GEOLOGICAL REPORT

SPECIALIST INPUT FOR THE ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED KAROO RENEWABLE ENERGY FACILITY ON A SITE SOUTH OF VICTORIA WEST, NORTHERN AND WESTERN CAPE PROVINCE, SOUTH AFRICA

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List of abbreviations and definitions

AMSL:	Above mean sea level
ECO:	Environmental Control Officer
EIA:	Environmental Impact Assessment
EMP:	Environmental Management Plan
ER:	Engineer's representative
Ma:	Million years ago
NGL:	Natural ground level
Study area:	The area delineated on Figure 1

1. INTRODUCTION

1.1. Background

South African Renewable Green Energy (Pty) Ltd (SARGE) is proposing to establish a commercial renewable energy facility consisting of both a wind energy facility component and a photovoltaic solar facility component, as well as associated infrastructure on a site located approximately 34 km south of Victoria West in the Northern Cape. Based on a pre-feasibility analysis and site identification processes undertaken by SARGE, a favourable area has been identified for consideration and evaluation through an Environmental Impact Assessment (EIA).

The site under investigation for the proposed facility covers an approximate area of 200 km^2. The proposed facility is proposed to accommodate up to 500 MW which would comprise a combination of the following technologies:

» up to **150 wind turbines** with a generating capacity of up to 450MW;
» An array of **photovoltaic (PV) panels** with a generating capacity of up to 50MW.
» Each turbine will be a **steel tower** (between 80 and 125m in height), a **nacelle** (gear box) and three **rotor blades** with a rotor diameter of between 90 and 100 m (i.e. each blade ranging from 45 to 50m in length);
» Two (2) **132 kV substations** with high-voltage (HV) yard footprints of approximately 50m x 50m;
» **Foundations** to support both the turbine towers as well as the PV panels;
» **Cabling** between the project components, to be lain underground where practical;
» Two (2) new **overhead 132 kV power lines** to turn-in to the existing Hutchinson/Biesiespoort-1 132kV line and Droerivier/Hydra-2 400kV line;
» **Internal access roads** (minimum width of 6.5 m depending on the proposed crane) linking the wind turbines and PV component with the other infrastructure on the site. Existing farm roads will be used as far as possible. However, the dispersed distribution pattern of wind turbines will necessitate the construction of a number of new roads; and
» **Small office and/or workshop building** for maintenance and storage purposes

1.2. Legislation

In terms of the EIA regulations published in terms of Section 24(5) of the National Environmental Management Act (NEMA, No 107 of 1998), the applicant requires authorisation from the National Department of Environmental Affairs (DEA) (in consultation with the Eastern Cape Department of Economic Development) for the undertaking of the proposed project. This specialist study fulfils the requirements under section 33 of the EIA regulations in terms of NEMA, published in the Government Gazette R385 of 2006.

1.3. Terms of reference

Savannah Environmental has been appointed by South African Renewable Green Energy (Pty) Ltd (SARGE) to carry out the EIA process for the proposed activity. Specialist geological input is required in order to assess the environmental impacts on the geology and soil profile and to assess the degradation potential over the study area. Savannah Environmental has appointed Outeniqua Geotechnical Services to conduct a specialist geological study of the study area.

The following scope of work has been given:

- Conduct a site visit to collect visual data pertaining to the geology, soil types, and potential soil degradation issues.
- Describe the geological environment and discuss the potential environmental impacts on the geological environment that may be associated with the proposed activity.
- Assess the potential impacts and provide mitigating measures for inclusion in the EMP.
- Provide a preliminary geotechnical assessment of potential constraints that may affect the civil and structural engineering design for the proposed development.

1.4. Limitations

Information provided in this specialist report has been based on information provided by the developer, published scientific literature and maps. The study area was visited briefly but no detailed soil investigation or verification of the official geological maps was conducted. The information provided in this report is deemed adequate for the EIA process and preliminary planning phase but further geotechnical information will be required for the detailed engineering design phase.

1.5. Authors credentials & declaration of independence

The author of this report, Iain Paton of Outeniqua Geotechnical Services cc (OGS), is a professional engineering geologist registered with the South African Council for Natural and Scientific Professions (Pr Sci Nat # 400236/07) with 12 years experience in the mining, energy and construction industries. Iain Paton is a member of the South African Institute of Engineering and Environmental Geologists (SAIEG) and the Geotechnical Division of the South African Institute of Civil Engineering (SAICE). Iain Paton declares that he does not have any financial interest in the undertaking of the activity, other than remuneration for work performed in the compilation of this specialist report.

2. SITE DESCRIPTION

2.1. Location

The project is proposed on portions of the following Farms: Nobelsfontein 227, Annex Nobelsfontein 234, Ezelsfontein 235, Rietkloofplaaten 239, Modderfontein 228 and PhaisantKraal 1. The site proposed for the facility falls within the Ubuntu- as well as the Beaufort West Local Municipality. A broader area of approximately 20 222 ha is being considered within which the facility is to be constructed. Refer to **Figure 1** for locality map of the proposed site.

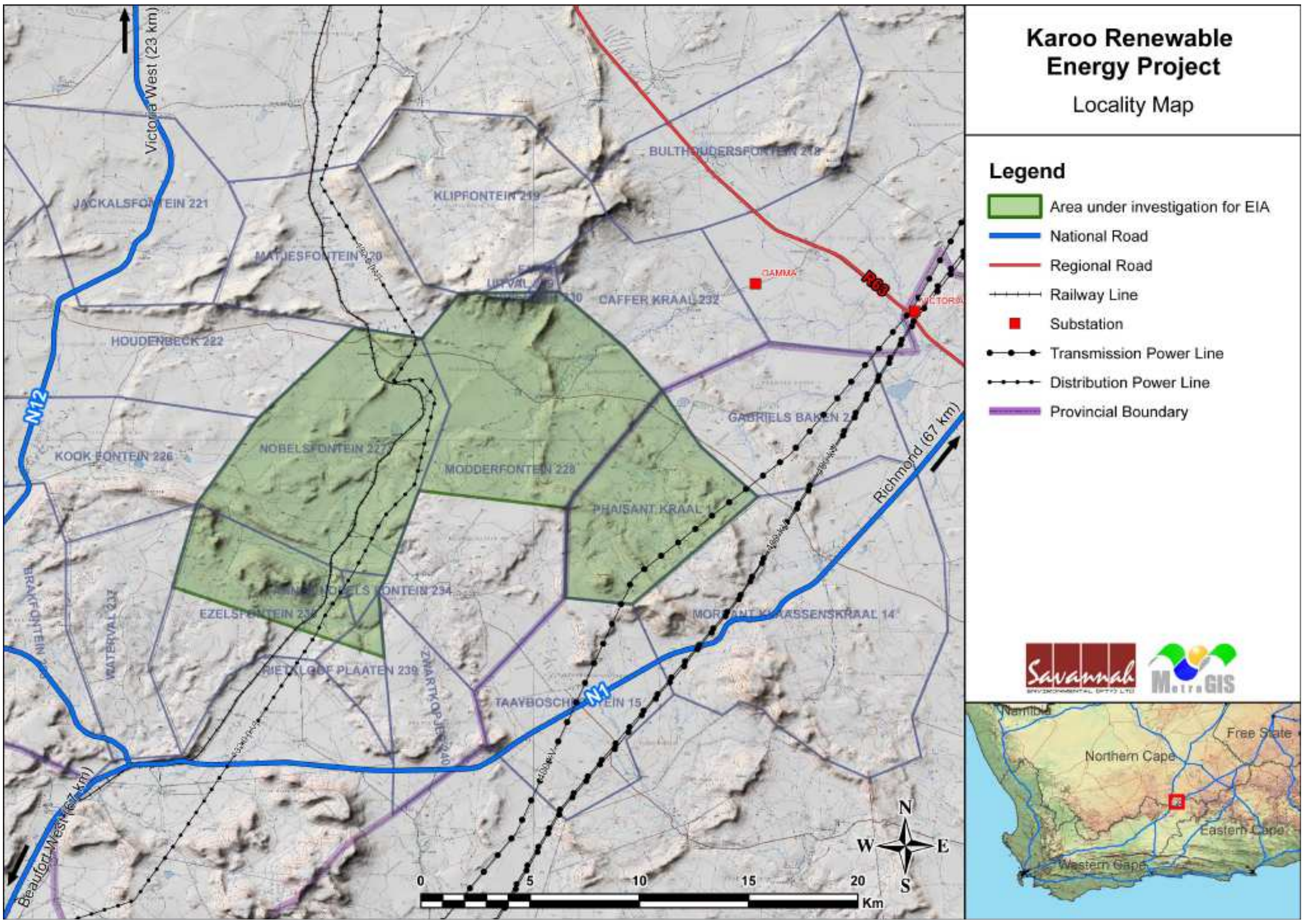

Figure 1: Locality map of the study area

2.2. Topography, climate, & vegetation cover

The topography of the study area is characterised by a combination of lowland areas of low relief and mountainous terrain of high relief with several typical Karoo *koppies* and mountainous ridges around the perimeter of the study area attaining a maximum height of 1813m AMSL (Gys Roosberg in the northern portion of the study area). There are numerous well-defined drainage lines traversing the study area which drain the site into major rivers to the south and east.

The area is semi-arid, with an annual rainfall of less than 350mm[2] and the vegetation cover typically comprises tufty grasses and Karoo shrubs on the slopes and upland areas with thick Acacia Karoo thorn trees along the drainage lines.

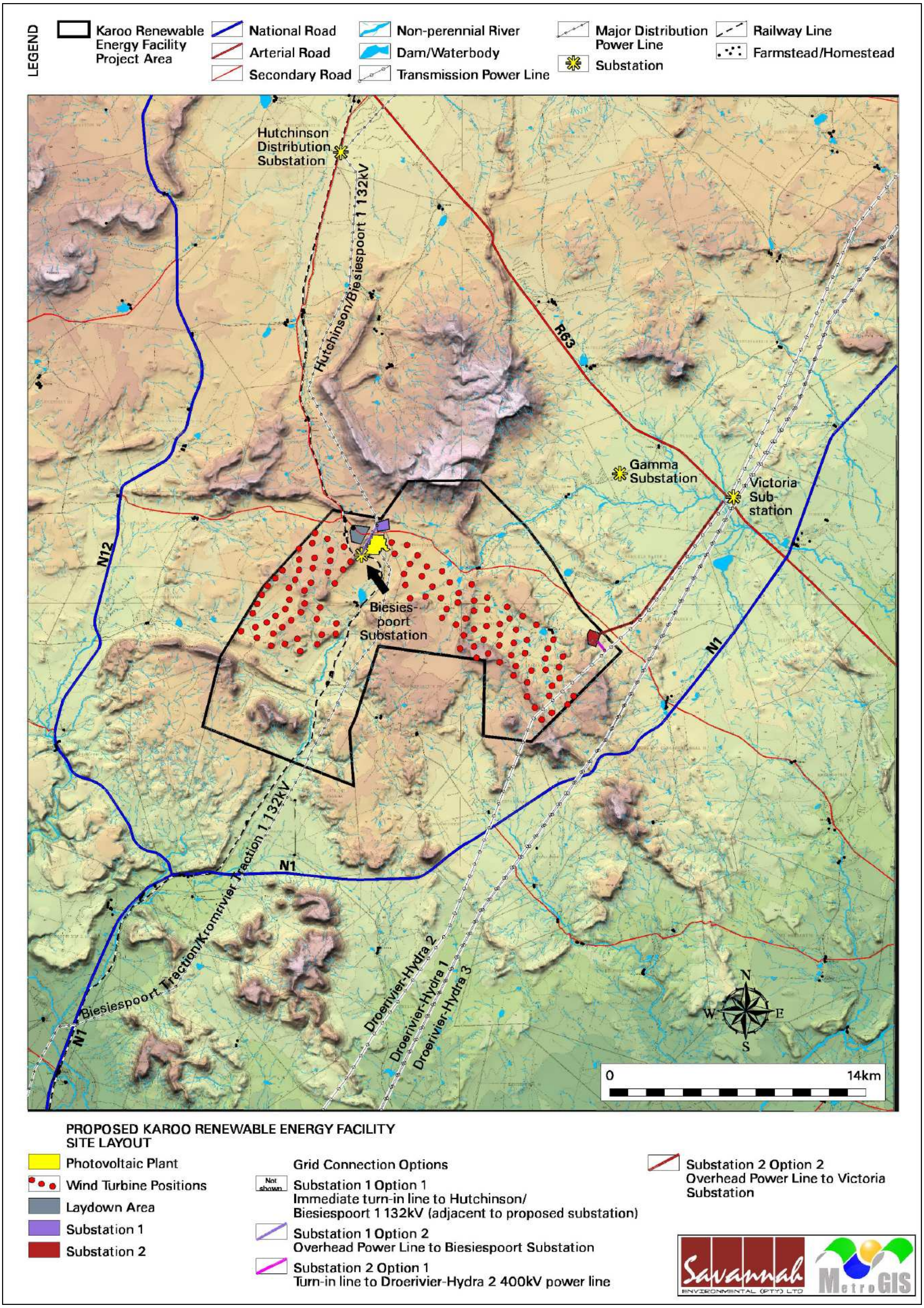

Figure 2: Topographical map of site showing the proposed infrastructure layout

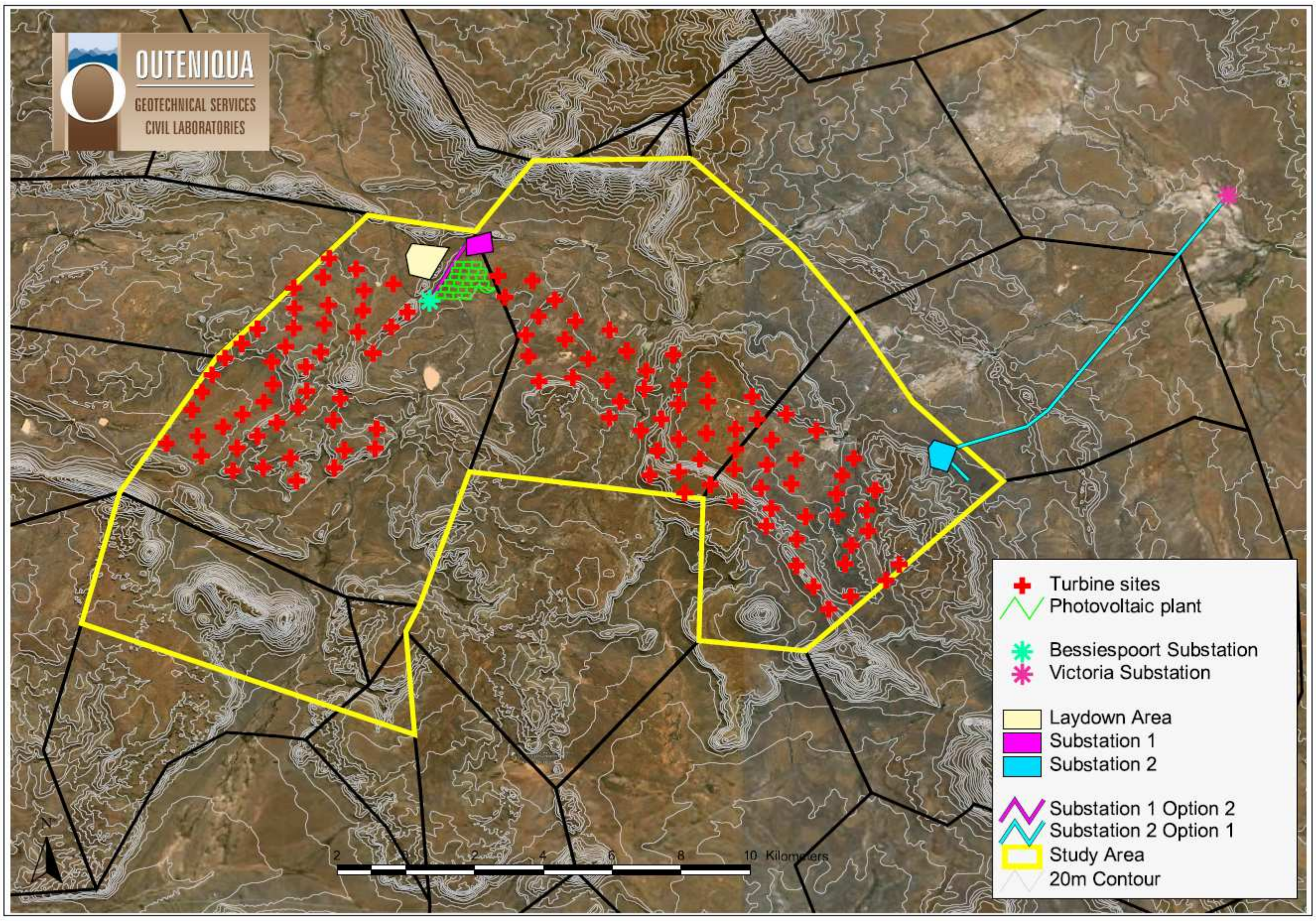

Figure 3: Aerial photo of study area showing contours and proposed infrastructure

2.3. Geology & soil types

The study area is dominantly underlain by the relatively arenaceous Poortjie Member (Permian era) of the Teekloof Formation which forms the upper part of the Adelaide Subgroup of the Beaufort Group to the west of 24°E. The Teekloof Formation comprises mainly mudstones and subordinate sandstones but the Poortjie Member has a slightly higher ratio of sandstone to mudstone than the rest of the Teekloof Formation and is thus mapped as a separate unit at the base of this formation.[8] Isolated outcrops of Hoedemaker and Oukloof Members occur overlying the Poortjie Member at higher altitudes in the southwestern, southeastern and northern extremities of the study area.

There are numerous Jurassic dolerite intrusions (dykes and sills) mapped within the study area and these features have a distinct control over the landscape development as the dolerite is generally harder than the country rocks into which they are emplaced. Consequently, the dolerite outcrops form areas of higher relief.

Quaternary alluvium is mapped along major drainage lines and in lowland areas where thick accumulations of unconsolidated sediment have accumulated. Rock outcrops are widespread in the upland areas of high relief.

There are no geological faults mapped on the 1:250 000 scale in the study area or in the immediate vicinity thereof. The anticipated seismic activity is rated as VI on the Modified Mercalli

Scale but peak horizontal ground accelerations are typically less than 50cm/s with a 10% chance of being exceeded at least once in a 50 year period.

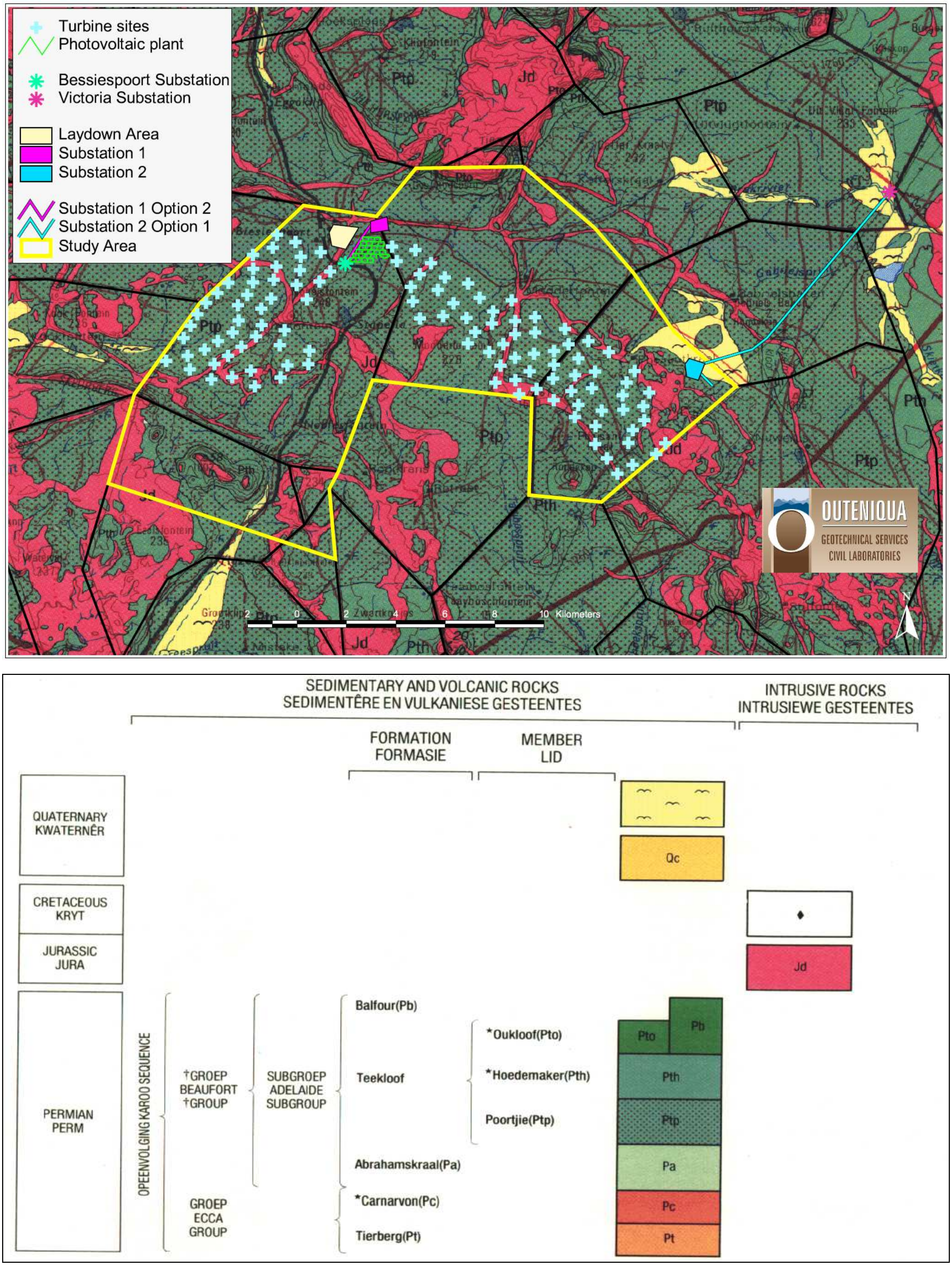

Figure 4: Geological map of the study area.

2.4. Hydrology

There are numerous dendritic and braided ephemeral drainage lines which drain the study area and there are also numerous small dams along these drainage lines. The eastern portion of the study area forms the source of the Brakrivier which which is a first order tributary of the Buffelsrivier which eventually flows into the Kariegarivier 80km east of Beaufort West. The western portion of the study area drains southwestwards into the Kromrivier which is a first order tributary of the Soutrivier which joins the Kariegarivier at Beervleidam and forms the Grootrivier.

3. GEOLOGICAL IMPACT ASSESSMENT

The geological impact assessment aims to assess the impact that the proposed development will have on the geological environment which includes the bedrock and the natural soil overburden.

Important or prominent geological features (geosites) that contribute to the aesthetic scenery or geological interest in the area, such as fossil sites, prominent rock outcrops or features are also considered in the impact study. Geological features, such as caves, addits, middens, worship rocks, etc. which are important from historical, cultural, archaeological or religious heritage standpoint are not assessed in this report as they are covered in the Heritage Impact Assessment. Geohydrological assessments also do not form part of this study.

3.1. Soil degradation

Soil degradation is the removal, alteration, or damage to soil and soil forming processes, usually due to human activity. The stripping of vegetation or disturbance to the natural ground level over disturbance areas will negatively affect soil formation, natural weathering processes, moisture levels, soil stability, and biological activity. Soil degradation includes erosion (i.e. due to water and wind), soil removal, mixing, wetting, compaction, pollution, salinisation, crusting, and acidification.

The proposed activity may potentially result in all or some of the above negative direct impacts. The proposed activity could also result in negative indirect impacts, such as increased siltation in waterways downstream from the site or dust pollution in the area surrounding the site. The severity or significance of the various impacts is related to the nature and extent of the activity.

There are no known positive impacts relating to the geological environment and the impacts are dominantly related to the construction phase with insignificant additional impacts in the post construction and decommissioning phases.

Soil erosion is a natural process whereby the ground level is lowered by wind or water action and may occur as a result of *inter alia* chemical processes and/or physical transport on the land surface[1]. Soil erosion induced or increased by human activity is termed "accelerated erosion" and is an integral element of global soil degradation. Accelerated soil erosion is generally considered the most important geological impact in any development due to its potential impact on a local and regional scale (i.e. on and off site) and as a potential threat to agricultural potential. Soil erodability – the susceptibility of soil to erosion – is a complex variable, not only because it depends on soil chemistry, texture, and characteristics, but because it varies with time and other variables[8], such as mode of transport (i.e. wind or water).

Water erosion is generally considered as more important due to the magnitude of the potential impact over a relatively short period of time which can be very difficult to control. Water erosion occurs when the force exerted on the soil by flowing water exceeds the internal shear strength of the soil and the soil fails and becomes mobilised into suspension. Erosion potential is increased on construction sites where soil is loosened and vegetation cover is stripped. Erosion sensitivity can be broadly mapped according to the severity of the potential erosion if land disturbing activities occur and this is generally controlled by the geology, soil types and the topography. Unconsolidated or partly consolidated fine-grained soils of low plasticity along drainage lines and on moderate to steep slopes or at the base of steep slopes are most vulnerable to severe levels of water erosion. These areas are typically called "highly sensitive" areas. Minor erosion will continually occur all over the site, as this is a natural process, but severe erosion is usually related to human impacts and this needs to be restricted as far as possible.

The geological map in **Figure 4** indicates that the majority of the site is underlain by rocks of the Teekloof Formation at a relatively shallow depth and the soil cover in this area is likely to be less than 1m thick. In the southeastern portion of the site, thick Quaternary alluvium consisting mainly of gravelly silty sands, has been mapped and this soil cover is likely to be thicker than 1m. This area, and other similar areas, will be sensitive to severe water erosion. The presence of shallow rock in most other areas, and in particular in areas of high relief, will restrict severe erosion.

Table 1 summarises the site sensitivity in terms of water erosion susceptibility and the spatial distribution of these categories is illustrated in **Figure 4**.

Table 1: Erosion sensitivity

Sensitivity Level	Area/Terrain	Comments/Recommendations
High	Natural drainage lines/watercourses	No-go areas. Erosion presently taking place.
Moderate	Areas underlain by thick Quaternary alluvium* (an accurate distribution of which needs to be determined by means of a geotechnical investigation).	Significant erosion taking place at present. Special mitigating measures apply.
Low	Areas underlain by shallow Teekloof Formation rock.*	Generally minor erosion taking place at present. Normal mitigating measures apply

*Refer to Figure 4

The spatial distribution of areas underlain by thick deposits of Quaternary alluvium and hillwash will only be accurately determined by means of a detailed geotechnical investigation including test pits.

Wind erosion from areas that are stripped of vegetation should not be underestimated and can lead to severe dust pollution which will attract negative response from neighbours.

3.2. Degradation of parent rock

No quarrying activities have been proposed and excavations for foundation are typically localised and limited to a depth of approximately 3 m. Therefore the impact on the bedrock is likely to be minor in terms of these activities. The cutting of access roads through areas of high relief will involve significant excavations into bedrock and this activity could carry a moderate to high impact on bedrock, depending on the proposed road layouts. The main environmental impacts of cutting into bedrock include unsightly scars in the hillside, alteration of the hydrological regime, soil degradation and stability of ground.

3.3. Degradation of geo-sites

Geo-sites are interesting or academically important geological exposures or features that require protection for obvious reasons and the environmental impact process needs to cater for these aspects, if they occur within the site. The occurrence of these sites is not always apparent unless the particular feature is well known. Geo-sites that are less well-known or that have local significance are usually brought to light during the Public Participation Process. At this stage, there are no known geo-sites on the site.

3.4. Assessment of impacts

The environmental impact assessment aimed to evaluate the impact that the proposed activity will have on the geological environment and attempted to provide mitigating measures to minimise the impact.

The most significant activity in terms of impacts on soil is the bulk earthworks for platforms for structures including turbines and substations and the construction of internal access roads. Relatively minor earthworks are envisaged for the proposed new power lines from the proposed new substation to the existing Eskom infrastructure.

The most important geological issues are the direct negative impacts of soil and rock degradation in the proposed areas of activity. This would affect ecosystems operating in the soil and the hydrological regime. Indirect negative impacts could include increased siltation in watercourses downstream caused by an increase in erosion from the site or increased dust pollution away from the site. There are no positive impacts envisaged. Direct, indirect, and cumulative negative impacts are assessed in terms of the following criteria:

- The nature of the impact - what causes the impact, what will be impacted and how it will be impacted;
- The extent of the impact - whether it is local (limited to the immediate area or site of the development) or regional (on a scale of 1 to 5).
- The duration of the impact – whether it will be very short (less than 1 year), short (1-5 years), medium (5-15 years), long (>15 years) or permanent (on a scale of 1 to 5, respectively).

- The magnitude, quantified on a scale of 0-10, where 0 is small and will have no impact on the environment, 2 is minor and will not result in an impact on processes, 4 is low and will have a slight impact on processes, 6 is moderate and will result in processes continuing, but in a modified way, 8 is high and processes are altered the extent that they temporarily cease, and 10 is very high and results in complete destruction of patterns and permanent cessation of processes.
- The probability of occurrence, which describes the likelihood of the impact actually occurring (on a scale of 1 to 5 – very improbable to definite).
- The significance, which is determined through a synthesis of the characteristics described above and is assessed as low, medium or high.
- The status, which is described as positive, negative or neutral.
- The degree to which the impact can be reversed.
- The degree to which the impact may cause the irreplaceable loss of resources.
- The degree to which the impact can be mitigated.
- The possibility of significant cumulative impacts of a number of individual areas of activity.
- The possibility of residual impacts existing after mitigating measures have been put in place

The significance is calculated by combining the criteria in the following formula:
S = (E+D+M) P

Where:
S = Significance weighting
E = Extent
D = Duration
M = Magnitude
P = Probability
The significance weightings for each potential impact are as follows:

<30 points: **Low** (i.e. where this impact would not have a direct influence on the decision to develop in the area);
30-60 points: **Moderate** (i.e. where the impact could influence the decision to develop in the area unless it is effectively mitigated);
>60 points: **High** (i.e. where the impact will influence the decision to develop in the area).

3.4.1. Direct impacts

An assessment of the individual direct potential impacts associated with the proposed activity is outlined in **Table 2**.

Table 2: Assessment of potential direct impacts

Nature: Soil degradation – Excavation and removal of soil for roads and structures.		
	Without mitigation	***With mitigation***
Extent	Local (1)	Local (1)
Duration	Long term (4)	Medium term (3)
Magnitude	Moderate (6)	Low (4)

Probability	Definite (5)	Definite (5)
Significance	**Moderate (55)**	**Moderate (40)**
Status	Negative	Negative
Reversibility	Partially reversible	Partially reversible
Irreplaceable loss of resources?	Yes	Yes
Can impacts be mitigated?	Yes, to a certain extent.	
Mitigation:	» Use existing roads where possible. » Design platforms and roads according to contours to minimise cut and fill operations. » Control activity outside of construction disturbance areas. » Rehabilitate soil in disturbance areas after construction.	
Cumulative impacts:	» Although the impact of soil removal for the proposed activity has a moderate significance, the cumulative impact of soil removal in the area is considered low due to undeveloped nature of the area.	
Residual impacts:	» Minor negative – slow regeneration of topsoil.	

Nature: Soil degradation – Loosening, mixing, wetting & compacting of in situ soil during earthworks.		
	Without mitigation	***With mitigation***
Extent	Local (1)	Local (1)
Duration	Medium term (3)	Short term (2)
Magnitude	Moderate (6)	Low (4)
Probability	Definite (5)	Definite (5)
Significance	**Moderate (50)**	**Moderate (35)**
Status	Negative	Negative
Reversibility	Irreversible	Reversible
Irreplaceable loss of resources?	Yes	Minor
Can impacts be mitigated?	Yes, to a certain extent	
Mitigation:	» Use existing roads where possible. » Design platforms and roads according to contours to minimise cut and fill operations. » Control activity outside of construction disturbance areas. » Rehabilitate soil in disturbance areas after construction.	
Cumulative impacts:	» Although the impact for the proposed activity has only moderate-low significance, the cumulative impact of earthworks in the area is considered low due to the undeveloped nature of the area	
Residual impacts:	» Minor negative – slow regeneration of vegetation & soil.	

Nature: Soil degradation – Pollution of soil by waste products (human and synthetic) and contaminants used in construction (e.g. fuel, oil, chemicals, cement).		
	Without mitigation	***With mitigation***
Extent	Local (1)	Local (1)

Duration	Medium term (2)	Very short term (1)
Magnitude	Low (4)	Minor (2)
Probability	Probable (3)	Probable (3)
Significance	**Low (21)**	**Low (12)**
Status	Negative	Negative
Reversibility	Partially reversible	Partially reversible
Irreplaceable loss of resources?	Yes	Minor
Can impacts be mitigated?	Yes, to a certain extent	
Mitigation:	» Control use and disposal of potential contaminants or hazardous materials. » Control human ablution facilities » Remove contaminants and contaminated topsoil and replace topsoil in affected areas.	
Cumulative impacts:	» The cumulative impact of soil pollution is considered low due to the undeveloped nature of the study area.	
Residual impacts:	» Minor negative – slow regeneration of soil processes in and under topsoil	

Nature: Soil degradation – Soil erosion by wind and water.		
	Without mitigation	***With mitigation***
Extent	Local (1)	Local (1)
Duration	Medium term (3)	Very short term (1)
Magnitude	Moderate (6)	Low (4)
Probability	Probable (3)	Probable (3)
Significance	**Moderate (30)**	**Low (18)**
Status	Negative	Negative
Reversibility	Irreversible	Practically irreversible
Irreplaceable loss of resources?	Yes, moderate to low	Minor
Can impacts be mitigated?	Yes	
Mitigation:	» Restrict size of construction disturbance areas. » Control activity outside of disturbance areas. » Implement effective erosion control measures. » Carry out earthworks in phases across site to minimise exposed ground at any one time. » Keep to existing roads, where practical, to minimise loosening of undisturbed ground. » Protect and maintain bare slopes, excavations and material stockpiles to minimise erosion and instability	
Cumulative impacts:	» The cumulative impact of soil erosion in the area is considered low due to the undeveloped nature of the area.	
Residual impacts:	» Minor – Localised movement of sediment. Slow regeneration of soil processes	

3.4.2. Indirect impacts

An assessment of the indirect potential impacts associated with the proposed activity is outlined in **Table 3** below.

Table 3: Assessment of potential indirect impacts

Nature: Siltation of waterways and dams downstream from site.		
	Without mitigation	***With mitigation***
Extent	Regional (3)	Local (1)
Duration	Long term (4)	Long term (4)
Magnitude	Low (4)	Minor (2)
Probability	Highly probable (4)	Probable (3)
Significance	**Moderate (44)**	**Low (21)**
Status	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes, low	Yes, minor
Can impacts be mitigated?	Yes	
Mitigation:	» Install anti-erosion measures such as silt fences, geosynthetic erosion protection and/or flow attenuation along watercourses below construction sites. » No development in or near water courses/natural drainage lines as sediment transport is higher in these areas.	
Cumulative impacts:	» The cumulative impact of siltation in the area is considered low.	
Residual impacts:	» Minor localised movement of soil across site	

Nature: Dust pollution from construction site affecting areas surrounding site.		
	Without mitigation	***With mitigation***
Extent	Regional (2)	Local (1)
Duration	Very short term (1)	Very short term (1)
Magnitude	Low (4)	Minor (2)
Probability	Highly probable (4)	Highly probable (4)
Significance	**Moderate (28)**	**Low (16)**
Status	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes, low	Yes, minor
Can impacts be mitigated?	Yes	
Mitigation:	» Place dust covers on stockpiles » Use suitable gravel wearing course on access roads » Apply straw bales or dampen dusty denuded areas.	
Cumulative	» The cumulative impact of dust in the area is considered low.	

impacts:	
Residual impacts:	» Minor localised movement of soil across site

3.4.3. Impact statement

The REF is proposed to be located on a site which appears to be suitable for development and the activity has a low to moderate impact significance on the geological environment. With effective implementation of mitigating measures the impacts identified above can be reduced to an acceptable level.

A more detailed assessment of the soils and erosion potential of the site should be conducted during a detailed geotechnical investigation.

The cumulative impact on the geological environment is considered low due to the localised and scattered nature of the proposed activity and the scarcity of development in the vicinity of the site.

3.4.4. Alternatives

There is no site alternative but individual turbines and internal access roads can be repositioned according to site sensitivity as required.

The proposed transmission infrastructure includes two options for each of the two (2) substations (refer to **Figure 2**):

From Substation 1:

- Substation 1 Option 1: To turn-in directly to the existing Hutchinson/Biesiespoort-1 132kV line; or alternatively
- Substation 1 Option 2: To connect to Eskom's existing Biesiespoort substation (approximately 2 km length of power line).

From Substation 2:

- Substation 2 Option 1: To turn-in directly to the existing Droerivier/Hydra-2 400kV line; or alternatively
- Substation 2 Option 2: construct an overhead power line of approximately 10km in length in order to connect Substation 2 to Eskom's existing Victoria Substation.

The options with the longer transmission lines have obvious greater potential impact. Therefore Substation 1 Option 1, and Substation 2 Option 1 are the preferred alternative options for connecting the proposed facility to the power grid.

3.5. Environmental Management Plan (EMP) guidelines for earthworks

Negative impacts can be mitigated to a large degree by the implementation of an appropriate and effective EMP. The following generic guidelines relate specifically to the earthworks contract:

3.5.1. Earthworks

1. Prior to earthworks (including site clearance) starting on the site, a plant search and rescue operation shall be undertaken as per the requirements set out in the EMP.
2. All earthworks shall be undertaken in such a manner so as to minimise the extent of any impacts caused by such activities.
3. Defined access routes to and from the area of operations as well as around the area of operation shall be detailed in a method statement for approval by the Site Manager.
4. No equipment associated with the activity shall be allowed outside of these areas unless expressly permitted by the Site Manager.
5. Mechanical methods of rock breaking, including Montabert-type breakers and jackhammers, have noise and dust impacts, and must be addressed in the EMP.
6. Residents shall be notified at least one week prior to these activities commencing, and their concerns addressed.
7. Chemical breaking shall require a method statement approved by the Engineer's Representative (ER).

3.5.2. Topsoil

1. Prior to construction, the topsoil areas to be disturbed should be stripped to a depth to be confirmed by the ER and set aside for spreading to all areas to be reinstated after the construction. Temporary topsoil stock piles must be covered with net, shade cloth or straw bales to protect them.
2. Once all grades have been finalised and prepared, topsoil should be spread evenly to all affected areas to be re-vegetated.

3.5.3. Erosion and sedimentation control

1. During construction the contractor shall protect areas susceptible to erosion by installing necessary temporary and permanent drainage works as soon as possible and by taking other measures necessary to prevent the surface water from being concentrated in streams and from scouring the slopes, banks or other areas.
2. A method statement shall be developed and submitted to the ER to deal with erosion issues prior to bulk earthworks operations commencing.
3. Any erosion channels developed during the construction period or during the vegetation establishment period shall be backfilled and compacted and the areas restored to a proper condition.
4. Stabilisation of cleared areas to prevent and control erosion shall be actively managed. The method of stabilisation shall determine in consultation with the ECO. Consideration and provision shall be made for the following methods (or combination):
   a) Brush cut packing
   b) Mulch or chip cover
   c) Straw stabilising
   d) Watering
   e) Planting/sodding
   f) Hand seed-sowing
   g) Hydroseeding

h) Soil binders and anti erosion compounds
i) Gabion bolsters & mattresses for flow attenuation
j) Geofabric
k) Hessian cover
l) Log/ pole fencing

5. Traffic and movement over stabilised areas shall be restricted and controlled and damage to stabilised areas shall be repaired and maintained to the satisfaction of the ECO.
6. Anti-erosion compounds shall consist of all organic or inorganic material to bind soil particles together and shall be a proven product able to suppress dust and erosion. The application rate shall conform to the manufacturer's recommendations. The material used shall be approved by the ECO.

3.5.4. Blasting (If required)

1. A current and valid authorisation shall be obtained from the relevant authorities and copied to the ER prior to any blasting activity.
2. A method statement shall be required for any blasting related activities.
3. All laws and regulations applicable to blasting activities shall be adhered to at all times.
4. A qualified and registered blaster shall supervise all blasting and rock splitting operations at all times.
5. The contractor shall ensure that appropriate pre-blast monitoring records are in place (i.e. photographic and inspection records of structures in close proximity to the blast area).
6. The contractor shall allow for good quality vibration monitoring equipment and record keeping on site at all times during blasting operations.
7. The contractor shall ensure that emergency services are notified, in writing, a minimum of 24 hours prior to any blasting activities commencing on site.
8. The contractor shall take necessary precautions to prevent damage to special features and the general environment, which includes the removal of fly-rock. Environmental damage caused by blasting / drilling shall be repaired at the contractor's expense to the satisfaction of the ER.
9. The contractor shall ensure that adequate warning is provided immediately prior to all blasting. All signals shall also be clearly given.
10. The contractor shall use blast mats for cover material during blasting. Topsoil may not be used as blast cover.
11. During demolition the contractor shall ensure, where possible that trees in the area are not damaged.
12. Appropriate blast shaping techniques shall be employed to aid in the landscaping of blast areas, and a method statement to be approved by the ER, shall be required in this regard.
13. At least one week prior to blasting, the relevant occupants/owners of surrounding land shall be notified by the contractor and any concerns addressed. Buildings within the potential damaging zone of the blast shall be surveyed preferably with the owner present and any cracks or latent defects pointed out and recorded either using photographs or video. Failing to do so shall render the contractor fully liable for any claim of whatsoever nature, which may arise. The contractor shall indemnify the employer in this regard.

3.5.5. Borrow pits and quarries (If required)

1. All borrow pit sites shall be clearly indicated on plan.
2. Prior to the onset of any quarrying or borrow pit activities the contractor shall establish from the ER whether authorisation has been obtained, both in terms of the Minerals and Petroleum Resources Development Act 28 of 2002 (via the compilation of an Environmental Management Programme Report) and in terms of the National Environmental Management Act (via the Environmental Impact Assessment process). No excavation or blasting activities shall commerce before the necessary authorizations are in place.
3. Borrow pits to be used must be approved by the ER and shall at all times be operated according to the regulations promulgated in terms of the Occupational Health & Safety Act (No 85 of 1993) and Noise Regulations of the Environment Conservation Act (No 73 of 1989).
4. Only a single lane access for construction vehicles shall be provided at borrow pit and quarry sites. New access roads require approval by the Engineer.
5. Stormwater and groundwater controls shall be implemented.
6. Machinery, fuels and hazardous materials vulnerable to flooding shall be stored out of flood risk areas.
7. Vehicles leaving borrow pits shall not deposit/shed mud, sand and debris onto any public road.
8. All loads shall be covered with a tarpaulin or similar to prevent dangers and nuisance to other road users.
9. Borrow pits shall be fenced to prevent unauthorized persons and vehicles from entering the area. Fences shall also be stock and game proof.
10. Rehabilitation and re-vegetation of borrow pits sites shall be according to a method statement to be approved by the ECO.
11. The contractor shall ensure that blasted faces of the pit shall be shape-blasted to the approval of the site manager.
12. Where required, dust and fly-rock prevention methods shall be detailed in a Method Statement to be approved by the site manager.
13. During the rehabilitation of borrow bits, the slope or the borrow pit shall be graded to blend with the natural terrain and be stabilized to prevent erosion.

3.5.6. Drilling and jack-hammering

1. The contractor shall submit a method statement detailing his proposals to prevent pollution during drilling operations. This shall be approved by the site manager prior to the onset of any drilling operations.
2. The contractor shall take all reasonable measures to limit dust generation as a result of drilling operations.
3. Noise and dust nuisances shall comply with the applicable standards according to the Occupational Health and safety (Act No. 85 of 1993).
4. The Contractor shall ensure that no pollution results from drilling operations, either as a result of oil and fuel drips, or from drilling fluid.
5. All affected parties shall be informed at least one week prior to the onset of the proposed drilling/jackhammering operations, and their concerns addressed.
6. Drill coring with water or coolant lubricants shall require a method statement approved by the Site Manager.

7. Any areas or structures damaged by the drilling and associated activities shall be rehabilitated by the contractor to the satisfaction of the site manager.

3.5.7. Trenching

1. Trenching shall be kept to a minimum through the use of single trenches for multiple service provision.
2. The planning and selection of trench routes shall be undertaken in liaison with the ER and cognisance shall be given to minimising the potential for soil erosion.
3. Trench routes with permitted working areas shall be clearly defined and marked with painted stakes prior to excavation.
4. The stripping and separation of topsoil shall occur as stipulated by the ER. Soil shall be stockpiled for use as backfilling as directed by the ER.
5. Trench lengths shall be kept as short as practically possible before backfilling and compacting.
6. Trenches shall be backfilled to the same level as (or slightly higher to allow for settlement) the surrounding land surface to minimise erosion. Excess soil shall be stockpiled in an area approved by the engineer.
7. Immediately after backfilling, trenches and associated disturbed working areas shall be planted with a suitable plant species and regularly watered. Where there is a particularly high erosion risk, a fabric such as Geojute (biodegradable) shall be used in addition to planting.

3.5.8. Dust

1. The contractor shall be solely responsible for the control of dust arising from the contractor's operations and for any costs against the employer for damages resulting from dust.
2. The contractor shall take all reasonable measures to minimise the generation of dust as a result of construction activities to the satisfaction of the site manager.
3. Removal of vegetation shall be avoided until such time as soil stripping is required and similarly exposed surfaces shall be re-vegetated or stabilised as soon as is practically possible.
4. Excavation, handling and transport of erodible materials shall be avoided under high wind conditions or when a visible dust plume is present.
5. During high wind conditions the site manager will evaluate the situation and make recommendations as to whether dust damping measures are adequate, or whether working will cease altogether until the wind speed drops to an acceptable level.
6. Where possible, soil stockpiles shall be located in sheltered areas where they are not exposed to the erosive effects of the wind. Where erosion of stockpiles becomes a problem, erosion control measures shall be implemented at the discretion of the site manager.
7. Vehicle speeds shall not exceed 40km/h along dust roads or 20km/h when traversing unconsolidated and non-vegetated areas.
8. Appropriate dust suppression measures shall be used when dust generation as unavoidable, e.g. dampening with water, particularly during prolonged periods of dry weather in summer. Such measures shall also include the use of temporary stabilising measures (e.g. chemical soil binders, straw, brush packs, clipping etc.)

9. Straw stabilisation shall be applied at a rate of one bale/ 10m^2 and harrowed into the top 100mm of top material for all completed earthworks.

3.5.9. Imported materials and stockpiles

1. Imported materials shall be free of weeds, litter and contaminants.
2. Sources of imported material shall be listed and approved by the ER on site.
3. The contractor shall provide samples to the ER for approval.
4. Stockpile areas shall be approved by the ER before any stockpiling commences.

3.5.10. Summary of objectives and performance monitoring

A summary of the project components, potential impacts, mitigating measures and performance monitoring is outlined in **Table 4.**

Table 4: Summary of objectives of the EMP

OBJECTIVE: Soil and rock degradation and erosion control

The natural geological profile including bedrock and soil cover must be preserved as far as possible to minimise unforeseen impacts on the surrounding environment.

A set of strict mitigation measures are required to effectively limit the impact on the geological environment. The proposed disturbance areas - where construction activity is likely to occur - are the focus of the mitigation measures laid out below.

Project component/s	• Wind turbines • Photovoltaic solar panels • Access roads • Substation linking the facility to the electricity grid • Underground cabling • Power lines
Potential Impact	• Soil and rock removal • Soil mixing, wetting, stockpiling, compaction • Soil pollution • Accelerated soil erosion • Increased deposition of soil into drainage systems • Increased run-off over the site • Dust pollution
Activity/risk source	• Construction activity – earthworks & transportation across site • Machinery, chemicals and human waste – soil pollutants • Rainfall - water erosion of disturbed areas • Wind erosion of disturbed areas
Mitigation: Target/Objective	• To minimise size of construction disturbance areas • To minimise destructive activity within disturbance areas & prevent unnecessary activity outside of disturbance areas • To minimise soil degradation (removal, excavation, mixing, wetting, compaction, pollution, erosion, etc.)

	• To minimise deposition of soil into drainage lines • To minimise dust pollution

Mitigation: Action/control	Responsibility	Timeframe
Identify areas of high erosion risk (drainage lines/watercourses). Only special works to be undertaken in these areas to be authorised by ECO and Engineer's representative (ER)	ECO/ER/Contractor	Before and during construction
Identify disturbance areas for general construction work and restrict construction activity to these areas.	ECO/ER/Contractor	Before and during construction
Prevent unnecessary destructive activity within disturbance areas (prevent over-excavations and double handling)	ECO/ER/Contractor	Before and during construction
Access roads to be carefully planned and constructed to minimise the impacted area and prevent unnecessary degradation of soil. Special attention to be given to roads that cross drainage lines and roads on steep slopes (to prevent unnecessary cutting and filling operations).	ECO/ER/Contractor	Before and during construction
Dust control on construction site: Wetting or covering of cleared areas.	Contractor	During construction
Minimise removal of vegetation which aids soil stability.	ECO/Contractor	During construction
Rehabilitate disturbance areas as soon as an area is vacated.	Contractor	During and after construction
Soil conservation: Stockpile topsoil for re-use in rehabilitation phase. Protect stockpile from erosion.	Contractor	Before and during construction
Erosion control measures: Run-off control and attenuation on slopes (sand bags, logs), silt fences, stormwater channels and catch-pits, shade nets, soil binding, geofabrics, hydroseeding or mulching over cleared areas.	Contractor/ECO	Erection: Before construction Maintenance: Duration of contract
Where access roads cross natural drainage lines, culverts must be designed to allow free flow. Regular maintenance must be carried out	ECO/ER/Contractor	Before construction and maintenance over duration of contract
Control depth of excavations and stability of cut faces/sidewalls	ECO/ER/Contractor	Before construction and maintenance over duration of contract

Performance Indicator	» Only authorised activity outside disturbance areas » No activity in no-go areas » Acceptable level of activity within disturbance areas, as determined by ECO » Acceptable level of soil erosion around site, as determined by ECO » Acceptable level of increased siltation in drainage lines, as determined by ECO » Acceptable level of soil degradation, as determined by ECO » Acceptable state of excavations, as determined by ER & ECO
Monitoring	» Fortnightly inspections of the site » Fortnightly inspections of sediment control devices » Fortnightly inspections of surroundings, including drainage lines » Immediate reporting of ineffective sediment control systems

	» An incident reporting system will record non-conformances

4. GEOTECHNICAL ASPECTS

4.1 Foundations for wind turbines

The design of foundations for wind turbines primarily concerns the resistance to overturning forces induced by wind loading and the foundation type is largely dependent on geotechnical conditions.

The simplest form of foundation is the spread footing on competent rock or engineered fill. This is essentially a gravity foundation that relies upon the weight of the soil overburden and concrete to provide sufficient vertical force to counteract horizontal forces during extreme wind loading. These footings are typically suited to a relatively shallow founding medium of a few meters and a trench is excavated to reach this level. The typical geometry of a spread footing for a wind turbine is 15-20m in diameter/width and 2-3m thick, resulting in an excavation of some 600m3 of material.

Rock socketed piers are used where a competent rock layer exists at relatively shallow depths and rely primarily upon end bearing and secondarily upon side wall friction and sufficient lateral earth pressures.

Piled foundations are used in areas where competent founding mediums are found at greater depths.

Rock anchored footings are used where hard competent rock is found at surface or at very shallow depths and the footing is attached to the rock with steel anchors.

The site under consideration is largely underlain by shallow sandstone and mudstone rock which is would be the targeted founding medium. A comprehensive geotechnical investigation will have to be undertaken by the developer in order to determine the geotechnical characteristics of the rock in order to allow the engineer to design the foundations.

4.2. Internal access roads and crane platforms

External access roads are required onto site as well as internal access roads between the turbines and solar panels for the transportation of components. The access roads are normally constructed with a gravel wearing course on a selected subgrade and the roads need to be wide enough to accommodate abnormally long low-beds with restricted turning capabilities. Maximum road curvatures, camber and gradients are strictly adhered to in the design process. The natural gradients of the site are gentle to moderate and some cut and fill operations may be required for the construction of internal access roads. Steep inclines may require surfacing to aid traction.

A stable platform is required at the site of each turbine for the operation of cranes to be used in the construction process. The footprint of the platform is typically $1000m^2$. This crane pad is typically constructed on a cut and/or filled levelled platform upon which imported sub-base gravel layers are placed and compacted. Imported natural construction materials may be required for the construction of the platforms, depending on the findings of the geotechnical investigation (still to be commissioned).

4.3. Underground services

Excavations for underground services are likely to encounter shallow rock in certain areas. In some areas a tracked excavator with a rock bucket may be required to rip through weathered rock. Excavated material is unlikely to meet specifications for selected granular material for pipe bedding (SABS 1200 LB) but may be used as selected fill material if approved by the engineer. Pipe bedding materials are likely to be imported from nearby commercial quarries.

4.4. Summary of geotechnical constraints

A basic preliminary assessment of the geotechnical nature of the study area affords the opportunity to identify any potential fatal flaws with the proposed site, such as potentially unstable geology, and other geotechnical information which will aid the design process. A basic assessment of the main geotechnical constraints that may impact on the civil engineering design is given in **Table 5**.

Table 5: Geotechnical constraints on the proposed development

Geotechnical Constraint	Effect on the proposed development	Severity	Comment & recommendations
Collapsible & compressible soil	Soil horizons with a potentially collapsible or compressible fabric unsuitable for foundations.	Medium-high	Transported and residual soils are potentially compressible and possibly collapsible. Heavy structures & turbines should be founded on competent rock or engineered fill, depending on local conditions and expected loads.
Differential settlement (DS)	Foundations placed across different soil types or rock may settle differentially.	Medium	Rock types and soil thickness will vary across the site. Recommend found individual turbines on similar mediums.
Bearing capacity	Soils with low in situ bearing capacity resulting in high settlements of heavy structures if not compacted or engineered properly	Medium	Transported soils: 30-80kPa, depending on level of consolidation. Not suitable for turbines. Residual soils: 80-500kPa, depending on type, structure and consistency. Not suitable for turbines. Weathered rock: 500kPa-1mPa, depending on lithology, structure and state of weathering. Possibly suitable. Fresh, competent rock: >1mPa. Ideal.
Saturated soils, groundwater problems, perched or permanent water tables	Seepage from sidewalls of excavations affecting stability or dewatering of trenches necessary.	Low	Minor shallow perched water tables may occur at the interface between transported soils and residual soil or weathered rock, but unlikely to pose problems.

Geotechnical Constraint	Effect on the proposed development	Severity	Comment & recommendations
Active soil	Heaving clays affecting foundation stability	Low-Medium	Presence of active clay is possible in residual weathered mudstone. Turbines should be founded below clay on competent rock.
Topography	Sites with high relief resulting in higher construction costs.	Medium-high	Access is generally easy to most of the site but some localised, but significant, cut and fill operations will be required for access roads in areas of high relief. These areas will be expensive to develop.
Excavations	Boulders or rock affecting excavations	Medium-high	Shallow weathered rock expected in most areas
	Unstable excavations requiring shoring	Low-Medium	Excavations into soil with vertical sidewalls will be unstable. Excavations into rock to be checked for stability by geologist.
Slope stability	Geological instability causing damage to structures founded on slopes	Medium	All natural steep slopes should be considered marginally stable at best. Slopes steeper than 1:4 are generally not recommended for development.
Seismic activity	Structures at risk of damage due to seismicity	Low	Area is considered to be seismically inactive.
Flood potential or storm water damage	Low lying areas affected by poor drainage.	Low	The flood potential of low-lying areas needs to be assessed.
	Steep slopes affected by uncontrolled run-off	Low-medium	All slopes steeper than 1:4 are not recommended for development.
Unconsolidated fill	Unconsolidated fill material affecting foundations	Low	Minor fill associated with existing farm buildings and dams
Availability of local construction material	Large distances to nearest quarry for sources of suitable construction material negatively affect construction costs	High	No commercial sources of aggregate and road materials near site. Potential sources need to be investigated.
Mining Activity	Past, present or future mining activity which may affect development of the site	Low	Minor borrow pit activities have taken place in the past. No known commercial mining activity.

The above geotechnical appraisal highlights some potential constraints, none of which are considered insurmountable, but the remote and rugged terrain will place heavy financial burden on the project. A detailed geotechnical investigation should be undertaken before the engineering design phase to provide more detail and to confirm the recommendations given herein. Specialist geotechnical input is recommended during the construction of foundations.

5. CONCLUSIONS

The proposed development carries a potentially low to moderate impact on the geological environment but these impacts can be largely mitigated to an acceptable level if appropriate mitigating measures are diligently applied.

The preliminary geotechnical assessment has identified some potential constraints but more detailed geotechnical investigations should be undertaken by the developer to determine the severity of the constraints on the proposed development.

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