Appendix C: Technical Engineering Report & Geotechnical and Thermal Report

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

DETAILS OF SPECIALIST AND DECLARATION OF INTEREST

	(For official use only)
File Reference Number:	12/12/20/
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Date Received:	

Application for authorisation in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended and the Environmental Impact Assessment Regulations, 2010

PROJECT TITLE

ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED CONTINUOUS ASH DISPOSAL FACILITY FOR THE MATIMBAPOWER STATION IN LEPHALALE, LIMPOPO PROVINCE

Specialist:	Jeffares and Green (Pty) Ltd		
Contact person:	Mr Richard Emery		
Postal address:	P O Box 38561, Pinelands		
Postal code:	7430	Cell:	084 611 7080
Telephone:	021 532 0940	Fax:	021 532 0950
E-mail:	emeryr@jgi.co.za		
Professional affiliation(s) (if any)	CESA, SAICE		

Project Consultant:	Royal HaskoningDHV		
Contact person:	Prashika Reddy		
Postal address:	PO Box 25302, Monument Park, Gauteng, South Africa		
Postal code:	0105	Cell:	083 2848687
Telephone:	012 367 5973	Fax:	012 367 5878
E-mail:	prashika.reddy@rhdhv.com		

4.2 The specialist appointed in terms of the Regulations_

I, Richard Emery, declare that -- General declaration:

I act as the independent specialist in this application

I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant

I declare that there are no circumstances that may compromise my objectivity in performing such work;

I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;

I will comply with the Act, regulations and all other applicable legislation;

I have no, and will not engage in, conflicting interests in the undertaking of the activity;

I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;

all the particulars furnished by me in this form are true and correct; and

I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of section 24F of the Act.

Signature of the specialist:

Jeffares and Green (Pty) Ltd

Name of company (if applicable):

04 April 2014

Date:

Technical Engineering Report

TECHNICAL REPORT FOR:

ENVIRONMENTAL IMPACT ASSESSMENT AND WASTE MANAGEMENT LICENSE APPLICATION FOR THE PROPOSED ASH DISPOSAL FACILITY, AT THE MATIMBA POWER STATION, LEPHALALE, LIMPOPO PROVINCE

October 2015

Prepared by:

Jeffares & Green (Pty) Ltd

P.O. Box 38561
PINELANDS
7405

Contact Person: Mr Richard Emery

Tel: 021 532 0940
Email: emeryr@jgi.co.za
www.jgi.co.za

Prepared for:

Royal HaskoningDHV

P.O. Box 25302
MONUMENT PARK
0105

Contact Person: Mrs Prashika Reddy

Tel: 012 367 5800
Email: prashika.reddy@rhdhv.com
www.rhdhv.co.za

Jeffares & Green
ENGINEERING & ENVIRONMENTAL CONSULTING

VERIFICATION PAGE

TITLE :

TECHNICAL REPORT FOR: ENVIRONMENTAL IMPACT ASSESSMENT AND WASTE MANAGEMENT LICENSE APPLICATION FOR THE PROPOSED ASH DISPOSAL FACILITY, AT THE MATIMBA POWER STATION, LEPHALALE, LIMPOPO PROVINCE REV 3

JGI NO. :	DATE :	REPORT STATUS :
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CARRIED OUT BY :	COMMISSIONED BY :
Jeffares & Green (Pty) Ltd. Cape Town PO Box 38561 PINELANDS 7430 Tel (021) 532-0940 Fax (021) 532-0950 Email: emeryr@jgi.co.za	Royal Haskoning DHV PO Box 25302 Monument Park Tel : 021 863 2810 Email: Prashika.Reddy@rhdhv.com
AUTHOR :	**CLIENT CONTACT PERSONS :**
Lloyd Wallace	Prashika Reddy

SYNOPSIS :

The purpose of this report is to provide engineering input as part of the waste management license application for the proposed ash disposal facility (ADF) at the Matimba Power Station in accordance with the National Environmental Management Waste Act (NEMWA- Act 59 of 2008) and the Environmental Impact Assessment (EIA) Regulations (2010) promulgated in terms of the National Environmental Management Act (NEMA), Act No. 107 of 1998, as amended.

KEY WORDS :

Geotechnical, Thermal, Temperature, Monitoring, Matimba, Ash Landfill, Licensing, Ash waste

QUALITY VERIFICATION

This report has been prepared under the controls established by a quality management system that meets the requirements of ISO9001: 2008 which has been independently certified by DEKRA Certification under certificate number 90906882

Quality Management ISO 9001:2008
Voluntary participation in regular monitoring
DEKRA Certification
DEKRA certified

Verification	Capacity	Name	Signature	Date
By Author	Design Engineer	L Wallace		21/10/2015
Checked by	Discipline Head	R Emery		21/10/2015
Authorised by	Discipline Head	R Emery		21/10/2015

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Acronyms and Abbreviations

ADF	Ash Disposal Facility
ARL	Acceptable Risk Levels
CCL	Compacted Clay Liner
DEA	Department of Environmental Affairs
DWA	Department of Water Affairs
DWAS	Department of Water Affairs & Sanitation
EEC	Estimated Environmental Concentration
EIA	Environmental Impact Assessment
GCL	Geosynthetic Clay Liner
MAR	Mean Annual Precipitation
MRs	DWAF Minimum Requirements, 1998
NEMA	National Environmental Management Act (Act 107 of 1998), as amended
NEMWA	National Environment Management: Waste Act (Act 59 of 2008)
NGL	Natural Ground Level
PCD	Pollution Control Dam
TIA	Traffic Impact Assessment
WCMR	Waste Classification and Management Regulations
WMA	Water Management Area

1. THIS REPORT

The purpose of this report is to provide engineering input as part of the waste management license application for the proposed ash disposal facility (ADF) at the Matimba Power Station in accordance with the National Environmental Management Waste Act (NEMWA- Act 59 of 2008) and the Environmental Impact Assessment (EIA) Regulations (2010) promulgated in terms of the National Environmental Management Act (NEMA), Act No. 107 of 1998, as amended.

The original report was compiled in June 2015, using information supplied from Eskom, *via* Royal Haskoning DHV. This "REV 3" takes into account comments by Eskom received June 2015.

2. PROJECT PURPOSE

Eskom requires the licencing of the ash disposal facility for its continuous (and continued) operation in terms of the National Environmental Management Waste Act (NEMWA), Act no 59 of 2008.

The report aims to provide technical arguments regarding the engineering aspects of the two proposed site alternatives and takes a technical view of the probable licence and design requirements for the legal operation of the ash disposal processes.

3. LEGAL REQUIREMENTS

Eskom requires the licensing of the waste disposal facility to comply with the regulatory requirements of the National Water Act (NWA), Act No 36 of 1998; the National Environmental Management Waste Act (NEMWA), Act No 59. of 2008 as well as the EIA Regulations (2010) promulgated in terms of the National Environmental Management Act (NEMA), Act No. 107 of 1998, as amended.

These Terms of Reference are applicable to the licensing of the proposed ash disposal facility.
All design recommendations and proposals are made and accordance with the following Acts, Standards and Guidelines:

- Notice 634 of 2013 Waste Classification and Management Regulations
- Notice 635 of 2013 National Norms and Standards for the Assessment of Waste for Landfill Disposal
- Notice 636 of 2013 National Norms and Standards for Disposal of Waste to Landfill
- Minimum Requirements for Waste Disposal by Landfill: Second Edition 1998: Department of Water Affairs and Forestry (Trilogy of documents);
- The National Environmental Management Waste Act (NEMWA- Act 59 of 2008)

Consideration is also given to:

- National Waste Management Strategy, 2011;
- National Water Act (Act No. 36 of 1998);
- National Environmental Management Act (Act No. 107 of 1998);
- Constitution (No. 108 of 1996);
- National Environmental Management: Air Quality Act (Act No. 39 of 2004)
- National Environmental Management: Air Quality Amendment Act (Act No. 20 of 2014)

4. PROJECT DESCRIPTION

Eskom Holdings SOC (Ltd) is the South African utility that generates, transmits and distributes electricity. Eskom supplies approximately 95% of the country's electricity.

The Matimba Power Station is an active power station using coal from nearby open-cast mining nearby. Ash is generated as a by-product due to the combustion of coal from the power station. This ash is currently being disposed by means of ‘dry ashing’ within the premises of the Matimba Power Station, on Eskom owned land.

Eskom Holdings SOC (Ltd) wish to extend the life of the ADF so as to provide sufficient cell capacity for the next 43 years of operation as of 2011. Two alternative sites have been considered in the licence application. The first alternative evaluates the extension the existing ADF and the second alternative assesses the development of a new site to the north of Matimba power station. Both alternatives have been considered from an engineering perspective and are discussed below in this report.

5. DESCRIPTION OF THE RECEIVING ENVIRONMENT

Studies were undertaken by the specialist team for both site alternatives by others and provided to J&G. These studies inform the Environmental Impact Assessment and the site selection process. The receiving environment, as described in the specialist studies, has been briefly summarised below as it is relevant to the engineering design and largely affects site boundaries, drainage and excavation (bulk earthworks) on site.

5.1. Climate and Surface Hydrology

The information presented below are excerpts from the Hydrological Assessment Report (GCS Water & Environmental Consultants, August 2013).

The Matimba ash dump falls within the Lephalale area. Lephalale normally receives about 400mm of rain per year, with most rainfall occurring during mid-summer. It receives the lowest rainfall in June and the highest in January. The average midday temperatures for Lephalale range from 22.3℃ in June to 31.9℃ in January. The region is the coldest during July when temperatures drop to 3.7℃ on average during the night.

The Mean Annual Precipitation (MAP) of the Limpopo Water Management Area (WMA), into which the project site falls, is 471mm and the quaternary catchment (A42J) into which the site falls has an MAP of 428mm (Middleton & Bailey, 2009). The design rainfall estimation for South Africa software (Alexander, 2002) calculated an MAP for the site of 465mm and the Daily Rainfall Data Extraction Utility (ICFR, 2012) data series indicated an MAP for the site of 534mm. The nearest rainfall station with good quality rain data is Ellisras Police Station (0674400W) (TR102 data) (Adamson, 1981). This station had data from 1967 to 2004 and showed an MAP of 385mm.

The environment of both sites is generally dry and flat. No water or clear drainage paths were visible flowing towards the Sandloop River.”

<u>Site Alternative 1</u>

The site alternative 1 consists of current ash disposal activities as well as bushveld. The area of the existing Matimba Ash disposal facility (ADF) consists of two existing, lined storm water dams and one *large, lined pollution control dam (PCD) under construction[1]. Stormwater channels and berms and an artificial pan used by local wildlife for drinking water were identified on site.*

The catchment area of Alternative 1 contains a very small tributary of the Sandloop River. An additional watercourse occurs to the west of Alternative 1 which also drains toward the Sandloop River.

The proposed ash disposal facility is located at some distance from the Matimba Power Station and straddles a catchment divide. With the exception of the extreme south-west corner of the proposed site, there are no upstream catchments that could contribute clean water flows to the site. Water tends to drain naturally away from the site.

The entire ash disposal facility site should be regarded as a dirty water area. Runoff from the site could, however, be easily captured in a down-slope drain system and removed to a PCD. A single, large PCD is recommended to the south of the ash disposal site and below all likely spoil heaps. The layout of recommended storm water management measures is detailed in ***Figure 1*** *below:*

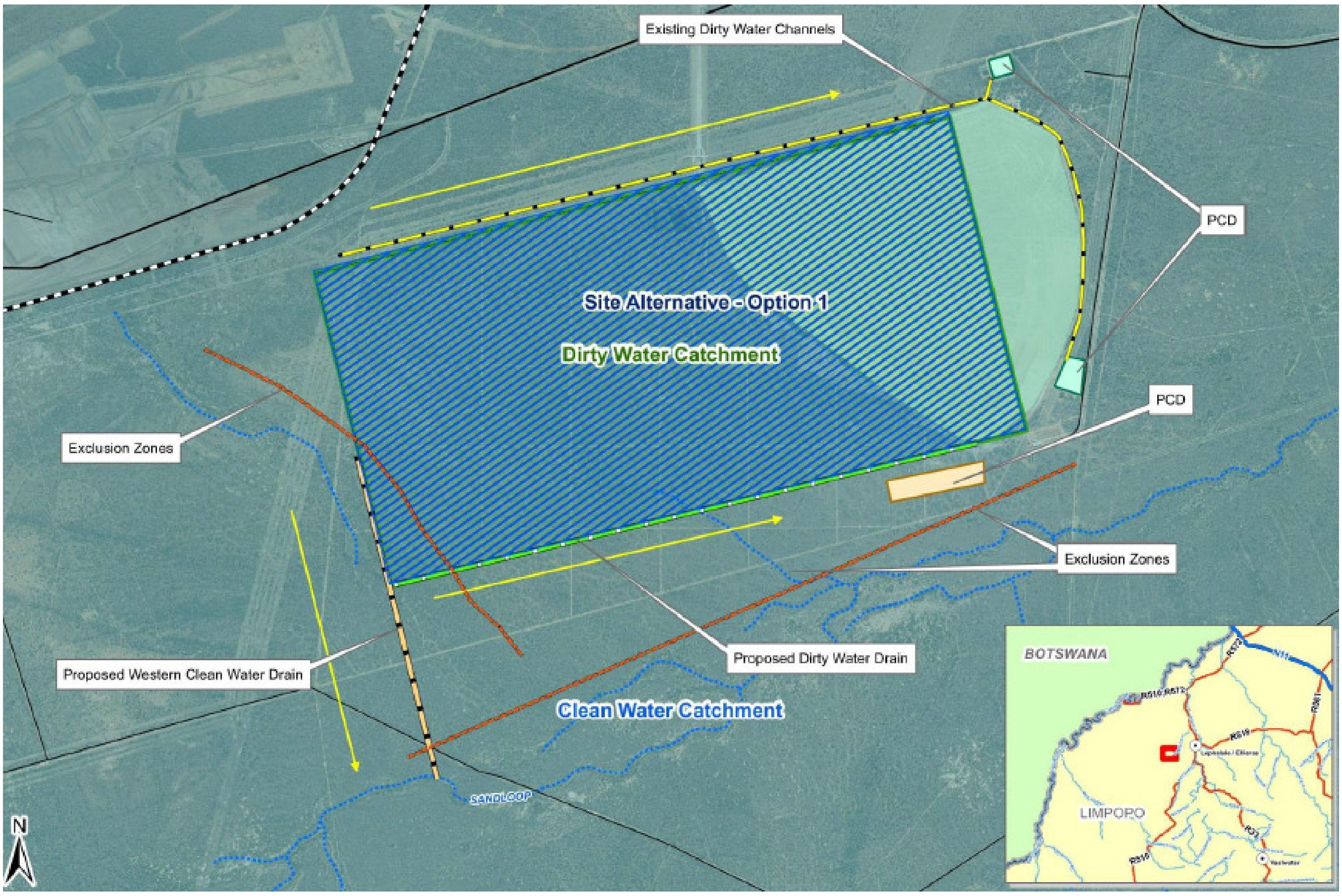


Figure 1: Site Alternative 1-Recommended Storm water Management Measures (GCS,2013)

Site Alternative 1 requires a Pollution Control Dam (PCD) with storage capacity for a dam that spills on average only once in 50 years, of 203 600 m³. Matimba Power Station has already commissioned an independent PCD design of approximately this capacity for this site. The GCS analysis confirms this

[1] This text is taken from the hydrological assessment (GCS, 2013). The Metsimaholo Dam (PCD) is now constructed.

dam's design capacity. It is suggested that the main toe drain indicated on the figure above should be capable of conveying a peak flow rate of 0.88 m³/sec.

<u>*Site Alternative 2*</u>

Site Alternative 2 is a greenfields area largely comprising bushveld and grassland. Water features identified during the site visit include an artificial pan used by local wildlife for drinking water.

In line with best management practices and recommendations from the specialists, all clean stormwater runoff entering the proposed site will be intercepted and diverted around the proposed ADF. This site alternative lies more on a hill-slope with runoff from above the site that needs to be diverted away. A long clean-water drain will be constructed to capture this runoff and convey clean water runoff to a south-eastern discharge point.

The flow path of the river adjacent to the site is poorly defined. A 100 m buffer zone was identified to indicate areas that appear to be safe from flooding. A large area of the proposed site towards the northern and western boundaries of the site is overlapped by this buffer thus excluding it from the site footprint. ***Figure 2*** *shows the recommended storm water management measures from the hydrological report (GCS, 2013)**.***

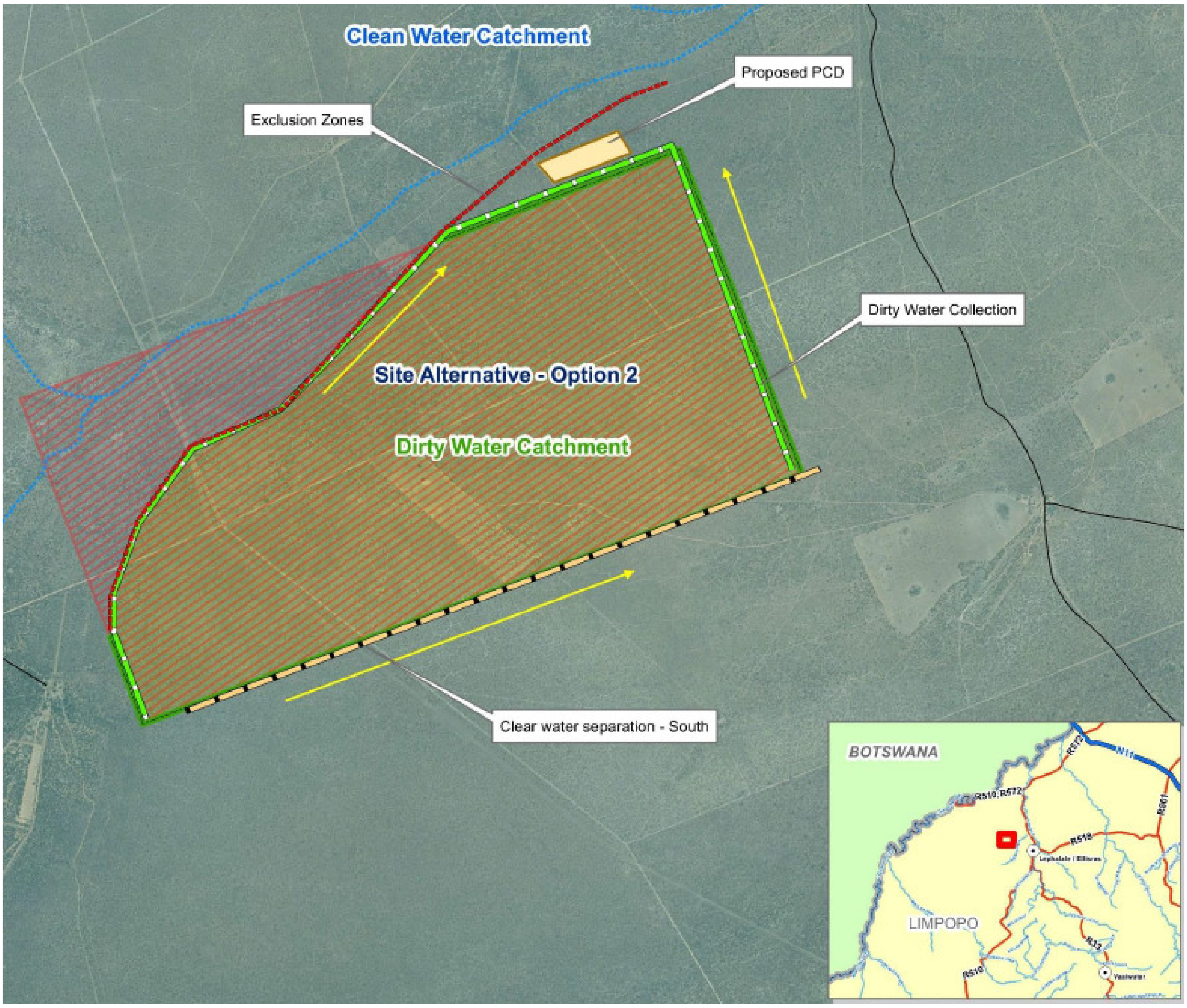


Figure 2: Site Alternative 2-Recommended Storm water Management Measures (GCS,2013)

5.2. Geology

The information presented below is taken from the Geotechnical Investigation Report (Kai Batla Mineral Industry Consultants, August 2013)

"Vegetation across both sites consists essentially of thick indigenous bush and trees up to approximately 12 metres in height. Grass cover is sparse and access for conventional vehicles is difficult due to heavy undergrowth and loose sandy surface.

Groundwater was not encountered across Site Alternatives 1 and 2 during the course of the field investigation. However, it is anticipated that a perched groundwater table will be encountered across the study area during high rainfall events, typically in the range 1.0 to 3.0 metres below existing ground level.

It is considered that both site alternatives are stable and suitable for development provided that the recommendations given in this report are adhered to.

Site Alternative 1

The general geology of Site Alternative 1 is characterised by Aeolian (wind-blown) sands of the Karoo Supergroup, which overlie conglomerate and sandstone bedrock of the Waterberg Group, Sandriviers Formation.

Twenty-seven inspection pits (IP) for Site Alternative 1, were excavated throughout the site. The inspection pits reached refusal depths in the range of 0.5 to 3.1 metres below existing ground level.

Refusal depths are significant in that they determine the depth to which the cell could extend below natural ground level (ngl). In order to maintain free gravity flow within the leachate collection drains, which lie at the basin of the cell, a minimum of 1:120 fall along the cell basin is required. A total difference of 15m is required from the lowest to the highest point of the short side of the cell basin. The refusal depth limit the depth of excavation below ngl to around 3m which indicates that significant fill above ngl is required or alternatively blasting of hard materials can be considered.

Site Alternative 2

The general geology of Site Alternative 2 is characterised by colluvial sandy soils and Aeolian (wind-blown) sands of the Karoo Supergroup, which overlie pedogenic soils (calcrete) and sandstone bedrock of the Ellisras Basin, Clarens Formation.

Twenty-nine inspection pits for Site Alternative 2, were excavated throughout the site. The inspection pits were extended to depths in the range of 2.0 to 4.5 metres below existing ground level. A height difference of roughly 16m is required along the basin of the cell and thus a substantial fill is required above ngl to maintain gravity flow of leachate."

5.3. Hydrogeology

The following is taken from the hydrogeological report (GCS, 2013):

"*According to the 1:500 000 Hydrogeological Map of Polokwane 2326 (2003), the southern portion of the study area, south of the Eenzaamheid fault as well as the Grootegeluk Formation is mostly associated with fractured aquifers based on the geology. The average groundwater yields associated with these aquifers, range from 0.5-2 l/s. Numerous faults transect the study area. Lithology north of the Eenzaamheid fault consists of intergranular and fractured aquifers associated with the Swartrant* *and Clarens Formations with yields ranging from 0.5-2.0 l/s for the Swartrant Formation and 0.1-0.5l/s for the Clarens Formation.*

Groundwater occurs within the joints, bedding planes, and along dolerite contacts within the Waterberg Group sediments. Groundwater potential is generally low in these rocks, with 87% of borehole with yields less than 3 l/s.

Site Alternative 1
Majority of the boreholes identified surrounding Alternative 1 during the hydrocensus were Matimba monitoring boreholes. In total 10 water levels were recorded in these boreholes. The water levels ranged from 5.63mbgl to 21.47mbgl. The water use is mostly for domestic purposes as well as stock watering.

Site Alternative 2
In total 16 boreholes were identified surrounding Alternative 2 including the boreholes drilled for this project. The water levels ranged from 17mbgl to 23.94mbgl. The water use is mostly for domestic purposes as well as stock watering.

Based on the risk rating of the site, Alternative 1 is identified as the most suitable site for the ash disposal facility and will have the smallest impact due to the following reasons:

- *Depth to water level – Slightly deeper when compared with Alternative 2;*
- *Presence of intrusive lithologies – Further distance to intrusive lithologies in comparison to Alternative 2;*
- *Proximity of production boreholes – Only 1 production borehole was identified in the 2km radius of the site compared to the 13 production boreholes in use surrounding Alternative 2.*
- *The risk rating of Alternative 1 is reduced by placing the ash disposal facility adjacent to the existing ash disposal facility where a contamination plume already exists and which was confirmed to be localised during the investigation.*

A comparison in the groundwater chemistry was made between the boreholes surrounding site Alternative 1 and site Alternative 2; there is a clear distinction between the results. Although several boreholes associated with site Alternative 2 indicated elevated concentrations of parameters mentioned earlier which appear to be problematic, it is clear that the concentrations in general are much lower than those associated with boreholes surrounding site Alternative 1. "

6. DESIGN CRITERIA BY CLIENT

It is required to determine a suitable site for the construction of an ash disposal facility for the remaining life of Matimba Power Station. The site should be adequate to accommodate site infrastructure and the cell with sufficient airspace for the landfill lifespan of 43 years.

No particular design criteria/ requirements, with respect to infrastructure or material types have been communicated by Eskom other than to align proposals with their current method of disposal (as far as legally possible).

6.1. Waste Generation

The required airspace is dependent on the tonnage of coal combusted throughout the 43 year lifespan, the dry density and percentage of ash. **Table 1** below summarises the design criteria applied in order to calculate the total airspace required**.** An additional 0.44 % has been allowed for daily cover resulting a total required airspace of approximately **276 249 000 m^3.**

Table 1: Summary of Applied Design Criteria

ITEM	AIRSPACE REQUIREMENTS BY ESKOM	UNIT	QUANTITY	SOURCE
1.01	Coal Combusted (input to Matimba Power Station process)	tons/annum	15 050 000	Eskom (2013)
1.02	Ash percentage of the coal that is combusted (output from Matimba Power Station to ADF)	% (by mass)	34.00%	Figure Updated by Andre Kruiter of Eskom (email 03 Dec 2014)
1.03	Growth in output (year 2012 to year 2055)	%	0.00%	Eskom (2013)
1.04	Dry Density of "dry-ash" being disposed	kg/m³	800	Figure Updated by Andre Kruiter of Eskom (meeting minutes 06 Oct 2014)
1.05	Design Life of proposed Ash Disposal Facility (ADF) (year 2012 to year 2055)	years	43	Eskom (2013)
1.06	Ash Volume	m³/annum	6 396 250	Calculation (Jeffares& Green,2015)
1.07	Airspace Requirement	m³	275 038 750	Calculation (Jeffares& Green,2015)
1.08	Add Daily Cover	percent	0.44%	Figure Updated by Andre Kruiter of Eskom (email 03 Dec 2014)
1.09	**ESTIMATED TOTAL AIRSPACE REQUIRED**	m³	**276 249 000**	**Calculation (Jeffares& Green,2015)**
ITEM	**APPLIED DESIGN CRITERIA FOR ADF**	**UNIT**	**QUANTITY**	**SOURCE**
1.10	Waste Type	Type	Type 3	Waste Classification Report (Jeffares & Green ,2013)
1.11	Barrier System	Class	Class C	Waste Classification and Management Regulations (WCMR 636, 2013)
1.12	Maximum Recorded Temperature (over 3 month period, Mar 2014 to Feb 2015)	°C	48	On-Site Thermal Investigation (Jeffares & Green, 2013)
1.13	Applied Acceptable Leakage Rate	L/ha/day	200	US Environmental Protection Agency
1.14	Applied Action Leakage Rate	L/ha/day	500	US Environmental Protection Agency
1.15	Acceptable Risk Level in All Contaminants	Y/N	Yes	Risk Assessment Analysis (Jeffares & Green, 2013)
1.16	Estimated Leakage Rate	L/ha/day	1.31	Circular Defect Formula (Giroud,1997)
1.17	Longitudinal Basin Grade (average)	V:H	1:120	
1.18	Cross Fall Basin Grade (average)	%	5	
1.19	Capping Components Regulations	Class	G:L:B-	Minimum Requirements (DWA,1998)
1.20	Capping Layerworks	Class	G:L:B- (No Gas Layer)	(Jeffares & Green,2013)

Table 1: Summary of Applied Design Criteria (continued)

ITEM	APPLIED DESIGN CRITERIA-CONTAMINANTED STORMWATER POND	UNIT	QUANTITY	SOURCE
1.21	Pond Capacity (Site Alternative 1)	m^3	203 600	Hydrological Assessment Report (GCS,2013)
1.22	Pond Capacity (Site Alternative 2)	m^3	180 000	Hydrological Assessment Report (GCS,2013)
1.23	Pond Side Slopes (average)	V:H	1:3	
1.24	Pond Depth (max)	m	2	
1.25	Total Freeboard	m	0.8	SANCOLD Volume II (2011)
1.26	Peak Flow Rates in Toe Drains (Site Alternative 1)	m^3 /sec	0.88	Hydrological Assessment Report (GCS,2013)
	Peak Flow Rates in Toe Drains (Site Alternative 2)	m^3 /sec	0.75	Hydrological Assessment Report (GCS,2013)

6.2. Waste Classification

A waste classification report was compiled in May 2013 by Jeffares & Green (Pty) Ltd. The purpose of the report was to classify the ash waste generated at the Eskom Matimba Power Station, Limpopo. The classification was done in accordance with the National Environmental Management Waste Act (NEMWA- Act 59 of 2008), Minimum Requirements trilogy (DWAF, 1998) and draft Regulations (GNR 613 to 615, 2012) in order to determine the necessary liner requirements and related disposal mechanisms and methods for such a waste type, for the proposed ash disposal facility (ADF).

The draft Regulations (GNR 613 to 615, 2012) have since been promulgated in August 2013 and the documents (GN 634-636, 2013- also referred to as the *Waste Classification and Management Regulations* (WCMR, 2013)) now apply. The promulgation of the WCMR regulations supersede the Minimum Requirements trilogy (DWAF, 1998).

The results of the waste classification yield that the ash is classified as a Type 3 Waste and must be disposed on a landfill site with a Class C barrier system.

6.3. Climatic Water Balance

A climatic water balance was undertaken as per the requirements in the Minimum Requirements (DWA trilogy of documents, 1998). The results of the climatic water balance are shown in **Table 2**.

Table 2: Climatic Water Balance Lephalale*

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
E max (mm)	Maximum Evaporation	254	224	191	164	130	109	109	157	182	211	207	234	2172
R max (mm)	Maximum Precipitation	117	185	80	28	11	0	3	43	33	48	92	58	698
B max	**Water Balance**		**-39**	**-111**	**-136**	**-119**	**-109**	**-106**	**-114**	**-149**	**-163**	**-115**	**-176**	**-1474**
E min (mm)	Minimum Evaporation	167	113	160	153	129	99	102	137	169	211	201	234	1875
R min (mm)	Minimum Precipitation	51	47	41	23	0	0	0	0	0	58	74	58	352
B min	**Water Balance**	**-116**	**-66**	**-119**	**-130**	**-129**	**-99**	**-102**	**-137**	**-169**	**-153**	**-127**	**-176**	**-1523**

** Data is taken from Hydrological Information Publication 13, DWA*

The climatic water balance concludes that the area is not classified as a leachate generating catchment as annual evaporation is higher than annual precipitation.

7. TECHNICAL DESIGN CRITERIA

7.1. Waste Disposal

In response to the waste classification, the primary waste to be disposed is Dry Ash from the Matimba Power Station. The Matimba Power Station is an active power station using coal from open-cast mining nearby.

Ash is generated as a by-product due to the combustion of coal from the power station. This ash is currently being disposed by means of 'dry ashing' within the premises of the Matimba Power Station, on Eskom owned land.

The ash is currently transported via conveyors from the power station to the ADF. The Ash waste is placed using a radial shifting stacker and spreader system. The option to change from radial to parallel shifting stacker and spreader systems is currently under consideration by the operators of the ADF. The ash does not undergo any post placement compaction efforts.

The stacker spreader system develops a front stack area in lifts of approximately 45m high. The back stack face develops behind the initial front stack lift and is placed in lifts of approximately 12m high. Any further proposed height gain will be developed in the same manner by shifting the stacker and spreader conveyor system on top of the existing waste pile and disposal operations shall continue as defined above. (Refer to **Section 7.16** for the Operational Control Plan).

It is envisaged that the operators of the ADF will make use of <u>parallel and/or radial shifting stacker systems</u> in order to place the ash waste to accommodate the total volume of disposed ash over the design life of the facility.

It is proposed that the new facility will dispose of the ash waste utilising this disposal methodology. A slope stability analysis was undertaken to investigate possible geotechnical risks. The conclusion of the slope stability report is in support of this proposed disposal methodology.

According to draft regulations GNR. 634 of 2013 (GNR 634 of 2013, DEA), Eskom are "Waste Generators" and "Waste Managers". This needs to be noted for responsibility issues (Refer to **Figure 3**).No burning of waste will be allowed on site.

(b) waste generators must ensure that the disposal of their waste to landfill is done in accordance with the Norms and Standards for Disposal of Waste to Landfill set in terms of section 7(1) of the Act; and

(c) waste managers disposing of waste to landfill must only do so in accordance with the Norms and Standards for Disposal of Waste to Landfill set in terms of section 7(1) of the Act.

Figure 3 - Excerpt from Regulation 634 of 2013, Section 8

7.2. Stability Analysis

A geotechnical assessment (stability assessment) of the existing Matimba ADF (existing ash pile) was undertaken by Jeffares and Green titled "Geotechnical Assessment and Thermal Investigation at the Matimba Power Station Ash Disposal Facility, Lephalale, Limpopo Province; February 2014".

This assessment was carried out over and above the work presented in the report by Kai Batla Minerals Industry Consultants entitled, "Detailed Geotechnical Investigation for the Proposed Continuous Ash Disposal Facility for the Matimba Power Station in Lephalale, Limpopo Province, South Africa", dated 9th August 2013. The purpose of the additional geotechnical assessment was to undertake on-site (in-situ) soils testing of the existing coal ash waste and foundation soils with the vision of disposing of ash on top of the existing ash pile (piggy-backing).

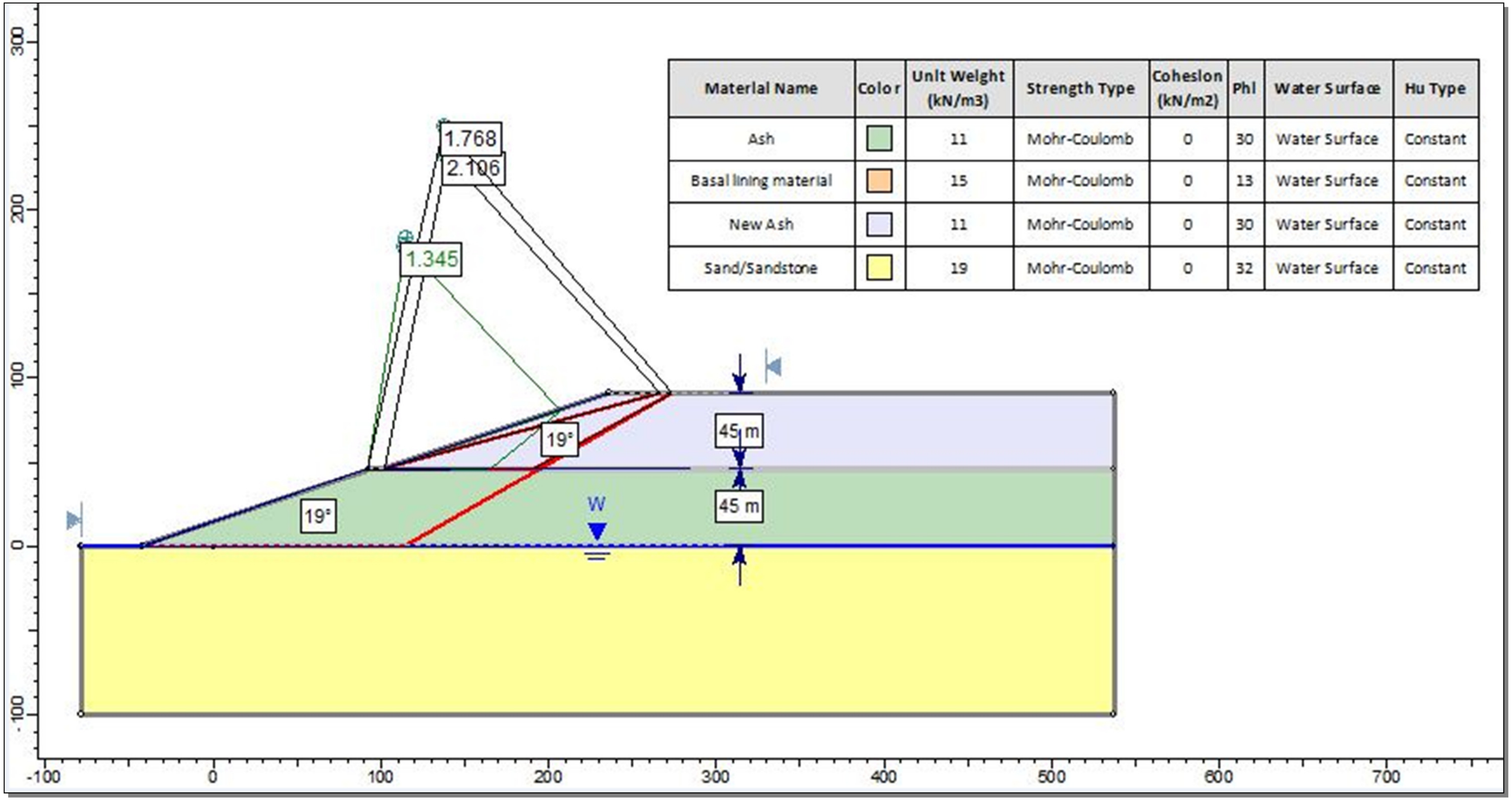
Geotechnical parameters of the materials were obtained from the on-site geotechnical investigations and used to undertake a slope stability analysis of the proposed landfill construction at the Matimba ADF.

Figure 4 shows a summary of the block failure analysis of the piggy-backing alternative utilising an existing waste pile height of 45m high and a new coal ash waste pile of 45m (on top of the aforementioned 45m-high pile) with a continuous side slope of 1V:3H.

Figure 5 shows a summary of the circular slip failure analysis of the piggy-backing alternative utilising an existing waste pile height of 45m high and a new coal ash waste pile of 45m at a continuous side slope of 1V:3H.

The results of the geotechnical analysis confirmed the following:

- *The slope stability analyses shows that the gradient of proposed ADF should not exceed 1V:2H (26°). The ash waste material is shown to stabilise at the natural angle of repose of 1V:2H approximately (approximately 30°).*
- *When the ash is placed with the stacker spreader conveyor system it will settle close to its friction angle value of approximately 30° as seen in current operations.*
- *The analysis confirms that the concept of developing the new ADF over the existing ADF through the concept of piggy-backing over the existing facility can be considered providing the above parameters and factors of safety are not exceeded.*
- *The "piggy-backing" of the new facility on top of the existing facility is not expected to bring about excessive differential settlements that could compromise stability or the integrity of any separator basal lining between the existing and the new.*



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface	Hu Type
Ash		11	Mohr-Coulomb	0	30	Water Surface	Constant
Basal lining material		15	Mohr-Coulomb	0	13	Water Surface	Constant
New Ash		11	Mohr-Coulomb	0	30	Water Surface	Constant
Sand/Sandstone		19	Mohr-Coulomb	0	32	Water Surface	Constant

Figure 4 - Block Failure with a slope gradient of 1V:3H (Piggy-backing Scenario)

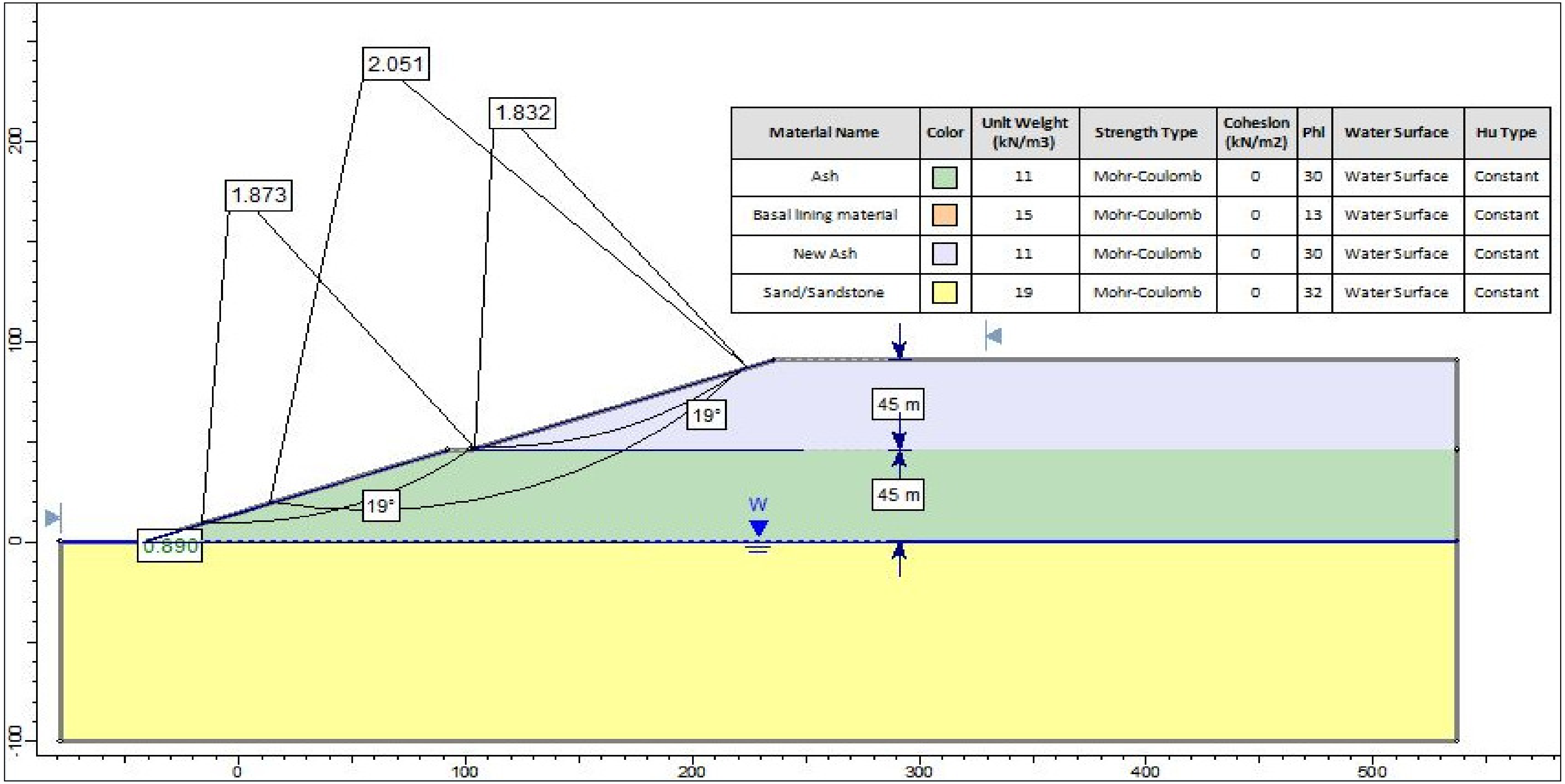


Figure 5 – Circular Slip Failure with a slope gradient of 1V:3H (Piggy-backing Scenario)

7.3. Side Slope

During the development of the landfill, the ash waste will be placed using a stacker and spreader system and be placed at approximately **1V:2H** (the natural average slope of repose). This was not shown to have stability concerns however localised sloughing of the slopes is expected (Jeffares & Green, Geotechnical Assessment, 2014).

The maximum final finished capped side slope of the proposed ADF should not be steeper than **1V:3H** to ensure long term stability of the slope.

A side slope of 1V:3H has been shown to be stable (See Section 7.2) and the side slope presented in the Waste License should be based on a 1V:3H gradient.

The side slope has been chosen as a final capped slope for the following reasons:

- Easier to vegetate and undergoes erosion less readily than steeper slopes.
- Conformation to a more natural slope gradient (from an aesthetics point of view).
- Easier access for vehicle access for trucks.

If the new ADF is developed using the same current placement methodology, final side slopes for the new ADF will be in the region of **1V:5H**. A side slope of **1V:5H** has been used in modelling the estimated airspace for the new ADF as it presents a more conservative airspace model than a side slope of **1V:3H**.

7.4. Basal Lining System

The existing coal ash waste has been classified as a "Type 3" waste in accordance with the National Norms and Standards for Disposal of Waste to Landfill (WCMR, GNR 636, 2013). The specified basal lining system is classified as a "Class C" system.

The presence of clay (suitable in terms of quality for the Compacted Clay Liner (CCL) in the basal lining system) in the area immediately surrounding the proposed facility is assumed to be limited. The proposed basal liner system presented in the design substitutes the required CCL with a Geosynthetic Clay Liner (GCL) of equivalent or better performance.

The proposed basal liner is shown in **Drawing No. 3145-C006** is presented and deemed to comply with legislative requirements and current industry trends. There are three basal lining details shown in **Drawing No. 3145-C006** and the systems are proposed to cover the following construction elements:

- Typical basal lining system over greenfields areas
- Typical basal lining system on embankment slopes
- Typical basal lining system under the proposed pollution control dam.

It is understood that continuous disposal as per current practices will continue during the transition period until the proposed basal lining system is constructed and ready for receiving the ash waste. The final shape and size of the waste disposal cells will be investigated at detail design and is a factor of the decisions taken by Eskom at that time regarding cell life expectancy and approved construction budgets.

The possible thermal management system (refer to **Section 7.8.2**) has been shown in the basal lining design for greenfields areas. This system is an optional design element that is required should the requirements of **Section 7.8.1** not be satisfied at detail design phase.

The proposed construction methodology involves piggy-backing a portion of the new proposed ADF over the existing ADF. The client is of the opinion that it will not be necessary to install a geosynthetic basal lining system on top of the existing dump before the additional piggy back ash layer is placed on it, as the height of the dump shouldn't affect any potential pollution plume. It is the professional opinion of Jeffares & Green, however, that a simplified, formal geosynthetic basal lining system be placed over the existing ADF should the piggy-backed construction cover the full extent of the existing ADF take place in order to comply with the prescriptive legislation (GNR 634 – 636, DEA, 2013).

Geosynthetics manufacturers offer alternative product materials[2] that cater specifically to ash wastes in the form of:

- Geosynthetic Clay Liners - Polymer enhanced GCL which reduce (slow down) cation exchange improving long term performance.
- Drainage Geotextiles - Showing improved transmissivity and reduced clogging when exposed to typical coal ash particles.
- Geomembranes – High temperature stabilised geomembranes designed for use in aggressive environments where elevated temperatures can be expected.

The feasibility of utilising an ash waste specific geosynthetic in the design of the ADF should be investigated at detail design phase.

7.5. Geosynthetic Specifications

The following section presents minimum material specifications for the selection of the geosynthetic materials that are to be used for the construction of the ADF. This specification is to be refined and further developed at detail design phase.

7.5.1. Construction Quality Assurance and Construction Quality Control

The detail design and construction of the geosynthetic systems proposed for this ADF are to comply with construction quality assurance and construction quality control documents which are to be put in place during the detail design phase.

Construction Quality Assurance and Construction Quality Control are defined as follows (in SANS 10409 and SANS 1526: 2003):

> Construction Quality Assurance (CQA): *Includes inspection, verifications, audits and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. CQA also refers to measures taken by the Engineer to assess if the Installation and Civils Contractors are in compliance with the drawings and specifications for a project.*
>
> Construction Quality Control (CQC): *refers to measures taken by the Civils and Installation Contractor to determine compliance with the requirements for materials and workmanship as stated in the drawings and specifications for the project.*

A construction quality control plan (CQCP) for the proposed geosynthetic construction activities has been developed and is presented in **Annexure A** at the end of this document.

[2] *Such geosynthetic products as offered by GSE Environmental or equally approved could be considered at detail design phase.*

7.5.2. Geotextile Specifications

<u>Geotextile:</u> A planar, permeable, polymeric (synthetic or natural) textile material, which may be non-woven, knitted or woven, used in contact with soil/rock and/or any other geotechnical material in civil engineering applications.

All geotextiles must be stable in the presence of the chemicals typically found in an ADF and should be resistant to attack from these chemicals. All geotextiles should be stable at a temperature of 100 °C.

i. TYPE A – Separation Geotextile

The Type A geotextiles shall be Kaytech "A5 Bidim" or a similar approved non-woven needle punched polyester or polypropylene geotextile and shall comply with the following material specifications presented in **Table 3**.

Table 3: Type A Geotextile Specifications

Material property		**Units**	**Type A**	**Test method**	**Manufacturing Quality Control testing frequency**
Mass, Min. nominal		g/m²	270	ASTM D1910	Every roll
Max. Pore Size, AOS	O_{95W}	µm	165	Franzius Institute	Every 50 rolls
	O_{95H}	µm	125	NFG 38.C17	
Minimum Permeability		m/s	5.4×10^{-3}	SABS 0221-88	Every 10 rolls
Min. Porosity (applicable for non-woven's) under 2 kPa		%	93		Every 10 rolls
Min. Trapezoidal tear (weakest direction)		N	480	ASTM D4533-85	Every 10 rolls
Min. CBR Puncture		kN	3.6	SABS 0221-88	Every 10 rolls
Min. Tensile strength (weakest direction)		kN/m	20	SABS 0221-88	Every 10 rolls
Min. UV Light Stability (150 hrs)			N/A	ASTM D4355	

This material is a separation geotextile.

ii. TYPE B – Protection Geotextile

The Type B geotextile shall be Kaytech "A7 Bidim" or similar approved non-woven needle punched polyester or polypropylene geotextile and shall comply with the following material specifications presented in **Table 4**.

Table 4: Type B Geotextile Specifications

Material property	**Units**	**Type B**	**Test method**	**Manufacturing Quality Control testing frequency**
Mass, Min. nominal	g/m²	550	ASTM D1910	Every Roll
Minimum Permeability	m/s	4.8×10^{-3}	SABS 0221-88	Every 50 rolls
Min. Grab Strength	N	2100	ASTM D4632	Every 10 rolls

(weakest direction)				
Min. Trapezoidal tear (weakest direction)	N	1050	ASTM D4533-85	Every 10 rolls
Min. CBR Puncture	kN	6.5	SABS 0221-88	Every 10 rolls
Min. Tensile strength (weakest direction)	kN/m	35	SABS 0221-88	Every 10 rolls
Min. UV Light Stability (150 hrs)		N/A	ASTM D4355	

This material is a protection geotextile.

7.5.3. Geosynthetic Membrane Specifications

Geosynthetic membrane (GSM): A geosynthetic barrier is employed to prevent migration of liquids and contaminants.

High Density Polyethylene Geomembrane (HDPE) and Linear Low Density Polyethylene (LLDPE): A planar, essentially impermeable, polymeric sheet used in contact with soil/rock and/or any other geotechnical material in civil engineering applications, which is manufactured from a polyethylene resin with a density of generally less than 0.945 g/cm^3, but greater than 0.930 g/cm^3.

The types of geomembranes to be manufactured and installed are the following (but is subject to change during this Project):

- 1.5mm thick double-textured High Density Polyethylene (HDPE) geomembrane
- 1.5mm thick smooth-smooth High Density Polyethylene (HDPE) geomembrane
- 1.0mm thick smooth-smooth linear low Density Polyethylene (LLDPE) geomembrane

The resin, must adhere to the GRI–GM13 for HDPE and GRI-GM17 for LLDPE

i. HDPE Geomembrane

Smooth Geomembranes

The material specifications are based on GRI – GM13 Specifications for smooth HDPE Geomembranes.

Textured Geomembranes

The material specifications are based on GRI – GM13 Specifications for textured HDPE Geomembranes. A width of approximately 150mm on the lengthwise edges of each sheet shall be left untextured for ease of seaming.

ii. LLDPE Geomembrane

Smooth Geomembranes
The material shall be in compliance with GRI–GM17 Specifications for smooth LLDPE Geomembranes. The material shall comply with all properties for Smooth LLDPE geomembranes. The widths of the panels are to be min 7.0m wide.

7.5.4. *Geosynthetic Clay Liner (GCL) Specifications*

GCLs are to be used as the mineral liner replacing the 2 x 150 mm Compacted Clay Liner (CCL) as shown in GNR 636 (DEA, 2013). In this project the GCLs are to be placed immediately below the High Density Polyethylene Liner (HDPE).

The GCL material to be supplied and installed for this Contract shall be GRI-GCL3 (Reinforced GCL GT related) GCL. The carrier layer shall be a woven geotextile only.

A sample of Eccabond K bentonite was sourced from Cape Bentonite by Kaytech Engineered Fabrics. A swell index test was carried out using this sample of bentonite and a leachate generated from samples of ash taken at the existing Matimba ADF. The results of the 14-day swell index test are presented in **Figure 6**. The conclusion of the test shows that the bentonite used in the range of GCL barriers offered by Kaytech Engineered Fabrics is likely to hydrate adequately when exposed to leachate from the Matimba ADF.

Date Start	Sample Ref	Quantity (g)	PH	EC us/cm before	EC us/cm after	Swell Index 16hrs	Temp End of test °C	Water Used	Date Fin
19-05-2015	1: Control	2		0.5		**32**	22	Distilled water	20-05-2015
21-05-2015	2: Matimba (new)	2	10.5			**28**	21.5	Leachate @ 7 days	22-05-2015
21-05-2015	3: Matimba (old)	2	10.5			**31**	21	Leachate @ 7 days	22-05-2015
28-05-2015	4: Matimba (new)	2	10.2	729	896	**24**	20.8	Leachate @ 14 days	29-05-2015
28-05-2015	5: Matimba (old)	2	10.5	579	776	**25**	20.7	Leachate @ 14 days	29-05-2015
						RESULT			

Notes: The liquid used in this test is a leachate being generated by mixing 6kg of ash in 12 litres of tap water
The slurry mixture is stirred once daily and a swell test done every 7 days
The swell requirement for a bentonite sample is 24ml/2g

Deviation: The swell test on the bentonite samples have been conducted using a leachate generated from the ash samples referred to as Matimba (New) and Matimba (Old)
A control test was done on the Bentonite sample using distilled water

Figure 6 - GCL Swell Index Test Results

In addition to the swell index test. The chemical compatibility of Eccabond K bentonite against potential leachate from the Matimba ADF was assessed by smectologists from SmecTech Research Consulting (Victoria, Australia). The assessment concluded that leachate from the Matimba ADF is expected to be fully compatible with an Eccabond K bentonite provided that the leachate is not generated from significantly acidic liquid. Based on the ionic strength, the saturated hydraulic conductivity can be expected to increase by less than an order of magnitude from e.g., ~2-4x10^-11 m/s to perhaps ~8x10^-11 m/s over time, and when coupled with cation exchange to increase a further 2x, to about ~2x10^-10 m/s. The hydraulic performance of the GCL will be therefore moderately negatively impacted by interaction with this leachate. This negative impact will be even less of a concern as the effective stresses on the GCL are above 100 kPa.

Based on discussions with the waste manager, potential leachate will be generated from rainfall and water from the pollution control dams at the ADF that is periodically used for dust suppression. A chemical analysis of the water from the pollution control dams showed the process water to have a pH between 7.19 and 9.36 (Refer to **Table 5**). Potential leachate generated at the ADF is thus expected to be alkaline and to be compatible with the proposed GCL barrier lining system.

Table 5: pH from Chemical Testing of Stormwater Dams at Matimba ADF for Dust Suppression

Constituents	North Storm Dam			Evaporation West			Evaporation East			Metsi-Magolo
	May-15	Jun-15	Jul-15	May-15	Jun-15	Jul-15	May-15	Jun-15	Jul-15	
pH	7.45	7.67	9.26	7.19	8.92	7.26	8.76	7.19	9.36	8.43

7.5.5. *Cuspated Leakage Detection Drain Specifications*

Cuspated Drain: A single cuspated high density polyethylene core which has a high compressive strength and in-plane flow capacity to convey leachate without clogging, to be used in landfill engineering applications as a leak detection layer. The core material is to have a flat bottom surface and a cuspated top surface (although may not necessarily be installed this way), and to provide protection and minimal stresses on the geosynthetic membranes directly in contact with the core.

The oxidation induction time (OIT) of the cuspated drain is to comply with the specified OIT for a 1.0mm HDPE geomembrane as specified in GRI – GM 13.
The cuspated drain specifications are shown in **Table 6**.

Table 6: Cuspated Drain Specifications

Physical Property	Test Method	Specified Value	Manufacturing Quality Control testing frequency
1. Material:		High Density Polyethylene	No test required
2. Type:		Single Cuspated	No test required
3. Average Mass/unit area (maximum deviation for any test result value to be 5%)	EN ISO 9864	700 g/m^2	1 in 20 000
4. Average sheet thickness (maximum deviation for any test result value to be 5%)		0.75 mm	-
5. Cusp height	EN ISO 9863-1	4.8 mm (Min)	-
6. Cusp centres	-	5mm (Min)	-
7. Minimum Compressive Strength	ASTM D1621 (Mod)	500 kPa	1 in 25 000
8. Minimum In-plane water flow at 600kPa pressure (at a hydraulic gradient of 0.01)	EN ISO 12958	0.02 l/m.sec	1 in 75 000
9. Minimum Life Expectancy	-	100 years	-
10. Working Temperature	-	0^0 to 80^0C	-
11.Compressive Creep Strain	SIM (Stepped Isothermal Method)/ASTM D 6364-06	Compressive creep strain < 20% at 500 kPa at 100 yrs (with sand filled in cusps)	1 in 75 000
12. Tensile Strength	EN ISO 10319	(MD/CD) 8/5 kN/m (Min)	1 in 75 000
13. Static puncture (CBR)	EN ISO 12236	1000 N (Min)	1 in 75 000

7.6. On-site Internal Temperature Modelling

Internal ambient temperature within the proposed ADF during the design life was highlighted as a concern at the start of the project.

Hydration of pozzolans within fly ash has been shown to be an exothermic reaction. The heat of hydration has been used in the concrete industry to predict heat build-up in large scale concrete construction (Hasset and Eylands, 1997).

Limited literature is available when it comes to predicting heat build-up in a waste disposal facility that receives a homogenous Ash Waste as a singular waste.

The concentration of Calcium Oxide (CaO) in a source of fly ash is seen as an indicator to the cementitious nature of the fly ash and thus results in a difference in the heat of hydration (Blondin et al., 1999). The generation of heat within an ash landfill has been shown to reach temperatures in the order of 60 to 90 degrees Celsius, due to the hydration of pozzolans within the ash. A detailed literature review and on-site thermal investigation was carried out at the existing ADF, undertaken by Jeffares and Green and is presented in the report titled *"Geotechnical Assessment and Thermal Investigation at the Matimba Power Station Ash Disposal Facility, Lephalale, Limpopo Province; February 2014"* which is to be read in conjunction with the technical Engineering Report.

Variables from the heat modelling equation by Yoshida and Rowe (2003) were obtained as part of the testing schedule undertaken at the soils laboratory. This was done in order to carry out a rudimentary comparison of the ash waste at Matimba against the available literature. When comparing the thermal conductivity and specific heat of the Matimba Ash Waste against the values presented, it was noted that both the thermal conductivity and the specific heat of the Matimba Ash Waste are lower than in the example presented by Yoshida and Rowe (2003).

Based on the above, the report anticipated that the temperatures measured on-site during the thermal investigation would be lower than the temperatures predicted by Yoshida and Rowe (2003).

A detailed on-site thermal investigation was undertaken. Jeffares & Green oversaw the continuous thermal monitoring of the four test stations from the 28^{th} February 2014 to the 4^{th} February 2015. The thermal logging instrumentation has remained installed at the logging stations and the instrumentation was left to continue capturing thermal data.

Since the submission of the Geotechnical Assessment and Thermal Investigation Report (J&G, 2014), additional temperature monitoring data has been obtained which has increased the temperature logging period from the 30^{th} April 2014 to 4^{th} February 2015. This additional information has been incorporated into the results from the original report.

This time period for the monitoring is seen as "short term" in the scheme of such a Facility, although hydration of the ash is understood to predominantly occur over a few days, depending on the receiving environment.

<u>The maximum recorded temperature (not considered a gross outlier due to technical fault) across all four logging stations did not exceed 48℃. The standard deviation for thermoprobes that did not experience technical disruptions was less than 2℃ which has given further confidence in the results.</u>

A tabular summary of the thermal investigation (from 28th February 2014 to 28 February 2015 is presented in **Table 7**. Temperatures were recorded in freshly placed ash and in ash placed 1 – 1.5 years ago. **Figure 8** presents a graphical representation of the temperatures recorded in borehole monitoring station 2 (including the extended logging period). **Figure 9** shows a graphical representation of a probe placed into newly placed ash against a probe that was left to lie exposed on the surface of the ADF adjacent to the monitoring station. This graph is of significance because it shows the development of heat as soon as the pozzolanic reaction takes place (the yellow line in the graph). The temperature of the freshly placed ash (Refer to **Figure 9**) is shown to be increasing.

With Reference to **Figure 8,** the 10m deep probe shows a higher temperature (approximately 10℃) than the other depths. This is assumed to be due to conveyor belt operational changes that could have resulted in the ash within the top 10-15m being "younger" than the ash situated at the bottom of the 45m high exiting ADF (Comment from Andre Kruiter, Eskom, June 2015).

Inspection of the rate of temperature rise in the station measuring indicates the rate of temperature increase reduces over time and the final recorded temperature appears to be close to reaching a plateau for the maximum temperature.

Figure 7 shows that the rate of temperature increase has decreased since establishing the monitoring program.

<u>Conservative estimates from analysing the data indicate that the temperature in the ash pile is unlikely to go above 50℃ before the temperature begins to drop. Analysis of the results from the boreholes placed in older ash waste pile shows that the temperature of the newly placed ash pile is expected to decrease and stabilise between 30℃ and 40℃ by the end of 2015 (i.e. 2 years from placement).</u>

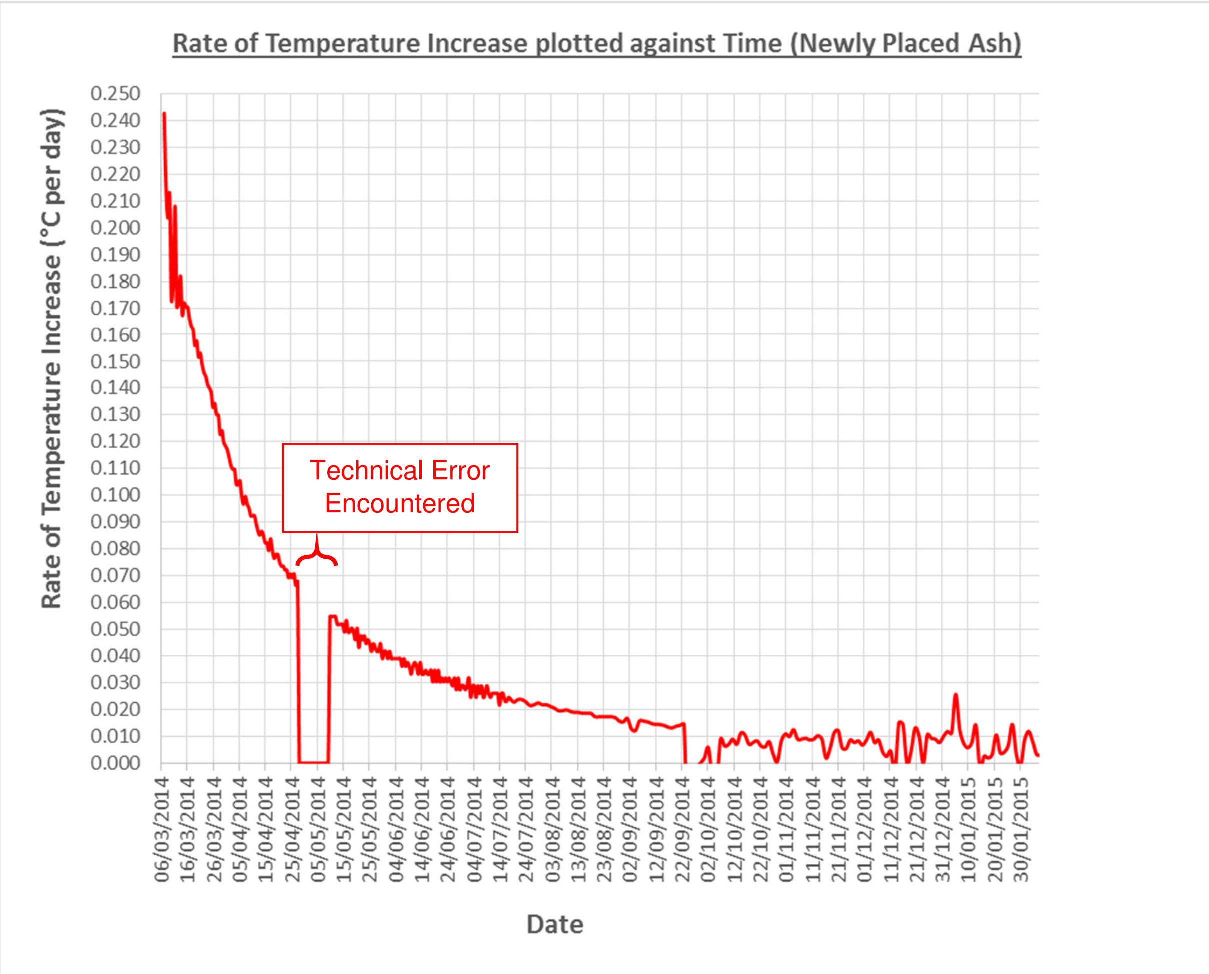


Figure 7 - Rate of Temperature Increase for the newly placed ash pile

Table 7: Summary of Temperature Monitoring undertaken at the Matimba Ash Disposal Facility

Logging station	Nature of Logging Station	Estimated Time Elapsed since Ash Placement	Probe Depth				Minimum Temp	Maximum Temp	Max Temp at Basal Lining Level	Comments
			Probe 1	Probe 2	Probe 3	Probe 4				
1	Borehole	1 - 1.5 years	5m	10m	43m	48m	27.9℃	39.8℃	31.8℃	- Weather Damage experienced at the end of March. - Thermocouple (TC) 3 had a technical malfunction at the end of April.
2	Borehole	1.5 - 2.5 Years	5m	10m	43m	48m	31℃	40.12℃	31.0℃	- Thermocouple (TC) 3 showed irregular temperature oscillations from the beginning of the investigation.
3	Borehole	1 - 1.5 Years	5m	10m	40m	45m	21℃	41.2℃	40.4℃	- Logging station went offline from the beginning to the middle of March due to weather damage.
4	New Ash Waste Pile	Newly Placed Ash (Ash Placed on 26th Feb 2014)	Landfill Surface	Landfill Surface	15m (offline)	30m	36.5℃	48.0℃	48.0℃	- Two TCs were placed into the advancing Ash Pile. One of the TC went offline post placement and is not shown in this report. - Temperatures recorded at the Landfill Surface were not included for presenting the Maximum and Minimum temperatures.

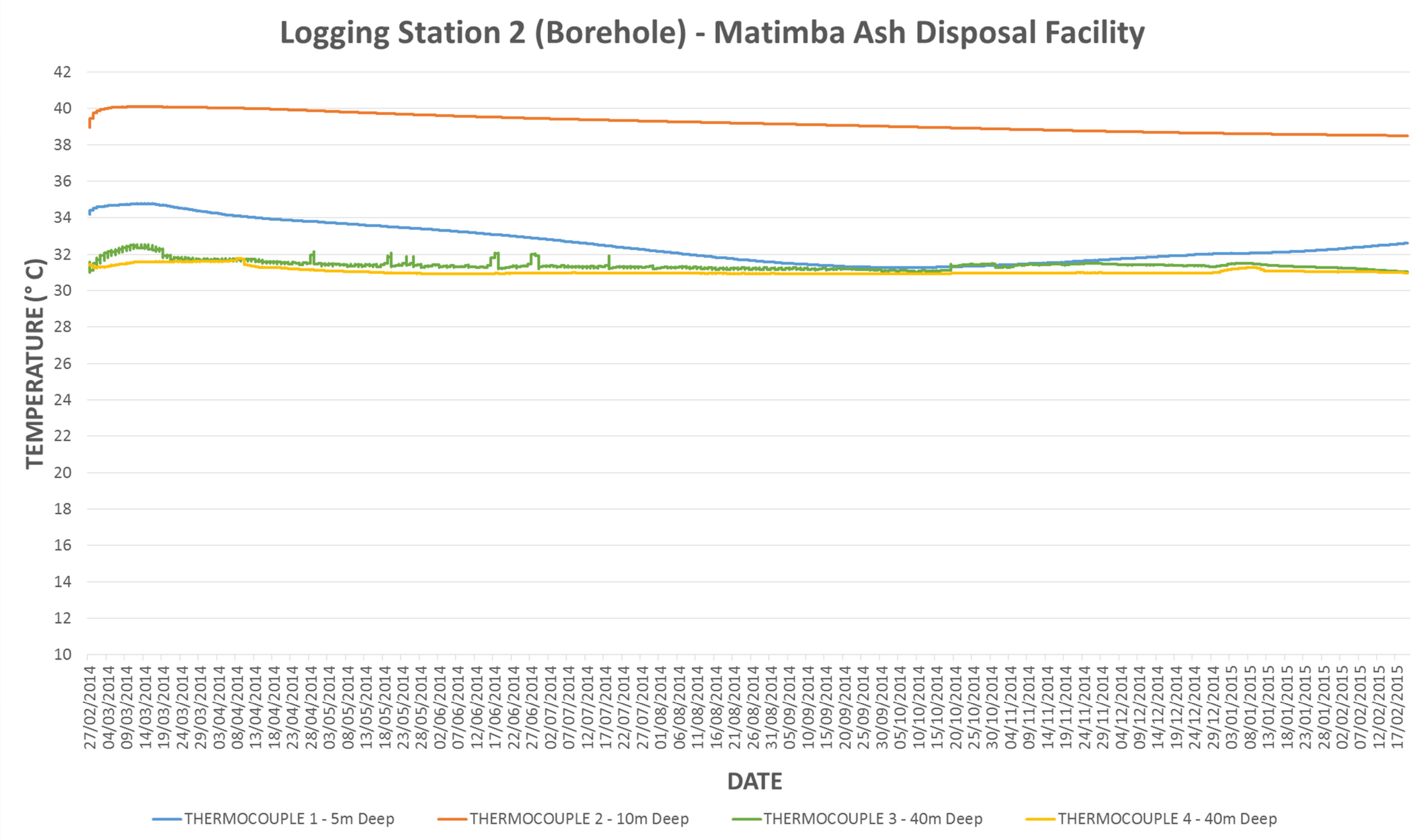


Figure 8 - Temperatures recorded at Logging Station 2 (Borehole 2) from April 2014 to February 2015

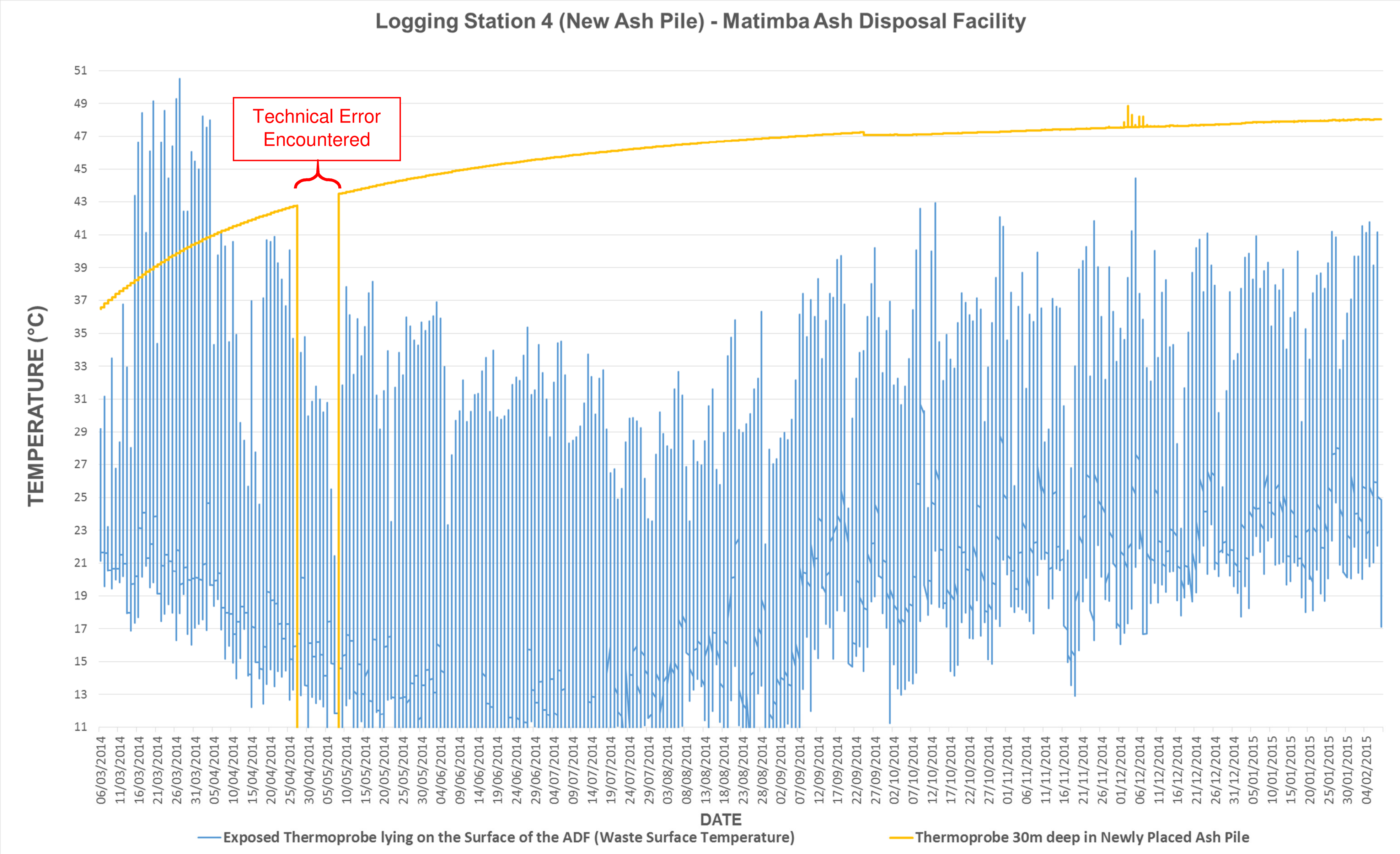


Figure 9 - Temperatures recorded at Logging Station 4 (New Ash Pile) from February 2014 to February 2015

7.7. Acceptable effective Service Life of the Geosynthetic Components

The ADF is expected to be in operation until 2055 (**Section 6.1**) with pollution monitoring operations continuing for a further 30 years (until 2085). Based on the expected landfill construction practices, closure and capping will follow soon after the development of each subsequent waste cell to facilitate dust suppression.

The ash waste not should not:

- generate gas due to the homogenous nature of the waste and the lack of an organic component;
- present chemical instability because of its homogenous nature;
- generate any internal leachate from chemical or biological reactions within the waste due for the reasons listed above;

Therefore, any leachate generated in the ADF will be from the infiltration of rainfall and water from the pollution control dams used for dust suppression which will slowly permeate through the waste body to the leachate collection system of the basal lining system.

This permeation of leachate is expected to be gradual due to the fine particle size and homogeneity of the ash waste. The climatic water balance from the area **(refer to Section 6.3)** indicates shows that annual evaporation exceeds the annual precipitation by a large margin, infiltration of runoff into the ADF is expected to be low. Final capping is to be undertaken so as to maximise overland runoff away from the landfill and limit infiltration. The final cap will be constructed long before the end of the pollution monitoring period.

Based on the arguments above, **the estimated acceptable service life of the geosynthetic barrier system is defined as 70 years from the installation of the barrier lining system**. After this point it is anticipated that the potential for contamination of the facility would have reduced significantly due to the expected reduction in leachate generation.

7.8. Internal Temperature Management

A rise in liner temperature will cause antioxidant depletion in a geomembrane, potential dehydration in clay liners beneath a geomembrane, and increase diffusion and/or moisture movement through liners (Yoshida & Rowe, 2003). Increased liner temperatures have been shown to have significant impact on the useful service life of geosynthetic barrier lining systems (Rowe, 2005).

Internal temperature modelling on-site (**see Section 7.6**) shows that the temperature at the basal lining system could reach an estimated maximum temperature of 50℃ in the first year, after which point it is expected that temperatures will reduce to the region of 30 - 40℃. From Rowe (2005) a conservative effective service life of geosynthetic components at 50℃ and 40℃ is predicted to be 50 and 120 years respectively, refer to **Table 8**. It is expected that the unadjusted service life prediction would apply in this case due to the low leachate generating potential of the ADF.

Two design options are proposed that will enable the geosynthetic components to reach the specified effective service life of 70 years.

Both design options presented below are based on a literature review of the risk to geosynthetic components from increased internal temperatures.

<u>The designs are based on sound principles in order to demonstrate the ability to mitigate temperature issues in the context of this concept design report</u>. Detail design will incorporate designing the systems such that the risk to the geosynthetic components is mitigated to an acceptable level in order

to guarantee the specified effective service life for the geosynthetic components. Detail design must take into account the requirement to be as cost effective as possible to prevent unnecessary expenditure.

Table 8: Effect of Basal Lining Temperature on the Estimated Service Life of a Geomembrane (Taken from Rowe, 2005)

(1) Temp: °C	(2) Stage 1: years Simulated,* t_{siml}	(3) Stage 2: years Base,† t_V	(4) Stage 2: years Adjusted,‡ t_{Va}	(5) Stage 3: years Base,§ t_B	(6) Stage 3: years Adjusted,¶ t_{Ba}	(7) Service life: years Unadjusted,** t_{SL}	(8) Service life: years Adjusted,†† t_{SLa}
10	280	50	30	2445	1380	2775	1690
20	115	15	10	765	440	900	565
30	50	6	4	260	150	315	205
35	35	4	2	155	90	190	130
40	25	2	1	95	55	120	80
50	10	1	0·6	35	20	50	35
60	6	0·4	0·3	15	9	20	15

*Based on simulated liner antioxidant depletion tests (Table 5).
†Calculated using data from Viebke *et al.* (1994) for 2·1 mm wall thickness pipe with water inside and air outside.
‡As per previous note, but adjusted for possible effect of leachate using equation (35) and data from Table 5.
§Calculated using activation energy from Viebke *et al.* (1994) for 2·1 mm wall thickness pipe with water inside and air outside and half-life of 90 days at 115°C from Bonaparte *et al.* (2002).
¶As per previous note, but adjusted for possible effect of leachate using equation (36) and data from Table 5.
**$t_{SL} = t_{siml} + t_V + t_B$.
††$t_{SLa} = t_{siml} + t_{Va} + t_{Ba}$.

7.8.1. Thermal Management Design Option 1: Temperature Resistant Geosynthetic Components

The minimum material specifications for the selected geosynthetic components have been given in **Section 7.5**. Recent movements by geosynthetics manufacturers have seen increased focus on developing thermal stabilised geosynthetic materials. If the service life of thermally stabilised temperature resistant geosynthetics is shown to be equal to or exceed the required effective service life of 70 years and are shown to comply with the material specifications presented in **Section 7.5**, such components could be considered at detail design without further concern with regards to internal temperature management of the ADF.

7.8.2. Thermal Management Design Option 2: Thermal Management System

Rowe et al. (2010) present a numerical model that evaluates the use of an HDPE pipe network as a system to reduce temperatures at the basal lining system in a landfill facility. The numerical model has shown to be a good theoretical fit based on the on-site thermal modelling presented in **Section 7.6.** The research paper models a facility that reaches temperatures in the region of 40℃ to 50℃ and evaluates the possibility of reducing the landfill temperature to increase the effective service life of the geosynthetics.

The research paper presents various configurations for the HDPE pipe network. The thermal management system for the ADF uses a similar cross sectional pipe configuration to that shown in **Figure 10** as this configuration offers the best thermal conductivity (for effective heat transfer away from the geosynthetics) (Rowe, 2010). This configuration places the heat collection pipes in a layer of sand <u>below</u> the leachate collection system, this reduces the conveyance of heat through the sand layer through the leachate which allows the sand to behave as a passive thermal protection buffer (Hoor, 2012).

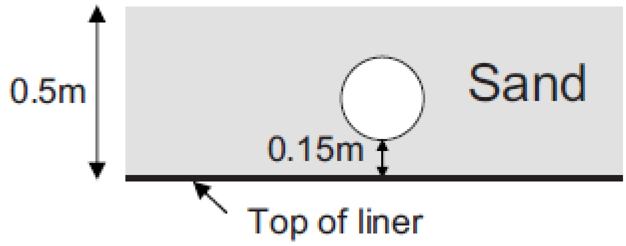


Figure 10 - Location of the cooling pipes taken from Rowe et al. (2010)

Rowe et al. (2010) models the effect of thermal management using a pipe spacing of 9m with a total length of 400m from inlet to outlet (Refer to **Figure 11**). This configuration was shown to reduce temperatures at the basal lining system by between 7.5 – 19.1℃ in the numerical model based on an inlet temperature of 15℃ (Rowe et al., 2010).

The efficacy of the heat removal is shown to be a function of (Rowe et al., 2010):

- HDPE pipe diameter – *the study uses a pipe diameter of 50mm however larger pipe diameters are expected to be more effective in terms of heat removal;*
- thermal conductivity of the sand of HDPE pipes – *the thin wall thickness of the HDPE pipes shows that the low thermal conductivity of HDPE will have insignificant effect on the heat transfer;*
- mass transfer rate – *increasing the mass transfer rate will increase heat removal up to the point that the flow rate is too high to render the heat extraction effective.*

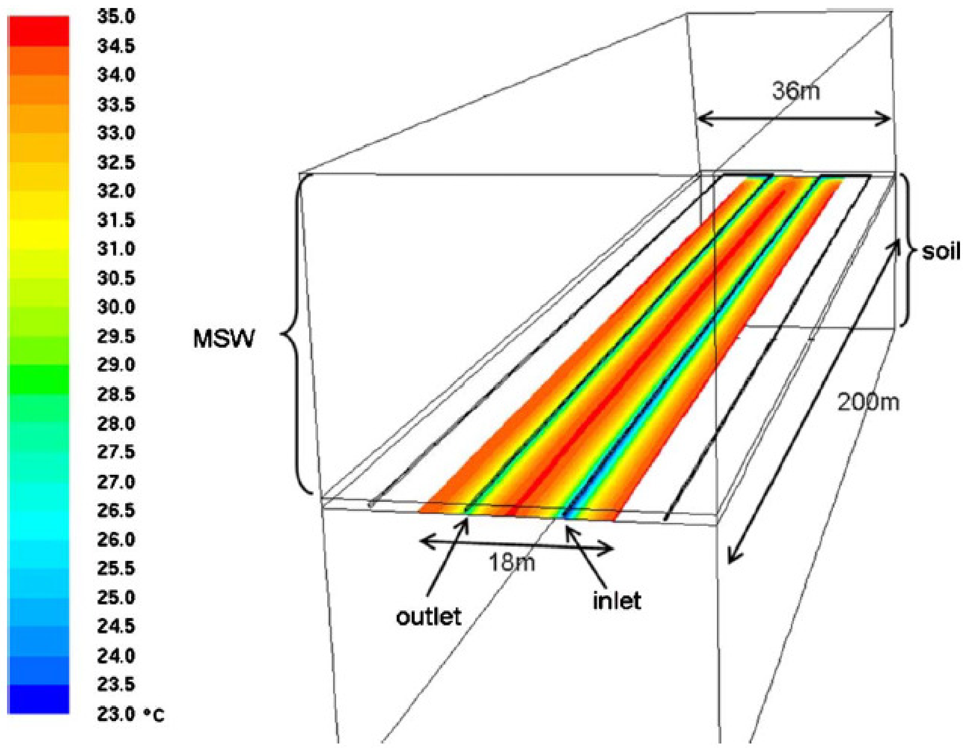


Figure 11 - Periodic Pipe Layout for a pipe spacing of 9m and mass transfer rate of 0.3 kg/s taken from Rowe et al. (2010)

The proposed thermal management system for the Matimba ADF is shown in **Figure 12**. The HDPE network is to be installed in the sand layer below the leachate collection pipework in modules that consist of five heat extraction lines, spacing of 10m, that run between inlet and outlet structures. The inlet and outlet stuctures are to be located outside of the waste cells with a maximum waste cell width defined as 1200m.

Thermocouples are to be installed at the basal lining system at equal intervals between the inlet and outlet structures to monitor basal lining temperatures for effective thermal management.

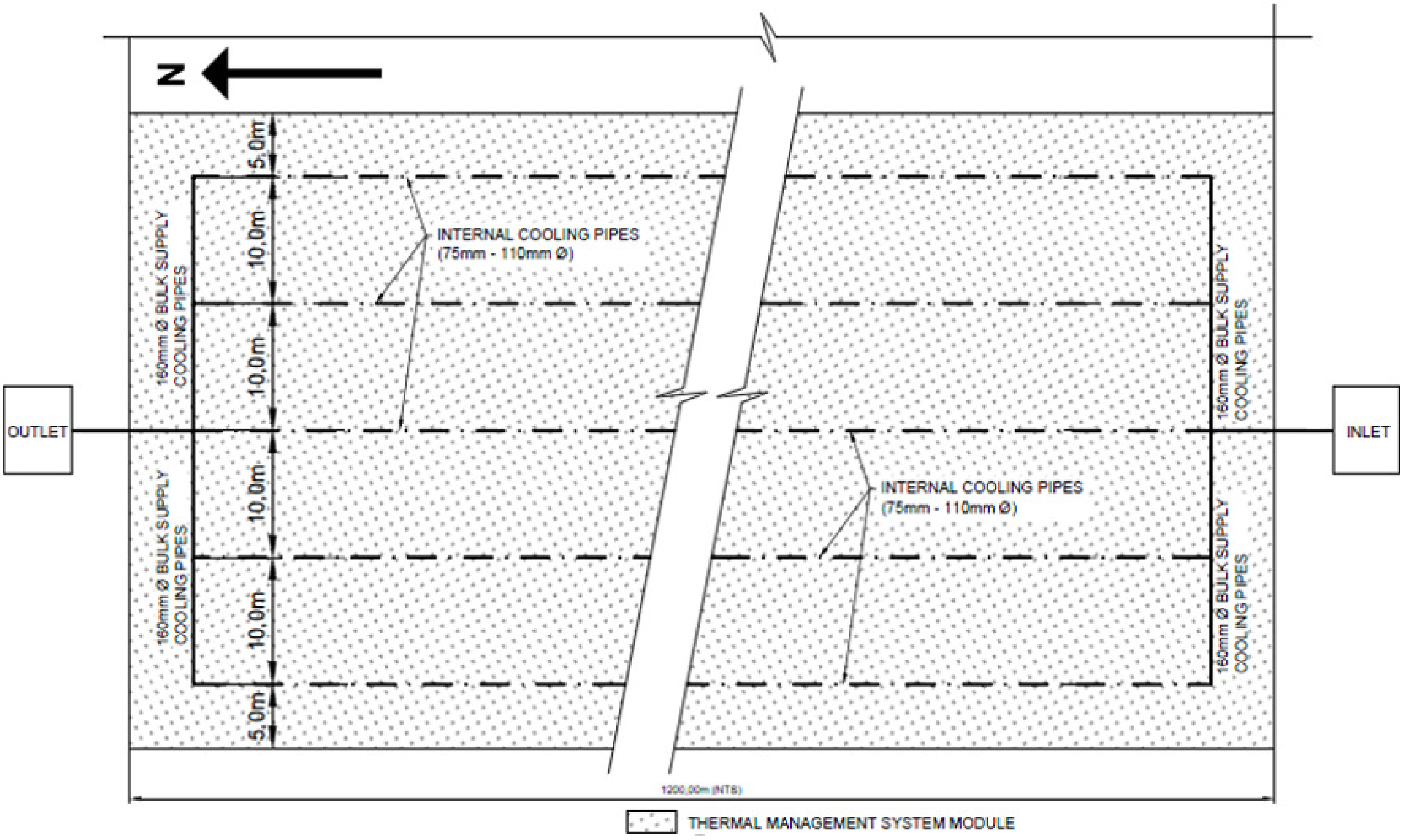


Figure 12 - Proposed thermal management system module for ADF waste cells

The temperature ash waste disposed to the ADF is expected to stop increasing within the 1.5 years post placement at which point it is anticipated that the temperatures at the basal lining system will begin to reduce until stabilising between 30 to 40℃ (See **Section 7.6**).

Figure 13 shows an example of how temperatures across the waste cell are expected to change once the TMS becomes active. The three suitable time intervals are to be specified at detail design phase; the main objective of the TMS is to reduce the temperature at the basal liner to a suitable level to achieve the required effective service life of the geosynthetic components (See **Section 7.7**).

The graph at ΔT1 shows how the basal liner closest to the inlet for the TMS is the first portion of basal liner to experience a reduction in heat before the temperature of the fluid in the TMS rises to that of the general waste temperature before the installation of the TMS.

At the second time interval after continuous implementation of the TMS (graph for ΔT2) the effect of the cooling measures have increased to incorporate portions of the waste cell that are further away from the inlet structure.

The graph at ΔT3 shows the net effect of the thermal control measures whereby heat has been removed from the system to the extent that the temperatures at the basal liner across the entire waste cell (from inlet to outlet) have been reduced to an acceptable limit that does not pose a threat to the effective service life of the geosynthetic components.

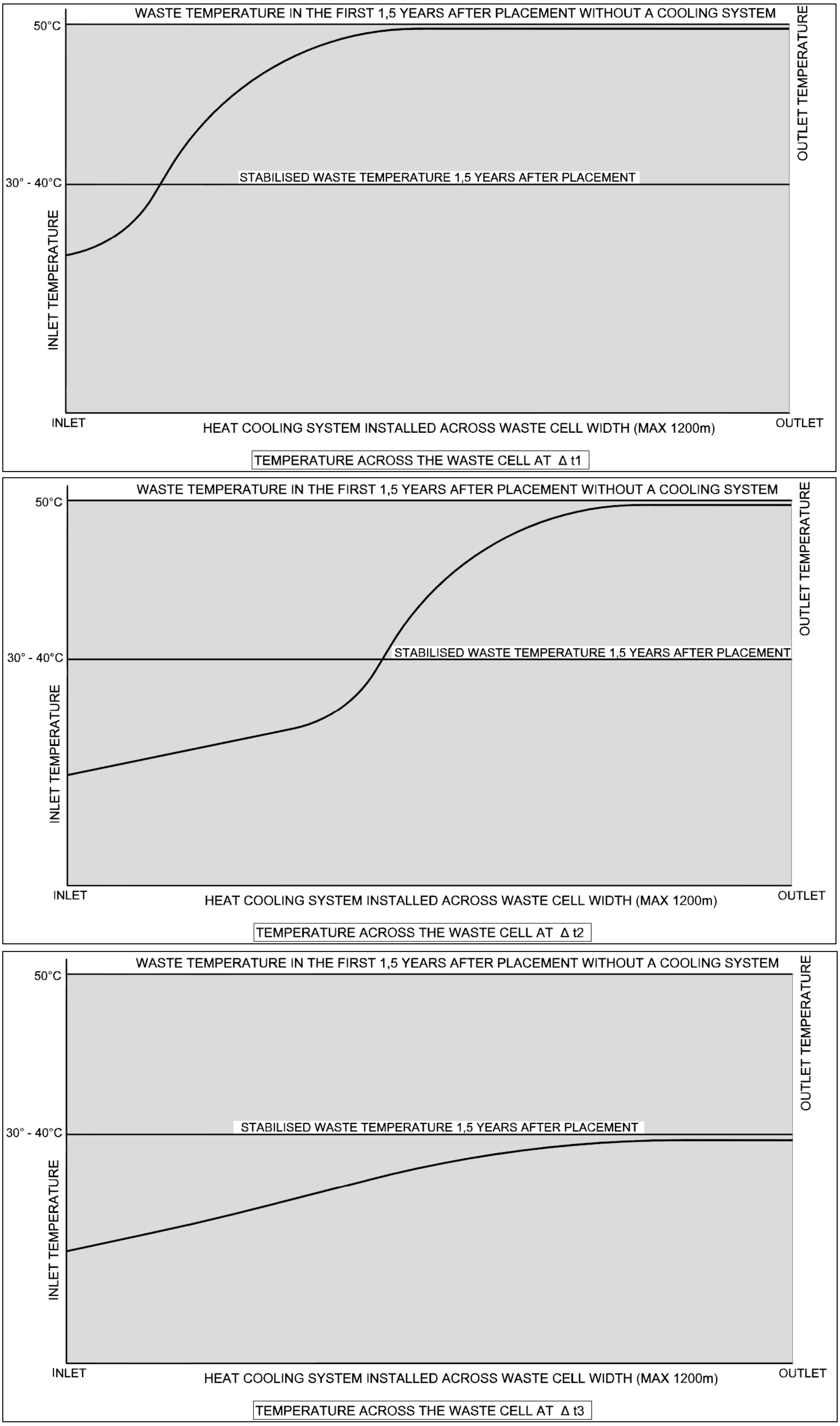


Figure 13 - Theorised Effect of the Thermal Management System at Different Time Intervals

It is proposed that the thermal management system be broken up into three operational phases that involve varying levels of intervention by the waste management team. These phases shall be triggered based on temperatures at the basal liner and subsequent perceived risk to the effective service life of the ADF.

i. Phase 1: Thermal Management System

The first phase of the thermal management system (TMS) involves the installation of a wind-driven ventilation system at the outlet of each TMS module that is installed. An example of such a ventilation system is shown in **Figure 14**. The ventilation system would constantly draw ambient air through the TMS pipework which would assist in reducing the temperatures at the basal lining increasing the effective service life of the geosynthetics. Average maximum and minimum temperatures at Lephalale are shown in**Table 9**. It can be seen that the average temperatures are well below the levels of concern regarding geosynthetic service life. This phase is to be implemented until the basal lining system reaches the temperature threshold for Phase 2 activation (**Phase 2 Temperature Threshold is 50°C**).

Figure 14 - Wind-driven ventilation system

ii. Phase 2: Thermal Management System

<u>The second phase of the thermal management system (TMS) will trigger when the basal lining system reaches an internal temperature of 50°C.</u>

This management phase incorporates the installation of an active electric motor driven ventilation system at the inlet of each TMS module that has been installed in the waste cell. The ventilation system would constantly force ambient air through the TMS at a much higher flow rate than what the wind-driven ventilation system could achieve. A higher flow rate (or mass transfer rate) would increase the efficacy of heat removal further reducing the temperatures at the basal lining increasing the effective service life of the geosynthetics. Average maximum and minimum temperatures at Lephalale are shown in **Table 9**. This active ventilation system could be programmed to take advantage of lower night time temperatures which would reduce the inlet temperature subsequently improving heat removal. This phase is to be implemented until the basal lining system reaches the temperature threshold for Phase 3 activation (**Phase 3 Temperature Threshold is 56°C**).

Table 9: Average Temperatures (Lephalale, Weather tables Appendix 2, DEA)

Average Maximum Temperature

Average Summer	**(November - February)**	**32.4**
Average Winter	**(May - August)**	**25.3**
Average Spring	**(September - October)**	**31.1**
Average Autumn	**(March - April)**	**30.0**

Average Minimum Temperature

Average Summer	**(November - February)**	**19.8**
Average Winter	**(May - August)**	**7.4**
Average Spring	**(September - October)**	**15.2**
Average Autumn	**(March - April)**	**16.5**

iii. Phase 3: Thermal Management System

The third phase of the thermal management system (TMS) will trigger when the basal lining system reaches an internal temperature of 56℃.

This management phase requires a change in the TMS coolant fluid type. The system will change from being air-cooled to liquid cooled. Detail design phase is to confirm whether the system will run from independent basal lining cooling dams or rather recirculate contaminated stormwater runoff from the pollution control dams through the TMS (preferred option). Substituting liquid in favour of air as a cooling medium will dramatically increase the heat transmission coefficient of the coolant. The air transmission coefficient is in the order of 5 to 8 W/m²K whereas the water transmission coefficient is shown to be approximately 300 to 400 W/m²K (www.theengineeringtoolbox.com, 2015).

Based on Rowe et al. (2010) a mass transfer flow rate of 0.4 kg/s would result in a significant drop in basal liner temperature. This flow rate could be increased up to a point to increase the efficacy of the heat removal of the system. It is anticipated that the rate of temperature increase in the ash waste disposed to the ADF will stop within the first year to year and a half (See **Section 7.6**) at which point the waste temperature has been shown to reduce. Pipe selection for this concept stage has been based on the transfer of a liquid through the TMS at a flow rate of 0.4 L/s in each cooling line of the module. A summary of the design is shown in **Table 10**.

Table 10: Design of the pipes for the Thermal Management System

	Pipe Length (m)	Pipe Roughness (C Value)	Mass Flow Rate (kg/s)	Volumetric Flow Rate (L/s)	Pipe Diameter (mm)	Frictional Losses (m/100m)	Frictional Losses
Internal Cooling Pipes *(Located in the Waste Cell above the primary Geomembrane)*	600	140	0.4	0.4	50	9.00	54
					75	1.25	7.5
					110	0.19	1.14
	1200	140	0.4	0.4	**50**	**9.00**	**108**
					75	**1.25**	**15**
					110	**0.19**	**2.28**
	2000	140	0.4	0.4	50	9.00	180
					75	1.25	25
					110	0.19	3.8
Bulk Supply Cooling Pipes *(Supply pipes feeding the internal pipe mattress)*	60	140	-	2	110	3.82	2.29
					160	**0.62**	**0.37**
	100	140	-	2	110	3.82	3.82
					160	0.62	0.62

In reviewing the development of heat in landfills during the literature review, it becomes apparent that very little is understood in predicting the likelihood of the basal lining system acting as a thermal insulator that prevents thermal transmissivity from the waste body into the underlying foundation materials (in-situ soil)

Although the on-site thermal investigations found the anticipated maximum temperature to be in the region of 50 degrees Celsius, when one introduces the composite barrier lining system, this maximum temperature could increase due to a potential reduction in the rate of heat transfer into the ground below the landfill.

The strategy is to install a Thermal Management System (TMS) as part of the basal lining system as fixed infrastructure. At a later stage or during ash filling, Eskom or the Operator can monitor and manage temperature gain/reduction as time passes. The operational infrastructure such as pumps, water, air ventilators, etc are all seen as temporary (non-fixed/ re-usable) infrastructure for future cells or other operations by Eskom.

7.9. Dust Suppression

The current operations use water for dust suppression which, if managed correctly, will solidify the ash increasing density and stability of the ash pile. It is recommended that dust suppression through water irrigation continues at the new proposed ADF.

Dust suppression is a vital component of the operational controls that need to be established. Stormwater and leachate is to be directed to a central collection pond where there is a possibility of irrigating the waste pile for dust suppression, thus negating the need to use clean, potable water for dust suppression. Regular water quality testing of the leachate will need to be undertaken to mitigate the health and safety risk that arises due to the recirculation of leachate.

Dust suppression methodologies during periods of rainfall and high wind conditions will form part of the operational controls of the site.

7.10. Allowable and Action Leakage Rates

Since the promulgation of the WCMR (DEA, 2013), total solute seepage, acceptable leakage rates and allowable leakage rates need to be motivated as part of a waste license application (See **Figure 15**).

(2) The following containment barrier requirements must be included in an application for waste management licence approval of a landfill site or cell —

(a) design reports and drawings that must be certified by a registered, professional civil engineer prior to submission to the competent authority;

(b) service life considerations that must be quantified taking into account temperature effects on containment barriers;

(c) total solute seepage (inorganic and organic) that must be calculated in determining acceptable leakage rates and action leakage rates;

(d) alternative elements of proven equivalent performance which has been considered, such as the replacement of —

(i) granular filters or drains with geosynthetic filters or drains;

Figure 15 - New License Requirements (WCMR, DEA, 2013)

The WCMR do not stipulate actual values for acceptable or action leakage rates, rather designers need to motivate leakage rates based on total solute seepage and an acceptable risk assessment. Stipulation of leakage rates were not previously required under the Minimum Requirements (MRs) of 1998.

The literature review indicated that the US Environmental Protection Agency are in favour of setting acceptable leakage rates in the order of 50 L- 200 L(litres) per hectare per day for general waste facilities with action leakage rates being accepted based on motivation from the landfill designers.

A risk assessment was carried out utilising the leachable concentrations of the Contaminants of Concern (CoCs) from the waste classification report (Jeffares and Green, 2013) and subsequent Estimated Environmental Concentration (EEC) of each CoC. The EECs were then compared against Acceptable Risk Levels (ARLs) from the MRs (DWAF, 1998) and the Canadian Water Quality Guidelines (Canadian Council of Ministers for the Environment, 2009) when the MRs failed to provide an ARL for a specific CoC.

The risk assessments conducted were based on the following leakage rates:

- ACCEPTABLE LEAKAGE RATE: 200 L/ha/day
- ACTION LEAKAGE RATE: 500 L/ha/day

The results from the risk assessments are shown in **Table 11** and
Table 12 below and indicate that the risk to the environment is acceptable at the stipulated leakage rates.

Table 11: Risk Assessment at Leakage Rate of 200 L/ha/day (EEC vs ARL)

Contaminant Of Concern	Highest Leachable Concentration In The 6 Waste Types	CoC In The Disposal Stream At A Leakage Of 200 L/Ha/Day	EEC	ARL	Leakage Acceptable
	(mg/L)	*(g/month/ha)*	*ppb*	*ppb*	*Y/N*
B	0.914	5.667	3.740	1500	Y
Cr	0.173	1.073	0.708	470	Y
Cr (VI)	0.194	1.202	0.792	20	Y
Mo	0.186	1.153	0.761	20[3]	Y

Table 12: Risk Assessment at Leakage Rate of 500 L/ha/day (EEC vs ARL)

Contaminant Of Concern	Highest Leachable Concentration In The 6 Waste Types	CoC In The Disposal Stream At A Leakage Of 500l/Ha/Day	EEC	ARL	Leakage Acceptable
	(mg/L)	*(g/month/ha)*	*ppb*	*ppb*	*Y/N*
B	0.914	14.167	9.350	1500	Y
Cr	0.173	2.682	1.770	31	Y
Cr (VI)	0.194	3.007	1.985	20	Y
Mo	0.186	2.883	1.903	20[2]	Y

[3] *The ARL of Molybdenum is not defined in the MRs (DWAF,1998). The LD50 of Mo has been shown to be in the order of 200 ppm, LD50 of Cr (VI) is between 50 – 150 ppm thus the ARL of Cr (VI) has been utilised for this calculation and is seen as conservative.*

7.11. Estimated Leakage Rate for the Proposed Basal Lining System

The estimated leakage through the proposed primary composite liner (as proposed herein) into the leakage detection layer was calculated based on the paper by Giroud (1997) Refer to **Figure 16**.

Circular defect:

$$Q = C_{qo}\ [1 + 0.1\ (h / t_s)^{0.95}]\ a^{0.1}\ h^{0.9}\ k_s^{0.74}$$

Figure 16 - Leakage through Composite Liners (from Giroud 1997)

Leakage through the primary liner was estimated at **1,31 L/ha/day**[4] based on the assumptions in **Table 13**. This is well below the acceptable and action leakage rates specified above.

Table 13: Assumptions for Leakage through the Proposed Primary Composite Liner

Description	Unit	Quantity
Number of holes	Holes per Hectare	10
Shape of Hole		Circular
Hole Diameter	mm	2
Leachate Head above Primary Lining System*	mm	300
Thickness of the GCL Barrier	mm	5
Permeability of GCL Barrier	m/s	$2,25 \times 10^{-11}$
C_{qo} (Based on Good Contact)		0.21

7.12. Leachate Management

The leachate collection, treatment and disposal systems must be carefully considered. The waste material (dry ash) has a very fine particle size which may clog a typically used stone drainage layer (leachate collection layer) solidifying the drainage layer and preventing proper leachate collection and drainage. A Herring-bone slotted pipe system is proposed to be installed within the stone aggregate layer to facilitate leachate flow and disposal.

The cell basin is proposed to be constructed in a series of troughs and berms as illustrated in

Figure 17. This design ensures that there is an adequate slope (5%) for gravity flow drainage. In addition, a longitudinal grade of 1V:120H along the basin of the cell further assists in promoting the free gravity flow of the leachate (See **Figure 18)**. The conceptual floor layout and proposed leachate collection system is shown in **Drawing No. 3145 – C002** for site alternative 1 and **Drawing No. 3145 – C004** for site alternative 2.

4 Estimated value is subject to the assumptions made at concept design level and may change based on final design and on-site conditions. Actual leakage at the proposed facility is to comply with the acceptable and action leakage rates specified.

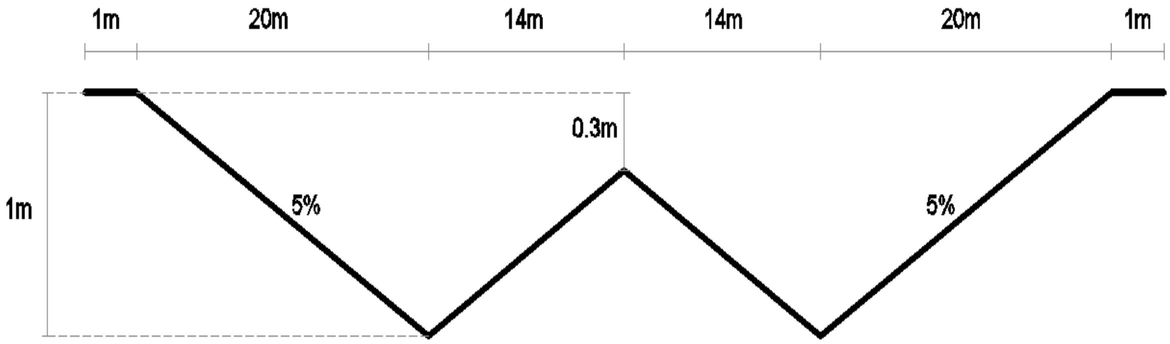


Figure 17: Cross Section through Landfill Floor Layout

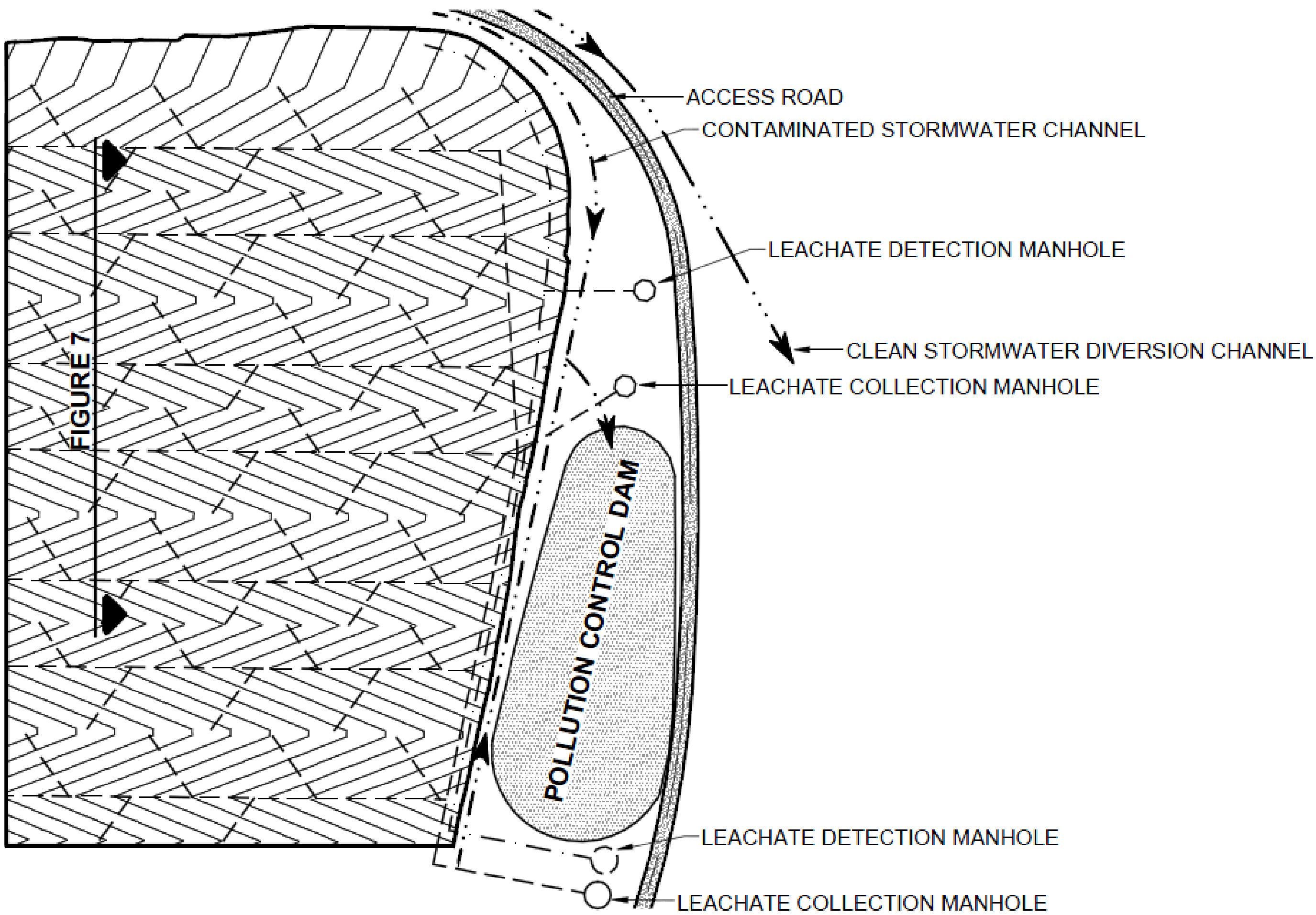


Figure 18: Herringbone Arrangement of Leachate Collection Pipes

Any leachate which may form in the cell will be collected in the leachate collection layer of the basal lining system and will be directed toward a leachate collection manhole (Refer to **Drawing No. 3145 – C006**). Contaminated stormwater will be directed into the proposed PCD. It is proposed that the side slopes of the PCD be 1V:3.5H to a depth of 2.3m (1.5m water level and 0.8m freeboard).

Leachate from the leachate collection manholes could be tested to ascertain its suitability for recirculation (along with the contaminated stormwater) back over the waste pile to make use of evaporation in reducing the total quantity of leachate. This concept is to be further developed at the detail design phase based on the final cell development philosophy.

7.13. Stormwater Management

Based on best practice and specialist recommendations, the entire ash disposal facility site should be regarded as a contaminated water runoff area, until the ash pile has received its final capping layer (at which point the runoff can possibly be classified as clean stormwater). Runoff from the site will be captured in a long down-slope drain system able to accommodate a 0.75 m^3 /sec flow rate (GCS Report, 2013). The runoff will be conveyed into a pollution control dam (PCD) located at the low point of the ADF and below all likely spoil heaps. Refer to Site Layout drawing **Drawing No. 3145 – C002** and **Drawing No. 3145 – C004**.

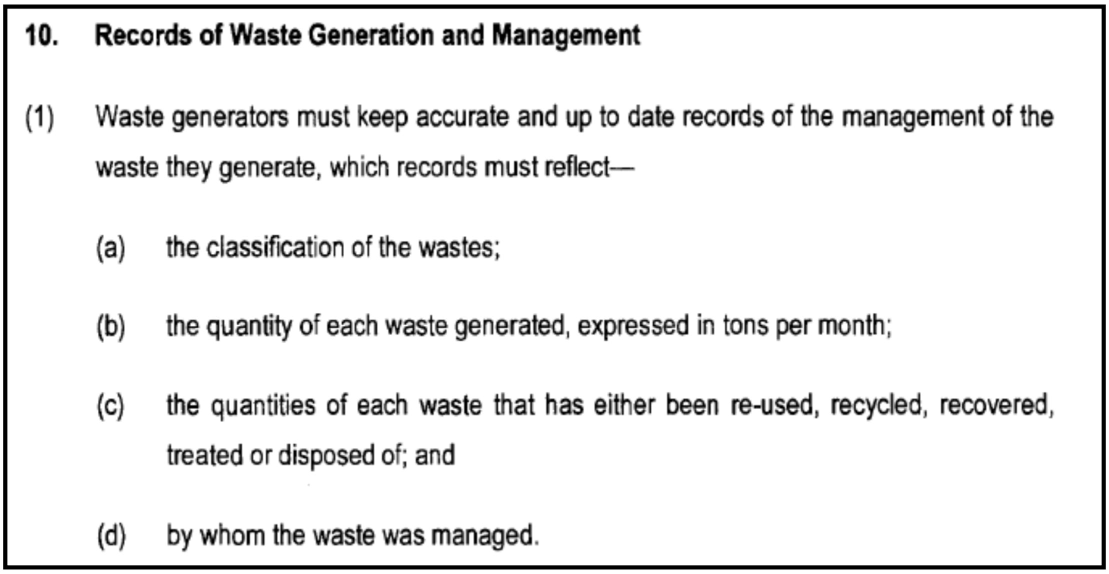
Clean stormwater generated on-site and received from upstream areas should be kept separate from contaminated stormwater that has come into contact with the ash waste. The hydrology and stormwater management reports (GCS, 2013) recommend that clean stormwater diversion drains be installed. These clean stormwater drains are shown in **Drawing No. 3145 – C002** and **Drawing No. 3145 – C004** respectively.

7.14. Record Keeping

According to the WCMR (GNR 634 of 2013, DEA), the “Waste generator” and the “Waste Manager” (Eskom in both cases) is required to keep detailed records of waste generation and disposal (Refer to **Figure 19**).

Records of operation are to be submitted as per The National Waste Information Regulations (NWIR, GNR 625 of 2012).

The quantity of waste disposed will be measured by mass meters on the conveyor system and detailed records are to be kept as a part of the on-going operational controls of the proposed ADF. Refer to National Waste Information Regulations (Gazette number 35583, August 2012) for detail on duties by “Waste generator” and the “Waste Manager”.



10. Records of Waste Generation and Management

(1) Waste generators must keep accurate and up to date records of the management of the waste they generate, which records must reflect—

(a) the classification of the wastes;

(b) the quantity of each waste generated, expressed in tons per month;

(c) the quantities of each waste that has either been re-used, recycled, recovered, treated or disposed of; and

(d) by whom the waste was managed.

Figure 19 - Excerpt from WCMR 634 of 2013, Section 10

7.15. Capping System

The final capping layerworks needs to prescribe the fill slope of the ash-pile or be in response to the fill-pile, as applicable.

It is assumed that the current practice of exploiting the in-situ materials from in front of the advancing face of the disposal facility as capping will continue. Any shortfall (towards the end of the life of the disposal facility) will be sourced from nearby borrow pits, suitably licenced.

<u>It is anticipated that there will be insufficient cover and capping material available on-site due to the shallow refusal depths encountered. As such it is imperative that suitable borrow pits (of a suitable size) for capping material be identified early on at the detail design phase.</u>

Refer to the Geotechnical Report (Kai Batla, 2013) which describes the existing soil to be fine grained, silty sand.

Any soil recovered on site from cell construction would be used for the final cover layer. If no suitable material is found on-site, soil for the final cover would need to be imported from surrounding areas or commercial sources.

Capping requirements are prescribed by the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998). Refer to **Table 14**.

Table 14: Excerpt from Minimum Requirements for Waste Disposal by Landfill Second Edition 1998 (Table 8.2)

Minimum Requirements for Capping Components

LEGEND
B^- = No significant leachate produced
B^+ = Significant leachate produced
R = Requirement
N = Not a requirement

CLASSIFICATION SYSTEM	G General Waste								H Hazardous Waste	
	C Communal Landfill		S Small Landfill		M Medium Landfill		L Large Landfill		H:h Hazard Rating 3 & 4	H:H Hazard Rating 1-4
CAPPING COMPONENTS	B^-	B^+	B^-	B^+	B^-	B^+	B^-	B^+		
5 Layer of Topsoil	R	R	R	R	R	R	R	R	R	R
4 Compacted Clay Layer	N	N	R	R	R	R	R	R	R	R
3 Geotextile Layer	N	N	N	N	N	R	N	R	R	R
2 Gas Drainage Layer	N	N	N	N	N	R	N	R	R	R
1 Shaped and Compacted Waste Surface	R	R	R	R	R	R	R	R	R	R

Note: Numbers 1 - 5 indicate order of construction.

A Class C facility in the WCMR (2013, DEA) is equivalent to a G:L:B - facility in the MRs (1998). The climatic water balance shows that the facility should not generate significant leachate (See **Section 6.3**)

A literature review by Jeffares and Green shows that Coal Ash Waste does not readily produce gases due to the low concentration of organics in the waste (Wallace, 2013). As such, a gas drainage layer has not been proposed. Due to the high evaporation versus precipitation and the small, homogenous particle size, infiltration into the capped ADF is expected to be minimal and a clay capping layer has not been proposed.

The design proposed thus includes capping components 1 and 5 from the table above.

The capping designs for both flat gradients and sloped embankments are proposed in **Drawing No. 3145-C006**.

The design is presented in accordance with applicable legislation and current industry trends.

Progressive capping/rehabilitation services are to be carried out in order to protect the side slopes of the proposed ADF from erosion, reduce contaminated stormwater collection volumes and to lessen the visual impact of the ash pile.

7.16. Operational Control Plan

The proposed ADF will be operated and controlled by Eskom (the waste manager). Access control, emergency control procedures and the provision of ablutions, personal protection equipment (PPE) and appropriate signage around the disposal cell and access road will form part of the Safety, Health and Environmental (SHE) requirements.

The Client is in favour of using a conveyor stacker and spreader system (using a combination of radial and parallel shifting stacker and spreading system) to transport and dispose of the waste on-site, as per the current operations at the existing ADF. Post placement manipulation and compaction of the ash waste will not be undertaken during the construction and development phases (in line with the current operational methodologies).

A fence must be installed around the facility to control access to the site. No salvaging will therefore be undertaken as the site is to remain secure.

The placement of ash and subsequent dust suppression during periods of rainfall and high wind conditions shall form part of the on-going operational controls of the site and the methodologies thereof shall be governed in the Operational Control Plan.

It is assumed that dust suppression measures will negate the requirement for daily cover. Should daily cover be required and no suitable material found on-site, soil for the final cover would need to be imported.

<u>Ash Placement</u>

Coal ash is a silt sized particle that is highly susceptible to changes in moisture content and thus adequate stormwater control is vital in the landfill design and erosion control.

The stacker spreader system develops a front stack area in lifts of approximately 45m high. The back stack face develops behind the initial front stack lift and is placed in lifts of approximately 12m high. The ash waste that is placed in this manner will come to rest at the angle of repose, at approximately 1V:2H. The geotechnical assessment (Jeffares & Green, 2013) has shown that the existing ADF dries and stabilises at a moisture content very close to optimum compaction. The assessment further showed that the waste is stable near the angle of repose (approximately 1V:2H). Post placement manipulation and compaction is not a requirement in the construction and development of the proposed ADF as the side slope has been shown to be stable and is acceptable during the construction of the landfill. **Figure 20** below illustrates the development and capping process.

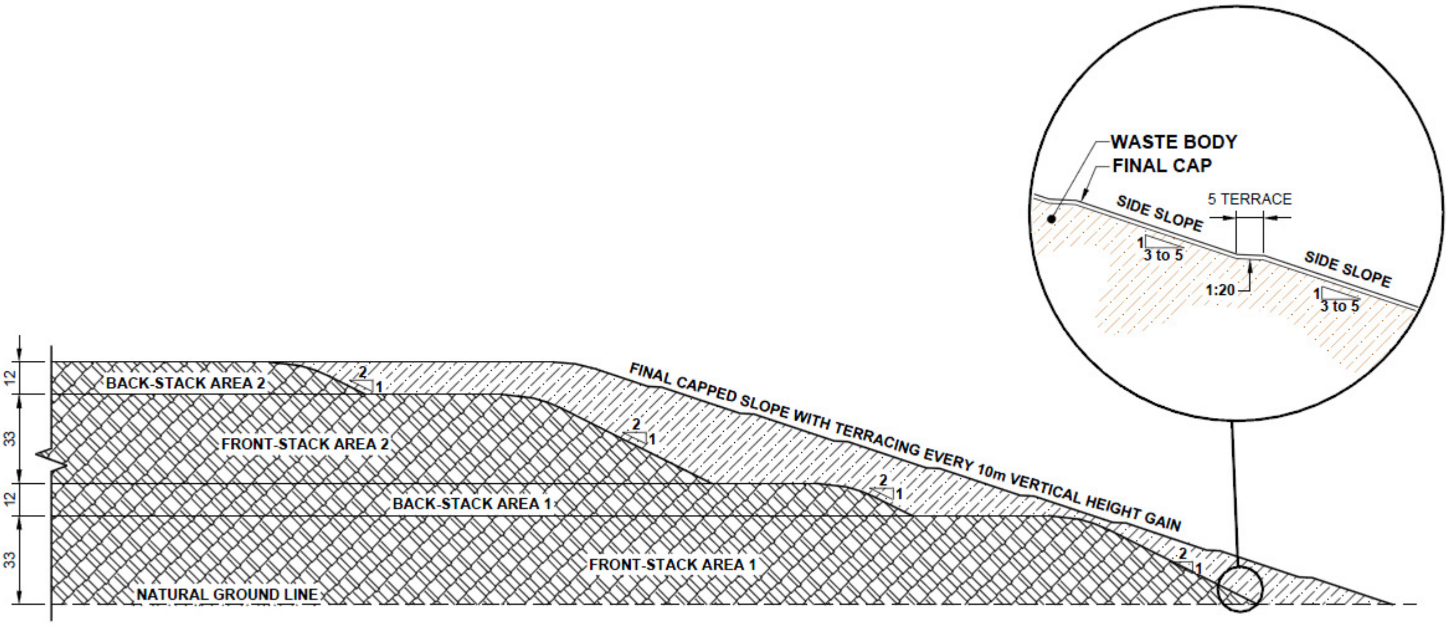


Figure 20: Ash Landfill Development and Final Capping

<u>Any further proposed height gain will be developed in the same manner by shifting the stacker spreader conveyor system on top of the existing waste pile and disposal operations shall continue as defined above.</u>

Lifts are to be constructed such that any stormwater runoff or water accumulating due to dust suppression is immediately diverted away from the landfill cells and directed to the toe drain/contaminated stormwater channel system as required. Effective stormwater conveyance interventions are to form part of the detail design phase with the incorporation of hardened stormwater channels along the terraced slopes to effectively convey stormwater away from the ADF. Potential erosion areas are to be carefully managed to reduce the incidence of erosion at the ADF.

Additional drainage between lifts is not envisaged provided that moisture content is monitored throughout the construction of the landfill and all surface water accumulating is diverted to the leachate collection infrastructure. The high rate of evaporation experienced at the proposed site will assist in maintaining optimum moisture content.

It is assumed that the current practice of exploiting the in-situ materials from in front of the advancing face of the ADF as capping will continue. The continued utilisation of these material is encouraged as it offers the following advantages:

- It provides a ready source of good quality capping materials and facilitates dust suppression
- It increases the ADF capacity.
- It provides enhanced founding on rock, both in terms of bearing capacity and stability.

Progressive capping is encouraged to reduce the amount of contaminated stormwater generated on-site. The construction is to be divided into suitable cell divisions at detail design phase with input from the client.
The final capped slope is to be manipulated prior to capping to be no steeper than 1V:3H in order to ensure long term slope stability (See **Section 7.3**).

7.17. Pollution Monitoring

Monitoring boreholes were established during the investigation (GCS, *Hydrogeological Report*, 2013). The co-ordinates of the boreholes are presented in **Table 15** and **Table 16** and their locations are shown on **Drawing No. 3145-C001** and **3145-C003**.

Table 15: Groundwater Monitoring Boreholes – Site Alternative 1 (Amended From Hydrogeological Report, 2013)

BH name	Co-ordinates, WGS 84 Geographic		Depth (m)	Water level (mbgl)	Pump type
	S	E			
MA 01	-23.71	27.58282	40	17.63	GCS Pump installed
MA 02	-23.7305	27.58542	40	15.45	GCS Pump installed
MA 03	-23.7213	27.61943	40	Dry	Dry
MA 04	-23.7213	27.61943	40	Dry	Dry
GHT 01	-23.7256	27.60345	35	Dry	None - Monitoring BH
GHT 02	-23.7269	27.59853	35	17.1	None - Monitoring BH
P 12	-23.6984	27.61783	15	Dry/collapsed	None - Monitoring BH
P01	-23.7012	27.619	30	6.21	None - Monitoring BH
P 03	-23.6972	27.61782	40	14.26	None - Monitoring BH
P 02	-23.7041	27.60293	40	21.47	None - Monitoring BH
P 31	-23.7236	27.60577	30	14.06	None - Monitoring BH
P29	-23.7204	27.61705	30	5.63	None - Monitoring BH
P 23	-23.7143	27.6216	40	8.16	None - Monitoring BH
P20	-23.6973	27.62408	40	7.09	None - Monitoring BH
P21	-23.7015	27.6235	40	5.72	None - Monitoring BH
HP 01	-23.6854	27.60393	Unknown	Approx 7m	Submersible

Table 16: Groundwater Monitoring Boreholes – Site Alternative 2 (Amended From Hydrogeological Report, 2013)

BH name	Co-ordinates, WGS 84 Geographic		Depth (m)	Water level (mbgl)	Pump type
	S	E			
APV 02	-23.6257	27.58165	100	17.75	Submersible
APV 01	-23.6291	27.58563	65	17.74	Submersible
NGA 096	-23.6166	27.56757	65	-	Mono
WB 31	-23.6082	27.57072	Approx 80	23.94	Submersible
MA 05	-23.6157	27.63042	40	22.87	GCS Pump installed
DHL 123	-23.616	27.6355	Unknown	-	Submersible
DHL 05	-23.6154	27.6336	Approx 80m	-	Submersible
DHL 07	-23.6157	27.62408	Approx 80m	-	Submersible
DHL 08	-23.6265	27.61908	Approx 80m	-	Submersible
GPN 07	-23.5851	27.60082	Approx 65m	19.11	Windpump - Broken
GPN 06	-23.596	27.59937	Approx 100m	-	Mono
GPN 01	-23.5895	27.62602	Unknown	-	Mono
GPN 05	-23.597	27.63763	80	23.11	GCS Pump installed
GPN 04	-23.5884	27.62388	Approx 40m	17	Not equipped
GPN 03	-23.5881	27.62575	Unknown	-	Mono
GPN 02	-23.5901	27.62632	100m	22.71	Submersible

No gas monitoring boreholes have been identified at this stage. Coal ash waste has been shown to comprise a low concentration of organics and as such produces minimal gases. Gas monitoring boreholes are not seen as a requirement but should be revisited at the detail design phase. Refer to **Section 7.19** regarding the monitoring of air quality.

A monitoring committee for the proposed ADF must be established by way of the existing public discussion forum hosted quarterly by the waste managers.

7.18. Closure and End Use of the Site

It is envisaged that the final closed waste disposal facility will be a natural, open, green dome area. This will be confirmed in the closure application.

7.19. Air Quality

An air quality impact assessment for the proposed ADF was conducted by Royal Haskoning DHV (2013) The report following conclusion is taken from the report:

- *The higher concentrations at Site Alternative 1 are likely caused due to short high wind speed events, and therefore it is recommended that wind breaks, dust suppression, and reducing activity when wind speeds increase significantly.*
- *With these mitigation measures, it is expected that the site will adequately comply with all environmental legislation.*

No buffer zone has been recommended in the air quality assessment. The recommended air quality buffer is to be informed by the Waste Management Officer as part of a licence condition.

7.20. Risk of Analysis

Much of the assessment thus far, as outlined in this report, is based on the newly published WCMR regulations (2013, DEA). The DWAF Minimum Requirements, 1998 are deemed to be partially superseded. The National Environmental Management; Waste Act also repealed certain sections of the Environmental Conservation Act (Act No. 73 of 1989) which was the main enabling legislation for the DWAF Minimum requirements.

That said, the MRs are still applicable to sections not governed by the WCMR, for example capping design. As a result, there are conflicting minimum requirements depending on the legislation considered. As a minimum the recommendations in this technical report are based on ‘best practice’, and have factored in the precautionary principle as well as specialist inputs/ findings as part of the design process. Engagement with National Authorities in this regard is critical as part of the process moving forward.

The design of the entire basal lining and capping system is based on the following key information:

- An assessment and classification of the envisaged waste material to be disposed of at the proposed ADF.
- The context of the receiving environment of the existing site and its current operations.
- The presence of an underlying aquifer.
- The prevailing geological conditions.

It is critical to obtain agreement with the responsible authorities on the waste classification and the associated mitigation measures proposed in the technical design.

8. ALTERNATIVE 1: SITE SPECIFIC DESIGN CRITERIA

8.1. Site Layout

The ADF was designed with the intention to maximise the available footprint of the site to meet the airspace requirements for future waste disposal.

The available site boundary is taken as the remaining portion of land currently owned by Eskom utilised for the existing ADF. The entire site spans approximately 4400m by 2600m. Of the site area available, approximately 510 ha is available for the development of a greenfields site with the remaining 190 ha being available through construction of the new ADF over the existing ADF by way of piggy-backing.

A 10m wide servitude area between the site boundary and the foot of the cell has been incorporated into the design. This servitude area makes allowances for a haul road, storm water channel and any services such as electrical cables, leachate collection pipes and manholes.

A haul road along the perimeter of the site will allow for easy access to all areas of the cell for loading and maintenance.

An open contaminated stormwater channel will run next to the foot of the cell and will collect all runoff from the cell and from the haul road. All runoff from the open channel and leachate from the leachate collection system within the cell will collect at the PCD. The PCD was sized so as to accommodate 203 600m^3 as specified in the hydrological assessment report. The resulting pond size is ***450m x 350m*** with side slopes of 1V:3.5H to a total depth of 2.3m (1.5 m water level and 0.8m freeboard), depending on progress of any progressive capping.

Site Alternative 1 has already been developed and it is envisioned that the existing office and plant-yard facilities will remain in use throughout the construction of the new ADF.

<u>In order to accommodate the full airspace requirements, the conceptual design of Site Alternative 1 proposes that the new ADF be constructed over the existing ADF by way of a piggy-backing concept</u>. It is proposed that approximately one third of the new ADF (by footprint area) be constructed over the existing ADF.

<u>**The final finished height of the proposed waste cell is approximately 90m above the average NGL of the site. The new waste cell will be approximately 45m higher than the existing ADF from a piggy-backing perspective.**</u>

The general layout is presented in **Drawing No. 3145 – C001**. Conceptual profiles of the proposed ADF are shown in **Drawing No. 3145 – C002.**

A 3D representative model of the proposed ADF has been created and is shown in **Figure 21** (Refer to **Drawing No. 3145 – C005**).

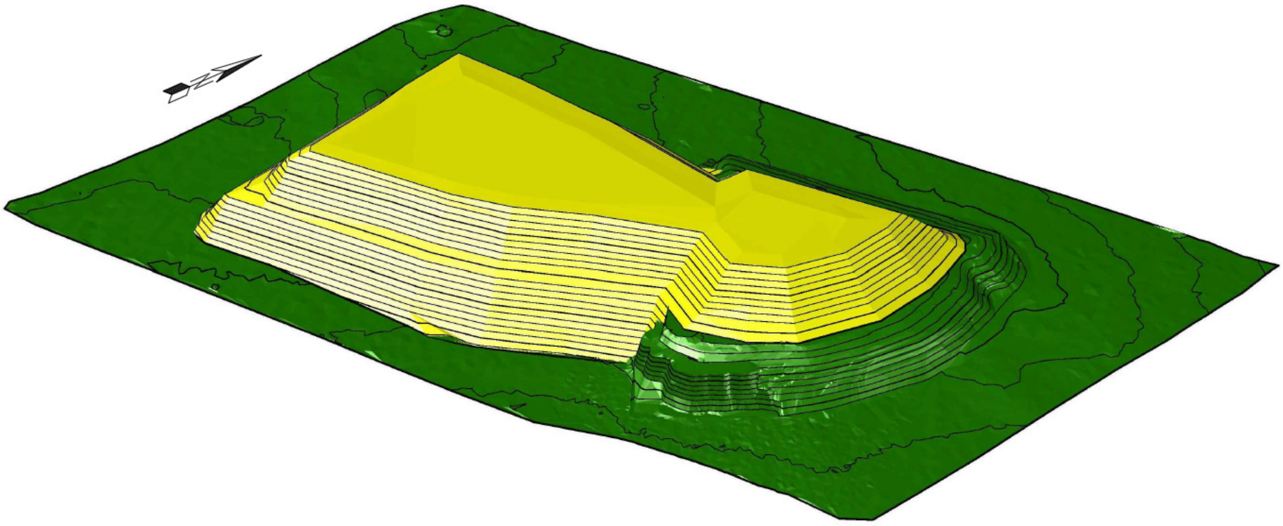


Figure 21 - 3D Representative Model of Site Alternative 1

8.2. Site Access

The Traffic Impact Assessment (TIA) Report (RHDHV, 2013) identified the existing road infrastructure as follows:

The existing main access to the existing ash disposal facility is from Nelson Mandela Drive (D1675). Road D1675 can be classified as a paved Class 2 Rural Two-lane Highway with a speed limit of 80km/h without shoulders on either side of the road.

The access is located 2.8km southeast from the Matimba Power Station access and 1.1km southeast from the Medupi Power Station turn-off. It intersects with road D1675 at GPS coordinates S23 41.636 E27 37.503. This is a priority controlled intersection with STOP control at the access road and priority on Road D1675. The access road to the Ashing Site is a gravel road with a level crossing from road D1675.

8.3. Cell Development

The division of the proposed ADF into cells is to reduce the area developed at any one time to a manageable size and to facilitate clean stormwater diversion until the facility approaches design life capacity.

The development of the proposed 700ha waste disposal facility has been broken up into 2 types of waste cells namely greenfields and piggy-backed waste cells. Detailed cell development is to be defined at detail design phase and is to be informed by the requirements from the client.

The greenfields cells will be developed to reach a final finished height of approximately 90m above NGL while the piggy-backed cells shall be developed to reach a final finished height of approximately 45m above the existing ADF.

8.4. Air Space Modelling

In order to optimise the site the final ADF is an irregular shape flanked by the buffer zones and infrastructure areas on the site. The height of the cell was determined by the required volume capacity (Refer to **Section 6.1**).

The resulting available site boundary spans 3900m by 2300m. Of the site area available, approximately 510 ha is available as a greenfields site with the remaining 190 ha being available through construction of the new ADF over the existing ADF by way of piggy-backing.

The cell spans ***90m*** high, terraced every 10m for increased slope stability resulting an airspace capacity of 325 000 000m^3 which is in excess of the required airspace.

In order to accommodate the full airspace requirements, the conceptual design of Site Alternative 1 proposes that the new ADF be constructed over the existing ADF by way of a piggy-backing concept. It is proposed that approximately one third of the new ADF be constructed over the existing ADF.

The assumptions of the model and the airspace approximation are presented in **Table 17** below.

Table 17: Air Space Model Design Criteria-Site Alternative 1

Item	Quantity	Unit
Approximate Airspace for the fully Developed Cell	**325 000 000**	**m^3**
Footprint Area of the fully Developed Cell	**700**	**ha**
Height from average NGL	90	m
Terrace Width	5	m
Side Slope of Landfill Embankment	1:5	V : H
Slope of Terrace	1:20	V : H
Slope of Cap on Landfill Dome	1:500	V : H

The conceptual model proposed has sufficient airspace available to contain the waste generated for the desired design life of the proposed Ash Disposal Facility.[5]

[5] *Based on the assumptions provided in this report.*

9. ALTERNATIVE 2: SITE SPECIFIC DESIGN CRITERIA

9.1. Site Layout

The ADF was designed with the intention to maximise the available footprint of the site to meet the airspace requirements for future waste disposal.

A 10m wide servitude area between the site boundary and the foot of the cell has been incorporated into the design. This servitude area makes allowances for a haul road, storm water channel and any services such as electrical cables, leachate collection pipes and manholes. A haul road along the perimeter of the site will allow for easy access to all areas of the cell for loading and maintenance.

An open contaminated stormwater channel will run next to the foot of the cell and will collect all runoff from the cell and from the haul road. All runoff from the open channel and leachate from the leachate collection system within the cell will collect at the PCD. The PCD was sized so as to accommodate 180 000m^3 as specified in the hydrological assessment report. The resulting pond size is ***450m x 190m*** with side slopes of 1V:3.5H to a total depth of 2.3m (1.5 m water level and 0.8m freeboard).

Site Alternative 2 is an undeveloped site and thus an additional area of has been allocated to allow for infrastructure which may be required. The possible infrastructure includes:

- Access control
- Guardhouse (Typically 4m x 4m)
- Weighbridge system (Typically 24m x 3.2m)
- Offices & Ablutions (Typically 30m x 15m)
- Parking (Typically 20m x 15m)
- Plant yard (Typically 100m x 95m)
- Vehicle wash (Typical 50m x 7.4m)

The cell spans 3800m by 2030m and is 56m high.

The general layout is presented in **Drawing No. 3145 – C003**. Conceptual profiles of the proposed ADF are shown in **Drawing No. 3145 – C004.**

A 3D representative model of the proposed ADF over the existing ADF has been created and is shown in **Figure 22** (Refer to **Drawing No. 3145 – C005**).

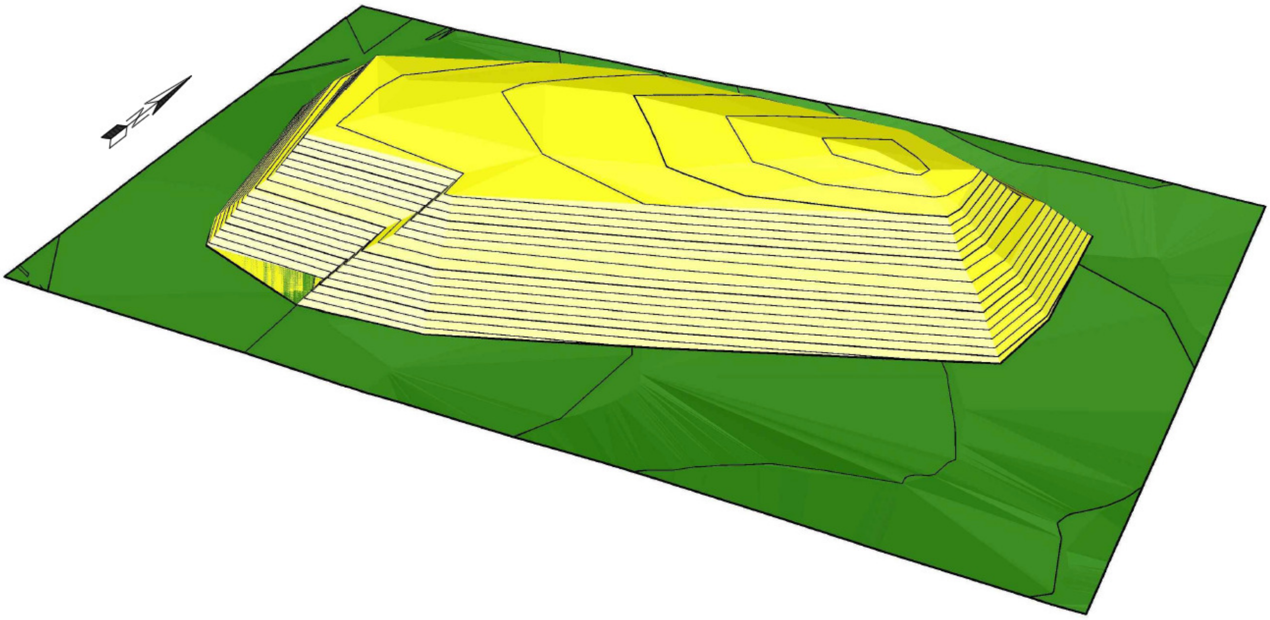


Figure 22 – 3D Representative Model of Site Alternative 2

9.2. Site Access

The Traffic Impact Assessment (TIA) Report (RHDHV, 2013) identified a possible new access road to alternative site 2.

North of the Grootegeluk Coal Mine, Road D2001 is a gravel road up to its intersection with Road P84/1 near the Stockpoort border post. Access to the Site Alternative 2 will be from Road D2001 and there will be a guardhouse and weighbridge system at the site entrance for security and control measures

The TIA recommended that a short right-turn lane from Road D2001 into the Access road be provided to ensure that a turning vehicle will not hinder through traffic on Road D2001. The proposed new access road as identified in the Traffic Impact Assessment Report (RHDHV, 2013) is as in **Figure 23**.

Figure 23: Proposed New Access Road to Site Alternative 2 (RHDHV, 2013)

9.3. Cell Development

The division of the proposed ADF into cells is to reduce the area developed at any one time to a manageable size and to facilitate clean stormwater diversion until the facility approaches design life capacity. The ADF is to be constructed using the same stacker and spreader methodology as used for Site Alternative 1.

9.4. Air Space Modelling

The height of the cell was determined based on the height of the ADF for Site Alternative 1 (to allow for comparison).

The cell spans 3800m by 2030m and is ***85m*** high, terraced every 10m for increased slope stability resulting an airspace capacity of 350 000 000 m³ which in excess of the required airspace (Refer to **Section 6.1**).

The assumptions of the model and the airspace approximation are presented in **Table 18.**

Table 18: Air Space Model Design Criteria- Site Alternative 2

Item	Quantity	Unit
Approximate Airspace for the fully Developed Cell	**350 000 000**	**m^3**
Footprint Area of the fully Developed Cell	**660**	**ha**
Height from average NGL	84	m
Terrace Width	5	m
Side Slope of Landfill Embankment	1:5	V : H
Slope of Terrace	1:20	V : H
Slope of Cap on Landfill Dome	1:500	V : H

The conceptual model proposed has sufficient airspace available to contain the waste generated for the desired design life of the proposed Ash Disposal Facility.[6]

10. CONCLUSION AND RECOMMENDATIONS

The result of the slope stability assessment confirms that developing Site Alternative 1 to a final finished height of 45m above the existing ADF does not pose any major threat from a slope stability perspective (providing the ash filling operations remains within the prescribed parameters of this report).

This report confirms that by developing the ADF by way of piggy-backing over the existing ADF (based on the design criteria presented in **Table 1**), the required design life of 43 years should be achievable.

From a technical (engineering perspective) either Site Alternative 1 or Site Alternative 2 could be used, or a combination thereof.

It is likely that the usage of Site Alternative 1 would be more cost effective to develop and operate due to the existing infrastructure at Site Alternative 1 and would thus be the preferred site (in this respect).

[6] *Based on the assumptions provided in this report.*

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ANNEXURE A

Construction Quality Plan

CONSTRUCTION QUALITY ASSURANCE (CQA) PLAN

FOR THE INSTALLATION OF GEOSYNTHETIC LINING SYSTEMS

TABLE OF CONTENTS

SUMMARY

This plan contains the procedures and verification methods regarding the quality of the construction for geosynthetic lining systems (manufacture, transportation, storage and installation).

This plan should be read in conjunction with the project specific material specifications.

This plan is written for the specialist geosynthetic material installer and Construction Quality Assurance Officer (CQAO) for the project.

The construction quality assurance plan and documentation is split into the following scenarios:

Quality procedures and related documents prior to site establishment and construction:

- Manufacturer Quality Control (MQC) and Manufacturer Quality Assurance (MQA), including; sampling reports, testing reports, quality assurance manuals and the construction quality controllers (CQC) project quality plan;

Quality procedures and related documents during construction:

- Construction Quality Assurance (CQA), including; method statements, as-built drawings, panel seaming reports, destructive and non-destructive test results, defect and repair reports and certificates of acceptance;

- Construction Quality Assurance (CQA) Site Captured Data, including; daily reports, certificates of acceptance, panel placement forms, panel seaming forms, trial seam information report forms, field destructive testing forms, non-destructive testing forms and repair reports;

1 DEFINITIONS

This CQA Plan is devoted to Construction Quality Assurance. In the context of this document, Construction Quality Assurance and Construction Quality Control are defined as follows (in **SANS 10409** and **SANS 1526: 2003**):

Construction Quality Assurance (CQA): Includes inspection, verifications, audits and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. CQA also refers to measures taken by the Engineer to assess if the Installation and Civils Contractors are in compliance with the drawings and specifications for a project.

Construction Quality Control (CQC): refers to measures taken by the Civils and Installation Contractor to determine compliance with the requirements for materials and workmanship as stated in the drawings and specifications for the project.

Formulation: The mixture of a unique combination of ingredients identified by type, properties and quantity. For linear low density polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

Geotextile: A planar, permeable, polymeric (synthetic or natural) textile material, which may be nonwoven, knitted or woven, used in contact with soil/rock and/or any other geotechnical material in civil engineering applications.

Geosynthetic membrane (GSM): A geosynthetic barrier to prevent migration of liquids.

High Density Polyethylene Geomembrane (HDPE): A planar, relatively impermeable, polymeric sheet used in contact with soil/rock and/or any other geotechnical material in civil engineering applications, which is manufactured from a polyethylene resin with a density of generally less than 0.945 g/cm^3, but greater than 0.930 g/cm^3.

Geosynthetic Clay Liner (also known as Clay Geosynthetic Barriers): An assembled structure of geosynthetic materials and low hydraulic conductivity earth materials (clay or bentonite), in the form of a manufactured sheet, used in contact with soil/rock and/or any other geotechnical material in civil engineering applications.

Carrier Layer: The material that forms the base layer of a needlepunched GCL. This consists of a nonwoven or woven geotextile, or a combination of these.

Cover Layer: The material that forms the top layer of a needlepunched GCL. This consists of a non-woven geotextile.

Geofilm: a thin polymeric film which is essentially impermeable.

Geosynthetic: A planar, polymeric (synthetic or natural) material used in conjunction with soil/rock and/or any other geotechnical material in civil engineering applications.

Geotextile, non-woven: A geotextile in the form of a manufactured sheet or web of directionally or randomly orientated fibres, filaments or other elements, mechanically and/or thermally and/or chemically bonded.

Geotextile, woven: A geotextile produced by interlacing, usually at right angles, two or more sets of yarns, fibres, filaments, tapes or other elements.

Reinforced GCL: A GCL in which the carrier and cover layers are mechanically linked through the bentonite component to provide internal shear strength to the GCL.

Bentonite: a distinct type of fine-grained clay soil typically containing not less than 80% Montmorillonite clay, usually characterized by high swelling upon wetting. For this project the type of

Montmorillonite mineral is a Sodium (Na) Montmorillonite mineral. The type of Montmorillonite is a naturally occurring Sodium (Na) Montmorillonite mineral. No activated Sodium (Na) Montmorillonite minerals will be acceptable. The Bentonite must be similar to “Wyoming”-type Bentonite or similar approved. The Bentonite must be rich in Smectites and dominated by Smectites and Montmorillonite.

GRI-GCL3: The listed “GRI” specification for GCLs on the http://www.geosynthetic-institute.org website or any website replacing this address (managed by GRI).

Cuspated Drain: A single cuspated high density polyethylene core which has a high compressive strength and in-plane flow capacity to convey leachate without clogging, to be used in landfill engineering applications as a leak detection layer. The core material is to have a flat bottom surface and a cuspated top surface (although may not necessarily be installed this way), and to provide protection and minimal stresses on the geosynthetic membranes directly in contact with the core.

GSM Manufacturer Tracking List: Cross referencing list delineating the corresponding lots for the materials used in the production of the rolls delivered.

Manufacturing Quality Control Data: The manufacturing quality control test data indicating the actual test values.

Physical Properties Sheet: The material specification for the geomembrane supplied in accordance with this specification.

Letter of Certification: The letter indicating that the material is in conformance with the physical properties specified.

2 PARTIES TO THE CONSTRUCTION QUALITY ASSURANCE

The following parties are directly involved in the constriction quality assurance

- Employer
- Engineer and their Personnel
- Main Contractor
- Civil Contractor
- Geosynthetic Membrane (GSM) Manufacturer
- Transporter
- Installation Supervisor
- Land Surveyor
- Geosynthetic Membrane (GSM) Installer
- Construction Quality Assurance Officer (CQAO)
- Construction Quality Assurance Laboratory

Engineer and their Personnel

The personnel of the Engineer includes:

- The CQA Officer, who may be the same person as the Engineers representative;
- The Engineer's representative who is located at the site; and
- Any other staff or assistant who may be used on the site.

CQA Officer (CQAO)

A detailed schedule of the duties of the CQA Officer will be provided throughout this CQA plan. The general duties are set out below.

The CQA Officer shall review all other site specific documentation, proposed panel layouts, GSM Installer's construction programme and methods, and Geosynthetic membrane Installer's internal CQA Plan and he shall attend the Site Meetings where necessary.

The CQAO shall administer the CQA programme, i.e. assign and manage all CQA personnel, review all field reports, and provide engineering review of all CQA related issues. He may undertake some, or all, of these duties himself.

The CQAO shall provide quality control of the CQA personnel, including making site visits, review the record drawings and prepare the final report and he shall report to the Engineer's Representative and discuss all GSM related matters.

Geosynthetic Membrane (GSM) Manufacturer

All parties must be qualified to perform the responsibilities and have extensive experience of geosynthetic materials and the application thereof.

Details of the Manufacturer shall be provided by the GSM Installer in the Appendices forming part of their Tender documentation. The Manufacturer shall be able to provide sufficient production capacity and qualified personnel to meet the demands of the project. The Manufacturer shall be approved by the Engineer and the Employer. For this purpose the following information regarding the Manufacturer, as a minimum, must be submitted with their Tender documentation.

- Corporate background and information

- Manufacturing capabilities:
    - information on plant size, equipment, number of shifts per day, and capacity per shift, quality control manual for manufacturing
    - list of material properties, including certified test results

- A list of at least 10 completed projects totalling a minimum area of 2,000,000 m2 for which the Manufacturer has manufactured geomembrane materials from the same type as that proposed to be used for the project. For each facility, the following information will be provided:
    - purpose of installation, its location, and start/finish dates
    - name of facility owner, engineer and/or Project Manager
    - type, thickness, and surface area of the installed geomembrane

- Manufacturing quality control and manufacturing quality assurance manuals and related documentation.

It is required that the manufacturer of the geosynthetic membrane has ISO 9002: 1994 or ISO 9001:2000 certification.

Geosynthetic Membrane (GSM) Installer

Details of the GSM Installer shall be provided as part of their Tender.

The GSM installer is responsible for delivery to site, storage, field handling, deploying, anchoring, seaming and field quality control of the geomembrane.

The Installer must be trained and qualified to install the GSM's specified in the project. If the Contractor is not an installer with the necessary experience and qualification on his staff then a suitably qualified firm of installers must be sub-contracted.

The following information regarding the GSM Installer must be submitted with the Tender:

- Installation capabilities:
    - information on equipment and personnel;
    - anticipated daily production;
    - quality control manual for installation;
    - written confirmation that all design features, Specifications, and requirements of the CQA Plan can be complied with.

- A list of at least three completed facilities totalling a minimum area of 100,000 m², for which the Installer has installed similar geomembranes. For each installation, the following information must be provided:
    - purpose of installation, its location, and start/finish dates
    - name of facility owner, Project Manager and /or engineer
    - type, thickness, grade, and surface area of the installed geomembranes

- The Installation Supervisor must be qualified by experience. The Supervisor must have supervised the installation of a minimum of 100,000 m² of geosynthetic membrane. He must also exhibit good management and communications skills. His appointment must be approved by the Engineer.

Construction Quality Assurance Laboratory(ies)

The CQA Laboratories must have experience in geomembrane's and shall be familiar with ASTM, NSF, GRI, FTMS, DIN and other applicable test standards. Copies of valid calibration certificates for all test equipment will be required. The laboratory shall be accredited by the Geosynthetics Accreditation Institute Laboratory Accreditation Program (GAILAP) for those tests included in the Specifications and the CQA Plan. The CQA Laboratory(ies) shall be approved by the Engineer and the Employer, before any testing is undertaken.

2.1 COMMUNICATION AND PROJECT CONTROL

All formal communications between the Engineer or his Representative, and the GSM Installer must be in writing.

A description of the channels of communication will be given at the resolution meeting.

The Contractor is to ensure that the CQA officer is provided with all information and documentation with respect to the quality control and quality assurance of the manufacture, delivery, storage and installation of the geosynthetic membranes, in a timely manner, in full compliance with the Specifications.

Following the award of the Contract and prior to the commencement of construction work, a Resolution Meeting will be held. This meeting will include all parties involved, including the CQAO, the Engineer, the Design Engineer, the General Contractor, and the Installer.

The purpose of this Resolution Meeting is to begin planning for coordination of tasks, to anticipate any problems which might cause difficulties and delays in construction, and, above all, to present the CQA Plan to all of the parties involved. It is very important that the procedures regarding testing, repair, etc., be known and accepted by all. This site specific CQA Plan may be amended at the Resolution Meeting, after review by the CQA Officer.

The first part of the Resolution Meeting may be devoted to a review of the design drawings and specifications.

This meeting should include all of the following activities:

- review critical design details of the project;
- review the Project Specifications;
- review the CQA Plan;
- review the Manufacturer's and Installer's QC Programs for compatibility with other project documents;
- review the panel layout drawing supplied by the Installer;
- make appropriate modifications to the CQA Plan to ensure that it identifies all necessary CQA;
- make appropriate modifications to documents to ensure their integration and compatibility;
- reach a consensus on the CQA and quality control procedures, especially on methods of determining acceptability of the geomembranes;
- assign the responsibilities of each party;
- decide the number of geomembrane seaming units to be maintained on-site by the Installer (this number depends on the number of seaming crews and on the type of seaming equipment);
- establish work area security and health and safety protocols;
- confirm location of nearest medical centre, hospital, and police station;
- confirm the methods for documenting and reporting data, and for distributing documents and reports; and
- confirm the lines of authority and communication.

The meeting will be chaired by the Engineer and will be documented by a person designated at the beginning of the meeting, or by the CQAO. Minutes will be transmitted to all parties by fax.

A special meeting will be held when, and if, a problem or deficiency has occurred, or is likely to occur that requires special action decisions by several parties. The meeting will be attended by the Engineer, the CQAO, and other involved parties. If the problem requires a design modification, the Design Engineer should also be present. The purpose of the meeting is to define and resolve the problem or work deficiency as follows:

Define the problem or deficiency:

- Establish the cause;
- Define possible solutions;
- Select a suitable technical solution agreeable to all parties; and
- Define an action plan to implement the solution.

3 MATERIAL SPECIFICATIONS

The following standard specifications should be read in conjunction with the project specific Material Specifications;

HDPE and LLDPE Geomembrane:
The specification on the Standardised Specifications of SANS 10409:2005 and SANS 1526:2003. The Geosynthetic Research Institute's (GRI) Test Method GM13 for HDPE and GM17 for LLDPE.

Geosynthetic Clay Liner (GCL):
The Geosynthetic Research Institute's (GRI) GRI-GCL3: Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCLs)

The GRI is based in the USA and together with the Geosynthetic Information Institute (GII), Geosynthetic Education Institute (GEI), Geosynthetic Accreditation Institute (GAI), and Geosynthetic Certification Institute (GCI) fall under an umbrella organisation known as the Geosynthetic Institute (GSI).

4 MANUFACTURING QUALITY CONTROL (MQC) AND ASSURANCE (MQA)

4.1 Introduction

The Manufacturers Quality Control (MQC) is carried out by the manufacturer at their certified testing laboratory. The manufacturer is required to submit the test results for a sample taken from each and every roll (or as otherwise agreed) that is manufactured for the project to the Construction Quality Control Officer for verification to ensure compliance with the material specification.

The Manufacturing Quality Assurance (MQA) program requires the testing of materials, sampled by an independent third party, for conformance testing. Conformance testing is not an attempt to reproduce the Manufacturer's QA testing programme, but is a check to provide confirmation that the material delivered to site is satisfactory.

4.2 Manufacturing Quality Control (MQC)

Internal Quality Assurance testing will be carried out by the geomembrane Manufacturer to demonstrate that the incoming resin meets this specification. At the Client's discretion, additional conformance testing may be carried out at the CQA Laboratory. If the results of the Manufacturer's Quality Control (QC) Laboratory and the CQA Laboratory testing differ, the testing will be repeated by the CQA Laboratory, and the Manufacturer will be allowed to monitor this testing. The results of this latter series of tests will prevail, provided that the applicable test methods have been followed.

Prior to the installation of any geomembrane material, the Manufacturer will provide the CQAO with the following information:

- The origin (resin Supplier's name), identification (type, lot number), and production date of the resin
- a copy of the Quality Control certificates issued by the Resin Supplier;
- reports on the tests conducted by the Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the project. At a minimum, these tests should include specific gravity (ASTM D792 Method A or ASTM D1505), and Melt Index (ASTM D1238 (190/2.16))
- The Manufacturers QC documents indicating the process followed by the manufacturer to ensure that the resin supplied for the manufacture of the geomembrane delivered to the site complies with the required specifications.

The CQAO will review these documents and report any discrepancies to the Engineer.

The GSM manufacturer shall issue Quality Control submissions to the Engineer and CQA officer for each delivery of material prior to the shipment of any geomembrane. The submissions shall include the following information:

- A certified properties sheet including, at a minimum, all specified properties, and test methods indicated in the specifications;
- A list of quantities and descriptions of materials other than the base polymer which comprise the geomembrane; and
- The internal MQC sampling procedures, frequencies of testing, and results of testing of material supplied to the project.

The CQAO will verify that:

- the property values certified by the Manufacturer meet all of the Manufacturer's specifications; and
- the measurements of properties by the Manufacturer are properly documented, the test methods used are acceptable, and the geomembrane meets the Project Specifications.

4.3 Manufacturing Quality Assurance (MQA)

4.3.1 Plant Audit

The Engineer may perform an audit of the manufacturing and quality control procedures used by the Manufacturer, specifically for the production of the geomembranes to be used for installation at the Employer's facility. The Manufacturer shall give the Engineer at least one month's notice of the start of production of geomembrane for this project. Quality Control tests shall be performed as the geosynthetic membrane is manufactured.

The Engineer shall monitor production and testing of GSM material allocated for this project. If material for this project has already been manufactured, the Engineer shall monitor production of the same type of GSM on the same production line to verify that manufacturing controls are in place. Additional tests by one independent laboratory are also required before the material will be approved. The Engineer shall review the QC certificates and notify the Manufacturer in writing which geomembrane rolls are approved for shipping. The Engineer shall be allowed to monitor the loading of the geomembrane for shipping.

Where material, which has already been manufactured and has been delivered to storage in South Africa, the Engineer shall be furnished with the test results from an independent laboratory and the QC certificates and will notify the Manufacturer in writing which geomembrane rolls are approved for shipping from storage. The Engineer shall be allowed to monitor the loading of the geomembrane for shipping from storage.

4.3.2 In Plant Conformance Testing

Conformance Testing may, at the discretion of the Engineer, be carried out by an independent laboratory (QCA laboratory). Conformance testing is not an opportunity to reproduce the QC testing program. It is a check to provide confirmation that satisfactory material is delivered to the site. The testing frequency shall be at the discretion of the Engineer but the frequency shown in the project specifications. The name and address of the laboratory shall be approved by the Engineer. The engineer has the right to reject any roll or production batch if the samples do not pass the conformance testing.

The purpose of In-plant Material Conformance Test Sampling is to verify that geomembrane material which is designated for the project is confirmed as meeting the project specifications prior to shipment to the site. Thus, barring a transportation accident, the geomembrane can be installed immediately it arrives on site.

The CQAO shall send to the CQAO Laboratory conformance samples for testing. The frequency of sampling shall be at the discretion of the CQAO but shall typically be between each 10,000 and 25,000 m2 of geomembrane. No material shall be shipped to the site until conformance test results are obtained. The CQAO shall report any non-conformance of sampling procedures.

If In-Plant conformance testing is not performed, upon delivery of the rolls of geomembrane to the site, the CQAO will ensure that samples are removed at the frequency specified in the Project Specifications and forwarded to the CQA Laboratory for testing to ensure conformance to both the Project Specifications and the Manufacturer's list of guaranteed properties.

Sampling Procedure

Samples will be taken across the entire width of the roll and will not include the outer wrap of the roll. Unless otherwise specified, samples will be 500 mm long by the roll width. Specimens for testing will be taken across the full width of the sample.

If more than one resin type is used, each resin type shall be sampled at the same frequencies and tested.

If roll numbers are very different and non-sequential, consideration should be given to testing each block of roll numbers at the same frequency.

Test results

The CQAO will examine all results from laboratory conformance testing and will report any non-conformance to Engineer.

The following procedure will apply whenever a sample fails a conformance test that is conducted by the CQA Laboratory:

- The Manufacturer will replace the roll of geomembrane that is in non-conformance with the specifications with a roll that meets specifications.
- The CQAO will remove conformance samples for testing by the CQA Laboratory from the next higher and lower numbered rolls. These two samples must both conform to specifications. If either of these samples fail, testing shall continue until the defective rolls are isolated. These rolls will be replaced by the Manufacturer, at no expense to the Owner. This additional conformance testing will be at the expense of the Manufacturer.
- The CQAO will document actions taken in conjunction with conformance test failures.

Packaging and Identification

All geomembrane roll cores shall be sufficiently strong to resist collapse during transit and handling. The Engineer has the right to reject any roll if, upon delivery onto site, the core has collapsed or if the roll is damaged in any other way.

Before shipment, the manufacturer shall label each roll, both on the geomembrane roll and on the surface of the geomembrane or any plastic protective sleeve. Labels shall be resistant to fading and moisture degradation to ensure legibility at the time of the installation. At a minimum, the roll labels shall identify the following:

- Product Name and Grade
- Length and width of roll
- Total weight of roll
- Production Lot number and Individual roll number

4.3.3 Transportation, Handling and storage of Geosynthetic Liners

The Installer shall contact the supplier before shipment to determine if the unloading methods and equipment differs from that specified below. Significant deviations from these procedures shall be pre-approved by the Engineer in writing.

Geomembranes must be supported during handling to ensure worker safety and to prevent damage to the product. Under no circumstances may the rolls be dragged, lifted from one end, lifted with only the forks of a lift truck or dropped on to the ground from the delivery vehicle.

The CQA officer shall verify that proper handling equipment exists which does not pose any danger to installation personnel or risk of damage or deformation to the liner material itself. Suitable handling equipment is described below:

The CQAO shall be notified in a timely manner when delivery and unloading is to take place.

Each roll shall be visually inspected when unloaded to determine if any packaging or material has been damaged during transit. Possible product conditions and actions are listed below.

- Rolls, including the roll cores, exhibiting damage shall be marked and set aside for closer examination during deployment. Minor rips or tears in the plastic packaging shall be repaired with moisture resistant tape before being placed in storage to prevent moisture damage.
- The presence of free flowing water within any roll packaging shall require that roll to be set aside for further examination to ascertain the extent of any damage.
- Geomembrane rolls delivered to the project site shall be only those indicated on the geomembrane manufacturing quality control certificates.
- Repairs to damaged geomembrane rolls shall be performed in accordance with PC-10.5 of this specification.

The Engineer reserves the right to reject any roll at any stage prior to installation should it exhibit any of the above damages or non-conformance.

Storage of the geomembrane rolls shall be the responsibility of the Installer. All geomembrane rolls shall be stockpiled and maintained dry in a well-drained flat location area away from high traffic areas but sufficiently close to the active work area to minimise handling.

Rolls shall not be stacked on uneven or discontinuous surfaces, in order to prevent bending, deformation, and damage to the geomembrane or cause difficulty inserting the carpet spike or core pipe. The rolls shall be protected from puncture, abrasion, excessive heat or cold, material degradation or other damaging circumstances.

Geomembranes shall not be stored more than four rolls high, or limited to the height at which installation personnel may safely manoeuvre the handling apparatus, whichever is lowest. Stacks or tiers of rolls must be situated in a manner that prevents sliding or rolling by chocking the bottom layer of the rolls. Storage shall not result in crashing of the coves on flattening of the rolls.

An additional tarpaulin or plastic sheet shall be used over the stacked rolls to provide extra protection for geomembrane material stored outdoors.

4.3.4 Manufacturing Quality Assurance Documentation

Geomembrane Manufacturing Quality Assurance (MQA) sampling and testing for compliance with the specification shall be co-ordinated by the Construction Quality Assurance (CQA) officer as necessary to support the manufacturer's Manufacturing Quality Control (MQC) data. The following information shall be submitted with their Tender:

- Statement of experience from the proposed GSM manufacturer/supplier.
- Statement of experience from the proposed GSM Installer.
- Statement of the details of the supplier/manufacturer of the GSM.
- Geomembrane material specification sheet.

Prior to shipment, the Manufacturer will furnish the CQAO with Quality Control certificates covering each roll of geomembrane and welding rod provided. (NOTE: Tests do not have to be done on each roll, they simply need to be done according to the frequency, defined in the specifications) The Quality Control certificate will be signed by a responsible party employed by the Manufacturer, preferably the QC Laboratory Manager. The Quality Control certificates will include:

- resin Manufacturer, resin type, resin lot number, and geomembrane roll numbers; and
- results of Quality Control tests. At a minimum, results will be given for thickness, specific gravity/density, uniaxial tensile strength and elongation at yield and break, single point stress rupture time, and carbon black content and dispersion, evaluated in accordance with the methods indicated in the specifications or equivalent methods previously approved by the Project Manager and CQAO. No material will be installed until complete QC test data have been provided.

The CQAO will:

- verify that the Quality Control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls and resin related to it; and
- review the Quality Control certificates and verify that the certified roll properties meet the Manufacturer's and Project Specifications.

The geomembrane Manufacturer's Quality Control Certifications shall be submitted by the Principal Contractor to the Engineer before the deployment of any geomembrane material to ensure that the materials and subgrade preparation meet the requirements of this specification

5 CONSTRUCTION QUALITY CONTROL (CQC) AND ASSURANCE (CQA)

5.1 Introduction

CQA refers to means and actions employed by the Engineer to assure conformity (to this CQA Plan, the Specifications and the Drawings) of the geomembrane manufacture, installation, testing procedures and results, and to assure at least a state of practice quality of workmanship. CQA is provided by a party independent from the Manufacturer, Installer, and Employer/Owner.

CQC refers to those actions taken by Manufacturers, Fabricators, Installers, and Contractors to ensure that the materials provided to them, the materials they produce, and their own workmanship, meet the requirements of their own specifications, their quality control programme, the specifications and drawings. In the case of the geosynthetic membranes, CQC is provided by the Manufacturer and Installer of the geosynthetic membrane.

An example of a typical construction quality plan checklist for the installation geosynthetic lining systems is included in Figure 1 below:

PROJECT QUALITY PLAN - INSPECTION CHECKLIST							
PROJECT:		DOC. NO:					
CLIENT:		REVISION:					
CONTRACT NO:		DATE:					
No.	Activity	Inspection			Signature		
		Sub Contractor	Main Contractor	Engineer (Quality Assurance Officer)	Sub Contractor	Main Contractor	Engineer (Quality Assurance Officer)
1.	Receive and confirm all Manufacturing Quality Control and Assurance Documentation	H	H	A & R			
2.	Receive and confirm all materials and equipment on site.	A	S	W			
3.	Approve surface finish of prepared earthworks.	A	W & H	W & H			
4.	Measure, cut and install Geosynthetic Geomembrane Liner by starting with sheet 1, and following the sheet layout drawing numerically.	A	W	W & H			
5.	Do morning and afternoon samples, and record.	A	W	W			
6.	Carry out wall and floor seams.	A	W	W			
7.	Do destructive testing and record.	A	W	W			
8.	Do non-destructive testing and record.	A	W	W			
9.	Do all necessary repairs and record.	A	W	W			
10.	Complete all QC Documentation.	A	W	W			
11.	Inspect liner and hand over to client.	A	W & H	W & H			
12.	Measure, cut and install CUSPATED DRAIN, by starting with sheet 1, and following the sheet layout drawing numerically.	A	W	W & H			
13.	Complete all QC Documentation.	A	W	W			
14.	Inspect liner and hand over to client.	A	H	W & H			
15.	Measure, cut and install Bidim A7 through dam on top of the HDPE 1.5 Smooth / Textured membrane.	A	W	W & H			
16.	Inspect liner and hand over to client.	A	H	W & H			
17.	Measure, cut and install Geosynthetic Clay Liner, by starting with sheet 1, and following the sheet layout drawing numerically.	A	W	W			
18.	Complete all QC Documentation.	A	W	W			
19.	Inspect liner and hand over to client.	A	H	W & H			

INSPECTION LEVEL: **H** = HOLD POINT **W** = WITNESS POINT **PI** = PATROL INSPECTION **F** = FINAL REVIEW **S** = SURVEILLANCE **P** = PROGRESS INSPECTION **A** = ACTION POINT **R** = REVIEW

APPROVED BY :	APPROVED BY :
-- SIGNATURE	------------------ SIGNATURE
-- DATE	------------------ DATE

Figure 1: Typical Construction Quality Plan Checklist for the Installation Geosynthetic Lining Systems

An example of a typical Earthworks/Geosynthetic Layerworks Inspection sheet is included in Figure 2 below:

Revision No.	Page 1 of 1					Ref No.
Approval Sheet – Earthworks/Layerworks						
Project name:						
Project No.						
Location:			**Layer:**			
Material Type			**Weather**			
Material Source:			**Time**			
Checks	**Surv.**		**Contractor**		**Engineer**	
	Date	Innit	Date	Innit	Date	Innit
Earthworks						
Setting out						
Density						
PI						
Grading						
CBR						
Visual Inspection						
Level						
Thickness						
Geosynthetic Layerworks						
Seams; Edge Tie-in; Overlaps						
Surface finish						
Anchor trench						
Destructive Testing						
Non-destructive Testing						
Remarks:						
Foreman:			**Signature:**		**Date:**	
Site Agent:			**Signature:**		**Date:**	
For Engineer:			**Signature:**		**Date:**	

Figure 2: Typical Earthworks/Geosynthetic Layerworks Inspection Sheet

5.2 Construction Quality Control for the Installation of Geosynthetic Geomembrane Lining Systems

5.2.1 Subsurface preparation

The Civil Contractor will be responsible for preparing the supporting soil according to the project specifications. The subgrade is to be prepared such that:

- the lines and levels of the surface are according to the drawings and specifications;
- the supporting soil meets the density specification;
- the surface to be lined has been finished so as to be free of irregularities, protrusions, loose soil, dessication cracks and abrupt changes in grade;
- the 50 mm surface layer of the supporting soil does not contain stones or other objects larger than 5mm which may be damaging to the geomembrane; and
- there are no areas excessively softened by high water content.
- there are no equipment tracks or footprints present on the subgrade.

The Civil Contractor is to request the CQAO's approval of the subgrade in writing. The CQAO is to inspect the subgrade to verify that it meets the specification and confirm this in writing. The Installer will certify in writing that the surface on which the geomembrane will be installed within the next 24 hr is acceptable. The certificate of acceptance will be given by the Installer to the CQAO prior to commencement of geomembrane installation in the area under consideration.

The CQAO will also acknowledge the approval of the subgrade in writing. After the supporting soil has been accepted by the Installer, it will be the Installer's responsibility to indicate to the CQAO any change in the supporting soil condition that may require repair work. If the CQAO concurs with the Installer, then the Installer will ensure that the supporting soil is repaired.

The Installer is responsible for maintaining the condition of the subgrade after approval up until the placement of the geomembrane.

5.2.2 Geosynthetic Geomembrane layer

Prior to the deployment of any geotextile, as well as other underlying geosynthetic materials upon which the geomembrane material may be installed, the subgrade shall be inspected and approved in writing by the CQAO and Installer as described in Section 5.2.1.

It shall remain the responsibility of the Main Contractor to install the geotextiles in a manner such that the subgrade or other surfaces do not become disturbed and such that the composite lining system is not adversely affected either during construction or during the life of the facility. Where such disturbance does occur, the Main Contractor shall reinstate the area to conform to the requirements of this Specification.

The geotextile shall always be ballasted and anchored within anchor trenches or by using sand filled ballast bags and similar, to ensure that the geotextile is not displaced or uplifted by wind or other cause.

5.2.3 Anchorage Trenches and Edge Tie-in

Anchor Trenches

Anchor trenches will be excavated by the Civil Contractor (unless otherwise specified) to the lines and dimensions shown on the design drawings, prior to geomembrane placement.

The edge of the trench, over which the geomembrane enters the trench, will be rounded to avoid sharp bends in the geomembrane. There shall be no sharp protrusions on the inside wall of the trench. No loose soil will be allowed to underlie the geomembrane in the trenches.

Water shall not be allowed to stand, or soften the soil, in the anchor trench. Responsibility for dewatering of the anchor trench shall reside with the Main Contractor.

The anchor trench shall be inspected as well as approved by the Engineer and CQAO officer before geomembrane placement, backfilling and compaction of the anchor key material.

The backfilling of the trenched shall be done in accordance with the project specifications.

Edge Tie-in

Where indicated on the drawings, the installer shall tie-in to the existing geomembranes installed in existing cells on the site. The Civil Contractor (unless otherwise specified) shall excavate to expose the edges of the existing linings along the tie-in length, and shall take all precautions necessary to avoid undue damage of the existing linings. The contractor shall excavate trial holes to determine the depth of excavation necessary to expose the existing linings. Upon written instruction by the Engineer, excavation within 200mm (unless otherwise specified) of the linings shall be undertaken by hand.

The lining installer shall clean, trim and repair the existing lining edge as necessary and weld the new geomembranes to the existing geomembranes and ensure continuity of the membranes. The edge tie-in construction shall meet all the requirements of this Specification.

5.2.4 Geomembrane Placement

Before any geomembrane is deployed all MQC and MQA documentation listed in Section 4.3.4 above must be received from the Main Contractor and be reviewed and approved by the CQAO.

Field Panel Identification

A field panel is a single piece of geomembrane (other than a patch or cap strip) which is seamed in the field: i.e. a roll or a portion of roll cut in the field.

It will be the responsibility of the CQAO to ensure that each field panel is given an "identification code" (number or letter-number) consistent with the layout plan, which is supplied by the Installer. This identification code will be agreed upon by the Installer and the CQAO. This field panel identification code should be as simple and logical as possible. It will be the responsibility of the Installer to ensure that each field panel placed is marked with the original roll number as well as the panel identification code. The identification code and roll number will be marked at a location agreed upon by the Installer and CQAO.

Typically, panels will be numbered in the order in which they are placed. The Installer shall keep accurate records of the positions, dimensions and numbering of panels for submittal to the CQAO at weekly intervals. The CQAO will establish a table or chart showing correspondence between roll numbers and field panel identification codes. The field panel identification code will be used for all CQA records.

Field Panel Placement

No geosynthetics shall be deployed, joined, or tested unless a representative of the Engineer is present to monitor such activities. Field panel placement shall not be undertaken in the presence of excessive moisture, in an area of standing water, or during high winds. The Civil Contractor shall ensure that run-off water is diverted from the area surrounding the lining installation.

The Installer will record the identification code, roll number, location, weather conditions, and date of installation of each field panel. The information shall be submitted to the CQAO on a weekly basis.

If a portion of a roll is set aside to be used at another time, the roll number shall be written on the remainder of the roll in several places.

The CQAO will verify that field panels and seam orientations are approximately as indicated in the Installer's approved layout plan, or as modified.

Compensation for Material Expansion and Contraction

The Installer will be responsible for determining the required amount of compensation that must be installed in the geomembrane to ensure that it will not be unduly tensioned due to temperature variations in service. Such calculations shall be shown to the CQAO and Resident Engineer. The Installer will be responsible for ensuring that sufficient geomembrane is installed to compensate for contraction of the material during anticipated lower temperatures and to prevent expansion and excessive wrinkling at possible higher covering temperatures.

The methods of installing compensation will be discussed with, and approved by, the Engineer and the CQAO.

The geomembrane must not be tensioned and must be fully supported by the subgrade when it is covered by soil or liquid ballast.

Intimate Subgrade Contact

Only that amount of geomembrane will be deployed in one day that can be covered by the required thickness of cover soil in the following day. The cover soil will initially be placed as ballast around the periphery of that section of geomembrane.

The CQAO will monitor the placement of geomembrane and soil to confirm that the geomembrane is essentially in complete contact with the subgrade at the end of the working day, and is restrained in this position, without excessive tension, by the peripheral soil.

The CQAO will monitor the spreading of cover soil at the start of the first shift of the next day to confirm that no standing or folded wrinkles in the geomembrane are covered by soil. The geomembrane must be in intimate contact with the subgrade.

At all times the exposed edges of geosynthetics will be kept clean and protected from damage.

Installation Schedule

Field panels will be placed one at a time, and each field panel will be seamed immediately after its placement (in order to minimize the number of unseamed field panels exposed to wind).

It is beneficial to "shingle" overlaps in the downslope direction to facilitate drainage in the event of precipitation, shingling should also be done in the downstream direction to minimize resistance to flow. It is also beneficial to proceed downslope and in the direction of (with) prevailing winds. Scheduling decisions must be made during installation, in accordance with varying environmental conditions. In any event, the Installer will be fully responsible for the decisions made regarding placement procedures.

The CQAO will evaluate every change in the schedule proposed by the Installer and advise the Engineer on the acceptability of that change. The CQAO will verify that the condition of the supporting soil is still satisfactory for installation of geomembrane.

Weather Conditions

Geomembrane placement will not proceed at geomembrane temperatures below 0°C or above 75°C unless approved by the Engineer.
Geomembrane placement will not be done during any precipitation, conditions with excess moisture (e.g. fog, dew) in an area of ponded water, or during excessive winds except as approved in an Action Decision Meeting.
NOTE: The only temperature of significance is the actual geomembrane temperature, not the ambient temperature. When exposed to sunlight the geomembrane temperature will be significantly higher than ambient.

The CQAO will verify that the above conditions are observed. Additionally, the CQAO will verify that the supporting soil has not been damaged by weather conditions.

The CQAO will inform the Engineer if the above requirements are not observed.

Geomembrane Placement

The Installer shall be responsible to ensure that:

- Equipment used does not damage the geomembrane as a result of handling, trafficking, excessive heat, leakage of hydrocarbons, or by other means;
- Any All-Terrain Vehicles (ATVs) used to deploy geosynthetics exert ground pressures less than 55 kPa (8 psi).
- ATVs are not operated: 1) at excessive speeds, 2) in tight turning circles, 3) under extreme breaking and accelerating conditions, 4) with dirty tires, and 5) over wrinkles, that might damage the geomembrane.
- The prepared surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement;
- Any geosynthetic elements immediately underlying the geomembrane are clean and free of debris;
- Personnel working on the geomembrane do not smoke, do not wear hard-soled shoes, and do not engage in activities which could damage the geomembrane;
- Frequently used pathways up and down geomembrane on slopes are protected by a roll of geotextile;
- The methods used to unroll the panels do not cause excessive scratches or crimps in the geomembrane and do not damage the supporting soil;
- The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels);
- Geomembrane is not allowed to unroll freely down a slope;
- Geomembrane is not placed under tension, unless approved by the Engineer in writing;
- Adequate temporary loading and/or anchoring (e.g., sand bags, tires), that does not damage the geomembrane, has been placed to prevent uplift by wind;
- Direct contact of equipment with the geomembrane shall not be allowed, except as previously described for ATVs used to deploy geosynthetics. The geomembrane shall be protected by geotextiles, extra geomembrane, soil layers, or suitable materials, in areas where equipment may be used or traffic may be expected;
- Only hook bladed utility knives are used to cut through the geomembrane.
- Appropriate care is to be taken to prevent shock and explosions caused by static electricity discharges.
- All handholds cut for moving panels and damage caused by clamps are repaired;
- Panels are not moved such that subgrade soil can peel the underside seam flap.
- Motorized equipment contact and /or traffic shall not be allowed on the liner.
- Portable generators may be positioned on the lined area provided that the liner is protected by an adequate cushion of geotextile or an additional layer of liner material.
- The Installer shall not refuel generators or other equipment that uses petroleum products while the equipment is located on the liner.
- Equipment shall be maintained such that no petroleum products come into contact with the liner.
- No equipment or tools shall damage the liner by handling, traffic, or by other means.
- Use of metal tools shall be kept to a minimum.

The CQAO will inform the Engineer if the above requirements are not observed.

Temporary Ballasting

Temporary ballasting around the edges of the installed liner shall be done with sandbags or equivalent non-damaging ballast material (e.g. tires without reinforcing wires exposed). Sandbags shall be of a size and weight so as to enable handling by one person and shall be spaced to provide adequate uplift protection against typical winds that might reasonably be expected to occur prior to the addition of adjacent panels or prior to permanent ballasting.

Damage

The CQAO will visually examine each panel, after placement and prior to seaming, for damage.

The CQAO will advise the Engineer which panels, or portions of panels, should be rejected or repaired. Damaged panels or portions of damaged panels, which have been rejected will be marked, and their removal from the work area recorded by the CQAO. Repairs will be made according to procedures described in Section 5.2.7.

At a minimum, the Installer will be responsible to ensure that:

- each panel is placed in such a manner that it has not been, or is unlikely to be, damaged; and
- any tears, punctures, holes, thin spots, and damaging inclusions, gouges, and protuberances etc., are marked for repair and brought to the attention of the CQAO.

5.2.5 Field Seaming

The Installer will provide the Engineer and the CQAO with a proposed panel layout drawing at least 15 working days prior to the commencement of installation activities. The CQAO will review the panel layout drawing and verify that it is consistent with the accepted state-of-practice and this CQA Plan. The layout shall be such as to keep the number and length of field seams to a minimum. No panels may be seamed in the field without the Engineers representative's written approval. In addition, panels that significantly change the layout drawing (e.g. that change the orientation of seams) shall not be installed without the Engineer's prior approval.

In general, seams should be oriented parallel to the line of maximum slope, i.e., oriented up and down, not across, the slope. In corners and other geometrically complex locations, the number of seams should be minimized. No base seam or tee seam will be less than 2 m from the toe of slopes, or areas of potential stress concentrations, unless otherwise authorized by the Engineer in writing. Horizontal and T-shaped seams shall not be placed on slopes.

If roll end seams are unavoidable on slopes, the upslope panel shall overlap the downslope panel and adjacent panel cross-seams shall be staggered by at least 2 m.

A seam numbering system compatible with the panel numbering system will be agreed upon at the Resolution Meeting.

Seams are usually identified by the panel numbers on each side, e.g. seam 1 / 2, for the seam between panels 1 and 2.

Welding is to extend at least 500mm beyond the crest and into the anchor trench.

Approved methods for field seaming are thermal fusion (hot wedge, hot air, or combination) seaming and extrusion seaming. Proposed alternate methods will be documented and submitted with the tender. Only apparatus that has been specifically approved by make and model will be used. The Installer will use appropriate measuring equipment to ensure that required temperatures are being achieved.

Fusion Seaming

Seaming equipment shall comply with the requirements of GRI Test Method GM 19 and all equipment used shall comply with national regulations and statutory requirements on accident prevention.

The fusion seaming machines will be equipped with gauges giving hot wedge temperatures. Temperature, speed, and nip roll pressure settings will be verified by the Installer prior to each seaming period. Nip roll and wedge geometries shall be such as to minimize residual stresses at the edge of the seam, i.e. to minimize reduction in stress cracking resistance of the geomembrane.

The Installer will log ambient conditions, geomembrane temperatures, seaming apparatus temperatures and speeds, equipment serial number, and operator initials.

The Installer is responsible to ensure that:

- The number of operable seaming machines decided at the Resolution Meeting are maintained on site at all times;
- equipment used for seaming does not damage the geomembrane;
- for tee seam intersections, all edge flaps are cut back to the edge of the outer-most peel-tested track of the seam prior to seaming;
- electric generators and fuel containers are placed on a smooth protective layer such that no damage occurs to the geomembrane;
- a smooth insulating plate or fabric is placed beneath the hot seaming apparatus after usage;
- the geomembrane is protected from damage in heavily-trafficked areas; and
- build-up of moisture or dirt between the sheets is prevented. To accomplish this a movable protective layer may be used directly below each overlap of geomembrane that is to be seamed.

Extrusion Seaming

Extrusion welding shall be used only at areas which cannot be welded by using fusion seaming.

Extrusion-seaming apparatus will be equipped with gauges giving the relevant temperatures of the apparatus such as the temperatures of the extrudate, nozzle, and preheated air.

The Installer will provide documentation (including QC certificates) regarding the welding rod or resin pellets to the CQAO, that show that the resin is the same HDPE resin as the geomembrane itself. Other seaming resins must be approved by the CQAO.

The Installer will log apparatus temperatures, extrudate temperatures, ambient conditions, and geomembrane temperatures at appropriate intervals.

The CQAO will verify that:

- the Installer maintains on-site the number of operable seaming machines decided at the Resolution Meeting are maintained on site;
- equipment used for seaming will not damage the geomembrane;
- the extruder is purged prior to seaming until all heat-degraded extrudate has been removed from the barrel;
- feed resin is maintained clean and dry;
- the electric generator and fuel containers are placed on a smooth intermediate layer such that no damage occurs to the geomembrane;
- a smooth insulating plate or fabric is placed beneath the hot seaming apparatus after usage; and
- the geomembrane is protected from damage in heavily trafficked areas.

Seam Preparation

The Installer is responsible to ensure that:

- prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, foreign material, and any mechanical damage;
- if seam overlap grinding is required, the process is completed according to the Manufacturer's instructions but within 30 minutes of the seaming operation, and in a way that does not damage the geomembrane;

- the abrading does not remove more than 10 percent of the thickness of the geomembrane, and the resulting abrasion marks are covered by the finished extrusion bead;
- any visible abrasion marks, after seaming, are essentially perpendicular to the direction of the seam;
- the abrading does not introduce damaging gouges in the geomembrane; and
- seams/panels are aligned with a minimum of wrinkles and "fishmouths".

Weather Conditions for Seaming

The following protocols will be observed during seaming:

- Unless authorized in writing by the Engineer, no seaming will be attempted at geomembrane temperatures below -0°C or above 75°C.
- Below a geomembrane temperature of 5°C, the need for pre-heating and additional testing should be discussed with the Engineer and CQAO.
- In all cases, the geomembrane in the seaming area will be dry and protected from wind and airborne particulates.
- Geomembrane temperatures will be measured with a surface temperature thermocouple or a calibrated infrared pyrometer.
- Care shall be taken that wind chill does not reduce the geomembrane temperature such that fusion is inadequate or that excess heat is being used to overcome the wind chill.
- If the Installer wishes to use methods which may allow seaming at geomembrane temperatures below 0°C or above 75°C, the Installer will demonstrate (by testing trial seams) that such methods produce seams which are entirely equivalent to seams produced at geomembrane temperatures above 0°C and below 75°C, and that the overall quality of the seam and durability of the geomembrane are not adversely affected. In addition, the Installer will prepare written certification that states that the seaming procedure does not cause any physical or mechanical modification to the geomembrane that will generate any short or long-term damage to the geomembrane liner.
- The CQAO will verify that these requirements are observed and will advise the Engineer if potential problems are perceived. The Engineer will then decide if the seaming will be stopped or postponed. Such decisions may be the subject of an Action Decision Meeting.
- Seaming shall not take place during precipitation, conditions of excess moisture (e.g. fog, dew), or excessive wind.

Overlapping and Temporary Bonding

The Installer is responsible to ensure that:

- the panels of geomembrane have an overlap of approximately 100 mm, sufficient to allow peel tests to be performed on the inner track of the seam;
- there is a free flap at the edge of the top geomembrane a minimum of approximately 10 mm wide, to allow a peel test to be performed on the outer track of the seam;
- no solvent or adhesive is used unless the product is approved in writing by the Engineer (samples must be submitted to the Engineer for testing and evaluation);
- any procedure used to temporarily bond adjacent panels together does not damage the geomembrane. In particular, the temperature of hot air at the nozzle of any spot seaming apparatus will be controlled such that the geomembrane is not damaged. "Damage" includes a loss in durability; and
- temporary bonds do not interfere with the ability to perform shear and peel tests on the actual production seam.

The CQAO will log all relevant temperatures and conditions, and will log and report any non-compliance to the Engineer.

If protective layers of geomembrane are placed on the barrier layer geomembrane for any purpose (e.g. puncture protection in drainage trenches), they shall not be tack or spot welded to the barrier layer. They shall be fully welded, except a small pressure relief segment, along the complete periphery of the protective layer or they shall not be welded at all.

Trial Seams

Trial seams will be made by each machine/operator combination on strips of geomembrane to verify that seaming can be successfully performed. Trail seams shall be made under the same surface and environmental conditions as the production seams. Such trial seams will be made at the beginning of each seaming period (i.e., at the beginning and middle of each working shift), but at least once every five hours or as requested by the Engineer or CQAO, for each seaming apparatus/operator combination used in the seaming period. In addition, a new trial seam will be conducted when a welding apparatus has been restarted after being switched off. A trial seam will also be made in the event that the geomembrane temperature changes more than 25°C since the last passing trial seam. When geomembrane temperatures are below 5°C or higher than 75°C more frequent trial seams may be required. In general, trial seams will be conducted as follows:

The trial seam sample will be at least 1.5 m long by 0.3 m wide with the seam centred lengthwise. Seam overlap will be as indicated above. The CQAO will observe all trial seam procedures.

All trial seams shall be conducted under the same conditions as will be encountered during actual seaming.

Four specimens, each 25 mm wide and a minimum of 150 mm long, will be cut from the center section of the trial seam sample by the Installer. Two specimens will be tested in shear and two in peel using a calibrated field tensiometer (supplied by the Installer). They should meet project specifications. If any specimen fails, the entire operation will be repeated. If the second trial seam fails, the seaming apparatus and seamer will not be approved for production seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved. If no subsequent machines can successfully seam the material, then the material roll shall be rejected.

The remainder of the successful trial seam samples will be assigned a number and marked accordingly by the Installer, who will also log the date, time, geomembrane temperature, number of seaming unit, settings, name of seamer, and pass or fail description. The CQAO shall inspect trial seams for uniformity and general appearance.

A trial seam shall also be prepared by each seaming machine/operator at the completion of seaming each day to determine whether changes in seam quality might have occurred during the last part of the seaming period.

No seaming equipment will be allowed to perform production welds until equipment and operators have successfully completed trial seams. Once the seaming process has been qualified by successfully passing a trial weld, seaming technicians shall not change parameters without performing another trial seam.

General Seaming Procedure

Unless otherwise specified, the general seaming procedure used by the Installer will be as follows:

- For fusion seaming, a movable protective layer of plastic may be placed directly below each overlap of geomembrane that is to be seamed. This is to help prevent any moisture build-up between the sheets to be seamed.
- If required, a firm substrate may be provided by using a flat board, or other similar hard surface placed directly under the seam overlap.
- Fishmouths or wrinkles at the seam overlaps will be cut along the peak of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles will be seamed and any portion where the overlap is inadequate will then be patched with an oval or round patch of the same geomembrane material extending a minimum of 150 mm beyond the cut in all directions. The end of the cut should be rounded.

- If seaming operations are carried out at night, adequate illumination will be provided.
- Seaming will extend at least 0.5m into the material in the anchor trench.
- Each seam will be labelled with the seaming machine number, the operator's initials, machine temperature and speed settings, date, time, and direction seamed.

The CQAO will monitor the above seaming procedures, and will inform the Engineer of any unsatisfactory deviations from standard practice.

T-joints

T-joints are formed where a longitudinal seam is intersected by another seam. T-joints shall be staggered between panels to avoid the formation of cross joints.

T-joints shall be constructed so as to ensure the water tightness of the point where the two seam intersect. The procedure for forming a hot-wedge seamed T-joint shall be as per SANS 10409:2005, Clause 10.4.4.4, with the inclusion of 10.4.4.4(g).

5.2.6 Seam Continuity Testing

5.2.6.1 Non-destructive Seam Continuity Testing

The Installer will non-destructively test all field seams over their full length using a vacuum test unit, air pressure test (for double fusion seams only), spark test, or other approved method. Vacuum testing, air pressure testing, and spark testing are described in the section below. The purpose of non-destructive testing is to check the continuity of seams. It does not provide any information on seam strength. Continuity testing will be carried out as the seaming work progresses, not at the completion of all field seaming. Non-destructive testing will not be permitted unless there is, in the opinion of the CQAO, adequate illumination.

The CQAO will:

- observe all non-destructive testing;
- record location, date, test unit number, operator, and outcome of all testing
- mark the seams (on the geomembrane) that have been tested; and
- log and inform the Installer and Engineer of any required repairs.

If repairs are required the Installer will complete the repairs in accordance with Section 5.2.7

The CQAO will:

- observe the repair and re-testing of the repair;
- mark on the geomembrane that the repair has been successfully made and tested; and
- document the results.

The following procedures will apply to segments of seams that cannot be non-destructively tested:

- All such seam segments will be cap-stripped with the same type of geomembrane material, or
- All such seam segments will be very carefully prepared and welded by the master seamer under the observation of the consultant.
- If the seam is accessible to testing equipment prior to final installation (e.g. after prefabrication), the seam will be non-destructively tested prior to final installation.
- The seaming and cap-stripping operations must be observed for proper procedures by the CQAO and Installer's QC representative.

The Installer will write the details of each seam non-destructive test on the geomembrane with a permanent marker. For air pressure tests this will include the initials of the tester, the date, start time and pressure, end time and pressure, and pass or fail result. For vacuum testing this will include the initials of the tester, the date, and pass or fail result. For spark testing this will include the initials of the tester, the date, voltage setting, and pass or fail result. When a test fails, the number of the appropriate repair will also be recorded on the geomembrane.

Prior to any non-destructive testing, the Installer shall submit to the CQAO calibration certificates for all pressure gauges to be used during vacuum and air pressure testing, or shall otherwise demonstrate that all gauges are in satisfactory working condition.

Vacuum Box Testing:

The equipment will be comprised of the following:

- a vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole, valve assembly, and a vacuum gauge;
- a vacuum tank and pump assembly equipped with a pressure controller and pipe connections;
- a pressure/vacuum hose with fittings and connections;
- a soapy solution that does not cause environmental stress cracking in the geomembrane, and
- a soap solution applicator.

The following procedure will be followed:

- for fusion seams (not normally tested with a vacuum box), cut off the free flap with an approved cutter (so that the lower geomembrane is not damaged) prior to testing the seam;
- energize the vacuum pump and reduce the tank pressure to approximately 5 kPa gauge;
- with a soapy solution, wet a strip of geomembrane which is wider and longer than the vacuum box;
- place the box over the wetted area;
- close the pressure relief valve and open the vacuum valve;
- ensure that a leak-tight seal is created;
- examine the geomembrane seam through the viewing window for the presence of soap bubbles (large bubbles, or fine froth) for a period of not less than 5 seconds;
- if no bubbles or foam appear after 5 seconds, close the vacuum valve and open the pressure relief valve. Move the box over to the adjoining section of seam, with some overlap, and repeat the process;
- all areas where soap bubbles appear will be marked and repaired in accordance with Section 5.2.7.
- excess soap solution shall be cleaned or rinsed off the geomembrane and seam.

Air Pressure Testing:

The following procedures are applicable to those seaming processes which produce a double track seam with a central channel.

The equipment will be comprised of the following:

- an air pump equipped with a pressure gauge capable of generating and sustaining a pressure between 160 and 280 kPa mounted on a cushion to protect the geomembrane;
- a pressure hose with fittings and connections;
- a sharp hollow needle, or other approved pressure-feed device attached to a pressure gauge; and
- clamps or other devices to seal the ends of the seam to be tested.

The following procedures will be followed:

- seal both ends of the seam to be tested;
- insert the pressure-feed device into the channel of the seam;
- energize the air pump to a pressure between 185 and 275 kPa (depending on geomembrane thickness) as indicated in the project specification, close the valve, and allow the temperature of the air in the channel, and thus the pressure, to stabilize for about 2 minutes;

Spark Testing:

Spark Testing shall be performed according to ASTM D6365 for short, detail (e.g. sump, penetration) extrusion welds that cannot be tested by vacuum box testing. It may also be used on long extrusion seams as the primary non-destructive test method.

It is recognized that this test requires no signal be generated for a passing result. There are many conditions in addition to adequate seaming under which no signal will be generated: proper connections may not be made, the voltage may be set too low, and the search electrode may be held too far away. Thus, this test method may only be used where no other non-destructive test method can be applied. Written approval must be obtained from the Engineer to perform this test and the CQAO must be informed and present during testing.

Visual Examination:

Air pressure, vacuum box, and spark testing methods apply only to seams. Installer and CQA personnel shall continuously visually examine the geomembrane panels for the presence of other penetrating and non-penetrating defects and shall continuously feel for protuberances when walking on the geomembrane.

The Installer shall inform the CQAO in writing and verbally of any penetrating or non-penetrating defects that he, his staff or anyone else may observe. Failure to do so will be seen in a very negative light by the Engineer.

Visual examination should take advantage of low angles of sunlight and early morning condensation on the geomembrane.

Immediately prior to covering, the geomembrane, seams, and non-seam areas shall be visually inspected by the QCAO and Installer for defects, holes, or damage due to weather conditions or construction activities. At the QCAO's discretion, the surface of the geomembrane shall be brushed, blown, or washed by the Installer if the amount of dust, mud, or foreign material inhibits inspection or functioning of the over lying material. Each suspect location shall be non-destructively tested in. Each location that fails non-destructive testing shall be repaired in accordance with Section 5.2.7.

5.2.6.2 Destructive Seam Testing

Destructive seam tests will be performed at selected locations. The purpose of these tests is to evaluate seam bond strength and the effects of seaming on the adjacent geomembrane. Seam strength testing will be done as the seaming work progresses, not at the completion of seaming.

The CQAO will select locations where seam samples will be cut out for laboratory testing. Those locations will be established as follows:

A minimum frequency of one sample for every 150 m of seam made by each extrusion machine/operator combination and each fusion machine each day - unless a different frequency is requested by the Engineer or CQAO.
Conditions under which testing frequency may be increased or decreased as the project progresses will be agreed upon by the Installer and CQAO at the Resolution Meeting.

Test locations will be determined during seaming at the CQAO's discretion. Selection of such locations may be prompted by suspicion of overheating, contamination, offset seams, or any other evidence of imperfect seaming.

If trial seams are not made at the end of the day, one sample for destructive testing shall be removed from the last seam made by each seaming machine at the end of each working day.

The Installer will not be informed in advance of the locations where the seam samples will be taken.

Test frequencies may be increased or decreased at the CQAO's discretion depending on the consistency of the test results.

Samples will be cut by the Installer as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material. **The CQAO will**:

- observe sample cutting;
- assign a number to each sample, and mark it accordingly; and
- record the sample location on the layout drawing.

All holes in the geomembrane resulting from destructive sample removal will be immediately repaired in accordance with repair procedures described in Section 5.2.7. The continuity of the new seams in the repaired area will be tested according to Section 5.2.6.

At a given sampling location, two types of samples will be taken by the Installer.

First, two pairs of specimens for field peel and shear testing will be taken. Each of these specimens will be 25 mm wide by at least 150 mm long, with the seam centred across the width. The distance between these two pairs of specimens will be 1.1 m. If both pairs of specimens pass the field tests described below, a sample for laboratory testing will be taken.

The sample for laboratory testing will be located between the two pairs of specimens taken for field testing. Unless determined otherwise at the Resolution Meeting, the destructive sample will be 0.3 m wide by 1.1 m long with the seam centred lengthwise. **The sample will be cut into three parts and distributed as follows:**

- one portion, measuring 0.3 m x 0.5 m, to the Installer for QC laboratory testing;
- one portion, measuring 0.3 m x 0.6 m, to the CQAO for CQA Laboratory testing.

<u>Field Testing</u>:

The four 25 mm wide specimens will be tested in the field, by a calibrated gauged tensiometer, one of each pair in peel and one in shear. If any field test specimen fails to pass the criteria of the project specifications, then the procedures outlined in section 5.1.1.3 will be followed.

The CQAO will witness all field tests and mark all samples and portions with their unique sample number. The CQAO will also log the date and time of sampling, and test pass or fail description.

If the two pairs of specimens meet the project specifications, the sample qualifies for testing in the laboratory; if they fail, the seam should be repaired in accordance with section 5.2.7.

<u>Construction Quality Assurance Laboratory Testing</u>:

Destructive test samples will be packaged and shipped to the CQAO laboratory by the CQAO, in a manner which will not damage the test sample. The Engineer will verify that packaging and shipping conditions are acceptable. The Engineer will be responsible for storing the archive samples. This procedure will be fully outlined at the Resolution Meeting. Test samples will be tested by the CQAO Laboratory.

Testing will follow ASTM D4437 as modified in NSF 54 Appendix A (1993), but with no requirement for sample conditioning time. The minimum acceptable values to be obtained in these tests are those indicated in the project specifications. Five specimens will be tested in peel and five in shear. Specimens will be selected alternately by test from the samples (e.g., peel, shear, peel, shear, etc.).

The CQAO will review laboratory test results as soon as they become available, and make appropriate recommendations to the Engineer.

<u>Procedures if Destructive Sample Fails</u>:

The following procedures will apply whenever a sample fails a destructive test, whether that test is conducted by the CQA Laboratory, the Installer's laboratory, or on the field tensiometer. **The Installer has two options**:

- Reconstruct the seam between the nearest passing destructive test locations on each side of the failed sample; or
- Trace the seaming path to an intermediate location (3 m minimum from the failed test location in each direction) and take a small sample for an additional field test at each location. If these additional samples pass tensiometer testing, then full destructive test samples should be taken. If these laboratory destructive test samples pass the tests, then the seam should be reconstructed between these locations by capping. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

If a fusion-type seam fails destructive testing and the Installer chooses to repair the seam, the only acceptable repair method is as described in Section 5.2.7. Applying topping (bead of extrudate) is not an approved method of capping any seam unless it can be shown that this procedure will not reduce the stress rupture resistance of the seam below 75% of that of the parent geomembrane.

Only seams bounded by two locations from which samples passing laboratory destructive tests have been taken will be considered acceptable. An additional destructive test sample will be taken from repair seams when the length of a reconstructed seam exceeds 50 m. This sample must pass destructive testing or the procedure outlined in this section must be repeated.

The CQAO will document all actions taken in conjunction with destructive test failures.

5.2.7 Defects and Repairs

All seams and non-seam areas of the geomembrane will be examined by the Installer and the CQAO for identification of defects, protruding and penetrating objects, lack of subgrade support, overheating, overgrinding, holes, blisters, undispersed raw materials, scratches and gouges, and any sign of contamination by foreign matter. To facilitate the examination the geomembrane surface will be kept clean by the Installer (or as agreed at the Resolution Meeting).

Each suspect location, both in seam and non-seam areas, will be non-destructively tested using an appropriate method, such as vacuum box testing. Additional methods, such as electrical methods and infrared thermography, may also be used. Each location which fails the non-destructive testing will be marked by the CQAO and repaired by the Installer. Work will not proceed with any materials which will cover locations that have been repaired until passing destructive and non-destructive test results have been obtained on the repairs.

Any portion of the geomembrane exhibiting a flaw, or failing a destructive or non-destructive test, will be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure will be agreed upon between the Engineer, Installer, and CQAO at the Resolution Meeting or at an Action Decision Meeting. **The procedures available include**:

- patching, used to repair all penetrating holes, tears, undispersed raw materials, and contamination by foreign matter;
- spot beading, used to repair small surface scratches, or other minor, localized non-penetrating flaws;
- capping with a strip of geomembrane, used to repair long lengths of failed seams;
- lip extrusion, an extrusion weld applied along the lip of the overlap of wedge welded seams;
- removal and replacement of a defective seam with new material that is wedge welded into place.

In addition, the following provisions will be satisfied:

- surfaces of the geomembrane which are to be repaired will be abraded no more than 30 minutes prior to the repair;

- all surfaces must be clean, free of all particulate matter, and dry at the time of the repair;
- all seaming equipment used in repairing procedures must be approved;
- the repair procedures, materials, and techniques will be approved in advance of the specific repair by the CQAO in writing;
- patches and caps will extend at least 150 mm beyond the edge of the defect, and all corners of patches will be rounded with a radius exceeding 75 mm;
- the geomembrane below large caps should be appropriately cut to avoid fluid entrapment between the two sheets and resultant pressure increases (that stress the seams) as the liner is covered;
- sharp ends of slits and cuts in the geomembrane should be rounded before patches are placed over them; and
- no more than one extrusion bead at any location will be used to make a repair - multiple beading (more than two beads at any one location) is not permitted and must be replaced with a patch.

Each repair will be numbered and logged. Each repair will be non-destructively tested using one of the methods described above or another method approved in writing by the Engineer. Repairs that pass the non-destructive test will be considered acceptable. Large caps may be of sufficient extent to require destructive testing, at the discretion of the CQAO. Failed tests will require the repair to be redone and retested until a passing test results. The CQAO should observe all non-destructive testing of repairs and will record the date of the repair and test result.

No repair shall be undertaken without the CQAO being informed of the repair both in writing and verbally at least 1 day prior to the repair taking place.

5.3 Construction Quality Control for the Installation of Geosynthetic Clay Lining Systems

5.3.1 Installation

Prior to commencing GCL installation the Contractor shall prepare and submit to the Engineer for approval a proposed panel layout drawing, drawn to scale, showing the proposed deployment pattern and sequence. The location of overlaps and details thereof must also be shown. No deployment of GCL shall commence until the Engineer has approved the panel layout. This deployment plan may be requested by the Engineer at the tender stage.

In preparing the panel layout, the Contractor shall take into account the construction schedule, access restrictions and the following limitations placed on seam locations:

- To the maximum extent possible, overlaps shall be parallel to the slope (down the slope).
- The number of transverse seams (perpendicular to slope) on slopes shall be minimized. Where such seams are unavoidable, the details of these seams must be approved by the Engineer.
- Seams at inside and outside corners, odd-shaped geometric configurations, seam convergences, and small panels shall be avoided if possible.

Each panel and penetration shall be given a simple and logical identification code consistent with the panel layout drawing. The panel identification should include the panel batch and roll number. The panel layout drawing shall be updated from time to time to reflect the actual deployment configuration.

On completion of the installation, the Contractor shall prepare and submit to the Engineer as-built drawings to scale showing the final panel layout.

5.3.2 Subsurface Preparation

Prior to deployment of GCL over the prepared subgrade, the Contractor shall inspect, with the earthworks contractor and construction quality assurance officer, all surfaces on and trenches in which the geosynthetic material is to be placed. The Contractor shall certify in writing that the subgrade is acceptable for the installation of the geosynthetic material. Surfaces not in compliance with the Specifications shall be rectified by the Contractor and be subjected to inspection and acceptance before the geosynthetic material is deployed.

The subgrade should be firm and unyielding, with no abrupt elevation changes, voids or open cracks, protrusions, and free from standing water.

The subgrade surface should be smooth and consist primarily of fine-grained soil that is free of sharp and protruding edges, construction debris and other foreign matter. Protrusions should not exceed 5mm.

Compaction of the subgrade should be in accordance with project specifications, and should be carried out in such a way that wheel ruts, footprints and other abrupt grade changes are removed by means of a smooth drum compactor. As a minimum, the level of compaction should be such that installation equipment or other construction vehicles that traffic the area of deployment do not cause significant rutting.

5.3.3 Anchor Trench

In some cases the GCL can be anchored in the same trench as any adjacent geosynthetic liner components (if used). Dimensions and location of the trench's are provided on the project drawing/s. The front edge of the trench is to be rounded, so as to prevent stress concentrations on the GCL. Care should be taken to preserve the integrity of the sides of the trench during GCL installation.

The backfill of the anchor trenches must only commence after the Engineer has inspected and accepted the trench for backfill. The Engineer requires the trench only to be backfilled after the final layer has been installed.

The backfilling of the trenched shall be done in accordance with the project specifications.

The GCL must be installed in the trench as detailed on the project drawings.

5.3.4 Deployment

The GCL shall be installed on the approved areas shown on the drawings, or as directed by the Engineer, using methods and procedures that ensure a minimum of handling. The orientation of the GCL, i.e. which side faces up, shall be in accordance with the drawings, or as instructed by the Engineer.

When possible, GCL deployment should begin at the higher elevations and proceed to the lower elevations. At no time shall GCL rolls be released and allowed to unroll freely under gravity. Damaged, faulty or suspect areas shall be marked for repair. The method used to unroll the GCL shall not damage any underlying geosynthetics or allow stones, mud, or debris to be trapped under the GCL. Care shall be taken to prevent damage to the bottom surface of the GCL when it is finally positioned across the subgrade or underlying geosynthetic.

The GCL shall be placed one panel at a time in a relaxed condition with the required overlap so that it is in intimate contact with the underlying surface at all locations and free of tension or stress upon completion of the installation. All necessary precautions, including installing extra material, shall be taken to avoid bridging of the material. Cutting and trimming of GCL placed over geomembranes shall be undertaken with hooked-blade knives or other approved cutter. Special care shall be taken to protect other geosynthetic materials from damage that could be caused when cutting.

It is important to ensure that the GCL is not left exposed to the elements and therefore the subsequent covering activities must be co-ordinated accordingly with the GCL installation.

The Contractor shall only deploy as much GCL that can be covered in a reasonably short time in the event of precipitation or as can be covered by the end of the working day with soil cover, geomembrane, or temporary plastic sheeting.

The layout and sequence of panel placement is determined by the direction of water run-off. Panels are laid out according to previously approved panel layout drawings. Generally, the installation is started at the up-wind side and at the highest elevation so that any rainfall runs off the lower part of the impoundment, preventing pooled water from hydrating the GCL.

If unplanned premature hydration occurs the Engineer shall be notified. If the extent of the premature hydration is such that, when an average weight person walking over the GCL causes ”toothpasting” to occur, the hydrated GCL may need to be replaced at the discretion of the Engineer in accordance with the requirements of Section 5.3.6.

The extent of the damage of the prematurely hydrated GCL section can be assessed taking the following into account:

- Separation and damage of the geotextiles
- Depth of indentations (and corresponding bentonite thinning) where it has been walked or driven on.
- The integrity of the overlaps and other bentonite enhanced seams.

A sharp utility knife should be used for cutting the GCL if required, e.g. around penetrations. Frequent blade changes are recommended to avoid damage to the geosynthetic components of the GCL during the cutting process. Removed blades should not be discarded on or under the installed GCL. Cutting should be done on an adequately sized, preferably wooden, cutting board.

5.3.5 Seaming

GCL seams shall be used where called for on the Drawings, shown on the approved panel layout, or as directed by the Engineer. The seam shall be created by overlapping adjacent edges and enhancing the seam as recommended by the manufacturer, or as instructed by the Engineer.

The overlap zone shall be kept clean and shall not be contaminated with loose soil or other debris. There shall be no folds in the overlap zone and no traffic or walking shall occur on the completed seam. No end overlaps shall be positioned in sumps or inverts.

Overlaps shall be 500mm minimum horizontally and vertically and shingled in the direction of anticipated water flow.

If the GCL does not incorporate a mechanism to ensure longitudinal overlap sealing overlap areas will require on site overlap bentonite sealing. Edges are pulled back and bentonite of the same source to that used in the product should be poured continuously along all seam edges. The amount of bentonite must be suffice to create a thin-paste layer over the entire overlap area.

Horizontal seams on steep slopes (greater than 1V:6H) should be avoided. However, these may be required for long slopes, in which case the horizontal seams shall be constructed as directed by the Engineer.

When the GCL is cut to fit into small areas, in corners or around structures adjacent panels should be overlapped a minimum 500mm or as directed by the Engineer, adding abundant bentonite in overlapped areas, if the overlapped area does not cover a bentonite enhanced longitudinal edge.

5.3.6 Repairs

Any portion of the GCL or seam showing a defect shall be repaired. Reasons for requiring repairs to the GCL installation include, but are not limited to:

- A hole, cut, or tear
- Insufficient overlap
- Bridging
- GCL material defects
- A hard object underneath the GCL
- Unconfined and unhydrated GCL material exposure to harmful liquids during installation. This could include hydrocarbon fuels, chemicals, pesticides or non-compatible leachate, as determined by the Engineer.
- Premature hydration

Agreement on the appropriate repair method shall be reached between the Contractor and the Engineer. Repairs shall be undertaken using one or a combination of the following methods:

Patching:

Patching shall be used to repair holes, cuts or tears, insufficient overlap, bridging, GCL material defects, and to remove hard objects underneath the GCL. Patching shall comprise installing a new piece of GCL of the same material type and thickness extending at least 500 mm beyond the affected area in each direction. This 500 mm area must be augmented with bentonite powder/granules to the supplier's normal jointing requirements for patches and to the Engineers approval. Patch seams shall be created as described in Section 5.3.6.

Patches on slopes steeper than 1V:6H shall be minimized, and in this case the Engineer shall approve the location and size of such a patch. In addition to bentonite augmentation around the edge of patches on slopes steeper than 1V:6H the patch shall be temporarily secured such that it is not displaced during cover placement. Patches may be tucked under the damaged area to limit patch movement.

No patches shall overlap. If this is required to make a repair, the entire area, including all previous patches in the near vicinity, shall be covered with a single large patch. The Engineer shall approve deviations from this requirement.

All patches on the GCL should be recorded by a GPS global positioning system as positions stored and given to the quality control officer/ Engineer.

5.3.7 Sealing Around Penetrations and Structures

The GCL shall be sealed around penetrations and structures embedded in the sub-grade. Bentonite powder/granules shall be used liberally to seal the GCL to these structures in accordance with the drawings. An example detail is shown in Figure 3 below.

When the GCL is placed over an earthen subgrade, a "notch" should be excavated into the sub-grade around the penetration. The notch should then be filled with bentonite or bentonite paste. A secondary collar of GCL should be placed round the penetration with a minimum overlap of 500mm.

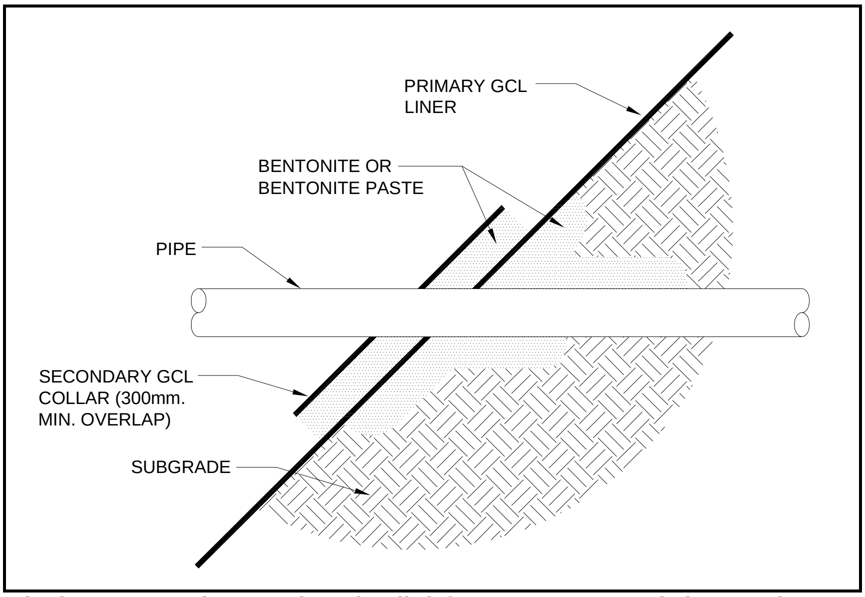

Figure 3: Typical pipe penetration section detail (after ASTM D 6102) (Note: change min overlap to 500mm)

5.3.8 Hydration

The GCL should always be placed against a moist soil layer to ensure adequate hydration after placement. Pre-hydration of the GCL should be considered very carefully by the Engineer and only used in unique project conditions, such as highly saline environments, relatively short-term applications or low quality cover soils.

5.3.9 Cover Placement

Soil Cover

Prior to the commencement of soil cover placement, the Contractor shall agree with the Engineer the procedure to be used for placement of soil cover, routes to be taken by construction equipment, and additional temporary cover that may be required on high traffic routes.

Cover soil specification to be approved by the Engineer taking into account the compatibility of the GCL and cover soil. As a minimum the soil shall be free from sharp stones, roots, construction debris, etc. that may damage the GCL.

Where soil cover is placed directly onto the GCL, the soil cover shall be placed in one layer to the thickness and density specified on the Drawings immediately following deployment and acceptance of the GCL. Equipment and procedures that minimize stress on the GCL and prevent soil from entering the seam overlaps. On flatter surfaces soil placement should be in the direction of the overlaps. On slopes, soil cover should be placed in an up-slope direction to minimize tensile forces on the GCL, while at the same time preventing soil from opening the seams. In some cases, however, it may be preferable (at the discretion of the Engineer) to place cover downhill. This must be done carefully with the machinery wheels on adequately thick soil cover.

No vehicles should be allowed to traffic the area directly above the GCL unless at least 400mm separation exists between the GCL and the vehicle to adequately distribute the vehicle load for a short period of time of pass-over. If frequent traffic is expected over a GCL lined area it is recommended to increase the soil cover to at least 600mm as directed by the Engineer. The soil cover shall be placed to within at least 750 mm of the leading edge of the GCL.

Important Note: Before the end of the working day, the remaining exposed GCL shall be covered with temporary plastic sheeting that is anchored under the leading edge of the soil cover and folded at least 300 mm under the leading edge of the GCL. The protected end of the GCL shall be held in place with temporary ballast until installation resumes.

Geomembrane Cover

Where a geomembrane is placed directly onto the GCL, the geomembrane shall be placed immediately following deployment and acceptance of the GCL using equipment and procedures that minimises stress on the GCL. This may be accomplished by using lightweight, rubber-tired equipment such as a 4-wheel all-terrain vehicle (ATV). This vehicle can be driven directly on the GCL, provided the ATV makes no sudden stops, starts, or turns. If such instances do occur, the CQA officer shall be notified immediately. The CQA officer shall then inspect the possible damage and may instruct repair in accordance with Section 5.3.6. When a textured geomembrane is installed over the GCL, the contractor shall take necessary measures to ensure the integrity of the installed GCL is not compromised in any way. This could necessitate the use of temporary slip-sheets to minimize friction between the GCL and geomembrane.

Low ground pressure devices such as ATVs or tractors to facilitate deployment over other geosynthetic layers should be used if no other method is possible. The machines should exert less than 50kN/m2.

The geomembrane shall be placed as close to the leading edge of the GCL without creating unnecessary additional seams in the geomembrane.

5.3.10 TOLERANCES

Manufacturing tolerances to be in accordance with GRI-GCL3 and any associated standards.

The maximum permissible deviations for overlaps in joints, patches and seams shall be 10% of the specified overlap.

5.3.11 TESTING

The GCL material shall be tested for compliance with the specifications listed in Table 1 (a) in GRI-GCL3 (Reinforced GCL GT related) by the test methods and frequencies indicated. Sampling of GCL is to be in accordance with ASTM D6072.

Immediately upon manufacture, Conformance Testing may, at the discretion of the Engineer, be carried out by an independent accredited laboratory (MQA laboratory). Common important conformance tests are listed in Table 1. Further tests, such as GCL shear strength (ASTM D 6243), may be required by the Engineer for specific projects. The testing frequency shall be at the discretion of the Engineer but the frequency shown in Table 1 (a) in GRI-GCL3 (Reinforced GCL GT related) can be used as a guideline. The Engineer shall approve the laboratory before any testing is done. The Engineer has the right to reject any roll or production batch if the samples do not pass conformance testing.

The Contractor shall supply with his tender, a Construction Quality Control Plan which clearly indicates documentation ensuring compliance with the necessary material specifications, and control points requiring quality control checking during construction/installation.

The engineer may request test results produced by a certified laboratory independent of the manufacturer to verify the claimed properties, prior to approval of the product(s) offered. All MQC and CQC testing and reporting thereon are described in the GRI GCL3 specification.

5.4 Construction Quality Control for the Installation of Geosynthetic Geotextile Lining Systems

The geotextile shall be delivered to site in rolls with the unique roll number, unit mass and product name clearly labelled on the surface of the roll. The roll shall be covered with an opaque plastic sheet to prevent damaged from sunlight. If the geotextile roll is exposed to sunlight, at the discretion of the engineer, the outer layers of the roll shall be cut off and discarded. The rolls shall be stored on a secure dry, free draining surface and shall be stored on wooden beams or pallets to prevent water damage. The rolls should be stacked on top of each other to a maximum height of four rolls.

Where the geotextile is being placed on the subgrade layer, it may be deployed by machine, otherwise geotextiles must be deployed by hand. All wheel tracks shall be removed prior to the geotextile being deployed onto an area. The geotextile shall be held in place with sandbags to prevent wind uplift. Should the geotextile be displaced by wind or any other force, the Engineer shall inspect the geotextile for damage and can instruct the Installer to remove the damaged geotextile and deploy a new roll.

All rolls (placed alongside one another or end-on-end) shall overlap by a minimum of 500mm 300mm or be sewn with a polyethylene thread or shall be heat bonded along overlapping edges. The overlaps shall be in such a direction that cover soil, when placed on the geotextile, is not pushed into the joint, under the top layer. The use of construction machinery directly over the geotextile is strictly prohibited.

A minimum thickness of 400 mm of cover shall be kept between heavy equipment and the geotextile at all times. No vehicles exerting more than 55 kPa may be driven directly over the geotextile until the proper thickness of cover had been placed.

5.5 Construction Quality Control for the Installation of Cuspated Drain Lining Systems

The Cuspated Drain materials shall be delivered to site in rolls with the unique roll number, unit mass and product name clearly labelled on the surface of the roll. If the material roll is exposed to sunlight, at the discretion of the engineer, the outer layers of the roll shall be cut off and discarded. The rolls shall be stored on a secure dry, free draining surface and shall be stored on wooden pallets to prevent water damage and to allow drainage. The rolls should be stacked on top of each other to a maximum height of three rolls. Any rolls that have fallen to the side or on top of each other should be lifted immediately and stacked appropriately.

The Contractor must use sufficient ballast to prevent the Cuspated Drain from moving when exposed. Should any areas of the Cuspated Drain become dislodged and move around, before the Cuspated Drain is covered, the Contractor will be required to obtain permission from the Engineer for its continued use, prior to covering the material. Should the sheets be displaced by wind or any other force, the Engineer shall inspect the sheets for damage and can instruct the Installer to remove the damaged sheets and deploy a new roll.

All rolls (placed alongside one another or end-on-end) shall overlap by a minimum of 200mm along both end and side overlapping edges. The overlaps shall be in such a direction that the top sheet is placed in the direction of flow. Sheets should be placed from the bottom of a gradient, working up the slope. No heavy vehicles may be driven directly over the sheets until the proper cover/protection layers have been placed.

Sheets shall be extrusion-welded together (tack-welded) every 2m along the length of the sheets, to ensure no movement before sand placement and the placement of subsequent layers.

The following steps must be taken when installing the Cuspated Drain:

- The Cuspated Drain is to be placed with the cusps facing down.

- The Engineer is to sign-off acceptance of the Cuspated Drain prior to unrolling the next geosynthetic layer or placing the cover material.

- An extrusion weld is to be placed every 2m along the seams (at the overlaps) of the Cuspated Drains. All seams should be ballasted sufficiently.

The Contractor will be required to cover the Cuspated Drain (with its sand fill) immediately after acceptance of the Cuspated Drain has been given by the Engineer.

5.6 Site Captured Data and Documentation

5.6.1 Geosynthetic Geomembrane Lining Systems

An effective CQA plan depends largely on recognition of all construction activities that must be monitored, and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The Engineer will ensure that all quality assurance requirements have been addressed and satisfied.

Standard reporting procedures shall include preparation of daily reports that, at a minimum, will consist of:

- field notes, including memoranda of meetings and/or discussions with the Contractor and GSM Installer;
- observation logs, and testing data sheets; and
- construction problem and solution data sheets.

This information must be regularly submitted to, and reviewed by the CQAO and the Engineer.

Observation logs and testing data sheets shall be prepared daily. At a minimum, these logs and data sheets shall include the following information:

- an identifying log/sheet number of cross-referencing and document control;
- date, client name, project name, location, and other identification;
- data on weather conditions;
- a site plan showing all active work areas and test locations;
- descriptions and locations of on-going construction;
- equipment and personnel in each work area, including those of all related sub-contractors;
- descriptions and specific locations of areas, or units, of work being tested and/or observed and documented;
- locations where tests were undertaken and samples taken;
- a summary of test results;
- calibrations of test equipment, and actions taken as a result of any non-conformance;
- off-site materials received, including quality verification documentation;
- decisions made regarding acceptance of units of work, and/or corrective actions to be taken in instances of non-conformance; and
- signatures of the CQA Officer and the CQA Monitors.

These logs must show all non-complying test results.

A comprehensive set of CQA Logs shall be kept by the Installer as follows:

- Manufacturer/GSM Installer Compliance Agreement
- Daily personnel attendance list
- Material inventory
- Conformance testing
- Subgrade acceptance

- Material deployment
- Trial seaming
- Production seaming
- Repairs
- Non-destructive testing
- Destructive testing
- Laboratory test results
- Problems and solutions
- Soil cover placement
- Daily report

These documents shall provide fully traceable records of men, machines, machine settings, materials, weather, and test results, in the event of in-service operational problems.

The CQA Officer shall incorporate all of these logs in the CQA Final Report.

5.6.2 Geosynthetic Clay Lining Systems

An effective construction quality assurance plan depends largely on recognition of all construction activities that must be monitored, and on assigning responsibility for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The Engineer will ensure that all quality assurance requirements have been addressed and satisfied.

Prior to installation the Installer/Contractor is to provide the following to the Engineer before installation on site:

- Manufacturers conformance certificates
- A drawing indicating the position and numbers of each individual panel that will be installed (Panel layout)
- A Method Statement describing the method of installation and quality control documentation to be completed
- A Project Quality Plan with organization chart and detailing inspection procedures

During installation the Installer/Contractor is to complete the following:

- Material receipt with roll numbers
- Subgrade surface acceptance documentation
- Panel layout – Panels installed and repair positions
- Panel Placement Form showing the location of all panels and joints
- Project Quality Plan – Signatures
- Certificate of Acceptance

The Engineers representative is to complete the following daily reports:

- Field notes, including memoranda of meetings and/or discussions with the Contractor and GCL Installer.
- Construction problems and solution data sheets
- Project Quality Plan – Signatures
- Data on weather conditions
- Safety Matters
- Soil cover details
- Signature of Completion Certificate

After installation the Installer/Contractor is to provide the following within 14 days to the Engineer:

- A complete Data Pack containing all completed and signed documentation as described herein (Installer/Contractor documentation).
- The Installer/Contractor Data Pack
- An outline of the project
- A description of the lining system
- GCL Material Specification
- Batch and roll numbers of panels used
- A summary of on-site CQA activities, quantities, samples etc.
- A photographic record of construction
- Discussion of problems and solutions
- As built drawings

The CQA Officer shall incorporate all of these logs in the CQA Final Report.

5.6.3 The Construction Quality Assurance Final Report

The CQA Final Report, will be submitted by the Engineer to the Employer within 40 days of completion of installation of the lining system.

At a minimum the CQA Final Report shall contain the following information:

- An outline of the project
- A description of the lining/system
- Reference to the CQA Plan and other documents used
- Geosynthetic membrane and other geosynthetic materials specifications
- A summary of on-site CQA activities and quantities (samples, failing results)
- A photographic record of construction
- Manufacturer/GSM Installer Compliance Agreement
- Subgrade acceptance certificates
- Copies of all logs
- All test results
- Discussion of problems and solutions
- Record drawings
- Certificate statement

The record drawings must show:

- Tolerances
- The locations of all geosynthetic membrane joints and the types of joints
- GSM panel and roll numbers, and GSM type
- The location of all geosynthetic membrane repairs and the types of repairs
- Toes of slopes
- Crests of slopes
- Location of anchor trenches
- Location and numbers of any GSM destructive test sample sites
- Construction details that differ from as-designed details.