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GEOTECHNICAL INVESTIGATION FOR THE PROPOSED SOLAR PHOTOVOLTAIC FACILITY, GROOTVLEI POWER STATION

1. INTRODUCTION AND TERMS OF REFERENCE

At the request of Mr N Durieux of Environmental Impact Management Services (Pty) Ltd (EIMS) acting on behalf of Eskom SOC Ltd, we have carried out a geotechnical investigation for the Photo-Voltaic Development, at Grootvlei Power Station. Confirmation of our appointment to proceed with the investigation was received via a sub-consultant agreement signed on 25 September 2012. Aerial photographs of the areas of investigation were received to facilitate the investigation. The proposed development will comprise banks of photoelectric volts used for electricity generation. The exact size and nature of the earthworks operation for the development are unknown at this stage.

The terms of reference for the investigation are as follows:

(i) to establish the nature and relevant engineering properties of the upper soil and rock strata underlying the site.

(ii) to comment on suitable excavation procedures for cut terrace excavations and for the installation of services.

(iii) to present comments on the use of the on site soils in the construction of bulk fill terraces, access roads and parking areas.

(iv) to give foundation recommendations for the proposed development.

(v) to comment on any other geotechnical aspects that may affect the development.

2. SITE DESCRIPTION

Four possible development sites were identified within the open land surrounding the Grootvlei Power Station. Site 1 and 2 are located to the south and south east of the power station, Site 3 to the east, and Site 4 to the north. The sites generally

slope gently towards the east and are covered by veld grass. Site 3 and the eastern portions of Site 1 are located upon existing ash dams associated with past activities at the power station.

3. NATURE OF INVESTIGATION

3.1 Fieldwork

A total of sixty four test pits (TP1 to TP64) were excavated across three of the possible sites from 17 to 20 September 2012 using a CAT422E tractor-loader-backhoe (backacter). The test pits were excavated to refusal or to the excavation limit of the machine. All test pits were profiled in situ by an engineering geologist and where necessary disturbed and undisturbed soil samples were taken for laboratory testing. Test pits TP1 to 25 were excavated across Site 4. Test pits TP26 to TP40 were excavated across Site 1. Test pits TP41 to TP64 were excavated across Site 2. The positions of the test pits are shown on Figure 1 to Figure 3 enclosed in Appendix A. Copies of the recorded test pit soil profiles are presented in Appendix B.

It is noted that no test pits were excavated across Site 3 as this area was located upon a large ash dam and as such was not deemed suitable for the proposed development. No comments or recommendations have thus been made regarding Site 3 in the current report.

3.2 Laboratory Testing

The following laboratory tests were carried out on the soil samples recovered from the test pits during the field investigation.

(i) Atterberg limits and particle size distribution analyses to determine basic engineering properties and to effect classification.

(ii) Moisture/density and California Bearing Ratio (CBR) tests to evaluate compaction and related strength characteristics.

(iii) Collapse potential test on an undisturbed sample to evaluate compressibility characteristics and behaviour upon saturation.

(iv) Electrical conductivity (EC) tests on the in situ soils.

(v) Natural moisture content determination tests.

Copies of the laboratory test results are presented in Appendix C.

4. SITE GEOLOGY/SOIL PROFILE

Available geological maps indicate that the area of investigation is underlain by **sandstone** of the Vryheid Formation, Ecca group, Karoo Supergroup. This was confirmed during the present investigation. Residual soils have developed from the weathering of the sandstone bedrock. A layer of hillwash occurs as the upper soil layer across the majority of the three sites. The hillwash is in turn underlain by transported alluvial soils across the majority of the three sites. The general soil profile for Sites 1, 2 and 4 are described in the following subsections.

4.1 Site 4

The in situ soils across Site 4 have been subdivided into two geotechnical zones The soil profile within each zone is summarized below.

Zone H1/H2 - Localized fill overlying hillwash overlying moderately to highly expansive transported alluvial soils (alluvium).

Zone P - Thick fill.

The zones are based on the classification system given by the NHBRC and SAICE Code of Practice (1995). The zones are described in the following subsections and their areal extent is shown on the site plan Figure 1 in Appendix A.

4.1.1 Zone H1/H2

Zone H1/H2 covers the majority of Site 4 (see test pits TP1 to TP2, TP14, TP15 and TP17 to TP25). The upper soil layer generally comprises loose to medium dense or soft to firm intact slightly clayey silty sand/clayey silty sand of **transported hillwash** origin. The hillwash is of the order of 0,4m to 1,1m thick (average thickness 0,7m). No hillwash was noted in test pits TP9 to TP12, TP14, TP15, TP17, TP18 and TP21 to TP23.

The upper soil layer in the vicinity of test pits TP10, TP12, TP17, TP21 and TP22 comprises soft to firm layered clayey silty sand with scattered gravel and builder's rubble in places. This material is of **fill** origin. The fill is of the order of 0,5m to 1,1m thick. No fill was observed in the remaining test pits across Site 4.

The fill and hillwash are underlain by soft to firm varying to stiff shattered slickensided and ferruginised slightly sandy silty clay/silty clay. This soil stratum represents **transported alluvial soils** (alluvium). Refusal of the backacter was obtained upon very stiff alluvium in test pits TP1, TP3, TP5, TP6, TP7 and TP21 at depths varying between 1,0m and 1,65m. The excavation limit of the machine was obtained within the alluvium at 3,0m depth in test pits TP2, TP4, TP8 to TP12, TP14, TP15, TP17, TP18, TP20 and TP22 to TP25.

4.1.2 Zone P

Zone P occurs across the south eastern portions of Site 4 (see test pits TP13 and TP16). The upper soil profile comprises medium dense to dense layered slightly clayey sandy silt and gravel of **fill** origin. The fill in both test pits is in excess of 3,0m thick, the excavation limit of the machine. The fill in Zone P appears to form part of a previous platform that was created to accommodate the cooling towers that lie to the south of Site 4.

4.2 Site 1

Site 1 is located to the south east of the existing Grootvlei Power Station (see test pits TP26 to TP40). Site 1 has been sub-divided into three geotechnical zones. The soil profile within each one is summarized below.

Zone P - Thick fill.

Zone C1 - Transported hillwash overlying reworked residual sandstone.

Zone H1/H2 - Localized fill or hillwash overlying moderately to highly expansive transported alluvial soils.

These zones are based on the classification system given by the NHBRC and SAICE Code of Practice (1995). The zones are described in the following subsections and their approximate areal extent is shown on the site plan Figure 2, Appendix A.

4.2.1 Zone P

Zone P occurs across the eastern portions of Site 1 upon which an ash dam has been placed (see test pits TP26 to TP30). The ash dam is of the order of 4,0m to 5,0m high. The test pits excavated on top of the ash dam revealed a capping layer of firm layered clayey silt of fill origin. The capping layer is of the order of 0,2m to 0,4m thick and is underlain by medium dense to dense apparently cemented layered ash **fill.** Refusal of the backacter was obtained on very dense ash fill at depths varying between 0,8m and 1,0m in test pits TP26 to TP30.

4.2.2 Zone C1

Zone C1 occurs across the majority of the western portions of Site 1 (see test pits TP31, TP32, TP35, TP36, TP38 and TP39). The upper soil layer comprises medium dense and firm in places intact slightly clayey silty sand/clayey silty sand of **transported hillwash origin**. The hillwash is of the order of 0,7m to 0,9m

thick. The hillwash is underlain by dense and stiff in places ferruginised slightly clayey silty sand/clayey silty sand **reworked residual sandstone.** The backacter refused on very dense/stiff reworked residual sandstone at depths varying between 1,5m and 2,1m across Zone C1.

4.2.3 Zone H1/H2

Zone H1/H2 occurs across the north western portions of Site 1 (see test pits TP33 and TP40) and in the vicinity of test pit TP37. The upper soil layer in the vicinity of test pit TP37 comprises 1,1m of loose to medium dense layered silty clay, silty sand and ash of **fill** origin. No fill was noted across the remainder of Zone H1/H2. The upper soil layer in the vicinity of test pit TP40 comprises 1,6m of soft to firm intact/weakly ferruginised clayey silty sand of **transported hillwash** origin. No hillwash was noted in test pits TP33 or TP40.

The fill and hillwash are underlain by firm/firm to stiff shattered, slickensided and ferruginised silty clay **alluvium.** The alluvium extends to depths in excess of 3,0m, the excavation limit of the machine. The alluvium occurs as the upper soil layer in the vicinity of test pit TP33.

4.3 Site 2

Site 2 lies to the south of the Grootvlei Power Station immediately to the west of Site 1 (see test pits TP41 to TP64). The in situ soils across Site 2 have been sub-divided into two geotechnical zones. The soil profile within each zone is summarized below.

Zone H1/H2 - Localized fill overlying hillwash overlying potentially moderately to highly expansive transported alluvial soils.

Zone C1 - Hillwash overlying reworked residual sandstone.

These zones are based on the classification system given by the NHBRC and SAICE Code of Practice (1995). The soil profile within each zone is described in the following sub-section and their approximate areal extent is shown on Figure 3, Appendix A.

4.3.1. Zone H1/H2

Zone H1/H2 covers the majority of Site 2 (see test pits TP41 to TP45, TP47 to TP56 and TP59 to TP63). The upper soil layer generally comprises soft to firm and loose to medium dense in places intact clayey silty sand/slightly clayey silty sand of **transported hillwash** origin. The hillwash is of the order of 0,45m to

0,9m thick. No hillwash was noted in test pits TP42 to TP44, TP48, TP49, TP51, TP55 and TP59 to TP61. The upper soil layer in the vicinity of test pits TP59 and TP61 comprises 0,45m to 0,7m of soft to firm layered clayey silty sand of **fill** origin. No fill was noted in the test pits across the remainder of Zone H1/H2.

The localized fill and hillwash are underlain by soft to firm/firm and stiff in places shattered, slickensided and ferruginised in places silty clay of **transported alluvial origin** (alluvium). The alluvium occurs as the upper soil layer in those test pits where the fill and hillwash is absent.

No fill was noted Refusal of the backacter was obtained on very stiff alluvium in test pits TP41, TP45, TP47, TP50 and TP63 at depths varying between 1,5m and 2,1m.

The excavation limit of the machine was obtained at 3,0m depth within the alluvium across the remainder of Zone H1/H2.

4.3.2. Zone C1

Zone C1 occurs as two minor areas across Site 2 in the vicinity of test pit TP46, north western portion of Site 2 and test pits TP57, TP58 and TP64, south eastern portion of Site 2.

The upper soil layer comprises medium dense intact slightly clayey silty sand representing **transported hillwash** soils. The hillwash is of the order of 0,5m to 0,9m thick. The hillwash is underlain by dense ferruginised slightly clayey silty sand **reworked residual sandstone.** Refusal of the backacter was obtained upon very dense reworked residual sandstone at depths varying between 1,3m and 1,7m across Zone C1.

4.4 Water Table

A **perched water table** was noted in test pits TP12, TP18 (Site 4) and TP44 (Site 2) at depths of 1,0m, 2,1m and 2,3m respectively. The flow rate was noted to be slight with standing water present at 2,3m in test pit TP44. No perched water table or zones of seepage were noted in any of the remaining test pits across the areas of investigation. Notwithstanding the above it is noted that areas of preferential drainage (low lying areas and seasonal stream courses) were noted upon Site 4 and Site 2 as well as immediately to the north of Site 1. These areas may become saturated at surface with areas of standing or flowing water in the rainy season.

5. EXCAVATION PROCEDURES

Excavation procedures for earthworks and for the installation of services have been evaluated according to the South African National Standards standardized classification for excavations (SANS 1200D, DA and DB). The excavation procedures for Site 1, 2 and 4 are summarized in Table 1 below, as the three sites investigated during the current investigation contain common geotechnical soil zones.

Table 1: Summary of Excavation Procedures for Geotechnical Soil Zones

Zone	Applicable Site	Excavation Procedures (SANS 1200D, DA and DB)			Comments
		Depth to Soft Excavation Material (m)	Depth to Intermediate Excavation Material (m)	Depth to Hard Rock Excavation Material (m)	
H1/H2	Site 1, 2 and 4	Generally>3,0; Locally 1,0 to 2,1	Locally below 1,0 to 2,1	None encountered	**Intermediate excavation material** envisaged on localized very stiff alluvium. This material could be removed using medium to heavy earthmoving equipment and/or power tools.
C1	Site 1 and 2	1,3 to 2,1	Below 1,3 to 2,1	None encountered	**Intermediate excavation material** envisaged on very dense / stiff reworked residual sandstone. This material could be removed using medium to heavy earthmoving equipment and/or power tools.
P	Site 1 and 4	>3,0 (Site 4); 0,8 - 1,0 (Site 1)	Below 0,8 to 1,0 (Site 1)	None encountered	**Intermediate excavation material** envisaged on very dense fill material within ash dam located upon Site 1. This material could be removed using medium to heavy earthmoving equipment and/or power tools.

6. MATERIALS USAGE

Laboratory testing has been carried out on the upper soil layers to assess their suitability for use in the construction of bulk fill terraces, access roads and parking areas. From the fieldwork and laboratory test results the following comments are considered pertinent to the on site soils for use in these operations.

- The upper 150mm of in situ soil across the sites contains abundant organic matter and is unsuitable for use as construction material. This material should be removed to spoil.

- The slightly clayey silty sand, fill, hillwash and reworked residual sandstone are considered to be suitable for use as general fill and lower selected layer material. Should these soils be required for use as upper selected layer material then they would have to be stabilized. Further laboratory testing would however have to be carried to establish suitable stabilizing agents and to optimize mix ratios.

- The clayey silty sand fill, hillwash and silty clay alluvium are considered to be moderately to highly plastic. These soils layers are thus unsuitable for use as construction material and should be removed to spoil where intersected in cut excavations.

7. EVALUATION OF FOUNDING CONDITIONS AND FOUNDATION RECOMMENDATIONS

As the three sites investigated during the current investigation contain common geotechnical zones, foundation recommendations for each of the zones are given below. These recommendations would apply to the relevant soil zones across Sites 1, 2 and 4

7.1 Zone H1/H2

The most important feature concerning the various soil layers underlying Zone H1/H2 as these soils may affect foundation solutions for the development and the design thereof, is the expansive nature of the alluvial slightly sandy silty clay / silty clay. From the in situ soil profiling and laboratory test results the alluvial slightly sandy silty clay / silty clay is potentially moderately to highly expansive. The expansive soils are commonly in excess of 3,0m thick

From the fieldwork and laboratory testing it is estimated that in the long term total heave / shrinkage movements of the order of 20mm to 40mm could occur across the site. Differential heave / shrinkage movements should be taken as 75 percent of the total heave / shrinkage movements. Such movements could not be accommodated by conventional construction methods and it is apparent that special foundation / structural procedures would have to be adopted for the development. One of the following solutions could be adopted.

- **Piles including suspended surface beds**. Further work such as auger hole drilling would have to be carried out to establish suitable pile types and pile founding depths.

  As indicated all surface beds would have to be designed as suspended slabs. A minimum void of 150mm should be provided below the surface beds as well as below and around all pile caps and ground beams so as to ensure that these structural members are not subjected to uplift.

- Structures could be placed on **suitably designed stiffened concrete raft** foundations founded at shallow depth within the hillwash / alluvium. The rafts would have to be designed to withstand total heave movements of the order of 10mm to 40mm due to the expansive alluvial soils.

7.2 Zone C1

The fill and hillwash across Zone C1 are considered to be potentially highly compressible / collapsible. This was confirmed by means of collapse potential tests carried out on undisturbed samples of the hillwash. Collapse potentials varying from 0,54% to 7,71% were recorded under an applied load of 200kPa.These soil layers are thus unsuitable for use as founding layers, even for proposed lightly loaded structures.

An allowable bearing pressure of 300kPa could be utilized for the medium dense to dense or better reworked residual sandstone across Zone C1. This founding layer occurs at depths varying between 0,5m and 0,9m across Site 1 and Site 2. Under the above load conditions total settlements of the order of 5mm to 10mm are envisaged. Differential settlements should be taken as 50% of the total settlements. Conventional strip/spread foundations could be employed as suitable foundation types.

7.3 Zone P

The fill material across Zone P (Site 4) appears to comprise compacted engineered fill material. The fill that comprises the ash dam across Site 1 appears to have undergone a cementation process resulting in dense or better fill material at shallow depth. It is our opinion that conventional strip/spread foundations could be placed upon the medium dense to dense fill material across Zone P provided bearing pressures are limited 150kPa. This founding layer occurs from depths varying between present ground level to 0,6m. Under the above load conditions total settlements of the order of 5mm to 10mm are envisaged. Differential settlements should be taken as 50% of the total settlements.

8. SURFACE BEDS (Zone C and Zone P)

The surface beds for the structures could be placed directly on top of the final terrace platforms with the following provisos:

- The surface beds could be placed conventionally on top of the in situ soil within areas of cut. The upper 150mm of soil should however be ripped and recompacted to 90% of Mod AASHTO density at optimum moisture content prior to placing of concrete.

- Within areas of engineered fill the fill should be compacted in 150mm thick layers to a minimum of 90% of Mod AASHTO density at optimum moisture content.

9. ACCESS ROADS AND IMPERMEABLE LAYERED WORK AREAS

The following comments are pertinent to the design and construction of the access roads and impermeable layered works.

- For impermeable layered works design purposes, it is estimated that the upper in situ subgrade material across Zone C1 and Zone P would have a CBR of the order of 5 to 7,5 percent if compacted to 90% of Mod AASHTO density at optimum moisture content, and of the order of 7,5 to 10 percent if compacted to 93% of Mod AASHTO density at optimum moisture content.

- The most important aspect related to the design and construction of access roads and impermeable areas across Zone H1/H2 is the relatively thick expansive soils underlying the zone from ground surface. In this regard it should be ensured that cover (including layerworks) to the expansive soils is at least 0,9m. Such cover would ensure that the long term performance of access roads and impermeable areas would not be affected by the expansive nature of the underlying soils. The nature of the in situ soils across the site is such that in general all layerworks for access roads and impermeable areas would have to be imported.

- It is recommended that the layer immediately below the impermeable layered works be stabilized. The purpose of the stabilized layer immediately below would be to seal the layerworks from stormwater ingress.

10. RECOMMENDATIONS FOR SUITABLE PV SITE

In our opinion significant difficulties and costs would be associated with attempting to construct the proposed PV development within the areas of the three sites underlain by Zone H1/H2.

Based on the above it is apparent that the most suitable areas for the installation of the PV development would be those areas of the sites underlain by Zone C1 or Zone P. Zone P and Zone C1 across Site 4 and 2 respectively cover only small portions of each site. However, Site 1 is covered by large areas of Zone P (eastern portions of Site 1) and Zone C1 (western portions of Site 1). It is therefore our opinion that the most suitable site in terms of favorable geotechnical conditions for the installation of the PV development would be Site 1.

11. GENERAL

- The present investigation is of a general nature and as such zonal boundaries are approximate. Further detailed geotechnical work would have to be carried out to accurately determine the zonal boundaries and the depths to the recommended founding layers across specific portions of the sites.

- Site 3 was not investigated during the present investigation as it was not deemed suitable for the proposed development owing to it being located upon a large ash dam. However, it is envisaged that the soil profile across Site 3 would be similar to that of the profile observed across the ash dam on Site 1 (Zone P) and as such the comments and recommendations given in the report regarding Zone P would likely be applicable to Site 3.

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