,502.1	
917.7	-25.4	164.6	-33.2	115.0	-40.1	929.60	-8.9	1,330.41	1.5	1,445.4	
994.5	8.4	157.7	-4.2	119.8	4.1	1,179.80	26.9	1,553.35	16.8	1,673.1	
899.8	-9.5	152.3	-3.4	108.1	-9.7	1,261.80	7.0	1,777.38	14.4	1,885.5	
1,127.0	25.2	220.9	45.0	134.3	24.2	1,080.60	-14.4	1,776.96	0.0	1,911.3	
1,240.6	10.1	251.1	13.7	172.6	28.5	1,485.30	37.5	2,160.97	21.6	2,333.6	
1,455.7	17.3	249.2	-0.8	162.2	-6.0	1,476.60	-0.6	2,268.69	5.0	2,430.9	

Appendix 4.5.2 Coefficient of Determination (r^2) of Bivariate Linear Relationships

	Petro. GDP at 1978 prices	Non-petro. GDP at 1978 prices	GDP total at 1978 prices	Gov't capital formation at 1978 prices	Private capital formation at 1978 prices	Private final consumption at 1978 prices
ELECTRICITY						
Electricity generated-Muscat	0.989	0.694	0.93	0.206	0.014	0.488
Electricity generated-Wadi Jizzi	0.951	0.649	0.882	0.334	1.191-E	0.569
WATER						
Private consumption	0.977	0.757	0.95		0.043	0.306
Government consumption	0.949	0.468	0.752	0.074		

Appendix 4.5.3 Changes in Load Factor (1983 - 1993)

Description / Year	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Muscat System	46.1%	50.9%	53.3%	50.6%	52.8%	53.5%	51.7%	52.7%	51.8%	53.5%	53.3%
Wadi Jizzi System	48.4%	59.8%	52.9%	52.4%	44.6%	46.0%	43.3%	42.2%	43.1%	44.9%	45.6%

APPENDIX 9.1
ANALYSIS FOR SEA WATER

Appendix 9.1 Analysis for Sea Water

Table 1 Result of Sea Water Quality Analysis (1)

Item \ Unit \ Sampling Date \ Sampling Station		⑧				⑦
		Feb. 6				Feb. 3
Sampling Depth	m	1.0	3.0	5.0	8.0	3.5
Temperature	℃	24.3	24.2	24.1	24.1	——
Turbidity		2.2	1.4	1.4	2.1	0.5
pH	——	8.1_3	8.1_7	8.1_6	8.1_7	8.1_8
Electric Conductivity	mS	56.0	56.1	56.0	56.2	55.5
Acid Consumption (Alkalinity)	mg$CaCO_3$/l	116	116	116	116	116
Total Hardness	mg$CaCO_3$/l	6,740	6,760	6,760	6,770	6,710
Suspended Matter (SS)	mg/l	1.8	1.2	0.8	2.0	< 0.5
TDS (110℃)	mg/l	39,600	39,600	39,700	39,700	39,400
TDS (480℃)	mg/l	35,600	35,500	35,700	35,500	35,200
COD_{Mn}	mg/l	1.3	1.1	0.9	0.8	0.8
COD_{OH}	mg/l	0.2	0.1	0.2	0.3	0.1
TOC	mgC/l	0.8	0.8	0.7	0.6	0.7
Cl	‰	20.44	20.42	20.50	20.50	20.36
SO_4	mg/l	2,940	2,920	2,950	2,950	2,930
NH_4-N	μg-at/l	2.4	2.7	2.9	3.0	4.9
NO_2-N	μg-at/l	< 0.05	0.06	< 0.05	< 0.05	0.06
NO_3-N	μg-at/l	0.07	< 0.05	0.06	0.07	0.13
T-N	μg-at/l	16.7	15.6	15.8	14.5	16.1
PO_4-P	μg-at/l	0.53	0.56	0.63	0.64	0.83
T-P	μg-at/l	1.10	1.08	1.16	1.19	1.14
SiO_4-Si	μg-at/l	5.0	4.8	4.5	3.7	4.2
Na	mg/l	10,700	11,700	12,300	12,400	12,100
Ca	mg/l	433	431	425	423	425
Mg	mg/l	1,370	1,380	1,380	1,390	1,370

Table 1 Result of Sea Water Quality Analysis (2)

Item	Sampling Station / Sampling Date / Unit	⑤			②
		Feb. 3			Feb. 3
Sampling Depth	m	1.0	3.0	5.0	1.5
Temperature	℃	24.4	24.3	24.2	——
Turbidity		＜0.5	＜0.5	＜0.5	0.9
pH	——	8.1_9	8.1_8	8.1_7	8.1_8
Electric Conductivity	mS	55.8	55.4	55.9	55.8
Acid Consumption (Alkalinity)	mg$CaCO_3$/l	116	116	116	116
Total Hardness	mg$CaCO_3$/l	6,730	6,720	6,740	6,740
Suspended Matter (SS)	mg/l	＜0.5	＜0.5	0.6	0.6
TDS (110℃)	mg/l	39,200	39,400	39,300	39,200
TDS (480℃)	mg/l	35,200	35,100	35,200	35,200
COD_{Mn}	mg/l	0.9	0.6	0.9	0.9
COD_{OH}	mg/l	0.2	0.1	0.1	0.2
TOC	mgC/l	0.7	0.7	0.9	1.0
Cl	‰	20.36	20.37	20.35	20.42
SO_4	mg/l	2,930	2,930	2,930	2,940
NH_4-N	μg-at/l	2.5	2.9	4.3	2.7
NO_2-N	μg-at/l	0.06	0.06	0.06	＜0.05
NO_3-N	μg-at/l	0.13	0.11	0.11	0.06
T-N	μg-at/l	13.4	13.6	16.7	16.1
PO_4-P	μg-at/l	0.63	0.70	0.82	0.63
T-P	μg-at/l	1.07	1.08	1.21	1.12
SiO_4-Si	μg-at/l	4.2	4.3	4.6	4.6
Na	mg/l	10,700	10,500	10,500	10,500
Ca	mg/l	421	423	427	421
Mg	mg/l	1,380	1,380	1,380	1,380

Table 2 Result of Sea Bottom Soil Analysis

Item \ Unit \ Sampling Date \ Sampling Station			①	④	⑧	⑪
			Feb. 3	Feb. 3	Feb. 3	Feb. 3
Appearance		—	Shell in Sand	Sand	Shell in Sand	Shell in Sand
Odor		—	Non	Non	Non	Non
Color Specification		—	Dark Olive Gray	Dark Green Gray	Olive Black	Olive Black
Water Contain Ratio		Wet	21.4	24.6	20.9	17.2
Ignition Loss		Dry	7.4	7.3	5.8	3.7
COD		Dry	1.2	0.3	2.1	1.8
Sulfide	Free Sulfide	Dry	＜0.02	＜0.02	＜0.02	0.02
	Total Sulfide	Dry	＜0.02	＜0.02	＜0.02	0.04
Specific gravity		—	2.82	2.79	2.77	2.79
Size and Soil Structure	Conglomerate 2.0mm 以上	%	0.5	0.5	5.5	19.0
	Co Sand 2.0 ~0.42mm	%	0.5	5.5	27.5	64.0
	Fine Sand 0.42~0.074mm	%	94.0	70.5	55.5	13.0
	Silt 0.074 ~0.005mm	%	5.0	20.5	9.5	4.0
	Clay, Colloidal Matter 0.005mm and less	%		3.0	2.0	
Particle Size Distribution	60%	mm	0.120	0.105	0.30	1.15
	30%	mm	0.092	0.080	0.110	0.58
	10%	mm	0.078	0.044	0.067	0.22
	50%	mm	0.110	0.095	0.21	0.90
Uniformity Coefficient		—	1.5	2.4	4.5	5.2
Curnature Coefficient		—	0.9	1.4	0.6	1.3

Table 3 Ghubrah Power Station Sea Water Temperature - (1)

1984		1983	
MONTH, DATE	S.W. TEMPERATURE (°C)	MONTH, DATE	S.W. TEMPERATURE (°C)
1. 4	23.7	1982.12.27	22.3
1.12	23.8	1. 9	23.3
1.18	23.5	1.12	23.0
2. 4	22.2	1.19	22.9
2.MIDDLE	23.6	1.25	22.4
2.25	22.5	2. 5	21.6
3. 5	24.4	4.15	25.0
3.11	24.0	4.MIDDLE	25.5
3.18	25.5	4.END	27.5
3.END	25.5	5.19	30.0
4. 3	27.0	6. 5	32.4
4.18	28.2	7. 4	33.5
5.11	29.0	7.12	31.4
5.END	30.5	7.19	31.0
6. 7	32.1	7.26	24.1
6.20	33.7	8. 4	21.5
6.25	32.2	8.11	22.3
7. 5	30.5	8.18	26.5
7.17	27.2	8.27	27.0
8.14	27	9. 5	27.0
8.26	28.4	10.18	30.0
2.END	23.6	10.END	29.0
		11.MIDDLE	27.0
		11.MIDDLE	26.8

Table 3 Ghubrah Power Station Sea Water Temperature - (2)

1982		1981	
MONTH, DATE	S.W. TEMPERATURE (°C)	MONTH, DATE	S.W. TEMPERATURE (°C)
2. 2	23.3	1980.12.26	23.4
4.17	28.3	2.25	22.6
4.26	28.7	4.25	28.5
5. 5	28.5	7.18	30.5
5.10	30.4	7.28	32.0
5.18	30.3	9. 5	29.4
6.26	32.2		
7.17	32.5		
7.28	27.5		
8. 4	31.2		
8.11	31.3		
8.20	30.2		
8.28	27.6		
9. 3	27.3		
9.11	30.5		
9.17	30.4		
9.25	30.6		
12.11	23.4		
12.19	23.8		

Appendix 9.2 Hybrid Combination with MSF and RO

Previously, it was studied how to improve the plant economy by means of combination with both, MSF and RO, at that time the RO process was staged on sea water desalination plant.

Such incentive to research the feasibility was that:

(1) RO could receive the electricity directly from a combined dual purpose MSF process plant so that it would be not constrained by electric power demand on external power transmission system, the exported power would be reduced from there.

(2) Due to raw sea water for RO process could be applied the one used for MSF process cooling with elevated temperature, the RO process would sustain its productivity even in winter using cold sea water. (In RO process, there is a character relatively to decrease permeate quantity at the same pressure as the sea water viscosity increased in lower temperature)

Considering the Barka plant, however, it does not seem so economical to adopt such hybrid combination plan: the reasons are:

(a) In case of Barka plant, capacity of power plant is very large and as power generation plant with MSF has only small share so power demand does not strain the production of water. Contrary, RO plant will be desirable as it consume more power than hybrid system.

(b) The minimum sea water temperature is 24 °C, and it needs to elevate the temperature not so more.

(c) In case construction of both, MSF and RO, in fifty-fifty, such construction cost will become the averaged value higher than RO process only, as simply minded.

(d) On parallel operation and maintenance work to such combined process plants, it has disadvantages to handle many kinds of chemicals and spare parts as well as more personnel are required, corresponding to them.

Appendix 9.3 Performance Ratio of MSF

For the optimum performance ratio of MSF process, it had been assessed with the feasibility stud by JICA in 1985. The conclusion was that the most effective one is 8 as performance ratio, based on a back pressure turbine type discount rate 10 %, and relative cost of other cases were as followings when the cost of performance ratio 8 is 1.0:

At performance ratio	6:	Cost 1.055
At performance ratio	10:	Cost 1.014

The actual performance ratio currently applied in the GC Countries are also around 8 ~ 9, and it is proven by the above conclusion.

APPENDIX 13.1

ANALYSIS FOR HOT WATER DIFFUSION

ANALYSIS FOR HOT WATER DIFFUSION

The analysis is carried out to calculate an area of diffusion under the following assumptions.

1. Hot water is discharged to an unlimited area (sea) through an open channel.
2. Tidal current and jet (discharge) are not considered.
3. Discharged hot water diffuses in a semicircular pattern from a discharged point.
4. Sea bed is flat.
5. Heat radiation to the atmosphere is neglected.

The area of hot water diffusion is calculated using Hirano's formula.

$$A = \frac{27}{4} \bullet \frac{d}{\Delta d} \bullet \frac{1}{g \bullet h^3} \bullet \frac{1}{2\pi} \bullet \{\frac{\Delta T}{\Delta Tr} - 1\}^2 \bullet Q^2$$

$$R = (2A / \pi)^{0.5}$$

where,

A	: area of diffusion (m^2)
d	: density of sea water (g/cm^3)
Δd	: difference of densities of dischaged water and sea water (g/cm^3)
g	: gravitational acceleration (m/s^2)
h	: depth of discharged water (m)
ΔT	: difference of temperatures of sea water and discharged water (°C)
ΔTr	: temperature rise (°C)
Q	: volume of discharged water (m^3/s)
R	: radius of area of diffusion (m)

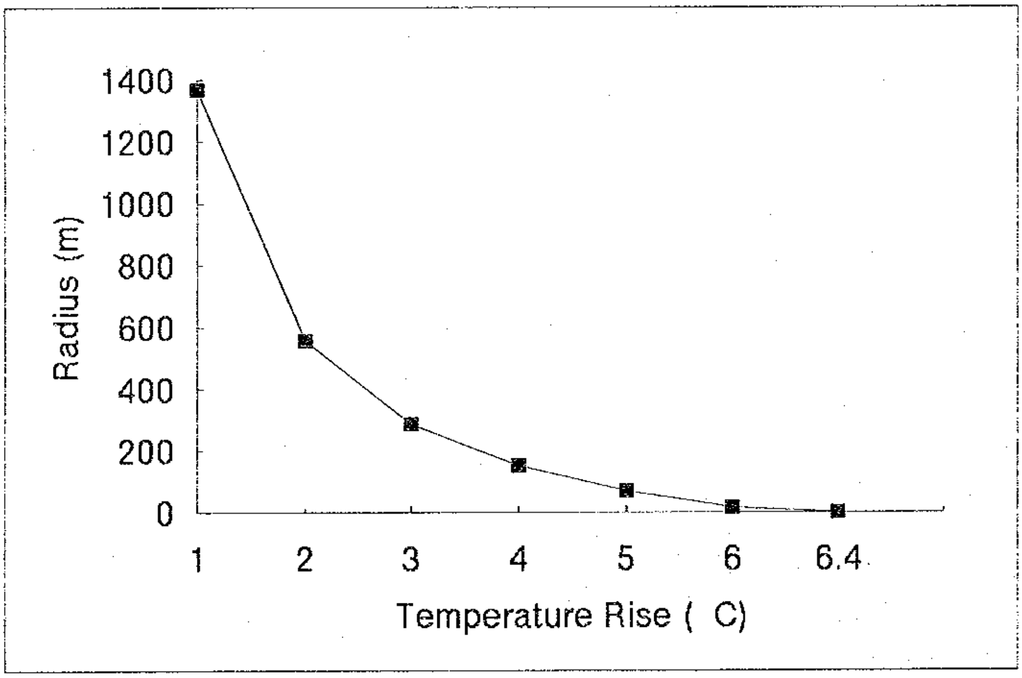
ANALYSIS FOR HOT WATER DIFFUSION

This is the analysis for hot water diffusion using Hirano's formula under the following assumptions.

1 Jet and tidal current are not considered.
2 Discharged hot water diffuses in a semicircular pattern from a dischaged point.
3 Heat radiation to the atmosphere is neglected.
4 Sea bed is flat.
5 Hot water is discharged to an unlimited area.

Density of sea water (R1)=	1.025 (g/m3)
Density of discharged water (R2)=	1.024 (g/m3)
Depth of dischaged water (H)=	1.5 (m)
Temperature of sea water (T1)=	30 (•C)
Temperature of dischaged water (T2)=	36.4 (•C)
Volume of dischaged water (Q)=	55 (m3/s)

Rise	1	2	3	4	5	6	6.4
Area (m2)	3E+06	487339	129331	36248	7894.1	447.51	5E-27
Radius (m)	1367.2	557	286.94	151.91	70.891	16.879	6E-14



```
CORMIX3 PREDICTION FILE:
33333333333333333333333333333333333333333333333333333333333333333333333333333
                      CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX3:                                          Subsystem version:
 Buoyant Surface Discharges                  CMX3 v.2.10          May 1993
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:          Barka^Power^and^Desali
 Design case:              Hot^Water^Diffusion
 FILE NAME:                cormix¥sim¥BARKAHTF.cx3
 Time of Fortran run:      07/21/94--18:12:02

ENVIRONMENT PARAMETERS (metric units)
 Unbounded section
 HA     =       4.00 HD     =        2.90
 UA     =       .200 F      =        .045 USTAR = .1500E-01
 UW     =      2.600 UWSTAR= .2900E-02
 Uniform density environment
 STRCND=  U          RHOAM = 1025.0000

DISCHARGE PARAMETERS (metric units)
 BANK   =  LEFT      DISTB =          .00  Configuration: flush discharge
 Rectangular channel geometry:
 B0     =     20.000 H0     =       1.500 A0     = .3000E+02  AR    =        .075
 SIGMA  =      90.00 SLOPE  =         .50
 U0     =      1.833 Q0     =      54.999        = .5500E+02
 RHO0   = 1024.0000  DRHO0  = .1000E+01  GP0    = .9567E-02
 C0     = .6400E+01  CUNITS=  degC
 IPOLL  =  3         KS     = .8000E-05  KD     = .0000E+00

FLUX VARIABLES (metric units)
 Q0     = .5500E+02  M0     = .1008E+03  J0     = .5262E+00
 Associated length scales (meters)
 LQ     =       5.48 LM     =       43.87 Lm     =     50.21  Lb    =       65.77
 LQ2D   =       7.50 LM2D   =       97.45 Lm2D   =    630.19

NON-DIMENSIONAL PARAMETERS
 FR0    =       8.00 FRCH   =       15.30 R      =      9.16

FLOW CLASSIFICATION
 333333333333333333333333333333333333333333
 3  Flow class (CORMIX3)      =    SA2    3
 3  Applicable layer depth HS =     2.90  3
 333333333333333333333333333333333333333333

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0     = .6400E+01  CUNITS=  degC
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =    4000.00 XMAX   =   4000.00

X-Y-Z COORDINATE SYSTEM:
   ORIGIN is located at the WATER SURFACE and at center of discharge
     channel/outlet:        .00 m  from the LEFT  bank/shore.
   X-axis points downstream
   Y-axis points to left as seen by an observer looking downstream
   Z-axis points vertically upward (in CORMIX3, all values Z = 0.00)
NSTEP = 30 display intervals per module

NOTE on dilution/concentration values for this HEATED DISCHARGE (IPOLL=3):
  S  = hydrodynamic dilutions, include buoyancy (heat) loss effects
```

C = corresponding temperature values (always in "degC"!), include heat loss

---

BEGIN MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)

VERTICAL MIXING occurs in the initial zone of flow establishment.
Profile definitions:
BV = Gaussian 1/e (37%) vertical thickness
BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
1.51	-14.66	0.00	1.0	.640E+01	3.03	10.46

Cumulative travel time = 8. sec

END OF MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)

BEGIN MOD318: WEAKLY DEFLECTED JET (2-D) WITH LEESIDE RECIRCULATION ZONE

Surface JET into a crossflow

Profile definitions:
BV = water depth (vertically mixed)
BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
1.51	-14.66	0.00	1.0	.640E+01	3.03	10.46
5.69	-30.05	0.00	1.3	.503E+01	3.16	14.22
10.39	-45.45	0.00	1.5	.423E+01	3.30	17.72
15.52	-60.84	0.00	1.7	.369E+01	3.43	21.05
21.04	-76.24	0.00	1.9	.330E+01	3.57	24.27
26.92	-91.63	0.00	2.1	.299E+01	3.70	27.40
33.12	-107.02	0.00	2.3	.274E+01	3.83	30.46
39.63	-122.42	0.00	2.5	.254E+01	3.97	33.47
46.43	-137.81	0.00	2.7	.239E+01	4.00	36.43
53.50	-153.21	0.00	2.8	.228E+01	4.00	39.35
60.83	-168.60	0.00	2.9	.218E+01	4.00	42.24
68.40	-184.00	0.00	3.1	.210E+01	4.00	45.09
76.22	-199.39	0.00	3.2	.202E+01	4.00	47.92
84.27	-214.79	0.00	3.3	.195E+01	4.00	50.73
92.53	-230.18	0.00	3.4	.189E+01	4.00	53.51
101.01	-245.58	0.00	3.5	.183E+01	4.00	56.28
109.70	-260.97	0.00	3.6	.178E+01	4.00	59.03
118.60	-276.37	0.00	3.7	.173E+01	4.00	61.76
127.68	-291.76	0.00	3.8	.169E+01	4.00	64.48
136.96	-307.16	0.00	3.9	.164E+01	4.00	67.18
146.43	-322.55	0.00	4.0	.161E+01	4.00	69.87
156.08	-337.95	0.00	4.1	.157E+01	4.00	72.55
165.91	-353.34	0.00	4.2	.154E+01	4.00	75.22
175.91	-368.74	0.00	4.2	.151E+01	4.00	77.88
186.09	-384.13	0.00	4.3	.148E+01	4.00	80.52
196.43	-399.53	0.00	4.4	.145E+01	4.00	83.16
206.94	-414.92	0.00	4.5	.142E+01	4.00	85.79
217.61	-430.32	0.00	4.6	.140E+01	4.00	88.41
228.43	-445.71	0.00	4.7	.137E+01	4.00	91.03
239.42	-461.11	0.00	4.7	.135E+01	4.00	93.63
250.56	-476.50	0.00	4.8	.133E+01	4.00	96.23

Cumulative travel time = 895. sec

Some concentration build-up near bank/shore due to recirculation effects.
Find concentration and thickness values for the RECIRCULATION REGION
at end of MOD329!

END OF MOD318: WEAKLY DEFLECTED JET (2-D) WITH LEESIDE RECIRCULATION ZONE

BEGIN MOD328: STRONGLY DEFLECTED JET (2-D) WITH LEESIDE RECIRCULATION ZONE

Profile definitions:
BV = water depth (vertically mixed)
BH = Gaussian 1/e (37%) horizontal half-width, measured normally from shore
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
250.56	-476.50	0.00	4.8	.133E+01	4.00	297.42
299.91	76.81	0.00	2.1	.307E+01	2.23	230.95
349.25	34.19	0.00	2.5	.258E+01	2.60	236.07
398.60	-5.56	0.00	2.9	.223E+01	2.95	240.85
447.95	-42.93	0.00	3.2	.197E+01	3.27	245.34
497.30	-78.31	0.00	3.6	.177E+01	3.58	249.59
546.65	-111.99	0.00	4.0	.161E+01	3.88	253.63
596.00	-144.19	0.00	4.2	.154E+01	4.00	257.50
645.34	-175.10	0.00	4.2	.151E+01	4.00	261.21
694.69	-204.84	0.00	4.3	.149E+01	4.00	264.79
744.04	-233.56	0.00	4.3	.148E+01	4.00	268.24
793.39	-261.35	0.00	4.4	.146E+01	4.00	271.58
842.74	-288.28	0.00	4.4	.144E+01	4.00	274.81
892.09	-314.45	0.00	4.5	.142E+01	4.00	277.96
941.44	-339.90	0.00	4.5	.141E+01	4.00	281.01
990.78	-364.70	0.00	4.6	.139E+01	4.00	283.99
1040.13	-388.88	0.00	4.6	.138E+01	4.00	286.90
1089.48	-412.51	0.00	4.7	.137E+01	4.00	289.74
1138.83	-435.60	0.00	4.7	.135E+01	4.00	292.51
1188.18	-458.21	0.00	4.8	.134E+01	4.00	295.23
1237.53	-480.35	0.00	4.8	.133E+01	4.00	297.89
1286.87	-502.05	0.00	4.9	.132E+01	4.00	300.49
1336.22	-523.34	0.00	4.9	.131E+01	4.00	303.05
1385.57	-544.25	0.00	4.9	.129E+01	4.00	305.56
1434.92	-564.79	0.00	5.0	.128E+01	4.00	308.03
1484.27	-584.97	0.00	5.0	.127E+01	4.00	310.46
1533.62	-604.83	0.00	5.1	.126E+01	4.00	312.84
1582.96	-624.37	0.00	5.1	.126E+01	4.00	315.19
1632.31	-643.61	0.00	5.1	.125E+01	4.00	317.50
1681.66	-662.56	0.00	5.2	.124E+01	4.00	319.78
1731.01	-681.23	0.00	5.2	.123E+01	4.00	322.02

Cumulative travel time = 8297. sec

Some concentration build-up near bank/shore due to recirculation effects.
Find concentration and thickness values for the RECIRCULATION REGION
at end of MOD329!

END OF MOD328: STRONGLY DEFLECTED JET (2-D) WITH LEESIDE RECIRCULATION ZONE

BEGIN MOD329: STRONGLY DEFLECTED PLUME WITH LEESIDE RECIRCULATION ZONE

This flow region is INSIGNIFICANT in spatial extent and will be by-passed.

The near-shore RECIRCULATION REGION extends back to the discharge location:
Concentration C within that region: .614E+00

Layer thickness BV within that region: 4.00

END OF MOD329: STRONGLY DEFLECTED PLUME WITH LEESIDE RECIRCULATION ZONE

** End of NEAR-FIELD REGION (NFR) **

The initial plume WIDTH values in the next far-field module will be CORRECTED by a factor .75 to conserve the mass flux in the far-field!

BEGIN MOD341: BUOYANT AMBIENT SPREADING

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

Profile definitions:
BV = top-hat thickness,measured vertically
BH = top-hat half-width, measured horizontally from bank/shoreline
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH
1731.01	.00	0.00	5.2	.123E+01	4.00	358.11
1806.64	.00	0.00	5.3	.120E+01	3.87	380.01
1882.28	.00	0.00	5.5	.117E+01	3.76	401.23
1957.91	.00	0.00	5.6	.114E+01	3.67	421.84
2033.54	.00	0.00	5.8	.111E+01	3.59	441.90
2109.17	.00	0.00	5.9	.108E+01	3.53	461.46
2184.81	.00	0.00	6.1	.105E+01	3.47	480.56
2260.44	.00	0.00	6.2	.103E+01	3.43	499.24
2336.07	.00	0.00	6.4	.100E+01	3.40	517.53
2411.71	.00	0.00	6.6	.975E+00	3.37	535.46
2487.34	.00	0.00	6.7	.949E+00	3.35	553.05
2562.97	.00	0.00	6.9	.924E+00	3.34	570.33
2638.61	.00	0.00	7.1	.899E+00	3.33	587.32
2714.24	.00	0.00	7.3	.875E+00	3.33	604.03
2789.87	.00	0.00	7.5	.850E+00	3.34	620.48
2865.50	.00	0.00	7.7	.827E+00	3.34	636.68
2941.14	.00	0.00	8.0	.804E+00	3.36	652.65
3016.77	.00	0.00	8.2	.781E+00	3.37	668.41
3092.40	.00	0.00	8.4	.759E+00	3.39	683.96
3168.04	.00	0.00	8.7	.737E+00	3.41	699.31
3243.67	.00	0.00	8.9	.716E+00	3.44	714.48
3319.30	.00	0.00	9.2	.695E+00	3.47	729.47
3394.94	.00	0.00	9.5	.675E+00	3.50	744.29
3470.57	.00	0.00	9.8	.655E+00	3.54	758.94
3546.20	.00	0.00	10.1	.636E+00	3.58	773.45
3621.83	.00	0.00	10.4	.618E+00	3.62	787.80
3697.47	.00	0.00	10.7	.599E+00	3.66	802.02
3773.10	.00	0.00	11.0	.582E+00	3.71	816.10
3848.73	.00	0.00	11.3	.565E+00	3.75	830.04
3924.37	.00	0.00	11.7	.548E+00	3.80	843.87
4000.00	.00	0.00	12.0	.532E+00	3.86	857.57

Cumulative travel time = 19396. sec

Simulation limit based on maximum specified distance = 4000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD341: BUOYANT AMBIENT SPREADING

APPENDIX 13.2

CALCULATION FOR SOx/NOx EMISSION RATE

Calculation for SOx Emission Rate ------- Distillate Oil
(Gas Turbine)

1. Fuel Consumption

Basic Specification	Abbreviation/Unit		Assumed Value
1) Output at generator end	Po	MW	100
2) Power plant thermal efficiency	ηp	%	30
3) Fuel combustion ratio	α	%	100
4) High heat value of fuel	Hh'	kcal/kg	10,900

Calculation

• Fuel consumption	Fo	T/hr	26.3

$$Fo = \frac{Po \times 860 \times \frac{\alpha}{100}}{\frac{\eta p}{100} \times Hh'}$$

2. Flue Gas Volume

Flue Gas Volume	Gr	Nm^3/hr	$1,008 \times 10^3$
		Nm^3/s	280

3. Calculation of Emission Rate

Basic Specification			
1) Fuel consumption	Fo	T/hr	26.3
2) Sulphur component	So	%	0.44
3) Flue gas volume	Gr	Nm^3/hr	$1,008 \times 10^3$
		(Nm^3/s)	(280)

Calculation of SOx Emission

• SOx volume = 7 (Fo x So)	q_1	Nm^3/hr	81.0
		(Nm^3/s)	(0.0225)
• SOx density in ppm $= \frac{q_1}{G_r} \times 10^6$	q_2	ppm	80
• SOx density in $g/Nm^3 = 2,857 \times q_2 \times 10^{-6}$	q_3	g/Nm^3	0.229

Calculation for NOx Emission Rate ------- Natural Gas

(Gas Turbine)

1. Fuel Consumption

Basic Specification	Abbreviation	Unit	Assumed Value
1) Output at generator end	Po	MW	100
2) Power plant thermal efficiency	ηp	%	30
3) Fuel combustion ratio	α	%	100
4) High heat value of fuel	Hh'	kcal/kg	9,450
Calculation			
• Fuel consumption	Fo	T/hr	30.3

$$Fo = \frac{Po \times 860 \times \frac{\alpha}{100}}{\frac{\eta p}{100} \times Hh'}$$

2. Flue Gas Volume

Flue Gas Volume	G_T	Nm^3/hr	$1{,}008 \times 10^3$
		Nm^3/s	280

3. Emission Rate

Emission Rate	q_1	ppm	100
$= \frac{G_T}{3600} \times q_1 \times 10^{-6}$	q_2	Nm^3/s	0.028
$= \frac{q_1}{487}$	q_3	g/Nm^3	0.2

Notes:

Flue gas volume and emission rate for the gas turbine are assumed by using the data sheets for the past project because of the following reasons:

1) They are obtained based on characteristics and specifications of equipment.

2) NOx consists of fuel NOx and thermal NOx.
The latter is generally determinant for a total NOx and depends on specifications of equipment.

<u>Calculation for SOx Emission Rate ------- Distillate Oil</u>

(Boiler)

1. Fuel Consumption

Basic Specification	Abbreviation/Unit		Assumed Value
1) Output at generator end	Po	MW	60
2) Power plant thermal efficiency	ηp	%	40
3) Fuel combustion ratio	α	%	100
4) High heat value of fuel	Hh'	kcal/kg	10,900
Calculation			
• Fuel consumption	Fo	T/hr	11.8

$$Fo = \frac{Po \times 860 \times \frac{\alpha}{100}}{\frac{\eta p}{100} \times Hh'}$$

2. Combustion Gas Volume

Basic Specification			
1) Hydrogen	ho'	%	12.0
2) Low heat value of fuel	Hl'	kcal/kg	10,252
3) O_2 content in flue gas	O_2	%	4.0
Calculation			
• Excess air ratio m	m	-	1.24

$$m = \frac{21}{21 - O_2}$$

• Combustion Gas Volume			
• Theorethical air volume	Ao'	Nm^3/kg-fuel	10.71

$$Ao' = 0.85 \times Hl' \times 10^{-3} + 2.0$$

• Theorethical combustion gas volume	Go'	Nm^3/kg-fuel	11.38

$$Go' = 1.11 \times Hl' \times 10^{-3}$$

• Actual combustion gas volume			
at Wet gas condition	G'w	Nm^3/kg-fuel	13.95

$$G'w = Go' + (m - 1)\ Ao'$$

at Dry gas condition	G'd	Nm^3/kg-fuel	12.61

$$G'd = G'w - \frac{0.224}{18}(9 \times ho')$$

3. Flue Gas Volume at Boiler end

at wet condition			
$QwB = (Fo \times G'w) \times 10^3$	QwB	Nm^3/hr	165
at dry condition			
$QdB = (Fo \times G'd) \times 10^3$	QdB	Nm^3/hr	149

4. Calculation of Emission Rate

<u>Basic Specification</u>			
1) Fuel consumption	Fo	T/hr	11.8
2) Sulphur component	So	%	0.44
3) Flue gas volume at dry state	QdB	Nm^3/hr (Nm^3/s)	149 (41.4)
4) O_2 content in flue gas	O_2	%	4.0
<u>Calculation of SOx emission</u>			
• SOx volume $= 7\ (Fo \times So)$	q_1	Nm^3/hr (Nm^3/s)	36.3 (0.010)
• SOx density in ppm $= \frac{q_1}{QdB} \times 10^6$	q_2	ppm	244
• SOx density in g/Nm^3 $= 2,857 \times q_2 \times 10^{-6}$	q_3	g/Nm^3	0.697

Calculation for NOx Emission Rate ------- Natural Gas
(Boiler)

1. Fuel Consumption

Basic Specification	Abbreviation/Unit		Assumed Value
1) Output at generator end	Po	MW	60
2) Power plant thermal efficiency	ηp	%	40
3) Fuel combustion ratio	α	%	100
4) High heat value of fuel	Hh'	kcal/kg	9,450
Calculation			
• Fuel consumption	Fo	T/hr	13.7

$$Fo = \frac{Po \times 860 \times \frac{\alpha}{100}}{\frac{\eta p}{100} \times Hh'}$$

2. Flue Gas Volume	GT	Nm^3/hr	185×10^3
		Nm^3/s	51

3. Emission Rate

$= 20.69 \times 10^{-5} \times \frac{Hh' \times Fo \times 10^3}{G_T}$	q_1	g/Nm^3	0.146
$= 487 \times q_1$	q_2	ppm	71
$= q_2 \times G_T \times 10^{-6}$	q_3	Nm^3/s	0.0036

Note:

Flue gas volume and NOx emission rate for the boiler are assumed by using the data sheets shown in "Manual for the Regulation of NOx Total Emission".

APPENDIX 13.3

ANALYSIS FOR AIR POLLUTION

ANALYSIS FOR AIR POLLUTION

The analysis is carried out to calculate an hourly concentration at the ground level (receptor) for the following two cases.

Case 1 Dispersion when wind blows in a certain direction

Case 2 Dispersion when no wind blows

In the prediction of an average concentration in a long term, the concentrations calculated for the above cases for every hour in a year are multiplied by probability factors for wind speed, wind direction and atmospheric stability and, subsequently, the average concentration at a certain receptor is obtained. For this prediction, the following meteorological data covering whole a year is essential for obtaining the probability factors.

a. Hourly wind speed and direction
b. Hourly dry bulb temperature
c. Hourly sky cover
d. Hourly cloud height
e. Daily upper air observation data
- early morning mixing height
- afternoon mixing height

It is seldom that all of the above data can be obtained from a meteorological station located in the vicinity of a project site. Such data is generally collected in the course of study on an environmental impact for a certain project area, for which it takes at least a year.

In case that the probability factors are not considered, a concentration is calculated for a certain critical condition in a short period. The F/S will examine this critical concentration in a short term. The method of analysis is as described below.

1. Case 1 --- wind condition ($Us \geq 1.0$ m/sec)

The plume model is used for the analysis.

$$C(x,y,z) = \frac{Q_p}{2\pi \sigma_y \sigma_z U} \cdot \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \cdot F \qquad (1\text{-}1)$$

$$F = \exp\left\{-\frac{(z - He)^2}{2\sigma_z^2}\right\} + \exp\left\{-\frac{(z + He)^2}{2\sigma_z^2}\right\} \qquad (1\text{-}2)$$

where,

x : distance from a stack to a receptor along the centerline of plume (m)
y : distance from a centerline of plume to a receptor in the direction perpendicular to the axis x (m)
z : height of a receptor from the bottom of stack (m)
Q_p : pollutant emmision rate (g/sec)
U : wind speed at the top of stack (m/sec)
He : effective stack height (m)
C : concentration at a receptor (x,y,z) (g/m^3)

Óy,Óz : dispersion parameters (m) obtained from Briggs' proposal

Pasquill stability	Óy'	Óz
A	$0.22x(1+0.0001x)^{-0.5}$	$0.20x$
B	$0.16x(1+0.0001x)^{-0.5}$	$0.12x$
C	$0.22x(1+0.0001x)^{-0.5}$	$0.08x(1+0.0002x)^{-0.5}$
D	$0.22x(1+0.0001x)^{-0.5}$	$0.06x(1+0.0015x)^{-0.5}$
E	$0.22x(1+0.0001x)^{-0.5}$	$0.03x(1+0.0003x)^{-1}$
F	$0.22x(1+0.0001x)^{-0.5}$	$0.016x(1+0.0003x)^{-1}$

Notes : 1. $100 \leq x \leq 10{,}000$m
2. Óy = Óy' • $(t/tp)^s$ = 1.82Óy'
t = 60min ; tp = 3min ; s = 0.2

Furthermore, U and He are calculated by the following formulas.

$$U = Us \cdot \left(\frac{Ho}{Zs}\right)^p$$

where,

Us : measured wind speed (m/sec)
Zs : height of measurement of wind speed (m)
Ho : height of stack (m)
p : index given by EPA

Pasquill stability	A	B	C	D	E	F
p	0.1	0.15	0.2	0.25	0.25	0.3

$He = Ho + \Delta H = Ho + 0.175 \cdot Q_H^{0.5} \cdot U^{-0.75}$ (from CONCAWE's formula)

where,

Q_H : calory of exhaust gas (cal/sec) = $r \cdot Q \cdot Cp \cdot \Delta T$

r : density of exhaust gas at 15°C = 1.225×10^3 (g/m^3)
Q : exhaust gas volume (Nm^3/sec)
Cp : specific heat at constant pressure = 0.24 (cal/K•g)
ΔT : = exhaust gas temperature (Tc) - 15°C

2. Case 2 --- no wind condition (Us < 0.5 m/sec)

Concentration at a receptor is calculated by the simplified puff model assuming Us = 0.

$$C(R) = \frac{2Q_p}{(2\pi)^{1.5} b} \cdot \left(R^2 + \frac{a^2}{b^2} He^2 \right)^{-1}$$

where,

R : distance from a stack to a receptor (m)

a, b : constants subject to Pasquill stability

Pasquill Stability	A	B	C	D	E	F	G
a	0.948	0.781	0.635	0.470	0.439	0.439	0.439
b	1.569	0.474	0.208	0.113	0.067	0.048	0.029

He : effective height of stack (m)

$He = Ho + \Delta H = Ho + 1.4 \cdot Q_H^{0.25} \cdot (dt / dz)^{-(3/8)}$ (Briggs' formula)

Q_H : see Case 1

dt / dz : vertical gradient of potential temperature

0.003 °C/m in daytime

0.010 °C/m in nighttime

3. Classification of Pasquill Stability

Us (m/s)	Solar Radiation (T) kW/m2				Radiation Balance (Q) kW/m2		
	T≥0.60	0.60>T ≥0.30	0.30>T ≥0.15	0.15>T	Q>-0.02	-0.02≥Q >-0.04	-0.04≥Q
<2	A	A-B	B	D	D	(G)	(G)
2~3	A-B	B	C	D	D	E	F
3~4	B	B-C	C	D	D	D	E
4~6	C	C-D	D	D	D	D	D
6<	C	D	D	D	D	D	D

ANALYSIS FOR AIR POLLUTION - WIND (DAYTIME)

This is "Single Source Model" of the analysis for air pollution considering wind and calculates an average concentration for an hour at the ground level under the following assumptions.

1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

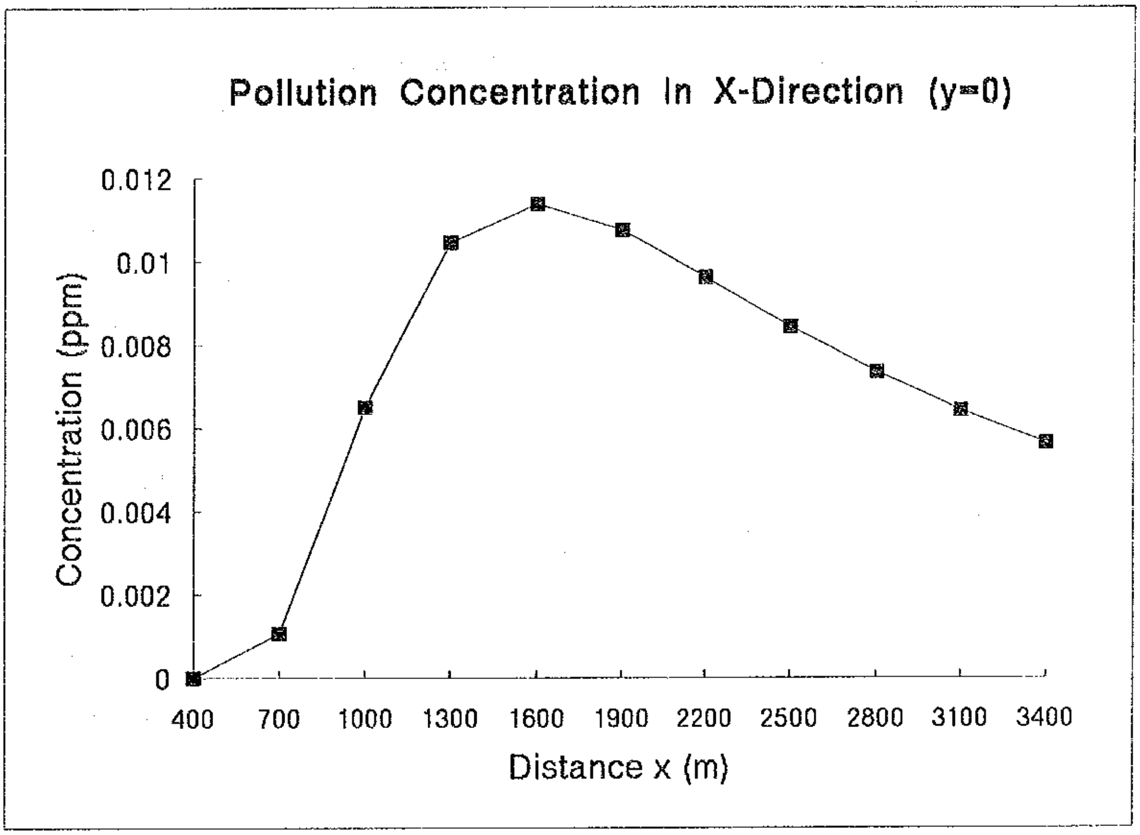
Pollutant : NOx by Natural Gas

Wind speed at Zs (Us) =	2.6	(m/s)
Height of wind measurement (Zs) =	10	(m)
Height of Stack (Ho) =	100	(m)
Exhaust gas temperature (Tc) =	90	(•C)
Exhaust gas volume (Q) =	280	(Nm3/s)
Calory of exhaust gas (Qh) =	6174000	(cal/s)
Pollutant emission rate (Qp) =	0.028	(Nm3/s)
Pasquill stability (St) =	B	

Wind speed at top of stack (U) =	3.67	(m/s)
Plume rise (dH) =	163.8705	(m)
Effective stack height (He) =	263.8705	(m)

Estimated Ground-Level Concentrations (ppm)

x(m) \ y(m)	0	100	200	300	500	700	900	1100
400	1.21E-07	8.27E-08	2.62E-08	3.85E-09	8.37E-12	8.47E-16	3.99E-21	8.78E-28
700	0.001055	0.000928	0.000631	0.000331	4.22E-05	1.92E-06	3.12E-08	1.81E-10
1000	0.006492	0.006085	0.005009	0.003621	0.001283	0.00027	3.39E-05	2.54E-06
1300	0.010448	0.010044	0.008924	0.007327	0.003899	0.001514	0.000429	8.86E-05
1600	0.011363	0.011064	0.010212	0.008935	0.005827	0.003069	0.001305	0.000448
1900	0.010742	0.010535	0.009938	0.009018	0.006608	0.004144	0.002225	0.001023
2200	0.009618	0.009476	0.009062	0.008413	0.006633	0.004643	0.002885	0.001592
2500	0.008438	0.008339	0.008049	0.007588	0.006284	0.004735	0.003246	0.002026
2800	0.007363	0.007292	0.007084	0.006751	0.005788	0.004594	0.003376	0.002297
3100	0.006432	0.00638	0.006228	0.005983	0.005261	0.004338	0.003354	0.002432
3400	0.005642	0.005604	0.00549	0.005305	0.004756	0.004036	0.003243	0.002467


Pollution Concentration In X-Direction (y=0)
0.012
0.01
0.008
0.006
0.004
0.002
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Concentration (ppm)
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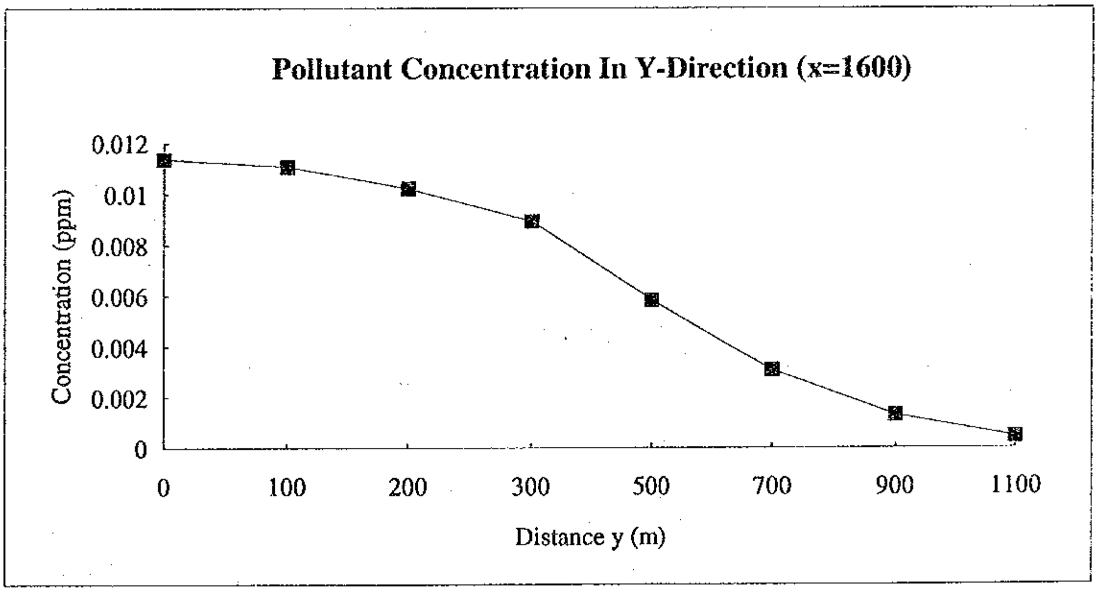
700
1000
1300
1600
1900
2200
2500
2800
3100
3400
Distance x (m)


Pollutant Concentration In Y-Direction (x=1600)
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0.006
0.004
0.002
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Concentration (ppm)
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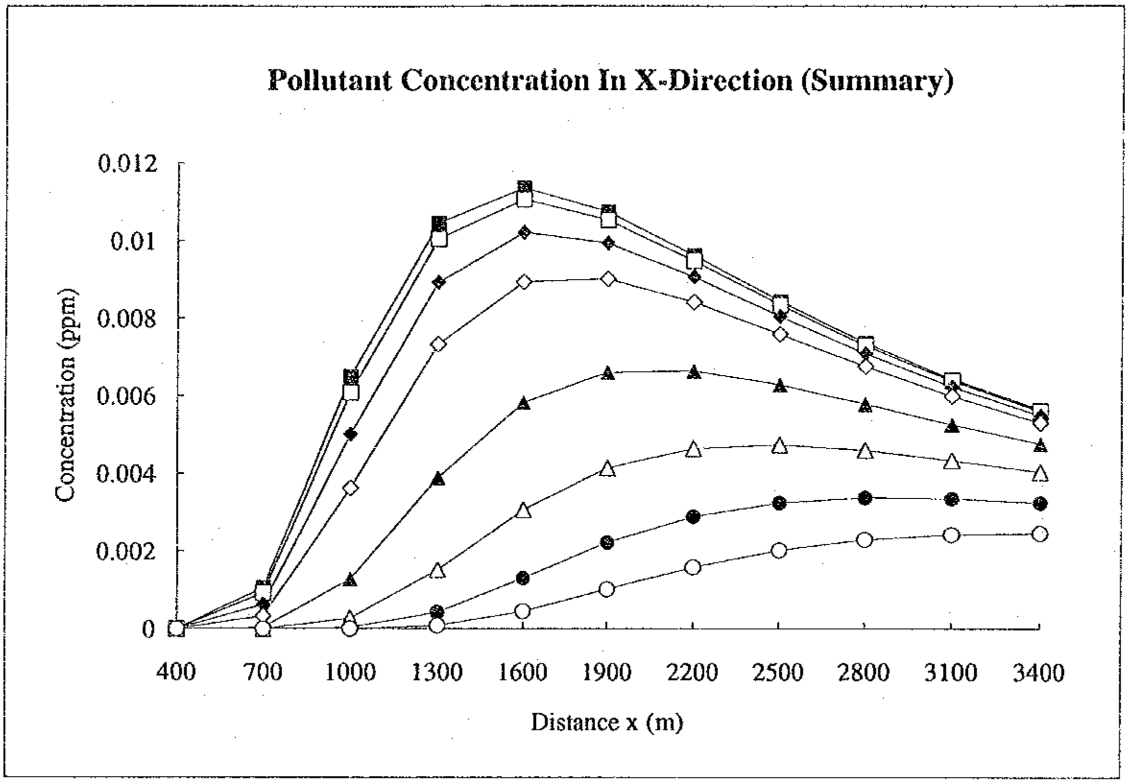
200
300
500
700
900
1100
Distance y (m)


Pollutant Concentration In X-Direction (Summary)
Concentration (ppm)
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0.01
0.008
0.006
0.004
0.002
0
400
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1600
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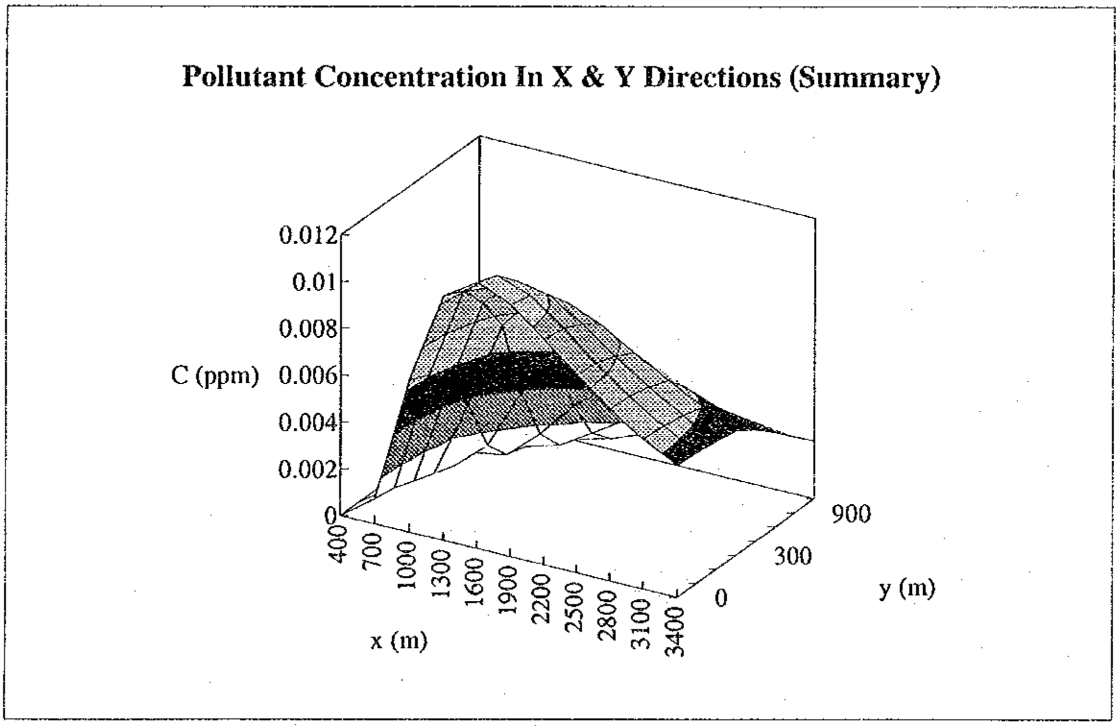
2200
2500
2800
3100
3400
Distance x (m)


Pollutant Concentration In X & Y Directions (Summary)
C (ppm)
0.012
0.01
0.008
0.006
0.004
0.002
0
400
700
1000
1300
1600
1900
2200
2500
2800
3100
3400
x (m)
900
300
0
y (m)

ANALYSIS FOR AIR POLLUTION - WIND (NIGHT)

This is "Single Source Model" of the analysis for air pollution considering wind and calculates an average concentration for an hour at the ground level under the following assumptions.

1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

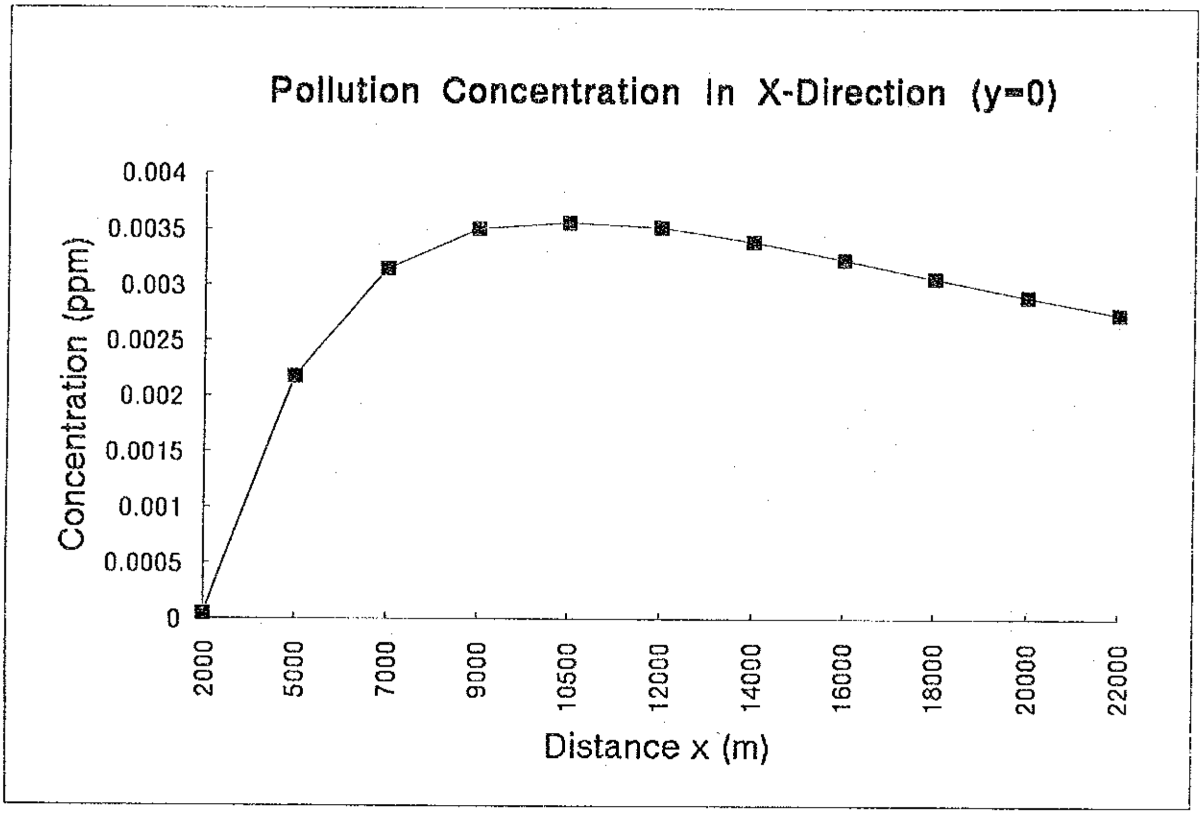
Pollutant : NOx by Natural Gas

Wind speed at Zs (Us) =	2.6 (m/s)
Height of wind measurement (Zs) =	10 (m)
Height of Stack (Ho) =	100 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.028 (Nm3/s)
Pasquill stability (St) =	D

Wind speed at top of stack (U) =	4.62 (m/s)
Plume rise (dH) =	137.8799 (m)
Effective stack height (He) =	237.8799 (m)

Estimated Ground-Level Concentrations (ppm)

x(m) \ y(m)	0	200	400	700	1000	1300	1600	2000
2000	4.67E-05	3.52E-05	1.5E-05	1.46E-06	3.95E-08	2.99E-10	6.34E-13	2.38E-17
5000	0.002178	0.002058	0.001737	0.001089	0.000529	0.000199	5.82E-05	7.58E-06
7000	0.003148	0.003047	0.002762	0.002108	0.001389	0.00079	0.000388	0.000119
9000	0.003502	0.003425	0.003205	0.00267	0.002014	0.001375	0.00085	0.000383
10500	0.003554	0.003492	0.003313	0.002866	0.002292	0.001693	0.001156	0.000615
12000	0.003512	0.003462	0.003316	0.002944	0.00245	0.00191	0.001396	0.000831
14000	0.003386	0.003347	0.003233	0.002939	0.002537	0.002078	0.001616	0.001067
16000	0.003226	0.003195	0.003104	0.002868	0.002539	0.002152	0.001747	0.001237
18000	0.003057	0.003033	0.002959	0.002767	0.002494	0.002167	0.001814	0.001353
20000	0.002893	0.002873	0.002812	0.002653	0.002424	0.002146	0.00184	0.001426
22000	0.002738	0.002721	0.00267	0.002536	0.002343	0.002104	0.001837	0.001467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Concentration (ppm)
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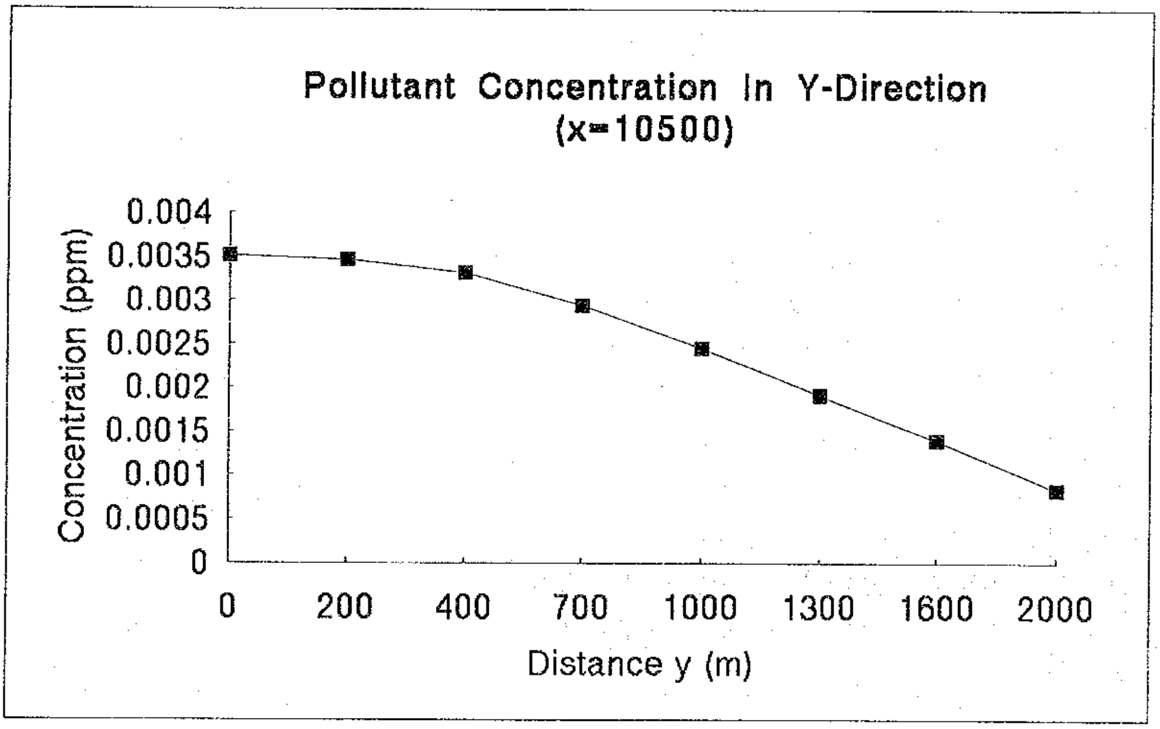
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
2000
5000
7000
9000
10500
12000
14000
16000
18000
20000
22000
Distance x (m)


Pollutant Concentration In Y-Direction
(x=10500)
Concentration (ppm)
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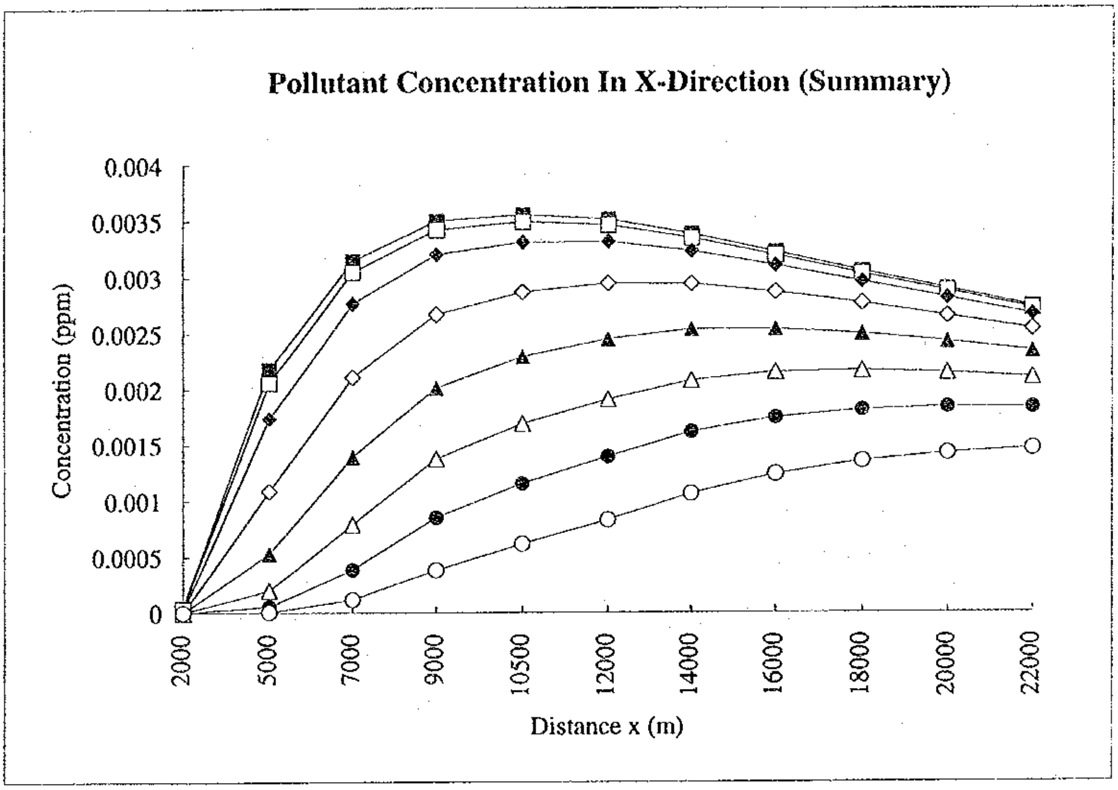
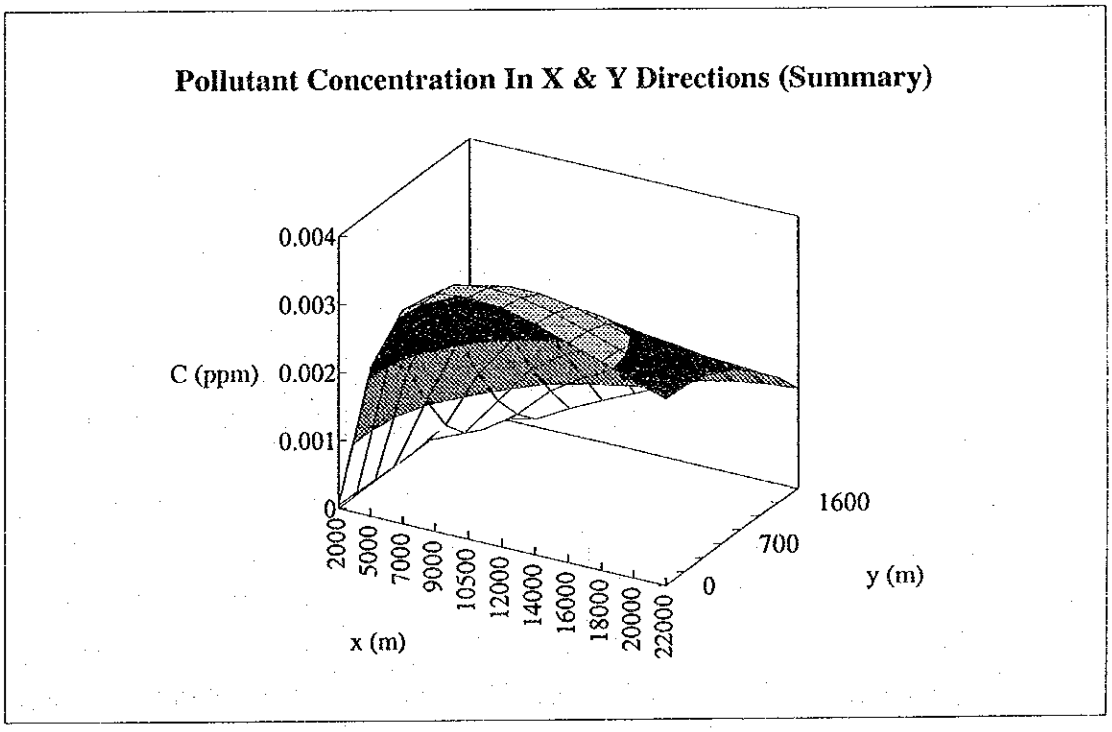
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
200
400
700
1000
1300
1600
2000
Distance y (m)


Pollutant Concentration In X-Direction (Summary)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Concentration (ppm)
2000
5000
7000
9000
10500
12000
14000
16000
18000
20000
22000
Distance x (m)


Pollutant Concentration In X & Y Directions (Summary)
0.004
0.003
C (ppm)
0.002
0.001
0
2000
5000
7000
9000
10500
12000
14000
16000
18000
20000
22000
x (m)
0
700
1600
y (m)

ANALYSIS FOR AIR POLLUTION - WIND (DAYTIME)

This is "Single Source Model" of the analysis for air pollution considering wind and calculates an average concentration for an hour at the ground level under the following assumptions.

1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

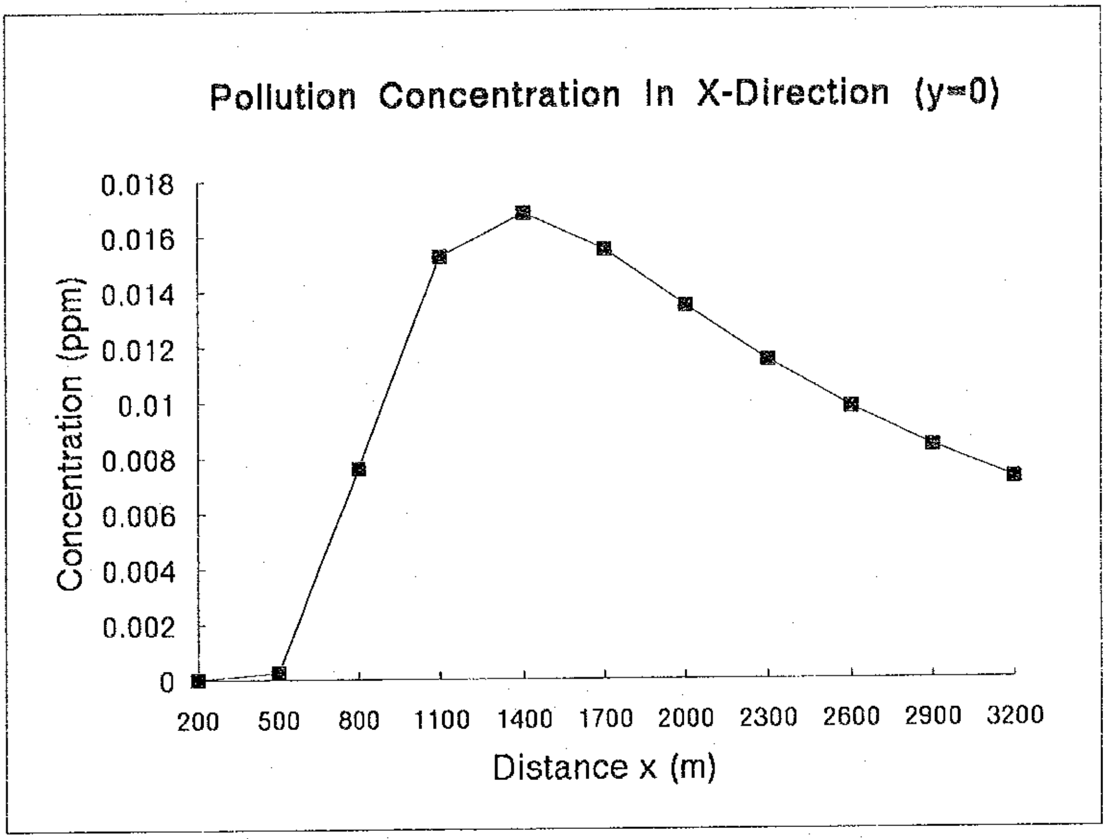
Pollutant : NOx by Natural Gas

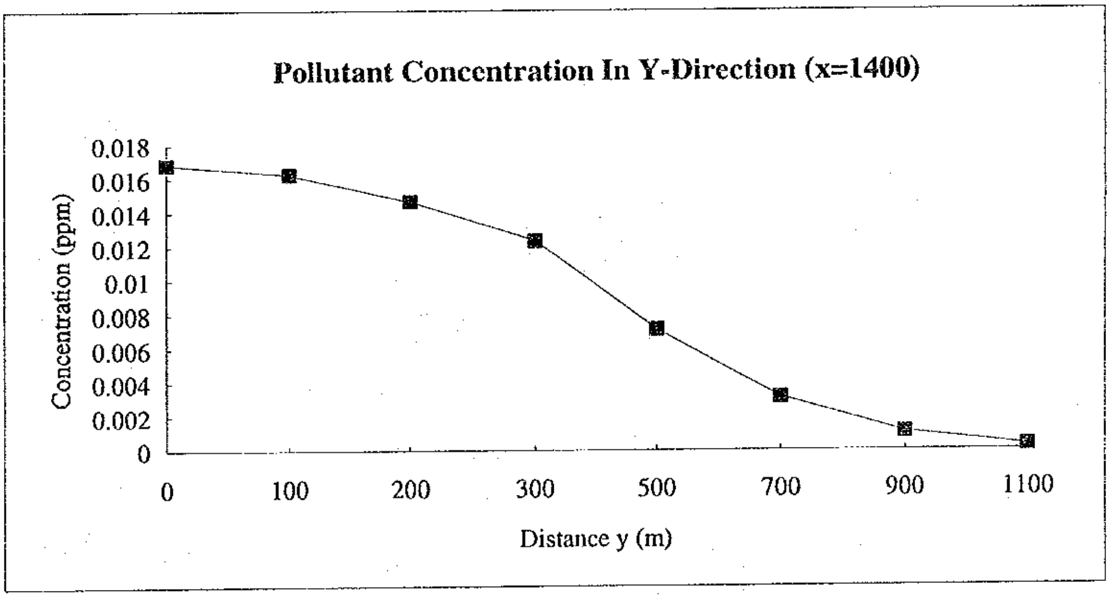
Wind speed at Zs (Us) =	2.6 (m/s)
Height of wind measurement (Zs) =	10 (m)
Height of Stack (Ho) =	50 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.028 (Nm3/s)
Pasquill stability (St) =	B

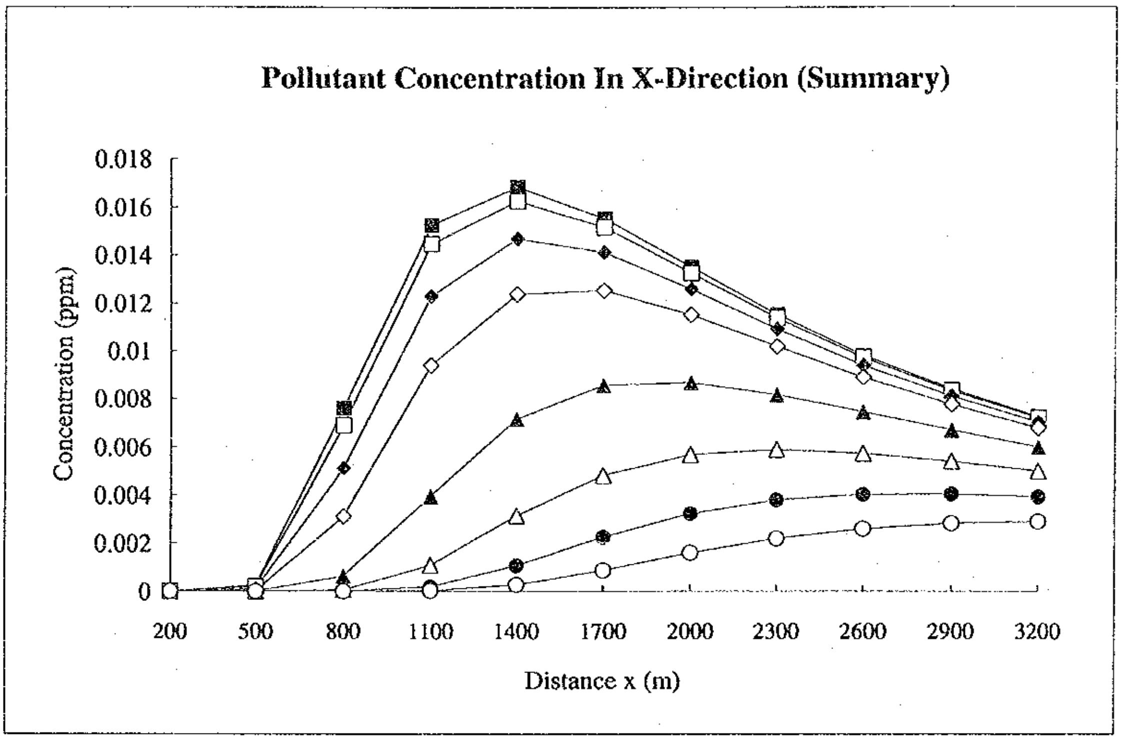
Wind speed at top of stack (U) =	3.31 (m/s)
Plume rise (dH) =	177.1604 (m)
Effective stack height (He) =	227.1604 (m)

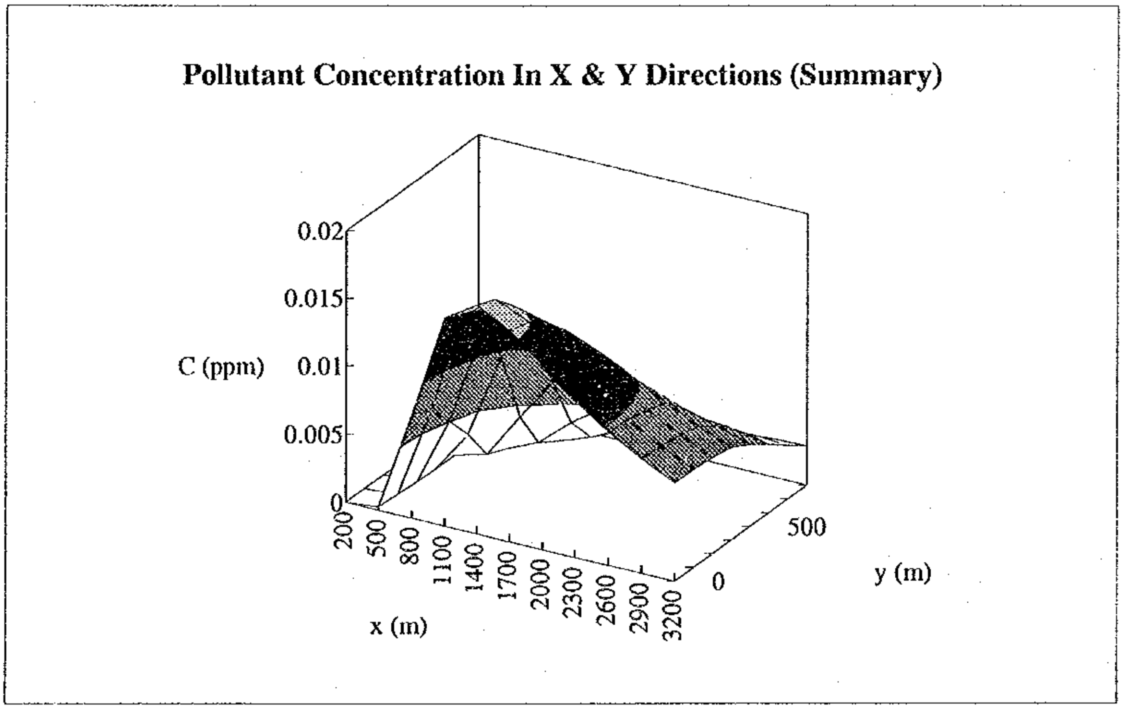
Estimated Ground-Level Concentrations (ppm)

x(m) \ y(m)	0	100	200	300	500	700	900	1100
200	6.85E-20	1.52E-20	1.67E-22	9.09E-26	3.24E-36	6.9E-52	8.77E-73	6.7E-99
500	0.000244	0.00019	9.05E-05	2.62E-05	4.99E-07	1.31E-09	4.73E-13	2.36E-17
800	0.007612	0.006891	0.005113	0.003109	0.000633	5.81E-05	2.41E-06	4.49E-08
1100	0.015262	0.014458	0.012292	0.00938	0.003947	0.001078	0.000191	2.19E-05
1400	0.016827	0.01626	0.01467	0.012358	0.007139	0.003135	0.001046	0.000265
1700	0.015515	0.015149	0.014102	0.012516	0.008542	0.004817	0.002244	0.000864
2000	0.013484	0.013247	0.012563	0.011499	0.008665	0.005667	0.003218	0.001586
2300	0.011514	0.011357	0.010899	0.010177	0.008173	0.005881	0.003793	0.002192
2600	0.009816	0.009709	0.009394	0.008892	0.007458	0.005729	0.00403	0.002597
2900	0.00841	0.008334	0.008111	0.007752	0.006708	0.005399	0.004042	0.002815
3200	0.007258	0.007203	0.007041	0.006778	0.006002	0.005001	0.003921	0.002893


Pollution Concentration In X-Direction (y=0)
Concentration (ppm)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
200
500
800
1100
1400
1700
2000
2300
2600
2900
3200
Distance x (m)


Pollutant Concentration In Y-Direction (x=1400)
Concentration (ppm)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
100
200
300
500
700
900
1100
Distance y (m)


Pollutant Concentration In X-Direction (Summary)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Concentration (ppm)
200
500
800
1100
1400
1700
2000
2300
2600
2900
3200
Distance x (m)


Pollutant Concentration In X & Y Directions (Summary)
0.02
0.015
C (ppm)
0.01
0.005
0
200
500
800
1100
1400
1700
2000
2300
2600
2900
3200
x (m)
500
0
y (m)

ANALYSIS FOR AIR POLLUTION - WIND (NIGHT)

This is "Single Source Model" of the analysis for air pollution considering wind and calculates an average concentration for an hour at the ground level under the following assumptions.

1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

Pollutant : NOx by Natural Gas

Wind speed at Zs (Us) =	2.6 (m/s)
Height of wind measurement (Zs) =	10 (m)
Height of Stack (Ho) =	50 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.028 (Nm3/s)
Pasquill stability (St) =	D

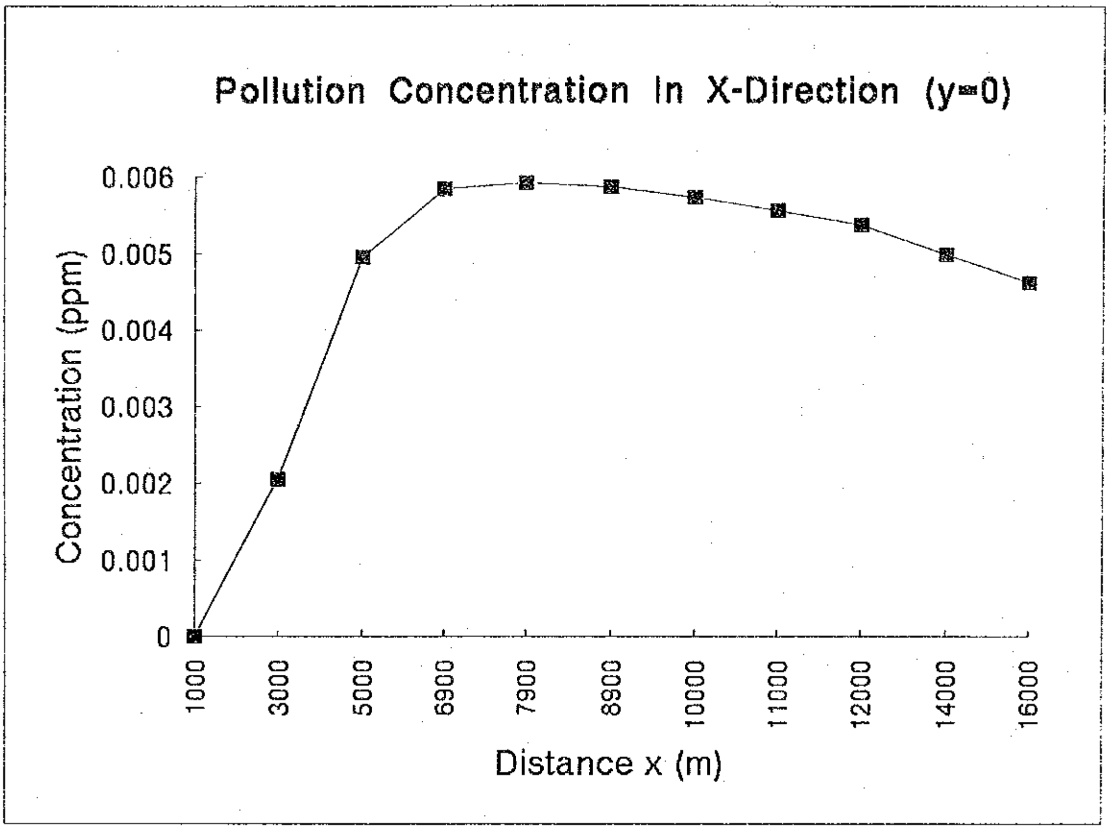
Wind speed at top of stack (U) = 3.89 (m/s)

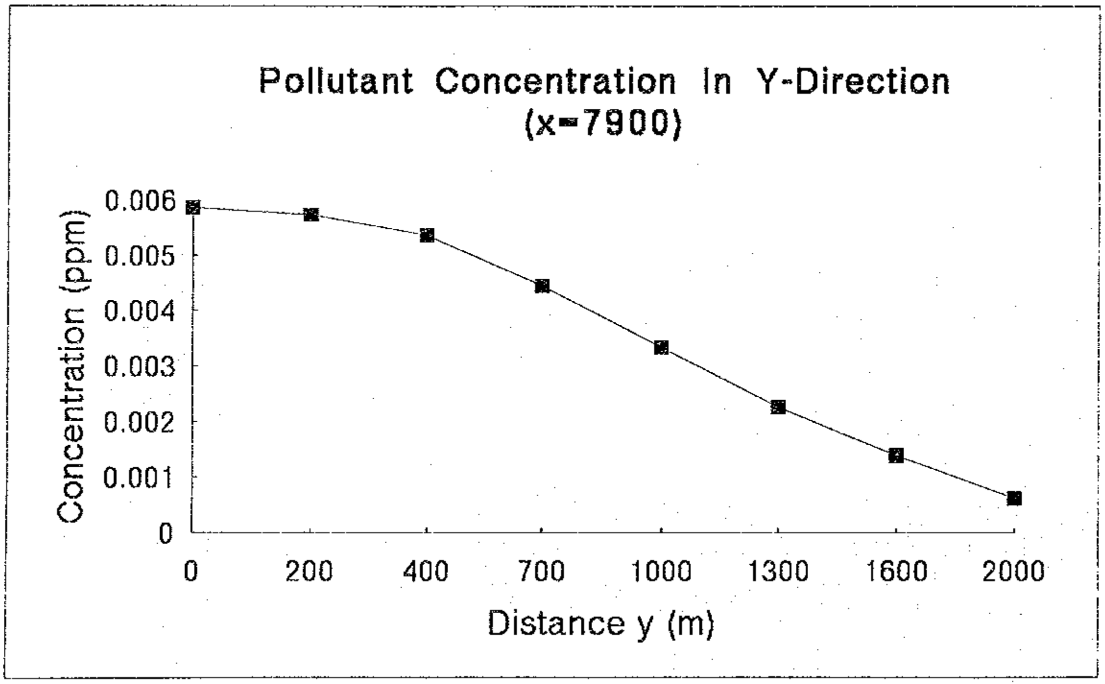
Plume rise (dH) = 157.016 (m)

Effective stack height (He) = 207.016 (m)

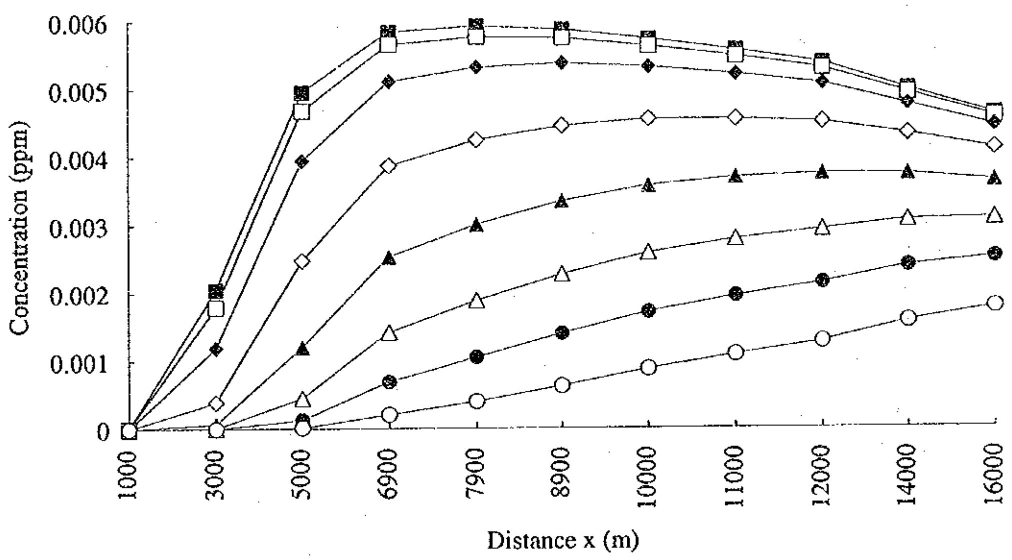
Estimated Ground-Level Concentrations (ppm)

x(m) \ y(m)	0	200	400	700	1000	1300	1600	2000
1000	1.5E-07	5.31E-08	2.36E-09	4.52E-13	8.1E-19	1.36E-26	2.15E-36	1.28E-52
3000	0.002052	0.001791	0.00119	0.000387	6.8E-05	6.48E-06	3.35E-07	2.48E-09
5000	0.004953	0.004681	0.00395	0.002476	0.001203	0.000453	0.000132	1.72E-05
6900	0.005841	0.005648	0.005109	0.003875	0.002529	0.001419	0.000685	0.000205
7900	0.005921	0.005762	0.005313	0.00425	0.00301	0.001887	0.001048	0.000396
8900	0.005869	0.005738	0.005363	0.004454	0.003343	0.002267	0.00139	0.000618
10000	0.005727	0.00562	0.005311	0.004545	0.003573	0.002581	0.001712	0.000868
11000	0.005559	0.005468	0.005206	0.004548	0.003691	0.002783	0.001949	0.001081
12000	0.005372	0.005295	0.005071	0.004502	0.003747	0.002922	0.002136	0.001271
14000	0.004988	0.00493	0.004762	0.004329	0.003736	0.003061	0.002381	0.001571
16000	0.004621	0.004577	0.004447	0.004109	0.003637	0.003083	0.002503	0.001773

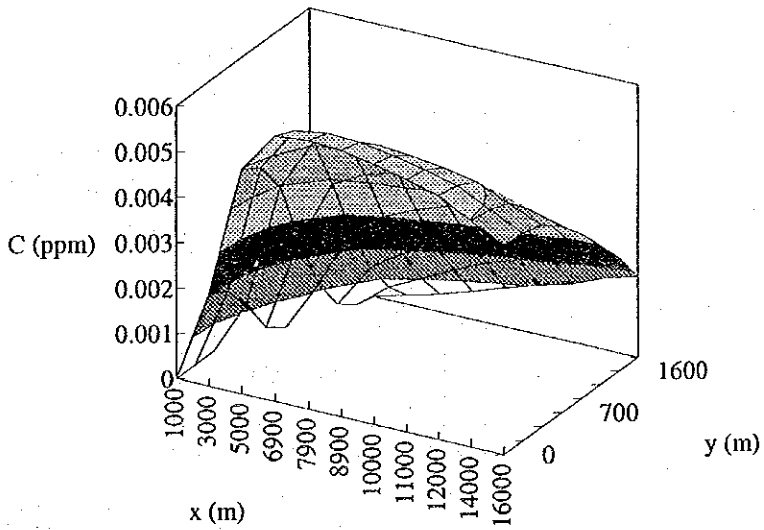

Pollution Concentration In X-Direction (y=0)
Concentration (ppm)
0.006
0.005
0.004
0.003
0.002
0.001
0
1000
3000
5000
6900
7900
8900
10000
11000
12000
14000
16000
Distance x (m)


Pollutant Concentration In Y-Direction
(x=7900)
Concentration (ppm)
0.006
0.005
0.004
0.003
0.002
0.001
0
0
200
400
700
1000
1300
1600
2000
Distance y (m)

Pollutant Concentration In X-Direction (Summary)



Pollutant Concentration In X & Y Directions (Summary)



ANALYSIS FOR AIR POLLUTION - WIND (DAYTIME)

This is "Single Source Model" of the analysis for air pollution considering wind and calculates an average concentration for an hour at the ground level under the following assumptions.

1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

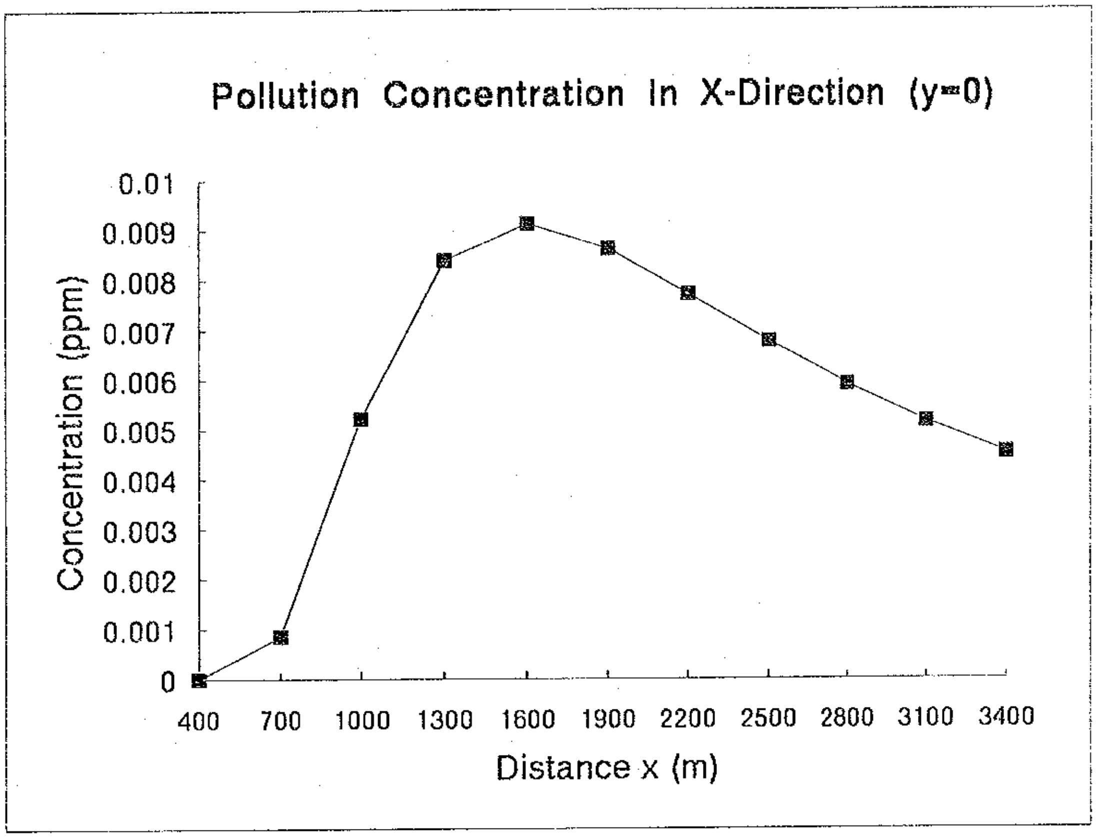
Pollutant : SOx by Distilated Oil

Wind speed at Zs (Us) =	2.6 (m/s)
Height of wind measurement (Zs) =	10 (m)
Height of Stack (Ho) =	100 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.0225 (Nm3/s)
Pasquill stability (St) =	B

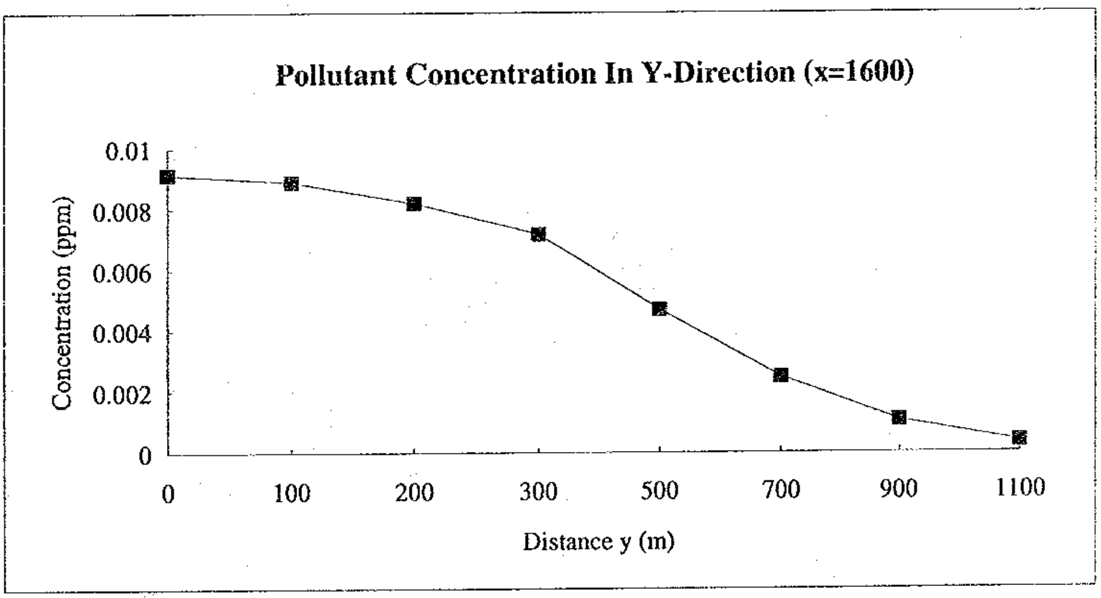
Wind speed at top of stack (U) =	3.67 (m/s)
Plume rise (dH) =	163.8705 (m)
Effective stack height (He) =	263.8705 (m)

Estimated Ground-Level Concentrations (ppm)

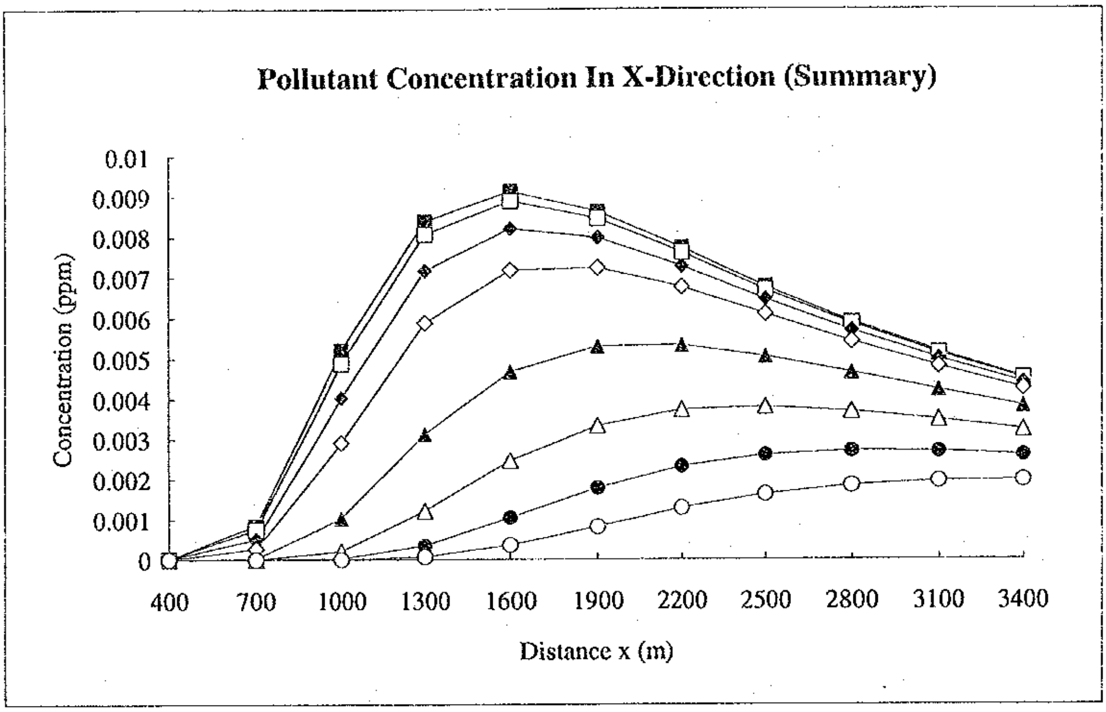
x(m) \ y(m)	0	100	200	300	500	700	900	1100
400	9.75E-08	6.64E-08	2.1E-08	3.1E-09	6.72E-12	6.8E-16	3.21E-21	7.05E-28
700	0.000848	0.000746	0.000507	0.000266	3.39E-05	1.54E-06	2.51E-08	1.45E-10
1000	0.005217	0.004889	0.004025	0.00291	0.001031	0.000217	2.73E-05	2.04E-06
1300	0.008396	0.008071	0.007171	0.005888	0.003133	0.001216	0.000344	7.12E-05
1600	0.009131	0.008891	0.008206	0.00718	0.004682	0.002466	0.001049	0.00036
1900	0.008632	0.008466	0.007986	0.007247	0.00531	0.00333	0.001788	0.000822
2200	0.007728	0.007614	0.007282	0.006761	0.00533	0.003731	0.002319	0.00128
2500	0.006781	0.006701	0.006468	0.006098	0.005049	0.003805	0.002609	0.001628
2800	0.005916	0.00586	0.005693	0.005425	0.004651	0.003691	0.002713	0.001846
3100	0.005168	0.005127	0.005005	0.004808	0.004227	0.003486	0.002695	0.001954
3400	0.004534	0.004503	0.004411	0.004263	0.003822	0.003243	0.002606	0.001983



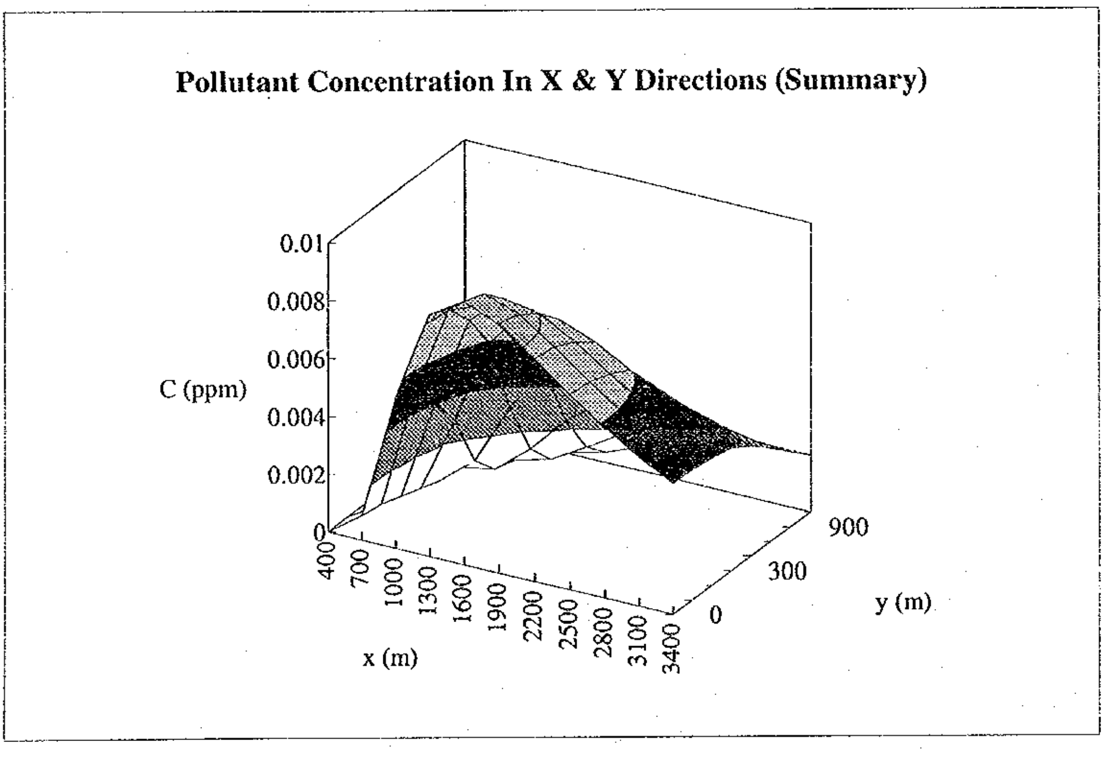
Pollution Concentration In X-Direction (y=0)
Concentration (ppm)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
400
700
1000
1300
1600
1900
2200
2500
2800
3100
3400
Distance x (m)



Pollutant Concentration In Y-Direction (x=1600)
Concentration (ppm)
0.01
0.008
0.006
0.004
0.002
0
0
100
200
300
500
700
900
1100
Distance y (m)



Pollutant Concentration In X-Direction (Summary)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Concentration (ppm)
400
700
1000
1300
1600
1900
2200
2500
2800
3100
3400
Distance x (m)



Pollutant Concentration In X & Y Directions (Summary)
0.01
0.008
0.006
0.004
0.002
0
C (ppm)
400
700
1000
1300
1600
1900
2200
2500
2800
3100
3400
x (m)
900
300
0
y (m)

ANALYSIS FOR AIR POLLUTION - WIND (NIGHT)

This is "Single Source Model" of the analysis for air pollution considering wind and calculates an average concentration for an hour at the ground level under the following assumptions.

1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

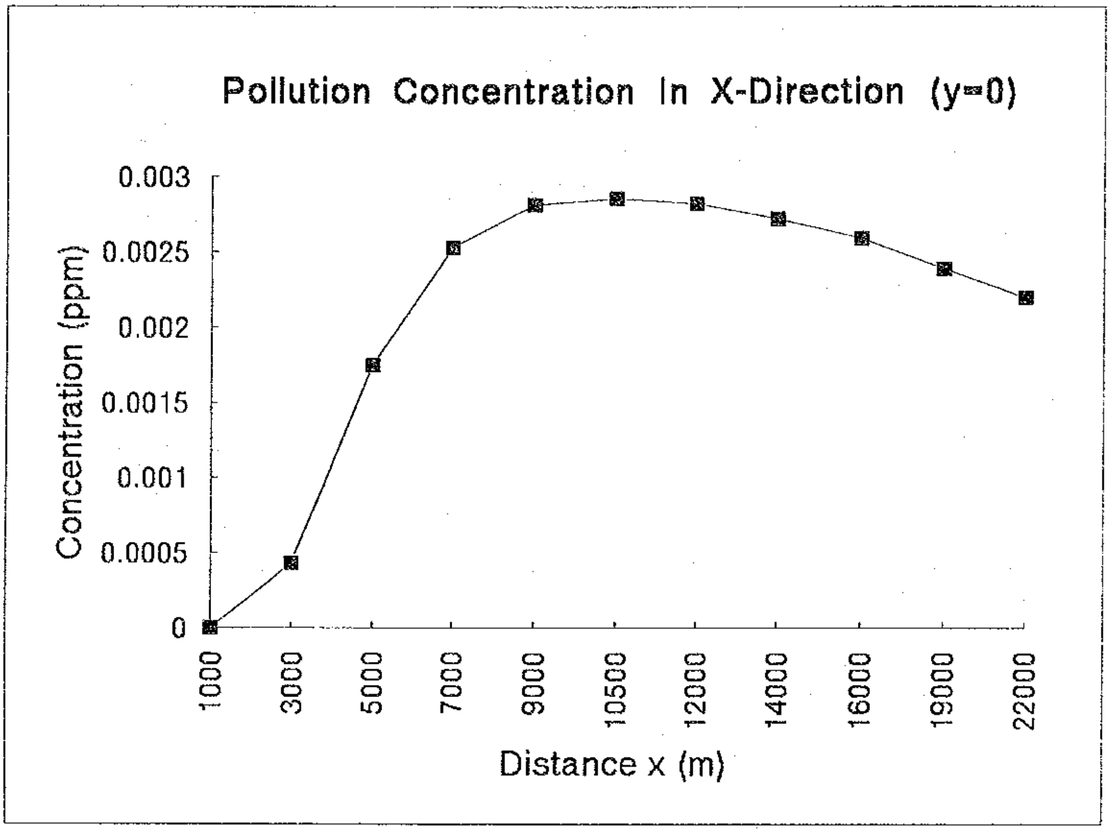
Pollutant : SOx by Distilated Oil

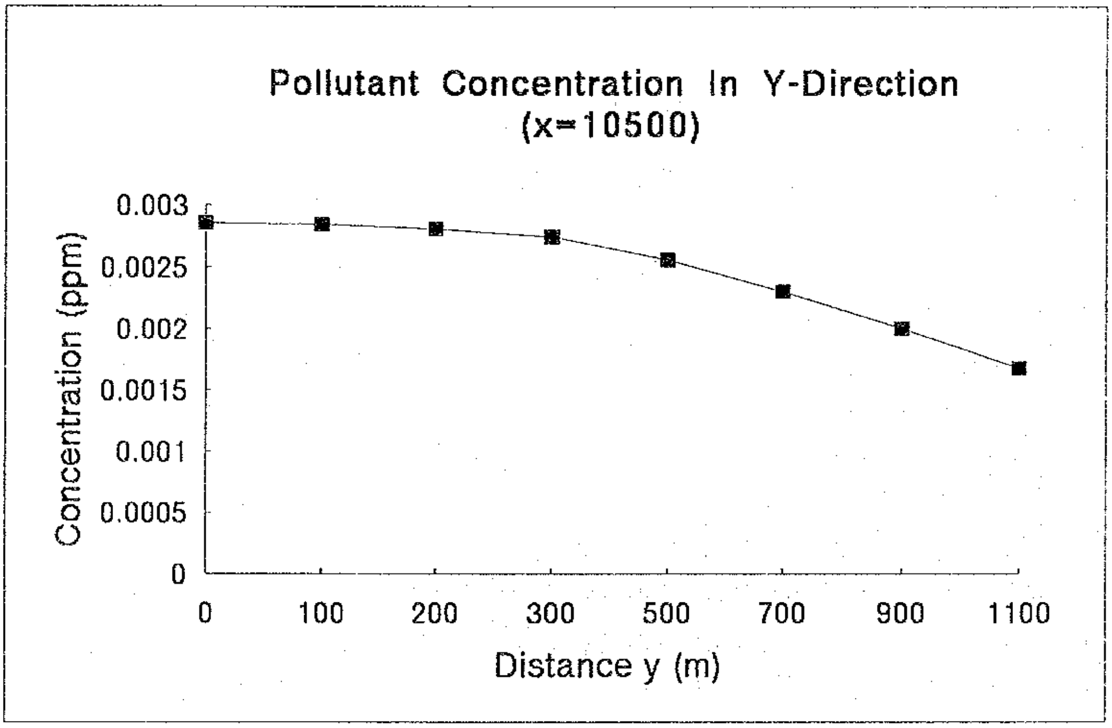
Wind speed at Zs (Us) =	2.6 (m/s)
Height of wind measurement (Zs) =	10 (m)
Height of Stack (Ho) =	100 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.0225 (Nm3/s)
Pasquill stability (St) =	D

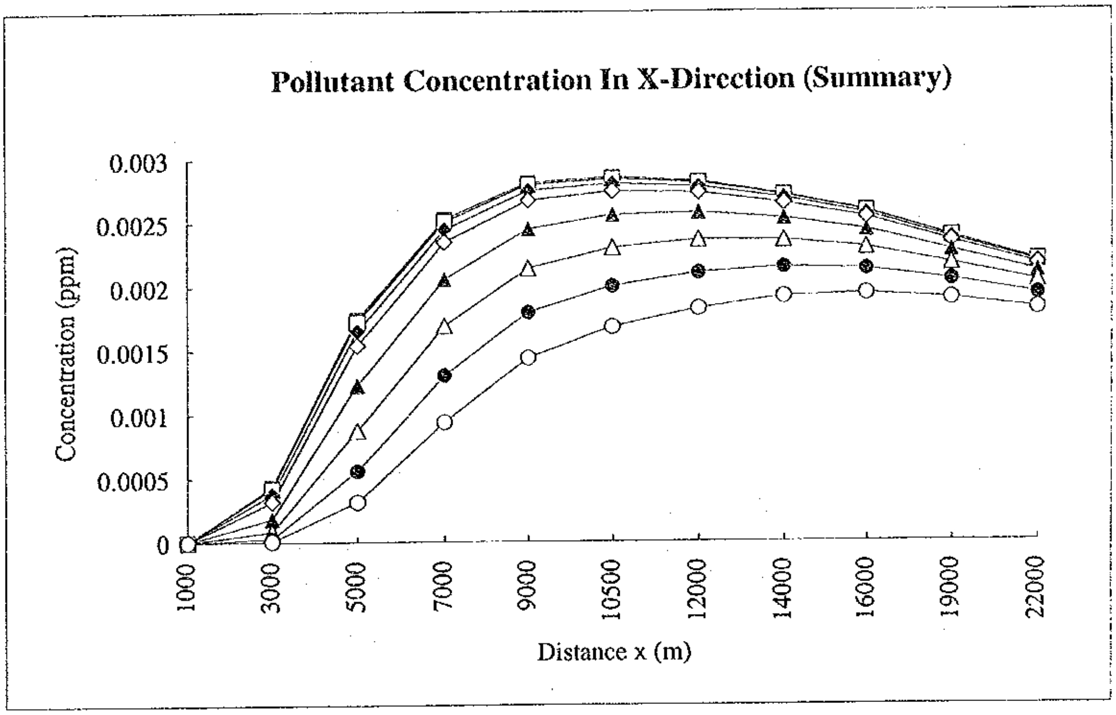
Wind speed at top of stack (U) =	4.62 (m/s)
Plume rise (dH) =	137.8799 (m)
Effective stack height (He) =	237.8799 (m)

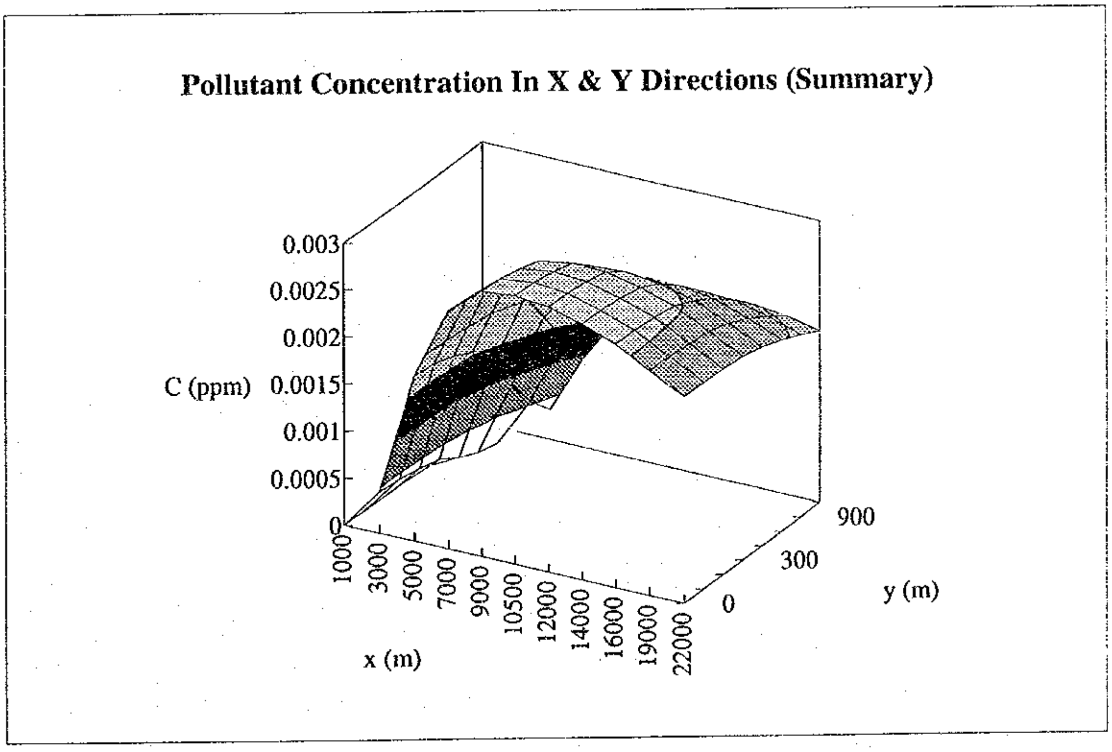
Estimated Ground-Level Concentrations (ppm)

x(m) \ y(m)	0	100	200	300	500	700	900	1100
1000	8.62E-10	6.65E-10	3.05E-10	8.34E-11	1.31E-12	2.6E-15	6.44E-19	2E-23
3000	0.000432	0.000418	0.000377	0.000318	0.000184	8.14E-05	2.74E-05	7.01E-06
5000	0.00175	0.001725	0.001654	0.001541	0.001229	0.000875	0.000556	0.000316
7000	0.00253	0.002509	0.002448	0.00235	0.002062	0.001694	0.001304	0.00094
9000	0.002814	0.002798	0.002752	0.002677	0.00245	0.002146	0.001798	0.001441
10500	0.002856	0.002843	0.002806	0.002745	0.002559	0.002303	0.002002	0.00168
12000	0.002822	0.002812	0.002782	0.002732	0.002579	0.002366	0.002108	0.001825
14000	0.002721	0.002713	0.002689	0.002651	0.002531	0.002362	0.002153	0.001918
16000	0.002592	0.002586	0.002567	0.002537	0.002441	0.002305	0.002135	0.00194
19000	0.00239	0.002386	0.002372	0.00235	0.00228	0.002178	0.00205	0.0019
22000	0.0022	0.002197	0.002186	0.002169	0.002116	0.002038	0.001939	0.001822


Pollution Concentration In X-Direction (y=0)
Concentration (ppm)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
1000
3000
5000
7000
9000
10500
12000
14000
16000
19000
22000
Distance x (m)


Pollutant Concentration In Y-Direction (x=10500)
Concentration (ppm)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
100
200
300
500
700
900
1100
Distance y (m)


Pollutant Concentration In X-Direction (Summary)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Concentration (ppm)
1000
3000
5000
7000
9000
10500
12000
14000
16000
19000
22000
Distance x (m)


Pollutant Concentration In X & Y Directions (Summary)
0.003
0.0025
0.002
C (ppm)
0.0015
0.001
0.0005
0
1000
3000
5000
7000
9000
10500
12000
14000
16000
19000
22000
x (m)
900
300
0
y (m)

ANALYSIS FOR AIR POLLUTION - WIND (DAYTIME)

This is "Single Source Model" of the analysis for air pollution considering wind and calculates an average concentration for an hour at the ground level under the following assumptions.

1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

Pollutant : SOx by Distilated Oil

Wind speed at Zs (Us) =	2.6 (m/s)
Height of wind measurement (Zs) =	10 (m)
Height of Stack (Ho) =	50 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.0225 (Nm3/s)
Pasquill stability (St) =	B

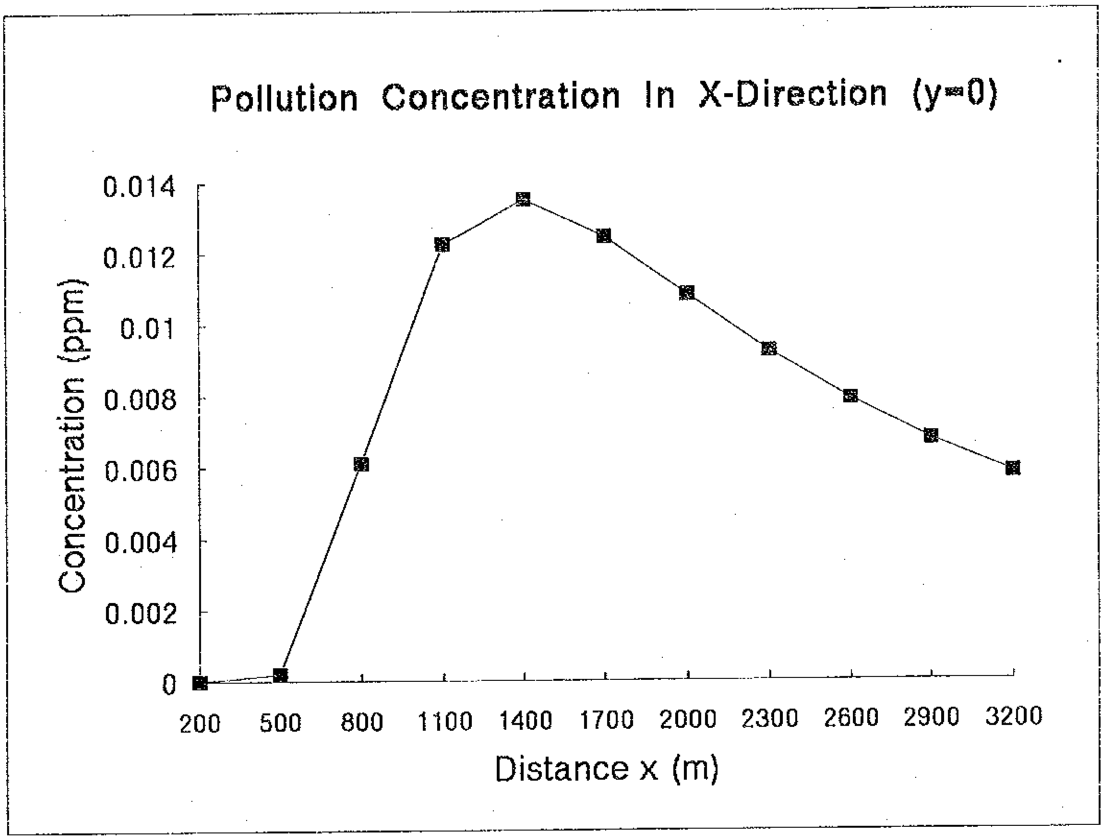
Wind speed at top of stack (U) = 3.31 (m/s)

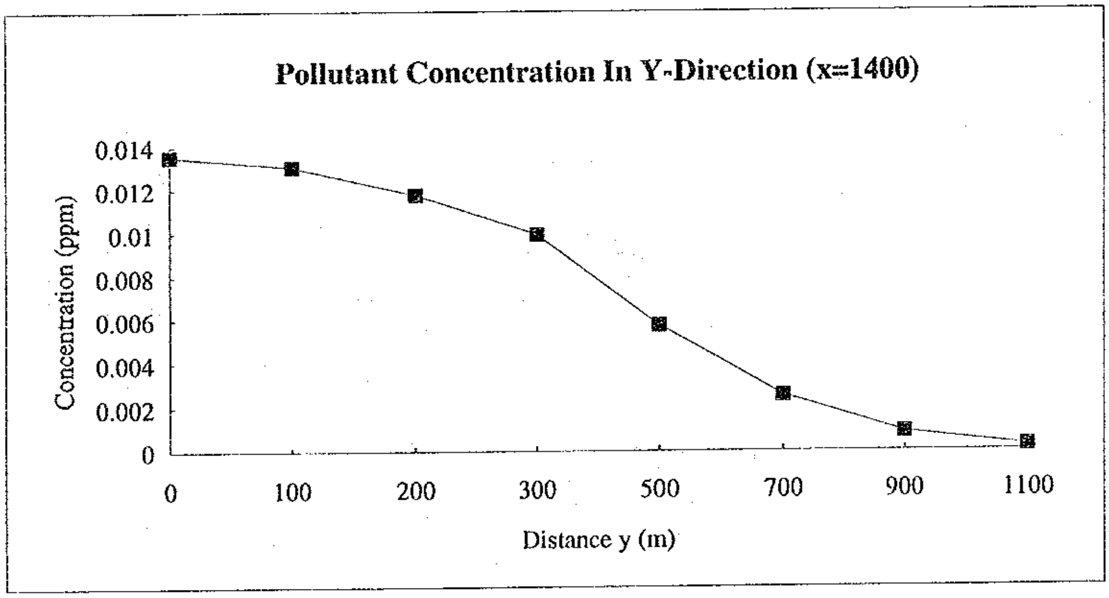
Plume rise (dH) = 177.1604 (m)

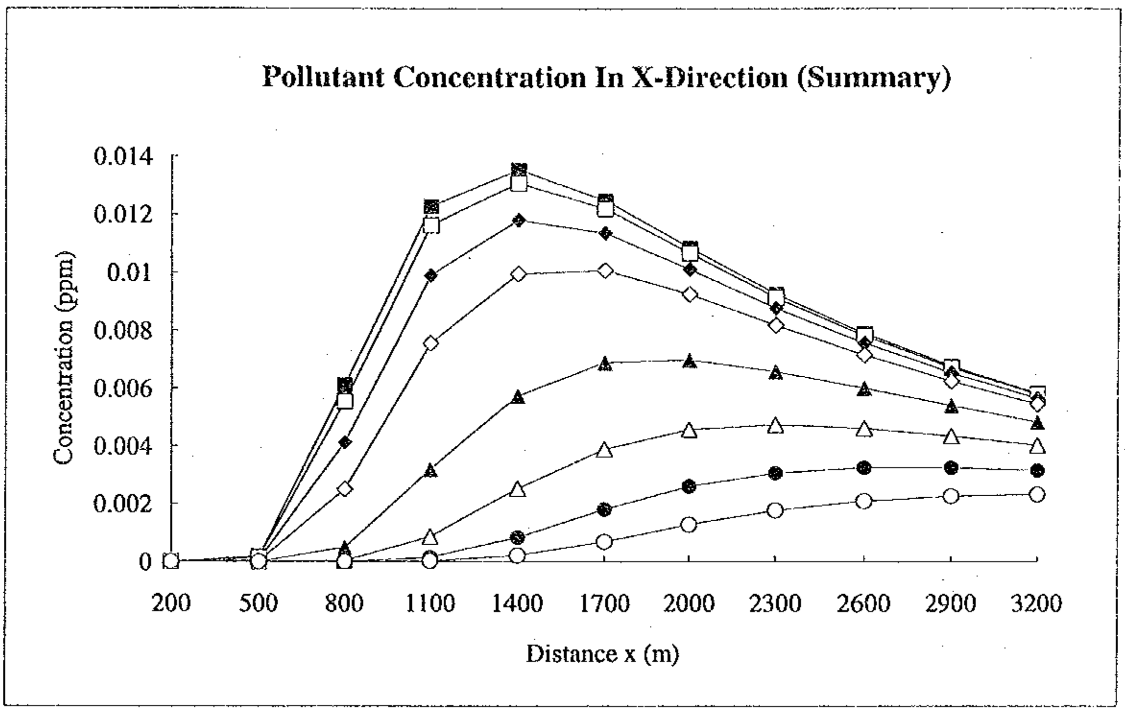
Effective stack height (He) = 227.1604 (m)

Estimated Ground-Level Concentrations (ppm)

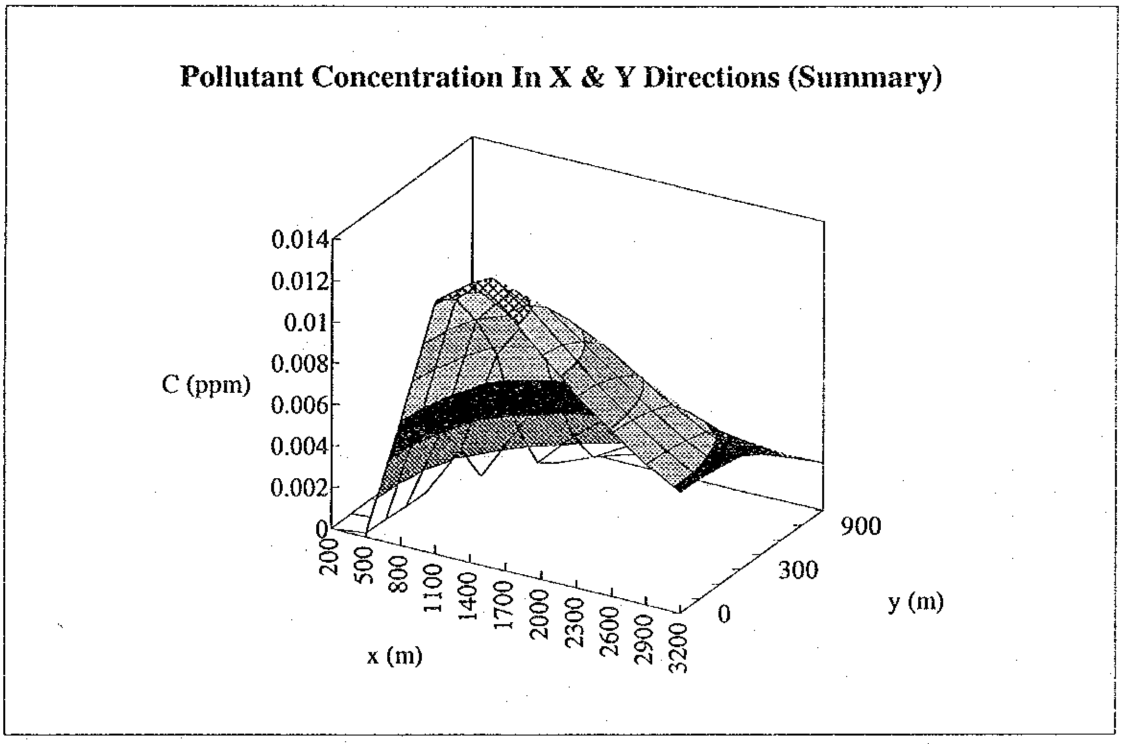
x(m) \ y(m)	0	100	200	300	500	700	900	1100
200	5.5E-20	1.22E-20	1.34E-22	7.31E-26	2.6E-36	5.54E-52	7.04E-73	5.3E-99
500	0.000196	0.000153	7.27E-05	2.11E-05	4.01E-07	1.05E-09	3.8E-13	1.9E-17
800	0.006117	0.005538	0.004108	0.002498	0.000508	4.67E-05	1.93E-06	3.61E-08
1100	0.012264	0.011618	0.009878	0.007537	0.003172	0.000866	0.000153	1.76E-05
1400	0.013522	0.013066	0.011788	0.009931	0.005737	0.002519	0.000841	0.000213
1700	0.012468	0.012174	0.011332	0.010057	0.006864	0.003871	0.001803	0.000694
2000	0.010835	0.010645	0.010095	0.009241	0.006963	0.004554	0.002586	0.001274
2300	0.009252	0.009126	0.008758	0.008178	0.006567	0.004726	0.003048	0.001761
2600	0.007888	0.007802	0.007549	0.007145	0.005993	0.004604	0.003239	0.002087
2900	0.006758	0.006697	0.006518	0.00623	0.00539	0.004339	0.003248	0.002262
3200	0.005832	0.005788	0.005658	0.005447	0.004823	0.004019	0.003151	0.002325


Pollution Concentration In X-Direction (y=0)
Concentration (ppm)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
200
500
800
1100
1400
1700
2000
2300
2600
2900
3200
Distance x (m)


Pollutant Concentration In Y-Direction (x=1400)
Concentration (ppm)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
100
200
300
500
700
900
1100
Distance y (m)



Pollutant Concentration In X-Direction (Summary)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Concentration (ppm)
200
500
800
1100
1400
1700
2000
2300
2600
2900
3200
Distance x (m)



Pollutant Concentration In X & Y Directions (Summary)
0.014
0.012
0.01
0.008
C (ppm)
0.006
0.004
0.002
0
200
500
800
1100
1400
1700
2000
2300
2600
2900
3200
x (m)
900
300
0
y (m)

ANALYSIS FOR AIR POLLUTION - WIND (NIGHT)

This is "Single Source Model" of the analysis for air pollution considering wind and calculates an average concentration for an hour at the ground level under the following assumptions.

1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

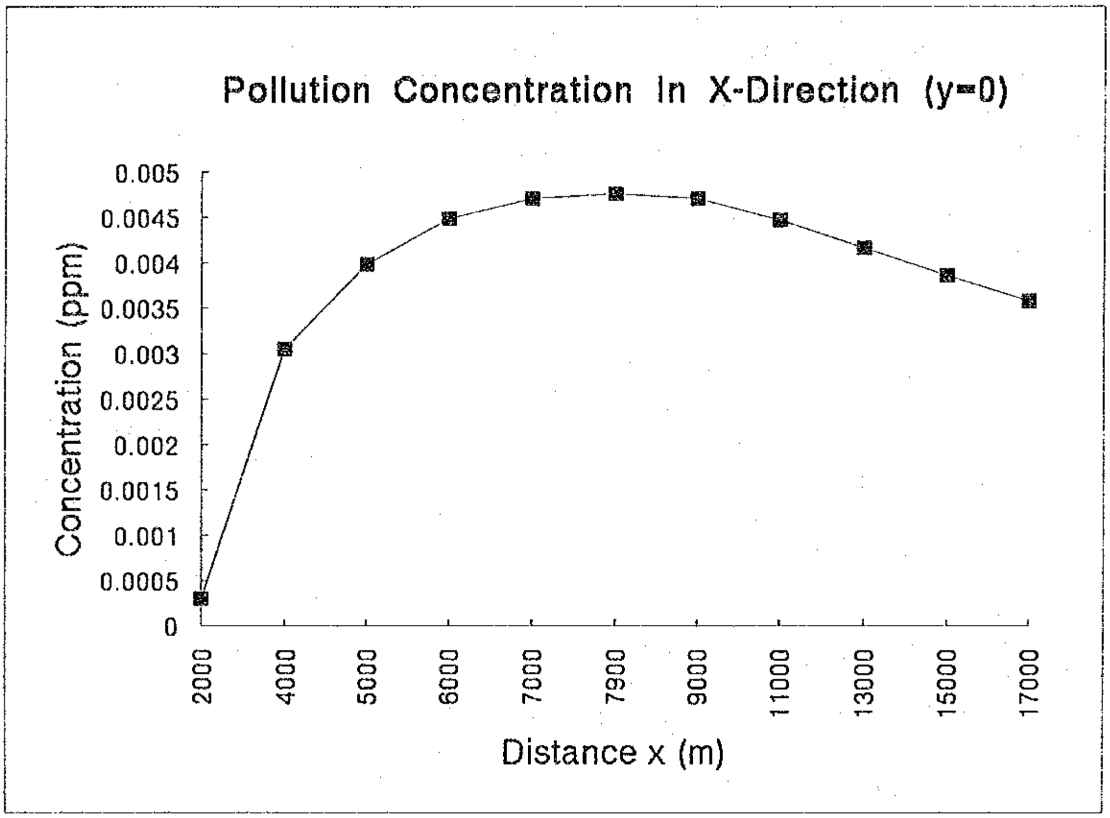
Pollutant : SOx by Distilated Oil

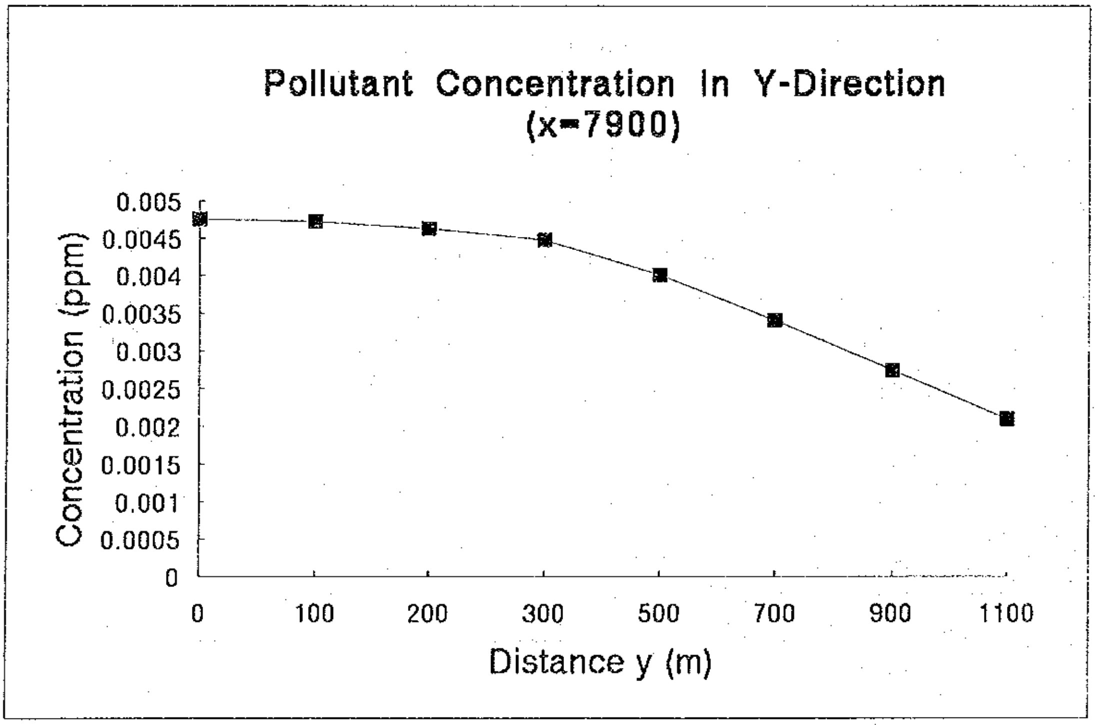
Wind speed at Zs (Us) =	2.6 (m/s)
Height of wind measurement (Zs) =	10 (m)
Height of Stack (Ho) =	50 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.0225 (Nm3/s)
Pasquill stability (St) =	D

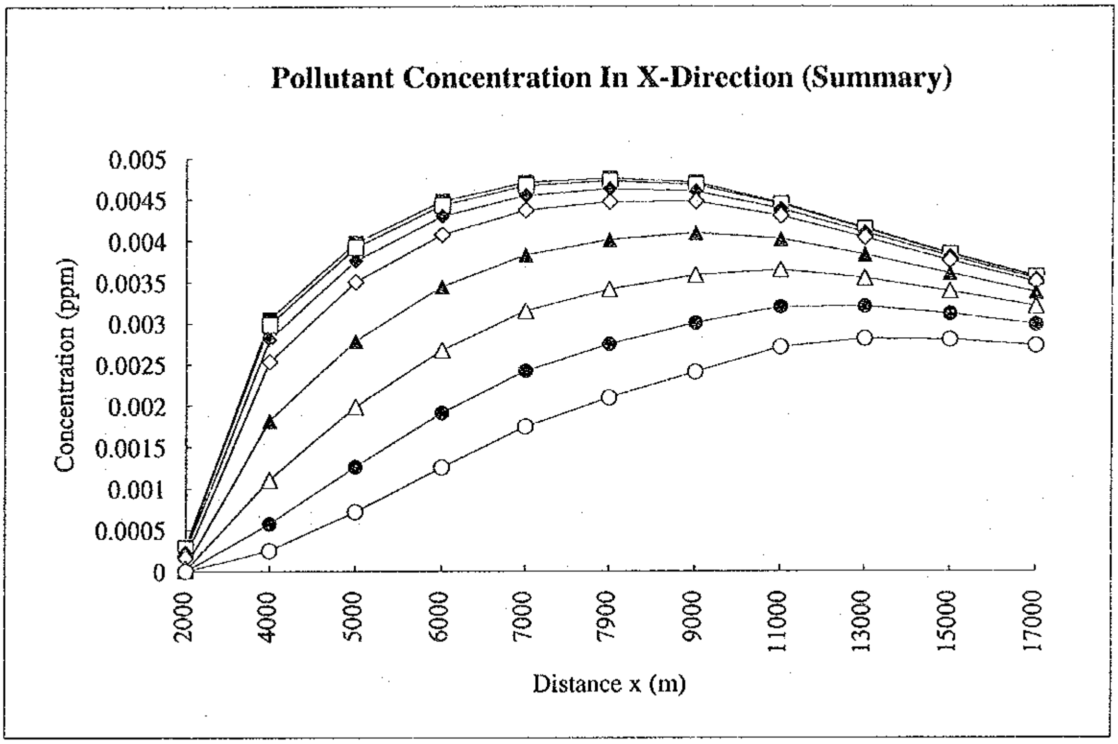
Wind speed at top of stack (U) =	3.89 (m/s)
Plume rise (dH) =	157.016 (m)
Effective stack height (He) =	207.016 (m)

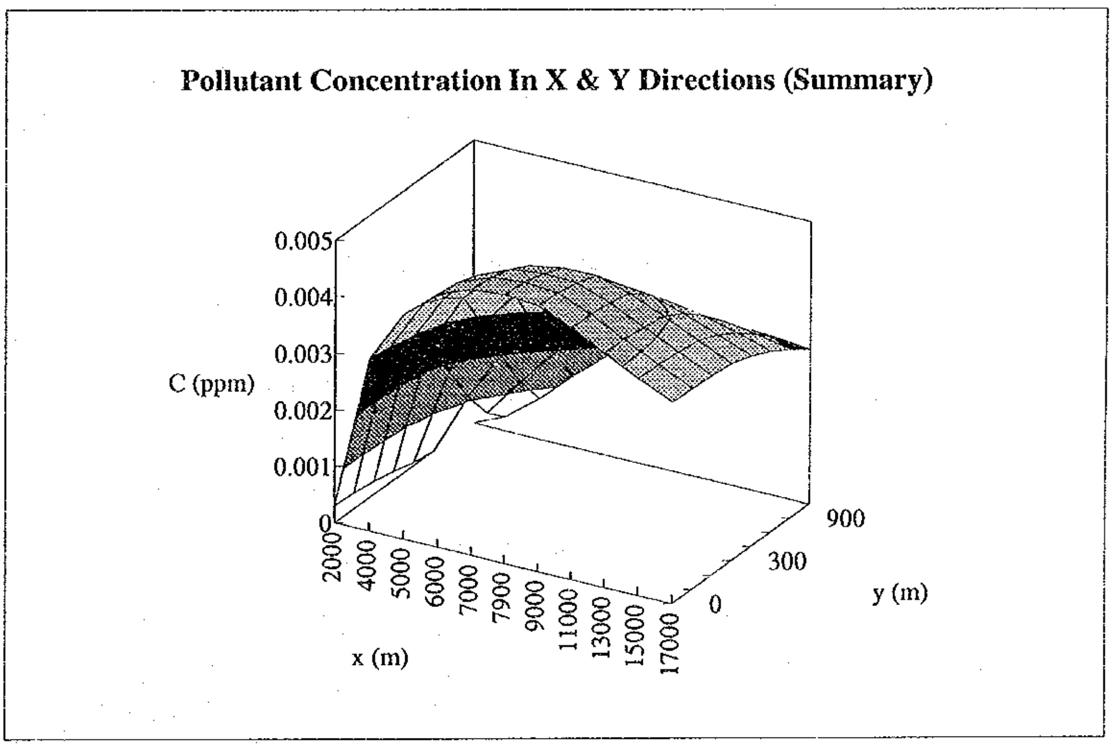
Estimated Ground-Level Concentrations (ppm)

x(m) \ y(m)	0	100	200	300	500	700	900	1100
2000	0.0003	0.00028	0.000226	0.000159	5.12E-05	9.37E-06	9.74E-07	5.75E-08
4000	0.003052	0.00299	0.00281	0.002535	0.001822	0.00111	0.000574	0.000251
5000	0.00398	0.003924	0.003761	0.003504	0.002794	0.00199	0.001265	0.000718
6000	0.004484	0.004438	0.0043	0.004081	0.003451	0.002683	0.001918	0.001261
7000	0.004707	0.004668	0.004555	0.004372	0.003836	0.003152	0.002426	0.001749
7900	0.004758	0.004726	0.004631	0.004477	0.004017	0.003415	0.002751	0.002098
9000	0.004708	0.004682	0.004605	0.004479	0.0041	0.00359	0.003008	0.00241
11000	0.004467	0.004448	0.004394	0.004305	0.004032	0.003655	0.003206	0.002722
13000	0.004162	0.004149	0.004109	0.004043	0.003841	0.003556	0.003209	0.002822
15000	0.003858	0.003848	0.003818	0.003768	0.003613	0.003393	0.00312	0.002809
17000	0.003576	0.003568	0.003544	0.003506	0.003384	0.00321	0.002991	0.002739


Pollution Concentration In X-Direction (y=0)
Concentration (ppm)
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
2000
4000
5000
6000
7000
7900
9000
11000
13000
15000
17000
Distance x (m)


Pollutant Concentration In Y-Direction
(x=7900)
Concentration (ppm)
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
100
200
300
500
700
900
1100
Distance y (m)


Pollutant Concentration In X-Direction (Summary)
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Concentration (ppm)
2000
4000
5000
6000
7000
7900
9000
11000
13000
15000
17000
Distance x (m)


Pollutant Concentration In X & Y Directions (Summary)
C (ppm)
0.005
0.004
0.003
0.002
0.001
0
2000
4000
5000
6000
7000
7900
9000
11000
13000
15000
17000
x (m)
0
300
900
y (m)

ANALYSIS FOR AIR POLLUTION - NO WIND (DAYTIME)

This is "Single Source Model" of the analysis for air pollution when no wind blows and calculate an average concentration for an hour at the ground level under the following assumptions.

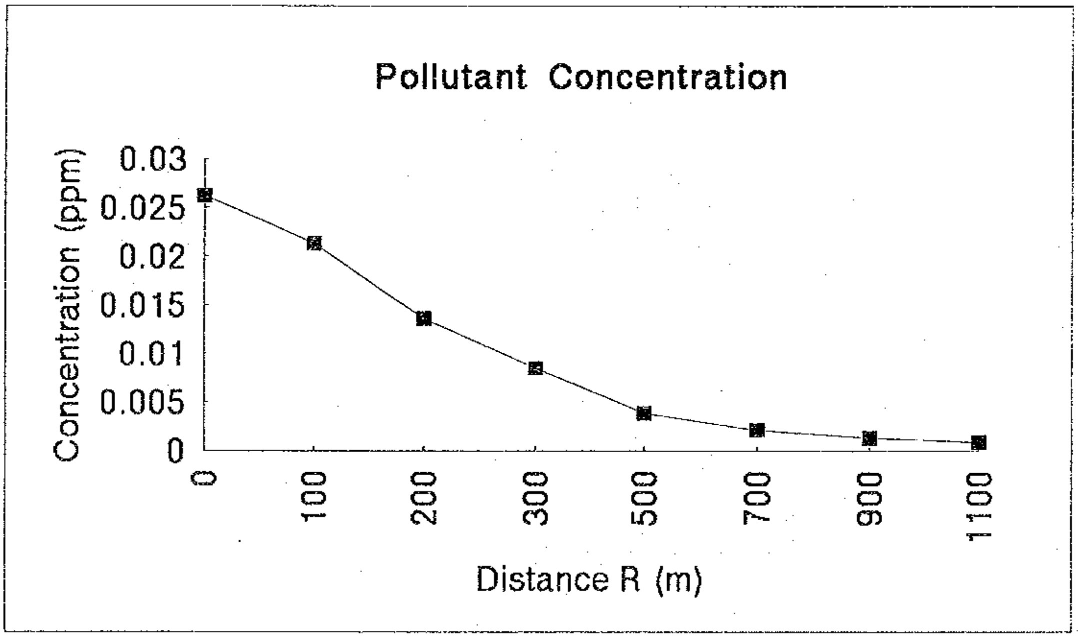
1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

Pollutant : NOx by Natural Gas

Daytime or night? (D or N)	D
Vertical temperature gradient (Tz)=	0.003 (•C)
Height of Stack (Ho) =	100 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.028 (Nm3/s)
Pasquill stability (St) =	A
Plume rise (dH) =	107.9196 (m)
Effective stack height (He) =	207.9196 (m)

Estimated Ground-Level Concentrations (ppm)

R(m)	0	100	200	300	500	700	900	1100
C	0.02621	0.021286	0.013614	0.008505	0.003864	0.002125	0.001328	0.000904



ANALYSIS FOR AIR POLLUTION - NO WIND (NIGHT)

This is "Single Source Model" of the analysis for air pollution when no wind blows and calculate an average concentration for an hour at the ground level under the following assumptions.

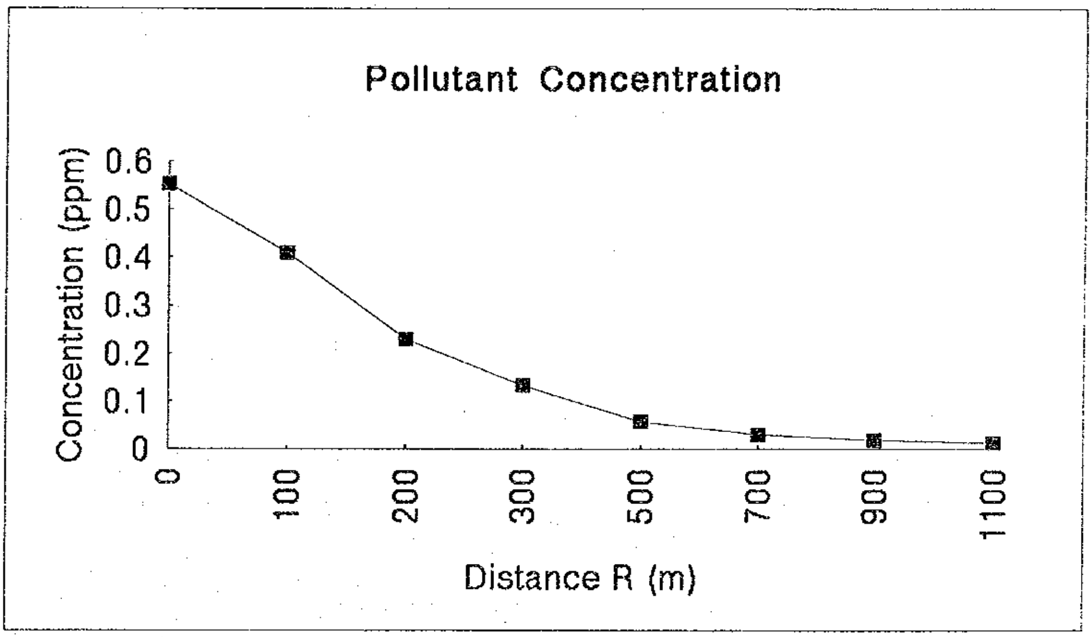
1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

Pollutant : NOx by Natural Gas

Daytime or night? (D or N)	N
Vertical temperature gradient (Tz)=	0.01 (•C)
Height of Stack (Ho) =	100 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.028 (Nm3/s)
Pasquill stability (St) =	D
Plume rise (dH) =	68.71015 (m)
Effective stack height (He) =	168.7101 (m)

Estimated Ground-Level Concentrations (ppm)

R(m)	0	100	200	300	500	700	900	1100
C	0.552413	0.408856	0.229744	0.132789	0.056496	0.030344	0.018764	0.012703



ANALYSIS FOR AIR POLLUTION - NO WIND (DAYTIME)

This is "Single Source Model" of the analysis for air pollution when no wind blows and calculate an average concentration for an hour at the ground level under the following assumptions.

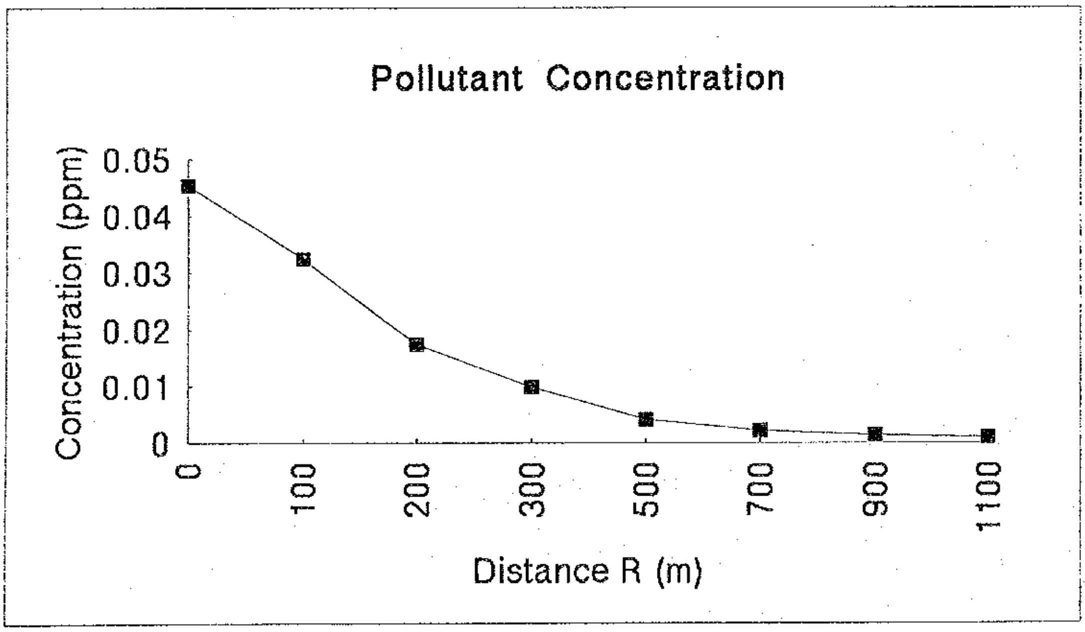
1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

Pollutant : NOx by Natural Gas

Daytime or night? (D or N)	D
Vertical temperature gradient (Tz)=	0.003 (•C)
Height of Stack (Ho) =	50 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.028 (Nm3/s)
Pasquill stability (St) =	A
Plume rise (dH) =	107.9196 (m)
Effective stack height (He) =	157.9196 (m)

Estimated Ground-Level Concentrations (ppm)

R(m)	0	100	200	300	500	700	900	1100
C	0.045435	0.032431	0.017449	0.009858	0.004121	0.0022	0.001357	0.000918



ANALYSIS FOR AIR POLLUTION - NO WIND (NIGHT)

This is "Single Source Model" of the analysis for air pollution when no wind blows and calculate an average concentration for an hour at the ground level under the following assumptions.

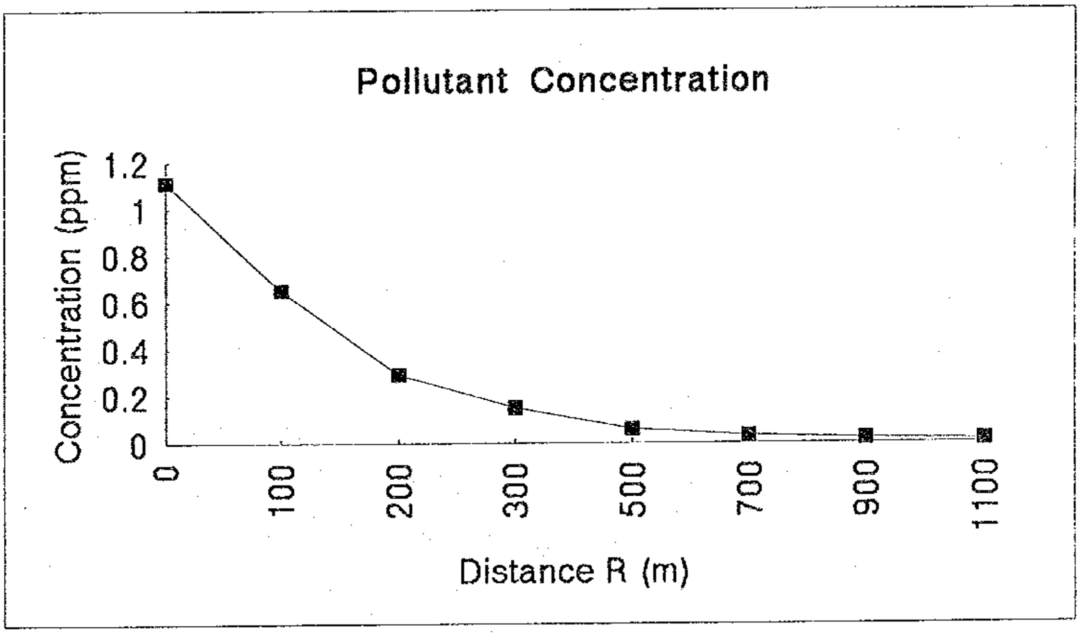
1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

Pollutant : NOx by Natural Gas

Daytime or night? (D or N)	N
Vertical temperature gradient (Tz)=	0.01 (•C)
Height of Stack (Ho) =	50 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.028 (Nm3/s)
Pasquill stability (St) =	D
Plume rise (dH) =	68.71015 (m)
Effective stack height (He) =	118.7101 (m)

Estimated Ground-Level Concentrations (ppm)

R(m)	0	100	200	300	500	700	900	1100
C	1.115068	0.652564	0.290762	0.151119	0.05957	0.031209	0.019091	0.012853



ANALYSIS FOR AIR POLLUTION - NO WIND (DAYTIME)

This is "Single Source Model" of the analysis for air pollution when no wind blows and calculate an average concentration for an hour at the ground level under the following assumptions.

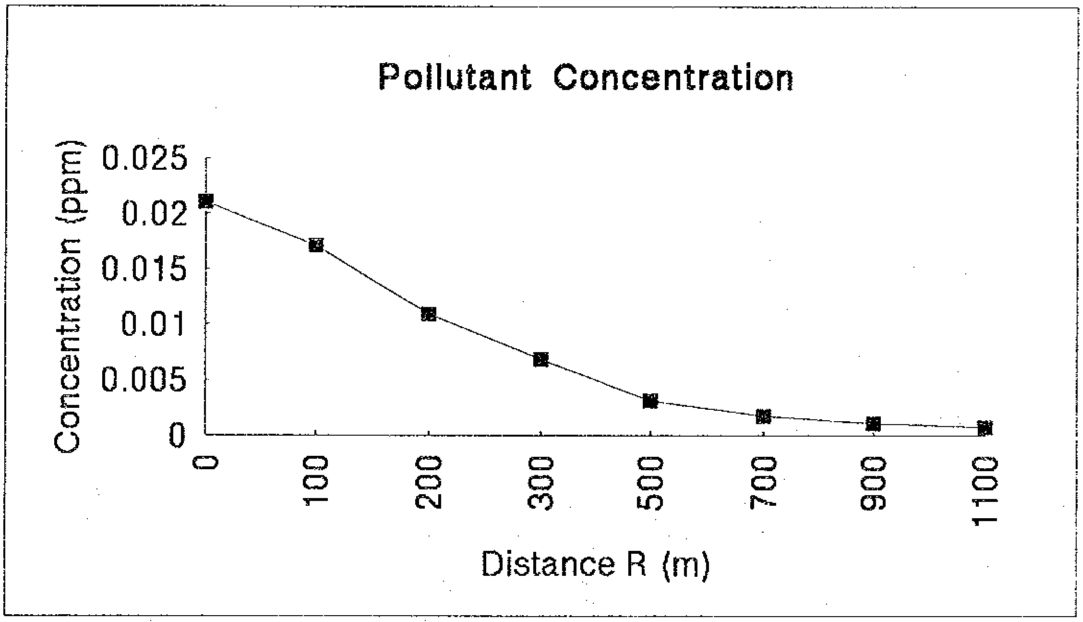
1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

Pollutant : SOx by Distilated Oil

Daytime or night? (D or N)	D
Vertical temperature gradient (Tz)=	0.003 (•C)
Height of Stack (Ho) =	100 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.0225 (Nm3/s)
Pasquill stability (St) =	A
Plume rise (dH) =	107.9196 (m)
Effective stack height (He) =	207.9196 (m)

Estimated Ground-Level Concentrations (ppm)

R(m)	0	100	200	300	500	700	900	1100
C	0.021062	0.017105	0.01094	0.006834	0.003105	0.001708	0.001067	0.000727



ANALYSIS FOR AIR POLLUTION - NO WIND (NIGHT)

This is "Single Source Model" of the analysis for air pollution when no wind blows and calculates an average concentration for an hour at the ground level under the following assumptions.

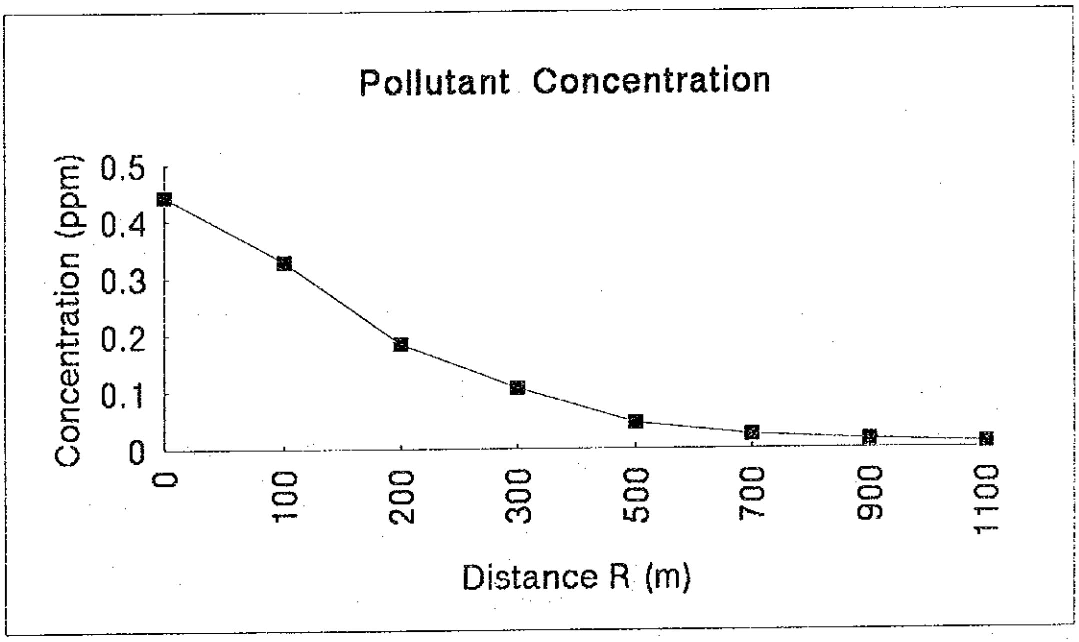
1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

Pollutant : SOx by Distilated Oil

Daytime or night? (D or N)	N
Vertical temperature gradient (Tz)=	0.01 (•C)
Height of Stack (Ho) =	100 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.0225 (Nm3/s)
Pasquill stability (St) =	D
Plume rise (dH) =	68.71015 (m)
Effective stack height (He) =	168.7101 (m)

Estimated Ground-Level Concentrations (ppm)

R(m)	0	100	200	300	500	700	900	1100
C	0.443903	0.328545	0.184615	0.106706	0.045398	0.024384	0.015078	0.010208



ANALYSIS FOR AIR POLLUTION - NO WIND (DAYTIME)

This is "Single Source Model" of the analysis for air pollution when no wind blows and calculates an average concentration for an hour at the ground level under the following assumptions.

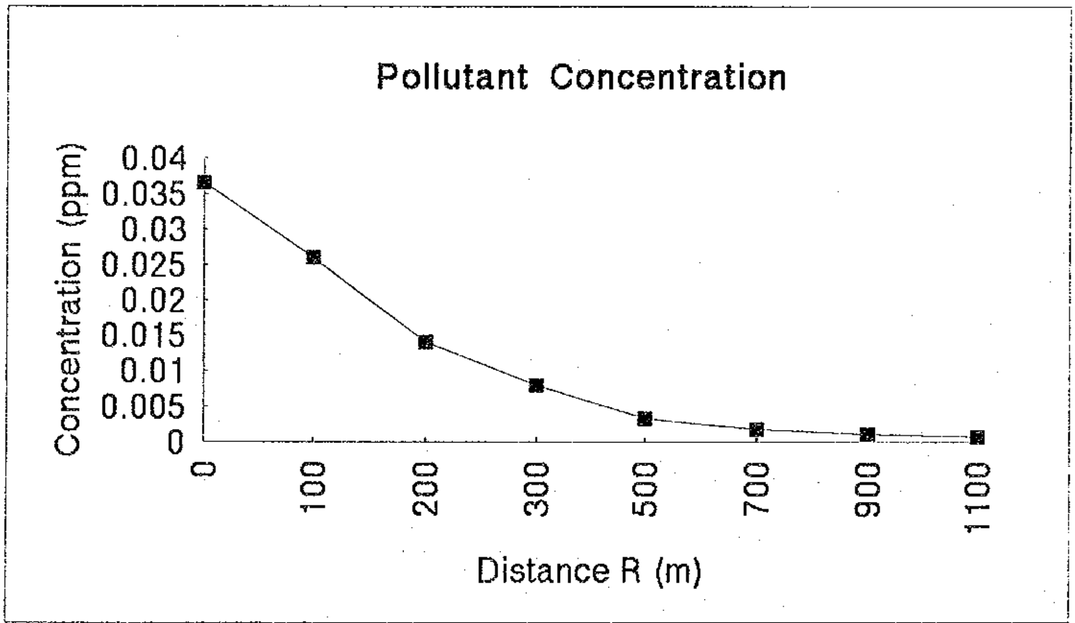
1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

Pollutant : SOx by Distilated Oil

Daytime or night? (D or N)	D
Vertical temperature gradient (Tz)=	0.003 (•C)
Height of Stack (Ho) =	50 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.0225 (Nm3/s)
Pasquill stability (St) =	A
Plume rise (dH) =	107.9196 (m)
Effective stack height (He) =	157.9196 (m)

Estimated Ground-Level Concentrations (ppm)

R(m)	0	100	200	300	500	700	900	1100
C	0.03651	0.02606	0.014021	0.007922	0.003312	0.001768	0.001091	0.000737



ANALYSIS FOR AIR POLLUTION - NO WIND (NIGHT)

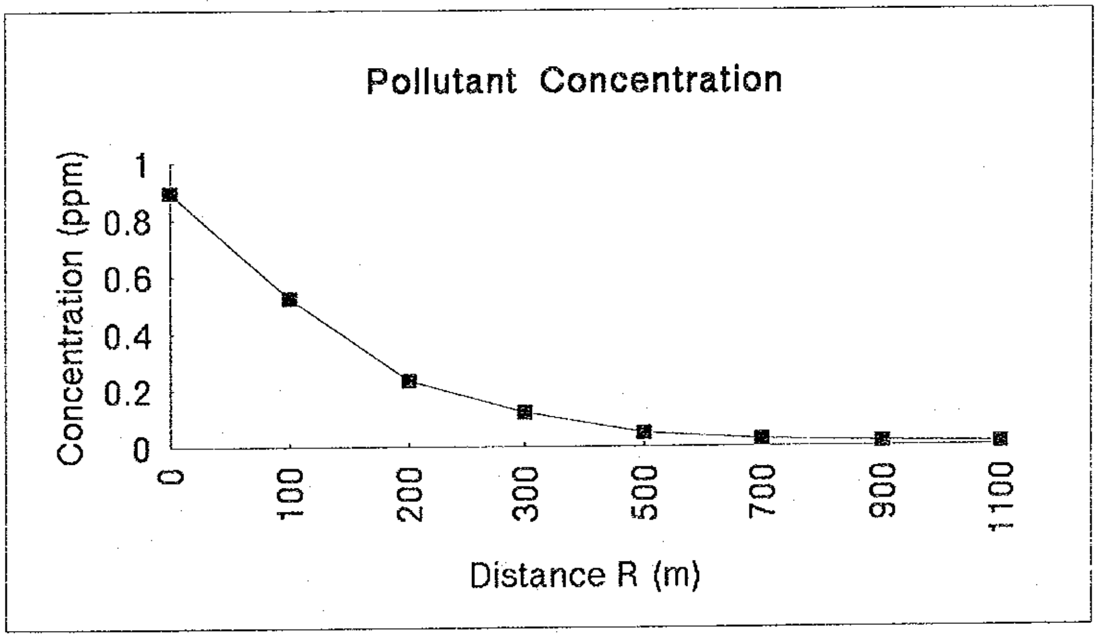
This is "Single Source Model" of the analysis for air pollution when no wind blows and calculates an average concentration for an hour at the ground level under the following assumptions.
1 Ground levels at receptors are uniform (z=0).
2 Mixing height (lid height) is not considered.

Pollutant : SOx by Distilated Oil

Daytime or night? (D or N)	N
Vertical temperature gradient (Tz)=	0.01 (•C)
Height of Stack (Ho) =	50 (m)
Exhaust gas temperature (Tc) =	90 (•C)
Exhaust gas volume (Q) =	280 (Nm3/s)
Calory of exhaust gas (Qh) =	6174000 (cal/s)
Pollutant emission rate (Qp) =	0.0225 (Nm3/s)
Pasquill stability (St) =	D
Plume rise (dH) =	68.71015 (m)
Effective stack height (He) =	118.7101 (m)

Estimated Ground-Level Concentrations (ppm)

R(m)	0	100	200	300	500	700	900	1100
C	0.896037	0.524382	0.233648	0.121435	0.047869	0.025079	0.015341	0.010328



Appendix 16.1 Billing charges

		Collection (annual aggregate)	Rate of charge
		R.O.	
Government consumers	up to	5,000,000	1.5%
		15,000,000	1.75%
	over	15,000,000	2%
Private consumers	up to	5,000,000	3.75%
		15,000,000	4.85%
	over	15,000,000	5.95%

Note: Charges are made to the Government by a company named Oman Investment and Finance Company, which is contracted by the Governmeent for the metering and billing.

Appendix 16.2 Capital investments in water transmission/distribution facilities

1991-1995

	Item	Total	Disbursement schedule 1991	1992	1993	1994	1995
1	Improvements to the water network	9,000,000	9,000,000				
2	Automatic gaging of water level and ourflows in tanks	150,000		150,000			
3	Control in water leakage	550,000		550,000			
4	Purchasing pipes and valves--Phase 1	250,000		250,000			
5	Computerization	50,000		50,000			
6	Extension of water network (Muscat buckets)	75,000	15,000	15,000	15,000	15,000	15,000
7	Improvement in water quality for the purpose of flexibility and better operation	200,000		200,000			
8	Repair, replacement of water meters and valves in tanks	200,000			200,000		

Note: 1991-1993: Actually disbursed.
In addition, 65,000,000 R.O. has been allocated for desalination facilities.
It is reported that 41 kilometers of 1,000 mm transmission pipe line was installed last year, for which cost does not appear in this table.

APPENDIX 16.3 Economic Prices

The overall goal of the financial and economic analysis is to assess the level of "profitability" of the project concerned. In doing so, the financial analysis takes the market prices for the project's inputs and outputs, as those prices are actual to the project. The economic analysis, on the other hand, is concerned about the profitability of investing in the project to the society as a whole or the overall impact of the project on the nation's economy. Therefore, it is concerned about the real costs and benefits of the project's inputs and outputs to the nation, which may not be represented accurately by their market prices. Market prices can be distorted by the monopolistic practices of industries, and taxes, subsidies, quotas, and other regulatory measures of the country. Those distorted prices do not present real economic values and therefore, they, in the economic analysis, have to be "shadow priced" to reflect such values.

1. Economic prices of inputs

Project inputs are often classified into three broad categories, traded goods, non-traded goods, and primary production factors such as land and labor. Traded goods are imported goods, and non-traded goods are domestically produced goods. The main traded goods, as far as the Project is concerned, are power generation and desalination plant equipment. Cement, which is produced by the Oman Cement Company, can also be a traded good, when it, if not consumed locally, is exported. Non-traded goods are those which by their nature are supplied and consumed locally, and cover internal transportation (including that for imported capital equipment), overhead expenses, and construction materials such as gravels and sand.[1]

Economic prices or shadow prices of traded goods are international prices, or to be more accurate, so-called border prices. For the border price of an import good, the shadow price would be the c.i.f. (cost including insurance and freight) price at the nearest port plus related local transportation cost.[2] The foreign cost components are all at c.i.f. prices, and include the transportation costs from the Madinat Qaboos Port to Barka. For financial costs, import duties, if any, have to be added to the economic costs. We, however, expect that no import taxes will be applied to the Project.

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1 The outputs of the Project, namely, electricity and water are also non-traded goods, as they are only for domestic consumption.

2 Border prices for export goods are FOB minus domestic transfer costs.

Costs of none of the non-traded goods for the Project are comparatively large. In this case, it is not improper to use an average factor to derive shadow prices for all the non-traded goods. This factor can be called supplied conversion factor, and is meant to serve as an average of the conversion factors for various non-traded goods.[3] Because domestic industries are protected from foreign competition and also because the competition among local industries is relatively low in Oman, prices of domestic products may be distorted by the industries' monopolistic behavior. Non-traded goods may contain trade materials, which are subject to 5% duties. Taking into account these elements, we assume a standard conversion factor of 0.9.

Natural gas will be used as the main fuel for the operation of the Project. The county's gas is currently consumed domestically, and not exported, while studies have been made into possible sales to foreign countries through undersea pipe line transportation or in the form of LNG. Since 1985, the price of gas has been kept at 0.0283 R.O. per cubic meter. Regarding the real economic price of gas, we will make an analysis immediately after this section. Also, for the economic price of electricity, the actual generation cost will be adapted.

Land and labor are the primary production factors of the Project. The Project's site is located along the beach, outside the town of Barka, and is as large as 61 hectares. Since the land is contributed by the Royal Family, no financial cost will be incurred to the Project. The adjacent area of the site is under-utilized, with no houses or agricultural activities. The land has no unique features, with many comparable properties along the coast. The land price could be a few millions of Real Omani. Nevertheless, simply because the land price would be small compared to the total cost of the Project and because the foregone cost of not using the land for other purposes would be insignificant, we will disregard the land cost in our economic analysis.

Most of the labor required, both skilled and non-skilled workers, will be from foreign countries. Foreign labor is a traded input, of which conversion factor can be computed by dividing the forgone foreign exchange plus the workers' subsistence in the country by the financial wages paid by the Project. We assume the overall conversion factor of the labor required will be at 0.9, indicating that the economic border value of labor is 90% of what the Project will pay for the labor.

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3 Conversion factor = Economic border value / Financial value.

In sum, for domestic cost components including non-traded goods and labor, we will apply the conversion factor of 0.9. No economic cost is assumed for the land.

2. Economic price of natural gas

Compared with the initial capital investment, the cost of fuel (natural gas) for the operation of the Project is not high. In the long run, however, it is worth assigning an economic price to the natural gas.

The country has proven reserves of natural gas amounting 17 TCF. If the reserved gas is consumed in such a way in which it depletes in 20 years, approximately 260 billion cubic feet of gas can be consumed annually. By comparison, 2.044 billion cubic feet of gas was consumed in 1993, including 1.577 billion cubic feet for power generation and 0.467 for water production.

In determining the economic value of natural gas or its opportunity cost, options have to be explored for the "use" of natural gas. First, gas can be left underground for future use, say, until oil runs out. Secondly, gas can be liquidified and exported by ship. Negotiations are reportedly under way with potential partners for a LNG project. Thirdly, gas can be exported through gas pipes. In fact, a feasibility study was proposed in 1993 for a plan to install undersea gas pipes to India, although the proposal was reportedly dropped later. This option is not likely to be taken, and therefore is not considered here.

The first option concerns the opportunity cost of not deterring the use of natural gas until sometime in the future. We assume that the country's oil will be exhausted in 20 years and then gas will be used as the main energy source. The opportunity cost, therefore, will be equivalent to the present worth of oil used in 20 years from now. We assume the discount factor at 8% and the oil price in 20 years at US$28 per barrel. With the calorific values of 10.35 KWH/CM for natural gas and 10.6 KWH/l for crude oil, the opportunity cost is computed at $0.04200 per cubic meter (= $28/barrel / 159l/barrel x 10.6 KWH/l / 10.3 KWH/CM x 0.2317). The biggest problem of this option is simply that future is not known regarding the availability or the reserve of oil and/or natural gas.

The second option concerned is the world LNG price, although LNG prices vary significantly among projects. It is reported that the prices of LNG currently offered include \$7.936 x 10^{-6} per kcal by Vietnam and \$12 x 10^{-6} per kcal by Qatar. At the calorific value of 7,968 kcal/m^3 for Oman's natural gas, these prices are equivalent to \$0.063234 per cubic meter and \$0.095616 per cubic meter, respectively. It should be noted that these prices are merely asking prices, and the final prices agreed by both parties can be significantly lower.

Taking the average of these two prices as the price of the second option, the current actual price, the price of the first option and the price of the second option are compared to each other as follows:

Actual (market) price:	\$7.36 x 10^{-2}/m^3 (2.83 x 10^{-2} R.O./m^3)
Price of 1st option:	\$4.20 x 10^{-2}/m^3
Price of 2nd option:	\$7.94 x 10^{-2}/m^3

With too many unknowns, however, we do not shadow-price the cost of natural gas. And for the purpose of simplification, the actual price will be shadow-priced at the same conversion factor that is used for other local input components.

3. Economic prices of outputs

The shadow price or the economic price of the project outputs can be measured by the benefits received from the increased supply of the outputs. It can be also measured by consumer surplus, which is the difference between what consumers are prepared or willing to pay for the outputs and what they actually pay.[4]

For a utility project, even a crude estimation of its benefit is difficult, as we do not know how to measure the benefit an individual gets, for example, by becoming able to use an air-conditioner. The consumer surplus of an industrial enterprise for public power can be measured by comparing the cost it pays for the power and the cost it would have to pay by having its own captive power. This type of case, however, is quite rare.

Basically, benefits generated by utilities projects are not quantifiable. For this reason, the usual practice is to ignore the consumer surplus and equate the benefits with the revenues received from the consumers. It must be noted, however, that this revenue-base approach is likely to underestimate the benefits, as the consumer surplus is often

4 Strictly speaking, there may be external benefits that the individual consumers do not perceive, and as a result, their willing to pay will be underestimated.

grossly higher than what consumers pay even in countries where utilities are provided at cost.

In this study, we take a revenue-based approach as well as an approach where the Project's cost is compared with the cost that would be incurred by an alternative method of producing or supplying the same outputs.

APPENDIX 16.4 Capital and operating costs

Table 1 shows the unit rate of operating cost used for the calculation of the operating cost of each alternative. Some explanation concerning the unit rate is also provided below. Tables 2 to 5 compare estimated capital and operating costs of four alternatives.

Table 1 Unit rate of operating cost

Electricity				
Item		Unit	BPST	CC
Fuel cost		R.O./kWh	0.00444	0.00703
Manpower		R.O./kWh	0.00042	0.00021
Spares		R.O./kWh	0.00057	0.00029
Others		R.O./kWh	0.00020	0.00010
Sub total		R.O./kWh	0.00563	0.00763
Water				
Item		Unit	MSF	RO
Fuel cost		R.O./m3	0.30114	
Electric. cost		R.O./m3		0.09520
Manpower		R.O./m3	0.01703	0.00538
Chemicals & consumables		R.O./m3	0.01708	0.02061
Spares & memblane replacement		R.O./m3	0.03102	0.09358
Sub total		R.O./m3	0.36627	0.21477
Unit rate of energy consumption				
Item		Unit	BPST/MSF	CC/RO
Calorific value of NG		kcal/m3N	7210	7210
Gene. effic.		%	19	48
NG consumption per kWh		m3N/kWh	0.62778305	0.24849746
NG cost		R.O./m3N	0.0283	0.0283
Power energy cost		R.O./kWh	0.01777	0.00703
Cost shear	Elec.		0.25	1
	Water		0.75	
NG cost per elect.		R.O./kWh	0.00444	
Power gene. per water		kWh/m3	22.6	
Power consumption per water		kWh/m3	5.4	6.8
Power export per water		kWh/m3	17.2	
Energy cost per water		R.O./m3	0.30114	
Export rate				
Item	Unit	C.C.	BPST	Water
Inplant consumption	%	2.0	24.2	2.0
Export rate		0.98	0.758	0.98

Note: CC: Combined cycle
BPST: Back pressure steam turbine

1. Unit rates for electricity (for power plant)

(1) Fusel cost

Fuel cost is calculated by using the following formula:

$$Gf = 860/(n.H)$$
$$Pf = Gf \times Uf$$

where,

Gf:	fuel consumption (m^3N/KWH)
Pf:	fuel cost (R.O./KWH)
n:	thermal efficiency of the plant 0.19 - Back pressure steam turbine plant (BPST) 0.48 - Combined cycle plant (C/C)
H:	heating value of natural gas LHV = 7,210 kcal/M^3N
Uf:	unit fuel cost 0.0283 R.O./m^3N

Further fuel cost Pf for BPST is shared between power plant and desalination plant as a ratio of 0.25 and 0.75 based on the heat utilization rate of 80% which is divided into 19% for power and 61% for water.

Thus Pf for the Barka Project is set at:

0.00444 R.O./KWH for BPST
0.00703 R.O./KWH for C/C

(2) Manpower

Manpower required for operation and maintenance of the plant is estimated according to the organization chart and the number of personnel provided in Chapter 12 Operation and Maintenance Plan. Manpower costs at the Ghubrah Power and Desalination Plant given in the MEW Annual Report of 1993 are also taken into consideration.

The unit rate for the manpower to be used for the Barka Project is set at 0.00021 R.O./KWH for both BPST and C/C.

(3) Spare parts

Spare parts and consumables necessary for operation and maintenance of the plant are estimated at 0.00029 R.O./KWH for both BPST and C/C based on data available from similar plants, in consideration of the data at the Ghubrah Plant.

(4) Others

Miscellaneous costs necessary for operation and maintenance of the plant are estimated at 0.0001 R.O./KWH for both BPST and C/C based on data available from similar plants, in consideration of the data at the Ghubrah Plant.

2. Unit rates for water (for desalination plant)

(1) Fuel cost

Fuel cost for the MSF process desalination plant is obtained from the fuel cost calculated above for BPST and converted into the unit fuel cost to produce a unit volume of water. The unit rate is set at 0.30114 R.O./m^3.

(2) Electricity cost

The RO process desalination plant requires only electrical energy, the unit rate of which is assumed to be 0.014 R.O./KWH, thus resulting in the unit electricity cost of 0.0952 R.O./m^3 to produce water.

(3) Manpower

Manpower required for operation and maintenance of the desalination plant is estimated according to the organization chart and the number of personnel provided in Chapter 12 Operation and Maintenance Plan. Manpower costs at the Ghubrah Power and Desalination Plant given in the MEW Annual Report 1993 are also taken into consideration.

The unit rate for the manpower to be used for the Barka Project is set at:

0.01703 R.O./m^3 for MSF process
0.00538 R.O./m^3 for RO process.

(4) Chemicals and consumables

Chemicals and consumables necessary for operation and maintenance of the plants are estimated below by using the data available from similar plants:

0.01708 R.O./m^3 for MSF process
0.02061 R.O./m^3 for RO process.

(5) Spare parts and membrane replacement

Spare parts and membrane replacement (the latter applicable to the RO process only) necessary for operation and maintenance of the plants are estimated below in consideration of the data at the Ghubrah Plant:

0.03102 R.O./m^3 for MSF process
0.09358 R.O./m^3 for RO process.

3. Energy consumption for desalination plant

As explained in Chapter 9 Conceptual Design of Desalination Plant, the power consumption to produce a unit volume of water is assumed at:

5.4 KWH/m^3 for MSF process
6.8 KWH/m^3 for RO process.

As power generated by BPST is assumed at 22.6 KWH/m^3, power available for export results in 17.2 KWH/m^3 (=22.6 - 5.4) in case of the MSF process desalination plant.

Energy cost per water of 0.30114 R.O./m^3 is obtained by the following formula:

Energy cost per water (R.O./m^3)
= fuel consumption (m^3N) x unit fuel cost (R.O./m^3N) ÷ water produced (m^3)

4. Export rate

Part of power generated or water produced by the Barka Plant will be used at the plant as station (in-plant) consumption for auxiliaries or other purposes, with the remainder being exported from the plant to consumers. The export rate is set at:

0.758 for power generated by BPST
0.980 for power generated by C/C
0.980 for water produced by the desalination plant

Appendix 16.4 Table 2 Capital and operating costs--Alternative 1

million R.O.

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1 Requirements																
Power																
1 Energy (MWH)			480,804	917,424	1,380,315	1,873,336	2,397,365	2,954,389	3,546,528	4,173,583	4,755,715	5,370,760	6,020,661	6,707,482	7,433,412	
2 Power (MW)			106	201	302	409	523	644	774	910	1,037	1,171	1,313	1,462	1,620	
3 Installed capacity (MW)																
C.C.			192	292	388	484	580	680	776	972	972	1,164	1,264	1,456	1,556	
BPST			0	60	60	60	120	120	120	120	180	180	180	240	240	
Total			192	352	448	544	700	800	896	1,092	1,152	1,344	1,444	1,696	1,796	
Water																
1 Water production (m3)				10,131	20,224	34,999	50,500	66,764	83,829	100,525	115,089	130,298	146,183	162,779	180,122	
2 Installed capacity (m3/d)																
2 Capital costs																
Power																
Foreign	16.92	127.81	19.12	3.59	36.40	45.09	12.84	47.05	37.73	9.35	62.68	27.85	62.68	7.08	0.00	516.19
Local	3.16	14.35	14.08	0.04	0.56	3.21	0.66	3.10	0.48	0.53	3.20	0.75	3.32	0.29	0.00	47.73
Sub total	20.08	142.16	33.20	3.63	36.96	48.30	13.50	50.15	38.21	9.88	65.88	28.60	66.00	7.37	0.00	563.92
Water																
Foreign	9.04	64.58	9.95	5.50	42.04	6.52	0.00	5.50	42.04	6.52	6.93	53.49	7.96	0.00	0.00	260.07
Local	3.80	21.05	13.15	1.02	5.39	3.81	0.00	1.02	5.39	3.81	1.38	7.52	4.86	0.00	0.00	72.20
Sub total	12.84	85.63	23.10	6.52	47.43	10.33	0.00	6.52	47.43	10.33	8.31	61.01	12.82	0.00	0.00	332.27
Total																
Foreign	25.96	192.39	29.07	9.09	78.44	51.61	12.84	52.55	79.77	15.87	69.61	81.34	70.64	7.08	0.00	776.26
Local	6.96	35.40	27.23	1.06	5.95	7.02	0.66	4.12	5.87	4.34	4.58	8.27	8.18	0.29	0.00	119.93
Total	32.92	227.79	56.30	10.15	84.39	58.63	13.50	56.67	85.64	20.21	74.19	89.61	78.82	7.37	0.00	896.19
3 Operating costs																
Power																
Foreign			0.14	0.31	0.45	0.59	0.80	0.97	1.15	1.32	1.57	1.74	1.93	2.18	2.40	15.53
Local			3.53	6.38	9.71	13.28	16.66	20.67	24.95	29.59	33.21	37.78	42.48	47.07	52.30	337.61
Sub total			3.67	6.68	10.16	13.87	17.46	21.64	26.09	30.91	34.78	39.52	44.41	49.25	54.70	353.14
Water																
Foreign				0.18	0.36	0.61	0.89	1.17	1.47	1.76	2.02	2.29	2.57	2.86	3.16	19.34
Local				1.18	2.35	4.06	5.86	7.75	9.74	11.67	13.37	15.13	16.98	18.90	20.92	127.91
Sub total				1.35	2.70	4.68	6.75	8.93	11.21	13.44	15.39	17.42	19.54	21.76	24.08	147.25
Total																
Foreign			0.14	0.48	0.80	1.21	1.69	2.14	2.62	3.09	3.59	4.02	4.50	5.04	5.56	34.87
Local			3.53	7.55	12.06	17.34	22.52	28.43	34.68	41.26	46.58	52.91	59.46	65.97	73.21	465.52
Total			3.67	8.04	12.86	18.55	24.21	30.57	37.30	44.35	50.17	56.94	63.95	71.01	78.78	500.39
4 Capital/Operating costs																
Foreign	25.96	192.39	29.21	9.57	79.24	52.82	14.53	54.69	82.39	18.96	73.20	85.36	75.14	12.12	5.56	811.13
Local	6.96	35.40	30.76	8.61	18.01	24.36	23.18	32.55	40.55	45.60	51.16	61.18	67.64	66.26	73.21	585.45
Grand total	32.92	227.79	59.97	18.19	97.25	77.18	37.71	87.24	122.94	64.56	124.36	146.55	142.77	78.38	78.78	1,396.58

Note: C.C.: Combined cycle
BPST: Back pressure steam turbine

Appendix 16.4 Table 3 Capital and operating costs--Alternative 2

million R.O.

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1 Requirements																
Power																
1 Energy (MWH)			475,898	913,345	1,376,776	1,872,470	2,399,234	2,959,055	3,554,049	4,183,412	4,767,198	5,383,898	6,035,450	6,723,916	7,451,482	
2 Power (MW)			106	202	304	413	529	652	783	921	1,050	1,185	1,329	1,480	1,640	
3 Installed capacity (MW)																
Total			192	388	484	580	680	776	972	1,068	1,164	1,360	1,456	1,652	1,848	
Water																
1 Water production (m3)				10,131	20,224	34,999	50,500	66,764	83,829	100,525	115,089	130,298	146,183	162,779	180,122	
2 Installed capacity (m3/d)																
2 Capital costs																
Power																
Foreign	15.16	114.11	19.54	23.65	42.35	12.57	44.46	27.19	23.23	44.87	30.31	48.57	51.95	24.66	0.00	522.62
Local	2.95	12.89	13.80	1.65	0.30	0.36	0.47	1.89	0.34	1.78	0.64	2.00	2.08	0.41	0.00	41.56
Sub total	18.11	127.00	33.34	25.30	42.65	12.93	44.93	29.08	23.57	46.65	30.95	50.57	54.03	25.07	0.00	564.18
Water																
Foreign	0.93	12.75	65.98	0.00	5.56	33.03	0.00	0.00	5.56	33.03	0.00	5.56	33.03	0.00	0.00	195.43
Local	1.14	8.63	23.75	0.00	1.11	9.92	0.00	0.00	1.11	9.92	0.00	1.11	9.92	0.00	0.00	66.61
Sub total	2.07	21.38	89.73	0.00	6.67	42.95	0.00	0.00	6.67	42.95	0.00	6.67	42.95	0.00	0.00	262.04
Total																
Foreign	16.09	126.86	85.52	23.65	47.91	45.60	44.46	27.19	28.79	77.90	30.31	54.13	84.98	24.66	0.00	718.05
Local	4.09	21.52	37.55	1.65	1.41	10.28	0.47	1.89	1.45	11.70	0.64	3.11	12.00	0.41	0.00	108.17
Total	20.18	148.38	123.07	25.30	49.32	55.88	44.93	29.08	30.24	89.60	30.95	57.24	96.98	25.07	0.00	826.22
3 Operating costs																
Power																
Foreign			0.14	0.26	0.39	0.53	0.68	0.84	1.01	1.19	1.36	1.53	1.72	1.92	2.12	13.71
Local			3.49	6.70	10.11	13.74	17.61	21.72	26.09	30.71	34.99	39.52	44.30	49.35	54.69	353.03
Sub total			3.63	6.96	10.50	14.28	18.29	22.56	27.10	31.90	36.35	41.05	46.02	51.27	56.82	366.73
Water																
Foreign				0.42	0.84	1.46	2.10	2.78	3.49	4.19	4.80	5.43	6.09	6.78	7.51	45.91
Local				0.37	0.74	1.28	1.85	2.45	3.08	3.69	4.23	4.78	5.37	5.98	6.61	40.44
Sub total				0.79	1.59	2.74	3.96	5.23	6.57	7.88	9.02	10.21	11.46	12.76	14.12	86.34
Total																
Foreign			0.14	0.68	1.24	1.99	2.79	3.63	4.51	5.38	6.16	6.97	7.81	8.70	9.63	59.61
Local			3.49	7.08	10.85	15.03	19.46	24.17	29.16	34.40	39.22	44.30	49.67	55.33	61.31	393.46
Total			3.63	7.76	12.08	17.02	22.25	27.80	33.67	39.78	45.37	51.27	57.48	64.03	70.94	453.08
4 Capital/Operating cost																
Foreign	16.09	126.86	85.66	24.33	49.15	47.59	47.25	30.82	33.30	83.28	36.47	61.10	92.79	33.36	9.63	777.66
Local	4.09	21.52	41.04	8.73	12.26	25.31	19.93	26.06	30.61	46.10	39.86	47.41	61.67	55.74	61.31	501.63
Grand total	20.18	148.38	126.70	33.06	61.40	72.90	67.18	56.88	63.91	129.38	76.32	108.51	154.46	89.10	70.94	1,279.30

Appendix 16.4 Table 4 Capital and operating costs--Alternative 3

million R.O.

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1 Requirements																
Power																
1 Energy (MWH)			480,804	917,424	1,380,315	1,873,336	2,397,365	2,954,389	3,546,528	4,173,583	4,755,715	5,370,760	6,020,661	6,707,482	7,433,412	
2 Power (MW)			106	201	302	409	523	644	774	910	1,037	1,171	1,313	1,462	1,620	
3 Installed capacity (MW)																
C.C.			480	680	680	680	680	680	872	872	1,556	1,556	1,556	1,556	1,556	
BPST				120	120	120	120	120	120	120	240	240	240	240	240	
Total			480	800	800	800	800	800	992	992	1,796	1,796	1,796	1,796	1,796	
Water																
1 Water production (m3)				10,131	20,224	34,999	50,500	66,764	83,829	100,525	115,089	130,298	146,183	162,779	180,122	
2 Installed capacity (m3/d)																
2 Capital costs																
Power																
Foreign	24.89	191.02	26.71	0.00	0.00	0.00	3.65	46.56	104.11	88.72	0.00	0.00	0.00	0.00	0.00	485.66
Local	3.45	16.67	14.39	0.00	0.00	0.00	0.02	1.17	7.74	1.41	0.00	0.00	0.00	0.00	0.00	44.85
Sub total	28.34	207.69	41.10	0.00	0.00	0.00	3.67	47.73	111.85	90.13	0.00	0.00	0.00	0.00	0.00	530.51
Water																
Foreign	13.81	101.61	15.47	0.00	0.00	0.00	0.00	10.31	79.17	12.04	1.43	11.45	1.44	0.00	0.00	246.73
Local	4.49	24.59	15.82	0.00	0.00	0.00	0.00	1.74	9.19	6.48	0.35	2.13	1.05	0.00	0.00	65.84
Sub total	18.30	126.20	31.29	0.00	0.00	0.00	0.00	12.05	88.36	18.52	1.78	13.58	2.49	0.00	0.00	312.57
Total																
Foreign	38.70	292.63	42.18	0.00	0.00	0.00	3.65	56.87	183.28	100.76	1.43	11.45	1.44	0.00	0.00	732.39
Local	7.94	41.26	30.21	0.00	0.00	0.00	0.02	2.91	16.93	7.89	0.35	2.13	1.05	0.00	0.00	110.69
Total	46.64	333.89	72.39	0.00	0.00	0.00	3.67	59.78	200.21	108.65	1.78	13.58	2.49	0.00	0.00	843.08
3 Operating costs																
Power																
Foreign			0.14	0.30	0.45	0.61	0.79	0.97	1.13	1.33	1.54	1.74	1.95	2.17	2.40	15.51
Local			3.53	6.42	9.66	13.11	16.78	20.67	25.05	29.48	33.46	37.79	42.36	47.19	52.30	337.79
Sub total			3.67	6.72	10.11	13.72	17.56	21.64	26.19	30.82	34.99	39.52	44.30	49.36	54.70	353.30
Water																
Foreign				0.18	0.36	0.61	0.89	1.17	1.47	1.76	2.02	2.29	2.57	2.86	3.16	19.34
Local				1.18	2.35	4.06	5.86	7.75	9.74	11.67	13.37	15.13	16.98	18.90	20.92	127.91
Sub total				1.35	2.70	4.68	6.75	8.93	11.21	13.44	15.39	17.42	19.54	21.76	24.08	147.25
Total																
Foreign			0.14	0.48	0.81	1.23	1.67	2.14	2.60	3.10	3.56	4.02	4.51	5.02	5.56	34.85
Local			3.53	7.60	12.01	17.17	22.64	28.43	34.79	41.16	46.82	52.92	59.33	66.09	73.21	465.71
Total			3.67	8.08	12.82	18.40	24.31	30.57	37.39	44.26	50.38	56.94	63.85	71.12	78.78	500.55
4 Capital/Operating costs																
Foreign	38.70	292.63	42.32	0.48	0.81	1.23	5.32	59.01	185.88	103.86	4.99	15.47	5.95	5.02	5.56	767.24
Local	7.94	41.26	33.74	7.60	12.01	17.17	22.66	31.34	51.72	49.05	47.17	55.05	60.38	66.09	73.21	576.40
Grand total	46.64	333.89	76.06	8.08	12.82	18.40	27.98	90.35	237.60	152.91	52.16	70.52	66.34	71.12	78.78	1,343.63

Appendix 16.4 Table 5 Capital and operating costs--Alternative 4

million R.O.

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1 Requirements																
Power																
1 Energy (MWH)			475,898	913,345	1,376,776	1,872,470	2,399,234	2,959,055	3,554,049	4,183,412	4,767,198	5,383,898	6,035,450	6,723,916	7,451,482	
2 Power (MW)			106	202	304	413	529	652	783	921	1,050	1,185	1,329	1,480	1,640	
3 Installed capacity (MW)																
Total			480	680	680	680	680	872	872	1,064	1,848	1,848	1,848	1,848	1,848	
Water																
1 Water production (m3)				10,131	20,224	34,999	50,500	66,764	83,829	100,525	115,089	130,298	146,183	162,779	180,122	
2 Installed capacity (m3/d)																
2 Capital costs																
Power																
Foreign	21.63	165.57	23.60	0.00	0.00	3.65	32.89	17.43	134.85	92.28	0.00	0.00	0.00	0.00	0.00	491.90
Local	3.12	14.25	13.84	0.00	0.00	0.02	0.20	0.77	5.93	1.42	0.00	0.00	0.00	0.00	0.00	39.55
Sub total	24.75	179.82	37.44	0.00	0.00	3.67	33.09	18.20	140.78	93.70	0.00	0.00	0.00	0.00	0.00	531.45
Water																
Foreign	0.92	17.63	94.62	0.00	0.00	0.00	0.00	0.00	10.40	61.30	0.00	0.00	0.00	0.00	0.00	184.87
Local	1.14	9.31	29.74	0.00	0.00	0.00	0.00	0.00	1.63	14.52	0.00	0.00	0.00	0.00	0.00	56.34
Sub total	2.06	26.94	124.36	0.00	0.00	0.00	0.00	0.00	12.03	75.82	0.00	0.00	0.00	0.00	0.00	241.21
Total																
Foreign	22.55	183.20	118.22	0.00	0.00	3.65	32.89	17.43	145.25	153.58	0.00	0.00	0.00	0.00	0.00	676.77
Local	4.26	23.56	43.58	0.00	0.00	0.02	0.20	0.77	7.56	15.94	0.00	0.00	0.00	0.00	0.00	95.89
Total	26.81	206.76	161.80	0.00	0.00	3.67	33.09	18.20	152.81	169.52	0.00	0.00	0.00	0.00	0.00	772.66
3 Operating costs																
Power																
Foreign			0.14	0.26	0.39	0.53	0.68	0.84	1.01	1.19	1.36	1.53	1.72	1.92	2.12	13.71
Local			3.49	6.70	10.11	13.74	17.61	21.72	26.09	30.71	34.99	39.52	44.30	49.35	54.69	353.03
Sub total			3.63	6.96	10.50	14.28	18.29	22.56	27.10	31.90	36.35	41.05	46.02	51.27	56.82	366.73
Water																
Foreign				0.42	0.84	1.46	2.10	2.78	3.49	4.19	4.80	5.43	6.09	6.78	7.51	45.91
Local				0.37	0.74	1.28	1.85	2.45	3.08	3.69	4.23	4.78	5.37	5.98	6.61	40.44
Sub total				0.79	1.59	2.74	3.96	5.23	6.57	7.88	9.02	10.21	11.46	12.76	14.12	86.34
Total																
Foreign			0.14	0.68	1.24	1.99	2.79	3.63	4.51	5.38	6.16	6.97	7.81	8.70	9.63	59.61
Local			3.49	7.08	10.85	15.03	19.46	24.17	29.16	34.40	39.22	44.30	49.67	55.33	61.31	393.46
Total			3.63	7.76	12.08	17.02	22.25	27.80	33.67	39.78	45.37	51.27	57.48	64.03	70.94	453.08
4 Capital/Operating costs																
Foreign	22.55	183.20	118.36	0.68	1.24	5.64	35.68	21.06	149.76	158.96	6.16	6.97	7.81	8.70	9.63	736.38
Local	4.26	23.56	47.07	7.08	10.85	15.05	19.66	24.94	36.72	50.34	39.22	44.30	49.67	55.33	61.31	489.35
Grand total	26.81	206.76	165.43	7.76	12.08	20.69	55.34	46.00	186.48	209.30	45.37	51.27	57.48	64.03	70.94	1,225.74

Appendix 16.5 Table 1 Discounted total cost--Alternative 1

1994 constant, million of R.O.

Year	Foreign (1)	Local (2)	Not shadow priced, total (3) = (1) + (2)	Shadow priced, local (4) = (2) x (0.9)	Shadow priced, total (5) = (1) + (4)	Discount fact (8%) (6)	Not shadow priced, discounted total (7) = (3) x (6)	Shadow priced, discounted total (BP) (8) = (5) x (6)
Capital costs								
1994						1.00		
1995						0.93		
1996	22.55	4.26	26.81	3.83	26.38	0.86	22.99	22.62
1997	183.20	23.56	206.76	21.20	204.40	0.79	164.13	162.26
1998	118.22	43.58	161.80	39.22	157.44	0.74	118.93	115.72
1999	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.00
2000	0.00	0.00	0.00	0.00	0.00	0.63	0.00	0.00
2001	3.65	0.02	3.67	0.02	3.67	0.58	2.14	2.14
2002	32.89	0.20	33.09	0.18	33.07	0.54	17.88	17.87
2003	17.43	0.77	18.20	0.69	18.12	0.50	9.10	9.07
2004	145.25	7.56	152.81	6.80	152.05	0.46	70.78	70.43
2005	153.58	15.94	169.52	14.35	167.93	0.43	72.70	72.02
2006	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00
2007	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00
2008	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00
2009	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00
Sub-total	676.77	95.89	772.66	86.30	763.07	9.85	478.65	472.13
Operating costs								
1994						1.00		
1995						0.93		
1996						0.86		
1997						0.79		
1998	0.14	3.49	3.63	3.14	3.28	0.74	2.67	2.41
1999	0.68	7.08	7.76	6.37	7.05	0.68	5.28	4.80
2000	1.24	10.85	12.08	9.76	11.00	0.63	7.61	6.93
2001	1.99	15.03	17.02	13.53	15.52	0.58	9.93	9.05
2002	2.79	19.46	22.25	17.52	20.31	0.54	12.02	10.97
2003	3.63	24.17	27.80	21.75	25.38	0.50	13.91	12.70
2004	4.51	29.16	33.67	26.25	30.75	0.46	15.60	14.25
2005	5.38	34.40	39.78	30.96	36.34	0.43	17.06	15.59
2006	6.16	39.22	45.37	35.29	41.45	0.40	18.02	16.46
2007	6.97	44.30	51.27	39.87	46.84	0.37	18.85	17.22
2008	7.81	49.67	57.48	44.70	52.51	0.34	19.57	17.88
2009	8.70	55.33	64.03	49.80	58.50	0.32	20.19	18.44
2010	9.63	61.31	70.94	55.18	64.81	0.29	20.71	18.92
Sub-total	59.61	393.46	453.08	354.12	413.73	9.85	181.41	165.61
Total								
1994						1.00		
1995						0.93		
1996	22.55	4.26	26.81	3.83	26.38	0.86	22.99	22.62
1997	183.20	23.56	206.76	21.20	204.40	0.79	164.13	162.26
1998	118.36	47.07	165.43	42.37	160.72	0.74	121.60	118.14
1999	0.68	7.08	7.76	6.37	7.05	0.68	5.28	4.80
2000	1.24	10.85	12.08	9.76	11.00	0.63	7.61	6.93
2001	5.64	15.05	20.69	13.54	19.19	0.58	12.07	11.20
2002	35.68	19.66	55.34	17.70	53.38	0.54	29.90	28.84
2003	21.06	24.94	46.00	22.45	43.50	0.50	23.01	21.76
2004	149.76	36.72	186.48	33.05	182.81	0.46	86.38	84.68
2005	158.96	50.34	209.30	45.30	204.27	0.43	89.76	87.61
2006	6.16	39.22	45.37	35.29	41.45	0.40	18.02	16.46
2007	6.97	44.30	51.27	39.87	46.84	0.37	18.85	17.22
2008	7.81	49.67	57.48	44.70	52.51	0.34	19.57	17.88
2009	8.70	55.33	64.03	49.80	58.50	0.32	20.19	18.44
2010	9.63	61.31	70.94	55.18	64.81	0.29	20.71	18.92
Grand total	736.38	489.35	1,225.74	440.42	1,176.80	9.85	660.06	637.74

Note: An average conversion factor (estimated) of 0.9 was applied to the local cost components.

Appendix 16.5 Table 2 Discounted total cost--Alternative 2

1994 constant, million of R.O.

Year	Foreign	Local	Not shadow priced, total	Shadow priced, local	Shadow priced, total	Discount factor (8%)	Not shadow priced, discounted total	Shadow priced, discounted total (BP)
	(1)	(2)	(3) = (1) + (2)	(4) = (2) x (0.9)	(5) = (1) + (4)	(6)	(7) = (3) x (6)	(8) = (5) x (6)
Capital costs								
1994						1.00		
1995						0.93		
1996	38.70	7.94	46.64	7.15	45.85	0.86	39.99	39.31
1997	292.63	41.26	333.89	37.13	329.76	0.79	265.05	261.78
1998	42.18	30.21	72.39	27.19	69.37	0.74	53.21	50.99
1999	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.00
2000	0.00	0.00	0.00	0.00	0.00	0.63	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00
2002	3.65	0.02	3.67	0.02	3.67	0.54	1.98	1.98
2003	56.87	2.91	59.78	2.62	59.49	0.50	29.90	29.76
2004	183.28	16.93	200.21	15.24	198.52	0.46	92.74	91.95
2005	100.76	7.89	108.65	7.10	107.86	0.43	46.60	46.26
2006	1.43	0.35	1.78	0.32	1.75	0.40	0.71	0.69
2007	11.45	2.13	13.58	1.92	13.37	0.37	4.99	4.92
2008	1.44	1.05	2.49	0.95	2.39	0.34	0.85	0.81
2009	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00
Sub-total	732.39	110.69	843.08	99.62	832.01	9.85	536.02	528.44
Operating costs								
1994						1.00		
1995						0.93		
1996						0.86		
1997						0.79		
1998	0.14	3.53	3.67	3.18	3.31	0.74	2.69	2.44
1999	0.48	7.60	8.08	6.84	7.32	0.68	5.50	4.98
2000	0.81	12.01	12.82	10.81	11.61	0.63	8.08	7.32
2001	1.23	17.17	18.40	15.46	16.69	0.58	10.74	9.74
2002	1.67	22.64	24.31	20.38	22.05	0.54	13.14	11.91
2003	2.14	28.43	30.57	25.59	27.73	0.50	15.29	13.87
2004	2.60	34.79	37.39	31.31	33.91	0.46	17.32	15.71
2005	3.10	41.16	44.26	37.04	40.14	0.43	18.98	17.22
2006	3.56	46.82	50.38	42.14	45.70	0.40	20.01	18.15
2007	4.02	52.92	56.94	47.63	51.65	0.37	20.94	18.99
2008	4.51	59.33	63.85	53.40	57.91	0.34	21.74	19.72
2009	5.02	66.09	71.12	59.48	64.51	0.32	22.42	20.34
2010	5.56	73.21	78.78	65.89	71.46	0.29	22.99	20.86
Sub-total	34.85	465.71	500.55	419.13	453.98	9.85	199.83	181.22
Total								
1994						1.00		
1995						0.93		
1996	38.70	7.94	46.64	7.15	45.85	0.86	39.99	39.31
1997	292.63	41.26	333.89	37.13	329.76	0.79	265.05	261.78
1998	42.32	33.74	76.06	30.37	72.68	0.74	55.90	53.42
1999	0.48	7.60	8.08	6.84	7.32	0.68	5.50	4.98
2000	0.81	12.01	12.82	10.81	11.61	0.63	8.08	7.32
2001	1.23	17.17	18.40	15.46	16.69	0.58	10.74	9.74
2002	5.32	22.66	27.98	20.40	25.72	0.54	15.12	13.89
2003	59.01	31.34	90.35	28.20	87.21	0.50	45.20	43.63
2004	185.88	51.72	237.60	46.55	232.43	0.46	110.06	107.66
2005	103.86	49.05	152.91	44.14	148.00	0.43	65.58	63.47
2006	4.99	47.17	52.16	42.46	47.44	0.40	20.71	18.84
2007	15.47	55.05	70.52	49.54	65.01	0.37	25.93	23.91
2008	5.95	60.38	66.34	54.35	60.30	0.34	22.58	20.53
2009	5.02	66.09	71.12	59.48	64.51	0.32	22.42	20.34
2010	5.56	73.21	78.78	65.89	71.46	0.29	22.99	20.86
Grand total	767.24	576.40	1,343.63	518.76	1,285.99	9.85	735.84	709.67

Appendix 16.5 Table 3 Discounted total cost--Alternative 3

1994 constant, million of R.O.

Year	Foreign	Local	Not shadow priced, total	Shadow priced, local	Shadow priced, total	Discount factor (8%)	Not shadow priced, discounted total	Shadow priced, discounted total (BP)
	(1)	(2)	(3) = (1) + (2)	(4) = (2) x (0.9)	(5) = (1) + (4)	(6)	(7) = (3) x (6)	(8) = (5) x (6)
Capital costs								
1994						1.00		
1995						0.93		
1996	16.09	4.09	20.18	3.68	19.77	0.86	17.30	16.95
1997	126.86	21.52	148.38	19.37	146.23	0.79	117.79	116.08
1998	85.52	37.55	123.07	33.80	119.32	0.74	90.46	87.70
1999	23.65	1.65	25.30	1.49	25.14	0.68	17.22	17.11
2000	47.91	1.41	49.32	1.27	49.18	0.63	31.08	30.99
2001	45.60	10.28	55.88	9.25	54.85	0.58	32.61	32.01
2002	44.46	0.47	44.93	0.42	44.88	0.54	24.27	24.25
2003	27.19	1.89	29.08	1.70	28.89	0.50	14.55	14.45
2004	28.79	1.45	30.24	1.31	30.10	0.46	14.01	13.94
2005	77.90	11.70	89.60	10.53	88.43	0.43	38.43	37.93
2006	30.31	0.64	30.95	0.58	30.89	0.40	12.29	12.27
2007	54.13	3.11	57.24	2.80	56.93	0.37	21.05	20.93
2008	84.98	12.00	96.98	10.80	95.78	0.34	33.02	32.61
2009	24.66	0.41	25.07	0.37	25.03	0.32	7.90	7.89
2010	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00
Sub-total	718.05	108.17	826.22	97.35	815.40	9.85	471.97	465.10
Operating costs								
1994						1.00		
1995						0.93		
1996						0.86		
1997						0.79		
1998	0.14	3.49	3.63	3.14	3.28	0.74	2.67	2.41
1999	0.68	7.08	7.76	6.37	7.05	0.68	5.28	4.80
2000	1.24	10.85	12.08	9.76	11.00	0.63	7.61	6.93
2001	1.99	15.03	17.02	13.53	15.52	0.58	9.93	9.05
2002	2.79	19.46	22.25	17.52	20.31	0.54	12.02	10.97
2003	3.63	24.17	27.80	21.75	25.38	0.50	13.91	12.70
2004	4.51	29.16	33.67	26.25	30.75	0.46	15.60	14.25
2005	5.38	34.40	39.78	30.96	36.34	0.43	17.06	15.59
2006	6.16	39.22	45.37	35.29	41.45	0.40	18.02	16.46
2007	6.97	44.30	51.27	39.87	46.84	0.37	18.85	17.22
2008	7.81	49.67	57.48	44.70	52.51	0.34	19.57	17.88
2009	8.70	55.33	64.03	49.80	58.50	0.32	20.19	18.44
2010	9.63	61.31	70.94	55.18	64.81	0.29	20.71	18.92
Sub-total	59.61	393.46	453.08	354.12	413.73	9.85	181.41	165.61
Total								
1994						1.00		
1995						0.93		
1996	16.09	4.09	20.18	3.68	19.77	0.86	17.30	16.95
1997	126.86	21.52	148.38	19.37	146.23	0.79	117.79	116.08
1998	85.66	41.04	126.70	36.94	122.59	0.74	93.13	90.11
1999	24.33	8.73	33.06	7.85	32.19	0.68	22.50	21.91
2000	49.15	12.26	61.40	11.03	60.18	0.63	38.69	37.92
2001	47.59	25.31	72.90	22.78	70.37	0.58	42.54	41.06
2002	47.25	19.93	67.18	17.94	65.19	0.54	36.30	35.22
2003	30.82	26.06	56.88	23.45	54.27	0.50	28.45	27.15
2004	33.30	30.61	63.91	27.55	60.85	0.46	29.60	28.19
2005	83.28	46.10	129.38	41.49	124.77	0.43	55.49	53.51
2006	36.47	39.86	76.32	35.87	72.34	0.40	30.31	28.73
2007	61.10	47.41	108.51	42.67	103.77	0.37	39.90	38.15
2008	92.79	61.67	154.46	55.50	148.29	0.34	52.59	50.49
2009	33.36	55.74	89.10	50.17	83.53	0.32	28.09	26.33
2010	9.63	61.31	70.94	55.18	64.81	0.29	20.71	18.92
Grand total	777.66	501.63	1,279.30	451.47	1,229.13	9.85	653.38	630.71

Appendix 16.5 Table 4 Discounted total cost--Alternative 4

1994 constant, million of R.O.

Year	Foreign	Local	Not shadow priced, total	Shadow priced, local	Shadow priced, total	Discount factor (8%)	Not shadow priced, discounted total	Shadow priced, discounted total (BP)
	(1)	(2)	(3) = (1) + (2)	(4) = (2) x (0.9)	(5) = (1) + (4)	(6)	(7) = (3) x (6)	(8) = (5) x (6)
Capital costs								
1994						1.00		
1995						0.93		
1996	25.96	6.96	32.92	6.26	32.22	0.86	28.22	27.63
1997	192.39	35.40	227.79	31.86	224.25	0.79	180.83	178.02
1998	29.07	27.23	56.30	24.51	53.58	0.74	41.38	39.38
1999	9.09	1.06	10.15	0.95	10.04	0.68	6.91	6.84
2000	78.44	5.95	84.39	5.36	83.80	0.63	53.18	52.81
2001	51.61	7.02	58.63	6.32	57.93	0.58	34.21	33.80
2002	12.84	0.66	13.50	0.59	13.43	0.54	7.29	7.26
2003	52.55	4.12	56.67	3.71	56.26	0.50	28.35	28.14
2004	79.77	5.87	85.64	5.28	85.05	0.46	39.67	39.40
2005	15.87	4.34	20.21	3.91	19.78	0.43	8.67	8.48
2006	69.61	4.58	74.19	4.12	73.73	0.40	29.46	29.28
2007	81.34	8.27	89.61	7.44	88.78	0.37	32.95	32.65
2008	70.64	8.18	78.82	7.36	78.00	0.34	26.84	26.56
2009	7.08	0.29	7.37	0.26	7.34	0.32	2.32	2.31
2010	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00
Sub-total	776.26	119.93	896.19	107.94	884.20	9.85	520.28	512.54
Operating costs								
1994						1.00		
1995						0.93		
1996						0.86		
1997						0.79		
1998	0.14	3.53	3.67	3.18	3.31	0.74	2.69	2.44
1999	0.48	7.55	8.04	6.80	7.28	0.68	5.47	4.96
2000	0.80	12.06	12.86	10.85	11.65	0.63	8.10	7.34
2001	1.21	17.34	18.55	15.61	16.82	0.58	10.82	9.81
2002	1.69	22.52	24.21	20.27	21.96	0.54	13.08	11.86
2003	2.14	28.43	30.57	25.59	27.73	0.50	15.29	13.87
2004	2.62	34.68	37.30	31.22	33.83	0.46	17.28	15.67
2005	3.09	41.26	44.35	37.14	40.22	0.43	19.02	17.25
2006	3.59	46.58	50.17	41.92	45.51	0.40	19.92	18.07
2007	4.02	52.91	56.94	47.62	51.65	0.37	20.94	18.99
2008	4.50	59.46	63.95	53.51	58.01	0.34	21.77	19.75
2009	5.04	65.97	71.01	59.38	64.42	0.32	22.39	20.31
2010	5.56	73.21	78.78	65.89	71.46	0.29	22.99	20.86
Sub-total	34.87	465.52	500.39	418.97	453.84	9.85	199.78	181.18
Total								
1994						1.00		
1995						0.93		
1996	25.96	6.96	32.92	6.26	32.22	0.86	28.22	27.63
1997	192.39	35.40	227.79	31.86	224.25	0.79	180.83	178.02
1998	29.21	30.76	59.97	27.68	56.89	0.74	44.08	41.82
1999	9.57	8.61	18.19	7.75	17.33	0.68	12.38	11.79
2000	79.24	18.01	97.25	16.21	95.45	0.63	61.28	60.15
2001	52.82	24.36	77.18	21.93	74.74	0.58	45.03	43.61
2002	14.53	23.18	37.71	20.87	35.39	0.54	20.37	19.12
2003	54.69	32.55	87.24	29.29	83.98	0.50	43.64	42.01
2004	82.39	40.55	122.94	36.50	118.89	0.46	56.95	55.07
2005	18.96	45.60	64.56	41.04	60.00	0.43	27.69	25.73
2006	73.20	51.16	124.36	46.04	119.24	0.40	49.38	47.35
2007	85.36	61.18	146.55	55.06	140.43	0.37	53.88	51.64
2008	75.14	67.64	142.77	60.87	136.01	0.34	48.61	46.31
2009	12.12	66.26	78.38	59.64	71.76	0.32	24.71	22.62
2010	5.56	73.21	78.78	65.89	71.46	0.29	22.99	20.86
Grand total	811.13	585.45	1,396.58	526.91	1,338.04	9.85	720.05	693.72

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