Chapter 8

Feasibility Study for the Priority Projects

8 Feasibility Study for the Priority Projects

8.1 Outline of the Projects

8.1.1 Target

Final disposal sites are indispensable components of the solid waste management for the GDF to provide cleansing services for the citizens. However, urbanization in and around the DF makes it difficult year by year for the GDF to secure lands for future final disposal sites. Furthermore, as an urgent and critical issue of the DF's SWM, the existing final disposal sites have a very limited remaining disposal capacity (i.e., the remaining service life is only up to the beginning of the year 2001.).

Therefore, actions for:

- minimization of final disposal amount; and
- establishment of a new final disposal site

are urgently required for the GDF to comply its mission of solid waste management. In order to facilitate the actions required for the "minimization of final disposal amount" and to solve the critical issue of "a new final disposal site establishment", priority projects are selected herewith, and their preliminary design, estimated cost, and feasibility are examined in its regard.

In practice, the priority projects comprise:

- **a composting plant** for processing organic wastes separately delivered from the sub-system, with a prime objective of prolongation of final disposal sites' service lives; and
- **the vertical expansion** of existing final disposal site **(BP-IV)** and the construction of a new **final disposal site (BP-V)**.

Figure 8-1 shows the location of those priority projects.

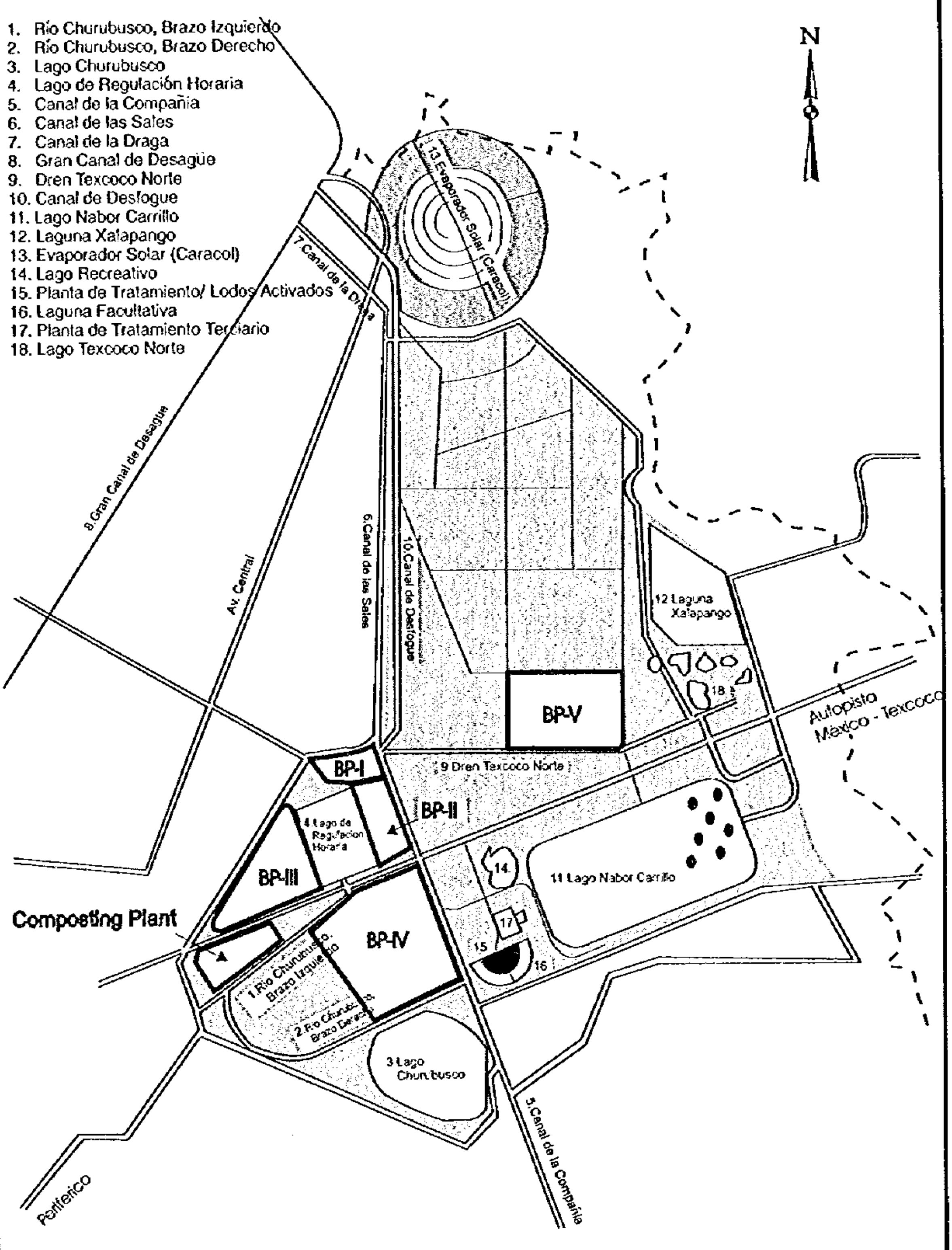


Figure 8-1:
Location of Priority Projects

KOKUSAI KOGYO Co., Ltd.

8.1.2 Outline of the Projects

Table 8-1 shows the outline of the projects.

Table 8-1: Outline of the Projects

		*Present	1999	2000	2001	2002	2003	2004
Population		8,610,000	8,654,000	8,698,000	8,747,000	8,796,000	8,846,000	8,896,000
Waste generation amount		(ton/year)						
Household		1,925,000	1,946,000	1,956,000	1,967,000	1,976,000	1,989,000	1,999,000
Commercial		1,210,000	1,217,000	1,221,000	1,225,000	1,230,000	1,234,000	1,238,000
Service		636,000	639,000	641,000	645,000	647,000	650,000	657,000
Special		133,000	135,000	135,000	135,000	137,000	137,000	137,000
Others		265,000	267,000	269,000	269,000	272,000	273,000	274,000
Total		4,169,000	4,204,000	4,222,000	4,241,000	4,262,000	4,283,000	4,302,000
Composting								
**Construction and Operation schedule		F/S	B/D,P/P(1)	P/P(2),D/D, S/V	CON(3/5)	OP(3/5) / CON(1/5)	OP(4/5) / CON(1/5)	OP(5/5)
Treatment capacity (t/d)		-	-	-	-	750	1,000	1,250
Treatment amount (t/y)		-	-	-	-	253,000	338,000	424,000
Final disposal								
**Construction and Operation schedule	BP-IV	F/S	B/D	D/D, CON	OP	-	-	-
	BP-V		B/D	D/D	CON	OP	OP	OP
Site to be used		BP-IV	BP-IV	BP- IV	BP- IV	BP-V	BP-V	BP-V
Disposal amount (t/y)		3,751,000	3,903,000	3,889,000	3,876,000	3,609,000	3,493,000	3,385,000

* : 1997/1998 data
** F/S : feasibility study, B/D : basic design, D/D : detailed design, CON : construction, OP : operation, S/V: supervision, P/P : Pilot Project
t/d : ton/day
t/y : ton/year

8.2 Preliminary Design of Technical System

8.2.1 Composting Facility

a. Examination of Design Condition

a.1 Design Capacity

Capacity of the composting plant is set out under the condition that the whole amount of organic waste generated in the sub-system are to be delivered and fed into the plant.

It is planned that the separate collection in the sub-system is introduced in the year 2000 and its total diffusion (100%) will be achieved in the year 2004. The estimation of organic wastes input amount for the composting plant until 2010 is shown in Table 8-3.

The operation of the composting plant is planned to start in the year 2002 and the organic waste separation in the year will be still about 60%, while the plant has to receive 100% of separated organic waste from the sub-system in the year 2004. Therefore, the plant should be constructed from 2001 to 2003 to improve its capacity in a stepwise manner, in order to meet the increase in the organic waste separation rate.

Table 8-2: Separate Discharge and Collection Plan

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Separate Discharge and Collection Plan	Mixed Discharge					100%		Separate Discharge				

Table 8-3: Organic Waste Collection Amount

unit : 1,000 ton/year

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Organic waste	0	84	168	253	338	424	425	426	428	429	430	431

a.2 Waste Composition

Composition of organic waste applied to the plant design is assumed as shown in Table 8-4, based on the future waste amount and composition trends assumed in the M/P framework. Source separation compliance rate is set out as 90% with reference to the 92% compliance recorded in the DGSU's pilot projects for source separation.

The design moisture content can be assumed to be:

- about 78%, which is calculated from the DGSU's empirical data for respective composition items, and from a set of empirical data recorded in Japan; and
- about 68%, which is the moisture content obtained in the field investigation of waste composition by the team.

Therefore, the design moisture content is set out between the **maximum 78%** and **minimum 68%**.

Table 8-4: Organic Waste Composition

Composition	Organic matter contents (%)	Moisture contents of each component (%)	Moisture contents (%)
Organic waste			
Vegetable fiber	2.29	*68	1.56
Bone	1.02	*68	0.69
Food waste	78.38	**90	70.54
Garden waste	8.3	***40	3.32
Organic total (a)	90	-	76.11
Recyclable waste			
Cardboard	0.99	***24	0.24
Synthetic fiber	0.19	***17	0.03
Vinyl	0.04	***17	0.01
Cans	0.27	***4	0.01
Metal	0.41	***4	0.02
Nonferrous metal	0.05	***4	0
Paper	0.46	***24	0.11
News paper	0.83	***24	0.2
Plastic film	0.77	***17	0.13
Hard plastic	0.67	***8	0.05
Color glass	0.34	***8	0.03
Transparent glass	0.58	***8	0.05

Composition	Organic matter contents (%)	Moisture contents of each component (%)	Moisture contents (%)
Recyclable total (b)	**5.58**	-	**0.88**
Non-recyclable waste			
Spatula	0	-	-
Cotton	0.23	***19	0.04
Leather	0.01	***9	0
Paper container	0.43	***24	0.1
Gauze	0	-	-
Disposable syringe	0	-	-
Ceramics	0.05	***8	0
Wood	0.33	***24	0.08
Construction waste	0.38	***8	0.03
Toilet paper	1.09	***24	0.26
Disposable diaper	0.25	***80	0.2
X-ray film	0	-	-
Polyurethane	0.02	***17	0
Foamed polyurethane	0.12	***17	0.02
Sanitary napkin	0	-	-
Rags	0.23	***19	0.04
Bandage	0	-	-
Fine fraction	0.92	***24	0.22
Others	0.35	***24	0.08
Non-recyclable total (c)	**4.42**	-	**1.07**
Total (a+b+c)	**100**	-	**78.06**

* : results of the waste composition survey

** : Harina Vegetal a Partir de Residuos Organicos, LUGARDA ARACELI SANTOS PEREZ, MARGARITA GUTIERREZ ROJAS, VICTOR MANUEL FLORES VALENZUELA, DGSU

***: Design guideline for municipal solid waste treatment facilities in Japan 1978(editorial supervision by ministry of health and welfare, JAPAN)

a.3 Geological Condition

Geological survey data in the composting plant candidate site is absent. However, the candidate site is located near the Bordo Poniente Etapa-IV, and its geological data (see Figure 8-2) is used for examining the design of the composting plant.

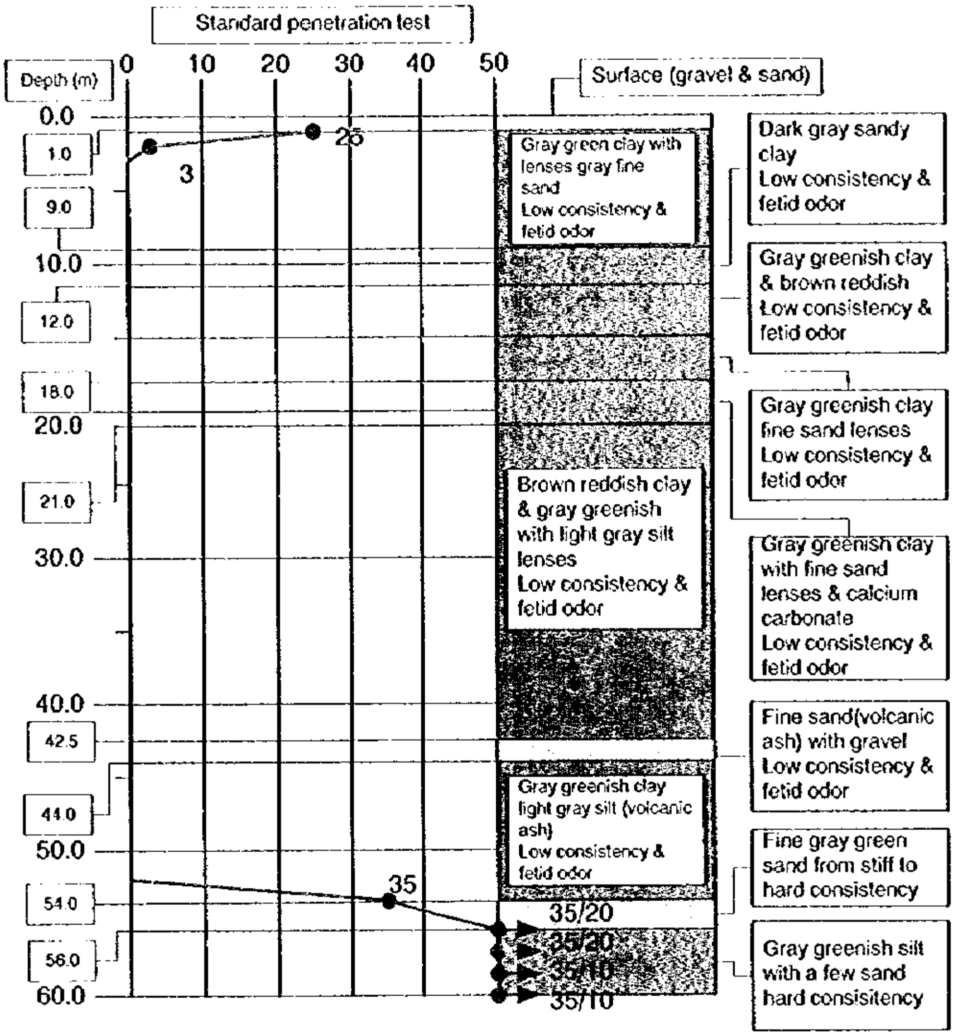


Figure 8-2: Results of "Etapa IV" Core Boring (SM-8)

b. Examination of Technical Alternative

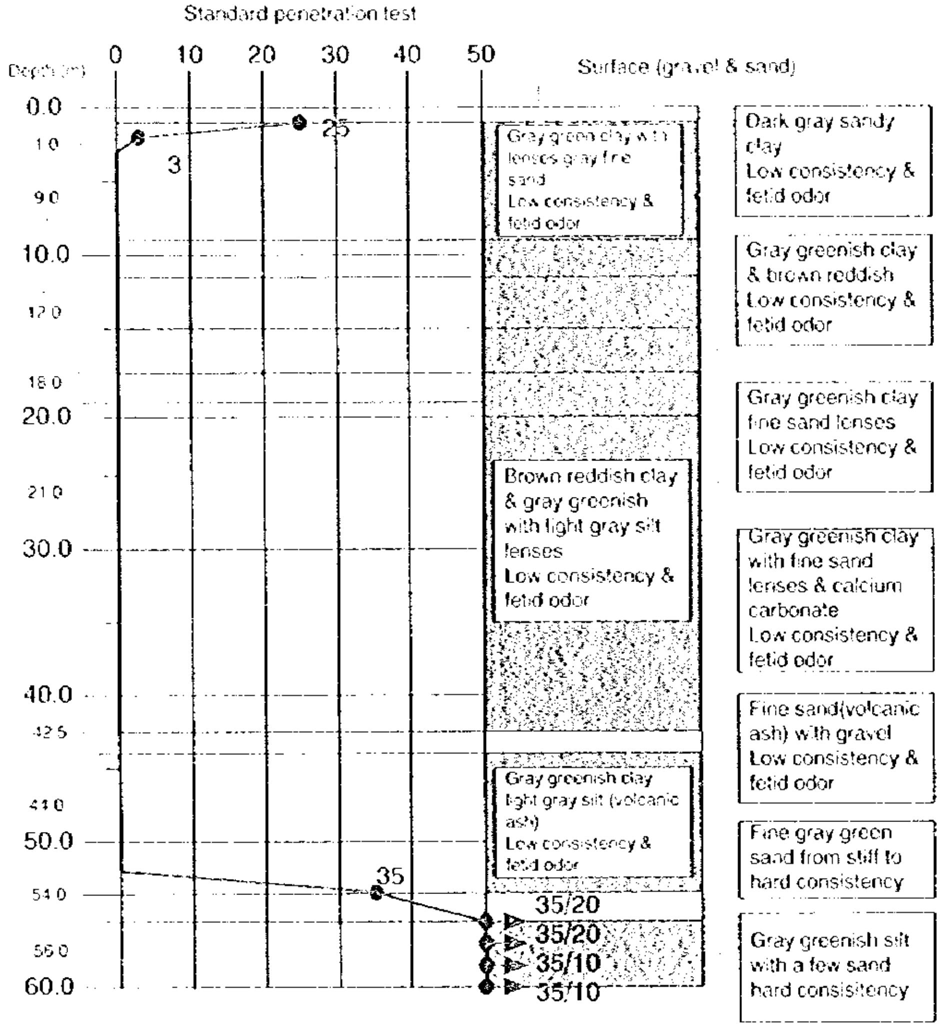
b.1 Basic Alternative

There are basically two types of composting process for organic fraction of municipal solid waste: "aerobic process" and "anaerobic process". Table 8-5 shows the comparison of the two processes.

Table 8-5: Comparison of Aerobic and Anaerobic Composting for Organic Fraction of Municipal SW

Characteristic	Aerobic process	Anaerobic process
Energy use	Net energy consumer	Net energy producer
End products	Humus, CO_2, H_2O	Sludge, CO_2, CH_4
Volume reduction	Up to 50%	Up to 50%
Processing time	20 to 30 days	20 to 40 days
Curing time	30 to 90 days	30 to 90 days
Primary goal	Volume reduction	Energy production
Secondary goal	Compost production	Volume reduction, waste stabilization

source : Integrated Solid Waste Management, McGraw-Hill



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Primary goal	Volume reduction	Energy production
Secondary goal	Compost production	Volume reduction, waste stabilization

source : Integrated Solid Waste Management, McGraw-Hill

As the composting plant is selected as one of the priority projects in the Study with the prime objective of "minimization of final disposal amount", the aerobic process is selected for the design of this project.

b.2 Examination of Technical Alternative

Aerobic composting can be operated by either: windrow composting; static pile composting; or in-vessel composting. Furthermore, the windrow composting has two types: minimal technology windrow; and high-rate windrow. Table 8-6 shows the comparison of those composting methods.

In view of the present situation where the DGSU has attained practical experiences and know-how of the high-rate windrow method through the on-going project of composting pruned branches, and the land area available in the candidate site is wide enough for establishing the high-rate windrow method, this project will be designed in line with the high-rate windrow method.

Table 8-6: Comparison of Composting Method

	Minimal technology windrow	High-rate windrow	Static pile	In-vessel
Outline	The minimal windrow technology approach involves forming large windrows (e.g. around 3.5m height by 7.3m width) that are turned only once a year with a front-end loader.	A high-rate windrow composting system employs windrow with smaller cross section, typically 1.5 to 2.0 m height by 4 to 5m width. The dimensions of the windrows depend on the type of equipment that will be used to turn the composting waste. Waste is turned twice per week while the temperature is maintained at around 55 Centigrade.	An aerated static pile system consists of a grid of aeration or exhaust piping over which the processed organic fraction of municipal solid waste is placed. Typical pile heights are 2 to 2.5 m. A layer of screened compost is often placed on top of the newly formed pile for insulation and odor control.	In-vessel composting contains an enclosed container vessel inside. The system can be divided into two major categories: plug flow and dynamic (agitated bed). In the plug flow system, the relationship between particles in the composting mass stays the same throughout the process, and system operates on first-in, first-out principle. In the dynamic system, the composting material is mixed mechanically during the processing.
Odors	Probably emits objectionable odors	Often releases offensive odors (accompanied turning)	Controllable	Less than static pile and controllable
Degradation period	Three to five years	Three to four weeks (composting) Three to four months (curing)	Three to four weeks (composting) Three to four months (curing)	One to two weeks (composting) Four to twelve weeks (curing)
Required area	Very large	Large	Large	Small
Construction cost	Very cheap	Cheap	Intermediate	High
O & M cost	Very cheap	Cheap	Intermediate	High

source : Integrated Solid Waste Management, McGraw-Hill

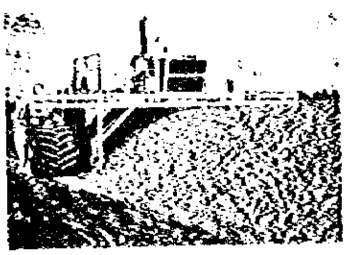
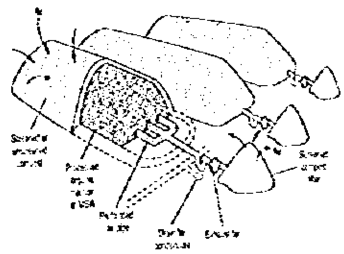
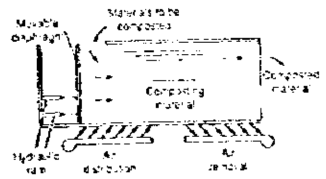
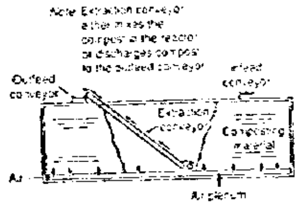
High-rate Windrow	Static Pile	In-vessel
		 Plug flow system  Dynamic system

Figure 8-3: Major Composting System

c. Conceptual Design and Cost Estimation

c.1 Outline

The composting plant is planned to be located within a triangular shaped area of about 85 hectares enclosed by (refer to Figure 8-6):

- the left branch of the Rio Churubusco adjacent to the Bordo Poniente Final Disposal Site-Etapa IV.
- the Mexico-Texcoco Toll Road.
- the Mexico City Peripheral Ring-Road.

Treatment capacity of the proposed plant is projected to be 1,250 ton/day, i.e.:

- by the Master Plan target year of 2010, 431,000 ton/year of organic waste is treated.
- the proposed plant operates 350 days per year.

Compost production is planned to be about 166 ton/day, or about 58,000 ton/year.

Main processes of the proposed facility comprise (refer to Figure 8-4):

- a composting process.
- a curing process.
- a separation process.

The process times are assumed for the purpose of the preliminary design to be 28 days for composting and 120 days for curing.

Auxiliary facilities of the plant comprise:

- truck scale.
- waste reception areas.
- temporary storage areas.

- machine/equipment maintenance workshop.
- site office and laboratory.

c.2 Definition of Terms

- **Raw material**: the material to be fed into the composting facility. Source separated organic wastes from the sub-systems is designated as the raw material.
- **Composting**: the controlled biological decomposition of organic solid waste materials under aerobic conditions. The product of this process is defined as **young compost**.
- **Composting period**: the period of decomposition of the raw material. For this preliminary design it is assumed to be **28 days**.
- **Turning**: action of agitating the windrows in order to maintain aerobic conditions inside the windrow.
- **Curing**: time for stabilization of young compost. The product of this process is defined as **mature compost**.
- **Curing Period** is defined as the maturation period. For this preliminary design the curing period is assumed to be **120 days**.
- **Separation**: the process of removing large-size particles, and non-compostables (e.g., plastics, glass, cans, metal, etc.) and not-yet-decomposed materials (e.g., paper and wood). Mature compost is passed through a trommel removing the large particles, then ferrous metal is removed with a magnetic separator.
- **Compost Product**: the end product resulting from the composting, curing, and separation processes.

c.3 Composting Facility Design Parameters

c.3.1 Design Principals

- It is planned that the composting plant starts operating in the year 2002, when separate collection of MSW from the subsystem is projected to reach about 60%. The required composting capacity at this time will be 750 ton/day. Separate collection is estimated to further increase to 80% by 2003, and to 100% by 2004.
- The implementation schedule for this design comprises phase 1 (a 750 ton/day windrow yard and a 240 ton/day curing yard in 2001) and phases 2 and 3, in 2002 and 2003 respectively (each consisting of a 250 ton/day windrow yard and a 80 ton/day curing yard). It is planned that the total composting capacity reaches 1,250 ton/day in 2004, and this capacity is maintained until 2010.
- Since stepwise improvement of the separation facility is neither practicable nor rational, it is planned to construct the 100% capacity separation facility in the year 2001.
- Considering that the proposed facility is to be constructed on highly compressible ground (in the ex-Lake Texcoco region), it is proposed that all

machinery and equipment are mobile, and buildings are lightweight, so that problems of ground subsidence will be reduced.

c.3.2 Main Design Parameters

Table 8-7 summarizes design parameters based on the design assumptions established above.

Table 8-7: Design Parameters

Composting section				
	Raw Material (Organic Waste)	Amount	431,000 ton/year	
		Compostable content	16.4 to 26.4 (% by wt.)	
		Moisture content	68 to 78 (% by wt.)	
		Bulk density	280 kg/m³	
		C/N ratio	20 - 27	
	Operation		350 day/year 24 hour/day	
	Treatment Capacity	Total	1,250 ton/day	
		Year 2002	750 ton/day	
		Year 2003	1,000 ton/day	
		Year 2004 and onward	1,250 ton/day	
	Windrow		Trapezoidal shape	*1
		Width (bottom)	5.0 m	*1
		Width (top)	3.0 m	*1
		Height	1.5 m	*1
		Cross section area	6.0 m²	*1
	Composting Period		28 days	
	Turning Frequency		1 time/5 - 6 days	
	Windrow Temperature		55°C	
Curing section				
	Operation		350 day/year 16 hour/day	
	Treatment Capacity	Young compost production	400 ton/day (max.)	*2
		Year 2002	240 ton/day	
		Year 2003	320 ton/day	
		Year 2004 and onward	400 ton/day	
		Moisture content	45 %	
		Bulk density	600 kg/m³	
	Curing Period		120 days	
Separation				
	Operation		350 day/year 16 hour/day	
	Treatment Capacity	Mature compost production	300 ton/day (max.)	*2
		Moisture content	30 %	
		Bulk density	600 kg/ m³	

*1 :These figures are referred to the specification of the turning machine used by the DGSU for composting green waste from public parks and gardens.

*2 :These figures are calculated from the *1 figures based on the conditions given in the section c.5 "Materials Balance".

c.3.3 Quantity and Quality of Compost Product

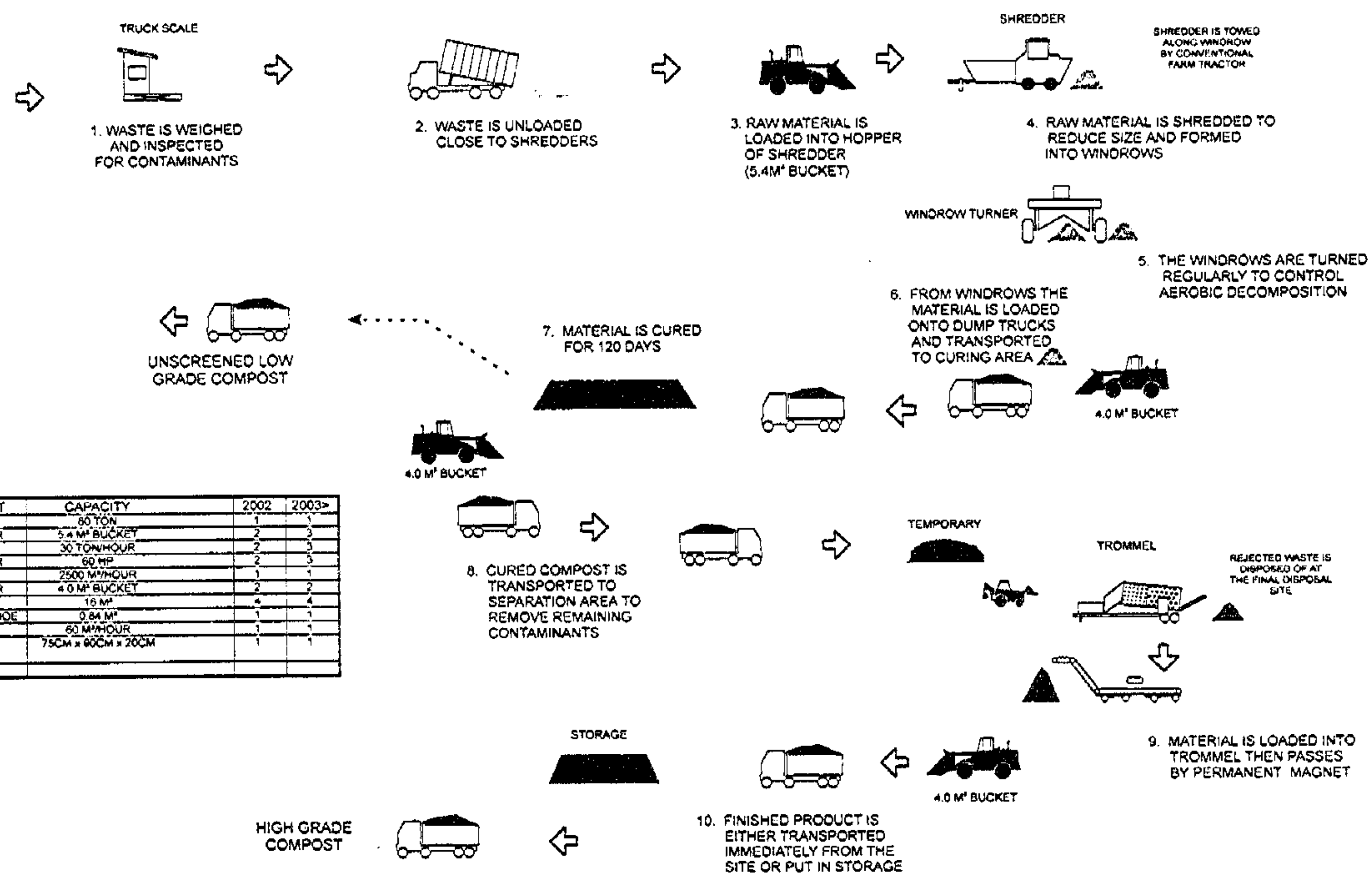
Table 8-8 shows the target quality and quantity of the compost product in the preliminary design.

Table 8-8: Quantity and Quality of Compost Product

Quantity		166 ton/day 58,000 ton/year
Quality	Moisture Content Bulk Density C/N ratio	30% by wt. 600 kg/m^3 < 15

c.4 Flow of Composting Process

Figure 8-4 shows the flow of the proposed composting process.



EQUIPMENT	CAPACITY	2002	2003>
TRUCK SCALE	60 TON	1	1
WHEEL LOADER	5.4 M^3 BUCKET	2	3
SHREDDER	30 TON/HOUR	2	3
FARM TRACTOR	60 HP	2	3
TURNER	2500 M^3/HOUR	1	1
WHEEL LOADER	4.0 M^3 BUCKET	2	2
DUMP TRUCK	16 M^3	4	4
LOADER/BACKHOE	0.84 M^3	1	1
TROMMEL	60 M^3/HOUR	1	1
PERMANENT MAGNET	75CM x 90CM x 20CM	1	1

Figure 8-4: Flow Sheet of Proposed Composting Facility

c.5 Material Balance

Figure 8-5 shows the material balance in the proposed composting facility for the case of 73% moisture content.

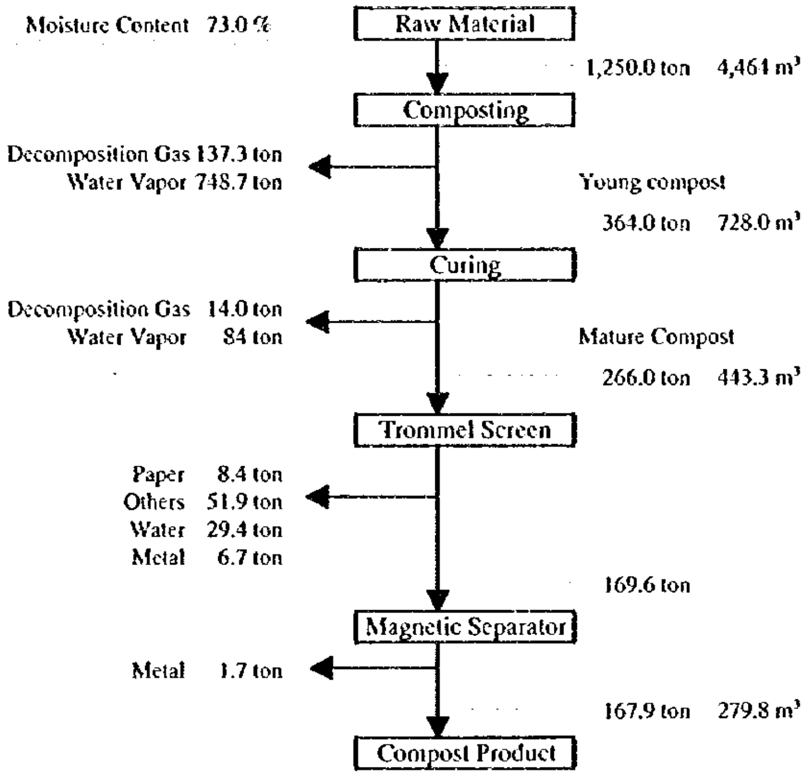


Figure 8-5: Materials Balance of Composting Facility

c.6 Layout of Proposed Composting Facility

The proposed layout of the composting facility was prepared taking the following into account.

- To avoid damaging the canal structures, the proposed facility is off-set at least 60 meters from the bank of a canal *Río Churubusco Brazo Izquierdo*.
- The composting windrow area accounts for a large portion of the total facility area. Therefore, the layout pays attention to: primarily the layout of the windrows, and subsequently the layout of the curing and separation areas to attain efficient on-site transport.
- The proposed site is located next to the Bordo Poniente Disposal Site Etapa IV and the selection plant, Construction of bridges are, however, necessary to establish direct transport routes between these sites as the Rio Churbusco lies between these and the proposed composting plant, and it is estimated that costs for the bridges are prohibitively expensive. While the site of the composting plant adjoins the Periferal Ring Road. So, the road is to be used for transportation of waste and compost without wasting a large expense for the construction of bridges.

- In order to mitigate odors and noise resulting from windrow formation and turning, at least 100 meters is maintained between the proposed windrows and nearby major roads.
- As strong winds often occur in the vicinity, the layout plan incorporates tree planting to act as a wind break. This buffer zone will also work as noise buffer and improve the appearance of the facility.

Figure 8-6 shows the proposed layout of the composting facility, and Figure 8-7 presents its cross section.

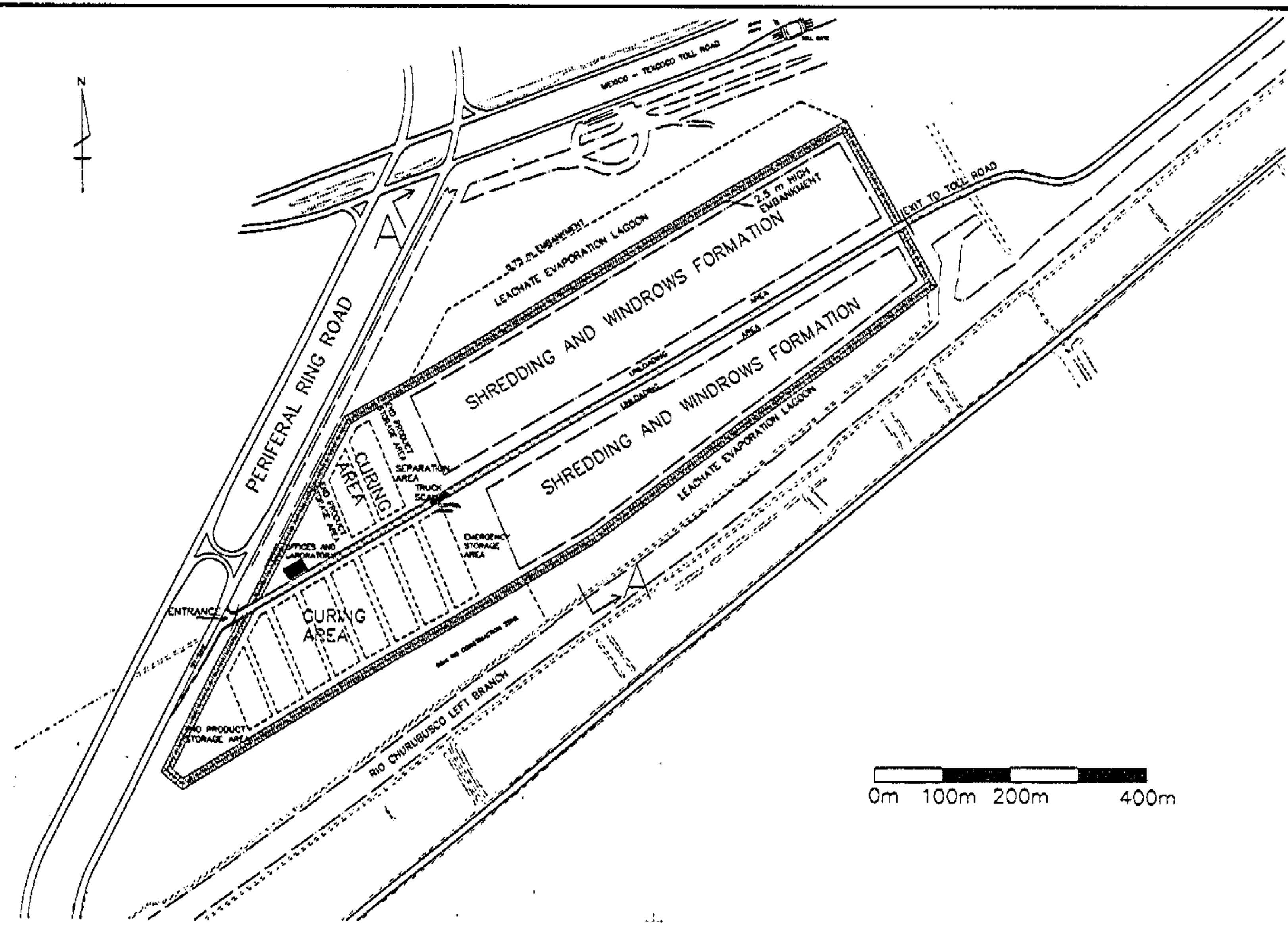


Figure 8-6: Layout of Proposed Composting Facility

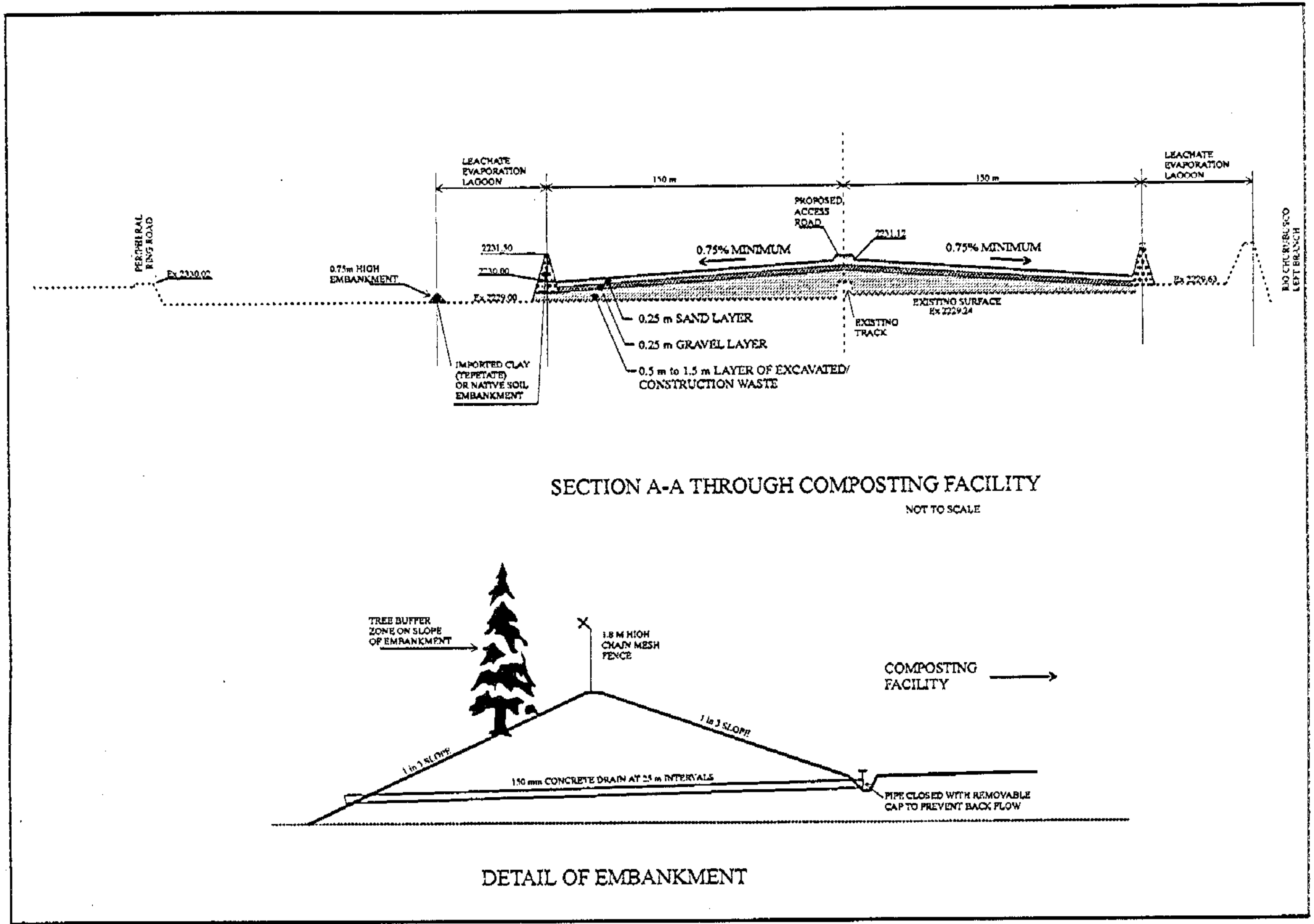


Figure 8-7: Cross Section A-A of Proposed Composting Facility

c.7 Construction Schedule

Table 8-9 shows the construction schedule of the composting plant.

Table 8-9: Construction Schedule of Composting Facility

Year	2001	2002	2003	2004	2010
Required Capacity (ton/day)	---	750	1,000	1,250	1,250
Composting Section (ton/day)	750	250	250	---	---
Curing Section (ton/day)	240	80	80	---	---
Separation Section (ton/day)	300	---	---	---	---

c.8 Operation Plan

The proposed operation plan is as follows.

c.8.1 Truck Scale

A truck scale measures the quantities of: raw material waste entering, compost product leaving the site, ferrous materials recovered, and rejected waste to be disposed of.

c.8.2 Composting Section

- Raw material input at 1,250 ton/day results in a total windrow length of 800 meters per day.

c.8.3 Curing Section

Considering the young compost amount to be handled daily and the work efficiency expected, it is designed to allocate two curing yards.

c.8.4 Separation Section

- Mature compost unloaded from dump trucks is fed (with small wheal loader) into a hopper, which feeds the mature compost to a trommel. Staff and workers are necessary for the feeding control and maintenance and cleaning of the separation yard.

- Compost after trommelling is transported to a compost product stock yard on a conveyor belt, passing a magnetic separator, which removes ferrous metal from the compost. Removed metal is periodically cleaned from the magnet and stored in the yard.

c.9 Staffing Schedule

Table 8-10 is the staffing schedule for the proposed composting facility. The number of operators and manual workers is derived from the volume of material processed and facility operation capacity. It is planned that by 2003, when facility capacity is 80%, the number of staff will reach its maximum. It is estimated that from the year 2003, 93 persons will be working in the proposed facility. Biological, physical and chemical analyses of compost for controlling the process and product's quality are to be conducted in the SJA's laboratory and/or others.

Table 8-10: Staffing Schedule

Position	2002				2003 -			
	Shift			total	Shift			total
	1	2	3		1	2	3	
ADMINISTRATION								
Site director	1	-	-	1	1	-	-	1
Finance and product promotion	1	-	-	1	1	-	-	1
Secretary	2	-	-	2	2	-	-	2
General helper	1	-	-	1	1	-	-	1
Driver	2	-	-	2	2	-	-	2
sub totals	7	0	0	7	7	0	0	7
OPERATION								
Sub-director process	1	-	-	1	1	-	-	1
Shredding supervisor	1	1	1	3	1	1	1	3
Turning and curing supervisor	1	-	-	1	1	-	-	1
Shredder operators	2	2	2	6	3	3	3	9
Loader operators	4	4	2	10	5	5	3	13
Tractor drivers	2	2	2	6	3	3	3	9
Small loader operators	1	1	-	2	1	1	-	2
Turner operator	1	-	-	1	1	-	-	1
Dump truck drivers	3	3	-	6	4	4	-	8
Waste inspectors	1	1	-	2	1	1	-	2
Traffic controllers	3	3	-	6	3	3	-	6
General Laborers	9	6	2	17	10	7	3	20
Truck scale attendant	1	1	-	2	1	1	-	2
Water truck driver	1	-	-	1	1	-	-	1
Security	2	2	2	6	2	2	2	6
sub totals	33	26	11	70	38	31	15	84
MAINTENANCE								
mechanics	1	1	-	2	1	1	-	2
sub totals	1	1	0	2	1	1	0	2
Totals	41	27	11	79	46	32	15	93

c.10 Cost Estimation

Preliminary cost estimate is presented in Table 8-11. The estimate has been divided into two sections; site improvements and equipment.

Table 8-11: Preliminary Cost Estimate of Composting Plant

Unit: US$ 1,000

Item	Details	unit	Unit Cost US$	Quantity	Cost US$	Cost Pesos P9.1=$1
SITE IMPROVEMENT						
earth works	spreading 1.0m layer of construction waste	m2	1.04	370,000	385,000	3,504,000
	gravel for base, t=0.25m, A=33ha	m3	4.2	91,000	382,000	3,476,000
	spreading sand surface, t=0.25m, A=33ha	m3	5.35	94,000	503,000	4,577,000
	grading of surface for drainage	m2	0.23	330,000	76,000	692,000
general improvements	embankment, exit track construction drainage, fencing, connect electricity lighting, access improvement, fuel tank water tank, portable buildings				599,000	5,451,000
Site improvement Total					1,945,000	17,700,000
Equipment						
truck scale	80 ton + foundations etc.	unit	60,000	1	60,000	546,000
wheel loader (A)	wheel loader with 5.4 m^3 refuse bucket	unit	125,400	3	376,000	3,422,000
wheel loader (B)	wheel loader with 4.0 m^3 refuse bucket	unit	100,320	2	201,000	1,829,000
compact loader	backhoe/loader, 2.36m/0.84m^3 bucket	unit	34,320	1	34,000	309,000
dump truck	16 m^3, 10 ton	unit	33,660	4	135,000	1,229,000
conventional farm tractor	60 hp (gross engine)	unit	33,000	3	99,000	901,000
water tanker	8,000 liters	unit	28,330	1	28,000	255,000
shredder	cap. 30 tons/hr, 175hp	unit	99,000	3	297,000	2,703,000
windrow turner	cap. 2500 tons/hr	unit	180,000	1	180,000	1,638,000
trommel	Screen 8 mm, & conveyors	unit	201,600	1	202,000	1,838,000
magnetic separator	permanent magnet + frame	unit	7,200	2	14,000	127,000
conveyors (separation)	w=600, side angle=25%	unit	15,000	3	45,000	410,000
pick up equipment	cap. 2 ton	unit	22,500	2	45,000	410,000
Equipment Total					1,716,000	15,617,000
sub-total (I)					3,661,000	33,317,000
miscellaneous	10%				367,000	3,332,000
Direct cost					4,028,000	36,649,000
general expenses/overhead	30%				1,209,000	10,995,000
total construction cost					5,237,000	47,644,000
physical contingency	10%				524,000	4,764,000
IVA	15%				785,000	7,147,000
Total Cost					6,546,000	59,555,000

Site improvements are based on the assumption that once it has been decided that the above site will be used for the composting facility, construction waste will be deposited at the site in order to form the platform on which the facility will be established.

The material is proposed to be compacted in layers forming a layer 0.5 m to 1.0 m thick. Over this sub-base will be placed a 0.25 m layer of gravel and over this a 0.25 m surface layer of sand. Surrounding the platform an embankment is proposed, rising 2.5 meters above the existing surface. This embankment is dual purpose, firstly, it provides a flood barrier against inundation resulting from the overflowing of the left branch of the Rio Churubusco. Secondly, by planting trees on the embankment a buffer zone will be formed. This buffer zone will help reduce dust, odor, and noise escaping from the site. It will also beautify the area for passers-by.

Unit costs for the supply and transport of soil and gravel and other civil works are based on those provided by DSGU.

Most equipment unit costs were obtained from local distributors. Some equipment selected for the feasibility study is not distributed in Mexico (i.e. the shredders) so manufacturers in the United States were contacted.

The exchange rate used in the cost estimation for the preliminary design is 9.1 pesos to the US dollar[1]

c.11 Priority Project Cost (Composting Facility)

Table 8-13 shows costs for the composting project from 1999 to 2010 annually. Two cases shown below were set for the cost estimates.

- Case 1: Investment and operation by the DGSU
- Case 2: Investment by the DGSU and contracting out operation

Namely, the DGSU invests in all construction, procures all equipment and operates the compost facility directly in Case 1, whereas the DGSU invests in all construction, procures some equipment and a private company supplies other equipment's and operates the compost facility under a contract with the DGSU in Case 2.

Table 8-12: Procurement of Equipment in Case 2

DGSU		Private company	
Truck scale:	1	Wheel loader (A):	3
Shredder:	3	Wheel loader (A):	2
Windrow turner:	1	Compact loader:	1
Trommel:	1	Dump truck:	4
Magnetic separator:	2	Farm tractor:	3
Conveyor:	3	Water tanker:	1
		Pick up equipment:	2

[1] Exchange rate based on the average of recent rates

Table 8-13: Priority Project Cost (Composting Facility)

unit : US$ 1,000

Case	Year	Basic Design		Pilot projects		Detail Design + supervision		Construction		Equipment		O & M (contract)		O & M (direct)		Land rental fee		Total		
		domestic	foreign	domestic	foreign	domestic	foreign	domestic	foreign	domestic	foreign	domestic	foreign	domestic	foreign	domestic	foreign	domestic	foreign	domestic + foreign
Case 1	1999	50	-	8	2	-	-	-	-	-	-	-	-	-	-	-	-	58	2	60
	2000	-	-	8	2	164	-	-	-	-	-	-	-	-	-	-	-	172	2	174
	2001	-	-	-	-	99	-	2,376	-	-	2,548	-	-	-	-	33	-	2,508	2,548	5,056
	2002	-	-	-	-	33	-	551	-	-	520	-	-	530	132	33	-	1,147	652	1,799
	2003	-	-	-	-	33	-	551	-	-	-	-	-	656	164	33	-	1,273	164	1,437
	2004	-	-	-	-	-	-	-	-	-	-	-	-	656	164	33	-	689	164	853
	2005	-	-	-	-	-	-	-	-	-	-	-	-	656	164	33	-	689	164	853
	2006	-	-	-	-	-	-	-	-	-	-	-	-	656	164	33	-	689	164	853
	2007	-	-	-	-	3	-	-	-	-	-	-	-	656	164	33	-	689	164	866
	2008	-	-	-	-	2	-	-	-	-	2,441	-	-	656	164	33	-	689	2,605	3,296
	2009	-	-	-	-	-	-	-	-	-	520	-	-	656	164	33	-	689	684	1,373
	2010	-	-	-	-	-	-	-	-	-	-	-	-	656	164	33	-	689	164	853
	Total	50	-	16	4	344	-	3,478	-	-	6,029	-	-	5,778	1,444	330	-	9,996	7,477	17,473
		50		20		344		3,478		6,029		-		7,222		330		---		
Case 2	1999	50	-	8	2	-	-	-	-	-	-	-	-	-	-	-	-	58	2	60
	2000	-	-	8	2	164	-	-	-	-	-	-	-	-	-	-	-	172	2	174
	2001	-	-	-	-	99	-	2,376	-	-	1,250	-	-	-	-	33	-	2,508	1,250	3,758
	2002	-	-	-	-	33	-	551	-	-	177	1,051	-	81	20	33	-	1,749	197	1,946
	2003	-	-	-	-	33	-	551	-	-	-	1,186	-	99	25	33	-	1,902	25	1,927
	2004	-	-	-	-	-	-	-	-	-	-	1,186	-	99	25	33	-	1,318	25	1,343
	2005	-	-	-	-	-	-	-	-	-	-	1,186	-	99	25	33	-	1,318	25	1,343
	2006	-	-	-	-	-	-	-	-	-	-	1,186	-	99	25	33	-	1,318	25	1,343
	2007	-	-	-	-	13	-	-	-	-	-	1,186	-	99	25	33	-	1,318	25	1,356
	2008	-	-	-	-	2	-	-	-	-	1,142	1,186	-	99	25	33	-	1,318	1,167	2,487
	2009	-	-	-	-	-	-	-	-	-	177	1,186	-	99	25	33	-	1,318	202	1,520
	2010	-	-	-	-	-	-	-	-	-	-	1,186	-	99	25	33	-	1,318	25	1,343
	Total	50	-	16	4	344	-	3,478	-	-	2,746	10,539	-	873	220	330	-	15,630	2,970	18,600
		50		20		344		3,478		2,746		10,539		1,093		330		---		

8.2.2 Final disposal Sites

Several alternatives have been examined under the circumstances that the remaining lifetime of the presently operated landfill (Etapa IV) is expected to be limited. Mexican side's estimation states that the landfill to the 8m elevation will be filled until February 2001. The alternatives examined, in view of making the lifetime of the landfill extended and/or securing sustainable waste disposal, were landfill mining, composting, incineration plant, acquiring a new site for landfill, etc.

As a result, vertical expansion of the existing landfill (Etapa IV) and a new landfill development (Etapa V) have been chosen as two of three priority projects. In this section, design conditions and alternatives of the two projects are examined, and conceptual design and cost estimates are carried out.

8.2.2.1 Vertical Expansion Plan of Etapa IV

Etapa IV is a landfill that is presently operated. However, its lifetime is limited as mentioned above. The vertical expansion plan proposes to place waste to 24m elevation in order to expand the lifetime.

a. Examination of Design Conditions

There are some important restrictions regarding this vertical expansion plan of Etapa IV that are:

- the agreement with CNA.
- NOM-083-ECOL-1996.
- technical restrictions.

The agreement with CNA restricting the height of the landfill as 8m needs to be altered to realize this plan.

NOM-083 is one of the Mexican Official Norms which establishes the requirements to be applied to new landfill development of municipal solid waste. The norm was not yet in force when the design of Etapa IV was completed in 1992. However, the design took into consideration some criteria of the US EPA's regulations, such as secureness of the distance from an airport. Such criteria were eventually included in the requirements of the norm. In fact, the status quo of the landfill basically appears to fulfill the requirements.

Other restrictions are technical requirements on the design of the plan. The major technical requirements are the examination of:

- physical impacts (subsoil settlement, etc.) which will be caused by landfill load.
- improvement of the leachate disposal.
- waste disposal amount.

a.1 Physical Impacts of Proposed Vertical Expansion

The Bordo Poniente area stands on the 60-meter thick highly compressible clayey layer of the ex-lake Texcoco area. Etapa IV is located on such soil conditions. The waste load causes settlement of the subsoil under the landfill due to the soil character. In the vertical expansion plan, further placement of waste on the existing one is forecast to cause further subsoil settlement. **In the circumstances, it is anticipated that the further subsoil settlement would damage a drainage canal (Canal de la Compañia) flowing along the landfill which is one of major drainage canals in the area, and it would stretch of the impermeable liner.**

It is also anticipated that the vertical expansion would make the landfill slope unstable.

In this section, issues examined regarding physical impacts of the proposed vertical expansion are:

- geological survey.
- influence on the Canal (Canal de la Compañia).
- influence on the impermeable liner.
- influence on stability of the landfill slope.

a.1.1 Geological Survey

i. Survey Items

The survey was carried out at Bordo Poniente Etapa IV. Number of borings and survey items are shown in Table 8-14.

Table 8-14: Work Quantity of Soil Survey at Etapa IV

Survey Items	Survey Contents
Boring	2 bore holes (0 to 40 m deep, and 0 to 60m deep)
Soil tests	liquid limit, plastic limit, unit weight, consolidation, grain size, water content, tri-axial compression

iii. Results of the Survey

The groundwater levels are shown in Table 8-15, and the soil characters acquired by the survey are summarized in Table 8-16.

Table 8-15: Groundwater level of Etapa IV

Site	Bore hole number	Groundwater level (m)
Etapa IV	SM-7	0.03
	SM-8	0.35

Table 8-16: Results of Soil Survey at Etapa IV

Characters \ Location	SM-7		SM-8		
	8.0-9.0m	15.0-16.0m	16.0-17.0m	32.0-33.0m	42.0-43.0m
Type of soil (Visual observation)	clay	clay	clay	clay	clay
Specific gravity	2.48	2.632	2.52	2.54	2.54
Unit weight (ton/m^3)	1.13	1.26	1.18	1.18	1.67
Void ratio	4.037	5.139	10.399	6.28	4.837
Degree of Saturation (%)	102.996	97.7	102.1	100	98.6
Water content (%)	167.7	238	421.3	247.7	187.2
Liquid limit (%)	256	158.3	365.3	270	169.4
Plastic limit (%)	126.7	35	175.9	94.7	76.8
Plasticity index (%)	129.3	112.6	189.4	175.3	92.6
Tri-axial undrained C (ton/m^2)	0.3	0.2	1.4	0.9	1.1
Angle of internal friction (deg.)	2	9	4	0	11
Simple compression qu (ton/m^2)	0	2.3	2.03	1.73	8.4
Grain size	100F	100F	100F	100F	-
N value	0	0	0	0	0
Consolidation (compression index)	1.456	3.825	6.395	5.033	3.392

iv. Findings

The surface stratum at the site, Etapa IV, is occupied more than 50m thick clayey lacustrine deposit. Almost all N values of the stratum show 0, zero. A stable layer of which N value shows more than 50 exists below the depth of 55m. The lacustrine deposit shows considerably high natural water contents of from 160 to 420% and low unit weight of about 1.20 ton/m^3. Therefore, it is judged that the lacustrine is considerably soft clay according to the soil surveys result.

a.1.2 Vertical Expansion Influence on the Canal

i. Conditions for Estimation of Influence

Data on soil layers at SM-8 bore hole are employed for the estimation. The lacustrine layer is subdivided into 10 layers as shown in Table 8-17. The waste load is assumed to be the one when the landfill becomes 24m high and the unit weight of waste after initial compression at the landfill is assumed to be 0.8 ton/m^3. And two cases are set depending on whether buoyancy caused by the groundwater is considered or not. Case 1 ignores such buoyancy, on the other hand, Case 2 takes buoyancy into consideration.

Table 8-17: Subsoil Conditions

Layer	Thickness of layer (m)	Unit weight (ton/m^3)
1	1.0	1.80
2	5.5	1.13
3	1.0	1.80
4	8.5	1.26
5	5.0	1.18
6	5.0	1.18
7	6.0	1.18
8	10.0	1.18
9	2.0	1.67
10	10.0	1.18

Note: The water level is assumed at 0m depth, because the groundwater level at SM-7 was 0.03m and at SM-8 was 0.35m.

ii. Results of the Estimation

The results are schematized in Figure 8-8. The result of Case 1, without consideration of the buoyancy, is that the final subsoil settlement (theoretical maximum) is 19.6 m in the landfill center which may cause 8cm settlement at the 80m off-set drainage canal. Meanwhile, the final subsoil settlement (theoretical maximum) of Case 2, with consideration of the buoyancy, is 12.6m in the landfill center which may cause 4cm subsidence at the 80m off-set drainage canal.

iii. Influence on the Canal (Canal de la Compañia)

In conclusion, the estimation shows only 8cm subsidence of the drainage canal under the theoretical maximum subsoil settlement caused by the vertical expansion. So, it can be said that the vertical expansion plan will not pose a serious problem on the drainage canal structure.

a.1.3 Vertical Expansion Influence on the Impermeable Liner

Figure 8-9 schematizes the subsoil settlement. The part of liner under the first lift's slope will undergo the largest tensile stress. The tensile stress can be expressed as 3.0% in elongation terms (32.47m/32m=1.015, i.e., 1.5% of stretch, taking into consideration the stretch of two-dimension, $32.47^2/32^2=1.030$, i.e., 3.0% of stretch, see Figure 8-9). This elongation would be absorbed in the tensile performance of the impermeable liner.

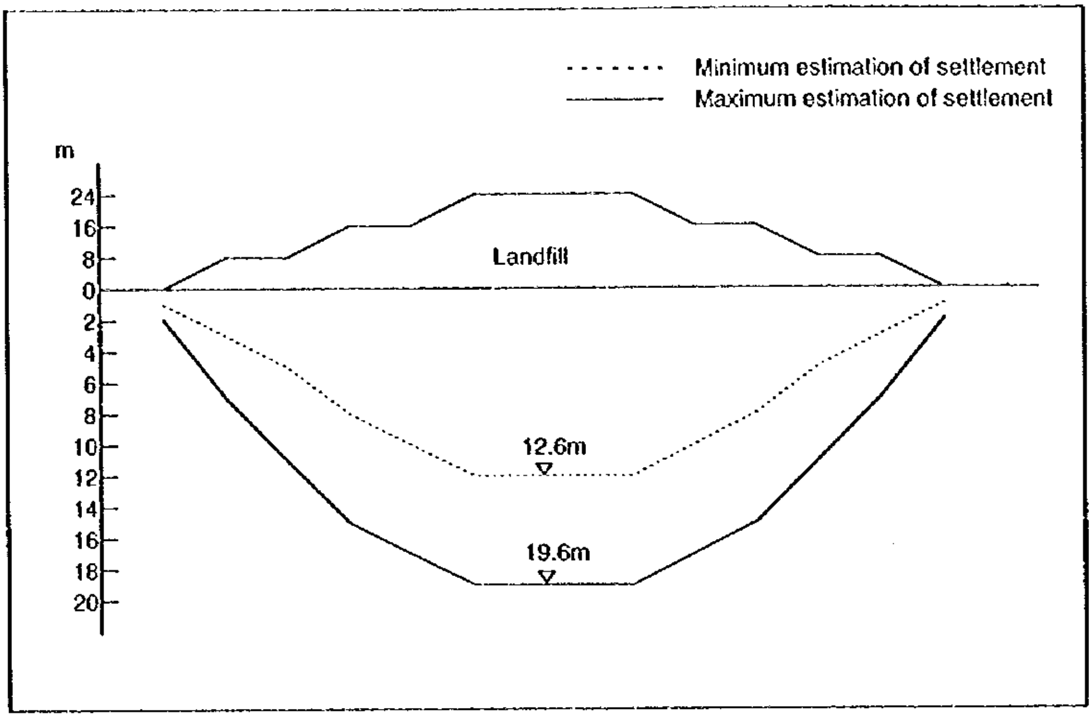


Figure 8-8: Subsoil Settlement

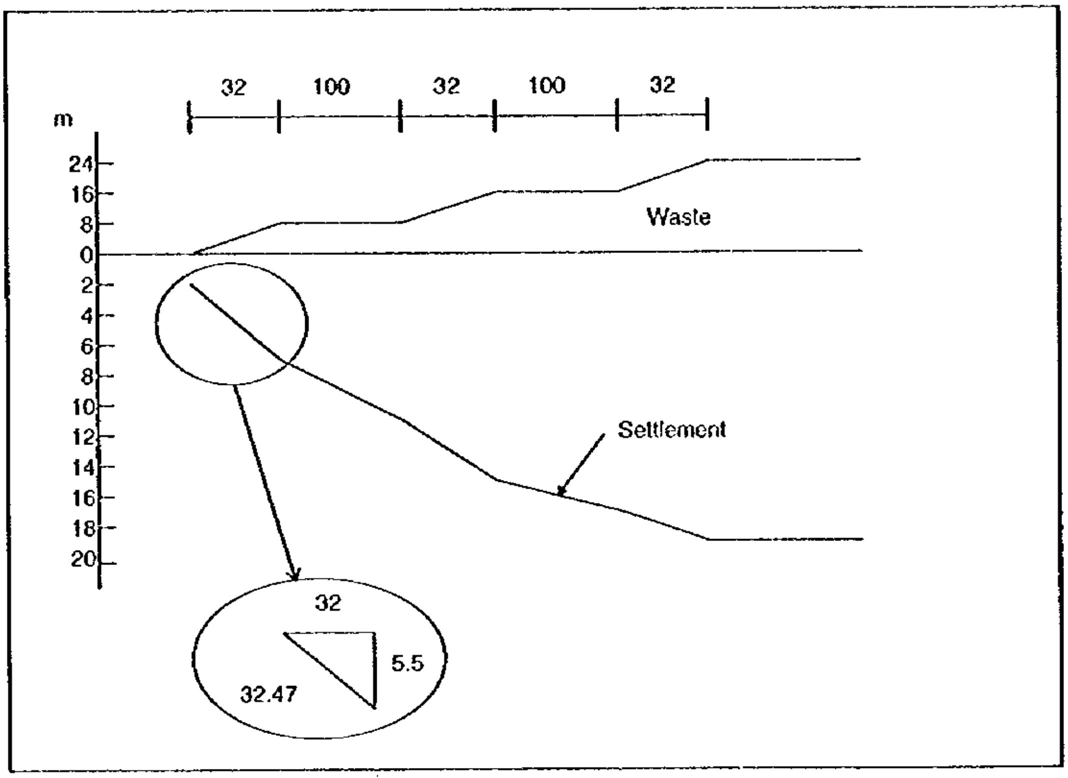


Figure 8-9: Subsoil Settlement and Liner

a.1.4 Vertical Expansion Influence on Stability of Landfill Slope

The soil data presented in Table 8-16 are employed in the Bishop Method for calculating the slope stability. The present landfill slope has an inclination of 1 in 4, and this inclination is also employed for both elevation of 8 to 16m and 16m to 24m. The minimum factor of the slope 0 to 8m shows 0.948 which is the least among others. Although slope failure could occur as the minimum factor is less than 1.0 theoretically, it has not happened. On the other hand, minimum factors of other slopes exceed 1.0, therefore, the vertical expansion is viable from a viewpoint of landfill slope stability.

Table 8-18: Result of Slope Stability Calculation (Etapa IV)

Slope	Landfill Height	Minimum Safety Factor	Coordinates of the Rotational Slope		Radius of the Rotational Slip (m)	Resist Moment (ton-m)	Slip Moment (ton-m)
			X	Y			
1	0 to 8m	0.948	10.00	15.00	30.13	2,001.15	2,111.67
2	8 to 16m	1.077	146.00	16.00	51.00	8,584.00	7,968.72
3	16 to24m	1.313	280.00	25.00	60.00	11,634.95	11,149.46

a.2 Leachate Management

i. Present Conditions

At present, leachate is sometimes seeping out at the cells bottom slope to the surrounding road. Trenches were dug around the cells to receive that leachate (possibly diluted with groundwater). Some amount of the leachate is collected by tank trucks and transported to an evaporation pond located at the east side of Etapa III. It is anticipated that the current leachate management in Etapa-IV is carried out irrelevant to estimation of leachate generation amount. Which should be very inefficient and ineffective in view of high possibility of dilution with groundwater and also the limited capacity of the evaporation pond.

ii. Existing Estimation of Leachate Generation

The existing estimation of leachate generation[2] says that 61 mm/year of leachate will be generated at the landfill under the present landfilling manner. However, the leachate presently generated is likely much more than the expected, although quantitative investigation has not been carried out. Meanwhile, another calculation in the same report shows that 182 mm/year of leachate will be generated.

The difference between the estimations is attributed to precipitation data used and estimation manner. The former estimation used the precipitation data of 347 mm/year at Bordo Poniente, and the duration subjected to the calculation was only one year. Meanwhile, the latter used the data of 617 mm/year at the airport next to the landfill area, and the duration was 5 years.

[2] Geo Ingenieria International, *Operacion de las celdas de evaporacion y experimentacion ubicadas en los III y IV Etapas de Bordo Poniente*, 1997

Table 8-19: Existing Leachate Generation Estimation

Station	Precipitation (mm/year)	Leachate generated (mm/year)
Bordo Poniente	347	61
Airport	617	182

iii. Leachate Generation Estimation

Estimation of leachate generation quantity, which will be generated under the existing situation, was carried out by using meteorological data at the Mexico City International Airport station (Estacion meteorologica Aeropuerto Internacional Benito Juarez). The result shows that 101 mm/year out of the precipitation will percolate through the cover soil, then water contents of waste and soil under the cover soil will reach the field capacities in 3 years, finally 101 mm/year of leachate will be generated at the bottom of the landfill in the 4th year and afterward (See Figure 8-10). Detail of the estimation is described Annex H.

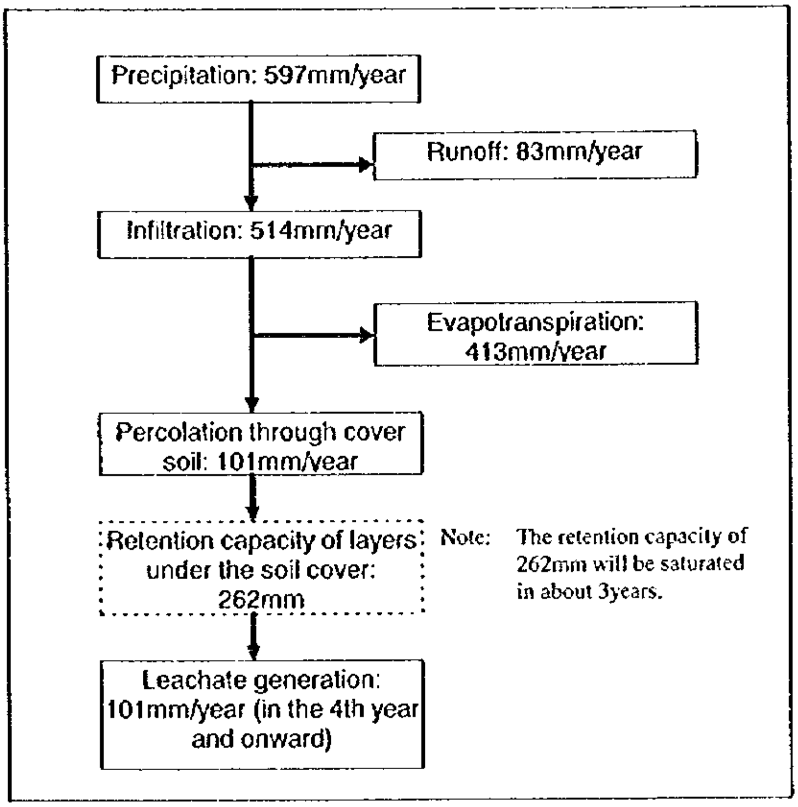


Figure 8-10: Leachate Generation

a.3 Waste Disposal Amount

According to the Master Plan, the landfills of Etapa IV and V have to have enough capacity to secure sound final waste disposal from 2001 to 2010. The forecast of waste amount to be disposed of during the 10 years is shown in Table 8-20.

Table 8-20: Waste Disposal Amount from 2001 to 2010

Year	Disposed Waste					
	Total		Etapa IV		Etapa V	
	1000 ton	1000 m^3	1000 ton	1000 m^3	1000 ton	1000 m^3
2001	3,876	4,845	3,876	4,845		
2002	3,609	4,511			3,609	4,511
2003	3,493	4,366			3,493	4,366
2004	3,385	4,231			3,385	4,231
2005	3,373	4,216	3,373	4,216		
2006	3,358	4,198	3,358	4,198		
2007	3,340	4,175			3,340	4,175
2008	3,321	4,151			3,321	4,151
2009	3,300	4,125	3,300	4,125		
2010	3,278	4,098	3,278	4,098		
Total	34,333	42,916	17,185	21,482	17,148	21,434

Note: bulk density of the waste at landfill is assumed to be 800kg/m^3.

b. Examination of Technical Alternatives

Major causes giving serious impacts on the environment in landfill development are leachate and landfill gas. Also, mitigation measures against them make landfill construction, operation and, furthermore, closure costly. Therefore, alternatives of mitigation measures such as landfill bottom liner, intermediate cover, final cover, surface drainage, leachate collection, leachate disposal, landfill gas disposal, etc. are of much technical interest. Although some issues can not be modified because Etapa IV is the existing landfill, the issues shown in Table 8-21 are examined technically, environmentally, and in view of costs in this section.

Table 8-21: Issues to be Examined as Technical Alternatives

Leachate/gas	Purpose	Issues to be examined
Leachate	How to make leachate generation quantity smaller.	During operation - intermediate cover After closure - final cover
	How to dispose of leachate.	- spray - re-circulation - evaporation pond - treatment facility
Landfill gas	How to dispose of landfill gas.	- passive control - active control

b.1 Intermediate Cover

In the manner of landfilling at Etapa IV, daily soil cover will also serve as an intermediate soil cover which is placed at 8m elevation. The soil for intermediate cover is expensive (about 20 pesos/m^3) as it is not available in the landfill area. Thus, placement of the intermediate soil cover considerably affects the operation costs. To find a way to make this cost smaller, i) thickness of the soil cover and ii) use of compost from the composting plant are examined. Finally, 30 cm thickness of cover soil the same as the present operation is recommendable (see Annex II).

b.2 Final Cover

Final cover should be employed to promote attenuation of landfills' harmful influence on surroundings, when they are closed. Major purposes of the final cover is i) to mitigate leachate generation, ii) to control landfill gas emission and iii) to improve landscape. With taking these purposes into account, 50 cm or more thickness of soil cover is recommended as the final cover (see Annex H).

b.3 Leachate Disposal

The present conditions of the landfill needs an appropriate leachate disposal manner. In this section, alternatives examined are following:

- spray on the landfill.
- re-circulation into the landfill.
- evaporation pond.
- leachate treatment.

First of all, it should be noted that leachate can not be extracted from the landfill by gravity due to flat ground of the area and the settlement. Then, all the alternatives need pumps to get leachate out of the landfill.

Wells for leachate extraction can not be constructed at a periphery of the landfill, they should be inside of the landfill, because the inner part is deeper than the periphery due to the settlement, leachate will gather the inner part. Due to this character of the landfill, re-circulation, evaporation pond and leachate treatment requires facilities in addition to ones of spray method. Then, the spray method is the least costs and uses the climatic advantage (small rainfall and large evaporation) efficiently for leachate disposal as stated in Table 8-22. Consequently, the spray method is a recommendable manner of leachate disposal.

Table 8-22: Comparison of Leachate Disposal Alternatives

Alternatives	Facility needed	Advantages	Disadvantages
Spray	- pumps - wells - nozzle (to spray)	- the least cost - the most efficient use of evaporation action (leachate can contact with air efficiently)	- unpleasant odor on the landfill surface
Re-circulation	- pumps - wells - pipes (to landfill gas extraction wells)	- the second least cost (pipes to connect landfill gas extraction wells are necessary in addition to the spray method) - attenuation of leachate quality	- need great care for landfill gas control (landfill gas tends to be larger in leachate re-circulation systems) - not efficient on reduction of leachate amount - may require further leachate treatment
Evaporation	- pumps - wells - pipes (to a evaporation pond) - evaporation pond	- simple operation	- requiring a large area - unpleasant odor on the evaporation pond - sludge disposal is necessary
Treatment	- pumps - wells - pipes (to treatment facilities) - treatment facilities	- it can control quality of discharge water.	- huge investment and operation costs - need a high level of technique for construction, operation and maintenance

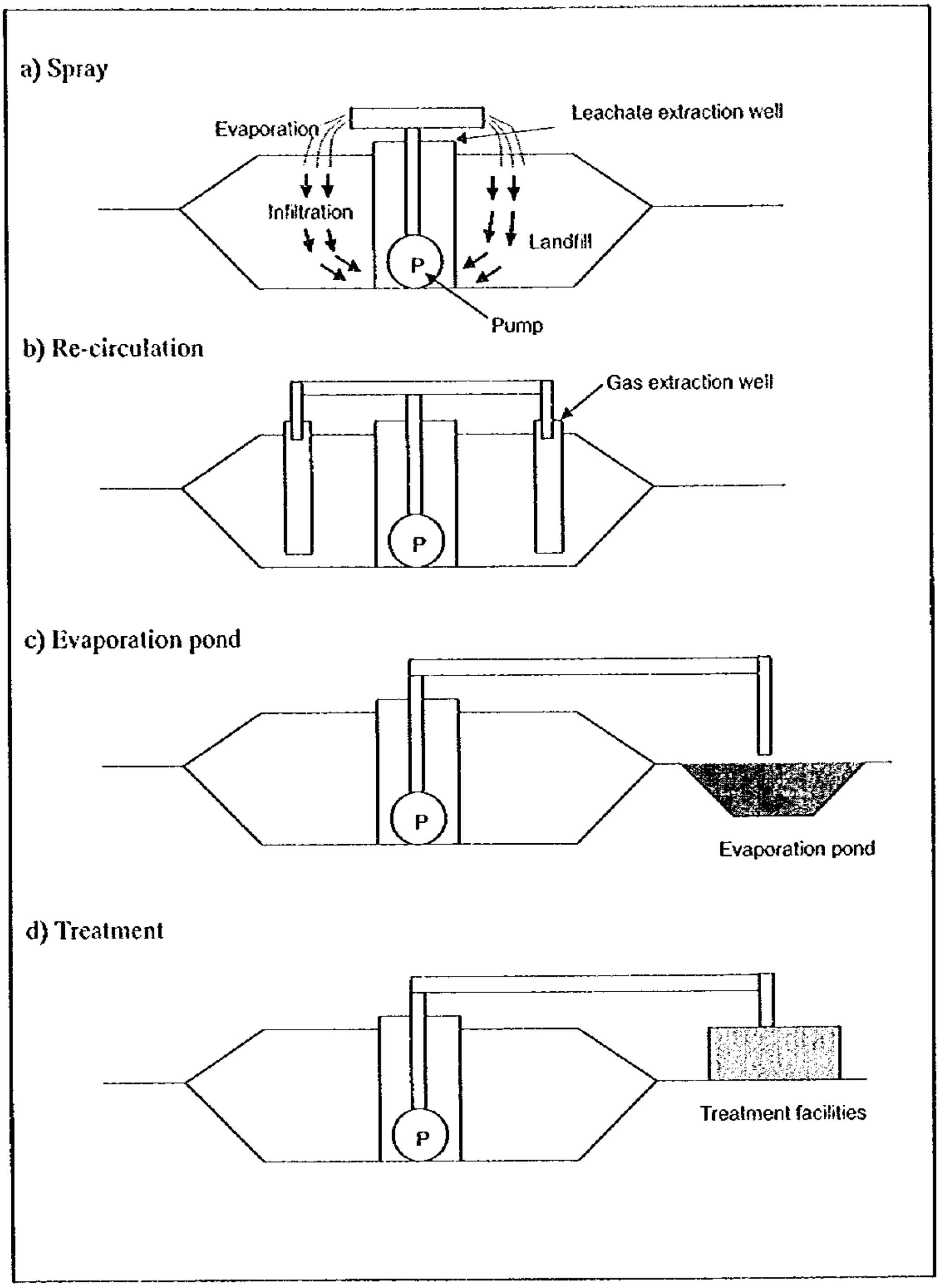


Figure 8-11: Leachate Disposal Alternatives

b.4 Landfill Gas Disposal

Landfill gas is generated through decomposition of biodegradable material. It is composed of several constituents. The principal gases are methane (CH_4) and carbon dioxide (CO_2) produced through the anaerobic decomposition.

Ways of controlling landfill gas can be classified as passive and active. The passive control uses pressure of landfill gas generated in the landfill to extract it through gas vents. On the other hand, the active control uses energy to pull it out. Therefore, the active control is generally more costly than the passive one. When gas energy recovery is preferable, or circumstances require strict landfill gas control, the active control may be taken.

As previously stated, the spray method is the recommended manner for leachate disposal. The manner does not encourage landfill gas generation so much as the re-circulation method. Also, there are no residential or commercial areas around the landfill like the surroundings of the Montana landfill which is equipped with modern biogas extraction facilities. Therefore, **the passive control is recommendable for the Etapa IV landfill.**

c. Conceptual Design and Cost Estimates

Outline of the conceptual design for the Vertical Expansion Plan is presented in Table 8-23.

Table 8-23: Outline of the Conceptual Design for the Vertical Expansion Plan

Items	Facilities
Landfill capacity	25,849,000m^3(20,679,000ton) is available for waste disposal.
Access	at 0m elevation outer road: 8,285m (existing) inner road: 26,675m (existing) at 8m elevation outer road: 7,075m inner road: 19,623m at 16m elevation outer road: 5,160m inner road: 6,453m
Leachate management	Leachate extraction wells concrete pipes with 600mm diameter: 24 nos. Leachate extraction pumps: 24 nos. Leachate collection lines at 0m elevation: 26,675m at 8m elevation: 26,708m at 16m elevation: 11,613m
Landfill gas management	Gas extraction wells concrete pipes with 600mm diameter: 198nos. Gas extraction pipes - PVC200 at 8m elevation: 141 nos. at 16m elevation: 102 nos.
Surface water management	Daily/intermediate soil cover: 30cm (Compost is also usable.)
Monitoring	Monitoring items: -settlement of the landfill -leachate quality -landfill gas quality
Aesthetic design	Mobile screen Daily/intermediate soil cover: 30cm (Compost is also usable.)
Closure and post-closure	Final soil cover: 60cm Greening by seeding the final cover with grass
Landfill equipment	Bulldozers (300hp class): 4 nos. Sprinkler trucks (15,000liter class): 2 nos. Excavators (85hp class): 2 nos.

c.1 Key Design Data

Key data for landfill design are set as follows:

- bulk density of waste after compaction in landfill: 800kg/m^3
- operation schedule of landfill: 24 hours/day, 365 days/year
- life year of trucks and heavy equipment: 7 years
- life year of building and civil works: 30 years
- exchange rate: US$ 1.00 = 9.1pesos
- daily (intermediate) soil cover: 30cm
- final landfill elevation: 24m

c.2 Landfill Capacity

Capacity of the vertical expansion in the part of 8 to 24m elevation is to be 26,926,000m^3. Of the capacity, 25,849,000m^3 will be occupied with waste and 1,077,000 m^3 with soil (See Annex H).

All the waste disposed of in 2001, 2005 and 2006, and part of waste in 2009 are to be placed in the lift of 8-16m elevation. The rest of waste in 2009 and all waste in 2010 are to be disposed of in the lift of 16-24m elevation. The remaining capacity of the landfill after 2010 will be 4,368,000m^3 for waste disposal, i.e., 3,494,000 ton of waste (See Table 8-24).

It should be noted that the calculation of landfill capacity does not take the settlement of subsoil and waste into account.

Table 8-24: Waste Disposal Amount in Etapa IV

Unit: 1,000m^3

Elevation	Landfill capacity	Waste disposal amount						Remaining capacity
		2001	2005	2006	2009	2010	Total	
8-16m	16,447	4,845	4,216	4,198	3,188		16,447	0
16-24m	9,402				937	4,098	5,035	4,367
Total	25,849	4,845	4,216	4,198	4,125	4,098	21,482	4,367

c.3 Access

In order to secure accessibility to waste unloading areas, outer roads and inner roads will be constructed on the 8m and 16m elevation respectively. The outer roads are to be used for monitoring and maintenance roads after completion of waste placement. The dimensions of roads are shown below.

- Carriage width: 9.0m
- Shoulder width: 0.5m at both sides
- Pavement: volcanic porous rocks or equivalent material

c.4 Leachate Management

The daily (intermediate) cover, whether using native soil or compost, must properly be conducted in order to minimize infiltration of rainfall. The top surface of the landfill should have an inclination for encouraging runoff on it.

Leachate generated in the landfill is to be sprayed by submergible pumps from leachate extraction wells. Pumps are necessary to get leachate out of the landfill due to the site's character (flat ground and anticipated subsoil settlement). Spraying leachate is to make good use of the climate character (small precipitation and large evaporation).

During operation, it is anticipated that 101mm/year of leachate will be generated. This results in 331,000m^3/year of leachate generation in total. This amount of leachate will be extracted and sprayed by the 24 submergible pumps. Leachate will show acidity in a certain stage of waste decomposition, and will contain a large amount of suspended solid. Therefore, it is anticipated that such character of leachate will make the lifetime of pumps short. The life time is assumed to be two years, although it depends on actual quality and quantity of leachate.

c.5 Landfill Gas Management

The passive control manner is to be employed for the landfill gas management. Uncontrolled dispersion of the gas from the landfill surface will be minimized by installation of gas removal pipes. PVC pipes with diameter of 200mm will be installed along the ring road and the outer roads, and concrete pipes with 600mm diameter will be in the inner part of the landfill. Some of the concrete pipes are also to be used for leachate extraction wells.

c.6 Surface Water Management

As mentioned above, the top surface of landfill should be sloped in order to encourage runoff on it. An inclination of 2% is recommendable.

c.7 Monitoring

Leachate quality and landfill gas have been monitored, and this should be continued. Recommendations on the present monitoring manner are:

- sample for leachate quality analysis should be taken from a leachate extraction well to be installed.
- the sampling manner of landfill gas should be improved not to mix the gas with air outside the landfill.

And monitoring of landfill elevation should be conducted in order to know:

- condition of waste decomposition.
- progress of waste and subsoil settlement.

c.8 Aesthetic Design Consideration

To avoid waste to be blown to the surroundings, use of mobile screens near the operating area is recommendable. Proper daily (intermediate) soil cover should be practiced in order to control birds, pests and vectors as well as to avoid wind-blown wastes.

c.9 Closure and Post-closure Care

The final cover of 60cm thickness will be employed when the landfill operation is completed. Major purposes of the final cover are i) to reduce leachate generation, ii) to avoid uncontrolled landfill gas diffusion, and iii) to improve outward appearance.

Greening the landfill surface is to be effective to encourage evapotranspiration on the surface, and this results in reduction of leachate generation. It will also have an effect on improving the appearance of the site.

c.10 Landfill Equipment

Equipment recommended for the sanitary landfill comprises:

- four (4) bulldozers (300hp class) for spreading and compacting both waste and cover material.
- two (2) sprinkler trucks (15,000liters class) for dust control.
- two (2) excavators (85hp class) for maintenance of roads and landfill slopes.

The bulldozers should properly be equipped for landfilling, e.g., trash blade for waste handling, measures to prevent a radiator from being plugged with waste, etc. The number of bulldozers were calculated as follows.

i. Productivity of Bulldozer (300hp class)

Probable cycle time (Cm)

Forward: 20m / 60m/min	=0.33 min
Reverse: 20m / 80m/min	=0.25 min
Others (loading and shifting gears)	=0.32 min
Total cycle time	=0.90 min

Output

$$Qh = \frac{60 \times q \times f \times E}{Cm}$$

Qh: Output per hour	(m^3/h)
q: Capacity of blade	(m^3)
f: Conversion factor of waste	1.0
E: Operation efficiency	0.6

Hence, Qh is 320 m^3/h.

ii. Required Number of Bulldozers

Weight of waste disposed of per day:	10,000 ton/day	
Volume of waste disposed of per day: (0.8: bulk density of waste)	10,000 / 0.8 = 12,500 m^3/day	
Operation hours of a bulldozer	:10 hours	
Volume of waste disposed of per hour	:12,500/10 = 1,250 m^3/day	
Required number of bulldozers	:1,250/320=3.91	say 4 units

c.11 Operation

The Etapa IV landfill has been operated in a proper manner, e.g., impermeable bottom liner installation, daily (intermediate) soil cover, recording waste amount disposed of by using weighbridges, etc., and such manner should be continued. What should be paid attention will only be a way of leachate disposal and filling plan for the multi-lift. The way of leachate disposal is mentioned before in the section of Leachate Management, and how to pile up the landfill is described in the next section of Sequence of the Vertical Expansion.

c.12 Sequence of BP-IV Vertical Expansion

At present, leachate is seeping out at cell's slope bottom on to the surrounding road. **It creates the problem of the operation today and the near future that the road condition is being deteriorated especially when it rains.**

In order to implement the "Vertical Expansion of BP-IV", the following components should be carried out in an appropriate sequential manner:

a. Bottom impermeabilization of roads part (0.0 meter elevation)
b. Provision of horizontal leachate collection system (0.0 meter elevation)
c. Approach road (from 0.0 meter to 8.0 meter elevation) construction
d. Roads (on 8.0 meter elevation) construction
e. Vertical shaft (for leachate collection/pump-up, biogas removal) construction
f. Filling of valleys on roads (0.0 to 8.0 meter elevation)
g. Leachate pump-up and spray (and/or impound) at 8.0 meter elevation

h. Landfilling (8.0 to 16.0 meter elevation)
b'. Provision of horizontal leachate collection system (on 8.0 meter elevation roads)
c'. Approach road (from 8.0 meter to 16.0 meter elevation) construction
d'. Roads (on 16.0 meter elevation) construction
e'. Expansion of vertical shaft (from 8.0 to 16.0 meter elevation)
f'. Filling of valleys on roads (8.0 to 16.0 meter elevation)
g'. Leachate pump-up and spray (and/or impound) for drying at 16.0 meter elevation

h'. Landfilling (16.0 to 24.0 meter elevation)
b". Provision of horizontal leachate collection system (on 16.0 meter elevation roads)
c". Approach road (from 16.0 meter to 24.0 meter elevation) construction
d". Roads (on 24.0 meter elevation) construction
e". Expansion of vertical shaft (from 16.0 to 24.0 meter elevation)
f". Filling of valleys on roads (16.0 to 24.0 meter elevation)
g". Leachate pump-up and spray (and/or impound) for drying at 24.0 meter elevation.

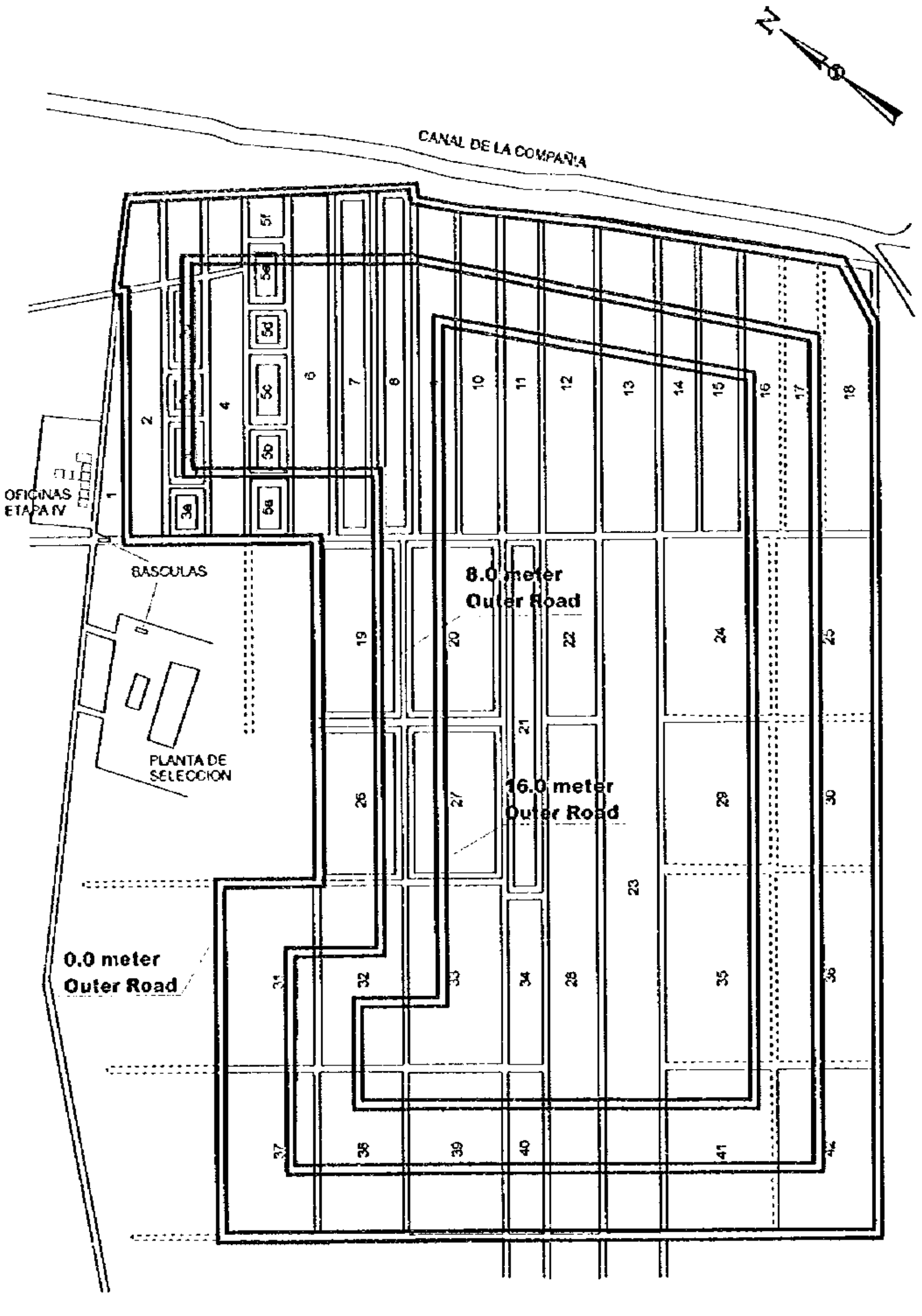


Figure 8-12:

Outer Roads on 0.0, 8.0 and
16.0 meter Elevation

Scale 1 : 150,000

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Table 8-25: Concept of Construction Schedule for Valley Filling

	Valley No.*																													
		c	c	c																										
		South Extension																												
			d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d												
1	19-20	a	b	e	f																									
2	20-21		a	b	e	f																								
3	21-22			a	b	e	f																							
4	22-23				a	b	e	f																						
5	20-27					a	b	e	f																					
6	27-21						a	b	e	f																				
7	21-28							a	b	e	f																			
8	22-28								a	b	e	f																		
9	28-23									a	b	e	f																	
10	21-34										a	b	e	f																
11	20-10											a	b	e	f															
12	21-11												a	b	e	f														
13	22-12													a	b	e	f													
14	11-12														a	b	e	f												
15	12-13															a	b	e	f											
16	23-13																a	b	e	f										
							East Extension																							
								d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d						
17	19-6						a	b	e	f																				
18	19-7							a	b	e	f																			
19	19-8								a	b	e	f																		
20	20-8									a	b	e	f																	
21	20-9										a	b	e	f																
22	7-6											a	b	e	f															
23	7-8												a	b	e	f														
24	6-5													a	b	e	f													
25	8-9														a	b	e	f												
26	5-5															a	b	e	f											
27	9-10																a	b	e	f										
28	5-4																	a	b	e	f									
29	10-11																		a	b	e	f								
30	4-3																			a	b	e	f							
31	3-3																				a	b	e	f						
32	3-2																					a	b	e	f					
												West Extension																		
													d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	
33	19-26											a	b	e	f															
34	26-27												a	b	e	f														
35	26-32													a	b	e	f													
36	27-33														a	b	e	f												
37	32-31															a	b	e	f											
38	32-33																a	b	e	f										
39	33-34																	a	b	e	f									
40	34-28																		a	b	e	f								
41	32-38																			a	b	e	f							
42	33-39																				a	b	e	f						
43	34-40																					a	b	e	f					
44	31-37																						a	b	e	f				
45	38-37																							a	b	e	f			
46	38-39																								a	b	e	f		
47	39-40																									a	b	e	f	
48	40-28																										a	b	e	f

Note: * Valley No. e.g. 19-20 represents the valley between the Cell No. 19 and the Cell No. 20.

c.13 Cost Estimates

Two cases are set for operation of the landfill as follows:

- Case 1: Investment and operation by the DGSU.
- Case 2: Investment by the DGSU and contracting out operation.

This makes cost estimates for this Vertical Expansion Plan different, so that the estimates are carried out in Case 1 and Case 2 respectively.

Difference between Case 1 and Case 2 is whether the landfill operation is conducted by the DGSU directly or by private company(s) under the DGSU's supervision. From a viewpoint of disbursement, the difference reflects payment for the landfill equipment. That is, the payment for landfill equipment in Case 1 has peaks in 2000 and 2007 due to procurement. Such peaks will not appear in Case 2, because the equipment will be delivered by the private company(s) under a contract.

Table 8-26 and Table 8-27 summarize the costs for the Vertical Expansion Plan. The costs estimated for Case 1 was US$ 28,677,000, and Case 2 was US$ 29,860,000.

Table 8-26: Summary of Costs for the Vertical Expansion Plan (Case 1)

Unit: US$ 1,000

Year	B/D	D/D	Con (Ini.)	Con(Rec)	Equip.	O&M	Land fee	Total
1999	33							33
2000		298	7,902		2,777			10,977
2001				2,164		728	425	3,317
2002						111	425	536
2003						21	425	446
2004						111	425	536
2005				1,883		728	425	3,036
2006				1,874		818	425	3,117
2007						21	425	446
2008						111	425	536
2009				1,773		728	425	2,926
2010				1,528		818	425	2,771
Total	33	298	7,902	9,222	2,777	4,195	4,250	28,677

B/D: Basic design for construction and equipment.
D/D: Detailed design for construction and equipment. The amount complies costs for supervision as well.
Con. (Ini.): Initial investment cost for construction
Con(Rec): Recurrent cost for construction
Equip.: Landfill equipment
O&M: Operation and maintenance
Land fee: Land rental fee

Table 8-27: Summary of Costs for the Vertical Expansion Plan (Case 2)

Unit: US$ 1,000

Year	B/D	D/D	Con. (Ini.)	Con(Rec)	Equip.	O&M	Land fee	Total
1999	33							33
2000		298	7,902					8,200
2001				2,164	901	619	425	4,109
2002						111	425	536
2003						21	425	446
2004						111	425	536
2005				1,883	901	619	425	3,828
2006				1,874	901	709	425	3,909
2007						21	425	446
2008						111	425	536
2009				1,773	901	619	425	3,718
2010				1,528	901	709	425	3,563
Total	33	298	7,902	9,222	4,505	3,650	4,250	29,860

B/D: Basic design for construction.
D/D: Detailed design for construction. The amount complies costs for supervision as well.
Con. (Ini.): Initial investment cost for construction
Con(Rec): Recurrent cost for construction
Equip.: Landfill equipment
O&M: Operation and maintenance
Land fee: Land rental fee

8.2.2.2 New Landfill Development (Etapa V)

The capacity of the vertically expanded part of Etapa IV is not enough to receive waste to be disposed of until 2010. Therefore, the development of a new landfill is crucial to sustain the sound waste disposal in the study area. After the Mexican side specified a candidate site for a landfill, surveys, i.e., soil, aerial and environmental survey, which are necessary for landfill planing were been conducted during the 2nd study work in Mexico. In this section, followings are to be presented.

- examination of design conditions.
- examination of technical alternatives.
- conceptual design and cost estimates.

a. Examination of Design Conditions

As mentioned previously, there is a norm NOM-083-ECOL-1996 which is one of the Mexican Official Norms to establish the requirements to be applied to new landfill development of municipal solid waste. The new landfill development at Etapa V has to follow this norm.

In this section, design conditions are examined basically according to the norm. In addition, other conditions, such as location and area are presented.

a.1 Location and Area

The site for Etapa V is located in the ex-Texcoco lake as well as Etapa IV, the latter being about 6km south-west of the former. The site has an area of 256 ha and its coordinates are 19°29'N (latitude 19 degrees 29 minutes north) and 98°58'W (longitude 98 degrees 58 minutes west). The nearest residential area is located at

2.2km away from the west border of the site. The Mexico City International Airport is situated about 10 km south-west of the site. The location of the site is shown in Figure 8-13.

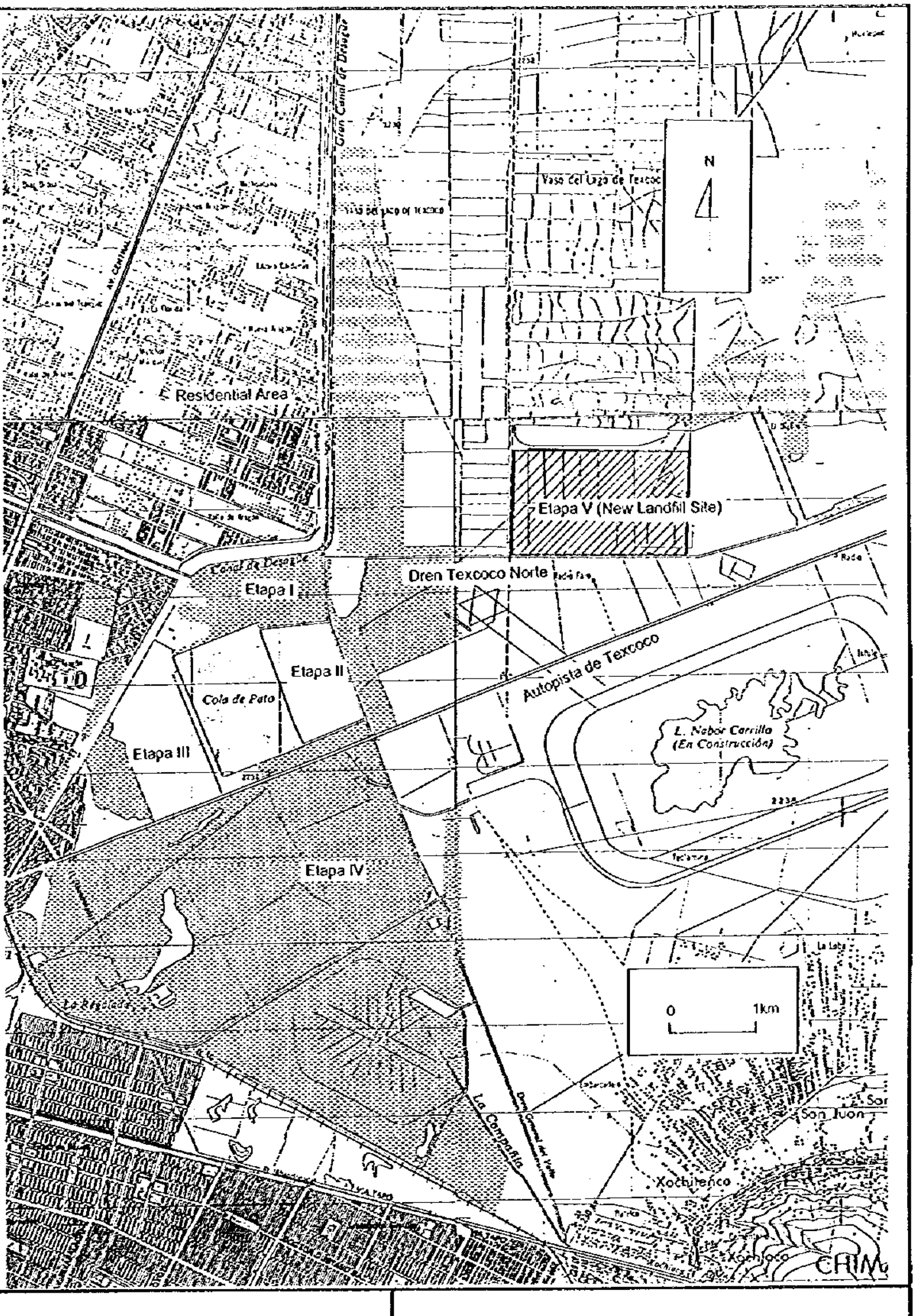

Figure 8-13:

Location of the New Site (Etapa V)

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a.2 NOM-083-ECOL-1996

In this section, the site conditions are screened according to each of the requirements stated in the NOM-083-ECOL by examining countermeasures which are needed for the site conditions to meet with the requirements (See Table 8-28).

Table 8-28: Consideration of NOM-083-ECOL

Issues stated in the norm	Site conditions	Necessity of counter-measures	Consideration/ countermeasures
General aspects			
The minimum distance of 3,000m should be secured from an airport where turbine engine airplanes are operated.	The distance to the nearest airport is about 10km.	No need.	Countermeasures are unnecessary.
The minimum distance of 1,500m should be secured from an airport where reciprocating engine airplanes are operated.	The distance to the nearest airport is about 10km.	No need.	Countermeasures are unnecessary.
The right of way of highways, railroads, main and secondary roads must be respected.	Autopista to Texcoco runs about 1.0km south of the site. It will be used for waste transportation.	Necessary.	U-turn part is to be widened to avoid adverse influence on traffic on the autopista, when waste transportation trucks come into and go out of the access road.
Sites should not be located in natural protected areas.	The site is not in a natural protected area.	No need.	Countermeasures are unnecessary.
The right of way of federal public works should be respected, such as oil and gas pipelines, electric power pylons, water pipes, etc.	An gas pipe line is laid in the ground at the south-west of the site. However, it is out of the site.	No need.	A map (Figure 8-14) shows the location of pipe installment.
The minimum distance of 1,500m should be secured from an edge of a residential area.	The nearest residential area is 2.2km away from the west border of the site.	No need.	Countermeasures are unnecessary.
Hydrological aspects			
The site must be outside of a flood plain with return periods of 100 years.	The site is not located in such a flood plain.	No need.	Countermeasures are unnecessary.
The municipal solid waste final disposal site will not be located at swamps, salty marshes and similar places.	The groundwater level is about 0.7m from the surface, and the water has salinity. But the site is not swamp/marsh.	No need.	Countermeasures are unnecessary.
The minimum distance of 1,000m should be secured from surface water bodies which have capacities for the 10 year return period rainfall.	The site is next to 'Dren Texcoco Norte' which is a sewer of municipal waste water. So this is not surface water body.	No need.	Countermeasures are unnecessary.

Issues stated in the norm	Site conditions	Necessity of counter-measures	Consideration/ countermeasures
Geological aspects			
The site must be located at a minimum distance of 60 meters away form active faults.	No fault is observed in the site and with in 60m from the site.	No need.	Countermeasures are unnecessary.
The site must be located outside of areas with unstable banks where soil movements may happen.	The site's subsoil is highly compressible clay as Etapa IV.	Necessary.	Landfill slope is to be inclined properly to avoid failure.
The zones, where serious settlements may happen, which lead to land fractures and increase risk of water-bearing strata pollution, must be avoided.		Necessary.	Impermeable liner is to be installed to avoid water-bearing strata pollution.
Hydrogeological aspects			
Infiltration rate to a water-bearing stratum must be less than $3x10^{-10}$ sec^{-1}.	The groundwater level is about 0.7m under the surface, but the water can not be used for potable water due to its high salinity.	Necessary.	Landfill bottom (impermeable) liner will be installed to avoid seepage of leachate to the surroundings.
The minimum distance, from the site to water extraction wells for domestic, industrial, irrigation and livestock farming use that are still operating or abandoned, must be 500m.	There are about 30 wells which were used for salt making in the site.	Necessary.	Well casings are needed to be removed, then sealed properly.

a.3 Access

Since it is necessary for waste transportation trucks ($70m^3$ truck trailers) to use part of the 'Autopista Mexico Texcoco' to reach the site, a certain agreement with an authority which is in charge of the autopista may be needed. Technically, the U-turn part should be widened enough for the trucks to go through easily, then to avoid adverse influence on traffic.

Waste transportation trucks will come from the autopista. There are two roads connecting the site to the autopista. One is running along the west border of the site, and its length from the site to the autopista is about 1.5km. The other runs along the east border, and the length to the autopista is about 0.6km. Both of roads do not have enough width of about 4m for the waste transportation trucks. Therefore, whichever road is used as an access road, expansion work is necessary.

There are some buildings of CNA at the entrance of the former road, and a gas pipeline (See Figure 8-14) is laid around the south-west corner of the site. On the other hand, only a gate and a small building to watch the gate exist at the entrance of the latter road. Consequently, it is recommended to use the latter road as an access road from the autopista to the site in order to avoid adverse influence on the buildings and the gas pipeline on the former load and make costs of the access road construction cheaper.

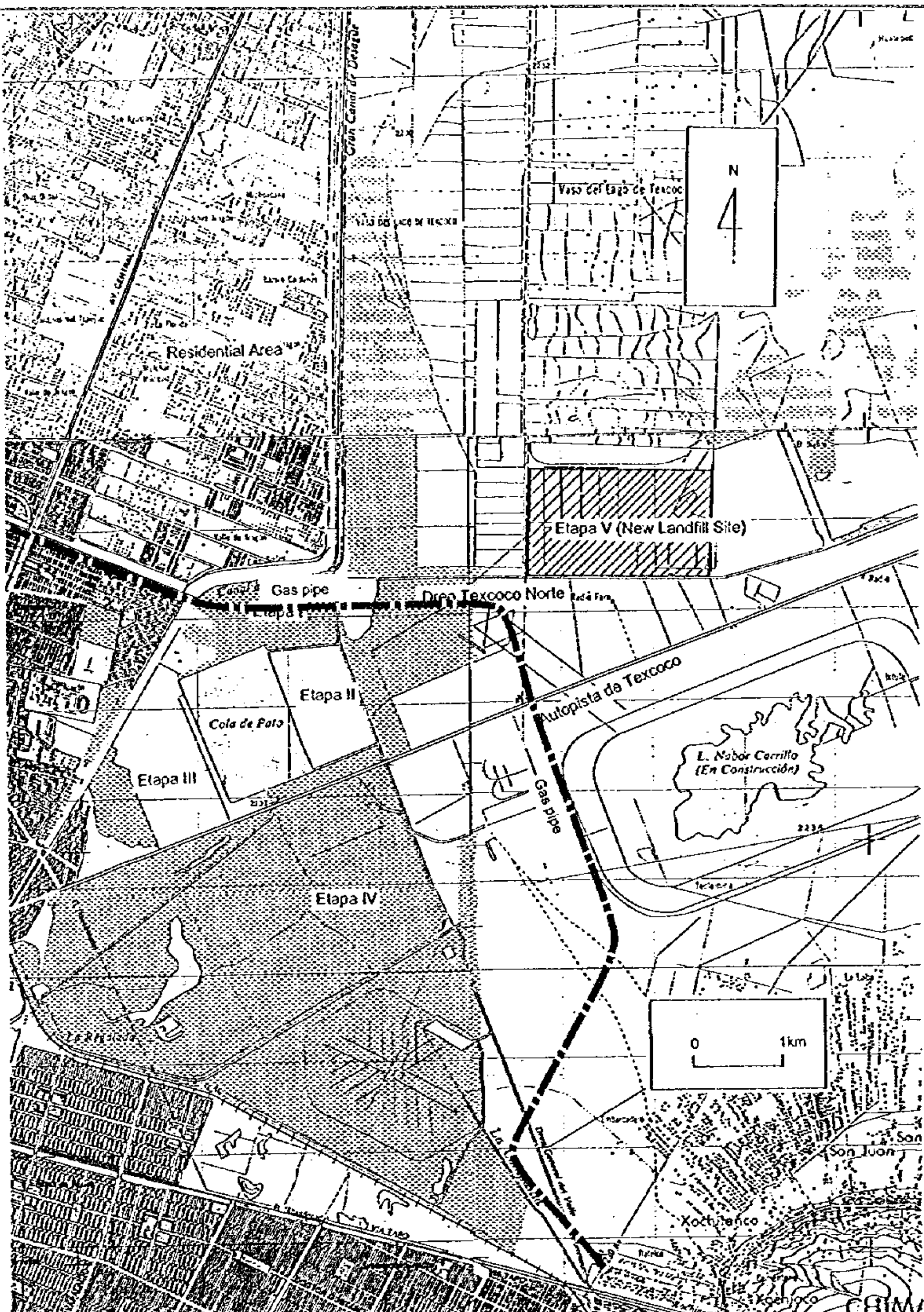

Figure 8-14:

Location of Gas Pipline

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a.4 Physical Impact of Proposed Landfill Development

Similarly to the Etapa IV landfill site, this candidate site for a new landfill is located on highly compressible clay layer of the ex-Texcoco area. Therefore, influence on a canal flowing along the site, influence on the impermeable liner and influence on stability of the landfill slope are examined on the basis of a geological survey conducted during the 2nd study work in Mexico.

a.4.1 Geological Survey

i. Objectives of the Survey

The objectives of the geological survey is to acquire soil data of the site in order to examine the technical feasibility of New Landfill Development.

ii. Survey Items

The survey was carried out at Bordo Poniente Etapa V. The number of borings and survey items are shown in Table 8-29.

Table 8-29: Work Quantity of Soil Survey at Etapa V

Survey Items	Survey Contents
Boring	0 to 40 m deep: 4 bore holes 0 to 60 m deep: 1 bore hole
Soil tests	liquid limit, plastic limit, unit weight, consolidation, grain size, water content, tri-axial compression

iii. Results of the Survey

The groundwater levels are shown in Table 8-30, and the soil characters acquired by the survey are summarized in Table 8-31.

Table 8-30: Groundwater level of Etapa V

Site	Bore hole number	Groundwater level (m)
Etapa V	SM-1	0.35
	SM-4	2.30
	SM-5	0.80

Table 8-31: Results of Soil Survey at Etapa V

Characters \ Location	SM-1		SM-2		SM-3		SM-4		SM-5			
	36.1-36.7m	39.7-40.3m	6.0-7.0m	33.3-34.3m	4.8-5.8m	12-12.6m	3.0-3.9m	18.9-19.5m	12.0-12.9m	18.6-19.2m	24.0-24.6m	55.0-55.6m
Type of soil (Visual observation)	clay	clay	clay	clay	clay	clay	clay	clay	clay	clay	clay	silty clay
Specific gravity	2.85	2.99	2.82	2.77	2.85	2.82	2.99	2.86	2.86	2.91	2.94	2.96
Unit weight (ton/m^3)	1.29	1.30	1.16	1.24	1.47	1.31	1.14	1.14	1.20	1.20	1.25	1.32
Void ratio	4.58	6.20	12.30	8.40	2.51	4.90	14.20	9.95	8.70	5.97	6.21	4.10
Degree of Saturation (%)	95.0	103.0	103.0	106.0	83.4	99.8	100.0	97.0	99.0	97.0	98.0	92.0
Water content (%)	152.0	136.0	447.1	321.7	83.4	173.7	398.0	302.0	281.0	147.0	193.0	129.0
Liquid limit (%)	140.7	158.8	354.0	244.8	108.8	259.0	443.0	356.0	320.0	148.0	202.0	134.0
Plastic limit (%)	31.7	33.4	29.8	32.7	34.2	33.8	78.8	33.2	32.7	25.6	24.1	31.0
Plasticity index (%)	109.0	125.4	324.2	212.1	74.6	225.2	364.2	322.8	287.3	122.4	177.9	103.0
Tri-axial undrained C (ton/m^2)	9	0.4	1	2	0.03	0.16	0	0	0.05	1.4	0	5
Angle of internal friction (deg.)	9	1	3	6	1	0	5	7	0.5	0.29	5	11
Simple compression qu (ton/m^2)	14.4	6.3	0	5.8	1.0	0.98	0.15	0.85	0.9	2.3	0.9	14.3
N value	0	0	0	0	0	0	0	0	0	0	0	15
Coefficient of consolidation (cm^2/s))	0.02	0.0091	0.0021	0.0067	0.0071	0.0105	0.0025	0.0063	0.0765	0.0199	0.0071	0.1294

iv. Findings

The surface stratum at the site is occupied with 45m thick clayey lacustrine deposit, which is divided into three layers by two sandy layers located at 32m and 37m in depth respectively. Almost all N values of the stratum show 0, zero. A stable layer of which N value shows more than 50 exists below the depth of 45m. The lacustrine deposit shows considerably high natural water contents of from 130 to 450% and low unit weight of about 1.20 ton/m^3. Therefore, it is judged that the lacustrine is considerably soft clay according to the soil surveys result.

a.1.2 Landfill Development Influence on Dren Texcoco Norte

Examination of influence on the canal, Dren Texcoco Norte, which is flowing the south side of the site, caused by the New Landfill Development was carried out by using soil data acquired through the soil survey. Conditions set for estimation of subsoil settlement and the results of the examination are presented below.

i. Conditions for Estimation of Influence

Data on soil layers at SM-1 bore hole are employed for the estimation. The lacustrine layer is subdivided into 8 layers as shown in Table 8-32. The waste load is assumed to be the one when the landfill becomes 24m high and the unit weight of waste after initial compression at landfill is assumed to be 0.8 ton/m^3. And two cases are set depending on whether buoyancy caused by the groundwater is considered or not. Case 1 ignores such buoyancy, on the other hand, Case 2 takes into consideration the buoyancy.

Table 8-32: Subsoil Conditions

Layer	Thickness of layer (m)	Unit weight (ton/m^3)
1	5.0	1.14
2	5.0	1.23
3	5.0	1.25
4	5.0	1.17
5	5.0	1.25
6	6.8	1.25
7	0.7	1.60
8	4.1	1.24

Note: The water level is assumed at 0m depth, because the groundwater level at SM-1 was 0.35.

ii. Results of the Estimation

The results are schematized in Figure 8-15. The result of Case 1, without consideration of the buoyancy, is that the final subsoil settlement (theoretical maximum) will be 13.82 m in the landfill center which may cause 5mm settlement at the 100m off-set drainage canal. Meanwhile, the final subsoil settlement (theoretical maximum) of Case 2, with consideration of the buoyancy, will be 9.35m in the landfill center which may cause 2cm subsidence at the 100m off-set drainage canal.

Duration of settlement was also estimated. As the result shows that it will take 3 to 4 years to reach 60% settlement (See Table 8-33). Therefore, it is recommended that enough interval should be secured before waste placement on a next lift, i.e., alternate use of Etapa IV and V is recommended.

Table 8-33: Duration of Settlement

Consolidation (%)	10	20	30	40	50	60	70	80	90	100
Duration (days)	19	74	186	384	726	1378	2667	5072	9879	-
Settlement (m)	1.38	2.76	4.14	5.52	6.91	8.29	9.67	11.05	12.44	13.82

(See Data L of Data Book)

iii. Influence on the Canal (Dren Texcoco Norte)

In conclusion, the estimation shows only 5mm subsidence of the drainage canal under the theoretical maximum subsoil settlement caused by the New Landfill Development. So, it can be said that the New Landfill Development will not pose a serious problem on the drainage canal structure.

a.1.3 Landfill Development Influence on the Impermeable Liner

Figure 8-16 schematizes the subsoil settlement. The part of liner under the first lift's slope will undergo the largest tensile stress. The tensile stress can be expressed as 1.1% in elongation terms (48.26m/48m=1.0054, i.e., 0.54% of stretch, taking into consideration the stretch of two-dimension, $48.26^2/48^2=1.011$, i.e., 1.1% of stretch, see Figure 8-16). This would be absorbed in the tensile performance of the impermeable liner.

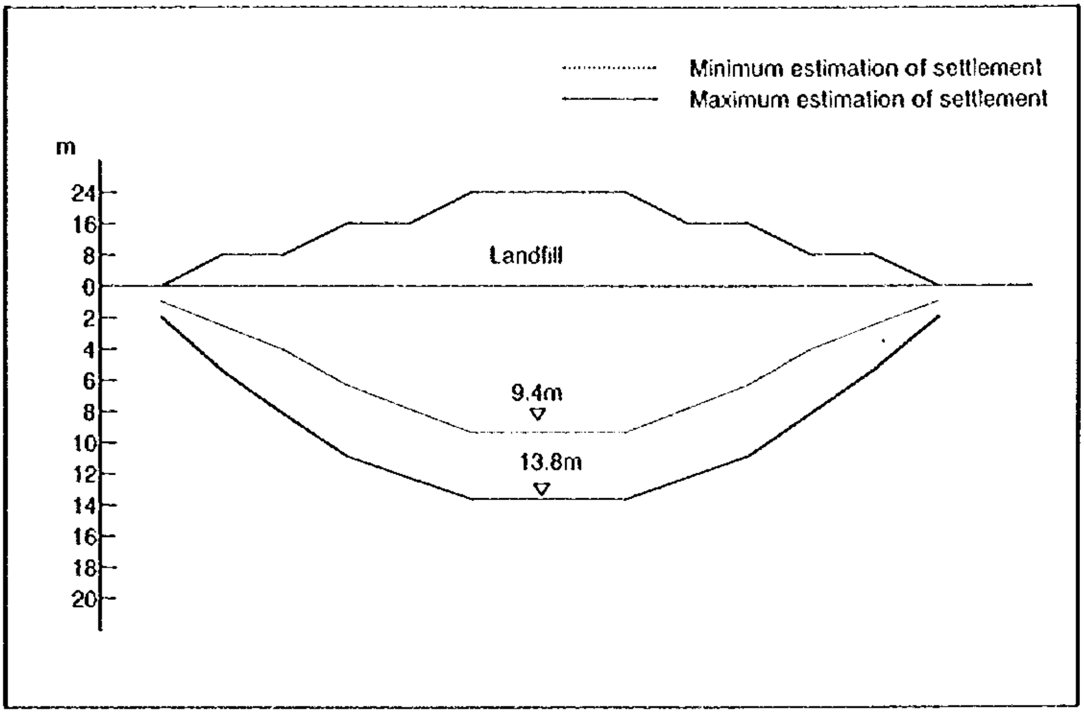

Figure 8-15: Subsoil Settlement

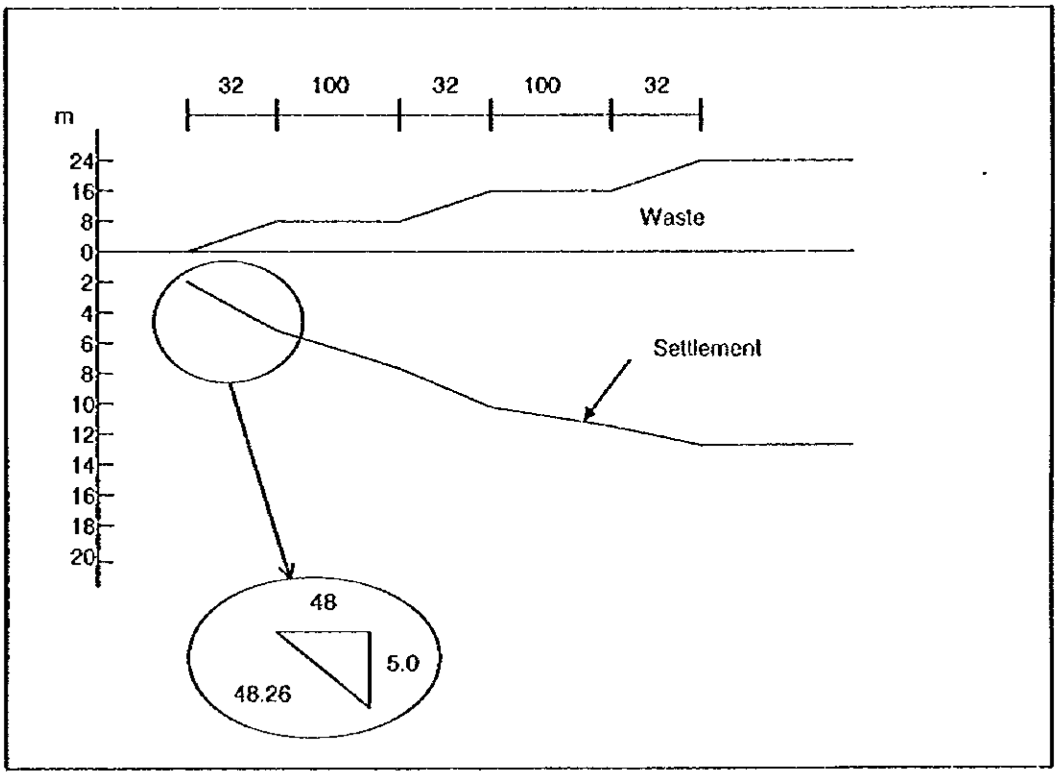

Figure 8-16: Subsoil Settlement and Liner

a.1.4 Influence on Stability of Landfill Slope

The characteristic data presented in Table 8-34 are employed in the Bishop Method for calculating the slope stability. The minimum factor of 0 to 8m elevation with a slope of 1 in 4 shows 0.920 which means that slope failure could occur as the minimum factor is less than 1.0. Although slope failure has not happened in the existing landfill of Etapa IV of which slope is 1 in 4, a gentler slope of 1 in 6 is recommendable for the first lift of 0 to 8m elevation as the minimum safety factor of the slope exceeds 1.0.

On the other hand, minimum factors of other slopes exceed 1.0, therefore, the vertical expansion is viable from a viewpoint of landfill slope stability.

Table 8-34: Result of Slope Stability Calculation (Etapa V)

Slope	Landfill Height	Minimum Safety Factor	Coordinates of the Rotational Slope		Radius of the Rotational Slip (m)	Resist Moment (ton-m)	Slip Moment (ton-m)
			X	Y			
1	0 to 8m (1:4)	0.920	15.00	15.00	29.91	1,668.55	1,812.72
1	0 to 8m (1:6)	1.044	25.00	25.00	41.55	3,632.08	3,478.33
2	8 to 16m	1.089	140.00	22.00	39.70	4,826.92	4,433.46
3	16 to24m	1.302	270.00	25.00	48.34	9,234.27	7,093.06

a.5 Waste Disposal Amount

Waste amount to be disposed of in Etapa V is shown with that of Etapa IV in the section of the 'Vertical Expansion Plan of Etapa IV' (See Table 8-20).

b. Examination of Technical Alternatives

The items (intermediate cover, final cover, leachate disposal, and landfill gas disposal) examined in the Vertical Expansion Plan of Etapa IV can be applied to this New Landfill Development. In addition to them, landfill bottom liner configurations was examined in view of the requirement about infiltration rate to a water-bearing stratum.

Landfill bottom liner

The ground water (salty water) level in the site is as high as that in Etapa IV. 0.35 to 2.30m of water levels are observed in the geological survey conducted during the 2nd study work in Mexico. The NOM-083-ECOL requires that infiltration rate to a water-bearing stratum must be less than $3x10^{-10}sec^{-1}$. Although, whether the stratum containing salty water is a water-bearing stratum is disputable, the stratum is regarded as a water-bearing one. Because the existing landfill of Etapa IV, has an impermeable liner to avoid to mix leachate with such groundwater. Therefore, this new landfill site should also have an impermeable liner to get consensus.

Figure 8-17 shows a recommended liner configuration, which is the same configuration as that of Etapa IV, that is so simple that mis-installation would be minimum.

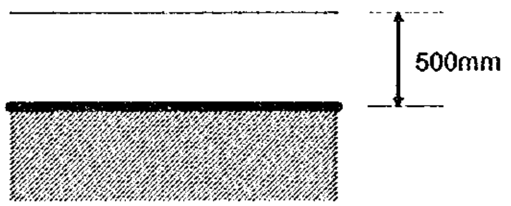

Figure 8-17: Landfill Bottom Liner Configuration

c. Conceptual Design and Cost Estimates

Outline of the conceptual design for the Vertical Expansion Plan is presented below.

Table 8-35: Outline of the Conceptual Design for A New Landfill Development

Items	Facilities
Area	Site area: 256ha Filling area: 194 ha
Landfill capacity	29,032,000m^3(23,226,000ton) is available for waste disposal.
Access	Access road: 605m Ring road: 5,950m at 0m elevation outer road: 5,950m inner road: 19,155m at 8m elevation outer road: 4,878m inner road: 11,743m at 16m elevation outer road: 3,854m inner road: 3,991m
Waste transport control facilities	gate: 1 (existing) weighbridge: 2 tire washing pit: 1 site office: 1 garage: 1 car park:1 parking area for heavy equipment and/or storage yard: 1
Leachate management	Leachate extraction wells concrete pipes with 600mm diameter: 15 nos. Leachate extraction and spray pumps: 15 nos. Leachate collection lines at 0m elevation: 25,105m at 8m elevation: 16,621m at 16m elevation: 7,845m