Japanese Technical Cooperation Project for Promotion of Regional Initiative on Solid Waste Management in Pacific Island Countries Phase II (J-PRISM II)

Development Guide and Operation Manual For Bouffa Disposal Site

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Waste Management, Environment and Health Division,
Port Vila City Council

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A. Development Guide

1 Development of Bouffa Disposal Site

1.1 History of the Bouffa Disposal site

August 1990: Initial assessment by WHO for the selection of a site for the transfer of the disposal site

December 1990: Environmental assessment of site selection by consultants Sinclair Knight & Partners

December 1990: Summary of environmental assessment of site selection by NZ consultants employed by UN EACAP and WB, and geological survey of site 1 by Department of Geology and Mines, Vanuatu Government

July 1992: A lease agreement is signed with the City of Port Vila for the use of the land as a disposal site for 50 years, with the Ministry of Land and Resources acting as lessor on behalf of the two tribes claiming ownership of the land (Eratap and Erakor).

December 1994: Trenching landfill operations commenced at the Bouffa landfill site as a condition of the 1991 loan agreement between the Government of Vanuatu and the World Bank for a new housing project, which required the closure and construction of a new disposal site.

1995: The access road from the ring road on Efate Island to the Bouffa disposal site is opened to coincide with the opening of the above disposla site.

2000-2003: Topographical surveying of the Bouffa disposal site carried out with JICA support.

2006-2008: With the support of JICA, rehabilitation of the existing landfill area (Area II) and construction of a new landfill area (Area I = Cell-1) were carried out.

2015: At J-PRISM I, the disposal site improvement was carried out along with the disaster waste treatment from Cyclone Pam and Cell 1 was expanded.

2016-2017: Sludge Treatment Facility was constructed under the Port Vila Urban Development Project supported by Australian Gov. & ADB.

2018- Under J-PRISM II, a waste management master plan was developed, including a medium- to long-term Bouffa disposal site expansion plan. Based on the detailed design of on-site road and Cell-2 and Cell3 developed in line with this master plan, PVCC has started the construction by using heavy machinery procured by J-PRISM II from mid-2022.

1.2 Topography and hydrogeology of the Bouffa Disposal Site

(1) Terrain

Vanuatu is a volcanically active island chain, with 35% of the country at altitudes of 300m or more above sea level, and 55% at steep slopes of 20 degrees or more.

According to the contour map of the island of Efate, where Bouffa is located, the disposal site is located in the zone of 80m to 100m above sea level, with a gentle downward slope (about 10 degrees) towards the east. We were also informed that JICA had previously carried out a more detailed topographical survey of the Bouffa landfill site. According to the results of this topographical survey, the eastern edge of the landfill area currently in use is around 84m above sea level and the area with the leachate control pond (not connected to the landfill area) is around 78-80m above sea level. The overall slope is gently downhill from west to east.

(2) Geological features

Efate Island consists of two volcanic eruptions, uplifted corals (limestone) and alluvial deposits. The area around the Bouffa landfill site consists mainly of palaeo-rising coral reefs mixed with clastic limestone of Pleistocene to Holocene age. At the eastern end of the site there is a fault that forms the western boundary of the north-south running Teouma Rift, which forms a cliff. The cliff is underlain in places by the undifferentiated Pumice Breccia Efate Pumice Formation with Lenses of Bokua Tuff and clays (Tp1).

As part of the preliminary investigations for the World Bank project to develop a new disposal site, we have obtained the results of a detailed geological survey carried out in 1990 to select an alternative site. This study involved the excavation of test pits and borehole investigations at five sites within the current repository site (see Figure 1 for the locations of the investigations).

The five test pit excavations all show a similar geological structure of approximately 300mm of topsoil, followed by approximately 50mm of brown clay/loam soil, followed by approximately 9m of clay layer, followed by volcanic tuff. Borehole investigations (borehole diameter 200mm) also yielded results as shown in Figure 2.

The report further concludes that the limestone is confined to the south-east of the site (an area of approximately 2,700 m2 and a volume of 18,800 m3, with an average layer of 4 m (6 m at most)), and that the rest of the site consists mainly of loam and clay, which acts as a natural liner to mitigate the effects of leachate infiltration. It concludes Furthermore, the water infiltration rates obtained from the water transmission rate tests carried out on borehole samples 268 and 269 are 1.45×10^{-5} m/sec and 1.23×10^{-6} m/sec respectively, and taking into account the soil properties of the tuff and clay These values are upper limits and the vertical permeability is further reduced to 1×10^{-6} m/sec.

(3) The water environment around Bouffa

The Bouffa disposal site is located in the Teouma catchment area, with the Teouma River, the largest river in Efate, flowing from north to south approximately 1km east of the site; the average annual flow of the Teouma River is $4m^3$ per second. The mouth of Teouma Bay is located about 5 km to the south. 3 km southwest of the site is the EmetenLagoon.

The above borehole report also indicates that there are no rivers or other major surface water bodies within the Bouffa disposal site, but that there appear to be a number of natural drainage channels within the site that flow as small streams during the wet season. Rainwater falling on the site is assumed to flow mostly through these natural drainage channels to TeoumaValley (River) to the north and east, and from the area to

the west and south-east of the site to the south via two different channels.

In addition, groundwater was encountered in borehole 268 during the above borehole investigation. The groundwater level was 7.39m below ground level on the first day of the borehole investigation, but it dropped to 7.51m and 7.58m in the following two days. The groundwater flow direction has not been determined due to the lack of detailed borehole elevation data and the lack of groundwater encountered in other boreholes at the time, but this study suggests that groundwater in the vicinity of the site is generally flowing in an easterly direction, judging from the location of the Teouma River and lagoons in the area. However, based on the location of the Teouma River and the lagoon, this study suggests that groundwater in the vicinity of the site flows in a generally easterly direction.

The Teouma catchment is not a groundwater conservation area because it is not a source of water for the city of Port Vila, although some small streams and the Teouma River in the Teouma catchment are used for drinking water by local residents. The Tagabe catchment, which is a source of water for the city of Port Vila and is designated as a groundwater conservation area, is located approximately 2km north-west of the disposal site and the groundwater in this area flows in the opposite direction to the disposal site.

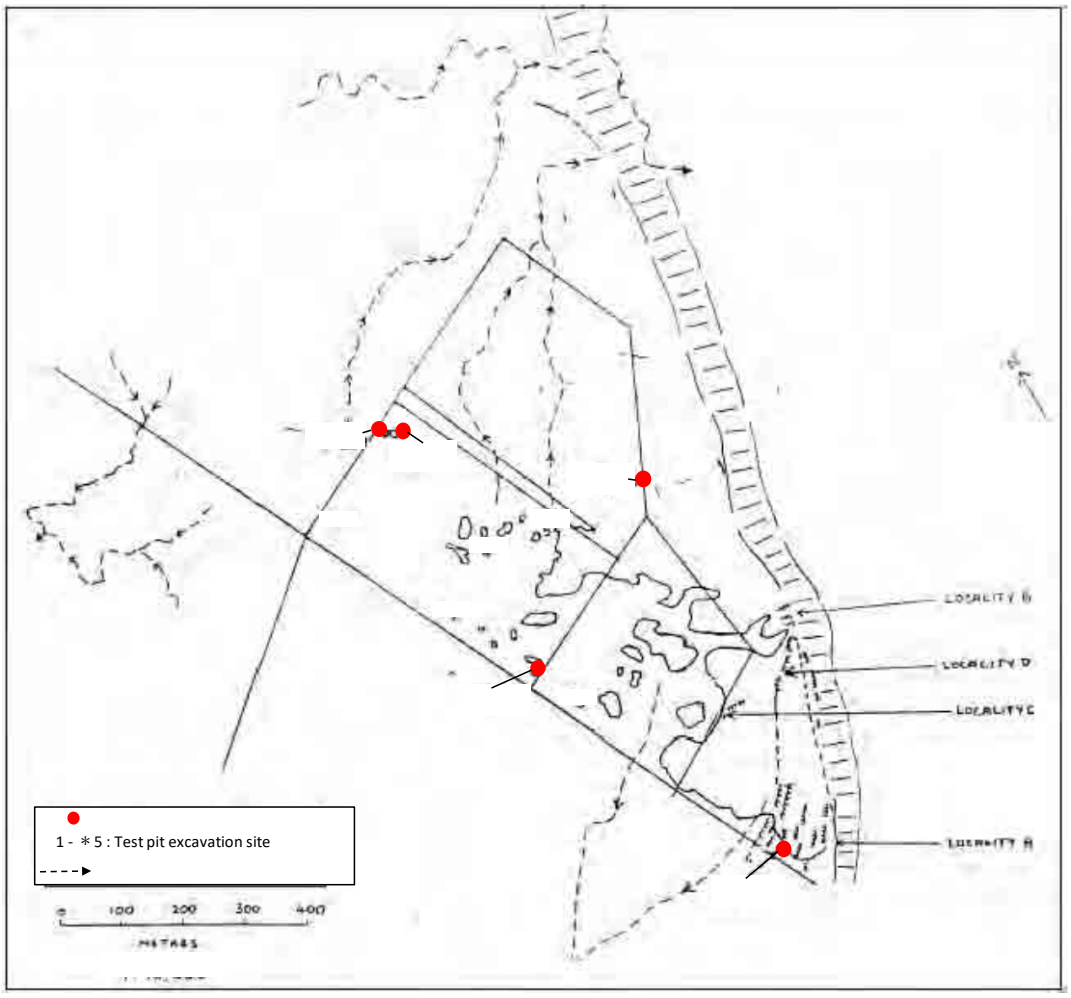


Figure 1: Borehole and trial pit locations during World Bank surveys (1990)

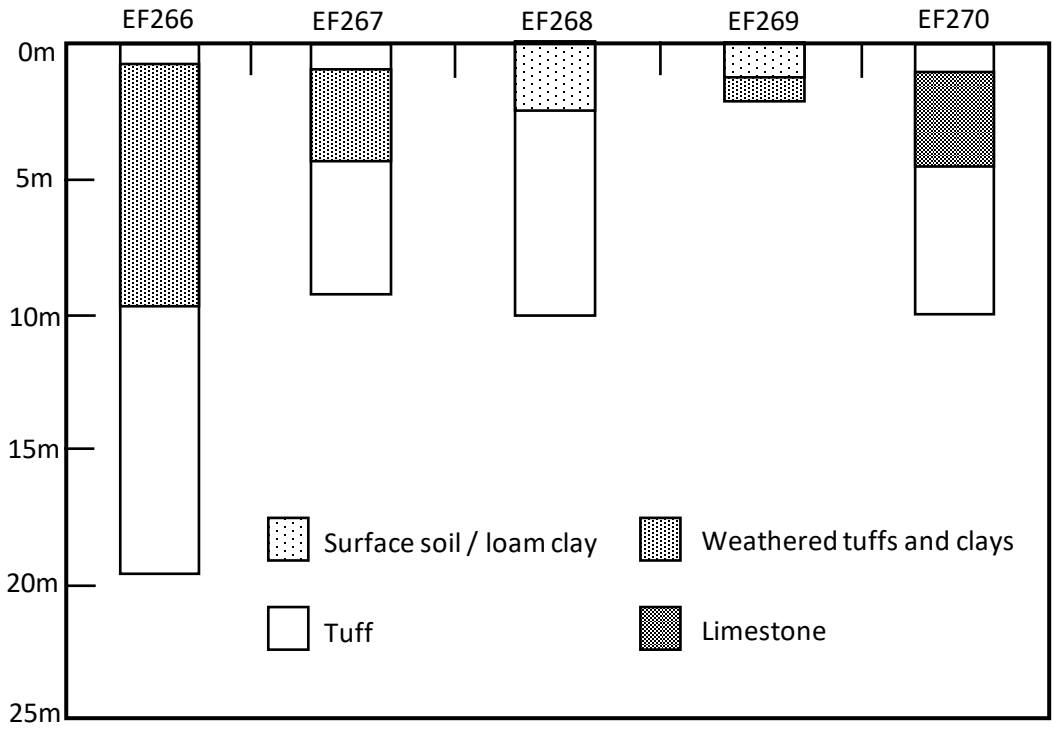


Figure 2: Log of drilling results

Log Summary

- Topsoil 0.05 ~ 2.5m
- Paleolithic coral limestone 0 ~ 6.0m
- Forari-type clay 0 ~ 10m
- Rentabau Tuff

At least 70m

- Undifferentiated pumice/angular conglomerate

Over 200m

1.3 Development Concept of Bouffa Disposal Site

1.3.1 General concept of final disposal

Landfill methods and its characteristics

Final disposal of waste is the process of reducing, stabilising, mineralising and rendering harmless the waste. The stabilisation process of disposed waste causes odours, vermin, leachate and other environmental problems. In order to minimise these environmental problems, a number of landfill methods have been adopted which incorporate various technical innovations. The more advanced the environmental measures, the higher the operating costs, and therefore the more economically viable landfill methods have been adopted by the organization that operates the disposal site. The table below shows the landfill methods and their characteristics.

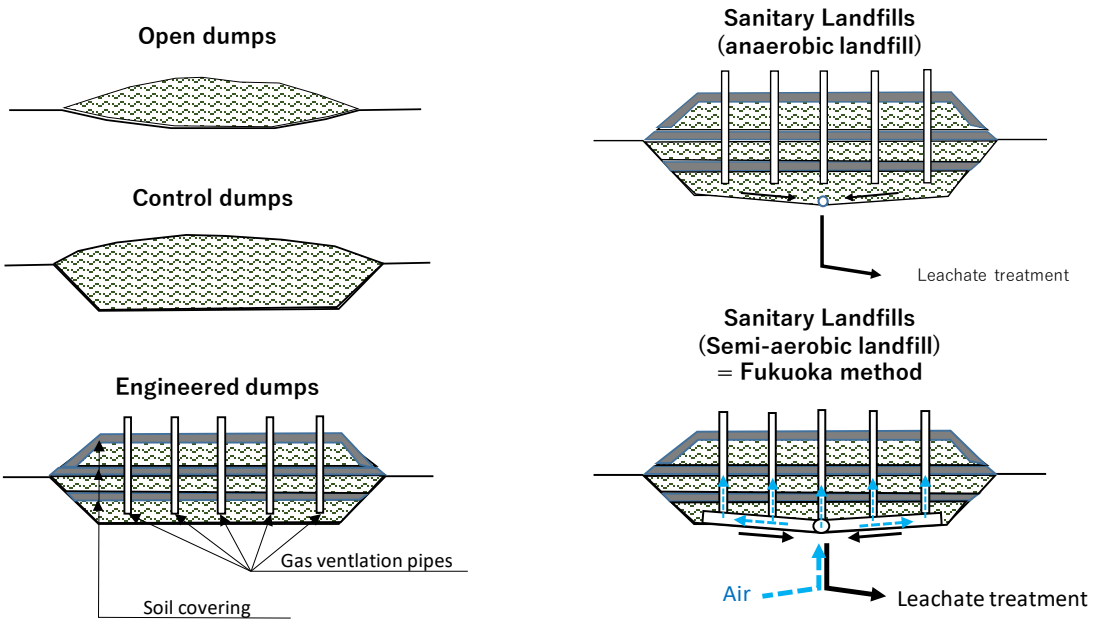


Figure 3: Conceptual diagram of Landfill method

Table 1: Landfill method and its characteristics (Overview)

Landfill method	Characteristics
Open dump	Waste is piled up in wetlands and other infrequently used land. The waste gradually decomposes, but the pile of waste expands rapidly as large amounts of plastic and other non-degradable waste are brought in or mixed in. The sanitary environment in the vicinity deteriorates significantly, and spontaneous ignition occurs due to fermentation and combined heat.
Controlled dump	This method involves excavating land with relatively low risk of groundwater contamination, such as impermeable layers, and dumping the waste. Landfill waste is moved, shaped, and compacted by heavy machinery, and this is a widespread method of disposing of small-scale, non-toxic waste.
Engineered dump	Landfill waste is covered with a thin layer of soil daily as a measure to prevent flies and other pests from swarming. Ventilation pipes are installed to vent the gases generated from under the soil cover. Leachate often percolates into the underground or seeps to the surroundings and causes problems.
Sanitary landfill (Anaerobic landfill)	An impermeable liner and a leachate collection pipe are installed at the bottom of the landfill, and the leachate is received by the recovery pit, aerated in an oxide pond, etc., and returned to the landfill for use in decomposing organic matter in the waste (closed system). Alternatively, the leachate is drained into the sewer and treated at a sewage treatment facility. This is also called anaerobic landfill because leachate occurs under anaerobic conditions. This landfill method is the mainstream method around the world, but the treatment cost increases because leachate containing a large amount of BOD/COD components and

	ammoniacal nitrogen continues to be generated for a long period of time.
Sanitary landfill Fukuoka method (Semi aerobic landfill)	This is the standard method in Japan, which was put to practical use in Fukuoka in 1975. The leachate is collected in a drainage pipe, and air flows into the pipe by natural convection caused by the heat of fermentation of the waste. This aeration effect causes aerobic biodegradation and a rapid decrease in BOD of the leachate. However, the operation and maintenance costs are high because the semi-aerobic conditions cannot be maintained without constant air flow through the leachate collection pipe.

1.3.2 Final disposal at the Bouffa Disposal Site

As mentioned above, the geology of the area where the Bouffa disposal site is located has a low permeability clay layer 5-10m below the surface, which is thought to act as a natural impermeable liner.

In December 1994, the Bouffa landfill site began to operate as a sanitary landfill (Anaerobic landfill) using the trenching method. In this method, trenches were prepared in advance and the waste was dumped into the trenches and covered with excavated soil. Leachate was collected in an oxidation pond at the bottom of the trench and discharged after aeration. The trenching system is effective when the amount of waste brought in is small, but due to the small capacity of the trenches, it is thought that the initially allocated landfill plots were full by the end of 2000.

PVMC implemented a JICA technical cooperation project from 2006 to 2008 to rehabilitate an existing trench-type landfill (Area B) and to construct a new landfill (Area A). In the construction of Area A (now called Cell-1), sanitary landfill (semi-aerobic landfill: Fukuoka method) was adopted in order to improve the quality of leachate, and leachate was collected in a regulation pond and then pumped back to the landfill area (so-called closed-system).

Cell-1 was used until 2014, when its capacity was filled and it was expanded in 2015 with support from JICA. Cell-1 was built and expanded on the basis of semi-aerobic landfill, but has not been covered with soil due to insufficient funds allocated for landfill operations.

As of October 2021, Cell-1 has already exceeded its capacity. The development concept of Cell-2 ~ 5 from a medium- to long-term perspective has already been approved by PVCC, and a construction plan for Cell-2 and 3 in the next disposal section based on this concept has already been formulated.

The medium- to long-term development concept of the Bouffa disposal site is explained below.

1.3.3 Expansion concept for the Bouffa disposal site

The facilities required for the operation of a sanitary landfill

Bouffa Landfill has operated as a sanitary landfill collecting leachate since 2008. Therefore, as explained in 1.3.1, Bouffa Landfill is classified as either an Anaerobic landfill or a Semi-aerobic landfill Sanitary landfill.

Sanitary landfills have a range of facilities that are necessary to sustain proper landfill

operations, from simply covering the landfill to collecting leachate to advanced treatment of the collected leachate. Since the operation of a landfill with all these facilities naturally requires costs and operating technology, it is realistic to raise the level of operation step by step in view of the existing landfill operating capacity (financial and technical).

Table 2: Facilities according to the level of operation of the sanitary landfill

Improvement issues	Level 1	Level 2	Level 3	Level 4
Permanent management facility (manager)	✔	✔	✔	✔
Management and weighing of carry-in waste	✔	✔	✔	✔
Maintenance of access roads and on-site roads	✔	✔	✔	✔
Installation of periphery banks and clarification of landfill boundaries		✔	✔	✔
Daily soil covering and installation of landfill gas ventilation pipe		✔	✔	✔
Anti-scattering mobile fence			✔	✔
Leachate circulation treatment			✔	✔
seepage control work				✔
Leachate purification treatment				✔

Prepared by J-PRISM II experts on the basis of "For capacity development support in the waste sector in developing countries", Table 2-17, JICA, 2004.11

1.3.4 Outline of Final Disposal Plan

(1) Area
- 48 ha

(2) Target level of Landfill operation
- Sanitary landfill
- Type of landfill: Semi-aerobic landfill (Fukuoka method)

(3) Acceptable waste at Bouffa disposal site
- Municipal waste: Household waste, Commercial waste, etc.
- Hazardous waste:

  Such as liquids containing heavy metals generated by school science experiments, but it must be small amounts.

  Note: Hazardous waste generated in industrial activities must be treated and disposed of at the responsibility of the producer

  Without the acceptance of hazardous wastes, they would be dumped without control. Therefore, it is recommended to isolate and store hazardous waste in a condition that can be monitored until it can be disposed of.
- Sewage sludge:

  Sewage sludge is collected separately from municipal waste and processed at the sludge treatment facility at Bouffa disposal site.

1.4 Target waste amount

The table below shows the Waste Flow shown in PVCC's Solid Waste Management

Plan 2021 – 2030. The target final disposal amount of the Bouffa disposal site is 11. MSW disposal and others brought in from Port Vila city area 12. Bulky waste, 13. Construction waste, 14. Medical waste and brought in from ports and airports 15. In Quarantine, the total is shown in 16. Total final disposal.

Table 3: Waste flow in Port Vila (unit: tons/day)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1. MSW generation	63.9	65.6	67.3	69.1	70.9	72.3	73.7	75.2	76.6	78.1
2. Household waste	38.2	39.1	40.1	41.0	42.0	42.9	43.7	44.5	45.4	46.3
3. Business waste	24.0	24.7	25.5	26.2	27.0	27.5	28.1	28.7	29.2	29.8
4. Market waste	1.7	1.7	1.8	1.8	1.8	1.9	1.9	2.0	2.0	2.0
5. Self-disposal from HH	10.3	9.8	9.2	8.6	7.9	7.2	6.4	5.6	4.8	3.9
6. Unmanaged waste	6.9	6.3	5.6	5.0	4.2	3.5	2.6	1.8	0.9	0.0
Home compost	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Market waste recycle	0.5	0.6	0.6	0.7	0.8	0.9	1.0	1.0	1.1	1.2
Material recovery	0.1	1.4	2.1	2.7	3.4	4.0	4.7	5.3	6.0	6.6
Discharged waste	46.6	49.4	52.4	55.4	58.6	61.5	64.5	67.6	70.7	74.0
8. PVMC collection	17.6	19.7	21.8	24.0	26.4	28.7	31.0	33.4	35.9	38.5
9. Private collection	18.7	19.2	19.7	20.2	20.8	21.2	21.6	22.0	22.5	22.9
10. Direct haulage	10.3	10.6	10.8	11.1	11.4	11.6	11.9	12.1	12.3	12.6
11. MSW disposal	46.0	47.5	49.7	52.0	54.4	56.6	58.9	61.2	63.7	66.2
12. Bulky waste	2.4	2.5	2.5	2.6	2.7	2.7	2.8	2.8	2.9	2.9
13. Construction waste	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7
14. Medical waste	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9
15. Quarantine	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total final disposal	**50.0**	**51.6**	**53.9**	**56.3**	**58.8**	**61.1**	**63.4**	**65.9**	**68.4**	**71.1**

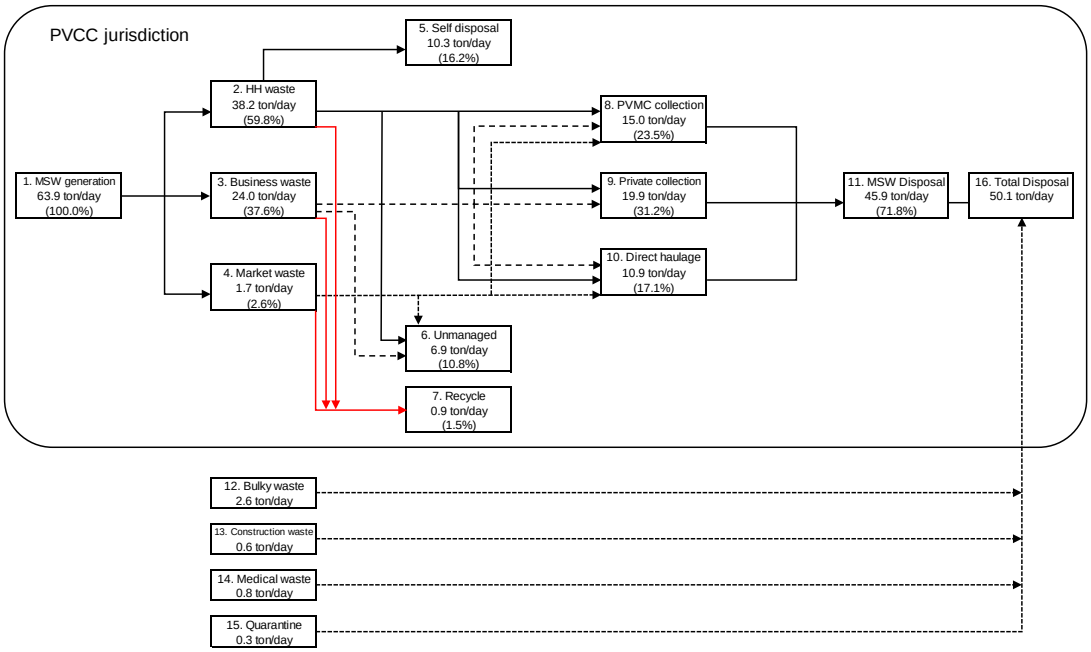


Figure 4: Waste flow in 2021

The table below shows the final disposal volumes expressed in terms of weight and converted into volumes. The apparent specific gravity of 0.8 tonnes/m3 is applied to

the calculation of the daily disposal volume, while the apparent specific gravity of 1.0 tonnes/m3 is applied to waste that has been in landfill for at least one year. The apparent specific gravity for waste that has been in landfill for at least one year is 1.0 ton/m3, because landfill operations need to take into account the condition of the waste as it is delivered to the landfill, and the condition of waste that has been compacted and left for a long time must be taken into account when estimating the long-term capacity of the landfill.

The landfill volume in the table below takes into account an intermediate cover of 20 cm for 3 m of landfill waste.

Table 4: Target disposal amount and volume for Bouffa Disposal Site

Year	Disposal amount		Disposal volume		Landfill volume
	(ton/day)	(ton/year)	(m3/year)	(m3/year)	(m3/year)
2021	50.1	18,291	18,291	18,291	18,291
2022	52.4	19,125	20,400	19,125	20,400
2023	54.8	19,989	21,322	19,989	21,322
2024	57.2	20,887	22,279	20,887	22,279
2025	59.8	21,814	23,269	21,814	23,269
2026	62.0	22,629	24,137	22,629	24,137
2027	64.3	23,467	25,031	23,467	25,031
2028	66.7	24,329	25,951	24,329	25,951
2029	69.1	25,216	26,897	25,216	26,897
2030	71.6	26,120	27,862	26,120	

Apparent specific gravity
- Waste at the time of landfill: 0.8 ton/m3
- Waste landfilled (at least one year has passed): 1.0 ton/m3

1.5 Bouffa disposal site development concept

The expansion plan for the Bouffa disposal site has sufficient capacity to enable final disposal by 2030, the final year of the PVCC SWM Plan.

The development concept of Bouffa disposal site was prepared by J-PRISM as shown below.

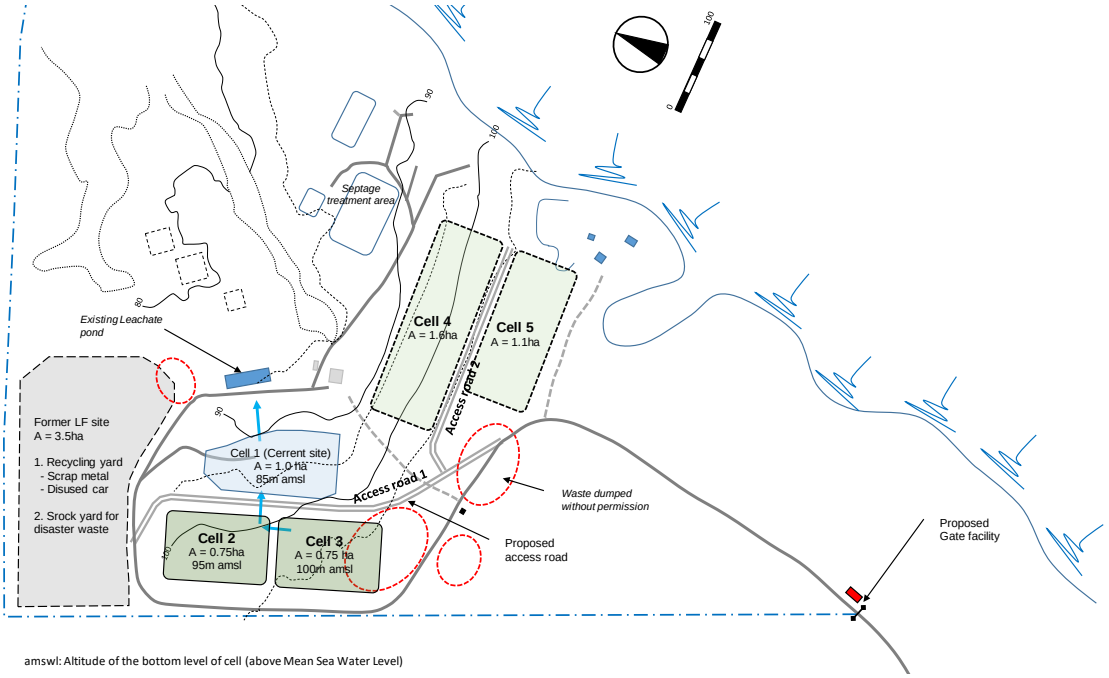


Figure 5: Development Concept of Landfill Cells

Table 5: Expected Landfill Capacity of Bouffa Disposal Site

Cell	Area (ha)	Capacity (m3)	Accumulated Volume (m3)
1	1.00	Almost full	0
2	0.75	75,000	75,000
3	0.75	75,000	150,000
4	1.60	160,000	310,000
5	1.13	113,000	423,000
Total	5.23	423,000	-

Source: JET

The table below shows the expansion schedule of the Bouffa disposal site required from the final disposal amount at the time of executing the SWM plan and the above landfill capacity.

The final disposal by 2030 can be covered by Cell-2-4. The landfill capacity including Cell-5 can cover up to around 2038 according to estimates by J-PRISM experts. During this period, if the amount of waste is reduced by promoting the 3Rs, it will be possible to make final disposal for a longer period of time.

A stacked landfill in the combined area of Cell-2 and 3 could also be considered. This can be envisaged as a way of ensuring the sustainability of final disposal in the event that the construction of Cell-4 is delayed for some reason.

Table 6: Expansion Schedule of Cells in Bouffa Disposal Site

Items	Unit	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Disposal Volume	m^3/year	18,291	19,125	19,989	20,887	21,814	22,629	23,467	24,329	25,216	26,120
Accumulated volume	m^3/year		19,125	38,249	58,239	79,126	100,940	123,569	147,035	171,364	196,580
Cell-1	Already full	- - - - -									
Cell-2	75,000m^3		Cell-2								
Cell-3	75,000m^3					Cell-3					
Cell-4	160,000m^3									Cell-4	

Upon improvement of the Bouffa disposal site, based on the EIA Act (to be revised in December 2018) enacted in 2011, PVCC must obtain approval of extension plan before construction of Cell-2 and 3

1.6 Development Plan of Cell-2 and 3

Based on the Bouffa disposal site development concept until 2030, J-PRISM II has carried out a preliminary design for the development of Cells-2 and 3 and submitted the report to the PVCC in March 2020.

As mentioned above, Cell-1 has already filled up the waste in excess of its capacity, but this landfill manual targets landfill operations after Cell-2, which is the next landfill section.

The development of Cells 2 and 3 is described in the next section.

2 Landfill Development

2.1 Extension procedure

It is desirable that the extension procedure from Cell-2 to Cell-5 is as follows.

Table 7: Extension of Bouffa Disposal Site

Step	Descriptions
1	Construction of on-site Access road-1 (during 2021) - This will be done in advance to access Cell-2 and 3. - Excavated soil will be used to cover Cell-1.
2	Construction of Cell-2 (by mid-2022) - Excavated soil will be spread and compacted in order to use the Former LF site as a temporary storage area for scrap metal and other materials, if there are no buyers.
3	Construction of Cell-3 (to start in early 2024 and be completed by mid-2025) - Excavated soil will be used as a covering material for Cell-2 if there are no buyers.
4	Construction of an on-site Access road-2 (to start in early 2028 and be completed by the end of the same year)
5	Construction of Cell-4 (to be completed by early 2028 to mid-2029). - Excavated soil is expected to be transported off-site with a sale destination.
6	Construction of Cell-5 (the start of construction will be determined by the remaining capacity of Cell-4)

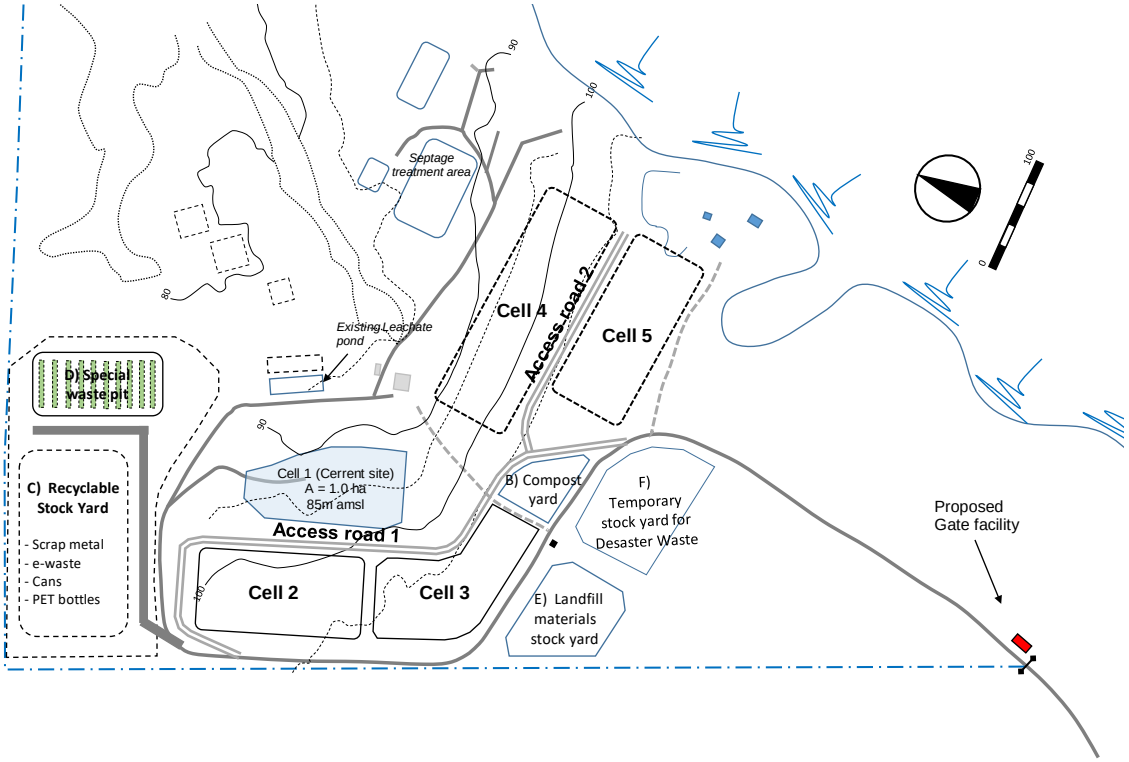


Figure 6: Layout of landfill facilities

2.2 Access Roads

There are three classes of roads to access the Bouffa repository, which are called Primary, Secondary and tertiary roads, respectively. The Primary road is a road connecting the ring road of Efate Island to the Bouffa disposal site, and is a two-way, two-lane road that opened in 1995. The Secondary road is a road inside the Bouffa disposal site and connects each facility (Landfill cells, Workshop, Recycle yard, etc.) from the entrance. Tertiary road is a temporary road for accessing the working face in the Landfill cell. Each road will be described below.

2.2.1 Primary road (Access road from Effate's annular road to Bouffa DS)

To reach the Bouffa disposal site, use the road of about 3.2km from the ring road of Efate Island to the Bouffa disposal site. This road was opened in 1995 when the Bouffa disposal site was put into service, but there are many ruts and the road surface is muddy when it rains, which hinders the passage of collection vehicles.

As an immediate measures, it is essential that the road surface is reshaped to remove ruts and that the drains on both sides of the road are repaired to restore their drainage function. These works should be carried out on a regular basis to ensure that the Access road remains in good condition.

On the other hand, the current road structure imposes a heavy burden on maintenance, so it is desirable to improve it as an all-weather road as shown in the figure below as a drastic measure.

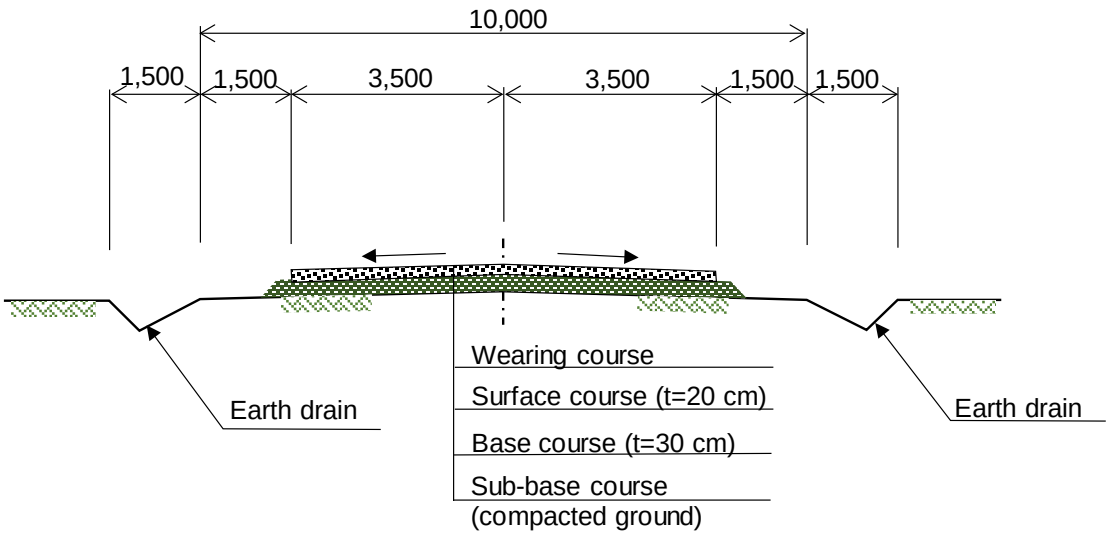


Figure 7: Typical Cross Section of Primary Access Road

2.2.2 Secondary road (Access road 1 & 2)

A typical cross section of the Secondary road is shown below. The carriageway will be 6m wide and paved with 20cm thick crushed stone with 30cm of sandy soil underneath. The base course of the road will be the excavated surface, which will be well shaped and compacted. In order to keep the roadway in good condition, it is necessary to have good rainwater drainage. For this reason, earthen ditches are provided at both ends of the 2m shoulders on both sides of the carriageway.

There is also a 3m space on the Cell side of the secondary road for the movement of landfill equipment. The reason for this is to prevent heavy machinery from damaging the Access road.

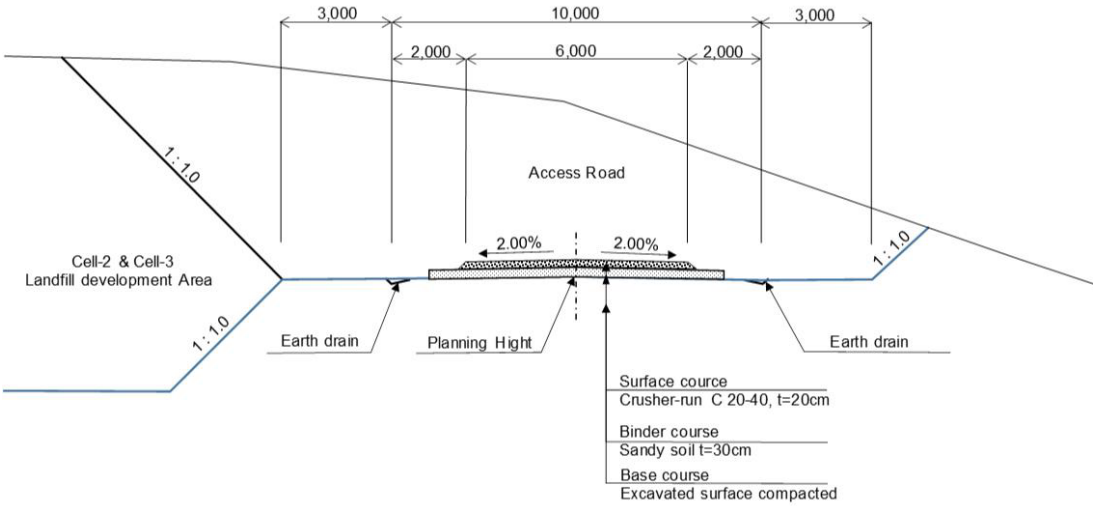


Figure 8: Typical Cross Section of Access Road1 & 2

2.2.3 Tertiary road (Temporary site road)

This is the road that provides access to the working face in the Cell. This road is placed on top of the landfilled waste and has to be replaced every time the height of the landfill is increased.

For this reason, it is proposed to use the structure shown in the figure below as a minimum cost solution.

Access to the working face has to be ensured even in wet weather. To ensure that rainwater does not remain on the road, the area where the road is to be built is raised 50cm to 60m above the surrounding area and compacted. On top of this, crushed stone or other non-slip material is laid to a thickness of 20cm. The width of the road should be 4m in case of one lane and 7~8m in case of two lanes.

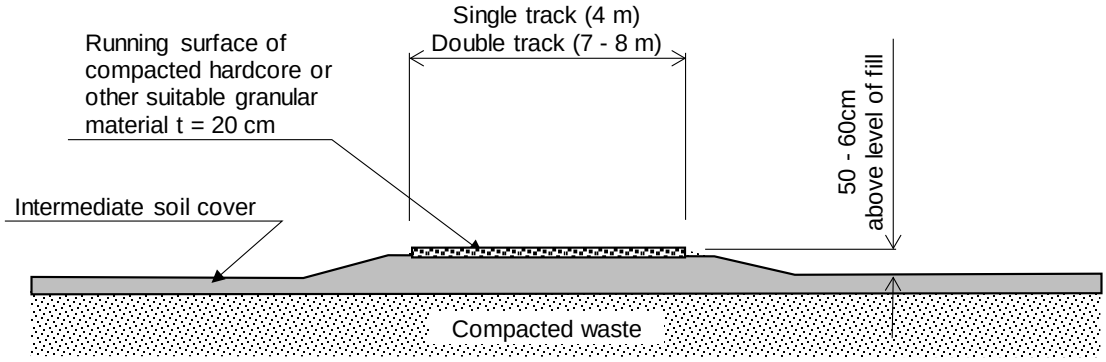


Figure 9: Cross section of tertiary road

For reference, the conceptual diagram of the tertiary road layout after the completion of the landfilling of the first layer of Cell-1 is shown in the figure below.

Tertiary road will be constructed from Accecc road 1 into Cell-1 surrounded by periphery bank and will be split into left and right in the middle of the Cell.

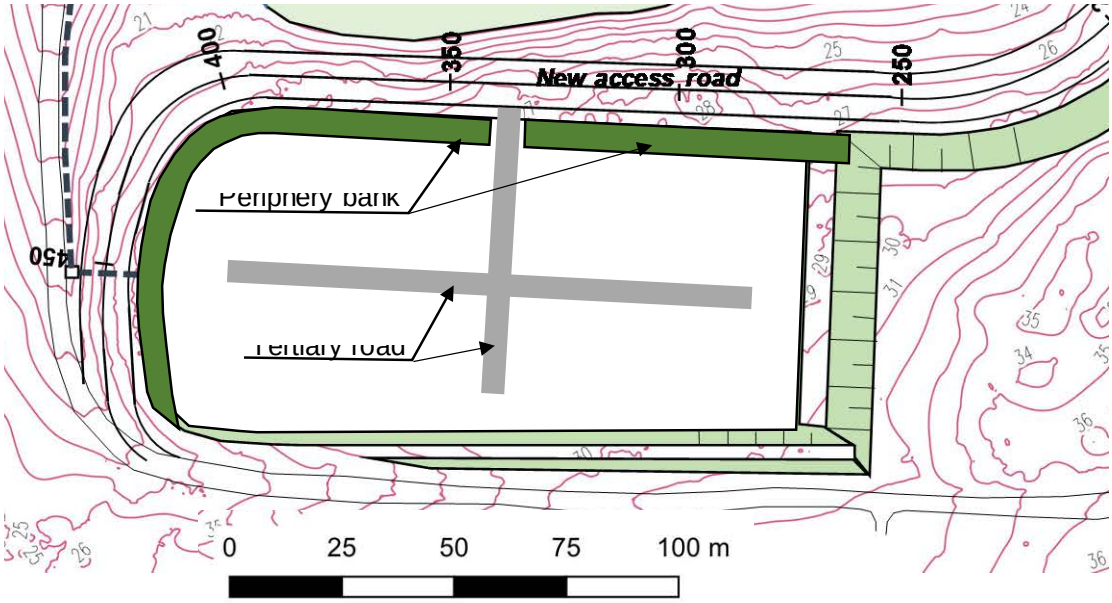


Figure 10: Layout of tertiary road (temporary site road)

2.2.4 Construction of Access road

Access road 1 will be constructed prior to Cells-2 and 3 and Access road 2 will be constructed prior to Cells-4 and 5. During construction, excavated soil will be used to cover Cell-1. If a buyer is found for the excavated soil, it will be given priority.

The access road is an indispensable infrastructure for moving the carried-in waste to a predetermined section, and is the most important for the smooth operation of the disposal site. For this reason, it is necessary to carry out regular maintenance even after construction to maintain good condition at all times. This is important not only for Access roads but also for existing on-site roads.

2.3 Landfill cells

Here, the construction of Cell-2 will be described, but the same applies to Cell-3 to 4 and 5.

The figure below shows a plan and a cross-sectional view taken from the preliminary design carried out for J-PRISM II.

Cell-2 is constructed by excavating the slope on the left side of Access road 1 as shown in the cross-sectional drawing. 3m below the road surface is the bottom of Cell-2 and the slope of the excavated surface is 1:1. The bottom of Cell-2 is 3m below the road level, and the slope of the excavation surface is 1:1. If the excavation height exceeds 7m on the mountain side, a small step of 3m is added. The slope of the bottom of the Cell-2 is 2% towards the centre to allow for drainage in the Cell.

Excavated soil will be taken off-site if it can be sold, otherwise it will be used for the final covering material of Cell-1 and surplus soil will be temporarily placed in a designated place.

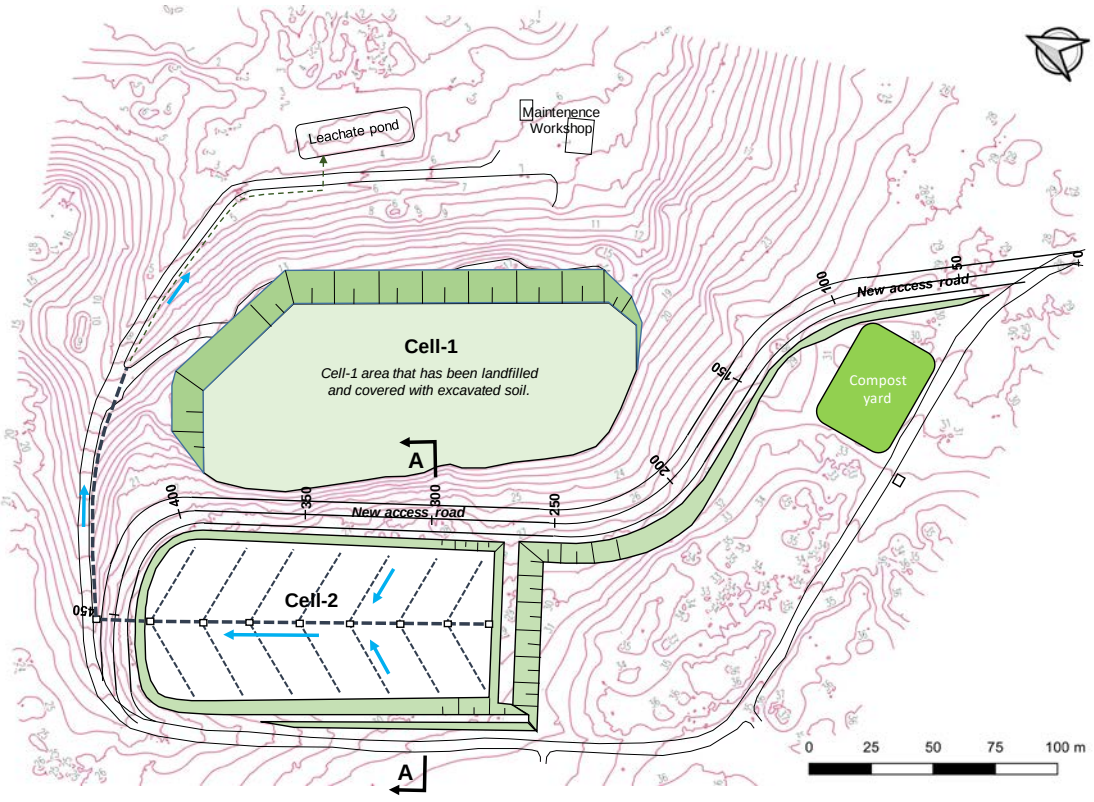


Figure 11: Development Plan of Cell-1

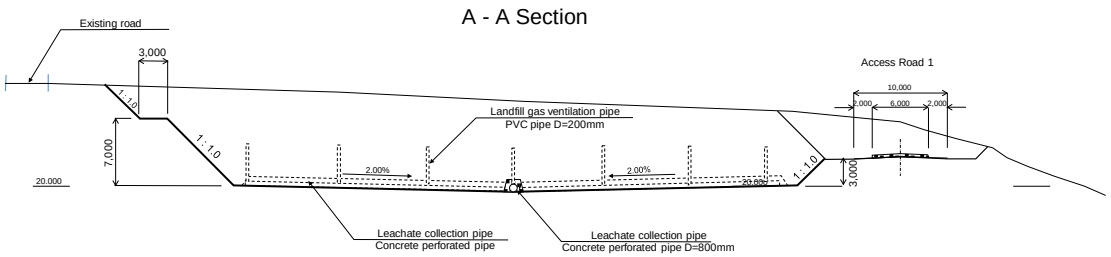


Figure 12: Cross Section of Cell-1

2.4 Leachate treatment system

2.4.1 Leachate collection

A leachate collection pipe is installed at the bottom of the cell to collect the leachate generated from the landfilled waste and lead it to the leachate regulation pond. The diameter of the collecting pipe at the bottom of the cell is 500mm of which adopted bigger size to allow air to flow into the landfilled waste. In this way, the organic matter in the landfill waste surrounding leachate collection pipe and landfill gas ventilation pipes is decomposed under the aerobic condition, which prevents the deterioration of the leachate quality and the generation of landfill gas. This method of landfill is called the Fukuoka method and is widely recognized as a method of reducing greenhouse gases.

Details of the leachate collection pipe is given in Annex "Construction Plan for Improvement of Bouffa Landfill in Port Vila, Vanuatu, June 2007", p12.

2.4.2 Overview of existing leachate treatment systems

The Leachate treatment system at the Bouffa disposal site was launched in 2008 with a collection pipe at the bottom of Cell-1 (then called Area 1), which collects leachate and stores it in the Leachate regulation pond via the Leachate receiving pond.

The leachate stored in the regulation pond is pumped to the landfill compartment to supply the water needed for the decomposition of the organic waste in the landfill. The leachate is then circulated from the landfill to the regulation pond in a so-called closed system, which means that no leachate is discharged to the outside.

The leachate generated in Cell-2 will be discharged to the north (left side of the drawing) as shown in Figure X Development Plan of Cell-1, and will be connected to the leachate drainage pipe installed along the existing secondary road and discharged to the leachate regulation pond.

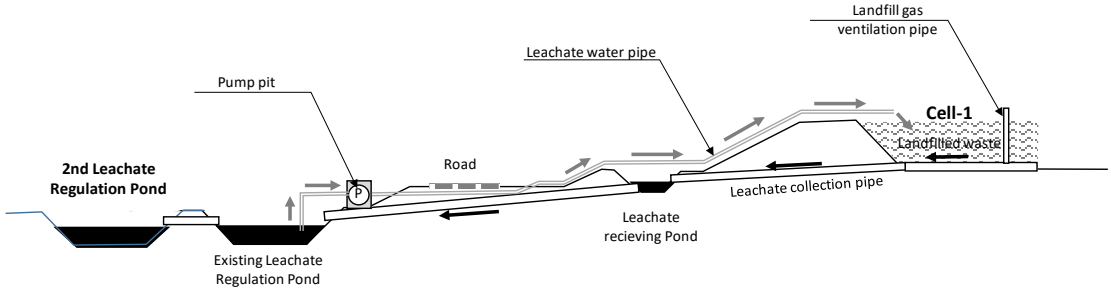


Figure 13: Leachate Circulation System

2.4.3 Increased leachate treatment capacity due to Cell expansion

The volume of leachate generated by the expansion of the Cells will also increase, so the treatment capacity needs to be strengthened.

(1) Expansion of leachate regulation pond

A secondary pond of the same size (41m x 10m at the base) as the current leachate regulation pond (called the primary pond) will be built on the east side to receive leachate that overflows from the primary pond beyond the capacity of the circulation pumps.

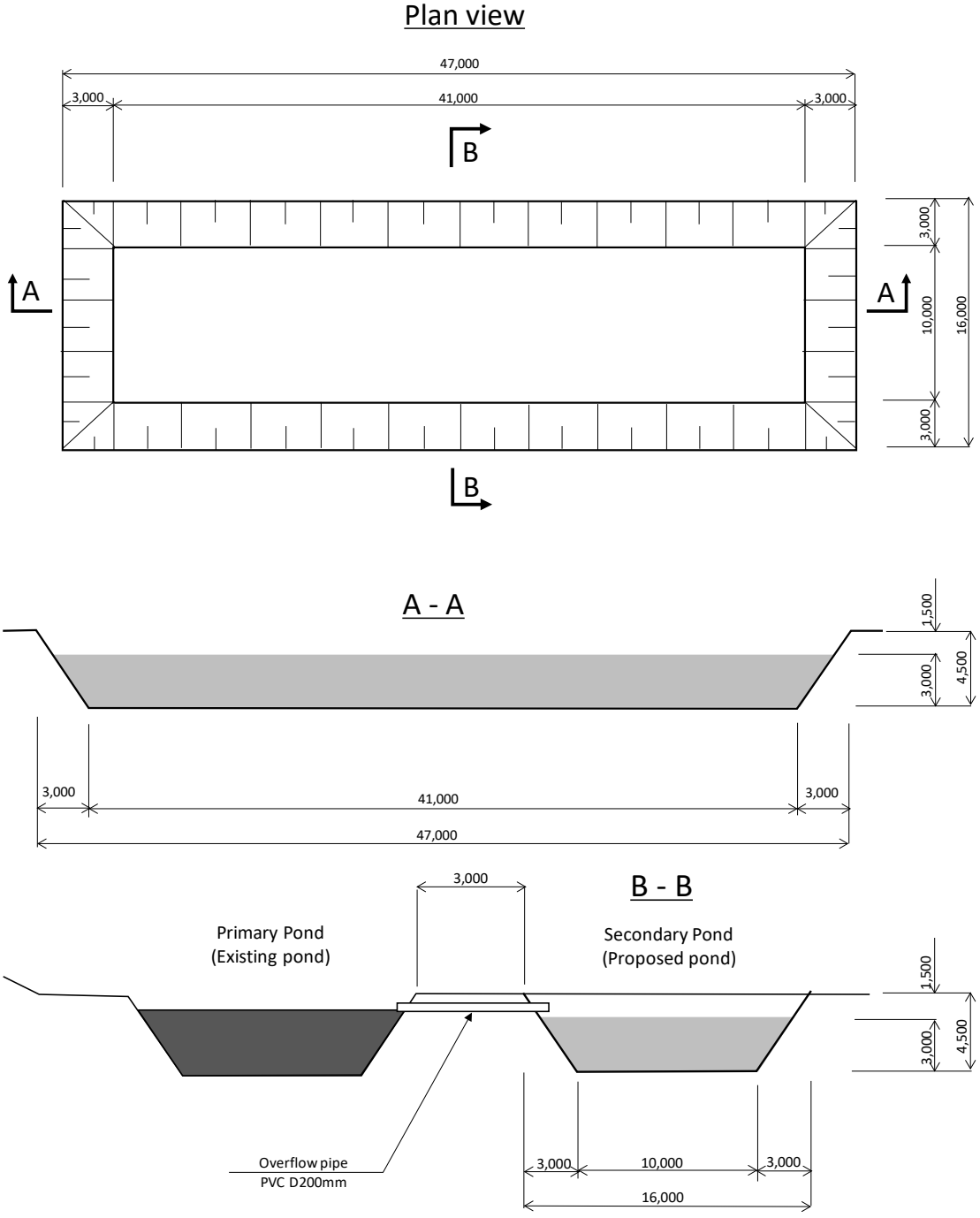


Figure 14: Expansion of Leachate Regulation Pond

(2) Improvement of water quality

As mentioned above, leachate treatment at the Bouffa Landfill is basically a closed system, where leachate is circulated within the landfill site and used to decompose organic matter in the landfill waste and not discharged outside the area.

However, if leachate exceeds the capacity of the two regulating ponds due to heavy rainfall, etc., the leachate is diverted to a leachate regulating ponds (with thriving wetland vegetation) constructed by the World Bank as part of the Housing Project in 1995. It is expected that the leachate will be purified in the process of slowly flowing down the regulating ponds where wetland vegetation thrives.

Waterway to regulating ponds

Regulating pond with thriving wetland vegetation

2.4.4 Landfill Gas ventilation

When landfill waste is covered by soil, landfill gas is retained in the landfilled waste. There is a risk of gas leaking from cracks in the soil cover, resulting in an explosion, so the gas must be properly vented.

The ventilation pipe will be installed in connection with the leachate collection pipe to allow as much air as possible into the landfilled waste. Details are given in Section 2.10 Landfill Gas Control and/or Annex "Construction Plan for Improvement of Bouffa Landfill in Port Vila, Vanuatu, June 2007", page 12.

B. Landfill Operation Manual

3 Landfill Operation

Proper day-to-day landfill operation at a disposal site is a very important routine task. Although the Bouffa disposal site uses the Fukuoka method, the function of a sanitary landfill will quickly deteriorate if the following operations are not carried out Once deteriorated, it will take a lot of effort and money to restore the functionality.

3.1 Site Record Keeping and Management

To properly operate and manage a landfill site, the first and most basic and important task that must be carried out is to ascertain the amount of landfilled waste (i.e. the amount of incoming waste). For every collection vehicle loaded with waste entering the disposal site, the following items should be elicited from the driver and recorded on a record form (Annex 1)

The record keeper can reduce errors by understanding why they are needed for the record items listed in the table below.

Table 8: Recording Items of Incoming Vehicle

Items	Hearing contents	Purpose
1. Incoming time	Incoming time	Grasp trends in the volume of incoming waste to disposal site on different days of the week and times of the day in order to improve the efficiency of landfill operations.
2. Vehicle Reg. No	Vehicle registration number	Identify the attributes of the incoming vehicle (type and size of vehicle, owner)
3. Owners of collection vehicles	Owner of collection vehicle (name of collection operator)	Identify who is responsible for the collection operation
4. Size of vehicle	Size of vehicle	Estimate the collection amount without weighbridge in place.
5. Origine of waste	Location of generation/collection of loaded waste	Grasp waste streams and quantities. Records should use the following abbreviation.
6. Type of waste	Type of waste	Grasp waste streams and quantities by type. Records should use the following abbreviation.
7. Disposal areas	Landfill area in the Bouffa DS	Know where the brought waste is disposed of in the Bouffa disposal site.

Abbreviation for Origine of waste: S = South Ward, C = Central Ward, F = Frestwota Tasiriki Ward, A = Anabrou Tebakor Ward, N = Northern Ward, R = Rural (*), Q = Quarantine

Abbreviation for Type of waste: H = Household waste, Mt = Maeket Waste, B =

Business Waste (Hotel, Restaurant, Office, etc.), C = Construction Waste, Me = Medical Waste, Q = Quarantine, Co = Condemned food stuff, Se = Septic Waste (Sludge)

3.2 Traffic control in the site

The traffic flow in the disposal site is shown in the figure below. Access road is basically two directions, but only Access road-1 is one-way.

In addition, the following should be thoroughly enforced as a rule when vehicles pass each other.

- Priority will be given to the vehicle carrying the load (waste or recyclable waste, etc.).
- If both vehicles are loaded with goods, the uphill vehicle will have priority.

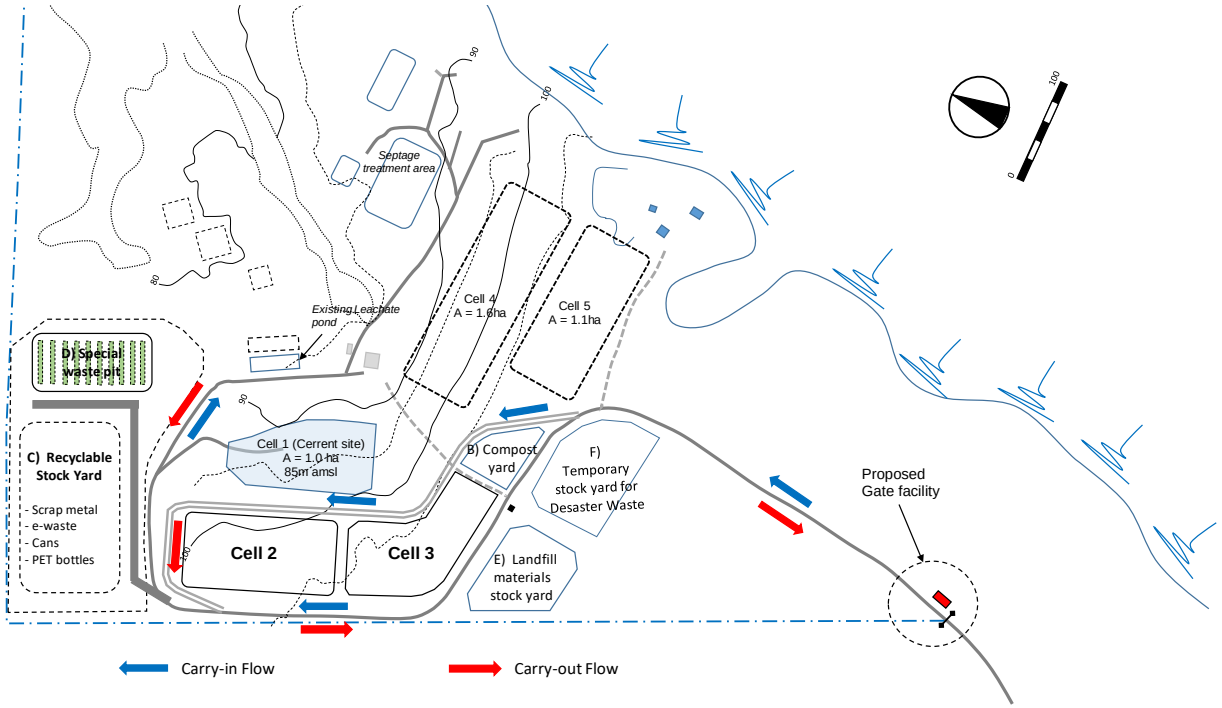


Figure 15: Traffic Flow in Bouffa Disposal Site

3.3 Waste emplacement

3.3.1 Waste acceptance

Various wastes are brought into the Bouffa disposal site. These wastes are classified according to their properties, and those that may have an impact on the environment if they are landfilled as they are, such as medical wastes and hazardous wastes, should be disposed of by an appropriate treatment method. In addition, for items that can be recycled, such as e-waste, it is important to select items that can be exported as valuable items and take them out of the site to reduce the amount of landfill waste as much as possible.

The following table shows the wastes accepted at the Bouffa disposal site and the methods used to treat and dispose of them at the site.

Table 9: Types and characteristics of incoming waste and disposal methods

Waste accepted	Characteristics and treatment in the disposal site
① General waste	It is so-called municipal waste such as household waste, commercial waste, institutional waste, and market waste, and is increasing year by year due to economic growth and population growth. For this reason, it is desirable to separate as much as possible before landfilling and take out recyclable materials to reduce the amount of landfill. In addition, organic matter, which accounts for 30 to 50% of general waste, generates methane gas in the process of decomposition, as well as leachate and foul odors, so environmental measures are required. Most of the market waste is organic, so it is desirable to recycle it as compost and return it naturally.
② Green waste	Green waste is like pruning waste, large branches, stems. Since green waste is bulky, it is inefficient to bury it with general waste, so it is ideal to chop large trunks and branches before disposing of them. In addition, since green waste is organic waste, it is desirable to stack chopped waste for a certain period of time and reuse it as compost.
③ Bulky waste	Bulky wastes such as furniture which, if landfilled as they are, will reduce the remaining landfill capacity, should be broken down to a minimum and disposed of after sorting out the recyclables. If E-waste is present, it should be treated and disposed of in accordance with the following section.
④ E-waste	Waste household electrical appliances, which include metals, plastics and, depending on the product, circuit boards, most of which are made from renewable materials. These are taken to the recyclable stock yard, where the valuable materials (those that can be exported) are disassembled and taken away by the recyclers, and the rest are temporarily stored in designated stockyards (to be taken out when they become valuable).
⑤ Special Waste	Special waste includes health care waste or medical waste, carcasses of animals, waste food, etc. Disposal of health care waste is basically under the jurisdiction of the Ministry of Health, but since there is a risk of infection, it is assumed that these wastes have been incinerated or sterilized at the source. In addition, rotten organic matter is a typical example of special waste, but since it has a bad odor, soil cover will be carried out on the same day.
⑥ Construction waste	These include concrete lumps and timber. The rubble and debris will be stored in temporary storage areas for reuse as materials for the maintenance of the on-site roads. Reinforced concrete is crushed to remove the reinforcing steel and stored together with the scrap metal sorted out in ③.
⑦ Hazardous waste	These are hazardous (mostly liquid) wastes from schools and other testing/laboratories. As there are currently no treatment/disposal facilities for these in Port Vila, they will be stored at the Bouffa disposal site for a period of time until a suitable treatment method can be established in the future.
⑧ Disaster waste	These wastes are generated in large quantities by cyclones, earthquakes, etc. As these wastes have to be removed from the city centre as soon as possible, space for their reception will be reserved close to the entrance of the Bouffa disposal site. Disaster waste should be sorted as soon as possible after being brought to the disposal site and disposed of via routes ① to ⑦.

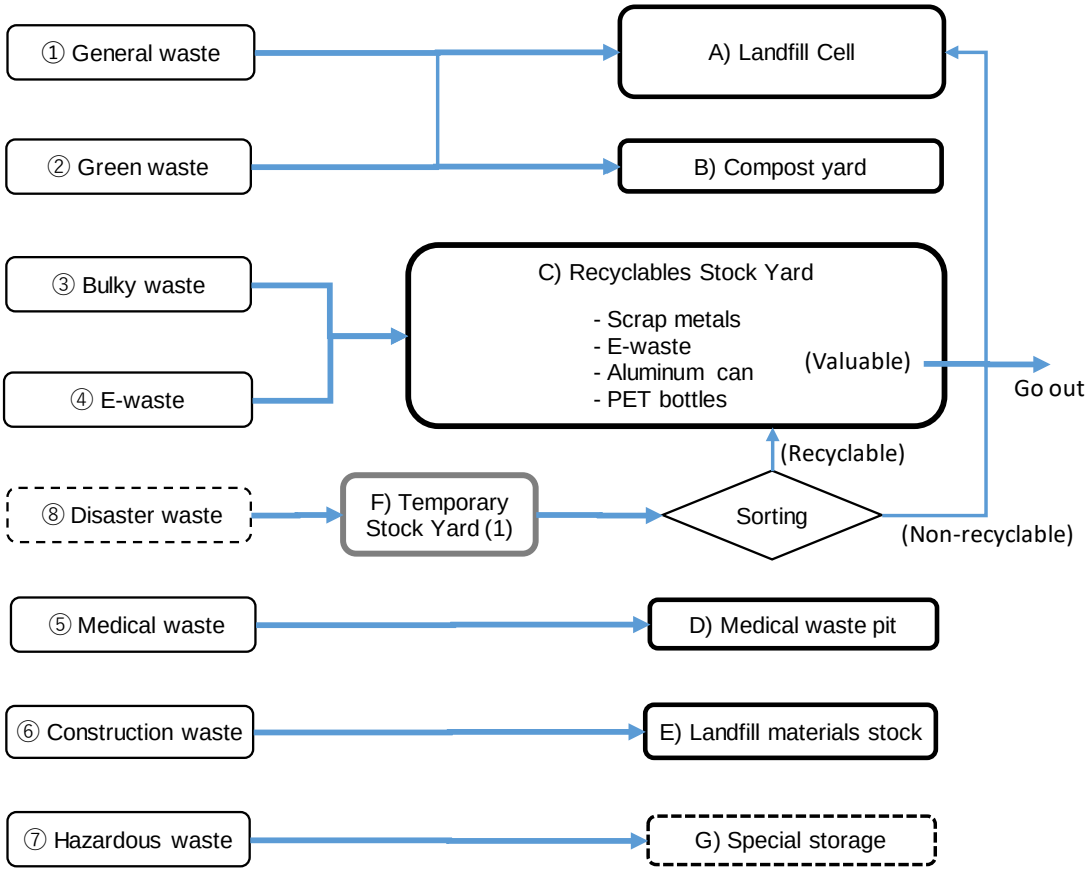


Figure 16: Classification of incoming waste and its disposal

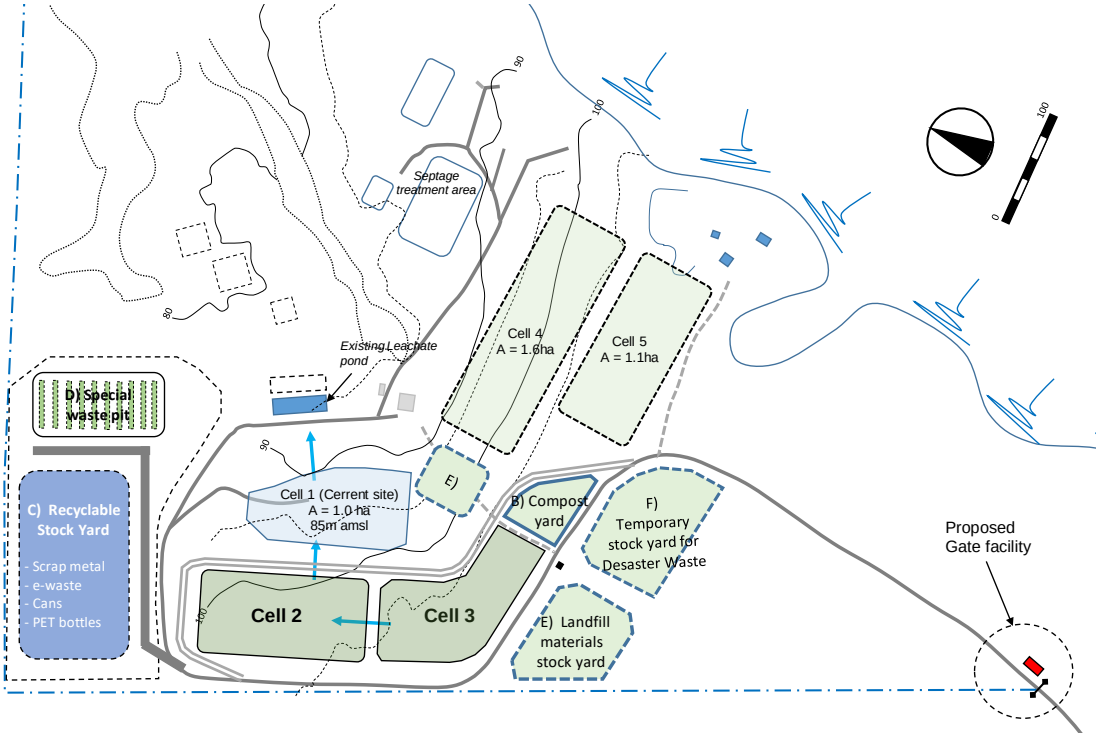


Figure 17: Layout of the disposal facilities

3.3.2 Disposal method

A) Landfill Cell

(1) Working face

The section where the landfill work is performed in the Cell is called "working face". The working face moves from the downstream side to the upstream side. It is desirable that the working face be as small as possible in order to properly manage the landfill and minimize the scattering of dust.

At the Bouffa disposal site, the required area for landfilling garbage for one week is about 150 m2. Considering the work space of heavy machinery, it is recommended to use a section of about 500m2 (example: 20mx25m), which is about three times as large as this, as the working face.

Landfill volume per week: 62.6m3 x 7 days = 438.2 ⇨ 450m3

Thickness of a landfill layer: 3.0m

Landfill area: 150m^2 (15m x 10m)

When the thickness of the landfill waste reaches 3m in this working face, the landfill work is moved to the next working face. In addition, the landfilled waste that has reached 3 m is covered with soil with an average thickness of 20 cm using the excavated soil generated when the Cell was constructed.

(2) Landfill work for the first layer

Cell is a depression excavated 3m from the Access road. When the waste is first landfilled in this Cell, the carry-in waste is unloaded from the side of the access road toward Cell-2. The dumped waste is moved into the Cell by an excavator, and is spread and compacted within a predetermined landfill area by a bulldozer.

The thickness of one layer of waste should be about 0.5 to 1.0 m, and the slope of the end should be 1: 3 so that the bulldozer can sufficiently roll the waste.

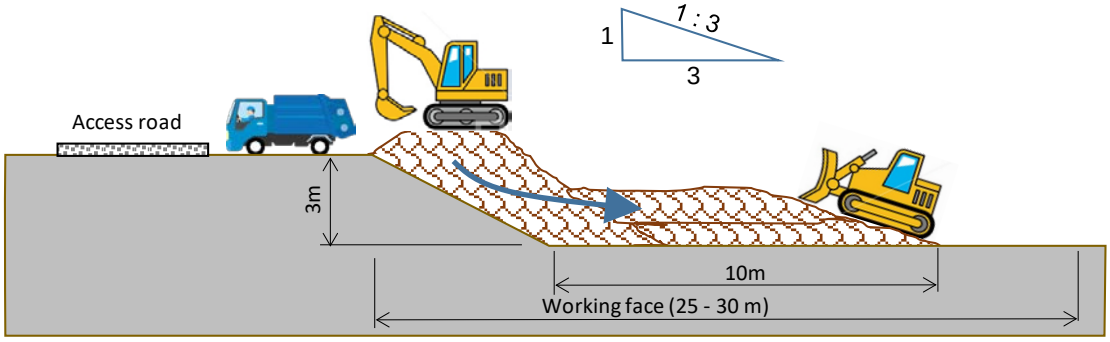


Figure 18: Landfill image of the first layer

The reclamation work is carried out by moving the working face sequentially. For access to the inside of the Cell from the access road, see Access road in the Cell described in the Road section.

(3) Landfill work from secondary layers

- Periphery bank

Since the landfill work for the second and subsequent layers will be higher than the access road, a "periphery bank" will be built on the access road side of the landfill area to prevent the landfilled garbage from spilling out (the mountain side is the cut slope).

The reclamation work will be carried out in an area bounded by a periphery bank and a mountainside cut slope. The periphery bank shown in the figure below will be made of aged landfilled waste and covered with soil .

The slope on the outside of the peripheraly bank has a slope of 1: 2, but it is recommended to use a piece of wood called Tombo so that the operator of heavy machinery can use it as a guide for shaping.

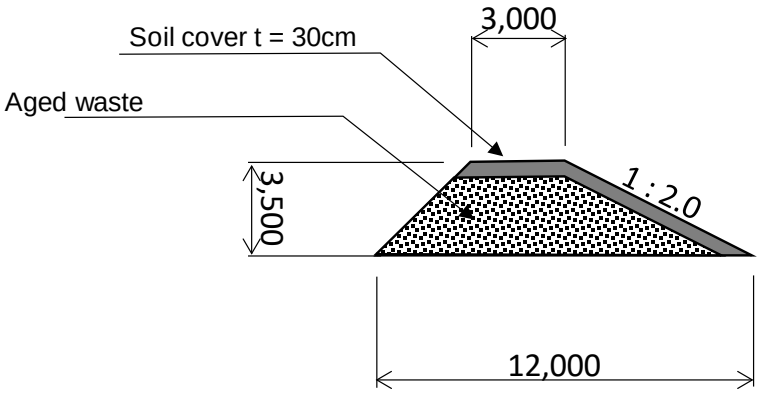


Figure 19: Shape of Periphery bank

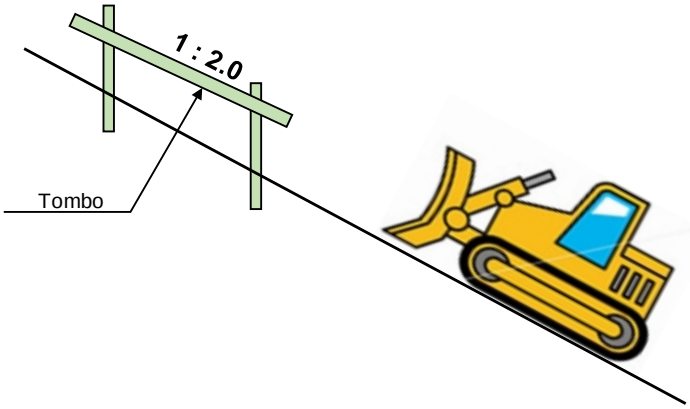


Figure 20: Slope shaping by heavy equipment

- Landfilling

Place a tertiary road to bring in waste to the working face. The image of the landfill of the unloaded waste is as shown in the figure below, and it is spread and compacted in a predetermined section with an Excavator and a Bulldozer.

Unlike the first layer, the reclamation work in the Cell surrounded by the periphery bank is done by piling up the unloaded waste from the collection vehicles. In this case as well, the thickness per layer is 0.5 to 1.0m and the slope at the edge is 1:3.

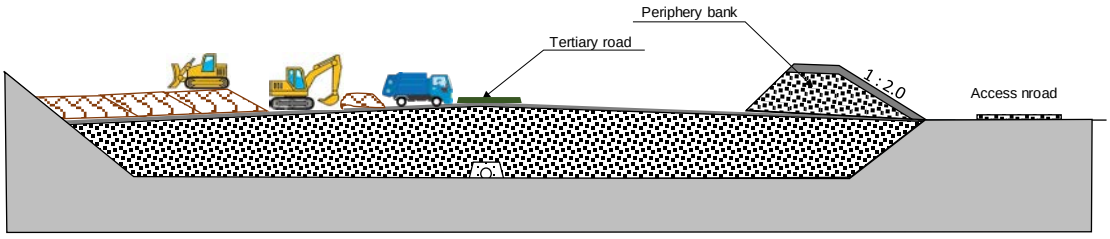


Figure 21: Image of landfill work on the first layer

B) Compost yard

Garbage received at compost facilities shall be market waste (vegetable waste). In compost production, it is important that the target waste is specialized for degradable waste, so it is premised that it is sorted when it is collected in the market.

Waste brought into Bouffa will be composted according to the following procedure.

① Remove impurities (non-degradable substances). The residue generated by this work is disposed of in the landfill area.

② Dry the vegetable waste in the sun and remove about half of the water.

③ Pile up the vegetable waste to a height of about 1.5 metres. It is also effective to cover with a tarpaulin to prevent the infiltration of rainwater and adjust the water content.

④ ② is turned back every week so that the air can flow inside.

⑤ A fully aged compost is sieved to remove impurities, and a compost product is completed.

As the compost products produced in this way can also be bagged and sold, it is worth considering employing west pickers as workers.

C) Recyclable stock yard

At present, scrap metal, e-waste and other bulky waste dumped randomly in the landfill site, as well as aluminium cans and PET bottles picked up by waste pickers from the landfilled waste, are accumulating here and there, obstructing the landfill operation. The scrap metal also causes damage to heavy machinery. In order to improve this situation, these wastes will be cleaned out from the landfill plot and its surroundings and consolidated in one place.

The Recyclable stock yard is to be used only as a temporary storage area for the following recyclable waste, which is to be purchased by recyclers.

- Scrap metal: Scrap metal including end of life vehicles should be temporarily placed in a disassembled state as much as possible to reduce the volume.
- E-waste: As far as possible, the products should be grouped together and temporarily stored in order to allow for future extraction of valuable materials.
- Aluminum cans & PET bottles etc.:

The Waste Management, Environment and Health Division (WMD) has instructed waste pickers to take these items to a temporary storage area in the recyclable stock yard. The WMD instructs waste pickers to bring these items to the temporary storage area provided in the recyclable stock yard.

The WMD will ensure that recyclers are allowed to purchase these valuable materials only within the recyclable stock yard, and that they are penalized for purchasing within the landfill area.

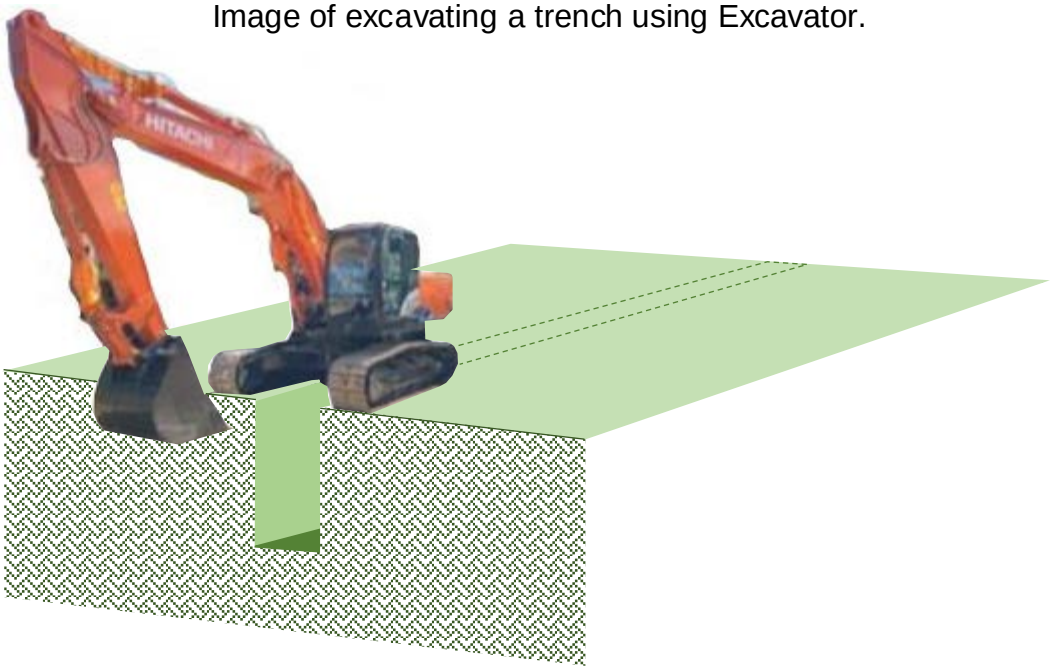
D) Special waste pit

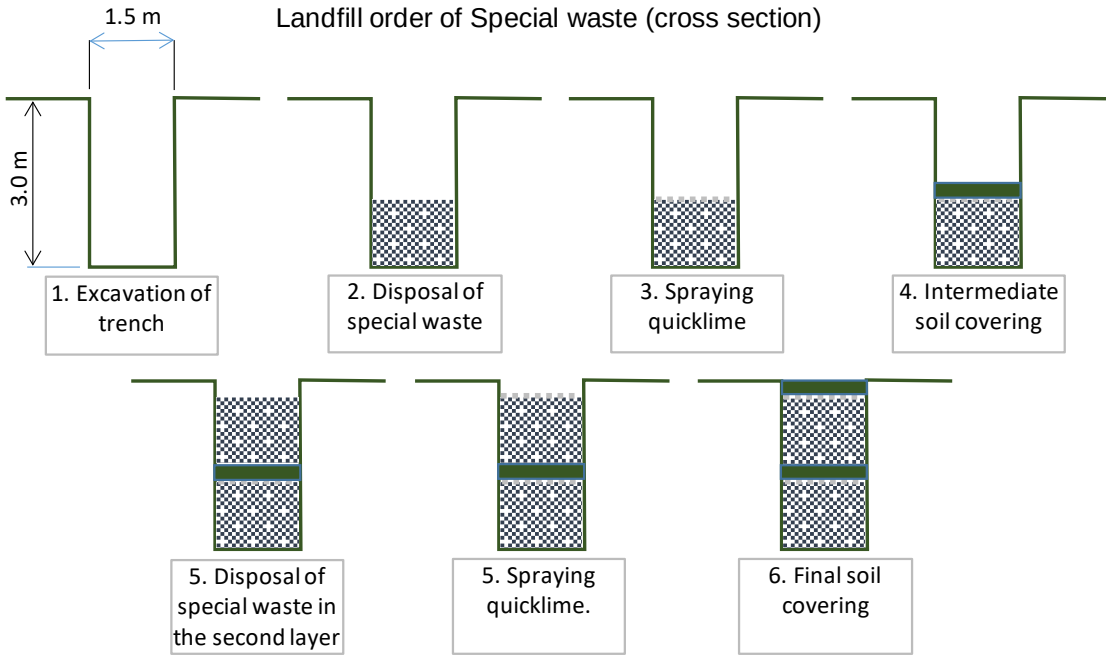
WMD must ensure that medical institutions strictly separate all waste they generate into general waste and medical waste. Depending on the medical institution, medical waste may be incinerated and discharged, but the incinerated ash must be disposed of separately from general waste in the same way as medical waste. Medical waste (including ash) brought into the Bouffa disposal site should be brought into the special waste pit on the east side of the recycling stockyard.

To prevent the spread of infection by medical waste, the special waste pit area will be surrounded by a barrier and access to the area will be strictly controlled.

The landfill method for medical waste is the trench method, in which quicklime is sprayed immediately after dumping, sterilized by heat, and then covered with soil on the same day. The procedure for landfill is as shown in the figure below.

Image of excavating a trench using Excavator.





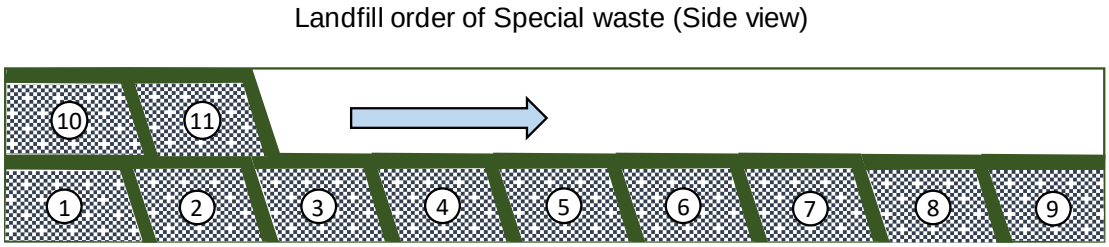


Figure 22: Trench method for special waste

Table 9: Advantages and Disadvantages of disposal by burial

	Advantages	Disadvantages
Sanitary landfill, trench method	• Simple and inexpensive operating costs. • Can be carried out using an existing municipal waste management system. Note: Waste pickers cannot access the health-carewaste if the landfill is well managed.	• The health-care wastes are not treatedand remain hazardous. • The landfill must be secure, fenced in, and guarded. • Waste pickers and animals need to be controlled. • A high degree of coordination is needed between collectors and landfill operators. • Makes health workers less aware of the need to sort the various types of waste. • Transport to the landfill can be a lengthy and costly operation. • Risk of water pollution.

Source: Medical waste management, International Committee of the Red Cross (ICRC)

E) Landfill material stock yard

In the sanitary landfill process, the waste is spread and compacted, and then periodically covered with soil to control pests such as flies and to reduce odours. This requires a large amount of covering material.

A large amount of excavated soil will be generated in the construction of the Cell at the Bouffa disposal site. The excavated soil will be temporarily placed in multiple places near the landfill area and used as a soil covering material.

F) Temporary stock yard for disaster waste

Various types of waste are mixed in the disaster waste generated by cyclones, earthquakes, and so on. Since disaster waste will be delivered to the disposal site in a short period of time, it will be temporarily stored, recyclable waste (including scrap metal and e-waste) will be sorted, and moved to the recyclable stock yard. The residue is treated in a landfill section of general waste.

Temporary storage areas for disaster waste should be flat, 30cm higher than the surrounding area and sloped to prevent rainwater from accumulating.

G) Special storage

As a rule, hazardous waste is disposed of by the generator himself. However, hazardous waste from schools and other public facilities may be taken to a disposal site without being treated.

Hazardous waste that cannot be treated at this time must be packed in a safe container and stored completely isolated from the outside. For this reason, attach a sticker with the contents, put it in a container, and store it in the building.

3.4 Leachate Control

3.4.1 Leachate collection system

Leachate is collected by a collection pipe installed at the bottom of the Cell, and is directed to the existing relay pond via the following pathway, which leads to the Leachate regulation pond.

Cell-3 ⇨ Cell-2 ⇨ Relay Pond ⇨ Leachate Regulation Pond

Cell-5 ⇨ Cell-4 ⇨ Relay Pond ⇨ Leachate Regulation Pond

3.4.2 Maintenance of Leachate treatment facilities

Regular maintenance is required to maintain the sound function of the facilities that make up the Leachate treatment system described in Section 2.4.

The current leachate regulation pond has a sand puddle and is overgrown with grass, which reduces the capacity of the pond, so it is advisable to regularly remove sand and other debris from the bottom.

Since no pump is currently installed in the pump hut installed beside the leachate regulating pond, leachate is continues to accumulate in the regulating pond. It is important to install the pump as soon as possible so that the circulation system function.

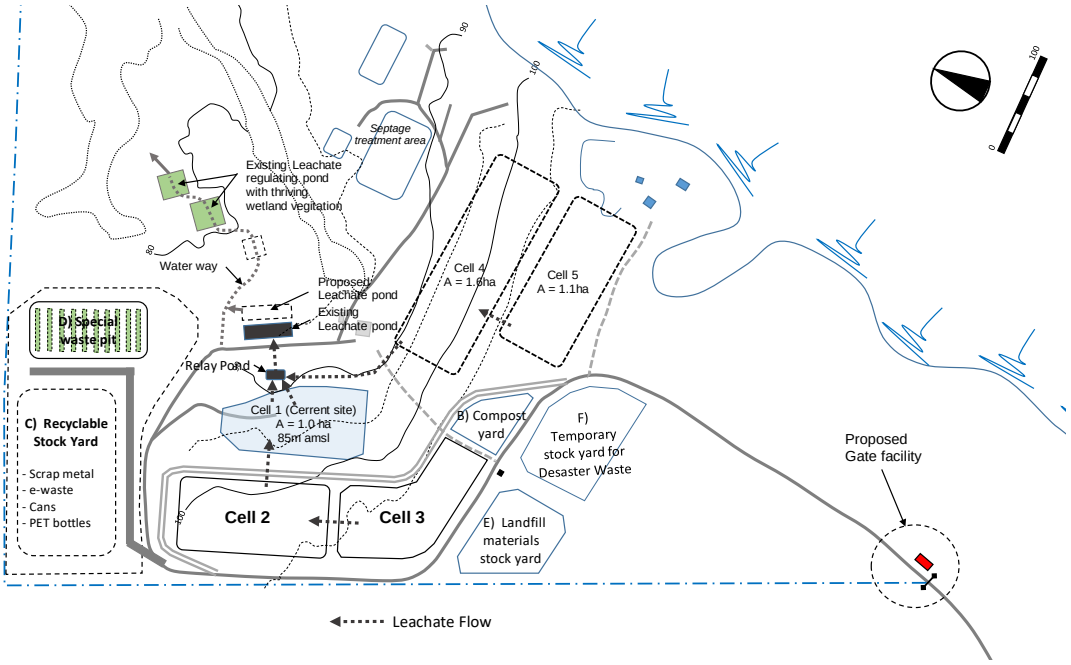


Figure 23: Leachate flow

3.5 Surface Water Control

The current Bouffa disposal site does not have a proper stormwater drainage system. This has led to problems such as rainwater eroding the roads within the site and leachate accumulating in depressions here and there, causing odours and encouraging mosquito breeding.

In order to improve this situation, a drainage network should be installed in the disposal site as shown in the figure below to properly drain the water. In addition, the installed drainage network must be maintained and managed on a regular basis to maintain the drainage function.

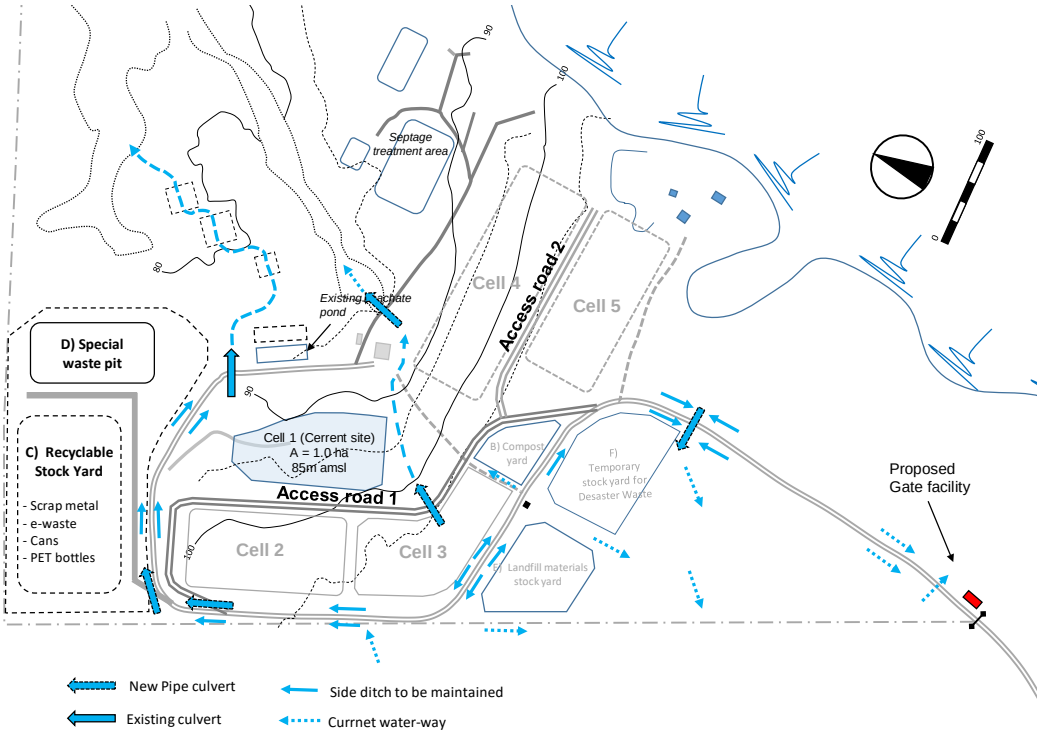


Figure 24: Drainage Network in Bouffa Disposal Site

3.6 Landfill Gas Control

The landfill ventilation pipe is a PVC pipe with a diameter of 200 mm, but since it stands up in the landfilled waste, operators such as bulldozers need to pay close attention so that they will not be damaged during landfill work.

Also, the landfill gas ventilation pipe will be added as the landfill height increases, and limestone will be piled up around the ventilation pipe placed in the center of the wire mesh, but try to stand as vertically as possible. The vertical joint of the landfill gas ventilation pipe is as shown in the figure below.

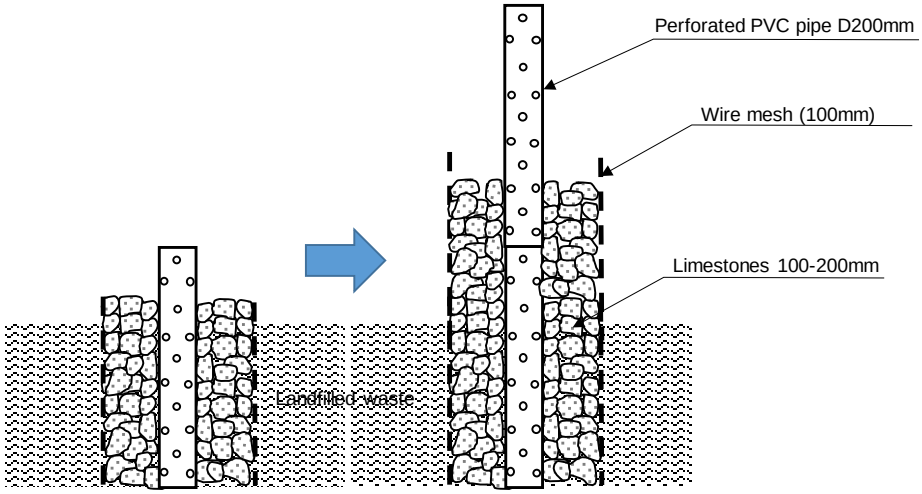


Figure 25: Procedure for joining the degassing pipe

3.7 Scattering of waste

The causes of the scattering of waste in the disposal site are the scattering of waste due to strong winds and the outflow of dumped waste during heavy rains.

(1) Scattering waste due to strong winds

To prevent waste from scattering against strong winds, install an anti-scattering fence on the leeward side of the work face. This shall be movable, and shall be a simple one with a stake and a net attached to it.

Figure 26: An example of a net fence to prevent scattering

(2) Outflowing waste due to heavy rains

Waste overflow during heavy rainfall is caused by the accumulation of waste in the waterways, so the first step is to collect the waste in place. On the other hand, it is essential to develop and maintain an appropriate drainage network on site to control the waterways. (See 3.5)

3.8 Fire measures

The main causes of fires at landfill sites are smoking by workers, ignition of landfill waste by west pickers burning waste containing valuable metals for recovery, and spontaneous ignition by glass and sunlight in the landfill waste. Since methane gas is produced inside the landfilled waste and once ignited, it will continue to burn for a long time. In the worst case, it can spread to the surrounding weeds and forests. For this reason, the following measures should be taken against fires in landfill site.

(3) To extinguish a fire in landfilled waste, the waste should be covered with soil to cut off the supply of oxygen. In order to do this, it is essential that soil is kept at all times in the temporary storage areas of the covering material at the disposal site.

(4) Secondary roads should be designated as fire protection areas and trees along the roads should be pruned to keep sufficient space.

In addition, since there is a risk of arson in the event of a fire in a facility such as a workshop, it is desirable that WMD request the local residents to cooperate in fire prevention and ensure thorough security at night. Measures against fire in the facility are;

(5) Install a rainwater tank so that it can be used as fire extinguishing water in the event of a fire.

3.9 Access Road

In order to make the access road always available, it is important to maintain and manage the drainage channels provided on both sides. Make sure that the water surface of the drainage channel is at least 30 cm below the road surface, and that the surface and base layers of the road are not submerged in water.

In addition, since the pavement material (limestone) on the road surface becomes thinner due to the passage of vehicles, secure the pavement material, and if the road surface is found to be damaged by the patrol inspection, fill the pavement material immediately.

Since the road surface may be rutted by the passage of heavy vehicles, the road should be unevenly landed on a regular basis (about half a year), paving material should be spread and compacted to maintain the function of the road at all times.

4 Emergency Measures

4.1 Emergency measures for the accident

The following is an emergency contact network in the event of a personal injury during landfill work or a traffic accident caused by a collection vehicle in the Bouffa disposal site.

In such an accident, the first priority is the measures taken by the injured person. Landfill workers present at the accident site first inform the disposal site manager. The disposal site manager determines the injured situation of the injured person (landfill worker / driver / worker of collection vehicle, Waste picker, etc.) and arranges an ambulance according to the degree of urgency. At the same time, the disposal site manager informs the person in charge of the Waste Management, Environment and Health Division of the response policy and obtains a prior consent.

In the event of an accident, the accident scene should be left as intact as possible at the time of the accident until further instructions are given by a police officer, as the scene will be examined by the police.

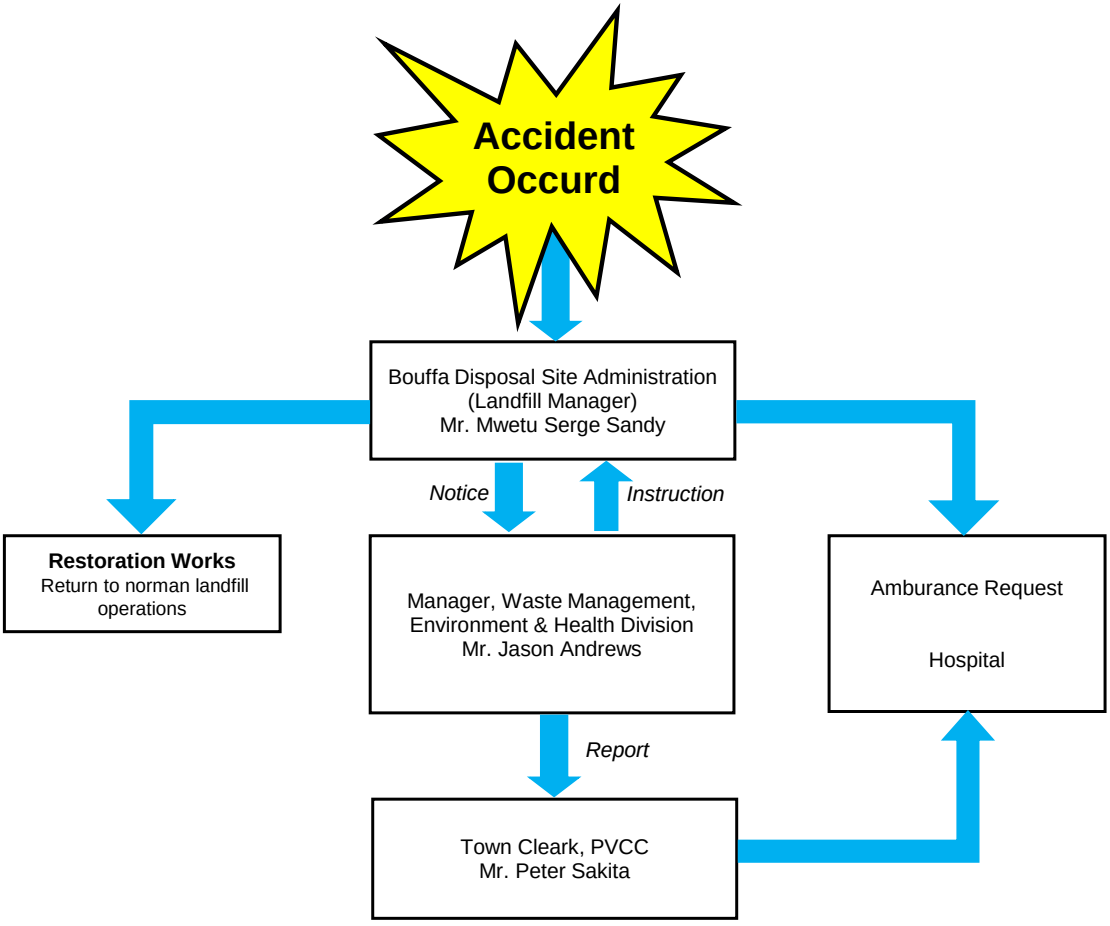


Figure 27: Emergency Contact Network for Bouffa Disposal Site

4.2 Emergency measures against fire

Cases of spontaneous combustion or arson of landfilled waste are expected in disposal site. In the event of a fire in the disposal site, the site worker (daytime) or security guard (nighttime) should inform the Landfill Manager of the fire and ask for instructions on how to respond.

The Landfill Manager will instruct the on-site workers on the measures that can be taken in response to the situation on site, bearing in mind the following procedure.

1. Evacuate waste pickers etc. from the scene of the fire.
2. Remove flammable materials, etc., paying attention to the direction of the wind to prevent the spread of fire to the disposal facilities.
3. If water for firefighting is available, arrange for a water sprinkler truck to extinguish the fire. If no water is available, carry earth and sand from the landfill material stock yard close to the fire and cover the fire with earth using an excavator.
4. Once landfilled rubbish burns, it will continue to burn for a long period of time, and workers should be deployed to observe the fire until it is confirmed that it is completely extinguished.

In addition, the disposal site personnel should be familiarized with the procedures for responding to fires through regular training.