GEOTECHNICAL INVESTIGATION REPORT FOR AEP KATHU SOLAR PV ENERGY FACILITY - GCS-RP/053/2015

Report Prepared for
AEP KATHU SOLAR (PTY) LTD

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EXECUTIVE SUMMARY

The proposed AEP Kathu Solar PV Energy Facility is located on a portion of the Remainder of the farm Legoko 460, Kathu Municipality, Northern Cape Province, located approximately 10 km south-south east from Kathu. The site is underlain by aeolian sand, calcrete and dolomite at depth, located on a valley floor land facet.

A total of 8 trial pits were profiled (10 planned) and 3 DCP test conducted on site. Two soil samples were collected from a potential problem soil horizon for laboratory analysis, and a dedicated borehole drilled to determine the depth to dolomite bedrock.

A geotechnical percussion borehole was planned to 100m but the hole was terminated at 65m due to difficult drilling conditions. Information received from Kumba indicated that the Dolomite bedrock is located between 60-70m below surface, with a cover of Kalahari deposits that includes a 35m thick hardpan calcrete.

Three soil profiles were identified:

Profile 1: Aeolian sand over hardpan calcrete

Profile 2: Aeolian sand and platy calcrete over hardpan calcrete

Profile 3: Aeolian sand with boulder calcrete overlying hardpan calcrete

Strip foot foundations with reinforcing where required is recommended for the conventional structures. Pre drilled, rammed pilled foundations are recommended for tracker PV structures. The length of the piles varies with the soil profiles; For profile area 1 and 2 a length of 2.5m is recommended, and on profile area 3 a length of 3.0m is recommended to generate sufficient shear resistance. For fixed PV structures smaller rammed piles or strip foot foundations can be used. The expected excavatability for service trenches is soft to hard depending on the thickness of the aeolian sand (ranging from 0.6 to 1.7m thick).

The potential for collapse of side walls of deep excavations is low. No shallow groundwater conditions were encountered. Construction materials should be sourced from commercial suppliers. Plant discard from iron ore mines can be used for road construction.

No mining activities impact the site. The inherent risk class dolomite instability is low. Although all sized of sinkholes can occur the likelihood of it occurring is low because the water table is stable, there are no record of sinkholes with a thick calcrete cover.

The geotechnical risk classification for the profile area 1 and 2 is F2 and the geotechnical classification for profile area 3 is F1, A2 due to the presence of potential collapsible aeolian sand that is thicker than 750mm.

For the solar park development shallow bedrock conditions and potential collapsible soil is not critical to the success of the development and thus not regarded as a critical constraint.

The geology along the connection corridor routes is similar to the conditions on site and no geotechnical risks are expected along either route. Access to the site is via existing roads from the N14. Grid connections will occur via a loop-in loop-out connection on site or via a self-built line of 5400m to connect to a new substation planned.

The assessment of the geotechnical conditions on site resulted in three land use areas being defined:

- LAND USE AREA A is classified as DEVELOPABLE with minor PRECAUTIONS due to the relative shallow calcrete conditions that will impact on the installation trenches for the

cabling and the low potential for sinkhole formation. The area is suitable for the installation of PV structures using pre-bored rammed piles.

- LAND USE AREA B (AEOLIAN SAND) is classified as DEVELOPABLE with minor PRECAUTIONS due to the impact of the loose settlable sand under the foundations of conventional structures and the low potential for sinkhole formation. The area is suitable for the installation of PV structures using pre-bored rammed piles.

From a geotechnical perspective the proposed development areas is suitable for the proposed development.

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1. TERMS OF REFERENCE

AEP KATHU SOLAR (PTY) LTD contracted Geotechnical Consult Services (GCS) to conduct a phase 2 geotechnical investigation for a proposed solar park development on a 314ha portion of Remainder of the farm Legoko 460, Kathu Municipality Northern Cape Province, located approximately 9 km south east of Kathu.

The aim of this investigation is to assist the developer, who wish to establish up to a 75MW photovoltaic solar energy generation facility on the 314ha site and to assess the potential issues raised by the Council for Geoscience with respect to development on dolomitic land.

1.1. Scope Of Work

The scope of work for this project as per Proposal no: GCS/PR/41/2015 for an Environmental Impact Assessment:

- Desktop assessment of soil and rock stratigraphy on the site
- Confirmation of soil and rock stratigraphy on site
- Identification of problem soils
- Assess the dolomite stability risk and recommend further work
- Evaluate the geotechnical land use and recommend the land use potential of the property at a feasibility level.

1.2. Limitations

The information provided in this specialist report is based on information provided by the client and/ or the client's representatives, published scientific literature, maps, and information published in the public domain and that collected by Geotechnical Consult Services during the site investigation in the area.

1.3. Author's Credentials And Declaration Of Independence

The Author of this report Carel J de Beer is a professional engineering geologist, registered with the South African Council of Natural and Scientific Professions (Pri. Sci. Nat # 400211/05).Carel has 19 years' experience in the mining and civil industries and is a member if the South African institute of Rock Engineers.

The compilation of the report, and any other work done by Geotechnical Consult Services (GCS) for the Client Company, is strictly in return for professional fees. Payment for the work is not in any way dependent neither on the outcome of the work, nor on the success or otherwise of the Company's own business dealings. As such there is no conflict of interest in GCS undertaking the study as contained in this document.

2. SITE CHARACTERIZATION

2.1. Location And Access To Site

The proposed AEP KATHU SOLAR (PTY) LTD facility is situated on a 314 ha portion of the Remainder of Legoko 460 (1371ha), located approximately 9km south east of Kathu, East of the N14. Access to the site will be along an existing farm road. Refer to Figure 1 for the locality of the site under investigation.

2.2. Current Land Use

The current land use on the study area is livestock and game farming. Cattle, sheep and game are currently on the farm. The landowner will move the livestock from the proposed development area prior to development. No infrastructure, including boreholes are present on the proposed development area.

2.3. Planned Land Use

The proposed project will make use of photovoltaic (PV) technology and will have a generating capacity of up to 75MW.
The PV facility will comprise of the following typical infrastructure which is included in the scope of this EIA:

- Arrays of PV panels and respective inverter stations
- Appropriate mounting structures
- Cabling between the project components, to be lain underground where practical
- An on-site substation including a building for control and storage
- Permanent laydown areas
- Laydown areas for the construction phase
- Internal access roads
- Fencing.

2.4. Climate

Kathu normally receives about 240mm of rain per year and most of its rainfall occurs during summer and autumn (October to April). It receives the lowest rainfall (0mm) from June to August and the highest (55mm) in March. The average midday temperatures for Upington range from 18.0°C in June to 33°C in January. The region is the coldest during July when the mercury drops to 0.2°C on average during the night.

2.5. Topography& Geomorphology

The proposed AEP Kathu Solar PV Energy Facility is situated on a gently undulating, gently westward sloping valley floor land facet at approximately 1245mamsl (Figure 2 and Figure 3). The highest point of the property is in the eastern corner at 1249mamsl, and the lowest point is at the western corner (1242mamsl).

2.6. DRAINAGE

Drainage on site occurs as sheet towards the south and east, in the direction of the Ga-Mogara River, A tributary of the Kuruman River that discharges via the Molopo River into the Orange River (Figure 3).

2.7. GEOLOGY

The proposed study area is underlain by a veneer of aeolian sand (Qs) covering tertiary calcrete deposits. The tertiary deposits (Tl) (Kalahari Formation) consist of calcrete and clay of substantial thickness of between 35 and 60m thick. Underlying the Kalahari Formation is dolomite of the Ghaap Plateau (Vgd) and scattered outcrops of the Voëlwater Formation (Vo) consisting of Jasper.

The Dolomite of the Ghaap Plateau are predominantly composed of two minerals; calcite ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$). When a carbonate rock is dominated by calcite (more than 95% with less than 5% dolomite), it is called limestone, when it is dominated by dolomite (the mineral) it is called dolomite (the rock). Limestone is a chemical or biochemical sediment consisting essentially of calcium carbonate ($CaCO_3$), primarily in the form of calcite, and minor constituents such as silica, feldspar, pyrite and siderite. Dolomite, as a rock, contains more than 90% dolomite and less than 10% calcite as well as detrital minerals and secondary silica (chert).

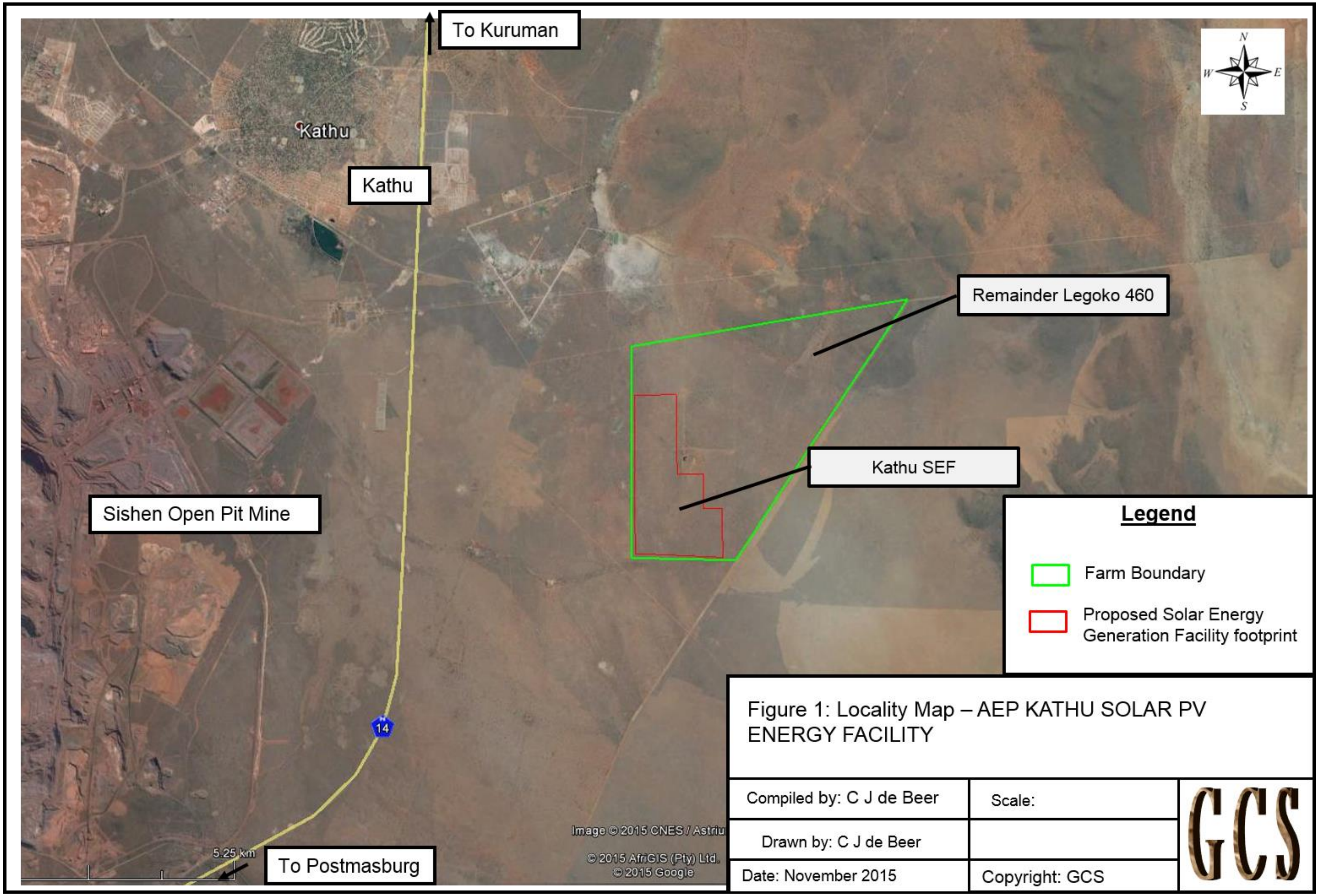
2.1. ENGINEERING GEOLOGY

The most prominent engineering geological phenomenon that occurs in limestone and dolomitic areas is karstification. Karst landforms are generally the result of mildly acidic water acting on weakly soluble bedrock such as limestone or dolostone. The mildly acidic water begins to dissolve the surface along fractures or bedding planes in the limestone bedrock. Over time, these fractures enlarge as the bedrock continues to dissolve. Openings in the rock increase in size, and an underground drainage system begins to develop, allowing more water to pass through the area, and accelerating the formation of underground karst features. When underground karst features daylight it is called a sinkhole.

Sinkholes are common where the rock below the land surface is dolomite or limestone. As the rock dissolves, spaces and caverns develop underground. These sinkholes can be dramatic because the surface land usually stays intact until there is not enough support. Then, a sudden collapse of the land surface can occur.

More commonly, sinkholes occur in urban areas due to water main breaks or sewer collapses when old pipes give way. They can also occur from the over pumping and extraction of groundwater. Some sinkholes form when the land surface is changed, such as when industrial and runoff-storage ponds are created; the substantial weight of the new material can trigger an underground collapse of supporting material, thus, causing a sinkhole.

The sinkhole risk classification for the site will be discussed in Section 5.


To Kuruman
Kathu
Kathu
Remainder Legoko 460
Kathu SEF
Sishen Open Pit Mine
N
W
E
S
14
5.25 km
To Postmasburg
Image © 2015 CNES / Astriu
© 2015 AfriGIS (Pty) Ltd.
© 2015 Google
Legend
Farm Boundary
Proposed Solar Energy Generation Facility footprint
Figure 1: Locality Map – AEP KATHU SOLAR PV ENERGY FACILITY
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Scale:
Drawn by: C J de Beer
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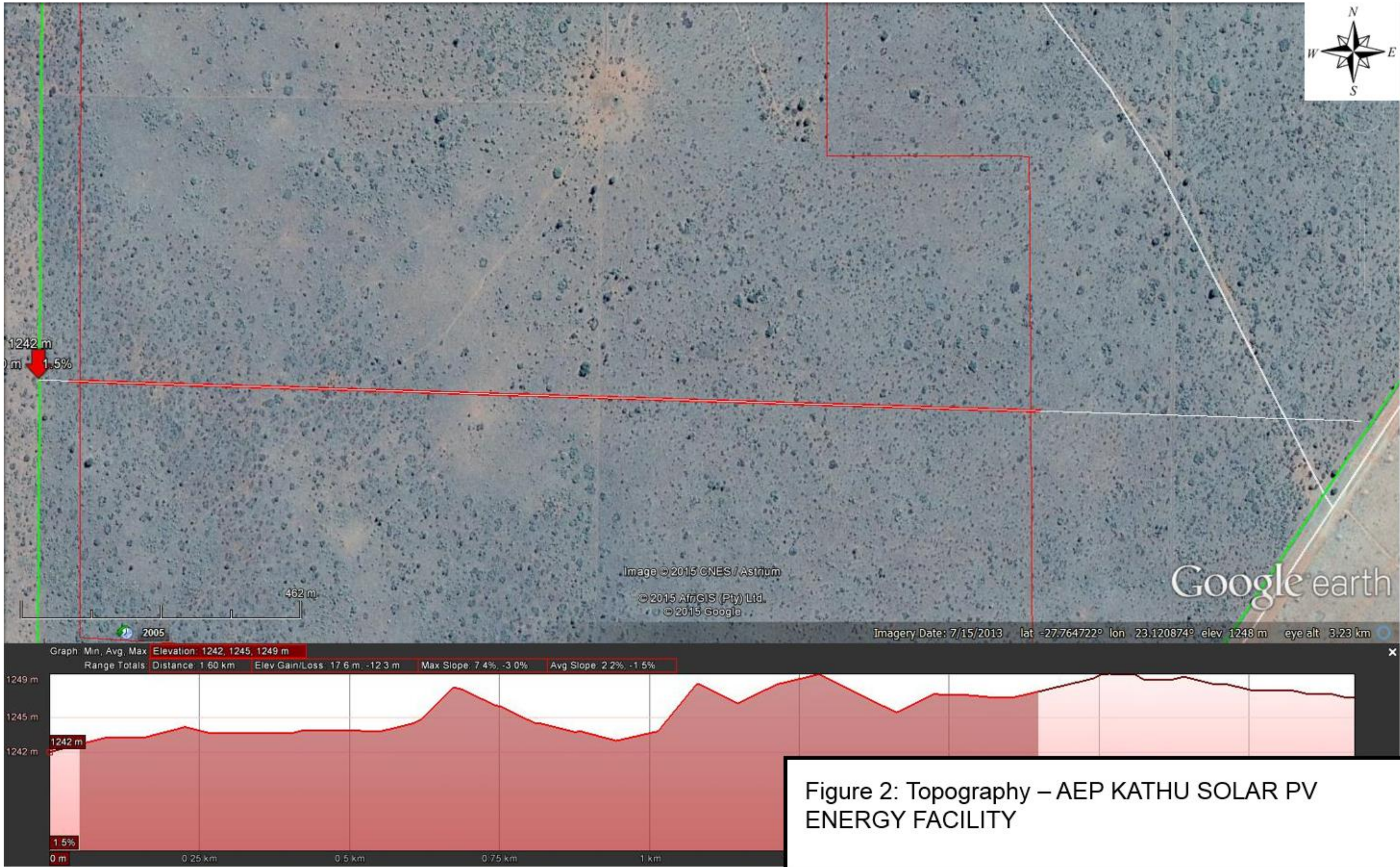

Figure 2: Topography – AEP KATHU SOLAR PV ENERGY FACILITY

Legend

Study Area

Section line

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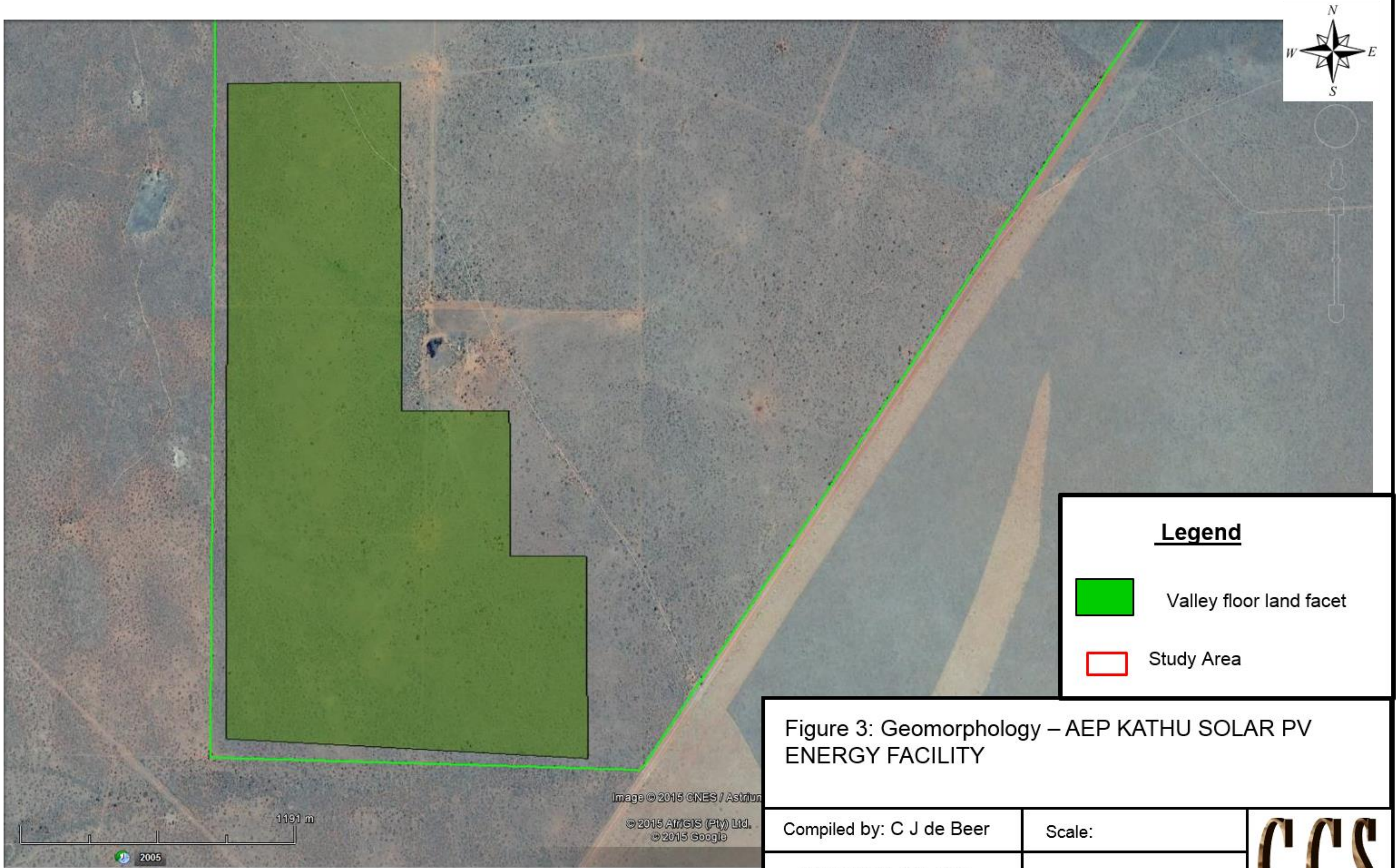

Figure 3: Geomorphology – AEP KATHU SOLAR PV ENERGY FACILITY

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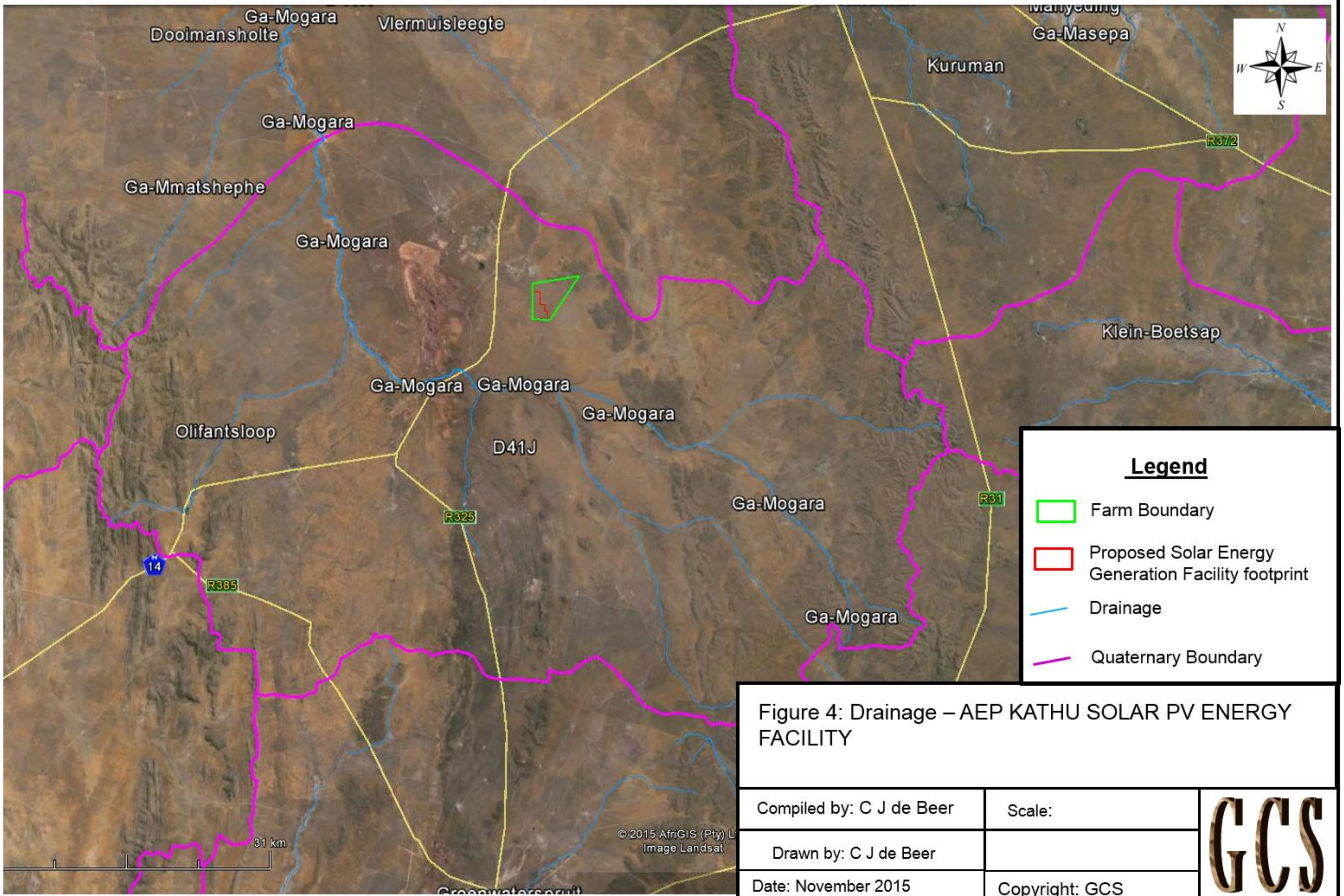

Figure 4: Drainage – AEP KATHU SOLAR PV ENERGY FACILITY

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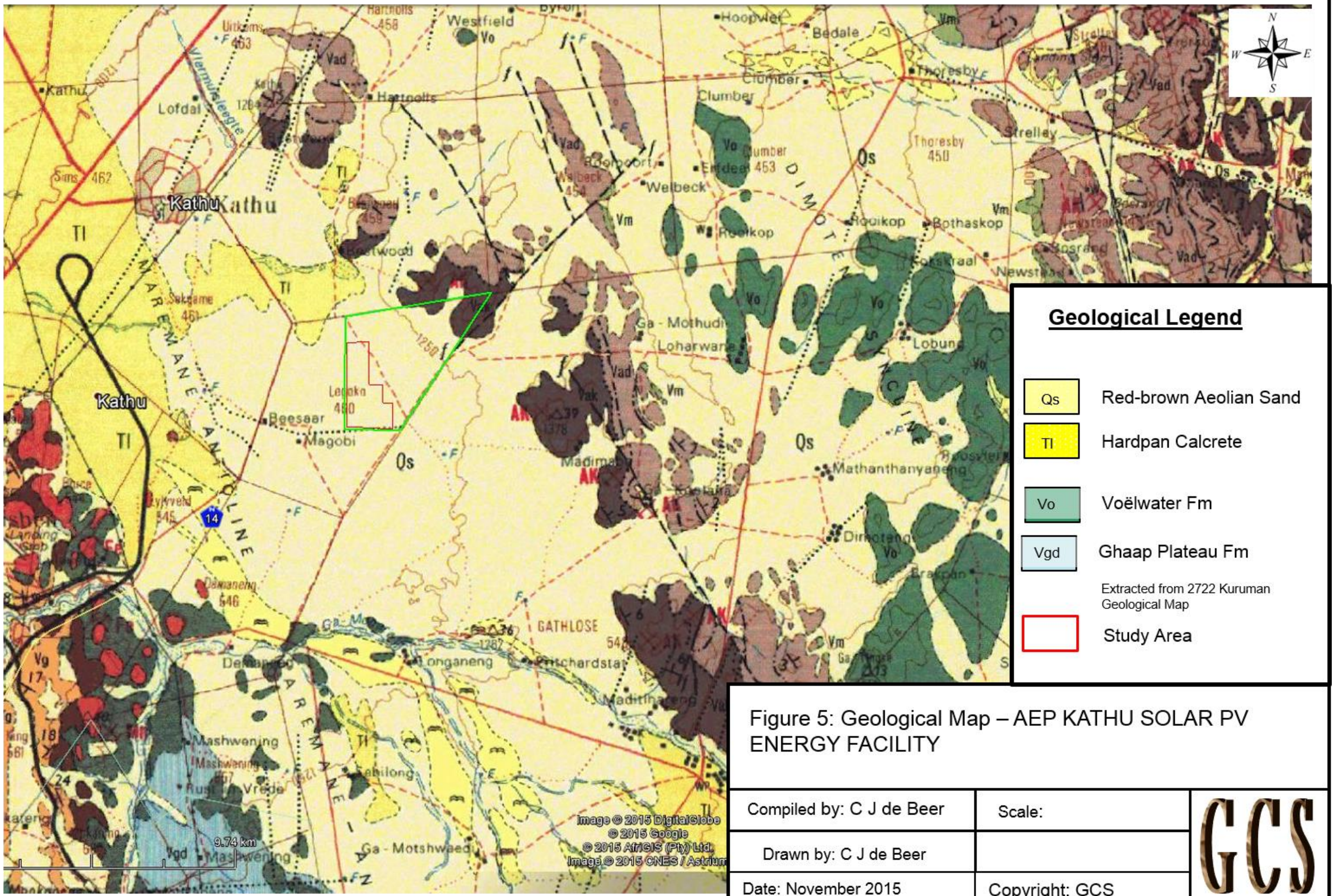

Figure 5: Geological Map – AEP KATHU SOLAR PV ENERGY FACILITY

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2.2. SEISMIC HAZARD

The Southern African region is known for its relative seismic stability. Only a small number of medium-intensity earthquakes have occurred since the 17th century.
On the other hand, between 40 and 60 tremors occur monthly, which occur primarily in the gold mining areas of Gauteng, North West and the Free State. Although the effects of these events are much less serious than those caused by larger earthquakes, extensive damage has occurred in one or two cases.
The seismically active areas in South Africa are broadly divided into two groups in SABS 0160 (1989), namely those where seismic activity is due to natural seismic events (Zone 1 areas), and those where it is predominantly due to mining activity (Zone 2 areas). It has been shown that mine tremors are not likely to produce any significant structural response in buildings with natural vibration frequencies of less than 2 Hz. Stiff structures such as low-rise, load-bearing masonry structures are therefore influenced the most by mining tremors
With reference to the South African National standards document:
"SANS 10160-4: BASIS OF STRUCTURAL DESIGN AND ACTIONS FOR BUILDINGS AND INDUSTRIAL STRUCTURES — PART 4: SEISMIC ACTIONS AND GENERAL REQUIREMENTS FOR BUILDING"
The SANS 10160-4 document define seismic zones applicable to South Africa Figure 5. Two zones are identified, namely:

a) Zone I : Natural seismic activity and
b) Zone II : Regions of mining-induced and natural seismic activity.

NOTE: The above zones are determined from the seismic hazard map which presents the peak ground acceleration with a 10% probability of being exceeded in a 50-year period. It includes both natural and mining-induced seismicity.
A reference peak ground acceleration is defined in clause 4.3 for buildings located in Zone 1. Buildings of Importance Class I, II and III (Table 1) in Zone II need only comply with clause 5 and with the minimum requirements for structural and non-structural components and with the requirements for ties, continuity and anchorage, all as detailed in clause 9. Buildings of Importance Class IV in Zone II shall be treated as buildings located in Zone 1.

TABLE 1: SEISMICITY - IMPORTANCE CLASSES OF STRUCTURES

Importance Class	Buildings	Importance factor γ_i
I	Buildings of minor importance for public safety, e.g. agricultural buildings, ect.	0.8
II	Ordinary buildings, not belonging to the other categories	1.0
III	Buildings for which seismic resistance is of importance in view of the consequences associated with the collapse, e.g. schools, assembly halls, cultural institutions, ect.	1.2
IV	Buildings for which integrity during earthquakes is of vital importance for protection, e.g. hospitals, fire stations, power plants, ect	1.4
Note: The numbering of importance classes differ from those in the Eurocode where from these definitions were taken.		

The Kathu Solar PV Energy Facility Site is classified as Ground Type 1: Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface where the average velocity propagation of S-waves in the upper 30 m of the soil profile at shear strains of 10-5 or less exceeds 800m/s.
The Kathu Solar PV Energy Facility Site area has a peak ground acceleration of less than 0.05 g and falls outside Zone 1 or Zone 2 (Figure 6). Therefore no provision has to be made for seismic loading in the design of the structures or foundations.

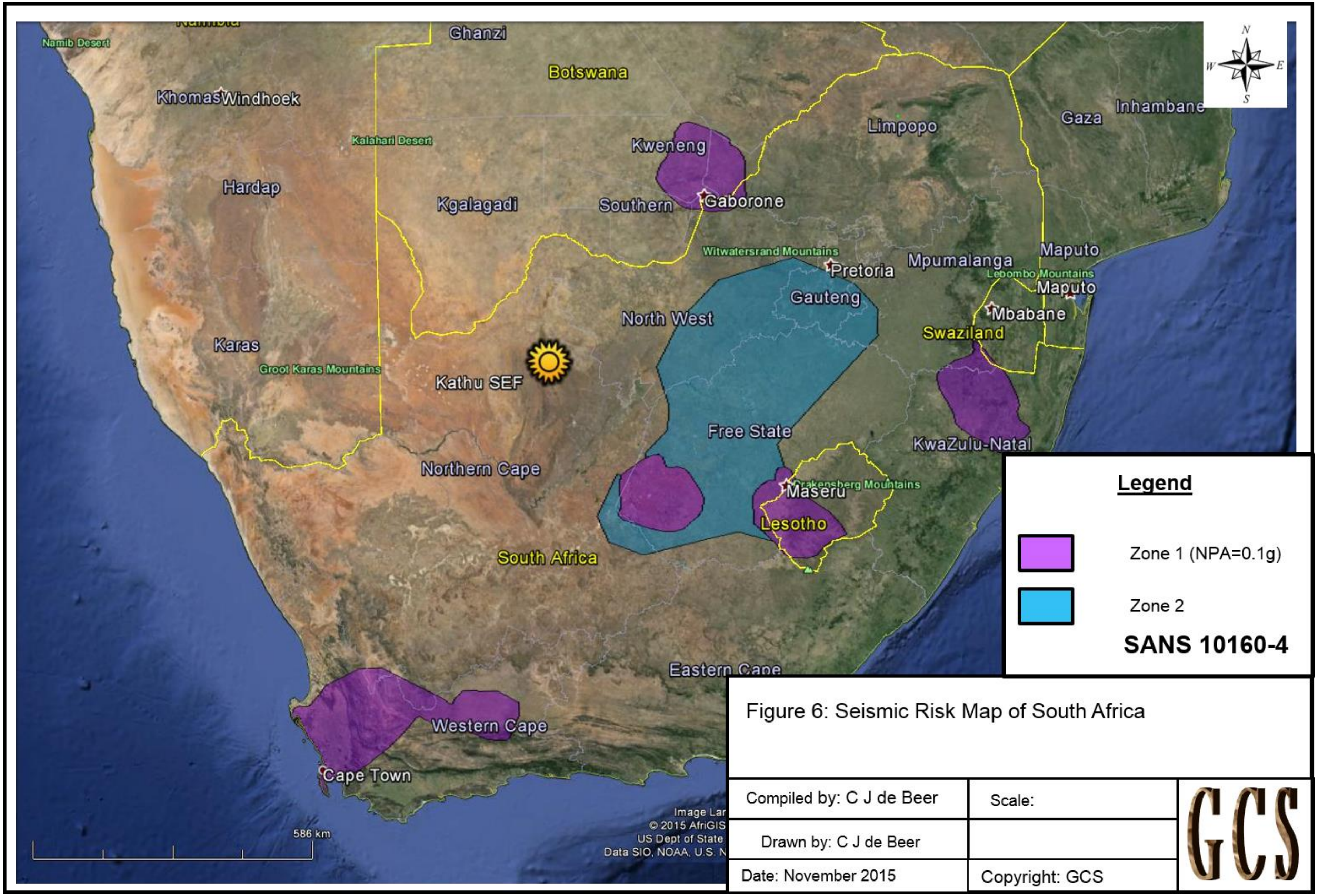

Figure 6: Seismic Risk Map of South Africa

3. DATA COLLECTION

3.1. Desktop Study

During the desktop study all the available information was collected and used to compile field maps and design the field investigation. A field map was compiled for the fieldwork stage from Google Earth images, site plans, and the 1:250 000 (2722 Kuruman) Geological Map.

3.2. Fieldwork

The fieldwork was conducted from 12 to 14 November 2015. Ten trial pits were planned and eight were excavated across the study (Figure 7), using a TERREX 840 tractor-loader-back-actor (TLB), (Photo 1). The two was not excavated due the consistent soul profile in the area. A total of 3 DCP test (Photo 2) were conducted at representative soil profile locations and 2 soil samples were collected for laboratory testing.

PHOTO 1: TLB USED TO EXCAVATE TRIAL PITS

PHOTO 2: DCP TEST

The 3 DCP tests were conducted next to each of the following trial pits; K_TP02, KTP06 and K_TP8.

The different soil horizons encountered in the trial pit was described using the moisture, colour, consistency, structure, soil type and origin (MCCSSO classification system), standard descriptors. Two disturbed soil samples were collected from potential problem soil horizons in trial pits K_TP07 and K_TP8 (Figure 7).

Due to the site potential being underlain by dolomite at depth, a percussion borehole was planned to a depth of 100m to determine the depth at which dolomite bedrock occurs and to evaluate the nature of the overlying blanket material. The borehole was planned and drilled with a truck mounted percussion drill rig (Photo 3) at the position indicated in Figure 8, on the neighbouring farm (Portion 1 of Legoko 460), just south of the site under consideration. This hole was located central to three proposed solar developments, and is deemed to be representative of the local geology on all three sites.

PHOTO 3: PERCUSSION DRILL RIG POSITIONED ON THE DRILLING POSITION, READY TO START DRILLING.

3.3. Laboratory Testing

The laboratory tests on the sample collected was conducted by RoadLab, a civil engineering materials laboratory in Germiston. The test conducted were:

- Grading analysis, including hydrometer tests (particle size distribution)
- Determination of Atterberg limits (shrinkage limit, plastic limit and liquid limit)
- Soil pH and electrical conductivity

Results of the above-mentioned tests were interpreted and used to substantiate the description of the site's geotechnical condition.

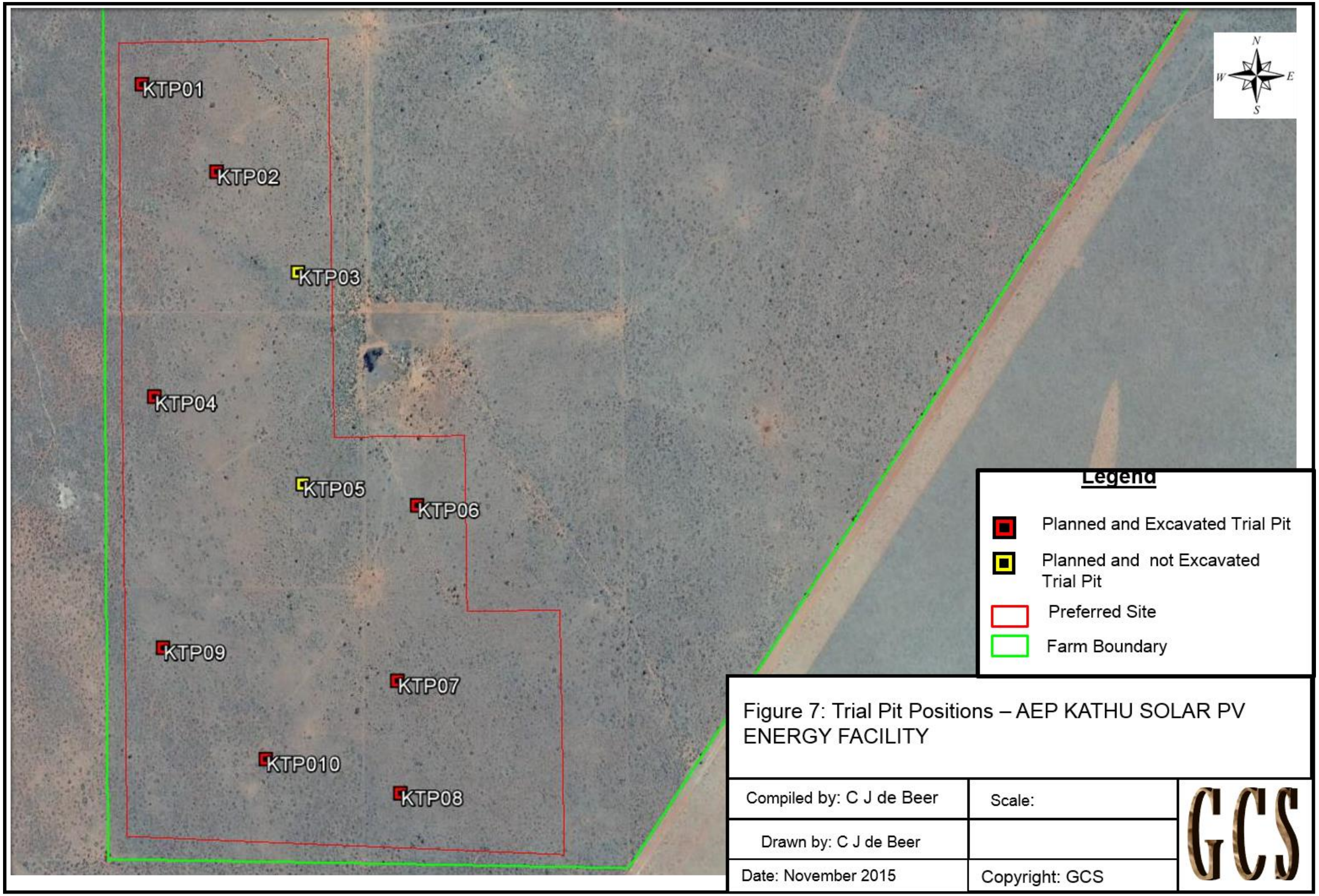

Figure 7: Trial Pit Positions – AEP KATHU SOLAR PV ENERGY FACILITY

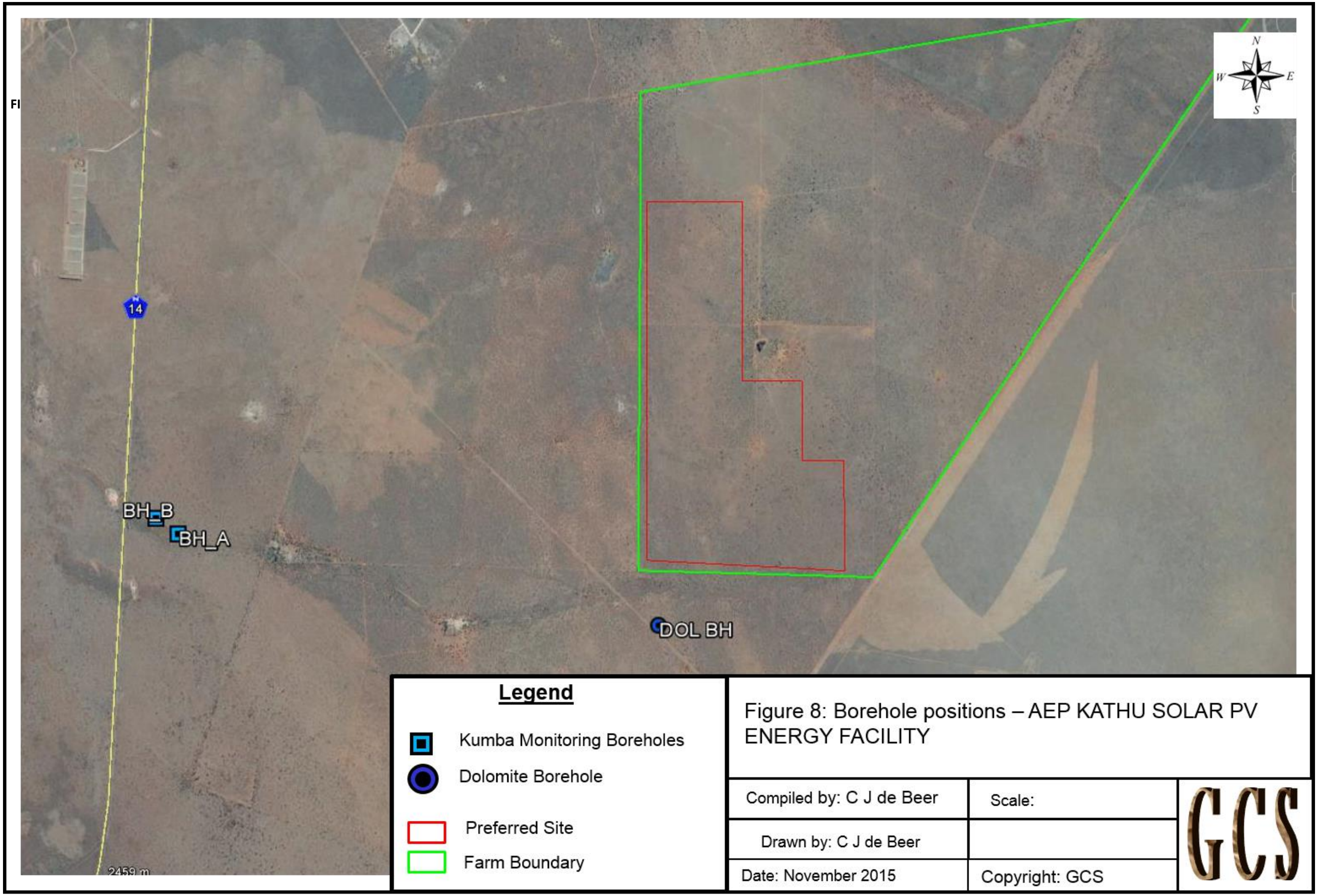

Figure 8: Borehole positions – AEP KATHU SOLAR PV ENERGY FACILITY

4. Site Investigation Results

4.1. Soil Profiles

The proposed development area is underlain by three soil profiles associated with the underlying geology, consisting of aeolian sand and different calcrete (see Figure 9):

- Profile 1, Shallow aeolian sand and hardpan calcrete
- Profile 2, Aeolian sand with platy calcrete overlying hardpan calcrete
- Profile 3, Aeolian sand with boulder calcrete overlying hardpan calcrete

The soil profiles from each trial pit is presented in Appendix 1.

4.1.1. Profile 1: Aeolian sand and Hardpan Calcrete

The north western and central part of the proposed Kathu Solar Facility is underlain by a thin aeolian sand cover overlying hardpan calcrete (Figure 9) The profile is encountered in trial pits K_TP02, and K_TP04 and consist of;

Dry, orange brown, very loose, intact, uniform silty sand, AEOLIAN (Kalahari Sand) with grass roots., overlying dry, orange brown, very loose, intact, uniform silty sand, AEOLIAN (Kalahari Sand), overlying HARDPAN CALCRETE. The TLB refused on hardpan calcrete at a depth of 0.5m, see Photo 4 and Table 2.

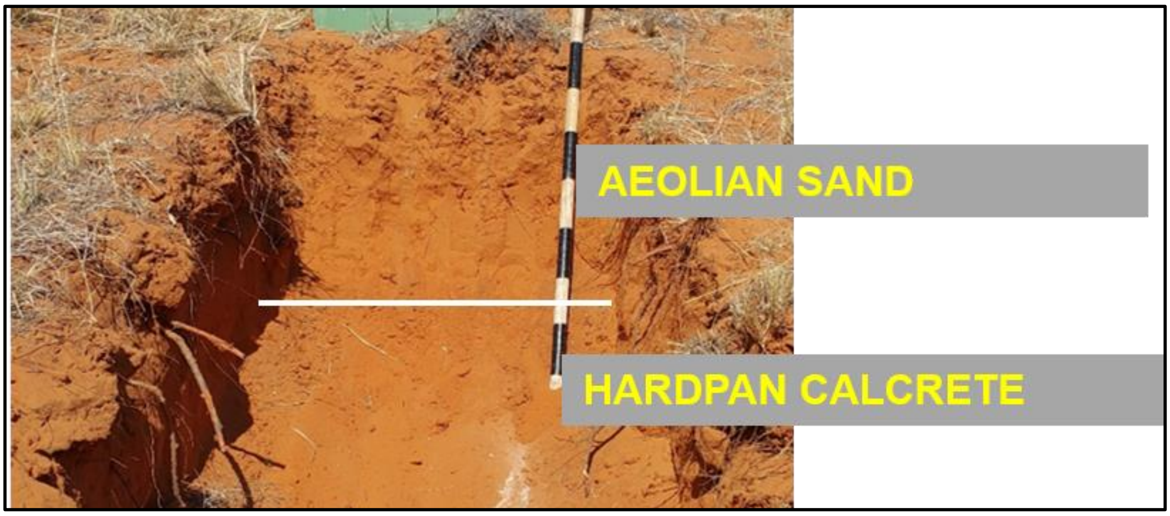

PHOTO 4: AEOLIAN SAND WITH HARDPAB CALCRETE

Profile	Depth to (m)	Description
	0,20	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with grass roots.
	0,40	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with weak to medium strong PLATEY CALCRETE
		End of Hole @ 0,40 m. TLB refusal on HARDPAN CALLCRETE. No groundwater encountered.

TABLE 2: PROFILE 1 – AEOLIAN SAND AND HARDPAN CALCRETE

4.1.2. Profile 2: Aeolian sand with platy calcrete overlying hardpan calcrete

The largest part of the central area of the site is underlain by aeolian sand with platy calcrete overlying hardpan calcrete. The platy calcrete is an indication of localized surface weathering of the hardpan calcrete. This soil profile was encountered in trial pit K_TP09. The TLB refused at 0.6m on the Hardpan Calcrete (Photo 5 and Table 3).

PHOTO 5: HILLWASH PROFILE

TABLE 3: PROFILE 2 – HILLWASH PROFILE

Profile	Depth to (m)	Description
	0,20	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with grass roots.
	0,80	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with weak to medium strong PLATEY CALCRETE
		End of Hole @ 0.80 m. TLB refusal on HARDPAN CALLCRETE. No groundwater encountered.

4.1.3. Profile 3: Aeolian sand with boulder calcrete overlying hardpan calcrete

Two areas in the north and south of the site is underlain by aeolian sand with boulder calcrete overlying hardpan calcrete. The boulder calcrete is an indication of localized weathering of the hardpan calcrete, similar to core stone formation. This soil profile was encountered in trial pits K_TP01, K_TP06, K_TP07,. K_TP08 and K_TP10. Excavatability is also variable and the depth to refusal of the TLB was between 1.10m and 1.7m (Photo 6 and Table 4).

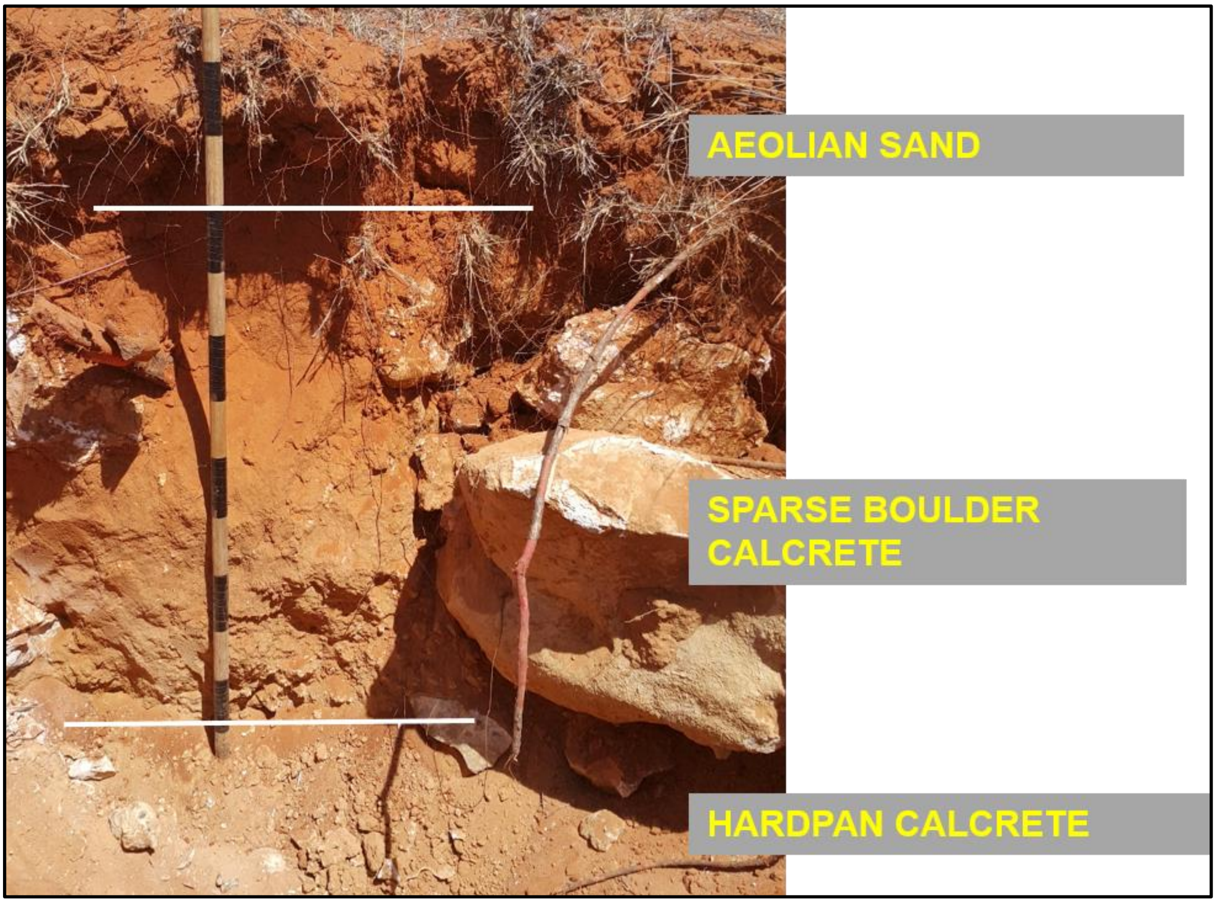

PHOTO 6: AEOLIAN/ ALLUVIUM OVERLYING SCHIST

TABLE 4: PROFILE 3 - AEOLIAN/ ALLUVIUM OVERLYING SCHIST

Soil Profile Description		
Profile	**Depth to (m)**	**Description**
	0,20	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with grass roots.
	1,20	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with BOULDER CALCRETE
		End of Hole @ 1,20 m. TLB refusal on HARDPAN CALLCRETE. No groundwater encountered.

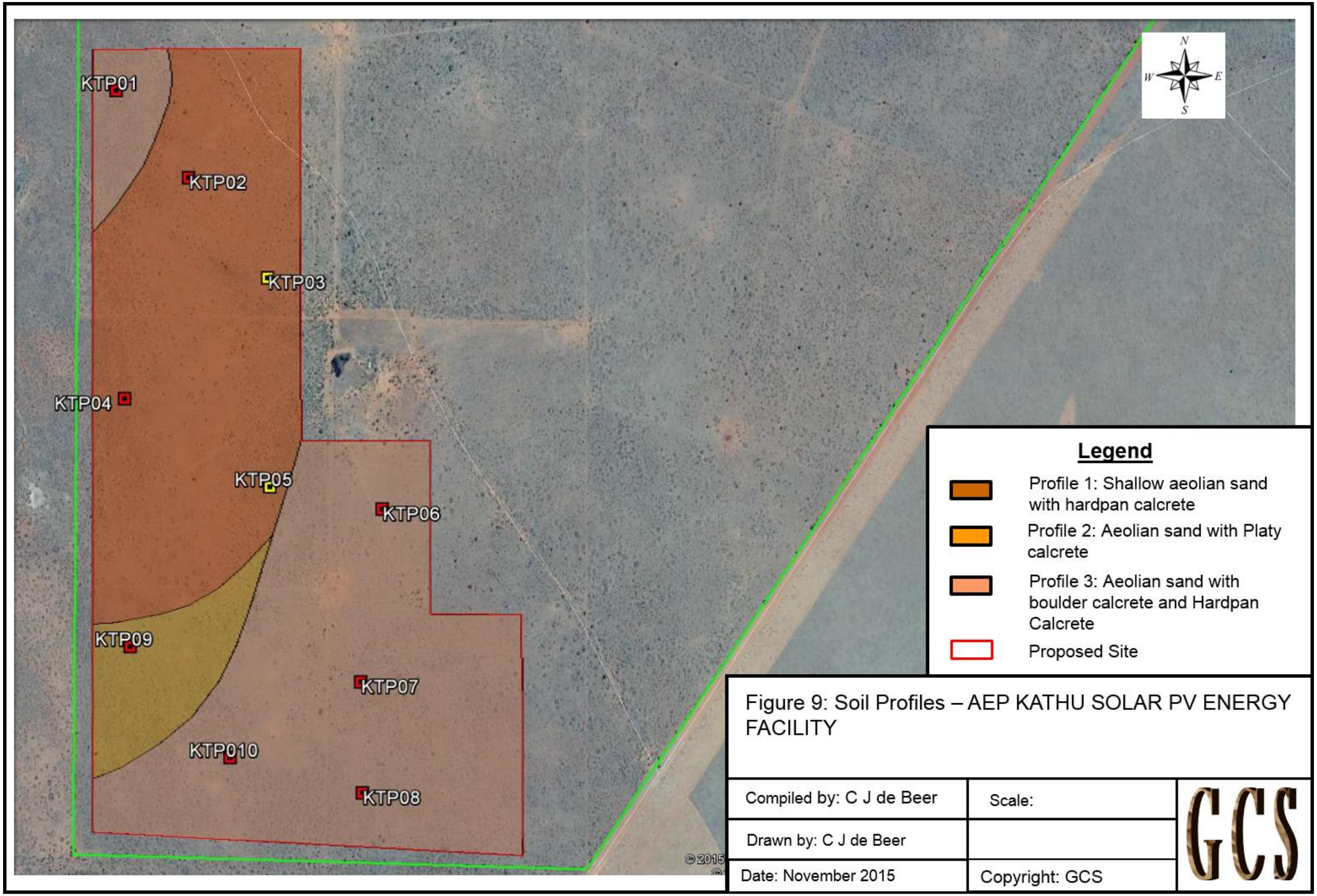

Figure 9: Soil Profiles – AEP KATHU SOLAR PV ENERGY FACILITY

4.2. Results Of The Laboratory Testing

The results of the laboratory testing conducted on the single soil sample is summarized in Table 6 below. The laboratory results are presented in Appendix 2.

The aeolian sand sample is plastic but the linear shrinkage is low. The pH of the soil is basic and the conductivity is low.

4.3. DCP Test Results

The results of the three DCP tests are presented in Appendix 3, the interpreted results per soil profile layer are presented inTable 5, below.

TABLE 5: DCP TEST RESULTS

Layer	DN	CBR	UCS (kPa)	Soil profile
K_TP02				
0-480mm	31	5	58	Aeolian sand
480-520mm	2	320	2251	Hardpan Calcrete
K_TP06				
0-1000mm	29	5	66	Aeolian sand
L1TP08				
0-1000mm	30	5	66	Aeolian sand

The consistency of the aeolian sand encountered in profile areas 2 is loose to very loose, resulting in a low soil strength. The hillwash layers are denser and the consistency is higher, resulting in a better bearing capacity and increased shear resistance.

The aeolian sand layers have variable consistency and thus also variable bearing capacities that tend to be low, between 20 and 160 kPa.

The DCP refusal indicate a bearing capacity and soil strength of the hardpan calcrete is better than 2200kPa.

The strength of the aeolian sand is in the order of 50 to 60 kPa.

TABLE 6: SUMMARY OF LABORATORY RESULTS

Sample nr	Sample Point	Depth (m)	Indicator tests					Material Type[1]	Soil Settlement Potential	pH	Conductivity (mS/m)	Soil Collapsibility	Soil Permeability (cm.s^{-1})
			Clay %	Silt %	Atterberg Limits								
					LL	PI	LS (%)						
K_TP07a	L1TP07	0.3-0.6	17.8	2.2	-	NP	-	Dark red orange clayey sand	high	6.99	6.44	Low	0.0001
L1TP08a	L1TP08	0.3-1.2	22	0	-	NP	-	Dark red orange clayey sand	high	6.68	8.03	Low	0.0001

1 According to the Revised Standard on the Unified Soil Classification System

2 Calculated using Van der Merwe's method

3 Evaluated after comparison with typical soil grading curves (Knight, 1961 and Errera, 1977)

4.4. BOREHOLE LOGS

The percussion borehole drilled on site DOL_BH (Figure 8) was planned to 100m but was terminated at 65m in loose pebbles at the base of the Kalahari Formation, in a pebble bed that most likely represent a paleo erosion surface correlated to the African2 erosion surface. This layer of pebbles is widespread throughout the area and is encountered in many boreholes. The reason for the termination of the borehole is that due to the fact that the hole was only planned as an exploratory hole and only a collar casing to 3m was installed. At depth the clays squeezed the drill string and the pebbles dropped in behind the hammer causing the drill to loose rotation and be at risk of locking the drill string up. The alternatives were to use a Cemetrix drill bit and install casing to the bedrock. At that time information regarding two monitoring boreholes drilled by Kumba (BH_A and BH_B in Figure 8) came to light. Chert -rich dolomite were intersected in both these boreholes at depths of of 63 and 68m respectively. The intersections of the dolomite bedrock and the pebble layer is indicated in Table 7, indicating that borehole DOL_BH was terminated very close to the upper contact of the dolomite. The borehole intersections also define the thickness and nature of the blanketing overburden above the dolomite
Refer to Appendix D for the borehole log of borehole DOL_BH.

TABLE 7: SUMMARY OF BOREHOLE INTERSECTIONS

Borehole	Depth to (m)	Formation
Dol BH	1	Kalahari sand
	12	Hardpan Calcrete
	37	Powdery Calcrete
	59	Yellow Clay
	65	Pebble Layer
BH_ A	63	Kalahari Fm and pebble layer
	140	Chert rich Dolomite
BH_B	68	Kalahari Fm and pebble layer
	91	Chert rich Dolomite

The water levels of all three boreholes were measured during the site visit and the results are presented in Table 7. The water level of borehole DOL_BH was measured 14 hours after the drill rods have been removed from the borehole to allow the water level to stabilize. One blow yield test were conducted and the indicated maximum yield of the borehole is in the order of 1200 to 2000 l per hour, this is however not an indication of the sustainable yield.

TABLE 8: WATER LEVELS OF BOREHOLES

Borehole	Static water level (m below surface)
DOL_BH	10.4
BH_A	11.3
BH_A	10.9

5. DOLOMITE STABILITY ASSESMENT

The inherent risk of the formation of sinkholes was evaluated according to the method proposed by Buttrick et al. The following observations is significant with respect to determination of the inherent risk classification for the site:

- The blanketing layer on site at least 60m thick, of which at least 35m is competent calcrete.
- The regional water table is shallow at around 10m and stable with no signs of drawdown from the mine.
- The 35m thick Hardpan calcrete forms a stable roof with the clay layer forming an effective aquitard and neutralizer for the low pH rainwater before it comes in contact with the dolomite
- No sinkholes have been reported in the area
- No significant point ingress of water is present on site or will originate from the proposed development

The potential for leaking pipes is only a risk around the offices the reservoir and piping between the two.

An aerial survey using airborne imagery and the site walkover did not identify any dolines or sinkholes on the property or the immediate area.

The maximum development space of sinkholes and dolines can be in excess of 15m due to the thickness of the overburden. It is however more likely that small solution cavities can develop in the calcrete than in the dolomite as a result of lowering of the water table or point ingress of water. Apart from the slightly lower pH of rainwater all the other surface water and borehole water are saturated or at least partly saturated with calcium carbonate. Therefore it is more likely that calcium carbonate will deposit from the water rather than dissolve it. The overlying calcrete also acts as a barrier to dolomite solution because the anion exchange will neutralize the pH in the percolating water.

5.1. Inherent Risk Classification

Although the potential for sinkhole formation exists, the local geological conditions and the absence of triggers and reported cases indicate that the inherent risk for the formation of all sizes of sinkholes are low, as a result the whole site is classified as a class 1 inherent risk (Figure 10).

5.2. NHBRC Site Class

Based on the NHBRC site class designation, the proposed development area can be classified as a D2 site where the general SANS 1936-3 precautionary measures intended to prevent concentrated ingress of water into the ground are regarded as sufficient.

5.3. LAND USE DEFINITION

The SANS 1936-1 standards does not make provision for solar energy generation facilities as such but a Land use C8 – parking areas is regarded as appropriate for the following reasons:

- The occurrence of a sinkhole of any size will have a limited impact as at most a few structures will be affected
- Exposure of people is very limited as only periodic inspections are done
- The control room and sub-station is more prone to risk but it is proposed that footprint investigations be conducted in those areas

5.4. DOLOMITE STABILITY RISK MANAGEMENT

It is recommended that prior to finalization of the layout a dolomite stability investigation be carried out around the critical structures such as the control room and sub-station as this is the areas where personnel will be present for most of the time on site.

The dolomite stability investigation consists of a geophysical survey to identify and delineate low density areas where solution cavities may be present. The geophysical survey consists of an initial gravimetric survey across the selected areas at a point spacing of 10m. Any anomalies with low gravimetric signature is then investigated using another geophysical technique called resistivity method. With this method it can be determined whether the anomaly is shallow or deep seated. All the features identified that pose a hazard to the project is then drilled and investigated in detail. If necessary remedial actions should be taken prior to construction or the structures relocated to a stable area on the site, if possible.

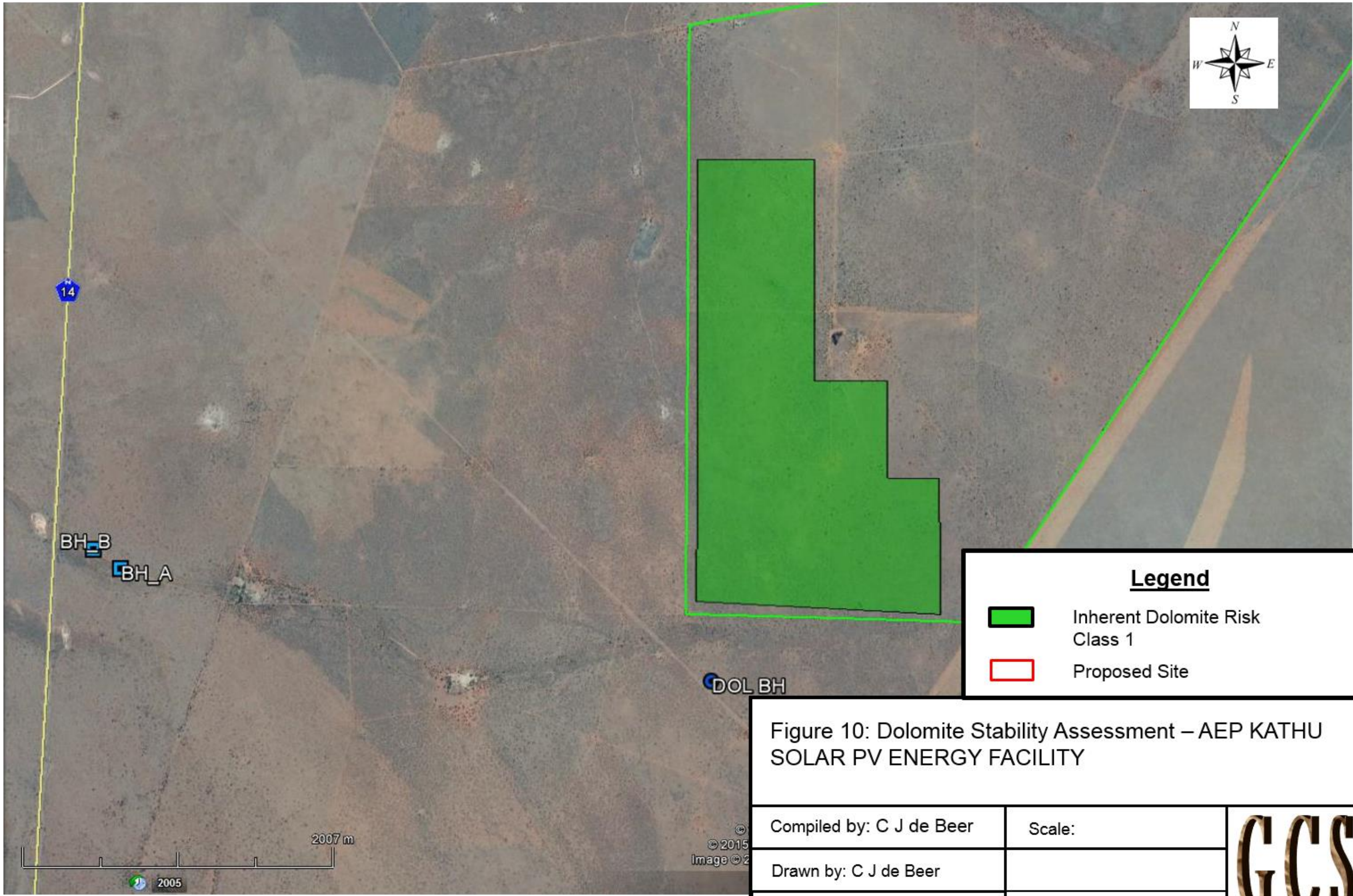

Figure 10: Dolomite Stability Assessment – AEP KATHU SOLAR PV ENERGY FACILITY

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Drawn by: C J de Beer		
Date: November 2015	Copyright: GCS	

6. GEOTECHNICAL SITE EVALUATION

The proposed development may have impacts on the geo-environment which may directly or indirectly affect the other environmental processes. This report focused on the soil and bedrock, but excludes features such as caves, addits, middens worship rocks etc., which are important as historical, cultural, archaeological or religious heritage sites. Important or prominent geological features (Geo-sites) that contribute to the aesthetic scenery or geological interest such as fossil sites, prominent rock outcrops or features are also considered in this study. A separate Heritage Impact Assessment has been conducted by the Developers to address any such potential sites. The expected geotechnical impacts and conditions are also presented in this section.

The dolomite stability risk for the site is considered low and the other geotechnical considerations such as problem soils excavatability founding conditions, shallow groundwater, construction materials and the impact of mining is considered in this section.

6.1. Problem Soils

No problem soils that will have a significant impact on the planned structures have been identified within any of the three profiles. The loose aeolian sand can exhibit significant settlement under load, where present under foundations. The thickness of the layer present under foundations will be considered in the relevant section

6.2. Excavatability And Installation Of Services

Using the COLTO Standard, excavatability is classified as hard (boulders larger than $0.1m^3$, blasting or pneumatic and Mechanical rock breaking tools required) or soft (all other conditions).
The excavatability of the Profile 1 area will be soft to intermediate up to 0.6m depth and hard below that. For the profile 2 area excavatability will be soft to 1.20m and intermediate to 1.8m and hard below that. The excavatability of profile area 3 is variable but soft to intermediate to1.8m and hard below that level (Figure 11).
It is recommended that the sidewalls excavated be battered back to a 1:1.5 grade slope or shored in excavations deeper than 1.5m to comply with minimum safety regulations.

6.3. Shallow Groundwater

No Shallow groundwater conditions were encountered in any of the trial pits on site. The static water level on site is in the order of 10m below surface.

6.4. Construction Materials

The transported soils encountered on site is not suitable for use as wearing course on roads but it can be used as backfill in trenches. Aggregate material and selected fill should be sourced from commercial suppliers in the area. Plant discard from Sishen mine and crushed calcrete is good construction material for roads.

For the solar park environment where dust should be kept to a minimum regular watering and slow speeds to supress the dust is recommended.

6.5. Mining

No mining activities either underground or open pit occur in the immediate area. The Sishen Iron Ore mine located 11km due west of the site will not have a negative impact on the solar energy facility.

6.6. Foundation Solutions

Depth to bedrock, in this case the hardpan calcrete, on the proposed development area is variable and range from outcrop to 1.7m below surface, the different foundation options are related to the soil profiles encountered in the trial pits, (see Figure 12).

For **the western part of the site** (hardpan calcrete shallower than 600mm) the use of strip foot foundations founded on the hardpan calcrete is recommended.
The proposed founding method for the PV structures is pre-bored rammed piles. A minimum length of 2.50m is recommended to ensure that adequate shear friction is generated along the shaft, embedded in the bedrock to resist the uplift forces. For fixed orientation installations slab on the ground foundations can also be considered. The weight and surface area of the PV structures as well as the diameter of the pile plays a role in determining the pilling depth. The length of piles indicated in this report is based on previous experience in similar conditions and is a rough guide only.

The **eastern part of the site** is underlain by thicker aeolian sand, the recommended foundation solution for conventional structures is re-enforced strip foot foundations founded in the loose sand. The thickness below the founding level (usually 600mm) is also in the order of 600mm but with calcrete boulders and platy fragments, occurring above the hardpan calcrete horizon. These boulders should be removed from the foundation trenches. The aeolian sand and loose boulders can either be removed or replaced with compacted dump rock (mine discard) or calcrete or re-enforced strip footings can be used. The PV tracker panels can again be founded in pre-bored rammed pile that are longer. The excavatable material above the hardpan calcrete has poor friction characteristics and cannot be counted on to generate significant shear friction. The recommended installation depth of the pre-bored rammed piles are 3.0m. Strip foot foundations is also an option for fixed PV installations.

6.7. Access Route and Powerline Corridors

The AEP Kathu Solar PV facility will be connected to a new substation to be constructed approximately 2.4 km due west of the site, across the N14. The connection distance between the onsite substation and the new substation is via a loop in loop out bus. The powerline corridor will cross the same land form, is underlain by the same geology as is present on site. Both the proposed routes are developable with minor risk (Figure 13).

Access to the solar facility will be via a 2700m long access road from the N14 road. The access road covers aeolian sand and calcrete and the conditions are similar to that on the proposed footprint of the PV plant.
No major geotechnical risks are expected along the access road or the powerline corridor.

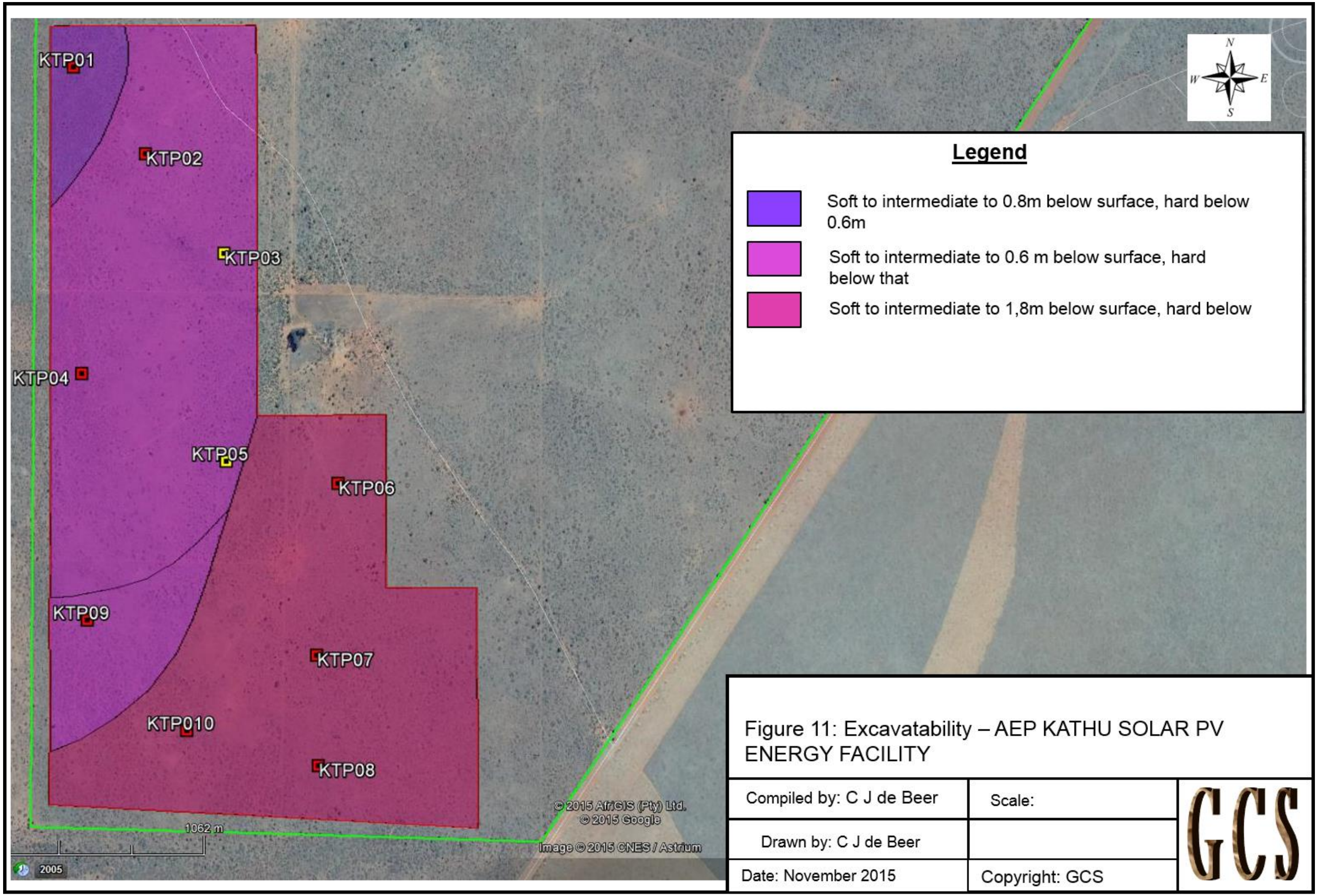


Figure 11: Excavatability – AEP KATHU SOLAR PV ENERGY FACILITY

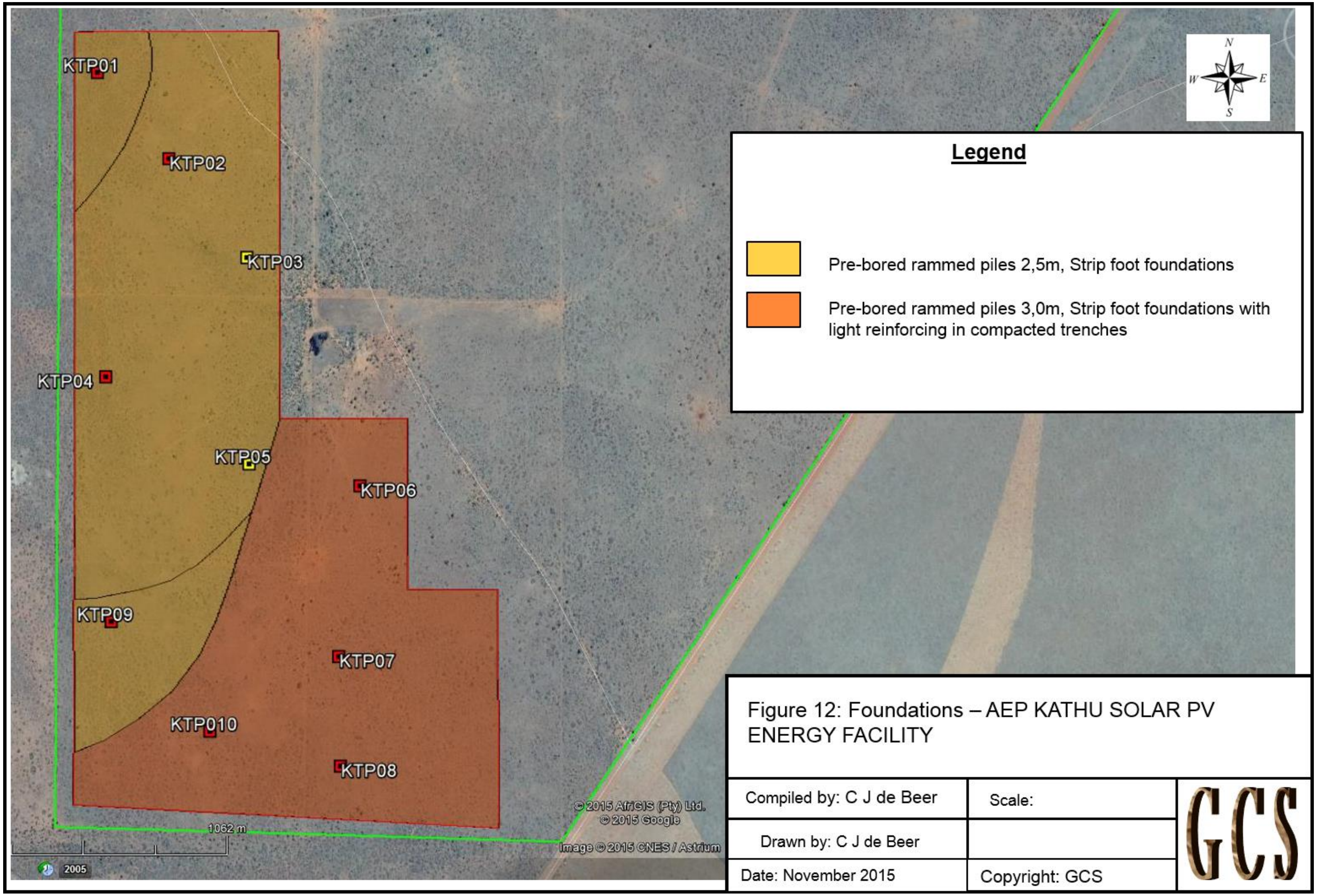


Figure 12: Foundations – AEP KATHU SOLAR PV ENERGY FACILITY

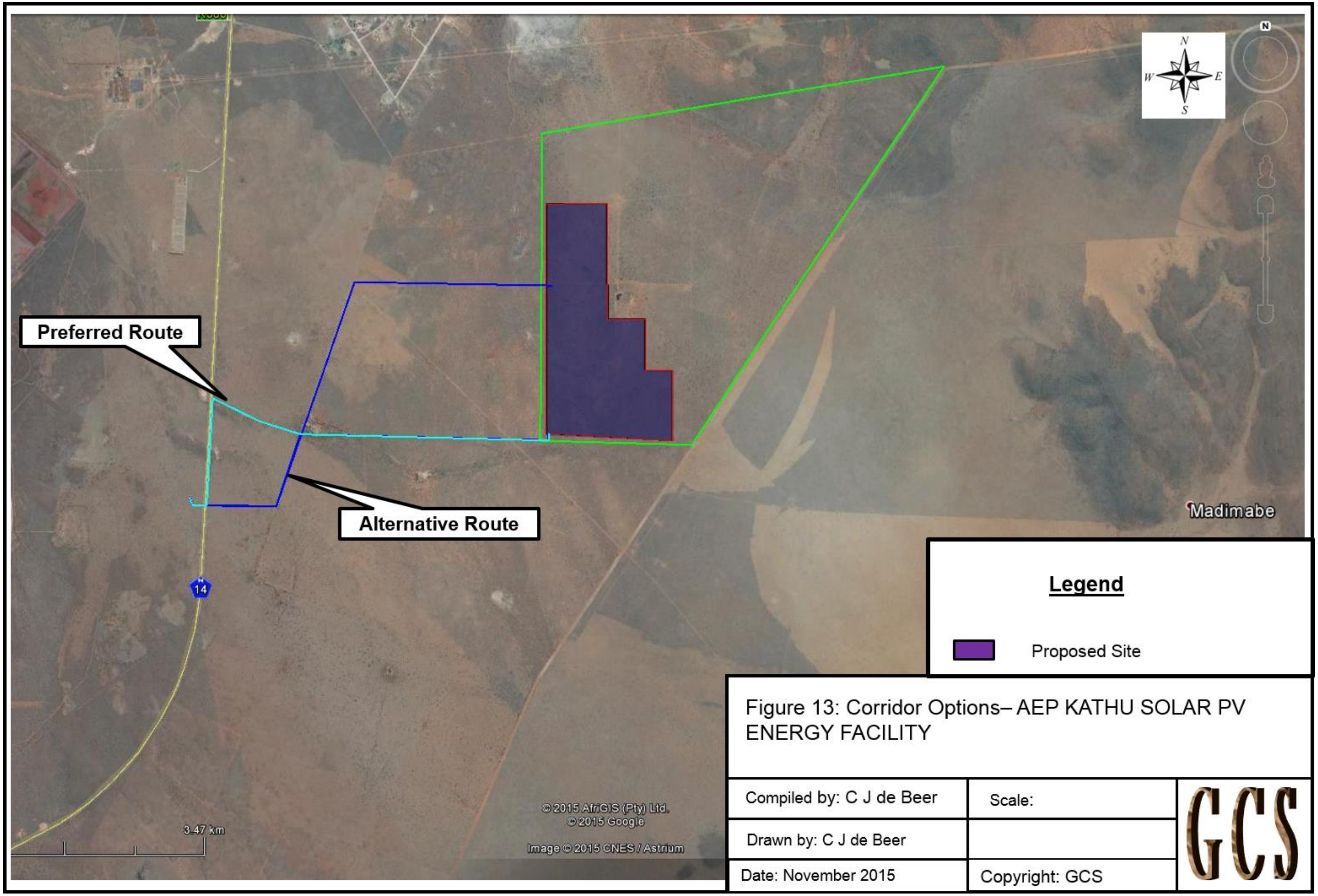


Figure 13: Corridor Options– AEP KATHU SOLAR PV ENERGY FACILITY

6.8. GEOTECHNICAL RISK ASSESSMENT

Based on information collected and tests conducted the proposed site is evaluated per soil profile area as defined and classified according to the geotechnical classification for urban development proposed by Partridge, Wood and Brink as summarized in Table 9 below.
Soil Profile Areas 1 to 3 is classed according to the Geotechnical Land Use Classification (Table 9) and the results is presented in tables 10 to 12.

TABLE 9: GEOTECHNICAL RISK CLASSIFICATION

CONSTRAINT		MOST FAVOURABLE (1)	INTERMEDIATE (2)	LEAST FAVOURABLE (3)
A	Collapsible Soil	Any collapsible horizon or consecutive horizons totalling a depth of less than 750 mm in thickness*	Any collapsible horizon or consecutive horizons totalling a depth of more than 750 mm in thickness*	A least favourable situation for this constraint does not occur
B	Seepage	Permanent or perched water table more than 1.5m below ground surface	Permanent or perched water table less than 1.5m below ground surface	Swamps and marches
C	Active Soil	Low soil-heave anticipated*	Moderate soil-heave anticipated	High soil-heave potential anticipated
D	Highly Compressible Soil	Low soil compressibility anticipated*	Moderate soil compressibility anticipated	High soil compressibility anticipated
E	Erodibility of Soil	Low	Intermediate	High
F	Difficult to excavate to 1.5m depth	Scattered or occasional boulders. Less than 10% of volume*	Rock or hardpan pedocretes between 10% and 40% of the total volume	Rock or hardpan pedocretes more than 40% of the total volume
G	Undermined Ground	Undermining at a depth greater than 240m below surface (except where total extraction mining has not occurred	Old undermined areas to a depth of 90 – 240 m below surface where stope closure has ceased	Mining within less than 90-240 m from surface or where total extraction mining has taken place
H	Stability (Dolomite and Limestone	Possibly stable. Areas of dolomite overlain by Karoo rocks or intruded by sills. Areas of Black Reef Rocks. Anticipated Inherent risk class 1	Potentially characterized by instability. Anticipated inherent Risk Classes 2-5	Known sinkholes and dolines in the area. Anticipated Inherent Risk Classes 6-8
I	Steep slopes	Between 2 and 6 degrees	Slopes between 6 and 18 degrees and less than 2 degrees (Natal and Western Cape) Slopes between 6 and 12 degrees and less than 2 degrees (all other regions)	More than 18 degrees (Natal and Western Cape) More than 12 degrees (all other regions)
J	Areas of unstable natural Slopes	Low Risk	Intermediate risk	High Risk (especially in areas subject to Seismic activity)
K	Areas subject to Seismic Activity	10% probability of an event less than 100 cm/s^2 within 50 years	Mining induced seismicity more than 100cm/s^2.	Natural Seismic activity more than 100 $cm.s^2$.
L	Areas subjected to flooding	A most favourable situation for this constraint does not occur	Areas adjacent to a known drainage channel or floodplain with a slope of less than 1%	Areas within a known drainage channel or floodplain

*These areas are designated 1A, 1C, 1D or 1F where localized occurrences of the constraint may arise.

6.8.1. PROFILE 1: AEOLIAN SAND AND HARDPAN CALCRETE

For profile 1 the geotechnical risk with respect to development is F2 (Table 10) indicating that shallow bedrock conditions exist where between 10 and 40 % of total excavation of 1.5m trenches will consist of bedrock.

TABLE 10: GEOTECHNICAL RISK EVALUATION PROFILE 1 AREA

Constraint		Site condition	Class
A	Collapsible soil	Any collapsible horizon or consecutive horizons totalling a depth of less than 750 mm in thickness	1
B	Seepage	Permanent or perched water table more than 1.5 m below the ground surface	1
C	Active soil	Low soil heave potential anticipated	1
D	Highly Compressible soil	Low soil compressibility anticipated	1
E	Erodibility of soil	Low	1
F	Excavatability to 1.5 m	Rock or hardpan pedocretes between 10 and 40% of the total volume	2
G	Undermined ground	Undermining at a depth greater than 240 m below surface (except where total extraction mining occurred)	1
H	Stability (dolomite and limestone)	No potential for karstification and possibly stable. Including areas of dolomite overlain by Karoo rocks or intruded by sills. Areas of Black Reef rocks (anticipated inherent risk class 1)	1
I	Steep slopes	Slopes are between 2 and 6 degrees	1
J	Unstable Natural Slopes	Low risk	1
K	Seismicity	10% probability of an event less than 100cm/s occurs within 50 years	1
L	Areas subjected to flooding	Potential for flooding is low	1

6.8.2. Profile 2: Hillwash

For profile 2 the geotechnical risk with respect to development is F2 (Table 11) indicating that shallow bedrock conditions exist where between 10% and 40 % of total excavation to 1.5m deep trenches will consist of hardpan calcrete.

TABLE 11: GEOTECHNICAL RISK EVALUATION PROFILE 2 AREA

Constraint		Site condition	Class
A	Collapsible soil	Any collapsible horizon or consecutive horizons totalling a depth of less than 750 mm in thickness	1
B	Seepage	Permanent or perched water table more than 1.5 m below the ground surface	1
C	Active soil	Low soil heave potential anticipated	1
D	Highly Compressible soil	Low soil compressibility anticipated	1
E	Erodibility of soil	Low	1
F	Excavatability to 1.5 m	Rock or hardpan pedocretes between 10 % an 40% of the total volume	2
G	Undermined ground	Undermining at a depth greater than 240 m below surface (except where total extraction mining occurred)	1
H	Stability (dolomite and limestone)	No potential for karstification and possibly stable. Including areas of dolomite overlain by Karoo rocks or intruded by sills. Areas of Black Reef rocks (anticipated inherent risk class 1)	1
I	Steep slopes	Slopes are between 2 and 6 degrees	1
J	Unstable Natural Slopes	Low risk	1
K	Seismicity	10% probability of an event less than 100cm/s occurs within 50 years	1
L	Areas subjected to flooding	Potential for flooding is low	1

6.8.3. Profile 3: Aeolian Sand

For profile 3 the geotechnical risk with respect to development is F1 and A2 (Table 12) indicating that the aeolian sand which is potentially collapsible, is thicker than 750mm.

TABLE 12: GEOTECHNICAL RISK EVALUATION PROFILE 3 AREA

Constraint		Site condition	Class
A	Collapsible soil	Any collapsible horizon or consecutive horizons totalling a depth of less than 750 mm in thickness	2
B	Seepage	Permanent or perched water table more than 1.5 m below the ground surface	1
C	Active soil	Low soil heave potential anticipated	1
D	Highly Compressible soil	Low soil compressibility anticipated	1
E	Erodibility of soil	Low	1
F	Excavatability to 1.5 m	Rock or hardpan pedocretes more than 40% of the total volume	2
G	Undermined ground	Undermining at a depth greater than 240 m below surface (except where total extraction mining occurred)	1

H	Stability (dolomite and limestone)	No potential for karstification and possibly stable. Including areas of dolomite overlain by Karoo rocks or intruded by sills. Areas of Black Reef rocks (anticipated inherent risk class 1)	1
I	Steep slopes	Slopes are between 2 and 6 degrees	1
J	Unstable Natural Slopes	Low risk	1
K	Seismicity	10% probability of an event less than 100cm/s occurs within 50 years	1
L	Areas subjected to flooding	Potential for flooding is low	1

In terms of the intended land use, the construction of a photovoltaic solar energy generation facility, limited excavatability Class F2 is not a critical element that will be a risk for the project. Suitable foundation options are available and development can occur on any of the three profile areas. The occurrence of dolomite at depth is also not considered a risk because suitable mitigating measures can be taken to safeguard critical infrastructure and reduce the risk to personnel. The loose aeolian sand is does not provide any support to the rammed piles and therefore adequate founding into the hardpan calcrete is required to generate sufficient shear friction to resist the loosening and uplift forces.

6.9. LAND USE EVALUATION

6.9.1. LAND USE AREA A (AEOLIAN SAND AND PLATY CALCRETE OVER HARDPAN CALCRETE)

Land Use Area B covers the soil profile 1 and2, area (aeolian sand and hardpan calcrete) and is classified as DEVELOPABLE with MINOR PRECAUTIONS due to the fact that although the dolomite hazard is low (Inherent Dolomite Risk Class 1) there still exist a potential risk and all due care should be taken to protect and safeguard personnel from the risk. The soil profile is with hardpan calcrete occurring at depths up to 0.6m below surface. Excavatability is soft to intermediate up to 0.6m and hard below that. (Geotechnical Class F2). The recommended foundation solution for tracker frames is pre-bored rammed piles of at least 2.50m long. For conventional structures and fixed PV arrays reinforced raft foundations are recommended. Foundations for conventional structures should be re-enforced strip foot foundations. All measures defined in SANS 1936-3 should be adhered to where applicable during construction of the offices and control room to mitigate against sinkhole formation.

6.9.2. LAND USE AREA B (AEOLIAN SAND WITH BOULDER CALCRETE OVER HARDPAN CALCRETE)

Land Use Area A covers the soil profile 3, area (aeolian sand with boulder calcrete and hardpan calcrete) and is classified as DEVELOPABLE with MINOR PRECAUTIONS due to the fact that although the dolomite hazard is low (Inherent Dolomite Risk Class 1) there still exist a potential risk and all due care should be taken to protect and safeguard personnel from the risk. The soil profile is thin with hardpan calcrete occurring at depths up to 1.70m below surface. Excavatability is soft to intermediate up to 1.70m and hard below that (Geotechnical Class F1). The recommended foundation solution for tracker frames is pre-bored rammed piles of at least 3.00m long. For conventional structures and fixed PV arrays reinforced raft foundations are recommended. Foundations for conventional structures should be strip foot foundations founded on hardpan calcrete. All measures defined in SANS 1936-3 should be adhered to where applicable during construction of the offices and control room to mitigate against sinkhole formation.

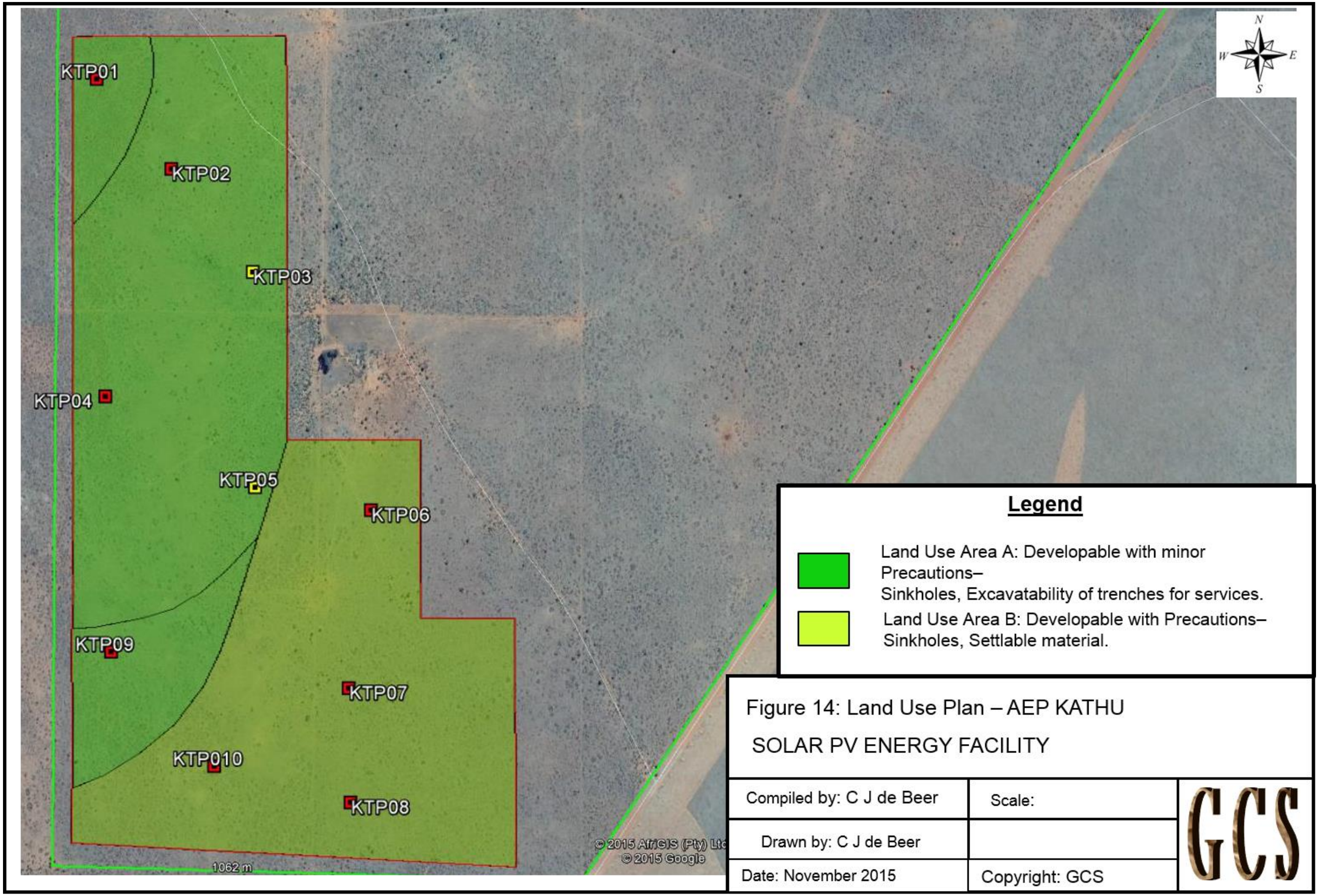


Figure 14: Land Use Plan – AEP KATHU SOLAR PV ENERGY FACILITY

7. RECOMMENDATIONS

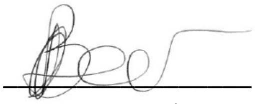
To follow on this study, it is recommended that the following be adopted prior to final design and construction:

- A design level geotechnical investigation and report, to define the design parameters for the selected foundation solution.
- Dolomite stability investigation of major, sensitive infrastructures such as the control room and sub-station.
- Installation trials and pull test to evaluate the suitability of the different mini pile options on the site.

8. CONCLUSIONS

- The proposed Kathu Solar PV Energy Facility is located on a portion of the Remainder of the farm Legoko 460, Kathu Municipality, Northern Cape Province, located approximately 10 km south-south east from Kathu.
- The site is underlain by aeolian sand, calcrete and dolomite at depth, located on a valley floor land facet
- A total of 8 trial pits were profiled (10 planned) and 3 DCP test conducted on site. Two soil samples were collected from a potential problem soil horizon for laboratory analysis, and a dedicated borehole drilled to determine the depth to dolomite bedrock
- The geotechnical borehole was planned to 100m but the hole was terminated at 65m due to difficult drilling conditions. Information received from Kumba indicated that the Dolomite bedrock is located between 60-70m below surface, with a cover of Kalahari deposits that includes a 35m thick hardpan calcrete.
- Three soil profiles were identified:
    - Profile 1: Aeolian sand over hardpan calcrete
    - Profile 2: Aeolian sand and platy calcrete over hardpan calcrete
    - Profile 3: Aeolian sand with boulder calcrete overlying hardpan calcrete
- Strip foot foundations with reinforcing where required is recommended for the conventional structures.
- Pre drilled, rammed pilled foundations are recommended for tracker PV structures. The length of the piles varies with the soil profiles; For profile area 1 and 2 a length of 2.5m is recommended, and on profile area 3 a length of 3.0m is recommended to generate sufficient shear resistance.
- For fixed PV structures smaller rammed piles or strip foot foundations can be used.
- The expected excavatability for service trenches is soft to hard depending on the thickness of the aeolian sand (ranging from 0.6 to 1.7m thick).
- The potential for collapse of side walls of deep excavations is low.
- No shallow groundwater conditions were encountered.
- Construction materials should be sourced from commercial suppliers. Plant discard from iron ore mines can be used for road construction.
- No mining activities impact the site.
- The inherent risk class dolomite instability is low. Although all sized of sinkholes can occur the likelihood of it occurring is low because the water table is stable, there are no record of sinkholes with a thick calcrete cover.
- The geotechnical risk classification for the profile area 1 and 2 is F2 and The geotechnical classification for profile area 3 is F1, A2 due to the presence pf potential collapsible aeolian sand that is thicker than 750mm.
- For the solar park development shallow bedrock conditions and potential collapsible soil is not critical to the success of the development and thus not regarded as a critical constraint.
- The geology along the connection corridor routes is similar to the conditions on site and no geotechnical risks are expected along either route.
- Access to the site is via existing roads from the N14.
- Grid connections will occur via a loop-in loop-out connection on site or via a self-built line of 5400m to connect to a new substation planned.

- The assessment of the geotechnical conditions on site resulted in three land use areas being defined:
    - LAND USE AREA A is classified as DEVELOPABLE with minor PRECAUTIONS due to the relative shallow calcrete conditions that will impact on the installation trenches for the cabling and the low potential for sinkhole formation. The area is suitable for the installation of PV structures using pre-bored rammed piles.
    - LAND USE AREA B (AEOLIAN SAND) is classified as DEVELOPABLE with minor PRECAUTIONS due to the impact of the loos settlable sand under the foundations of conventional structures and the low potential for sinkhole formation. The area is suitable for the installation of PV structures using pre-bored rammed piles.
- **From a geotechnical perspective the proposed development areas is suitable for the proposed development.**



Carel de Beer (Pri.Sci.Nat)

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- **APPENDIX 1 – SOIL PROFILES**

Soil Profile TP 1 (Kathu AEP)

Profiled by C de Beer
Diameter
Depth 0,80
Type: Trial Pit

Co-coordinates:
X-coord 27,74516º E
Y-coord 023,11138º S
Z-coord 1242

Contractor Kathu Profile
Machine Terrex 840TLB
Operator Jafta

Soil Profile Description

Profile	Depth to (m)		Description
	0,30		Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with grass roots.
	0,80		Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with sparse BOULDER CALCRETE
			End of Hole @ 0.80 m. TLB refusal on HARDPAN CALLCRETE. No groundwater encountered.

Comments

1 No DCP test Conducted
2 No disturbed sample collected

GCS

Soil Profile TP 2 (Kathu AEP)

Profiled by C de Beer
Diameter
Depth 0,50
Type: Trial Pit

Co-coordinates:
X-coord 27,74801º E
Y-coord 023,11406º S
Z-coord 1242

Contractor Kathu Profile
Machine Terrex 840TLB
Operator Jafta

Soil Profile Description

Profile	Depth to (m)	Description
	0,50	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with grass roots.
		End of Hole @ 0,50 m. TLB refusal on HARDPAN CALLCRETE. No groundwater encountered.

Comments

1 No DCP test Conducted
2 No disturbed sample collected

GCS

Soil Profile TP 4 (Kathu AEP)

Profiled by C de Beer
Diameter
Depth 0,30
Type: Trial Pit

Co-coordinates:
X-coord 27,75521º E
Y-coord 023,11169º S
Z-coord 1242

Contractor Kathu Profile
Machine Terrex 840TLB
Operator Jafta

Soil Profile Description

Profile	Depth to (m)	Description
	0,50	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with grass roots.
		End of Hole @ 0,30 m. TLB refusal on HARDPAN CALLCRETE. No groundwater encountered.

Comments

1 No DCP test Conducted
2 No disturbed sample collected

GCS

Soil Profile TP 6 (Kathu AEP)

Profiled by C de Beer
Diameter
Depth 1,70
Type: Trial Pit

Co-coordinates:
X-coord 27,75881º E
Y-coord 023,11138º S
Z-coord 1242

Contractor Kathu Profile
Machine Terrex 840TLB
Operator Jafta

Soil Profile Description

Profile	Depth to (m)	Description
	1,60	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with grass roots.
	1,70	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with sparse BOULDER CALCRETE
		End of Hole @ 1,70 m. TLB refusal on HARDPAN CALLCRETE. No groundwater encountered.

Comments

1 No DCP test Conducted
2 No disturbed sample collected

GCS

Soil Profile TP 7 (Kathu AEP)

Profiled by C de Beer
Diameter
Depth 1,30
Type: Trial Pit

Co-coordinates:
X-coord 27,76444º E
Y-coord 023,12041º S
Z-coord 1244

Contractor Kathu Profile
Machine Terrex 840TLB
Operator Jafta

Soil Profile Description

Profile	Depth to (m)	Description
	0,30	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with grass roots.
	1,30	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with sparse BOULDER CALCRETE
		End of Hole @ 1,30 m. TLB refusal on HARDPAN CALLCRETE. No groundwater encountered.

Comments

1 No DCP test Conducted
2 No disturbed sample collected

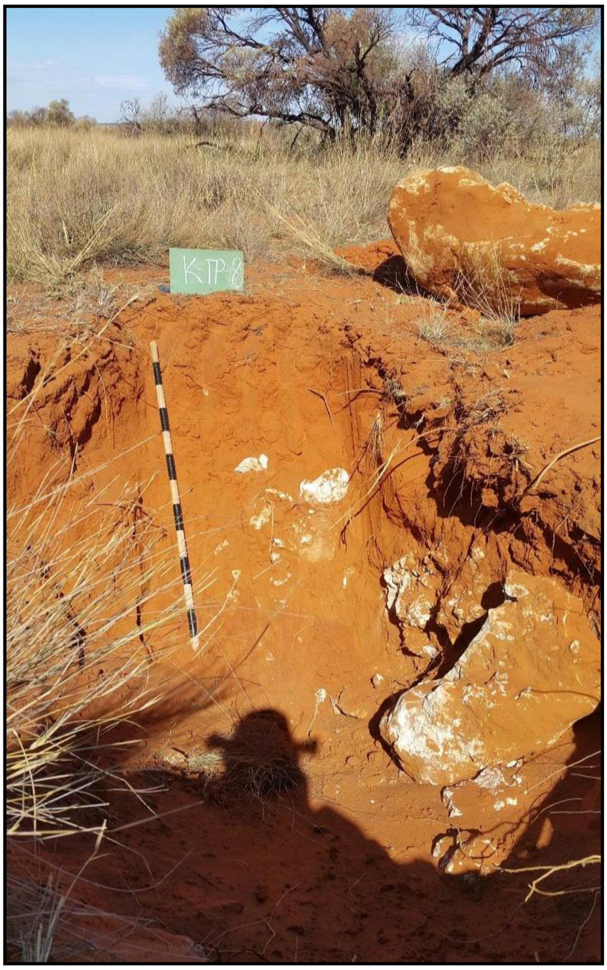
GCS

Soil Profile TP 8 (Kathu AEP)

Profiled by C de Beer
Diameter
Depth 1,30
Type: Trial Pit

Co-coordinates:
X-coord 27,76806º E
Y-coord 023,12047º S
Z-coord 1244

Contractor Kathu Profile
Machine Terrex 840TLB
Operator Jafta



Soil Profile Description

Profile	Depth to (m)	Description
	0,30	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with grass roots.
	1,30	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with sparse BOULDER CALCRETE Disturbed sample KTP08A collected from 0.2-1,3m
		End of Hole @ 1,30 m. TLB refusal on HARDPAN CALLCRETE. No groundwater encountered.

Comments

1 No DCP test Conducted
2 Disturbed sample K-TP 8A collected from 0,20 to 1,3m

GCS

Soil Profile TP 9 (Kathu AEP)

Profiled by C de Beer
Diameter
Depth 0,60
Type: Trial Pit

Co-coordinates:
X-coord 27,76329º E
Y-coord 023,11190º S
Z-coord 1243

Contractor Kathu Profile
Machine Terrex 840TLB
Operator Jafta

Soil Profile Description

Profile	Depth to (m)	Description
	0,20	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with grass roots.
	0,60	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with weak to medium strong PLATEY CALCRETE
		End of Hole @ 0.60 m. TLB refusal on HARDPAN CALLCRETE. No groundwater encountered.

Comments

1 No DCP test Conducted
2 No disturbed sample collected

GCS

Soil Profile TP 10 (Kathu AEP)

Profiled by C de Beer
Diameter
Depth 1,10
Type: Trial Pit

Co-coordinates:
X-coord 27,74516º E
Y-coord 023,11138º S
Z-coord 1242

Contractor Kathu Profile
Machine Terrex 840TLB
Operator Jafta

Soil Profile Description

Profile	Depth to (m)	Description
	0,30	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with grass roots.
	1,10	Dry, orange brown, very loose, intact, uniform sity sand, AEOLIAN (Kalahari Sand) with sparse BOULDER CALCRETE
		End of Hole @ 1,10 m. TLB refusal on HARDPAN CALLCRETE. No groundwater encountered.

Comments

1 No DCP test Conducted
2 No disturbed sample collected

GCS

- **APPENDIX 2 – LABORATORY TEST RESULTS**

ROADLAB
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Established 1965

HEAD OFFICE
207 Rietfontein Rd Primrose Germiston 1401
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www.roadlab.co.za

92/GEO007/01/0005/15 2015/11/26

Geotechnical Consult Services
11 Jakkals Weg
Van Riebeeck Park
Kempton Park
1619

ATTENTION: **Mr. C De Beer**

Dear Sir

Test Report : **KATHU SEF - FOUNDATION INDICATORS**

Herewith the laboratory foundation indicator test results for above mentioned project, as requested by you.
2x Samples were delivered to Roadlab.
*** Non accredited tests**

Kind Regards

Mr N Herbst

Mr D Juckers
TECHNICAL SIGNATORY

Remarks :

The samples were subjected to analysis according to TMH 1

The results reported relate only to the sample tested

Further use of the above information is not the responsibility or liability of Roadlab

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Compiled By : Perushnee Pillay

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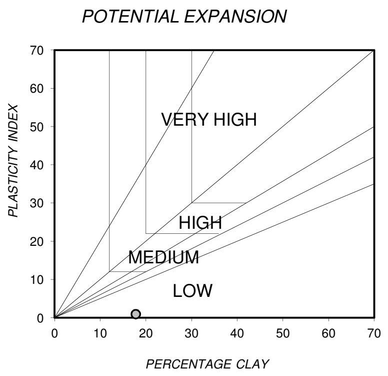
E-mail: info@roadlab.co.za
www.roadlab.co.za

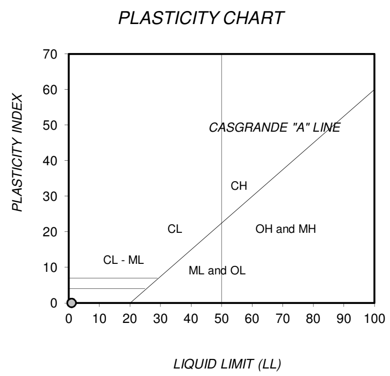
OUR REF : 92/GEO007/01/0005/15
CLIENT : Geotechnical Consult Services
SITE : KATHU SEF - FOUNDATION INDICATORS

DATE RECEIVED : 2015/11/19
CHAINAGE : Test Pit 07
LAYER : 0.3 - 0.6
SAMPLE No. : S/6190
SAMPLE DESCRIPTION : Dark Red Orange Clayey Sand

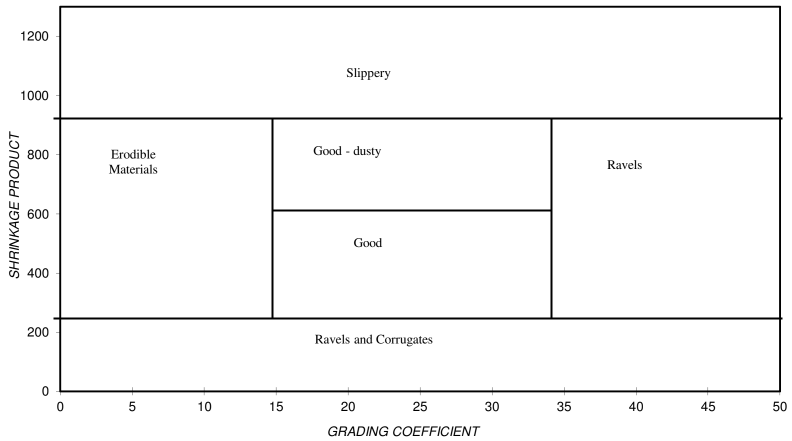
FOUNDATION INDICATOR RESULTS (TMH 1 : A1, A2, A3, A4, A5 & *ASTM D422)

Weighted PI		**0.9**
Sieve analysis Cumulative percentage passing (mm)	75.0	100
	63.0	100
	53.0	100
	37.5	100
	26.5	100
	19.0	100
	13.2	100
	4.75	100
	2.000	100
	0.425	90
	0.250	70
	0.150	50
	0.075	20
	0.050*	20
	0.005*	18
	0.002*	18
Soil Mortar Analysis % < 2.00mm	2.000 - 0.425	10.0
	0.425 - 0.250	20.0
	0.250 - 0.150	22.0
	0.150 - 0.075	29.0
	< 0.075	19.0
Effective size		0.001
Uniformity Coefficient		200.0
Curvature Coefficient		50.0
Oversize Index		0.0
Shrinkage Product		
Grading Coefficient		0.0
Grading modulus		0.90
Atter-berg Limits	Liquid Limit	-
	Plasticity Index	NP
	Linear Shrinkage	-
	PI < 0.075	-
Unified Soil Classification		SC
U.S. Highway Classification		A-2-4(0)
pH - Value		N/A
Conductivity mS/cm		N/A

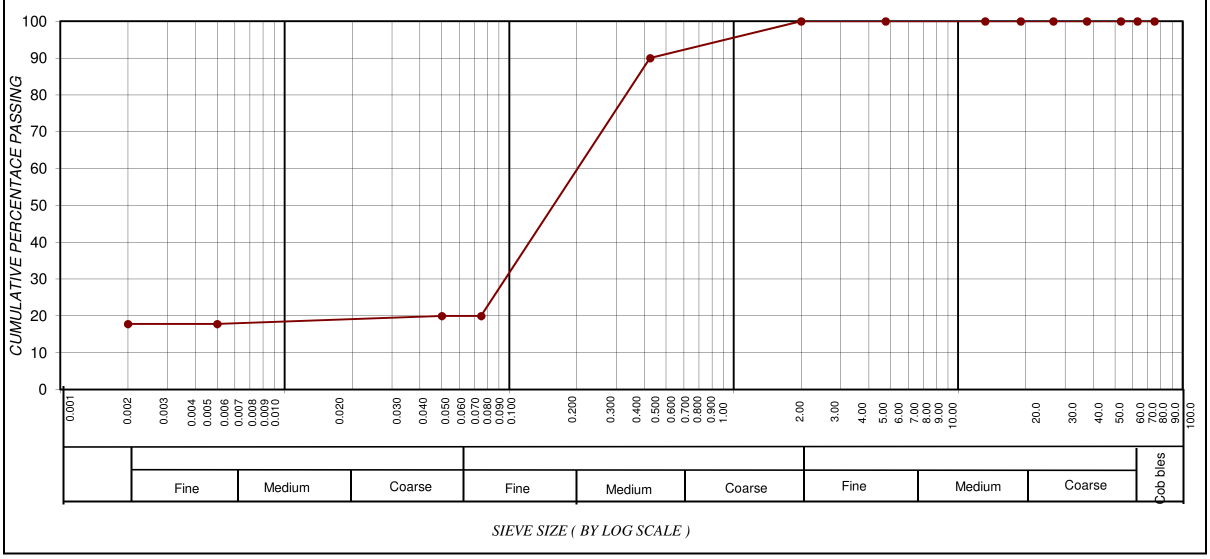




PERFORMANCE AS WEARING COURSE



SIEVE GRADING



CLAY (%) (0.001-0.002)	SILT (%) (0.002-0.060)	SAND (%) (0.060-2.00)	GRAVEL (%) (2.00-60.0)
17.8	2.2	80.0	0.0

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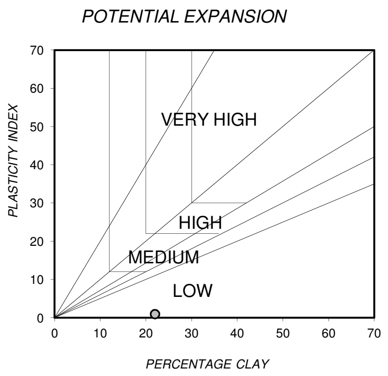
www.roadlab.co.za

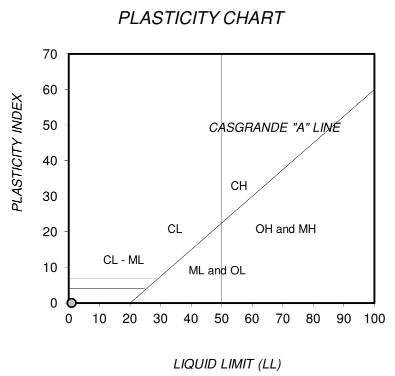
OUR REF : 92/GEO007/01/0005/15
CLIENT : Geotechnical Consult Services
SITE : KATHU SEF - FOUNDATION INDICATORS

DATE RECEIVED : 2015/11/19
CHAINAGE : Test Pit 08
LAYER : 0.2 - 1.3
SAMPLE No. : S/6191
SAMPLE DESCRIPTION : Dark Red Orange Clayey Sand

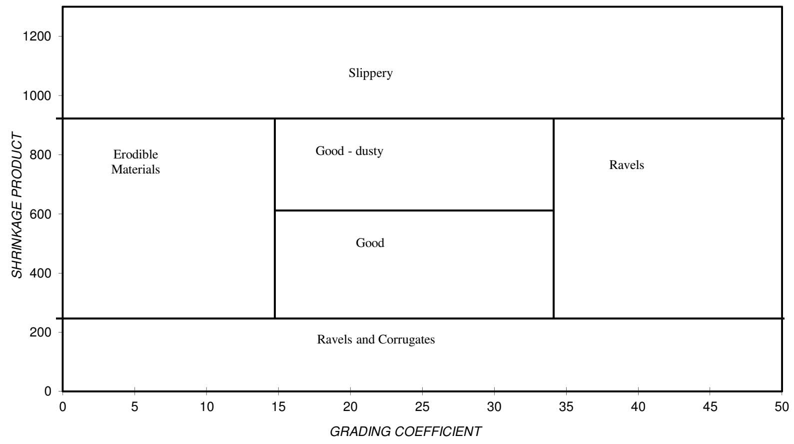
*FOUNDATION INDICATOR RESULTS (TMH 1 : A1, A2, A3, A4, A5 & *ASTM D422)*

Weighted PI		**0.9**
Sieve analysis Cumulative percentage passing (mm)	75.0	100
	63.0	100
	53.0	100
	37.5	100
	26.5	100
	19.0	100
	13.2	100
	4.75	100
	2.000	99
	0.425	87
	0.250	70
	0.150	50
	0.075	22
	0.050*	22
	0.005*	22
	0.002*	22
Soil Mortar Analysis % < 2.00mm	2.000 - 0.425	12.0
	0.425 - 0.250	16.0
	0.250 - 0.150	22.0
	0.150 - 0.075	28.0
	< 0.075	22.0
Effective size		0.001
Uniformity Coefficient		200.0
Curvature Coefficient		40.5
Oversize Index		0.0
Shrinkage Product		
Grading Coefficient		1.0
Grading modulus		0.92
Atter-berg Limits	Liquid Limit	-
	Plasticity Index	NP
	Linear Shrinkage	-
	PI < 0.075	-
Unified Soil Classification		SC
U.S. Highway Classification		A-2-4(0)
pH - Value		N/A
Conductivity mS/cm		N/A

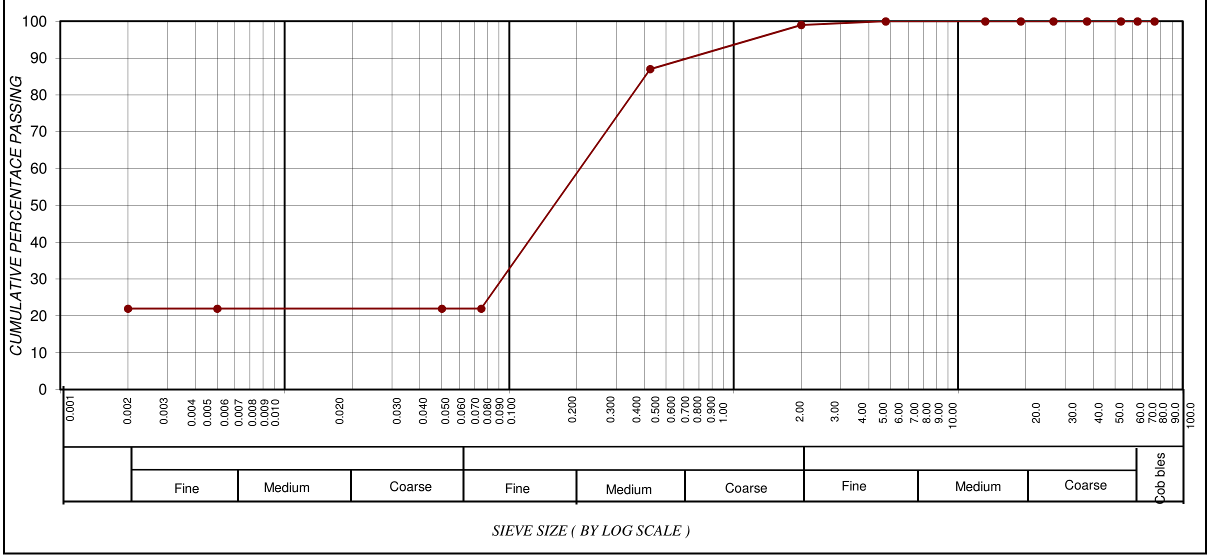




PERFORMANCE AS WEARING COURSE



SIEVE GRADING



CLAY (%) (0.001-0.002)	SILT (%) (0.002-0.060)	SAND (%) (0.060-2.00)	GRAVEL (%) (2.00-60.0)
22.0	0.0	77.0	1.0

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92/GEO007/01/0005/15 2015/10/28

Geotechnical Consult Services
11 Jakkals Weg
Van Riebeeck Park
Kempton Park
1619

ATTENTION: Mr. C De Beer

Test Report : **KATHU SEF- pH & CONDUCTIVITY TEST RESULTS**

Clients Marking: None
Sample Number: S/6190/S6191
Sample delivered to: Roadlab

Date Sampled: 2015/11/19
Date Received: 2015/11/19

Sample Number	Layer / Road :	Temperature (^{o}C) : Conductivity	Conductivity (ms/m)	Temperature (^{o}C) : pH	pH Value
S/6190	TP07: 0.3 - 0.6m	25.0	6.44	25.0	6.99
S/6191	TP08: 0.2 -1.3m	25.0	8.03	25.0	6.68

Kind Regards

Remarks :
The samples were subjected to analysis according to TMH 1
The results reported relate only to the sample tested
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Compiled By : Perushnee Pillay

Mr N Herbst

Mr D Juckers
TECHNICAL SIGNATORY

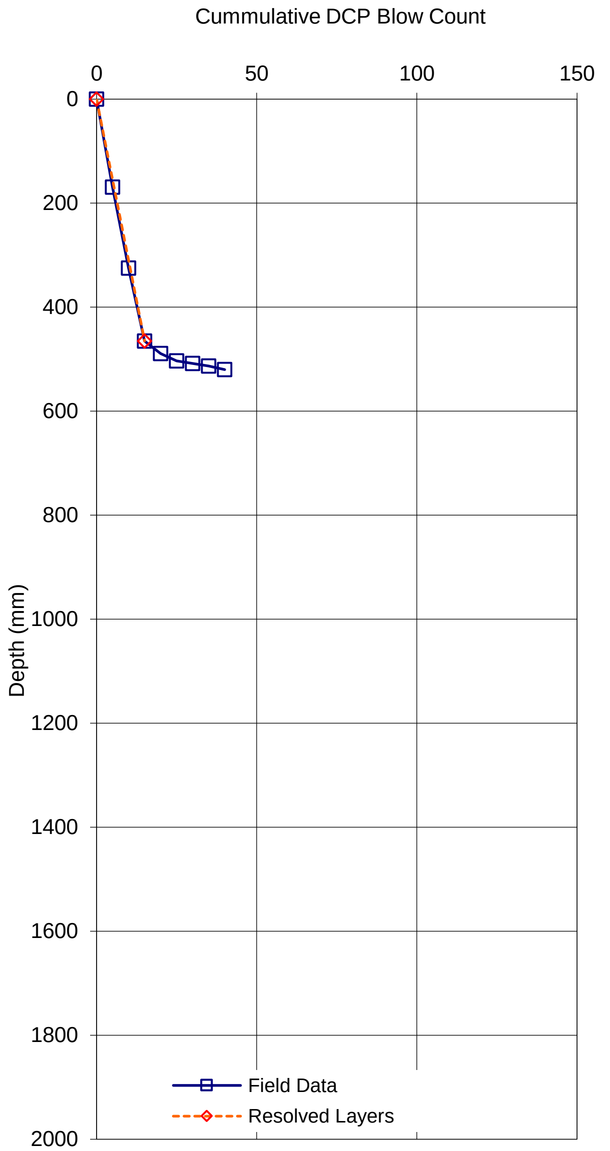
- **APPENDIX 3 – DCP RESULTS**

DCP No.	K-TP2
Project No.	Kathu SEF
Type:	DCP
Chainage:	
Offset:	0
Date:	
Technician:	

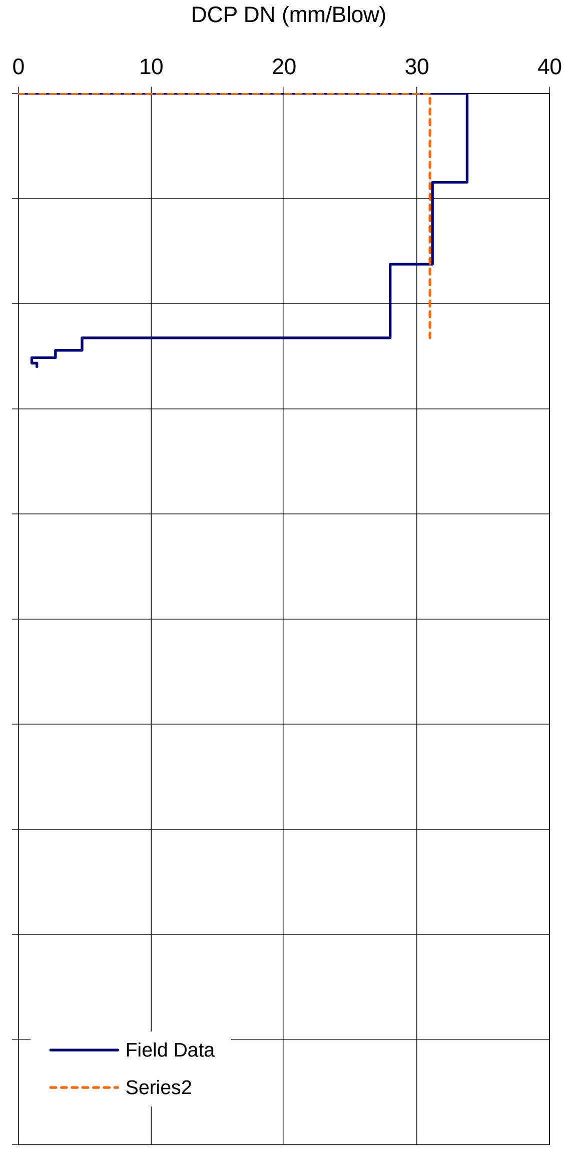
Field Data / Resolved Parameters

Depth Gnd Level (mm)	Interval (mm)	Blows	DPI (mm/Blow)	CBR (%)	UCS (kPa)	Cu (kPa)
0			0			
169	169	5	33,8	5	58	29
325	156	5	31,2	5	64	32
465	140	5	28,0	6	72	36
489	24	5	4,8	56	518	259
503	14	5	2,8	111	945	473
508	5	5	1,0	300	2270	1135
513	5	5	1,0	300	2270	1135
520	7	5	1,4	232	1810	905
		5				
		5				
		5				
		5				
		5				
		5				
		5				
		5				
		5				
		5				
		5				
		5				
		5				
		5				
		5				

Layer Summary



DCP DN (mm/Blow)	CBR (%)
31	5



DCP No.	K-TP6
Project No.	Kathu SEF
Type:	DCP
Chainage:	
Offset:	0
Date:	
Technician:	

Field Data / Resolved Parameters

Depth Gnd Level (mm)	Interval (mm)	Blows	DPI (mm/Blow)	CBR (%)	UCS (kPa)	Cu (kPa)
0			0			
161	161	5	32,2	5	62	31
307	146	5	29,2	6	69	34
467	160	5	32,0	5	62	31
592	125	5	25,0	7	82	41
708	116	5	23,2	8	89	44
829	121	5	24,2	7	85	42
939	110	5	22,0	8	94	47
1159	220	5	44,0	3	44	22
		5				
		5				
		5				
		5				
		5				
		5				
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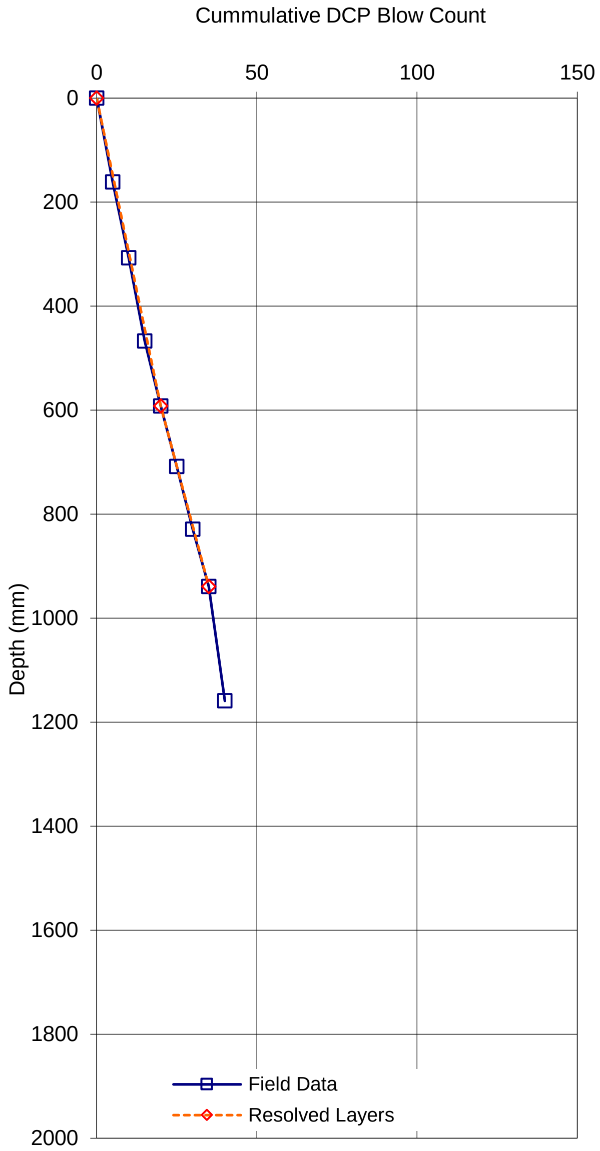
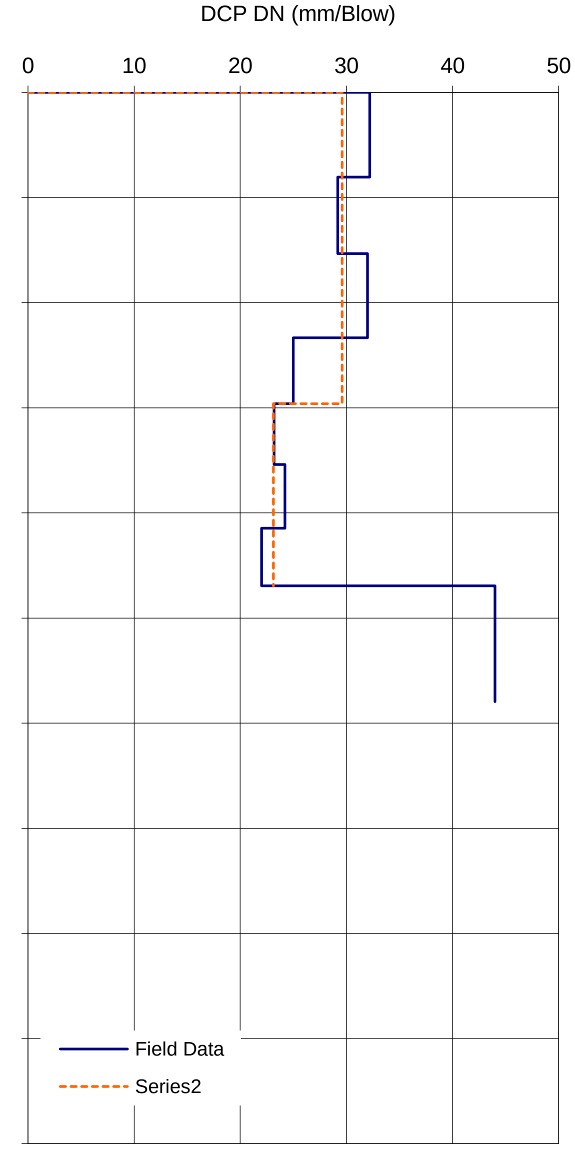
		5				

Layer Summary



DCP DN (mm/Blow)	CBR (%)
30	6
23	8



DCP No.	K-TP8
Project No.	Kathu SEF
Type:	DCP
Chainage:	
Offset:	0
Date:	
Technician:	

Field Data			Resolved Parameters			
Depth Gnd Level (mm)	Interval (mm)	Blows	DPI (mm/Blow)	CBR (%)	UCS (kPa)	Cu (kPa)
0			0			
155	155	5	31,0	5	64	32
315	160	5	32,0	5	62	31
455	140	5	28,0	6	72	36
609	154	5	30,8	5	65	32
727	118	5	23,6	7	87	44
845	118	5	23,6	7	87	44
1040	195	5	39,0	4	50	25
		5				
		5				
		5				
		5				
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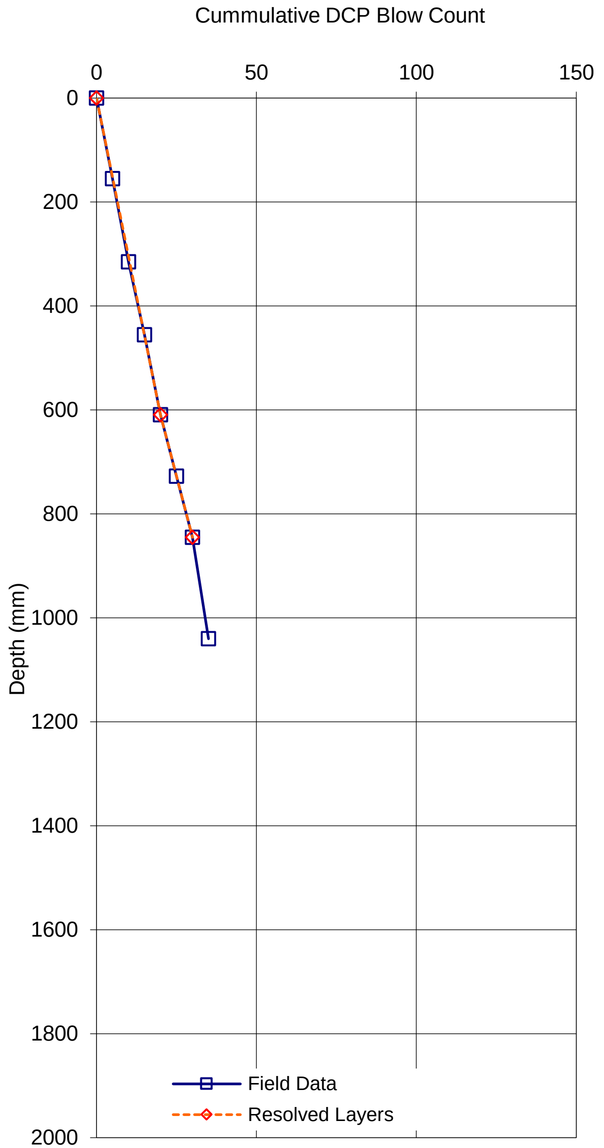
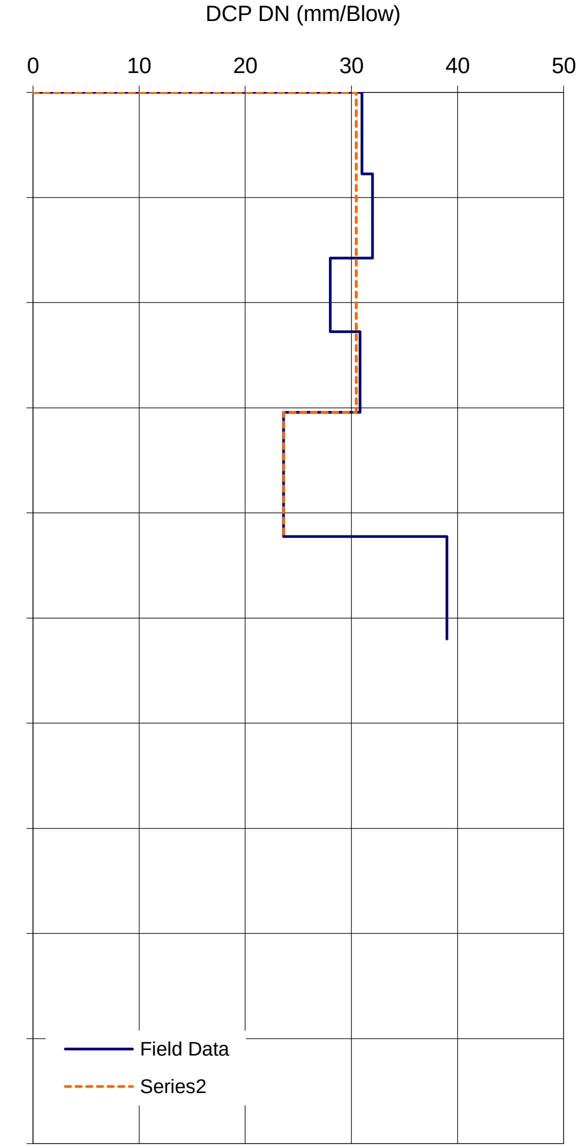
Layer Summary



DCP DN (mm/Blow)	CBR (%)
30	5
24	7



- **APPENDIX 4 – BOREHOLE LOGS**

PERCUSSION BOREHOLE LOG

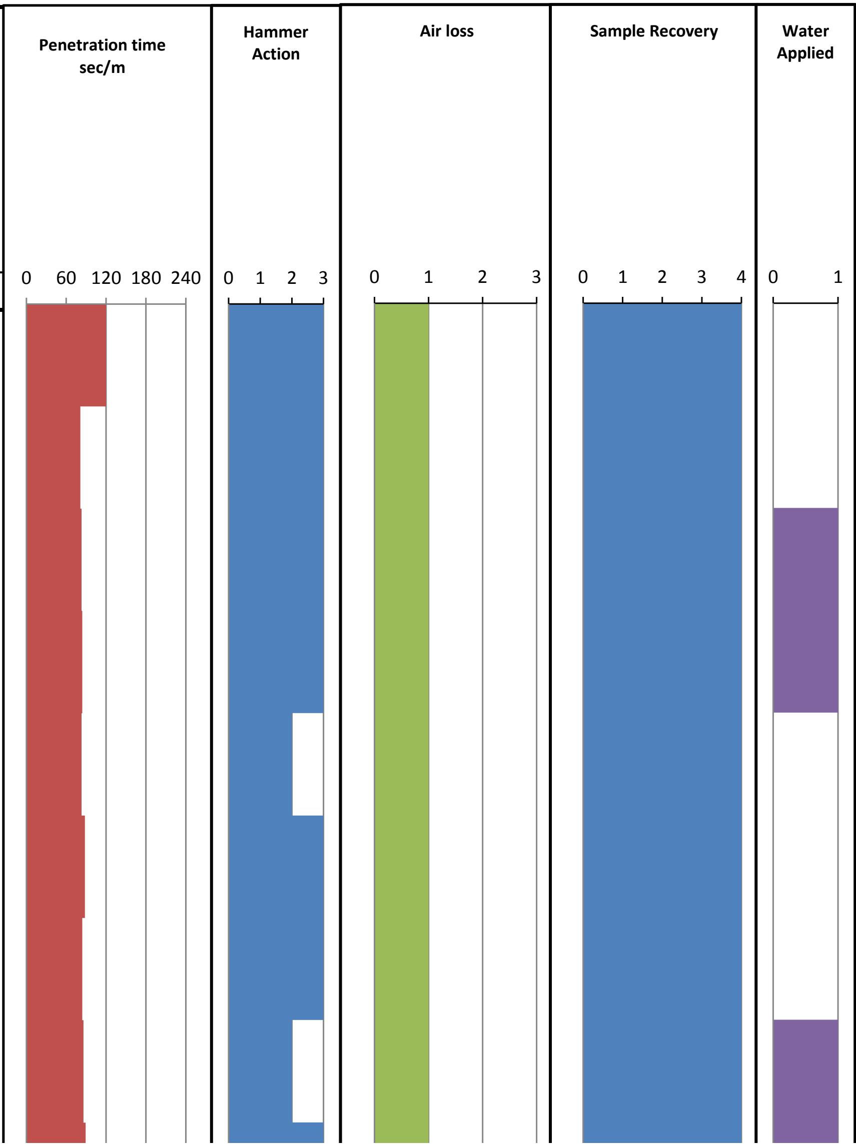
BOREHOLE : Legoko 1

Client	**AEP**	Total Depth	**16**	Diameter	165mm
Location	**Legoko 1**	Air Pressure	**18 bar**		
Date	**2015-11-12**	Water Strike	**37m 49m**		
		Water level	**-**		

X COORD: -27.773921°
Y COORD: 23.111483°
ELEVATION: 1245m

Depth (m)

From	TO
0	1
1	2
2	3
3	4
4	5
5	6
6	7
7	8
8	9
9	10
10	11
11	12
12	13
13	14
14	15
15	16
16	17
17	18
18	19
19	20
20	21
21	22
22	23



Geological Discription

Profile	From	To	
	0	1	Dry, orange brown, fine grained silty sand AEOLIAN DEPOSIT
	1	12	Dry, white to light grey, uniform,strong HARDPAN CALCRETE
	12	23	Dry, white, weak to medium strong, POWDERY CALCRETE

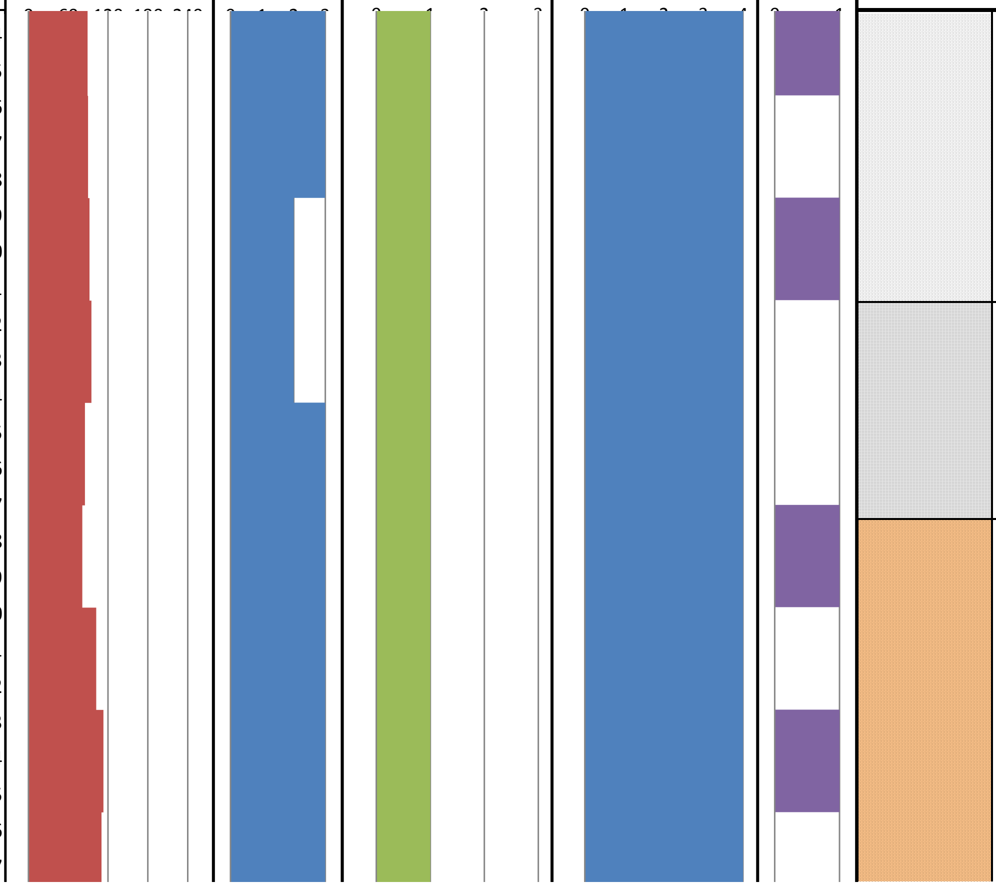
PERCUSSION BOREHOLE LOG

BOREHOLE : Legoko 1

Client	**AEP**	Total Depth	**16**	Diameter	165mm
Location	**Legoko 1**	Air Pressure	**18 bar**		
Date	**2015-11-12**	Water Strike	**37m 49m**		
		Water level	**-**		

X COORD: -27.773921°
Y COORD: 23.111483°
ELEVATION: 1245m

Depth (m) | **Penetration time sec/m** | **Hammer Action** | **Air loss** | **Sample Recovery** | **Water Applied**



Depth (m)	
23	24
24	25
25	26
26	27
27	28
28	29
29	30
30	31
31	32
32	33
33	34
34	35
35	36
36	37
37	38
38	39
39	40
40	41
41	42
42	43
43	44
44	45
45	46
46	47

Geological Discription

From	To	Description
23	**31**	Dry, white, weak, POWDERY CALCRETE
31	**37**	Dry, white, weak, POWDERY CALCRETE with minor CLAY
37	**49**	Moist, white to pale light orange brown, weak POWDERY CALCRETE with clay

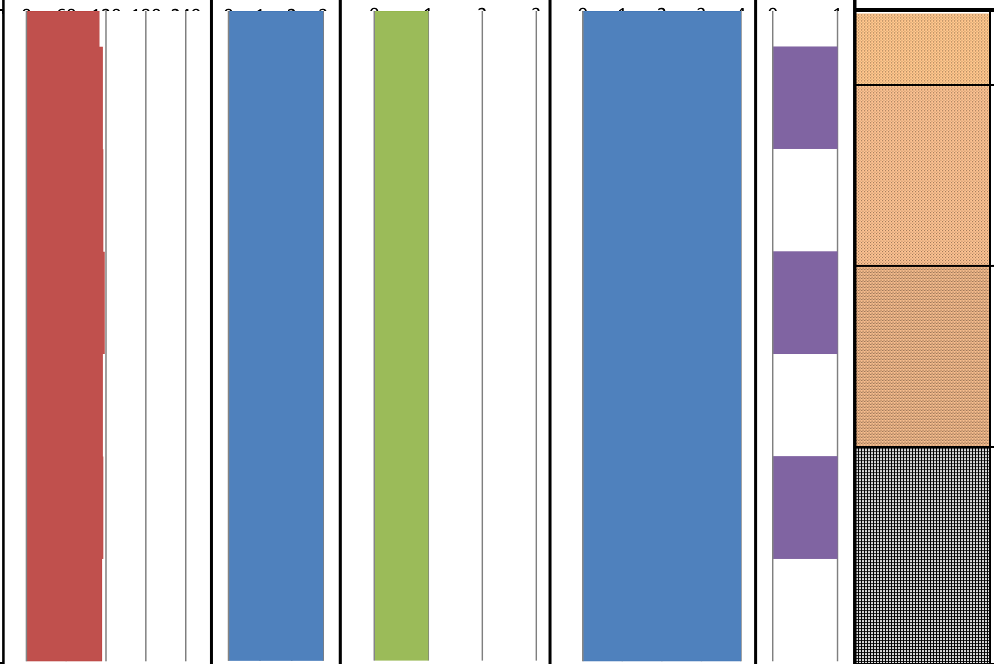
PERCUSSION BOREHOLE LOG

BOREHOLE : Legoko 1

Client	**AEP**	Total Depth	**16**	Diameter	165mm
Location	**Legoko 1**	Air Pressure	**18 bar**		
Date	**2015-11-12**	Water Strike	**37m 49m**		
		Water level	**-**		

X COORD: -27.773921°
Y COORD: 23.111483°
ELEVATION: 1245m

Depth (m) | **Penetration time sec/m** | **Hammer Action** | **Air loss** | **Sample Recovery** | **Water Applied** | Geological Discription



47	48
48	49
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62	63
63	64
64	65

From	To	Geological Discription
49	**54**	Moist to wet, pale orange brown, clayey POWDERY CALCRETE
54	**59**	Wet, pale yellow brown, CLAY
59	**65**	Wet, light grey to medium grey, pebbles (quartite, quarts and Bif) clast supported CONGLOMERATE

Hammer Action	Air loss	Sample Recovery	Water Applied
1=Very irregular 2=Irregular 3=regular	1=None 2=Slight 3=Medium 4=total	4=Good 3=Medium 2=Poor 1=None	0=No 1=Yes

Notes:
Hole was planned to 100m, rotation reduced due to pebbles wedging behind hammer. Hole terminated. 3m casing installed

PERCUSSION BOREHOLE LOG

Client	**AEP**	Total Depth	**16**	Diameter	165mm
Location	**Legoko 1**	Air Pressure	**18 bar**		
Date	**2015-11-12**	Water Strike	**37m 49m**		
		Water level	-		

BOREHOLE : Legoko 1

X COORD: -27.773921°
Y COORD: 23.111483°
ELEVATION: 1245m

Depth (m)	**Penetration time sec/m**	**Hammer Action**	**Air loss**	**Sample Recovery**	**Water Applied**	Geological Discription
	0 60 120 180 240	0 1 2 3	0 1 2 3	0 1 2 3 4	0 1	