# "Piggyback" Landfill System in Mozambique – A Geosynthetic Solution

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## Abstract

A mine situated in Mozambique was instructed by the authorities to close and remediate their existing Landfill site and therefore required a new General Waste Disposal Facility (facility). A trade-off assessment was developed to identify the preferred location for the new facility. The new facility is divided into three main areas namely; Landfill, Leachate pond and Recyclable and hazardous waste storage area. The hazardous and recycled waste will be collected and transported from site on a predefined frequency. A "Piggyback" Landfill system (a system which functions as a cover for the existing Landfill as well as a bottom liner for the new Landfill) that made extensive use of various geosynthetic materials, was implemented in the design. This paper discusses the conceptual design of the new facility, with particular emphasis on the unique challenges associated with the site, and the various solutions implemented as mitigation measures.

***Keywords:*** *Waste disposal Facility, Barrier, Landfill, Waste, Leachate*

## 1 Introduction

A mine situated in the Nampula province of Mozambique is in the process of closing and remediating their existing Landfill site due to instruction received by the local environmental authority. The instruction was given because the existing Landfill is unlicensed, unlined and no groundwater and/or leachate management are in place, as a preventative measure, to protect the receiving environment. Legislation governs that the receiving environment be protected from the potential impacts of a landfill site. Therefore a new General Waste Disposal Facility (facility) is required. The paper describe the conceptual design of a Landfill that will comply with the international best practices which was proposed to the client to replace the existing facility.

## 2 Background

The existing Landfill was used to dispose waste from 2009. The waste disposed on the existing Landfill predominantly comprised of general waste from the staff camp, mine offices and plant offices as well as waste from the plant and service building, some of which could potentially be hazardous. The hazardous waste, for example oil rags is placed into 220lt drums and then transported from site. The mine is recycling the waste by sorting the waste into suitable bins before transporting it from site. Due to the remoteness of the mine the need to provide temporary storage for the recycled and hazardous waste was identified.

In the absence of legislation/guidelines, that complies with international best practices, available in Mozambique, it was agreed that the South African landfill standards would be used as a guideline and basis for the design. The mine is situated in a very remote area, posing challenges. Both contractor's site establishment and the transportation of the various materials, used in the design, is very expensive. From the outset it was agreed that the Landfill development will be based on a phased approach to assist with capital expenses.

## 3 Trade-off assessment

To identify a suitable location for the new Landfill a trade-off assessment was developed to assess three alternative sites to determine the feasibility in terms of Engineering, Social, Economic and Environmental Impacts.

A desktop study augmented by a site investigation, provided the necessary background information to conduct the trade-off assessment. The site visit focused on determining the geotechnical properties of the *in-situ* material. The investigation yielded similar geotechnical properties for two (2) of the three (3) sites being sandy-silt soil with a high permeability. The third site (located on top of the existing Landfill) consisted of a sand-silt and waste mixture.

A site walkover was done to identify any notable design constraints as well as a meeting with the stakeholders to identify the waste management practices of the mine. Furthermore, groundwater depths (water table elevation) were determined for the three (3) sites by means of drilling and Groundwater prediction through modeling.

One of the major risks associated with waste disposal by landfill is groundwater contamination. The in-situ soil is very sandy and with a shallow aquafer found in the area, have an increased risk for groundwater contamination. The facility are situated in a high-risk cyclone region where high intensity rainfall event can be expected and must be designed for.

The concepts allowed the identification of engineering constraints associated with each site. After development of the trade-off assessment the preferred option, based on the impacts mentioned above, was identified as the "Piggyback" Landfill system. A "Piggyback" Landfill system functions as a cover for the existing Landfill as well as a bottom liner for the new Landfill. The major contributing factors in support of the alternative being selected included; existing infrastructure can be used for new facility, the facility is located on a brownfield site, and the newly constructed bottom liner will serve as a capping layer for the old Landfill. All of the above-mentioned factors resulted in the reduction of overall cost and environmental impacts. Once the detailed site investigation has been finalized a detail design will be developed for the preferred "Piggyback" Landfill system and implementation will follow.

It was determined that the "Piggyback" Landfill will be developed in two phases, each with a 10-year lifespan. The Landfill will accommodate a total of 20 years waste generation based on the current workforce at the mine.

## 4 Design of the new General Waste Disposal Facility

### 4.1 Factors and constraints that influenced the design

The conceptual design for the rehabilitation of the existing Landfill and development of the new facility started early in 2017. From the outset it was evident that the design would pose a number of challenges, which identified the following design constraints:

- The South African Norms and Standards were used in the absence of local legislation;
- The design of the new Landfill needed to cater for a total waste stream of 25 200$m^3$ over a 20-year design life;
- It was required that the recycled waste, which is disposed in appropriate bins, had to be temporarily stored;
- The hazardous waste had to be temporarily stored;
- The mine is situated in a very remote area, posing challenges;
- The new Landfill is planned to be constructed on top of the existing Landfill and therefore stability issues were identified. Hence the stabilization layer had to be sufficiently robust to accommodate long-term and differential settlement of the Landfill surface as the waste degrades over time;
- Provision had to be made to capture and manage Landfill gas generated by the Landfill in an environmentally acceptable and sustainable manner;
- No clay is available;
- The Landfill development will be based on a phased approach to assist with the mine's cash flow; and
- The Landfill is located in a high annual rainfall area.

### 4.2 General Waste Disposal Facility

To protect groundwater resources, landfills must be designed to meet stringent contaminant limits in accordance with the best international standards. The design of the "Piggyback" Landfill was based on the South African National Environmental Management Waste Act, 2008, international best practices and where applicable the US EPA Minimum Technology Guidance documents.

The "Piggyback" Landfill airspace required for the 20-year design life was 25 200$m^3$. This was estimated from the waste volumes, design period, the assumed growth rate and a 20% cover to waste ratio. It was determined that the proposed "Piggyback" Landfill cells will have a combined footprint area of 7800m2.

The new facility design incorporated an above the natural ground level construction resulting in fill construction which would require the importation of material to allow for construction of Landfill embankments, Leachate pond, existing Landfill rehabilitation and daily cover material for life of "Piggyback" Landfill.

Figure 1 below shows the general layout of the new facility.

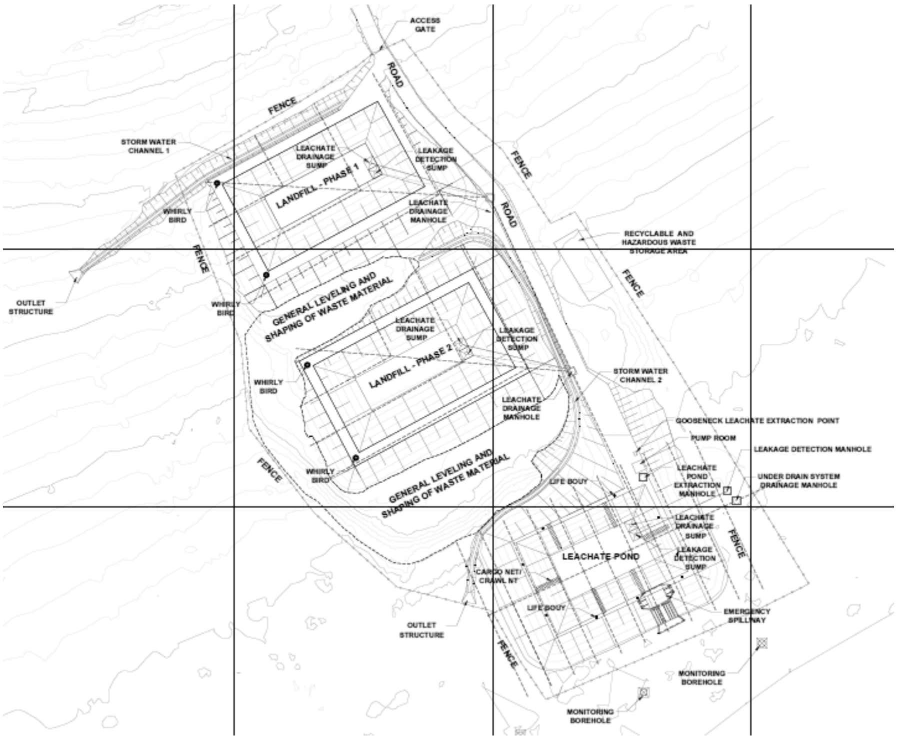


Figure 1: General Layout

As shown in Figure 1 above, a storm water channel will divert clean run-off around the facility and will discharge into the environment. The “Piggyback” Landfill will be built on part of the existing Landfill. The leachate in Phase 1 and Phase 2 will gravitate towards the eastern sump. The leachate in the sumps will gravitate towards the Leachate pond.

The hazardous waste will be temporarily stored in the Hazardous waste storage container until it is collected and disposed of at an accredited hazardous disposal site. While the recycled waste is stored in the Recycled waste storage container and collected on a predefined frequency.

Figure 2 shows the typical Landfill embankment configuration. The anchor trench can be seen as well as the leachate drainage sump, leachate drainage pipe and the underdrain main system outlet of the “Piggyback” Landfill.

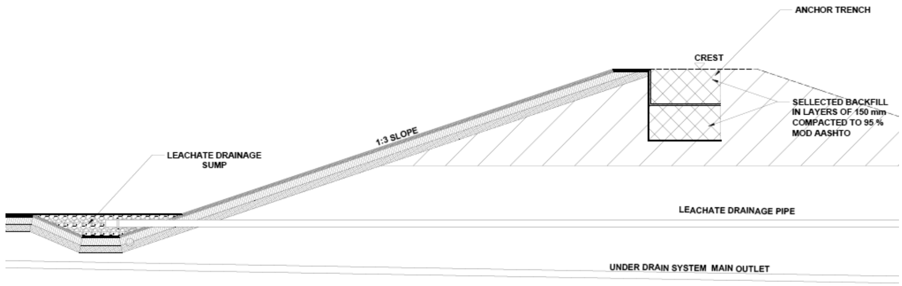


Figure 2: Typical Landfill embankment configuration

In Figure 3 a typical leachate sump cross-section is shown. The double liner penetration can be seen. Washed stone is placed between protection and filtration geotextiles.

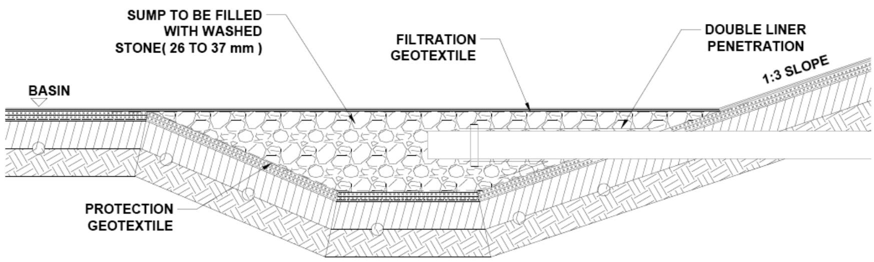


Figure 3: Typical leachate sump cross-section

### 4.2.1 Design of the barrier system of the "Piggyback" Landfill system

In the absence of suitable clay material it was decided that a double lined barrier system is recommended as the risk for groundwater contamination is high due to shallow groundwater levels. Various geosynthetic material were utilized in the design of the double lined barrier system.

The "Piggyback" Landfill barrier system composition can be seen in Figure 4 below.

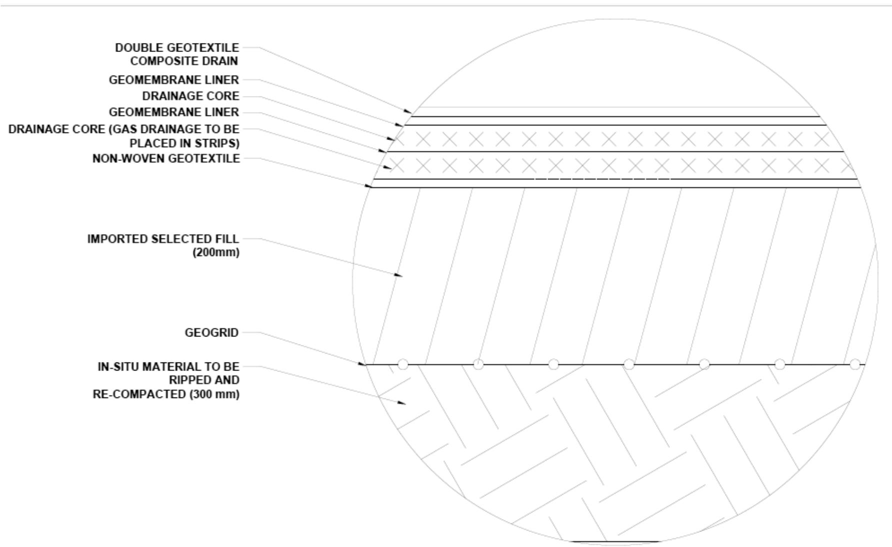


Figure 4: "Piggyback" Landfill barrier system

In the absence of suitable stone aggregate and the risk for biological clogging of sand it was decided that a composite drain will be used as the leachate drainage layer. The composite drain will transport the leachate to the collection drains.

The leakage drainage layer will consist of drainage core which is placed between two geomembrane liners. This system will allow the mine to monitor possible leakage flow rates between the two lining systems and to do maintenance on the system when an action limit is reached.

A drainage core will be used as the gas drainage layer. The drainage core will be placed in strips and will transport the gas to the whirlybird vents.

Geogrid will be placed below 200 mm of selected fill material. The imported material will have nominal compaction. The Geogrid increases the bearing capacity of the underlying waste, to protect the barrier system from failure due to ripping that may result from differential settlement. Differential settlement could occur as waste degrading takes place over time.

400 mm of 'in-situ' waste material will be compacted to 95% MOD AASHTO in 200 mm layers. This will serve as the foundation for the construction of the landfill.

### 4.2.2 Design of the Leachate Management System

High leachate generation is expected based on the climatic conditions associated with the mine's geographical location. A modular cellular development, with two phases (each with a 10-year lifespan) was proposed to assist with the mines cash flow.

The leachate system comprises of drainage core, draining towards a sump. The sump is connected to 160mm solid pipes which discharges into the Leachate pond. The pipes are all connected to a series of manholes to aid with leachate management during operation.

### 4.2.2 Design of the Groundwater Management System

A herringbone underdrain system is required below the “Piggyback” Landfill system due to the high groundwater table in the area. Filtration geotextiles is wrapped around washed stone. Perforated pipes is placed between the washed stones. The herringbones system drains towards a manhole. From the manhole the water gravitates, with pipes, to the Leachate pond.

## 4.3 Design for the Leachate pond

A static water balance was developed to size the Leachate pond. The water balance made use of available rainfall and evaporation data to determine contributing inflows. The water balance result indicated abstraction will be required to reach an equilibrium. Therefore, a sprayer system combined with abstraction for disposal at sewage works was introduced into the water balance. Due to the high leachate volumes, there is a need to develop a Leachate pond. In general, the liner of a general waste leachate pond would normally comprise of compacted clay (according to Minimum Requirements). Unfortunately, there is no clay in the surrounding area, therefore the liner proposed for the Leachate pond would comprise of the components shown in Figure 5.

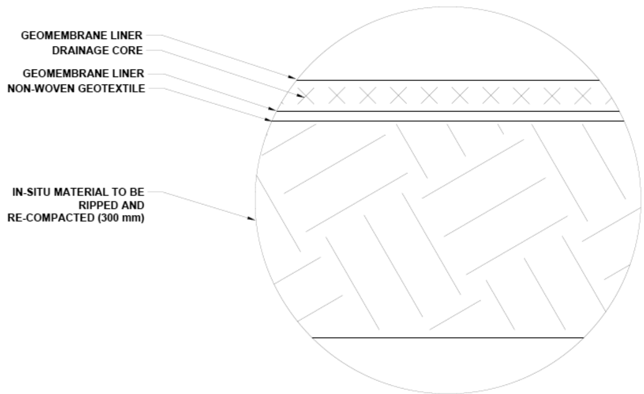


Figure 5: Leachate Pond barrier system

Drainage core is placed between two geomembranes. The drainage core will act as the leakage drainage layer. This layer will allow the owner to detect any possible leakage flow rates.

Due to the high groundwater table underneath the proposed Leachate pond, an underdrain system will be required. The underdrain consists of a herringbone system with filtration geotextiles wrapped around washed stone. Perforated pipes is placed between the washed stones. The herringbones system drains towards a manhole which in return is pumped out and released into the environment.

A layer of 300 mm in-situ material will be compacted to 93% MOD AASHTO.

## 4.4 Existing Landfill rehabilitation

The “Piggyback” Landfill system does not cover the entire existing Landfill and therefore the remaining part of the existing Landfill site will have to be covered with a temporary rehabilitation layer to reduce water ingress.

## 4.5 Storm water management

Storm water management is required upslope and on the eastern side of the facility, due to the topography. The clean water is channeled around the site with two trapezoidal storm water channels. The two storm water channels is lined with geomat and jute. Topsoil is imported and placed on top of the geomat. Vegetation is established by spraying indigenous seeds. The outlet structure, required for energy dissipation, consists of protection geotextile, geomat, overlain by hydroseeded topsoil and jute.

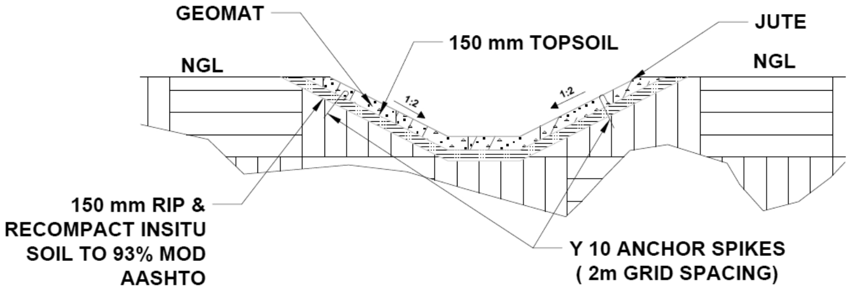


Figure 6: Typical storm water channel cross-section

### 4.6 Recycle and hazardous waste storage area

The waste is sorted at the source into appropriate bins. Due to the remoteness of the mine temporary storage is required for the recycled and hazardous waste. The storage area consists of three containers and is concrete lined. Two of the containers is for the hazardous and recycled waste respectively. The third container is for general storage of equipment etc.

The concrete lined area is sloped towards a sump to allow for the removal of any spillage and leakage that might take place when loading and unloading. A roof is placed over the concrete lined area to minimise contaminated water volumes when it is raining and to provide cover for the facility staff.

The water in the sump will be collected and taken to the sewage works for treatment.

## 5 Conclusion

The stabilization layer and geogrid increases the bearing capacity of the underlying waste, to protect the barrier system from failure due to ripping that may result from differential settlement. The "Piggyback" Landfill system serves as the capping layer for the existing Landfill as well a barrier for the new Landfill. One large Leachate pond is required. The General Waste Disposal Facility meets the disposal need and incorporates the necessary precautionary measures to mitigate the identified environmental impacts and critical factors. The "Piggyback" Landfill system made extensive use of various geosynthetic materials. Due to the "Piggyback" Landfill system concept, the overall rehabilitation cost will be reduced as well as the environmental impacts.

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