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CONCEPTUAL DESIGN REPORT FOR THE EXTENSION OF THE ASH DAM AT CAMDEN POWER STATION

Report No : 12670-Eng-01

Submitted to:

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EXECUTIVE SUMMARY

The Camden Power Station is located approximately 15 km to South East of the town of Ermelo in the Mpumalanga province and has a production capacity of 1,600 MW. The first of its eight units was commissioned in 1967. Half of the station was mothballed in 1988 with the rest of the station following suit in 1990. Increase in the demand for electricity lead to a decision being taken in 2003 to re-commission the Camden Power Station. The first unit was re-commissioned in 2005. The existing ash dam was adequate at that stage for future operation of the plant.

In 2010, following a stability assessment of the dam, it was revealed that due to the poor coal quality used at the power station, the ash dam has adequate capacity until 2014.

In June 2011 Eskom appointed Zitholele Consulting to conduct the EIA for the extension of the ash dam at the Camden Power Station. This conceptual engineering report was undertaken to underpin the Environmental application. Three alternate sites were looked at during the EIA process which was evaluated at an engineering level.

The scope of work for the conceptual designs entailed the following:

- Spatial modelling to determine the footprint.
- Design and layout of a leachate/drainage system.
- Design of surface/stormwater diversion/collection systems.
- Liner design, including a leak detection system.
- Design of ash return water dams.
- Layout for return water system.
- Layout of access roads.

The Phase I Geotechnical evaluation of the site revealed that Site 2 was not feasible due to the following site characteristics:

- It falls within the headwaters of a stream
- Shallow groundwater seepage
- Located on the geological contact between the dolerite and host sedimentary rocks. Fractures and joints are associated with this area.

The geotechnical evaluation also revealed that there are insufficient quantities of naturally graded clay available for the liner and alternatives must be looked at. This may entail using a geosynthetic clay liner (GCL).

The remaining sites were further evaluated. However, Site 3 was divided into two sites, 3A and 3B due to its topography and the watershed dividing the site equally. Conceptual designs were undertaken on these three sites.

The earthworks modelling of the site revealed that Site 1 is adequate for ash storage and is able to accommodate the entire 19 years production with a height restriction of 40 metres. Sites 3A and B could not achieve this individually and must be combined if this is to be achieved.

Sites 3A and B do not individually accommodate the ash production over the 19 years operation period and therefore cannot be compared directly to the cost of Site 1. However Sites 3A (R909,813,868) and 3B (R766,474,632) combined (R1,676,288,500) can be compared directly with Site 1 (R1,384,574,329) with regards to capital cost. However, this will entail operating one site first and on rehabilitation of the first site, commission the second site.

Site 1 is the preferred site as it can accommodate the full ash production for the 19 years ash production keeping within the 40 metres allowable height. The shape of the ash dam will also facilitate the ease of operations. The combination of Sites 3A and 3B may be looked at only as a back-up to Site 1.

The use of GCL in the liner system is recommended subject to detailed testing providing its acceptability. There exists a high probability of adequate quantities of natural clay not being available in close proximity to the site. Rates for the importation of clay from further away sources may increase the costs of the liner significantly. Other alternatives to the in-situ clay are HDPE and bauxite.

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1 INTRODUCTION AND BACKGROUND

The Camden Power Station is located approximately 15 km to South East of the town of Ermelo in the Mpumalanga province and has a production capacity of 1,600 MW. The first of its eight units was commissioned in 1967.

Half of the station was mothballed in 1988 with the rest of the station following suit in 1990. Increase in the demand for electricity lead to a decision being taken in 2003 to re-commission the Camden Power Station. The first unit was re-commissioned in 2005.

As part of the re-commissioning process, Eskom commissioned a study to verify the stability of the existing ash facility to cope with the increase in ash production and disposal. The investigations concluded that the existing facility was suitable for re-commissioning. An investigation in 2010 by Nico Barnard however concluded that the existing ash dam had adequate capacity until 2014. The reduction in the life span of the existing dam is due to the poor quality of coal supplied to station and hence the increase in the ash content.

In June 2011 Eskom appointed Zitholele Consulting to conduct the EIA for the extension of the ash disposal facility at the Camden Power Station. This report documents the conceptual engineering design of the new facility to support the EIA application.

The scope of work for the conceptual designs will entail the following:

- Spatial modelling to determine the footprint.
- Design and layout of a leachate/drainage system.
- Design of surface/stormwater diversion/collection systems.
- Liner design, including a leak detection system.
- Design of ash return water dams.
- Layout for return water system.
- Layout of access roads.

The current ash disposal facility is operated safely and therefore it is anticipated that the current method of operations will be retained. In the project initiation stage the design team will meet with the operational staff of the Power Station to establish the following amongst others:

- The method of ashing, including method of mixing (i.e. is the slurry a combination of course and fly ash or are they pumped separately),
- The ratio of ash to water (consistency of slurry),

- Slurry density,
- Method of deposition, including number of discharge points,
- Number of compartments operated,
- Method of daywall construction,
- Preferred method of decant (i.e. via decant penstocks or barge pumps),
- Safe angle for the outer slope,
- Starter wall heights and slopes and
- Preferred rate of raise (m/year).

The existing ash water return dam is a natural Pan (De Jagers Pan). New Return Water Dams are proposed to comply with the latest legislation.

2 WASTE CLASSIFICATION

A classification of the ash produced at the Camden Power Station was undertaken by Jones and Wagener (Report No.: JW1664/11/D116) in November 2011. The report is attached to the appendices.

3 BASIS OF DESIGN

3.1 Assumptions and Limitations

The following assumptions were made in developing the conceptual design:

- The life of the power station was taken as 2014 to 2033.
- The existing method of mixing, transporting and placing of ash would be retained.
- The sizing of the ash return water dam was based on the water balancing.
- The soils on and around the power station are unsuitable for use in the liner construction.
- The existing ash return water dam (De Jagers Pan) is unsuitable for reuse and hence a new return water dam (RWD) is required.
- None of the options have taken into account the requirements for the closure of the existing ash dam.
- As the current facility is operated safely operating methods are to be retained, it will be assumed that for the conceptual designs no stability analysis or material testing is required.

- The requirements for clean and dirty water systems stipulated in Regulation 704 (Section 6) and Regulation 1560 of the National Water Act will be adhered to.
- The quality of the coal will not change and hence the volume of ash produced will not change.
- The quality of the ash and hence the water to ash ratio will not change from what is currently being placed on the existing ash disposal facility.

3.2 Ash Characteristics

Based on previous studies on the existing ash disposal facility and literature the following ash characteristics were assumed:

Table 1: Ash Characteristics

Parameter	Unit	Value
Specific Gravity	N/A	2.1
Dry Density	kg/m^3	1,000
Slurry Density	kg/m^3	1,096
Ash to water ratio	N/A	1:5
Angle of friction	degrees	34

3.3 Grading

The fly ash varies from silty sand to silty clay using a triangular soil classification chart (US corps of Engineers). The grading curve exhibits a uniform particle size distribution. Crushed coarse bottom ash particle sizes ranges between 0.001 mm and 10 mm (Brackley et al, 1987). If not crushed, particles can be larger, possibly up 150 mm. These can be broken up during mixing and transport.

3.4 Stability

The stability of the residue and embankment walls must be ensured throughout the design life of the facility. No stability analyses were carried out for this study. However based on studies such as Brackley et al (1987) and stability analysis of the existing facility, the ash will be stable with an outer slope of 1:3. This is however dependent on a well-managed pool and drainage system.

The compacted earth starter walls with a crest width of 5 m, inner slope of 1:1.5 and outer operational slope of 1:3 and closure slope of 1:5 is considered stable founding conditions will have to be assessed later and modified if required.

Similarly the anticipated height of 40 m for some of the options must be evaluated as part of the next phase. A suitable and safe engineered wall and slope geometry must be determined.

The angle of friction of the ash at 20% moisture content and 1,000 kg/m^3 bulk density (simulating loosely placed ash dump conditions) is 35º and zero cohesion (Smith).

Pozzolanic properties of the ash can influence its strength.

3.5 Capacity Requirements

Eskom commissioned an investigation in 2010 by Nic Barnard on the life span of the existing ash disposal facility. The investigation concluded that the existing facility will run out of capacity by 2014. As the power station is expected to be operational until the year 2033, a new facility will have to be constructed to provide disposal capacity for 19 years.

The Camden Power Station burns on average 5,000,000 tons of coal annually. The ash content in the coal is taken as 32%. The Unit Weight of the ash is taken as 1t/m^3. The table below reflects the ash production for the life of the new ash disposal facility.

Table 2: Ash Production

YEAR	COAL BURN (TON)	ASH PERCENTAGE	ASH PRODUCTION (TON)	ASH PRODUCTION (M^3)	CUMULATIVE ASH PRODUCTION (M^3)
2011	5,039,000	32	1,612,480	1,612,480	1,612,480
2012	5,545,000	32	1,774,400	1,774,400	3,386,880
2013	5,096,000	32	1,630,720	1,630,720	5,017,600
2014	4,989,000	32	1,596,480	1,596,480	6,614,080
2015	5,195,000	32	1,662,400	1,662,400	8,276,480
2016	4,832,000	32	1,546,240	1,546,240	9,822,720
2017	4,960,000	32	1,587,200	1,587,200	11,409,920
2018	4,997,000	32	1,599,040	1,599,040	13,008,960
2019	5,194,000	32	1,662,080	1,662,080	14,671,040
2020	4,829,000	32	1,545,280	1,545,280	16,216,320
2021	4,829,000	32	1,545,280	1,545,280	17,761,600
2022	4,829,000	32	1,545,280	1,545,280	19,306,880
2023	4,829,000	32	1,545,280	1,545,280	20,852,160
2024	4,829,000	32	1,545,280	1,545,280	22,397,440
2025	4,829,000	32	1,545,280	1,545,280	23,942,720
2026	4,829,000	32	1,545,280	1,545,280	25,488,000
2027	4,829,000	32	1,545,280	1,545,280	27,033,280
2028	4,829,000	32	1,545,280	1,545,280	28,578,560

2029	4,829,000	32	1,545,280	1,545,280	30,123,840
2030	4,829,000	32	1,545,280	1,545,280	31,669,120
2031	4,829,000	32	1,545,280	1,545,280	33,214,400
2032	4,829,000	32	1,545,280	1,545,280	34,759,680
2033	4,829,000	32	1,545,280	1,545,280	36,304,960

3.6 Water Supply for Ashing

Water from the RWD, supplemented by blow down water, will be utilised in creating the ash slurry that is required for pumping to the ash disposal facility. The water requirement will be the same for the existing operations as it is assumed that the ash production, and disposal thereof, will be the same. Current operations will also continue.

3.7 Permeability

The permeability is largely dependent on the density of the ash on the facility. A value of 11.5 m/year for medium dense ash was assumed. This is the mean of 3 m/y (dense ash) to 20 m/year (loose ash) (Brackley et al, 1987) ($6.34*10^{-7}$ m/sec). This is required for calculating seepage from the pool to the leachate collection system.

3.8 Annual Rate of Rise

A preferred maximum rate of rise of 2.0 m/year was assumed for sizing the ash disposal facility. This is a manageable rate in terms of operating the facility using a cycled daywall construction method. Also, the 2 m/year rate of rise is below the accepted maximum for well drained disposal facilities.

3.9 Water Balance

A copy of the existing water balance for the Camden Power Station is attached to the appendices. The system does not generate excess water and hence no spillages are expected from the ashing system.

4 SITE SELECTION AND OPTIONS ANALYSIS

4.1 Description of Existing Site Conditions

The site of the existing ash disposal facility is situated outside the north western boundary of the power station and covers a total area of 120 hectares.

The study area is in a summer rainfall area with the annual precipitation in the 650 to 900 mm range with January being statistically the highest rainfall month. Average daily temperatures vary from 7°C minimum to 20°C maximum with extremes of -8°C and 32°C.

4.2 Site Selection Process

Four potential sites were identified initially using the following criteria:

- Ability to link into existing ash disposal facilities
- Must be within a 10 km radius from the existing disposal site and its associated facilities
- Had to have a minimum footprint area of 120 hectares

The four sites were identified during a workshop with all relevant stakeholders. These four sites were further evaluated using several “fatal flaw” identification criteria. Of the four sites, one was deemed to be fatally flawed and three were assessed further. This is discussed in detail in the Environmental Scoping Report. The proposed short listed sites are shown on Figure 4-1.

4.2.1 Description of Shortlisted Sites

The three sites chosen above are shown on the attached Site Locality drawing. All three sites are in close proximity to the existing site and are subject to similar site conditions as documented in the previous section.

4.2.2 Site 1

This site is located immediately north of the existing ash disposal facility and approximately 2.8 km north-west of the Camden Power Station. Approximately 300 m to the east of the proposed site is the village of Camden. The total area chosen is 272 hectares with the terrain sloping in the northerly direction (away from De Jagers Pan) at 2.6%. Vegetation cover consists of typical Highveld grass. The site is currently not used for any activities.

4.2.3 Site 2

The second site is located approximately 1.2 km south of the Camden power Station and immediately south of the South African Railways (SAR) servitude. Coal stockpiles and water storage facilities are located to the north and northwest of this area. The total area potentially available for development is 291 hectares. Natural drainage over the site is split in the north easterly and south easterly directions at approximately 4%. The site is currently undeveloped and there are no visible farming activities.

The site is situated within the headwaters of a non-perennial north flowing stream that flows into the Witpuntspruit approximately 3 km to the north-east.

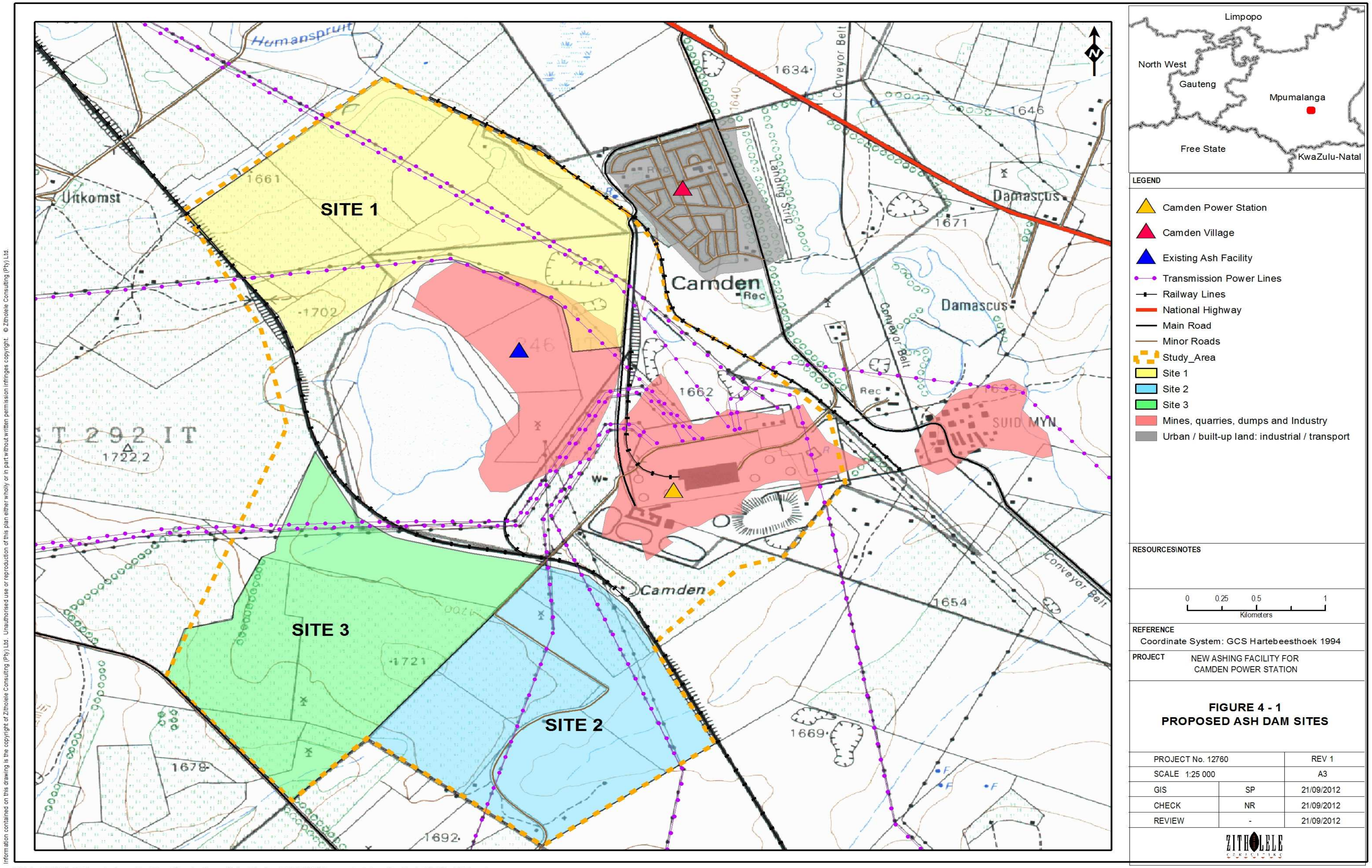

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Figure 4-1: Proposed Ash Disposal Sites

4.2.4 Site 3

This site is located immediately south of De Jagers Pan and the SAR servitude, approximately 3 km south west of the Camden Power Station. The total area available for development is 322 hectares. A natural watershed divides the site, sloping in a north easterly direction towards De Jagers Pan and in a south easterly direction away from the Pan at a constant grade of 4%. Some form of agricultural activity is currently taking place at this site.

The eastern side of the site partially encroaches a drainage course of a small north easterly flowing non-perennial stream.

4.3 Engineering Geological Evaluation

An Engineering Geological Evaluation of the shortlisted sites was then commissioned. A report of the investigation and findings is attached as Appendix B.

The objectives of the evaluation were to determine the geotechnical and geological conditions that prevail beneath each of the three shortlisted sites and to provide an assessment of:

- the soil conditions at surface
- the nature and extent of near surface and outcropping strata
- existence of potential fatal flaws
- comment on any geotechnical problems that may impact upon the site selection
- recommendations for mitigation

A brief summary for each site is given below.

4.3.1 Site 1

The entire site appears to be underlain by inter bedded sandstone and siltstone of the Vryheid formation. No evidence of the presence of intruded sills and dykes were identified. Groundwater seepage was not observed on the site and no seepage was recorded in the test pits. The underlying soils consist of a shallow horizon of transported soils to an approximate depth of 500 mm which is overly ferruginised, jointed re-worked residual siltstone. Weathering is expected to extend to a depth of between 3 to 5 m.

4.3.2 Site 2

From the geological information available it is apparent that the site straddles the contact between the host sedimentary formations on the western side and an intruded dolerite sill to the east. The contact between the two geological lithologies is approximately along the perennial stream mentioned above. Due to the emplacement of the igneous material, the contact zone is typically fractured and differential weathering of the rock may result in deep residual soils occurring along the boundary. The underlying soils on the site consist of a shallow horizon transported silty and clayey soils to an approximate depth of between 500 mm and one metre, which is overly ferruginised, jointed re-worked residual siltstone. The depth of weathering is anticipated to extend to a depth of between 3 to 5 m.

Shallow ground water seepage was observed on the northern portion of the site and due to the topographic setting, significant seepage and surface runoff must be expected during periods of high rainfall.

4.3.3 Site 3

The entire site is appears to be underlain by inter bedded sandstone and siltstone of the Vryheid formation. No evidence of the presence of intruded sills and dykes were identified. Groundwater seepage was not observed on the site and no seepage was recorded in the test pits. However, it is likely that the area may be subjected to seasonal seepage. The underlying soils consist of a shallow horizon of transported soils to an approximate depth of 500 mm which is overly ferruginised, jointed re-worked residual siltstone. Weathering is expected to extend to a depth of between 3 to 5 m.

4.3.4 Geotechnical recommendations

On the basis of this evaluation, it was derived that Site 2 is not suitable for the intended development and should not be considered for further investigation. This is due to the following site characteristics:

- It falls within the headwaters of a stream
- Shallow groundwater seepage
- Located on the geological contact between the dolerite and host sedimentary rocks. Fractures and joints are associated with this area.

The remaining sites are both considered to be suitable for further evaluation. From a geological and geotechnical perspective, Site 1 is the preferred site.

5 WATER BALANCE

It is assumed that there will be insignificant change to the overall water balance as the return water to the plant will be the same as the current operations. The current ratio of mixing and the slurry discharge rate will be maintained.

6 CONCEPTUAL DESIGN

6.1 Site Access and Roads

The site will be accessed via extensions to the existing roads. An access road exists on the eastern side of the existing ash dam and a road leads to the return water dam to the west of it. The roads are gravel and are in fair condition. It is proposed to link the new roads to the existing roads. A 5 m step-in is proposed on the ash dam for vehicular access. A gravel base with a stabilised wearing course is proposed for the site access roads. All accesses to the new facility will be fully secured by means of 1.8 m high diamond mesh fencing.

6.2 Site Services

Apart from the access roads, no other services are envisaged for the new development. Pipelines are discussed in subsequent sections.

6.3 Ash Disposal

The ash slurry is pumped from the power station to a central distribution point situated at a high point on the southern perimeter of the ash disposal facility. From the distribution point the fly ash and the coarse ash are channelled through various open trenches and allowed to gravitate into the appropriate paddocks.

The ash disposal deposition method will be the same for each option. Initial deposition needs to be contained using a starter earth wall for each compartment. This initial deposition area is thus very small and grows as the compartment basin fills. Due to the small area the rate of rise is high initially. The ash does not have enough time to consolidate and gain sufficient strength to support itself. The starter wall is thus built to a height where the rate of rise is 2 m/year. A transition from open end deposition to a spiggotting or daywall method is required once the starter wall height is reached. This is required for two reasons.

- Firstly the ash cannot be gravitated to the upper compartment from the level of the distribution box.

- Secondly, at this point the ash may be used to build walls in an upstream direction.

Spiggotting in a cycle around the entire perimeter of each compartment allows the walls to be built in a stable way and enables proper pool and freeboard control.

Spiggotting allows for the slurry to be deposited in thin layers, which are then allowed to dry out and consolidate. A specified cycle time is allowed between the layers which is dependent on the geometry of the deposit and consolidation parameters. The deposit thus gains sufficient strength and rises continuously. An increase of 2 m in height over a year period was accepted for this study.

Figure 6-1: Typical Ash Slurry Discharge

Figure 6-2: Typical Ash Distribution Channel

Water will be decanted from the pool using penstocks. Up to two temporary penstock inlets per compartment in the initial phases will be required. A permanent penstock, central to each compartment will then be installed and operated for the life of the facility.

Figure 6-3: Typical Penstock Decant

In developing these options various operational aspects were assumed which help reduce risks associated with the operation of the ash dam and reduce potential environmental impacts. These include, inter alia:

- The pool will be operated at a minimum level; i.e. water will not be stored on the ash dam except during major storm events, in which case the water will be decanted as quickly as the penstock will safely allow. If water is stored on the dam the ash dam will need to be licensed as a water dam with the dam safety office according to regulation 1560 of the National Water Act (1998).
- More than one compartment allows flexibility in terms of deposition if a compartment requires maintenance.

A penstock consists of a vertical decant tower and an inclined horizontal conduit. The penstock's function is to remove the free water from the top surface of the ash disposal facility, thereby recovering the water for re-use in the next cycle of ashing. The penstock has been designed to decant all the water from the ashing operations and is also capable of removing the storm water from a 1 in 50 year 24 hour storm in 96 hours off the facility with one penstock functioning, or 48 hours with two penstocks functioning.

Penstocks are a very important part of an ash disposal facility operation but are notoriously unreliable. For this reason most slimes dams have two penstocks. Should a penstock fail and need replacement, ashing could continue without disruption using the other penstock. There are currently two penstocks on either side of the dividing wall of the ash disposal facility. Theoretical calculations show that the concrete penstock rings can safely carry the forces resulting from an ash height of 24m. The rings will experience crushing failure from 35m of ash onwards.

In order to reduce the risk of cavity formation in the future, it is important to double wrap the vertical sections of the penstock decant tower with a U24 geotextile once the rings have been placed.

6.4 Pipelines

Once the existing ashing facility has reached its design capacity, the slurry pipeline will be discontinued to this discharge point. The pipeline will be extended from the existing pipeline to the new facility by a 6 mm thick, 350 mm diameter steel pipeline and approximately 2 kilometres long to the preferred site. This will be installed above surface and fixed to concrete plinths.

The existing return water pipeline from De Jagers Pan will need to remain in place after the existing facility has reached its design capacity. This will be required in order to manage stormwater that either runs off the contaminated terrain and side slopes of the facility or any stormwater that recharges through the facility before it is capped. A new return water pipeline will need to be installed from the return water dam back to the power station. A new 400 mm diameter High Density Polyethylene (HDPE) pipeline with a rating of PE80 PN 12.5 approximately 5 km long is proposed for the return water pipeline. This pipeline will be buried within a trench approximately 1.5 m deep.

6.5 Liner System

6.5.1 Liner Design

It should be noted that wet ashing is not a new solution for ash disposal and Eskom has developed this technology for a number of their power stations between 1960 and 1980 however, but the requirements for lining of the ash disposal facilities is new. This poses new challenges to the operating methods of ash disposal facilities. With the introduction of a liner system the management of compartments becomes critical, as it will not be practical to line the entire facility on initiation as the risk of liner damage will be high. The number and sequencing of compartments will have to be discussed and agreed with the operational staff and Eskom's technical managers/engineers as this impacts the cash flow of the project.

The interaction between the liner and the ash also needs to be investigated (both chemically and structurally). The Waste Classification report, attached to the appendices, proposes a Class C barrier as per the DEA's regulations (not promulgated as yet) for both the co-disposal as well as mono-disposal of ash. However, DWA Minimum requirements indicates that a H:H Lagoon Barrier System is required and this has been included in the design. The typical cross section of the H:H Lagoon Barrier System is given in Figure 6-4: H:H Lagoon Barrier System

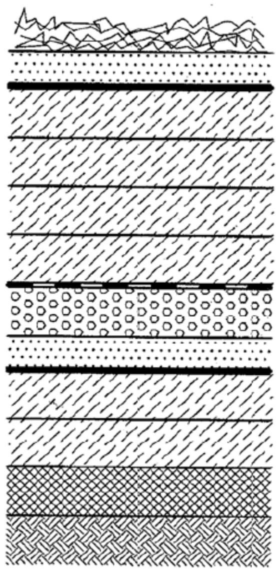

Figure 6-4: H:H Lagoon Barrier System

An HDPE sheet is used for the geomembrane indicated in Figure 6-4 above. The thickness of the HDPE sheet is indicated in the figure. River sand is proposed to be used for the cushion layer. Grade A4 bidim is proposed for the geotextile layer.

The liner system also calls for a 900mm clay layer. Large quantities of clay are not available on site. Importation of clay is possible however may not be economically viable. The following are alternatives to the clay liner:

- HDPE
- Geosynthetic Clay liner (GCL)
- Bauxite

These options need to be investigated during detailed design of the facility.

6.5.2 Liner Installation

For each option, the footprint area was determined at each 8 m height interval. These are shown in the three figures below. This was done in order to propose an optimal way of constructing the liner system for the facility without creating delays in deposition of the ash. It was assumed that the installed liner system must create adequate storage capacity for at least three years of operation.

This proposed exercise is carried forward to the staged costing of the facility and the applicable operating costs.

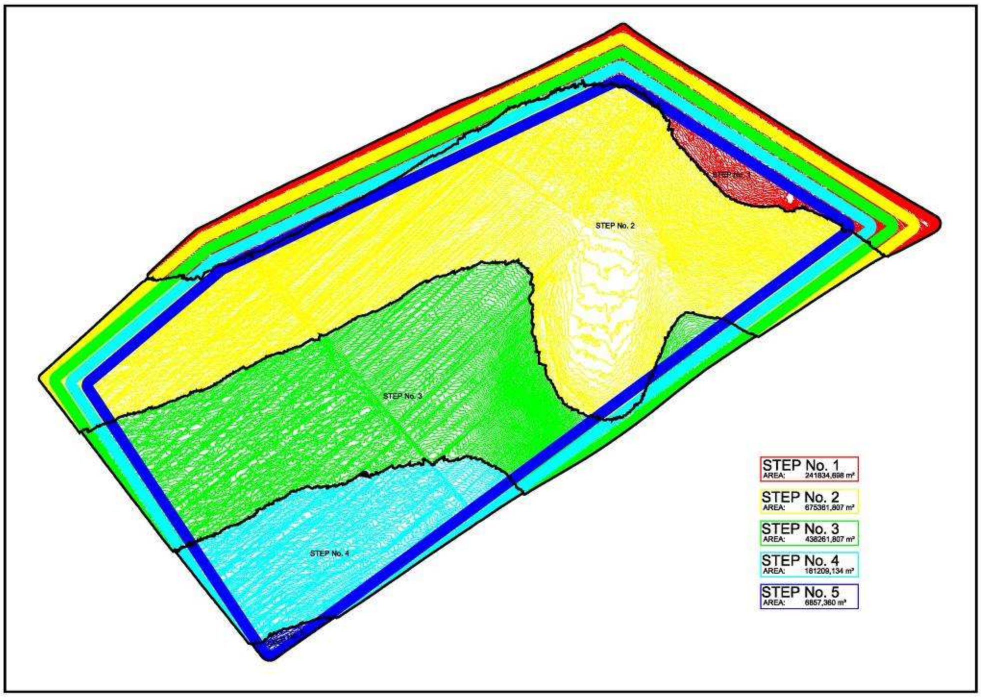

Figure 6-5: Phased Installation of Liner System for Site 1

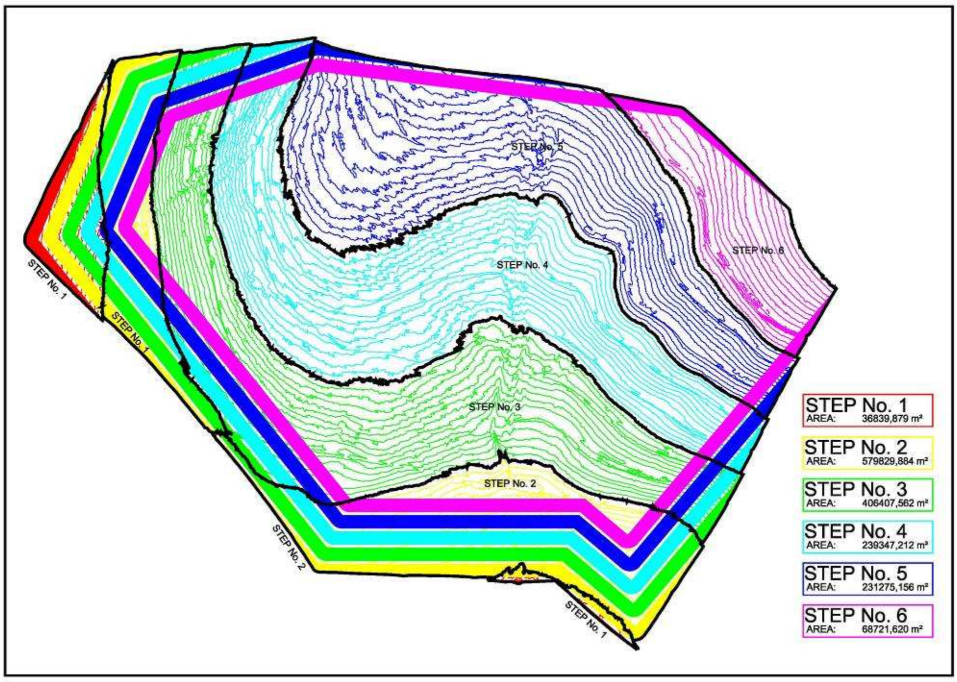

Figure 6-6: Phased Installation of Liner System for Site 3A

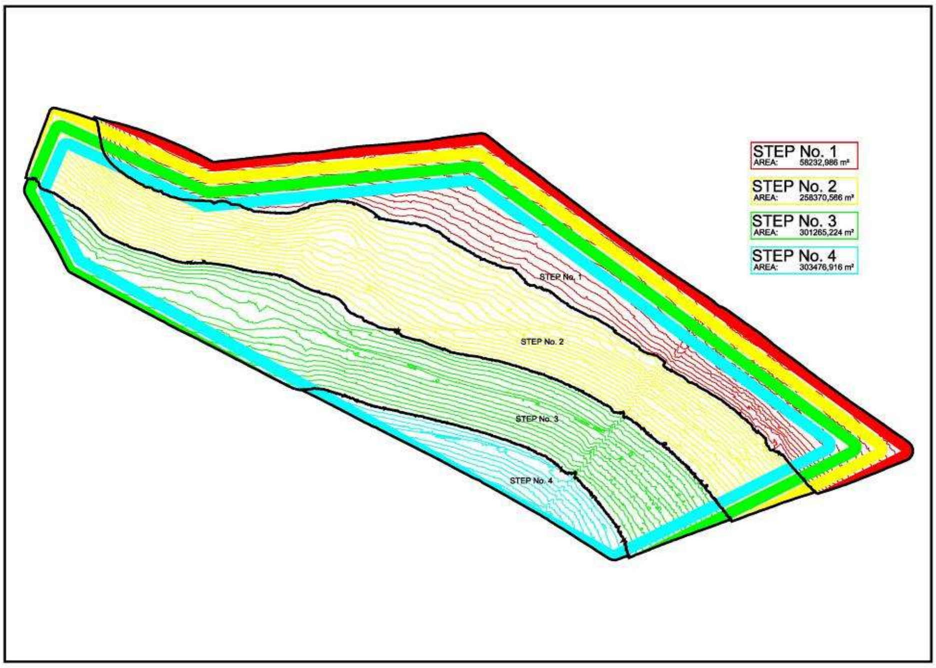

Figure 6-7: Phased Installation of Liner System for Site 3B

Each of the options was assessed in terms of the above methodology. The tables below summarise what is indicated graphically above and puts it into perspective by showing a time line.

Table 3: Liner Required for Site 1

Step No	Elevation	Footprint	Acc. Foot	Volume	Year	
	mamsl	m^2	m^2	m^3	From	To
						2014
1	1669.3	241,800	241,800	468,700	2014	2014
2	1677.3	675,400	917,200	4,425,200	2014	2015
3	1685.3	438,300	1,355,500	12,570,500	2015	2020
4	1693.3	181,200	1,536,700	22,192,100	2020	2027
5	1701.3	6,800	1,543,500	31,134,600	2027	2032

Table 4: Liner Required for Site 3A

Step No	Elevation	Footprint	Acc. Foot	Volume	Year	
	mamsl	m^2	m^2	m^3	From	To
						2014
1	1673.5	36,840	36,840	98,292	2014	2014
2	1681.5	579,830	616,670	906,215	2014	2014
3	1689.5	406,408	1,023,078	3,161,205	2014	2014
4	1697.5	239,347	1,262,425	6,876,435	2014	2017
5	1705.5	231,275	1,493,700	12,080,773	2017	2020
6	1713.5	68,722	1,562,422	17,379,228	2020	2023

Table 5: Liner Required for Site 3B

Step No	Elevation	Footprint	Acc. Foot	Volume	Year	
	mamsl	m^2	m^2	m^3	From	To
						2014
1	1693	58,233	58,233	934,204	2014	2014
2	1701	258,371	316,604	3,950,256	2014	2015
3	1709	301,265	617,869	8,731,753	2015	2018
4	1717	303,477	921,346	13,995,091	2018	2021

In order to achieve liner preparation for a minimum of three years, all three options can be achieved in three phases. However, due to the small quantities of the remaining footprint area, it is proposed that all three options be undertaken in two phases. This is summarised in the table below.

Table 6: Phased Installation of Liner System

Site No	Phase	Liner Area m^2
1	I	1,355,459
	II	188,066
3A	I	1,262,425
	II	299,997
3B	I	617,869
	II	303,477

There are several other methods of obtaining a phased approach of the liner installation. This may include determining the footprint area of the ash disposal site on a yearly basis. This will not be addressed at conceptual stage but should be looked at during preliminary design phase. A methodology for the phased approach is only demonstrated here.

6.6 Storm Water Management

For each of the feasible proposed sites, an upstream lined channel shall be constructed to divert clean water around the proposed facility and discharge into the natural environment. The channel will be sized to accommodate the 1 in 100 year storm event. Each site is positioned such that the area between the natural watershed and the proposed facility that is not impacted by ash is a minimum. The proposed sizes of the trapezoidal channels, with side slopes of 1.5:1 (h:v) and base width of 1 m, required are listed in the table below:

Table 7: Sizing of Clean Water Diversion Trench

Site No	"Clean" Area (ha)	Flow Rate (m^3/s)	Channel Length (m)	Channel Height (mm)	Channel Top Width (mm)
1	30.1	11.0	2100	800	3400
3A	13.1	10.1	1700	700	3100
3B	28.2	11.4	1800	700	3100
3B	27.5	10.4	1200	700	3100

The channels will be concrete lined in order to facilitate cleaning. The slope of the channels for Sites 3A and B are marginally steeper than that of Site 1.

Dirty water run-off generated off the side slopes will drain into a suitable sized "solution trench" running around the facility. These trenches will be designed to receive and convey run-off generated after a 50 year storm event. The solution trenches will also receive discharge from the leachate collection system and this flow will also be required to be included in its sizing. Conceptual sizes of the trapezoidal channels, with side slopes of 1.5:1 (h:v) and base width of 1 m, required are listed in the table below:

Table 8: Sizing of Solution Trenches

Site No	Channel ID	Flow Rate (m^3/s)	Channel Length (m)	Channel Height (mm)	Channel Top Width (mm)
1	A	3.7	850	500	2,500
	B	8.3	1,900	700	3,100
	C	14.4	900	900	3,700
	D	18.6	1,650	1,000	4,000
3A	A	6.3	1,700	500	2,500
	B	13.7	800	800	3,400
	C	5.9	580	500	2,500
	D	3.4	730	500	2,500
3B	A	7.5	1,300	600	2,800
	B	2.6	400	400	2,200
	C	6.6	700	600	2,800
	D	16.9	1,150	900	3,700
	E	22.9	570	1,000	4,000
	F	10.5	350	700	3,100

6.7 Leachate Collection and Management

The leachate collection system will comprise of a toe drain as well as a main drain system. A leachate collection system will be designed such that a maximum leachate head of 300 mm will be maintained over the liner system. The leachate will be drained to the solution trench, discussed below, which ultimately discharges to the RWD.

The leachate collection system will be designed using a cuspated drain with geomesh above to ensure structural integrity of the system. This will be located above the liner system. The permeability, as discussed in a previous section, varies between 3 to 20 m per year. Based on this, a conservative drainage rate of 5mm/h was assumed in order to determine the size of cuspated drain required for the leachate collection system. Conceptual flows draining to the respective return water dams via the solution trenches indicated in the previous section is indicated in the table below:

Table 9: Leachate Flow Rates

Site No	Max Area for Leachate (ha)	Flow Rate (m^3/s)
1A	154	2.2
3A	101	1.4
3B	92	1.3

6.8 Return Water Dam

All run-off generated within the footprint area of the facility will be captured in the new Return Water Dam (RWD). Although Government Notice 704 (GN704) stipulates that the RWD shall be sized to accommodate the 50 year 24 hour storm event, this is based on the assumption that the RWD is empty prior to this storm event. However, this is rarely the case and a more realistic approach should be adopted. It is Best Practice to undertake continuous modelling (a daily time step model) of the system in order to ascertain a more realistic capacity of the dam. This method takes into account the operating philosophy of the facility as well any abstractions from the dam including evaporation. As this report is of a conceptual nature, this will not be undertaken here but at preliminary design stage. In order to simulate this, an assumption was made that the RWD will be 25% full prior to the 1 in 50 year storm event. The table below gives the proposed sizes of the RWD for each of the proposed options for this method which complies with the requirements of GN704

Table 10: Sizing of Return Water Dam

Site No	"Contaminated" Area (ha)	Crest Height (mamsl)	RWD Size (m^3)
1A	198.0	1663.65	174,800
3A	162.3	1669.80	153,400
3B	214.5	1682.55	180,600

Stormwater captured at the Ash disposal site pool level will be conveyed to the RWD via penstocks. The penstocks and the discharge pipes will be design such that the flow is attenuated at the pool level and drained over a 24 hour period (with two penstock inlets in operation) to the RWD.

A silt trap will be installed to remove silt from the decanted water before is enters the lined return water dam. The amount of silt in the water will need to be determined and will provide input into the detailed sizing and cleaning frequency of the silt trap.

The positions of the RWD for the various options are shown on the General Arrangement drawing attached to the appendices. A well prepared and compacted base is essential for the liner. The liner requirement for the Return Water Dam is the same for the ash facility. The liner design is discussed in the previous sections.

A provisional position for the RWD is shown for the options. Refinement to fit within the property boundary and accommodate the silt trap at the inflow section will form part of the next design phase.

6.9 Construction Methods and Sequencing

The deposition method will be the same for each option. Initial deposition needs to be contained using a starter earth wall for each compartment. This initial deposition area is thus small and grows as the compartment basin fills. Due to the small area the rate of rise is high initially. The ash does not have enough time to consolidate and gain sufficient strength to support itself. The starter wall is thus built to a height where the rate of rise is 2.0 m/year. A transition from open end deposition to a spiggotting or daywall method is required once the starter wall height is reached. This is required for two reasons. Firstly the ash cannot be gravitated to the upper compartment from the level of the distribution box. Secondly, at this point the ash may be used to build walls in an upstream direction. Spiggotting in a cycle around the entire perimeter of each compartment allows the walls to be built in a stable way and enables proper pool and freeboard control.

Spiggotting allows for the slurry to be deposited in thin layers, which is then allowed to dry out and consolidate. A specified cycle time is allowed between the layers which is dependent on the geometry of the deposit and consolidation parameters. The deposit thus gains sufficient strength and rises continuously. An increase of 2.0 m increase in height over a year period was accepted for this study.

Water will be decanted from the pool using penstocks. Up to two temporary penstocks per compartment in the initial phases will be required. A permanent penstock, central to each compartment will then be installed and operated for an extended period.

A silt trap will be installed to remove silt from the decant water before is enters the lined return water dam. The amount of silt in the water will need to be determined and will provide input into the detailed sizing and cleaning frequency of the silt trap.

The positions of the RWD for each option are shown on the attached General Arrangement of the proposed works. The dam wall crest height for each of the options is given in the previous section. A well prepared and compacted base is essential for the liner. It is highly probable that a large amount of clay will need to be imported dependant on the costs. An alternative using a GCL should be considered. This will place the liner further below the NGL which could necessitate a complex drainage system below it to prevent uplift from underground water.

A provisional position for the dam is shown for the options. Refinement to fit within the property boundary and accommodate the silt trap at the inflow section will form part of the next design phase

In developing these options various operational aspects were assumed which help reduce risks associated with the operation of the ash dam and reduce potential environmental impacts. These include, inter alia:

- The pool will be operated at a minimum level; i.e., water will not be stored on the ash dam except during major storm events, in which case the water will be decanted as quickly as the penstock will safely allow. If water is stored on the dam the ash facility will need to be licensed as a water dam with the dam safety office according to regulation 1560 of the National Water Act (1998).
- The return water dam, containing dirty water, should not spill into the natural clean water environment. For this study it is assumed that a spill once in 50 years is acceptable. This conforms to the DWAF regulation 704 for mine waste disposal.
- More than one compartment allows flexibility in terms of deposition if a compartment requires maintenance.

6.10 Capacity Modelling for Selected Sites

Three sites were short listed after the initial workshop which was further subjected to a geotechnical assessment. Two of the sites were deemed feasible for further consideration following this assessment. One of the sites was eliminated due to underlying dolorites and fractures which compromised the bearing capacity of the proposed ash disposal facility footprint.

The proposed ash disposal facility shall have an overall capacity of 28.3 million m^3 for an operational period from 2014 to 2033 (19 years including contingencies). A maximum height of 40 m has been adopted for the modelling exercise. A step height of 8 m with a benching (roadway) of 5 m was used. Apart from the starter wall, all side slopes were taken as 1 in 3. The starter wall shall have an external side slope of 1 in 3.

An area-height method was used to model the capacity for the ash dam options. This includes the capacity within the compartment basin and the volume above this as the facility crest plan area diminishes. In order to evaluate the three options the height of the starter walls (and the respective earth volumes) was determined from a stage curve of the compartment basin. Thereafter the height to contain the total volume was determined. The capacity is based on 1 in 3 overall side slopes and a preferred maximum rate of rise is 2 m/year.

The stage curve for each option is given below. The stage curve does not taken into account the shape of the beach and this should be considered during the preliminary design phase of this project.

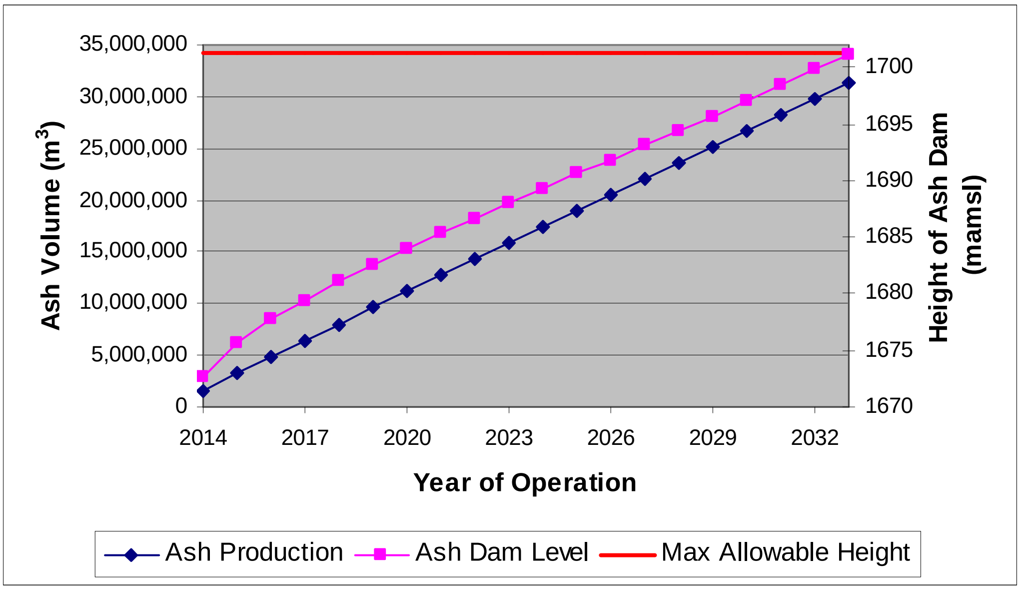

Figure 6-8: Ash Dam Stage Curve for Site 1

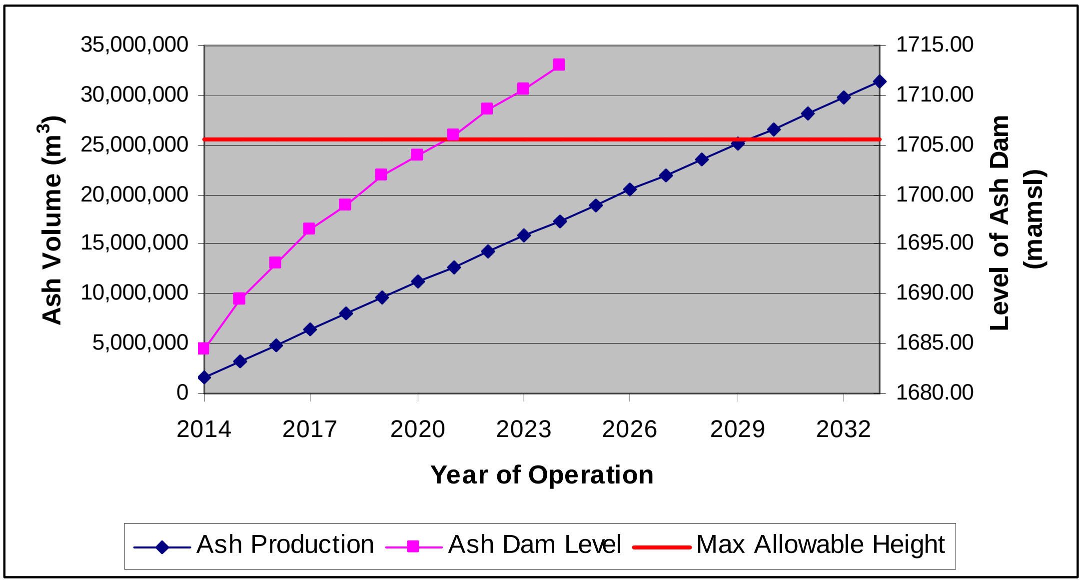

Figure 6-9: Ash Dam Stage Curve for Site 3A

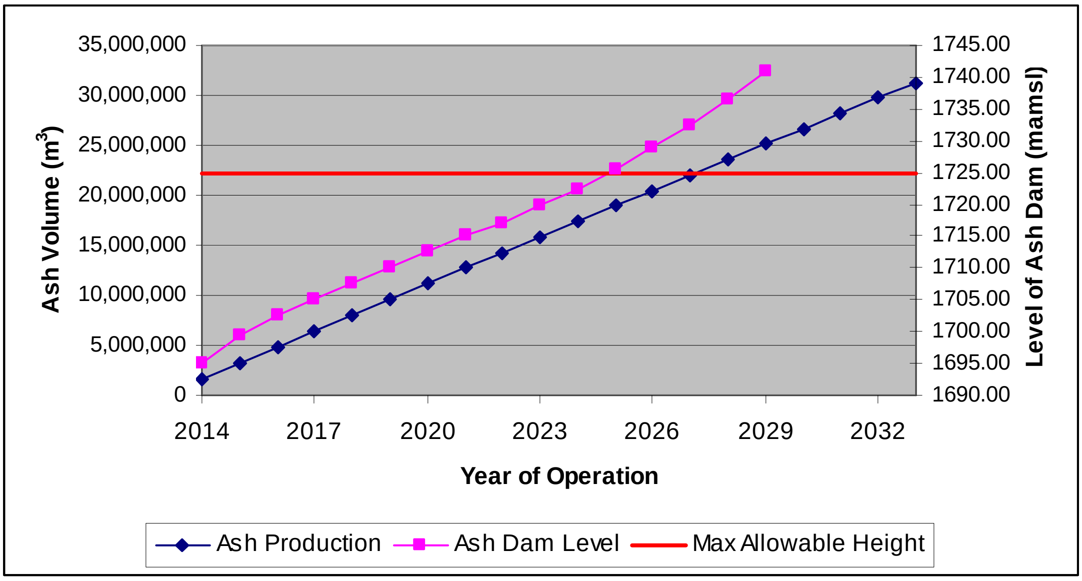

Figure 6-10: Ash Dam Stage Curve for Site 3B

The modelling indicates that only Site 1 is capable of achieving the height restrictions within the available footprint. Sites 3 A and B cannot accommodate the ash production over 19 years without significantly going over a maximum allowable height of 40 m. The model was run for Sites 3A and B up to a maximum height of 48 m and 56 m respectively. In both cases the total ash production could not be achieved, even at these heights, so the model was terminated without achieving the total required ash storage.

6.11 Relocation of services

The preferred site, Site 1, was revisited in order to determine services that may need to be relocated. There were no pipelines visible on the footprint of the site and the roads were restricted to informal tracks. This will not need relocation. Two sets of transmission lines will need realignment around the facility. A proposed route for realignment is shown on Figure 6-11.

There is sufficient area around the new facility to relocate this service.

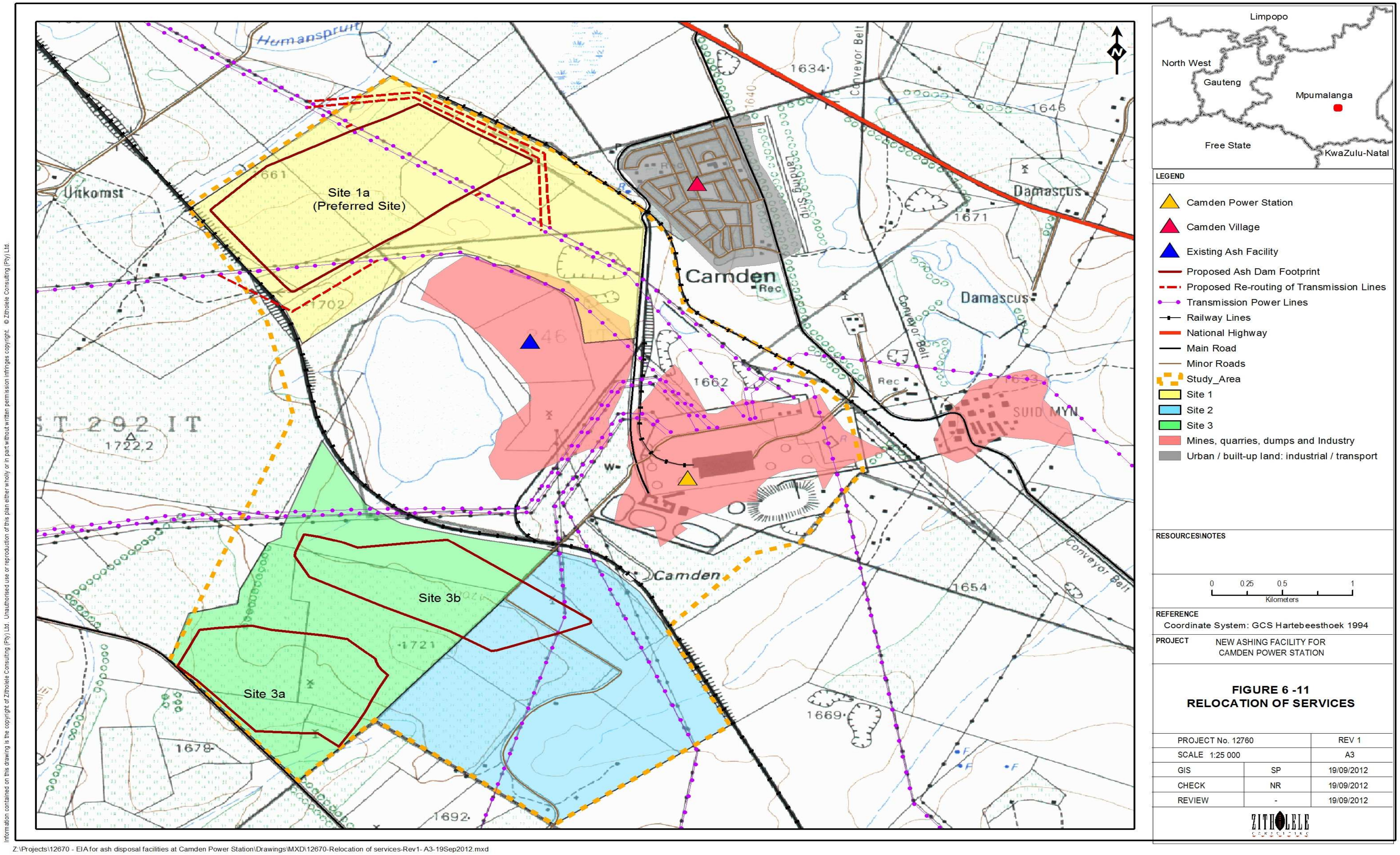

Figure 6-11: Relocation of Services

7 OPERATION AND MAINTENANCE PLAN

7.1 Introduction

This Operations Manual is to be used for the correct and cost efficient operation and maintenance of the ash disposal facility/ies at Camden Power Station. For purposes of this report, the site referred to is Site 1, the preferred site for the ash facility.

The Operations Manual is intended to inform and guide Camden's ash disposal facility operations and maintenance personnel on the requirements for the operation and maintenance of the ash facility. The design philosophies are described to assist the Operator to understand the reasons for having to carry out certain actions.

The Operations Manual first describes the philosophy of the design of the various components of the ash disposal facility and then details the requirements for the operation and maintenance of the various components. It also details the requirements for monitoring of the ash disposal facility and return water dams, maintenance procedures, rehabilitation of the facilities and environmental considerations. Lastly the legal and safety aspects relevant to the ash disposal facility are summarized.

7.2 Code requirements in terms of SABS 0286

SABS 0286 is the code of practice that regulates deposition practices of all mine residues in South Africa. This code has been introduced after the Merriespruit disaster where many people lost their life during the failure of a gold tailings dam. The code clearly defines accountabilities for the safe operation of a tailings facility. The ash disposal facility/ies at Camden power station will be operated in accordance with the SABS 0286. All references in the code to The Owner or The Mine Manager shall be read to mean The Power Station Manager. The following points from the code are highlighted for ease of reference:

7.2.1 Management

Refer to Clause 6 in the code.

A management framework, based on the ISO 14000 system shall be followed and will include the following components:

- Policy making
- Operation
- Setting of objectives
- Operation

- Conformance assessment
- Management review
- On-going improvement

7.2.2 Operational phase appointments

Refer to Clause 5.2.6 in the code.

The Power Station Manager shall appoint a manager to manage the ash disposal operation. This person is referred to as the Project Manager in the Operation and Maintenance Manual. The Project Manager is to appoint an appropriately qualified professional person (the Professional Engineer) to advise on the structural stability of the ash disposal facility and a second appropriately experienced person (the Contractor) to operate this facility.

The Professional Engineer is an appropriately qualified and experienced professional civil engineer in the field of mine residue deposits, who is registered with the Engineering Council of South Africa as a professional engineer or technologist.

7.2.3 Facility audit

Refer to Clause 6.4.4.6 of the code.

Audits are to be performed annually by a professional engineer for all facilities with a high hazard classification.

7.2.4 Hazard classification (See clause 7.4 of the code)

Refer to Clause 7.4 of the code.

An ash disposal facility can be given a hazard classification based on the criteria stipulated in SABS Code No 0286. The zone of influence is defined as the zone which will be affected by a failure of the tailings facility. This code provides the following three criteria to be used in determining the zone of influence for any wet tailings facility:

- A distance of 5H (H=height of the ash disposal facility at the point of consideration) upstream of the ash deposit or the distance where the natural ground reaches H/2 above the toe of the facility (whichever is the lesser).
- A distance of 10H on sides parallel to the slope of the ground.
- A distance of 100H on the downstream face of the facility.

The hazard classification is based on a number of criteria and is based on the table below:

Table 11: Hazard Classification

Workers	**Property (Millions)**	**Depth to underground mine workings**	**Classification**
<10	0-R2	>200	LOW
11-100	R2-R20	50 m -200 m	MEDIUM
>100	>R20	<50 m	HIGH

Please note the workers on the ash disposal facility are to be excluded from the total number of workers in the table above. The property includes only third party property and Eskom property should therefore not be included in the final analysis. The zone of influence, in the event of a failure, is to the north west of the site due to the topography of the site. There are between 1 and 10 residents in the zone of influence. There are less than 10 workers in the zone of influence. There is no underground mine established below the ash disposal facility. Based on this, the preferred ash disposal site at Camden, Site 1, will be classified as a **low hazard** facility.

Site 3B is considered **high risk** as it is located in close proximity and upslope of a major railway line. In the event that a facility located in this site fails, the result will be damages in excess of R20 million.

Site 3A is considered **medium risk** as it is located in close proximity and upslope of an arterial road. In the event that a facility located in this site fails, the result will be damages will be in between R2 million and R20 million.

7.2.5 Operating manual

Refer to Clause 10.4.5 of the code.

The operating manual is to be produced by a professional engineer for medium and high hazard residue deposits. The manual should address the following areas:

- Process circuit
- Water management plan
- Method of operation
- Environmental monitoring and auditing

- Safety surveillance
- Emergency response
- Decommissioning phase

7.3 Operation of the ash dam

7.3.1 Commencement of operations

The main objectives during the initial disposal of ash shall be:

- To cover all of the main and ancillary filter drains with a layer of coarse ash without washing away the top layer of the filter drains.
- To raise the day wall as quickly as possible.
- To train the operations staff to build the ash disposal facility in a controlled and safe manner.

7.3.1.1 Starter walls

To enable ash to be placed and contained within the required boundaries of the day wall, starter walls must be built. These are made by taking earth from the surrounding area and forming an earth wall against which ash can be placed. Refer to Figure 7-1and Figure 7-2.

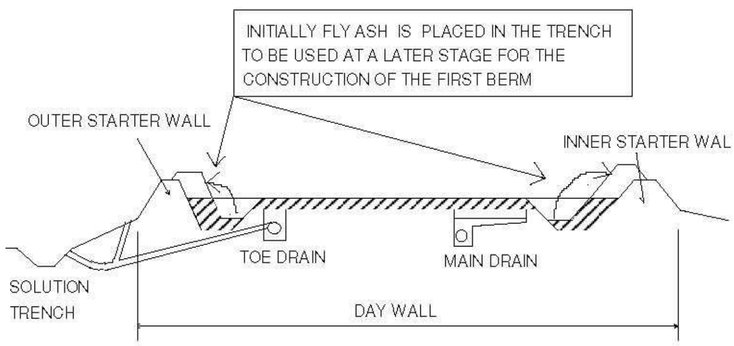

Figure 7-1: Construction of first ash berms

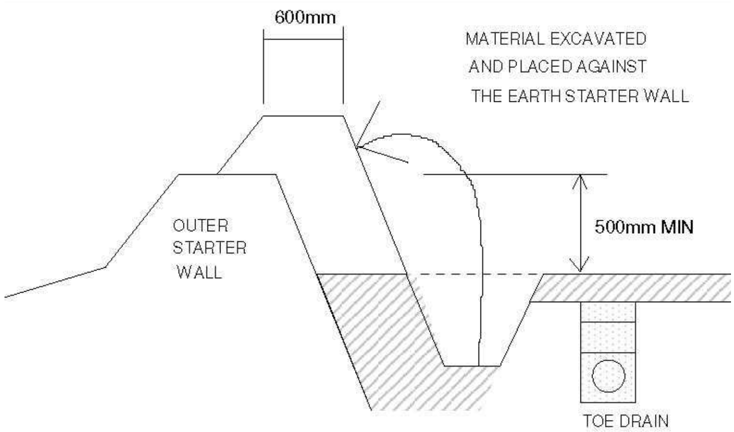

Figure 7-2: Construction of first berm and step

7.3.1.2 The initial covering of the main filter drain:

The initial method of covering the main and toe drains with ash is very important. The prime objective in covering these filter drains is to ensure they are covered with coarse ash to prevent the top layer of the filter drain from being eroded by the initial slurry flow.

7.3.1.3 Initial deposition of fly ash on the daywall

The prime objective in the initial deposition of fly ash on the day wall is to ensure that the day wall rises rapidly in the early stages so that a freeboard of at least 1 m above the night paddock is achieved and maintained. The freeboard must also not be less than 500mm above the 1:50 yr. maximum flood level (See Figure 7-3). The 1:50 yr. maximum flood level will be between 0.85 m and 1.75 m above the pool level. The actual rise in pool level is a function of the pool area. The Contractor may assume that the pool will rise by one metre under current conditions. The pool level must therefore be maintained at a level, which is at least 1.5 m below the lowest point plus the shape and slope of the area which surrounds the pool (See inside the day wall).

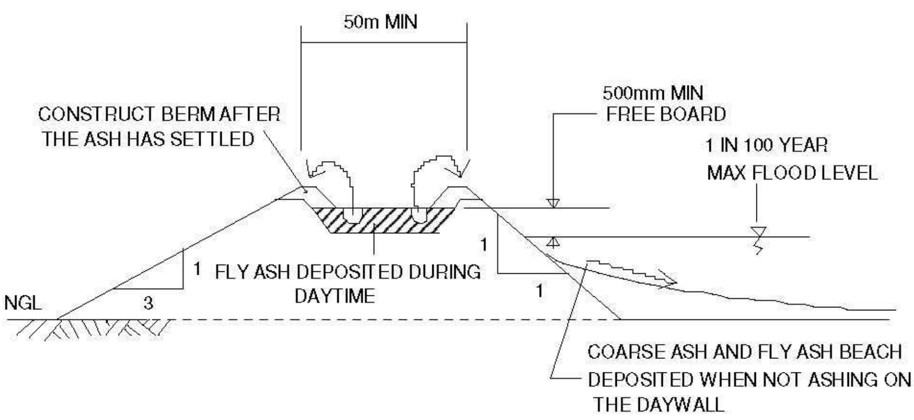

Figure 7-3: Wall building method

The day wall must be built using fly ash only. The small berms that have to be built to provide capacity for the next deposition of slurry shall be built with ash that is just dry enough to work with. This criterion will ensure that the pozzolanic action (cementing action) available in the fly ash takes place, thus reducing the future erodability of the side slope of the facility by both wind and water. If the ash is too dry, the chemical bonding will not take place and the wall will be much weaker and more permeable. Sludge from the power station may not be mixed with fly ash that is intended for use in day wall construction.

A competent backactor machine operator will be able to build 250 m of these berms in 8 hours. Compaction with a small vibratory roller will improve the pozzolanic bonding and reduce the permeability of the sides of the ash disposal facility thereby reducing its erodability. The crest width of the small berms shall not be more than 600 mm, as wider steps are unnecessary and increase the cost of running the backactor per tonne of ash deposited considerably. Wider steps require more labour and also result in greater wear on the vibratory roller. The optimum height of the step is a function of the size of the vibratory roller and the type of ash, and has to be determined on site. The berm must however be at least 500mm above the final level of the placed ash to allow for sufficient freeboard during high intensity storm conditions

7.3.1.4 Initial wall building

The prime objective of the initial wall building is to create sufficient freeboard and to build the walls in the correct place and in the correct way. Freeboard is the term used to describe the height difference between the maximum operating level of fluid in a structure and the overtopping level for that structure. Freeboard on an ash disposal facility is defined as the difference in level between the night paddock and the day wall. The minimum freeboard required by law on slime dams is 0,5m above the high water level of the dam after a 1:50 year 24hr storm. However, there are potential benefits if the freeboard is more than 0.5 m, since far more storage will be available in the case of a labour strike, machinery breakdowns or a major storm. The actual rise in the water level during a major storm depends on a number of factors such as the run-off coefficient of the top surface and the ratio of the catchment area to that of the pool area. The water level can rise between 850mm and 1750mm depending on the circumstances mentioned above. See Figure 7-3 and the more detailed explanation in the previous section. It is essential that the wall building grow above the main starter wall quickly to create this required freeboard.

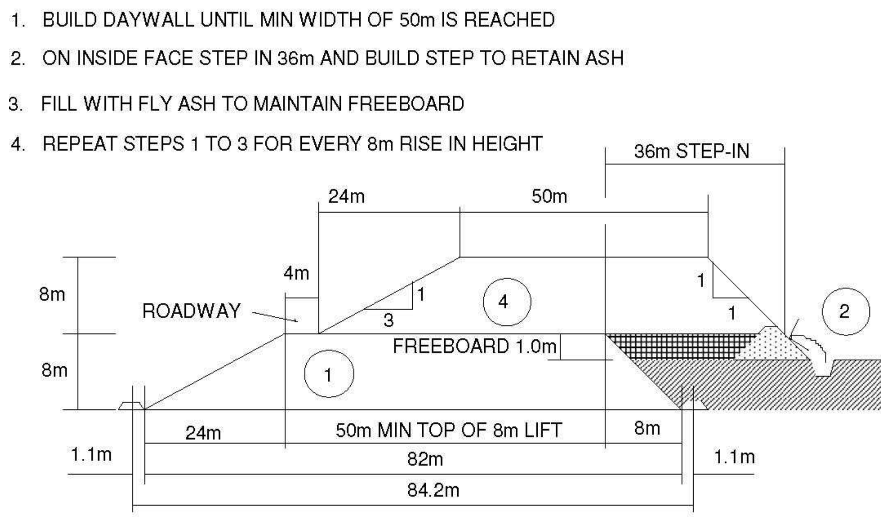

Figure 7-4: Daywall step-in process

The toe of the day wall must always tie in with the starter wall to ensure that the ash covers the toe drain and that the capacity of the ash disposal facility is maximized. Thus the steps of the ash disposal facility will not necessarily be constructed parallel to the starter wall but will bend outwards to meet the outer starter wall at the same elevation. The day wall berms or steps shall be constructed with ash that is just workable (not so wet that it cannot be worked with and not so dry that the bonded/hardened ash has to be broken) to ensure that pozzolanic and chemical bonding takes place. If the ash used for berm construction is too dry or has to be broken, the berms or steps will be susceptible to erosion and piping. The compaction of the steps with a vibratory roller will increase the density of the ash and enhance the resistance to erosion and piping.

Generally the steps should be constructed in such a way that the side of the ash disposal facility has a slope of 1 in 3 (1 metre rise for 3 metre step in), but with additional provision for access roads. The minimum width of the day wall is 50m and it must be stepped in when the minimum width has been reached.

Cross sections of the proposed facility are shown on the conceptual engineering drawings attached to the appendices.

7.3.2 Normal operation of the ash disposal facility

In any wall building operation it is essential to ensure that:

- The correct wall building procedures are being followed
- Adequate access for operation and rehabilitation is provided
- Planning and preparation for the step-in's are carried out timeously

- The total amount of wall building is optimized

7.3.2.1 Wall building

The correct wall building procedures as mentioned above should be used. As the ash disposal facility grows the day wall width will reduce to the point where there will be too much slurry to handle on the day wall. At this point it will then be necessary to step in the day wall. Typical sections showing how the step-ins will occur are shown on the conceptual engineering drawings attached to Appendix C.

Initially the day wall is 82 m wide. Generally the day wall step-in occurs where the day wall width has reduced to 50 m. The step in creates a new width of 87 m, including an allowance for a 5 m wide road.

The procedure for forming the step-ins is as follows:

1. On the inside face of the day wall step-in 36m and build up berm to a level at least 0.5m above the level of the day wall.

2. On outside face of the day wall step-in 4m for road access.

3. Fill with fly ash in separate lifts and maintain freeboard until width of day wall has reduced to 50m once again.

4. Repeat steps 1, 2, and 3 for each 8m rise in height.

This procedure will ensure that there is always sufficient capacity for daytime slurry operations and allow adequate access onto the facility.

The number of walls built to control and guide ash flow shall be kept to a minimum as the cost of operating the facility is almost directly proportional to the cost of wall building.

The 5m roadways as described above shall be covered with ferricrete gravel to reduce dust blow-off. They shall also be sloped inwards (towards the facility) with a drainage channel or take down chute leading the water down to the next roadway as shown in Figure 7-5: Roadway detail. This will reduce the amount of water running down the slopes and thereby minimize soil erosion.

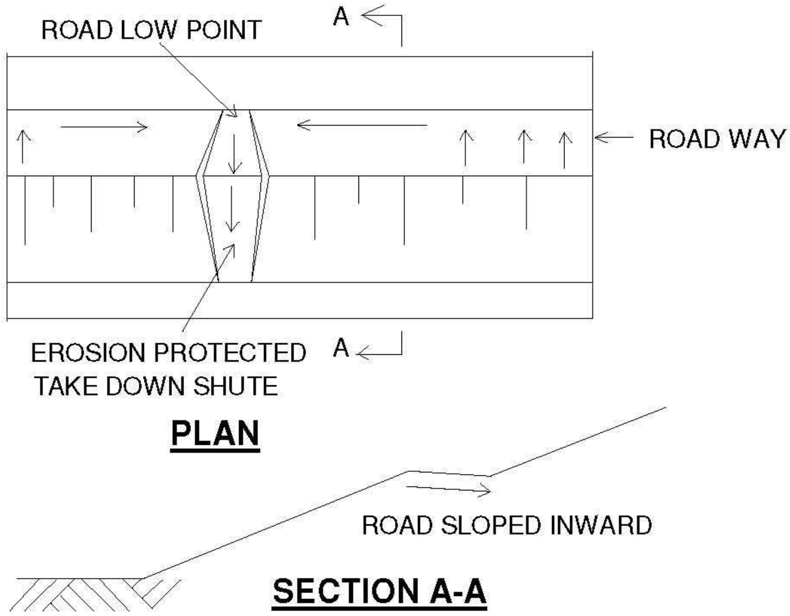

Figure 7-5: Roadway detail

7.3.2.2 Construction specification for the daywall, night-wall and innerwall sections

1. The station has four ash delivery cycles. Fine ash is transported daily at 7 AM and 7 PM and coarse ash at 3 AM and 3 PM. Camden's ash consists of 80% fine and 20% coarse ash.

2. The perimeter wall of the ash disposal facility is divided into two sections. The first section is called the day wall and runs along the outer perimeter of the facility. The day wall has a minimum width of 50 m and is used for transporting only fine ash slurry and only during daylight hours. Only fine ash from the 7 AM ashing cycle is therefore transported along the day wall. The second section is called the night wall and runs between the day wall and the inside of the facility. The night wall channels all the ash from both coarse ash cycles and the 7 PM fine ash cycle. The day wall therefore transports 40% and the night wall 60% of the station's total ash production. The rate of rise will be the same for both walls provided that the night wall has a width equal to 1.5 times that of the day wall. The daywall should always be 250 mm above the nightwall to further reduce the risk of an ash spillage during night hours. See Figure 7-6 below:

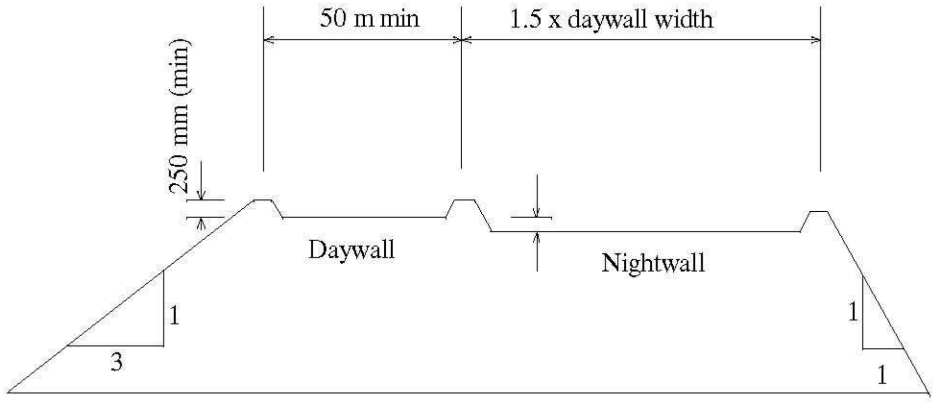

Figure 7-6: Daywall and nightwall construction

3. The floors of both the daywall and the nightwall are constructed to slope towards the inside of the facility. This will force the rainwater to drain along the inner berm thus avoiding any risk of erosion of the outer berm during a major storm.

4. All berms are constructed from relatively fresh ash that has been deposited a maximum of fourteen days prior to their utilisation. Ash at an age of more than fourteen days is too dry and must first be wetted up through at least two ashing cycles before being used in constructing the new berm.

5. Material for all berms is excavated at least one metre inward from the toe of the new berm.

6. Berms are compacted with the excavator bucket in layers not exceeding 200 mm. The Project Manager may specify a different compaction specification in areas where the standard method of compaction fails to achieve the required results.

7. The side slope for all berms will be at least 1:1 except for the outside slope of the outer daywall berm which will be at least 1:3.

8. The crest width of every berm will be at least 1 m for all the straight sections of the daywall.

9. The crest width will be increased to 2 m where the berm changes direction by more than 10 degrees. The transition distance from a 1 m crest width to a 2 m width will be at least 15m. The crest width will remain at 2 m for at least 10 m before being reduced back to 1 m over another transition distance of at least 15 m.

10. Any erosion of the berms will be repaired as soon as possible and no ash will be transported along a channel where the crest width of any of its berms has been eroded by more than 30% of the original width.

11. The freeboard of the berms shall be at least 250 mm above the ash level in the channel at all times.

12. An innerwall acts as a division wall between different pool areas inside the facility. The innerwall has a minimum width of 30 m and is used for transporting both coarse and fine ash slurry to various positions on the facility.

13. Berms for the innerwall have the same dimensions as the berms for the nightwall.

14. The ash slurry gravitates from a high point (distribution point) on the south side of the ash disposal facility along various distribution channels towards starting points on the daywall, the nightwall or the innerwall.

15. The ash slurry further gravitates along the day/night or innerwall sections to a deposition point from where the ash is allowed to flow into the facility and to beach towards the penstock intake structure.

16. A beach slope of approximately 1:500 along the centre lines of the day/night and innerwalls will ensure a continuous capability to gravitate ash along these routes.

17. Ash slurry will be channelled in such a way that the extreme fine portion of the fine ash be deposited away from the highest section of the facility. The low point in the channel should therefore never coincide with the high point on the ash disposal facility.

18. The rate of rise for the day/night and innerwalls shall not exceed 6 m per annum. (The maximum permissible rate of rise for the dam as a whole is 4 m per annum)

19. The level difference between adjacent ash transport channels may vary between a minimum of 250 mm and a maximum of 1000 mm. The level difference at the transition between the nightwall and the inside of the dam shall not exceed 3.5 m.

20. The Contractor may on occasion want to reduce the growth rate on the daywall section and can achieve this by channelling all the ash along the adjacent channel(s) for short periods of time.

7.3.2.3 Control of the pool on top of the ash disposal facility

The prime objective in the control of the pool on top of the ash disposal facility is to ensure that the pool is kept local to the decant tower inlet, and to ensure that the minimum freeboard of the maximum level of the water after a 1:50 year 24hr storm plus at least 0,5 m is maintained at all times. During severe rainfall periods the size of the pool could increase considerably but should be reduced as quickly as the penstocks and return water dams will allow. The excess stormwater must however be managed in such a way as to maximize the evaporation from the ash disposal facility and to reduce the amount of surplus water in the AWR dam.

Legislation (The Water Act -Act 54 of 1956 and Regulation R287 / 4989 / 20.2.1976) requires the minimum storage capacity of the system to be based on the normal operating water plus the average monthly rainfall less the gross mean monthly evaporation plus 1:50 year 24hr storm capacity plus 0,5 meter dry freeboard. Daywalls shall be constructed in such a way that the ash disposal facility will always have sufficient capacity for normal ash disposal operations plus the average monthly rainfall less the gross mean monthly evaporation plus a 1:50 year 24hr storm plus at least 0.5m of dry freeboard at the lowest point on the daywall.

7.3.2.4 Penstocks

Penstock rings are placed one on top of each other to form the decant tower as the level of the ash rises. They are also used to control the amount of water being drawn off the facility. Before the end of each day additional penstock rings must be placed on the decant tower to prevent water and ash being drawn into the decant tower during the night. In the morning the rings must be removed in order to enable water to be drawn off the facility. It must be borne in mind that, unless unavoidable; no water should be drawn off the pool while slurry is being run into the night paddock.

After severe storms it might be necessary to draw water off the facility while slurrying into the inner paddock but this occurrence should be the exception rather than the rule. The water level over the penstock ring should never be more than 160 mm as this will cause pressure surges in the pipe which could dislodge the penstock rings. Excess storm water must be decanted from the ash disposal facility within 4 to 5 days.

The pool level may rise between 450mm and 750mm during a 1:50 year storm event. The true value depends on the pool area and the beaching slope close to the penstock. The Contractor must keep enough penstock rings in stock to cater for at least 1500mm rise in the pool level

The outside of the decant tower is to be double wrapped using a geotextile to prevent piping of the fine ash particles through the joints between successive rings. Failure to do this can cause cavity formation which could lead to a penstock failure.

Decommissioning of the penstock must be carried out once it is no longer needed. This involves grouting up the decant tower by lowering a plug down to the bottom of the tower and then pouring a sand cement grout down to fill the tower.

It is extremely dangerous to place or remove penstock rings without a safety belt. A number of fatalities have occurred specifically in the area of the decant tower at various disposal facilities. The safety harness shall be attached to the catwalk column or balustrade, and shall always be worn when working in the vicinity of the penstock inlets.

7.3.2.5 Stormwater management

Management of stormwater on the ash disposal facilities is a critical part of the operation of the facility. Poor management of water on the facility could result in the failure of the impoundment. The volume of stormwater retained on the ash disposal facility must be kept to a minimum at all times. Excess stormwater must be drained from the facility within 2 to 3 days.

7.3.2.6 Solution trench

A regular monthly inspection of the solution trench shall be carried out to determine whether the trench has become choked by sediment or vegetation, or has been seriously eroded. Any damage shall be repaired as soon as possible. Grass and weeds growing through the concrete joints of the concrete lining shall be removed as soon as possible. Any trench crossings shall not encroach into the trench where the flow can be obstructed. Any seepage of water through the soil into the trench shall be noted, recording both the approximate flow rate and the location. The Project Manager must be notified of any such events. Any increase in the wetted area and/or flow from the toe of the ash facility is to be treated as an early indication that the filter drains are malfunctioning.

7.3.2.7 Stormwater diversion canal

The storm water diversion canal shall be checked fortnightly during the rainy season and also after severe storms. Erosion damage shall be repaired as soon as possible and logs, reeds and other large obstacles shall be removed. Grass and weeds growing through the concrete joints of the concrete lining shall be removed as soon as possible. Any canal crossings shall not encroach into the canal where the flow can be obstructed

7.3.2.8 Grass and reed cutting

The Contractor shall cut all grass vegetation once a year at the end of the growing season. Grass vegetation on the entire ash disposal area, enclosed by the storm water diversion canal on the south and the perimeter road elsewhere, shall be cut at this frequency. Reeds at the silt traps and AWR dam are to be cut at the same frequency.

7.3.2.9 Roads

Roads must be maintained according to the original design and construction specification. This includes cross slopes, road bed and wearing surface material, layer thickness and compaction of the layers. The roads must be kept in a condition acceptable to the Project

Manager at all times. Ponding of water on the road surface after a rainstorm shall not be permitted.

7.3.2.10 Walkway to penstock

Figure 7-7 below shows the recommended walkway construction for access to the penstock decant tower. The structure must be able to carry the load from several people carrying penstock rings. It must also be able to support the horizontal forces on handrails for balustrades as set out in the SABS 0160 loading code. This will ensure adequate support for the safety harnesses worn by personnel when adding or removing penstock rings.

The walkway platform will have to be raised regularly to ensure that the platform is never less than 0,5 m above the pool. In addition, the minimum height above the pool shall be such that adequate access will remain possible after a major rainstorm.

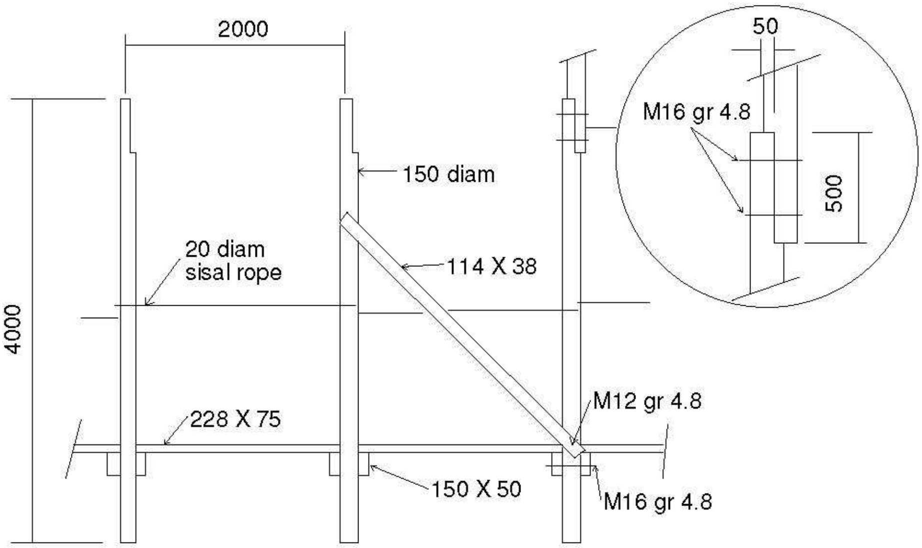

Figure 7-7: Typical walkway elevation

Timber used for the walkway is to be kept in good repair at all times. A walkway constructed from structural steel may also be used, but a timer structure is usually easier to raise and is therefore preferred.

7.3.2.11 Piezometers

Piezometers are necessary on an ash disposal facility in order to monitor the position of the water table within the wall of the facility. It is perhaps more economical to install the piezometers during the early stages of the facility and to extend them as the facility rises, rather than to drill holes and install them at a later stage. The piezometers will also tend to be far more reliable if installed in the early stages of the facility. Piezometers shall be read on a monthly basis.

The Contractor shall determine a safe phreatic surface and compare the readings against this. The Project Manager is to be provided with a set of all piezometer readings. Any increased risk due to a rising phreatic surface, shall be communicated immediately to the Project Manager and the professional engineer responsible for the facility.

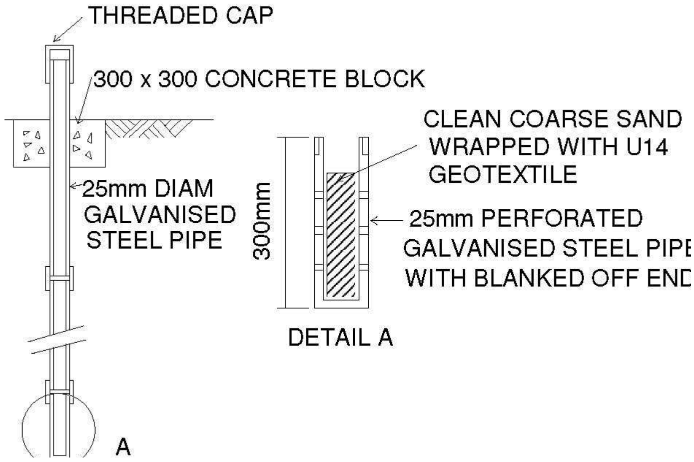

Figure 7-8: Typical piezometer detail

Figure 7-8 shows some typical details for the installation of a piezometer. The 300mm square by 300mm deep concrete block is only to be installed after the wall has reached the final level at this specific position. Galvanized steel pipe sections are also only required for the top 3 metres of the piezometer, the remaining sections may consist of PVC piping provided that suitable couplings between the two types of material are available. This is to reduce the risk of damaging the piezometer during the normal operation of the facility. Special caution shall also be exercised when top soil for rehabilitation is placed in the vicinity of a piezometer. The piezometer tip, shown in detail A, can also be a proprietary porous ceramic or plastic tip. The augured hole for the piezometer is to be thoroughly washed with water until the water flowing from the hole is clear prior to installing the piezometer. The following installation procedure is recommended:

- Lower the porous tip into position, about 200mm from the bottom of the hole.
- Pour a sand mixture down the hole until the tip is covered to a depth of 300mm. The sand shall have a D10 of between 0.1mm and 0.7mm.
- Seal off the sand layer using bentonite balls using a ring punner.
- Seal the remainder of the hole by pouring course ash grout down the hole.

7.3.2.12 Rainfall

Measurement of rainfall at the ash disposal facility is essential as there often appears to be local differences in rainfall between the power station terrace and area of the ash disposal facility. The Contractor shall record all the rain falling on this area. The Project Manager must agree to the position(s) for the rain gauges. Rainfall figures will help in the correlation of the changes in level of the water table in the area of the ash disposal facility and in the rise in the pool level. This will assist in confirming the run-off factor of 0.8 currently being used for the facility.

7.3.2.13 Ash disposal facility office

The Contractor shall maintain the facility to the satisfaction of the Project Manager.

7.3.3 Water management

Camden is actively trying to reduce the water consumption on the power station. Ashing operations have a significant impact on water consumption. Various actions to reduce water consumption have been identified and will be implemented as soon as possible. The Contractor is responsible to operate the ash disposal facility in such a manner that will minimize the water consumption by the ashing operations. The Contractor shall focus on the following areas of operation in order to reduce water usage on the facility:

7.3.3.1 Flushing of ash delivery lines.

The main objective is to reduce water usage per ashing cycle. Flushing shall only continue until the lines are cleared from ash. The Contractor telephonically notifies the relevant person in the station as soon as all ash has been cleared from the ash delivery lines and only clear water is being pumped into the distribution box on the ash disposal facility. This message is to be communicated after every ash deposition cycle. The Contractor notifies the Project Manager in the event that water continues to be pumped to the distribution point after the station has been notified that the lines are clear.

7.3.3.2 Drainage channels.

The Contractor must ensure that all drainage channels are kept clean from dirt, plant growth and any other items that can obstruct the free flow of water in these channels

7.3.4 Emergency procedure

The following situations are to be treated as emergency situations and the Contractor must deal with these in accordance with the relevant sections of the O&M Manual.

7.3.4.1 Inadequate freeboard

The Contractor immediately informs the Project Manager and the Responsible Professional Engineer when the level difference between the lowest point on the daywall and the decant pool level is less than 1.5 m.

7.3.4.2 Inadequate distance between the edge of the pool and the facility wall.

The Contractor immediately informs the Project Manager and the Responsible Professional Engineer when the pool moves closer than 200 m from the edge of the facility crest.

7.3.4.3 Inadequate storage capacity in the AWR-dam

The Contractor immediately informs the Project Manager and the Responsible Professional Engineer when the water level in the ash water return dam exceeds the design top water level before freeboard.

7.3.4.4 Polluted water spillage

The Contractor immediately informs the Project Manager and the Environmentalist on the station of any incident where polluted water from the ashing facility is spilled into the environment.

7.3.4.5 Penstock failure

The Contractor immediately informs the Project Manager when a penstock fails.

7.3.4.6 Slope failure

The Contractor immediately informs the Project Manager and the Responsible Professional Engineer when a slope failure occurs on the facility.

7.4 Operation of silt traps and ash water return dam

7.4.1 Ash water return dam

The prime objectives of the operation of the ash water return dam is:

- To prevent spillage of polluted water into the natural environment, by containing water from the ash disposal facility.
- To have sufficient storage capacity for stormwater runoff, generated from the impacted areas, from large storms.

- To minimize the need for make-up water for ashing at the station by having sufficient water in the ash water return dam

The storage capacity of the ash water return dam is discussed in the Conceptual Design of the facility, Section 6 of this report. The dam level is controlled by pumping ash water back to the high level ash water return dams. The Contractor shall at all times liaise closely with the operating staff from Camden power station to ensure that the water balance in the station, the stability requirements of the ash disposal facility and Eskom's zero effluent discharge philosophy are all adhered to. The Contractor should assist as far as possible with the level control of the ash water return dam by letting more water off the ash disposal facility when the level in the AWR dam drops below 500mm or by retaining more water on the facility when the level exceeds the design top water level before freeboard. The safety and the stability of the ash disposal facility will always take preference to any level control issues.

7.5 Monitoring and maintenance requirements

7.5.1 Ash disposal facility monitoring

The Contractor checks and presents in a format that is acceptable to the Project Manager the status of the following items on a monthly basis:

Pool

- Closest position of the pool to the daywall.
- The area of the pool.

Penstocks

- Verticality of the rings forming the decant tower.
- Presence of the geofabric wrapping around the decant towers.
- Flow depth at the crest of the decant tower.

Catwalk

- Availability and use of safety harness.
- Minimum height of the platform above the pool level.
- Structural integrity of the platform and handrails.

Daywall

- Age of the ash that is being used in daywall construction.
- Days of daywall ashing currently available.
- Total freeboard between daywall and the pool level.
- External and internal slope.
- Presence of any wet spots on the outer slope.
- Slope alignment maintained?

Road at step-ins.

- Is the road sloping inward?
- Is adequate drainage provided on the side slopes?

Ash facility perimeter access road.

- Properly graded to the required cross fall gradient?
- All water drained off the road surface after a rain storm?
- Road surface wearing course still intact?
- Structural layers still intact

Filter drain outlets

- Are the drains still functioning?
- Is the water from the drains clear or is ash silt present?
- Is chemical scaling occurring at the outlets?
- Is there any damage to the pipe or drainage system?

Solution trench

- Is the trench clear of any obstacles?
- Are the trench bottom and sides well maintained?

- Is all growth between expansion joints removed?

Stormwater diversion canals

- Is the canal clear of any obstacles?
- Are all growth between expansion joints removed? PIEZOMETERS
- Have they been installed in the areas required?
- Are those already installed, in good working order?
- Have the water table levels been recorded?
- Is the current phreatic surface within acceptable safety limits?

Barrier fence

- Is the fence still intact?
- Is unauthorized entrance prevented?

7.5.2 Piezometers

Readings are to be taken at monthly intervals. Weekly readings are to be taken when the phreatic surface has risen to a level that represents a high risk situation. A pool less than 200 metres from the outer crest of the daywall, is to be considered as a high risk situation and weekly readings will also be applicable in this instance.

7.5.3 Ash water return dam monitoring

The Contractor checks and presents in a format that is acceptable to the Project Manager the status of the following items on a monthly basis:

Water storage capacity

- The current water level.
- Check with Camden personnel that all the pumps are operational.
- Silt levels in the dam (annually).
- Is adequate storage capacity available for the maximum anticipated rainfall?

Ash Water Return Dam wall

- Any wet spots on the downstream slope?
- Any sign of erosion on the internal or external slopes?
- Any cracks along the crest?
- Any signs of settlement or movement.
- Are any shrubs or trees growing on the wall?

Downstream pollution

- Has any polluted water spilled into the environment?
- If so, was the Project Manager notified immediately thereafter of the volume and the reason for the spill?

7.5.4 Silt trap monitoring

The Contractor checks and presents in a format that is acceptable to the Project Manager the status of the following items on a monthly basis:

Retention storage capacity

- Water depth at the decant tower
- Silt levels in the dam.
- Is adequate retention storage capacity available to satisfy the de-silting requirements?

Dam wall

- Any wet spots on the downstream slope?
- Are both spillways in a good and functional condition?
- Any signs of piping between the horizontal penstock section and the dam wall?
- Any sign of erosion on the internal or external slopes?
- Any cracks along the crest?

- Any signs of settlement or movement?

- Are any shrubs or trees growing on the wall?

7.5.5 Groundwater monitoring

A system of groundwater monitoring points is proposed to be installed. The responsibility for the monitoring of the water quality will remain with the environmental section of the power station. The monitoring frequency is currently three monthly on the existing facility, but will be increased when a deterioration in the pollution levels is being detected. The changes in the monitoring programme will also be informed by the station’s Water Use Licence requirements.

7.5.6 Ash disposal facility contour survey

An aerial survey of the ash disposal facility area shall be carried out every two years. A contour plan with contours at 2m intervals and a digital file with the X, Y and Z coordinates of every survey point are to be produced after every aerial survey. In addition to the aerial survey, a representative number of spot levels are to be taken every six months to assess the rate of rise of the various wall areas. A number of survey beacons are to be constructed at strategic positions to serve as benchmark levels from where the relevant dam wall levels can be surveyed. An accuracy of approximately 200mm will be quite adequate for the six monthly surveys.

7.5.7 Coordination meetings

Coordination meetings are to be held at monthly intervals between the Project Manager and the Contractor. It is advisable to conduct a site inspection prior to each meeting. The Contractor provides the Project Manager and the responsible professional engineer with a copy of the results from the various monitoring activities at least one week before the next monthly coordination meeting.

7.5.8 Maintenance

Regular maintenance must be carried out throughout the life of the ash disposal facility in order to provide full and cost effective use of the facility. All maintenance actions that are identified at the coordination meetings shall be implemented before the next coordination meeting, unless otherwise agreed with the Project Manager. All maintenance work is to be done to a standard acceptable to the Project Manager.

7.5.9 Legal and safety requirements

Ash disposal facilities are hazardous areas, in terms of safety and the classification of the material, and unauthorized people shall not be allowed on to them for the following reasons:

1. The area around the pool of the ash facility is expected to behave like quicksand under certain conditions. "Sinkholes" may also occur in older facilities.

2. The ash will cause blistering of the skin after prolonged contact.

3. Ash water is poisonous. It is therefore essential to erect clearly visible warning signs and to keep the gates to the ash facility locked when there are no authorised ash disposal facility personnel on site.

Preventing public access to the facility is the legal responsibility of the Asset Owner. The minimum standards to which an ash facility is to be fenced in is set out in Regulation 26 of the Water Act (Act 54 of 1956) Section 26. The Contractor is responsible in terms of the ash facility construction and maintenance contract to prevent unauthorized access to the site. Safety on the facility shall be constantly reviewed and upgraded where necessary. Where work is being carried out on the surface of the facility, or off the beaten track, personnel shall work in pairs. Established routes across the ash paddocks shall be used wherever possible, even if this means having to walk further. Personnel shall be informed of the dangers of working on an ash disposal facility. If the above measures are adhered to a good safety record at the ash disposal site should be maintained.

The Occupational Health and Safety (OHS) Act must also be adhered to.

Stipulations and regulations of the Construction Regulations will be implemented as required.

7.5.10 Monitoring requirements during high rainfall periods

The Contractor increases the monitoring frequency for the piezometers, the filter drain outlets and the freeboard on the ash disposal facility to a weekly interval whenever the rainfall exceeds 100 mm per week. The Project Manager and the responsible professional engineer are to be notified immediately of every high rainfall incident.

The responsible professional engineer will visit the facility within three days from the date of notification and will advise the Project Manager of any additional actions that may be required.

7.6 Rehabilitation and environmental considerations

7.6.1 Environmental responsibilities

7.6.1.1 General

The Contractor shall be required to adhere to any applicable South African Environmental legislation during the construction, operation and management of the ash disposal facility/ies. The responsibility shall remain with the Contractor to keep up to date with any applicable revisions or new environmental legislation that come into effect during the contract period. In addition the Contractor shall also comply with Eskom specific Policies, Procedures and Guidelines. Copies of the relevant Eskom documents can be obtained from the Project Manager.

The following is a list of some of the relevant legislation and other environmental documents at the time of the compilation of this document:

South African Acts:

- The Environment Conservation Act (Act 73 of 1989)
- The Water Act (Act 54 of 1956)
- The Minerals Act (Act 50 of 1991)
- The Atmospheric Pollution Prevention Act (Act 45 of 1965)
- The Occupational Health and Safety Act (Act 85 of 1993)
- The Health Act (Act 63 of 1977)
- The Road Traffic Act (Act 29 of 1989)
- The Hazardous Substances Act (Act 15 of 1973)
- The new Construction Act
- The National Environmental Management Act, Act 107 of 1998
- The National Environmental Management Waste Act, Act 59 of 2008.

Subsequent amendments to any of the above Acts are also implied.

Eskom Policies and procedures

- ESKPBAAD6 Environmental Management Policy
- ESKPBAAA9 Environmental Impact Assessment
- ESKPVAAL7 Environmental Impact Assessment
- ESKPBAAA3 Air Quality Management Policy

- ESKPBAAD4 Herbicide Management
- ESKASAAL0 The Safe Use of Pesticides and Herbicides
- ESKPBAAA8 Energy and Environmental Policy and Strategy
- ESKPBAAAC4 Waste Management Policy and Strategy
- ESKPBAAA6 Coal Utilization
- GEM6 An Eskom Purchasing Policy for Buying Environmentally Friendly Products
- ESKADAAJ4 Water Management Policy
- ESKADAAJ5 Waste Management Policy
- ESKADAAP7 Investigation of Major Incidents
- GGS0350 Generation Fire Risk Management
- GEM BULLETIN 5 Problem Plant Species on Generation Sites

7.6.1.2 Water quality

Eskom will monitor water quality of surrounding streams and groundwater.

The Contractor shall be responsible for upkeep of solution trenches, stormwater channels, AWR dams and other such structures to ensure that they remain effective in maintaining a zero effluent discharge system.

The Contractor shall keep in mind that the ash system forms a part of the entire Power Station water balance. All failures on the ash disposal facility with regard to dams, drains etc. must be reported to the Project Manager and the Camden environmental department. An assessment of the effect of the failure in terms of water quality and water balance must be determined between the Project Manager and the Contractor.

7.6.1.3 Air quality

Wind pollution (due to ash blow off)

During the building of the ash facility the Contractor is to ensure that ash dust pollution is kept to a standard which is in accordance with the current South African legislation, as well as any Eskom policies that may be applicable. In general, windblown-dust shall be continuously controlled by the Contractor by regular moisture conditioning of the ash or by rehabilitating the exposed ash surfaces. The exposed section of the side slope of the ash disposal facility is normally only rehabilitated after the next step-in and vehicle access above the slope has been constructed. This delay in rehabilitation will result in an exposed slope of up to 25m wide along the perimeter of the facility. The Contractor is also responsible for dust control on this surface and may use any effective method, which is acceptable to the Project Manager, to control dust blow-off from this area. Acceptable methods are surface wetting, chemical stabilization or protection with shade cloth.

Wind pollution (construction works)

The construction plant access routes, haul, roads etc. are to be watered sufficiently to prevent any dust blow off during the entire contract period. Other dust suppression methods, deemed adequate, may also be used.

Should there be a suspicion that the air quality is in excess of the standard, then the Project Manager may arrange for the installation of dust monitors to verify the situation.

7.6.1.4 Waste management

No building rubble or other scrap is to be dumped on the ash disposal facility. Office waste shall be removed from site. The Contractor may contract with the current waste disposal contractor for Camden power station for a similar service. Cut vegetation may be used as compost for rehabilitation of the side slopes. The ash disposal facility shall at all times be completely fenced off and have the appropriate warning signs displayed. The Contractor shall be responsible for the maintenance of the fence.

Discard coal disposal

Small quantities of discard coal, not exceeding a total of 64 tons per month, can be dumped inside the ash dam. Coal transported by truck, is to be dumped at least 400m inside the crest perimeter of the ash disposal facility. The date and weight of every disposal event are to be recorded. Dumping should preferably occur in one location and should only change when access to an area becomes difficult. The trucking of discard coal will result in a well-controlled dumping operation. Limited quantities of coal discards, not exceeding 20 tons per month, may also be pumped together with the coarse ash to the ash facility. Coal has no cohesion and will reduce the strength of the outer wall of the dam if mixed with the fine ash from the precipitator fields. Mixing of coal discards with fine ash is therefore not permitted.

7.6.1.5 Land management

Veld fires

Any veld fires during the first two growing seasons after rehabilitation can be disastrous. The Contractor shall take all the steps necessary to control fires and a veld fire management plan shall be submitted timeously to the Project Manager for approval. The existing fire breaks are to be maintained to prevent any spread of veld fires from the ash disposal facility area.

Erosion control

The Contractor shall be responsible for the protection of all areas subject to erosion by providing any necessary drainage works, temporary or permanent and by taking all other reasonable precautions as may be necessary to prevent scouring of banks, ash slopes and other areas.

Any erosion damage occurring during the operation of the facility shall be thoroughly repaired and the areas restored to their original condition. Such repair work shall be carried out as soon as possible after damage was caused with all eroded topsoil reclaimed from drains and other areas where possible.

7.6.2 Rehabilitation requirements

7.6.2.1 General

This section comprises the proposed landscaping and re-vegetation procedures for the ash disposal facility. The Contractor shall, in accordance with the requirements of this document, be responsible for the:

- gradual stripping and stockpiling of topsoil
- gradual shaping of side slopes and top of the facility
- gradual spreading of topsoil to cover shaped the facility side slopes and top surface
- planting of grass for erosion control on prepared slopes
- establishment of veld grass on the prepared areas
- establishment of indigenous trees and shrubs
- aftercare of rehabilitated areas to ensure continued stability and eventual self-sustainability

- the upkeep of a complete rehabilitation progress manual

Pollution control

The Contractor shall take all reasonable measures to minimize dust, mud on nearby roads and walkways and inconvenience to the public or others because of the construction of the works.

Progress manual

The Contractor shall start and keep progress manuals fully documenting the progress made and significant factors influencing the rehabilitation process. The manual must be made available upon the Project Manager's request.

7.6.2.2 Materials

Whether the quality of material is specified or not, the Contractor shall at all times use material of the best possible quality and shall price his tender accordingly.

Plants

Plants shall be true to name, healthy and well rooted. Plants shall have a good form typical of their type unless specifically specified otherwise. Containerized plants shall not be root bound. Plants shall grow well and be free from scars or damage, insect pests, diseases or parasites.

Each plant shall be handled, packed and transported in the accepted industry manner for that species or variety and all the necessary precautions shall be taken to ensure that the plants will arrive at the site in a condition for successful growth.

During delivery to the site, plants shall be adequately protected from damage by sun, wind or other causes.

Containers shall be in good condition and the soil shall be free from weeds.

Containerized plants not planted out immediately shall be stored and maintained in nursery like conditions i.e. including storage under shade cloth, well watered and inspected for routine maintenance until they are planted out.

The Contractor shall be prepared to find plants anywhere in the country. Only if the Project Manager is convinced beyond doubt that the plants specified cannot be obtained, will substitutes be considered. Substitutes will be decided on by the Project Manager. The Contractor will be informed in writing.

The Contractor shall assure himself of the availability of specified plants before tendering.

Tree stakes

Tree stakes shall, unless otherwise specified, be treated poles (round droppers) complying with SABS 457, 35 mm minimum diameter and 2 400 mm long. These shall be used of both single and multiple staking. Creosoted timber will not be accepted.

Tree ties

Tree ties for fixing trees to stakes shall be of plastic, rubber or other similar material which supports the tree in a substantial manner, and shall be approved by the Project Manager. Ties shall be such to minimize abrasion and to allow for sufficient space around the tree trunk to permit growth.

7.6.2.3 Equipment

The Contractor shall provide sufficient plant and equipment of adequate capacity, suitable for the work and site conditions, to fulfil his obligations in terms of the Contract. In all cases the most suitable equipment for the particular application shall be used in the interests of time saving and efficiency. In each case the Project Manager shall be approached to authorize the proposed equipment.

7.6.2.4 Preliminary works

The rehabilitation of the ash disposal facility and other ashed areas to be rehabilitated shall take place in phases. Work shall commence as soon as an area becomes available for rehabilitation. The Contractor is to programme accordingly.

Stripping of topsoil

Topsoil shall be stripped and stockpiled for future use from those areas to be ashed on. The process shall be gradual and in accordance with the ashing programme.

The depth of stripping is to vary according to the soil formation. The Contractor shall in general strip soils down to the hydromorphic horizon. Soil from the hydromorphic horizons (such as soil with a high clay percentage and/or wet soils) shall not be acceptable for use as topsoil. Only topsoil with up to, but not exceeding, 30% of coarse particles and stone shall be acceptable. The stone or coarse particles shall also not exceed 250 mm in diameter. Where stripping takes place from areas which will not be ashed upon in the future the areas shall be contoured after stripping as to blend in smoothly with the existing levels. The areas shall be left without any slacks or hollows where water and contours can accumulate. Unless it is used immediately, the topsoil shall be stored in positions as indicated or approved by the Project Manager, in the following manner:

- establish veld grass, or other vegetation as instructed, on heaps to be left for periods in excess of three months
- take any further preventative steps necessary to protect the heaps from erosion.

The Contractor shall manage his rehabilitation programme in such a manner that stripped topsoil is re-used as soon as possible for rehabilitation purposes.

Preparation for planting

1) Slopes not exceeding 1:10

This includes the top of the ash disposal facility.

a) Topsoil Spreading.

i) Spread topsoil evenly to a minimum thickness of 200 mm over the total graded area.

b) Shaping

i) Work the topsoil in to a minimum depth of 200 mm ensuring a smooth final surface without any slacks and hollows where ponding can take place.

c) Fertilizers

i) Apply fertilizers evenly at the following rates:

(1) 250 kg/ha 4:3:4 (30) + Zn

(2) 300 kg/ha Superphosphate (10,5% P)

ii) Application shall be carried out not more than 1 week prior to planting. The mixing of inorganic fertilizers and seed shall not be acceptable.

2) Slopes in excess of 1:10 (10 %)

a) Grading of Side Wall Steps

i) Edge of side slope steps to be graded to create an even slope with a rough surface. Ash clods shall not exceed 350 mm in diameter.

b) Sodding

i) For erosion control purposes slopes exceeding 5 metres in length shall be stabilized by planting 450 mm wide sod strips. The strips shall be spaced 5 m apart measuring from the toe of the slope in each case. Sods shall be secured in place using pegs or any other approved method.

c) Topsoil Spreading

i) Topsoil shall be spread evenly to a minimum thickness of 300 mm over the total graded area.

d) Veld grass

i) Rough veld grass stalks shall be spread over topsoil to a depth of 40-60 mm.

e) Shaping

i) The slope shall be evenly smoothed ensuring that all signs of terracing are removed and that the ash, topsoil and veld grass are thoroughly mixed. Ash clods exceeding 100 mm in diameter may protrude through the topsoil layer.

f) Fertilizers

i) Apply fertilizers evenly at the following rates:

(1) 250 kg/ha 4:3:4 (30) + Zn

(2) 300 kg/ha Superphosphate (10,5% P)

ii) Application shall be carried out not more than 1 week prior to planting. The mixing of inorganic fertilizers and seed shall not be acceptable.

7.6.2.5 Planting procedure

Tree planting

To avoid erosion problems, trees shall not be planted on slopes in excess of 1:3. The trees shall be planted in groups of 3-5 plants ensuring a minimum coverage 50 plants/ha. Certain trees are sensitive to the direction of a slope and the planting plan shall take this into account.

The following plant species may be used:

- Acacia karroo (Sweet Thorn) – Plant on east and west slopes

- Diospyros (Blue Bush) – Plant on north lycoides slope
- Rhus pyroides (Common Wild Currant) – Plant on any slope
- Ziziphus (Buffalo Thorn) – Plant on north mucronata slope
- Rhus lancea (Karree) – Plant on east and west slopes

Scarifying

The total area to be seeded or planted shall be scarified to a minimum depth of 20 mm. Scarification shall be done horizontally across slopes. Seeding shall take place directly following scarifying. In the event of the scarified surface becoming smooth again before seeding, the Contractor shall re-scarify to ensure a suitable seed bed.

Seeding

Seeding shall take place as early as possible during the growing season. The Contractor is expected to programme accordingly. The seed mixture to be used shall be made up as follows unless agreed differently with the Project Manager:

Grass species	*Kg/ha*
Chloris gayana	2
Eragrostis tef	3
Eragrostis curvula	3
Aragrostis chloromelas	1
Aragrostis lehmanniana	1
Enneapogon cenchroides	2
Aragrostis echonochloidea	1
Themeda triandra	1
Digitaria eriantha	2
Cynodon dactylon	2
Hypperrhenia hirta	1
Panicum maximum	1

Where specific grass seed cannot be obtained by the Contractor, he may replace it with another species in consultation and agreement with the Project Manager. The change will be of the same monetary value.

No seeded sections shall be taken over prior to a successful germination rate of at least 70% (measured as 70% of the total area and/or 70% of any particular seeded area of at least 2 500m^2) can be proven by the Contractor. In addition, there shall be no bare patches in excess of 500 mm in diameter or half a meter squared in area. Germination shall be regarded as successful when the grass sward is 5 mm above ground level and identifiable as of the types sown.

7.6.2.6 Care after planting

The Contractor shall protect newly seeded/planted areas against undue traffic and/or other disturbances throughout the contract and maintenance periods.

7.6.2.7 Maintenance

The Contractor shall adequately maintain construction areas for a period of 6 months. Maintenance shall include:

- Continuous repair of damage caused by erosion or any other cause. Erosion gullies exceeding 100 mm in width may be repaired by placing Cynodon spp sods or clumps in the gullies that have begun to form so as to effectively stop them from developing.

- Maintenance of acceptable grass cover with reseeding/sodding as necessary.

The Contractor shall be required to apply a top dressing of 150 kg/ha ammonium sulphate to seeded areas 4 to 6 weeks after germination under favourable growing conditions. (If in doubt the Contractor should discuss this aspect with the Project Manager).

8 COST ESTIMATE / TRADE OFF STUDY

A cost estimate was undertaken for the capital works based on the conceptual design. The detailed breakdown of the costs is given in the appendices and the summary of cost estimate for Site 1 is presented in the table below.

Table 12: Capital Cost Estimate for Site 1

Item	Description	Amount (Rand)
1.1	Site Clearance	8,545,625.00
1.2	Earthworks	198,791,756.25
1.3	Liner	763,746,500.00
1.4	Structural Concrete	9,970,516.86
1.5	Penstocks and Outlet Pipe	4,762,500.00
1.6	Pipelines, Pump Station and Pumps	15,660,000.00
1.7	Access Roads	5,486,250.00
	Sub-total 1	1,006,963,148.11
1.8	Allow for Preliminary and General Items for the Contractor at 25 percent of Sub-total 1	251,740,787.03
	Sub-total 2	1,258,703,935.14
1.9	Allow for 10 percent of Sub-total 2 for Contingencies	125,870,393.51
	TOTAL CAPITAL COST ESTIMATE	**1,384,574,328.65**

Costing of the construction includes the major costs of site clearance, surface preparation, bulk earthworks and the lining system. Current estimates of South African rates, based on Zitholele's experience on other projects are used for the costing. Preliminary and general costs of 25% and contingencies of 10% were being applied for the capital requirement. The following is excluded from the cost estimate:

- Design fees
- Specialist study fees
- Escalation

The major cost is the lining system as it is design in accordance with the Department of Water Affairs Minimum requirements. In order to create flexibility in terms of capital expenditure the installation the liner has been phased as described in the previous sections. This includes staging the site clearance and surface preparation for those areas.

As indicated previously in the report, there is inadequate natural clay available at the proposed sites for the liner. This was derived during the geotechnical investigations of the sites. Alternatives to in-situ clay liner were given in the relevant section of this report. However, these were not considered in the cost estimate and could be followed up at preliminary design stage. The rate for clay used in the liner assumes that the clay is imported from one commercial source located in close proximity to the site. Geosynthetic Clay Liner (GCL) as an alternate option was priced and is marginally lower. By using the GCL, the risk of non-availability of clay may be mitigated. However, leachate tests will have to done on the GCL at preliminary design stage if this is opted for.

The operating cost for a wet ash system is substantial. The cost per tonne of ash deposited was obtained from records (2008) of Matla and Kriel and applied to the production at Camden. Operating costs for the existing ash dam located at Camden was not available. Matla currently has a contract with the operator for R111 million for 5 years and Kriel has a contract for R42 million for 3 years. If the average production per year (3.5 million tonne for Matla and 2.4 million tonne for Kriel) is related to the cost then the cost per tonne equates to R6.34 for Matla and R5.83 for Kriel. The average of these two values is R6.0 /tonne – this rate was escalated by 7% per year over the last 4 years (R8.80 /tonne) and used to estimate the future operating cost of the Camden ash disposal facility This rate includes all operating costs, from mixing and pumping the slurry to placement, RWD management and pumping, spares for the pumping stations as well as on-going rehabilitation. An operating cost of R13 600 000 per year will be required for the life of the facility.

9 RECOMMENDATION

Site 1 is the only site that can accommodate the ash within a single footprint and achieve the total production over the design period. The rate of rise is within the allowable maximum per year whereas Sites 3A and 3B exceed this due to their smaller footprints.

Sites 3A and B do not individually accommodate the ash production over the 19 years operation period and therefore cannot be compared directly to the cost of Site 1. However Sites 3A (R909,813,868) and 3B (R766,474,632) combined (R1,676,288,500) can be compared directly with Site 1 (R1,384,574,329) with regards to capital cost. However, this will entail operating one site first and on rehabilitation of the first site, commission the second site. This is not deemed practical in terms of operational requirements.

Site 1 is both technically and economically feasible over the other two sites and should be taken into the next phase, detail design. Site 1 is the preferred site as it can accommodate the full ash production for the 19 years ash production keeping within the 40 metres allowable height. The shape of the ash dam will also facilitate the ease of operations. The combination of Sites 3A and 3B may be looked at only as a back-up to Site 1.

The liner system (as per DWA Minimum Requirements) comes at a high cost and should be interrogated in order to motivate for a relaxation. The design should be within an Acceptable Risk Level (ARL) and this should be taken into account when the liner system is revisited. It is recommended that the Source Path Receptor (SPR) approach be adopted as a tool in the next phase to motivate for the relaxation of the liner requirements.

The use of GCL in the liner system is recommended subject to detailed testing providing its acceptability. There exists a high probability of adequate quantities of natural clay not being available in close proximity to the site. Rates for the importation of clay from further away sources may increase the costs of the liner significantly. Other alternatives to the in-situ clay are HDPE and bauxite.

10 CONCLUDING REMARKS

Conceptual Engineering design was undertaken for the three sites considered at this stage of the project. The technologies did not differ for any of the sites. Only Site 1 alone accommodates all the ash generated over the 19 years remaining life of the power station. It also poses a lesser hazard in the event of failure than the other two sites.

Site 1 is the preferred site and should be taken to the next phase.

ZITHOLELE CONSULTING (PTY) LTD

N Rajasakran S Pillay

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APPENDIX A

WASTE CLASSIFICATION REPORT

ZITHOLELE CONSULTING (PTY) LTD

WASTE CLASSIFICATION OF POWER STATION
ASH FROM THE CAMDEN POWER STATION

Report No.: JW164/11/D116 - REV 3

September 2012

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Executive Summary

Zitholele Consulting (Pty) Ltd is in the process of conducting and Environmental Impact Assessment (EIA) and Waste Management Licence Application for a new ash disposal facility at the Camden Power Station. The new ash disposal site will be approximately 100 hectares in size with a further 25 hectares for set aside for associated infrastructure.

Classification of the ash from the wet-ash deposition process at Camden Power Station is required for input into both the EIA and Waste Management Licence Application Report. In addition, the ash classification is required to determine its environmental risk profile and also determines the barrier or liner design criteria applicable to the new ash disposal facility.

The objective was to classify the ash, ash seepage water and reverse osmosis brine in terms of the Department of Water Affairs and Forestry's (the DWAF's) "Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste", Second Edition (DWAF, 1998). Cognisance has also be taken of the Department of Environmental Affairs (the DEA's) letters pertaining to waste classification dated April 2008 and June 2009 respectively.

In addition to the above, the ash has also been classified based on the draft waste regulations currently being developed by the DEA. This is required as the ash disposal facility may only be constructed by the time that the new regulations have been promulgated (expected late 2012/early 2013). For this classification the draft regulations promulgated in July 2011 for public comment were used. The reason for this inclusion is because Mr K. Legge of the Department of Water Affairs indicated that, where a new waste disposal facility is constructed after the date of promulgation of the regulations, the barrier (liner) system will have to comply with the new barrier system regulations (K. Legge, 2011). The new waste classification system dictates which barrier system will be required for the new waste disposal facility.

Based on the DWAF's Minimum Requirements waste classification methodology and, when subjected to an Acid Rain Leach Procedure, the Camden Ash is classified as a Hazard Group 1 waste, requiring disposal on a H:H waste disposal facility. This was caused by the concentration of leachable chrome VI (Hazard Group 1 waste) being higher than its Acceptable Risk Level (ARL) in the leach solution. Hazard Group 1 wastes need to be disposed of on H:H waste disposal facilities. However, when considering the quality of the ash seepage water from the current disposal facility, not one of the elements of concern was detected at a concentration higher than its respective ARL value. Therefore the ash and ash carrier water can be delisted to a general waste as per the Minimum Requirements for disposal purposes. Although delisted liquid waste should be disposed of on landfills with H:H Lagoon barrier systems, the ash and ash carrier can be disposed of on a $G:L:B^+$ waste disposal facility, provided the seepage water (leachate) head can be maintained at equal or less than 300mm on top of the barrier layer and the drainage piping system on the barrier is of adequate size, spacing and strength to ensure atmospheric pressure within the drainage system for the service life of the landfill.

The Reverse Osmosis brine was classified as a Hazard Group 2 waste or High Hazard Waste due to the lead concentration in the brine being greater than its ARL value. Lead is a Hazard Group 2 substance. The brine has to be disposed of on a hazardous lagoon (H:H lagoon).

Should consideration be given to the co-disposal of the ash and brine on a single facility, disposal should be acceptable on a H:H waste disposal facility with a H:H barrier system. This barrier system is required as the brine was classified as a Hazard Group 2 waste, which requires disposal on a H:H waste disposal facility.

The landfill classes for disposal of the wastes based on the Minimum Requirements classification methodology are summarised in **Table 1** below. A recommended barrier system is also given.

Table 1: Waste Type and Class of Landfill Required based on Minimum Requirements

Waste	Type of Waste	Disposal Scenario	Class of Landfill	Recommended Barrier System
Ash + Ash Carrier Water	Delisted	Mono-disposal	G:L:B$^+$	Class C*
Brine from Water Treatment Plant	Hazard Group 2 Waste	Mono-disposal	H:H Lagoon	H:H Lagoon
Ash + Ash Carrier Water + Reverse Osmosis Brine	Hazard Group 2 Waste	Co-disposal	H:H	H:H
*** Provided there is no significant water head (>300mm) on the barrier system and the drainage piping system on the barrier is of adequate size, spacing and strength to ensure atmospheric pressure within the drainage system for the service life of the landfill**				

In terms of the DEA's draft waste regulations for disposal, the Camden Ash was subjected to a Total Concentration (TC) extract and a distilled water (DI) leach. Two samples were used in the assessment, namely dusting ash (fine ash) and ashing ash (course) ash. In addition, the seepage water leaching from the current ash disposal facility was also analysed and compared to the respective leach concentration threshold values as prescribed in the draft regulations.

Based on the DI water leach results, both the dusting and ashing ash samples are classified as Type 3 wastes requiring disposal on a Class C landfill. This is because the TC concentrations of arsenic, barium, copper, lead and zinc where higher than the TCTi values. In addition, the leach concentrations (LC) of barium, chromium, hexavalent chromium and molybdenum were also higher than their respective LCTi values for the dusting ash. The ashing ash sample was also classified as a Type 3 waste because of the boron, mercury, molybdenum, TDS and sulphate LC values being higher than their respective LCTi values. In addition, the total dissolved salts (TDS) concentration of the DI water leach solutions were in both cases greater than the LCTi value of 250mg/ℓ. The leachate from the existing site also classifies as a Type 3 waste because of the barium, sulphate, chloride and TDS concentrations being higher than their respective LCTi values.

The Camden Power Station ash should therefore be disposed of on a facility that has been designed and constructed as a Class C landfill (DEA, 2011b). Class C landfills are very similar in design to the current G:L:B$^+$ landfills, with the major difference being the HDPE layer added to the barrier system, which replaces 2 x 150mm clay layers. This barrier system is considered appropriate for the wet ash disposal facility provided the seepage water (leachate) head can be maintained at equal or less than 300mm on top of the HDPE barrier layer and the drainage piping system on the barrier is of adequate size, spacing and strength to ensure atmospheric pressure within the drainage system for the service life of the landfill.

As the water treatment plant was not operational on the day that the samples were collected, the classification was undertaken on a modelled value provided by Eskom. When using the DEA draft regulations of July 2011, the brine classifies as a Type 3 waste due to the boron, mercury, chloride, TDS and sulfate concentrations of the modelled brine solution being greater than their respective LCTi values. Type 3 wastes should be disposed of on Class C landfills, but in the case of the brine, which is a liquid, the brine will have to be disposed of in a hazardous waste (H:H) lagoon disposal facility complying with the design requirements as given in the Minimum Requirements of 1998.

In the case that the brine is co-disposed with the ash on the new ash disposal facility, a Class C landfill barrier is considered appropriate for the ash disposal facility. It is a requirement that liquid waste should be disposed of in hazardous lagoon facilities, but provided the seepage water (leachate) head can be maintained at equal or less than 300mm on top of the primary HDPE barrier layer and the drainage piping system on the barrier is of adequate size, spacing and strength to ensure atmospheric pressure within the drainage system, a Class C barrier system is considered suitable for the co-disposal of the ash and brine.

Table 2 below summarises the classification of the ash and brine water based and also indicates the barrier systems required for the various disposal scenarios based on the draft waste classification regulations of July 2011.

Table 2: Waste Type and Class of Landfill Required based on draft Waste Regulations of July 2011

Waste	Type of Waste	Disposal Scenario	Class of Landfill	Recommended Barrier System
Ash + Ash Carrier Water	Type 3: Low Risk Waste	Mono-disposal	Class C	Class C*
Brine from Water Treatment Plant	Type 3: Low Risk Waste	Mono-disposal	H:H Lagoon	H:H Lagoon
Ash + Ash Carrier Water + Reverse Osmosis Brine	Type 3: Low Risk Waste	Co-disposal	Class C	Class C*
*** Provided there is no significant water head (>300mm) on the barrier system and the drainage piping system on the barrier is of adequate size, spacing and strength to ensure atmospheric pressure within the drainage system for the service life of the landfill**				

M van Zyl

Acronyms and abbreviations used in this document:

ARL	Acceptable Risk Level. (ARL = 0.1 x LC_{50})
ARLP	South African Acid Rain Leach Procedure
DEA	Department of Environmental Affairs
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
FAD5	Fine Ash Dam 5
G:L:B$^+$	General waste landfill receiving more than 500 tonnes of waste per day with a barrier system containing a leachate detection and collection layer
H:H	Hazardous waste disposal facility suitable for the disposal of all Hazard Group 1, 2, 3, 4 and general wastes. Comply with the most conservative design as indicated in the DWAF's Minimum Requirements
H:h	Hazardous waste disposal facility suitable for the disposal of all Hazard Group 3 and 4 wastes, and general wastes. Comply with the second most conservative design as indicated in the DWAF's Minimum Requirements
LC	Leach concentration in mg/ℓ
LC_{50}	The concentration at which 50% of test organisms will die after a certain exposure time
mg/kg	Milligram per kilogram
mg/ℓ	Milligram per litre
TC	Total concentration in mg/kg
TCLP	Toxic characteristic leach procedure
TDS	Total dissolved salts

DOCUMENT APPROVAL RECORD

Report No.: JW164/11/D116 - REV 3

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Prepared	Project Manager	M van Zyl	10 Nov 2011	
Prepared	Environmental Scientist	M. van Zyl	28 Sept 2012	
Reviewed	Technical Director	J Glendinning	28 Sept 2012	

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ZITHOLELE CONSULTING (PTY) LTD

WASTE CLASSIFICATION OF POWER STATION
ASH FROM THE CAMDEN POWER STATION

REPORT NO: JW164/11/D116 - REV 3

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APPENDICES

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WASTE CLASSIFICATION OF POWER STATION
ASH FROM THE CAMDEN POWER STATION

REPORT NO: JW164/11/D116 - REV 3

1. INTRODUCTION

1.1 Background

Zitholele Consulting (Pty) Ltd is currently in the process of conducting and Environmental Impact Assessment (EIA) and Waste Licence Application for a new ash disposal facility at the Camden Power Station. The new ash disposal site will be approximately 100 hectares in size with a further 25 hectares for associated infrastructure.

The classification of the ash from the wet-ash deposition process at Camden Power Station is required for input into both the EIA and Waste Licence Application Report. In addition, the ash classification is required to determine its environmental risk profile and also determines the barrier design criteria applicable to the new ash disposal facility.

1.2 Objectives

The objective was to classify the ash in terms of the Department of Water Affairs and Forestry's (the DWAF's) "Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste", Second Edition (DWAF, 1998). Cognisance was also taken of the Department of Environmental Affairs (the DEA's) letters pertaining to waste classification dated April 2008 and June 2009 respectively.

In addition to the above, the ash has also been classified based on the draft waste regulations currently being developed by the DEA. This is required as the ash disposal facility will only be constructed by the time that the new regulations have been promulgated (expected late 2012/early 2013). For this classification the draft regulations promulgated in July 2011 for public comment were used. The reason for this inclusion is because Mr K. Legge of the Department of Water Affairs indicated that where a new waste disposal facility is constructed after the date of promulgation of the regulations, the barrier (liner) system will have to comply with the new barrier system regulations (K. Legge, 2011). The new waste classification system dictates which barrier system will be required for the new waste disposal facility.

2. METHODOLOGY

2.1 Tests Conducted

Camden Power Station supplied representative samples of dry ash, wet ash (2 samples) and ash disposal site leachate (seepage water) – see **Photo 1**. These samples were then sent to the SGS Laboratory in Randburg for various leach analyses, total concentration (TC) determination and quantitative x-ray diffraction (XRD) analysis to determine the mineralogy.

The SGS laboratory subjected the dry ash to a Minimum Requirements' Acid Rain Leach Procedure (ARLP). The ARLP leach procedure is used in the current Minimum Requirements waste classification system where a waste is mono-disposed or stored or where it is co-disposed with other inorganic waste types not containing any decomposable compounds.

The dry ash sample was also subjected to a total extraction procedure in order to determine the TCs of the various elements.

In addition, the dry ash sample was subjected to a XRD analysis to determine the mineralogy.

Following the new DEA classification system for the mono storage and disposal of a waste, solids were firstly separated from the liquid fraction and the percentage solids determined. The solids fractions were then subjected to a deionised (DI) water leach test, where after the leach solution was analysed for various metals and other inorganic constituents. The water fractions of the two wet ash samples were also analysed for the various metals and inorganic constituents.

The two wet ash samples provided were termed dusting ash, that is the fine ash-water mixture used to develop the outer walls of the current ash disposal facility and ashing ash, the coarse ash-water mixture. The coarse ash is deposited in the middle of the ash disposal facility.

A sample of leachate (seepage water) was also analysed for various inorganic constituents.

The certificates of the results of the various tests conducted on the ash and leachate are included in **Appendix A**.

Although a sample of brine from the water treatment plant was requested for analyses, the plant was not operative on the day that the samples were collected. Theoretical values for the various constituents of concern were provided by Eskom Camden and these values were used in the classification.

Photo 1: **Four samples used in the classification of the Camden Power Station Ash, Ash Carrier Water and Ash Disposal Facility Seepage Water (Leachate)**

3. MINIMUM REQUIREMENTS (DWAF, 1998) WASTE CLASSIFICATION

3.1 Minimum Requirements Methodology

The Camden Ash was classified in terms of the Minimum Requirements (DWAF, 1998a) and the letters from the Department of Environment and Tourism (DEAT), titled "Waste Delisting Procedure", signed by their Director General, dated April 2008 and June 2009 respectively (DEAT, 2009). The hazard rating in this report is therefore in compliance with the Minimum Requirements as amended by the DEAT. The ash was hazard rated based on the leach results of the South African ARLP only.

The ARLP is used in cases where non-organic waste is mono-disposed or disposed with other waste not containing bio-degradable organic waste or in cases where a waste is to be used in an application where the chances of organic acid generation are minimal, such as road building and brick making.

The concentrations of the hazardous substances in the leach solutions were compared to the Acceptable Risk Levels (ARLs) for the aquatic environment as listed in the Minimum Requirements or as identified by J&W. The ARL, expressed in parts per million (ppm) or mg/ℓ = 0.1 x LC_{50} (mg/ℓ)[1]. Where the concentration in the leach solution is > than the ARL, the waste is classified as hazardous for that particular substance. The most hazardous substance dictates the Hazard Rating of the waste. Four Hazard Rating classes are specified in the Minimum Requirements ranging from Hazard Group 1 (Extreme Hazard) to Hazard Group 4 (Low Hazard).

The waste has been classified and hazard rated based on the most hazardous constituent of concern in the ash. Furthermore, the monthly loading rate, i.e., the amount of waste that can be disposed of in tons/hectare/month, has also been calculated, namely:

Monthly loading rate = Allowable dose per month (g/ha/month)/Concentration in leach solution, where allowable dose per month = ARL/0.66 [2]

The allowable maximum load per hectare for lined waste disposal facilities is again calculated from the dose as:

Total load (ton/hectare) = 100 x dose (g/ha/month)/mg of most hazardous substance per kilogram of waste

or, for unlined waste disposal facilities as:

Total load (ton/hectare) = 10 x dose (g/ha/month)/mg of most hazardous substance per kilogram of waste

A waste can be delisted to general waste in cases where the:

- Concentration in the leach solution < ARL for Hazard Group 2, 3 or 4 substances, or
- Concentration in the leach solution < 0.1 x Hazard Group 1, or
- An allowable load of [(ARL/0.66) / (Measured concentration)] is not exceeded.

[1] The factor of 0.1 is calculated from a cross section of typical dose response data, with a typical slope of dose response curves. From an exposure 10 times lower than the LC50, approximately 0,00034% or one in 300 000 of a population exposed to the contaminant, is likely to die (DWAF, 1998a).

[2] The factor 0.66 is derived from the ratio of the substance in a weight of underground body of water (DWAF, 1998). A correction factor of a 1000 was applied by the DWAF to obtain g/ha/month instead of mg/ha/month – this was never fully explained in the Minimum Requirements.

3.2 Primary Hazard Rating of the Camden Power Station Dry Ash

Based on the Minimum Requirements approach a waste is first categorised based on the industry type. In this case the waste is ash originating from the wet-ash process at the Camden Power Station for the generation of electricity. The ash is therefore classified as potentially hazardous, as the Energy Industry was identified in the Minimum Requirements as an industry generating potentially hazardous waste (DWAF, 1998a).

The next step in the primary hazard rating involves a TC analysis to determine the chemicals of concern. The TC analysis indicates that the dry ash contains between 6.86 and 7.03 % iron and between 488 and 508 mg/kg manganese, which, in terms of the Minimum Requirements, results in the ash being classified as potentially hazardous. Both iron and manganese are listed as potentially hazadous wastes in terms of the Minimum Requirements, as they have the potential to leach out of the ash it may therefore cause negative impacts in the environment.

3.3 Secondary Hazard Rating of the Camden Power Station Dry Ash

Based on the above Minimum Requirements approach, the dry ash was classified as a Hazard Group 1 or extreme hazardous waste due to the hexavalent chromium concentration (Cr VI) in the ARLP leach solution being greater than its ARL value – see **Table 3.3(a)** below.

The results indicate that disposal of the ash should be onto a facility that complies with the barrier (liner) performance requirements of a H:H waste disposal facility. An H:H waste disposal facility complies with the most stringent design requirements as per the Minimum Requirements.

The monthly loading rate for the ash, based on the ARLP results, is presented in **Table 3.3(b).** Based on the concentration of hexavalent chromium present in the ash – only 75 tons per hectare per month can be disposed of. The size of the ash disposal facility will determine the total amount of ash that can be disposed of per month.

Ms I. Hodgskin of the power station reported that 1.6 million tons of dry ash is deposited per annum. The monthly disposal rate will therefore be 133 333 tonnes, which requires a disposal site of 1 778 hectares in size. Clearly this is not achievable as the anticipated ash disposal facility size is only 100 hectares. This demonstrates that the loading rate principle of the Minimum Requirements is not practical. However, the actual leachate (seepage water) from the existing ash disposal facility was also analysed, and as the seepage water represents the actual impact on the environment, the seepage water was used as the basis for the classification – **see Section 3.4** below.

Table 3.3(a): Leach concentration of inorganic elements in the dry ash sample compared to their respective ARLs

Chemical Substance	ARLP (mg/ℓ)	ARL (ppm)	Hazard Group
Aluminium (Al)	0.069	10	4
Antimony (Sb)	0.013	0.070	3
Arsenic (As)	0.080	0.43	2
Barium (Ba)	0.21	7.8	3
Beryllium (Be)	<0.00010	7.8	3
Boron (B)	2.3	7.8	3
Bismuth (Bi)	<0.0010	_	_
Calcium (Ca)	200	_	
Cadmium (Cd)	<0.0020	0.031	1
Chloride (C)l	2.5	_	_
Chromium (Cr) (total)	0.40	4.7	3
Chromium VI (Cr VI)	0.40	0.02	1
Cobalt (Co)	<0.0020	6.9	3
Copper (Cu)	<0.0040	0.10	2
Fluoride as F	<0.050	_	_
Iron (Fe)	<0.050	9.0	3
Lead (Pb)	<0.0040	0.10	2
Lithium (Li)	0.073	15.8*	4
Magnesium (Mg)	45	_	_
Manganese (Mn)	0.049	0.30	2
Mercury (Hg)	0.0020	0.022	1
Molybdenum (Mo)	0.14	55	4
Nitrate as N	15	_	_
Nickel (Ni)	0.014	0.62	2
Potassium (K)	1.4	_	_
Selenium (Se)	0.026	0.26	2
Silicon (Si)	11	1000	4
Silver (Ag)	<0.0020	2.0	3
Sodium (Na)	5.4	_	_
Sulfate as SO_4	180	_	_
Tin (Sn)	<0.0070	2.99	3
Titanium (Ti)	0.023	0.73	2
Vanadium (V)	0.38	1.3	3
Zinc (Zn)	<0.010	0.7	2
	ARLP > ARL		

**Note: Although the DEA letter of 21 April 2008, list lithium as a hazardous substance with a LC50 of 1.4 mg/ℓ, there is no substantial evidence that lithium is highly eco-toxic. We have managed to obtain a quoted 96-hour LC50 value of 158mg/ℓ (rainbow trout) for lithium chloride, therefore an ARL of 15.8mg/ℓ. (FMC Corporation, 2006)*

Table 3.3(b): Monthly loading rate based on Chrome VI leach concentration

DRY ASH	
MONTHLY LOADING RATE: ARLP	
	Chromium VI
Concentration of element (ppm) in leach solution	0.4
Load for element in g/ha/month from Min Req.	30
Load in kg/ha/month	75000
Load in tons/ha/month	**75**
The monthly disposal rate is calculated by dividing the ARL by 0.66, which gives the load for the element in g/ha/month. The monthly load of the waste is then calculated by dividing the load (in g/ha/month) with the concentration of the component in the leach solution (ppb).	

3.4 Hazard Rating of Ash Seepage Water

Based on the actual seepage water (leachate) quality values, none of the elements analysed for exceeded their ARL values. Based on the Minimum Requirements methodology, the ash can be delisted to a general waste. Where a hazardous waste has been delisted, the waste must still be disposed of on a landfill site complying with the barrier system of a $G:L:B^+$ waste disposal facility.

Table 3.4: Concentrations of inorganic elements in the ash seepage water compared to their ARLs

Chemical Substance	Seepage Water (mg/ℓ)	ARL (ppm)	Hazard Group
Aluminium (Al)	<0.020	10	4
Arsenic (As)	0.0049	0.43	2
Antimony (Sb)	0.05*	0.07	3
Barium (Ba)	0.063	7.8	3
Beryllium (Be)	0.305	7.8	3
Boron (B)	2.5	7.8	3
Bismuth (Bi)	<0.0010	_	_
Calcium (Ca)	110	_	
Cadmium (Cd)	<0.0020	0.031	1
Chloride (C)l	160	_	_
Chromium (Cr) (total)	0.0051	4.7	3
Chromium VI (Cr VI)	<0.010	0.020	1
Cobalt (Co)	<0.0020	6.9	3
Copper (Cu)	<0.0040	0.10	2
Fluoride as F	<0.050	_	_
Iron (Fe)	<0.050	9.0	3
Lead (Pb)	<0.0040	0.14	2
Lithium (Li)	0.61	0.14	1

Chemical Substance	Seepage Water (mg/ℓ)	ARL (ppm)	Hazard Group
Magnesium (Mg)	8.7	_	_
Manganese (Mn)	<0.0030	0.30	2
Mercury (Hg)	0.00042	0.02	1
Molybdenum (Mo)	0.19	55	4
Nitrate as N	<0.10	_	_
Nickel (Ni)	<0.0070	0.62	2
Potassium (K)	39	_	_
Selenium (Se)	0.0047	0.26	2
Silicon (Si)	1.7	1000	4
Silver (Ag)	0.0037	2.0	3
Sodium (Na)	240	_	_
Sulphate as SO_4	450	_	_
Tin (Sn)	<0.0070	2.99	3
Titanium (Ti)	<0.0050	0.73	2
Vanadium (V)	<0.0010	1.3	3
Zinc (Zn)	<0.010	0.7	2
	ARLP > ARL		
NA	Not analysed		

*** Based on the results of the XRD analysis, which indicated a total concentrating of 0.89 mg/kg, which, if all the antimony leaches out of the ash, will result in a value of 0.05 mg/ℓ at a dilution factor of twenty**

3.5 Hazard Rating for the Camden Power Station Brine

Theoretical values for the reverse osmosis plant brine currently being generated at the Camden Power Station were supplied to J&W. Again, the primary hazard rating would indicate that the waste is potentially hazardous based on the industry type generating the waste i.e. the generation of electricity.

Based on the Minimum Requirements methodology, the brine is classified as a Hazard Group 2 or high hazard waste due to the lead concentration in the brine being greater than its ARL value – see **Table 3.5.** Lead is a Hazard Group 2 substance in terms of the Minimum Requirements.

The results indicate that disposal of the brine should be in a facility that complies with the barrier (liner) performance requirements of a H:H lagoon as given in the Minimum Requirements of 1998 (DWAF, 1998b).

Table 3.5: Concentrations of inorganic elements in the brine sample compared to their ARLs

Chemical Substance	Modelled values for Brine (mg/ℓ)	ARL (ppm)	Hazard Group
Aluminium (Al)	0.10	10	4
Arsenic (As)	NP	0.43	2
Antimony (Sb)	NP	0.070	3
Barium (Ba)	0.99	7.8	3
Beryllium (Be)	<0.0050	7.8	3
Boron (B)	1.4	7.8	3
Bismuth (Bi)	NP	_	_
Calcium (Ca)	877	_	
Cadmium (Cd)	<0.0050	0.031	1
Chloride (C)l	786	_	_
Chromium (Cr) (total)	0.10	4.7	3
Chromium VI (Cr VI)	NP	0.020	1
Cobalt (Co)	<0.0050	6.9	3
Copper (Cu)	<0.0050	0.10	2
Fluoride as F	0	_	_
Iron (Fe)	0.30	9.0	3
Lead (Pb)	0.27	0.10	2
Lithium (Li)	NP	0.14	1
Magnesium (Mg)	1.3	_	_
Manganese (Mn)	0.050	0.30	2
Mercury (Hg)	0.0040	0.022	1
Molybdenum (Mo)	0.10	55	4
Nitrate as N	<0.020	_	_
Nickel (Ni)	<0.0050	0.62	2
Potassium (K)	167	_	_
Selenium (Se)	NP	0.26	2
Silicon (Si)	NP	1000	4
Silver (Ag)	NP	2.0	3
Sodium (Na)	1 385	_	_
Sulphate as SO_4	4 009	_	_
Tin (Sn)	NP	2.99	3
Titanium (Ti)	NP	0.73	2
Vanadium (V)	0.10	1.3	3
Zinc (Zn)	<0.0050	0.7	2
	ARLP > ARL		
NP	Not provided		

4. DEA WASTE CLASSIFICATION

Although the Minimum Requirements waste classification system is currently still the official waste classification system, the ash was also classified in terms of the draft DEA waste classification system for disposal purposes (DEA, 2011a). The reason for this being that by the time that the new ash disposal facility is to be constructed, the new waste classification regulations will in all likelihood be applicable.

4.1 Waste Classification of Ash for Disposal Purposes

The draft classification system focuses on the long term disposal of waste (longer than 90 days) on land or waste disposal facilities. The system is based on the Australian State of Victoria's waste classification system for disposal, which uses the Australian Standard Leaching Procedure (ASLP) to determine the leachable concentrations (LCs) of pollutants (DEA, 2011a).

For the ASLP a number of leach solutions can be used. For waste to be disposed of with organic matter, an acetic acid leach solution is used. This leach solution is very similar to the currently used USEPA TCLP leach solution, except that the pH is 5.0, instead of pH 4.93. In cases where a waste has a high pH, and following an acid neutralisation capacity test, a pH 2.9 leach solution must be used.

In cases where non-organic waste is to be co-disposed with other non-organic waste, a basic 0.10M sodium tetraborate decahydrate solution of pH 9.2 ± 0.10 should be used in addition to the TCLP (DEA, 2011a). The objective of the sodium tetraborate test is to identify contaminants that are leached above the various leachable concentration thresholds (LCTs) trigger values at a high pH.

For waste that is to be left undisturbed on-site, or to be dispersed over land without confinement, or non-putrescible material, e.g. a mono-disposal scenario, reagent water (deionised water) (DI) must be used as a leach agent.

In addition to the above, and as a first step, the TC of the constituents of concern must also be determined and compared to specified total concentration threshold (TCT) values.

The inorganic constituents of concern are listed in **Table 4.1(a)**. The number of potentially hazardous substances in the new classification system has been significantly reduced from that listed in the Minimum Requirements of 1998 and brought in line with the potentially hazardous substances being used in other parts of the world to classify waste for disposal purposes. However, if a generator is aware of a hazardous substance other than those listed by the DEA, they are obliged to indicate this.

Once the analytical results are known, the waste is classified in line with the approach listed below:

- Wastes with any contaminant level above the leachable concentration threshold 2 (LCT2) or total concentration threshold 2 (TCT2) values, i.e., LC > LCT2 <u>or</u> TC > TCT2, are Type 0: Very High Risk Wastes. These wastes may not be disposed of on any landfill without prior treatment;
- Wastes with any contaminant level above the LCT1 but below LCT2 values (LCT1 < LC ≤ LCT2), <u>or</u> above the TCT1 but below TCT2 values (TCT1 < TC ≤ TCT2), are Type 1: High Risk Wastes. These wastes may only be disposed of on landfills with the most conservative barrier systems, improved from a typical H:H/H:h landfill liner system, and now termed a Class A landfill barrier system;

- Wastes with any contaminant level above the LCT0 but below the LCT1 and TCT1 values (LCT0 < LC ≤ LCT1 and TC ≤ TCT1) are Type 2: Moderate Risk Wastes. These wastes may only be disposed of on landfills with a double barrier system, improved from a typical G:L:B$^+$ system, and now termed a Class B landfill barrier system. These waste can also be disposed of on a Class A landfill;
- Wastes with all TC values less than twenty (20) times the LCT0 value (TC < 20 x LCT0), or wastes with all contaminant levels below both the LCT0 and TCT0 values (LC ≤ LCT0 and TC ≤ TCT0), are Type 3: Low Risk Wastes. These wastes may only be disposed of on a landfill with an improved G:L:B+ barrier system. The improved barrier system is now termed a Class C landfill barrier. These wastes can also be disposed of on Class A and Class B landfills;
- Wastes with TC values less than twenty (20) times the TCTi value (TC < 20 x TCTi) or wastes with all contaminant levels below the LCTi or TCTi values (LC ≤ LCTi or TC ≤ TCTi) are Inert Wastes or Type 4 wastes. These wastes may be disposed of on a landfill with G:S:B$^-$ base preparation system in compliance with the current Minimum Requirements. They may also be disposed of on landfills with a more conservative barrier system design.

For the Camden Power Station two ash samples were collected from the ash delivery lines. The first sample is a dusting ash, which comprised 48.3 % solids (fine ash) and 51.7% ash carrier water. The second sample, termed ashing ash, contained 6.37% solids (coarse ash) and 93.63% ash carrier water. The dusting ash is used to develop the perimeter walls of the ash disposal facility and the coarse ash is deposited within the perimeter walls. Both ashes are deposited hydraulically and the ash carrier water is returned to the power station to collect more ash. Fine ash is deposited mostly during day time and the coarse ash during night time operations. Ms I. Hodgskin of the power station reported that 1.6million tons of ash is deposited per annum (Hodgskin, 2011).

For both samples the ash carrier water was analysed for the various constituents. Both ash samples were subjected to a deionised water leach. In line with the Australian leach procedure, the percentage contribution of the various constituents of the water and solids were then calculated for each sample based on the percentage solids. The combined leach concentrations for each ash sample are presented in Tables 4.1a and 4.1c respectively. These results were then compared to the various leach concentration threshold (LCT) values and the total concentration threshold (TCT) values in order to classify the ash for disposal purposes. For the TC values, the dry ash sample aqua regia results were used.

Based on the DI water leach results, the dusting ash classifies as a Type 3 waste – see **Table 4.1(b).** This is because the LC values for barium, chrome, chrome VI, molybdenum and TDS were higher than the respective LCTi values for a Type 4 waste (inert waste). The TC values of arsenic, barium, copper, lead and zinc were also higher than the TCTi values. The ashing ash sample is also classified as a Type 3 waste because of the boron, mercury, molybdenum, TDS and sulphate LC values being higher than their respective LCTi values – see **Table 4.1(c)**. A Type 3 waste requires disposal on a waste management facility with a Class C barrier system, typical of the current G:L:B$^+$/G:M:B$^+$ liner system (DEA, 2011b).

The actual seepage water from the Camden ash disposal facility was also classified using the draft waste regulations. This water is classified as a Type 3 waste, which therefore confirms the classification of the ash as a Type 3 waste.

Table 4.1(a): Corrected concentrations for dusting ash sample based on % contribution of ash carrier water and ash content

DUSTING SAMPLE							
Percentage solids	**48.30%**						
WATER LEACH: DUSTING SAMPLE							
	Solid Phase			**Water Phase**			**Leach Concentration**
Element/Compound	**mg/ℓ**	**Contribution Factor**	**Corrected concentration in mg/ℓ**	**mg/ℓ**	**Contribution Factor**	**Corrected concentration in mg/ℓ**	**mg/ℓ**
As, Arsenic	0.0015	0.483	0.0007245	0.0015	0.517	0.0007755	0.0015
B, Boron	0.2	0.483	0.0966	0.11	0.517	0.05687	0.15347
Ba, Barium	0.84	0.483	0.40572	1.3	0.517	0.6721	1.07782
Cd, Cadmium	0.001	0.483	0.000483	0.001	0.517	0.000517	0.001
Co, Cobalt	0.001	0.483	0.000483	0.001	0.517	0.000517	0.001
Cr, Chromium - total	0.11	0.483	0.05313	0.15	0.517	0.07755	0.13068
Cr VI, Chromium VI	0.11	0.483	0.05313	0.15	0.517	0.07755	0.13068
Cu, Copper	0.002	0.483	0.000966	0.002	0.517	0.001034	0.002
Hg, Mercury	0.0003	0.483	0.0001449	0.00005	0.517	0.00002585	0.00017075
Mn, Manganese	0.0015	0.483	0.0007245	0.0015	0.517	0.0007755	0.0015
Mo, Molydenum	0.067	0.483	0.032361	0.19	0.517	0.09823	0.130591
Ni, Nickel	0.0035	0.483	0.0016905	0.0035	0.517	0.0018095	0.0035
Pb, Lead	0.002	0.483	0.000966	0.002	0.517	0.001034	0.002
Sb, Antimony	0.0035	0.483	0.0016905		0.517	0	0.0016905
Se, Selenium	0.002	0.483	0.000966	0.002	0.517	0.001034	0.002
V, Vanadium	0.045	0.483	0.021735	0.0021	0.517	0.0010857	0.0228207
Zn, Zinc	0.005	0.483	0.002415	0.005	0.517	0.002585	0.005
TDS, Total dissolved salts	272	0.483	131.376	1992	0.517	1029.864	1161.24
Cl, Chloride	2.1	0.483	1.0143	120	0.517	62.04	63.0543
SO_4, Sulphate	13	0.483	6.279	210	0.517	108.57	114.849
NO_3, Nitrate	1.5	0.483	0.7245	0.64	0.517	0.33088	1.05538
F, Fluoride	0.3	0.483	0.1449	0.73	0.517	0.37741	0.52231
Note: In order to calcuate the % contibution of each phase, values less than (<) the limit of report (LOR) were divided by 2							

Table 4.1(b): De-ionised Water Leach Test Results of Camden Power Station Ash (TC Dry Ash, LC Dusting sample)

Chemical Species	Camden Power Station Ash: Dusting Ash – Deionised Water Leach (LC)	Camden Power Station Ash: Dusting Ash – Total Concentration (TC)	Camden Power Station Ash: Dusting Ash – Limit of Report for LC	TYPE 4 WASTE	LCTi	TCTi	TYPE 3 WASTE	LCT0	TCT0	TYPE 2 WASTE	LCT1	TCT1	TYPE 1 WASTE	LCT2	TCT2	TYPE 0 WASTE
	mg/ℓ	mg/kg	mg/ℓ		mg/ℓ	mg/kg		mg/ℓ	mg/kg		mg/ℓ	mg/kg		mg/ℓ	mg/kg	
As	0.0015	13	0.0030		0.010	5.8		0.50	500		1.0	500		4.0	2 000	
B	0.15	NA	0.220		0.50	150		25	15 000		50	15 000		200	60 000	
Ba	1.1	716	0.030		0.70	62.5		35	6 250		70	6 250		280	25 000	
Cd	0.0010	<0.020	0.0020		0.0050	7.5		0.25	260		0.50	260		2.0	1 040	
Co	0.0010	16	0.0020		0.50	50		25	5 000		50	5 000		200	20 000	
Cr	0.13	113	0.040		0.10	46000		5.0	800 000		10	800 000		40	N/A	
Cr(VI)	0.13	NA	0.010		0.050	6.5		2.5	500		5.0	500		20	2 000	
Cu	0.0020	59	0.0040		1.0	16		50	19 500		100	19 500		400	78 000	
Hg	0.00017	<3.0	0.00010		0.0010	0.93		0.050	160		0.10	160		0.40	640	
Mn	0.0015	488	0.060		0.40	1 000		20	25 000		40	25 000		160	100 000	
Mo	0.13	5.2	0.020		0.070	40		3.5	1 000		7.0	1 000		28	4 000	
Ni	0.0035	51	0.0070		0.070	91		3.5	10 600		7.0	10 600		28	42 400	
Pb	0.0020	41	0.0040		0.010	20		0.50	1 900		1.0	1 900		4.0	7 600	
Sb	0.0017	0.89	0.0070		0.010	10		0.50	75		1.0	75		4.0	300	
Se	0.0020	<2.0	0.0040		0.010	10		0.50	50		1.0	50		4.0	200	
V	0.023	68	0.0030		0.10	150		5.0	2 680		10	2 680		40	10 720	
Zn	0.0050	314	0.080		3.0	240		160	160 000		320	160 000		1280	640 000	
TDS	1 161	NA	21		250	N/A		12 500	N/A		12 500	N/A		100 000	N/A	
Chloride	63	NA	0.50		100	N/A		5 000	N/A		10 000	N/A		50 000	N/A	
Sulphate as SO_4	115	NA	0.40		200	N/A		10 000	N/A		20 000	N/A		80 000	N/A	
NO_3 as N	1.1	NA	0.40		6.0	N/A		300	N/A		600	N/A		2 400	N/A	
Fluoride	0.52	NA	0.30		1.0	100		50	10 000		100	10 000		400	40 000	

NA	Not analysed
N/A	Not available
(orange)	TC > TCi or LC > LCTi
(green)	TCi < TC < TCT0/TCT1 or LCTi <LC < LCT0.
(blue)	LCT0 < LC < LCT1
(purple)	TCT0/TCT1 < TC < TCT2
(brown)	TC > TCT2 or LC > LCT2

Table 4.1(c): Corrected concentrations for ashing sample based on % contribution of ash carrier water and ash content

ASHING SAMPLE (Wet)							
Percentage solids	**6.37%**						
WATER LEACH: ASHING SAMPLE							
	Solid Phase			**Water Phase**			**Leach Concentration**
Element/Compound	**mg/ℓ**	**Contribution Factor**	**Corrected concentration in mg/ℓ**	**mg/ℓ**	**Contribution Factor**	**Corrected concentration in mg/ℓ**	**mg/ℓ**
As, Arsenic	0.012	0.064	0.00076	0.0015	0.9363	0.0014	0.0022
B, Boron	0.39	0.064	0.025	1.1	0.9363	1.03	1.1
Ba, Barium	0.059	0.064	0.0038	0.34	0.9363	0.32	0.32
Cd, Cadmium	0.0024	0.064	0.00015	0.0010	0.9363	0.00094	0.0011
Co, Cobalt	0.0027	0.064	0.00017	0.0010	0.9363	0.00094	0.0011
Cr, Chromium - total	0.0075	0.064	0.00048	0.029	0.9363	0.027	0.028
Cr VI, Chromium VI	0.0050	0.064	0.00032	0.030	0.9363	0.028	0.028
Cu, Copper	0.0020	0.064	0.00013	0.0020	0.9363	0.0019	0.0020
Hg, Mercury	0.00015	0.064	0.0000096	0.0012	0.9363	0.0011	0.0011
Mn, Manganese	0.0097	0.064	0.00062	0.0015	0.9363	0.0014	0.0020
Mo, Molydenum	0.012	0.064	0.00076	0.18	0.9363	0.17	0.17
Ni, Nickel	0.0035	0.064	0.00022	0.0035	0.9363	0.0033	0.0035
Pb, Lead	0.0020	0.064	0.00013	0.0020	0.9363	0.0019	0.0020
Sb, Antimony	0.0035	0.064	0.00022		0.9363	0	0.00022
Se, Selenium	0.0020	0.064	0.00013	0.0094	0.9363	0.0088	0.0089
V, Vanadium	0.022	0.064	0.0014	0.020	0.9363	0.019	0.020
Zn, Zinc	0.0050	0.064	0.00032	0.0050	0.9363	0.0047	0.0050
TDS, Total dissolved solids	64	0.064	4.1	856	0.9363	801	806
Cl, Chloride	1.7	0.064	0.11	97	0.9363	91	91
SO_4, Sulphate	19	0.064	1.2	380	0.9363	356	357
NO_3, Nitrate	0.28	0.064	0.018	3.2	0.9363	3.0	3.0
F, Fluoride	0.025	0.064	0.0016	0.74	0.9363	0.69	0.69
Note: In order to calcuate the % contibution of each phase, values less than (<) the limit of report (LOR) were divided by 2							

Table 4.1(d): De-ionised Water Leach Test Results of Camden Power Station Ash (TC Dry Ash, LC Ashing sample)

	Camden Power Station Ash: Ashing Sample															
Chemical Species	Deionised Water Leach (LC)	Total Concentration (TC)	Limit of Report for LC	TYPE 4 WASTE	LCTi	TCTi	TYPE 3 WASTE	LCT0	TCT0	TYPE 2 WASTE	LCT1	TCT1	TYPE 1 WASTE	LCT2	TCT2	TYPE 0 WASTE
	mg/ℓ	mg/kg	mg/ℓ		mg/ℓ	mg/kg		mg/ℓ	mg/kg		mg/ℓ	mg/kg		mg/ℓ	mg/kg	
As	0.0022	13	0.0030		0.010	5.8		0.50	500		1.0	500		4.0	2 000	
B	1.1	NA	0.220		0.50	150		25	15 000		50	15 000		200	60 000	
Ba	0.32	716	0.030		0.70	62.5		35	6 250		70	6 250		280	25 000	
Cd	0.0011	<0.020	0.0020		0.0050	7.5		0.25	260		0.50	260		2.0	1 040	
Co	0.0011	16	0.0020		0.50	50		25	5 000		50	5 000		200	20 000	
Cr	0.028	113	0.040		0.10	46 000		5.0	800 000		10	800 000		40	N/A	
Cr(VI)	0.028	NA	0.010		0.050	6.5		2.5	500		5.0	500		20	2 000	
Cu	0.0020	59	0.0040		1.0	16		50	19 500		100	19 500		400	78 000	
Hg	0.0011	<3.0	0.00010		0.0010	0.93		0.050	160		0.10	160		0.40	640	
Mn	0.0020	488	0.060		0.40	1 000		20	25 000		40	25 000		160	100 000	
Mo	0.17	5.2	0.020		0.070	40		3.5	1000		7.0	1000		28	4 000	
Ni	0.0035	51	0.0070		0.070	91		3.5	10 600		7.0	10 600		28	42 400	
Pb	0.0020	41	0.0040		0.010	20		0.50	1 900		1.0	1 900		4.0	7 600	
Sb	0.00022	0.89	0.0070		0.010	10		0.50	75		1.0	75		4.0	300	
Se	0.0089	<2.0	0.0040		0.010	10		0.50	50		1.0	50		4.0	200	
V	0.020	68	0.0030		0.10	150		5.0	2 680		10	2 680		40	10 720	
Zn	0.0050	314	0.080		3.0	240		150	160 000		300	160 000		1 200	640 000	
TDS	806	NA	21		250	N/A		12 500	N/A		25 000	N/A		100 000	N/A	
Chloride	91	NA	0.50		100	N/A		5 000	N/A		10 000	N/A		50 000	N/A	
Sulphate as SO_4	357	NA	0.40		200	N/A		10 000	N/A		20 000	N/A		80 000	N/A	
NO_3 as N	3.0	NA	0.40		6.0	N/A		300	N/A		600	N/A		2 400	N/A	
Fluoride	0.69	NA	0.30		1.0	100		50	10 000		100	10 000		400	40 000	

NA	Not analysed
N/A	Not available
	TC > TCi or LC > LCTi
	TCi < TC < TCT0/TCT1 or LCTi <LC < LCT0.
	LCT0 < LC < LCT1
	TCT0/TCT1 < TC < TCT2
	TC > TCT2 or LC > LCT2

4.2 Waste Classification of Brine for Disposal Purposes

The inorganic constituents of concern for the modelled brine are listed in **Table 4.2(a).** Based on these the brine is classified as a Type 3 waste.

A Type 3 waste (the reverse of omosis brine) may be disposed of on a Class C waste disposal facility provided the leachate head on the liner system can be managed and maintained equal or less than 300 mm. The design of Class C barrier systems is very similar to the current G:L:B$^+$ design - see **Figure 4.2(a)**. The most prominent design change is the replacement of 2 x 150mm clay layers with a 1.5mm thick high density polyethylene (HDPE) layer.

The brine is classified as a Type 3 waste due to the TDS and sulphate concentrations being greater than the leach concentration threshold levels for a Type 4 waste (LCTi), but below that of Type 2 - see **Table 4.2(a)**. In addition, boron, mercury and chloride were also found to be above their respective LCTi value – see **Table 4.2(a).** The values for the brine are modelled values and it is recommended that once a sample can be generated, a representative sample of the brine should be analysed to confirm the modelled results. As this waste is a liquid, it will have to be mono-disposed in hazardous waste lagoon facility in line with the design requirements for hazardous waste lagoons as per the Minimum Requirements (DWAF, 1998b). The design requirements for a H:H hazardous waste lagoon is given in **Figure 4.2(b)**.

In the case that the brine is co-disposed with the ash on the new waste disposal facility a Class C landfill barrier will be required for the ash disposal facility – see Figure 4, provided the leachate head on the liner system can be managed and maintained equal or less than 300 mm. The barrier design requirement for a Class C disposal facility is presented in **Figure 4.2(a)**.

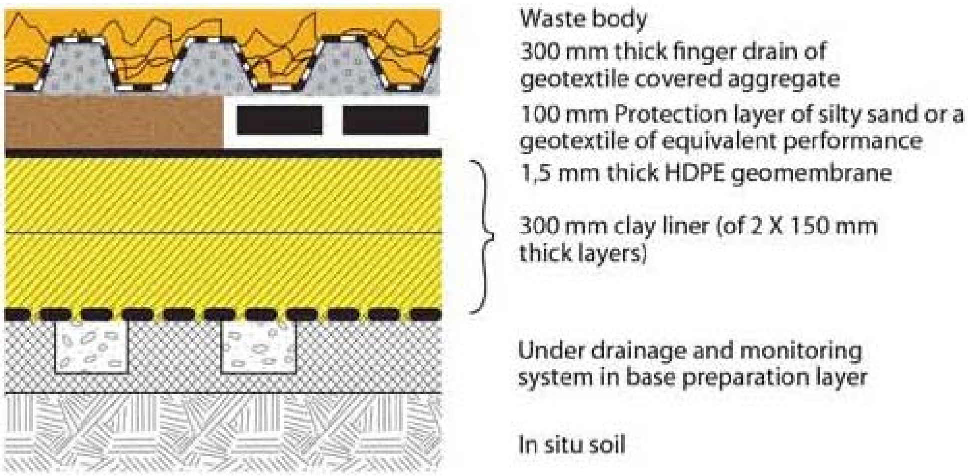

Figure 4.2(a): Proposed Class C landfill barrier system (DEA, 2011)

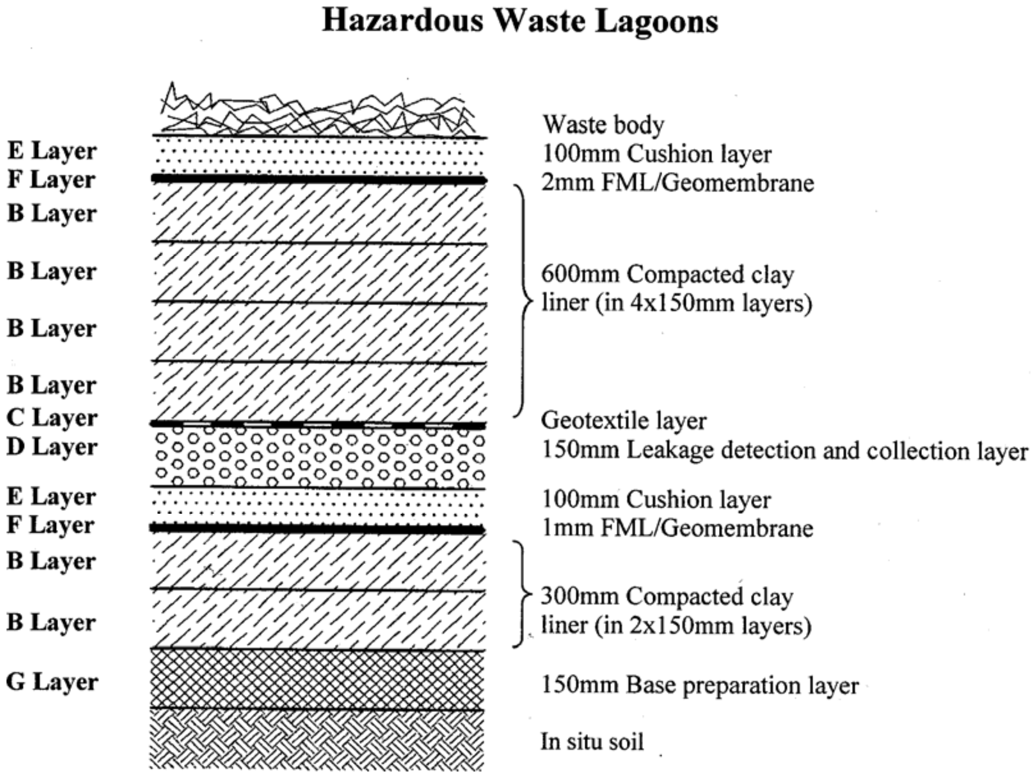

Figure 4.2(b): H:H Lagoon barrier system (DWAF, 1998b)

Table 4.2(a): Test results of Camden Power Station Ash Disposal Facility Leachate (seepage water) and theoretical results for Brine

	Camden Power Station Leachate and Brine															
Chemical Species	Leachate (LC)	Brine (results supplied) (LC)	Detection limit for LC		LCTi	TCTi		LCT0	TCT0		LCT1	TCT1		LCT2	TCT2	
	mg/ℓ	mg/ℓ	mg/ℓ		mg/ℓ	mg/kg		mg/ℓ	mg/kg		mg/ℓ	mg/kg		mg/ℓ	mg/kg	
As	0.0049	NP	0.0030	TYPE 4 WASTE	0.010	5.8	TYPE 3 WASTE	0.50	500	TYPE 2 WASTE	1.0	500	TYPE 1 WASTE	4.0	2 000	TYPE 0 WASTE
B	2.5	1.4	0.220		0.50	150		25	15 000		50	15 000		200	60 000	
Ba	0.063	0.99	0.030		0.70	62.5		35	6 250		70	6 250		280	25 000	
Cd	0.0010	<0.0050	0.0020		0.0050	7.5		0.25	260		0.50	260		2.0	1040	
Co	0.0010	<0.0050	0.0020		0.50	50		25	5 000		50	5 000		200	20 000	
Cr	0.0051	0.10	0.040		0.10	46 000		5.0	800 000		10	800 000		40	N/A	
Cr(VI)	0.0050	NA	0.010		0.050	6.5		2.5	500		5.0	500		20	2 000	
Cu	0.0020	<0.0050	0.0040		1.0	16		50	19 500		100	19 500		400	78 000	
Hg	0.00042	0.0040	0.00010		0.0010	0.93		0.050	160		0.10	160		0.40	640	
Mn	0.0015	0.0050	0.060		0.40	1 000		20	25 000		40	25 000		160	100 000	
Mo	0.19	0.10	0.020		0.070	40		3.5	1 000		7.0	1 000		28	4 000	
Ni	0.0035	<0.0050	0.0070		0.070	91		3.5	10 600		7.0	10 600		28	42 400	
Pb	0.0020	0.27	0.0040		0.010	20		0.50	1 900		1.0	1 900		4.0	7 600	
Sb	0	NP	0.0070		0.010	10		0.50	75		1.0	75		4.0	300	
Se	0.0047	NP	0.0040		0.010	10		0.50	50		1.0	50		4.0	200	
V	0.00050	0.10	0.0030		0.10	150		5.0	2 680		10	2 680		40	10 720	
Zn	0.0050	<0.0050	0.080		3.0	240		160	160 000		320	160 000		640 000	640 000	
TDS	764	7 477	21		250	N/A		12 500	N/A		25 000	N/A		100 000	N/A	
Chloride	160	786	0.50		100	N/A		5 000	N/A		10 000	N/A		50 000	N/A	
Sulphate as SO_4	450	4 009	0.40		200	N/A		10 000	N/A		20 000	N/A		80 000	N/A	
NO_3 as N	0.050	<0.020	0.40		6.0	N/A		300	N/A		600	N/A		2 400	N/A	
Fluoride	0.025	0	0.30		1.0	100		50	10 000		100	10 000		400	40 000	

NP	Not provided
N/A	Not available
	TC > TCi or LC > LCTi
	TCi < TC < TCT0/TCT1 or LCTi <LC < LCT0.
	LCT0 < LC < LCT1
	TCT0/TCT1 < TC < TCT2
	TC > TCT2 or LC > LCT2

5. CARCINOGENIC AND MUTAGENIC CHARACTERISTICS OF THE CAMDEN POWER STATION ASH

Based on the results obtained from the deionised leach solutions, the ash contains no inorganic carcinogens, mutagens or teratogens. However, the ARLP solution contained 15mg/ℓ nitrate. Nitrate has been identified as a Group 2A carcinogen (probably carcinogenic to humans) by the International Association for Research on Cancer (IARC) in 2010 (IARC, 2011). Nitrate may cause cancer when ingested under conditions that result in endogenous nitrosation. As it is unlikely that a person will ingest ash or ash carrier water and therefore the chances of cancer development is insignificant with regard to nitrate.

From the XRD analysis it is observed that the ash contains 45.2% silica dioxide. Silica dioxide has been classified as a Group 1 carcinogen by the IARC (IARC, 2011). This category is used when there is sufficient evidence of carcinogenicity in humans. It would appear that the respirable fractions of the silica are coated with amorphous aluminosilicate and thus renders the silica significantly less hazardous (Y. Nathan et al, 2009). Therefore coal ash, including bottom and fly-ash, is currently classified as a non-hazardous waste in the European Union, State of Maryland and Ireland, USA (EU, 2000 and Maryland Dept. of Health, 2007).

6. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.1 Minimum Requirements Classification

Based on the DWAF's Minimum Requirements waste classification methodology and when subjected to an Acid Rain Leach Procedure, the Camden Ash is classified as a Hazard Group 1 waste, requiring disposal on a H:H waste disposal facility. This is caused by the concentration of leachable chrome VI (Hazard Group 1) being higher than its ARL, which means that the waste cannot be delisted to a general waste. Hazard Group 1 wastes need to be disposed of on H:H waste disposal facilities. However, when considering the quality of the ash seepage water not one of the elements of concern was detected at a concentration higher than its respective ARL value. Therefore the ash and ash carrier water can be delisted to a general waste as per the Minimum Requirements for disposal purposes. Although delisted liquid waste should be disposed of on landfills with H:H Lagoon barrier systems, the ash and ash carrier can be disposed of on a G:L:B$^+$ waste disposal facility, provided the seepage water (leachate) head can be maintained at equal or less than 300mm on top of the barrier layer and the drainage piping system on the barrier is of adequate size, spacing and strength to ensure atmospheric pressure within the drainage system for the service life of the landfill.

The Reverse Osmosis brine was classified as a Hazard Group 2 waste or High Hazard Waste due to the lead concentration in the brine being greater than its ARL value. The brine has to be disposed of on a hazardous lagoon (H:H lagoon).

Should consideration be given to the co-disposal of the ash and brine on a single facility, disposal should be acceptable on a H:H waste disposal facility with a H:H barrier system. This barrier system is required as the brine was classified as a Hazard Group 2 waste, which requires disposal on a H:H waste disposal facility.

The landfill class for disposal of the wastes based on the Minimum Requirements are summarised in Table 6.1 below. A recommended barrier system is also given.

Table 6.1: Waste Type and Class of Landfill Required based on Minimum Requirements

Waste	Type of Waste	Disposal Scenario	Class of Landfill	Recommended Barrier System
Ash + Ash Carrier Water	Delisted	Mono-disposal	G:L:B+	Class C*
Brine from Water Treatment Plant	Hazard Group 2 Waste	Mono-disposal	H:H Lagoon	H:H Lagoon
Ash + Ash Carrier Water + Reverse Osmosis Brine	Hazard Group 2 Waste	Co-disposal	H:H	H:H
*** Provided there is no significant water head (>300mm) on the barrier system and the drainage piping system on the barrier is of adequate size, spacing and strength to ensure atmospheric pressure within the drainage system for the service life of the landfill**				

6.2 Department of Environmental Affairs Draft Waste Classification Regulations – July 2011 Classification

In terms of the DEA's draft waste regulations for disposal, the Camden Ash was subjected to a TC extract and a DI water leach. Two samples were used in the assessment, namely dusting ash (fine ash) and ashing ash (course) ash. In addition, the water leaching from the current ash disposal facility was also analysed and compared to the respective LCT values.

The DI water leach scenario is applicable in the case that ash is mono-disposed or stored in the environment at a permanent storage facility, i.e., the waste is stored for longer than 90 days. Based on the DI water leach results, both the dusting and ashing ash samples are classified as Type 3 wastes requiring disposal on a Class C landfill. This is because the TC concentrations of arsenic, barium, copper, lead and zinc where higher than the TCTi values. In addition, the leach concentrations (LC) of barium, chromium, hexavalent chromium and molybdenum were also higher than their respective LCTi values for the dusting ash. The ashing ash sample is also classified as a Type 3 waste because of the boron, mercury, molybdenum, TDS and sulphate LC values being higher than their respective LCTi values. In addition, the total dissolved salts (TDS) concentration of the DI water leach solutions were in both cases greater than the LCTi value of 250mg/ℓ. The leachate from the existing site also classifies as a Type 3 waste because of the barium, sulphate, chloride and TDS concentrations being higher than their respective LCTi values.

The Camden Power Station ash should therefore be disposed of on a facility that has been designed and constructed as a Class C landfill (DEA, 2011b). Class C landfills are very similar in design to the current G:L:B^+ landfills, with the major difference being the HDPE layer added to the barrier system replacing 2 x 150mm clay layers. This barrier system is considered appropriate for the wet ash disposal facility provided the seepage water (leachate) head can be maintained at equal or less than 300mm on top of the HDPE barrier layer and the drainage piping system on the barrier is of adequate size, spacing and strength to ensure atmospheric pressure within the drainage system for the service life of the landfill.

As the water treatment plant was not operational on the day that the samples were collected, the classification was undertaken on a modelled value provided by Eskom. Once the treatment plant is operative, approximately 500m^3 of brine will be generated per day. It is envisaged that the water treatment plant will only be operative for three years (I. Hodgskin, 2011). When using the DEA draft regulations, the brine classifies as a Type 3 waste due to the boron, mercury, chloride, TDS and sulfate concentrations of the modelled brine solution being greater than their respective LCTi values. Type 3 wastes should be disposed of on Class C landfills, but in the case of the brine, which is a liquid, the brine will have to be disposed of in a hazardous waste (H:H) lagoon disposal facility complying with the design requirements as given in the Minimum Requirements of 1998.

In the case that the brine is co-disposed with the ash on the new ash disposal facility, a Class C landfill barrier is considered appropriate for the ash disposal facility. It is a requirement that liquid waste should be disposed of in hazardous lagoon facilities, but provided the seepage water (leachate) head can be maintained at equal or less than 300mm on top of the primary HDPE barrier layer and the drainage piping system on the barrier is of adequate size, spacing and strength to ensure atmospheric pressure within the drainage system, a Class C barrier system is considered suitable for the co-disposal of the ash and brine.

Table 6.2 below summarises the classification of the ash and brine water based and also indicates the barrier systems required for the various disposal scenarios based on the draft waste classification regulations of July 2011.

Table 6.2 Waste Type and Class of Landfill Required based on draft Waste Regulations of July 2011

Waste	Type of Waste	Disposal Scenario	Class of Landfill	Recommended Barrier System
Ash + Ash Carrier Water	Type 3: Low Risk Waste	Mono-disposal	Class C	Class C*
Brine from Water Treatment Plant	Type 3: Low Risk Waste	Mono-disposal	H:H Lagoon	H:H Lagoon
Ash + Ash Carrier Water + Reverse Osmosis Brine	Type 3: Low Risk Waste	Co-disposal	Class C	Class C*
*** Provided there is no significant water head (>300mm) on the barrier system and the drainage piping system on the barrier is of adequate size, spacing and strength to ensure atmospheric pressure within the drainage system for the service life of the landfill**				

7. REFERENCES

i. Department of Water Affairs and Forestry, 1998a. Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste, Second Edition. Department of Water Affairs, Pretoria.

ii. Department of Water Affairs and Forestry, 1998b. Minimum Requirements for Waste Disposal by Landfill, Second Edition. Department of Water Affairs, Pretoria.

iii. Department of Environmental Affairs and Tourism, 2008. Waste delisting procedure, April 2008. Department of Environmental Affairs and Tourism, Pretoria.

iv. Department of Environmental Affairs, 2011a. *National Environmental Management: Waste Act (Act 59 of 2008). Draft Standard for Assessment of Waste for Landfill Disposal.* Notice 433 of 1 July 2011, Government Gazette No. 34415, Government Printer, Pretoria.

v. Department of Environmental Affairs, 2011b. *National Environmental Management: Waste Act (Act 59 of 2008). Draft National Standard for Disposal of Waste to Landfill.* Notice 432 of 1 July 2011, Government Gazette No. 34414, Government Printer, Pretoria.

vi. Legge, K., 2011. *Verbal communication.* Department of Water Affairs.

vii. International Agency for Research on Cancer, 2011. Agents Classified by the IARC Monographs, Volumes 1–100. http://monographs.iarc.fr/ENG/Classification/index.php

viii. Y, Nathan, et al, 2009. *Occupational health aspects of quartz in pulverized coal fly ash in Israel*. International Workshop on Environmental Aspects of Coal Ash Utilization 15 - 16 December 2009, Tel Aviv, Israel.

viii. Hodgskin, I., 2011. Verbal communication. Eskom, Camden Power Station.

Marius van Zyl
Project Manager

John Glendinning
Project Director

28 September 2012

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Document template: Report Clean_tem_Rev1_Jan10.dotx

Appendix A

SGS SOUTH AFRICA: LABORATORY CERTIFICATES

TEST REPORT

SGS South Africa (Pty) Ltd.
58 Melville Street
Booysens
Johannesburg

Sarah Newton
SGS Environmental Services
259 Kent Avenue
Randburg

MINERALOGICAL REPORT No: MIN 0911/192

Work Requested By: Sarah Newton

On Behalf Of: SGS Environmental

Date issued: 05 October 2011

Investigator: O.D Mosinyi

Analysis of Sample 1881-001 by XRD

O.D. Mosinyi

Mineralogist

L.L. Coetzee

Manager: Mineralogy

1. INTRODUCTION

Sarah Newton, on behalf of SGS Environmental Services, submitted one sample for X-ray diffraction mineralogical examination. The sample was labelled 1881-001, a dry ash sample.

2. METHODOLOGY

The sample was pulverized and analysed by X-ray diffraction utilising a Panalytical X'pert Pro Diffractometer employing Co-Kα radiation. Data interpretation was by means of Panalytical Highscore Plus analytical software, in conjunction with the PDF2 database. The XRD analysis was used to identify and quantify the crystalline phases present in the sample.

3. RESULTS

3.1 X-ray Diffraction Analyses

The crystalline phases that were detected by XRD are listed below in Table 1, and the diffractogram for the sample is shown in figure 1. There were four crystalline phases that were detected by XRD. These were mullite which made up 45.2%,of the sample, and quartz which also accounted for 45.2 % of the sample, calcite accounted for 6.5 % of the sample and lastly magnetite accounted for 3.1 % of the sample.

Table 1: Crystalline phases as determined by X-ray Diffraction

Mineral	Approx. Formula	01881-001 Mass %
Mullite	$Al_6Si_2O_{13}$	45.2
Quartz	SiO_2	45.2
Calcite	$CaCO_3$	6.5
Magnetite	Fe_3O_4	3.1

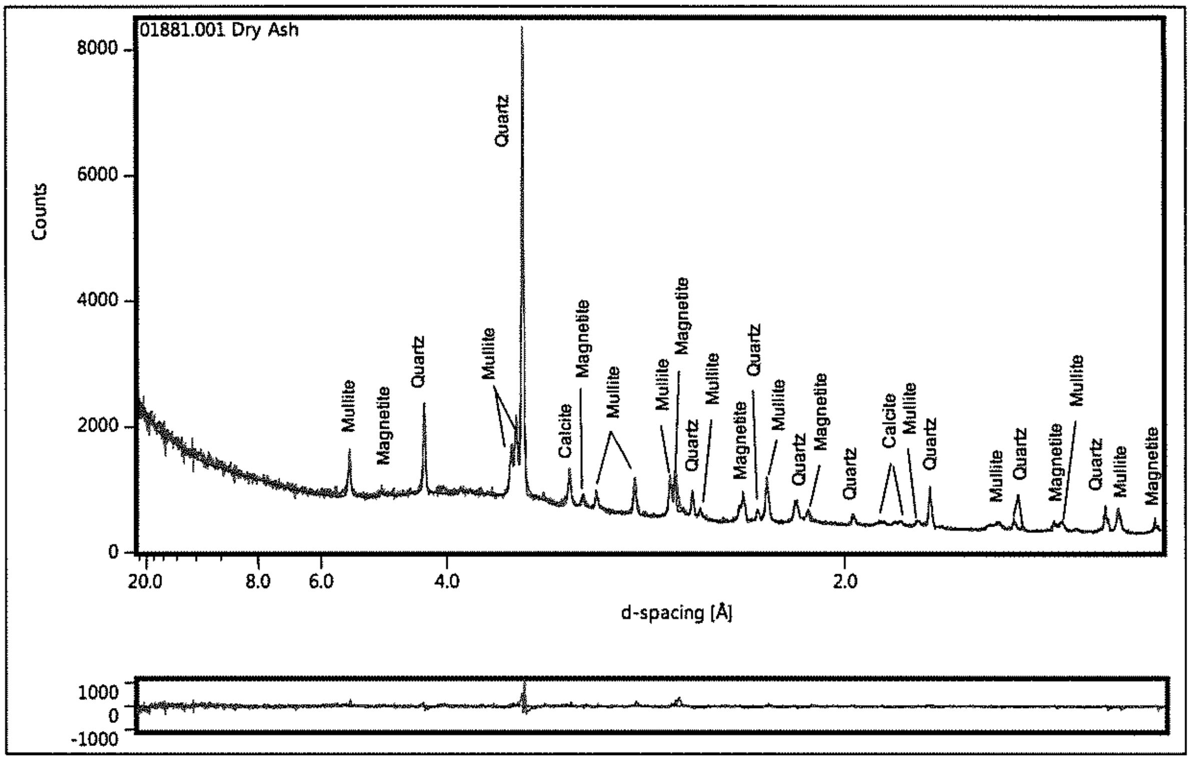

Figure 1: X-ray Diffractogram showing the composition of the sample 1881-001.The diffractogram in red shows the measured pattern, while the blue shows the calculated pattern obtained as part of the Rietveld refinement. The lower red pattern shows the difference between the measured and calculated pattern.

ANALYTICAL REPORT

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Marius Van Zyl	Laboratory	SGS South Africa (Pty) Limited
Client	Jones & Wagener (Pty) Ltd	Address	259 Kent Avenue Ferndale, 2194
Address	P.O. Box 1434 Rivonia 2128	Telephone	+27 (0)11 781 5689
Telephone	011 519 0200		
Facsimile	011 519 0201	Laboratory Manager	Mark Baird (acting)
Email	vanzyl@jaws.co.za	SGS Reference	JB11-01871 R0
Project	**11521199**	Report Number	0000001521
Order Number	**DI66/MVZ/19829**	Date Received	2011/09/12 11:49:42AM
Samples	1	Date Reported	2011/09/30 09:33:06AM
Sample matrix	SOIL		

COMMENTS

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0107.

Filter cake samples not dried prior to testing.

Sample(s) leached using ARLP leachate. Results reported on leachate.

SIGNATORIES

Gladness Radebe	Sarah Newton
Technical Supervisor/Technical Signatory	Technical Consultant/Technical Signatory

Sample Number	JB11-01871.001
Sample Name	Dusting Ash

Parameter	Units	LOR	
Acid Rain Leaching Procedure (ARLP) Method:			
Final pH*	-	-	7.9
Conductivity - Water Method: ME-ANA-AN-007			
Conductivity	mS/m	2.0	120
Total Dissolved Solids (TDS) in water Method: ME-ANA-AN-011			
Total Dissolved Solids	mg/l	21.0	528
Anions by Ion Chromatography Method: ME-ANA-AN-AN014			
Fluoride	mg/l	0.050	<0.050
Chloride	mg/l	0.050	2.5
Nitrate	mg/l	0.10	15
Sulphate	mg/l	0.050	180
Hexavalent Chromium by UV-VIS Method: ME-ANA-AN-018			
Hexavalent Chromium*	mg/l	0.010	0.40
Ammonia as N by UV Method: APHA4500_NH3			
Ammonia*	mg/l	0.050	<0.050
ICP-OES Metals in Water (Dissolved) Method: ME-ANA-AN-027			
Silver	mg/l	0.0020	<0.0020
Aluminium	mg/l	0.020	0.069
Boron	mg/l	0.0050	2.3
Barium	mg/l	0.0020	0.21
Beryllium	mg/l	0.00010	<0.00010
Calcium	mg/l	0.50	200
Iron	mg/l	0.050	<0.050
Potassium	mg/l	0.20	1.4
Lithium	mg/l	0.0050	0.073
Magnesium	mg/l	0.010	45
Sodium	mg/l	0.50	5.4
Silicon	mg/l	1.0	11
Strontium	mg/l	0.0010	2.6
Titanium	mg/l	0.0050	0.023
Vanadium	mg/l	0.0010	0.38
Zinc	mg/l	0.010	<0.010
ICP-MS Metals (Dissolved) Method: ME-ANA-AN-026			
Arsenic	mg/l	0.0030	0.080
Bismuth	mg/l	0.0010	<0.0010
Cadmium	mg/l	0.0020	<0.0020
Cobalt	mg/l	0.0020	<0.0020
Chromium	mg/l	0.0030	0.40
Copper	mg/l	0.0040	<0.0040
Mercury	mg/l	0.00010	0.0020
Manganese	mg/l	0.0030	0.049
Molybdenum	mg/l	0.0070	0.14
Nickel	mg/l	0.0070	0.014
Lead	mg/l	0.0040	<0.0040
Antimony	mg/l	0.0070	0.013
Selenium	mg/l	0.0040	0.026
Tin	mg/l	0.0070	<0.0070

METHOD	METHODOLOGY SUMMARY

FOOTNOTES

IS	Insufficient sample for analysis.	QFH	QC result is above the upper tolerance
LNR	Sample listed, but not received.	QFL	QC result is below the lower tolerance
*	This analysis is not covered by the scope of accreditation.	-	The sample was not analysed for this analyte
^	Performed by outside laboratory.		
LOR	Limit of Reporting		
↑↓	Raised or Lowered Limit of Reporting		

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Unless otherwise indicated, samples were received in containers fit for purpose.

ANALYTICAL REPORT

CLIENT DETAILS

Contact	Marius Van Zyl
Client	Jones & Wagener (Pty) Ltd
Address	P.O. Box 1434 Rivonia 2128
Telephone	011 519 0200
Facsimile	011 519 0201
Email	vanzyl@jaws.co.za
Project	11521195
Order Number	DI66/MVZ/19829
Samples	3
Sample matrix	WATER

LABORATORY DETAILS

Laboratory	SGS South Africa (Pty) Limited
Address	259 Kent Avenue Ferndale, 2194
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Laboratory Manager	Mark Baird (acting)
SGS Reference	JB11-01869 R0
Report Number	0000001519
Date Received	2011/09/12 10:00:46AM
Date Reported	2011/09/30 09:26:12AM

COMMENTS

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0107.

Samples filtered prior to analysis.

SIGNATORIES

Gladness Radebe
Technical Supervisor/Technical Signatory

Sarah Newton
Technical Consultant/Technical Signatory

SGS

ANALYTICAL REPORT

JB11-01869 R0

Report number 0000001519

Client reference: 11521195

Parameter	Units	LOR	Sample Number: JB11-01869.001 Sample Name: Seepage Water	JB11-01869.002 Ashing Water	JB11-01869.003 Dusting Water
pH in water Method: ME-ANA-AN-016					
pH		0.10	8.4	11.4	12.2
Conductivity - Water Method: ME-ANA-AN-007					
Conductivity	mS/m	2.0	160	190	740
Total Dissolved Solids (TDS) in water Method: ME-ANA-AN-011					
Total Dissolved Solids	mg/l	21.0	764	856	1992
Anions by Ion Chromatography Method: ME-ANA-AN-AN014					
Fluoride	mg/l	0.050	<0.050	0.74	0.73
Chloride	mg/l	0.050	160	97	120
Nitrate	mg/l	0.10	<0.10	3.2	0.64
Sulphate	mg/l	0.050	450	380	210
Ammonia as N by UV Method: APHA4500_NH3					
Ammonia*	mg/l	0.050	<0.050	<0.050	0.066
Hexavalent Chromium by UV-VIS Method: ME-ANA-AN-018					
Hexavalent Chromium*	mg/l	0.010	<0.010	0.030	0.15
ICP-OES Metals in Water (Dissolved) Method: ME-ANA-AN-027					
Silver	mg/l	0.0020	0.0037	0.0041	0.026
Aluminium	mg/l	0.020	<0.020	1.2	0.19
Boron	mg/l	0.0050	2.5	1.1	0.11
Barium	mg/l	0.0020	0.063	0.34	1.3
Beryllium	mg/l	0.00010	-1.30551E-	-2.85557E-	-6.56818E-
Calcium	mg/l	0.50	110	190	760
Iron	mg/l	0.050	<0.050	<0.050	<0.050
Potassium	mg/l	0.20	39	27	68
Lithium	mg/l	0.0050	0.61	0.85	3.8
Magnesium	mg/l	0.010	8.7	0.072	<0.010
Sodium	mg/l	0.50	240	160	210
Silicon	mg/l	1.0	1.7	7.6	<1.0
Strontium	mg/l	0.0010	3.9	3.6	39
Titanium	mg/l	0.0050	<0.0050	<0.0050	0.0098
Vanadium	mg/l	0.0010	<0.0010	0.020	0.0021
Zinc	mg/l	0.010	<0.010	<0.010	<0.010
ICP-MS Metals (Dissolved) Method: ME-ANA-AN-026					
Arsenic	mg/l	0.0030	0.0049	<0.0030	<0.0030
Bismuth	mg/l	0.0010	<0.0010	<0.0010	<0.0010
Cadmium	mg/l	0.0020	<0.0020	<0.0020	<0.0020
Cobalt	mg/l	0.0020	<0.0020	<0.0020	<0.0020
Chromium	mg/l	0.0030	0.0051	0.029	0.15
Copper	mg/l	0.0040	<0.0040	<0.0040	<0.0040
Mercury	mg/l	0.00010	0.00042	0.0012	<0.00010
Manganese	mg/l	0.0030	<0.0030	<0.0030	<0.0030
Molybdenum	mg/l	0.0070	0.19	0.18	0.19
Nickel	mg/l	0.0070	<0.0070	<0.0070	<0.0070
Lead	mg/l	0.0040	<0.0040	<0.0040	<0.0040
Selenium	mg/l	0.0040	0.0047	0.0094	<0.0040
Tin	mg/l	0.0070	<0.0070	<0.0070	<0.0070

METHOD	METHODOLOGY SUMMARY

FOOTNOTES

IS	Insufficient sample for analysis.	QFH	QC result is above the upper tolerance
LNR	Sample listed, but not received.	QFL	QC result is below the lower tolerance
*	This analysis is not covered by the scope of accreditation.	-	The sample was not analysed for this analyte
^	Performed by outside laboratory.		
LOR	Limit of Reporting		
↑↓	Raised or Lowered Limit of Reporting		

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Unless otherwise indicated, samples were received in containers fit for purpose.

SGS *Environmental* Services *Randburg* is accredited by *SANAS* and conforms to the requirements of ISO/IEC 17025 for specific test or calibrations as indicated on the scope of accreditation to be found at http://sanas.co.za.

sanas Testing Laboratory
T0107

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Internet: www.sgs.com

Sarah Newton

SGS Environmental Services SA
P.O. Box 82582
Southdale
2135

TEST REPORT

Lab Ref	LA117646
Client Ref	**JB11 - 01881**
Project	DEFAULT
Product Code	SOLIDS
Status	Final
Received	14/09/11
Reported	10/10/11
Samples	2
First Sample	1881 - 001
Last Sample	WASTE ROCK
Pages	10

Notes

Technical Signatory Name: .... ***Signature:***..

Technical Signatory Name: .... ***Signature:***..

Technical Signatory Name: .... ***Signature:***..

On behalf of: SGS South Africa

The results in the following analytical report pertain to this laboratory for preparation and/or analysis as requested by SGS Environmental Services SA.

The analytical results reported herein refer to the samples as received and are based on a dry basis where applicable.

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TEST REPORT

	WtRec	Al	Ba	Ca	Cr	Cu
Scheme	WGH79	ICM40B	ICM40B	ICM40B	ICM40B	ICM40B
Units	g	%	ppm	%	ppm	ppm
Detection Limit	0.01	0.01	5	0.01	1	0.5
1881 - 001	34.50	10.5	716	3.50	113	59.4
WASTE ROCK	-	0.28	94	0.03	22	14.6
GEOSTATS		4.34	36	1.13	1750	3880
LKSD-3SA		5.67	638	1.49	-	-
OREAS 100A		5.58	417	1.05	39	183
OREAS 101A		5.78	180	1.23	39	-
BLANK		<0.01	<5	<0.01	<1	<0.5
1881 - 001		10.8	777	3.63	119	62.4

- not analysed / -- element not determined / I.S. insufficient sample / L.N.R. listed not received / U.T.D. Unable To Determine

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Lab Ref LA117646
Client Ref **JB11 - 01881**
Project DEFAULT
Reported 10/10/11
Status Final

TEST REPORT

	Fe	K	Li	Mg	Mn	Na
Scheme	ICM40B	ICM40B	ICM40B	ICM40B	ICM40B	ICM40B
Units	%	%	ppm	%	ppm	%
Detection Limit	0.01	0.01	1	0.01	5	0.01
1881 - 001	6.86	0.50	181	0.82	488	0.12
WASTE ROCK	0.72	0.08	<1	<0.01	128	0.02
GEOSTATS	4.75	3.41	9	0.52	5230	1.60
LKSD-3SA	4.01	2.02	27	1.14	1410	1.97
OREAS 100A	4.21	3.79	20	0.85	579	0.14
OREAS 101A	10.4	2.26	44	1.24	1020	0.08
BLANK	<0.01	<0.01	<1	<0.01	<5	<0.01
1881 - 001	7.03	0.52	188	0.86	508	0.12

- not analysed / -- element not determined / I.S. insufficient sample / L.N.R. listed not received / U.T.D. Unable To Determine

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TEST REPORT

	P	S	Sr	Ti	V	Zn
Scheme	ICM40B	ICM40B	ICM40B	ICM40B	ICM40B	ICM40B
Units	ppm	%	ppm	%	ppm	ppm
Detection Limit	50	0.01	0.5	0.01	1	1
1881 - 001	1130	0.20	1010	0.71	68	314
WASTE ROCK	210	0.04	<0.5	0.01	3	39
GEOSTATS	460	0.96	43.7	0.21	45	5230
LKSD-3SA	1110	-	237	-	-	-
OREAS 100A	510	0.06	22.5	-	-	41
OREAS 101A	-	0.13	10.0	-	-	101
BLANK	<50	<0.01	<0.5	<0.01	<1	5
1881 - 001	1190	0.22	1050	0.74	77	336

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TEST REPORT

	Zr	Ag	As	Be	Bi	Cd
Scheme	ICM40B	ICM40B	ICM40B	ICM40B	ICM40B	ICM40B
Units	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.5	0.02	1	0.1	0.04	0.02
1881 - 001	254	<0.02	13	5.6	1.24	<0.02
WASTE ROCK	54.2	<0.02	2	0.1	0.31	<0.02
GEOSTATS	68.2	48.0	13	-	-	-
LKSD-3SA	-	2.87	27	1.8	-	-
OREAS 100A	121	-	-	-	-	-
OREAS 101A	91.0	-	-	-	-	-
BLANK	<0.5	<0.02	<1	<0.1	<0.04	<0.02
1881 - 001	275					
1881 - 001		<0.02	13	5.8	1.25	<0.02

- not analysed / -- element not determined / I.S. insufficient sample / L.N.R. listed not received / U.T.D. Unable To Determine

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TEST REPORT

	Co	Mo	Ni	Pb	Sb	Sc
Scheme	ICM40B	ICM40B	ICM40B	ICM40B	ICM40B	ICM40B
Units	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.1	0.05	0.5	0.5	0.05	2
1881 - 001	16.4	5.18	51.3	41.4	0.89	<2
WASTE ROCK	1.6	3.71	5.3	7.6	0.17	<2
GEOSTATS	2070	-	4030	1.21%	11.3	-
LKSD-3SA	29.0	-	46.7	29.3	1.36	-
OREAS 100A	16.4	20.7	-	13.4	-	-
OREAS 101A	47.0	20.5	-	21.3	-	-
BLANK	<0.1	<0.05	<0.5	<0.5	0.09	<2
1881 - 001	16.6	5.22	52.0	41.7	0.90	<2

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	Sn	Hg	Si
Scheme	ICM40B	IMS12B	ICP90A
Units	ppm	ppm	%
Detection Limit	0.3	3	0.1
1881 - 001	4.4	<3	19.2
WASTE ROCK	0.5	<3	20.8
GEOSTATS	-		
LKSD-3SA	-		
OREAS 100A	-		
OREAS 101A	-		
BLANK	<0.3		
BLANK		<3	
SARM5			-
BLANK			<0.1
1881 - 001			19.9
BCS176/2			1.27
1881 - 001		<3	
CCU-1C		30	
GXR-1		4	
1881 - 001	4.4		

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TEST REPORT

APPENDIX A - METHODS

METHOD NUMBER	METHOD DESCRIPTION	SCHEME CODE
ME-ZA-[MINANA]-[BYZ(FAS)]AN-001	Au by Lead Fusion followed by Atomic Absorption analysis or Gravimetric analysis	FAALA01, FAALA01D, FAGLA01, FAGLA02, FAGLA03, FAGLA04, FAGLA05
ME-ZA-[MINANA]-[BYZ(FAS)]AN-002	Au, Pt, Pd by Lead Fusion followed by	FAI313
ME-ZA-[MINANA]-[BYZ(FAS)]AN-003	Pt, Pd, Rh, Ru, Ir by Nickel Sulphide, ICP-OES finish	FAI363
ME-ZA-[MINANA]-[BYZ(XRF)]AN-001	Major Element Oxides by Borate fusion XRF	XRF79V, XRF79C
ME-ZA-[MINANA]-[BYZ(XRF)]AN-002	Base Metals by Potassium Pyrosulphate Fusion XRF	XRF77R
ME-ZA-[MINANA]-[BYZ(AAS)]AN-001	Acid Soluble Cu and Ni by Acid digestion and analysis by AAS	AAS13C
ME-ZA-[MINANA]-[BYZ(LEC)]AN-001	Total Sulphur and Carbon by Leco Combustion Infrared Detection	CSALA01, CSALA06
ME-ZA-[MINANA]-[BYZ(ICM)]AN-001	Total & Dissolved metals by ICP-OES & ICP-MS	ICP84T & IMS84T
ME-ZA-[MINANA]-[BYZ(XRF)]AN-003	Uranium Oxide, pressed powder analysis using XRF spectrometer	XRF75G
ME-ZA-[MINANA]-[BYZ(FAS)]AN-005	Rh by Pd fusion by ICP-OES finish	FAI353
ME-ZA-[MINANA]-[BYZ(WET)]AN-001	Chloride by Potentiometric titration	CLA27V

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Project	DEFAULT
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Status	Final
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TEST REPORT

METHOD DESCRIPTION	**SCHEME CODE**
Silver (Ag) by Fire Assay, gravimetric finish	FAGLA02
Trace elements by pressed pellet, XRF	XRF75G
Sulphide Sulphur (S2-) by Leco	CSA08V
Elemental sulphur (S°) by gravimetric finish	CSA12V
Aqueous sulphate (SO4) by Dionex	CLA31V
Sulphate (SO4) on solids by Dionex	CSA11V
Carbonate (CO3) by LECO	CSA02V
Graphite carbon by LECO	CSA10V
Organic carbon by LECO	CSA03V
pH determination	ISE06T
Conductivity (EC) determination	ISE09V
Total Hardness as CaCO3 (calc from ICP Ca, Mg analyses)	ICP84B
Anions by IC (F, Cl, NO2, NO3, SO4)	CLA31V
Ammonia (NH3) by spectroquant	CLA23V
Phosphate (PO4) by colourmetric analysis	CLA22V
Chemical Oxygen Demand (COD) by spectroquant	CLA24V
Suspended solids (TSS)	PHY18V
Total dissolved solids (TDS), gravimetric finish (180 °C)/Electrometric, conductivity meter	ISE10V
Alkalinity by titration	CLA28V
Chloride (Cl) by titration (solutions)	CLA27V
Chloride (Cl) by titration (solids)	CLA04E
Fluoride (F) by ISE (solutions)	ISE07W
Fluoride (F) by ISE (solids)	ISELA01
Acid Base Accounting (ABA)	CLA41V
Net acid generation (NAG) test (incl. S species)	CLA43V
Short term leach testing (ARLP, TCLP, SPLP, etc)	CLA40V
Deionised water (DI) leach (2 hours, L:S=10)	Leach
Cyanide (CN) species - Free, WAD & Total	CLA25V
Thiocyanate (SCN) by IC	CLA31V
Metals by AAS (solutions)	AAS84T
Gold (Au) in CN solutions by AAS	SOL81T
Silver (Ag) by acid digestion, AAS	AAS14E
Arsenic (As) by Aqua Regia digestion, AAS	AAS11C
Multi Acid digestion, AAS finish	AAS40D
Acid soluble Cu, Co by Sulphuric Acid leach, AAS	AAS72C
Aqua Regia digestion, ICP-OES finish	ICP13E
Multi Acid digestion, ICP-OES finish	ICP40D
Sodium Peroxide fusion, ICP-OES finish	ICP91B

- not analysed / -- element not determined / I.S. Insufficient sample / L.N.R. listed not received / U.T.D. Unable To Determine

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Lab Ref	LA117646
Client Ref	**JB11 - 01881**
Project	DEFAULT
Reported	10/10/11
Status	Final
Page	Page 10 of 10

TEST REPORT

METHOD DESCRIPTION	**SCHEME CODE**
Semi quantative ICP-OES +ICP-MS scan, Aqua Regia digestion	ICM12B
As, Hg, Se, Te by Aqua Regia digestion, ICP-MS finish	IMS12Q
Multi Acid digestion, semi quantative scan, ICP-OES + ICP-MS	ICM40B
Multi acid digestion, ICP-MS	IMS40B
Rare Earth Elements (REE) by Na2O2 fusion, ICP-MS	IMS90A
Free acid titration	CLA15F
Chloride (Cl) by manual titration (Metallurgical)	CLA26V
As 3+ by titration	CLA32V
As 5+ by calculation	CLA32V
Lime (CaO) by titration	CLA07C
Lime (CaO), calculation after AAS analysis	CLA07C
Ferrous (Fe2+) iron by titration (solids)	CLA34V
Ferrous (Fe2+) iron by titration (solutions)	CLA34V
Ferric (Fe3+) iron by diff (incl. Fe total, Fe2+) - solids	CLA34V
Ferric (Fe3+) iron by diff (incl. Fe total, Fe2+) - solutions	CLA35V
Iron (Fe) by titration (solids)	CLA35V
Tin (Sn) by titration (solids)	CON14V
Zinc (Zn) by EDTA titration (solids)	CON12V
Hexavalent chromium (Cr6+) in solutions	CLA21V
Manganese (Mn) by back titration	CON15V
Vanadium (V) by titration	CON16V
Chrome (Cr) by back titration	CON10B
Relative Density/Specific Gravity (by Le Chatelier flask)	PHY04V
Bulk density	PHY21V
Relative Density/Specific Gravity (by Helium pyncometer)	PHY03V
Grain density	PHY20V
Moisture (105 °C)	PHY08D
Ash/LOI (1050 °C)	PHY01K

- not analysed / -- element not determined / I.S. insufficient sample / L.N.R. listed not received / U.T.D. Unable To Determine

ANALYTICAL REPORT

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Marius Van Zyl	Laboratory	SGS South Africa (Pty) Limited
Client	Jones & Wagener (Pty) Ltd	Address	259 Kent Avenue Ferndale, 2194
Address	P.O. Box 1434 Rivonia 2128	Telephone	+27 (0)11 781 5689
Telephone	011 519 0200		
Facsimile	011 519 0201	Laboratory Manager	Mark Baird (acting)
Email	vanzyl@jaws.co.za	SGS Reference	JB11-01881 R0
Project	(Not specified)	Report Number	0000001593
Order Number	**DI66/MVZ/19829**	Date Received	2011/09/13 12:15:20PM
Samples	1	Date Reported	2011/10/10 11:32:03AM
Sample matrix	SOIL		

COMMENTS

Whilst SGS laboratories conform to ISO/IEC 17025 standards, results of analysis in this report fall outside of the current scope of accreditation.

Testing subcontracted to SGS Booysens.

Mineralogy results contained in their report, MIN 0911/192, appended.

SIGNATORIES

Gladness Radebe
Technical Supervisor/Technical Signatory

Sarah Newton
Technical Consultant/Technical Signatory

ANALYTICAL REPORT

Report number 0000001593
Client reference: DI66/MVZ/19829

		Sample Number	JB11-01881.001
		Sample Name	Dry Ash
		Sample Matrix	Soil
Parameter	**Units**	**LOR**	
SUB_Mineralogy Method: SUB			
XRD scan	No unit	-	MIN 0911/192
SUB_SGS Booysens Method: SUB_BOOY			
Silver	ppm	0.020	<0.020
Aluminium	%	0.010	11
Arsenic	ppm	1.0	13
Barium	ppm	5.0	720
Beryllium	ppm	0.10	5.6
Bismuth	ppm	0.040	1.2
Calcium	%	0.010	3.5
Cadmium	ppm	0.020	<0.020
Chromium	ppm	1.0	110
Cobalt	ppm	0.10	16
Copper	ppm	0.50	59
Iron	%	0.010	6.9
Mercury	ppm	3.0	<3.0
Potassium	%	0.010	0.50
Lithium	ppm	1.0	180
Magnesium	%	0.010	0.82
Manganese	ppm	5.0	490
Molybdenum	ppm	0.050	5.2
Sodium	%	0.010	0.12
Nickel	ppm	0.50	51
Phosphorus	ppm	50	1100
Lead	ppm	0.50	41
Sulphur	%	0.010	0.20
Antimony	ppm	0.050	0.89
Selenium	ppm	2.0	<2.0
Silicon	%	0.10	19
Tin	ppm	0.30	4.4
Strontium	ppm	0.50	1000
Titanium	%	0.010	0.71
Vanadium	ppm	1.0	68
Zinc	ppm	1.0	310
Zirconium	ppm	0.50	250

METHOD SUMMARY

Report number 0000001593
Client reference: DI66/MVZ/19829

METHOD — METHODOLOGY SUMMARY

FOOTNOTES

IS	Insufficient sample for analysis.	QFH	QC result is above the upper tolerance
LNR	Sample listed, but not received.	QFL	QC result is below the lower tolerance
*	This analysis is not covered by the scope of accreditation.	-	The sample was not analysed for this analyte
^	Performed by outside laboratory.		
LOR	Limit of Reporting		
↑↓	Raised or Lowered Limit of Reporting		

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Unless otherwise indicated, samples were received in containers fit for purpose.

ANALYTICAL REPORT (Amended)

CLIENT DETAILS

Contact	Marius Van Zyl
Client	Jones & Wagener (Pty) Ltd
Address	P.O. Box 1434 Rivonia 2128
Telephone	011 519 0200
Facsimile	011 519 0201
Email	vanzyl@jaws.co.za
Project	11521198
Order Number	DI66/MVZ/19829
Samples	2
Sample matrix	SOIL

LABORATORY DETAILS

Laboratory	SGS South Africa (Pty) Limited
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Laboratory Manager	Mark Baird (acting)
SGS Reference	JB11-01870 R0
Report Number	0000001540
Date Received	2011/09/12 11:20:06AM
Date Reported	2011/10/03 11:26:35AM

COMMENTS

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0107.

This report/certificate is a re-issued copy and replaces the originally issued document dated 2011-09-30. The reason for re-issue is that percent solids results were omitted from the original report.

Filter cake samples not dried prior to testing.

Sample(s) leached using deionised water. Results reported on leachate.

SIGNATORIES

Gladness Radebe
Technical Supervisor/Technical Signatory

Sarah Newton
Technical Consultant/Technical Signatory

SGS

ANALYTICAL REPORT

JB11-01870 R0

Report number **0000001540**
Client reference: **11521198**

			Sample Number	JB11-01870.001	JB11-01870.002
			Sample Name	Ashing Ash	Dusting Ash
			Sample Matrix	Ash sample	Ash sample
Parameter	**Units**	**LOR**			
Moisture Method:					
Solids content*	%	0.050		6.37	48.3
South African Standard Leach Procedure Method: AS 4439.3					
Final pH	-	-		10.9	11.8
Conductivity - Water Method: ME-ANA-AN-007					
Conductivity	mS/m	2.0		24	160
Total Dissolved Solids (TDS) in water Method: ME-ANA-AN-011					
Total Dissolved Solids	mg/l	21.0		64	272
Anions by Ion Chromatography Method: ME-ANA-AN-AN014					
Fluoride	mg/l	0.050		<0.050	0.30
Chloride	mg/l	0.050		1.7	2.1
Nitrate	mg/l	0.10		0.28	1.5
Sulphate	mg/l	0.050		19	13
Hexavalent Chromium by UV-VIS Method: ME-ANA-AN-018					
Hexavalent Chromium*	mg/l	0.010		<0.010	0.11
Ammonia as N by UV Method: APHA4500_NH3					
Ammonia*	mg/l	0.050		<0.050	<0.050
ICP-OES Metals in Water (Dissolved) Method: ME-ANA-AN-027					
Silver	mg/l	0.0020		<0.0020	<0.0020
Aluminium	mg/l	0.020		1.6	4.4
Boron	mg/l	0.0050		0.39	0.20
Barium	mg/l	0.0020		0.059	0.84
Beryllium	mg/l	0.00010		<0.00010	<0.00010
Calcium	mg/l	0.50		28	130
Iron	mg/l	0.050		<0.050	<0.050
Potassium	mg/l	0.20		0.45	1.0
Lithium	mg/l	0.0050		0.011	0.068
Magnesium	mg/l	0.010		0.46	0.018
Sodium	mg/l	0.50		3.5	5.0
Silicon	mg/l	1.0		7.1	4.3
Strontium	mg/l	0.0010		0.41	2.1
Titanium	mg/l	0.0050		<0.0050	<0.0050
Vanadium	mg/l	0.0010		0.022	0.045
Zinc	mg/l	0.010		<0.010	<0.010
ICP-MS Metals (Dissolved) Method: ME-ANA-AN-026					
Arsenic	mg/l	0.0030		0.012	<0.0030
Bismuth	mg/l	0.0010		0.0020	<0.0010
Cadmium	mg/l	0.0020		0.0024	<0.0020
Cobalt	mg/l	0.0020		0.0027	<0.0020
Chromium	mg/l	0.0030		0.0075	0.11
Copper	mg/l	0.0040		<0.0040	<0.0040
Mercury	mg/l	0.00010		0.00015	0.00030
Manganese	mg/l	0.0030		0.0097	<0.0030
Molybdenum	mg/l	0.0070		0.012	0.067
Nickel	mg/l	0.0070		<0.0070	<0.0070

			Sample Number	JB11-01870.001	JB11-01870.002
			Sample Name	Ashing Ash	Dusting Ash
			Sample Matrix	Ash sample	Ash sample
Parameter	**Units**	**LOR**			
ICP-MS Metals (Dissolved) Method: ME-ANA-AN-026 (continued)					
Lead	mg/l	0.0040		<0.0040	<0.0040
Antimony	mg/l	0.0070		<0.0070	<0.0070
Selenium	mg/l	0.0040		<0.0040	<0.0040
Tin	mg/l	0.0070		<0.0070	<0.0070

METHOD — METHODOLOGY SUMMARY

FOOTNOTES

IS	Insufficient sample for analysis.
LNR	Sample listed, but not received.
*	This analysis is not covered by the scope of accreditation.
^	Performed by outside laboratory.
LOR	Limit of Reporting
↑↓	Raised or Lowered Limit of Reporting
QFH	QC result is above the upper tolerance
QFL	QC result is below the lower tolerance
-	The sample was not analysed for this analyte

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Unless otherwise indicated, samples were received in containers fit for purpose.

APPENDIX B

GEOTECHNICAL INVESTIGATION REPORT

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ENGINEERING GEOLOGICAL EVALUATION REPORT FOR THE PROPOSED ASH DISPOSAL FACILITY, CAMDEN POWER STATION MPUMALANGA

1. INTRODUCTION

1.1. Preamble

During March 2011, Mr, K. Kruger from Zitholele Consulting invited Africa Exposed Consulting Engineering Geologists to submit a proposal to carry out a geotechnical evaluation of three alternative sites for the development of a proposed ash disposal facility at the Camden Power Station, Ermelo, Mpumalanga.

Subsequently on 14th June 2011 a letter of appointment was received from Zitholele Consulting, instructing Africa Exposed tp proceed with the geotechnical evaluation.

1.2. Objectives

The objectives of the evaluation is to determine the geotechnical and geological conditions that prevail beneath each of the three identified candidate sites and to provide an assessment of:-

the soil conditions at surface
the nature and extent of near surface and outcropping strata.
existence of potential “fatal flaws”
comment on any geotechnical problems that may impact upon the site selection.
recommendations of mitigation.

1.3. Scope of Work

The following scope of work was completed on each candidate site:

Desktop study of each of the three candidate sites, including aerial photo interpretation.
Site visit to each location with a brief walk over survey.
Excavation of test pits at randomly selected positions and soil sampling.
Prepare a report, addressing the objectives presented above.
Rank each site in order of preference based on geotechnical considerations.

2. FACTUAL REPORT

2.1 Programme of Work

2.1.1 *Literary Review*

This geological evaluation of the sites was initially confined to a literature search and a brief site visit. Appropriate information was obtained from the following sources:-

i. The 1: 250 000 geological maps, No 2628 East Rand and No. 2630 Mbabane.
ii. The 1 : 50 000 topo-cadastral map 2630 CA Camden, published by The Department of Survey and Mapping, Mowbray 1985.
iii. Google Earth satellite imagery, obtainable from http/.earth.google.com.
iv. "The geology of South Africa." edited by Johnson, M.R., Anhaeusser, C.R., and Thomas, R.J. published by the Council for Geoscience and the Geological Society of South Africa. 2006.
v. "Engineering Geology of Southern Africa" volume 3, by A.B.A. Brink (1979), published by Building Publications.
vi. "Minimum requirements for waste disposal by landfill." Third edition, published by the Department of Water Affairs and Forestry. 2005.
vii. "The Natural Road Construction Materials of Southern Africa" by H.H. Weinert (1980) published by Council for Scientific and Industrial Research, Pretoria.

2.1.2 *Field Work*

Initially a site visit was conducted on 16th May 201, where a number of potential sites were visited. Following the brief site visit three potential candidate sites were identified.

On 23rd June 2011, four test pits were augered on each site and a Dynamic Cone Probe (DCP) was advanced adjacent to each test pit in order to determine the soil consistency The layout of the test pits are shown on the Site Plan in Appendix 1 and each hole was profiled by an engineering geologist according to the Jennings, Brink and Williams system, sampled as necessary and backfilled. The detailed profile logs are shown in Appendix 2.

2.1.3 *Office and Laboratory Work*

From the soil samples recovered, six were selected for Foundation Indicator Tests and all the individual test results are included in Appendix 3 of this report.

2.2. Potential Candidate Sites

The current ash disposal facility at the Camden Power station is rapidly reaching the limit of its capacity. It is therefore required that an appropriately selected alternative site is located within reasonable proximity to the power station. The ash is transported via pipelines from the power station in the form of a slurry and the site selected for the disposal facility will be developed to comply with the Minimum Requirements for Waste Disposal by Landfill, third edition of 2005 as published by Department of Water Affairs and Forestry.

This proposed project is locate three potential candidate sites and to determine the geotechnical and geological suitability of each site. (see figure 1).

2.2.1. ***Site 1***

Site 1 is located immediately north of the existing ash disposal facility and the area identified for development covers a surface area of approximately 176ha. The area is largely flat with a gentle gradient of approximately 1% down towards the west.

2.2.2. ***Site 2***

The second site is located south of the Dejagers Pan and the main railway servitude. The site consists of three adjacent portions of ground, which combined make up a surface area of approximately 221ha.

2.2.3. ***Site 3***

The third alternative site is located immediately south of the power station and north of the main railway servitude. This site is approximately 142ha in extent.

2.3 Site Geology

From the available literature as well as the observations during the site investigation, it is apparent that all three sites are underlain by siltstone, mudstone and sandstone that belong to the Vryheid Formation of the Ecca Group, Karoo Supergroup.

The presence of intruded dykes and sills in the Karoo sediments is well known and simple perusal of a 1: 250 000 scale geological maps of the area will confirm this. These features may vary in size from centimetres to tens of metres in width. Dykes and sills originate from deep seated magma chambers which force molten rock into cracks, and fissures as well as along bedding planes in the host formation. During the intrusion under the influence of extremely high pressure the host rock is further fractured in a process not to dissimilar to the proposed hydraulic fracturing. These are the reasons why water preferentially accumulates adjacent to the dykes and may provide hydraulic continuity with deeper aquifers.

The geological lithologies identified on the site belong to the following stratigraphic unit:

Lithology	*Formation*	*Unit*
Diabase intrusions		Post Transvaal age
Siltstone mudstone sandstone	Vryheid formation	Karoo Sequence

2.3.1. ***Vryheid formation***

The Vryheid formation consists of coal seams, grit, sandstone, arkose and mudstone, all deposited under shallow sea conditions. A particularly significant feature of the formation is the close intercalation of the different rock types within it. It is not unusual for a lenticular body of coarse sandstone to occur within a predominantly argillaceous horizon, while a weak lens of mudstone occurring within a competent layer of sandstone is equally common. Similarly bands of rock may be laterally discontinuous and may suddenly pinch out and may reappear some distance away.

Generally these rocks will decompose in-situ, forming residual soils that may be silty and clayey, with the possibility of expansive soil being present. These soils are often blanketed by a considerable thickness of transported soils of colluvial origin that consist of silty and clayey fine sands.

2.3.2. ***Diabase Sills and Dykes***

The eastern portion of Area 3 is underlain by a dolerite sill and the contact between the intruded igneous rock and the host sedimentary formations is orientated approximately southwest to northeast through the center of the site. Due to the emplacement of the igneous material the contact zone is typically fractured and differential weathering of the rock may result in deep residual soils occurring along the boundary.

Limited surface exposures of dolerite are usually noted and the presence of the intrusive features are alluded to by the accumulation of well rounded igneous boulders at ground surface.

2.4 Hydrology

2.4.1 ***Surface Drainage***

The average annual rainfall in this area is approximately 750mm, most of which occurs as heavy, isolated thunder showers between October and March. Storm water runoff is generally in the form of sheetwash, which flows towards the nearest local drainage course and the adjacent Vaal river.

2.4.2 ***Perched Ground Water***

No groundwater seepage was encountered in the test pits and therefore the depth of the perched water table could not be determined. It was immediately evident from the aerial photographs and the site visit that localised areas particularly in the vicinity of standing surface water are subject to seasonal seepage.

The shallow perched water levels which often give rise to seepages on surface are usually in response to intense rainfall events, and this is not a sustainable source of ground water and is very dependant on rainfall.

Further evidence of the presence of a seasonal perched water table is the almost ubiquitous horizon of ferruginised soil, consisting of ferricrete nodules in a matrix of clayey and silty sand that is indicative of pedogenisis. Ferricrete forms by the relative accumulation of sesquioxides (Fe_2O_3) by the removal of the more soluble constituents of the soil, which occurs under conditions of seasonal saturation. The iron is mobilised under reducing conditions in the wet season and precipitated under oxidising conditions experienced in the dry season, thereby giving rise to the ferruginised soil horizons that generally occur within 1.0 to 2.0m of the surface.

2.4.3. *Permanent Ground Water*

The potentially deeply weathered sandstone and siltstone in the area will decompose to form residual soils with a clay-silt and sand texture and may extend to depths of up to 20m. As alluded to in 2.3.1 above the sedimentary rocks of the Vryheid formation are highly variable both horizontally and vertically. The sandstone which occur in the area are generally coarsely bedded and fractured and are also closely jointed, and it is within the structural fabric of the rock that a secondary aquifer of limited extent will be developed. These aquifers are usually restricted by the depth of weathering, the presence of aquatards, such as intruded dykes and the thickness of the geological formation. (see figure 2 below).

It is anticipated the phreatic surface will be encountered at a depth of approximately 20 to 30m (see figure 3 below).

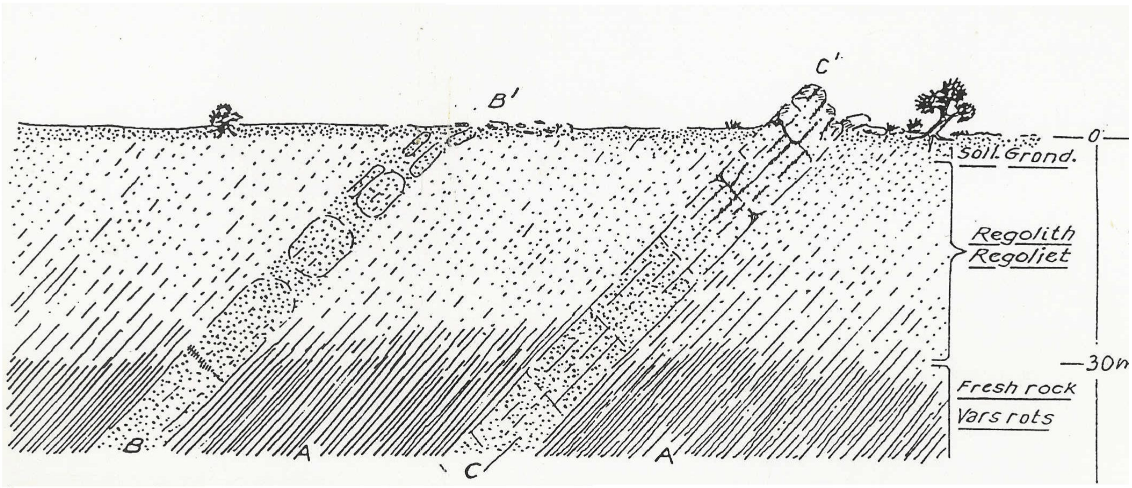

Figure 3. Different modes of weathering exhibited by different types of rock. Siltstone (A) weathers easily with a gradual transition to regolith, and is generally not exposed at surface. Sandstone (B and C) is more resistant, but joint weathering has broken the formation into residual blocks. The formation is likely to outcrop at surface or immediately beneath a thin mantle of transported soils. The secondary aquifer will be confined within the fractured and jointed rock usually within 30m of the surface .
(taken from "Introduction to Groundwater" GSSA, Ground Water Division 1992)

Due to the low permeability of the soils as well as the high degree of variability in the weathering of the sandstone and siltstone formations, particularly in the vicinity of Camden Power Station, groundwater yields will vary from borehole to borehole over even short distance and yields are typically poor (0.5-2.0l/s).

2.5 <u>Observations</u>

Twelve test pits were excavated to an average depth of 1.4m and medium hard excavation conditions were experienced in each hole. A summary of the prevailing soils is presented below, while the detailed soil profiles are included in Appendix 2.

2.5.1. *Transported Materials*

The entire area is covered by transported soil which may vary in thickness from a few centimetres up to several metres. Due to the transported origin of the soils the geotechnical characteristics are typically highly variable and difficult to predict.

The transported soils that occur on the lower slopes of the undulating topography are described as silty sand and gravels, of colluvial (hillwash) origin.
The soils are generally of loose to medium dense consistency, and is rich in organic matter.

The base of the transported soils is defined by the pebble marker which consists of a thin horizon (usually 20 to 40cm thick) that contains sub-rounded and angular quartz gravels, in a matrix of greyish brown silty sand.

2.5.2 *Alluvium*

Within the low lying portions along the western side of Area 2 and the eastern side of Area 1 that are occupied small non-perennial streams that flow towards the northeast, areas of recently deposited alluvial sediments occur. These soils are derived from the proximal rocks that occur in the area and the soil texture and mechanical properties are characterised by the lithologies from which they are derived. Typically the soils will be characterised by unconsolidated sediments that consist of sandy silt and clay with a high organic content. The thickness of these soils will vary considerably, and it must be anticipated that the soils may be potentially expansive as well as highly compressible.

2.5.3. *Pedogenic Soils*

The base of the transported soils is usually defined by the pebble marker that has been subjected to pedogenesis in places. The degree of cementation of the pedogenic material varies from scattered ferricrete nodules, honeycomb ferricrete to hardpan ferricrete. The consistency of the horizon is dependant on the degree pedogenisis, varying from dense to very soft rock consistency and is approximately from 0.3 to 0.5m thick.

2.5.4. *Residual soils*

A brief description of the residual soils derived from each of the geological formations is also presented.

2.5.4.1 *Diabase Intrusions.*

The post Transvaal age dolerite intrusions that occur in the area generally consists of completely weathered, coarse grained, closely jointed, medium hard rock, diabase. In the sub humid and humid warm climatic regions of the country, falling within the Wienert's climatic N value of less than 5 (Ermelo has a value of 1.8) such as the area investigated, the dolerite undergoes chemical decomposition, which produces residual soils which are commonly expansive. A particularly interesting feature about the dolerite sills in the eastern parts of South Africa is the extreme variability in the depth and degree of decomposition over a relatively short distance. Within a few meters of an outcrop of solid rock a test pit may disclose a substantial depth of decomposition.

2.5.4.2 *Vryheid formation*

The residual soils derived from the Vryheid formation weather to form stiff, fine grained sandy silt and clayey silt that may be weathered to depths of up to 20m . Typically the residual soils are 2 to 4m in thickness, grading into very soft rock siltstone or sandstone.

It is common that the residual siltstone and mudstone contain a high proportion of montmorillonite clays and lesser amounts of kaolinite, mica and quartz, which imply that these soils may be highly expansive.

2.6 Laboratory and Field Test Results

For more accurate identification and classification purposes, Particle Size Distribution and Atterberg Limits Tests were carried out on representative samples of the various soil horizons present within the site. The results are shown in Appendix 3 of this report and are summarised in Table 1 below.

TABLE 1. Summary of Indicator test results

TP No.	Depth (m)	Material	PI	PI (ws)	LS (%)	Activity
1	1.0-1.1	Silty sand and ferricrete. Ferruginised hillwash.	24	20	12	med
2	1.4-1.5	Silty clayey sand and ferricrete. Rew. Res. Siltstone	18	16	8	med
5	1.4-1.5	Silty sandy clay and gravel. Rew. Res. Siltstone	23	19	10	med
7	1.3-1.4	Silty clayey sand. Hillwash	15	10	7	low/med
9	1.1-1.2	Gravel and ferricrete with silty sand. Ferruginised Res. Siltstone	16	12	7	med
11	1.1-1.3	Silty clayey sand. Hillwash	16	8	7	low

3. INTERPRETIVE REPORT

3.1. Impact Assessment

The methodology employed to determine the environmental impact of the geotechnical aspects of the proposed project, were included in the Zitholele Consulting letter of appointment, dated 14 June 2011. In summary the method makes provision for the assessment of the impacts against the following criteria:

significance
spatial scale
temporal scale
degree of certainty

These impacts are assessed in both a qualitative and quantitative method.

Each candidate site was evaluated in terms of the recommendations of *Section 4, Site Selection* of the Minimum Requirements for Waste Disposal by Landfill (2005) document, and from a geotechnical and geohydrological perspective the following situations are considered to constitute a fatal flaw.

Area below the 1 in 100 year flood line.
Area in close proximity to significant water bodies.
Unstable areas.
Areas characterised by flat gradients, shallow or emergent ground water.
Area characterised by steep gradients where stability of slopes could be problematic.
Areas of ground water recharge on account of topography and or highly permeable soils.
Areas characterised by shallow bedrock with little soil cover.

Utilising the evaluation criteria listed above the impact of the proposed land use was determined.

3.1.1 ***Site 1***

i. This site is located immediately north of the existing ash disposal facility, and approximately 2.8km northwest of the Camden power station.
ii. The size of the area is approximately 176ha.
iii. The area is situated on a relatively flat portion of ground that has a gentle gradient down towards the west at 1 to 2%. The site is currently un used for any other activities and the vegetation consists of typical Highveld grasslands.
iv. The entire site appears to be underlain by inter bedded sandstone and siltstone of the Vryheid formation. No evidence of the presence of intruded sills or dykes were identified.
v. The Camden village is located approximately 300m to the east of the site.
vi. No ground water seepage was observed on the site and no seepage was recorded in the test pits.
vii. A drainage course that directs runoff from the existing ash disposal facility is located on the eastern side of the site, while the Dejagers pan is located within 500m to the south of the site.
viii. The underlying soils on the site consist of a shallow horizon of transported soils to an approximate depth of 500mm, which overly ferruginised, jointed reworked residual siltstone. The depth of weathering is anticipated to extend to a depth of approximately 3 to 5m.

The determined impact assessment is shown in table 2 below.

TABLE 2. Impact assessment of Site 1					
Criteria	**Significance**	**Spacial Scale**	**Temporal Scale**	**Probability**	**Rating**
Within 1 in 100 year flood line	NO IMPACT	*Proposed site*	Incidental	*Unlikely*	0.3
	0	1	1	2	
Proximity to significant water body	LOW	*Study Area*	Long term	*Could happen*	1.6
	2	2	4	3	
Unstable area	VERY LOW	*Proposed site*	Incidental	*Practically Impossible*	0.2
	1	1	1	1	
Flat gradient and emergent ground water	LOW	*Study Area*	Incidental	*Could happen*	1
	2	2	1	3	
Steep gradient and slope stability problems	NO IMPACT	*Proposed site*	Incidental	*Practically Impossible*	0.3
	0	1	1	1	
Area of groundwater recharge	LOW	*Local*	Long term	*Unlikely*	1.2
	2	3	4	2	
Shallow bedrock and poor soil cover	LOW	*Study Area*	Permanent	*Very likely*	2.4
	2	2	5	4	

3.1.2 ***Site 2***

i. This site is located immediately south of Dejagers Pan and the railway servitude, approximately 3.0km southwest of the Camden power station.
ii. The total area potentially available for development is approximately 221ha, of which it is considered that the eastern portion covering a surface area of some 98ha is the most suitable area.
iii. The area is situated on a shallow sloping site with a gradient down towards the north of 3 to 4% and the site is currently used for agricultural activity.
iv. The entire site appears to be underlain by inter bedded sandstone and siltstone of the Vryheid formation. No evidence of the presence of intruded sills or dykes were identified.
v. An electrified dual railway line is located immediately north of the proposed site and a powerline servitude is located along the eastern side.
vi. No ground water seepage was observed on the site and no seepage was recorded in the test pits, however it is likely that the area may be subjected to seasonal seepage.
vii. The eastern side of the site partially encroaches into drainage course of a small northeasterly flowing non-perennial stream. The Dejagers pan is located within 1.2km to the northwest of the site.
viii. The underlying soils on the site consist of a shallow horizon of transported soils to an approximate depth of 500 to 10000mm, which overly ferruginised, jointed reworked residual siltstone. The depth of weathering is anticipated to extend to a depth of approximately 3 to 5m.

The determined impact assessment is shown in table 3 below.

TABLE 3. Impact assessment Site 2					
Criteria	**Significance**	**Spacial Scale**	**Temporal Scale**	**Probability**	**Rating**
Within 1 in 100 year flood line	LOW	*Local*	Incidental	*Unlikely*	0.8
	2	3	1	2	
Proximity to significant water body	LOW	*Study Area*	Long term	*Could happen*	1.6
	2	2	4	3	
Unstable area	VERY LOW	*Proposed site*	Incidental	*Practically Impossible*	0.2
	1	1	1	1	
Flat gradient and emergent ground water	VERY LOW	*Study Area*	Incidental	*Could happen*	0.8
	1	2	1	3	
Steep gradient and slope stability problems	NO IMPACT	*Proposed site*	Incidental	*Practically Impossible*	0.1
	0	1	1	1	
Area of groundwater recharge	MODERATE	*Local*	Long term	*Could happen*	2
	3	3	4	3	
Shallow bedrock and poor soil cover	LOW	*Study Area*	Permanent	*Very likely*	2.4
	2	2	5	4	

3.1.3 *Site 3*

i. This site is located approximately 1.2km directly south of the Camden Power Station and immediately north of the SAR railway servitude.
ii. The total area potentially available for development is approximately 142ha.
iii. The area is situated within the headwaters of a non-perennial north flowing stream that flows into the Witpuntspruit some 3km to the northeast. The general slope of the site is approximately 1% down towards the northeast and the site is currently undeveloped.
iv. On the basis of the geological information available it is apparent that the site straddles the contact between the host sedimentary formations on the western side and an intruded dolerite sill to the east. The contact between the two geological lithologies is approximately along the non perennial stream mentioned in paragraph iii above. Due to the emplacement of the igneous material the contact zone is typically fractured and differential weathering of the rock may result in deep residual soils occurring along the boundary.
v. An electrified dual railway line is located immediately south of the proposed site and the coal stockpile and water storage facilities are located to the north and northwest of the area.
vi. Shallow ground water seepage was observed on the northern portion of the site and due to the topographic setting it must be anticipated that significant seepage and surface runoff will be encountered during periods of high rainfall.

vii. The underlying soils on the site consist of a shallow horizon of transported silty and clayey soils to an approximate depth of 500 to 10000mm, which overly ferruginised, jointed reworked residual siltstone. The depth of weathering is anticipated to extend to a depth of approximately 3 to 5m.

TABLE 4. Impact assessment Site 3					
Criteria	**Significance**	**Spacial Scale**	**Temporal Scale**	**Probability**	**Rating**
Within 1 in 100 year flood line	HIGH	*Regional*	long term	*Very likely*	4.8
	4	4	4	4	
Proximity to significant water body	LOW	*Study Area*	Long term	*Could happen*	1.6
	2	2	4	3	
Unstable area	VERY LOW	*Proposed site*	Incidental	*Practically Impossible*	0.2
	1	1	1	1	
Flat gradient and emergent ground water	VERY LOW	*Local*	Long term	*Could happen*	4.6
	4	3	4	3	
Steep gradient and slope stability problems	NO IMPACT	*Proposed site*	Incidental	*Practically Impossible*	0.1
	0	1	1	1	
Area of groundwater recharge	MODERATE	*Local*	Long term	*Could happen*	2
	3	3	4	3	
Shallow bedrock and poor soil cover	LOW	*Study Area*	Permanent	*Very likely*	2.4
	2	2	5	4	

3.2. Recommendations

On the basis of this evaluation it is apparent that site 3 is not suitable for the intended development, and should not be considered for further investigation. The remaining two target sites, namely Site 1 and Site 2 are both considered to be suitable for further consideration.

From a geological and geotechnical perspective it is considered that site 1 is the preferred option, however more detailed geotechnical and hydrogeological investigations will be required on both sites

AFRICA EXPOSED CONSULTING ENGINEERING GEOLOGISTS

J.K.A. ARKERT **Pr.Sci.Nat.**

REFERENCES

1. Brink A.B.A *"Engineering Geology of Southern Africa"* volume 1 and 3, published by Building Publications. 1979.

2. Fernandez L.M. and Guzman J.A. *"Earthquake hazard in southern Africa."* - Seismological Series 10. Geological Survey, 1979.

3. Geological Survey of RSA, *"Seismic Hazard Maps For Southern Africa"* Pretoria, 1992.

4. Jennings J.E. and Knight K. *"A guide to construction on or with materials exhibiting additional settlement due to collapse of grain structure."* - Proceedings of the 6th Regional Conference for Africa on Soil Mechanics and Foundation Engineering. Durban. 1975.

5. Jennings JE et al *. "Revised Guide to Soil profiling for Civil Engineering Purposes in Southern Africa"* - Civil Engineer in South Africa , January 1973

6. Johnson, M.R, Anhauesser, C.R. and Thomas, R.T, "The geology of South Africa" by published by Geological Society of South Africa in 2006.

7. Van der Merwe DH . *"The prediction of heave from the Plasticity Index and percentage clay fraction of soils"* - Civil Engineer in South Africa Vol 6, 1964.

8. Wilson,M.G.C and Anhaeusser, C.R. "*The Mineral Resources of South Africa."* Handbook 16, Sixth Edition. Council For Geoscience 1998.

9. Weinert H.H. *"The Natural road construction materials of South Africa."* - Academica (Cape Town), 1980.

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APPENDIX C

CONCEPTUAL ENGINEERING DRAWINGS

APPENDIX D

DESIGN CALCULATIONS FOR STORMWATER MANAGEMENT

APPENDIX D

DESIGN CALCULATIONS FOR STORMWATER MANAGEMENT

Rainfall Type: Triangular | Areal Reduction: Unspecif | Mean Annual Percipitation: 723 (mm)

I.D.F Type: HRU/78 | Time To Peak: 0.30 | Rainfall Region: Inland

Total Area(ha): 0.000

Project No/Name: 12670 Ash Dam for Camden

KAT0001	RES0001	198.000	0.0260	1	1,100.00	45	5	0.200	0.022	3.0	1.0	
KAT0002	RES0002	162.300	0.0400	1	1,000.00	45	5	0.200	0.022	3.0	1.0	
KAT0003	RES0003	214.540	0.0400	1	1,000.00	45	5	0.200	0.022	3.0	1.0	
KAT0004	0001	30.100	0.0260	2	150.00	45	5	0.200	0.022	3.0	1.0	
KAT0005	0002	32.200	0.0400	2	250.00	45	5	0.200	0.022	3.0	1.0	
KAT0006	0003	28.200	0.0400	2	150.00	45	5	0.200	0.022	3.0	1.0	
KAT0007	0004	27.500	0.0400	2	175.00	45	5	0.200	0.022	3.0	1.0	
KAT0008	<END>	5.220	0.3330	2	50.00	25	5	0.200	0.022	2.0	0.5	
KAT0009	<END>	11.810	0.3330	2	50.00	25	5	0.200	0.022	2.0	0.5	
KAT0010	<END>	9.990	0.3330	2	75.00	25	5	0.200	0.022	2.0	0.5	
KAT0011	<END>	18.890	0.3330	2	100.00	25	5	0.200	0.022	2.0	0.5	
KAT0012	<END>	10.300	0.3330	2	75.00	25	5	0.200	0.022	2.0	0.5	
KAT0013	<END>	10.600	0.3330	2	80.00	25	5	0.200	0.022	2.0	0.5	
KAT0014	<END>	8.100	0.3330	2	100.00	25	5	0.200	0.022	2.0	0.5	
KAT0015	<END>	4.900	0.3330	2	80.00	25	5	0.200	0.022	2.0	0.5	
KAT0016	<END>	13.400	0.3300	2	100.00	25	5	0.200	0.022	2.0	0.5	
KAT0017	<END>	4.700	0.3300	2	100.00	25	5	0.200	0.022	2.0	0.5	
KAT0018	<END>	7.600	0.3300	2	120.00	25	5	0.200	0.022	2.0	0.5	
KAT0019	<END>	18.900	0.3300	2	180.00	25	5	0.200	0.022	2.0	0.5	
KAT0020	<END>	11.300	0.3300	2	180.00	25	5	0.200	0.022	2.0	0.5	
KAT0021	<END>	5.700	0.3300	2	180.00	25	5	0.200	0.022	2.0	0.5	

Project Data Echo Report

Rainfall Type: Triangular

I.D.F Type: HRU/78

Areal Reduction: None

Time To Peak: 0.30

Total Area(ha): 834.250

Mean Annual Precipitation: 723 (mm)

Rainfall Region: Inland

0001	<END>	<NONE>	1.00	1.5000	1.5000	0.10	0.012		###.##	0.02600	100	0.298
0002	<END>	<NONE>	1.00	1.5000	1.5000	0.10	0.012		###.##	0.04000	100	0.369
0003	<END>	<NONE>	1.00	1.5000	1.5000	0.10	0.012		###.##	0.04000	100	0.369
0004	<END>	<NONE>	1.00	1.5000	1.5000	0.10	0.012		###.##	0.04000	100	0.369

Reservoir Data Echo

Rainfall Type: Triangular   Areal Red: Unspecif   M.A.F 723 (mm)   I.D.F Type: HRU/78   Time To Peak: 0.30

Project No/Name: 12670   Ash Dam for Camden   Reservoir Attenuation: 0.000
Total Area(ha): 834.250   Reservoir Lag Time: 0

			Outlet Works (Pipes)			Outlet Works (Culverts)				Outlet Works (Spillways)			
Node ID	Drain To	Elev Points	No	Diameter	Invert Lev	No	Width	Height	Invert Lev	No	Coef	Width	Invert Lev
RES0001	<NONE>	0	0	0.000	0.00	0	0.000	0.00	0.00	1	1.800	20.00	1659.00
								Reservoir Storage Contour:	No	Elevation		Storage Volume (m3)	
									1	1650.0000		0.000	
									2	1651.0000		20,000.000	
									3	1652.0000		40,000.000	
									4	1653.0000		60,000.000	
									5	1654.0000		80,000.000	
									6	1655.0000		100,000.000	
									7	1656.0000		120,000.000	
									8	1657.0000		140,000.000	
									9	1658.0000		160,000.000	
									10	1659.0000		180,000.000	
									11	1660.0000		200,000.000	
RES0002	<NONE>	0	0	0.000	0.00	0	0.000	0.00	0.00	1	1.800	20.00	1659.00
								Reservoir Storage Contour:	No	Elevation		Storage Volume (m3)	
									1	1650.0000		0.000	
									2	1651.0000		20,000.000	
									3	1652.0000		40,000.000	
									4	1653.0000		60,000.000	
									5	1654.0000		80,000.000	
									6	1655.0000		100,000.000	
									7	1656.0000		120,000.000	
									8	1657.0000		140,000.000	
									9	1658.0000		160,000.000	
									10	1659.0000		180,000.000	
									11	1660.0000		200,000.000	
RES0003	<NONE>	0	0	0.000	0.00	0	0.000	0.00	0.00	1	1.800	20.00	1659.00
								Reservoir Storage Contour:	No	Elevation		Storage Volume (m3)	
									1	1650.0000		0.000	
									2	1651.0000		20,000.000	
									3	1652.0000		40,000.000	
									4	1653.0000		60,000.000	
									5	1654.0000		80,000.000	
									6	1655.0000		100,000.000	
									7	1656.0000		120,000.000	
									8	1657.0000		140,000.000	
									9	1658.0000		160,000.000	
									10	1659.0000		180,000.000	
									11	1660.0000		200,000.000	

Simulation Maxima

Rainfall Type: Triangular Areal Red: Not Spec M.A.P: 723 (mm) Project No/Name: 12670

I.D.F Type: HRU/78 Time To Peak: 0.30 Total Area(ha): 834.250 Ash Dam for Camden

Multiple RI used for Analysis - The Simulation Maxima can ONLY be used to Identify Problem Areas

Node ID	Inlet Peak(m3)	Storage(m3)	Velocity (m/s)	Hazard Rating Factor	MaxDepth(m)	Ex Q(m/s)	Resize	Storm Duration
Output Summary for year recurrence Interval 1: 50								
Element Type: Catchments								
KAT0001	17.314	13		N/A	0.0350			81
KAT0002	17.333	13		N/A	0.0305			81
KAT0003	22.912	13		N/A	0.0305			81
KAT0004	8.273	7		N/A	0.0163			41
KAT0005	7.697	7		N/A	0.0190			41
KAT0006	8.502	7		N/A	0.0146			41
KAT0007	7.769	7		N/A	0.0158			41
KAT0008	3.506	3		N/A	0.0054			21
KAT0009	7.932	3		N/A	0.0054			21
KAT0010	6.068	3		N/A	0.0069			21
KAT0011	10.524	3		N/A	0.0081			21
KAT0012	6.256	3		N/A	0.0069			21
KAT0013	6.328	3		N/A	0.0071			21
KAT0014	4.513	3		N/A	0.0081			21
KAT0015	2.925	3		N/A	0.0071			21
KAT0016	7.456	3		N/A	0.0081			21
KAT0017	2.615	3		N/A	0.0081			21
KAT0018	3.993	3		N/A	0.0089			21
KAT0019	8.528	3		N/A	0.0111			21
KAT0020	5.099	3		N/A	0.0111			21
KAT0021	2.572	3		N/A	0.0111			21
Element Type: Channels								
0001	8.273		4.72	374 High	0.6193		0.700	41
0002	7.697		5.55	316 High	0.5361		0.600	41
0003	8.502		5.63	361 High	0.5637		0.600	41
0004	7.769		5.52	320 High	0.5385		0.600	41
Element Type: Reservoirs								
RES0001	17.314	183079		N/A	###.####			81
RES0002	17.333	181140		N/A	###.####			81
RES0003	22.912	184824		N/A	###.####			81

Simulation Maxima

Rainfall Type: Triangular Areal Red: Not Spec M.A.P: 723 (mm) Project No/Name: 12670

I.D.F Type: HRU/78 Time To Peak: 0.30 Total Area(ha): 834.250 Ash Dam for Camden

Multiple RI used for Analysis - The Simulation Maxima can ONLY be used to Identify Problem Areas

Output Summary for year recurrence Interval 1: 50

Element Type: Catchments

Node ID	Inlet Peak(m3)	Storage(m3)	Velocity (m/s)	Hazard Rating Factor	MaxDepth(m)	Ex Q(m/s)	Resize	Storm Duration
KAT0001	13.495	5		N/A	0.0401			30
KAT0002	14.303	5		N/A	0.0362			30
KAT0003	18.907	5		N/A	0.0362			30
KAT0004	8.314	5		N/A	0.0178			30
KAT0005	7.567	5		N/A	0.0205			30
KAT0006	8.679	5		N/A	0.0159			30
KAT0007	7.840	5		N/A	0.0172			30
KAT0008	3.666	2		N/A	0.0063			11
KAT0009	8.294	2		N/A	0.0063			11
KAT0010	6.114	3		N/A	0.0071			19
KAT0011	10.594	3		N/A	0.0082			20
KAT0012	6.304	3		N/A	0.0071			19
KAT0013	6.358	3		N/A	0.0073			19
KAT0014	4.542	3		N/A	0.0082			20
KAT0015	2.939	3		N/A	0.0073			19
KAT0016	7.503	3		N/A	0.0082			20
KAT0017	2.632	3		N/A	0.0082			20
KAT0018	3.996	3		N/A	0.0091			20
KAT0019	8.588	3		N/A	0.0108			23
KAT0020	5.135	3		N/A	0.0108			23
KAT0021	2.590	3		N/A	0.0108			23

Element Type: Channels

Node ID	Inlet Peak(m3)	Storage(m3)	Velocity (m/s)	Hazard Rating Factor	MaxDepth(m)	Ex Q(m/s)	Resize	Storm Duration
0001	8.314		4.87	378 High	0.6214		0.700	30
0002	7.567		5.51	309 High	0.5314		0.600	30
0003	8.679		5.74	371 High	0.5695		0.600	30
0004	7.840		5.52	324 High	0.5414		0.600	30

Element Type: Reservoirs

Node ID	Inlet Peak(m3)	Storage(m3)	Velocity (m/s)	Hazard Rating Factor	MaxDepth(m)	Ex Q(m/s)	Resize	Storm Duration
RES0001	13.495	108786		N/A	###.####			30
RES0002	14.303	107163		N/A	###.####			30
RES0003	18.907	125563		N/A	###.####			30

APPENDIX E

STAGE CURVES FOR ASH DAM OPTIONS

PHASING IN OF LINER INSTALLATION

Site 1

Min Height = 1661.3

Step No	Elevation	Footprint	Acc. Foot	Volume	Year	
	mamsl	m^2	m^2	m^3	From	To
						2014
1	1669.3	241,835	241,835	468,742	2014	2014
2	1677.3	675,362	917,197	4,425,160	2014	2015
3	1685.3	438,262	1,355,459	12,570,485	2015	2020
4	1693.3	181,209	1,536,668	22,192,142	2020	2027
5	1701.3	6,857	1,543,525	31,134,583	2027	2032

Site 3A

Min Height = 1665.5

Step No	Elevation	Footprint	Acc. Foot	Volume	Year	
	mamsl	m^2	m^2	m^3	From	To
						2014
1	1673.5	36,840	36,840	98,292	2014	2014
2	1681.5	579,830	616,670	906,215	2014	2014
3	1689.5	406,408	1,023,078	3,161,205	2014	2014
4	1697.5	239,347	1,262,425	6,876,435	2014	2017
5	1705.5	231,275	1,493,700	12,080,773	2017	2020
6	1713.5	68,722	1,562,422	17,379,228	2020	2023

Site 3B

Min Height = 1685

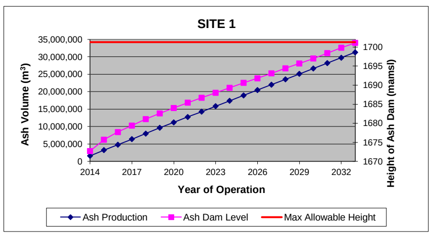
Step No	Elevation	Footprint	Acc. Foot	Volume	Year	
	mamsl	m^2	m^2	m^3	From	To
						2014
1	1693	58,233	58,233	934,204	2014	2014
2	1701	258,371	316,604	3,950,256	2014	2015
3	1709	301,265	617,869	8,731,753	2015	2018
4	1717	303,477	921,346	13,995,091	2018	2021

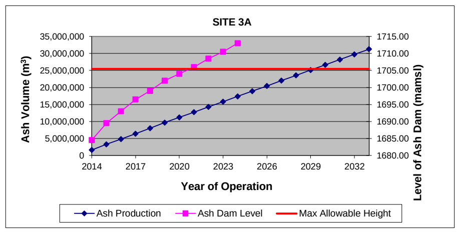
Ash Production	
0	2014
1,596,480	2014
3,258,880	2015
4,805,120	2016
6,392,320	2017
7,991,360	2018
9,653,440	2019
11,198,720	2020
12,744,000	2021
14,289,280	2022
15,834,560	2023
17,379,840	2024
18,925,120	2025
20,470,400	2026
22,015,680	2027
23,560,960	2028
25,106,240	2029
26,651,520	2030
28,196,800	2031
29,742,080	2032
31,287,360	2033

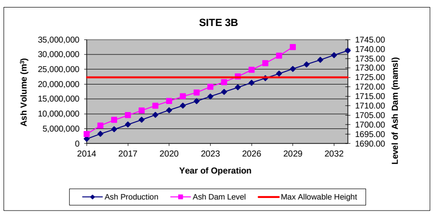
R 8.80 per tonne

YEAR	COAL BURN (TON)	ASH PERCENTAGE	ASH PRODUCTION (TON)	ASH PRODUCTION (M^3)	ACCUMULATIVE ASH PRODUCTION (M^3)	HEIGHT (MAMSL) OPTION 1	OPTION 3A	OPTION 3B	Operating Costs (Rands)
2014	4,989,000	32	1,596,480	1,596,480	1,596,480	1672.70	1684.50	1695.00	14,049,024
2015	5,195,000	32	1,662,400	1,662,400	3,258,880	1675.70	1689.50	1699.50	14,629,120
2016	4,832,000	32	1,546,240	1,546,240	4,805,120	1677.70	1693.00	1702.50	13,606,912
2017	4,960,000	32	1,587,200	1,587,200	6,392,320	1679.40	1696.50	1705.00	13,967,360
2018	4,997,000	32	1,599,040	1,599,040	7,991,360	1681.10	1699.00	1707.50	14,071,552
2019	5,194,000	32	1,662,080	1,662,080	9,653,440	1682.60	1702.00	1710.00	14,626,304
2020	4,829,000	32	1,545,280	1,545,280	11,198,720	1684.00	1704.00	1712.50	13,598,464
2021	4,829,000	32	1,545,280	1,545,280	12,744,000	1685.40	1706.00	1715.00	13,598,464
2022	4,829,000	32	1,545,280	1,545,280	14,289,280	1686.70	1708.50	1717.00	13,598,464
2023	4,829,000	32	1,545,280	1,545,280	15,834,560	1688.00	1710.50	1720.00	13,598,464
2024	4,829,000	32	1,545,280	1,545,280	17,379,840	1689.30	1713.00	1722.50	13,598,464
2025	4,829,000	32	1,545,280	1,545,280	18,925,120	1690.60		1725.50	13,598,464
2026	4,829,000	32	1,545,280	1,545,280	20,470,400	1691.80		1729.00	13,598,464
2027	4,829,000	32	1,545,280	1,545,280	22,015,680	1693.10		1732.50	13,598,464
2028	4,829,000	32	1,545,280	1,545,280	23,560,960	1694.40		1736.50	13,598,464
2029	4,829,000	32	1,545,280	1,545,280	25,106,240	1695.70		1741.00	13,598,464
2030	4,829,000	32	1,545,280	1,545,280	26,651,520	1697.00			13,598,464
2031	4,829,000	32	1,545,280	1,545,280	28,196,800	1698.40			13,598,464
2032	4,829,000	32	1,545,280	1,545,280	29,742,080	1699.80			13,598,464
2033	4,829,000	32	1,545,280	1,545,280	31,287,360	1701.10			13,598,464
									275,328,768

YEAR	MAXIMUM HEIGHTS (MAMSL) OPTION 1	OPTION 3A	OPTION 3B	RATE OF RISE (m/year) OPTION 1	OPTION 3A	OPTION 3B
2014	1701.300	1705.500	1725.000	0	0	0
2015	1701.300	1705.500	1725.000	3.00	5.00	4.50
2016	1701.300	1705.500	1725.000	2.00	3.50	3.00
2017	1701.300	1705.500	1725.000	1.70	3.50	2.50
2018	1701.300	1705.500	1725.000	1.70	2.50	2.50
2019	1701.300	1705.500	1725.000	1.50	3.00	2.50
2020	1701.300	1705.500	1725.000	1.40	2.00	2.50
2021	1701.300	1705.500	1725.000	1.40	2.00	2.50
2022	1701.300	1705.500	1725.000	1.30	2.50	2.00
2023	1701.300	1705.500	1725.000	1.30	2.00	3.00
2024	1701.300	1705.500	1725.000	1.30	2.50	2.50
2025	1701.300	1705.500	1725.000	1.30		3.00
2026	1701.300	1705.500	1725.000	1.20		3.50
2027	1701.300	1705.500	1725.000	1.30		3.50
2028	1701.300	1705.500	1725.000	1.30		4.00
2029	1701.300	1705.500	1725.000	1.30		4.50
2030	1701.300	1705.500	1725.000	1.30		
2031	1701.300	1705.500	1725.000	1.40		
2032	1701.300	1705.500	1725.000	1.40		
2033	1701.300	1705.500	1725.000	1.30		







SITE 1 VOL	SITE 1 ELEV	SITE 1 VOL	SITE 3A VOL	SITE 3A ELEV	SITE 3A VOL	SITE 3B VOL	SITE 3B ELEV	SITE 3B VOL
0	1661.300	0	0	1665.500	0	0	1685.000	0
1	1661.400	1	236	1666.000	236	654	1685.500	654
6	1661.500	6	876	1666.500	876	3408	1686.000	3408
16	1661.600	16	2127	1667.000	2127	10206	1686.500	10206
32	1661.700	32	4075	1667.500	4075	23084	1687.000	23084
56	1661.800	56	6728	1668.000	6728	44217	1687.500	44217
95	1661.900	95	10149	1668.500	10149	74825	1688.000	74825
151	1662.000	151	14415	1669.000	14415	115764	1688.500	115764
226	1662.100	226	19596	1669.500	19596	167830	1689.000	167830
321	1662.200	321	25655	1670.000	25655	230707	1689.500	230707
435	1662.300	435	32552	1670.500	32552	303631	1690.000	303631
571	1662.400	571	40314	1671.000	40314	385932	1690.500	385932
731	1662.500	731	48992	1671.500	48992	477593	1691.000	477593
928	1662.600	928	58653	1672.000	58653	578578	1691.500	578578
1163	1662.700	1163	69832	1672.500	69832	688537	1692.000	688537
1425	1662.800	1425	83285	1673.000	83285	807171	1692.500	807171
1718	1662.900	1718	98292	1673.500	98292	934204	1693.000	934204
2044	1663.000	2044	115100	1674.000	115100	1066641	1693.500	1066641
2401	1663.100	2401	135195	1674.500	135195	1204492	1694.000	1204492
2786	1663.200	2786	159045	1675.000	159045	1350658	1694.500	1350658
3196	1663.300	3196	186793	1675.500	186793	1504760	1695.000	1504760
3629	1663.400	3629	218591	1676.000	218591	1666410	1695.500	1666410
4079	1663.500	4079	255038	1676.500	255038	1835638	1696.000	1835638
4549	1663.600	4549	296281	1677.000	296281	2012709	1696.500	2012709
5047	1663.700	5047	341957	1677.500	341957	2197664	1697.000	2197664
5584	1663.800	5584	392596	1678.000	392596	2390234	1697.500	2390234
6160	1663.900	6160	448688	1678.500	448688	2590420	1698.000	2590420
6764	1664.000	6764	510199	1679.000	510199	2798577	1698.500	2798577
7393	1664.100	7393	577497	1679.500	577497	3014437	1699.000	3014437
8045	1664.200	8045	650597	1680.000	650597	3237582	1699.500	3237582
8719	1664.300	8719	729750	1680.500	729750	3468021	1700.000	3468021
9414	1664.400	9414	815824	1681.000	815824	3705543	1700.500	3705543
10137	1664.500	10137	906215	1681.500	906215	3950256	1701.000	3950256
10894	1664.600	10894	1000623	1682.000	1000623	4199382	1701.500	4199382
11697	1664.700	11697	1101536	1682.500	1101536	4452603	1702.000	4452603
12577	1664.800	12577	1208825	1683.000	1208825	4712809	1702.500	4712809
13552	1664.900	13552	1322574	1683.500	1322574	4980675	1703.000	4980675
14637	1665.000	14637	1442261	1684.000	1442261	5256808	1703.500	5256808
15867	1665.100	15867	1567929	1684.500	1567929	5542035	1704.000	5542035
17276	1665.200	17276	1699610	1685.000	1699610	5836702	1704.500	5836702
18887	1665.300	18887	1837321	1685.500	1837321	6139512	1705.000	6139512
20718	1665.400	20718	1981514	1686.000	1981514	6448883	1705.500	6448883
22790	1665.500	22790	2132084	1686.500	2132084	6763630	1706.000	6763630
25135	1665.600	25135	2288667	1687.000	2288667	7082914	1706.500	7082914
27800	1665.700	27800	2451030	1687.500	2451030	7406200	1707.000	7406200
30849	1665.800	30849	2619406	1688.000	2619406	7733168	1707.500	7733168
34312	1665.900	34312	2794224	1688.500	2794224	8063416	1708.000	8063416
38178	1666.000	38178	2975814	1689.000	2975814	8396351	1708.500	8396351
42478	1666.100	42478	3161205	1689.500	3161205	8731753	1709.000	8731753
47215	1666.200	47215	3350319	1690.000	3350319	9064987	1709.500	9064987
52384	1666.300	52384	3545589	1690.500	3545589	9395602	1710.000	9395602
58023	1666.400	58023	3746738	1691.000	3746738	9727865	1710.500	9727865
64162	1666.500	64162	3953862	1691.500	3953862	10061428	1711.000	10061428
70842	1666.600	70842	4166759	1692.000	4166759	10395737	1711.500	10395737
78061	1666.700	78061	4385095	1692.500	4385095	10730447	1712.000	10730447
85806	1666.800	85806	4608777	1693.000	4608777	11065140	1712.500	11065140
94096	1666.900	94096	4837949	1693.500	4837949	11399412	1713.000	11399412
102940	1667.000	102940	5072530	1694.000	5072530	11732699	1713.500	11732699
112374	1667.100	112374	5312621	1694.500	5312621	12064291	1714.000	12064291
122405	1667.200	122405	5558194	1695.000	5558194	12393460	1714.500	12393460
133023	1667.300	133023	5809643	1695.500	5809643	12719721	1715.000	12719721
144237	1667.400	144237	6067475	1696.000	6067475	13043008	1715.500	13043008
156040	1667.500	156040	6331582	1696.500	6331582	13363328	1716.000	13363328

168421	1667.600	168421
181373	1667.700	181373
194905	1667.800	194905
209034	1667.900	209034
223785	1668.000	223785
239158	1668.100	239158
255124	1668.200	255124
271691	1668.300	271691
288860	1668.400	288860
306624	1668.500	306624
324988	1668.600	324988
343950	1668.700	343950
363506	1668.800	363506
383663	1668.900	383663
404432	1669.000	404432
425826	1669.100	425826
447264	1669.200	447264
468742	1669.300	468742
490834	1669.400	490834
513544	1669.500	513544
536881	1669.600	536881
560851	1669.700	560851
585453	1669.800	585453
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636535	1670.000	636535
663012	1670.100	663012
690126	1670.200	690126
717885	1670.300	717885
746273	1670.400	746273
775291	1670.500	775291
804965	1670.600	804965
835304	1670.700	835304
866296	1670.800	866296
897935	1670.900	897935
930204	1671.000	930204
963081	1671.100	963081
996568	1671.200	996568
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1065387	1671.400	1065387
1100720	1671.500	1100720
1136670	1671.600	1136670
1173239	1671.700	1173239
1210436	1671.800	1210436
1248274	1671.900	1248274
1286750	1672.000	1286750
1325849	1672.100	1325849
1365568	1672.200	1365568
1405910	1672.300	1405910
1446883	1672.400	1446883
1488479	1672.500	1488479
1530684	1672.600	1530684
1573507	1672.700	1573507
1616954	1672.800	1616954
1661032	1672.900	1661032
1705751	1673.000	1705751
1751116	1673.100	1751116
1797135	1673.200	1797135
1843810	1673.300	1843810
1891137	1673.400	1891137
1939112	1673.500	1939112
1987758	1673.600	1987758
2037084	1673.700	2037084
2087092	1673.800	2087092
2137806	1673.900	2137806
2189226	1674.000	2189226
2241351	1674.100	2241351
2294190	1674.200	2294190
2347753	1674.300	2347753
2402040	1674.400	2402040
2457045	1674.500	2457045
2512793	1674.600	2512793
2569303	1674.700	2569303
2626601	1674.800	2626601
2684823	1674.900	2684823
2744171	1675.000	2744171
2804874	1675.100	2804874
2866991	1675.200	2866991
2930596	1675.300	2930596
2995768	1675.400	2995768
3062383	1675.500	3062383
3130315	1675.600	3130315
3199434	1675.700	3199434
3269615	1675.800	3269615
3340768	1675.900	3340768
3412843	1676.000	3412843
3485840	1676.100	3485840
3559720	1676.200	3559720
3634452	1676.300	3634452
3710025	1676.400	3710025
3786399	1676.500	3786399
3863604	1676.600	3863604
3941671	1676.700	3941671
4020598	1676.800	4020598
4100358	1676.900	4100358
4180924	1677.000	4180924
4262303	1677.100	4262303
4343718	1677.200	4343718
4425160	1677.300	4425160
4507399	1677.400	4507399
4590439	1677.500	4590439
4674279	1677.600	4674279
4758898	1677.700	4758898
4844269	1677.800	4844269
4930366	1677.900	4930366
5017155	1678.000	5017155
5104617	1678.100	5104617
5192747	1678.200	5192747
5281532	1678.300	5281532
5370975	1678.400	5370975
5461059	1678.500	5461059
5551753	1678.600	5551753
5643060	1678.700	5643060
5734963	1678.800	5734963
5827424	1678.900	5827424
5920430	1679.000	5920430
6013977	1679.100	6013977
6108053	1679.200	6108053
6202621	1679.300	6202621
6297639	1679.400	6297639
6393093	1679.500	6393093
6488967	1679.600	6488967
6585246	1679.700	6585246
6681934	1679.800	6681934
6779035	1679.900	6779035
6876536	1680.000	6876536
6974446	1680.100	6974446
7072765	1680.200	7072765
7171467	1680.300	7171467
7270541	1680.400	7270541
7370005	1680.500	7370005
7469878	1680.600	7469878
7570139	1680.700	7570139
7670779	1680.800	7670779
7771798	1680.900	7771798

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7154554	1698.000	7154554
7439342	1698.500	7439342
7731030	1699.000	7731030
8029846	1699.500	8029846
8336497	1700.000	8336497
8651139	1700.500	8651139
8972978	1701.000	8972978
9301110	1701.500	9301110
9634770	1702.000	9634770
9973583	1702.500	9973583
10317387	1703.000	10317387
10665674	1703.500	10665674
11017586	1704.000	11017586
11371820	1704.500	11371820
11727430	1705.000	11727430
12080773	1705.500	12080773
12431770	1706.000	12431770
12783818	1706.500	12783818
13136882	1707.000	13136882
13490845	1707.500	13490845
13845575	1708.000	13845575
14200738	1708.500	14200738
14555947	1709.000	14555947
14910933	1709.500	14910933
15265523	1710.000	15265523
15619757	1710.500	15619757
15973552	1711.000	15973552
16326616	1711.500	16326616
16678685	1712.000	16678685
17029601	1712.500	17029601
17379228	1713.000	17379228

47.500

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14301561	1717.500	14301561
14600135	1718.000	14600135
14895841	1718.500	14895841
15188688	1719.000	15188688
15478681	1719.500	15478681
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16331611	1721.000	16331611
16610262	1721.500	16610262
16886095	1722.000	16886095
17159117	1722.500	17159117
17429335	1723.000	17429335
17696756	1723.500	17696756
17961388	1724.000	17961388
18223236	1724.500	18223236
18482309	1725.000	18482309
18733920	1725.500	18733920
18978109	1726.000	18978109
19219608	1726.500	19219608
19458424	1727.000	19458424
19694564	1727.500	19694564
19928035	1728.000	19928035
20158845	1728.500	20158845
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20835376	1730.000	20835376
21055610	1730.500	21055610
21273217	1731.000	21273217
21488206	1731.500	21488206
21700581	1732.000	21700581
21910352	1732.500	21910352
22117524	1733.000	22117524
22317535	1733.500	22317535
22510447	1734.000	22510447
22700893	1734.500	22700893
22888880	1735.000	22888880
23074414	1735.500	23074414
23257504	1736.000	23257504
23438156	1736.500	23438156
23616377	1737.000	23616377
23792174	1737.500	23792174
23965555	1738.000	23965555
24136525	1738.500	24136525
24305093	1739.000	24305093
24471266	1739.500	24471266
24635050	1740.000	24635050
24796452	1740.500	24796452
24955479	1741.000	24955479

56.000

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8179738	1681.300	8179738
8282698	1681.400	8282698
8386049	1681.500	8386049
8489811	1681.600	8489811
8593976	1681.700	8593976
8698515	1681.800	8698515
8803438	1681.900	8803438
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9014449	1682.100	9014449
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9226910	1682.300	9226910
9333665	1682.400	9333665
9440770	1682.500	9440770
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9764200	1682.800	9764200
9872694	1682.900	9872694
9981526	1683.000	9981526
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10200212	1683.200	10200212
10310025	1683.300	10310025
10420158	1683.400	10420158
10530618	1683.500	10530618
10641412	1683.600	10641412
10752538	1683.700	10752538
10863998	1683.800	10863998
10975797	1683.900	10975797
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11200381	1684.100	11200381
11313165	1684.200	11313165
11426278	1684.300	11426278
11539688	1684.400	11539688
11653379	1684.500	11653379
11767365	1684.600	11767365
11881644	1684.700	11881644
11996216	1684.800	11996216
12111076	1684.900	12111076
12226206	1685.000	12226206
12341631	1685.100	12341631
12456400	1685.200	12456400
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12684826	1685.400	12684826
12799404	1685.500	12799404
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13029249	1685.700	13029249
13144531	1685.800	13144531
13260072	1685.900	13260072
13375868	1686.000	13375868
13491907	1686.100	13491907
13608197	1686.200	13608197
13724732	1686.300	13724732
13841485	1686.400	13841485
13958451	1686.500	13958451
14075636	1686.600	14075636
14193043	1686.700	14193043
14310677	1686.800	14310677
14428513	1686.900	14428513
14546524	1687.000	14546524
14664721	1687.100	14664721
14783105	1687.200	14783105
14901669	1687.300	14901669
15020416	1687.400	15020416
15139342	1687.500	15139342
15258458	1687.600	15258458
15377771	1687.700	15377771
15497274	1687.800	15497274
15616961	1687.900	15616961
15736810	1688.000	15736810
15856809	1688.100	15856809
15976958	1688.200	15976958
16097249	1688.300	16097249
16217670	1688.400	16217670
16338213	1688.500	16338213
16458898	1688.600	16458898
16579725	1688.700	16579725
16700674	1688.800	16700674
16821734	1688.900	16821734
16942907	1689.000	16942907
17064193	1689.100	17064193
17185583	1689.200	17185583
17307075	1689.300	17307075
17428671	1689.400	17428671
17550358	1689.500	17550358
17672127	1689.600	17672127
17793986	1689.700	17793986
17915941	1689.800	17915941
18037977	1689.900	18037977
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18404544	1690.200	18404544
18526845	1690.300	18526845
18649178	1690.400	18649178
18771545	1690.500	18771545
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19016362	1690.700	19016362
19138810	1690.800	19138810
19261269	1690.900	19261269
19383734	1691.000	19383734
19506205	1691.100	19506205
19628683	1691.200	19628683
19751174	1691.300	19751174
19873666	1691.400	19873666
19996139	1691.500	19996139
20118602	1691.600	20118602
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20363488	1691.800	20363488
20485886	1691.900	20485886
20608260	1692.000	20608260
20730609	1692.100	20730609
20852922	1692.200	20852922
20975198	1692.300	20975198
21097431	1692.400	21097431
21219620	1692.500	21219620
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21463885	1692.700	21463885
21585963	1692.800	21585963
21707995	1692.900	21707995
21829968	1693.000	21829968
21951877	1693.100	21951877
22072602	1693.200	22072602
22192142	1693.300	22192142
22311613	1693.400	22311613
22431009	1693.500	22431009
22550327	1693.600	22550327
22669571	1693.700	22669571
22788736	1693.800	22788736
22907809	1693.900	22907809
23026787	1694.000	23026787
23145666	1694.100	23145666
23264447	1694.200	23264447
23383123	1694.300	23383123

23501685	1694.400	23501685
23620131	1694.500	23620131
23738460	1694.600	23738460
23856665	1694.700	23856665
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24092671	1694.900	24092671
24210470	1695.000	24210470
24328131	1695.100	24328131
24445653	1695.200	24445653
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24680279	1695.400	24680279
24797383	1695.500	24797383
24914348	1695.600	24914348
25031173	1695.700	25031173
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25264406	1695.900	25264406
25380814	1696.000	25380814
25497083	1696.100	25497083
25613213	1696.200	25613213
25729204	1696.300	25729204
25845056	1696.400	25845056
25960770	1696.500	25960770
26076345	1696.600	26076345
26191781	1696.700	26191781
26307079	1696.800	26307079
26422238	1696.900	26422238
26537259	1697.000	26537259
26652141	1697.100	26652141
26766885	1697.200	26766885
26881491	1697.300	26881491
26995958	1697.400	26995958
27110287	1697.500	27110287
27224478	1697.600	27224478
27338531	1697.700	27338531
27452446	1697.800	27452446
27566223	1697.900	27566223
27679862	1698.000	27679862
27793363	1698.100	27793363
27906726	1698.200	27906726
28019952	1698.300	28019952
28133040	1698.400	28133040
28245990	1698.500	28245990
28358803	1698.600	28358803
28471478	1698.700	28471478
28584016	1698.800	28584016
28696417	1698.900	28696417
28808680	1699.000	28808680
28920806	1699.100	28920806
29032795	1699.200	29032795
29144647	1699.300	29144647
29256361	1699.400	29256361
29367938	1699.500	29367938
29479378	1699.600	29479378
29590681	1699.700	29590681
29701848	1699.800	29701848
29812878	1699.900	29812878
29923771	1700.000	29923771
30034527	1700.100	30034527
30145147	1700.200	30145147
30255630	1700.300	30255630
30365976	1700.400	30365976
30476186	1700.500	30476186
30586260	1700.600	30586260
30696197	1700.700	30696197
30805998	1700.800	30805998
30915663	1700.900	30915663
31025191	1701.000	31025191
31134583	1701.100	31134583

APPENDIX F

CAPITAL COST ESTIMATE BREAKDOWN

SITE 3B

CLEAN WATER DIVERSION TRENCHES

Site No.	Channel Base Width (m)	Channel Height (m)	Channel Width (m)	Channel Length (m)	Channel Excavate Vol (m)	Concrete Liner (m)	Volume Concrete Liner (m^3)	Mesh Ref 500 (m^2)
3B	1	0.7	3.1	3000	4,305	4.12	1,237	12,372
Totals					4,305		1,237	12,372

SOLUTION (DIRTY WATER) TRENCHES

Site No.	Channel Base Width (m)	Channel Height (m)	Channel Top Width (m)	Channel Length (m)	Channel Excavate Vol (m)	Concrete Liner (m)	Volume Concrete Liner (m^3)	Mesh Ref 500 (m^2)
A	1	0.6	2.8	1,300	1,482	3.76	489	4,892
B	1	0.4	2.2	400	256	3.04	122	1,217
C	1	0.6	2.8	700	798	3.76	263	2,634
D	1	0.9	3.7	1,150	2,432	4.84	557	5,572
E	1	1.0	4.0	570	1,425	5.21	297	2,967
F	1	0.7	3.1	350	502	4.12	144	1,443
Totals					6,896		1,873	18,726

SITE CLEARANCE **5,404,125.00**

	Area m^2	RATE	AMOUNT
Ash Dam Footprint	921,300	5.00	4,606,500.00
Clean Water Channels	9,300	5.00	46,500.00
Dirty Water Channels	14,100	5.00	70,500.00
Return Water Dam	110,000	5.00	550,000.00
Roads	26,125	5.00	130,625.00
Totals	1,080,825		

EARTHWORKS **114,556,182.50**

	Area m^2	Depth/ Length (m)	Volume m^3		
Excavation for Ash Dam Liner	921,300	1.4	1,289,820	45.00	58,041,900.00
Construction of Ash Dam starter wall	232	2,740	635,680	65.00	41,319,200.00
Excavation for RWD Liner	110,000	1.4	154,000	45.00	6,930,000.00
Construction of RWD wall	105	1,050	110,250	65.00	7,166,250.00
Clean water channels (from above)			0	45.00	0.00
Dirty water channels (from above)			6,896	45.00	310,297.50
Excavation for penstock outlet pipe	1.8	1,050	1,848	45.00	83,160.00
Box-cut for roads	26,125	0.6	15,675	45.00	705,375.00
Totals			2,214,169		

LINER SYSTEM **477,373,300.00**

	Area m^2	Volume m^3	Length m	***Totals***		
HDPE for Ash Dam	921,300		2	1,842,600	60.00	110,556,000.00
HDPE for RWD	110,000		2	220,000	60.00	13,200,000.00
Clay for Ash Dam	921,300	829,170		829,170	200.00	165,834,000.00
Clay for RWD	110,000	99,000		99,000	200.00	19,800,000.00
River Sand for Ash Dam	921,300	184,260		184,260	130.00	23,953,800.00
River Sand for RWD	110,000	22,000		22,000	130.00	2,860,000.00
Bidim for Ash Dam	1,842,600			1,842,600	45.00	82,917,000.00
Bidim for RWD	220,000			220,000	45.00	9,900,000.00
Geopipes for Leachate (AD)			16,200	16,200	120.00	1,944,000.00
Leak detection stone 19mm (AD)	921,300	138,195		138,195	300.00	41,458,500.00
Leak detection stone 19mm (RWD)	110,000	16,500		16,500	300.00	4,950,000.00

Liner rate R/m^2 *462.88*

STRUCTURAL CONCRETE **6,560,788.64**

	Area m^2	Volume t or m^3	Length m	***Totals***		
RWD Silt Trap Concrete		300		300	1,100.00	330,000.00
RWD Silt Trap Rebar		45		45	11,000.00	495,000.00
Clean Water Channels Concrete		0		0	1,100.00	0.00
Clean Water Channels Mesh	0			0	40.00	0.00
Dirty Water Channels Concrete		1,873		1,873	1,100.00	2,059,840.16
Dirty Water Channels Mesh	18,726			18,726	40.00	749,032.78
Penstock Outlet Encasing Concrete	1.01	1,064		1,064	1,100.00	1,170,766.28
Penstock Outlet Encasing Rebar		160		160	11,000.00	1,756,149.42

PENSTOCKS AND PIPES **3,637,500.00**

	Area m^2	Volume t or m^3	Length m	No		
Precast concrete penstock rings 750mm dia				4050	250.00	1,012,500.00
Outlet pipe 450 mm diameter			1,050		2,500.00	2,625,000.00

PUMP STATION AND PIPEWORK
(same for all three options) **1,500,000.00**

	Area m^2		
Return Water Pump Station	100	10,000.00	1,000,000.00
Pumps and associated pipework	Allow for provisional sum	500,000.00	500,000.00

ROADS **1,627,500.00**

	Area m^2	Depth/ Length (m)	Volume m^3	***Totals***		
Rip and recompact in-situ	9,300			9,300	10.00	93,000.00
G9 lower sub-grade	9,300	0.15	1395	1395	200.00	279,000.00
G7 upper sub-grade	9,300	0.15	1395	1395	250.00	348,750.00
C4 sub-base	9,300	0.15	1395	1395	300.00	418,500.00
G2 base	9,300	0.15	1395	1395	350.00	488,250.00

TOTAL			**610,659,396.14**
TOTAL (using GCL)	425,025,396.14	56,721,500.00	**481,746,896.14**

PIPELINES **11,630,000.00**

Slurry pipelines (350 steel)	2500	3,500.00	8,750,000.00
Return water (400 HDPE)	2400	1,200.00	2,880,000.00

SUMMARY

1.1	SITE CLEARANCE	5,404,125.00
1.2	EARTHWORKS	114,556,182.50
1.3	LINER SYSTEM	412,520,000.00

1.4	STRUCTURAL CONCRETE	6,560,788.64
1.5	PENSTOCKS AND PIPES	3,637,500.00
1.6	PUMP STATION AND PIPEWORK	13,130,000.00
1.7	ROADS	1,627,500.00
	SUB-TOTAL	557,436,096.14
1.8	ALLOW FOR PRELIMINARY AND GENERAL ITEMS AT 25%	139,359,024.03
	SUB-TOTAL	696,795,120.17
1.9	ALLOW FOR 10% CONTINGENCIES	69,679,512.02
	TOTAL CAPITAL COST	**766,474,632.19**

SITE 3A

CLEAN WATER DIVERSION TRENCHES

Site No.	Channel Base Width (m)	Channel Height (m)	Channel Top Width (m)	Channel Length (m)	Channel Excavate Vol (m)	Concrete Liner (m)	Volume Concrete Liner (m^3)	Mesh Ref 500 (m^2)
3A	1	0.7	3.1	1700	2,440	4.12	701	7,011
Totals					2,440		701	7,011

SOLUTION (DIRTY WATER) TRENCHES

Site No.	Channel Base Width (m)	Channel Height (m)	Channel Top Width (m)	Channel Length (m)	Channel Excavate Vol (m)	Concrete Liner (m)	Volume Concrete Liner (m^3)	Mesh Ref 500 (m^2)
A	1	0.5	2.5	1,700	1,488	3.40	578	5,785
B	1	0.8	3.4	800	1,408	4.48	359	3,588
C	1	0.5	2.5	580	508	3.40	197	1,974
D	1	0.5	2.5	730	639	3.40	248	2,484
Totals					4,042		1,383	13,830

SITE CLEARANCE **5,642,925.00**

	Area m^2	RATE	AMOUNT
Ash Dam Footprint	1,010,000	5.00	5,050,000.00
Clean Water Channels	5,270	5.00	26,350.00
Dirty Water Channels	10,245	5.00	51,225.00
Return Water Dam	82,500	5.00	412,500.00
Roads	20,570	5.00	102,850.00
Totals	1,128,585		

EARTHWORKS **118,231,276.25**

	Area m^2	Depth/ Length (m)	Volume m^3

Excavation for Ash Dam Liner	1,010,000	1.4	1,414,000	45.00	63,630,000.00
Construction of Ash Dam starter wall	232	2,740	635,680	65.00	41,319,200.00
Excavation for RWD Liner	82,500	1.4	115,500	45.00	5,197,500.00
Construction of RWD wall	105	1,050	110,250	65.00	7,166,250.00
Clean water channels (from above)			2,440	45.00	109,777.50
Dirty water channels (from above)			4,042	45.00	181,878.75
Excavation for penstock outlet pipe	1.8	900	1,584	45.00	71,280.00
Box-cut for roads	20,570	0.6	12,342	45.00	555,390.00
Totals			2,295,837		

LINER SYSTEM **505,586,500.00**

	Area m^2	Volume m^3	Length m	***Totals***		
HDPE for Ash Dam	1,010,000		2	2,020,000	60.00	121,200,000.00
HDPE for RWD	82,500		2	165,000	60.00	9,900,000.00
Clay for Ash Dam	1,010,000	909,000		909,000	200.00	181,800,000.00
Clay for RWD	82,500	74,250		74,250	200.00	14,850,000.00
River Sand for Ash Dam	1,010,000	202,000		202,000	130.00	26,260,000.00
River Sand for RWD	82,500	16,500		16,500	130.00	2,145,000.00
Bidim for Ash Dam	2,020,000			2,020,000	45.00	90,900,000.00
Bidim for RWD	165,000			165,000	45.00	7,425,000.00
Geopipes for Leachate (AD)			16,200	16,200	120.00	1,944,000.00
Leak detection stone 19mm (AD)	1,010,000	151,500		151,500	300.00	45,450,000.00
Leak detection stone 19mm (RWD)	82,500	12,375		12,375	300.00	3,712,500.00
					Liner rate R/m^2	*462.78*

STRUCTURAL CONCRETE **6,459,861.91**

	Area m^2	Volume t or m^3	Length m	***Totals***		
RWD Silt Trap Concrete		300		300	1,100.00	330,000.00
RWD Silt Trap Rebar		45		45	11,000.00	495,000.00
Clean Water Channels Concrete		701		701	1,100.00	771,166.66
Clean Water Channels Mesh	7,011			7,011	40.00	280,424.24
Dirty Water Channels Concrete		1,383		1,383	1,100.00	1,521,289.82
Dirty Water Channels Mesh	13,830			13,830	40.00	553,196.30
Penstock Outlet Encasing Concrete	1.01	912		912	1,100.00	1,003,513.95
Penstock Outlet Encasing Rebar		137		137	11,000.00	1,505,270.93

PENSTOCKS AND PIPES **3,262,500.00**

Area	Volume	Length	No

		m^2	t or m^3	m					
Precast concrete penstock rings 750mm dia					4050			250.00	1,012,500.00
Outlet pipe 450 mm diameter				900				2,500.00	2,250,000.00
PUMP STATION AND PIPEWORK									
(same for all three options)	**1,500,000.00**	Area m^2							
Return Water Pump Station		100						10,000.00	1,000,000.00
Pumps and associated pipework		Allow for provisional sum						500,000.00	500,000.00
ROADS	**3,599,750.00**								
		Area m^2	Depth/ Length (m)	Volume m^3	***Totals***				
Rip and recompact in-situ		20,570			20,570			10.00	205,700.00
G9 lower sub-grade		20,570	0.15	3085.5	3085.5			200.00	617,100.00
G7 upper sub-grade		20,570	0.15	3085.5	3085.5			250.00	771,375.00
C4 sub-base		20,570	0.15	3085.5	3085.5			300.00	925,650.00
G2 base		20,570	0.15	3085.5	3085.5			350.00	1,079,925.00
						TOTAL			**644,282,813.16**
						TOTAL (using GCL)	447,632,813.16	60,087,500.00	**507,720,313.16**
PIPELINES	**17,400,000.00**								
Slurry pipelines (350 steel)			3600					3,500.00	12,600,000.00
Return water (400 HDPE)			4000					1,200.00	4,800,000.00

SUMMARY

1.1	SITE CLEARANCE	5,642,925.00
1.2	EARTHWORKS	118,231,276.25
1.3	LINER SYSTEM	505,586,500.00
1.4	STRUCTURAL CONCRETE	6,459,861.91
1.5	PENSTOCKS AND PIPES	3,262,500.00
1.6	PUMP STATION AND PIPEWORK	18,900,000.00
1.7	ROADS	3,599,750.00
	SUB-TOTAL	661,682,813.16

1.8	ALLOW FOR PRELIMINARY AND GENERAL ITEMS AT 25%	165,420,703.29
	SUB-TOTAL	827,103,516.45
1.9	ALLOW FOR 10% CONTINGENCIES	82,710,351.65
	TOTAL CAPITAL COST	**909,813,868.10**

SITE 1

CLEAN WATER DIVERSION TRENCHES

Site No.	Channel Base Width (m)	Channel Height (m)	Channel Top Width (m)	Channel Length (m)	Channel Excavate Vol (m)	Concrete Liner (m)	Volume Concrete Liner (m^3)	Mesh Ref 500 (m^2)
1	1	0.8	3.4	2100	3,696	4.48	942	9,417
Totals					3,696		942	9,417

SOLUTION (DIRTY WATER) TRENCHES

Channel No.	Channel Base Width (m)	Channel Height (m)	Channel Top Width (m)	Channel Length (m)	Channel Excavate Vol (m)	Concrete Liner (m)	Volume Concrete Liner (m^3)	Mesh Ref 500 (m^2)
A	1	0.5	2.5	850	744	3.40	289	2,892
B	1	0.7	3.2	1,900	2,793	4.12	784	7,835
C	1	0.9	3.7	900	1,904	4.84	436	4,360
D	1	1.0	4.0	1,650	4,125	5.21	859	8,589
Totals					9,565		2,368	23,677

SITE CLEARANCE **8,545,625.00**

	Area m^2	RATE	AMOUNT
Ash Dam Footprint	1,540,000	5.00	7,700,000.00
Clean Water Channels	7,140	5.00	35,700.00
Dirty Water Channels	18,135	5.00	90,675.00
Return Water Dam	112,500	5.00	562,500.00
Roads	31,350	5.00	156,750.00
Totals	1,709,125		

EARTHWORKS **198,791,756.25**

	Area m^2	Depth/ Length (m)	Volume m^3	Rate	Amount
Excavation for Ash Dam Liner	1,540,000	1.4	2,156,000	45.00	97,020,000.00
Construction of Ash Dam starter wall	232	5,700	1,322,400	65.00	85,956,000.00
Excavation for RWD Liner	112,500	1.4	157,500	45.00	7,087,500.00
Construction of RWD wall	105	1,050	110,250	65.00	7,166,250.00
Clean water channels (from above)			3,696	45.00	166,320.00
Dirty water channels (from above)			9,565	45.00	430,436.25
Excavation for penstock outlet pipe	1.8	1,500	2,640	45.00	118,800.00
Box-cut for roads	31,350	0.6	18,810	45.00	846,450.00
Totals			3,780,861		

LINER SYSTEM **763,746,500.00**

	Area m^2	Volume m^3	Length m	***Totals***	Rate	Amount
HDPE for Ash Dam	1,540,000		2	3,080,000	60.00	184,800,000.00
HDPE for RWD	112,500		2	225,000	60.00	13,500,000.00
Clay for Ash Dam	1,540,000	1,386,000		1,386,000	200.00	277,200,000.00
Clay for RWD	112,500	101,250		101,250	200.00	20,250,000.00
River Sand for Ash Dam	1,540,000	308,000		308,000	130.00	40,040,000.00
River Sand for RWD	112,500	22,500		22,500	130.00	2,925,000.00
Bidim for Ash Dam	3,080,000			3,080,000	45.00	138,600,000.00
Bidim for RWD	225,000			225,000	45.00	10,125,000.00
Geopipes for Leachate (AD)			16,200	16,200	120.00	1,944,000.00
Leak detection stone 19mm (AD)	1,540,000	231,000		231,000	300.00	69,300,000.00
Leak detection stone 19mm (RWD)	112,500	16,875		16,875	300.00	5,062,500.00

Liner rate R/m^2 *462.18*

STRUCTURAL CONCRETE **9,970,516.86**

	Area m^2	Volume t or m^3	Length m	***Totals***	Rate	Amount
RWD Silt Trap Concrete		300		300	1,100.00	330,000.00
RWD Silt Trap Rebar		45		45	11,000.00	495,000.00
Clean Water Channels Concrete		942		942	1,100.00	1,035,905.88
Clean Water Channels Mesh	9,417			9,417	40.00	376,693.05
Dirty Water Channels Concrete		2,368		2,368	1,100.00	2,604,513.85
Dirty Water Channels Mesh	23,677			23,677	40.00	947,095.95

Penstock Outlet Encasing Concrete	1.01	1,520		1,520	1,100.00	1,672,523.26
Penstock Outlet Encasing Rebar		228		228	11,000.00	2,508,784.89

PENSTOCKS AND PIPES **4,762,500.00**

	Area m^2	Volume t or m^3	Length m	No		
Precast concrete penstock rings 750mm dia				4050	250.00	1,012,500.00
Outlet pipe 450 mm diameter			1,500		2,500.00	3,750,000.00

PUMP STATION AND PIPEWORK
(same for all three options) **1,500,000.00**

	Area m^2		
Return Water Pump Station	100	10,000.00	1,000,000.00
Pumps and associated pipework	Allow for provisional sum	500,000.00	500,000.00

ROADS **5,486,250.00**

	Area m^2	Depth/ Length (m)	Volume m^3	***Totals***		
Rip and recompact in-situ	31,350			31,350	10.00	313,500.00
G9 lower sub-grade	31,350	0.15	4702.5	4702.5	200.00	940,500.00
G7 upper sub-grade	31,350	0.15	4702.5	4702.5	250.00	1,175,625.00
C4 sub-base	31,350	0.15	4702.5	4702.5	300.00	1,410,750.00
G2 base	31,350	0.15	4702.5	4702.5	350.00	1,645,875.00

TOTAL			**992,803,148.11**
TOTAL (using GCL)	695,353,148.11	90,887,500.00	**786,240,648.11**

PIPELINES **14,160,000.00**

Slurry pipelines (350 steel)	2400	3,500.00	8,400,000.00
Return water (400 HDPE)	4800	1,200.00	5,760,000.00

SUMMARY

1.1	SITE CLEARANCE	8,545,625.00
1.2	EARTHWORKS	198,791,756.25
1.3	LINER SYSTEM	763,746,500.00
1.4	STRUCTURAL CONCRETE	9,970,516.86
1.5	PENSTOCKS AND PIPES	4,762,500.00
1.6	PUMP STATION AND PIPEWORK	15,660,000.00
1.7	ROADS	5,486,250.00
	SUB-TOTAL	1,006,963,148.11
1.8	ALLOW FOR PRELIMINARY AND GENERAL ITEMS AT 25%	251,740,787.03
	SUB-TOTAL	1,258,703,935.14
1.9	ALLOW FOR 10% CONTINGENCIES	125,870,393.51
	TOTAL CAPITAL COST	**1,384,574,328.65**