K.2 Preliminary Design of Technical System

K.2.1 Final Disposal Project

a. Examination of Design Conditions

a.1 Target Waste

Target wastes are all municipal solid wastes except hazardous wastes.

a.2 Related Laws and Regulations

At present, MINSA is formulating technical standards on construction of landfills. However, it is unknown when the standards will enact. Meanwhile, ANAM has established standards on effluent to public water body. This will control the effluent from leachate treatment facilities in this plan. Table K-3 shows the effluent standards set by ANAM.

Table K-3: Effluent Standards set by ANAM

Item		Unit	Discharge limit
Oil and grease		mg/liter	20
Aluminum	Al	mg/liter	5
Arsenic	As	mg/liter	0.50
Boron	Br	mg/liter	0.75
Cadmium	Cd	mg/liter	0.01
Calcium	Ca	mg/liter	1,000
Total cyanide	CN	mg/liter	0.2
Residual chlorine	Cl	mg/liter	1.5
Chlorine	Cl_2	mg/liter	400
Copper	Cu	mg/liter	1
Total coliform		NMP/100 ml	1,000
Phenol compound		mg/liter	0.5
Hexavalent chromium	Cr^{+6}	mg/liter	0.05
Total chromium	Cr	mg/liter	5
Biochemical oxygen demand	BOD	mg/liter	35
Chemical oxygen demand	COD	mg/liter	100
Detergent		mg/liter	1
Foaming	PE	mm	7
Fluorine	F	mg/liter	5
Total phosphorus	T-P	mg/liter	5
Total hydrocarbon		mg/liter	5
Iron	Fe	mg/liter	5
Manganese	Mn	mg/liter	0.3
Mercaptan		mg/liter	0.02
Mercury	Hg	mg/liter	0.001
Molybdenum	Mo	mg/liter	2.5
Nickel	Ni	mg/liter	0.2
Nitrite	NO_3	mg/liter	6
Total organic nitrogen	N	mg/liter	10

Item		Unit	Discharge limit
Ammonium-nitrogen	NH_3-N	mg/liter	3
Smell		-	No perceptible
Organic chlorine		mg/liter	1.5
Penta chlorine phenol	C_6OHCl_5	mg/liter	0.009
pH		mg/liter	5.5. to 9.0
Lead	Pb	mg/liter	0.050
Selenium	Se	mg/liter	0.01
Sodium	% Na	%	35
Sedimentable solid	S. SED	mg/liter	15
Suspended solid	SS	mg/liter	35
Total dissolved solid	TDS	mg/liter	500
Sulphide	SO_4^{-2}	mg/liter	1,000
Temperature		°C	+,- 3 N.T
Toluene	$C_6H_5CH_3$	mg/liter	0.7
Trichloro-etane	HC_2Cl_3	mg/liter	0.04
Trichlorometan	$CHCl_3$	mg/liter	0.02
Turbidity		NTU	30
Xylene		$C_6H_4C_2H_6$	0.05
Zinc	Zn	mg/liter	3

source : Normas para Aguas Residuakes ANAM /DGNTI-COPANIT 35-2000

a.3 Location and Area

a.3.1 Location

Cerro Patacon site is located about 5km to the northwest of the city center; from the locality off Bethanaia along the Cerro Patacon Avenue. It has paved access road and electrical power supply.

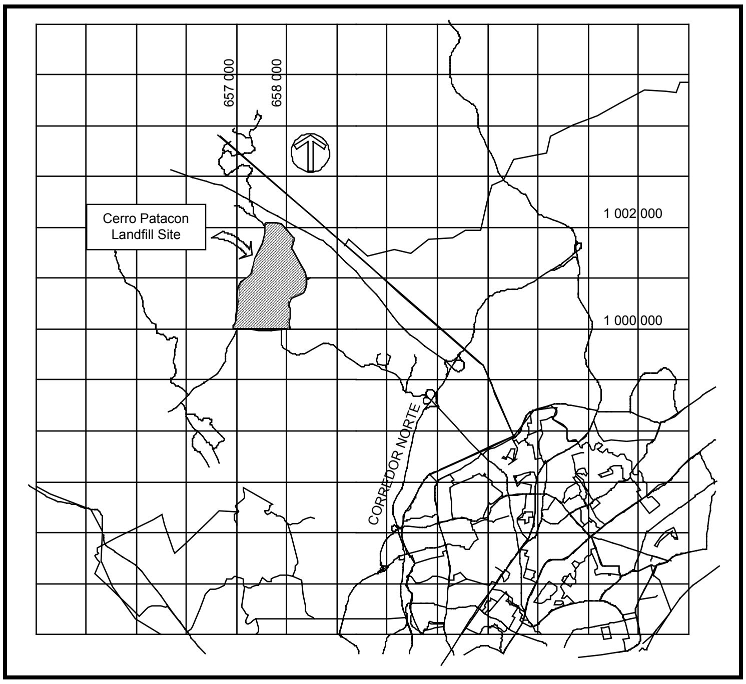


Figure K-1: Location Map of Cerro Patacon

a.3.2 Project Site

The project site is in the Cerro Patacon Landfill that has an area of 130 ha. Besides, 9 ha will be added with the new landfill development, Etapa 3. Profile of the project site is as follows.

- The maximum height: 106 masl
- The minimum height: 43 masl
- Area: about 28ha

There is a small hill at the north and a shallow valley at the south in the project site. Around the project site, there is a hill at the north, the existing landfill (Etapa I) at the south, a river at the east and other existing landfill (Etapa II) at the west.

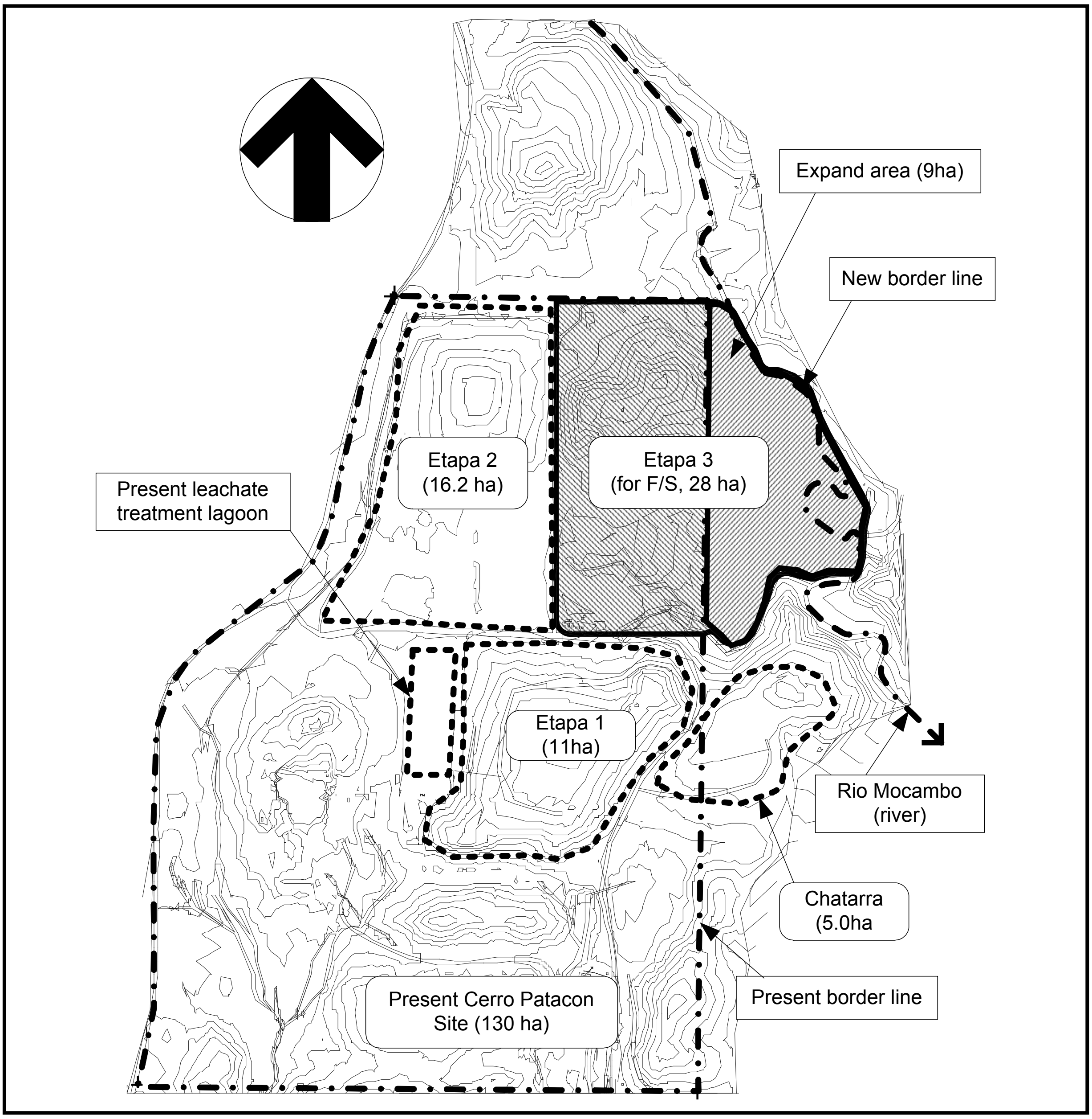


Figure K-2: Project Site

a.4 Geological Conditions

Geological condition of the project site consists of silt and/or clay at the upper part and weathered rock at the lower part. Hydraulic conductivity of the upper part is between 10^{-4} and 10^{-6}(cm/sec). In the Study, a geological survey was conducted. Locations of drilling surveys carried out in the geological survey are shown in Figure K-3. Figure K-4, Figure K-5, Figure K-6 and Figure K-7 present cross sections of the geological condition. As the figures show, the base layer of the project site consists of rock. Therefore, it can be judged that the base layer will bear increased stress to be caused by waste disposition.

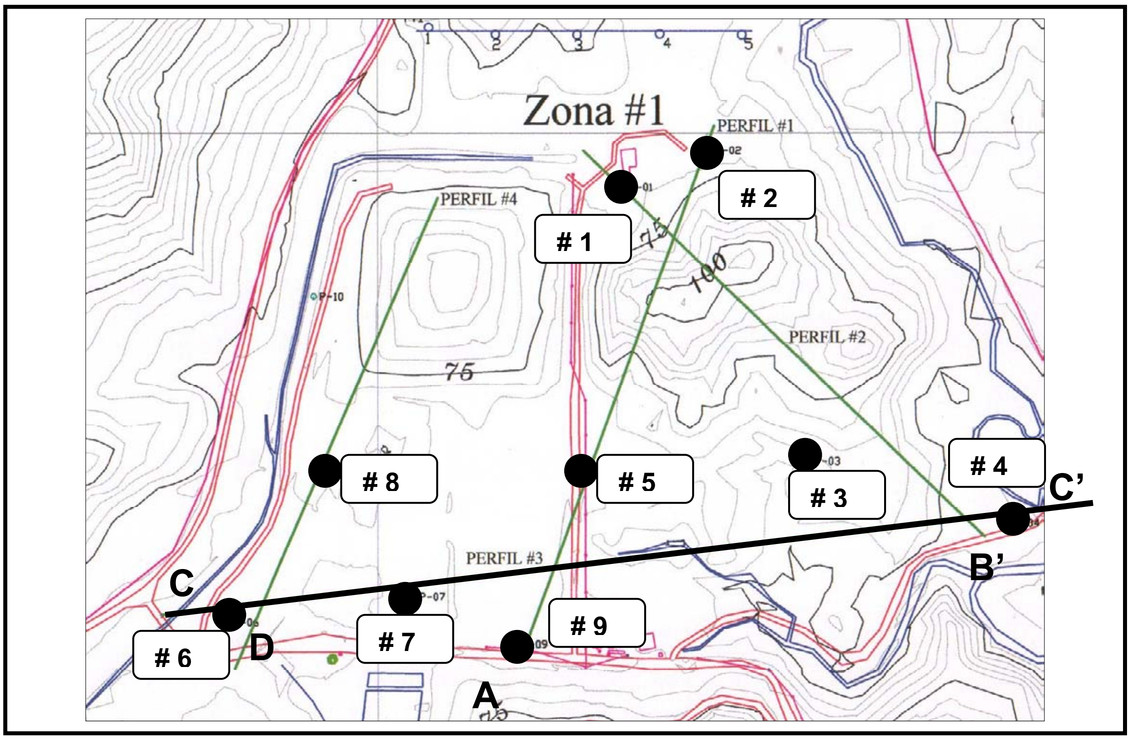


Figure K-3: Location Map of Boring Survey

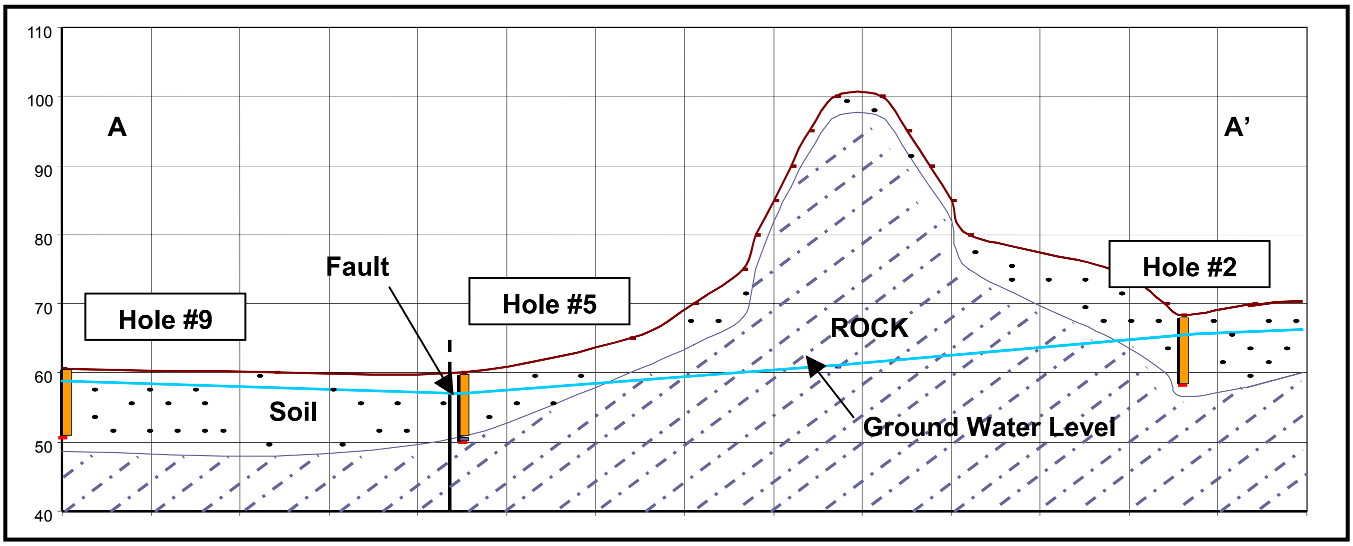


Figure K-4: Section A-A'

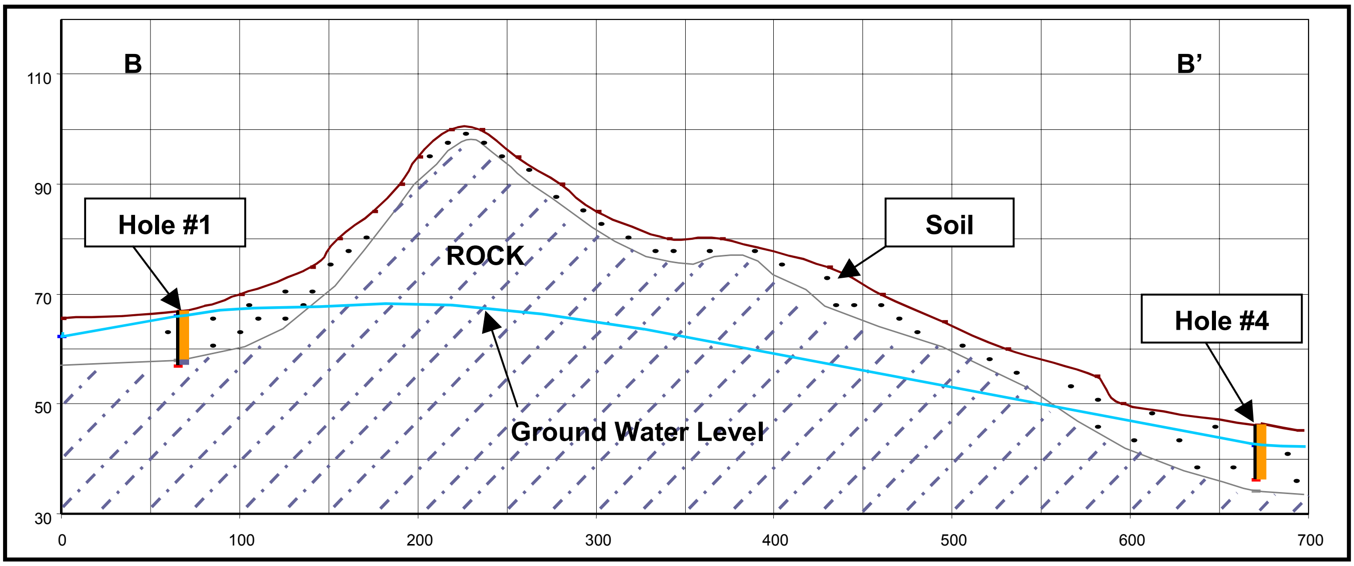
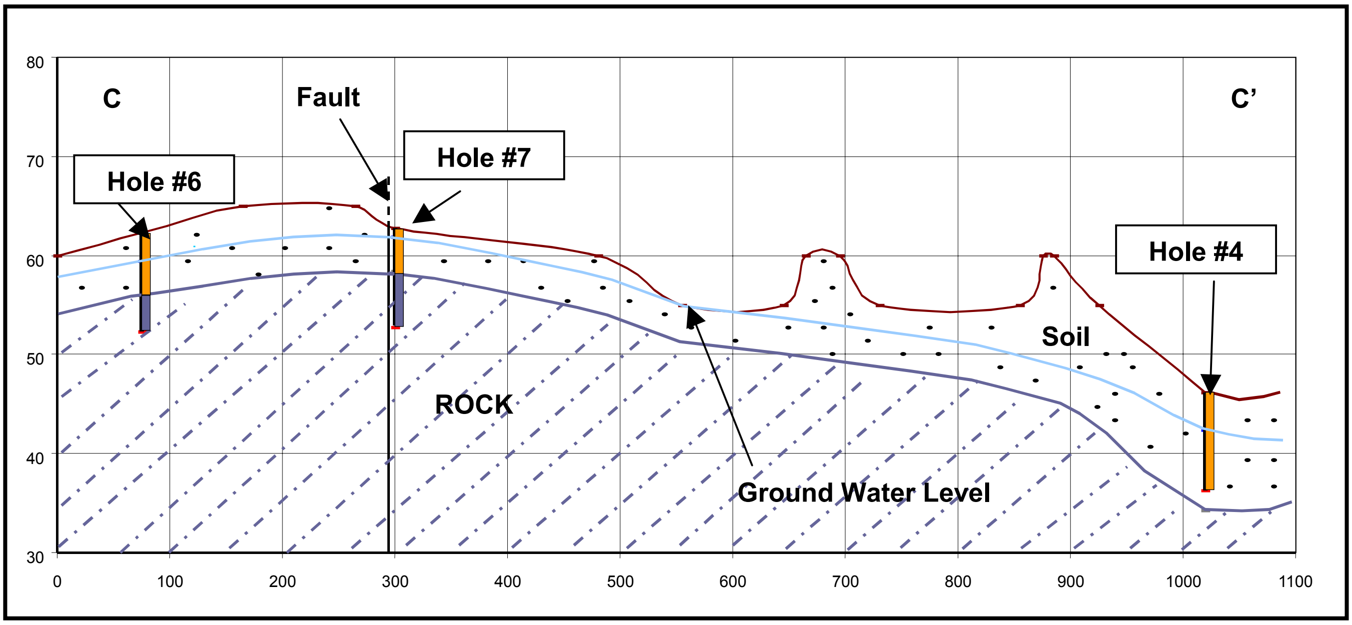


Figure K-5: Section B-B'

Figure K-6: Section C-C'



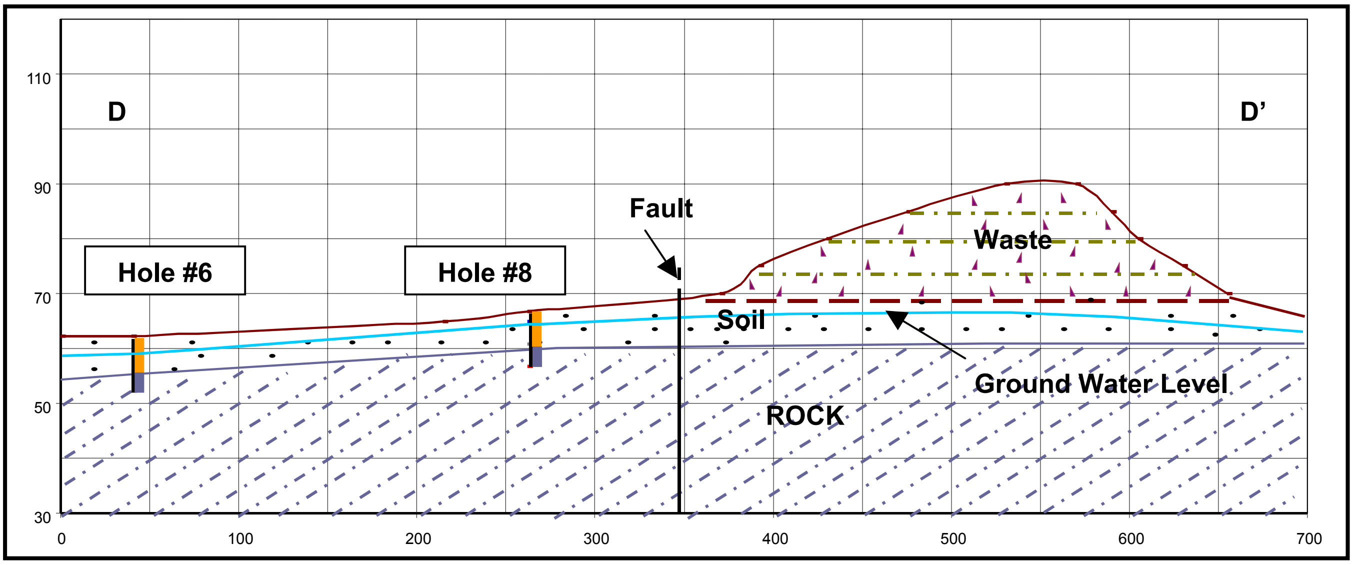


Figure K-7: Section D-D'

a.4.1 Ground Water Table

According to the drilling survey, it is estimated that the groundwater flows from the northwest to the southeast under the project site. There will be fissure water as the rock has many cracks.

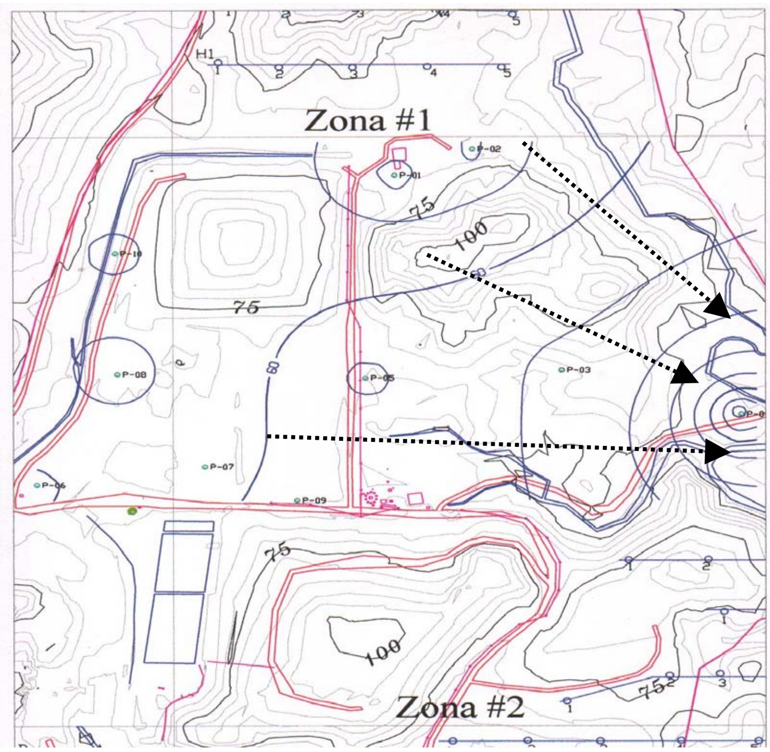


Figure K-8: Direction of Ground Water Flow

a.4.2 Permeability

In situ permeability tests were carried out at the drilling wells. Table K-4 shows results of the test.

Table K-4: Results of Permeability Survey

Number of holes	LOCATION	K (m/s)	K (cm/s)	PERMEABILITY CLASS
P # 1-02	**1001434.42 N, 657796.87 E**	**8.24 E-07**	**8.24 E-05**	Very small
P # 2-02	**1001478.89 N, 657900.95 E**	**5.09 E-07**	**5.09 E-05**	Practically impermeable
P # 3-02	**1000987.18 N, 658073.14 E**	**3.59 E-08**	**3.59 E-06**	
P # 4-02	1001028.35 N, 658260.56 E	1.57 E-07	1.57 E-05	
P # 5-02	**1001090.35 N, 657757.58 E**	**2.14 E-07**	**2.14 E-05**	
P # 6-02	1000909.59 N, 657317.57 E	2.32 E-06	2.32 E-04	Very small
P # 7-02	1000940.26 N, 657542.50 E	6.84 E-08	6.84 E-06	Practically impermeable
P # 8-02	1001097.23 N, 657425.56 E	6.00 E-08	6.00 E-06	

No. 1, 2, 3, and 5 are in the project site. All of them indicate considerably lower permeability, i.e., between 10^{-5} and 10^{-6} cm/sec. The values imply that the site might need synthetic liner at the bottom of a landfill. Meanwhile, the base layer consists of the weathered rock and fissure water exists. Therefore, it can be concluded that the bottom of the landfill will require a synthetic liner, although the upper part show the low permeability.

a.5 Meteorological Conditions

There exist three meteorological stations (Gamboa, PMG and B.AFF) in the neighborhood of the project site. Figure K-9 shows their locations.

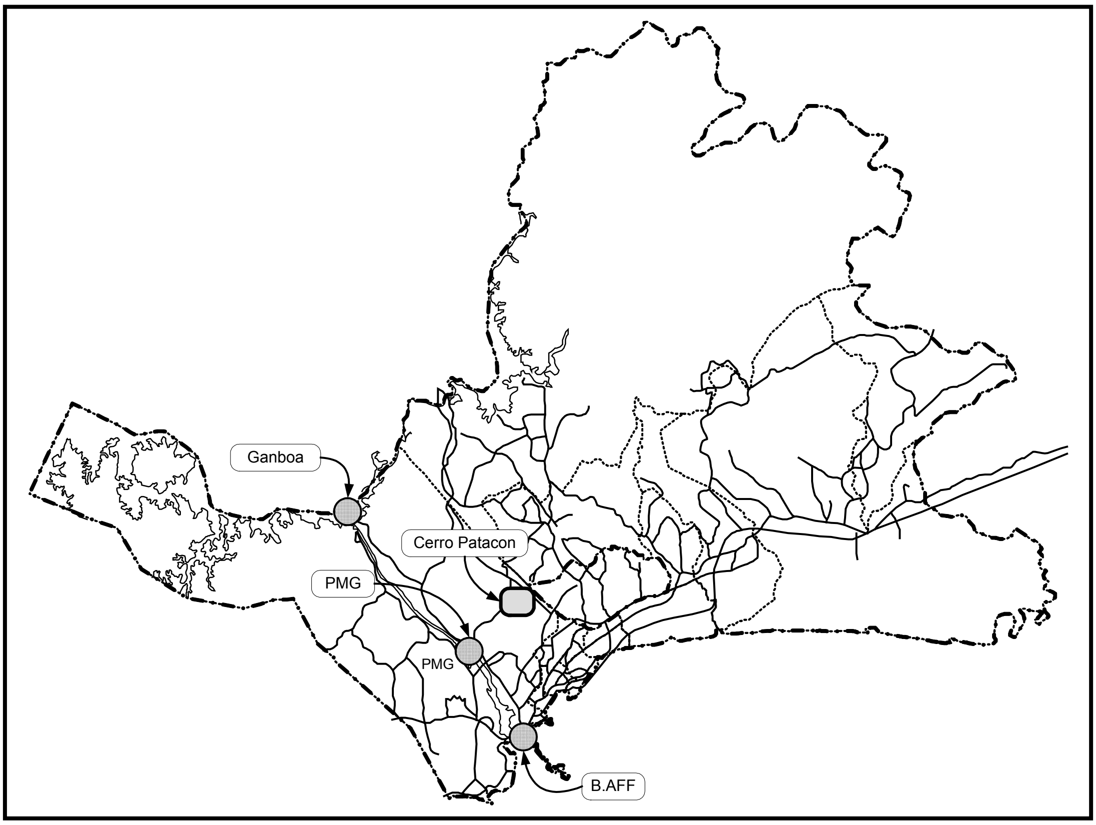


Figure K-9: Location of Meteorological Stations

a.5.1 Precipitation

Precipitation data shows below.

Table K-5: Precipitation Data of Gamboa Station

Year		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Day/year		366	365	365	365	366	365	365	365	366	365
Nos. of observation day		366	365	365	365	366	365	365	365	366	365
Annual precipitation (mm)		1,996.44	**2,626.36**	2,428.24	2,280.92	2,298.70	1,714.50	2,199.64	2,468.88	2,270.76	1,887.22
Daily average precipitation (mm)		5.50	7.20	6.70	6.20	6.30	4.70	6.00	6.80	6.20	5.20
Monthly precipitation (mm/month)	Jan.	10.16	109.22	22.86	17.78	233.68	12.70	0.00	33.02	35.56	25.40
	Feb.	5.08	5.08	15.24	2.54	17.78	5.08	2.54	101.60	7.62	2.54
	March	0.00	66.04	53.34	30.48	40.64	2.54	2.54	35.56	2.54	25.40
	April	99.06	127.00	15.24	121.92	60.96	12.70	218.44	96.52	91.44	35.56
	May	187.96	162.56	363.22	302.26	256.54	317.50	190.50	274.32	330.20	119.38
	June	373.38	365.76	238.76	297.18	238.76	152.40	223.52	276.86	314.96	190.50
	July	378.46	231.14	190.50	259.08	215.90	241.30	261.62	96.52	160.02	236.22
	Aug.	187.96	223.52	266.70	226.06	309.88	182.88	322.58	284.48	274.32	236.22
	Sept.	284.48	523.24	330.20	332.74	256.54	134.62	289.56	373.38	304.80	238.76
	Oct.	274.32	388.62	368.30	264.16	320.04	383.54	210.82	218.44	317.50	193.04
	Nov.	144.78	340.36	482.60	294.64	309.88	254.00	289.56	304.80	215.90	304.80
	Dec.	50.80	83.82	81.28	132.08	38.10	15.24	187.96	373.38	215.90	279.40
Monthly maximum daily precipitation (mm/day)	Jan.	5.08	38.10	10.16	7.62	66.04	10.16	0.00	20.32	17.78	20.32
	Feb.	5.08	5.08	5.08	2.54	5.08	2.54	2.54	30.48	2.54	2.54
	March	0.00	50.80	33.02	20.32	30.48	2.54	2.54	15.24	2.54	15.24
	April	40.64	38.10	7.62	81.28	25.40	10.16	99.06	30.48	30.48	15.24
	May	45.72	68.58	93.98	60.96	68.58	66.04	38.10	76.20	68.58	50.80
	June	96.52	50.80	30.48	99.06	48.26	43.18	38.10	38.10	60.96	43.18
	July	83.82	63.50	33.02	40.64	68.58	53.34	43.18	17.78	35.56	45.72
	Aug.	53.34	48.26	86.36	35.56	66.04	63.50	73.66	86.36	58.42	60.96
	Sept.	43.18	81.28	73.66	71.12	81.28	22.86	96.52	71.12	55.88	35.56
	Oct.	60.96	91.44	71.12	40.64	40.64	91.44	58.42	35.56	58.42	30.48
	Nov.	27.94	101.60	78.74	48.26	58.42	55.88	78.74	58.42	45.72	83.82
	Dec.	15.24	25.40	20.32	20.32	12.70	12.70	45.72	45.72	106.68	55.88

Table K-6: Precipitation Data of PMG Station

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Day/year		365	365	366	365	365	365	366	365	365	365	366	365
Nos. of observation day		365	365	366	365	365	365	366	365	365	365	366	365
Annual precipitation (mm)		1,922.78	2,311.40	2,044.70	2,197.10	1,968.50	1,971.04	**2,367.28**	1,668.78	2,189.48	2,270.76	2,138.68	1,963.42
Daily average precipitation (mm)		5.30	6.30	5.60	6.00	5.40	5.40	6.50	4.60	6.00	6.20	5.80	5.40
Monthly precipitation (mm/month)	Jan.	22.86	5.08	0.00	93.98	10.16	5.08	144.78	38.10	2.54	81.28	45.72	12.70
	Feb.	0.00	0.00	2.54	0.00	0.00	2.54	55.88	12.70	0.00	81.28	7.62	0.00
	March	0.00	5.08	2.54	17.78	142.24	20.32	73.66	0.00	0.00	27.94	0.00	2.54
	April	106.68	228.60	45.72	83.82	45.72	149.86	88.90	17.78	33.02	63.50	144.78	40.64
	May	213.36	350.52	220.98	218.44	347.98	215.90	381.00	154.94	314.96	220.98	200.66	172.72
	June	177.80	266.70	345.44	459.74	170.18	330.20	208.28	121.92	243.84	360.68	302.26	132.08
	July	335.28	274.32	266.70	292.10	142.24	266.70	119.38	279.40	299.72	127.00	236.22	261.62
	Aug.	294.64	276.86	251.46	200.66	233.68	177.80	342.90	149.86	337.82	220.98	271.78	142.24
	Sept.	193.04	325.12	309.88	279.40	236.22	149.86	177.80	185.42	215.90	337.82	236.22	266.70
	Oct.	327.66	228.60	353.06	218.44	279.40	256.54	332.74	347.98	279.40	297.18	347.98	340.36
	Nov.	137.16	317.50	190.50	238.76	355.60	347.98	347.98	332.74	274.32	208.28	167.64	332.74
	Dec.	114.30	33.02	55.88	93.98	5.08	48.26	93.98	27.94	187.96	243.84	177.80	259.08
Monthly maximum daily precipitation (mm/day)	Jan.	15.24	2.54	0.00	50.80	7.62	5.08	60.96	27.94	2.54	40.64	15.24	7.62
	Feb.	0.00	0.00	2.54	0.00	0.00	2.54	17.78	10.16	0.00	73.66	5.08	0.00
	March	0.00	5.08	2.54	10.16	101.60	12.70	53.34	0.00	0.00	12.70	0.00	2.54
	April	81.28	111.76	17.78	40.64	17.78	71.12	35.56	12.70	17.78	22.86	71.12	40.64
	May	33.02	91.44	60.96	35.56	66.04	45.72	93.98	48.26	81.28	45.72	30.48	45.72
	June	30.48	43.18	96.52	121.92	38.10	86.36	60.96	53.34	83.82	76.20	50.80	27.94
	July	104.14	68.58	45.72	68.58	25.40	88.90	50.80	55.88	60.96	35.56	50.80	50.80
	Aug.	73.66	83.82	86.36	53.34	68.58	27.94	88.90	45.72	68.58	30.48	48.26	38.10
	Sept.	76.20	68.58	73.66	48.26	58.42	43.18	33.02	45.72	35.56	60.96	38.10	78.74
	Oct.	48.26	71.12	172.72	40.64	76.20	55.88	48.26	78.74	66.04	91.44	71.12	66.04
	Nov.	25.40	71.12	45.72	38.10	91.44	53.34	48.26	73.66	66.04	43.18	30.48	45.72
	Dec.	58.42	17.78	25.40	17.78	2.54	17.78	20.32	22.86	60.96	38.10	55.88	40.64

Table K-7: Precipitation Data of B.AFF Station

Year		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Day/year		366	365	365	365	366	365	365	365	366	365
Nos. of observation day		366	365	365	365	366	365	365	365	366	365
Annual precipitation (mm)		2,207.26	2,443.48	2,100.58	**2,875.28**	2,451.10	1,905.00	1,953.26	1,940.56	1,927.86	1,684.02
Daily average precipitation (mm)		6.00	6.70	5.80	7.90	6.70	5.20	5.40	5.30	5.30	4.60
Monthly precipitation (mm/month)	Jan.	0.00	68.58	0.00	0.00	154.94	170.18	0.00	43.18	53.34	17.78
	Feb.	5.08	0.00	33.02	0.00	99.06	15.24	15.24	17.78	81.28	0.00
	March	0.00	91.44	55.88	63.50	76.20	0.00	0.00	86.36	22.86	0.00
	April	22.86	76.20	40.64	81.28	91.44	0.00	73.66	68.58	76.20	50.80
	May	269.24	487.68	314.96	393.70	337.82	144.78	373.38	223.52	180.34	203.20
	June	213.36	205.74	248.92	566.42	254.00	215.90	279.40	241.30	287.02	254.00
	July	256.54	462.28	129.54	304.80	200.66	134.62	198.12	165.10	195.58	119.38
	Aug.	299.72	215.90	266.70	215.90	167.64	147.32	172.72	132.08	149.86	71.12
	Sept.	271.78	292.10	182.88	490.22	142.24	360.68	254.00	172.72	256.54	266.70
	Oct.	431.80	172.72	320.04	401.32	317.50	358.14	167.64	203.20	292.10	223.52
	Nov.	299.72	254.00	411.48	157.48	408.94	347.98	218.44	335.28	200.66	241.30
	Dec.	137.16	116.84	96.52	200.66	200.66	10.16	200.66	251.46	132.08	236.22
Monthly maximum daily precipitation (mm/day)	Jan.	0.00	35.56	0.00	0.00	35.56	71.12	0.00	17.78	27.94	15.24
	Feb.	5.08	0.00	33.02	0.00	27.94	7.62	7.62	7.62	30.48	0.00
	March	0.00	45.72	30.48	33.02	45.72	0.00	0.00	43.18	12.70	0.00
	April	10.16	38.10	20.32	40.64	38.10	0.00	48.26	35.56	45.72	40.64
	May	81.28	104.14	83.82	152.40	78.74	27.94	134.62	55.88	63.50	83.82
	June	53.34	76.20	73.66	190.50	93.98	71.12	93.98	50.80	83.82	50.80
	July	60.96	152.40	43.18	55.88	55.88	35.56	68.58	63.50	35.56	43.18
	Aug.	58.42	68.58	48.26	53.34	27.94	78.74	38.10	35.56	20.32	17.78
	Sept.	66.04	50.80	60.96	162.56	38.10	134.62	60.96	50.80	53.34	55.88
	Oct.	83.82	35.56	73.66	88.90	66.04	91.44	71.12	58.42	63.50	40.64
	Nov.	48.26	40.64	152.40	35.56	73.66	101.60	45.72	76.20	27.94	58.42
	Dec.	27.94	35.56	63.50	38.10	40.64	10.16	27.94	53.34	43.18	91.44

a.5.2 Temperature

Monthly average temperature data shows below.

Table K-8: Monthly Average Temperature Data of Gamboa Station

unit : Celsius

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan.	27.2	25.4	25.3	25.6	25.4	25.5	27.0	26.3	25.6	25.2
Feb.	27.7	25.6	25.5	25.5	25.8	26.7	27.3	25.8	26.1	25.7
March	28.2	26.4	25.8	26.1	26.2	26.2	27.7	26.3	26.3	25.8
April	28.6	26.6	26.6	26.7	26.7	27.0	28.0	26.7	26.8	26.9
May	28.1	26.7	26.2	26.3	26.4	27.5	27.5	26.4	26.2	26.6
June	27.5	26.3	25.6	26.4	26.0	26.9	26.8	25.6	25.7	26.5
July	27.0	26.4	25.9	25.6	25.5	27.2	26.3	25.9	25.7	25.7
Aug.	27.3	26.2	25.5	25.8	25.5	27.3	26.0	25.6	25.9	26.7
Sept.	26.9	25.7	25.6	26.0	25.5	26.3	26.1	25.4	25.3	25.9
Oct.	25.8	25.8	25.1	25.6	25.6	26.6	26.2	25.4	25.3	26.4
Nov.	25.3	24.9	24.9	25.5	25.1	26.2	25.7	25.2	25.8	25.9
Dec.	25.6	25.6	25.5	25.7	25.7	26.9	25.7	24.7	25.4	26.1

Table K-9: Monthly Average Temperature Data of B.AFF Station

unit : Celsius

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan.	27.2	26.7	26.9	27.5	25.5	25.7	27.8	26.1	25.4	26.1
Feb.	27.5	27.3	27.3	27.5	26.1	27.0	27.9	26.4	26.4	26.7
March	27.3	27.9	27.6	27.5	26.5	26.9	28.7	26.9	26.8	26.9
April	27.6	27.8	28.2	27.6	27.1	27.7	28.5	27.0	27.4	27.8
May	26.7	27.5	27.0	27.0	26.3	27.8	27.7	26.4	26.6	26.8
June	26.1	27.2	26.8	27.3	26.2	26.7	27.1	25.9	26.3	26.6
July	27.5	27.1	27.2	26.0	25.9	27.3	26.6	26.1	26.2	26.1
Aug.	25.1	27.2	26.5	25.9	25.9	27.3	26.3	25.8	26.1	26.9
Sept.	26.5	26.0	27.0	26.4	25.8	26.4	26.5	25.7	25.3	25.6
Oct.	26.4	26.6	26.3	25.9	25.8	26.5	26.5	25.7	25.6	25.9
Nov.	26.2	26.1	26.3	25.7	25.6	26.3	25.8	25.4	25.6	25.4
Dec.	26.7	26.8	26.9	25.7	25.7	27.3	25.6	25.0	25.6	25.7

a.5.3 Sunshine Hours

Sunshine hours are not recorded at present as it has been stable over years. Table K-10 presents monthly average sunshine hours measured at B.AFF between 1908 and 1965.

Table K-10: Average Monthly Sunshine Hours (1908 to 1965)

unit : hours/month

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
263	246	255	209	162	135	147	147	148	147	143	208	2,210

a.6 Landfill Amount

When the new landfill starts its operation from the year 2006, the expected final disposal amount by the year 2015 is estimated in the following table.

Table K-11: Prospect of Required Landfill Volume and Construction Plan

unit : m^3

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Waste volume	470,385	957,627	1,458,540	1,974,352	2,503,536	3,047,121	3,605,239	4,179,252	4,769,424	5,376,784
Cover soil volume	94,077	191,525	291,708	394,870	500,707	609,424	721,048	835,851	953,885	1,075,357
Total	564,462	1,149,152	1,750,248	2,369,222	3,004,243	3,656,545	4,326,287	5,015,103	5,723,309	6,452,141
*Required volume of Etapa 3	286,462	871,152	1,472,248	2,091,222	2,726,243	3,378,545	4,048,287	4,737,103	5,445,309	6,174,141
Service period	Phase 1		Phase 2			Phase 3		Phase 4		
Available volume	1,300,000 m^3		1,200,000 m^3			1,100,000 m^3		2,800,000 m^3		
Total available volume	1,300,000 m^3		2,500,000 m^3			3,600,000 m^3		6,400,000 m^3		

notes : *assumed Etapa 2 remaining volume of end year 2006 is about 278,000 m^3

b. Conceptual Design

b.1 Landfill Site

b.1.1 Site Development Plan

Basic Concept

The planed landfill capacity is about 6.4 million m^3. Possible development area is about 26 ha with taking into account 50 m width of a buffer zone along the river. The landfill will have a maintenance road at its periphery. Consequently, an area to be used for a landfill is about 20 ha.

A layout plan and a land reclamation plan are formulated based on the basic concept shown in Table K-12 with taking into account of examples in Japan and safety. Due to the land features of the site, there are some points where 50 m of buffer zone from the river cannot be achieved. In such points, it is aimed at securing 30m at least.

Table K-12: Basic Concept of Site Development Plan

Item	Descriptions
Internal road	width :10.0m
Access road	width : 10.0 m, maximum vertical slope : 8.000%
Access road for leachate treatment facilities	width : 6.0 m, maximum vertical slope : 8.000%
Cut slope grade	1:2
Bank slope grade	1:3
Slope grade in the landfill site	1:2, width of scarcement : 2.0m
Landfill slope grade	1:3, width of scarcement : 2.5m
Elongation from river	norm :50 m, minimum : 30 m

Site Development Plan

The landfill construction is divided in three phases as shown in Figure K-10. Phase 1 is the southern part, Phase 2 is the northwestern part and Phase 3 is the northeastern part. The depth of the landfill is set at 10 m. Waste will be raised up to 80 masl at each phase. Then, the three areas will be combined and the height will reach at 110 masl as Phase 4. Capacities of respective those phases are shown Table K-13, which are estimated based on a map of 1 in 2,500.

Table K-13: Prospective Landfill Amount

Phase	Landfill amount (m^3)
Phase 1	1,300,000
Phase 2	1,200,000
Phase 3	1,100,000
Phase 4	2,800,000
Total	6,400,000

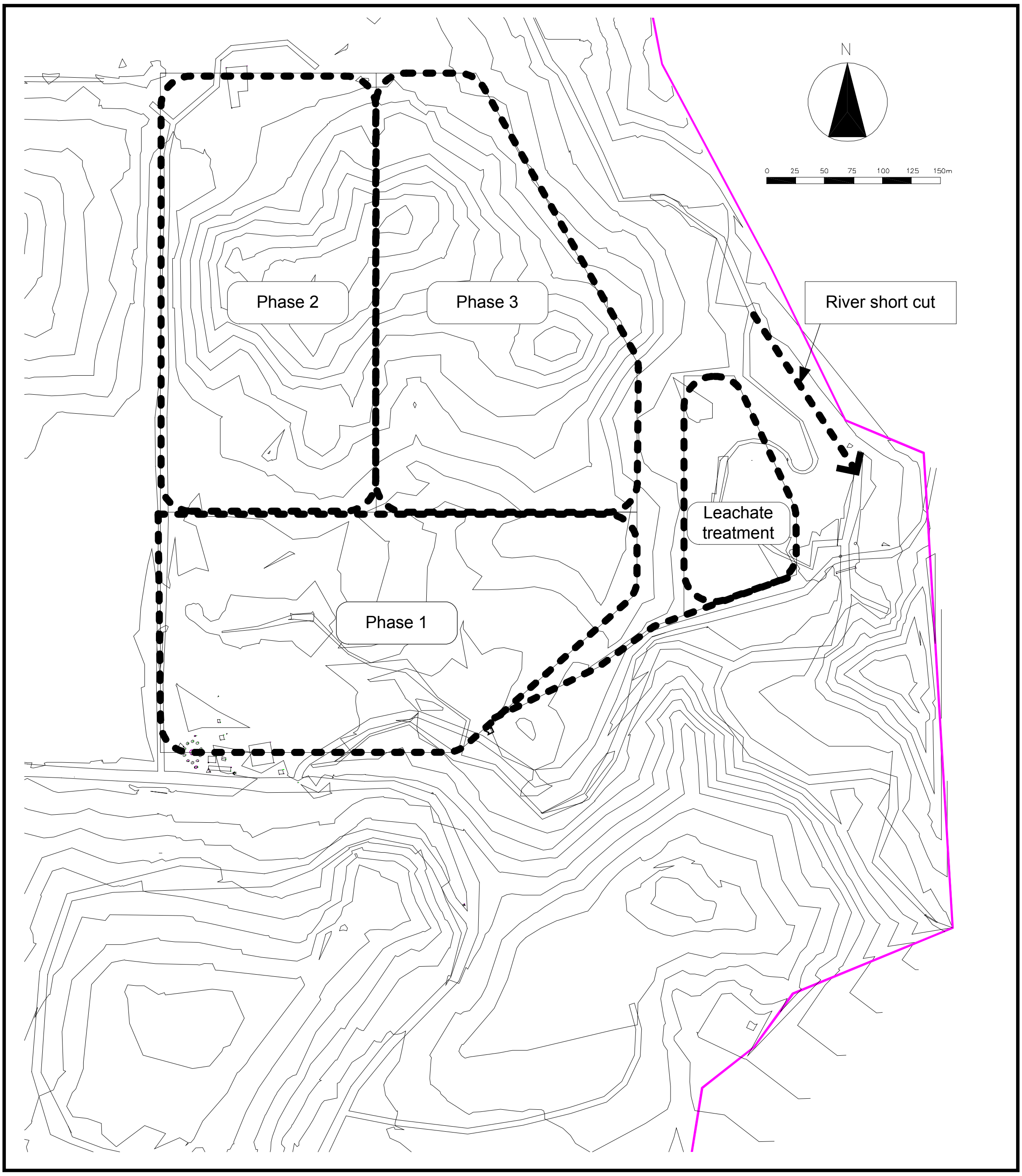


Figure K-10: Zoning Plan for Site Development

Earth Wok Plan

Table K-14 shows required earthwork. The huge earthwork in Phase 2 and 3 will be unavoidable in order to obtain enough capacity of landfill. If the excess soil will be used for about 1.4 million of cover material, the remains will be about 2.1 million. The northern area next to the project site has capacity to receive 2.2 million of soil (See Figure K-11).

Table K-14: Earth Work Volume

	Cut volume (m^3)	Embankment volume (m^3)	Balance (m^3) (cut – embankment)
Phase 1	406,000	15,000	391,000
Phase 2	1,973,000	4,000	1,969,000
Phase 3	1,192,000	26,000	1,166,000
Phase 4	0	1,000	-1,000
Total	3,571,000	46,000	3,525,000

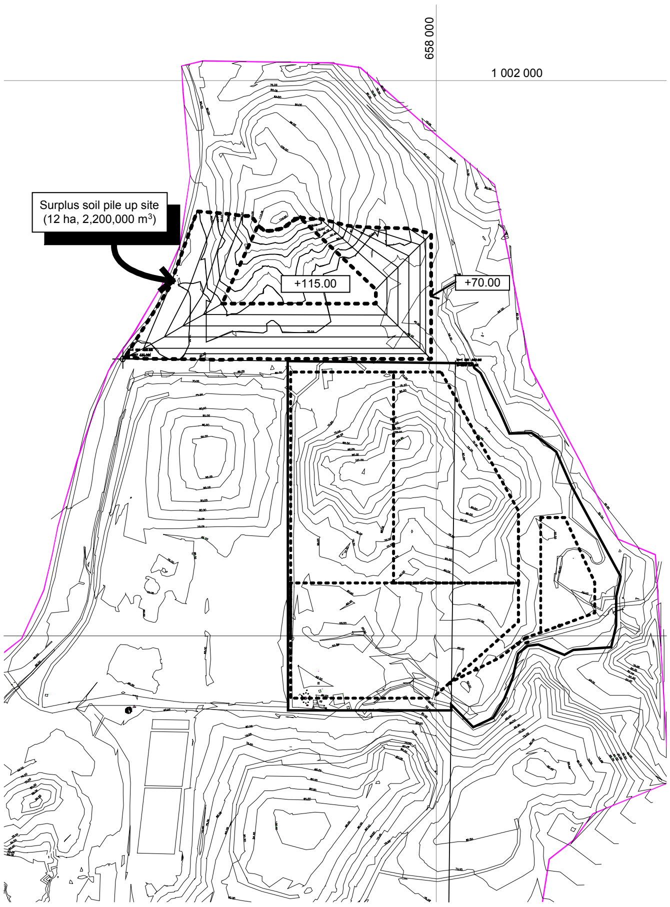


Figure K-11: Surplus Soil Pile Up Site

Table K-15: Total Volume of Surplus Soil Pile Up Site

Level	Area 1(m^2)	Ave. area (m^2)	Height (m)	Volume (m^3)
+70.00	48,500	58,300	5	291,500
+75.00	68,100	63,900	10	639,000
+85.00	59,700	55,150	10	551,500
+95.00	50,600	45,350	10	453,500
+105.00	40,100	33,800	10	338,000
+115.00	27,500			
Total				2,273,500

Waste Retaining Structure

The waste retaining structure, embankment, serves to contain waste in the landfill and to temporally store unexpected large amount of leachate caused by heavy rain. The construction of embankment will be partially, as the majority of the landfill will be dig up. The height of the embankment is to be 10 m from the bottom of the landfill. The inner slope of the embankment has ascent of 1 to 2 and the outer has 1 to 3 with taking into account stability. The embankment will be made of a good material obtained in the project site.

b.1.2 Groundwater Collection Plan

Present Situation

According to the geological survey, the groundwater level is fairly shallow. It is conjectured that the groundwater would flow from the northwest to the southeast. Rock is found at a shallow level. However, it will not be impermeable layer, as there exists many cracks through which the groundwater can flow.

Set Out of Groundwater Drainage Facility

Drainage facility will be distributed to drain the ground water under the landfill. The drainage facility is to consist of main lines and branch lines. The main lines will be placed at food of the embankment and at the scarcement. The branch lines will be distributed in 3,000 m^2 (about at an interval of 30 m).

Structure of Groundwater Drainage Facility

Structure of the groundwater drainage facility is shown in Figure K-12. The structure is designed based on case examples in Japan. Perforated polymer pipes are to be surrounded by crushed stones. The main line has a diameter of 300 mm. The branch line is 200 mm, which can avoid to block up with soil.

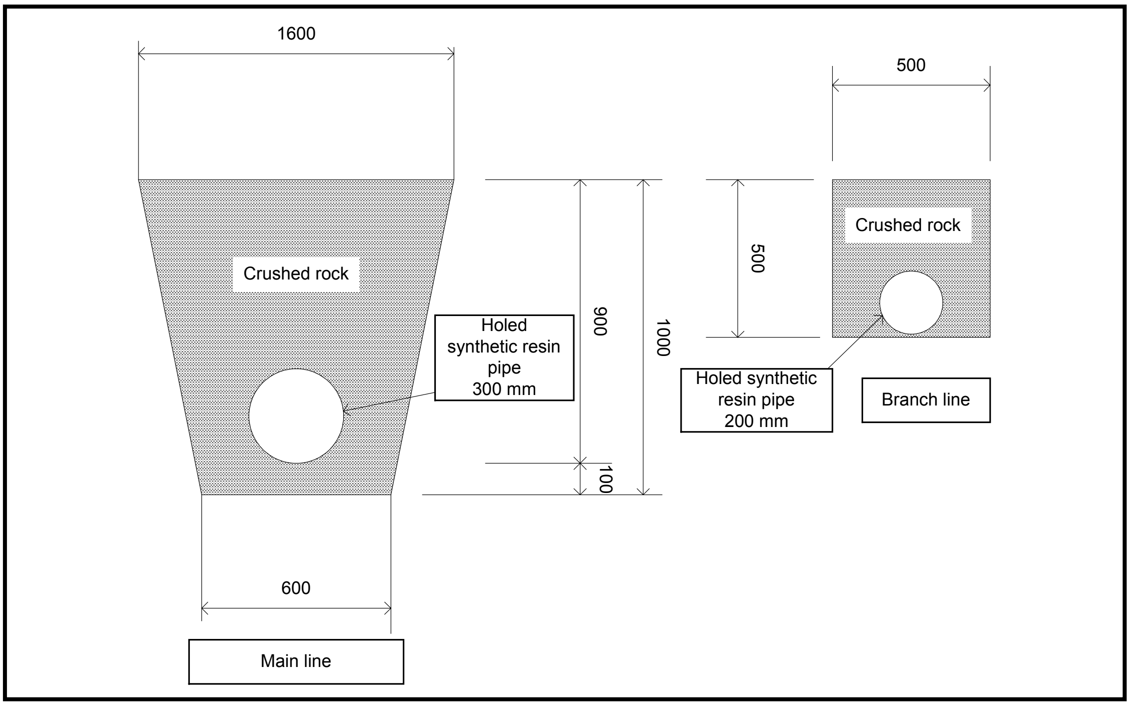


Figure K-12: Cross Section of Ground Water Drainage

b.1.3 Leachate Management Plan

b.1.3.1 Seepage Control Plan

The basic layer at the project site is rock. The rock has many cracks and it is conjectured that the groundwater will flow through the cracks as aforementioned. Even though the rock itself has high impermeability, the layer as a whole should be regarded as permeable. Therefore, seepage control is to be planned in order to avoid contamination of groundwater with leachate.

There are two type of seepage control. One is construction of vertical impervious wall, which can be applied when an impermeable layer exists clearly. The other is surface lining, which covers whole surface of bottom of landfill with impermeable material. According to the geological condition, the surface lining is recommendable.

Synthetic liner is commonly used as impermeable liner. The liner is not thick, then, it could be damaged by improper manner. Major causes that possibly damage the liner are summarized in Table K-16.

Table K-16: Major Causes of Synthetic Liner Damage

Item	Trigger
Ground	salience, round settlement, ground depression, etc.
Ground water	up lifting, etc.
Landfill work	scratching of landfill equipment, etc.
Waste	keen-edged waste, live load of waste
Climate	ultraviolet degradation, thermal stress, stress cracking, etc.
Installation	scratching of construction equipment, joint defects, etc.

Major causes to damage the liner are physical stress from above. In order to avoid that the liner is damaged, the liner is to be protected enough thickness of soil and geotextile. Consequently, a surface lining system presented in Figure K-13 is designed.

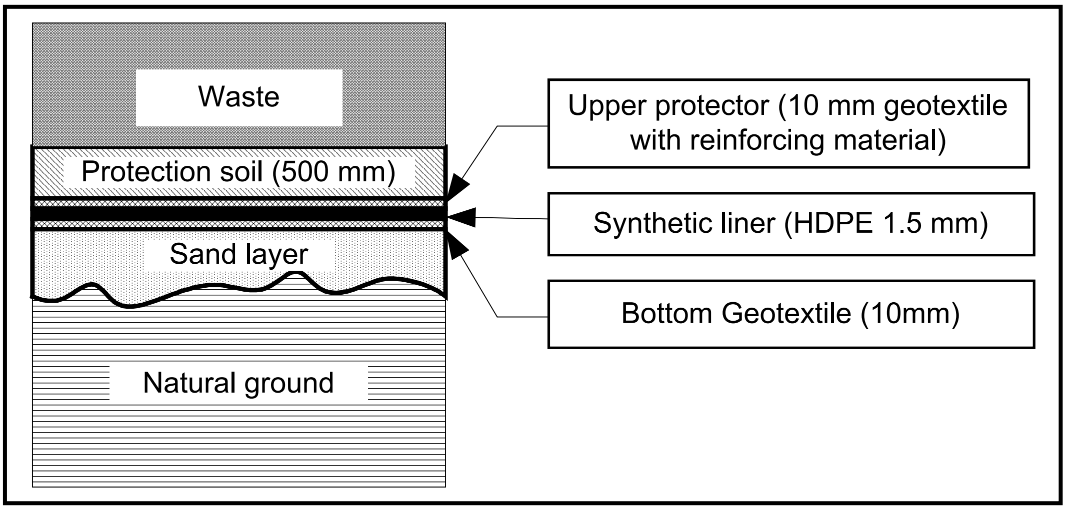


Figure K-13: Seepage Control Lining System

b.1.3.2 Leachate Collection

Leachate Runoff Amount

Leachate has to be drained immediately so as not to hamper landfill operation. Meanwhile, leachate will not seep from the damaged part of the lining system, if there is no leachate stored in the landfill. Therefore, the leachate collection system should have enough capacity to drain the leachate immediately. Design leachate runoff amount is computed by the rational formula, where the same amount of leachate as rainfall will be drained immediately.

$$Q=1/360\times c\times r\times A$$

where ;

Q	:	leachate runoff amount (m^3/sec)
c	:	runoff rate
r	:	rainfall intensity (mm/hour)
A	:	catchments area (hectare)

Runoff rate

Between 0.6 and 0.7 is commonly used as runoff rate, “c.” In order to shorten retention time of leachate in the landfill, 0.7 is applied for “c.”

Rainfall intensity

The probability precipitation in two years of 65 mm/hr is to be used, which was obtained from Panama Canal Authority.

Catchment area

Landfill areas of respective phases are regarded as catchment areas.

Arrangement of collection pipe

Collection pipes consist of main lines and branch lines. Main lines are to be placed at centers of landfills and branch lines are distributed in every 3,000 m^2 (about an interval of 30 m).

Size of collection pipe

Perforated polymer pipes will be used as collection pipes. Size of pipes is to be decided based on computation by means of Manning Formula. It is assumed that whole cross section area is to be used in the computation.

Table K-17: Flow Calculation Table for Leachate Collection System

Network number	Catchments area	Runoff rate	rainfall intensity	Leachate amount	Size of pipe	Inclination	Roughness	Velocity	Allowable flow	Remarks
	(ha)	-	(mm/hr)	(m^3/sec)	(mm)	(%)	-	(m/sec)	(m^3/sec)	
Main line										
Phase 1										
1	6.87	0.7	65	**0.868**	φ700	0.811	0.012	2.348	**0.904**	
Phase 2										
2	6.47	0.7	65	**0.818**	φ700	1.304	0.012	2.977	**1.146**	
Phase 3										
3	6.30	0.7	65	**0.796**	φ700	1.200	0.012	2.856	**1.099**	
Phase 4										
4	7.36	0.7	65	**0.930**	φ800	0.627	0.012	2.257	**1.134**	to No. 6
5	2.69	0.7	65	**0.340**	φ500	0.748	0.012	1.802	**0.354**	to No. 6
6	13.08	0.7	65	**1.653**	φ900	0.748	0.012	2.666	**1.696**	
Branch line										
Common	0.30	0.7	65	**0.038**	φ200	1.200	0.012	1.239	**0.039**	

b.1.4 Rainwater Drainage Plan

Rainwater Runoff Amount

The rational formula is also applied to obtain design rainwater runoff amount.

$$Q=1/360\times f\times r\times A$$

where ;
- Q : rainwater runoff amount (m^3/sec)
- f : runoff rate
- r : rainfall intensity (mm/hour)
- A : catchments area (hectare)

Runoff rate

Runoff rate, "f," is depending on surface conditions of catchment area. Characteristics of the rainwater catchment area are hilly and vegetated. Therefore, 0.6 is applied for "f" according to Table K-18.

Table K-18: Runoff Ratio for Peak Flow

Topographic features	f p
Precipitous terrain	0.75～0.90
Rolling hill and/or forest	0.50～0.75
Agricultural land	0.45～0.60

source: Japan Society of Civil Engineers,1999

Rainfall intensity

The probability precipitation in two years of 65 mm/hr is to be used, which was obtained from Panama Canal Authority.

Catchments area

Catchment area will change according to progress of landfilling, e.g., the area will be the largest at completion of Phase 4. Drainage ditches are designed based on the largest catchment area.

Drainage system

Trapezoid drainage ditch with concrete pavement will be employed. Size of drainage ditches is computed by means of Manning Formula with 20% of depth of freeboard.

Table K-19: Flow Calculation Table for Rainwater Drainage System

Network number	Catchments area	Runoff rate	rainfall intensity	Discharge amount	Channel section			Inclination	Roughness	Velocity	Allowable flow	Remarks
	(ha)	-	(mm/hr)	(m^3/sec)	Top width (mm)	Bottom width (mm)	Depth (mm)	(%)	-	(m/sec)	(m^3/sec)	
Phase 1												
1	17.0	0.6	65	1.842	1700	500	1200	0.483	0.015	1.795	0.379	
2	23.5	0.6	65	2.546	1700	500	1200	1.953	0.015	2.419	1.269	
3	2.4	0.6	65	0.260	900	500	400	0.748	0.015	2.500	1.548	
4	9.8	0.6	65	1.062	1300	500	800	0.748	0.015	4.731	3.909	
5	11.5	0.6	65	1.246	1400	500	900	0.721	0.015	3.485	2.217	
6	35.3	0.6	65	3.824	1700	500	1200	2.000	0.015	2.416	1.537	discharge to river, energy absorbed by stairs structure
Cross over structure 1	17.0	0.6	65	1.842	φ900			1.500	0.013	1.795	0.379	Inlet
Cross over structure 2	11.5	0.6	65	1.246	φ900			0.721	0.013	2.419	1.269	Internal road of leachate treatment facility
Phase 2												
7	9.6	0.6	65	1.040	1200	500	700	1.053	0.015	2.710	1.184	
8	2	0.6	65	0.217	800	500	300	1.622	0.015	2.328	0.346	
9	5.6	0.6	65	0.607	1100	500	600	0.627	0.015	1.957	0.695	
Cross over structure 3	2.4	0.6	65	0.260	φ500			0.748	0.013	1.663	0.327	connect to No.3 of Phase 1
Phase 3												
10	3.4	0.6	65	0.368	900	500	400	1.163	0.015	2.239	0.473	discharge to river
11	4.2	0.6	65	0.455	1000	500	500	0.699	0.015	1.911	0.535	
12	4.3	0.6	65	0.466	1000	500	500	2.000	0.015	3.233	0.905	discharge to river, energy absorbed by stairs structure
13	2.2	0.6	65	0.238	900	500	400	0.769	0.015	1.820	0.384	
Cross over structure 4	9.8	0.6	65	1.062	φ800			0.700	0.013	2.201	1.106	connect to No.4 of Phase 1

b.2 Leachate Treatment System

b.2.1 Treatment Amount

Leachate amount will change depending on precipitation and evaporation. Rain season is distinctly different from dry season in the study area, where the most of rainfalls happen in the rain season. In this case, it is not economical to design leachate treatment facilities based on the maximum rainfall. In order to avoid this uneconomical case, there is a manner to construct a regulation pond to average the leachate amount to be treated. Figure K-14 shows concept of the manner. This manner lowers the design capacity of the facilities and reduces costs, but also makes operation easy as the leachate amount will be stable.

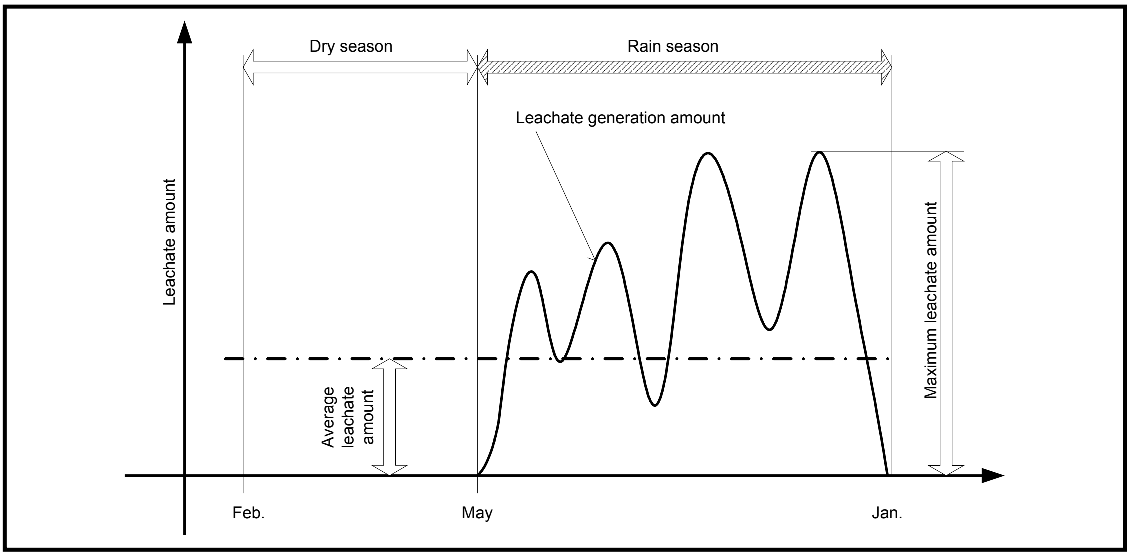


Figure K-14: Concept of Maximum and Average Leachate Generation Amount

Required Leachate Regulation and Treatment Amount

Leachate amount is depending on precipitation and evaporation. Required capacity of leachate treatment facilities is subject to capacity of a regulation pond. Figure K-15 shows this concept.

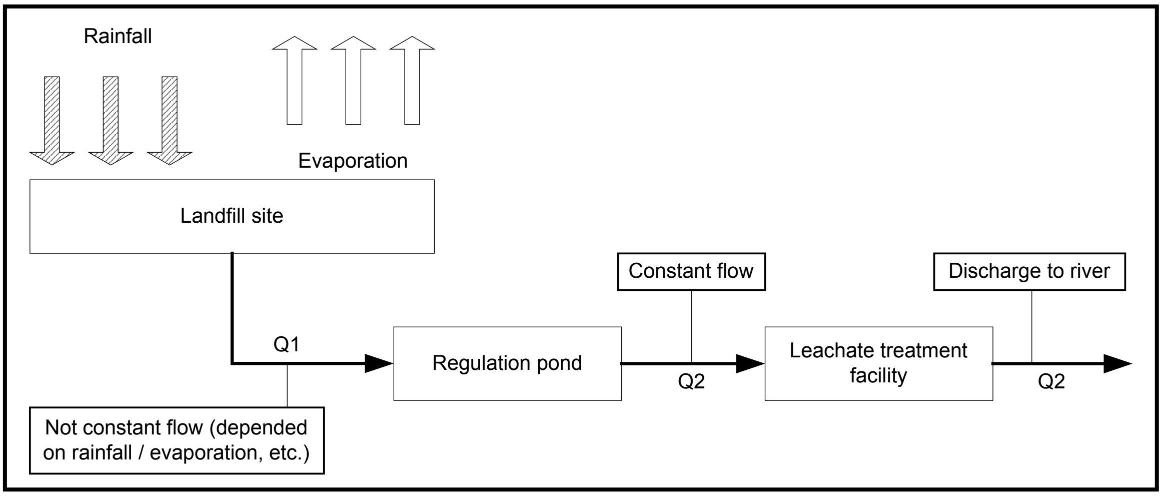


Figure K-15: Concept of Leachate Regulation and Treatment Amount

Leachate amount is computed by means of the following formula.

$$Q = \frac{I(C1 \times A1 + C2 \times A2)}{1{,}000}$$

where ;

I	:	Rainfall intensity (mm/day)
Q	:	Leachate generation amount (m^3/day)
C1	:	Infiltration coefficient for landfill operation area
A1	:	Landfill operation area (m^2)
C2	:	Infiltration coefficient for closed landfill area
A2	:	Closed landfill area (m^2)

$$C1 = 1 - ET / IM$$

where;

ET	:	Monthly possible evaporation amount (mm) (ET=0.7Et)
Et	:	Monthly evaporation amount (mm)

$$Et = 0.245 \times K \times Cj \times tj \qquad Cj = \frac{dj}{\sum dj \times 100}$$

where;

dj	:	Monthly sunshine hour (hour)
tj	:	Monthly average air temperature (Fahrenheit)

Infiltration coefficient

Table K-20, Table K-21 and Table K-22 present infiltration coefficients, c1 and c2, obtained based on meteorological data at respective stations.

Table K-20: Infiltration Coefficient at Gamboa

	tj (F)	dj (hr)	Cj (%)	Et (mm)	ET (mm)	I (mm/month)	C1	C2
Jan.	78.6	252	10.6	127.0	88.9	50.0	-0.78	-0.47
Feb.	79.2	240	10.1	121.9	85.3	16.5	-4.17	-2.5
March	79.7	269	11.3	137.3	96.1	25.9	-2.71	-1.63
April	80.8	243	10.2	125.6	87.9	87.9	0	0
May	80.2	189	8.0	97.8	68.5	250.4	0.73	0.44
June	79.3	157	6.6	79.8	55.9	267.2	0.79	0.47
July	79.0	160	6.7	80.7	56.5	227.1	0.75	0.45
Aug.	79.2	159	6.7	80.9	56.6	251.5	0.77	0.46
Sept.	78.6	174	7.3	87.4	61.2	306.8	0.8	0.48
Oct.	78.4	167	7.0	83.6	58.5	293.9	0.8	0.48
Nov.	77.9	151	6.4	76.0	53.2	294.1	0.82	0.49
Dec.	78.3	210	8.9	106.2	74.3	145.8	0.49	0.29
Average	79.1	197.583	8.317	100.35	70.242	184.8	-0.14	-0.09

Table K-21: Infiltration Coefficient at PMG

	tj (F)	dj (hr)	Cj (%)	Et (mm)	ET (mm)	I (mm/month)	C1	C2
Jan.	79.7	263	11.9	144.5	101.2	38.5	-1.63	-0.98
Feb.	80.6	246	11.1	136.3	95.4	13.5	-6.07	-3.64
March	81.1	255	11.5	142.1	99.5	24.3	-3.09	-1.85
April	81.9	209	9.5	118.6	83.0	87.4	0.05	0.03
May	80.6	162	7.3	89.7	62.8	251.0	0.75	0.45
June	79.9	135	6.1	74.3	52.0	259.9	0.80	0.48
July	79.9	147	6.7	81.6	57.1	241.7	0.76	0.46
Aug.	79.3	147	6.7	81.0	56.7	241.7	0.77	0.46
Sept.	79.0	148	6.7	80.7	56.5	242.8	0.77	0.46
Oct.	79.0	147	6.7	80.7	56.5	300.8	0.81	0.49
Nov.	78.4	143	6.5	77.7	54.4	270.9	0.80	0.48
Dec.	79.0	208	9.4	113.2	79.2	111.8	0.29	0.17
Average	79.9	184.167	8.342	101.7	71.192	173.7	-0.42	-0.25

Table K-22: Infiltration Coefficient at B AFF

	tj (F)	dj (hr)	Cj (%)	Et (mm)	ET (mm)	I (mm/month)	C1	C2
Jan.	79.7	263	11.9	144.5	101.2	50.8	-0.99	-0.59
Feb.	80.6	246	11.1	136.3	95.4	26.7	-2.57	-1.54
March	81.1	255	11.5	142.1	99.5	39.6	-1.51	-0.91
April	81.9	209	9.5	118.6	83	58.2	-0.43	-0.26
May	80.6	162	7.3	89.7	62.8	292.9	0.79	0.47
June	79.9	135	6.1	74.3	52.0	276.6	0.81	0.49
July	79.9	147	6.7	81.6	57.1	216.7	0.74	0.44
Aug.	79.3	147	6.7	81.0	56.7	183.9	0.69	0.41
Sept.	79.0	148	6.7	80.7	56.5	269.0	0.79	0.47
Oct.	79.0	147	6.7	80.7	56.5	288.8	0.80	0.48
Nov.	78.4	143	6.5	77.7	54.4	287.5	0.81	0.49
Dec.	79.0	208	9.4	113.2	79.2	158.2	0.50	0.30
Average	79.9	184.167	8.342	101.7	71.192	179.1	0.04	0.02

Landfill Area

As mentioned before, the project site is divided into three sections, or Phase 1, Phase 2 and Phase 3. Then, valleys, which will appear between the sections after completion of those three phases, will be filled with waste; this is Phase 4.

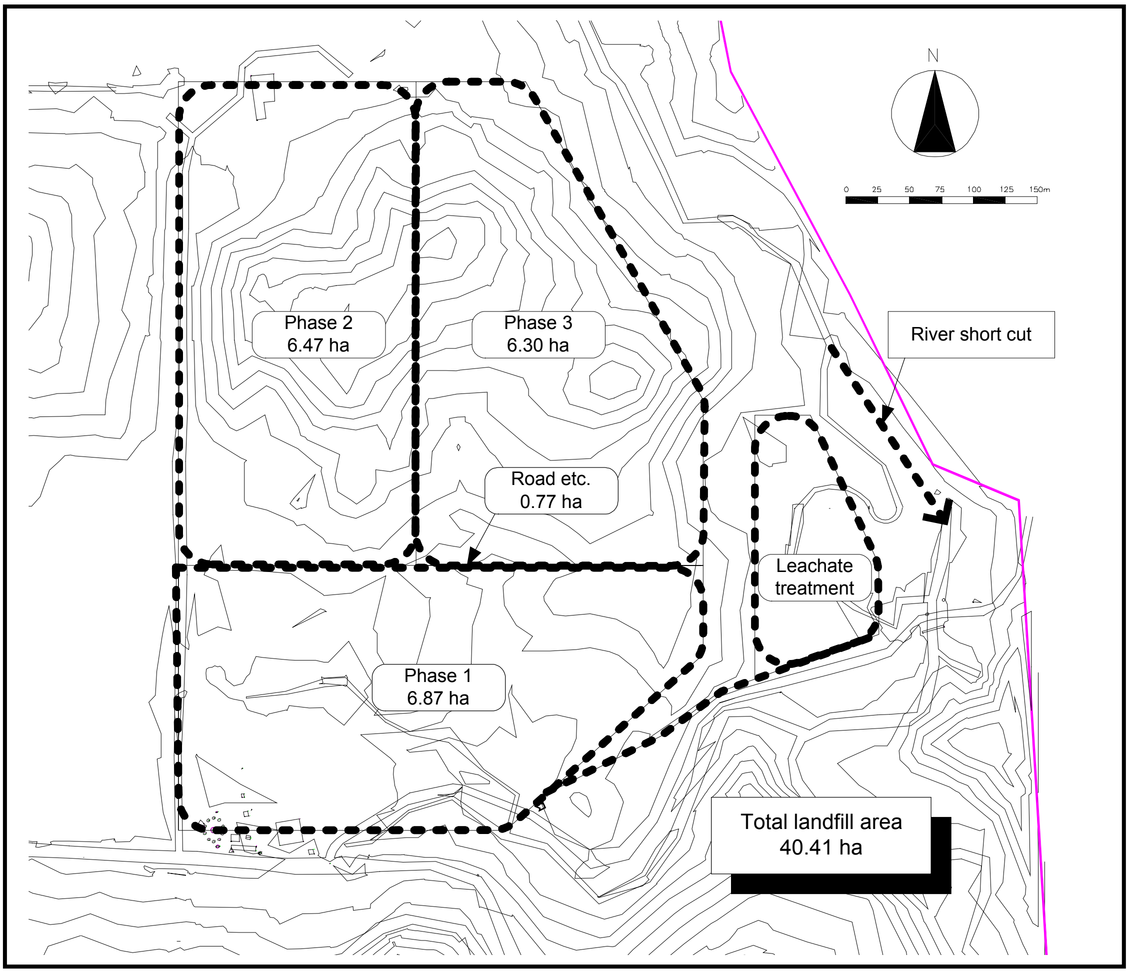


Figure K-16: Landfill Area

Operation area and closed area are considered as shown in Table K-23 for leachate calculation.

Table K-23: Calculation Cases

	Landfill phase	Operation area (ha)	Closed area (ha)
Case 1	Phase 1	6.87	0
Case 2	Phase 2	6.47	6.87
Case 3	Phase 3	6.30	13.34
Case 4	Phase 4	6.50	13.91
Case 5	Closed	0	20.41

The maximum annual rainfall in the last 10 years will be used of the calculation.

Table K-24: Maximum Rainfall Year (1992 to 2001)

	Gamboa	PMG	B AFF
Maximum year	1993	1996	1995
Annual rainfall (mm/year)	2,626	2,367	2,875

Leachate Generation Amount

Results of leachate amount calculation in respective cases and in respective stations are shown in the following figures.

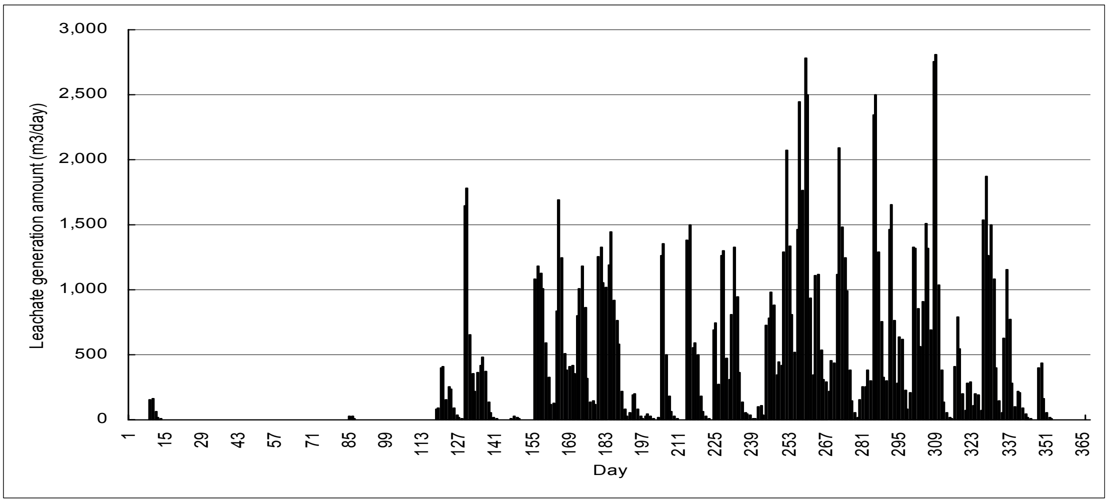


Figure K-17: Leachate Generation Amount (Gamboa Case 1)

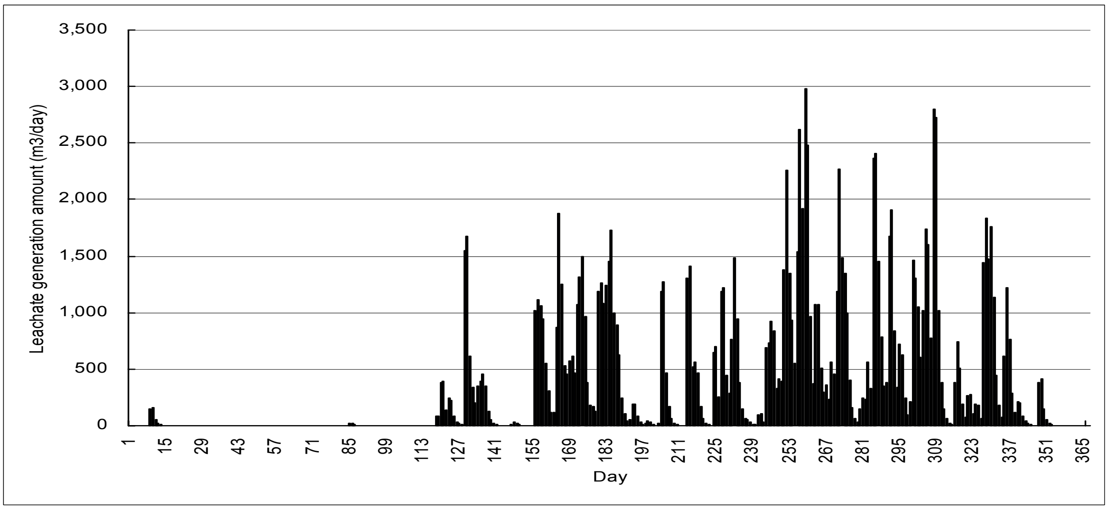


Figure K-18: Leachate Generation Amount (Gamboa Case 2)

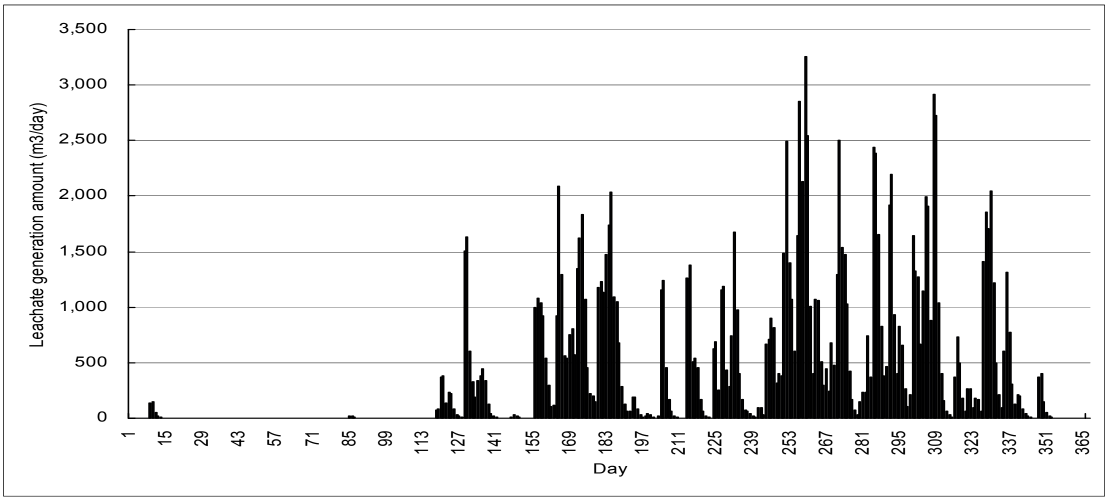


Figure K-19: Leachate Generation Amount (Gamboa Case3)

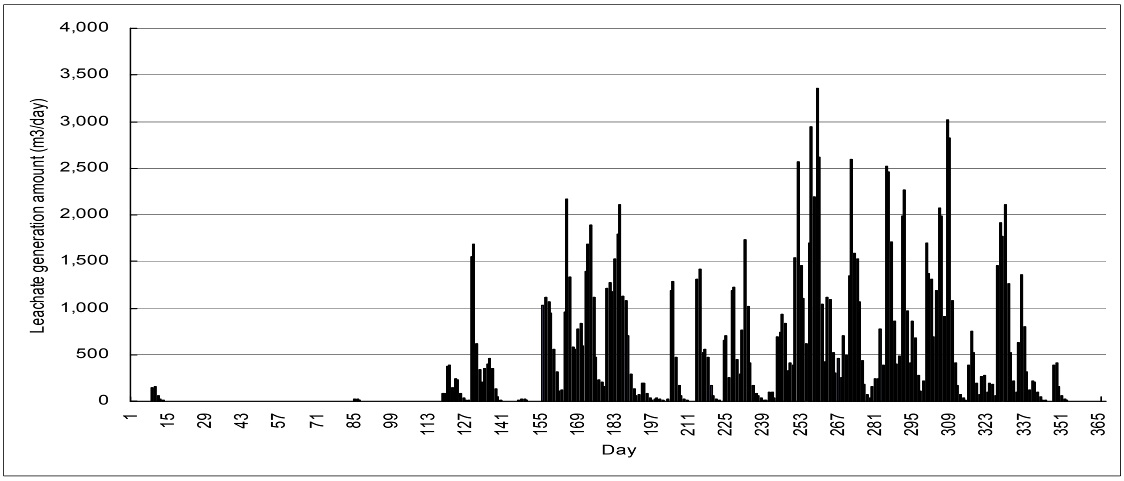


Figure K-20: Leachate Generation Amount (Gamboa Case 4)

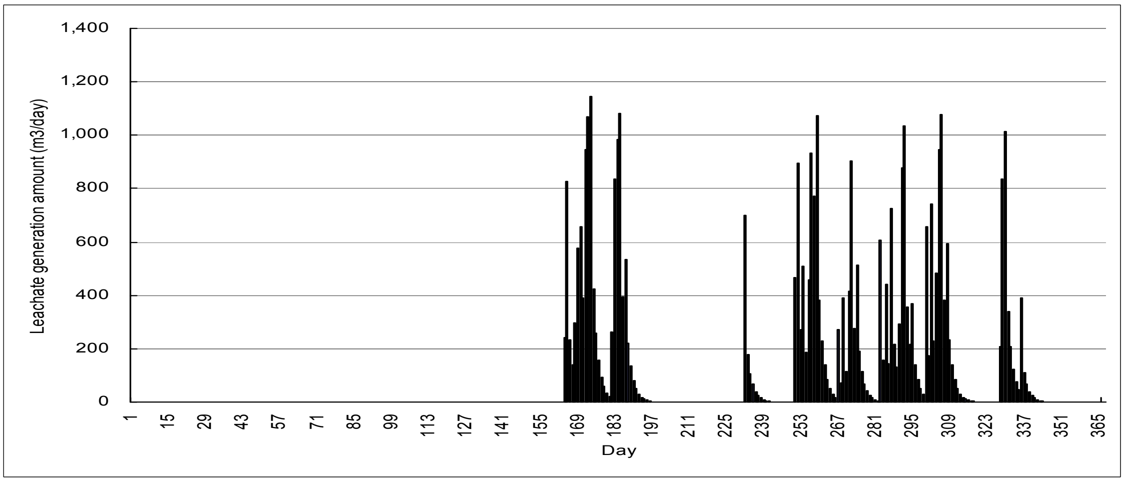


Figure K-21: : Leachate Generation Amount (Gamboa Case 5)

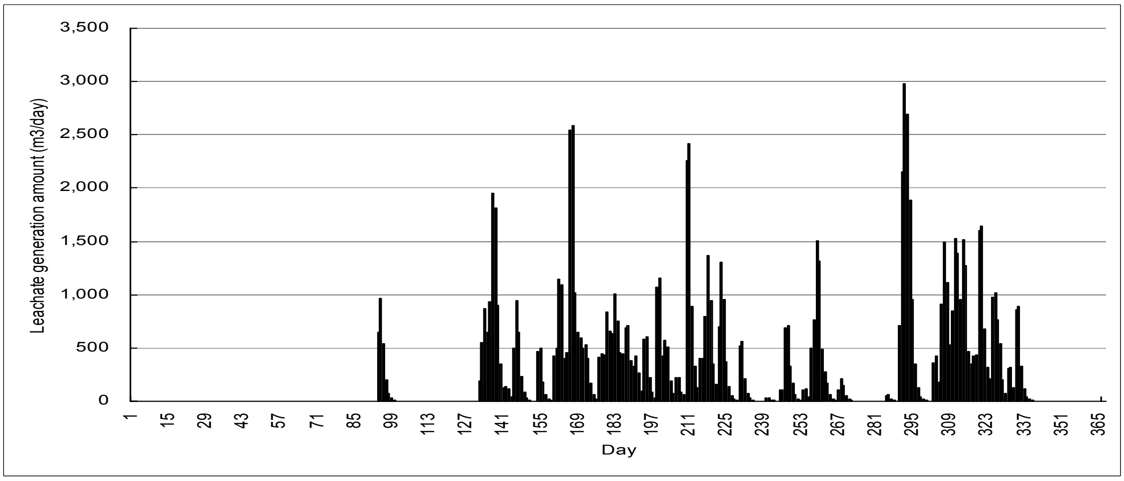


Figure K-22: : Leachate Generation Amount (PMG Case 1)

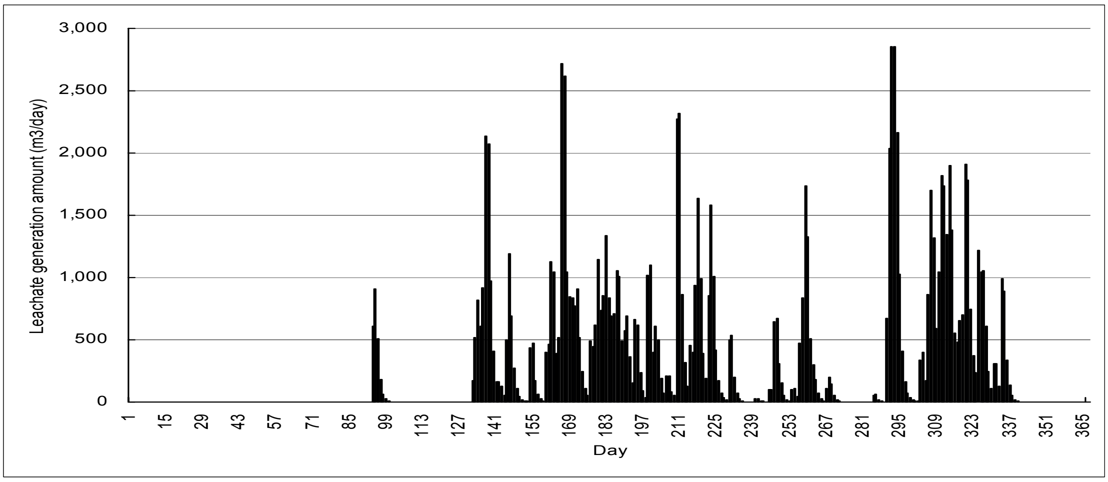


Figure K-23: Leachate Generation Amount (PMG Case 2)

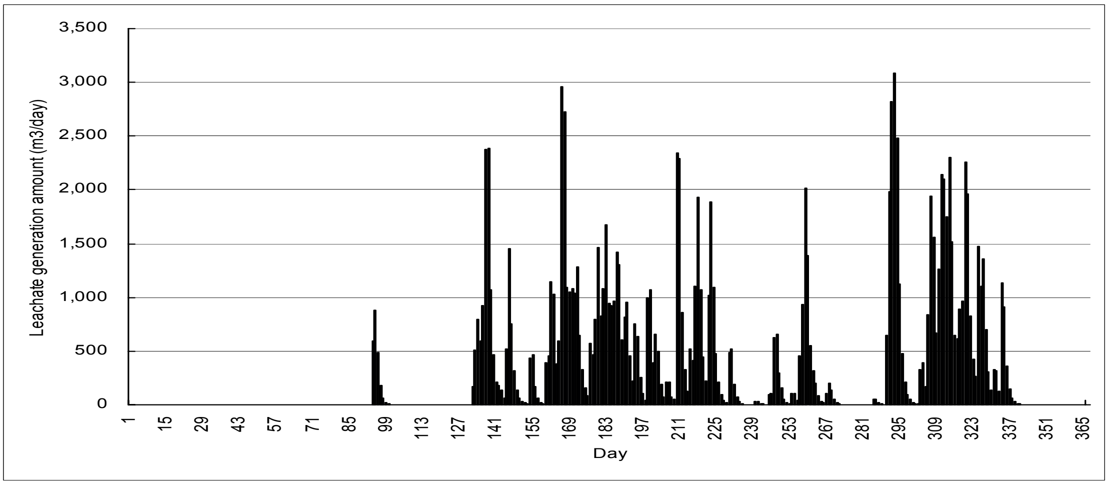


Figure K-24: : Leachate Generation Amount (PMG Case 3)

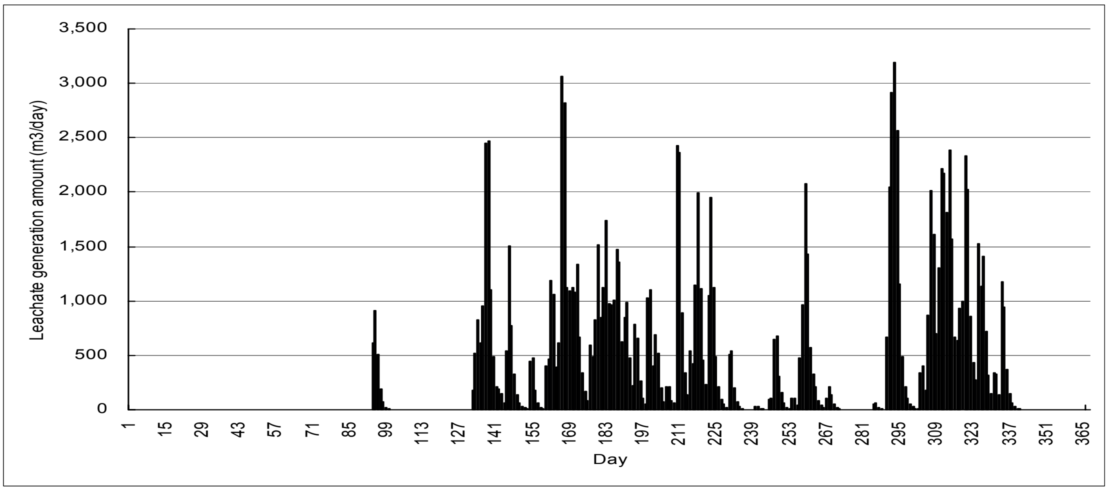


Figure K-25: Leachate Generation Amount (PMG Case 4)

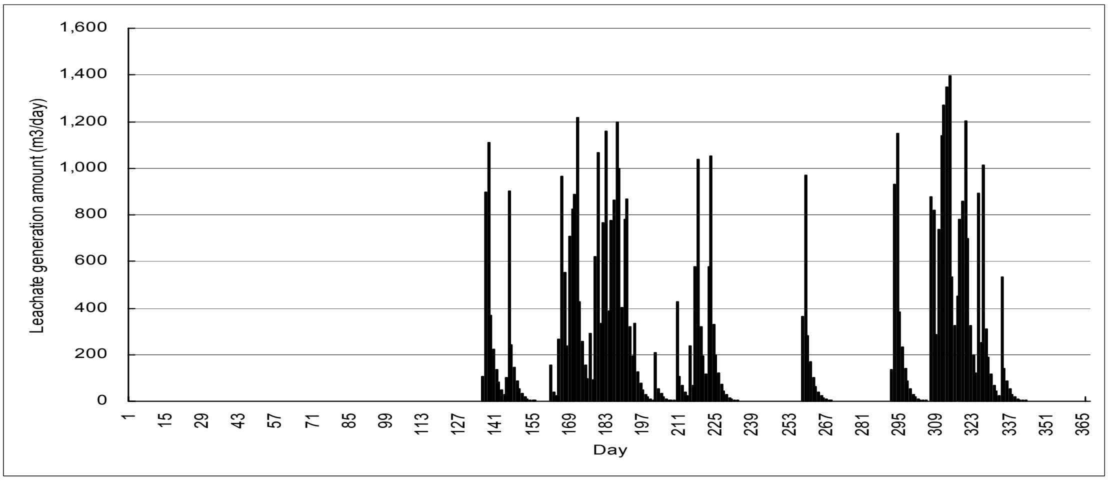


Figure K-26: : Leachate Generation Amount (PMG Case 5)

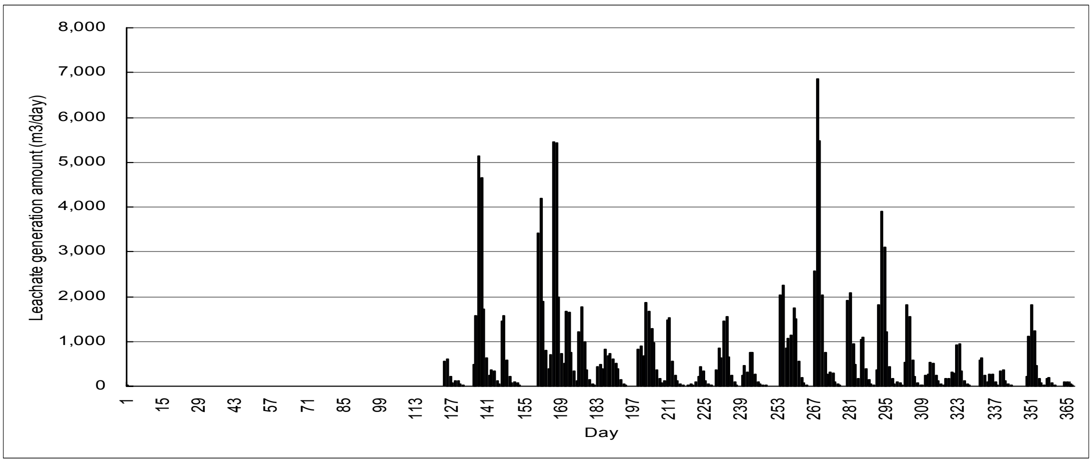


Figure K-27: Leachate Generation Amount (B AFF Case 1)

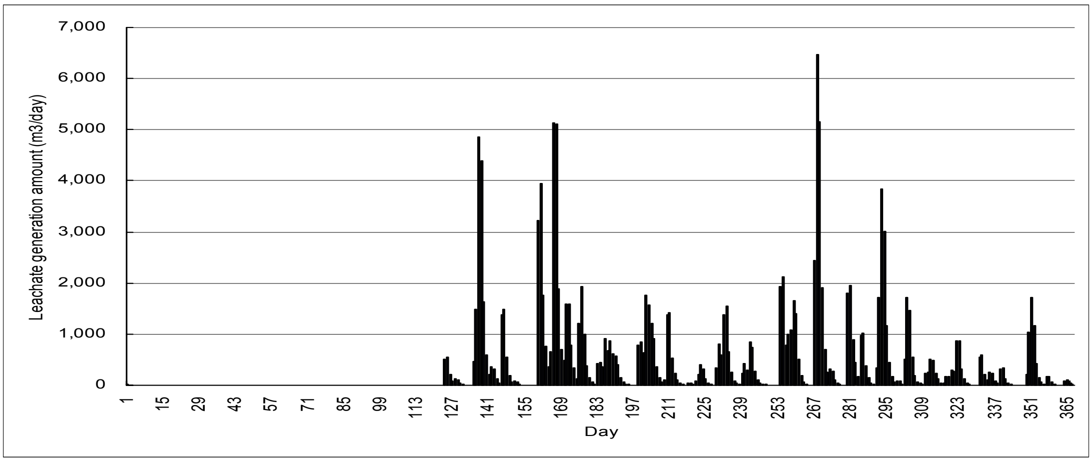


Figure K-28: Leachate Generation Amount (B AFF Case 2)

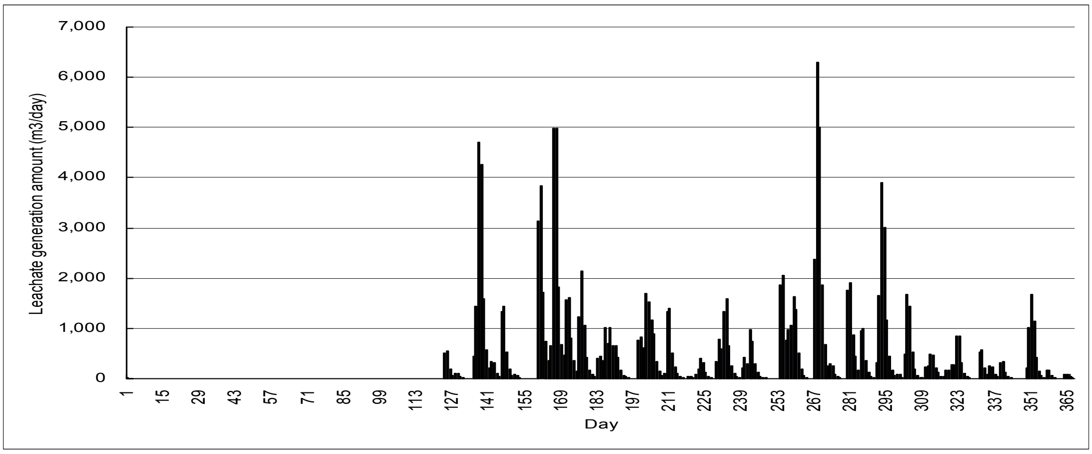


Figure K-29: Leachate Generation Amount (B AFF Case 3)

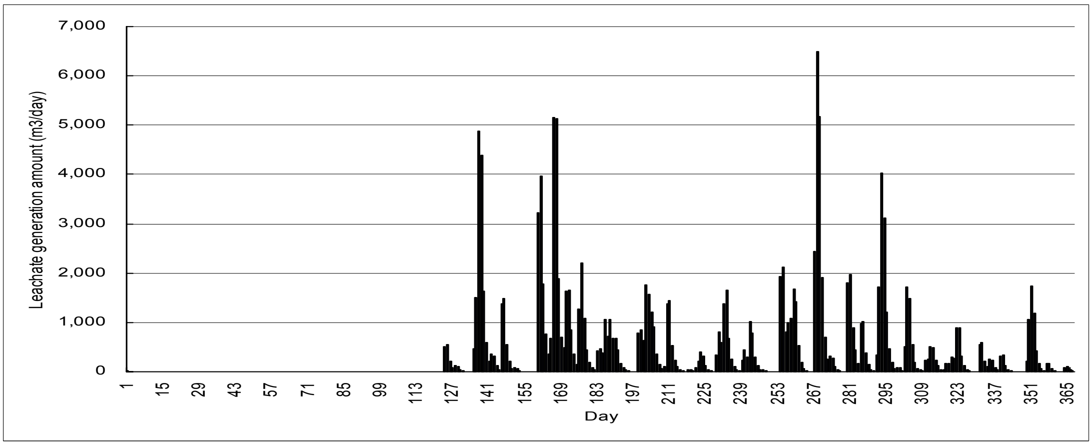


Figure K-30: Leachate Generation Amount (B AFF Case 4)

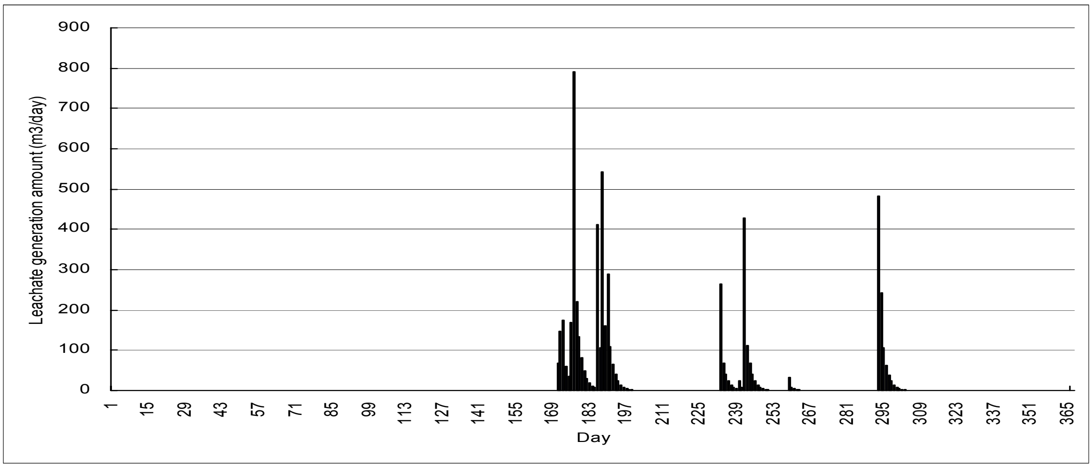


Figure K-31: Leachate Generation Amount (B AFF Case 5)

Required Treatment Capacity and Regulation Amount

Table K-25 shows relation between required capacities of the treatment facilities and the regulation pond obtained based on the leachate generation amounts. Site conditions define capacity of the regulation pond, i.e., 24,000 m^3. Then, the required capacity of leachate treatment facilities, which matches with the pond, can be obtained from the table as 800 m^3/day.

Table K-25: Treatment Capacity and Regulation Amount

	Landfill phase	Gamboa		PMG		B AFF	
		Treatment capacity (m^3/day)	Regulation amount (m^3)	Treatment capacity (m^3/day)	Regulation amount (m^3)	Treatment capacity (m^3/day)	Regulation amount (m^3)
Case 1	Phase 1	650	21,178	400	19,597	**700**	**22,914**
		700	18,153	450	16,325	750	20,764
Case 2	Phase 2	700	21,874	500	18,803	700	20,388
		750	18,874	550	16,853	750	18,355
Case 3	Phase 3	800	21,189	**600**	**20,089**	650	21,754
		850	18,189	650	18,139	700	18,604
Case 4	Phase 4	**800**	**23,539**	650	19,656	700	21,193
		850	20,539	700	17,733	750	19,075
Case 5	Closer	800	763	650	2,965	700	90

b.2.2 Water Quality

Leachate quality varies depending on types of wastes disposed, climate, etc. In the Study, leachate quality of the existing landfill was surveyed at a time. BOD 762 mg/l and COD 1,009 mg/l were obtained from the results. These values are considerably lower than typical leachate quality shown in Table K-26.

Table K-26: Typical Data of Leachate Quality

	Range (mg/liter)	Typical (mg/liter)
BOD	2,000 to 30,000	10,000
COD	3,000 to 60,000	18,000
Organic nitrogen	10 to 800	200
Ammonia nitrogen (NH_3-N)	10 to 800	200
Total phosphorus	5 to 100	30
Nitrate	5 to 40	25

source : integrated solid waste management, McGraw-Hill

It is judged risky to use the obtained values of leachate quality as design conditions. Then, the typical values are applied as design conditions, influent quality, for the leachate treatment facilities in this plan. Meanwhile, the effluent standards set by ANAM are regarded as design effluent quality of leachate. Table K-27 summarizes the design conditions of the leachate treatment facilities, i.e., influent and effluent qualities.

Table K-27: Design Conditions for Leachate Treatment Facility

	Influent quality (mg/liter)	Effluent quality (mg/liter)
BOD	10,000	35
COD	18,000	100
Organic nitrogen	200	10
Ammonia nitrogen (NH_3-N)	200	3
Total phosphorus	30	5
Nitrate	25	6

b.2.3 Treatment Process

Process Flow Sheet

The existing leachate treatment method is the aerobic-anaerobic (facultative) pond. This method cannot achieve the effluent standards above. Especially, it is difficult to attain the standard set for nitrate. Activated sludge method removes nitrogenous matters effectively. However, its operation requires sophisticated technology. Consequently, oxidation ditch method, which can remove nitrogenous matters and is relatively easy to operate, with physical-chemical treatment to remove phosphorus and heavy metals is applied in this plan.

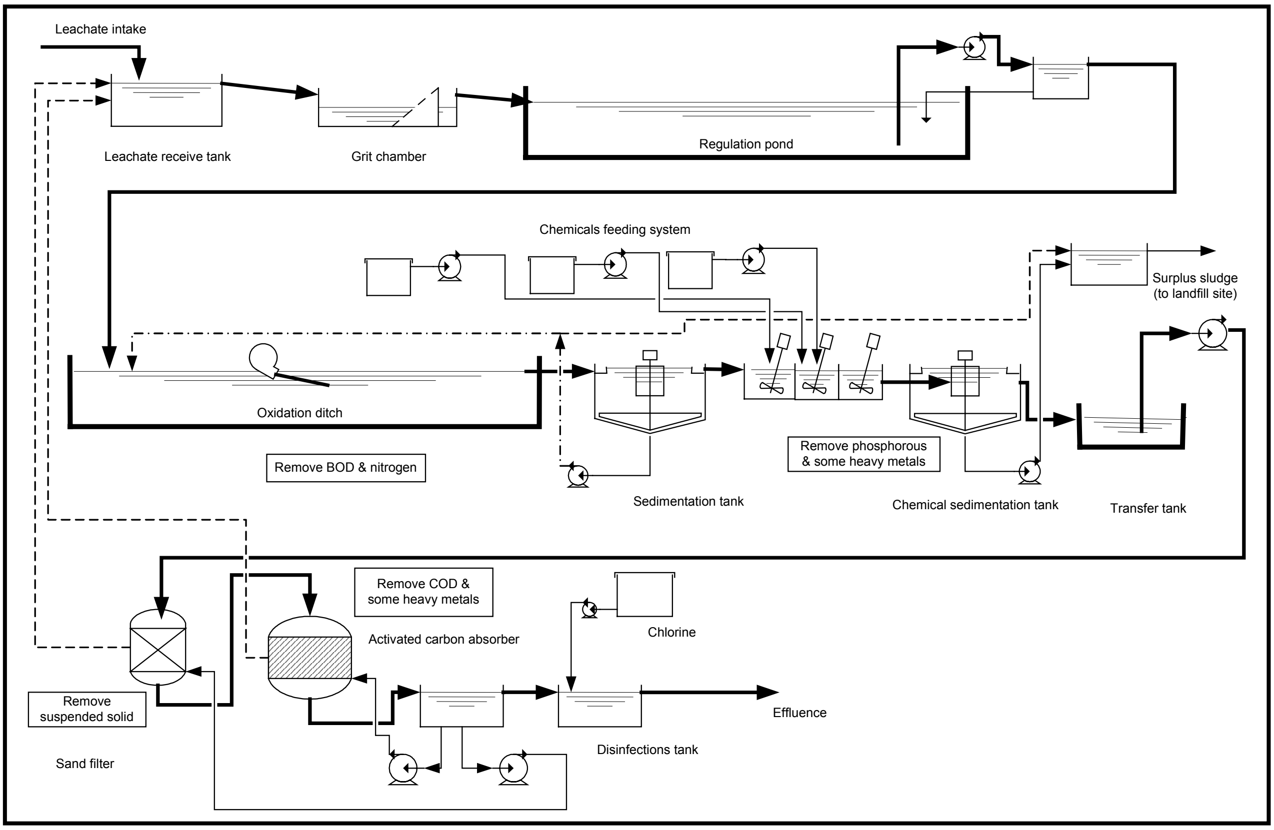


Figure K-32: Leachate Treatment Process Flow Sheet

Process Calculation

Volume of Oxidation Ditch

Total recycle ratio

$$R = \frac{(NH_3 - N)_{in} - (NH_3 - N)_{out}}{(NO_3^- - N)_{out}} - 1$$

$$R = \frac{200 - 3}{6} - 1 = 31.8$$

Overall sludge age

$$\theta_c^{'} = \frac{\theta_c}{V_{aerobic}} = \frac{8.9}{0.71} = 12.5 days$$

Detention time for BOD removal

f_{vss}=MLVSS/MLSS = 0.7

$$\theta_a = \frac{\theta_c^{'} Y_h (S_0 - S)}{X_a \left[1 + k_d f_{vss} \theta_c^{'}\right]} = \frac{0.55 \times (10{,}000 - 35) \times 12.5}{2{,}500[1 + (0.04 \times 0.70 \times 12.5)]} = 20.30 days$$

Detention time for de-nitrification

$$\theta'_{DN} = \frac{N_{Denit}}{U_{DN} X_a} = \frac{(200-3-6)}{0.042 \times 2{,}500} = 1.82 days$$

Required total detention time

$$\theta_a + \theta'_{DN} = 20.30 + 1.82 = 22.12 days$$

Sedimentation and Chemical Sedimentation Tank

Detention time : 6.0 hours
Water flow surface loading: $15 m^3/m^2/day$

Required volume $V = \frac{800}{24} \times 6 = 200 m^3$

Required surface area $A = \frac{800}{15} = 53.3 m^2$

Sand filter and Activated carbon absorber

Filtration rate : 100 m/day

Required filtration area $A_f = \frac{800}{100} = 8.0 m^2$

Summary of Leachate Treatment Facility

Summary of the leachate treatment facility shows below table.

Table K-28: Summary of Leachate Treatment Facility

Item	Description
Regulation pond	24,0000 m^3
Treatment capacity	800 m^3/day
Treatment method	Oxidation ditch with chemical sedimentation, sand filtration and activated carbon absorption
Oxidation ditch	17,600 m^3 (detention time 22 days)
Sedimentation tank	200 m^3 / 54 m^2 (detention time 6 hour)
Chemical sedimentation tank	200 m^3 / 54 m^2 (detention time 6 hour)
Sand filter	Pressed sand filter (diameter: 3.5 m, nos. : 2)
Activated carbon absorber	Pressed type (diameter: 3.5 m, nos. : 2)

c. Cost Estimation

c.1 Investment Cost

c.1.1 Civil Works

Results of cost estimation are shown in tables below.

Table K-29: Civil Work Phase 1

Item 1	Item 2	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
Site preparation							
	Tree trimming, etc.	heavy equipment	m2	112,000.0	0.01	1,120	
Temporary works						3,495	
	Temporary sedimentation pond for earth works		nos.	1.0	2,198.63	2,199	
	Soil escape prevention fence		m	300.0	4.32	1,296	
Earth works						1,258,003	
	Cut 1	soil and sand	m3	203,000.0	0.60	121,800	50%
	Cut 2	soft rock	m3	203,000.0	1.57	318,710	50%
	Embankment	variation rate=0.9	m3	16,700.0	1.49	24,883	15,000÷0.9
	Transport & stockpiling	distance=1.2 km	m3	469,000.0	1.69	792,610	391,000×1.2
Slope works						30,659	
	Cut slope finishing	1 : 2	m2	4,190.0	2.73	11,439	
	Greening for cut slope	seeding	m2	4,190.0	0.36	1,508	
	Banking slope finishing	1 : 3	m2	3,740.0	1.82	6,807	
	Greening for banking slope	seeding	m2	3,740.0	0.36	1,346	
	Finishing of flat area		m2	6,330.0	0.98	6,203	
	Greening of flat area	seeding	m2	6,330.0	0.53	3,355	
Bottom lining of landfill site						1,147,818	
	Preparation of surface for HDPE liner	slope	m2	22,650.0	1.36	30,804	
	Preparation of surface for HDPE liner	base	m2	48,020.0	0.09	4,322	
	Under surface geotextile	bonded textile, t=10mm	m2	70,670.0	0.00	0	
	Synthetic liner	HDPE、t=1.5mm	m2	70,670.0	10.00	706,700	
	Upper surface geotextile	bonded textile with reinforcing material, t=10mm	m2	70,670.0	4.66	329,322	
	Protective soil layer	t=50cm	m3	23,140.0	2.00	46,280	
	Anchor for synthetic liner	concrete 0.5m×0.5m	m	2,330.0	12.84	29,917	
	Mechanical joint of synthetic liner	for concrete structure	m	8.0	59.09	473	leachate drainage
Underground water drainage						54,926	
	Main collector	φ300, holed synthetic resin pipe with gravel filter	m	1,000.0	29.81	29,810	
	Branch collector	φ200, holed synthetic resin pipe with gravel filter	m	2,730.0	9.20	25,116	

Item 1	Item 2	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
Rain water drainage						70,292	
	Trapezoidal lined ditch	W900×B500×H400	m	180.0	27.24	4,903	
	Trapezoidal lined ditch	W1300×B500×H800	m	230.0	46.73	10,748	
	Trapezoidal lined ditch	W1400×B500×H900	m	290.0	51.61	14,967	
	Trapezoidal lined ditch	W1700×B500×H1200	m	490.0	66.52	32,595	
	Concrete pipe	φ900 、with 360° concrete foundation	m	40.0	176.97	7,079	
Leachate collection system						101,613	
	Main line	φ700, holed synthetic resin pipe with gravel filter	m	370.0	157.45	58,257	
	Branch line	φ200, holed synthetic resin pipe with gravel filter	m	1,700.0	19.85	33,745	
	Transmission pipe	φ700, synthetic resin pipe	m	80.0	92.86	7,429	
	Transmission pipe joint	concrete structure	nos.	1.0	289.35	289	
	Vertical leachate collection pipe	φ200, holed synthetic resin pipe	nos.	23.0	82.30	1,893	combined gas ventilation
Road works						47,684	
	preparation of roadbed		m2	13,100.0	0.44	5,764	
	gravel pavement	t=150mm	m2	13,100.0	3.20	41,920	
Fencing						37,887	
	Fencing	H=2.3 m	m	1,180.0	30.13	35,553	
	Gate	W=8.0m	nos.	1.0	2,333.33	2,333	
Modification of river						16,479	
	Cut 1	soil and sand	m3	1,660.0	0.60	996	50%
	Cut 2	soft rock	m3	1,660.0	1.57	2,606	50%
	Transport & stockpiling	distance=1.2 km	m3	3,980.0	1.69	6,726	3,320×1.2
	Cut slope finishing	1 : 2	m2	1,670.0	2.73	4,559	
	Greening for cut slope	seeding	m2	1,670.0	0.36	601	
	Raise up riverbed		m2	1,010.0	0.98	990	
Operation facilities						140,000	
	Site office	Reinforced concrete	m2	100.0	500.00	50,000	
	Workshop	Steel structure	m2	300.0	300.00	90,000	
Sub-total of direct cost			set	1.0		2,909,974	
Miscellaneous			%	10.0		290,997	
Direct cost						3,200,971	
Overhead			%	30.0		960,291	
Total construction cost						4,161,262	
TAX			%	5.0		208,063	
Project cost (phase I)						4,369,325	

Table K-30: Civil Works Phase 2

Item 1	Item 2	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
Site preparation							
	tree trimming, etc.	heavy equipment	m2	99,000.0	0.01	990	
Temporary works						86	
	Soil escape prevention fence		m	20.0	4.32	86	
Earth work						11,987,226	
	Cut 1	soil and sand	m3	493,000.0	0.60	295,800	25%
	Cut 2	soft rock	m3	493,000.0	1.57	774,010	25%
	Cut 3	rock	m3	987,000.0	5.00	4,935,000	50%
	Embankment	variation rate=0.9	m3	4,400.0	1.49	6,556	4,000÷0.9
	Transport & stockpiling	distance=1.2 km	m3	2,362,000.0	2.53	5,975,860	1,969,000×1.2
Slope works						102,568	
	Cut slope finishing	1 : 2	m2	31,980.0	2.73	87,305	
	Greening for cut slope	seeding	m2	31,980.0	0.36	11,513	
	Finishing of flat area		m2	3,000.0	0.98	2,940	
	Greening of flat area	seeding	m2	3,000.0	0.27	810	
Bottom lining of landfill site						1,220,951	
	Preparation of surface for HDPE liner	slope	m2	24,100.0	1.36	32,776	
	Preparation of surface for HDPE liner	base	m2	42,700.0	0.09	3,843	
	Under surface geotextile	bonded textile, t=10mm	m2	66,800.0	2.01	134,268	
	Synthetic liner	HDPE、t=1.5mm	m2	66,800.0	10.00	668,000	
	Upper surface geotextile	bonded textile with reinforcing material, t=10mm	m2	66,800.0	4.66	311,288	
	Protective soil layer	t=50cm	m3	20,450.0	2.00	40,900	
	Anchor for synthetic liner	concrete 0.5m×0.5m	m	2,290.0	12.84	29,404	
	Mechanical joint of synthetic liner	for concrete structure	m	8.0	59.09	473	leachate drainage
Underground water drainage						63,659	
	Main collector	φ300, holed synthetic resin pipe with gravel filter	m	1,330.0	29.81	39,647	
	Branch collector	φ200, holed synthetic resin pipe with gravel filter	m	2,610.0	9.20	24,012	
Rain water drainage						29,880	
	Trapezoidal lined ditch	W800×B500×H300	m	180.0	22.46	4,043	
	Trapezoidal lined ditch	W1100×B500×H600	m	230.0	37.06	8,524	
	Trapezoidal lined ditch	W1200×B500×H700	m	290.0	41.86	12,139	

Item 1	Item 2	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
	Concrete pipe	φ500, with 360° concrete foundation	m	10.0	95.17	952	
	Scarcement drainage		m	2,080.0	2.03	4,222	
Leachate collection system						119,144	
	Main line	φ700, holed synthetic resin pipe with gravel filter	m	350.0	157.45	55,108	
	Branch line	φ200, holed synthetic resin pipe with gravel filter	m	1,670.0	19.85	33,150	
	Transmission pipe	φ700, synthetic resin pipe	m	310.0	92.86	28,787	
	Transmission pipe joint	concrete structure	nos.	1.0	289.35	289	
	Vertical leachate collection pipe	φ200, holed synthetic resin pipe	nos.	22.0	82.30	1,811	combined gas ventilation
Road works						29,047	
	preparation of roadbed		m2	7,980.0	0.44	3,511	
	gravel pavement	t=150mm	m2	7,980.0	3.20	25,536	
Fencing						30,800	
	Fencing	H=2.3 m	m	740.0	30.13	22,296	
	Move existing fence	H=2.3 m	m	420.0	17.47	7,337	
	Move existing gate	W=8.0m	nos.	1.0	1,166.67	1,167	
Sub-total of direct cost			set	1.0		13,584,352	
Miscellaneous			%	10.0		1,358,435	
Direct cost						14,942,788	
Overhead			%	30.0		4,482,836	
Total construction cost						19,425,624	
TAX			%	5.0		971,281	
Project cost (phase II)						20,396,905	

Table K-31: Civil Works Phase 3

Item 1	Item 2	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
Site preparation							
	tree trimming, etc.	heavy equipment	m2	42,000.0	0.01	420	
Temporary works						432	
	Soil escape prevention fence		m	100.0	4.32	432	
Earth work						7,207,850	
	Cut 1	soil and sand	m3	298,000.0	0.60	178,800	25%
	Cut 2	soft rock	m3	298,000.0	1.57	467,860	25%
	Cut 3	rock	m3	596,000.0	5.00	2,980,000	50%
	Embankment	variation rate=0.9	m3	28,000.0	1.49	41,720	26,000÷0.9
	Transport & stockpiling	distance=1.2 km	m3	1,399,000.0	2.53	3,539,470	1,166,000×1.2
Slope works						6,481,080	
	Cut slope finishing	1 : 2	m2	3,360.0	818.00	2,748,480	
	Greening for cut slope	seeding	m2	3,360.0	214.00	719,040	
	Banking slope finishing	1 : 3	m2	3,960.0	547.00	2,166,120	
	Greening for banking slope	seeding	m2	3,960.0	214.00	847,440	
Bottom lining of landfill site						1,200,433	
	Preparation of surface for HDPE liner	slope	m2	23,740.0	1.36	32,286	
	Preparation of surface for HDPE liner	base	m2	41,940.0	0.09	3,775	
	Under surface geotextile	bonded textile, t=10mm	m2	65,680.0	2.01	132,017	
	Synthetic liner	HDPE、t=1.5mm	m2	65,680.0	10.00	656,800	
	Upper surface geotextile	bonded textile with reinforcing material, t=10mm	m2	65,680.0	4.66	306,069	
	Protective soil layer	t=50cm	m3	20,190.0	2.00	40,380	
	Anchor for synthetic liner	concrete 0.5m×0.5m	m	2,230.0	12.84	28,633	
	Mechanical joint of synthetic liner	for concrete structure	m	8.0	59.09	473	leachate drainage
Underground water drainage						43,911	
	Main collector	φ300, holed synthetic resin pipe with gravel filter	m	720.0	29.81	21,463	
	Branch collector	φ200, holed synthetic resin pipe with gravel filter	m	2,440.0	9.20	22,448	
Rain water drainage						18,313	
	Trapezoidal lined ditch	W900×B500×H400	m	180.0	27.24	4,903	
	Trapezoidal lined ditch	W1000×B500×H500	m	230.0	32.06	7,374	
	Concrete pipe	φ800 with 360° concrete foundation	m	40.0	150.91	6,036	

Item 1	Item 2	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
Leachate collection system						81,101	
	Main line	φ700, holed synthetic resin pipe with gravel filter	m	250.0	157.45	39,363	
	Branch line	φ200, holed synthetic resin pipe with gravel filter	m	1,580.0	19.85	31,363	
	Transmission pipe	φ700, synthetic resin pipe	m	90.0	92.86	8,357	
	Transmission pipe joint	concrete structure	nos.	1.0	289.35	289	
	Vertical leachate collection pipe	φ200, holed synthetic resin pipe	nos.	21.0	82.30	1,728	combined gas ventilation
Road works						17,108	
	preparation of roadbed		m2	4,700.0	0.44	2,068	
	gravel pavement	t=150mm	m2	4,700.0	3.20	15,040	
Fencing						28,600	
	Fencing	H=2.3 m	m	580.0	30.13	17,475	
	Move existing fence	H=2.3 m	m	570.0	17.47	9,958	
	Move existing gate	W=8.0m	nos.	1.0	1,166.67	1,167	
Sub-total of direct cost			set	1.0		15,079,818	
Miscellaneous			%	10.0		1,507,982	
Direct cost						16,587,799	
Overhead			%	30.0		4,976,340	
Total construction cost						21,564,139	
TAX			%	5.0		1,078,207	
Project cost (phase III)						22,642,346	

Table K-32: Civil Works Phase 4

Item 1	Item 2	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
Earth work						2,088	
	Embankment		m3	800.0	2.61	2,088	700÷0.9
Bottom lining of landfill site						137,412	
	Preparation of surface for HDPE liner	base	m2	7,710.0	0.09	694	
	Under surface geotextile	bonded textile, t=10mm	m2	7,710.0	2.01	15,497	
	Synthetic liner	HDPE、t=1.5mm	m2	7,710.0	10.00	77,100	
	Upper surface geotextile	bonded textile with reinforcing material, t=10mm	m2	7,710.0	4.66	35,929	
	Protective soil layer	t=50cm	m3	3,860.0	2.00	7,720	
	Mechanical joint of synthetic liner	for concrete structure	m	8.0	59.09	473	leachate drainage
Leachate collection system						136,677	
	Main line	φ500 holed synthetic resin pipe with gravel filter	m	180.0	140.12	25,222	
	Main line	φ800 holed synthetic resin pipe with gravel filter	m	370.0	163.86	60,628	
	Main line	φ900 holed synthetic resin pipe with gravel filter	m	220.0	176.47	38,823	
	Transmission pipe	φ900 synthetic resin pipe	m	70.0	135.40	9,478	
	Transmission pipe joint	concrete structure	nos.	1.0	385.80	386	
	Vertical leachate collection pipe	φ200, holed synthetic resin pipe	nos.	26.0	82.30	2,140	combined gas ventilation
Fencing						12,173	
	Move existing fence	H=2.3 m	m	630.0	17.47	11,006	
	Move existing gate	W=8.0m	nos.	1.0	1,166.67	1,167	
Sub-total of direct cost			set	1.0		288,350	
Miscellaneous			%	10.0		28,835	
Direct cost						317,185	
Overhead			%	30.0		95,155	
Total construction cost						412,340	
TAX			%	5.0		20,617	
Project cost (phase IV)						432,957	

Table K-33: Overall Cost for Civil Works

Item 1	Item 2	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
Overall cost of Civil Works							
							Adjustment
Phase I						4,369,325	**4,400,000**
Phase 2						20,396,905	**20,400,000**
Phase 3						22,642,346	**22,700,000**
Phase 4						432,957	**500,000**
Total						47,841,534	**48,000,000**

c.1.2 Leachate Treatment Facility

Results of cost estimation are shown in tables below.

Table K-34: Leachate Treatment Facility

Item 1	Item 2	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
Civil works						1,540,848	
	Retaining wall	H=5.0	m	450.0	678.72	305,424	
	Retaining wall	H=1.0 to 5.0	m	80.0	475.10	38,008	
	Ditch	W=15, H=4	m	450.0	1,847.88	831,546	
	Synthetic liner	HDPE 1.5mm	m2	8,600.0	10.00	86,000	
	Pavement	t=0.1	m2	6,850.0	12.00	82,200	
	Sedimentation tank		Am3	450.0	166.67	75,002	
	Reaction tank		Am3	150.0	166.67	25,001	
	Chemical sedimentation tank		Am3	450.0	166.67	75,002	
	Foundations	SF, AC	set	1.0	1,666.67	1,667	
	Control house		m2	70.0	300.00	21,000	
Equipment						1,315,000	
	Grit chamber		set	1.0	20,000.00	20,000	
	Flow control system	control tank and pump	set	1.0	20,000.00	20,000	
	Aerator		set	2.0	166,666.67	333,333	
	Sedimentation tank	clarifier D=10m	set	1.0	53,333.33	53,333	
	Chemical pumps		set	3.0	13,333.33	40,000	
	Mixer		set	3.0	2,000.00	6,000	
	Sand filter	dia 3.5m	set	2.0	65,000.00	130,000	
	Pumps for SF		set	2.0	2,666.67	5,333	
	Activated carbon absorber	dia 3.5m	set	2.0	130,000.00	260,000	
	Pumps for AC		set	2.0	2,666.67	5,333	
	Chlorinator		set	1.0	3,333.33	3,333	
	Installation and piping		%	50.0		438,333	
Electric facility and installation			set	1.0		438,333	50%of equipment

Item 1	Item 2	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
Civil works			set	1.0		1,540,848	
Equipment			set	1.0		1,315,000	E&E
Electric facility and installation			set	1.0		438,333	
total						3,294,182	1,753,333
Miscellaneous			%	10.0		329,418	175,333
Direct cost						3,623,600	1,928,666
Overhead			%	30.0		1,087,080	578,600
Total construction cost						4,710,680	2,507,266
TAX			%	5.0		235,534	125,363
Project cost (leachate treatment)		Total				4,946,214	2,632,629
		Adjustment				**5,000,000**	2,700,000

c.2 Operation and Maintenance Cost

c.2.1 Landfill

Annual landfill operation costs are shown in the table below.

Table K-35: Annual Operation Cost for Landfill (2004 to 2011)

Item	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
Heavy equipment						
Bulldozer	CAT D8 class (inc. operator, fuel, maintenances, etc.)	nos.	4	438,000	1,752,000	lease U$50/hour 365 days/year
Excavator	CASE 580 class (inc. operator, fuel, maintenances, etc.)	nos.	1	120,450	120.450	lease U$27.5/hour 182.5 days/year
Total					1,872,450	
Miscellaneous		%	10		187,245	
Direct cost					2,059,695	
Overhead		%	30		617,909	
Total					2,677,604	
TAX		%	5		133,880	
Annual operation cost					**2,811,484**	**U$/year**

Table K-36: Annual Operation Cost for Landfill (2012 to 2015)

Item	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
Heavy equipment						
Bulldozer	CAT D8 class (inc. operator, fuel, maintenances, etc.)	nos.	5	438,000	2,190,000	lease U$50/hour 365 days/year
Excavator	CASE 580 class (inc. operator, fuel, maintenances, etc.)	nos.	1	120,450	120.450	lease U$27.5/hour 182.5 days/year
Total					2,310,450	
Miscellaneous		%	10		231,045	
Direct cost					2,541,495	
Overhead		%	30		762,449	
Total					3.303,944	
TAX		%	5		165,197	
Annual operation cost					**3,469,141**	**U$/year**

c.2.2 Leachate Treatment Facility

Annual operation cost for leachate treatment facility shows below table.

Table K-37: Annual Operation and Maintenance Cost for Leachate Treatment

Item	Specifications	Unit	Quantity	Unit cost (U$)	Cost (U$)	Remarks
Operation and maintenance cost	5% of investment cost for equipment and electricity	set	1		135,000	

c.3 Overall Cost

Overall cost for new landfill shows below table.

Table K-38: Overall Cost

unit : U$ 1,000

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Landfill site													
Investment													
Design & supervision	66	66	306	306	341	341	8	8					1,442
Construction		4,400		20,400		22,700		500					48,000
O&M		2,811	2,811	2,811	2,811	2,811	2,811	2,811	3,469	3,469	3,469	3,469	33,553
Total	**66**	**7,277**	**3,117**	**23,517**	**3,152**	**25,852**	**2,819**	**3,319**	**3,469**	**3,469**	**3,469**	**3,469**	**82,995**
Leachate treatment													
Investment													
Design & supervision	75	75											150
Construction		5,000											5,000
O&M		135	135	135	135	135	135	135	135	135	135	135	1,485
Total	**75**	**5,210**	**135**	**135**	**135**	**135**	**135**	**135**	**135**	**135**	**135**	**135**	**6,635**
Overall cost													
Investment total	141	9,541	306	20,706	341	23,041	8	508	0	0	0	0	54,592
O & M total	0	2,946	2,946	2,946	2,946	2,946	2,946	2,946	3,604	3,604	3,604	3,604	35,038
Total	**141**	**12,487**	**3,252**	**23,652**	**3,287**	**25,987**	**2,954**	**3,454**	**3,604**	**3,604**	**3,604**	**3,604**	**89,630**

d. Closure Plan

d.1 Final Cover

Final cover is very important for use of closed landfill and control of leachate and landfill gas. Figure K-33 proposes a final cover structure.

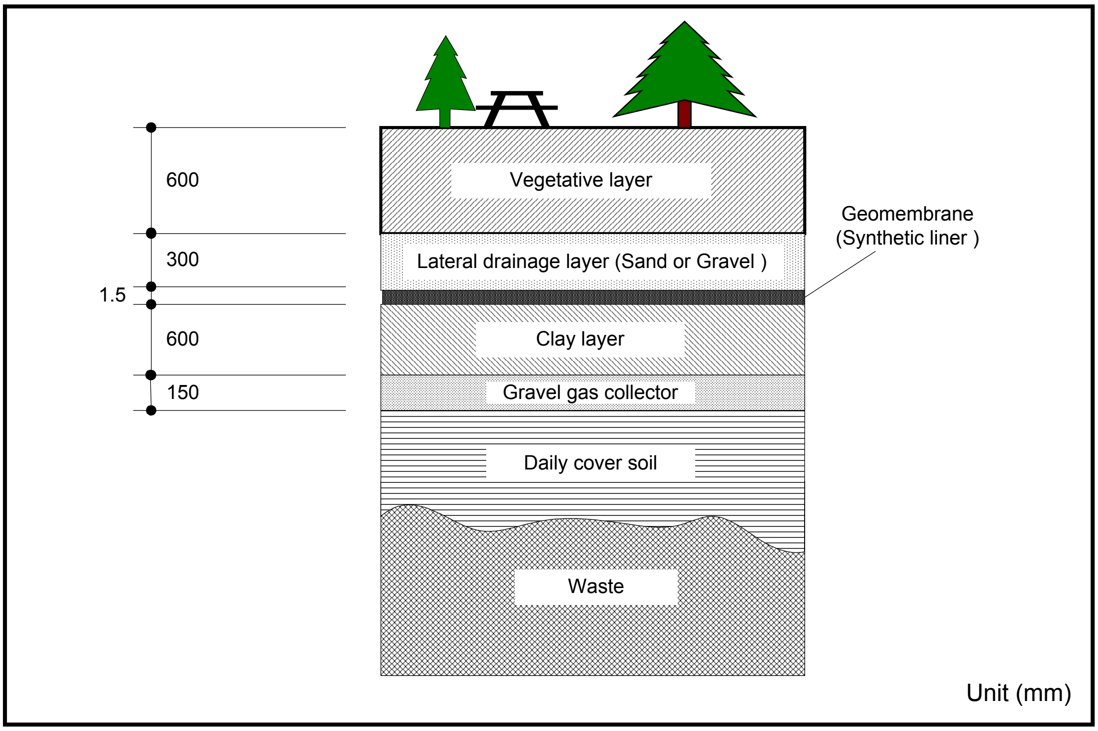


Figure K-33: Proposed Final Cover Structure

d.2 Post-closure Utilization Plan

Site of closed landfill is not stable during waste being decomposed, which lasts for a long time. Then, the site is not suit to construction of a large size facility. The Cerro Patacon Landfill is next to a national park at the west side. ARI has a plan to develop an industrial area at the east side. Consequently, it is recommendable to revegetate the closed site to harmonize with the national park and to use a partial area as a park.

d.2.1 Design Area

The leachate treatment facility will operate after the landfill is closed. The area except the facility is about 22 ha. This is the design area of the closure plan.

d.2.2 Zoning

Zoning plan is as presented in Figure K-34.

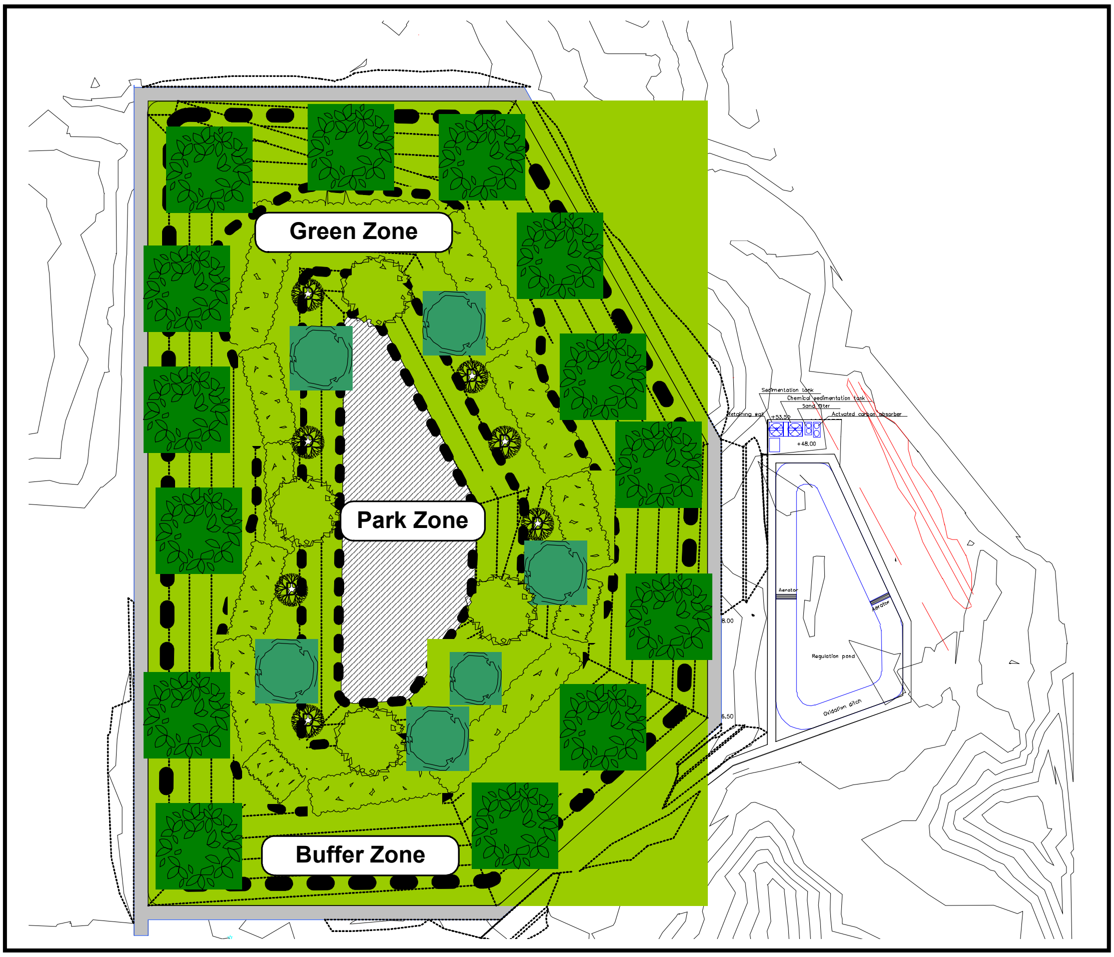


Figure K-34: Zoning Plan