#### a.5.3 Sunshine Hours

Sunshine hours are not recorded at present as it has been stable over years. Table 11-10 presents monthly average sunshine hours measured at B.AFF between 1908 and 1965.

Table 11-10: 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 11-11: 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 11-12 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 11-12: 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 11-6. 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 m(ALS) at each phase. Then, the three areas will be combined and the height will reach at 110 m as Phase 4. Capacities of respective those phases are shown Table 11-13, which are estimated based on a map of 1 in 2,500.

Table 11-13: 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 |

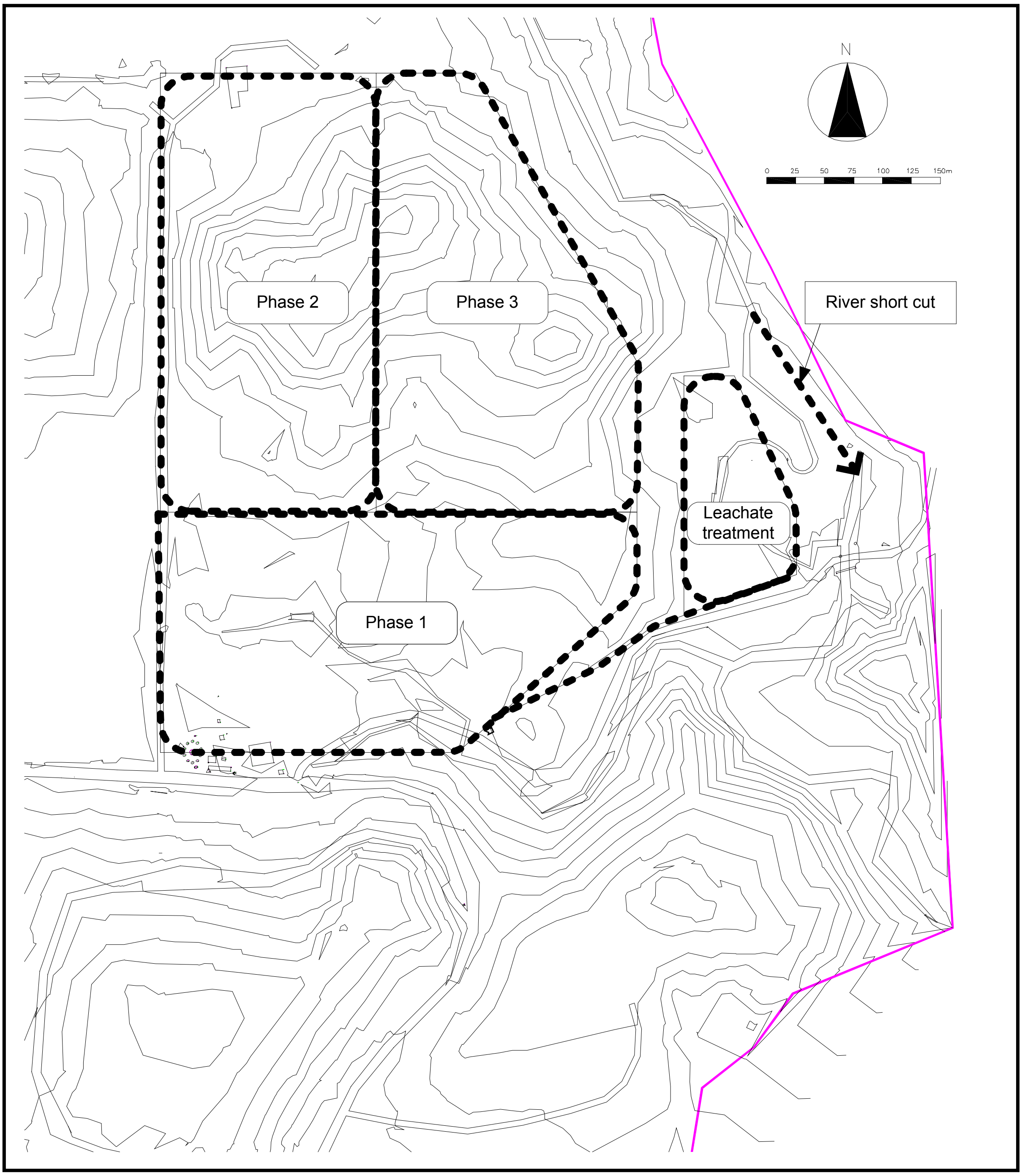


Figure 11-6: Zoning Plan for Site Development

**Earth Wok Plan**

Table 11-14 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 11-7).

Table 11-14: 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 |

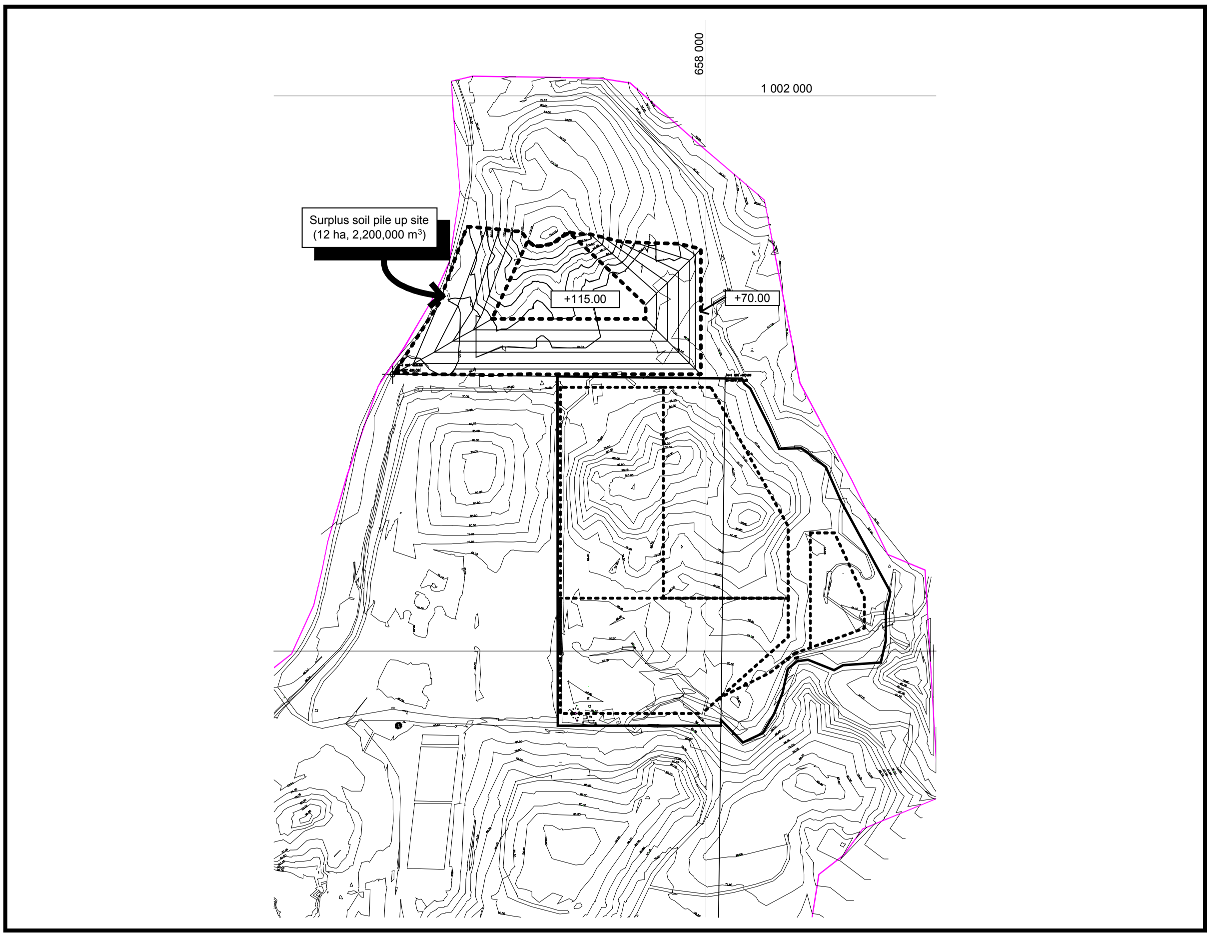


Figure 11-7: Surplus Soil Pile Up Site

Table 11-15: 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 11-8. 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.

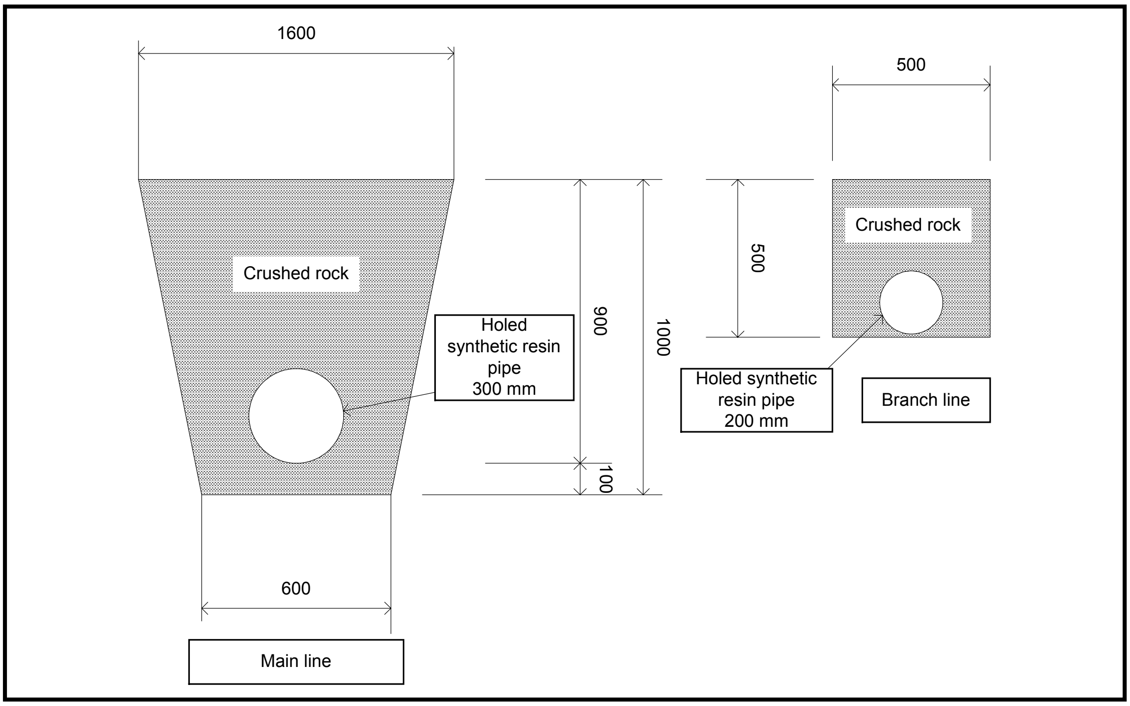


Figure 11-8: Cross Section of Ground Water Drainage

### 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 11-16.

Table 11-16: 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 11-9 is designed.

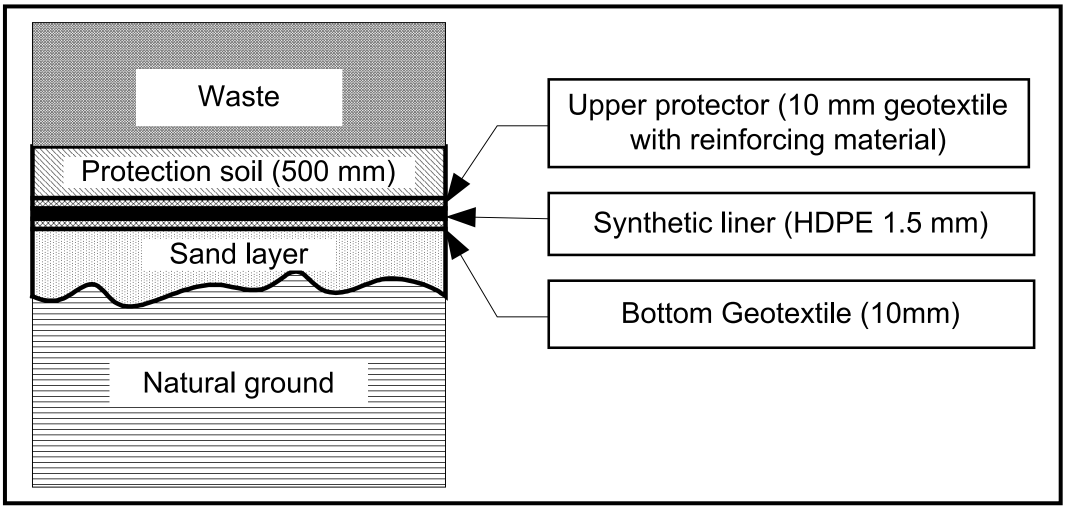


Figure 11-9: Seepage Control Lining System

### 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 11-17: 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 11-18.

Table 11-18: 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 11-19: Flow Calculation Table for Rainwater Drainage System

| Network number | Catchments area (ha) | Runoff rate (-) | rainfall intensity (mm/hr) | Discharge amount (m³/sec) | Channel section: Top width (mm) | Channel section: Bottom width (mm) | Channel section: Depth (mm) | Inclination (%) | Roughness (-) | Velocity (m/sec) | Allowable flow (m³/sec) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 11-10 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.

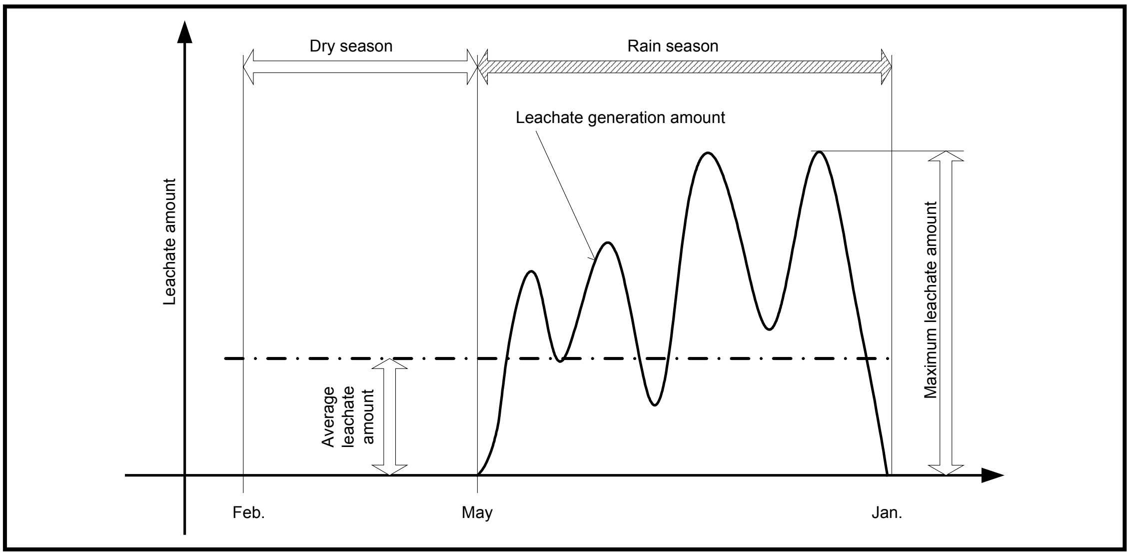


Figure 11-10: Concept of Maximum and Average Leachate Generation Amount

**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 11-11 shows this concept.

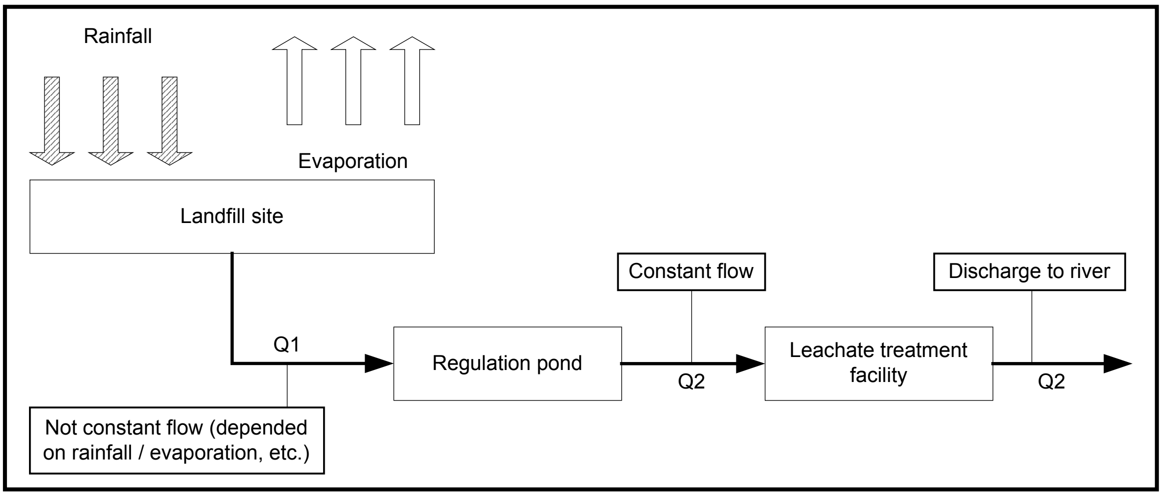


Figure 11-11: Concept of Leachate Regulation and Treatment Amount

Leachate amount is computed by means of the following formula.

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

where ;

I : Rrainfall 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)

**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.

Operation area and closed area are considered as shown in Table 11-20 for leachate calculation.

Table 11-20: 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 11-21: 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 |

**Required Treatment Capacity and Regulation Amount**

Table 11-22 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 11-22: 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 11-23.

Table 11-23: 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 11-24 summarizes the design conditions of the leachate treatment facilities, i.e., influent and effluent qualities.

Table 11-24: 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 physico-chemical treatment to remove phosphorus and heavy metals is applied in this plan.

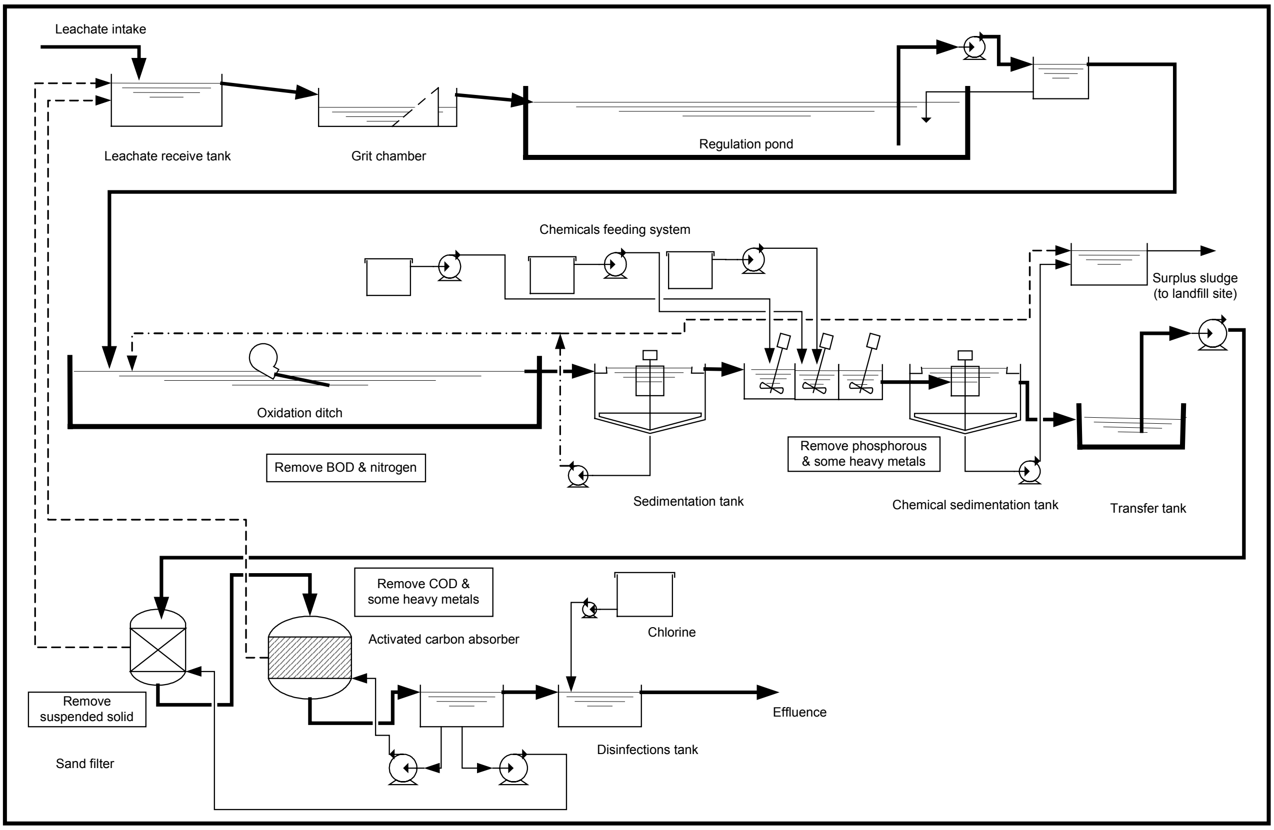


Figure 11-12: Leachate Treatment Process Flow Sheet

**Summary of Leachate Treatment Facility**

Summary of the leachate treatment facility shows below table.

Table 11-25: 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

Overall cost for new landfill shows below table.

Table 11-26: 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 11-13 proposes a final cover structure.

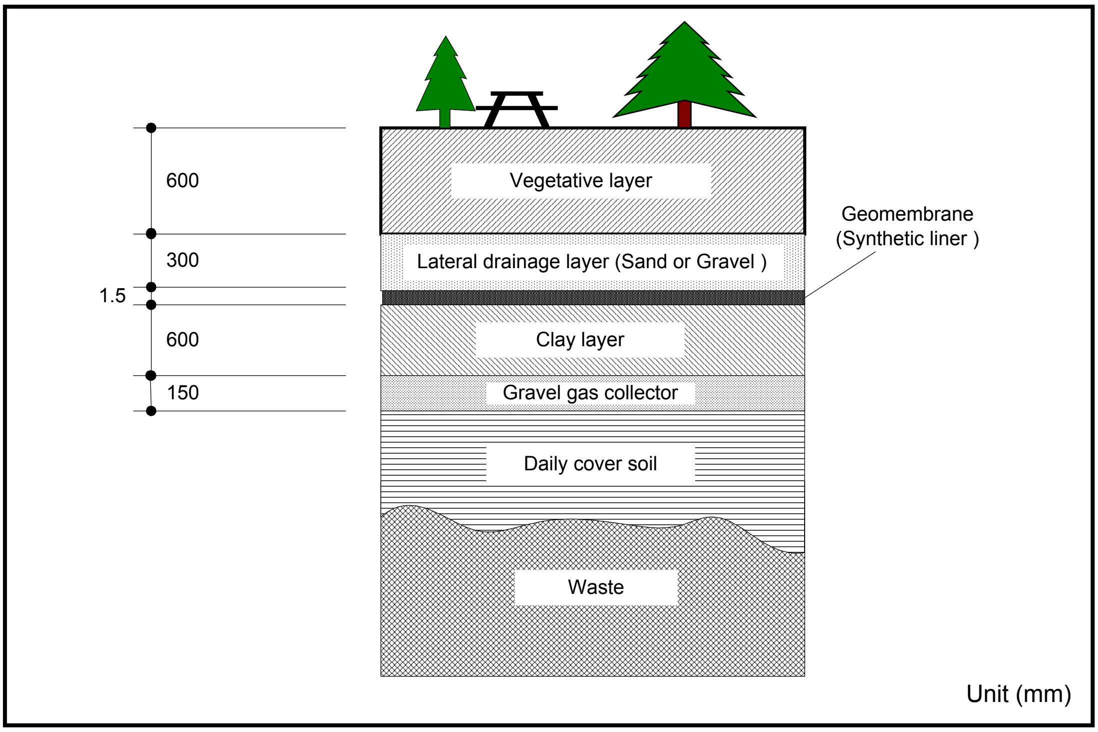


Figure 11-13: Proposed Final Cover Structure

#### 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 11-14.

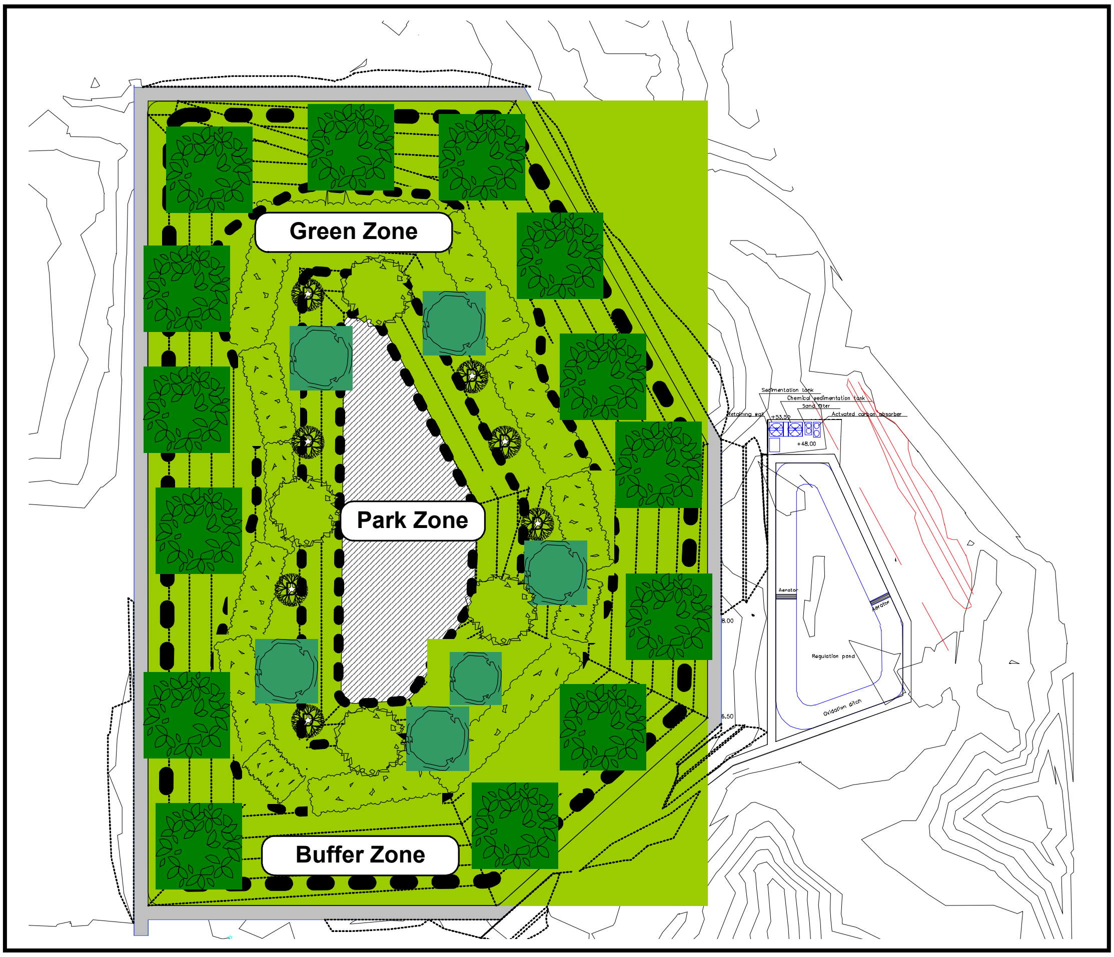


Figure 11-14: Zoning Plan

**Park Zone**

The top is to have an area of about 19,000m$^2$. The area will be used as a multi-purpose space, where it is possible to have a football pitch, a baseball field, tennis courts, etc.

**Green Zone**

Open forest will be developed in the upper slope, where people can have a stroll along nature trail.

**Buffer Zone**

Vegetated buffer zone will be established in the lower slope, which harmonizes with the surrounding green area.

### 11.2.2 Pre-feasibility Study on Transfer and Transport System

**a. Consideration of Necessity of Transfer and Transport System**

**a.1. Background**

The District has experienced an expansion toward the North and the East. The Corregimientos to the North, Chilibre and Las Cumbres, experienced a population growth of 49% and 64% from 1990 to 2000 respectively. On the other hand, the Eastern Corregimientos, San Martin, Pacora and Tocumen, experienced a growth of 44%, 132%, and 77% from 1990 until 2000 respectively.

The collection system in the Eastern part is done mostly with compactors of 12.2 $m^3$ (16 $yd^3$); and the eventual use of compactors of 15.3 $m^3$ (20 $yd^3$), especially for areas where highly concentrated and residential sectors are found such as Mall Los Pueblos, San Joaquín, and Jardín Olímpico routes. DIMAUD´s data suggests that the current collection amount is about 70 tons/day.

On the other hand, the collection system in the Northern part was initially done with compactors of 12.2 $m^3$; however, with the recent acquisition of additional 15.3 $m^3$ compactors, collection is done with 15.3 $m^3$ compactors for the most distant part to the North, such as Chilibre Centro and Quebrada Ancha routes; and a small dump-truck of 3.1 $m^3$ (4 $yd^3$) for areas where the 15.3 $m^3$ compactor can not access. According to data from DIMAUD´s collection service, from those two routes an average of 7.6 tons are collected on a daily basis.

Although the current waste amount collected in the East is not so large and the one in the North is small, there is a growing need to evaluate transfer stations due to the rapid population growth in the areas. Consequently, a pre-feasibility study has been conducted for a transfer and transport system.

**a.2. Compliance with Norms, Regulations and other Plans**

**a.2.1 City Planning**

**East**

Decree 205 has approved the "Urban Development Plan for the Metropolitan Areas in the Pacific and the Atlantic" defined provisions for infrastructure systems for "...Drinking Water, Drainage, Waste Water, Electricity, Telecommunications, and Solid Wastes..." The Plan, in fact, considers a Tocumen Transfer Station located to only 1.5 km to the West from the Airport, which would serve Pacora, San Martin, and Tocumen. The population to be serviced would be 148,442 persons by 2020. However, provisions should also be taken into consideration because that same Decree 205 (December 28th, 2000) establishes "Tocumen Airport and its surroundings" as a Functional Special Area which is defined as a "zone which requires more detailed studies to ensure that the character and function of its future development are compatible with the rest of the urban area." A Transfer and Transport system might not be compatible with the functions of an International Airport operation and its expansion.

**North**

A Transfer and Transport System for the North will have special considerations due to the following:

a) Many of the most important population centers to the North, such as, Alcalde Díaz, Villa Esperanza, Don Bosco, and Chilibre, are located within the Panama Canal Basin and along the Trans-Isthmian Corridor.

b) The Trans-Isthmian Corridor is defined by Decree 205[1] (December 28, 2000) as "a special area of critical concern where every consideration related to the Corridor´s management should have as a primary goal to rehabilitate and to protect the natural environment, specifically the water resource which serves to operate the Panama Canal and supplies of drinking water to the metropolitan population".

c) There is an explicit policy to "direct the urban growth along the coast shores and outside the Panama Canal Basin...." (Law No. 21[2], Categories for Territorial Planning, Urban Areas, July 2, 1997). Currently, the Authority of the Panama Canal (ACP) is promoting a regulation of Law No. 21 and a draft of this regulation is expected to be ready by the end of the year 2002.

d) MIVI and other related institutions are reviewing a document titled "Normative for the Urban Development of Localities in the Chilibre and Las Cumbres Corregimientos" which will regulate the population settlement for those two Corregimientos inside the Panama Canal Basin. The Normative will regulate urban expansion mostly by defining areas for specific purposes and with defined minimum areas for residential constructions for example. The Normative is expected to be enacted during the year 2002.

Consequently, the urban growth and the projected amount of waste generated by its population should be carefully evaluated.

On the other hand, the concept of Transfer Stations to provide service to the Eastern and Northern part of the city is also included in the Report for the "Plan of Urban Development of the Metropolitan Areas in the Pacific and the Atlantic."[3] In fact, Decree 205 establishes considerations for this type of facilities because it defines provisions for infrastructure

1 Decree which approved the Urban Development Plan in the Metropolitan Areas of the Pacific and the Atlantic which is ascribed to the General Direction of Urban Development of MIVI
2 Law by which it is approved the Regional Plan for the Development of the Inter-oceanic Region and the General Plan to Use, to Conserve, and to Develop the canal area
3 Prepared by Dames & Moore

systems for "...Drinking Water, Drainage, Waste Water, Electricity, Telecommunications, and Solid Wastes..."

The report by Dames & Moore proposed a T/S denominated Las Cumbres which would service José Domingo Espinar, Belisario Porras, and Integrated zone No. 4 (Las Cumbres and Chilibre). The total population to be serviced would be 495,595 persons by 2020. It should be noted that Jose Domingo Espinar and Belisario Porras belong now to San Miguelito District, which is currently serviced by a private collection company.

#### a.2.2 Transport

Panama does not have specific environmental regulations related to Transfer Stations and Transport. However, there are other regulations related to these facilities, for example, Law 10 (enacted on January 27th, 1989) which deals with the Weight and Dimensions of Heavy duty vehicles that transit through public roads. The entity in charge to enforce Law 10 is the Authority for Terrestrial Transit and Transport (ATTT).

Transfer and transport systems often employ tractor-trailer for transportation to carry a large amount of waste at once. A typical tractor-trailer corresponds to a truck-tractor of three axles and a semi-trailer of two axles. This type of combination is denominated T3-S2 according to the ATTT. The Authority restricts the total maximum weight for this type of vehicle to 38.3 Tons. If a vehicle exceeds the defined weight, Law 10 requires the user to obtain a special permit from the Ministry of Public Works. The recommended transport system, i.e., tractor-trailer (payload 20 ton), would exceed the limit depending on specifications. Nonetheless, the client can also request the manufacturer to construct a trailer that suits the needs and restrictions at hand, i.e., meet the required payload (20 tons) and the maximum weight regulation (38.3 tons).

### a.3. Future Waste Amount

Corregimientos covered with the transfer stations were defined, based on trials of break-even analysis that is described in the later part, where the transfer and transport system would be more beneficial than the conventional collection system. Those corregimientos are as follows.

- East: Tocumen, Pacora and San Martin
- North: Chilibre

Waste Amount in the future in the areas is forecast as shown in Table 11-27 and Table 11-28. It should be noted that the population forecast is based on the trend of population growth in the recent years, but does not take into account the policies on the Panama Canal Basin as there are many uncertainties to consider such policies in the population forecast.

Table 11-27: Forecast of Waste Collection Amount in the East

| Year | | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Population | Pacora | 79,175 | 86,108 | 93,648 | 101,848 | 110,766 | 120,465 | 131,014 | 142,486 | 154,963 | 168,532 | 183,290 | 199,339 | 216,795 |
| | San Martín | 3,990 | 4,139 | 4,293 | 4,453 | 4,619 | 4,792 | 4,970 | 5,156 | 5,348 | 5,547 | 5,754 | 5,969 | 6,191 |
| | Tocumen | 98,708 | 104,501 | 110,633 | 117,126 | 123,999 | 131,276 | 138,980 | 147,136 | 155,770 | 164,911 | 174,589 | 184,834 | 195,681 |
| | Total | 181,873 | 194,748 | 208,574 | 223,427 | 239,384 | 256,533 | 274,964 | 294,778 | 316,081 | 338,990 | 363,633 | 390,142 | 418,667 |
| Waste Amount (ton/day) | | 205.2 | 221.8 | 240.3 | 261.0 | 280.6 | 299.4 | 319.5 | 340.5 | 362.9 | 386.8 | 411.6 | 438.1 | 466.0 |

Table 11-28: Forecast of Waste Collection Amount in the North

| Year | | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Population | Chilibre | 45,634 | 47,495 | 49,433 | 51,449 | 53,548 | 55,733 | 58,007 | 60,373 | 62,836 | 65,400 | 68,068 | 70,845 | 73,735 |
| Waste amount (ton/day) | | 27.1 | 28.8 | 30.5 | 32.4 | 33.7 | 35.1 | 36.5 | 38 | 39.5 | 41.1 | 42.7 | 44.4 | 46.2 |

### a.4. Break-even Analysis

#### a.4.1 Key Data

Key data for break-even analysis of the transfer and transport system vs. the conventional transport system which is done by collection vehicles are set as shown in Table 11-29.

Table 11-29: Key Data for Break-even Analysis

**i. Basic Parameters**

| Item | Unit | Value |
|---|---|---|
| **Basic parameter** | | |
| Daily working hour | hr | 16 |
| Operating time | hr | 14 |
| Maintenance time | hr | 2 |
| Nos. of shift | nos. | 2 |
| Working days | day | 300 |

**ii. Conventional Transport System**

| Item | Unit | Value |
|---|---|---|
| **Compactor truck (12.2 m$^3$)** | | |
| Payload | ton/truck | 5 |
| Trip time of collection | hr/trip | 5.0 |
| Nos. of trip | nos./day | 2.4 |
| Waste amount collected | ton/truck/day | 12 |
| Economic life | years | 4 |
| Distance per trip | km | 50[a] – 60[b] |
| Annual mileage | km | 36,000[a]-43,200[b] |
| Fuel consumption | km/liter | 2.2 |
| Driver | person | 1 |
| Worker | person | 3 |

| Item | Unit | Value |
|---|---|---|
| **Compactor truck (15.3 $m^3$)** | | |
| Payload | ton/truck | 7.7 |
| Trip time of collection | hr/trip | 4.5 |
| Nos. of trip | nos./day | 2.7 |
| Waste amount collected | ton/truck/day | 21 |
| Economic life | years | 4 |
| Distance per trip | km | 50[a] – 60[b] |
| Annual mileage | km | 40,500[a]-48,600[b] |
| Fuel consumption | km/liter | 2 |
| Driver | person | 1 |
| Worker | person | 3 |

[a] For the Transport and Transfer system to the East
[b] For the Transport and Transfer system to the North

### iii. Transfer and Transport System for the East

| Item | Unit | Value |
|---|---|---|
| **Tractor and trailer (65 $m^3$)** | | |
| Payload | ton/trailer | 20 |
| Trip time of transport | hr/trip | 4 |
| Nos. of trip | nos./day | 3 |
| Waste amount transported | ton/trailer/day | 60 |
| Economic life | years | 7 |
| Distance per trip | km | 50 |
| Annual mileage | km | 45,000 |
| Fuel consumption | km/liter | 1.8 |
| Driver | person | 1 |
| Worker | person | 0 |

| Item | Unit | Value |
|---|---|---|
| **Transfer Station** | | |
| Capacity | ton/day | 570 |
| Service Life | years | 15 |
| Total Cost | USD | 10,449,000 |

### iv. Transfer and Transport System for the North

| Item | Unit | Value |
|---|---|---|
| **Roll on/off & container of 22.9 $m^3$** | | |
| Payload | ton/truck | 6.5 |
| Trip time of Collection | Hr/trip | 4 |
| Nos. of trip | nos./day | 3 |
| Waste amount collected | ton/truck/day | 20 |
| Economic life | years | 5 |
| Distance per trip | km | 60 |
| Annual mileage | km | 54,000 |
| Fuel Consumption | km/liter | 2 |
| Driver | person | 1 |
| Worker | person | 3 |
| Capacity to be handled | ton/day | 60 |
| No. of Containers of 22.9 $m^3$ to be used from 2003 to 2015 | Units | 67 |

### a.4.2 Analysis on the East

The break-even analysis is conducted based on the waste collection amount forecast in the M/P's target year 2015.

#### a.4.2.1. Transfer and Transport System

Required capacity of the transfer and transport system in the East is calculated as shown in Table 11-30 by taking into account that there are 300 working days per year. In year 2015, the required capacity of the system would be 570 ton/day, which is enough large to apply combination of a transfer station and a large scale of transport equipment. Therefore, the transfer and transport system for the analysis is set as shown in Table 11-31.

Table 11-30: Required Capacity of Transfer Station in the East

Unit: ton/day

| Year | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Required capacity | 250 | 270 | 300 | 320 | 350 | 370 | 390 | 420 | 450 | 480 | 510 | 540 | 570 |

Table 11-31: Transfer and Transport System in the East

| Item | Specification |
|---|---|
| Transfer station | 570 ton/day of direct dump station |
| Transport equipment | Tractor and trailer, 65 $m^3$ (payload 20 ton) |

#### a.4.2.2. Results of Analysis

The break-even analysis was carried out based on the following unit costs which were derived from the key data mentioned previously.

Table 11-32: Cost Estimates for Transfer and Transport System for the East

| Item | Unit | Value |
|---|---|---|
| **Conventional Transport** | | |
| Compactor Truck (15.3 $m^3$) | USD/ton-min | 0.044 |
| Compactor Truck (12.2 $m^3$) | USD/ton-min | 0.058 |
| **Transfer Station Proposed** | | |
| Capacity | ton/day | 570 |
| Unit Cost Estimate | USD/ton | 3.06 |
| **Transport Proposed** | | |
| Tractor-trailer (65 $m^3$) | USD/ton-min | 0.0103 |

The cost estimates were graphed and the intersection point between the conventional transport and the proposed systems represents the break-even point (See Figure 11-15).

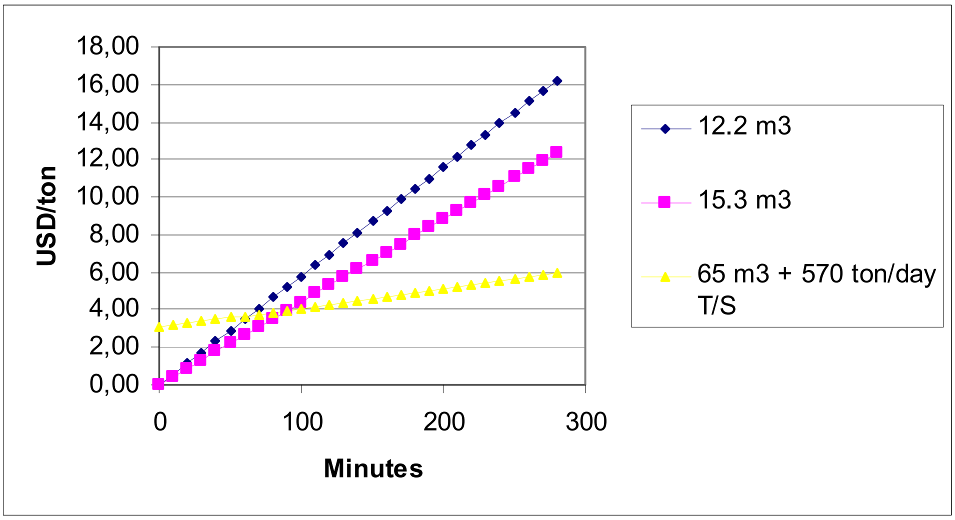


Figure 11-15: Break-even Analysis in the East

These results can be included in a table in the following manner:

| | Break-even Time (min.) 65 $m^3$ + 570 tons/day T/S | Break-even Distance (km)[a] 65 $m^3$ + 570 tons/day T/S | Distance from Tocumen to Patacón Round-trip (km)[b] |
|---|---|---|---|
| 12.2 $m^3$ | 64 | 32 | 48 |
| 15.3 $m^3$ | 90 | 45 | 48 |

[a] The break-even distance was calculated based on an average velocity of 30 km/hr
[b] The distance was measured by the Study Team from Tocumen Airport until Patacon

The results show that a transfer station of 570 tons/day with a transport done by a 65 $m^3$ tractor-trailer is feasible compared to the transportation done by the 12.2 $m^3$ compactor for the area located further than 32 km from Cerro Patacon landfill (round trip), and compared to the transportation done by the 15.3 $m^3$ compactor for the area further than 45 km from the landfill (round trip). Tocumen Airport (Central part of Tocumen Corregimiento) is located to 24 km from Patacon landfill site (48 km round trip). Pacora and San Martin are found to the east of Tocumen Airport. Consequently, it can be concluded that a transfer and transport system will be feasible financially in Tocumen, Pacora, and San Martin.

### a.4.3 Analysis on the North

#### a.4.3.1. Transfer and Transport System

Required capacity of the transfer and transport system in the North is calculated as shown in Table 11-33 by taking into account that there are 300 working days per year. In year 2015, the required capacity of transfer station would be 60 ton/day. As the scale of the system is too small to apply the same system as one for the East, combination of Roll-on/Roll-off truck and 22.9 $m^3$ (30 $yd^3$) of container is applied as the transfer and transport system for the North.

Table 11-33: Required Capacity of Transfer Station in the North

Unit: ton/day

| Year | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Required capacity | 40 | 40 | 40 | 40 | 50 | 50 | 50 | 50 | 50 | 60 | 60 | 60 | 60 |

Table 11-34: Transfer and Transport System in the North

| Item | Specification |
|---|---|
| Transfer station | 22.9 $m^3$ (30 $yd^3$) container and site for placement of container |
| Transport equipment | Roll-on/Roll-off truck |

#### a.4.3.2. Results of Analysis

The break-even analysis was based on the following unit costs which were derived from the key data mentioned previously.

Table 11-35: Cost Estimates for Transfer and Transport System for the North

| Item | Unit | Value |
|---|---|---|
| **Conventional Transport** | | |
| Compactor Truck (15.3 $m^3$) | USD/ton-min | 0.045 |
| Compactor Truck (12.2 $m^3$) | USD/ton-min | 0.059 |
| **Transfer System Proposed** | | |
| Capacity | ton/day | 60 |
| Number of Containers of 22.9 $m^3$ | Units/year | 6 |
| Unit Cost Estimate | USD/ton | 3.35 |
| **Transport Proposed** | | |
| Roll-on/Roll-off (22.9 $m^3$) | USD/ton-min | 0.031 |

The cost estimates were graphed and the intersection point between the conventional transport and the proposed systems represents the break-even point (See Figure 11-16).

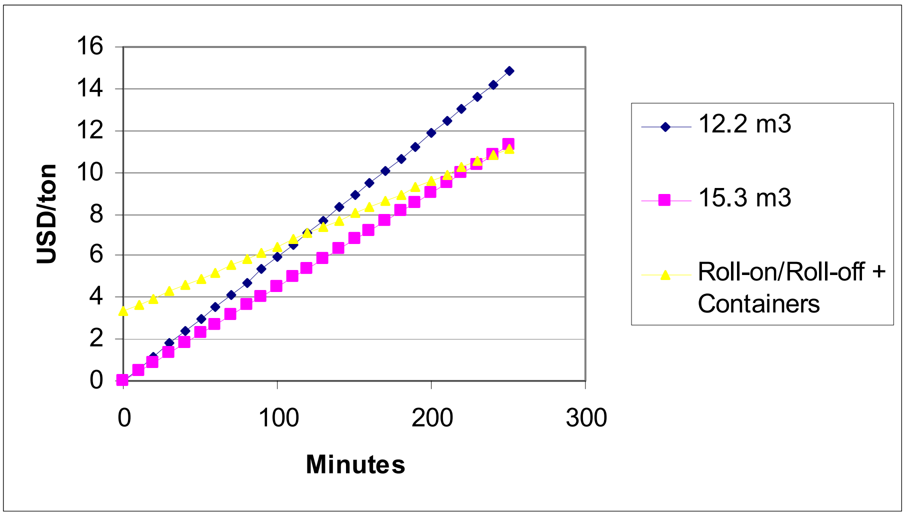


Figure 11-16: Break-even Analysis in the North

These results can be included in a table in the following manner:

| | Break-even Time (min.) Roll-on/Roll-off | Break-even Distance (km) Roll-on/Roll-off[a] | Distance from Chilibre Centro to Patacon Round-trip (km)[b] |
|---|---|---|---|
| 12.2 $m^3$ | 119 | 60 | 58 |
| 15.3 $m^3$ | 240 | 120 | 58 |

[a] The break-even distance was calculated based on an average velocity of 30 km/hr
[b] The distance was measured by the Study Team from Chilibre Centro to Patacon

These results show that the Roll-on/Roll-off system of transport is feasible compared to the compactor (conventional transport system) only when the round-trip distances are farther than 60 km for the 12.2 $m^3$ compactor or farther than 120 km for the 15.3 $m^3$ compactor. Chilibre Centro is located to 29 km (58 km round-trip) from the landfill site. The population of Chilibre is concentrated along the Trans-isthmian road which center can be located precisely in Chilibre Centro where the proposed Roll-on/Roll-off system might be feasible only for the 12.2 $m^3$, but not for the case of the 15.3 $m^3$ compactor which is precisely the type of vehicle that is currently providing service to Quebrada Ancha and Chilibre Centro.

### a.5. Conclusion

**East**

- The population growth toward the East is projected to continue high as the two previous censuses, which were conducted in 1990 and 2000, showed. This trend might be even promoted by explicit policies, e.g. Law 21, which discourage additional settlements to the North, but it promotes them toward the East.