Appendix 5.2

Leachate Generated from Landfill

APPENDIX 5.2 LEACHATE GENERATED FROM LANDFILL

A. EXTREME RAINFALL DATA

To design a leachate treatment facility, the worst-case scenario of peak runoff production during humic climatic conditions is adopted. Extreme Values of rainfall data between 1947 to 2005 are obtained from the Hong Kong Observatory and are summarised below.

Table 1 Extremes Rainfall Data (mm) observed at the Hong Kong Observatory between 1995-2005

Month	Hourly maximum	Daily Maximum	5-Day Extremes Rainfall	10-Day Extremes Rainfall	Half-month Extremes Rainfall
Jan	-	-	48.5 16-20/01/2004	-	-
	-	-	70.2 21-25/01/2000	-	-
Mar	52.5 23/03/2002	130.0 23/03/2002	163.8 22-26/03/2002	237.6 21-31/03/2002	-
Jun	-	411.3 09/06/1998	471.7 5-9/06/1998	-	-
	-	-	479.2 20-24/06/2005	575.8 21-30/06/2005	-
Jul	-	-	372.4 30/06–4/07/1997	429.3 1-10/07/1997	547.1 01-15/071997
Aug	-	-	387.6 9-13/08/1995	-	816.3 1-15/08/1995
	-	-	564.0 19-23/08/2005	809.8 11-20/08/2005	757.2 16-31/08/2005
	-	-	-	640.1 21-31/08/1999	-
Sept	-	-	511.2 13-17/09/2002	478.3 1-10/09/2001	484.3 1-15/09/2001
Oct	-	-	-	462.2 1-10/10/1995	476.0 1-15/10/1995
Dec	-	-	50.6 12-16/12/2000	-	-

As shown in the above table, extreme rainfall events were recorded during summer season from July to October in Year 1995, 1997, 2001 and 2005. Rainfall in winter season is only half of that in summer times and will not be a concern.

"Technical Note No. 107 on Climate Change in Hong Kong" published by the Hong Kong Observatory had been reviewed. It is observed that maximum annual rainfall and hourly rainfall were recorded in Year 1997 and 2001 as shown in the Figure 1 and Figure 2 below. It is also revealed from Figure 2 that the occurrence of hourly rainfall greater than 30 mm in Year 2001 is higher than that of 1997. It is therefore recommended to use meteorological data of Year 2001 to represent the worst-case scenario for leachate generation in the landfill extension.

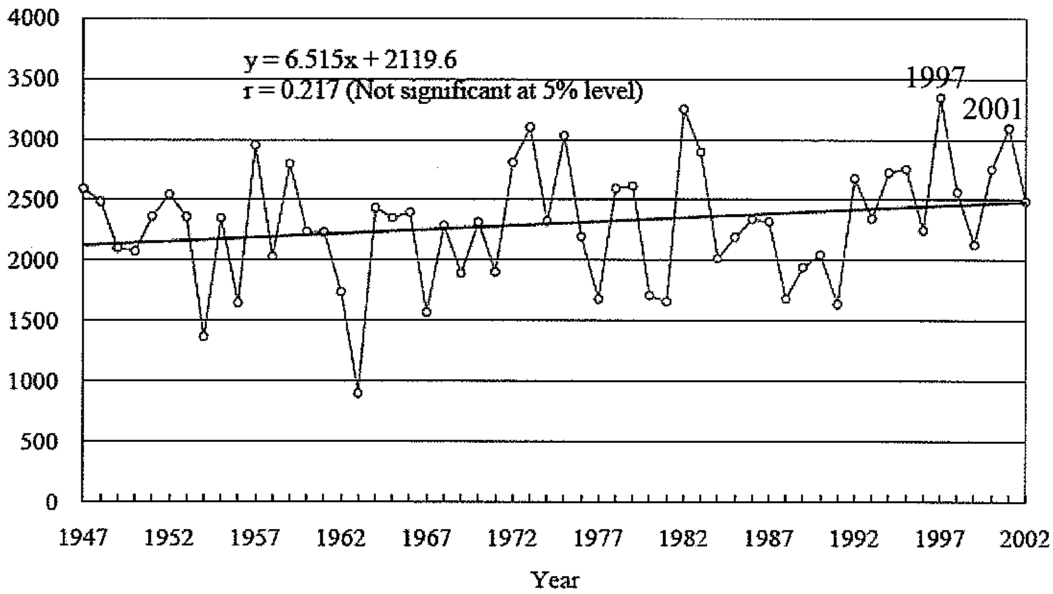


Figure 1 **Annual Rainfall at Hong Kong Observatory Headquarters (1947-2002) [Extract from Figure 18 of Technical Note No. 107]**

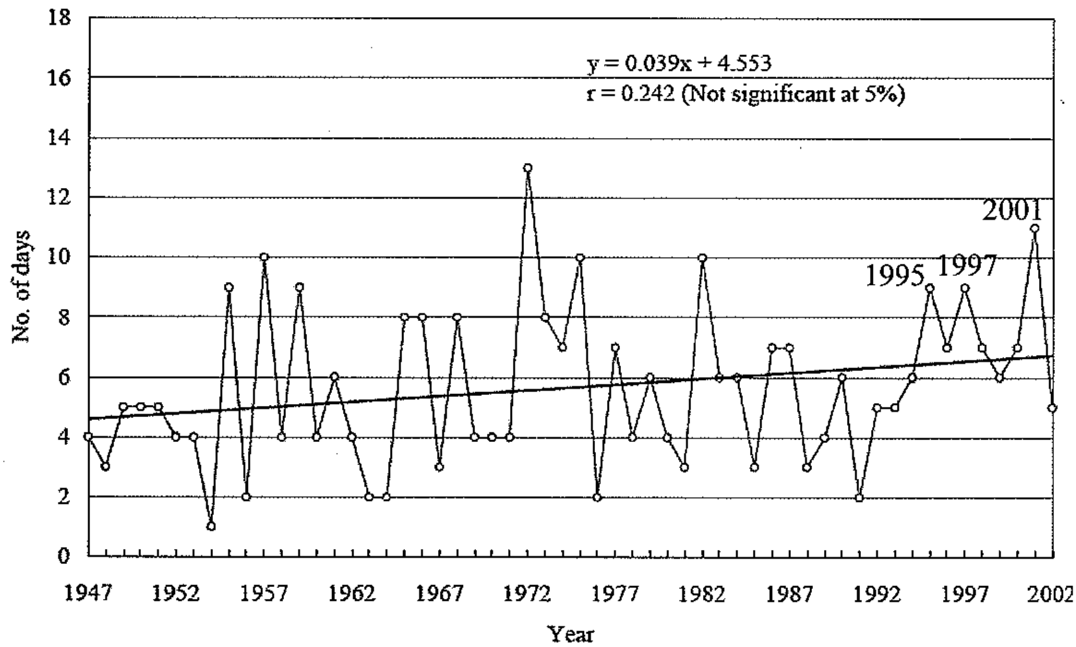


Figure 2 **Number of days with hourly rainfall greater than 30mm recorded at Hong Kong Observatory Headquarters (1947-2002) [Extract from Figure 20 of Technical Note No. 107]**

B. AVERAGE ANNUAL RAINFALL DATA

"Technical Note No. 94 on Climatology of Ta Kwu Ling 1986-1997" published by the Hong Kong Observatory had been reviewed. It was observed from the Technical Note that a monthly maximum rainfall of 666.5mm was recorded in August 1995.

Mean Meteorological Data in Hong Kong Observatory and Ta Kwu Ling Station from Year 1999 to 2005 have also been studied. Rainfall data in Ta Kwu Ling Station from Year 1999 to 2005 is summarised below.

Table 2 Rainfall Data (mm) in Ta Kwu Ling Station from Year 1999 to 2005

	1999	2000	2001	2002	2003	2004	2005
Jan	7.5	90.5	42.5	0.0	18.0	36.5	2
Feb	0.0	27.0	21.0	0.0	5.5	55	25.5
Mar	24.0	41.5	47.5	10.5	35.0	83	45
Apr	47.5	550.0	159.5	9.0	24.5	83	46.5
May	12.5	134.5	185.5	260.0	413.5	173.5	149
Jun	267.0	229.0	817.5	132.0	453.0	128.5	539.5
Jul	122.5	403.0	591.5	246.0	104.0	285.5	287.5
Aug	781.5	385.5	273.0	420.5	307.0	316	571.5
Sep	330.5	88.0	345.0	522.0	394.0	75	270
Oct	26.5	141.5	20.0	62.0	14.5	8.8	10.5
Nov	12.5	77.5	0.0	18.0	24.5	0.5	12
Dec	29.0	58.0	0.0	49.0	1.5	0	4
Total	**1661.0**	**2226.0**	**2503.0**	**1729.0**	**1795.0**	**1245.0**	**1963.0**

The average annual rainfall from Year 1999 to 2005 is calculated to be 1875mm and is therefore adopted for the estimation of peak leachate over the long operation life of the NENT Landfill Extension.

For sensitivity checking, a more conservative estimate was also conducted based on the severe storm event in Year 2001. The Year 2001 data with total annual rainfall of 2503mm will be used for sizing of leachate storage within the NENT Landfill Extension in the peak operation year. It also consists of monthly maximum rainfall of 817.5mm in June 2001, which is the highest monthly rainfall recorded during 1986 to 2005.

Table 3A and 3B show the Meteorological Data obtained from Ta Kwu Ling Station from Year 1999 to Year 2005, extracted from the "Summary of Meteorological Observation in Hong Kong 2001" published by the Hong Kong Observatory. The effective rainfall is calculated based on the recorded rainfall minus the potential evaporation.

Table 3A Average Meteorological Data from 1999 to 2005 (Normal Condition)

Month	Rainfall (mm/month)	Potential Evaporation (mm/day)	Potential Evaporation (mm/month)	Effective Rainfall (mm/month)
Jan	31.8	1.0	32.5	0
Feb	15.7	1.3	37.8	0
Mar	35.6	1.6	48.8	0
Apr	119.5	1.6	47.2	72.3
May	139.0	2.5	76.6	62.3
Jun	612.4	1.2	36.0	576.4
Jul	443.1	2.3	72.0	371.1
Aug	204.5	3.7	113.8	90.7
Sep	258.4	1.7	51.7	206.8
Oct	15.0	3.4	106.8	0
Nov	0.0	2.8	85.4	0
Dec	0.0	1.9	60.4	0
Total	**1875.0**		**768.9**	**1379.6**

Table 3B Ta Kwu Ling Station Meteorological Data in Year 2001 (Severe Storm Condition)

Month	Rainfall (mm/month)	Potential Evaporation (mm/day)	Potential Evaporation (mm/month)	Effective Rainfall (mm/month)
Jan	42.5	1.4	43.4	0
Feb	21.0	1.8	50.4	0
Mar	47.5	2.1	65.1	0
Apr	159.5	2.1	63	96.5
May	185.5	3.3	102.3	83.2
Jun	817.5	1.6	48	769.5
Jul	591.5	3.1	96.1	495.4
Aug	273.0	4.9	151.9	121.1
Sep	345.0	2.3	69	276.0
Oct	20.0	4.6	142.6	0.0
Nov	0.0	3.8	114	0
Dec	0.0	2.6	80.6	0
Total	**2503.0**		**1026.4**	**1841.7**

C. LANDFILL DEVELOPMENT PHASING

A knowledge of the likely leachate generation of a landfill is a pre-requisite to the planning of a leachate management strategy. An assessment of leachate generation rate cannot not be prepared in the absence of a phasing sequence plan.

The size of the phase is dictated by engineering, operation and financial considerations. Phases are divided into smaller cells for control of leachate generation and for operation convenience. A minimum size for manoeuvring of vehicles is also necessary.

According to the Weekly Operation Programme from the existing NENT Landfill, an active tipping cell is about 40m x 30m. For the landfill to be operated in 52 weeks per year, the annual tipping area is 40*30*52= 62,400m² (i.e. about 6 ha per year).

Assuming the landfill extension will operate in the similar order of tipping area with a active tipping face of 6 ha per year and site formation working face of 6 ha per year, the landfill phasing development could be established as shown in Table 4.

Table 4 Assumed Landfill Extension Phasing Plan A

Year	Active Tipping Face (ha)	Temporary Restored Area (ha)	Permanent Restored Area (ha)	Total Area (ha)
0	0	0	0	0
1	6	6	0	12
2	6	12	0	18
3	6	18	0	24
4	6	24	0	30
5	6	30	0	36
6	6	36	0	42
7	6	42	0	48
8	6	48	0	54
9	6	54	0	60
10	6	54	6	66
11	6	30	30	66
12	6	10	54	70
13	0	0	70	70
14	0	0	70	70

Notes :

1. Active tipping face is assumed to 6ha per year (similar to existing NENT Landfill) for ease of maintanence and odour control.
2. To maintain a 6ha working face per year, the site formation work is estimated to be a min. of 6ha per year.
3. For conservative estimate, the permanent restoration will be assumed to be carried out at a later stage of the landfill life.
4. Active tipping face - areas where waste is being actively tipped.
5. Temporary restored area - site formation areas + areas which have been temporarily restored.
6. Permanent restored area - areas which have been permanently restored or finally capped.

D. ESTIMATION OF LEACHATE FLOW

The leachate generated from the landfill site in different year can be calculated by :

Leachate generation = runoff coeff. * operation area * effective rainfall

where runoff coefficient for different type of landfill is assumed to be :

Table 5 Runoff Coeff. for Different Type of Landfill

Landfill Type	Runoff coeff.	Remarks
Active tipping face	1.00	100% of surface water infiltrated into leachate collection system of landfill
Temporary restored area	0.30	70% of surface water will be convey to surface channel / stormwater system
Permanent restored area	0.10	90% of surface water will be convey to surface channel / stormwater system

Notes:

1. Reference is made to DSD Stormwater Manual Clause 7.5.2. "The value of C depends on the impermeability, slope and retention characteristics of the ground surface. It also depends on the characteristics and conditions of the soil, vegetation cover, the duration and intensity of rainfall, and the antecedent moisture conditions, etc. In Kong Kong, a value of C =1.0 is commonly used in developed urban areas. In less developed areas, the following C values may be used."

Surface Characteristics	*Runoff coefficient, C*
Asphalt	0.70 - 0.95
Concrete	0.80 - 0.95
Brick	0.70 - 0.85
Grassland (heavy soil)	
Flat	0.13 - 0.25
Steep	0.25 - 0.35
Grassland (sandy soil)	
Flat	0.05 - 0.15
Steep	0.15 - 0.20

[Extracted from DSD Stormwater Drainage Manual Page 42]

2. As per the recommendation of DSD Manual, a value of C =1.0 is commonly used in developed urban areas, which conveys all the surface face to the adjacent drainage system. Similarly, a runoff coeff. of 1.0 is used for the tippling face in order to convey all leachate to the treatment plant. Runoff coeff. of 0.30 for heavy steep soil is adopted for site formation work. Runoff coeff. of 0.10 for sandy flat soil is adopted for the permanent restored surface with top soil and plantation.

Table 6A Leachate Generation – With Average Annual Rainfall 1875mm under Normal Condition

Year	Calculation of Infiltration			Leachate Generation	
	Working Area (m^3/day)	Temporary Restored Area (m^3/day)	Permanent Restored Area (m^3/day)	(m^3/year)	(m^3/day)
1	82,777	24,833	0	107,610	294.82
2	82,777	49,666	0	132,443	362.86
3	82,777	74,499	0	157,277	430.89
4	82,777	99,333	0	182,110	498.93
5	82,777	124,166	0	206,943	566.97
6	82,777	148,999	0	231,776	635.00
7	82,777	173,832	0	256,609	703.04
8	82,777	198,665	0	281,442	771.07
9	82,777	223,498	0	306,276	839.11
10	82,777	223,498	8,278	314,553	861.79
11	82,777	124,166	41,389	248,332	680.36
12	82,777	41,389	74,499	198,665	544.29
13	0	0	96,573	96,573	264.58
14	0	0	96,573	96,573	264.58

Table 6B Leachate Generation – With Peak Annual Rainfall 2503mm under Severe Storm Condition (for Sensitivity Testing)

Year	Calculation of Infiltration			Leachate Generation	
	Working Area (m^3/day)	Temporary Restored Area (m^3/day)	Permanent Restored Area (m^3/day)	(m^3/year)	(m^3/day)
1	110,502	33,151	0	143,653	393.57
2	110,502	66,301	0	176,803	484.39
3	110,502	99,452	0	209,954	575.22
4	110,502	132,602	0	243,104	666.04
5	110,502	165,753	0	276,255	756.86
6	110,502	198,904	0	309,406	847.69
7	110,502	232,054	0	342,556	938.51
8	110,502	265,205	0	375,707	1,029.33
9	110,502	298,355	0	408,857	1,120.16
10	110,502	298,355	11,050	419,908	1,150.43
11	110,502	165,753	55,251	331,506	908.24
12	110,502	55,251	99,452	265,205	726.59
13	0	0	128,919	128,919	353.20
14	0	0	128,919	128,919	353.20

It is noted from the above Table 6A that the landfill extension will generate a maximum leachate flow of 860 m^3/day during its operation life under the normal rainfall condition. After closure of the landfill with final capping being installed, there will still be 265m^3 leachate generated per day. Because of the similar nature and site area, the restored NENT Landfill, will also generate a peak flow of 265 m^3/day under the normal rainfall.

It is also noted that the NENT Landfill Extension will start receiving waste-deliveries only when the Existing NENT Landfill has ceased operation. Therefore, the leachate generated from the restored NENT Landfill and the NENT Landfill Extension at its peak operation life will be 265 m^3/day and 860 m^3/day respectively. The total leachate generated from the existing landfill and its extension would be (265 + 860 =) 1,125 m^3/day.

During the severe storm condition (the worst case scenario), the NENT Landfill Extension will generate a peak flow of 1,150 m^3/day during the peak operation period. At the same time, the restored NENT Landfill will also generate a peak flow of about 350 m^3/day. Thus, a total amount of about (1,150 + 350 =) 1,500 m^3/day of leachate will be generated from the landfill extension and the restored landfill (at the worst case scenario).

E. LEACHATE STORAGE AND TREATMENT

The existing leachate treatment plant consists of six leachate lagoons and an ammonia stripping plant for nitrogen removal. The design capacity of the leachate treatment plant is about 1,200m^3/day. The total storage capacities of the existing leachate lagoons are about 84,500m^3, which have a detention period for peak flow of (84,500 / 1,200 =) 70 day. Treated leachate is pumped to the existing DSD Pumping Station and then conveyed to the Shek Wu Hui Sewage Treatment Works for further treatment.

The existing treatment plant is capable to handle the leachate flows from the two landfills under normal conditions.

During severe storm event, temporary storage lagoons will be constructed to storage the contaminated rainfall infiltration.

In the emergency case that the leachate collection pipe is blocked / the leachate treatment plant is shut down. Leachate generated from the landfill will be stored within the landfill bowl. From Table 1, it is noted that the extremely daily maximum rainfall was recorded in June 1998 with 411.3mm/day.

Leachate generated from the landfill in this extremely severe storm condition + emergency case is summarised below.

1. Rainfall infiltrated to the active tipping face = 411.3mm x 40m x 30m = 493m^3,

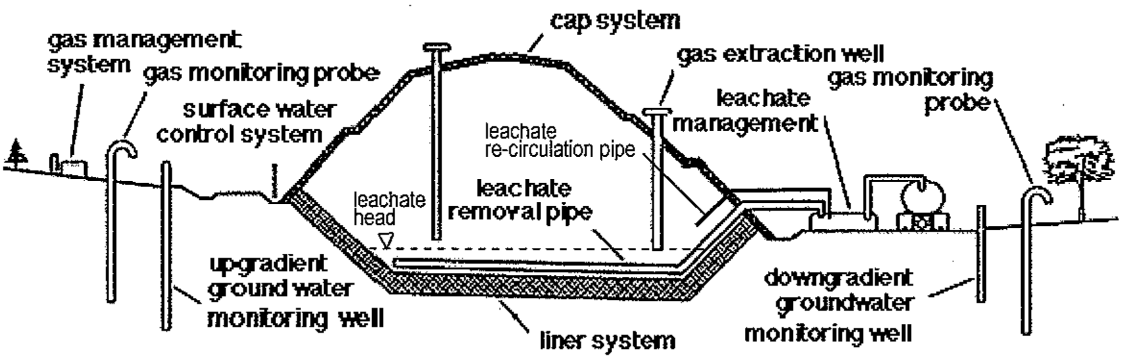
   (where typical active tipping area for daily operation = 40m x 30m)

2. Surface runoff generated from the landfill site = 411.3mm x 70 ha = 287,910m^3,

   (where the total site area is about 70 ha)

3. Assuming that all the surface runoff is contaminated (extremely worst-case scenario), the leachate conveyed to the leachate treatment plant = 288,400m^3.

4. The storage capacity of the treatment plant is only 84,500m^3. The remaining leachate of (288,400m^3 - 84,500m^3 =) 203,900m^3 will be re-circulated to the landfill bowl. A leachate head of (203,900m^3 / 70 ha =) 290mm will be generated within the landfill bowl, see diagram below.



5. The NENT Landfill Extension is designed to withstand a leachate head of 1 metre. There is sufficient storage capacity within the landfill cell to hold the rainfall infiltrated as well as the contaminated surface water in severe storm event.

As discussed above, it is therefore concluded that the existing leachate treatment plant in NENT Landfill have sufficient capacity to treat the raw leachate from the NENT Landfill and its extension. The existing storage lagoons and the landfill cell itself provide sufficient storage capacity to cater the extremely severe storm event as well as the contaminated surface runoff generated from the landfill.