GEOLOGICAL REPORT

SPECIALIST INPUT FOR THE ENVIRONMENTAL BASIC ASSESSMENT FOR THE PROPOSED MIDDELBURG SOLAR PARK, EASTERN CAPE PROVINCE, SOUTH AFRICA

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List of abbreviations

AMSL:	Above mean sea level
ECO:	Environmental Control Officer
EIA:	Environmental Impact Assessment
EMP:	Environmental Management Programme
ER:	Engineer's representative
Ma:	Million years
MW:	Megawatt
NEMA:	National Environmental Management Act 107 of 1998
NGL:	Natural ground level
PV:	Photovoltaic

1. INTRODUCTION

1.1. Background info

African Clean Energy Developments (Pty) Ltd is in the process of investigating the feasibility of a solar energy facility, consisting of two separate parks on adjacent farm portions north of Middelburg in the Eastern Cape Province of South Africa. The proposed activity is defined as the establishment of a solar energy facility and associated infrastructure, including the construction of photovoltaic (PV) panels, access roads, buried pipelines and ducting, overhead electrical power lines, a workshop, storeroom and maintenance/control building. The two solar parks will each have a maximum generating capacity of 75MW, therefore the total capacity will be 150MW.

1.2. Legislation

In terms of the Environmental Impact Assessment (EIA) regulations published in terms of Section 24(5) of the National Environmental Management Act (NEMA, Act No. 107 of 1998), the applicant requires authorisation from the National Department of Environmental Affairs (DEA) in consultation with the Eastern Cape Provincial Department for the undertaking of the proposed project.

This specialist geological study is undertaken in accordance with Regulation 17 of the NEMA.

1.3. Terms of reference

Savannah Environmental has been appointed by African Clean Energy Developments (Pty) Ltd to carry out a Basic Assessment for the proposed activity. Savannah Environmental has appointed Outeniqua Geotechnical Services to conduct a specialist geological study of the proposed site and assess the environmental impacts on the geological environment, with specific focus on soil erosion.

The following scope of work has been given:

- Conduct a brief visit to the proposed site in order to obtain data.
- Describe the geology of the site and discuss the potential environmental impacts on the geological environment that may be associated with the proposed activity.
- Assess the potential negative and positive impacts and provide mitigating measures for inclusion in the Environmental Management Programme (EMP).

1.4. Limitations

Information provided in this specialist report has been based on information provided by the developer, Savannah Environmental (Pty) Ltd, published scientific literature and maps. The proposed site was visited briefly but no detailed soil investigation or geological mapping was conducted. The information provided in this report is deemed adequate for the EIA process.

1.5. Authors credentials & declaration of independence

The author of this report, Iain Paton of Outeniqua Geotechnical Services cc, is a professional engineering geologist registered with the South African Council for Natural and Scientific Professions (Pr Sci Nat # 400236/07) with 13 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 neither he nor his company has any financial interest in the proposed development, other than remuneration for work performed in the compilation of this report.

2. SITE DESCRIPTION

2.1. Location & land usage

The proposed development is located on the following farm portions:

- Remainder of Farm 11 (Middelburg Solar Park 1);
- Portion 4 of Farm 11 Twee Fontein (Middelburg Solar Park 2).

Both parks are easily accessible from the N9 and the present land use is agricultural grazing for sheep and cattle. The landowner, Mr Erasmus, lives on the farm in the dwelling named "Beskuitfontein", which is located approximately 3km northeast of the proposed sites (see **Figure 1**).

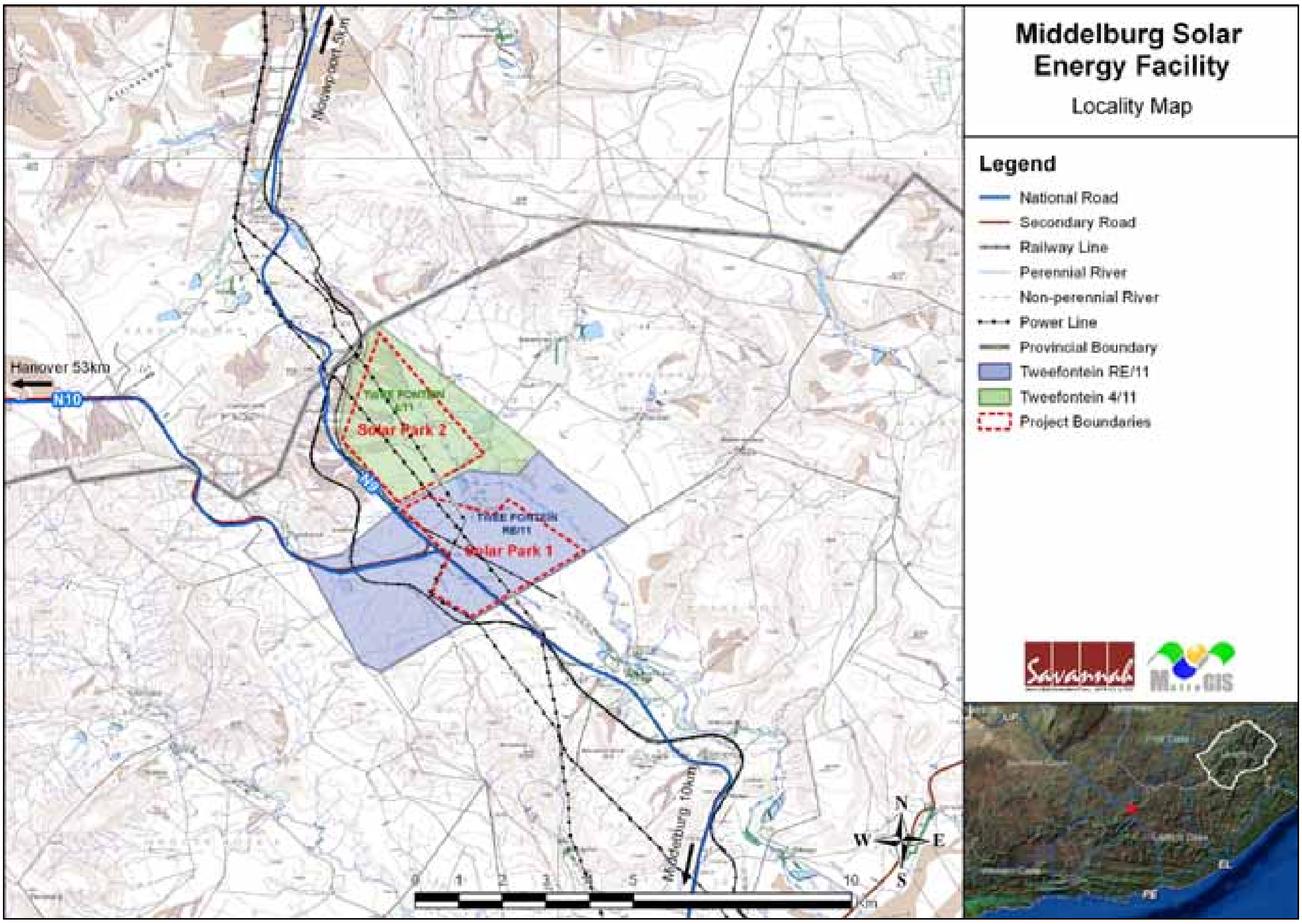

Figure 1: Locality map.

2.2. Topography, climate, & vegetation cover

The proposed solar parks are situated in a wide drainage basin surrounded by prominent mountainous terrain. The most prominent peaks surrounding the valley are Carlton Hills (1862m), which is situated to the northwest, and Bakkeneeskop (1838m), which is situated to the east of the site. The valley floor is drained by numerous ephemeral channels which generally flow in a south-easterly direction.

The climate of the area is generally dry (Wienert No.5-10). Middelburg receives a mean annual rainfall of 234mm, with the majority falling during autumn. It receives the lowest rainfall (3mm) in July and the highest (51mm) in March. The average midday temperatures for Middelburg range from 15°C in June to 30°C in January. The region is the coldest during July when the minimum average temperature is 0°C. [2]

The natural vegetation of the area typically consists of low thorny shrubs and indigenous grasses. Acacia Karroo (Sweetthorn) trees are common along natural drainage lines.

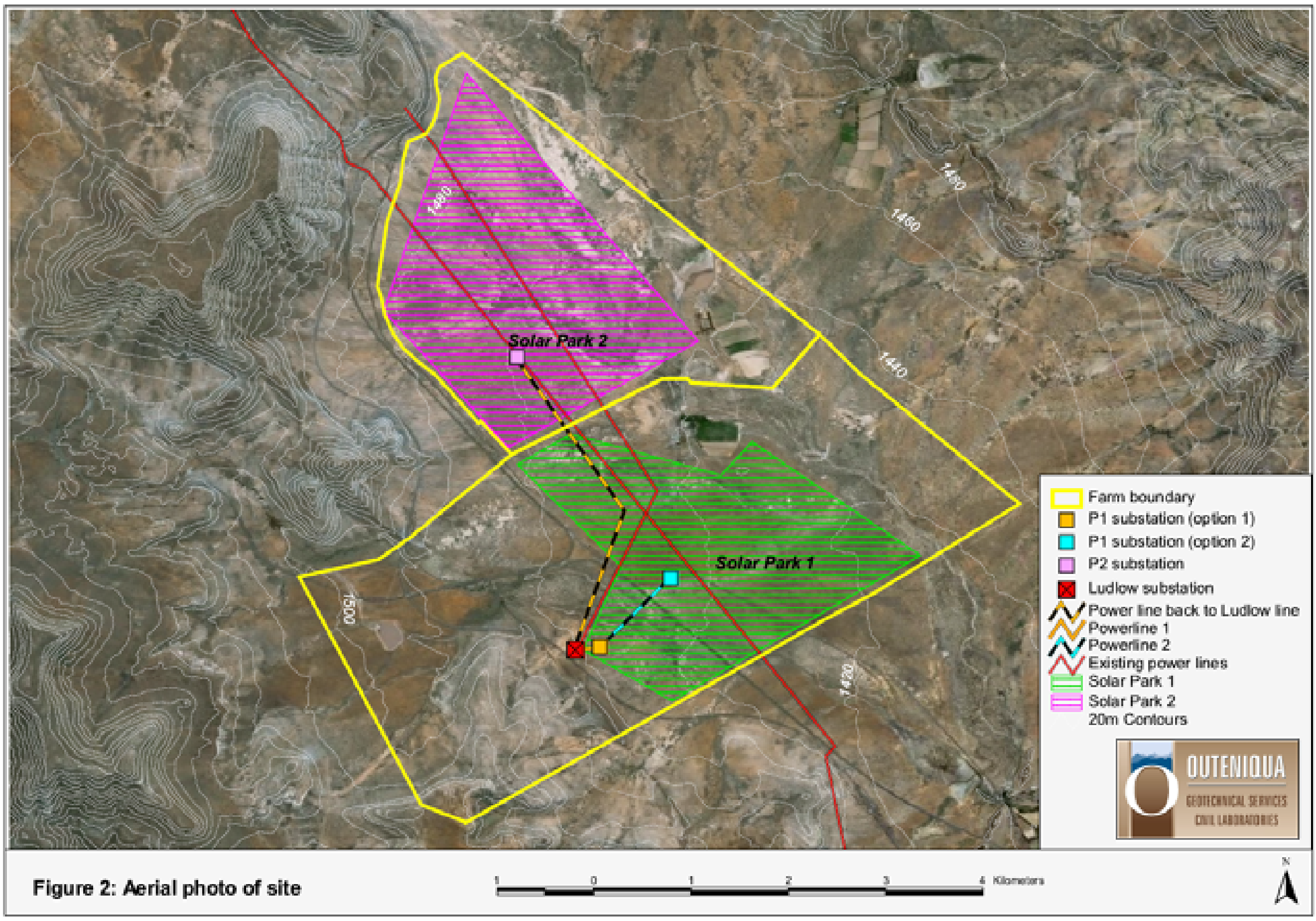

Figure 2: Aerial photo showing proposed development sites

2.3. Geology & soil types

The proposed site is underlain by significantly thick deposits of largely unconsolidated alluvium of Quaternary age (less than 2Ma). This alluvium has been deposited over many thousand years from the continual erosion of the surrounding hills. The alluvium is underlain at an unknown depth by interbedded layers of fine grained sandstone and red, green or grey mudstone of the Katberg Formation (Triassic age). Similarly, the surrounding hills are also formed from the same rock types. In places, these sedimentary rocks have been intruded by Jurassic-age dolerite dykes and sills. Horizontal dolerite intrusions (sills) typically form resistant caps to the surrounding hills, inhibiting erosion of the underlying softer sedimentary strata, and thus resulting in flat-topped hills. This is a common topographical feature in the Karoo landscape. Two inconspicuous dolerite dykes, trending north-south and east-west occur on the valley floor in close proximity to the proposed sites, crossing each other in the vicinity of the Guest Lodge (depicted as red lines in **Figure 3**). The dykes form very low ridges on the valley floor and are not easily detected by the untrained eye.

There are no geological faults indicated on the 1:250 000 map in the immediate vicinity of the site and the site is situated in a zone of low seismic activity.

The soil texture on the site is variable, ranging from alluvial gravels to fine silt deposits. The latter type is highly erodible and significant erosion has taken place in this area in the past. Pro-active measures have been put in place by the farmers in affected areas in order to attenuate stormwater flow from the surrounding hills and reduce erosion of valuable soil.

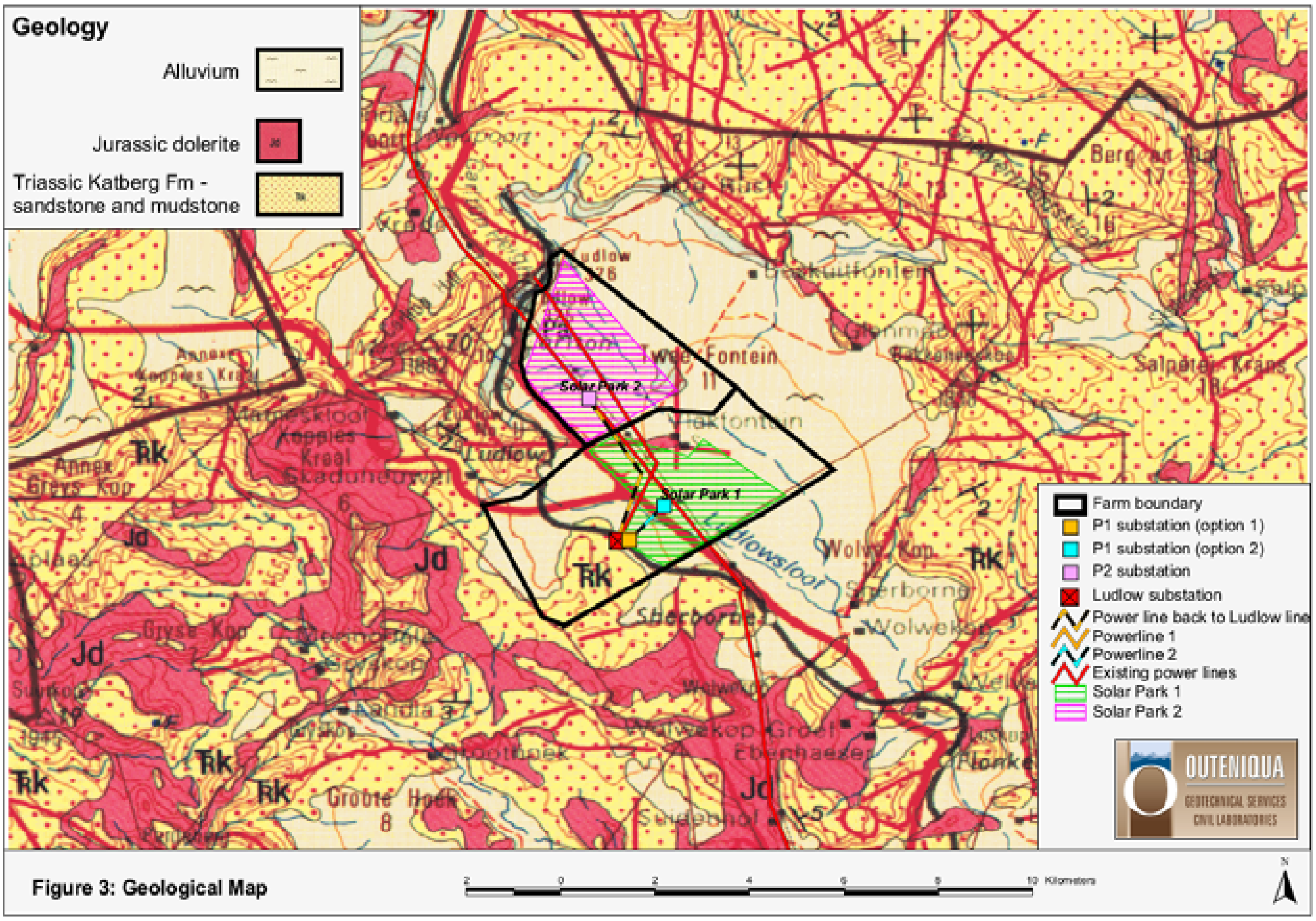

Figure 3: Geological map of the proposed sites.

2.4. Hydrology

The slopes surrounding the valley are generally well drained by numerous small channels leading down onto the valley floor. The valley floor is characterised by low gradients and flooding is common. The general drainage direction is to the southeast, following the national road towards Middelburg. There are no large rivers in the site area and the valley floor is drained by small furrows which may break their banks during peak flow periods.

Although the region has a typically semi-arid dry climate, flash-floods do occur infrequently and it is important not to underestimate this in the assessment of water erosion potential. Water erosion potential is directly related to the hydrology of the site which is, in turn largely affected by the geology. Infiltration of rainfall into the ground is largely determined by the thickness and permeability of the soil cover and the depth to rock. Infiltration is likely to be higher where the soil cover is thicker and relatively low in areas where the bedrock is near or at surface. Infiltration is inversely proportional to run-off, and therefore in areas where infiltration into the ground is high, run-off is generally low, up to a point where the amount of rainfall exceeds the infiltration rate, and beyond that point excess rainfall ends up as run-off. Run-off is the primary trigger of erosion. High run-off is expected during peak rainfall periods and high levels of erosion are expected along main drainage lines. This is historically been a problematic area for erosion management and effective engineering measures are sought to attenuate flow from the surrounding hills.

3. GEOLOGICAL IMPACT ASSESSMENT

The geological impact assessment aims to assess the impact that the proposed development may have on the geological environment which includes the natural soil cover and the underlying bedrock. Important geological landforms that contribute to scientific interest or the natural beauty of the area are also considered in the impact study. Palaeontological features such as fossil sites, middens, addits, etc. which are important from a scientific or heritage perspective are not covered in this report. The impact on the geohydrology of the area is also not assessed in this study.

The proposed activity may potentially cause a negative direct impact of degradation of soil and/or rock (excavation/removal, loosening, compaction, contamination/pollution, etc) which may also lead to indirect impacts such as dust pollution and siltation away from the site. Impacts on bedrock could indirectly affect hydrology and slope stability. The severity or significance of the various impacts is related to the nature and extent of the activity.

Potential direct positive impacts could potentially include a reduction in soil erosion in areas where new engineering measures are put in place to rectify certain problems, such as improved drainage along poorly constructed and maintained existing roads. The negative impacts are dominantly related to the construction phase with insignificant additional impacts in the post construction and decommissioning phases.

Potential indirect positive impacts relating to the geological environment could include a reduction in the demand for non-renewable energy sources on a national scale (such as coal or uranium).

3.1. Soil degradation

Soil degradation is the negative alteration of the natural soil profile, usually directly or indirectly related to human activity. Soil degradation due to construction activity will negatively affect soil formation, natural weathering processes, moisture levels, and soil stability. This will, in turn, affect biological processes operating in the soil. Soil degradation includes erosion (i.e. due to water and wind), soil removal, mixing, wetting, compaction, pollution, salinisation, crusting, and acidification.

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 global 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).

Erosion of soil due to water run-off 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 or rehabilitate. Erosion by water 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 typically increased in areas where soil is loosened and vegetation cover is stripped (such is the case on construction sites). Removal of vegetation (ground cover) may increase the risk of soil erosion, making the soil less fertile, and less able to support the regeneration of vegetation in future.

Erosion sensitivity can be broadly mapped according to the severity of the potential erosion if land disturbing activities occur and this is generally affected by to the geology, soil types, topography and proximity to natural drainage lines. Generally speaking, thick deposits of unconsolidated or partly consolidated fine-grained soils of low plasticity occurring along drainage lines, moderate to steep slopes or at the base of steep slopes are most vulnerable to severe levels of erosion due to water run-off. Areas where these factors occur simultaneously are typically called “highly sensitive” areas.

Specifically relating to the site in question, the geological map (**Figure 3)** indicates that the proposed development is potentially underlain by thick deposits of unconsolidated alluvium. Certain parts of the site have been identified as being sensitive in terms of erosion (see **Figure 4**). **Table 1** broadly outlines the erosion sensitivity of the site.

Table 1: Water erosion sensitivity

Sensitivity Level	Geological Formation/Terrain Units	Comments/Recommendations
High	Natural drainage lines/watercourses	No-go areas without special mitigating measures. Erosion presently taking place.
Medium	Other areas underlain by unconsolidated sediment (e.g. alluvium, aeolium)*	Moderate levels of erosion will occur if land-disturbing activities take place (construction). Mitigating measures to be applied to minimise impact.

Low	Areas underlain by shallow rock*	Minor erosion will naturally occur. Normal mitigating measures apply.

*See **Figure 4** for spatial distribution

In the event of heavy rainfall, surface run-off will result in erosion along drainage lines (see **Figures 5&6**) and in areas that are cleared of vegetation, although in the case of this development, full vegetation clearing is not envisaged across the entire site (vegetation will be shortened/maintained to prevent spread of fire and shadows on the panels).

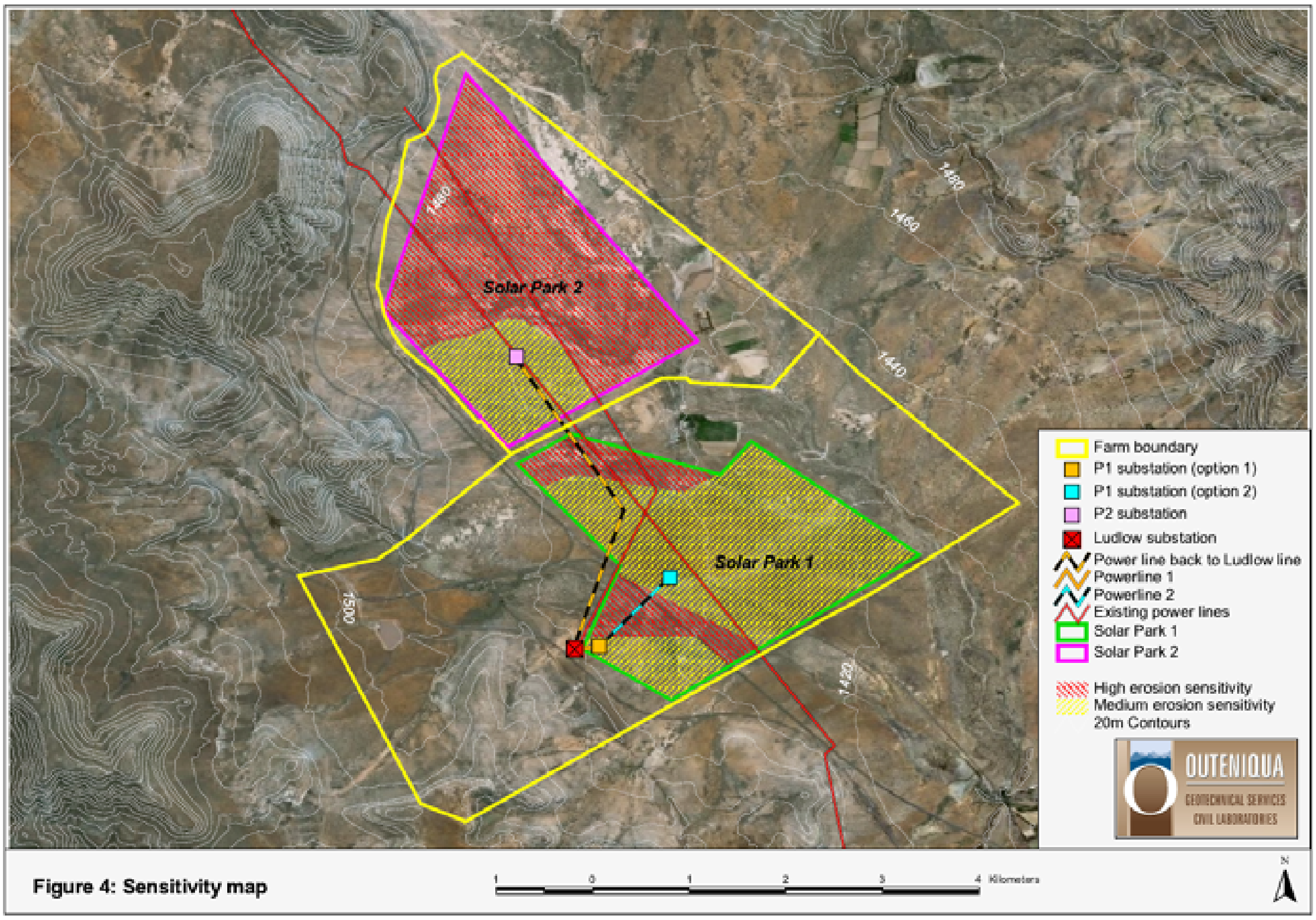

Figure 4: Erosion sensitivity map

Figure 5: Photo along of one of the drainage lines traversing Solar Park 2 from Carlton Hills (looking SE).

Figure 6: Ludlowsloot in traversing Solar Park 1 (looking SE towards the N9 road).

The proposed sites for Park 1 and Park 2 are presently in a moderate to poor state of erosion, specifically in the highly sensitive areas identified in **Figure 4**. This has been an historical problem on the farm which is actively being addressed by the current landowner. Additional development could aid this process if it is handled carefully.

3.2. Degradation of bedrock, topography and landforms

Earthworks for the proposed structures and access roads are likely to be minimal due to the gentle terrain on the site and typically shallow and simple foundation systems utilised for the proposed infrastructure.

3.3. Assessment of impacts

The environmental assessment aims to evaluate the impacts that the proposed activity will have on the environment and attempts to provide mitigating measures to minimise negative impacts.

Direct, indirect, and cumulative negative impacts are assessed in terms of the following criteria (as specified by Savannah Environmental):

- 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).

3.3.1. Potential impacts on the PV park sites

There are no site alternatives under consideration and both Park 1 & 2 are being assessed individually for potential development. The do-nothing alternative will have no negative impact on the geological environment.

The proposed photovoltaic (PV) technology typically makes use of a light-weight frame upon which the PV panels are attached. The frame is usually anchored to the ground by means of steel poles which are emplaced into pre-drilled holes or screwed into the ground (screwpiles). Alternatively, shallow concrete pads are cast to secure the top structure. In any case, minimal earthworks are involved in the foundations and the frames can be erected on moderate slopes without resorting to cut and fill operations.

An assessment of the individual potential <u>direct</u> impacts on the geological environment associated with each of the proposed PV parks is tabulated in **Table 3 (Park 1) and Table 4 (Park 2)**.

Table 3: Potential direct impacts – Park 1

Nature: Soil and rock degradation (soil/rock removal, mixing, compaction, etc) due to the construction of foundations for infrastructure.		
	Without mitigation	***With mitigation***
Extent	Local (1)	Local (1)
Duration	Short term (2)	Very Short term (1)
Magnitude	Minor (2)	Minor (2)
Probability	Definite (5)	Definite (5)
Significance	**Low (25)**	**Low (20)**
Status	Negative	Negative
Reversibility	Partially reversible	Partially reversible
Irreplaceable loss of resources?	Yes	Yes
Can impacts be mitigated?	Yes, to a certain extent.	
Mitigation:	» Rehabilitate topsoil & vegetation around site after construction.	
Cumulative impacts:	» The cumulative impact of earthworks in the area is considered low at this stage due to the low density of development in the area at present. Further development of the area may have increasing impact on the natural soil.	
Residual impacts:	» Minor negative – slow regeneration of topsoil.	

Nature: Soil and rock degradation (soil/rock removal, mixing, compaction, etc) due to the construction of new access roads (cut and fill).		
	Without mitigation	***With mitigation***
Extent	Local (1)	Local (1)
Duration	Long term (4)	Long term (4)
Magnitude	Low (4)	Minor (2)
Probability	Definite (5)	Definite (5)
Significance	**Moderate (45)**	**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 if possible/practical. » Minimise the length and width of new access roads. » Minimise access roads in steep terrain in order to minimise cut and fill operations » Maintain access roads in good condition, preventing detours due to bad road conditions	
Cumulative impacts:	» The cumulative impact of earthworks in the area is considered low at this stage due to the low density of development in the area at present. Further development of the area may have an increasing impact on the natural soil.	

Residual impacts:	» Minor negative – slow regeneration of vegetation & topsoil along roadside.

Nature: Soil degradation due to pollution of soil by contaminants used on site during construction (e.g. fuel, oil, chemicals, cement).		
	Without mitigation	***With mitigation***
Extent	Local (1)	Local (1)
Duration	Medium term (3)	Very short term (1)
Magnitude	Minor (2)	Minor (2)
Probability	Probable (3)	Probable (3)
Significance	**Low (18)**	**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. » Remove contaminants and contaminated topsoil and replace topsoil in affected areas.	
Cumulative impacts:	» The cumulative impact of soil pollution is considered low at present due to the undeveloped nature of the study area but further development may have an increasing impact.	
Residual impacts:	» Minor negative – slow regeneration of soil processes in and under topsoil	

Nature: Soil degradation due to increased soil erosion by wind and/or water on construction areas.		
	Without mitigation	***With mitigation***
Extent	Local (1)	Local (1)
Duration	Long term (4)	Short term (1)
Magnitude	Moderate (6)	Low (4)
Probability	Very probable (4)	Very probable (4)
Significance	**Moderate (44)**	**Low (24)**
Status	Negative	Negative
Reversibility	Irreversible	Practically irreversible
Irreplaceable loss of resources?	Yes, minor	Yes, minor
Can impacts be mitigated?	Yes. However, large tracts of the site is presently in a moderate to poor state of erosion	
Mitigation:	» Minimise size of the construction footprint/camp around each panel array. » Restrict activity outside of construction camp areas. » Implement effective erosion control measures. » Carry out earthworks in phases across site to reduce the area of exposed ground at any one time. » Protect and maintain denuded areas and material stockpiles to minimise erosion and instability	
Cumulative impacts:	» The cumulative impact of soil erosion in the area is considered low at present due to the undeveloped nature of the area but further development may have an increasing impact on soil erosion. At this stage, large tracts of the site are presently in a moderate to poor state of erosion	
Residual impacts:	» Minor localised erosion.	

Table 4: Potential direct impacts – Park 2

Nature: Soil and rock degradation (soil/rock removal, mixing, compaction, etc) due to the construction of foundations for infrastructure.		
	Without mitigation	***With mitigation***
Extent	Local (1)	Local (1)
Duration	Short term (2)	Very Short term (1)
Magnitude	Minor (2)	Minor (2)
Probability	Definite (5)	Definite (5)
Significance	**Low (25)**	**Low (20)**
Status	Negative	Negative
Reversibility	Partially reversible	Partially reversible
Irreplaceable loss of resources?	Yes	Yes
Can impacts be mitigated?	Yes, to a certain extent.	
Mitigation:	» Rehabilitate topsoil & vegetation around site after construction.	
Cumulative impacts:	» The cumulative impact of earthworks in the area is considered low at this stage due to the low density of development in the area at present. Further development of the area may have increasing impact on the natural soil.	
Residual impacts:	» Minor negative – slow regeneration of topsoil.	

Nature: Soil and rock degradation (soil/rock removal, mixing, compaction, etc) due to the construction of new access roads (cut and fill).		
	Without mitigation	***With mitigation***
Extent	Local (1)	Local (1)
Duration	Long term (4)	Long term (4)
Magnitude	Low (4)	Minor (2)
Probability	Definite (5)	Definite (5)
Significance	**Moderate (45)**	**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 if possible/practical. » Minimise the length and width of new access roads. » Minimise access roads in steep terrain in order to minimise cut and fill operations » Maintain access roads in good condition, preventing detours due to bad road conditions	
Cumulative impacts:	» The cumulative impact of earthworks in the area is considered low at this stage due to the low density of development in the area at present. Further development of the area may have an increasing impact on the natural soil.	
Residual impacts:	» Minor negative – slow regeneration of vegetation & topsoil along roadside.	

Nature: Soil degradation due to pollution of soil by contaminants used on site during construction (e.g. fuel, oil, chemicals, cement).		
	Without mitigation	***With mitigation***
Extent	Local (1)	Local (1)
Duration	Medium term (3)	Very short term (1)
Magnitude	Minor (2)	Minor (2)
Probability	Probable (3)	Probable (3)
Significance	**Low (18)**	**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. » Remove contaminants and contaminated topsoil and replace topsoil in affected areas.	
Cumulative impacts:	» The cumulative impact of soil pollution is considered low at present due to the undeveloped nature of the study area but further development may have an increasing impact.	
Residual impacts:	» Minor negative – slow regeneration of soil processes in and under topsoil	

Nature: Soil degradation due to increased soil erosion by wind and/or water on construction areas.		
	Without mitigation	***With mitigation***
Extent	Local (1)	Local (1)
Duration	Long term (4)	Short term (1)
Magnitude	Moderate (6)	Low (4)
Probability	Very probable (4)	Very probable (4)
Significance	**Moderate (44)**	**Low (24)**
Status	Negative	Negative
Reversibility	Irreversible	Practically irreversible
Irreplaceable loss of resources?	Yes, minor	Yes, minor
Can impacts be mitigated?	Yes. However, large tracts of the site is presently in a moderate to poor state of erosion	
Mitigation:	» Minimise size of the construction footprint/camp around each panel array. » Restrict activity outside of construction camp areas. » Implement effective erosion control measures such as silt fences, geosynthetic erosion protection, and/or flow attenuation along watercourses around construction sites. » Carry out earthworks in phases across site to reduce the area of exposed ground at any one time. » Protect and maintain denuded areas and material stockpiles to minimise erosion and instability	
Cumulative impacts:	» The cumulative impact of soil erosion in the area is considered low at present due to the undeveloped nature of the area but further development may have an increasing impact on soil erosion. At this stage, large tracts of the site are presently in a moderate to poor state of erosion	
Residual impacts:	» Minor localised erosion.	

An assessment of the potential indirect impacts associated with the proposed PV Park sites are tabulated in **Table 5 (Park 1) Table 6 (Park 2)**.

Table 5: Potential indirect impacts – Park 1

Nature: Soil degradation due to increased siltation along drainage lines downstream from site.		
	Without mitigation	***With mitigation***
Extent	Regional (3)	Local (1)
Duration	Long term (4)	Long term (4)
Magnitude	Moderate (4)	Minor (2)
Probability	Probable (3)	Probable (3)
Significance	**Moderate (33)**	**Low (21)**
Status	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes	Yes
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. » Strictly control activity near water courses/natural drainage lines as sediment transport is higher in these areas. » Minimise increased run-off from hard surfaces (PV panels) by channelising and capturing rainwater for re-use (rainwater harvesting)	
Cumulative impacts:	» The cumulative impact of siltation in the area is considered low at present but further development may have an increasing impact on siltation of waterways.	
Residual impacts:	» Minor localised movement of soil across site	

Nature: Increased dust pollution from construction sites affecting surroundings.		
	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	**Low (28)**	**Low (16)**
Status	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes, minor	Yes, insignificant
Can impacts be mitigated?	Yes	
Mitigation:	» Apply dust control measures such as straw bales or dampen dusty denuded areas.	
Cumulative impacts:	» The cumulative impact of dust in the area is considered low.	
Residual impacts:	» Minor localised dust pollution	

Nature: Reduction in demand for non-renewable energy sources.		
	Without mitigation	***With mitigation***
Extent	National (3)	n/a
Duration	Long term (4)	n/a
Magnitude	Moderate (6)	n/a
Probability	Very probable (4)	n/a
Significance	**Moderate (52)**	n/a
Status	Positive	
Reversibility		
Irreplaceable loss of resources?		
Can impacts be mitigated?		
Mitigation:		
Cumulative impacts:	» The cumulative positive impact on a national scale is considered very high.	
Residual impacts:		

Table 6: Potential indirect impacts – Park 2

Nature: Soil degradation due to increased siltation along drainage lines downstream from site.		
	Without mitigation	***With mitigation***
Extent	Regional (3)	Local (1)
Duration	Long term (4)	Long term (4)
Magnitude	Moderate (4)	Minor (2)
Probability	Probable (3)	Probable (3)
Significance	**Moderate (33)**	**Low (21)**
Status	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes	Yes
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. » Strictly control activity near water courses/natural drainage lines as sediment transport is higher in these areas. » Minimise increased run-off from hard surfaces (PV panels) by channelising and capturing rainwater for re-use (rainwater harvesting)	
Cumulative impacts:	» The cumulative impact of siltation in the area is considered low at present but further development may have an increasing impact on siltation of waterways.	
Residual impacts:	» Minor localised movement of soil across site	

Nature: Increased dust pollution from construction sites affecting surroundings.		
	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	**Low (28)**	**Low (16)**
Status	Negative	Negative
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	Yes, minor	Yes, insignificant
Can impacts be mitigated?	Yes	
Mitigation:	» Apply dust control measures such as straw bales or dampen dusty denuded areas.	
Cumulative impacts:	» The cumulative impact of dust in the area is considered low.	
Residual impacts:	» Minor localised dust pollution	

Nature: Reduction in demand for non-renewable energy sources.		
	Without mitigation	***With mitigation***
Extent	National (3)	n/a
Duration	Long term (4)	n/a
Magnitude	Moderate (6)	n/a
Probability	Very probable (4)	n/a
Significance	**Moderate (52)**	n/a
Status	Positive	
Reversibility		
Irreplaceable loss of resources?		
Can impacts be mitigated?		
Mitigation:		
Cumulative impacts:	» The cumulative positive impact on a national scale is considered very high.	
Residual impacts:		

3.3.2. Potential impacts along the proposed new power line routes

The proposed PV parks will connect to the existing Ludlow substation via new overhead power lines as indicated in **Figure 4.** There are no alternatives and the following potential connections are being considered:

» Park 1 – 2 substation (132kv) options with 2x 132 kV lines running back to Ludlow;

» Park 2 – 1 substation option (66kv) connecting directly into 66 kV line or running line (66/132 kV) back to Ludlow.

The proposed power line routes are likely to be underlain by unconsolidated alluvium deposits which typically occur in the area. The depth to solid bedrock is undetermined at this stage but is likely to vary from 1-20m. The construction of power lines is likely to involve the same impact types that are associated with the PV Parks. However, the earthworks associated with power lines is generally limited to the construction of foundations for pylons and minor work involved in creating temporary access tracks along the routes for construction purposes. The erosion sensitivity along the proposed routes is broadly indicated in **Figure 4**.

3.4. Impact Statement

The most significant potential negative impacts on the geological environment are potential soil degradation issues as a result of construction activity and its effect on soil stability and soil-forming processes. However, with effective implementation of mitigating measures, these impacts are considered to have a low to moderate localised significance, requiring diligent attention from the engineers, environmental officers and contractors, but not posing a significant threat to the environmental status-quo or the feasibility of the development.

The potential positive impacts on the geological environment are considered to have a moderate significance on a local scale but the cumulative impact of a reduction in demand and extraction/mining of non-renewable energy sources on a national scale is significant.

3.5. Environmental Management Programme (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 should be undertaken as per the requirements set out in the EMP.
2. All earthworks shall be undertaken in such a manner 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 adhered to.
4. No equipment associated with the activity shall be allowed outside of these areas unless expressly permitted by the Environmental Control Officer (ECO).
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. 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.

3.5.5. Trenching

1. Trenching shall be kept to a minimum using 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.

3.5.6. 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.

3.5.7. 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.

3.5.8. Summary of objectives and performance monitoring

A summary of the project components, potential impacts, mitigating measures and performance monitoring is outlined below.

OBJECTIVE: Minimise soil degradation and erosion

» Soil degradation including erosion (by wind and water) and subsequent deposition elsewhere is of a concern in areas which are underlain by fine grained soil which can be mobilised when disturbed, even on relatively low slope gradients (accelerated erosion).
» Uncontrolled run-off relating to the construction activity (excessive wetting, uncontrolled discharge, etc) will also lead to accelerated erosion and possible sedimentation along natural drainage lines or catchment areas.
» Degradation of the natural soil profile due to excavation, removal or topsoil, stockpiling, wetting, compaction, pollution and other construction activities will affect soil forming processes and associated ecosystems. Degradation of parent rock is considered low as there are no deep excavations planned.

Project Component/s	• PV arrays and foundations to support them. • Access roads. • Underground cabling. • Storage and maintenance facilities and foundations to support them. • Overhead power lines and substation linking the facility to the electricity grid.
Potential Impact	• Soil removal. • Soil mixing, wetting, stockpiling, compaction. • Soil pollution. • Increased run-off and erosion. • Increased siltation along drainage lines. • Dust pollution.
Activity/Risk Source	• Earthworks & transportation across site. • Rainfall and concentrated discharge causing water erosion of disturbed areas. • Wind - erosion of disturbed areas.
Mitigation: Target/Objective	• Minimise soil degradation (removal, excavation, mixing, wetting, compaction, pollution, etc.). • Minimise erosion. • Minimise sediment transport downstream (siltation). • Minimise dust pollution.

Mitigation: Action / Control	Responsibility	Timeframe
Identify areas of high erosion risk (drainage lines/watercourses, existing problem areas). Only special works to be undertaken in these areas to be authorised by ECO and Engineer's representative (ER)	ECO/ER	At design stage.
Identify construction areas for general construction work and restrict construction activity to these areas.	ECO/ER/Contractor	At design stage and during construction
Prevent unnecessary destructive activity within construction areas (prevent over-excavations and double handling)	ECO/ER/Contractor	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	At design stage and during construction
Dust control on construction site through wetting or covering of cleared areas.	Contractor	Daily during construction
Minimise removal of vegetation which aids soil stability.	ECO/Contractor	Continuously during construction
Rehabilitate disturbance areas as soon as an area is vacated.	Contractor	Continuously during and after construction
Soil conservation - stockpile topsoil for re-use in rehabilitation phase. Protect stockpile from erosion.	Contractor	Continuously 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 construction areas » No activity in no-go areas. » Acceptable level of activity within construction areas, as determined by ECO. » Acceptable level of soil erosion around site, as determined by ECO. » Acceptable level of sedimentation along 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	» Monthly inspections of the site by the ECO. » Monthly inspections of sediment control devices by the ECO. » Monthly inspections of surroundings, including drainage lines by the ECO. » Immediate reporting of ineffective sediment control systems by the ECO. » An incident reporting system will record non-conformances.

4. CONCLUSIONS

If suitable mitigating measures are applied, the proposed development will have a low to moderate potential *negative* impact on the geological environment. The proposed development can potentially make a significant indirect *positive* impact on the geological environment in terms of a reduction in demand (and exploitation) for non-renewable energy sources on a national scale.

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