THE DESIGN OF THE NEW MESAIEED LANDFILL IN QATAR

S. SATTAR, J. A. COETZEE and C. WISE

Jeffares and Green (Pty) Ltd., PO Box 38561, Pinelands, 7430, South Africa
Tel: +27 21 532 0940, Fax: +27 21 532 0950,
E-mail: sattars@jgi.co.za, coetzeej@jgi.co.za, wisec@jgi.co.za

SUMMARY

The uncontrolled deposition of waste resulted in a waste pile of 6,5 million cubic meters on what is now the intended site for the New Doha International Airport (NDIA) in Qatar. The waste will be removed to a new, engineered landfill located near the town of Mesaieed approximately 40km away to make way for the NDIA.

Jeffares and Green (Pty) Ltd in association with Demos Dracouledes and Associates Environmental Engineers were appointed by KEO International Consultants to provide the technical design and documentation for the development of the New Mesaieed Landfill.

This paper presents, as a case study, the New Mesaieed Landfill which occupies a footprint of approximately 80 hectares and shall be constructed, filled and capped within a sixteen-month period. The paper explores the rationale behind the landfill design with reference to the findings of the Environmental Impact Assessment and Geotechnical Investigation carried out for the project.

Factors affecting the design included harsh climatic conditions (including high temperatures and strong winds), a maximum footprint of 100 hectares for the landfill, a shallow water table, permeable surface soil horizon and the need for protection against groundwater contamination as well as minimising the visual impact of the final capped landfill. It was envisaged that construction of the landfill would begin early in 2005.

INTRODUCTION

As part of its development plans for the country, the government of Qatar has commissioned the construction of a new international airport. Overseas Bechtel Incorporated was appointed by the Qatar Government in January 2004 to provide project management, design and construction services for the development of the airport, which is located in Doha, east of the existing Doha International Airport.

The development of the New Doha International Airport (NDIA) in Qatar requires the reclamation of a large area that was previously utilised for the deposition of waste. Between the 1950's and 1990, approximately 6,5 million cubic meters of waste was disposed to the NDIA site. As part of the NDIA project, this waste would be relocated to an engineered landfill approximately 40 km away, close to the town of Mesaieed.

KEO International Consultants was sub-contracted to carry out the Environmental Impact Assessment (EIA), Environmental Management Plan (EMP), planning, design and contract document supervision of the New Doha International Airport Engineered Landfill Project. Two South African consultants, Jeffares and Green Pty (Ltd) in association with Demos Dracouledes and Associates Environmental Engineers, were in turn appointed by KEO to undertake the technical design and documentation for the development of the New Mesaieed Landfill.

This paper discusses the design philosophy and final design solution for the New Mesaieed Landfill, which was developed within the framework of the geological and topographical characteristics of the area, as well as the environmental and operational constraints of the project.

DESIGN REQUIREMENTS

The project required the design of the following components of the landfill: shaping of the landfill basin, the basin lining system including provision for leachate collection and disposal if necessary, the profile of the filled landfill and the final capping.

It is unusual for the design of a new landfill to incorporate all aspects of the landfilling operation for a waste quantity of such magnitude, and the design of the facility was challenging given the short time frames, harsh climate and difficult site conditions.

The design was to take into consideration all aspects of the existing site conditions, including topography, geology, presence of groundwater and utilisation of locally available materials for construction. It was also important that the final capped landfill be in harmony with the existing site landscape and environment, and imposed the least visual impact.

FACTORS DICTATING THE DESIGN

Time Frames

In order to meet the Project programme for the NDIA, it was required that the entire waste volume be excavated and transported to the New Mesaieed Landfill site over a period of twelve months. It was decided that the wastes from the NDIA site would initially be stockpiled at designated areas adjacent to the landfill site before final deposition into the engineered landfill. Once a sufficient number of engineered landfill cells were constructed, the wastes would be disposed of directly into the landfill without prior temporary stockpiling.

Climatic Conditions

Qatar has a hot desert climate with maximum day temperatures ranging from 21.9^{o}C in January (winter) to 34.5^{o}C in July (summer), and minimum night temperatures of 3.8^{o}C and 23.5^{o}C respectively. The winters are characterised by strong north-westerly winds that can reach gale force and cause sand and dust storms. Qatar is frost-free and rainfall is scant with an average annual rainfall of 79.9mm (KEO International Consultants, 2004).

Waste Composition and Volume

The composition of the waste to be deposited at the Mesaieed Landfill was based on the information provided by the NDIA EIA study. The waste quantities per waste type are tabulated in Table 1.

Table 1: Composition of Waste

Type of waste	Volume m^3	Percentage %
Construction material	1,008,750	16%
Tyres	134,500	2%
Wood	134,500	2%
Steel	67,250	1%
Organic & plastic	2,515,000	39%
Fabric	1,257,500	20%
Paper and card	754,500	12%
Glass	503,000	8%
Total	**6,375,000**	**100.0%**

The waste pile is composed primarily of domestic waste, but due to the uncontrolled deposition of waste at the site throughout its lifespan, it was anticipated that some unknown quantity of hazardous contaminants would be present in the waste. Due to the tight time schedule for the removal of the waste, waste separation was deemed to be unfeasible. Hazardous waste encountered at the NDIA site during removal would not be deposited in the New Mesaieed Landfill, but disposed of to a hazardous landfill facility.

The total estimated volume of 6,375,000 m^3 of waste from the NDIA site would be transferred to the New Mesaieed Landfill. This quantity is roughly equivalent to the total waste volume (including industrial and commercial waste) currently produced by the City of Cape Town in three years.

Maximum Rate of Deposition (MRD)
It was reported that the excavated waste did not bulk (Halcrow, 2004). For the design of the landfill airspace, it was assumed that a compacted density of 1,000kg/m^3 would be achieved using a heavy-duty landfill compactor to compact the waste. The landfill was therefore designed to accommodate airspace of 6,500,000m^3, inclusive of daily cover material volumes. The average rate of disposal to the landfill would be 531,250m^3/month.

Leachate Generation Potential
The weather conditions have a significant effect on the leachate generation potential of a landfill site. In order to determine the necessity of a leachate management system for the New Mesaieed landfill site, its climatic water balance was determined. The Climatic Water Balance (B) was calculated from the two climatic components of Rainfall (R) and Evaporation (E).

$$B = R - E$$

Where: B: is the climatic water balance in mm of water
R: is the rainfall in mm
E: is the evaporation from a soil surface, taken as 0.70 x A-pan evaporation

By definition, if B were negative, the site would have a water deficit for that particular period, provided that only dry waste is deposited and the landfill is correctly designed and operated. In this case only sporadic leachate will be generated (Koerner, 1999).

The rainfall in Qatar is very low with an average annual value of 79.9mm. Based on the average wettest month with a rainfall of 20.5mm (March) and the equivalent evaporation at Decca (near

Doha) for the same month of 149mm, the water balance is –83.8mm. The same calculation for the average annual rainfall and evaporation in Qatar is –1,536mm.

The calculations indicate that on average, the New Mesaieed site is located in a water deficit area, and no significant leachate quantities would be generated even for the wettest month of the year.

The moisture content of the waste was not known, but up to 7% of the waste was considered to be saturated with water. This could have an effect on the initial generation of leachate at the new Mesaieed Landfill. However, there were provisions made to dry the waste or mix it with dry waste whilst at the NDIA site, prior to transportation to the landfill, which would limit the production of leachate.

Landfill Site Topography

The primary site for the engineered landfill occupies an area of one square kilometre and is adjacent to the site of the Hazardous Waste Treatment Centre in Mesaieed. The site topography is characterised by a slope from the high ground to the North West border of the site, to lower areas covering the rest of the site. The highest ground lies approximately seven meters above sea level and the lowest ground lies approximately at sea level.

Geology

Materials encountered on the site can be classified as Residual Desert soil and Aeolian-derived sand resting on Limestone Bedrock, of which the Aeolian-derived sands and residual soils were found to be very permeable. The bedrock was encountered at depths that ranged from 0.25m to 8.0m below ground level. Aeolian sands in the form of Barcan dunes are present adjacent to the site and satellite imagery indicates that the dunes in the project area move at variable rates between 1 and 6 meters per year.

Groundwater

Samples of groundwater were taken from existing boreholes in the area and analysed. The groundwater was found to be substantially unpolluted (KEO International Consultants, 2004). A factor important in the design of the landfill was that the water table in the site's area is very high and varies between 5m and 0.5m below the natural ground level. The design of the final selection of the site's orientation, cell formation and liner system considered the importance of the existing ground water, its current unpolluted state as well as the high water table.

DESIGN SOLUTION

Landfill Basin

The New Mesaieed Landfill was designed to cover approximately 80% of the available area. A buffer of 50.0m was provided on the southern, northern and eastern edges to allow for access and services, and for the construction of the earth basin embankments. The western edge was extended to an existing ridge formation.

In determining the levels of the landfill basin, the level of the prevailing water-table as well as the levels of the rock formation were taken into account so as to attain a balance between achieving a reasonable depth of unsaturated material between the water-table and the primary liner, minimising the need for hard rock excavation, and achieving a least final height of the landfill above the existing ground level.

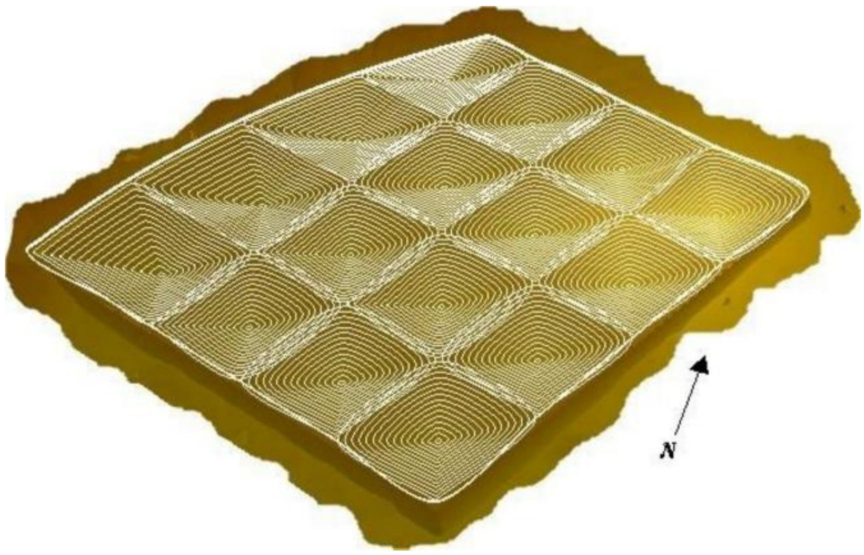

Figure 1: Terrain model of the New Mesaieed Landfill Basin

The landfill basin was shaped to provide minimum falls of 1,5% for the collection and disposal of leachate. The basin was divided into sixteen adjacent cells, each being 200m by 225m except along the western edge of the landfill where it ties-in to the existing ridge formation (see Figure 1).

It is usual practice to shape cells to drain towards the outer edges of the landfill, as the leachate collection system would then be accessible for maintenance purposes. In this particular instance that approach was unfeasible as, due to the enormity of the landfill, it would have entailed deep excavations to achieve minimum falls necessary for drainage. This would have resulted in the leachate collection system being below the water table. Each cell was instead designed to fall to a central low point that lay at 0.75m above mean sea level thereby keeping the floor above the water table. The estimated high water table level was at 0.0m and the average ground level is approximately 1.0m above mean sea level.

The basin floor design required approximately 566,000m^3 of imported fill material which could be sourced from nearby borrow pits and quarries, or obtained from the airport site by processing uncontaminated selected excavated materials.

Basin Floor Lining

Although no significant leachate production was anticipated from the New Mesaieed Landfill, it was determined that a liner would be necessary as unknown concentrations of hazardous substances were contained in the NDIA waste. The close proximity of the groundwater body to the landfill basin floor and the absence of a meaningful unsaturated zone below the liner also influenced the decision to specify a liner, as it was important to protect the groundwater resources from contamination by any possible landfilled pollutants.

The selection and specification of the primary liner was based on the need to balance economics and environmental protection. There are currently no minimum requirements for landfilling in Qatar. In order to ascertain what type of lining would be necessary for the site conditions, the lining systems at a recently constructed hazardous waste site in Mesaieed were investigated. It was found that a 2mm HDPE/GCL composite liner was utilised for the H:H landfill, and a 2mm HDPE membrane was used for the H:h site.

A 2.0mm thickness HDPE geomembrane was selected and specified as the primary liner. The final design of the basin floor lining system is illustrated in Figure 2.

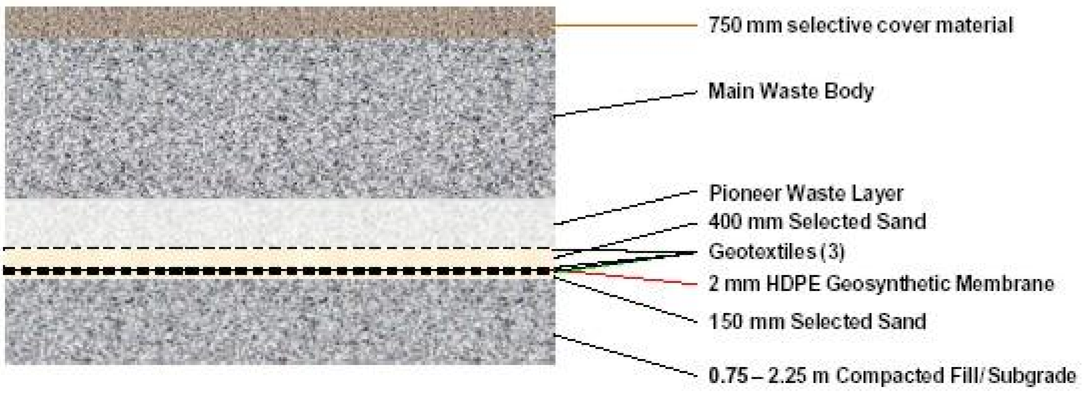

Figure 2: Typical section showing the lining and construction layers

Daily temperature differentials generally cause waves/wrinkles to occur in geosynthetic membranes during installation. Due to the high temperatures experienced at the site, a white geomembrane was considered, but proved to be economically unfeasible due to the extent of the site. In order to meet the specified "wave-height" tolerance of less than 150mm, it was important that the installed liner be covered with a sand protection layer as construction proceeded.

Two types of geotextile were specified for use in the landfill liner system:

- Type A: 340g/m^2 non-woven needle punched geotextile
- Type B: 120g/m^2 non-woven needle punched geotextile

The primary function of the Type A geotextile was to provide the HDPE membrane with protection against puncturing by stones protruding from the underlying subgrade. The required mass per unit area of the geotextile is a critical factor, and a design method presented by Wilson-Fahmy, Narejo, and Koerner (Koerner, 1999) was used to determine this property. The method uses a conventional factor of safety equation.

The Type B geotextile lay above the 400mm sand layer and its function was to prevent sand in the sand protection layer from being blown away by the very strong desert winds before waste could be deposited onto the layer. Since the protection and drainage characteristics of the geotextile is only of a secondary design function, a light 120g/m^2 geotextile was specified.

Leachate Collection and Disposal

It was not possible to accurately determine what quantities of leachate would be produced, as the majority of the waste to be disposed of is old, dry waste, except for 7% of the waste that lay below the water-table at the NDIA site. Also, the landfill is situated in a water deficit area, and hence no significant quantities of leachate are expected to be generated once the landfill is constructed and capped.

It was envisaged that the highest volume of leachate or contaminated water would be produced during a rainfall event while the cells were being landfilled, particularly during the time that the pioneer waste layer was only partially completed. Taking this into consideration, a leachate collection system was designed to meet these requirements.

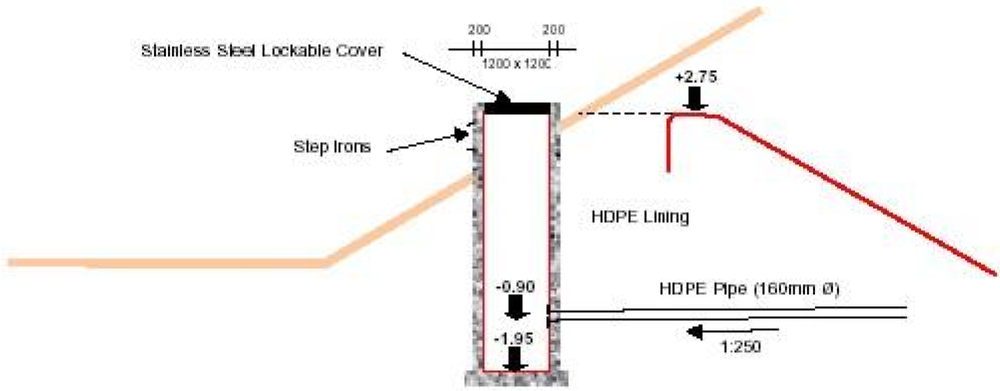

Figure 3: Typical detail showing leachate collection manhole

Leachate would be collected in sand/geotextile layers immediately above the HDPE membrane, led to a central sump in each cell, from where leachate would be piped in a 160mm diameter HDPE pipeline to a drainage manhole chamber (see Figure 3).

It was specified that the pipes would be encased in concrete so as to reduce the possibility of damage due to the high loading anticipated during the construction phase. It was of critical importance to ensure pipe integrity, as the pipes would not be accessible after construction of the landfill. The pipes would be cleaned by access through the manholes.

The leachate would be pumped from the manholes onto the working face of the waste pile before the capping layer is constructed for disposal through evaporation, or alternatively it could be pumped into a tanker and used for dust suppression on the lined landfill. The separate landfill cells would each serve as a detention pond to contain leachate until such time as the leachate is removed by pumping.

After the completion of the capped landfill, any leachate collected should be pumped into a tanker and disposed of at a hazardous waste site.

Landfill Profile

One of the requirements for the design of the landfill was that the final capped landfill should be as low as possible, given the physical constraints of the allocated site, so as to impose the least visual impact. The gradients of the embankments and basin floor were also designed so as to ensure structural stability and to afford effective drainage of leachate and stormwater. A maximum slope of 1:3,5 was specified for embankment sides.

A Digital Terrain Model was developed for the landfill site to aid the design process and a three dimensional model of the proposed final profile was produced (see Figure 4). The final profile of the capped landfill was designed to simulate the shape of the sand dunes adjacent to the site.

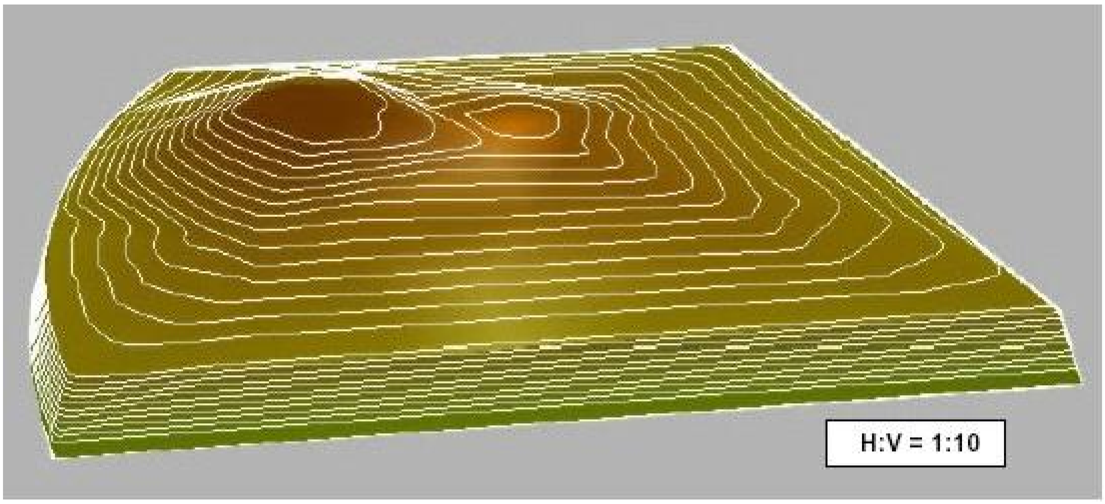

Figure 4: Terrain Model of the New Mesaieed Landfill Final Profile

The upper surface of the landfill is 'domed' to control stormwater runoff velocities and thereby prevent scouring of the capping layers. The maximum height at the crest of the landfill was designed to be 16.5m above mean sea level and is at approximately the same elevation as the highest crest of the nearby hazardous waste landfill. Due to shaping and contouring of the landfill's final profile, the average height of the landfill is approximately 7,75m above mean sea level.

Capping Layer

Due to the strong winds and high temperatures experienced in the area, a geomembrane was ruled out as a possible solution for the capping layer as the risk of potential damage to the membrane was high. Natural materials found in the area were recommended instead.

A 750mm capping layer was designed and comprised of 300mm of low permeability soils covered by 450mm of coarse gravel. The soil layer acts as a water store-and-release system that takes advantage of the high evaporation rates in the area and minimises the percolation of water into the waste, and generation of leachate.

A 450mm layer of coarse gravel was specified to cover the soil layer and provide resistance to wind erosion. The gravel is similar to the surrounding surface soils and will allow the landfill to blend in with its environment.

Landfill Gas Management

The waste from the NDIA site is primarily old waste, and the generated gas quantities are expected to have reduced by at least 35% since its closure. Since the soil capping layers are more permeable than compacted clay liners or a geomembrane (HDPE) barrier, any landfill gas produced at the New Mesaieed Landfill will diffuse naturally through the capping. This reduces the risk of lateral migration of landfill gas.

A formal gas extraction system was not introduced as the environmental requirements did not indicate a necessity for extraction and flaring of gas for the New Mesaieed Landfill. In addition, no structures or utilities will be constructed on or around the site and there are no communities situated in close proximity to the landfill.

Construction Programme

It was envisaged that the project for the construction, landfilling and capping of the New Mesaieed Landfill would require a minimum of 16 months to complete. The programme would require several teams working on at least two cells at a time with construction taking place continuously over a 24 hour day, six days a week. As of the end of June 2005, two of the sixteen cells were complete and had started to receive waste.

Monitoring Systems

Leachate, ground and surface water and gas monitoring is to take place during the construction period and following closure of the site in accordance with the environmental monitoring requirements of the Environmental Management Plan for the New Mesaieed Landfill Site.

Frequent visual inspections of the leachate level in the manholes will be necessary. It is envisaged that samples of leachate will be collected from the manholes on a monthly basis and tested by an accredited chemical testing facility. Landfill gas monitoring will be required at the eight leachate detection manholes since leachate may not be present and gas could vent through the leachate collection pipes. The frequency of the monitoring will coincide with the leachate monitoring frequency.

The groundwater quality in the surrounding area of the site will be measured by a total of 6 monitoring boreholes. During the construction of the site, tests will be performed at monthly intervals and thereafter biannually.

CONCLUSION

The project for the development of the proposed New Doha International Airport requires that approximately 6.5 million m^3 of general wastes are excavated and disposed of to a remote engineered landfill site over a period of twelve months.

The site for the New Mesaieed Landfill is not ideal for landfill disposal due to the close proximity of the water table to the ground surface. Furthermore, the flat topography and shallow soil formation will require a large volume of fill material to form the basin floor of the landfill.

It was against the above background that the landfill design was developed with a view to achieving an appropriate, robust and cost-effective solution that addressed all environmental impacts and satisfied accepted national and international standards.

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