Chapter 3

Preliminary Design of the New Kunduchi Disposal Site

3 Preliminary Design of the New Kunduchi Disposal Site

3.1 Introduction

This chapter presents the conceptual design for the proposed new sanitary landfill in Kunduchi Ward, Kinondoni District. The new landfill will be designed, constructed and operated in accordance with the following principles.

- The site is located near the Indian Ocean (2.5 km) in a rural area with substantial excavations from quarrying of coral stones. From an environmental point of view the selected site for the sanitary landfill in Kunduchi is appropriate as its proximity to the Indian Ocean will mean that leachate will cause little impact on the surroundings. Further, the site is located in an area where saline ground water flows toward the Ocean.

- Two alternative concepts for handling leachate have been considered.
  - *Either* to furnish the landfill with a less permeable bottom liner, leachate drains and the required installations for collection and evaporation of leachate from ponds and by irrigating/sprinkling on top of old landfill sections.
  - *or* to construct the landfill without any bottom liner, and thus also no facilities for treatment of leachate.

Since no potential drinking water resources are threatened because of leachate from the landfill, it has been decided that the landfill shall be constructed in accordance with the later concept, i.e a landfill without a bottom liner, thus enabling free seepage of leachate to the Indian Ocean.

- The waste is carefully *compacted and covered with soil.* The waste is compacted daily in layers of not more than 2 metres. Each layer and the daily tipping front are overlaid with a thin layer of soil to prevent insects, birds etc. from gaining access to the waste. When the final height and shape have been reached, the landfill is furnished with a final soil coverage to allow plants and trees to grow.

- The landfill is *supervised and monitored* on a regular basis to ensure that it does not have any adverse impacts on the surroundings.

- The *use of biogas from the landfill will not be feasible.* Therefore, the landfill shall be furnished with a final soil coverage and gas vents to ensure controlled biogas exhaustion into to the atmosphere. However, the feasibility of utilising biogas from the landfill shall be assessed when there is enough waste for its production.

3.2 Location of the New Kunduchi Disposal Site

The site of the new landfill is situated in the Kunduchi New MECCO quarries in Kunduchi Ward, Kinondoni District.

The site is located in a rural area along Bagamoyo Road approximately 19 km north of the city centre of Dar es Salaam. The road has recently been rehabilitated and provides good access for the waste collection trucks from Dar es Salaam. The location of the landfill site is presented in Figure 3-1.

The site is located 2.5 km from the Indian Ocean, 2 km from Tegeta River, and 2 km south of Tegeta village.

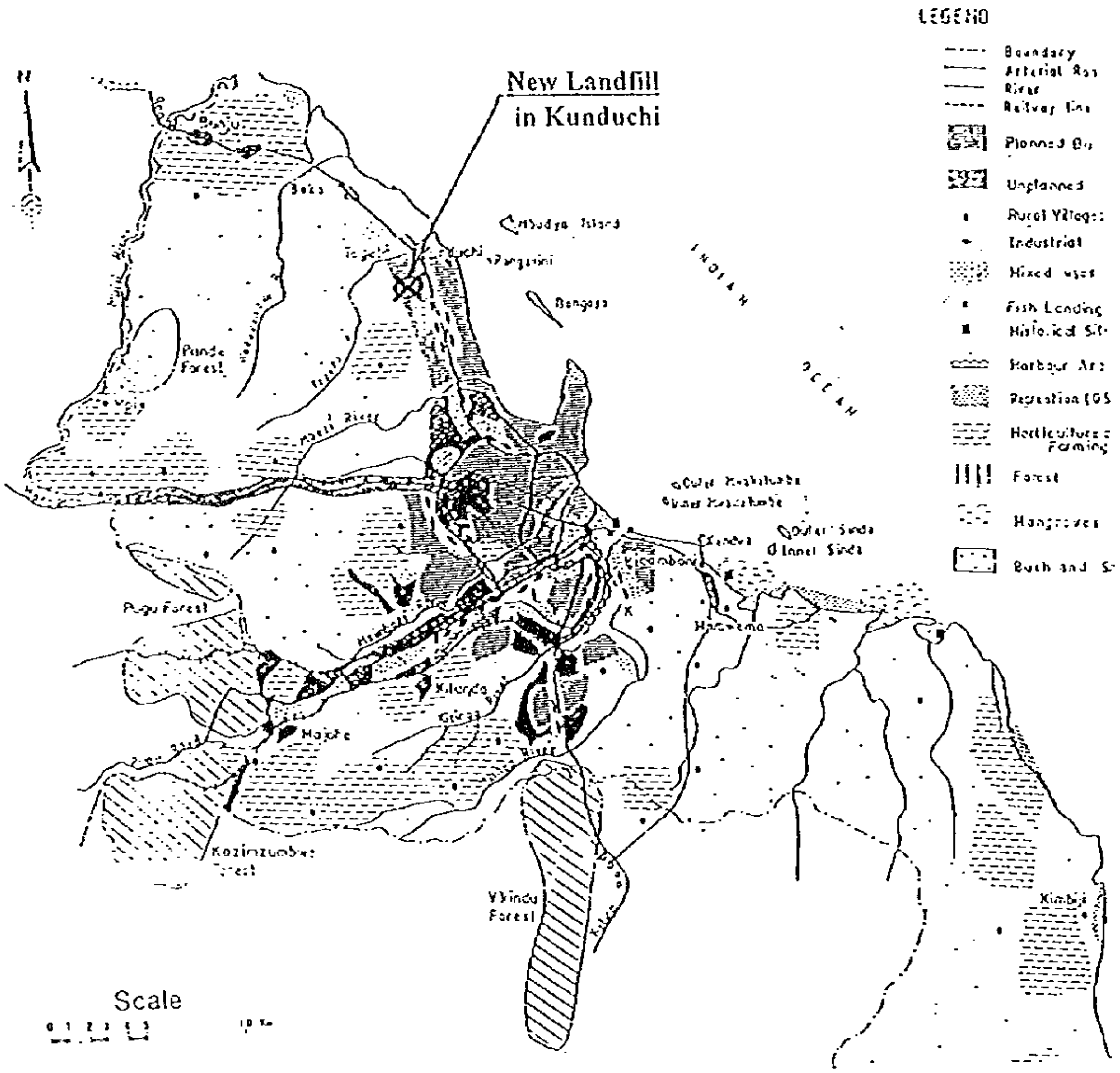


Figure 3-1: Location of the New Landfill in Kunduchi.

3.3 Current Conditions of the Proposed Site

3.3.1 The Site and its Surroundings

The site has an original ground elevation of 50 to 65m above sea level. However, a substantial part of the site has been excavated for coral stones found 43 to 48 m deep. Mecco is still operating a crushing plant on the site although it is on a lower scale because most materials are depleted. Manual excavation is being carried out at various parts of the quarry by the private sector.

The land is owned by the Government and is under the control of the Ministry of Energy and Minerals which has leased most of the mining rights to companies as shown in Figure 3-2, that also presents the proposed boundary of the landfill.

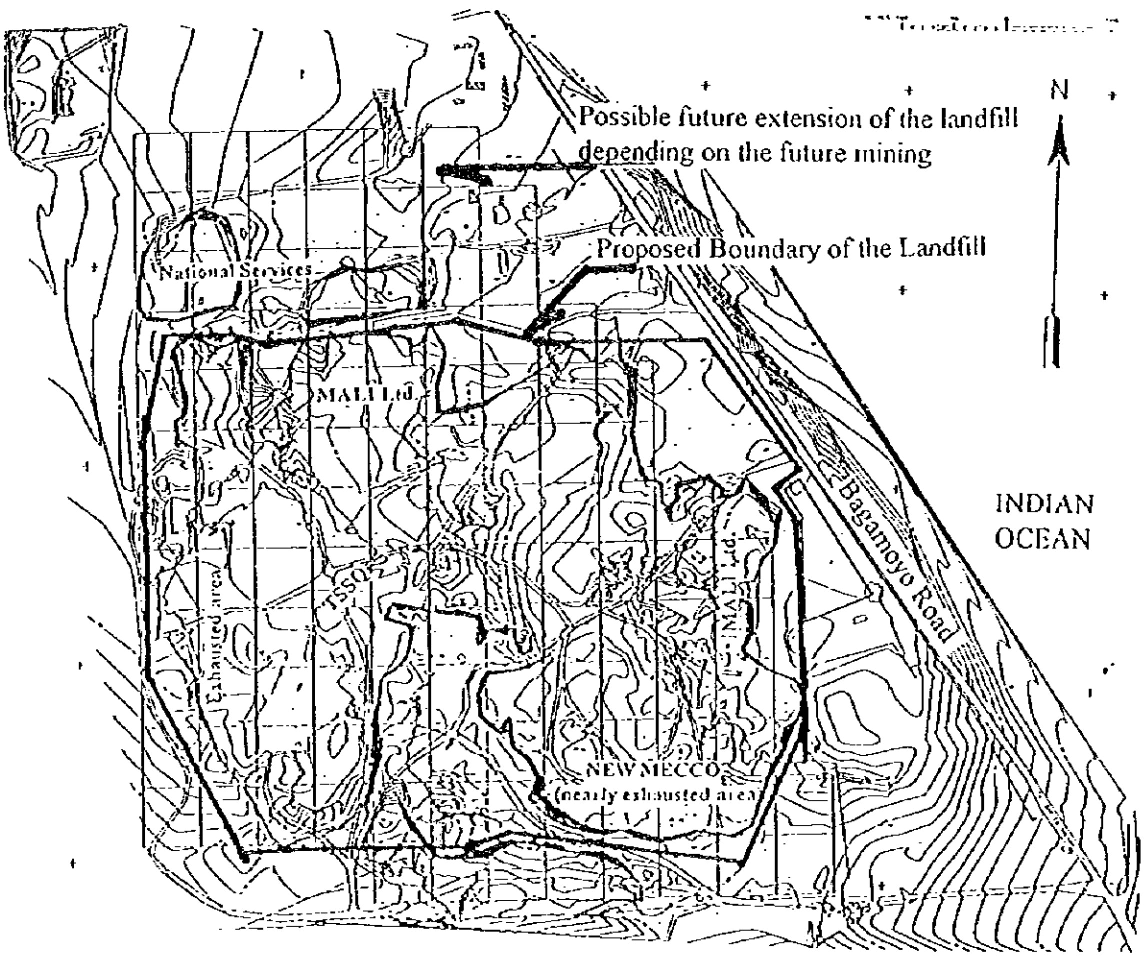
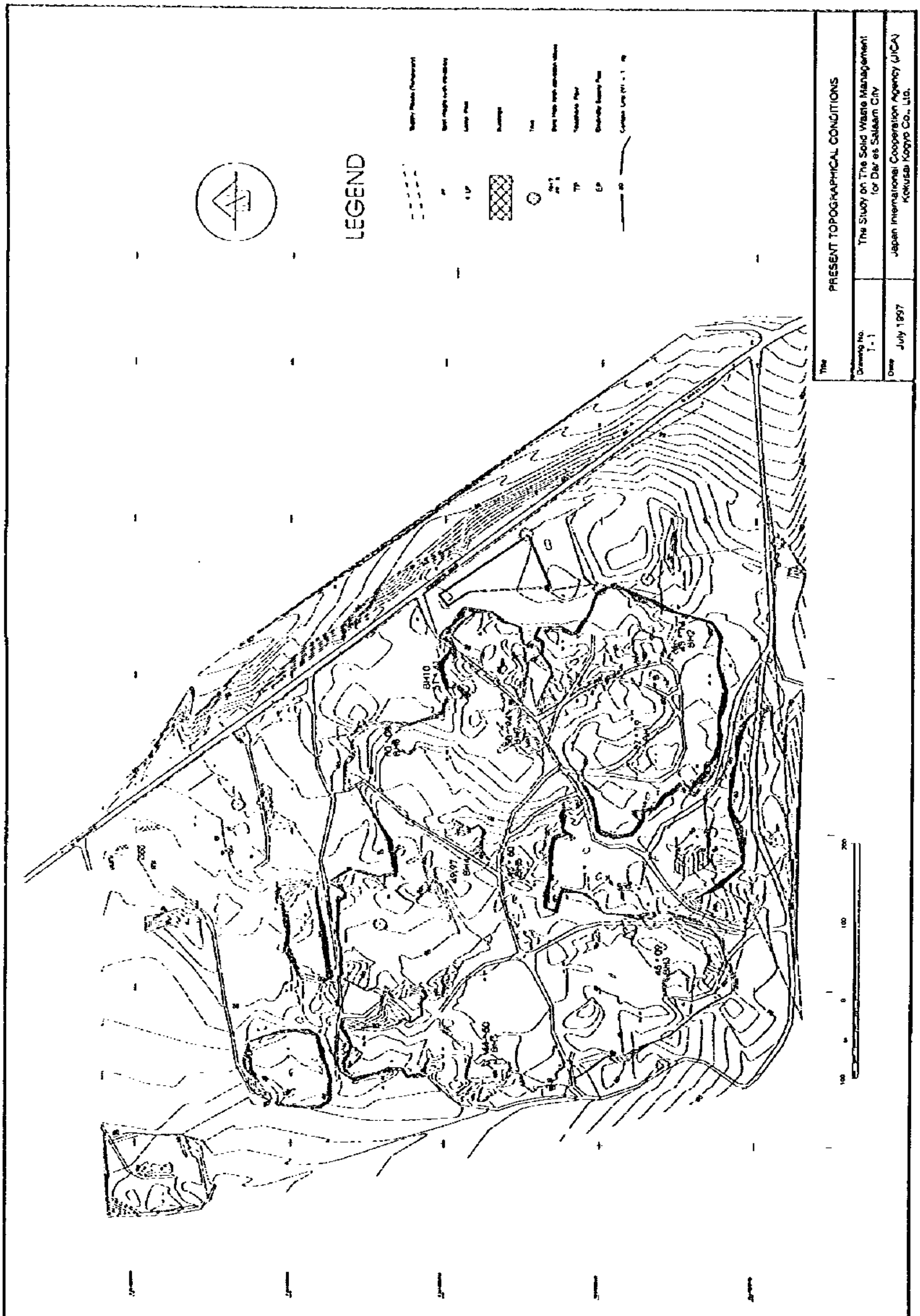


Figure 3-2: Mining Rights and Proposed Boundary of the Landfill.
(The mining rights shown by squares are held by: New Mecco, the Military, MALI Ltd., and TSSQ.)



Drawing No.1: Present Topographical Conditions of the Site

With the proposed boundary the site comprises an area of approximately 30 ha. The conditions of the area are presented in Drawing No. 1.

The nearest neighbour is a brick factory situated at the eastern boundary of the site. The construction of the landfill will not require the displacement of any neighbours.

To the east of Bagamoyo Road are the Old MECCO quarries. Kunduchi Mtongani village is situated in the old quarries along Kunduchi Road approximately 700 m east of the site. The village mainly comprises unplanned infrastructure and buildings.

Further to the east the terrain, there is a steep fall towards a swamp with mangroves. Salt pans are found in the area. The Indian Ocean is located approx. 2.5 km east of the site.

To the north, west and south, the site borders on agricultural land, sparsely populated. The main crops include bananas, palms, oranges, water melon and green vegetables. Poultry and livestock farming are also conducted in the area.

The area outside the quarries slope towards a valley west of the site. The main water pipes from the Lower Ruva Water Treatment Plant, feeding approximately 2/3 of Dar es Salaam, are situated in the valley. The pipe line also provides water to people living along it, including neighbours of the landfill site and villages between Bagamoyo Road and the Indian Ocean.

The main power supply line (11 kV) is situated along Bagamoyo Road. The Radio Tanzania transmitter and a telephone transmitter are situated 200 m south of the site.

3.3.2 Hydrogeological Conditions

The study on hydrogeological conditions of the area was based on reports from previous investigations carried out for the area as well as results from 13 exploratory boreholes and other geotechnical investigations carried out in connection with this study.

Based on reports from these investigations, the hydrogeological conditions of the area are described in the 1997 Report carried out by Mr. S. Mgana, a lecturer at the University College of Lands and Architectural Studies (UCLAS), Dar es Salaam.

The hydrogeological conditions of the area are summarised as follows. (see Figure 3-3 for reference)

The site comprises an area elevated to 50 to 65 m above sea level. A substantial part of the site has been excavated for coral stones at a range between 43 and 48 m.

The presence of old corral reefs at this level above the present sea level is explained by ancient, tectonic movements (500 mill. years ago when India drifted away from Africa).

The primary groundwater flows toward the Indian Ocean and at the landfill site the groundwater is at approximately 20 m. Thus, none of the boreholes carried out in connection with this study reaches ground water. The boreholes were carried out to a depth of up to 15 m below the bottom of the present excavations.

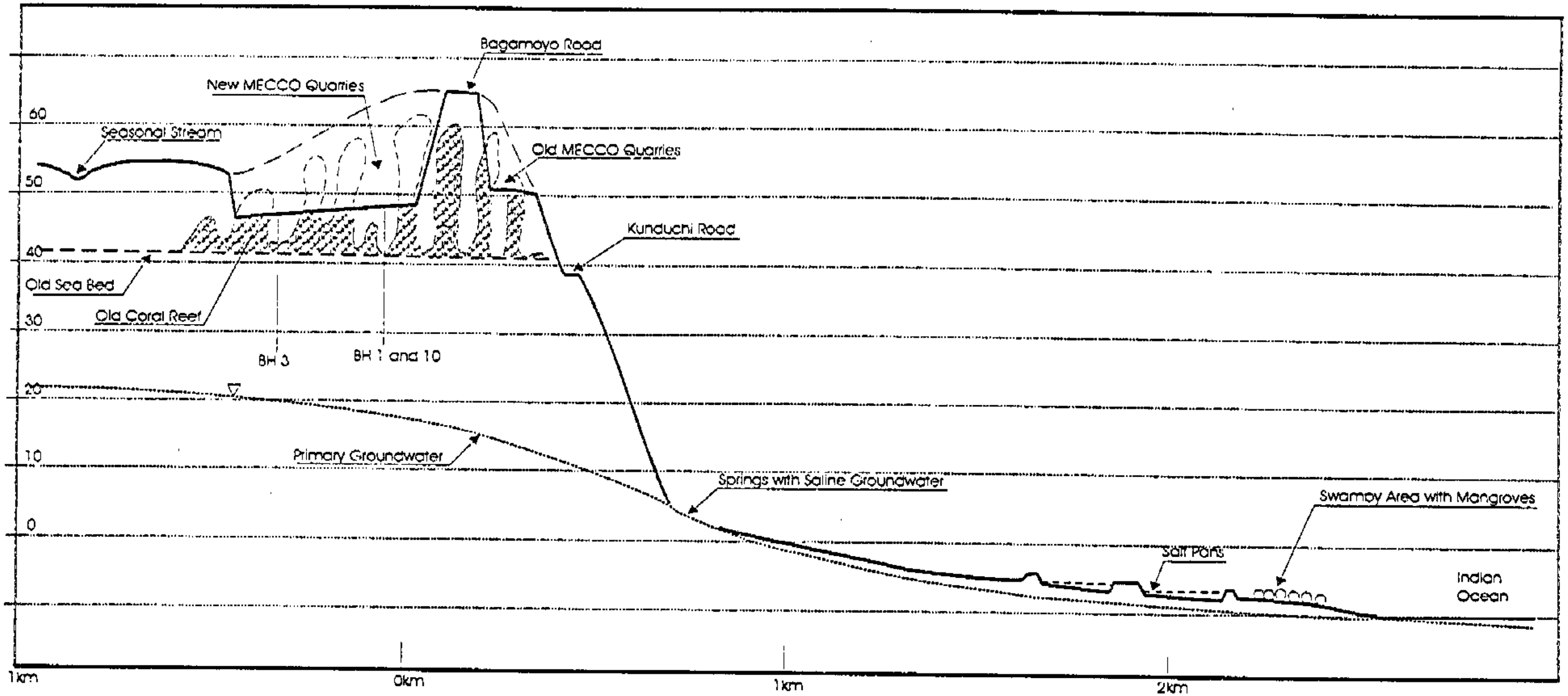


Figure 3-3: Cross Section through the Landfill Site to the Indian Ocean

The groundwater is saline, thus, all houses and villages in the vicinity of the landfill site fetch water piped from the Lower Ruvu Water Treatment Plant.

The high chloride concentrations in the boreholes throughout the Dar es Salaam area is not explained clearly (refer to "Coast/Dar es Salaam Regions Water Master Plan" prepared by the Canadian company CBA Engineering Ltd. in 1979). Near the coast, there is saltwater intrusion. However, sometimes water further inland has also been shown to have excessive chloride concentrations. A number of explanations have been suggested, including: chloride released by solutions of host minerals, as a result of previous sea water inundation or from airborne salt particles etc.

East of Bagamoyo Road and from the bottom of the Old MECCO quarries the terrain falls relative sharply to approximately 10 m where springs carrying the saline groundwater is found. It was confirmed that the water here was not used for drinking.

From the steep slope with the saline springs at the foot, there is a swamp approximately 2 km wide with mangroves which gently slopes toward the Indian Ocean.

In the swampy area, there are salt pans to the north-east and south-east of the landfill site. It was confirmed by the owners of these pans that the bottom never reached any groundwater (otherwise the pans cannot be used for salt production). A borehole carried out in connection with this study confirmed this statement. The groundwater which was encountered approx. 1 m below the bottom of the deepest salt pans was polluted probably by the nearby village and pit latrines.

Surface water from the area outside the quarries of the landfill site is drained off to the valley west of the site. The bottom of the valley is approximately 45 m deep. The valley contains a stream that is dry most of the year. However, during the rainy season it joins Tegeta River that flows into the Indian Ocean approximately 2 km Northeast of the landfill site.

In the valley, shallow sections of sand with their own water tables were encountered above clay. Thus, shallow pits (approx.1 m deep) are found in the valley containing water even during the dry seasons. Before the pipeline from the Lower Ruvu Water Treatment Plant was constructed these water holes were used as a source of water. Now, the water holes are occasionally used during periods of water shortages from the Ruvu River.

The conclusion of the hydrogeological investigations is that leakage of leachate from the new landfill in the New MECCO quarries will seep through to the saline ground water and flow into the Indian Ocean.

3.3.3 Borrow Pits for Clay

The following sites were investigated for formations of clay that could be used for the construction of a bottom liner for the landfill in Kunduchi.

- The surroundings of the landfill site in Kunduchi.
- A site in Kinzudi located approximately 10 km from the landfill site.
- A site in Pugu located approximately 45 km from the landfill site.

a. The surroundings of Kunduchi landfill site

Sandy clay was found 4-6 m deep in some of the boreholes carried out in the quarry. The formations were thin (0.5 m) and found not to have a continuous series of clay that could be exploited for the construction of a clay liner.

In the surroundings of the landfill site, clay was found in the valley west of the site and in a relatively small swampy area immediately south of the landfill site. Also, these clay formations were found to be too small and they are located on agricultural land.

b. The Site in Kinzudi

The site in Kinzudi was previously investigated by Kisarawe Brick Factory for clay that could be used for the manufacturing af bricks. Further, geotechnical investigations have been carried out earlier since it was suggested as a possible landfill site.

Two boreholes 5 m deep were constructed on the site and samples of clay formations were analysed in the laboratory. The main results are shown in the following Table.

Table 3-1: Analysis of Clay from Kinzudi

Borehole	Clay content	Permeability coefficient (m/sec.)	Natural moisture content
1	~ 0 %	3.2×10^{-9}	6 %
2	12 %	4.2×10^{-7}	5 %

The clay was found to be inaccessible since it was overlaid by more than 3 m of sandy soil.

The clay was also found to be unsatisfactory ($k > 10^{-10}$ m/sec) for constructing a clay liner.

c. The Site in Pugu

The site in Pugu is used by Kisarawe Brick Factory as a borrow pit for extracting clay to manufacture bricks.

Large clay formations are found in the area.

Two types of clay are found: red clay and bentonite clay (grey). Samples were analysed in the laboratory and the main results are shown in the following table.

Table 3-2: Analysis of Clay from Pugu

Clay sample	Clay content	Permeability coefficient (m/sec.)	Natural moisture content
Red clay	18 %	2.5×10^{-8}	6 %
Bentonite clay (grey)	37 %	2.3×10^{-11}	9 %

The permeability coefficient of the red clay from Pugo was found to be unsatisfactory ($> 10^{-10}$ m/sec).

The bentonite clay has a high clay content. When properly moistened the clay is highly plastic and when properly compacted, it exhibits low permeability. However, also when properly moistened, the clay is expected to be very sensitive to heavy traffic and compaction, especially vibration caused by vehicles and machinery.

It was suggested that the bentonite clay could be used for the construction of a bentonite liner for the Kunduchi landfill. Therefore, laboratory tests were undertaken to investigate the permeability of mixtures from the bentonite clay and sand excavated from the bottom of MECCO quarries.

The following samples clay were prepared by weight:

- 75 % sand and 25% bentonite clay
- 60 % sand and 40% bentonite clay
- 40 % sand and 60% bentonite clay
- 25 % sand and 75% bentonite clay

The results are shown in the following table.

Table 3-3: Permeability of bentonite liners

Sample	Permeability coefficient (m/sec.)	Optimum Moisture Content
25 % bentonite clay	2.0×10^{-10}	16 %
40 % bentonite clay	1.6×10^{-11}	17 %
60 % bentonite clay	1.8×10^{-10}	25 %
75 % bentonite clay	0.9×10^{-10}	28 %

The permeability coefficient of the sample with 25% bentonite clay was found to be satisfactory if the landfill is to be furnished with a bottom liner constructed from bentonite clay.

3.3.4 Landfill Volume and Future Utilization of the Area

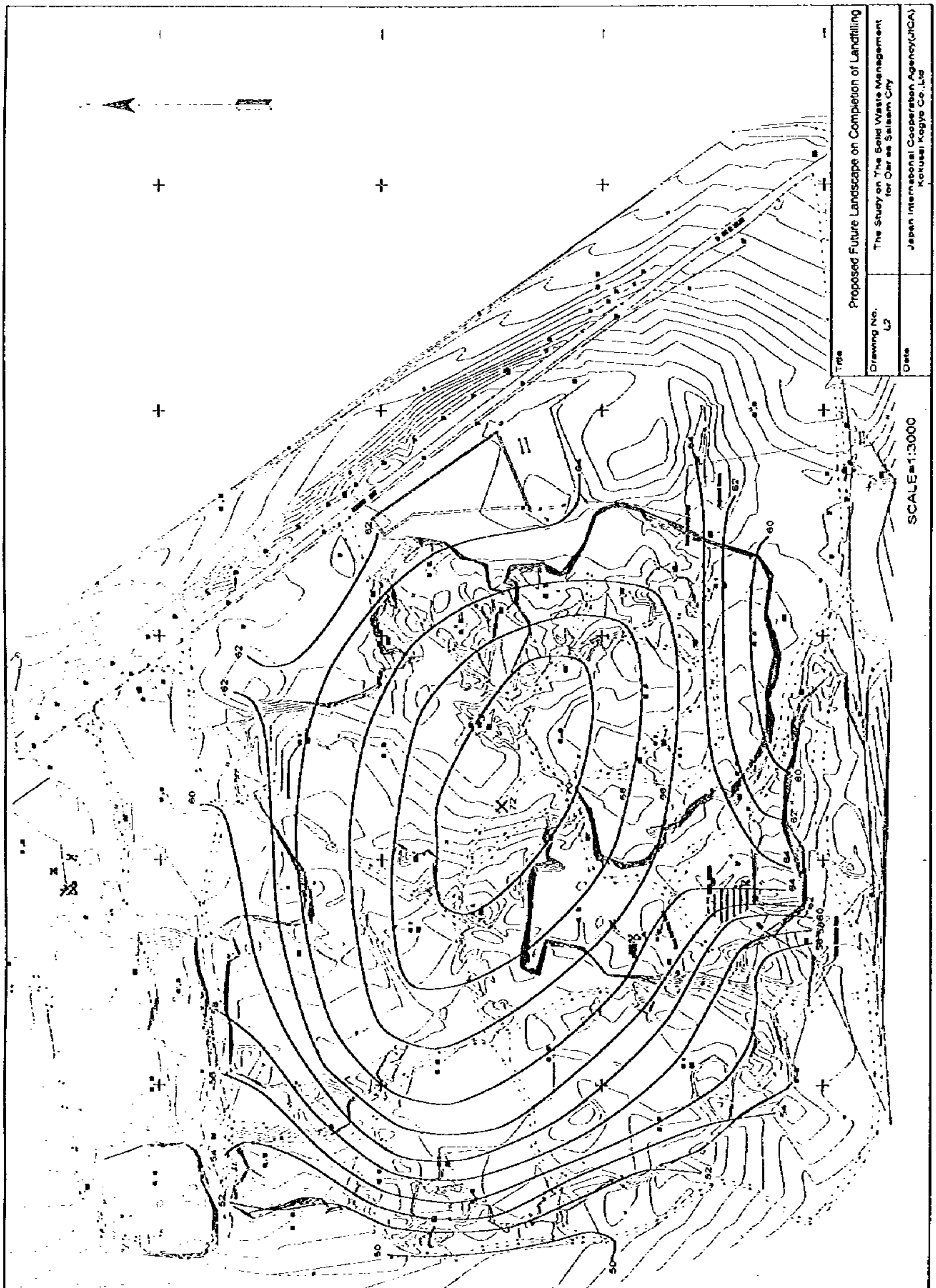
Having terminated waste disposal in the sanitary landfill it is recommended that the area should be converted for agricultural or recreational purposes. This future use of the area allows for the construction of a hilly terrain that provides optimum utilisation of the area.

The recommended future landscape is presented in Drawing No. 2.

It is proposed that the future landscape should comprise a hill approx. 72 m, i.e. 10 m above Bagamoyo Road. The top of the hill will be situated approximately 250 m from the road and it is proposed to have a relatively moderate decline (1:15) towards Bagamoyo Road.

The hill is proposed to be more steep towards the eastern valley, however it is not to be any steeper than 1:3 to ensure long-term stability. The maximum filling height will be about 25 m with an average filling height of 13 m.

It is recommended that areas along the boundary of the planned area are filled with soil to provide an appropriate link between the surroundings and the future "waste hill". The required soil shall be excavated on site to increase the volume of the landfill.


Title
Proposed Future Landscape on Completion of Landfilling
Drawing No.
L2
The Study on The Solid Waste Management for Dar es Salaam City
Date
Japan International Cooperation Agency(JICA)
Kokusai Kogyo Co.,Ltd
SCALE=1:3000

An area of approx. 26 ha will be used for waste filling, while the remainder of the planning area is too small.

Based on the recommended future landscape the total volume for waste is estimated to be **3.5 mill. m³**.

The capacity of the landfill might be increased by raising the height of the hill. However, due to aesthetic reasons and its proximity to Bagamoyo Road, this is considered unacceptable.

3.3.5 Projection for Waste Quantities and Division into Landfill Sections

The following table shows the summary of projections and targets as adopted by this study for Dar es Salaam.

Table 3-4: Projections and Targets for Waste Generation and Collection.

Year	Population Projection	Forecast for Waste Generation (tons/day)	Target for Waste Collection (%)	Target for Waste Collection (tons/day)
1996	2.0 mill.	1,771	8.0	141
1997	2.2 mill.			206
1998	2.3 mill.			279
1999	2.5 mill.	2,145	16.9	362
2000	2.7 mill.			545
2001	2.9 mill.			747
2002	3.1 mill.	2,682	37.4	1,001
2003	3.4 mill.			1,392
2004	3.7 mill.			1,653
2005	4.0 mill.	3,466	56.6	1,960

At this stage it is assumed that the new landfill at Kunduchi will be constructed in 1999 and will start operating at the beginning of the following year.

Further, in accordance with the basic concept of solid waste management for Dar es Salaam, each district should operate a disposal site. Therefore, it is assumed that new landfills will start operating in 2003 at Ilala and Temeke.

Based on the projections presented in Table 3-4, the following table provides a forecast for the waste quantities to be disposed of at the new landfill in Kunduchi during the period up to 2005.

The waste density is estimated to be 390 kg/m³ when collected and 900 kg/m³ when compacted in the landfill. The daily soil coverage is assumed to take up 18 % of the landfill volume.

Table 3-5: Forecast for the Waste Disposal and the Required Landfill Volume of the New Kunduchi Disposal Site

Year	Waste Collection (tons/day)	Waste disposal at Kunduchi (tons/day)	Ilala and Temeke (tons/day)	Required landfill Volume in Kunduchi (m^3/year)	Accumulated (m^3)
2000	545	545	0	260,813	260,813
2001	757	757	0	362,267	623,079
2002	1,001	1,001	0	479,067	1,102,146
2003	1,392	571	821	273,030	1,375,177
2004	1,653	653	1,000	312,475	1,687,652
2005	1,960	743	1,217	355,732	2,043,384

With a landfill capacity of 3.5 mill. m^3 (or 2.8 mill. tonnes waste) and an estimated waste disposal of 300,000 m^3/year after 2005, the landfill in Kunduchi (New MECCO quarries), is expected to operate for 11 years (2000 to 2010).

It is recommended that the area for waste disposal (26 ha) is divided into sections, with a planned filling period of 2 to 3 years for each.

The main objective of dividing the disposal area into sections is to minimise the generation of leachate (there is a direct correlation between waste disposal area and volume of leachate produced).

Furthermore, the division into sections provides a sound time schedule for investment into the landfill.

The landfill is recommended to be divided into 4 sections as shown in Drawing No. 3. Landfill Sections 1A and 1B is recommended to be constructed in 1999. However, the filling of waste in Landfill Section 1B should not commence until Section 1A is full.

The division pays due regard to the existing conditions of the quarries. Thus, the area for Landfill Section 1A is naturally delimited to the north by the existing access road used by MECCO. Except for some manual quarry excavation still being carried out at the north eastern boundary, the area for Landfill Sections 1A and 1B is depleted of minerals. Also, materials along the north eastern boundary will soon be exhausted.

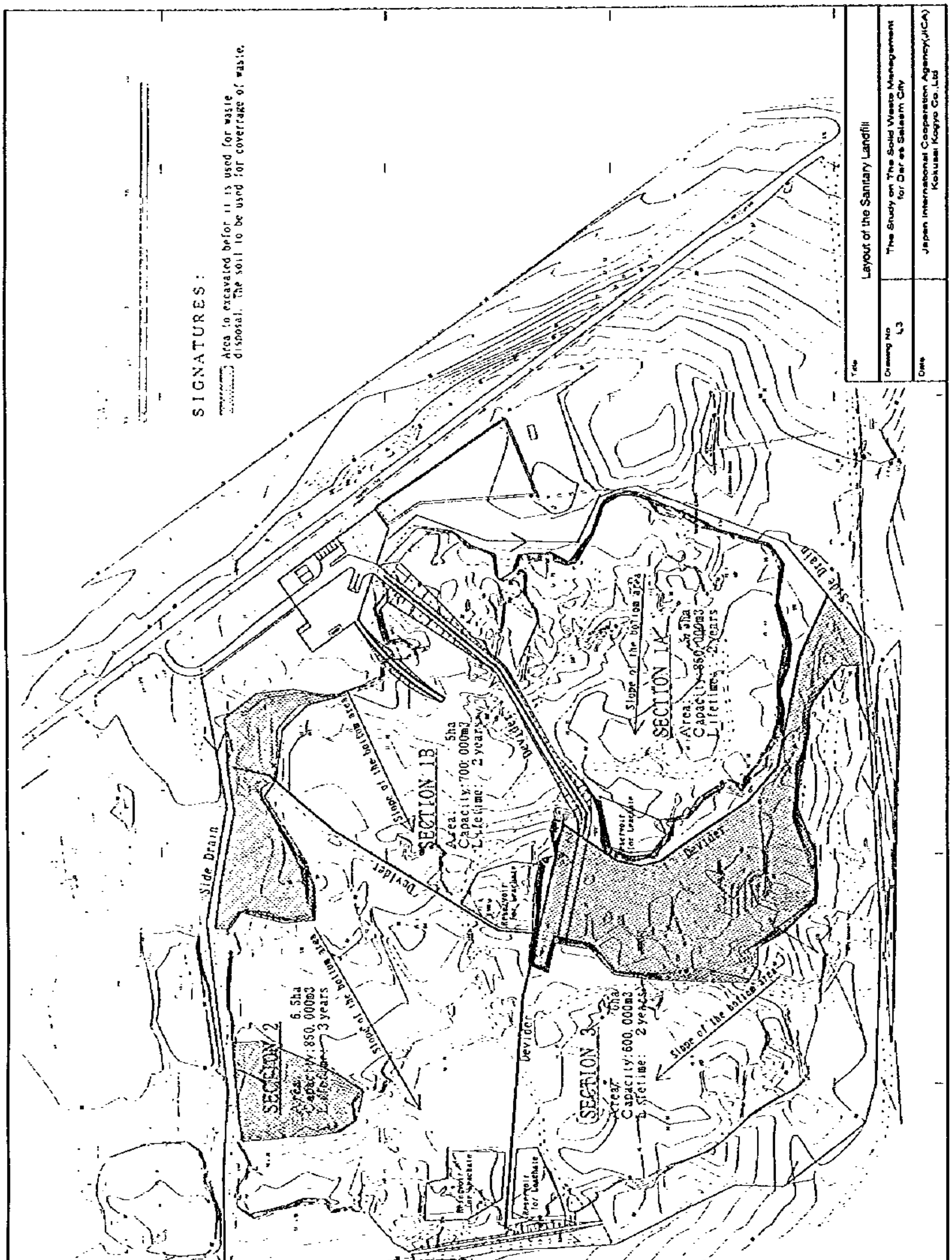
The capacity and operation period for each landfill section is presented in the following Table.

Table 3-6: Capacity of the Landfill Sections

Landfill Section No.	Area (ha)	Capacity of Landfill Section (m^3)	Life Span (years)	Disposal Period (year)
1A	6	900,000	2.5	2000-2002
1B	5	700,000	2.0	2003-2004
2	8	1,000,000	3.5	2005-2007
3	7	900,000	3.0	2008-2010
Total	26	3,500,000	11.0	2000-2010

After having finished landfilling in one section, it will be covered by a thick (1 m) layer of soil and planted with flora appropriate for the future utilisation of the area.

The soil which is required for the final coverage of waste will be excavated when preparing areas for other sections of the landfill. In that way, the total landfill capacity is maximised.


SIGNATURES:
Area in excavated befor it is used for waste disposal. The soil to be used for coverage of waste.
Layout of the Sanitary Landfill
The Study on The Solid Waste Management for Dar es Salaam City
Japan International Cooperation Agency (JICA)
Kokusai Kogyo Co., Ltd
SECTION 1A
Area:
Capacity:
Lifetime:
SECTION 1B
Area: 5ha
Capacity: 700,000m3
Lifetime: 2 years
SECTION 2
6.5ha
850,000m3
3 years
SECTION 3
Capacity: 600,000m3
Side Drain
Devider
Slope of the bottom area
Reservoir for Leachate

3.3.6 Waste Composition

The landfill is expected to receive the following types of waste:

- Residential waste (e.g. from kitchens)
- Bulky waste (furniture, refrigerators, etc.)
- Commercial waste (from shops and restaurants)
- Market waste (mainly vegetables and paper)
- Institutional waste
- Garden waste
- Street sweeping waste
- Industrial waste (non hazardous waste)
- Construction and demolition waste.
- Stabilised non-toxic dry sewage sludge

The most common type of waste to be disposed at the new landfill will be waste from residential areas, i.e. the waste will mainly be derived from households and shall include a substantial portion (60 %) of organic matter.

Disposal of hazardous and chemical wastes (batteries and accumulators, paint residues, infectious waste from hospitals etc.) should not be allowed on the sanitary landfill. These types of waste must be collected separately and treated chemically or by incineration to be neutralised before being disposed of on a landfill. Thus, the landfill will not receive the following types of waste.

- Hazardous and toxic waste from industries, commerce, institutions etc.
- Infectious waste, syringes, hypodermic needles, etc. from hospitals, clinics and dentists.
- Radioactive waste of any type.
- Liquid waste of any type.

3.3.7 Landfill Gas

The biodegradation of municipal solid waste in a landfill result in the generation of biogas (a water saturated mixture of methane (CH_4, 40-55% vol.), carbon dioxide (CO_2, 30-40% vol.), nitrogen (N_2, 10-20%), and in small quantities odorous and other gases). The theoretical quantity of biogas generated during the breakdown of kitchen waste is estimated at 150-200 litres per kilo of dry waste.

The quantity of methane gas which will be generated from Kunduchi landfill is estimated to be about 100-150 mill. Nm^3 from the 2.7 mill tonnes of wet municipal waste that will be disposed of at the landfill. However, only a small quantity (10 - 40 %) can be exploited, because a substantial volume will escape before the landfill is furnished with a final soil coverage. Further the volume of gas generated will decrease during the course of the biodegradation period of the waste, perhaps over 50 years.

Thus, it is expected that the use of biogas from the landfill will not be feasible. However, the feasibility of using biogas from the landfill shall be assessed when there is enough waste for its production.

The technology of exploiting landfill gas for energy production is relatively simple; all that is required is a series of perforated pipes in the landfill together with a pump to extract the gas. Further, the landfill should be furnished with a dense final soil coverage that will prevent air from the atmosphere to be sucked into the landfill and cause the creation of an explosive gas.

However, the economics of such a system for exploiting landfill gas largely depend on the availability of a reasonable market for the gas within perhaps two kilometres of the landfill. Such a large scale user is not found in proximity of Kunduchi landfill.

Therefore, it is assumed that landfill gas shall be exhausted in a controlled manner into the atmosphere. The controlled venting of the landfill gas is required for safety reasons (i.e. because of a possible future proximity of residential buildings).

Since uncontrolled diffusion of gas from the landfill may result in spontaneous combustion and damaged vegetation, it is recommended that the sides of the landfill are furnished with a permeable sand layer that is connected to the outside by a number of gas vents (see Drawing No. 7). Further, the landfill should be furnished with final soil coverage that enables ventilation of landfill gas.

3.3.8 Climatic Conditions and Leathate Generation

The following table presents monthly and annual values for the precipitation and the evaporation, as obtained from the Meteorological Station at Dar es Salaam International Airport.

Table 3-7: Precipitation and Pan Evaporation at Dar es Salaam

Month	Precipitation (1954-1970) (mm)			Pan Evaporation (1957-1970) (mm)		
	Mean	Highest	Lowest	Mean	Highest	Lowest
January	74	216	6	201	283	150
February	83	192	15	174	248	147
March	143	306	30	176	229	128
April	273	446	163	138	189	98
May	152	372	28	158	198	129
June	34	86	2	149	183	124
July	32	155	2	151	177	134
August	28	95	1	170	212	130
September	26	94	5	176	222	150
October	60	285	13	190	265	143
November	122	415	0	185	250	131
December	108	304	16	191	268	159
Annual	1,135	1,730	731	2,059	2,493	1,787

Similar data for the period between 1983-1994 were obtained. The data is very similar but is less plausible than those stated above.

At the new landfill in Kunduchi the mean annual precipitation is expected to be 1150 mm/year.

The mean pan evaporation is expected to be 2050 mm/year and the potential evaporation is assessed as 70% i.e. 1430 mm/year.

The actual evaporation from an area depends on the climatic conditions (precipitation, temperature, wind factor, etc.), the kind of topsoil of and vegetation.

The following table presents a water balance calculation ("Top Layer Model") for a landfill section with final soil coverage (1 m sandy clay) and with surface vegetation e.g. grass, trees, and bushes. The quantity of run-off water from the sloping ground (≈ 1:20) of the landfill is estimated to be approx. 20 % of the precipitation.

Table 3-8: Water Balance for a Landfill Section with Final Soil Coverage and Vegetation and for a Year with Average Precipitation and Evaporation.

(Units in mm)		Month												Annual
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
A	Average Precipitation	74	83	143	273	152	34	32	28	26	60	122	108	1135
B	Run-off water	15	15	25	50	25	5	5	5	5	10	20	20	200
C	Infiltration (A - B)	59	68	118	223	127	29	27	23	21	50	102	88	935
D	Potential Evaporation	140	120	120	100	110	100	110	120	120	130	130	130	1430
E	C - D	-81	-52	-2	123	17	-71	-83	-97	-99	-80	-28	-42	
F	Water deficit	100	100	100	0	0	71	100	100	100	100	100	100	
G	Leachate Generation	0	0	0	23	17	0	0	0	0	0	0	0	40
H	Actual Evaporation	59	68	118	100	110	100	56	23	21	50	102	88	895
I	Pot.-Act. Evap. (D-H)	81	52	2	0	0	0	54	97	99	80	28	42	535

Note: The water deficit expresses the quantity of water that is missing in the top layer before it is moisture-saturated.

Because of the high evaporation rates, leachate generation as well as groundwater recharge and run-off occurs, if at all, only during the three wettest months of the year: March, April, and May. In other months of the year rain completely evaporates.

From Table 3-8 the annual average leachate generation from a landfill section with final soil coverage and surface vegetation is calculated at 40 mm/year. However, it should be noted that the leachate generation may vary considerably from year to year.

Average evaporation from a landfill section with final soil coverage and surface vegetation is estimated at 900 mm/year. Further, it is foreseeable that evaporation may be higher between July and March.

The top layer of a landfill section in operation without final soil coverage and vegetation has a smaller water content. Thus, the annual evaporation from a landfill section during operation will be less than from one with final soil coverage and vegetation. However, no data on the evaporation from a landfill section during operation is available for the Dar es Salaam area.

The actual average annual evaporation at the landfill in Kunduchi is assumed to be the following.

- Landfill area during operation (based on experience from landfills in Europe and considering the actual climatic conditions) — 700 mm/year
- Landfill area with final soil coverage and surface vegetation, e.g. grass and bushes (in accordance with Table 3-8) — 900 mm/year

The average annual leachate generation at the landfill in Kinduchi is therefore estimated as follows.

- Landfill area during operation 350 mm/year
  (1150 mm/year precipitation - 700 mm/year evaporation - 0 mm/year run-off water - 100 mm/year absorbed in waste = 350 mm/year)

- Landfill area with final soil coverage and surface vegetation, e.g. grass and bushes (refer to Table 3-8) 50 mm/year

3.4 Appropriate Sanitary Level of the Disposal Site

Sanitary landfill levels are classified as follows.

- Level 1: Controlled tipping.
- Level 2: Sanitary landfill without a bottom liner but operating with daily soil coverage of waste.
- Level 3: Sanitary landfill with a bottom liner, leachate collection system and installations for recirculation/evaporation of leachate.
- Level 4: Sanitary landfill with a bottom liner, leachate collection system and installations for treatment of leachate

For the landfill in Kunduchi two alternative concepts have been considered.

Level 2: Landfill without a bottom liner and with percolation of leachate to the ground water/Indian Ocean.

Level 3: Landfill with a bottom liner and facilities for collection and evaporation of leachate.

In this case, Level 2 is recommended for the following main reasons:

- The landfill site is located near the Indian Ocean (2.5 km) and the groundwater flows towards the Ocean. Therefore, the leachate generated in the landfill will have minimum impact on potential groundwater sources.

- The groundwater in the area of the landfill site is saline. All inhabitants in the area are already furnished with piped water and therefore do not use the ground water for drinking.

- The required installations for evaporation of leachate, if a bottom liner is placed, are not easily maintained. Due to ferrous compounds in the leachate, the installations require constant supervision and cleaning to prevent pipes from clogging. Treatment methods other than evaporation of leachate (e.g. combined treatment of leachate and sewage in a municipal sewage treatment plant) are not considered to be feasible in the near future in Dar es Salaam.

- Investments (construction and operation costs) for a landfill with a bottom liner and leachate treatment are considerable compared with the amount required for a landfill that allows leachate to seep into the Indian Ocean

The Table 3-9 shows that Level 3 landfills require a considerable amount of financing in comparison with Level 2.

Table 3-9: Cost Comparison between Level 2 and Level 3 Sanitary Landfills

Landfill in accordance with	Construction Costs (Mill. Tsh)	O & M Costs (Mill. Tsh)	Total (Mill. Tsh)	Unit Costs (Tsh/ton)
Level 2	3,121	1,589	4,710	1,682
Level 3	7,210	1,650	8,860	3,164
Level 3/Level 2	2.31	1.04	1.88	1.88

Note:

- The Kunduchi New MECCO landfill is assumed to be operated from 2000 to 2010.
- The total waste quantity for this period is estimated at 2.8 million tonnes.
- For details, reference is made to Table 3-8 and Table 3-31.

Applying the "user-pays-principle", the tipping fee at the Kunduchi New MECCO landfill will be almost four times the present fee (800 Tsh/ton) if it is a Level 3 landfill. This may lead to the rise in illegal dumping.

The alternative concepts are described as follows.

3.4.1 Level 2: Landfill without Bottom Liner

As can be seen from Figure 3-3, leachate will seep into the ground and follow the ground water to the Indian Ocean. The ground water is already saline and cannot be used for drinking.

The layout and operation of the landfill (Level 2) are described in detail in Sections 5 and 6.

Cost estimates are provided in Section 3.8. Table 3-31 provides a summary of the investments required for a level 2 sanitary landfill.

3.4.2 Level 3: Landfill with a Bottom Liner

Landfills in accordance with Level 3, are constructed with the following facilities for collection and treatment of leachate.

- Bottom liner constructed sloping towards the leachate drains.
- Leachate drainage system.
- Installations for treatment of leachate.

The facilities are briefly described as follows.

a. **Bottom Liner**

The bottom liner prevents leachate from penetrating the ground. Thus, the liner must be resistant to chemical compounds formed during the degradation of waste and also the physical loads to which it is exposed during the construction and operation of the landfill.

The following bottom liners which fulfil the above-mentioned requirements, are generally recommended.

- Polymeric membrane liners

- Clay liners
- Bentonite liners

Polymeric membrane liners are not feasible for the Kunduchi landfill because they require the import of lining material (normally polyethylene), and the assembling on site requires a specially trained workforce.

The clay liner or the bentonite liner are the most economical solutions provided that suitable clay or bentonite is available on or nearby the landfill site.

Clay fulfilling the following properties has proved to provide the required permeability (k less than 10^{-10} m/s, measured in the laboratory).

- The clay material should have a clay content exceeding 14%.
- The clay should have a plasticity index exceeding 5%.
- The water content of the clay should, at the time of application, be superior to the optimum water content, determined by the Standard Proctor tests.

The geotechnical investigations carried out for the landfill site in Kunduchi proved that no clay formation which was large enough and easily available could be found at or near the site (refer to Section 3.3).

However in Pugu Ward, bentonite clay which could be used for the construction of a liner was found. The site in Pugu is situated approximately 40 km from the landfill site in Kunduchi.

Therefore, if the landfill in Kunduchi must be furnished with a bottom liner, a bentonite liner is recommended.

The required thickness of the bentonite liner is at least 0.1 m (Danish standard). It consists of dry sand mixed at 20 to 25% by weight of bentonite e.g. in a concrete mixer. Other careful mixing methods may be adopted provided test results has proved it to be satisfactory.

It should be noted that it is difficult to obtain a completely homogeneous mixture unless the soil is very dry, which is difficult to compact after mixing. Thus, the bentonite liner may be constructed by laying the mixed bentonite/sand on the surface with the required slope gradient. The drainage layer (30 cm coarse sand, see below) should be laid immediately above the bentonite liner. Finally, the drainage layer should be watered and compacted.

Further, the weather conditions should be considered during the construction phase of a bentonite liner, which is a matter of utmost importance. Thus, construction works cannot be carried out during the rainy season. During the entire liner work efficient control of all works and materials should be carried out and constant supervision is required.

Considering the proximity to the Indian Ocean and because the saline ground water cannot be used as drinking water, it is proposed that the existing steep sides of the landfill should not be furnished with a liner. The construction of such a side liner would require a considerable amount of earthworks - levelling of sides to a gradient of approximately 1:3 on which the bentonite liner could be constructed.

b. Leachate Drainage System

The purpose of the drainage system is to collect leachate from the bottom liner and transfer it to the leachate treatment facility. The leachate drainage system consists of the following elements.

- Drainage layer on top of the bentonite liner.
- Leachate drains constructed in the drainage layer.

Drainage Layer

The drainage layer covering the entire bentonite liner serves the following purposes.

Drainage of leachate to the drains to reduce the hydraulic pressure on the bottom liner to a minimum.

Protection of the bentonite liner against erosion until the first waste layer has been placed.

The drainage layer consists of a layer approx. 0.3 m of coarse sand free from clay and silt. The quality of the material used for the drainage layer will influence the number of leachate drains required. Thus, a permeability coefficient of more than 10^{-3} m/s is required for the sand/gravel to allow a reasonably large distance (approx. 20 m) between the leachate drains.

Leachate Drains

Each landfill section will be furnished with a system of leachate drains constructed in the drainage layer. Each drainage system consists of a primary drain and a network of secondary drains constructed with a recommended distance of less than 20 m.

The primary leachate drains discharges leachate to a reservoir furnished with a bentonite liner and a pump.

c. Installations for Treatment of Leachate

Due to the high potential evaporation in the Dar es Salaam area, evaporation is recommended as a method of treating leachate.

The average, annual leachate generation from a landfill section in operation is estimated to be 350 mm/year, and from a landfill section furnished with final soil coverage and surface vegetation the leachate generation is estimated to be 50 mm/year (refer to Section 3.8).

This leachate quantity can be reduced by irrigating or sprinkling the leachate to old landfill sections between June and February. The landfill sections that are used for leachate evaporation should preferably have a final soil coverage and vegetation that will ensure maximum evaporation.

However, sprinkling of "young leachate" should be handled with care due to potential nuisances created by its odour. If necessary, evaporation of "young leachate" could take place from a leachate pond.

Installations for evaporation of leachate include:

- a reservoir for collection of leachate.

- installations for pumping leachate from the reservoir to the top of an old landfill section.

All pipes must be cleaned on a regular basis to prevent clogging of pipes due to ferrous compounds in the leachate.

d. Construction and Operation Costs

The cost estimate for investments into the reception area and buildings is 370 mill Tsh as provided in Table 3-22.

The following cost estimates presents the construction and operation costs for the disposal area in accordance with Level 3: "Landfill with a bottom liner and leachate treatment".

Landfill Section 1A has a disposal area of 6 ha.

Table 3-10: Construction Costs for Landfill Sections 1A, Level 3

Item		Quantity	Unit Price	Tsh
Earthworks				
- Clearing of site	m2	60.000	200	12.000.000
- Excavation and leveling of the bottom area	m3	20.000	6.000	120.000.000
- Excavation for the leachate reservoir	m3	3.000	6.000	18.000.000
- Construction of embankments	m3	6.000	4.500	27.000.000
- Procurement of clay from Pugu	m3	1.500	4.000	6.000.000
- Transport of clay from Pugu	m3	1.500	10.000	15.000.000
- Construction of bentonite liner	m2	60.000	6.000	360.000.000
- Laying of drainage layer (0.3m)	m2	60.000	3.000	180.000.000
- Leachate drains, secondary	m	3.000	20.000	60.000.000
- Leachate drains, primary	m	500	40.000	20.000.000
Installations for leachate				
- Pump sump	nos.	1	1.000.000	1.000.000
- Pump installations, electrical and pipe works	LS	1	40.000.000	40.000.000
Other				
- Ditches for run-off water	m	600	3.000	1.800.000
- Fences	m	800	25.000	20.000.000
Overhead, 30%				264.240.000
TOTAL, excl. procurement of land and provision of consultancy services				**1.145.040.000**

The following Table presents cost estimates for construction of further landfill sections in accordance with Level 3.

Table 3-11: Construction Costs for Further Landfill Sections, Level 3

Landfill Section	Area (ha)	Year of Construction	Construction Costs (mill. Tsh)
1A	6	1999	1,150
1B	5	1999	960
2	8	2004	1,530
3	7	2007	1,340

Most of Section 1A will have a final soil coverage including the required installations for gas ventilation in 2002 when landfill operations in Section 1B commences.

The following table presents the construction costs for final soil coverage including the required installations for gas ventilation of Landfill Section 1A.

Table 3-12: Final Soil Coverage of Landfill Section 1A in the Year 2002

Item		Quantity	Unit Price	Tsh
Final soil coverage of Landfill Section 1A				
- 0,2 m gravel/sand layer	m2	60.000	2.000	120.000.000
- 1m soil coverage	m2	60.000	3.000	180.000.000
- Planting	m2	60.000	500	30.000.000
- Gas drains	m	600	2500	1.500.000
- Manholes for gas ventilation	nos.	13	100.000	1.300.000
Overhead, 30%				99.840.000
TOTAL, excl. procurement of land and provision of consultancy services				432.640.000

The following table presents cost estimates for final soil coverage and installations for gas ventilation from further landfill sections.

Table 3-13: Final Soil Coverage of Further Landfill Sections

Landfill Section	Area (ha)	Year of Construction	Construction Costs (mill. Tsh)
1A	6	2002	430
1B	5	2004	360
2	8	2007	570
3	7	2011	500

Assuming all waste collected in Dar es Salaam is disposed of on the landfill in Kunduchi (740 tons/day in year 2000 and 1140 tons/day in year 2002), the following Table presents the average annual operation costs for Landfill Section 1A, in accordance with Level 3: "Landfill with a bottom liner and leachate treatment"

Table 3-14: Operation Costs for Landfill Section 1A in accordance with Level 3

Item	Tsh/Year
Salary:	15,500,000
- 1 site manager, 300,000 Tsh/month	
- 1 operator of weigh bridge, 80,000 Tsh/month	
- 1 inspector, 60,000 Tsh/month	
- 5 operators of landfill equipment, 80,000 Tsh/month each	
- 2 operators of the pump installation for leachate, 40,000 Tsh/month each	
- 7 workers, 40,000 Tsh/month each	
- 2 security guards, 40,000 Tsh/month	
Diesel:	50,000,000
- 2 bulldozers, 2 x 150 litres/day, 275 Tsh/litre	
- 1 excavator and 2 truck for soil coverage, construction of internal roads, precautions against gas and other soil works, 3 x 80 litres/day, 275 Tsh/litre	
- Other equipment: tractor sweeper, water tanker etc.	
Maintenance of landfill equipment:	45,000,000
- 5% of investment in equipment	
Operation and maintenance of pump installation for leachate:	17,000,000
Monitoring:	1,000,000
- Leachate, 2 times a year	
- 2 boreholes for ground water, once a year	
Miscellaneous, approx. 20%:	321,500,000
TOTAL	160,000,000

Based on the cost estimate for operating Landfill Section 1A, cost estimates for operating further landfill sections are provided as follows.

Table 3-15: Average Operation Costs for the Landfill Sections, Level 3

Landfill Section	Average Waste Quantity tons/day	Average Operation Costs Tsh/year
1A	840	125,000,000
1B	815	120,000,000
2	645	95,000,000
3	720	105,000,000

When the sanitary landfill is closed and has a final soil coverage, expenses relating to the following activities will remain for the landfill constructed in accordance with Level 3.

- Treatment of leachate, which for many years will remain polluted and require treatment.
- Monitoring of ground water and leachate.

e. Summary of Investments

The following Table provides a summary of investments required for the sanitary landfill in Kunduchi in accordance with Level 3: "Landfill with a bottom liner and treatment of leachate".

Table 3-16: Summary of Investments for the Sanitary Landfill at Kunduchi (Capacity 3.5 mill m^3) constructed and operating at Level 3: "Landfill with a bottom liner and leachate treatment"

	Investment and Year (mill. Tsh, Price Level February 1997)													
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Operation Period, (section)				1A		1B			2			3		
Construction Costs:														
Procurement of land.	-													
Access road, reception area, and buildings		370												
Construction of landfill sections 1A and 1B		2110												
Final soil coverage and gas drainage for landfill section 1A					430									
Construction of landfill section 2 and final soil coverage and gas drainage for landfill section 1B.							1890							
Construction of landfill section 3 and final soil coverage and gas drainage for landfill section 2.										1910				
Final soil coverage and gas drainage for landfill section 3.														500
Operation Costs:														
Salary, diesel, maintenance, and monitoring			160	160	160	160	160	160	160	160	160	160	160	
After closing the landfill: treatment of leachate														10 (each year)
TOTAL	-	2480	125	125	550	120	1995	95	95	2005	105	105	105	510

3.5 Preliminary Design

The sanitary landfill is proposed to have the following facilities:

1. Access road and reception area.
2. Disposal area
3. Ditches for run-off water from the surroundings.
4. Fencing and plantation.
5. Precautions against landfill gas.
6. Final soil coverage.
7. Landfill equipment.

3.5.1 Access Road and Reception Area

The recommended layout of the reception area is presented in Drawing no. 4.

The reception area is proposed to be located at the boundary of the site and as close to Bagamoyo Road as possible. However, trucks using the landfill should not be required to queue on Bagamoyo Road.

Thus, an access road approximately 150 m long providing a parking lane for trucks waiting for the weighbridge is recommended to be situated along Bagamoyo Road. The access road should be paved with asphalt.

The following facilities will be located in the reception area:

- Administration building with control facilities and facilities for staff and management.
- Weighbridge
- Workshop and parking area for landfill equipment.
- Washing yard.

The reception area will have electric lighting. The buildings will be equipped with running water and a power supply.

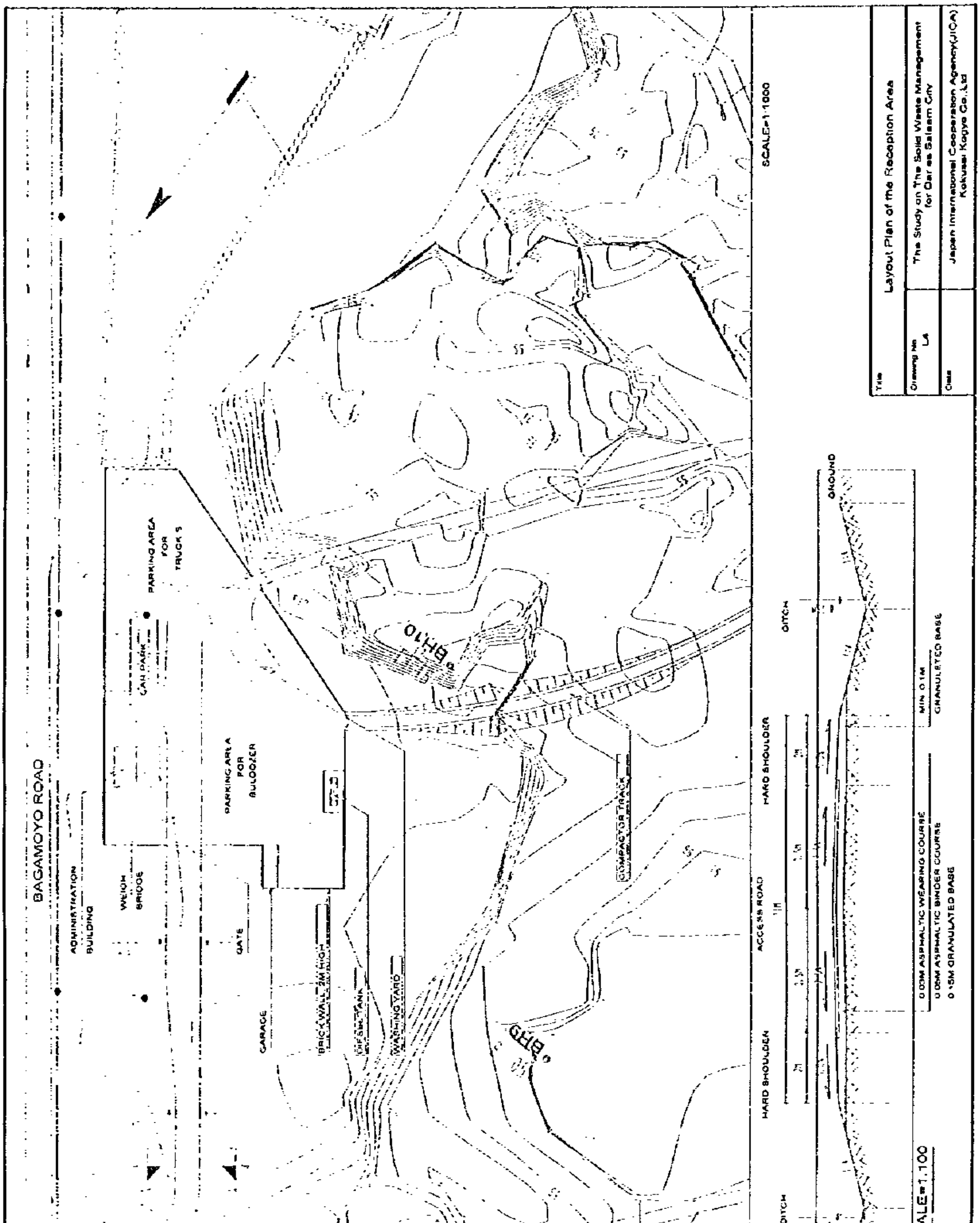
The whole reception area will be safe guarded and enclosed by a 2m brick wall.

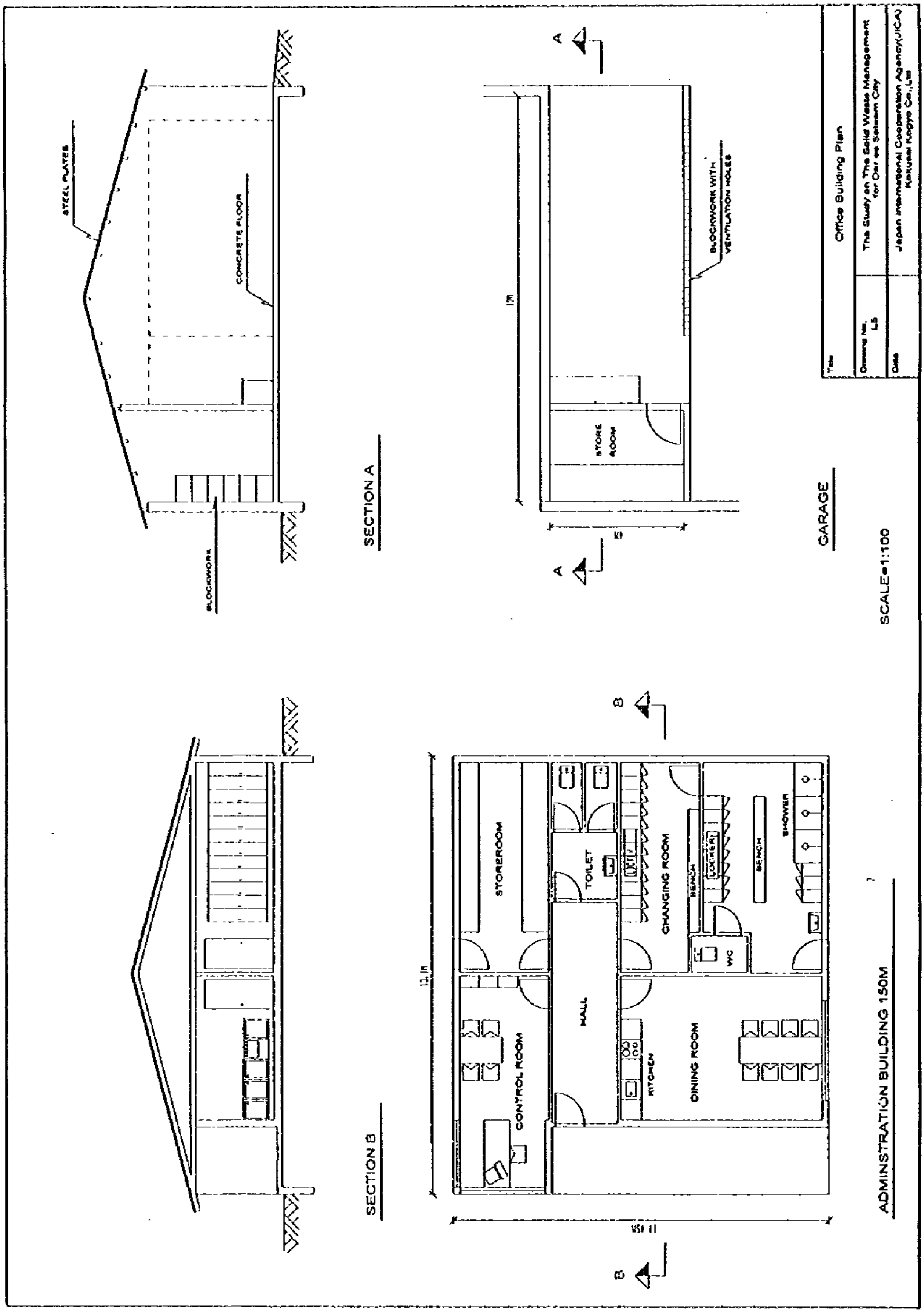
a. Administration Building

The layout of the administration building is presented in Drawing no. 5.

The building (approximately 150 m^2) includes a control room and facilities for staff and management.

The control room, will be constructed and equipped in a way that facilitates easy control and registration of incoming trucks at the weighbridge. The introduction of a computerised weighbridge enables detailed registration of waste as well as a more accurate billing and accounting system. The control room will be furnished with a separate entrance for truck-drivers who may need to enter the control room.


BAGAMOYO ROAD
ADMINISTRATION BUILDING
WEIGH BRIDGE
GATE
CAR PARK
PARKING AREA FOR TRUCKS
PARKING AREA FOR BULDOZER
GARAGE
BRICK WALL 2M HIGH
WASHING YARD
COMPACTOR TRACK
BH10
BH9
SCALE=1:1000
GROUND
DITCH
HARD SHOULDER
ACCESS ROAD
HARD SHOULDER
DITCH
GROUND
0.03M ASPHALTIC WEARING COURSE
0.05M ASPHALTIC BINDER COURSE
0.15M GRANULATED BASE
MIN 0.1M
GRANULATED BASE
SECTION A, SCALE=1:100
Title
Layout Plan of the Reception Area
Drawing No
L4
The Study on The Solid Waste Management for Dar es Salaam City
Japan International Cooperation Agency(JICA)
Kokusai Kogyo Co.,Ltd



Drawing No.5: Buildings

The facilities for staff and management include:

- Hall way and toilets with running hot and cold water.
- Changing room ("clean room") where private clothes are stored during the working day.
- Changing room ("unclean room"), where the work clothes are stored at night. The room is furnished with toilets and showers with running hot and cold water.
- Canteen with cooking facilities and a refrigerator. The canteen may also be used for meetings etc.
- Storageroom

An asphalt paved parking area for workers' and guests' cars will be constructed next to the administration building.

b. Weighbridge

The waste registration at the reception building serves the following purposes.

- Access control.
- Control of incoming waste.
- Obtaining data for collection of fees.
- Collection of data for further planning of landfill extensions.

The installations outside the control building will comprise:

- a weigh bridge with weighing cells in a concrete structure, 12 x 3 m. The recorded weight of a full truck is transmitted to the computer in the control building.
- an access control gate or traffic light controlled by the computer in the control building.

The installations inside the control building will comprise:

- a conventional personal computer.
- an intercom system for exchanging information with the truck driver on the weighbridge and the operators of the bulldozers working on the site.

c. Garage

The layout of the garage is presented in Drawing no. 5.

The garage (approximately 50 m^2) will serve only as an area for preventive maintenance of landfill equipment. It is recommended to service the landfill equipment at a mobile workshop and major repairs to be commissioned to private workshops.

Parking facilities for the landfill equipment will be provided at the garage. The parking area will also have fuel storage tanks.

A separate track, the "compactor track", will be constructed between the disposal area and parking area for the landfill equipment (see Drawing No. 4). The track will be for the heavy landfill equipment preventing wearing of the normal access road.

d. Washing Yard

The washing yard will provide washing facilities not only for the landfill equipment but also for trucks. The trucks may become dirty when it rains and litter public roads if the wheels are not washed before leaving the landfill.

3.5.2 Fencing and Plantation

Fencing and plantation around the landfill area will be used to prevent scattered waste from leaving the sanitary landfill. Furthermore, the fencing will prevent unauthorised access to the landfill by scavengers and the plants will be used as a visual shield for the disposal area.

Along the greater part of Bagamoyo road a visual shield to the disposal area is already provided by existing plants and mounds of soil.

It is recommended to fence off the parking area for the landfill equipment with a brick wall.

3.5.3 Disposal Area

The disposal area totalling an area of 26 ha is divided into landfill sections as shown in Drawing no. 3.

Each landfill section will be filled in accordance with the planned future terrain (see Drawing no. 2) which will take 2-3 years to reach its maximum capacity. In this way the leachate generation will be minimised.

Complying with projections for the waste quantities and the recommended capacities of the landfill sections, the time taken for constructing and operating each landfill section are presented in the following table.

Table 3-17: Capacity and Year of Construction/Operation of the Landfill Sections.

Section No.	Capacity of Section (m^3)	Year of Construction	Disposal Period (year)
1A	900,000	1999	2000-2002
1B	700,000	1999	2003-2004
2	1,000,000	2004	2005-2007
3	900,000	2007	2008-2010
Total	3,500,000	-	2000-2010

The disposal area will be constructed according to Level 2 standard i.e. sanitary landfill without a bottom liner and with percolation of leachate to the ground water/Indian Ocean. (refer to Section 3.4):

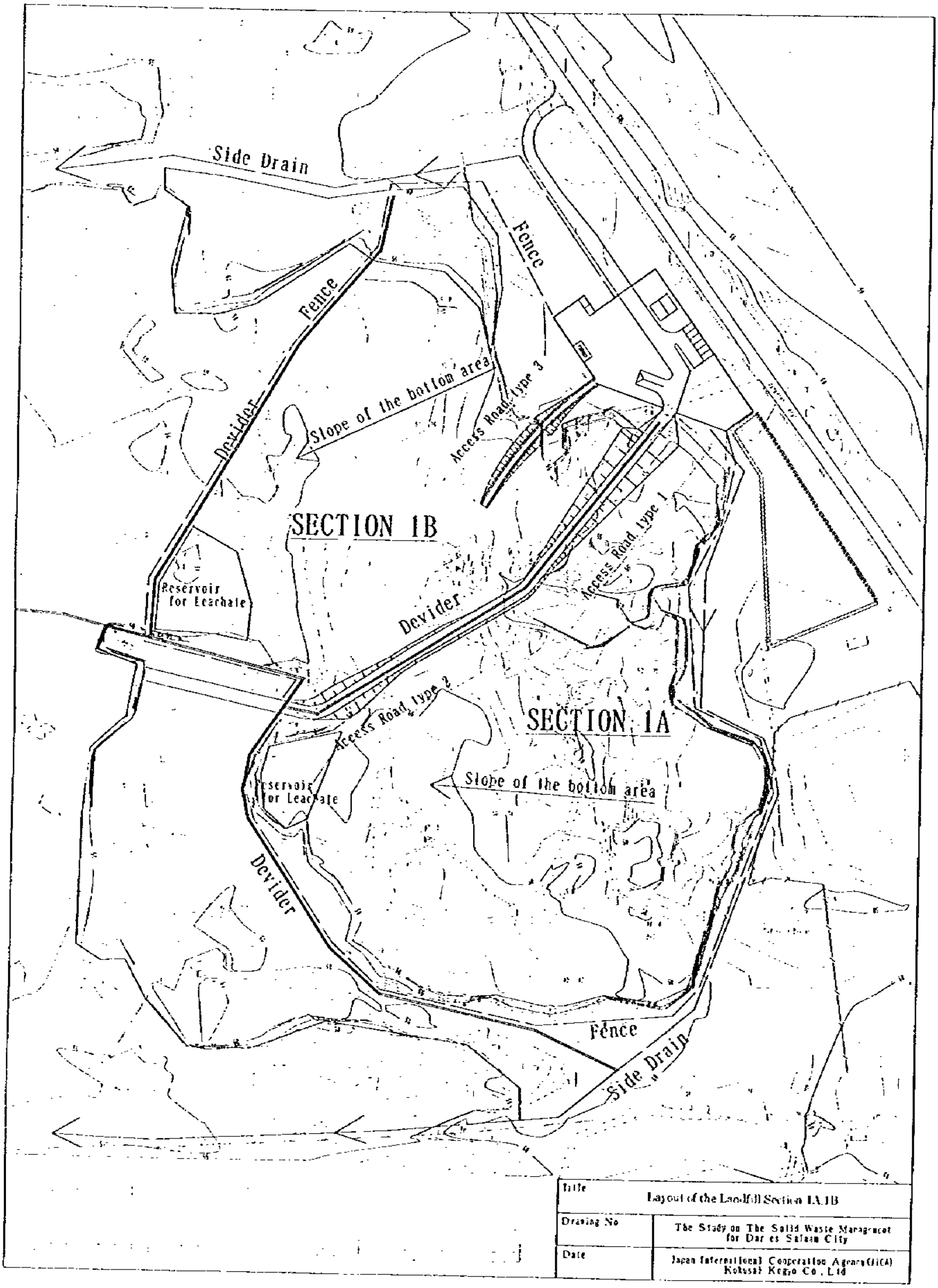
Drawing Nos. 6 and 7 show the earthworks to be carried out for Landfill Sections 1A and 1B. Each landfill section is delimited by:

- escarpments which can reach up to 10 m in the present quarry. To prevent gas from diffusing, the escarpments are covered by a permeable layer of sand. The lower part of this sand filling will be constructed when levelling the bottom for the landfill section, (refer to Section b, Drawing no. 6). The upper part of the sand filling will be constructed when the landfill is in operation

- embankments that will be constructed between the landfill sections. The embankments will be at least 1.5 m high and will be connected to leachate drains at the foot of the embankment, leachate is therefore prevented from seeping to areas that are not yet ready for waste disposal. (refer to Section a, Drawing no. 6).

To prevent leachate from penetrating the embankments especially during the rainy season, leachate drains will be constructed along them. The drains discharge leachate to reservoirs as shown in Drawing no. 6. From the leachate reservoirs, the leachate percolates into the ground or will be evaporated.

The leachate drains are to be constructed from well graded gravel. They consist of an inner coarse gravel core surrounded by gravel filters with a smaller grain size to prevent particles from clogging up the drains. The leachate drains are additionally furnished with a drainage pipe. The drains constructed from gravel ensures stability even when a large quantity of waste is deposited on top of the drains.



Title	Layout of the Landfill Section 1A,1B
Drawing No	The Study on The Solid Waste Management for Dar es Salaam City
Date	Japan International Cooperation Agency(JICA) Kokusai Kogyo Co., Ltd

3.5.4 Ditches for Run-off Water from the Surroundings

Clean run-off water from surroundings must be diverted from the disposal area in order to restrict the generation of leachate. Thus, a system of ditches is to be constructed along the edge of the quarry excavation that will be used for Landfill Section 1 (see Drawing no. 6). The system of ditches will be extended when a new landfill section is constructed.

3.5.5 Monitoring Boreholes

The construction of two boreholes for monitoring ground water east of Bagamoyo Road is recommended, i.e. downstream from the landfill. The required depth of the boreholes is estimated at 35 m.

In order to acquire sufficient information on the background quality of the ground water, the boreholes must be constructed prior to or at the same time as the construction works for the landfill.

Monitoring of ground water will be carried out as described in Section 6.

3.5.6 Precautions Against Gases

The feasibility of using biogas from the landfill shall be assessed when it has stored enough waste for its production.

However, the use of biogas from the landfill will probably be unfeasible, and that the landfill shall be equipped with installations for controlled exhaustion of gas into the atmosphere.

Such installations are constructed during the operation of the landfill and when covering the landfill with a final soil layer. The installations are presented in Drawing No. 7. They inlude:

- a sand filling along the embankments of the present quarry; it prevents gas from diffusing through the soil to neighbouring areas.
- a system of ventilated gas pipes constructed along the border of the disposal area and at the top of the future waste hill.
- final soil coverage enabling some biodegradation of methane and odourous gases. The soil coverage is underlain by a layer of sand to prevent pressure accumulating and uncontrolled diffusion of gas.

3.5.7 Final Soil Coverage

When the planned height and shape of the landfill have been reached, it will be covered by a final layer of soil allowing plant life to grow.

During the final filling of a landfill section, attention must be paid to the following aspects.

- Due to the biodegradation of the waste, some settling is expected to take place after the final soil coverage has been carried out. Ten percent settlement of well-compacted waste is considered normal.

- Slopes should not be steeper than 1:3 due to varying shear strength of the waste and to avoid soil erosion caused by heavy rain.
- The final soil coverage should be carried out without any shallow depressions in order to minimise filtration of rain-water into the waste.

The recommended final soil coverage is presented in Drawing no. 7. It consists of soil at least 1 m deep and an underlying layer of sand that is vented to prevent uncontrolled diffusion of gas. It is advisable to include compost in the upper 0.2 m of the final soil coverage to improve fertility.

Ditches will be constructed as required to prevent soil erosion on steep slopes caused by heavy rain.

Most of the soil required for the final coverage will be excavated on site when preparing further landfill sections, thereby, maximising the landfill volume.

3.5.8 Landfill Equipment

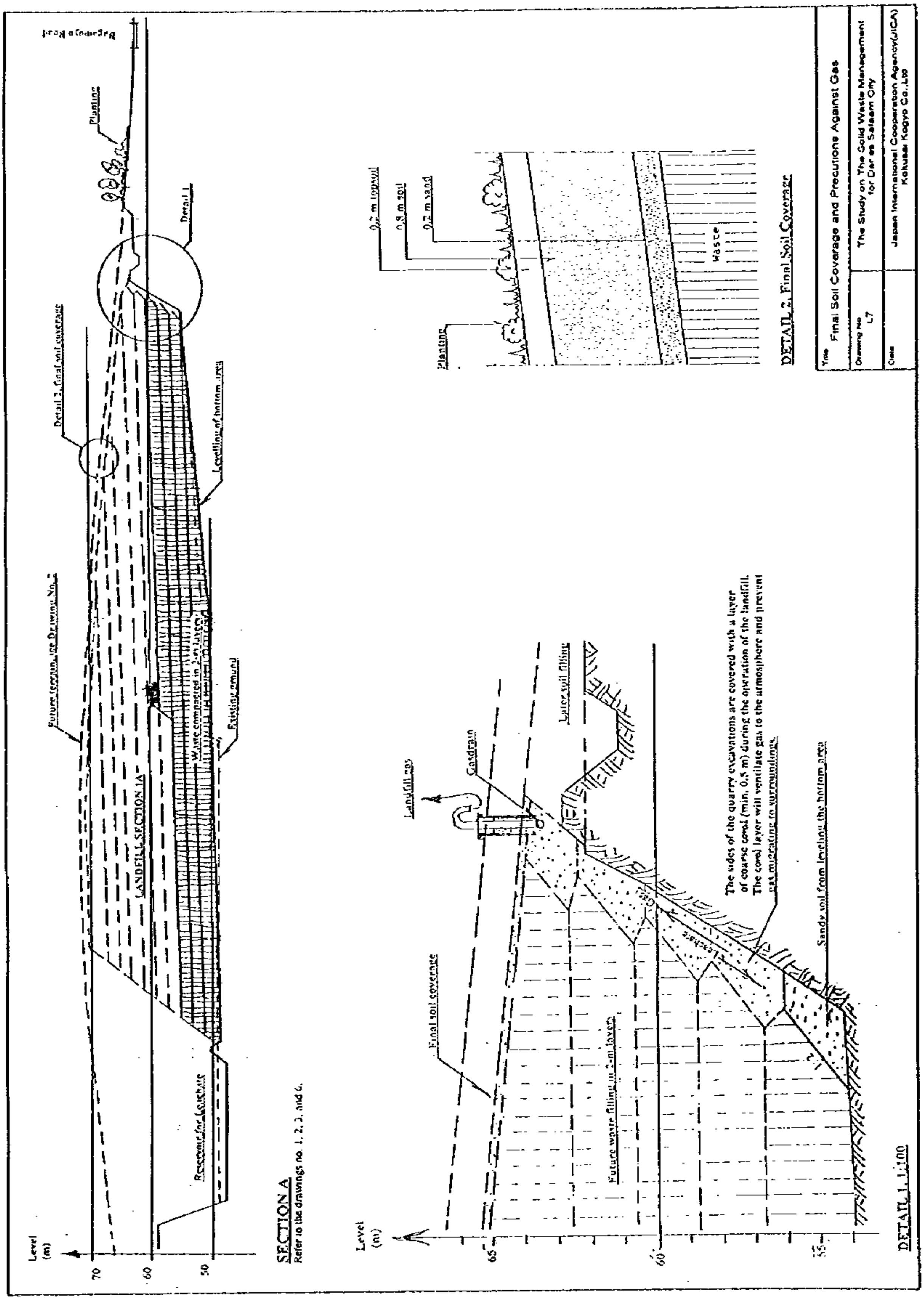
Permanent equipment recommended for the sanitary landfill comprises:

- two bulldozers for waste disposal (no less than 20 tonnes).
- one excavator for excavation and loading of soil for daily soil coverage.
- two dump trucks for transporting soil for the daily soil coverage and sand (precaution against gas) for filling along the edge of the quarry.
- One water tanker for sprinkling roads inside the landfill site during dry spells.

The waste produced in Dar es Salaam can be adequately handled and compacted using a bulldozer working from the bottom of the tipping face and moving up and down the slope, spreading the waste in progressive layers, each layer being no more than 0.3 m thick. The greater the number of waste layers, the better the compaction, but operational considerations generally limit the number of layers to between two and six.

The bulldozers are required as compaction of waste is a prerequisite for proper landfilling - not only because carefully compacted waste prevents nuisances such as pests and spontaneous combustion, but also because the landfill volume is utilised optimally.

Because of the high density and moisture content of the waste produced in Dar es Salaam, the use of landfill compactors on the landfill is not recommended. These machines were developed to achieve high in-place densities on landfills in industrialised countries where composition of the waste is considereably different (it is much less dense) and has a lower moisture content.


SECTION A
Refer to the drawings no. 1, 2, 3, and 6.
Level (m)
70
60
50
Reservoir for Leachate
LANDFILL SECTION 1A
Future terrain, see Drawing No. 2
Existing ground
Levelling of bottom area
Detail 2, final soil coverage
Detail 1
Planting
Bagamoyo Road
DETAIL 1, 1:100
Level (m)
65
60
55
Final soil coverage
Future waste filling in 2-m layers
Landfill gas
Gasdrain
Later soil filling
Leachate
Sandy soil from leveling the bottom area
The sides of the quarry excavations are covered with a layer of coarse coral (min. 0.5 m) during the operation of the landfill. The coral layer will ventilate gas to the atmosphere and prevent gas migrating to surroundings.
DETAIL 2, Final Soil Coverage
Planting
0.2 m topsoil
0.8 m soil
0.2 m sand
Waste
Title
Final Soil Coverage and Precautions Against Gas
Drawing No.
L7
The Study on The Solid Waste Management for Dar es Salaam City
Japan International Cooperation Agency (JICA)
Kokusai Kogyo Co., Ltd.

3.5.9 Time Schedule for Construction Works

The following time schedule provides a summary of the construction works to be carried out for Landfill Sections 1A, 1B and the reception area.

Table 3-18: Time Schedule for Construction Works,Landfill Sections 1A, 1B, and Reception Area

	Month								
Activity	1	2	3	4	5	6	7	8	9
Clearing of site	X								
Reception Area									
- Earthworks	X	X							
- Drainage and sewerage		X	X						
- Track for bulldozers						X			
- Weighbridge				X	X	X		X	X
- Brick wall				X	X	X	X	X	
- Lighting									X
- Pavements							X	X	X
Buildings									
- Administration building		X	X	X	X	X			
- Garage							X	X	
Landfills Sections 1A and 1B									
- Excavation of bottom area and construction of embankments		X	X	X	X	X	X		
- Leachate drains				X	X	X	X	X	
Others									
- Power supply	X	X							
- Water supply from Mtongani				X	X	X	X		
- Fences and planting								X	X
- Monitoring boreholes			X	X	X				
Hand-over and start disposal									X

3.6 Operation of the Disposal Site

3.6.1 Crew Plan

It is proposed that the sanitary landfill should be operated by the following full time employees.

- A site manager having the overall financial responsibility and managerial duties, including:
  a. management and supervision of operations, maintenance of landfill equipment, and performance of control procedures, e.g. registration of waste and control of ground water.

  b. planning of future extensions to the landfill, e.g. the construction of further landfill sections and preparation of new excavation areas for soil coverage.

- A weighbridge operator.
- An inspector undertaking the control of the flow of trucks to the weighbridge and guiding trucks to the correct site for unloading.
- Operators of landfill equipment. The operators are responsible for the operations at the disposal area (e.g. compaction and daily soil coverage of waste) and the preventive maintenance of landfill equipment.
- Workers undertaking any job, including maintenance and cleaning at the landfill.
- Security guard responsible for the security of buildings and landfill equipment.

The opening hours of the sanitary landfill are proposed to be the same as those of the landfill in Vingunguti, i.e.:

- Monday - Saturday : 07.30 - 18.00
- Sunday and public holidays: closed

3.6.2 Daily Operations

a. Registration and Control at the Weighbridge

All trucks will be registered upon arrival at the reception building. The information recorded at the weighbridge will include:

- registration number of the truck.
- type of waste.
- quantity of waste
- origin of the waste (district, address of industry, institution etc.).

The staff at the reception building will undertake in preliminary control of the waste. Special attention will be paid to chemicals and hazardous waste which is not allowed on the sanitary landfill. These types of waste should be rejected on inspection and if there are suspicious cases, it should be further examined during the unloading at the tipping front.

After registration, the truck will be directed to the unloading area. Appropriate signposting must clearly indicate the correct route and place. While being unloaded, the waste should be checked again by the operators of the landfill equipment. If the waste is unsuitable for landfilling, the truck driver is obliged to remove the waste. Radio contact between the reception building and the operators of the landfill equipment ensures that certain suspicious looking loads will be controlled thoroughly.

Incoming soil as well as construction and demolition waste should be directed to a soil deposit. In that way, it may be used for daily coverage of waste or for construction of temporary roads in the disposal area.

b. Waste Disposal and Daily Soil Coverage

Upon unloading at the tipping front, the waste will be compacted into 0.3 m layers on top of each other forming a daily waste layer of approximately 2 m.

At the end of each working day, the layer of waste and the tipping front and flanks will be covered by a thin layer of soil (10-15 cm). The main purpose is to minimise nuisances (odour, scattered paper and pests).

In order to minimise the quantity of soil required for daily soil coverage, as well as potential problems with odour, pests, etc., the unloading of waste must be confined to a small tipping area as possible.

The soil for daily coverage must at any time be available in stock situated close to the tipping front. The soil will be excavated from areas where further landfill sections will be constructed or it is brought in by incoming trucks.

c. Treatment of Leachate

Level 2 sanitary landfills do not require any treatment of leachate.

The leachate will partly evaporate or will drain into the ground and flow with the saline ground water into the Indian Ocean.

d. Other Operations

Tidiness of the landfill and its surroundings must be maintained. Care must be taken to remove litter from roads and scattered materials must be collected on a regular basis.

In cases of spontaneous combustion, immediate extinction using soil must be effected. No fires should be started deliberately.

Unauthorised persons including scavengers should be prohibited from the landfill and must be denied access.

3.6.3 Control Procedures

To ensure that the landfill does not impose any negative impact on the surroundings, the sanitary landfill must be supervised regularly and monitored. Reports on the monitoring should be available at any time for inspection by authorities.

The monitoring programme should include issues described below.

a. Waste Control

Ongoing monitoring of waste is to be carried out at the weighbridge. Monthly and annual reports based on registration of waste should be prepared.

b. Monitoring Programme for Ground Water and Leachate

Monitoring should be carried out to closely watch for changes in ground water and leachate qualities.

The recommended monitoring programme is described in the following table. The frequency and the parameters may be altered in accordance with the changes in the leachate and ground water quality.

The ground water in the borehole should be monitored once a year in order to detect changes in the ground water quality.

Routine monitoring of the leachate quality should be carried out regularly for each landfill section. The leachate should be subject to a comprehensive analysis including other parameters, e.g. heavy metals which should take place frequently, say once a year.

Table 3-19: Proposed Monitoring Programme for Ground Water and Leachate.

Parameter	Ground water	Frequency per year	Leachate	Frequency per year
pH			X	2
Conductivity	X	1	X	2
Dry matter	X	1	X	2
NH_4			X	2
Cl	X	1	X	2
SO_4^{--}	X	1	X	1
Fe	X	1	X	1
BOD			X	2
COD	X	1	X	2

Note: The programme may be extended if suspicion of pollution arise.

The parameters for monitoring ground water will be decided on the basis of the ground water quality and the polluting compounds found in the leachate. Thus, for later reference, the ground water must be analysed before the opening of the sanitary landfill.

c. **Control of Surface Waters**

The sanitary landfill is expected to have no impact on the seasonal stream west of the landfill. However, it is recommended that the stream is inspected regularly and appropriate action taken in case of any suspicion of pollution from the landfill.

3.6.4 Operation Manual and On the Job Training

A detailed operation manual should be prepared and made available to all staff at the sanitary landfill as well as to management and authorities. The manual should describe all daily routines as well as actions to be taken in case of emergency e.g. defective equipment, fires, accidents etc.

Further, the manual should include, but not be limited to the following items: ownership of the landfill, responsibility for the proper operation of the landfill, restrictions regarding waste reception, principles for the arrangement and functioning of the landfill, operational and maintenance procedures, monitoring procedures, precautions against environmental nuisances, actions in case of accidents, etc.

The operation manual must be read by the entire staff before the operation of the sanitary landfill is initiated and later on by all new employees.

Further, proper operation of the landfill should be ensured by on the job training of all personnel, thus assuring personnels' full understanding of the biological processes, potential hazards and methods of minimising environmental impact.

3.7 Examination on Predicted Pollution Sources

Since a very large quantity of waste is disposed of on a very limited area, a great number of physical, chemical, and biological processes take place within a landfill to decompose the waste. The residues (e.g. leachate and gas) from these processes may, if not collected and treated, pollute the environment.

This section provides a description of sources and precautions taken against pollution from the sanitary landfill in Kunduchi. The sources of pollution from the landfill are as follows.

- Leachate
- Gas
- Dust, odour, windblown waste and pests
- Fires
- Sanitary waste water
- Noise

The recommended design of the landfill is planned to minimise the environmental impacts. Therefore, many of the following paragraphs refer to previous descriptions.

3.7.1 Leachate

Leachate is polluted water which is generated when it seeps through waste.

3.7.2 Forecast for the Leachate Quantity

The quantity of leachate that is generated in a landfill section is estimated using the following equation:

$Q = A \times (N - E_a - Q_R - Q_A) \times 10^{-3}$, where:

- Q is the leachate quantity in m^3/year
- A is the area of the landfill section in m^2 (see below).
- N is precipitation. The annual average precipitation in the Dar es Salaam area is estimated at 1150 mm/year (refer to Section 3.8).
- E_a is the actual evaporation:
  - E_a for a landfill section during operation is estimated at 700 mm/year in the Dar es Salaam area (refer to Section 3.8).
  - E_a for a landfill section with final soil coverage and surface vegetation is estimated at 900 mm/year in the Dar es Salaam area (refer to Section 3.8).
- Q_R is the quantity of run-off water from the landfill.
  - QR is estimated at 0 mm/year for landfill sections during operation.
  - QR is estimated at 200 mm/year for landfill sections with final soil coverage and vegetation.
- Q_A is the quantity of water absorbed by the waste.
  - Q_A is estimated at 100 mm/year for landfill sections during operation.

- Q_A is estimated at 0 mm/year for landfill sections with final soil coverage and vegetation.

The sanitary landfill in Kunduchi will be divided into 4 sections, each with a planned filling period of 2-3 years. Each landfill section is filled up according to the planned future terrain and given a final soil coverage before filling in a new landfill section. In this way, the total landfill area with waste rain water is kept to a minimum. Hence, the generation of leachate is kept to a minimum.

Forecasts regarding size and type of surface cover of the landfill sections are provided in the following Table. Reference is made to Section 3.5 regarding sizes and periods of operating the landfill sections.

Table 3-20: Forecast for the Size and Soil Coverage of Landfill Sections

		Landfill Section				
Year	Soil Coverage	1A (ha)	1B (ha)	2 (ha)	3 (ha)	Total (ha)
2000	Open	6				6
	Final soil coverage					
2001	Open	6				6
	Final soil coverage					
2002	Open	6				6
	Final soil coverage					
2003	Open		5			5
	Final soil coverage	6				6
2004	Open		5			5
	Final soil coverage	6				6
2005	Open			8		8
	Final soil coverage	6	5			11
2006	Open			8		8
	Final soil coverage	6	5			11
2007	Open			8		8
	Final soil coverage	6	5			11
2008	Open				7	7
	Final soil coverage	6	5	8		19
2009	Open				7	7
	Final soil coverage	6	5	8		19
2010	Open				7	7
	Final soil coverage	6	5	8		19
Later years	Open					
	Final soil coverage	6	5	8	7	26

Figure 3-4 provides a forecast for the leachate generation assuming an annual average leachate generation of 350 mm/year (1150-700-0-100-0 mm/year) from the sections during operation and at 50 mm/year (1150-900-200-0-0 mm/year) from completed sections with final soil coverage and surface vegetation.

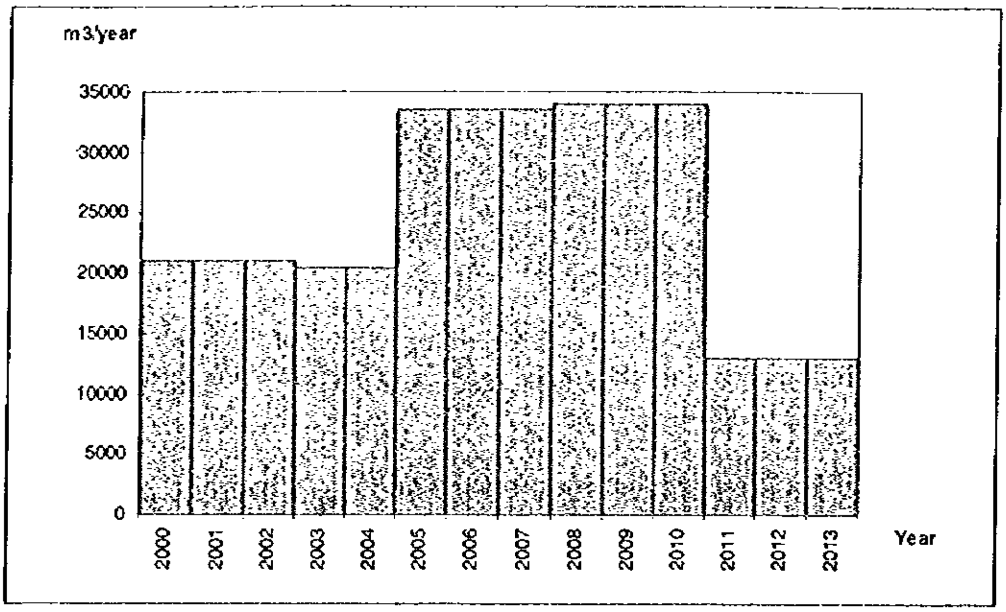


Figure 3-4: Forecast for the Annual Leachate Generation

It should be noted that annual leachate generation may vary considerably from year to year, furthermore, the leachate generation fluctuates throughout the year. Thus, it is assumed that 50 - 100 % of the leachate generation will occur during April and May.

3.7.2.1 Forecast for the Leachate Composition

The following Table presents the typical compositions of "young leachate" from 2-5 year old landfill sections and "old leachate" from older landfill sections. The compositions are based on experience from Japanese and European sanitary landfills receiving municipal solid waste only, i.e. mainly waste from households.

A substantial variation in the leachate composition is usual from landfill to landfill, depending on the actual type of waste being disposed of. However, it is assumed that the composition of leachate from the landfill in Kunduchi will be similar to the compositions presented in Table 3-21.

Table 3-21: Forecast for the Leachate Composition.

Typical leachate composition	'Young leachate'	'Old leachate'
pH	6-7	7-8
BOD_5 mg/l	15,000	200
COD mg/l	21,000	2,000
NH_4-N mg/l	900	900
Total-N mg/l	1,000	1,000
Total-P mg/l	max. 15	max. 15
Chloride, Cl mg/l	2,000	2,000
Sodium, Na mg/l	1,500	1,500
Calcium, Ca mg/l	1,200	100
Sulphate, SO^{2-}_4 mg/l	500	20
Sulphide, S mg/l	0	- varies -
Iron, Fe mg/l	500	25
Zinc, Zn mg/l	max. 10	max. 0.5
Lead, Pb mg/l	max. 0.5	max. 0.05
Chromium, Cr mg/l	max. 0.5	max. 0.05
Cadmium, Cd mg/l	max. 0.1	max. 0.01

Source: RAMBOLL's (Danish consultants) experience from supervision of many landfills receiving municipal solid waste (i.e. not including cinders/fly ash from waste incineration). Also reference is made to DS-Recommendation DS/R 466 table C1.1.

3.7.3 Landfill Gas

The biological processes in a landfill with municipal solid waste result in the generation of biogas (a water saturated mixture of methane (CH_4, 40-55% vol.), carbon dioxide (CO_2, 30-40% vol.), nitrogen (N_2, 10-20%), and in small quantities odorous and other gases). The theoretical quantity of biogas generated during the degradation of kitchen waste is estimated at 150-200 litres per kilo of dry waste.

However, a large proportion of the biogas is generated while the landfill is in operation, and experience has shown that only 10-40 % of the total gas generation can be extracted and exploited. Thus, it is expected that the use of biogas from the landfill will not be economical, and that the landfill shall be furnished with installations for controlled ventilation of gas to the atmosphere. Using biogas from the landfill shall be assessed once the landfill has stored enough waste for its production.

Since uncontrolled diffusion of gas from the landfill may result in spontaneous combustion and damage to vegetation, it is exhausted in a controlled manner into the atmosphere. The controlled venting of the landfill gas is required for safety reasons (i.e. because of a possible future proximity to residential buildings).

Thus, the sides of the landfill are furnished with a permeable layer of sand that is connected to the outside by a number of gas vents (refer to Drawing No. 7).

3.7.4 Dust, Odour, Wind-blown Paper, and Pests

During the operation of a landfill, nuisances may be created from dust, odour, scattered paper and pests. These nuisances are most likely to occur if the waste is not handled properly, i.e. if large tipping fronts are not covered with soil and if waste is not compacted.

a. Precautions Against Dust, Odour, Wind-blown Paper and Pests

The landfill will be operated with a relatively small tipping front, and the waste will be covered in soil daily. After unloading at the tipping front, the waste will be compacted into layers no more than 2m thick. Each layer and the daily front and flank will be covered by a thin (10-15 cm) layer of soil to prevent insects, birds, wind etc. from gaining access to the waste.

A mobile fence should be erected near the current tipping front, and airborne waste should be frequently removed from the fence and the surroundings.

Littering of public roads caused by dirty trucks will be limited by cleaning them at the washing yard before leaving the landfill.

3.7.5 Fire

In case of fire, large quantities of environmentally harmful gasses, dust, etc. such as dioxin, is emitted from uncontrolled and incomplete fires. Therefore, no fires are allowed on the landfill.

At a well-controlled and operated sanitary landfill spontaneous combustion is very rare. This is due to the relatively small tipping front, the compaction, and the daily soil coverage of the waste.

Fires should be extinguished by covering with soil in order to confine and stop the fire from spreading.

3.7.6 Noise

The possible sources of noise from the landfill are:

- incoming trucks.
- trucks dumping waste on the landfill.
- bulldozers working on the landfill.
- bulldozers, excavators etc. preparing new landfill sections.

The soil embankments at the landfill as well as the plantation will contribute towards noise reduction at the landfill. Furthermore, it is recommended that the landfill equipment should be equipped with adequate silencers.

3.7.7 Sanitary Waste Water

A relatively small quantity of sanitary waste water will be generated from the staff facilities at the waste reception area. Septic tanks, as required, will be provided.

3.8 Costs Estimates

The following cost estimates meets the construction and operation costs of the sanitary landfill in Kinduchi constructed and operated at Level 2: Sanitary landfill without a bottom liner and with percolation of leachate to the ground water/Indian Ocean.

The estimates are based on preconditions as follows.

- The estimates do not include costs for the procurement of land.

- The estimates do not include costs for consultancy services/design and supervision.
- The estimates are based on unit prices obtained in Dar es Salaam as of February 1997.
- The estimates are based on Tanzanian prices as of February 1997

  1 USD = 600 Tsh (Tanzanian Shillings).

3.8.1 Construction Costs

The cost estimate presented in Table 3-22 meets the construction costs for the initial investments in roads, buildings, and other installations that will be utilised throughout the operation period (2000 to 2010) of the landfill.

Table 3-22: Initial Investments in Reception Area, Buildings, and Other Facilities

Item	Unit	Quantity	Unit Price	Tsh
Reception area				
• Clearing of site	m2	8,000	500	4,000,000
• Earthwork	m3	2,000	2,000	4,000,000
• Drainage and sewerage	LS	1	5,000,000	5,000,000
• Access road (asphalt pavement)	m2	2,000	30,000	60,000,000
• Weighbridge including computer	nos	1	50,000,000	50,000,000
• Parking area (asphalt pavement)	m2	400	30,000	12,000,000
• Washing yard (asphalt pavement)	m2	150	30,000	4,500,000
• Cutting and filling	m3	3,000	12,000	36,000,000
• Water Supply from Mrongani	LS	1	30,000,000	30,000,000
• Power supply including sub-station	LS	1	22,500,000	22,500,000
• Illumination	LS	1	3,000,000	3,000,000
Buildings				
Reception building	m2	150	300,000	45,000,000
Garage	m2	50	150,000	7,500,000
Other				
• Brick wall (2m high) and gates	m	350	50,000	17,500,000
• Tank installation for diesel	LS	1	5,000,000	5,000,000
• Monitoring boreholes, each 35 m deep	nos	2	4,500,000	9,000,000
• Planting	m2	5,000	500	2,500,000
Overhead 30 %				**85,200,000**
Total, excluding procurement of land and provision of consultancy services				**402,700,000**

Table 3-23 and Table 3-24 present the construction costs for Landfill Sections 1A and 1B in accordance with Level 2 standards. The landfill sections are expected to be constructed in 1999.

Landfill Section 1A comprises a disposal area of 6 ha, a capacity of 900,000 m^3 and a life span of 2.5 years assuming all waste collected in Dar es Salaam is disposed of at the landfill in Kunduchi.

Landfill Section 1B comprises a disposal area of 5 ha, a capacity of 700,000 m^3 and a life span of 2 years.

Table 3-23: Construction Costs for Landfill Section 1A

Item	Unit	Quantity	Unit Price	Tsh
Earthwork				
Clearing or site	m2	60,000	200	12,000,000
Excavation and leveling of the bottom area	m3	60,000	1,500	90,000,000
Excavation for the leachate reservoir	m3	3,000	6,000	18,000,000
Construction of embankments	m3	7,900	4,500	35,550,000
Construction of leachate drain	m	300	40,000	12,000,000
Other				
Ditch for run-off water	m	600	3,000	1,800,000
Fences	m	800	25,000	20,000,000
Overhead, 30 %				43,890,000
Total, excl. procurement of land and provision of consultancy services				233,240,000

Table 3-24: Construction Costs for Landfill Section 1B.

Item	Unit	Quantity	Unit Price	Tsh
Earthwork				
Clearing or site	m2	50,000	200	10,000,000
Excavation and leveling of the bottom area	m3	50,000	1,500	75,000,000
Excavation for the leachate reservoir	m3	3,000	6,000	18,000,000
Construction of embankments	m3	7,000	4,500	31,500,000
Construction of leachate drain	m	250	40,000	10,000,000
Other				
Ditch for run-off water	m	350	3,000	1,050,000
Fences	m	500	25,000	12,500,000
Overhead, 30 %				37,065,000
Total, excl. procurement of land and provision of consultancy services				195,115,000

3.8.2 Operation Costs

Assuming all waste collected in Dar es Salaam is disposed of at the landfill in Kunduchi (740 tons/day in year 2000 and 1150 tons/day in year 2002), Table 3-25 presents the average annual operation costs for Landfill Section 1A in accordance with Level 2: "Landfill without bottom liner and with percolation of leachate to the ground water/Indian Ocean".

Table 3-25: Operation Costs for Landfill Section 1 A

Item	Description	unit	2000	2001	2002	2003	2004	2005
Required Quantity								
Labour	Landfill manager	persons	1	1	1	1	1	1
	Foreman	persons	2	2	2	2	2	2
	Operator	persons	6	6	7	7	7	7
	Weighbridge operator	persons	3	3	3	3	3	3
	Mechanic	persons	1	1	1	1	1	1
	General worker	persons	12	12	12	12	12	12
	Watchmen	persons	3	3	3	3	3	3
Material	Diesel	l/d	510	510	660	660	660	660
Others	Gas removal	LS	1	1	1	3	3	3
Operation Cost								
Labour	Landfill manager	M.Tsh	2	2	2	2	2	2
	Foreman	M.Tsh	2	2	2	2	2	2
	Operator	M.Tsh	6	6	7	7	7	7
	Weighbridge staff	M.Tsh	3	3	3	3	3	3
	Mechanic	M.Tsh	1	1	1	1	1	1
	General worker	M.Tsh	6	6	6	6	6	6
	Watchmen	M.Tsh	1	1	1	1	1	1
	Sub-total		20	20	21	21	21	21
Material	Diesel		44	44	57	57	57	57
	Oil		4	4	6	6	6	6
	Miscellaneous		16	22	29	29	29	29
	Sub-total		64	70	92	92	92	92
Maintenance Cost								
Equipment		th USD	100	100	125	125	125	125
		M.Tsh	60	60	75	75	75	75

3.8.3 Later Investments

a. Final Soil Coverage of Landfill Section 1A

Most of Landfill Section 1A have a final soil cover including the required installations for gas ventilation in 2002 when Landfill Section 1B is opened. These works may to a greater extent be carried out by their own landfill equipment, but are included as if carried out by a contractor.

Table 3-26: Final Soil Coverage of Landfill Section 1A in Year 2002.

Item		Quantity	Unit Price	Tsh
Final soil coverage of Landfill Section 1A				
- 0,2 m gravel/sand layer	m2	60.000	2.000	120.000.000
- 1m soil coverage	m2	60.000	3.000	180.000.000
- Planting	m2	60.000	500	30.000.000
- Gas drains	m	600	2500	1.500.000
- Manholes for gas ventilation	nos.	13	100.000	1.300.000
Overhead, 30%				99.840.000
TOTAL, excl. procurement of land and provision of consultancy services				432.640.000

b. Landfill Section 2 and Final Soil Coverage of Landfill Section 1B.

Landfill Section 2 is to be constructed in the year 2004. Section 2 comprises a disposal area of 8 ha, a capacity of 1,000,000 m^3 and a life span of 3.5 years. It is assumed that Landfill Section 1B will be furnished with final soil coverage when constructing Landfill Section 2.

Table 3-27: Construction Costs for Landfill Section 2 and Final Soil Coverage of Landfill Section 1B in Year 2004.

Item		Quantity	Unit Price	Tsh
Earthworks for Landfill Section 2				
- Clearing of site	m2	80.000	200	16.000.000
- Excavation and leveling of the bottom area	m3	13.000	6.000	78.000.000
- Excavation for the leachate reservoir	m3	3.000	6.000	18.000.000
- Construction of embankments	m3	7.000	4.500	31.500.000
- Construction of leachate drain	m	300	40.000	12.000.000
Other				
- Fences	m	500	25.000	12.500.000
- Ditches for run-off water	m	300	3.000	900.000
Final soil coverage of Landfill Section 1B				
- 0,2 m gravel/sand layer	m2	50.000	2.000	100.000.000
- 1m soil coverage	m2	50.000	3.000	150.000.000
- Planting	m2	50.000	500	25.000.000
- Gas drains	m	500	2500	1.250.000
- Manholes for gas ventilation	nos.	11	100.000	1.100.000
Overhead, 30%				133.875.000
TOTAL, excl. procurement of land and provision of consultancy services				**580.125.000**

c. Landfill Section 3 and Final Soil Coverage of Landfill Section 2.

Landfill Section 3 is to be constructed in the year 2007. The Landfill Section has a disposal area of 7 ha, a capacity of 900,000 m^3 and a lifetime of 3 years. It is assumed that Landfill Section 2 will be furnished with final soil coverage when constructing Landfill Section 3.

Table 3-28: Construction Costs for Landfill Section 3 and Final Soil Coverage of Landfill Section 2 in Year 2007.

Item		Quantity	Unit Price	Tsh
Earthworks for Landfill Section 3				
- Clearing of site	m2	70.000	200	14.000.000
- Excavation and leveling of the bottom area	m3	12.000	6.000	72.000.000
- Excavation for the leachate reservoir	m3	3.000	6.000	18.000.000
- Construction of embankments	m3	6.000	4.500	27.000.000
- Construction of leachate drain	m	300	40.000	12.000.000
Other				
- Fences	m	500	25.000	12.500.000
- Ditches for run-off water	m	300	3.000	900.000
Final soil coverage of Landfill Section 2				
- 0,2 m gravel/sand layer	m2	80.000	2.000	160.000.000
- 1m soil coverage	m2	80.000	3.000	240.000.000
- Planting	m2	80.000	500	40.000.000
- Gas drains	m	800	2500	2.000.000
- Manholes for gas ventilation	nos.	17	100.000	1.700.000
Overhead, 30%				180.030.000
TOTAL, excl. procurement of land and provision of consultancy services				780.130.000

d. Final Soil Coverage of Landfill Section 3

Landfill Section 3 is assumed to be furnished with final soil coverage in the year 2011. The following cost estimate meets the construction costs.

Table 3-29: Costs Estimate for Final Soil Coverage of Landfill Section 3 in Year 2011.

Item		Quantity	Unit Price	Tsh
Final soil coverage of Landfill Section 3				
- 0,2 m gravel/sand layer	m2	70.000	2.000	140.000.000
- 1m soil coverage	m2	70.000	3.000	210.000.000
- Planting	m2	70.000	500	35.000.000
- Gas drains	m	700	2500	1.750.000
- Manholes for gas ventilation	nos.	15	100.000	1.500.000
Overhead, 30%				116.475.000
TOTAL, excl. procurement of land and provision of consultancy services				504.725.000

e. Operation Costs, Later Investments

Based on the cost estimate for operating Landfill Section 1A receiving 740 tons/day in year 2000 and 1150 tons/day in year 2002 (refer to Table 3-25), cost estimates for operating later landfill sections are as follows.

Table 3-30: Average Operation Costs for the Landfill Sections

Landfill Section	Average Waste Quantity tons/day	Average Operation Costs Tsh/year
1A	840	115,000,000
1B	815	110,000,000
2	645	90,000,000
3	720	100,000,000

3.8.4 Summary of Investments

The following table provides a summary of the investments required for the sanitary landfill in Kunduchi in accordance with a Level 2 landfill.

Table 3-31: Summary of Investments for the Sanitary Landfill at Kunduchi (Capacity 3.5 mill m^3) constructed and operated in accordance with concept, **Level 2: "Landfill without bottom liner and with percolation of leachate to the ground water/Indian Ocean".**

	Investment and Year (mill. Tsh, Price Level February 1997)													
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Operation Period, section			←	1A	→	1B	↔		2	→		3	→	
Construction Costs:														
Procurement of land.	-													
Access road, reception area, and buildings		403												
Construction of landfill section 1A and 1B		428												
Final soil coverage and gas drainage for landfill section 1A					430									
Construction of landfill section 2 and final soil coverage and gas drainage for landfill section 1B.							580							
Construction of landfill section 3 and final soil coverage and gas drainage for landfill section 2.										780				
Final soil coverage and gas drainage for landfill section 3.														500
Operation Costs:														
Salary, diesel, maintenance, and monitoring			144	150	188	133	135	139	140	140	140	140	140	
TOTAL	-	831	144	150	618	133	715	139	140	920	140	140	140	500

Chapter 4

Preliminary Design of Collection and Transportation System

4 Preliminary Design of Collection and Transportation System

4.1 Design Condition

a. Planned Waste Collection Amount

Table 4-1 shows the waste collection amount per day based on 7 days collection per week.

Table 4-1: Waste Generation and Collection Amount per Day Based on 7 Collections Days per Week

Category of Waste	Description	unit	2000	2001	2002	2003	2004	2005
Household	Generation	t/d	1,838	1,979	2,140	2,323	2,530	2,769
	Collection	t/d	380	535	705	705	705	705
	Collection Rate	%	20.7%	27.0%	33.0%	30.4%	27.9%	25.5%
Commercial	Generation	t/d	69	83	98	115	134	155
	Collection	t/d	49	66	88	88	88	88
	Collection Rate	%	70.0%	80.0%	90.0%	76.8%	65.8%	56.6%
Institution	Generation	t/d	13	14	15	17	18	20
	Collection	t/d	9	11	14	14	14	14
	Collection Rate	%	70.0%	80.0%	90.0%	82.9%	76.1%	69.6%
Market	Generation	t/d	78	92	108	125	145	168
	Collection	t/d	55	74	97	97	97	97
	Collection Rate	%	70.0%	80.0%	90.0%	77.3%	66.7%	57.6%
Street Sweeping	Generation	t/d	3	3	3	3	4	4
	Collection	t/d	3	3	3	3	3	3
	Collection Rate	%	100%	100%	100%	92%	85%	77%
Informal	Generation	t/d	299	305	314	324	335	348
	Collection	t/d	50	68	94	94	94	94
	Collection Rate	%	16.7%	22.3%	30.0%	29.1%	28.1%	27.0%
Total	Generation	t/d	2,300	2,476	2,678	2,906	3,165	3,464
	Collection	t/d	545	757	1,001	1,001	1,001	1,001
	Collection Rate	%	23.7%	30.6%	37.4%	34.4%	31.6%	28.9%

b. Average Transportation Distance to the New Kunduchi Disposal Site

Only the new Kunduchi disposal site is to be constructed as the first priority project. All wastes collected in DSM will be transported there for disposal. The average transportation distance from DSM to the New Kunduchi Disposal Site is determined as 18 km.

4.2 Planning the Collection and Transportation System

a. Productivity of Refuse Collection Vehicles

This section compares six different refuse collection trucks in terms of unit collection cost.

a.1 Equation for Calculating Productivity

The following equations were adopted for calculating productivity.

$$Tr = \frac{60 \times t1 - t2 \times E}{D \div V + t3 + t4}$$

Tr: Number of trips per day (trips)
D: Travel distance per trip (km)
V: Velocity of a vehicle (km/h)
t1: Working hours per day (hours)
t2: Time of daily service for inspection and fuelling, etc. (min)
t3: Time of loading waste (min)
t4: Time of unloading waste (min)
E: Work efficiency

$$Qd = q \times d \times f \times Tr$$

Qd: Waste carried per day
q: Volume capacity of a skip container or a tipping truck (m^3)
d: Density of waste when it is being transported (ton/m^3)
f: Work efficiency

a.2 Determination of Refuse Collection Truck Productivity

Table 4-2: Productivity Determination

Items	unit	Skip truck			Tipper truck			Compactor
Capacity in weight	t	4	8	10	4	6	8	4
Capacity in volume	m^3	5	8	12	6	10	15	8
One trip distance	km	36	36	36	36	36	36	36
Velocity of vehicle	km/h	40	40	40	40	40	40	40
Density of waste when transported	t/m^3	0.39	0.39	0.39	0.39	0.39	0.39	0.585
t1:Working hour	h	7.5	7.5	7.5	7.5	7.5	7.5	7.5
t2:Daily service time	min	30	30	30	30	30	30	30
t3:Loading time per trip	min	5	5	5	66	110	165	64
t4:Unloading time	min	5	5	5	10	10	10	10
E: Working efficiency of transport		0.8	0.8	0.8	0.8	0.8	0.8	0.8
f: Work efficiency of transportation		0.8	0.8	0.8	0.8	0.8	0.8	0.8
Nos of trips per day	times	5.25	5.25	5.25	2.58	1.93	1.47	2.63
Waste carried per day	t/d	8.19	13.10	19.66	4.84	6.02	6.87	9.83

a.3 Type of Refuse Collection Truck

Taking into account their productivity, workability and needs of maintenance, the following type of vehicles were selected.

- 6 ton tipper trucks
- 8 ton skip trucks

They are proposed to be assigned as follows.

Table 4-3: Assignment Plan of Refuse Collection Truck

Area	2000-2002
UA	100%: 6 ton tipper trucks
SUPA	35-25%: 6 ton tipper trucks 65-75%: 8 ton skip container trucks
SUUA	10%: 6 ton tipper trucks 90%: 8 ton skip container trucks

b. Cost Estimation

b.1 Investment

b.1.1 Required Number of Equipment

Table 4-4 shows the required number of equipment which were calculated by their productivities and the distances of a return trip.

Table 4-4: Required Number of Equipment

Items	Unit	2000	2001	2002	2003	2004	2005
6 ton tipper trucks	units	40	45	50	50	50	50
8 ton tipper trucks	units	31	47	67	67	67	67
8 m3 container with a lid	nos.	62	94	134	134	134	134
8 m3 container without a lid	nos.	248	376	536	536	536	536

b.1.2 Procurement Schedule of Equipment

Table 4-5 shows the procurement schedule of equipment: their economic life has been taken into account.

Table 4-5: Procurement Schedule

Items	unit	1999	2000	2001	2002	2003	2004	2005
6t tipper truck	units	40	5	5	0	0	0	0
8t skip truck	units	31	16	20	0	0	0	0
8 m3 container with a lid	units	62	32	40	0	0	0	0
8 m3 container without a lid	units	248	128	160	0	0	0	0

b.1.3 Investment Schedule of Equipment

Table 4-6 shows the investment schedule for procuring equipment in accordance with the previous schedule.

Table 4-6: Investment Schedule

Items	unit	unit rate	1999	2000	2001	2002	2003	2004	2005
6t tipper truck	th. USD	53.1	2,122	265	265	0	0	0	0
8t skip truck	th. USD	74.7	2,314	1,194	1,493	0	0	0	0
8 m3 container with lid	th. USD	6.0	369	190	238	0	0	0	0
8 m3 container without lid	th. USD	5.2	1,290	666	832	0	0	0	0
Total in USD	th. USD		6,095	2,316	2,828	0	0	0	0
Total in Tsh	M.Tsh	597.8	3,644	1,384	1,691	0	0	0	0

b.2 Operation Costs

The required quantities of manpower and materials for collection and transportation are shown in Table 4-7 and the required costs are summarised in Table 4-8.

Table 4-7: Required Quantities for Operation

		unit	2000	2001	2002	2003	2004	2005
Labour Driver	8t skip	persons	31	47	67	67	67	67
	6t tipper	persons	40	45	50	50	50	50
	Total	**persons**	**71**	**92**	**117**	**117**	**117**	**117**
Labour Collection worker	8t skip	persons	0	0	0	0	0	0
	6t tipper	persons	200	225	250	250	250	250
	Total	**persons**	200	225	250	250	250	250
Required Diesel	6t tipper	l/d	960	1,080	1,200	1,200	1,200	1,200
	8t skip	l/d	1,519	2,303	3,283	3,283	3,283	3,283
	Total	**l/d**	2,479	3,383	4,483	4,483	4,483	4,483

Table 4-8: Required Operation Cost

	unit	2000	2001	2002	2003	2004	2005
Labour, driver	M.Tsh/y	51	66	84	84	84	84
Labour, collection worker	M.Tsh/y	96	108	120	120	120	120
Diesel	M.Tsh/y	213	291	386	386	386	386
Lubricant	M.Tsh/y	21	29	39	39	39	39
Total	**M.Tsh/y**	382	494	629	629	629	629

b.3 Maintenance Costs

The maintenance cost include prices of spare parts and costs incurred when repairs are commissioned to outside garages. The costs of preventive maintenance which will be provided by the central workshop are included in the maintenance shop costs as indirect costs.

The maintenance costs for vehicles is regarded as 10 % of basic prices and for skip containers 3 % of basic prices. The estimated maintenance costs are summarised in Table 4-9.

Table 4-9: Required Maintenance Costs Schedule

Item 1	Item 2	Item 3	unit	2000	2001	2002	2003	2004	2005
Vehicles	Basic Price	6t tipper	th. USD	2,432	2,736	3,040	3,040	3,283	4,013
		8t skip	th. USD	2,651	4,019	5,729	5,729	6,926	8,123
		4 t compactor	th. USD	0	0	0	566	728	809
		Total	th. USD	5,083	6,755	8,769	9,335	10,937	12,944
	Repair Cost	10 % of Basic Price	th. USD	508	675	877	933	1,094	1,294
Skip Container	Basic Price	8 m3 with a lid	th. USD	391	592	844	844	1,021	1,197
		8 m3 without a lid	th. USD	1,438	2,181	3,109	3,109	3,758	4,408
		Total	th. USD	1,829	2,773	3,953	3,953	4,779	5,605
	Repair Cost	3 % of Basic Price	th. USD	55	83	119	119	143	168
Total Repair Cost in USD			th. USD	563	759	995	1,052	1,237	1,463
Total Repair Cost in Tsh			M.Tsh/y	337	454	595	629	740	874

b.4 Summary of Cost Estimation

Table 4-10 shows the summary of required costs for secondary collection and transportation.

Table 4-10: Estimated Costs of Secondary Collection and Transportation

Description	unit	1999	2000	2001	2002	2003	2004	2005
1. Investment								
Equipment	M.Tsh	3,644	1,384	1,691	298	1,284	1,496	478
2. Operation								
Labour Cost	M.Tsh	0	147	174	204	219	246	296
Material and Fuel, etc.	M.Tsh	0	235	320	424	444	524	619
3. Maintenance	M.Tsh	0	337	454	595	629	740	874
Total	M.Tsh	3,644	2,103	2,639	1,521	2,577	3,005	2,267

4.3 Planning the Street Sweeping System

a. Description of Street Sweeping Plan

- The SWM Master Plan concerns only collecting wastes littered on streets, excluding sand and grass cuttings, which is currently being conducted by the Department of Works in DCC and the Ministry of Works.
- Only asphalt paved streets are planned to be swept.
- Planned length to be swept is as follows:

Year	2000	2001	2002	2003	2004	2005
Length to be swept	67 km	83 km	100 km	100 km	100 km	100 km

Street sweeping shall be done is the manually. The required resources are:

Machinery	Trucks
Labour	Drivers Collection workers
Material	Broom Handcart Waste basket Traffic safety devices
Fuel	Petrol or diesel

b. Investment

Table 4-11 shows the schedule of required equipment and manpower concerning street sweeping work.

Table 4-11: Required Equipment and Manpower

Items	unit	1999	2000	2001	2002	2003	2004	2005
4t truck	units	3	4	5	6	6	6	6
Driver	persons	3	4	5	6	6	6	6
No. of worker	persons	110	147	183	220	220	220	220

Table 4-12 shows the schedule of Procurement and Investment.

Table 4-12: Procurement and Investment Schedule

Item		1999	2000	2001	2002	2003	2004	2005
Procured	4t truck	1	1	1	0	0	0	0
Investment	M. Tsh	23	23	23	0	0	0	0

c. Operation Cost

Table 4-13 shows the operation cost schedule until 2005.

Table 4-13: Operation Cost Schedule

Category	Description	unit	2000	2001	2002	2003	2004	2005
Labour	Driver	M.Tsh	3	4	4	4	4	4
	Worker	M.Tsh	71	88	106	106	106	106
Fuel	Diesel, Petrol, Lubricant	M.Tsh	5	6	8	8	8	8
Material	Broom, handcart, safety con, etc.	M.Tsh	20	25	30	30	30	30
Total		M.Tsh	99	123	148	148	148	148

d. Maintenance Cost

The maintenance cost include prices of spare parts and costs incurred when repairs are commissioned to outside garages. The costs of preventive maintenance which will be provided by the central workshop are included in the maintenance shop costs as indirect costs.

The maintenance costs for vehicles is regarded as 10 % of basic prices. The estimated maintenance costs are summarised in Table 4-14.

Table 4-14: Maintenance Cost Schedule

Item	unit	2000	2001	2002	2003	2004	2005
Repair	M.Tsh	9	12	14	14	14	14

4.4 Planning the Maintenance System (Nyerere Workshop)

The Nyerere depot which is currently closed is proposed to work as a central workshop for SWM equipment. The function of this workshop is to provide preventive maintenance. Major repair works are planned to be done at private garages.

a. Investment

All improvement works of the Nyerere Workshop in the Master Plan are recommended to be implemented in 1999.

a.1 Facilities

Total investment for facilities is 42 million Tsh as shown below.

Water Tank	5 M.Ths
Pavement	15 M.Ths
Drainage	10 M.Ths
Car washing pit	5 M.Ths
Sub-station	5 M.Ths
Furniture	3 M.Ths
Total	42 M.Ths

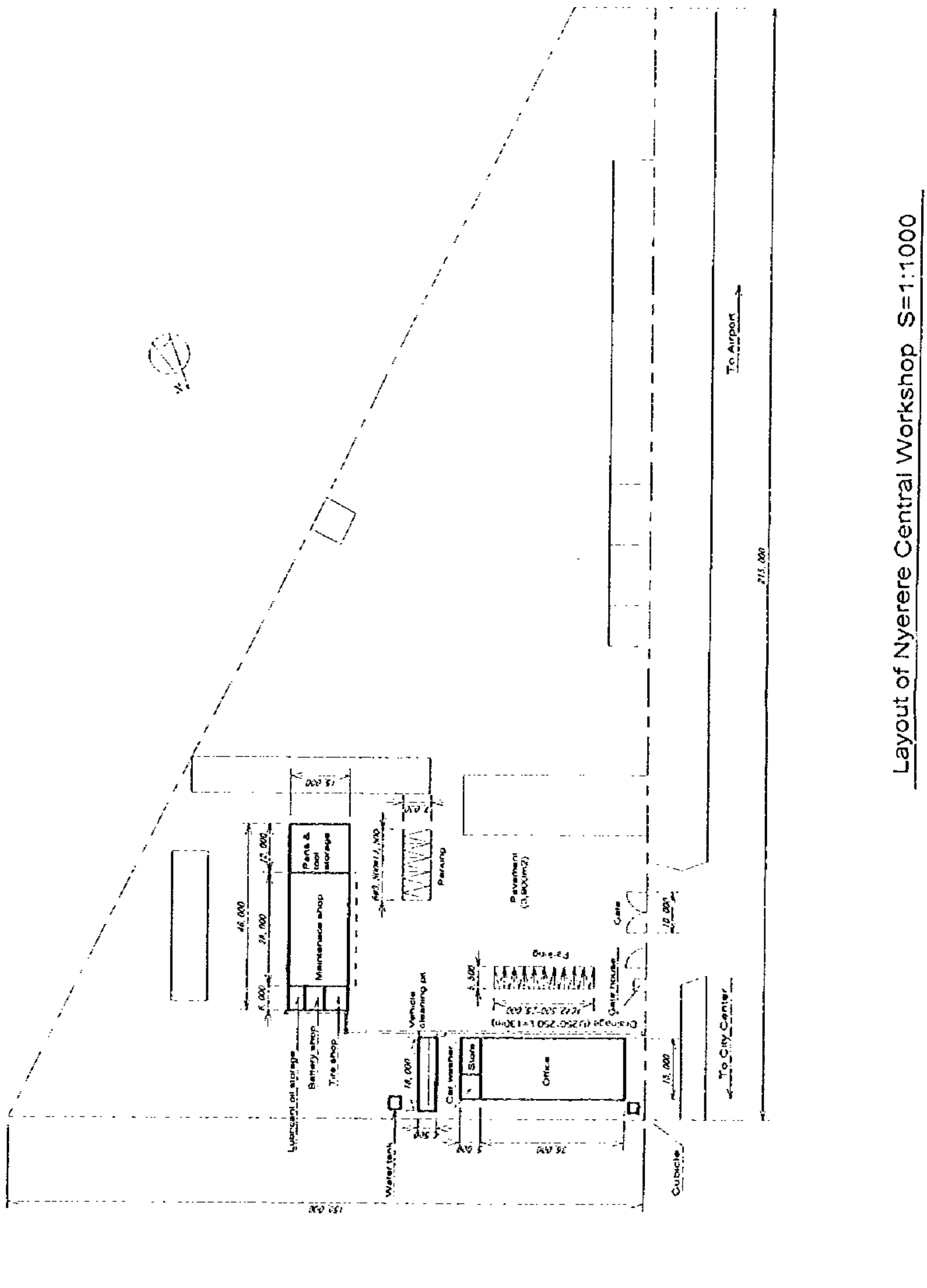


Figure 4-1: General Layout of the Nyerere Workshop

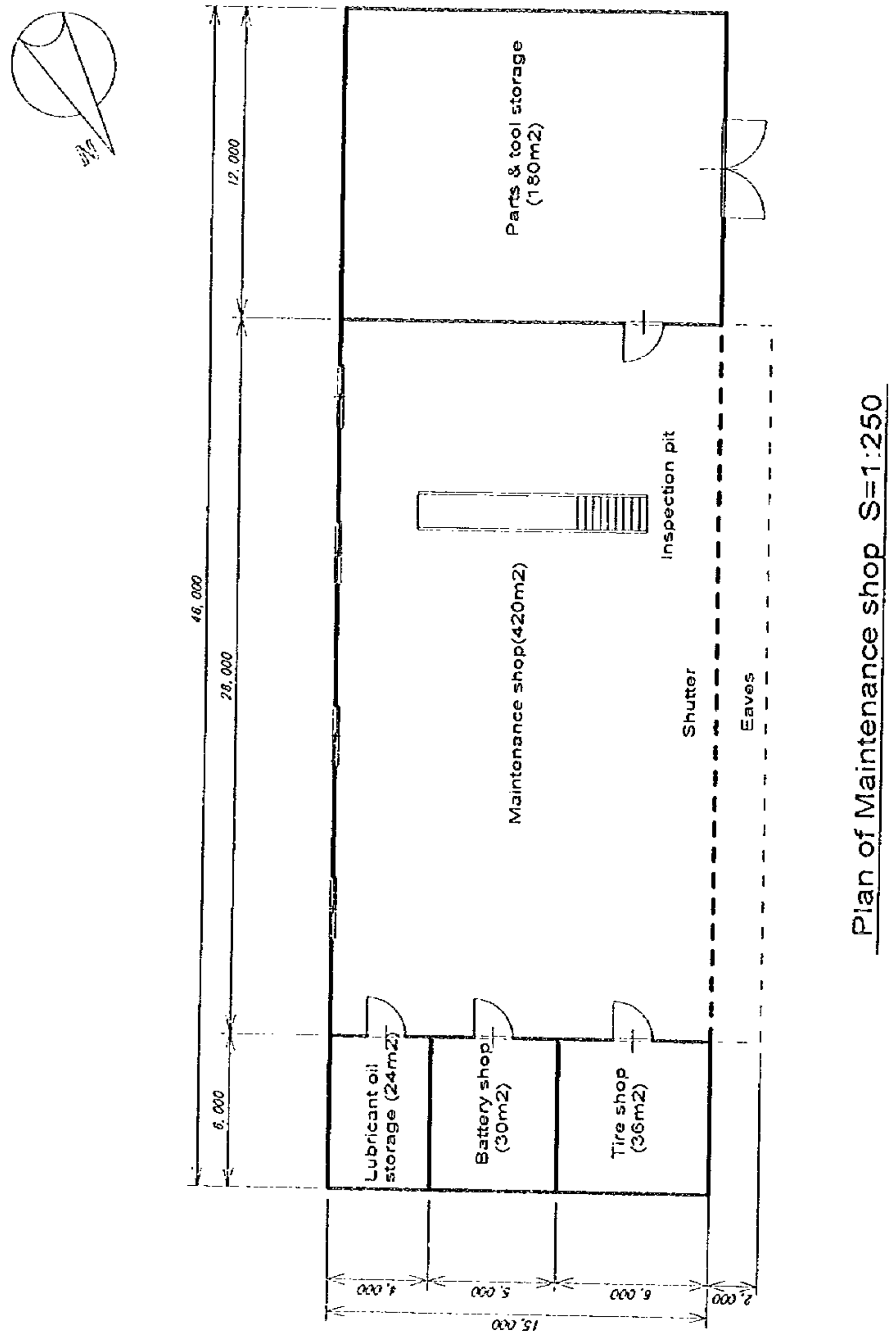


Figure 4-2: Plan of the Maintenance Workshop

a.2 Machinery

Total investment for machinery is 297 million Tsh as shown below.

Description	Amount (USD)	Amount (M. Tsh)
Battery Shop	4,279	3
Inspection Pit	22,646	14
Welding Equipment	6,665	4
General Maintenance & Repair	78,850	47
Tire Shop	15,982	10
Other Equipment	287,189	172
Training Material	80,880	48
Total	496,490	297

b. Operation and Maintenance Costs

Table 4-15 shows the schedule of required manpower for operating the Nyerere Workshop.

Table 4-15: Manpower Schedule

Description	unit	1999	2000	2001	2002	2003	2004	2005
Manager	persons	1	1	1	1	1	1	1
Mechanical Engineer	persons	0	3	3	4	4	4	4
Mechanic	persons	0	8	10	13	13	13	13
Assistant Mechanic	persons	0	27	34	43	43	43	43
Security Guard	persons	0	4	4	4	4	4	4
Total	persons	1	43	52	65	65	65	65

Table 4-16 shows the schedule of operation and maintenance from 1999 to 2005.

Table 4-16: O & M Cost Schedule

Category	Description	unit	1999	2000	2001	2002	2003	2004	2005
Labour	Manager	M.Tsh	4	4	4	4	4	4	4
	Mechanical Engineer	M.Tsh	0	4	4	5	5	5	5
	Mechanic	M.Tsh	0	6	7	9	9	9	9
	Assistant Mechanic	M.Tsh	0	13	16	21	21	21	21
	Security Guard	M.Tsh	0	2	2	2	2	2	2
	Total	M.Tsh	4	28	33	40	40	40	40
Material	Power supply	M.Tsh	0	3	4	5	5	5	5
	Water supply	M.Tsh	0	3	4	5	5	5	5
	Others	M.Tsh	0	4	5	7	7	7	7
	Total	M.Tsh	0	11	14	17	17	17	17
Maintenance		M.Tsh		15	18	22	22	22	22
Total		M.Tsh	342	54	64	80	80	80	80

4.5 Administrative Cost

The headquarters of the Waste Management Authority to be established shall be at the Nyerere Workshop. One of the buildings is planned to be renovated and furnished for a proper office.

a. Investment

Description	unit	1999	2000	2001	2002	2003	2004	2005
Quantity								
Personnel	persons	30	40	40	40	40	40	40
4wd Pickup	units	0	5	6	7	7	7	7
Mobile video set	unit	0	1	1	1	1	1	1
Computer	sets	0	2	2	2	2	2	2
Furniture	sets	30	40	40	40	40	40	40
Procurement								
4wd Pickup	units	5	1	1	0	0	0	0
Mobile video set	units	1	0	0	0	0	0	0
Computer	sets	2	0	0	0	0	0	0
Furniture	sets	10	10	10	0	0	0	0

Description	units	1999	2000	2001	2002	2003	2004
Equipment							
4wd Pickup	M.Ths	97	19	19	0	0	0
Vehicle with AV equipment	M.Ths	20	0	0	0	0	0
Computer	M.Ths	5	0	0	0	0	0
Furniture	M.Ths	2	2	2	0	0	0
Sub-total	M.Ths	123	21	21	0	0	0
Facility							
Renovation	M.Ths	29	0	0	0	0	0

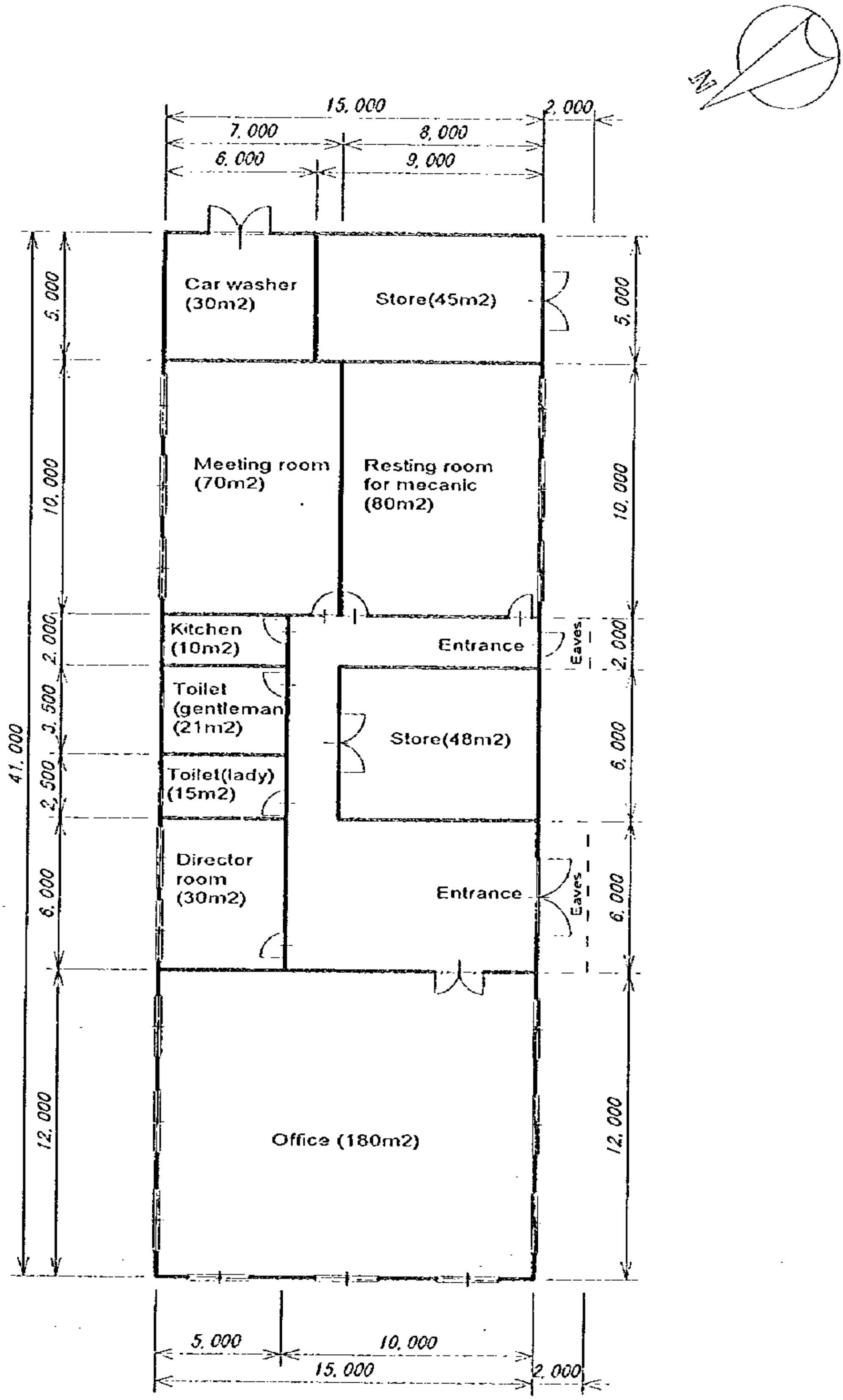
b. Operation and Maintenance

Description	unit	1999	2000	2001	2002	2003	2004	2005
Cost for administrators	M.Ths	38	48	58	67	67	67	67
Petrol	M.Ths	0	8	10	11	11	11	11
Miscellaneous	M.Ths	4	4	5	6	6	6	6
Total	M.Ths	42	60	72	85	85	85	85

Table 4-17 shows the administrative cost schedule.

Table 4-17: Administrative Cost Schedule

Items	1999	2000	2001	2002	2003	2004	2005
Inv. for facilities	29	0	0	0	0	0	0
Inv. for equipment	123	21	21	0	0	0	21
O&M for labor	38	48	58	67	67	67	67
O&M for material & fuel	0	8	10	11	11	11	11
Spare parts & repair	4	4	5	6	6	6	6
sub-total	194	81	93	85	85	85	106
Total	536	142	165	202	215	241	268



Plan of Office S=1:250

Figure 4-3: Layout of the Waste Management Authority's Office

4.6 Operation Plan

a. Motor Pools

Each district is planned to have its motor pool in order to shorten the travel distances of refuse collection vehicles. This system helps supervisors stationed at the motor pools to give proper instructions timely. Preventive checks on refuse collection vehicles will be also carried out at each motor pool. The proposed locations of motor pools are as follows. Refer to Figure 4-4.

- Kinondoni District: Mwananyamala depot.
- Ilala District: DRIMP depot.
- Temeke District: Temeke District Office

There will be no need for land acquisition because all of the proposed sites are owned by DCC.

Every site already has a fence and security guards. The present conditions of these facilities are satisfactory for the use as a motor pool, and therefore further investment is unnecessary. Only operation costs are therefore included.

Table 4-18: Operation Cost Schedule

unit: M.Tsh

District	Site	Description	2000	2001	2002	2003	2004	2005
Kinondoni	Mwananyamala	2 security guards	1	1	1	1	1	1
		Miscellaneous	1	1	1	1	1	1
		sub-total	2	2	2	2	2	2
Ilala	DRIMP	2 security guards	1	1	1	1	1	1
		Miscellaneous	1	1	1	1	1	1
		sub-total	2	2	2	2	2	2
Temeke	Temeke District Office	2 security guards	1	1	1	1	1	1
		Miscellaneous	1	1	1	1	1	1
		sub-total	2	2	2	2	2	2
Total	Labour		3	3	3	3	3	3
	Miscellaneous		4	4	4	4	4	4
G-Total			7	7	7	7	7	7

b. Works to be contracted out to Private Sectors

b.1 Programme of Contracting-Out

It is considered to be difficult for DCC to operate all vehicles directly because the required number of refuse collection vehicles is 71 in 2000 and 117 in 2002, while the number of trucks being operated is only about 14. Therefore, the total number of vehicles to be under the responsibility of DCC should be controlled by contracting some of refuse collection works out to private contractors. Table 4-19 shows the programme of contracting-out.

Table 4-19: Programme of Contracting-Out Works

Year	Area	2000	2001	2002	2003	2004	2005
Waste Amount Collected	UA	86	88	90	93	97	100
(tons/day)	SUPA	394	510	649	894	1,064	1,269
	SUUA	158	284	427	626	744	880
	RA	0	0	0	11	23	37
	Total	638	882	1,167	1,624	1,928	2,286
Rate of Works to be Contracted	UA	100%	100%	100%	100%	100%	100%
Out	SUPA	40%	60%	80%	100%	100%	100%
	SUUA	0%	0%	0%	10%	20%	30%
	RA	0%	0%	0%	0%	0%	0%
Waste Collection Amount to	UA	86	88	90	93	97	100
be Contracted Out	SUPA	158	306	519	894	1,064	1,269
(tons/day)	SUUA	0	0	0	63	149	264
	RA	0	0	0	0	0	0
	Total	244	394	609	1,050	1,310	1,633
Waste Amount to be directly	UA	0	0	0	0	0	0
collected by DCC	SUPA	237	204	130	0	0	0
(tons/day)	SUUA	158	284	427	563	596	616
	RA	0	0	0	11	23	37
	Total	395	488	557	574	619	653
Percentage of Contractors' Work		38%	45%	52%	65%	68%	71%
Percentage of DCC's Work		62%	55%	48%	35%	32%	29%

According to the programme the total amount of waste to be directly collected by DCC' can be controlled below 700 tonnes in 2005.

However, the private sectors' capacity will not be enough to collect the planned amount of waste. Therefore DCC should provide them with assistance as stated below until they will obtain the enough capacity.

- To provide them with refuse collection vehicles for collecting refuse.
- To make a payment term short.
- To provide them with training on waste management, such as management, maintenance of equipment, how to drive trucks, how to keep hygienic conditions, etc.

4.6.1 Maintenance Plan

The Nyerere workshop, which is currently not in use, will be improved as a central workshop for refuse equipment. The general improvement plan of Nyerere workshop is shown in Figure 4-4. The workshop is planned to provide only preventive maintenance services. Complex and heavy repair services are planned to be conducted in private garages.

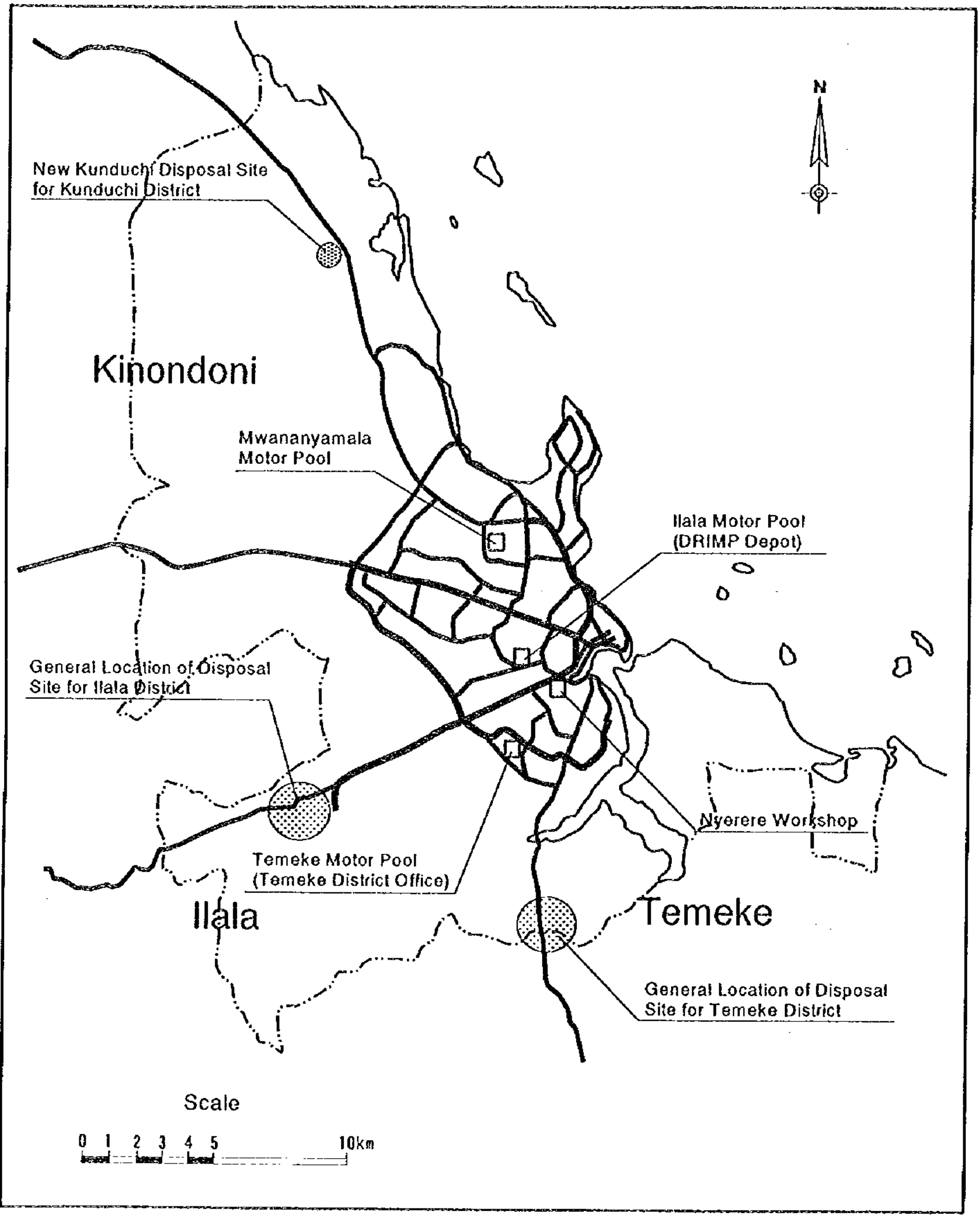


Figure 4-4: Location Plan of SWM Facilities

4.7 Project Summary

4.7.1 Summary of Items to be Invested in the Priority Projects

Table 4-20: Summary of Items to be invested in the Priority Projects

	Contents of Projects	Type	1999	2000	2001
1	Improvement of Waste Collection and Transport				
	• 6 ton tipper truck	units	40	5	5
	• 8 ton skip truck	units	31	16	20
	• 8m³ skip container with lid	nos.	62	32	40
	• 8m³ skip container without lid	nos.	248	128	160
2	Development of the New Kunduchi Disposal Site				
	• Construction of the landfill section 1A and 1B	set	1	0	0
	• Construction of the basic facilities for the disposal site: e.x. access road, site office, weighbridge, car wash, etc.	set	1	0	0
	• Bulldozer, 210 HP class	units	2	0	0
	• Backhoe, 0.7 m³ class	units	1	0	0
	• Tipper truck, 10 ton class	units	3	0	0
	• Pickup, 2 ton class	units	1	0	0
3	Improvement of Street Sweeping				
	• 4 ton truck		1	1	1
4	Improvement of the Nyerere Workshop				
	• Construction of basic facilities: pavement, drainage, water tank, car cleaning, electricity sub-station, furniture	set	1	0	0
	• Equipment for battery shop	set	1	0	0
	• Equipment for inspection pit	set	1	0	0
	• Welding equipment	set	1	0	0
	• Equipment for general maintenance and repair	set	1	0	0
	• Equipment for tire shop	set	1	0	0
	• Training material	set	1	0	0
	• Mobile workshop	set	1	0	0
	• Miscellaneous	set	1	0	0
5	Improvement of Administrative System				
	• Renovation of the office space	set	1	0	0
	• 4 WD pickup	units	5	1	1
	• Vehicle with AV equipment	units	1	0	0
	• OA equipment	set	2	0	0
	• Furniture and miscellaneous	set	10	10	10

Note:
* The amount of required grant covers the investment required in 1999 which will play a role in a take-off project.

4.7.2 Project Cost Schedule

Table 4-21 summarises the project cost schedule from 1999 to 2005 to implement the complete master plan projects.

Table 4-21: Project Costs Summary

unit: M.Tsh

Category	Category	Description	1999	2000	2001	2002	2003	2004	2005
Direct Cost	Collection and Transportation	Invest. for equipment	3,644	1,384	1,691	0	0	0	0
		O&M for labour	0	147	174	204	204	204	204
		O&M for material & fuel	0	235	320	424	424	424	424
		Spare parts & repair	0	337	454	595	595	595	595
		sub-total	3,644	2,103	2,639	1,224	1,224	1,224	1,224
	Final Disposal Kunduchi Site	Invest. for facilities	831	0	0	430	580	0	0
		Invest. for equipment	600	0	150	0	0	0	0
		O&M for labour	0	20	20	21	21	21	21
		O&M for material & fuel	0	64	70	92	92	92	92
		Spare parts & repair	0	60	60	75	75	75	75
		sub-total	1,431	144	300	617	767	187	187
	Street Sweeping	Invest. for equipment	23	23	23	0	0	0	0
		O&M for labour	0	73	91	110	110	110	110
		O&M for material & fuel	0	25	31	38	38	38	38
		Spare parts & repair	0	9	12	14	14	14	14
		sub-total	23	132	158	162	162	162	162
	Total Direct Cost		5,098	2,378	3,097	2,023	2,153	1,573	1,573
Indirect Cost	Maintenance Workshop	Invest. for facilities	42	0	0	0	0	0	0
		Invest. for equipment	297	0	0	0	0	0	0
		O&M for labour	4	28	33	40	40	40	40
		O&M for material & fuel	0	11	14	17	17	17	17
		Spare parts & repair	0	15	18	22	22	22	22
		sub-total	342	54	64	80	80	80	80
	Motor Pool	O&M for labour	0	3	3	3	3	3	3
		O&M for material & fuel	0	4	4	4	4	4	4
		sub-total	0	7	7	7	7	7	7
	Administration	Invest. for facilities	29	0	0	0	0	0	0
		Invest. for equipment	123	21	21	0	0	0	21
		O&M for labour	38	48	58	67	67	67	67
		O&M for material & fuel	0	8	10	11	11	11	11
		Spare parts & repair	4	4	5	6	6	6	6
		sub-total	194	81	93	85	85	85	106
	Total Indirect Cost		536	142	165	171	171	171	192
Grand Total			5,634	2,521	3,261	2,174	2,324	1,744	1,765

b. Unit SWM Cost

Table 4-22 shows the unit SWM costs for Case 1, where only the first priority project is implemented and Case 2, where all projects proposed in the Master Plan are implemented. It should be reminded that unit costs exclude the financial costs such as interest.

Table 4-22: Unit Solid Waste Management Cost

Type of Works	Case 1 Only the first priority project is implemented		Case 2 All projects in the Master Plan are implemented.	
	Tsh/ton	USD/ton	Tsh/ton	USD/ton
Collection and Transportation plus Street Sweeping	7,098	11.87	5,209	8.71
Final Disposal	2,051	3.43	3,049	5.10
Total	9,150	15.31	8,258	13.81

The indirect costs composed of maintenance workshop, motor pools and administration expenses were distributed to the two direct costs consisting of collection and transportation plus street sweeping cost and the final disposal cost in accordance with their percentages in the total direct cost.

The reason why the unit final disposal cost in Case 2 is 50 % more expensive than Case 1 is because the proposed landfill structures for Ilala and Temeke districts to be constructed in 2002 are based on Level 3 while the Kunduchi landfill site to be constructed in 1999 is based on Level 2. If appropriate sites which do not require impermeable landfill in terms of environmental preservation are selected, the unit final disposal cost for Case 2 could be cheaper by about 20 %, around 2,450 Tsh. In that case, the total SWM cost will be about 7,660 Tsh per ton, cheaper by 598 Tsh per ton. It will contribute to a lower total SWM cost in 2005 by 427.8 million Tsh.

Therefore, the selection of disposal sites is very important in terms of SWM cost.