Member of the Surbana Jurong Group

GEOTECHNICAL DESKTOP STUDY

Paulputs Wind Farm, Northern Cape Province

January 2019

Ref. C1752/01/2019/2786

AUSTRALIA | ASIA | MIDDLE EAST | AFRICA | PACIFIC

Project Name:	Geotechnical Desktop Study for Paulputs Wind Farm
Report Number:	C1752/01/2019/2786
Report for:	Arcus Consulting

REVISIONS

Revision #	Date	Change Overview	Prepared by	Reviewed by
0	18/01/2019	Draft	A. Lodenkemper	R. Roberts
1	22/01/2019	Draft	A. Lodenkemper	Client
2	24/01/2019	Final	A. Lodenkemper	R. Roberts

APPROVAL

Approver Name:	Alex Lodenkemper	**Reviewer Name:**	Richard Roberts
Position Held:	Engineering Geologist	**Position Held:**	Geotechnical Engineer
Approver Signature:		**Reviewer Signature:**	
Date:	24/01/2019	**Date:**	24/01/2019

ISSUE REGISTER

Distribution List	Date Issued	Number of Copies
Client: Arcus Consulting	24/01/2019	1 Electronic
Client Associate: Paulputs Wind Energy Facility (Pty) Ltd.		1 Electronic
SMEC staff: Alex Lodenkemper, Richard Roberts		1 Electronic
Office Library: SMEC Cape Town		1 Hard Copy
SMEC Project File: C1752 Div. H		1 Hard Copy

SMEC COMPANY DETAILS

SMEC South Africa (Pty) Ltd

65 Riebeek Street, Cape Town, 8001

Tel: **021-417-2900**

Email: **Alex.lodenkemper@smec.com**

Website: **www.smec.com**

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

DETAILS OF THE SPECIALIST, DECLARATION OF INTEREST AND UNDERTAKING UNDER OATH

	(For official use only)
File Reference Number:	
NEAS Reference Number:	DEA/EIA/
Date Received:	

Application for authorisation in terms of the National Environmental Management Act, Act No. 107 of 1998, as amended and the Environmental Impact Assessment (EIA) Regulations, 2014, as amended (the Regulations)

PROJECT TITLE

Paulputs WEF & GRID CONNECTION, NORTHERN CAPE PROVINCE

Kindly note the following:

1. This form must always be used for applications that must be subjected to Basic Assessment or Scoping & Environmental Impact Reporting where this Department is the Competent Authority.
2. This form is current as of 01 September 2018. It is the responsibility of the Applicant / Environmental Assessment Practitioner (EAP) to ascertain whether subsequent versions of the form have been published or produced by the Competent Authority. The latest available Departmental templates are available at https://www.environment.gov.za/documents/forms.
3. A copy of this form containing original signatures must be appended to all Draft and Final Reports submitted to the department for consideration.
4. All documentation delivered to the physical address contained in this form must be delivered during the official Departmental Officer Hours which is visible on the Departmental gate.
5. All EIA related documents (includes application forms, reports or any EIA related submissions) that are faxed; emailed; delivered to Security or placed in the Departmental Tender Box will not be accepted, only hardcopy submissions are accepted.

Departmental Details

Postal address:
Department of Environmental Affairs
Attention: Chief Director: Integrated Environmental Authorisations
Private Bag X447
Pretoria
0001

Physical address:
Department of Environmental Affairs
Attention: Chief Director: Integrated Environmental Authorisations
Environment House
473 Steve Biko Road
Arcadia

Queries must be directed to the Directorate: Coordination, Strategic Planning and Support at:
Email: EIAAdmin@environment.gov.za

1. SPECIALIST INFORMATION

Specialist Company Name:	SMEC SOUTH AFRICA			
B-BBEE	Contribution level (indicate 1 to 8 or non-compliant)	1	Percentage Procurement recognition	135%
Specialist name:	GERNA VAN JAARSVELD			
Specialist Qualifications:	B(TOWN AND REGIONAL PLANNING); MSc (TRANSPORT PLANNING)			
Professional affiliation/registration:	PROFESSIONAL PLANNER (SA) (A/2406/2016)			
Physical address:	267 KENT AVENUE FERNDALE JOHANNESBURG 2194			
Postal address:	PO BOX 1462 PINEGOWRIE			
Postal code:	2123		Cell:	
Telephone:	(011) 369 0703		Fax:	(011) 886 4589
E-mail:	GERNA.VANJAARSVELD@SMEC.COM			

2. DECLARATION BY THE SPECIALIST

I, GERNA VAN JAARSVELD, declare that –

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

[signature]

Signature of the Specialist

SMEC SOUTH AFRICA

Name of Company:

08/08/2019

Date

3. UNDERTAKING UNDER OATH/ AFFIRMATION

I, GERNA VAN JAARSVELD, swear under oath / affirm that all the information submitted or to be submitted for the purposes of this application is true and correct.

Signature of the Specialist

SMEC SOUTH AFRICA

Name of Company

08/08/2019

Date

Signature of the Commissioner of Oaths

08-08-2019

Date

LISA MARY SMIT
Commissioner of Oaths
Reference: RO-12/02/2019
267 Kent Avenue, Ferndale
Randburg, 2194

Alex Lodenkemper

Professional Engineering Geologist

Professional Overview

Alex is a professionally registered Engineering Geologist (Pr.Sci.Nat) with the South African Council for Natural Scientific Professions (SACNASP). Upon completion of his post graduate studies at Rhodes University, where he specialised in the field of geology, Alex joined WorleyParsons' geotechnical division. During his four year tenure Alex gained experience as an Engineering Geologist conducting geotechnical field investigations; desktop studies; laboratory analyses; geotechnical report writing and the general procurement and management of geotechnical projects. Alex pursued his interest in the geotechnical environment further by starting his MEng (geotechnical engineering) at Stellenbosch University wherefrom he graduated in 2017. During his MEng studies Alex started his own geotechnical consultancy – SustainStability (Pty) Ltd - from which he procured and managed a number of geotechnical projects around the Cape Peninsula as a freelance geotechnical consultant. In 2017 Alex joined SMEC at their Cape Town offices to assist in the development of their geotechnical division. Alex has embraced the SMEC culture with enthusiasm and has procured and undertaken a number of geotechnical investigations whilst at the firm.

Relevant Project Experience

Vlakteplaas Housing Project, Strand, Cape Town, South Africa,| R>800m
Date: August - October 2018
Client: The City of Cape Town
Client Contact Details: Errol van Amsterdam (email: Errol@c2cafrica.co.za)
Description: Geotechnical field investigation of a 130Ha site for the future development of 4500 low cost housing units.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Field investigations according to the NHBRC's generic guidelines for geotechnical investigations for housing developments (Phase 1-2). Investigations included test pitting; profiling; sampling; in situ density testing (DPL) and laboratory results analyses. A geotechnical report was compiled designating the site residential classes with recommendations made on foundations and material utilization on site.

Koeberg Insulator Pollution Test Station, Melkbosstrand, Cape Town, South Africa,| ~R10m
Date: June - August 2018
Client: Eskom Holdings Soc Ltd.
Client Contact Details: Ricardo Davey (email: DaveyRL@eskom.co.za)
Description: Geotechnical field investigation for the development of new laboratory testing facilities and access roads.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Field investigations involving the excavation of test pits, in-situ density (DPL), in-situ permeability and laboratory testing of site soils for determination of utilization in the construction of new access roads and platforms for the proposed laboratory facilities.

Personal Info

- ID Nr.: 890303 5007 084
- Country of Birth: South Africa
- Nationality: South African
- Date joined the Firm: July 2017

Years of Industry Experience

6 Years

Countries of Experience

- South Africa
- Zambia
- Swaziland

Qualifications and Memberships

- MEng Geotechnical Engineering, Stellenbosch University, 2017
- Registered Geologist #3000183257, NHBRC, 2017
- Professional Engineering Geologist (Pr.Sci.Nat #400057/17), SACNASP, 2017
- Registered Member, SAIEG, 2014
- BSc Honours Geology, Rhodes University, 2012
- BSc (Geology & Chemistry), Rhodes University, 2011

Key Skills and Competencies

- Geotechnical Investigations and Reporting
- Supervision of Geotechnical Contractors
- Marketing and Project Procurement
- Project Management
- Field Mapping
- Soil and Rock Profiling
- Material Classification and Utilization
- Rockmass Rating
- Slope Stability Assessments via Kinematic Analyses

Penhill Housing Project, Kuilsriver, Cape Town, South Africa,| >R800m
Date: September 2017 – April 2018
Client: Western Cape Government Department of Human Settlements
Client Contact Details: Peter Sibernagl (email: peter.sibernagle@westerncape.gov.za)
Description: Geotechnical field investigation of a 200Ha site for the future development of 8000 low cost housing units.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Field investigations according to the NHBRC's generic guidelines for geotechnical investigations for housing developments (Phase 1-2). Investigations included test pitting; profiling; sampling; in situ density testing (DPSH) and laboratory results analyses. A geotechnical report was compiled designating the site a residential class with recommendations made on foundations and material utilization on site as well as conducting a detailed settlement analysis and feasibility study.

Wingfield Interchange Project, Cape Town, South Africa,| >R1b
Date: October 2017-January 2018
Client: Western Cape Government Department of Transport
Client Contact Details: Cobus Hendriksz (email: Cobus.Hendriksz@smec.com)
Description: Preliminary geotechnical investigations at six existing bridges and five new bridge localities due for upgrade/construction for one of Cape Town's largest infrastructure projects.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Management and procurement of drilling contractor, full-time on-site supervision and logging of drilling activities, management of traffic accommodation requirements, laboratory sampling. Preliminary investigations included rotary-cored drilling of 19 boreholes at 12 structures. A geotechnical report was compiled for the client with recommendations for piled foundations and material utilization for approach embankments.

Ngabwe Bridge, Central Province, Zambia, | ~R500m
Date: August-December 2017
Client: SMEC International and the Road Development Agency of Zambia
Client Contact Details: Jonathan Adams (email: Jonathan.Adams@smec.com)
Description: Detailed geotechnical investigations for a greenfield bridge crossing the Kafue River.
Role: Lead Engineering Geologist.
Responsibilities: Field investigations included full-time on-site supervision of the drilling contractor on site. Rotary cored boreholes, test pitting, laboratory sampling, SPT and DPSH testing were conducted during field activities. A detailed geotechnical report was compiled for the client detailing piling recommendations as well as foundation requirements for approach embankments.

Kuilsriver Development, Kuilsriver, Cape Town, South Africa, | R10m
Date: July-August 2017
Client: NWE Consulting Engineers
Client Contact Details: Frans Odendaal (email: frans@nweng.co.za)
Description: Geotechnical field investigation for the extension of facilities at Caltex garage in Kuils River.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Field investigations including test pitting; profiling; sampling; in situ density testing and laboratory results analyses. A geotechnical report was compiled with recommendations made on foundations and material utilization on site.

Boys Town Housing Project, Nyanga, Cape Town, South Africa,| >R500m
Date: September-October 2017
Client: Western Cape Government Department of Human Settlements
Client Contact Details: Peter Sibernagl (email: peter.sibernagle@westerncape.gov.za)
Description: Geotechnical field investigation of a 40Ha site for the future development of 1500 low cost housing units.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Field investigations according to the NHBRC's generic guidelines for geotechnical investigations for housing developments (Phase 1-3). Investigations included test pitting; profiling; sampling; in situ density testing and laboratory results analyses. A geotechnical report was compiled designating the site a residential class with recommendations made on foundations and material utilization on site.

Sheffield Housing Project, Phillipi East, Cape Town, South Africa,| R>300m
Date: July-August 2017
Client: The Housing Development Agency
Client Contact Details: Peter Sibernagl (email: peter.sibernagle@westerncape.gov.za)
Description: Geotechnical field investigation of a 10Ha site for the future development of low cost housing.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Field investigations according to the NHBRC's generic guidelines for geotechnical investigations for housing developments. Investigations included test pitting; profiling; sampling; in situ density testing and laboratory results analyses. A geotechnical report was compiled designating the site a residential class with recommendations made on foundations and material utilization on site.

City of Cape Town Chipping Sheds, Cape Peninsula, South Africa, | R100m
Date: June - July 2017
Client: NWE Consulting Engineers
Client Contact Details: Frans Odendaal (email: frans@nweng.co.za)
Description: Detailed geotechnical investigations at four proposed chipping sheds at four landfill sites: Kommetjie; Hout Bay; Wynberg and Gordon Bay.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Detailed field investigations at each chipping shed included test pitting; dynamic in situ density testing and laboratory analysis of soils. A geotechnical report was compiled for each chipping shed with recommendations on foundations; groundwater and material utilization.

Buffeljags Wind Turbines, Buffeljags Abalone Farm Gansbaai, Western Cape, South Africa, | R50m
Date: February – June 2017
Client: EMPA Structures (Raubex Group)
Client Contact Details: Cameron Bain (email: cameron@empa.co.za)
Description: Detailed geotechnical investigation at two newly proposed wind turbine localities at Buffeljags abalone farm.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Field investigations involving test pitting, rotary-cored drilling and rock and soil sampling. Drilling subcontractor procurement, project management, foundation inspections and compilation of a detailed geotechnical report with emphasis on foundation recommendations and material utilization.

Mazeppa Bay to Centane Bridge, Eastern Cape, South Africa,| R150m
Date: 2016
Client: Nonxuba Consulting Engineers
Client Contact Details: Mahomba Nonxuba (email: mahomba@nonxubaconsulting.co.za)
Description: Detailed geotechnical investigation at a newly proposed bridge site.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Detailed rotary cored drilling investigations, procurement and management of subcontractors, laboratory analyses and compilation of a geotechnical report with emphasis on rockmass categorization, foundation recommendations and material utilization from a nearby greenfield dolerite quarry.

Lephalale Landfill, Limpopo, South Africa, | R50m
Date: 2016
Client: Advisian Environmental (WorleyParsons Group)
Client Contact Details: Pieter Kriel (email: pieter.kriel@advisian.com)
Description: Detailed geotechnical investigation for the extension of the current Lephalale landfill.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Field investigations involving test pitting, soil sampling, dynamic in situ density tests, in situ permeability testing and borehole well monitoring. Compilation of geotechnical report with emphasis on material utilization for landfill liner and analysis of site regarding potential for leachate pollution into groundwater.

Tarkastad Quarry, Tarkastad, Eastern Cape, South Africa,| R20m
Date: 2016
Client: SANRAL
Client Contact Details: Bradley Marais (email: bradley.marais@advisian.com)
Description: Reconnaissance and detailed investigation for quarry base and subbase course material for route maintenance along the R61 in the Eastern Cape.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Procurement and management of drilling subcontractor, field investigations involving borehole siting, quarry locating and borehole logging. Compilation of a detailed geotechnical report with emphasis on quarry extension plans, reserve potential and material quality for use as crushed stone aggregate for pavement construction.

Harrogate Office and Workshop, Midrand, Gauteng, South Africa, | R20m
Date: 2016
Client: Harrogate Civil and Construction
Client Contact Details: Sean Rabitte (email: sean@harrogateprojects.co.za)
Description: Detailed geotechnical investigation for a two storey office block and workshop facility.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Field investigations involving test pitting, soil sampling and dynamic in situ density testing. Office site located on residual Halfway House granite, as such the collapse potential across the site was evaluated with emphasis on foundation design; site development and material utilization.

Port Elizabeth Schools, Eastern Cape, South Africa,| >R200m
Date: 2016
Client: Mkhonza Architectural Group
Client Contact Details: Bongani Mkhonza (email: bongani@mkhonzaarchitects.co.za)

Description: Detailed geotechnical investigation at five schools within the Port Elizabeth metropolis.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Field investigations at each school site included test pitting; soil profiling; laboratory sampling; permeability testing and dynamic in situ density tests. Management of subcontractors on site. Compilation of detailed geotechnical report with emphasis on foundation recommendations and material utilization.

Bhisho Office Park, Bhisho East London, Eastern Cape, South Africa, | >R100m
Date: 2015
Client: SKG Property Developers
Client Contact Details: Rhett Shaw (email: Rhett.shaw@skg.co.za)
Description: Detailed geotechnical investigation for an eight storey office structure and two storey basement parking.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Detailed field investigations including test pitting and rotary cored drilling. Management of subcontractors on site; profiling soil and rock; laboratory analyses; rockmass categorization and slope stability assessments. Compilation of detailed report with emphasis on rock stability in cut and foundations for the superstructure.

Sandile to Kenton-on-sea Bulk Water Supply Scheme, Eastern Cape, South Africa,| >R2b
Date: 2015
Client: Aurecon and Amatola Water
Client Contact Details: Pieter Martinson (email: Pieter.martinson@aurecongroup.com)
Description: Newly proposed 190km pipeline route including reservoirs; pipe bridges; borrow pits and quarry investigations.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Management of geotechnical team and subcontractors (plant; laboratory; geophysics and cathodic protection) to conduct detailed investigations along the proposed water pipe centre line. Investigations included a walkover survey; test pitting along pipe centreline (every km); test pitting at structure localities; material prospecting (borrow pits and quarries); geophysical surveying at river crossings and cathodic protection surveys for mitigation of corrosive material. Compilation of detailed geotechnical report with emphasis on pipeline excavatability; foundation recommendations; material utilization for pipe bedding and cathodic protection measures to limit corrosion of the pipeline.

Xhora Bulk Water Supply Scheme, Eastern Cape, South Africa, | >R500m
Date: 2015
Client: Hatch Goba
Client Contact Details: Lindile Mato (email: lmato@hatch.co.za)
Description: Material investigation for pipe bedding source for newly proposed water pipeline as well as reservoir foundation investigations.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Prospecting of eleven borrow pit sites involving reconnaissance investigations; test pitting; laboratory testing and foundation investigations at three newly proposed reservoir sites. Compilation of a detailed geotechnical report highlighting borrow pit reserve potential and material suitability for pipe bedding, as well as foundation recommendations for reservoirs.

Noupoort Wind Farm, Noupoort, Eastern Cape, South Africa, | >R2b
Date: 2015
Client: Murray and Roberts
Client Contact Details: Carol Knickelbein (email: carol@guncrete.co.za)
Description: Detailed foundation inspections of newly excavated wind turbine foundations at Noupoort wind farm.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Inspection of exposed rock in wind turbine foundation excavations. Sign-off on bases after inspection so that foundations could be constructed.

Asidi 2nd Batch Schools, Eastern Cape, South Africa, | >R500m
Date: 2014
Client: NN Architects
Client Contact Details: Bongani Mkhonza (email: bongani@mkhonzaarchitects.co.za)
Description: Six newly proposed schools located across the Eastern Cape.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Detailed field investigations at each school site included test pitting; soil profiling; laboratory sampling; permeability testing and dynamic in situ density tests. Management of subcontractors on site. Compilation of detailed geotechnical report with emphasis on foundation recommendations and material utilization.

Kempston Motor City Development, East London, Eastern Cape, South Africa, | R50m
Date: 2014
Client: Kempston Group
Client Contact Details: Wesley Norris (email: wesley.norris@kempston.co.za)
Description: Newly proposed motor city development in East London.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Detailed field investigations included test pitting; soil profiling; laboratory sampling and dynamic in situ density tests. Management of subcontractors on site. Compilation of detailed geotechnical report with emphasis on foundation recommendations and material utilization.

Grahamstown Housing Development, Eastern Cape, South Africa, | >R300m
Date: 2014
Client: Belmont Development Company
Description: Conversion of old Grahamstown golf course to a housing development comprising of 600 middle income units as well as a shopping centre.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Detailed field investigations across the property as per NHBRC guidelines for housing developments. Compilation of a detailed geotechnical report with emphasis on the zoning of the site according to site class designations with recommendations made on foundations and material utilization.

Coffee Bay RDP Housing, Eastern Cape, South Africa, | >R150m
Date: 2014
Client: Summerlane Trading
Client Contact Details: Louis Coetzer (email: louisc@summerlanetrading.co.za)
Description: Development of 60 new residential low cost housing units in the Transkei.
Role: Geotechnical project manager and lead Engineering Geologist.

Responsibilities: Detailed field investigations as per NHBRC guidelines for housing developments. Compilation of a detailed geotechnical report with emphasis on the zoning of the site according to site class designations with recommendations made on foundations and material utilization.

Steve Biko Building, Port Elizabeth, Eastern Cape, South Africa, | >R100m
Date: 2014
Client: Qhama Housing Development
Description: Detailed geotechnical investigation for a ten storey apartment building in the Port Elizabeth CBD.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Detailed field investigations including rotary-cored drilling, dynamic in situ density testing and laboratory analyses. Management of subcontractors on site; profiling soil and rock boreholes; laboratory analyses; rockmass categorization and slope stability assessments. Compilation of detailed report with emphasis on soil and rock stability in cut and foundations for the superstructure.

Ncera Macadamia Nut Irrigation Project, East London, Eastern Cape, South Africa, | >R200m
Date: 2014
Client: Aurecon
Client Contact Details: Tiaan Nel (email: Tiaan.Nel@aurecongroup.com)
Description: Detailed geotechnical investigation for the Nerca irrigation pipeline; reservoirs; pump stations, balancing dam and new roads.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Detailed field investigations including test pitting along pipe centreline and new structures; dynamic in situ density testing; geophysical surveying and material prospecting for gravel wearing course and pipe bedding material. Compilation of detailed geotechnical report with emphasis on pipeline excavatability; structure foundations; material utilization and suitability of material sources for utilization in pavement design and as pipe bedding.

Matatiele Bulk Water Supply, Eastern Cape, South Africa, | >R500m
Date: 2014
Client: Hatch Goba
Client Contact Details: Lindile Mato (email: lmato@hatch.co.za)
Description: Detailed geotechnical investigations for existing and newly proposed water pipeline network in Matatiele and surrounding areas including material prospecting and investigations at new reservoirs and pump stations.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Management of geotechnical team and subcontractors (plant and laboratory) to conduct detailed investigations along proposed water pipe centre lines and new structures. Investigations included a walkover survey; test pitting along pipe centrelines (every km); test pitting at structure localities and material prospecting (borrow pits. Compilation of detailed geotechnical report with emphasis on pipeline excavatability; foundation recommendations and material utilization for pipe.

Caca Dam, Eastern Cape, South Africa, | >R800m
Date: 2014
Client: Hatch Goba
Client Contact Details: Lindile Mato (email: lmato@hatch.co.za)
Description: Newly proposed earth embankment dam located in the Transkei.
Role: Lead Engineering Geologist.
Responsibilities: Detailed geotechnical investigation including test pitting; drilling and geophysical surveying. Test pitting was conducted within the proposed reservoir footprint to locate suitable material for use as earth dam core and shell material. Borrow pits and quarries were also prospected for rip rap; gravel wearing course; crushed stone aggregate and earth dam material. The foundations of the dam wall were evaluated by inspecting borehole logs and geophysical data. Recommendations were made in the geotechnical report with emphasis on foundations; material utilization and site development.

N2 Upgrades between Grahamstown and the Great Fish River Pass, Eastern Cape, South Africa, | >R1b
Date: 2014
Client: PDNA and Bosch Stemele JV/ SANRAL
Client Contact Details: Gary Hughes (phone: +27 (0) 437210135).
Description: The upgrading of national route (N2) section 13 and section 14.

Role: Lead Engineering Geologist.
Responsibilities: Detailed geotechnical investigations including material prospecting for base and subbase material at twenty potential borrow pit sources and eleven potential quarry sources as well as detailed evaluation of four cuttings. Cutting investigations included slope stability evaluations with recommendations made for slope stability designs. Management of subcontractors (drillers, lab and plant) on site.

Katberg GWC Road Upgrade, Katberg Golf Estate, Eastern Cape, South Africa, | R100m
Date: 2014
Client: Eastern Cape Department of Roads and Public Works
Description: The upgrading of the 13km long gravel wearing course road leading to Katberg.
Role: Lead Engineering Geologist.
Responsibilities: Detailed geotechnical investigations along the road centreline including test pitting; sampling; dynamic cone penetrometer testing and laboratory analyses. Compilation of the geotechnical report with emphasis on material utilization and CBR strength for new pavement design.

Milani Link Road, Mount Fletcher, Eastern Cape, South Africa, | >R200m
Date: 2014
Client: Masilakhe Consulting Engineers
Client Contact Details: Mandisi Masilakhe (email: mandisi@masilakhe.co.za)
Description: Greenfield gravel wearing course road linking two rural towns near Mount Fletcher.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Detailed geotechnical investigations along the newly proposed road centreline including test pitting; sampling; dynamic cone penetrometer testing and laboratory analyses. The 5km stretch of road traversed steep and windy slopes and as such detailed evaluations were made on slope stability in cut. Borrow pits and quarries were also prospected for. Compilation of the geotechnical report with emphasis on material utilization, CBR strength for new pavement design and slope stability analyses.

Foxwood Dam, Adelaide, Eastern Cape, South Africa, | >R1b
Date: 2013
Client: Arup and Amatola Water
Client Contact Details: James Bristow (email: james.bristow@arup.com)
Description: Newly proposed earth embankment dam located in Adelaide in the Eastern Cape.
Role: Geotechnical project manager and lead Engineering Geologist.
Responsibilities: Detailed geotechnical investigation including test pitting; drilling and geophysical surveying. Test pitting was conducted within the proposed reservoir footprint to locate suitable material for use as earth dam core and shell material. Borrow pits and quarries were also prospected for rip rap; gravel wearing course; crushed stone aggregate and earth dam material. The foundations of the dam wall were evaluated by inspecting borehole logs and geophysical data. Recommendations were made in the geotechnical report with emphasis on foundations; material utilization and site development.

Professional History

July 2017 – Present: SMEC Cape Town – Professional Engineering Geologist

December 2016 – June 2017: SustainStability – Director & Professional Engineering Geologist

December 2015 – December 2016: WorleyParsons Cape Town – Candidate Engineering Geologist

February 2013 – November 2015: WorleyParsons East London – Candidate Engineering Geologist

Courses & Conferences attended

2018: University of Pretoria - In-situ testing for Geotechnical and Tailings Applications Course
2017: Young Geotechnical Engineers – 9th Triennial YGE Conference
2017: Institution of Civil Engineers – ICE Africa Regional Conference
2017: Stellenbosch University – Applied Foundation Design and Applied Geomechanics Course
2016: Stellenbosch University – Pavement Materials, Soil Behaviour and Advanced Geotechnics Courses
2016: University of Cape Town – Geosynthetics Engineering Course
2014: Maccaferri – Rockfall Hazard Mitgation, River Protection, Geosynthetics and Soil Reinforcement Techniques

2014: Young Geotechnical Engineers – 8th Triennial YGE Conference
2013: Kaytech – Geosynthetics Course

Publications & Papers presented

September 2017: The viability and feasibility of using recycled concrete and masonry aggregates in the pipe laying industry. Presented at YGE 9th Triennial Conference.

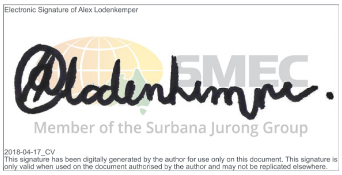
Language Skills

Mother Tongue: English

Languages	**Speak**	**Read**	**Write**
English	Excellent	Excellent	Excellent
Afrikaans	Fair	Fair	Fair
German	Fair	Fair	Fair

Certification

I, the undersigned, certify that to the best of my knowledge and belief, this CV correctly describes my qualifications, my experience, and myself. I understand that any wilful misstatement described herein may lead to my disqualification or dismissal, if engaged.



Date: **29-01-2019**

(Signature of staff member or authorised representative of the firm) *Day/Month/Year*

Full name of staff member: **Alex Lodenkemper**

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1. INTRODUCTION

1.1 Background and Project Description

Arcus Consulting have been appointed by Paulputs Wind Energy Facility (RF) (Pty) Ltd to conduct an environmental impact assessment (EIA) for the proposed Paulputs wind farm. As part of the EIA report Arcus requires a geotechnical desktop study of the wind farm footprint. Together the studies will fulfil the Department of Environmental Affairs (DEA) requirements in terms of ascertaining the pre-feasibility of the project. The proposed wind farm is located along national route N14 and is approximately 40 km east of Pofadder (**Figure 2.1**).

1.2 Terms of Reference

Arcus Consulting appointed SMEC South Africa (Pty) Ltd. on 14 January 2019 to provide professional geotechnical services in accordance with SMEC's geotechnical proposal, 1815EB, dated 28 November 2018.

The geotechnical appointment forms part of the pre-feasibility of the project and comprises a desktop study of the proposed area for development.

1.3 Objectives and Methodology

The objectives of the desktop study are:

- Identification of regional and local geological conditions
- Review of site topography and climate and their influence on rock decomposition and subsequent soil formation
- Provide insight into the perceived geotechnical conditions of the site (viz. foreseeable soil formations, depth and quality of underlying rockmass)
- Identify any inherent fatal flaws that may impact the proposed development, with respect to the geology and geotechnical conditions that are expected on the site
- Comment on the feasibility of the wind farm development from a geotechnical perspective

The following methodology was adopted to realise the objectives of the investigation:

- Review of available geological records including 1:250 000 geological maps and 1:50 000 topographic sheets
- Evaluation of SMEC's geotechnical database of projects conducted near the site and within similar geotechnical zonations/ geological sequences
- Review and assessment of appropriate geotechnical/ geological references to assess the anticipated conditions of the proposed site

1.4 Codes of Practices and Standards

SMEC used the following standard practice codes and guideline documents in performing this investigation:

- Site Investigation Code of Practice. SAICE Geotechnical Division (2010)
- Eurocode 7: Geotechnical Design Part 1: General Rules. European Committee for Standardisation (2004)
- Probability of Risk of Slope Failure. Silva et al (2008)

1.5 Limitations of Assessment

The services performed by SMEC South Africa (Pty) Ltd. were conducted in a manner consistent with the level of care and skill ordinarily exercised by members of the geotechnical profession practising under similar conditions for the requirements of a geotechnical desktop evaluation (SAICE, 2010). This desktop report is based on data obtained from a limited number of sources, including geological records, topographic maps, aerial imagery and geotechnical and geological literature available for the greater Pofadder region. The nature of geotechnical engineering is such that variations in soil and rock conditions may occur even where sites seem to be consistent. Variations in what is reported here will become evident during site investigation and construction. It is imperative that potential variations in geological and geotechnical conditions described herein are delineated via preliminary and detailed geotechnical investigations of the subject site.

It is noted, that on a conceptual basis, the current project may be considered as a Category 4 project (Silva et al, 2008) requiring desktop study equivalent information to determine the pre-feasibility of the project. However, once the project progresses to preliminary and thereafter to detailed design it will then class as a Category 2 and Category 1 project respectively requiring equivalent geotechnical input. Thus, to lower the probability of failure of the final designed structures, as well as to avoid over-design to compensate for tolerable risk, a detailed geotechnical investigation of the site must be considered mandatory as the project approaches Category 2 and 1 status. This philosophical approach forms the basis of Eurocode 7 (2004) where geotechnical design and structural design go hand-in-hand. Thus, this desktop evaluation report will culminate with recommendations for detailed geotechnical investigations that will provide the engineer with the necessary parameters for detailed design purposes.

This report has been prepared for the exclusive use of Arcus Consulting and their Client: Paulputs Wind Energy Facility (Pty) Ltd. with specific application to the Paulputs Wind Farm Project. Intellectual property rights associated with this report remain with SMEC South Africa (Pty) Ltd.

2. SITE CHARACTERISATION AND LITERATURE REVIEW

2.1 Site Location

The proposed Paulputs wind farm is located 40 km east of Pofadder (**Figure 2.1**) in the Northern Cape Province. Client supplied Google Earth imagery indicates that the wind farm is bisected by national route N14 and occupies approximately 12 500 Ha of undeveloped land.

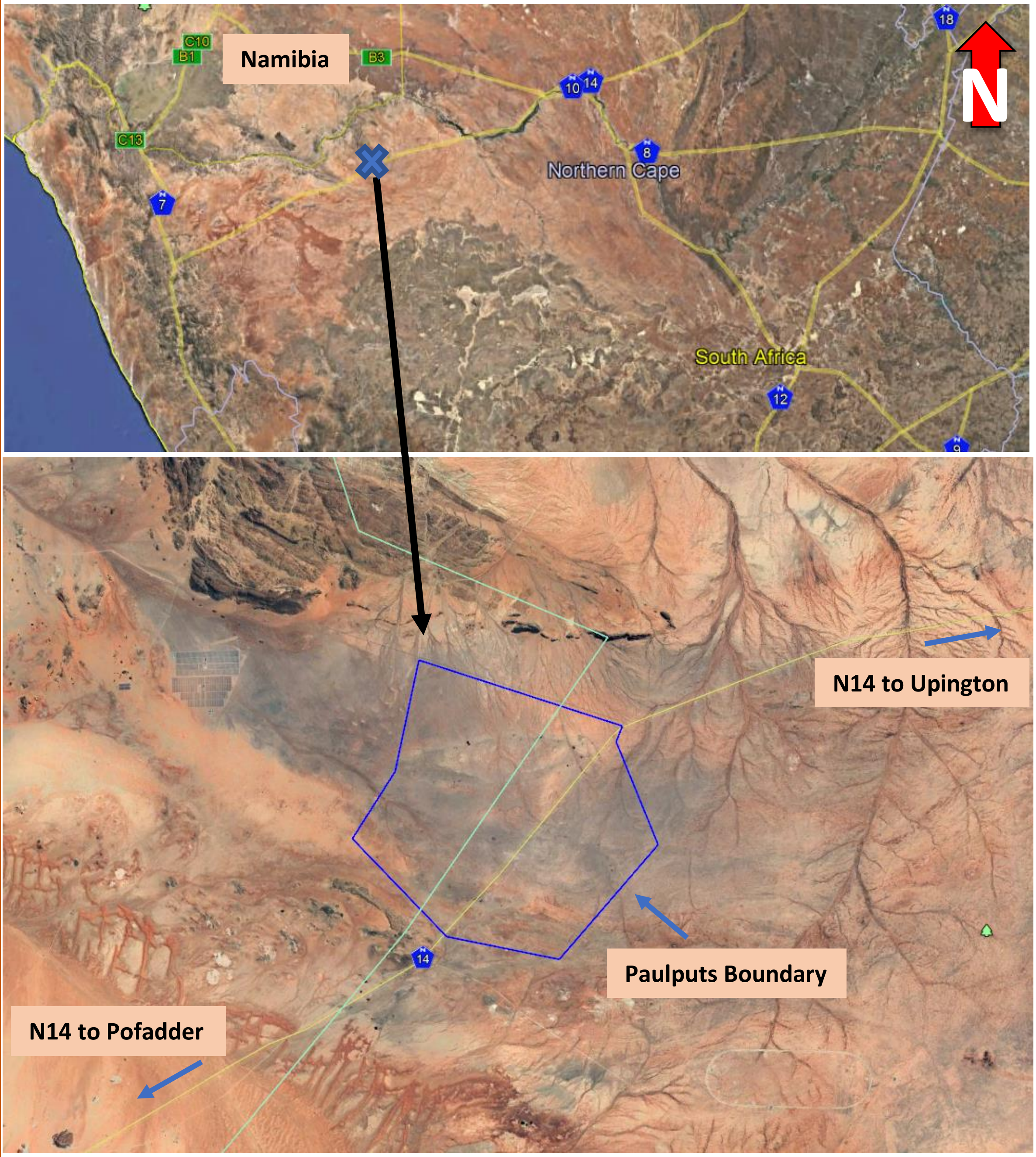


Figure 2.1: Paulputs Wind Farm Locality Plan

2.2 Climate

Climatic data available for Pofadder, indicates that the portion of the Northern Cape in which the wind farm is proposed experiences an arid climate, comprising hot; dry summers and cool; very dry winters. Climatic data available from January 2009 to December 2018 indicates that the average maximum daily temperatures vary from 34˚C in January to 18˚C in July (WWO, 2019). Corresponding average minimum temperatures for these months are 24˚C and 8˚C, respectively (**Figure 2.2**). The mean annual precipitation over this ten-year period is approximately 108 mm per annum, falling mainly during the summer months (**Figure 2.3**) due to low pressure systems developing over the hot arid landscape which draw cooler moist air from the coastline, resulting in periodic and brief thunder showers.

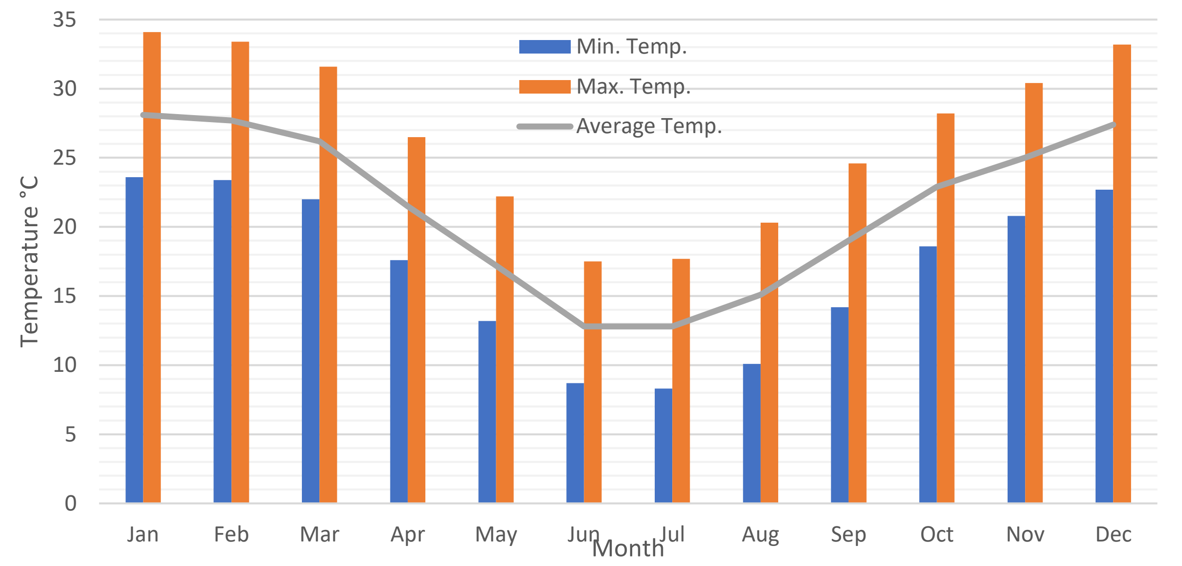


Figure 2.2: Monthly Temperature Fluctuations – Pofadder

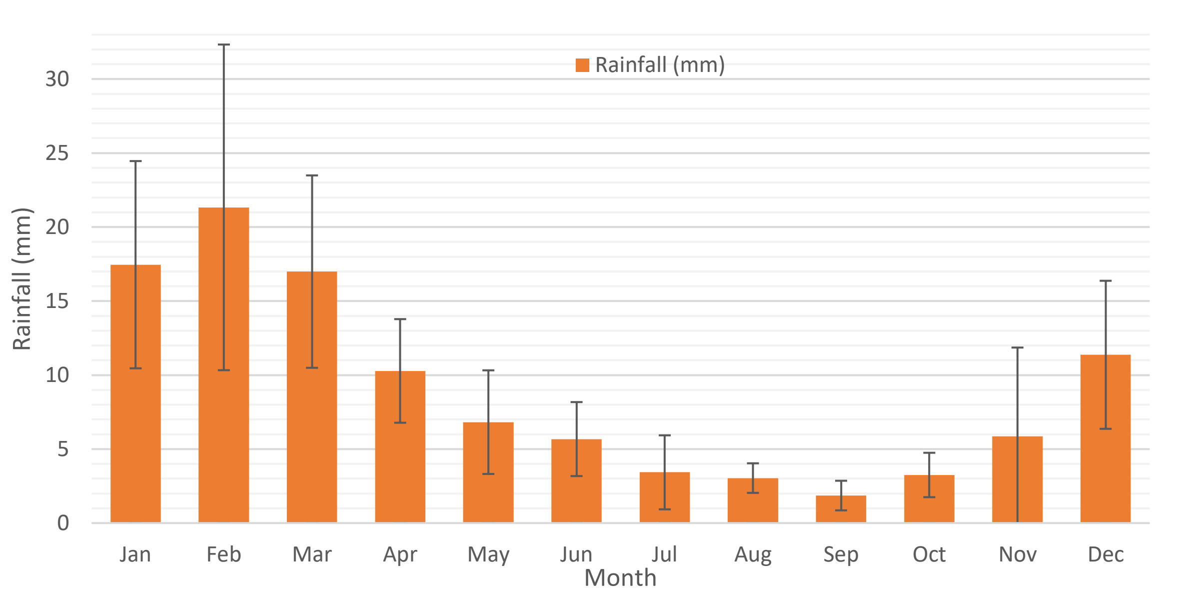


Figure 2.3: Monthly Rainfall Fluctuations – Pofadder

Climate is a pivotal factor for geotechnical considerations as it determines the mode and rate of rockmass weathering and thus the formation of soils. The effect of climate on the weathering process can be empirically derived from the climatic N-value as defined by Weinert (1980). The approximate N-value for the Pofadder area is in the range of 40 - 50, which indicates that evaporation far exceeds precipitation and that in general the region lacks surface water.

This indicates that, although chemical decomposition of rockmasses may occur in localities where water may be abundant (viz. preferential drainage paths such as fault and joint planes), mechanical disintegration of rockmasses is the predominant weathering mechanism in Pofadder and surrounds.

2.3 Topography, Drainage and Vegetation

Satellite imagery and available topographic data (map sheets 2819 DD, 2820 CC, 2919 BB, 2920 AA) indicate that the Paulputs wind farm is located on flat topography with a shallow downward inclination (less than 5°) in a north/ north - west direction towards the Orange River. Major drainage paths, all of which are non-perennial, are located east, west and south of Paulputs. **Figure 2.4** portrays conceptually that any rainfall that does occur in the area is drained from rather than into the boundaries of Paulputs.

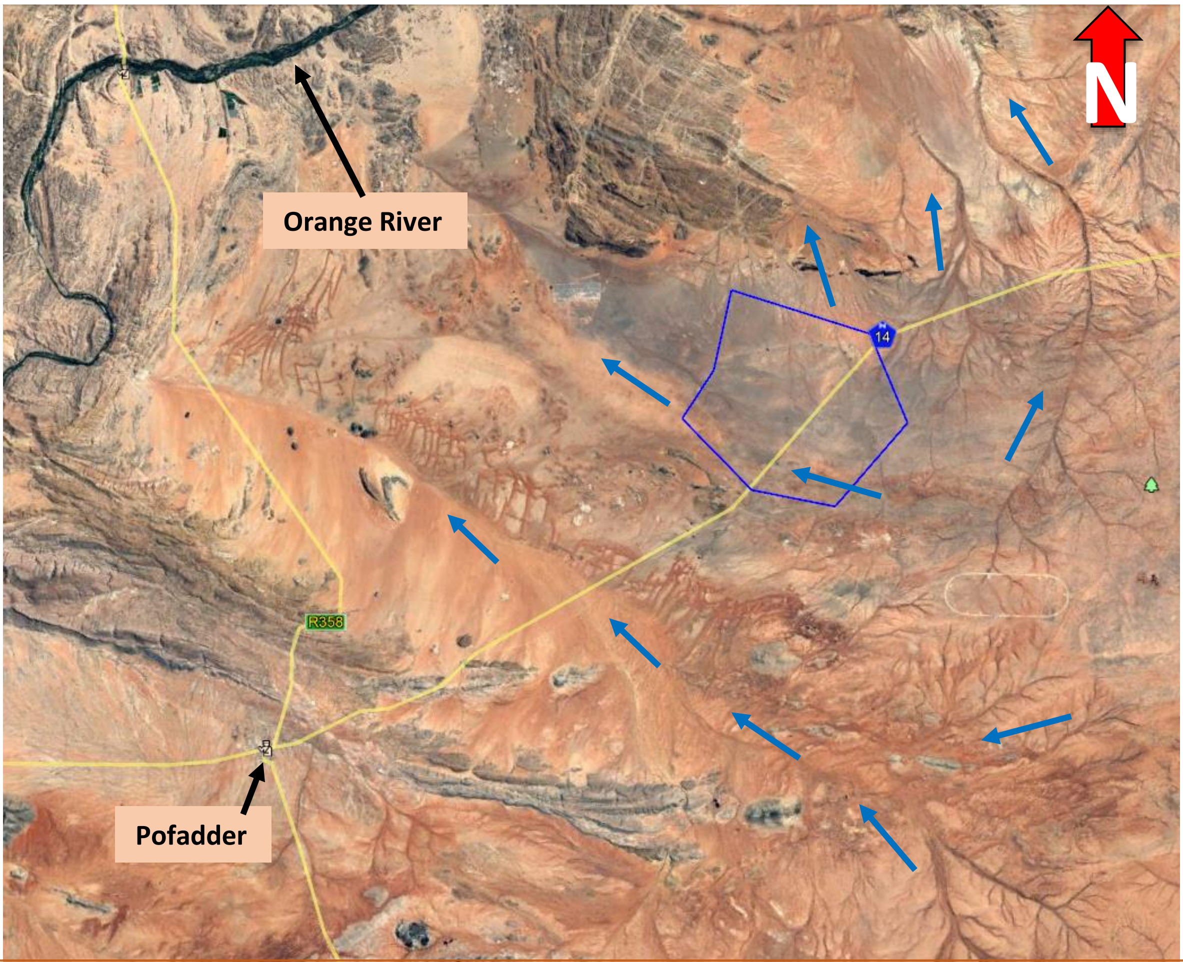


Figure 2.4: Notable Drainage Lines - Paulputs

Vegetation cover in the area is thinly developed and comprises of Bushmanland Arid Grassland in the low lying and flat areas whereas Lower Gariep Broken Veld vegetation is more common in the highland areas (Mucina et al, 2005). Grassland and small thorny shrubbery is typical along drainage paths.

Localised thundershowers typical in the region combined with sparse vegetation suggest that the area is prone to rapid and turbulent runoff in the highland whilst slower sheet wash is expected in the lowland.

2.4 Geology

The greater Pofadder area, including Paulputs, is underlain by the tectono-stratigraphic Namaqua-Natal Metamorphic Province which comprises of igneous and metamorphic rocks formed or metamorphosed during the mesoproterozoic Namaqua Orogeny (Cornell et al, 2006). Numerous tectono-stratigraphic terranes exist within the greater Namaqua-Natal Metamorphic Province which are bounded by shear zones. Cornell et al (2006) identify three primary lithostratigraphic components that make up the terranes:

i. Reworked basement rocks

ii. Juvenile supracrustal and plutonic rocks assembled and metamorphosed during rifting and subduction events

iii. Extensive granitoid batholith intrusions

The latter two are of prime interest in this desktop study forming the basis of rocks anticipated below the proposed wind farm. Paulputs may be underlain by two terranes, comprising lithostratigraphic unit (ii) which has been intruded by lithostratigraphic unit (iii). The two terranes and their prime lithological units (Cornwell et al, 2006) are as follows:

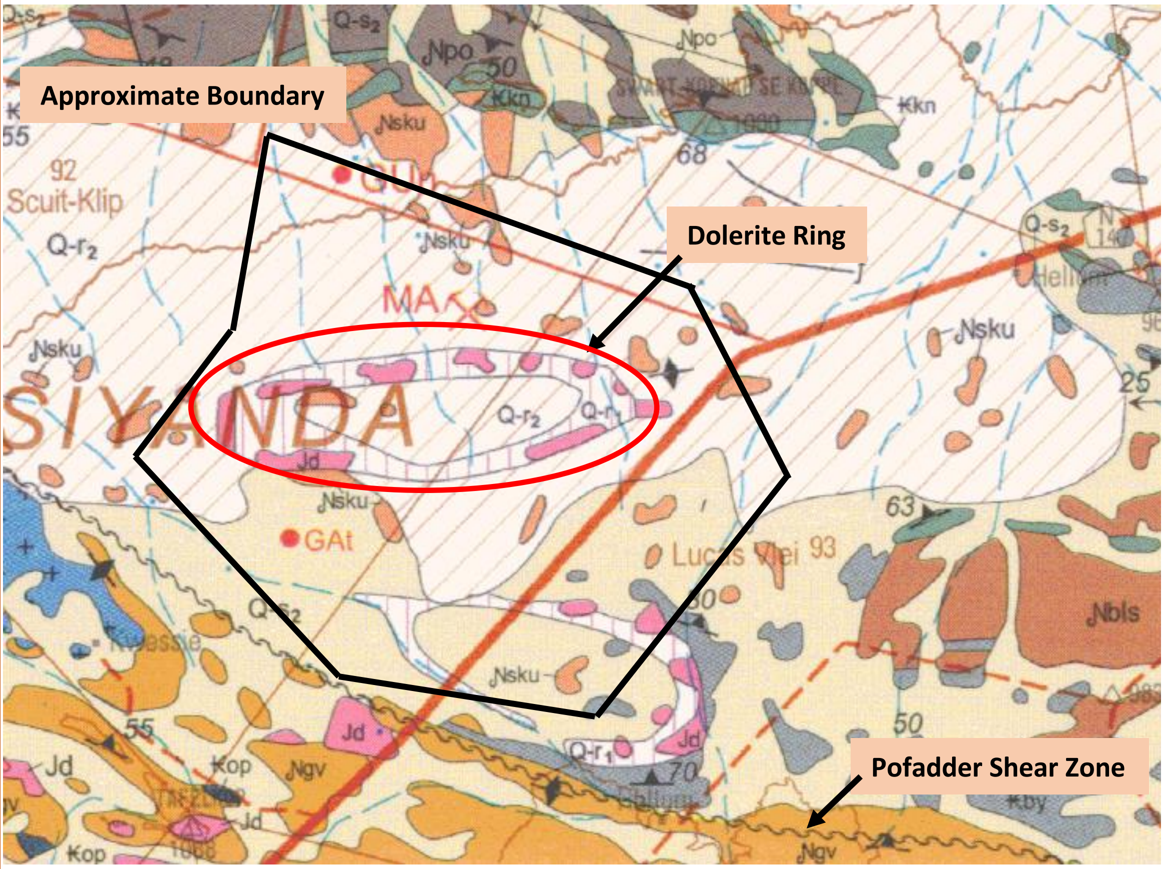
i. <u>Namaquan Period: Richtersveld Subprovince:</u> comprising low to medium grade metamorphosed volcano-sedimentary sequences and extensive granitoid intrusions

ii. <u>Namaquan/ Kheisian Period: Bushmanland Terrane</u>: comprising medium to high grade gneisses, volcano-sedimentary sequences and granitoid intrusions

A review of the geological map of Onseepkans (map series 2818, 1:250 000 scale) indicates that Paulputs is underlain by the Richtersveld Subprovince. An extract of this map, indicating the site, is shown in **Figure 2.5** overleaf. The stratigraphic units anticipated within the boundaries of Paulputs include Bladgrond and Gemsbokvlakte gneiss and Skuitklip granite all of which have been intruded locally by younger dolerite dykes. Overlying these predominantly intrusive rock types are quaternary age surficial clayey/ sandy soils and gravels. These soils are predominant in the low lying regions and primarily comprise of in-situ residual derivatives of the granite and dolerite rocks or transported versions thereof. Whereas soils on the nearby foothills and mountain slopes are primarily disintegrated debris from the mechanical weathering of their parent rockmass.

Due to intense temperature fluctuations and sporadic/ sudden precipitation in the area, localised cementation of calcareous minerals and oxidation of ferrous minerals has occurred in these surficial deposits resulting in nodule formation, weakly cemented/ oxidised soils and/ or calcrete and ferricrete hardpan (pedocretes).

Figure 2.5. Extract from Onseepkans (2818) Geological Map



Symbol	Stratigraphy	Lithology	Lithostratigraphic Origin
Q-r1	Quaternary Deposits	Brown clayey, partly calcretised soil	Residual Dolerite
Q-r2		Coarse pink feldspathic gravel	Residual Granite
Q-s2		Red sand, scree, gravelly and sandy soil	Transported Hillwash
J-d	Intrusion	Dolerite	Jurassic Intrusion
Nsku	Skuitklip Granite	Coarse, megacrystic biotite granite	Granitoid Intrusion
Ngv	Gemsbokvlakte Gneiss	Medium grained leucocratic gneiss	Metamorphosed Plutonic
Nbls	Bladgrond Gneiss	Medium grained leucocratic granite gneiss	Metamorphosed Plutonic

2.5 Seismicity

South Africa is located on the African Tectonic Plate which, in comparison to other tectonic plates, is fairly stable with low degrees of movement. Much of the African Plate – except the East African Rift Zone – can be considered to be a zone of low tectonic activity. This does not suggest that no seismic activity occurs but rather that the probability of same is much lower. Seismic hazard is represented by the peak horizontal ground acceleration (PGA) of any particular area: the greater the PGA the greater the probability of seismic activity.

Seismicity data compiled by the Council of Geoscience (2011) provides probable ground accelerations for South Africa based on historic earthquake activity (**Figure 2.6**). This data reveals that Paulputs is situated within an area of medium (light pink) susceptibility to seismic activity. The seismic activity is categorized as strong (degree VI) in terms of the modified Mercalli scale which suggests that the region is susceptible to peak horizontal ground accelerations of 0.5 – 1.0 m/s^2. This level of seismicity is indicative of a 10 % probability of exceeding the peak ground acceleration in a 50 year period.

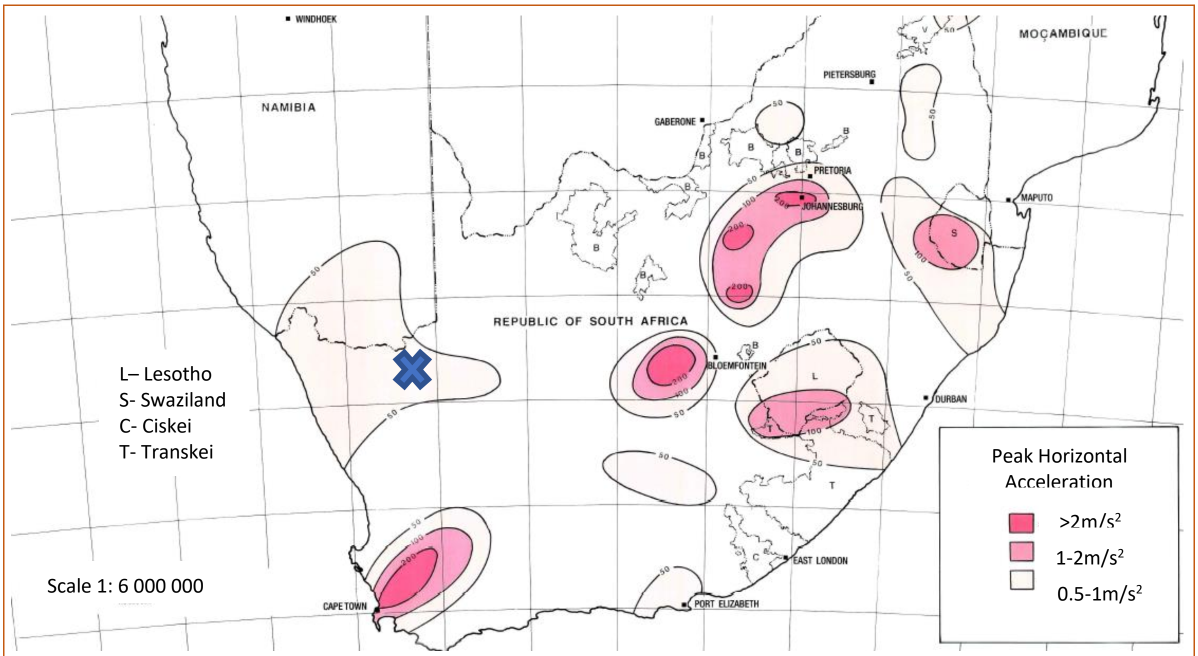


Figure 2.6: Seismicity Map of South Africa (CGS, 2011)

The degree of seismicity anticipated at Paulputs is in general higher than most parts of South Africa and is likely due to the numerous shear zones that separate the Namaqua-Natal Metamorphic Terranes. As depicted in **Figure 2.5** Paulputs is located adjacent to the Pofadder Shear Zone (PSZ) and thus the degree of seismicity in the surrounding area is likely attributed to sporadic shifts in pressure along this shear zone. Paulputs' vicinity to the PSZ, with associated probability of seismic activity, warrants the consideration of appropriate seismic load factors in the design of the proposed wind turbine structures. For this purpose a g-factor of no less than 0.1 should be considered at this pre-feasibility stage.

2.6 Previous Investigations

SMEC have historically conducted geotechnical investigations near Paulputs, namely in the towns of Kakamas and Aggeneys located 70 km and 90 km from the site respectively. Although these sites are located a fair distance from Paulputs, the geological units are similar and are also part of the Namaqua-Natal Metamorphic Province. Thus, at this pre-feasibility stage, the investigations undertaken in these geological units may provide:

i. Type, depth and extent of surficial soil deposits expected at Paulputs

ii. A high-level indication as to the variability and depth of rockmass weathering in the region, and

iii. The extent of investigations required to fully explore the anticipated variability in rockmass and soil lithologies

Pertinent information obtained from previous geotechnical investigations (SMEC database report references # 641 and # 642) are summarised hereunder:

2.6.1 Surface and Subsurface Investigations at the Proposed Plant Site at Aggeneys, Northern Cape Province

Investigations were undertaken by SMEC (then VKE Consulting Engineers) in March 1975. These investigations involved test pitting, seismic refraction surveying and percussion borehole drilling. The results of the investigations revealed the following:

i) On average in excess of 3 m of overburden soil comprising of clayey sands and gravels with occasional pebbles and cobbles

ii) Localised calcite carbonation and iron oxidation resulting in weakly cemented calcretised and ferric soils with nodules and minor hardpan

iii) Highly variable rock depth (from surface outcrop to 50 m below ground level) due to variable nature of metamorphic sequences

iv) Bedrock generally comprised moderately weathered, medium hard rock gneiss. Where located at depth the rock was overlain primarily by transported soils (gulley wash fan deposits) with minimal residual overburden

v) Calcrete and ferricrete cementation limited effects of seismic refraction and thus gravity surveying techniques are more preferential

vi) Weak cementation of transported sand and gravel deposits infers high susceptibility to collapse settlement

vii) High degree of soluble salts in transported deposits infers high corrodibility towards buried foundations

viii) Surrounding rock outcrops (primarily dolerite, granite, quartzite and amphibolite) provide ample and good sources for construction material)

3. GEOTECHNICAL EVALUATION

3.1 Proposed Development

It is proposed that the Paulputs farm be developed into a wind farm. At this pre-feasibility stage the exact quantity and type of turbine structures are not known, however taking the size of the area (approximately 12 500 Ha) into consideration it is estimated that no less than 85 no. turbines will be planned for construction as well as associated ancillary infrastructure.

Typical wind farms in South Africa comprise circular concrete foundations often in excess of 20 m in diameter that support tower masts between 80 – 120 m in height. For the Paulputs wind farm it is proposed that 140 m hub heights be utilised. These structures will not only impose high bearing loads, but also moment and cyclic loads, due to forces generated by the rotating blades. These loads need to be accommodated by the supporting substrate and thus require significant foundations that work in unison with the underlying geology. It is on this premise that the geotechnical evaluation hereunder and recommendations for further geotechnical investigations have been made.

3.2 Conceptual Geotechnical Model

A review of the South African Geology, with emphasis on the Namaqua-Natal Metamorphic Province, as compiled by Johnson et al (2006) has been discussed in detail under Section 2.4. Via desktop review of past geotechnical investigations it has been established that the geological lithologies, as depicted by the Council of Geoscience's geological map series, can be confirmed on site and that the perceived geological lithologies at Paulputs are intrusive and metamorphosed rocks comprising of granite, dolerite and gneiss respectively. The predominant mineral assemblages for granite and gneiss are quartz and feldspar, whilst dolerite is comprised predominantly of only feldspar.

Weinert (1980) discusses the genesis of soil via the effects of topography and climate on the mineral assemblage of rocks. Quartz is a robust mineral as it crystallizes at low temperature-pressure intervals and thus, when exposed to surface pressure and temperature, is able to resist the effects of chemical decomposition and mechanical disintegration. When quartz does breakdown via mechanical means it forms gravelly and sandy soil deposits. Feldspar however, has two derivatives, orthoclase and plagioclase, both of which crystallize at higher temperature-pressure intervals and thus are both more susceptible to the effects of weathering.

In low climatic N-value regions and/ or areas of poor drainage the chemical disintegration of feldspars produces clay (Weinert, 1980). Given that granite and gneiss comprise predominantly of quartz and feldspar the residual soil derivatives of these rocks are thus clayey sandy soils. Whereas, the residual derivatives of dolerite are more clay-rich soils. Paulputs is however, located in a region of high climatic N-value thus, thick residual soil horizons and clay deposits are not anticipated on site where these receive good drainage. Nevertheless, this does not preclude to the fact that these deposits may occur where drainage stagnates and water accumulates (viz. low lying areas, shear zones and contacts between differing rock types). Rather the Paulputs site is likely to be underlain by relatively shallow rockmass however, with localities underlain by thick transported soils (within troughs of locally undulating rockmass).

It is well established (Brink, 1981; Schwartz, 1985) that these residual and transported soils often comprise of a collapsible soil structure whereby colloidal particles (clay, cemented/ oxidized minerals) bridge open gaps between loosely packed soil particles. This phenomenon was observed during previous investigations conducted in Aggeneys (SMEC reports #641 and #642) and thus will be a key feature to observe at Paulputs.

A review of **Figures 2.4** and **2.5** reveal some important points:

i) The majority of the site and, in general the central portion, appears to be underlain by dolerite which has intruded granite parent rockmass

ii) The site borders the Pofadder Shear Zone

iii) There is a notable drainage lining bisecting the southern portion of the site (running roughly east to west), and

iv) There is a notable drainage line along the northern portion of the site (running roughly south to north)

Based on these observations and literature offered, the following geotechnical model for the site is conceptualised:

3.2.1 Northern Boundary

- Zonation 1 (potentially collapsible): predominantly thick (viz. >5 m) horizons of transported sandy and gravelly soils with weakly cemented/ ferruginised pedocrete lenses, underlain by
- Zonation 2 (potentially collapsible): thin horizon of residual clayey sand/ gravel, underlain by
- Zonation 1: undulating weathered granite rockmass

3.2.2 Central

- Zonation 1: localised dolerite outcrops at surface with associated boulders directly underlain by highly weathered rock derivatives (contact zone between granite and dolerite)
- Zonation 2 (potentially collapsible): where dolerite is not at surface anticipate relatively thin (viz. >3 m) transported clayey sand/ gravelly soils with weakly cemented/ ferruginised pedocrete lenses, underlain by
- Zonation 3: highly to moderately weathered rockmass at interface between dolerite and granite

3.2.3 Southern Boundary

- Zonation 1 (potentially collapsible): predominantly thick (viz. >10 m) of transported sandy and gravelly soils with weakly cemented/ ferruginised pedocrete lenses, underlain by
- Zonation 2 (potentially collapsible): thin horizon of residual clayey sand/ gravel, underlain by
- Zonation 3: deep seated and undulating weathered granite rockmass. Anticipate highly fractured rockmass and high degree of weathering due to Pofadder Shear Zone

3.3 Concerns Regarding Site Development

The greatest geotechnical concerns towards the proposed turbine structures are highlighted hereunder. These concerns will form the objective of further geotechnical investigations for preliminary and detailed design of the structures.

i) Thickness and variability in consistency of transported and residual soil horizons

ii) Collapse and high settlement potential of transported and residual soil horizons

iii) Density/ stiffness of pedocrete lenses and influence on founding solutions

iv) Extent of residual soil and degree of rockmass weathering at zones where dolerite has intruded granite

v) Extent of rockmass fracturing and weathering along the southern boundary near the Pofadder Shear Zone

vi) Depth to and undulating nature of foundation rockmass across the site as a whole

vii) Extent of influence of Pofadder Shear Zone on local geology and seismicity

3.4 Conceptual Foundation Solutions

Provided hereunder are possible foundation solutions for the geotechnical model conceptualised for the site. These solutions are conceptual in nature, however have been incorporated in foundation design of turbines under similar geotechnical conditions. It should be noted that possible foundation solutions be reaffirmed after the necessary geotechnical site investigations.

3.4.1 Northern Boundary

- Option 1: soil improvement via dynamic compaction (breakdown collapsible soil structure) inclusive of local soil reinforcement
- Option 2: localised soil improvement/ reinforcement and enlarged gravity foundations
- Option 3: localised soil compaction with stiffened raft solution and concrete platform

3.4.2 Central

- Option 1: deep-seated foundations on suitable (R3 or greater) rockmass horizon
- Option 2: localised soil improvement/ reinforcement and enlarged gravity foundations

3.4.3 Southern Boundary

- Same options as Northern boundary with one other: piled foundation solution

3.5 Geotechnical Feasibility of Project

Based on geological and geotechnical information obtained for Paulputs and interpretation thereof, there appears to be no geotechnical reason for the wind farm development not to proceed.

Foundation solutions appropriate for the site's anticipated geotechnical conditions can be conceptualised and are provided. SMEC cannot comment on the overall feasibility of the project however, from a geotechnical point of view the project can surpass pre-feasibility stage and move to feasibility level investigations.

4. FURTHER GEOTECHNICAL INVESTIGATIONS

This desktop evaluation has been compiled for pre-feasibility purposes only, thus the information presented here will be suitable for a Category 4 project whereby a probability of failure, no matter the designed factor of safety, will be greater than 1 in 100 (Silva et al, 2008). Thus, for economic design, and to reduce the probability of failure of the proposed wind turbine structures at Paulputs, preliminary and detailed geotechnical field and laboratory work will be required for engineering design. This will elevate the development to Category 2 and 1 status, whereby the probability of failure may be reduced well below 1 in 1 000 000. Based on information obtained from this desktop study SMEC South Africa (Pty) Ltd. recommend the following preliminary and detailed geotechnical investigations as per guidelines offered by Eurocode 7 (2004) and SAICE (2010):

4.1 Preliminary Investigations

The following broad scope of work should be considered as a minimum for preliminary geotechnical investigations at Paulputs in order to assist in delineating the geotechnical risks as defined in Section 3.3:

- Site walkover survey and surface mapping of geological features
- Excavation of test pits across the site by an excavator to a minimum depth of 4.5 m below ground level
- Profiling of soil and rock horizons by a registered professional Engineering Geologist or Geotechnical Engineer

- In situ soil density testing utilising Dynamic Probe Light (DPL) soundings for ancillary buildings and associated infrastructure
- Bulk sampling of soil and rock for determination of index properties including, but not limited to:
  - Foundation Indicator tests including determination of Atterberg limits, grading and hydrometer analyses to determine clay content and activity
  - Modified AASTHO/ CBR and compactability tests to determine utilisation of in situ material in new construction activities
  - Moisture content and chemical analyses tests on soil samples to determine aggressiveness towards buried ferrous services and foundations
  - Shearbox testing to empirically derive soil geomechanical properties
  - Oedometer tests on soil samples to determine soil collapse potential

4.2 Detailed Investigations

The following broad scope of work is considered mandatory for detailed design of wind turbine structures at Paulputs in order to quantify the risks as detailed in Section 3.3 and assign key geomechanical design parameters. Although considered mandatory this scope of work will largely be defined by the results of the aforementioned preliminary investigations and may be optimised therefrom:

- Rotary cored drilling of one borehole per turbine structure to a minimum depth of 25 m below ground level or at least into 3 m of competent (R3 or greater) bedrock
- In situ soil density testing in each borehole utilising the Standard Penetration Test (SPT) method
- In situ deformation testing (Pressuremeter/ Goodman Jack) to establish horizontal elastic deformation properties for foundation design
- On site supervision of drilling contractor for quality control purposes
- Profiling of soil and rock horizons by a registered professional Engineering Geologist or Geotechnical Engineer
- Geophysical surveying of problematic (as determined by drilling) turbine foundations to ascertain extent of soil/ poor rock formation below foundation and derive key design parameters
- In situ soil resistivity testing (electrical and thermal) for application in design of earth mats and electrical cable bedding

- Bulk sampling of soil and rock for determination of index properties including, but not limited to:
    - Triaxial testing on undisturbed cohesive soil samples to determine soil shear characteristics; porewater pressures and essential geomechanical properties for foundation design
    - Shearbox testing on undisturbed non-cohesive soil samples to determine soil shear characteristics and essential geomechanical properties for foundation design
    - Oedometer tests on undisturbed soil samples to determine soil collapse potential
    - Unconfined Compressive Strength with Moduli of reaction (UCM) to determine rockmass integrity for foundation design
    - Chemical analyses on groundwater samples to determine aggressiveness towards foundations
- Prospecting and proofing (exploratory pits; boreholes and laboratory testing) of viable material sources for construction materials (viz. concrete stone; bedding material; pavement layerworks)

5. CONCLUSIONS

This desktop study report highlights the anticipated geological and subsequent ground conditions to be expected at the proposed Paulputs Wind Farm located 40 km east of Pofadder, Northern Cape Province.

Based on this desktop evaluation, a basic geotechnical model of the site has been conceptualised. The main geotechnical conditions to be expected during construction activities, as well as their variability across the site and associated characteristic geotechnical issues are discussed based on this model.

Briefly the geotechnical model indicates the following perceived conditions:

- Variable thickness, however predominantly thick (viz. >5 m), of transported sandy and gravelly soils interlayered with pedocrete lenses across the site. This horizon is considered potentially collapsible
- Localised dolerite rock outcrops underlain by highly weathered rockmass at contacts between dolerite and parent granite rockmass
- Generally a thin horizon of residual soils (potentially collapsible) underlying the transported soils (where drainage is free flowing)

- Variable depth (viz. mostly > 5m) to undulating weathered granite and/ or dolerite rockmass

The main concerns regarding development of the site and which will need to be determined via on-site investigations are:

- Thickness and variability in consistency of transported and residual soil horizons
- Collapse and high settlement potential of transported and residual soil horizons
- Density/ stiffness of pedocrete lenses and influence on founding solutions
- Extent of residual soil and degree of rockmass weathering at zones where dolerite has intruded granite
- Rockmass quality near the Pofadder Shear Zone
- Depth to and undulating nature of founding rockmass
- Generally above normal seismicity (0.5 – 1.0 $m/^2$ PGA) of the Pofadder area

Although there are foreseeable geotechnical risks to development of the site, there are also well-known founding solutions that can accommodate this risk such as:

i) Soil improvement techniques (dynamic compaction) to initiate and eliminate soil collapse potential

ii) Enlarged foundation bases (gravity foundations)

iii) Stiffened raft solutions

iv) Deep-seated foundations on rockmass

v) Piled solutions

SMEC are therefore of the opinion that the project meets pre-feasibility criteria and may move to feasibility-level investigations which will assist in defining and quantifying the geotechnical risks to development and in choosing the most appropriate founding solution.

This report acts merely to aid in pre-feasibility determination of the project and it is imperative that geotechnical investigations of the site be undertaken, should the development move forward. SMEC has undertaken a number of investigations for similar developments and has highlighted the minimum requirements (Eurocode 7, 2004; SAICE, 2010) for both preliminary and detailed geotechnical investigations that will inform the respective preliminary and detailed engineering design. Undertaking geotechnical investigations will generate the necessary geomechanical design parameters of the soils and rockmass that will mitigate the risk of failure of the proposed structures and unforeseen geotechnical issues across the site.

It must be noted that the information and recommendations given in this desktop study are generalised and based on limited data for the Pofadder area and surrounds. It is therefore highly possible that inconsistencies from what has been reported here may be observed.

Furthermore, all recommendations made in this report serve merely as guidelines for the consideration of the Client. Anticipated founding conditions and conceptual solutions, as described herein, must be proven prior to design and construction to ensure proper economic viability of the proposed project.

We trust that this report will be found to be complete and adequate for your consideration. Should further elaboration be required for any portion of this project, we would be pleased to provide assistance.

SMEC South Africa appreciates the opportunity of providing our services on this project and look forward to providing detailed geotechnical investigations in the future.

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