Appendix H.7

PALAEONTOLOGICAL ASSESSMENT

Palaeontological Impact Assessment for the proposed Dalmanutha WEF with two alternate layouts, south of Belfast and eNtokozweni, Mpumalanga Province

Desktop Study (Phase 1)

For

Beyond Heritage

22 April 2023

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Expertise of Specialist

The Palaeontologist Consultant: Prof Marion Bamford
Qualifications: PhD (Wits Univ, 1990); FRSSAf, mASSAf
Experience: 34 years research and lecturing in Palaeontology
26 years PIA studies and over 350 projects completed.

Declaration of Independence

This report has been compiled by Professor Marion Bamford, of the University of the Witwatersrand, sub-contracted by Beyond Heritage, Modimolle, South Africa. The views expressed in this report are entirely those of the author and no other interest was displayed during the decision making process for the Project.

Specialist: Prof Marion Bamford

Signature: 

Executive Summary

A Palaeontological Impact Assessment was requested for the proposed Dalmanutha Wind Energy Facility (WEF) project south of Belfast and eNtokozweni, Mpumalanga Province. Two options are being considered: Alternate 1 comprises up to 70 turbines to produce 300 MW. Alternate 2 is a hybrid system with up to 44 turbines and a solar facility that combined will generate 300MW. The same land area would be occupied by either of the alternatives, spread over approximately 9 197ha.

To comply with the regulations of the South African Heritage Resources Agency (SAHRA) in terms of Section 38(8) of the National Heritage Resources Act, 1999 (Act No. 25 of 1999) (NHRA), a desktop Palaeontological Impact Assessment (PIA) was completed for the proposed development.

The proposed site lies on the potentially very highly sensitive rocks of the Vryheid Formation (Karoo Supergroup), the highly sensitive rocks of the Silverton, Rooihoogte and Magaliesberg Formations (Transvaal Supergroup) and non-fossiliferous Jurassic dolerite. The walkdown and site verification survey was done in December and February. NO FOSSILS of any kind were found in the project footprint. Much of the area has been farmed in the past, parts are still being farmed. Some parts are not actively farmed. Nonetheless, a Fossil Chance Find Protocol should be added to the EMPr. Based on this information, it is recommended that no further palaeontological impact assessment is required unless fossils are found by the contractor, environmental officer or other designated responsible person once excavations or drilling for foundations, infrastructure, above or below-ground cabling activities have commenced. Since the impact will be low, as far as the palaeontology is concerned, the project should be authorised.

Both Alternatives 1 and 2 have the same palaeontological impact; low pre-mitigation and very low post-mitigation; there is no cumulative impact, and there are no no-go areas from a palaeontological perspective.

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1. Background

Two projects are being proposed to generate electricity, the Dalmanutha West Wind Energy Facility and the **Dalmanutha Wind Energy** Facility. Both projects will be located approximately 12km south-southeast of Belfast, within the Emakhazeni Local Municipality, in the Mpumalanga Province. The Projects are being developed in the context of the Department of Mineral Resources and Energy's (DMRE) Integrated Resource Plan (IRP), and the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), with further potential for private off-take by nearby mining and industrial operations. The proposed Projects ultimately will connect to the existing 132/400kV Gumeni Main Transmission Substation (MTS).

The 33/132kV on-site IPP substations for both Dalmanutha WEF and Dalmanutha West WEF will be located adjacent to the 132kV Common Collector Switching Station. There will be a medium voltage collector system comprising cables up to and including 33kV that run underground, except where a technical assessment suggests that overhead lines are required, within Dalmanutha WEF and Dalmanutha West WEF connecting the turbines to the Dalmanutha West and Dalmanutha on-site IPP substations. The on-site IPP substations will in turn be connected to the 132kV Common Collector Switching Station via separate over the fence 132kV cables to enable the evacuation of the generated power to the national grid. There is a preferred 132kV grid line and an alternate one that are considered in a separate application.

The proposed Dalmanutha WEF has two alternative layouts and both are considered in this report:

Alternative 1 comprises up to 70 turbines and is described below (Figures 1-2).
Alternative 2 is a hybrid concept with 44 turbines as well as two solar fields (Figures 3-4).

Dalmanutha Wind Facility – Alternative 1

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- The proposed Dalmanutha WEF will be developed with a capacity of up to 300 megawatts (MW), and will comprise the following key components:

WIND TURBINES

- Up to 70 wind turbines[1], each with a foundation of approximately 25m^2 in diameter (500m^2 area and requiring ~2 500m^3 concrete each) and approximately 3m depth;
- Turbine hub height of up to 200m;
- Rotor diameter up to 200m; and
- Permanent hard standing area for each wind turbine (approximately 1ha). **Error! Reference source not found.** illustrates the typical hardstanding requirements for the construction of each turbine (it should be noted that the figure below is for illustration purposes only – the exact layout and specification of the hardstanding area will be determined once the design phase has been completed).

IPP PORTION ONSITE SUBSTATION AND BATTERY ENERGY STORAGE SYSTEM (BESS)

- IPP portion onsite substation of up to 4ha. The substation will consist of a high voltage substation yard to allow for multiple up to 132kV feeder bays and transformers, control building, telecommunication infrastructure, access road, etc.; and
- The Battery Energy Storage System (BESS) storage capacity will be up to 300MW/1200 megawatt-hour (MWh) with up to four hours of storage. It is proposed that Lithium Battery Technologies, such as Lithium Iron Phosphate, Lithium Nickel Manganese Cobalt oxides or Vanadium Redox flow technologies will be considered as the preferred battery technology; however, the specific technology will only be determined following Engineering, Procurement, and Construction (EPC) procurement. The main components of the BESS include the batteries, power conversion system and transformer which will all be stored in various rows of containers.

OPERATION AND MAINTENANCE BUILDING INFRASTRUCTURE

- Operations and maintenance (O&M) building infrastructure will be required to support the functioning of the WEF and for services required by operations and maintenance staff. The O&M building infrastructure will be near the onsite substation and will include:
- Operations building of approximately 200m^2;
- Workshop and stores area of approximately 150m^2 each;
- Stores area of approximately 150m^2; and
- Refuse are for temporary waste and septic/conservancy tanks with portable toilets to service ablution facilities.

The total combined area of the buildings will not exceed 5 000m^2.

CONSTRUCTION CAMP LAYDOWN

- Temporary laydown or staging area -Typical area 220m x 100m = 22 000m^2.
- Laydown area could increase to 30 000m^2 for concrete towers, should they be required.
- Sewage: septic and/or conservancy tanks and portable toilets.
- Temporary cement batching plant, wind tower factory & yard of approximately 7ha, comprising amongst others, a concrete storage area, batching plant, electrical infrastructure and substation, generators and fuel stores, gantries and loading facilities, offices, material stores (rebar, concrete, aggregate and associated materials), mess rooms, workshops, laydown and storage areas, sewage and toilet facilities, offices and boardrooms, labour mess and changerooms, mixers, moulds and casting areas, water and settling tanks, pumps, silos and hoppers, a laboratory, parking areas, internal and access roads - Gravel and sand will be stored in separate heaps whilst the cement will be contained in a silo. The maximum height of the silo will be 20m.

ACCESS ROADS

- The Project site can be accessed easily via either the tarred R33 or the N4 national road which run along the northern and western boundaries of the site.
- There is an existing road that goes through the land parcels to allow for direct access to the project development area.

- Internal and access roads with a width of between 8m and 10m, which can be increased to approximately 12m on bends. The roads will be positioned within a 20m wide corridor to accommodate cable trenches, stormwater channels and bypass /circles of up to 20m during construction. Length of the internal roads will be approximately 60km.

ASSOCIATED INFRASTRUCTURE

- The medium voltage collector system will comprise of cables up to and including 33kV that run underground, except where a technical assessment suggest that overhead lines are required, within the facility connecting the turbines to the onsite substation.
- Over the fence 132kV cable to connect the onsite IPP substation to the Common Collector Switching Station.
- Fencing of up to 4m high around the construction camp and lighting.
- Lightning protection.
- Telecommunication infrastructure.
- Stormwater channels.
- Water pipelines.
- Offices.
- Operational control centre.
- Operation and Maintenance Area / Warehouse/workshop.
- Ablution facilities.
- A gatehouse.
- Control centre, offices, warehouses.
- Security building.
- A visitor's centre.
- Substation building.

The proposed development footprint (buildable area) is approximately 400ha (subject to finalisation based on technical and environmental requirements), and the extent of the project area is approximately 9 197 ha. The development footprint includes the turbine positions and all associated infrastructure as outlined above.

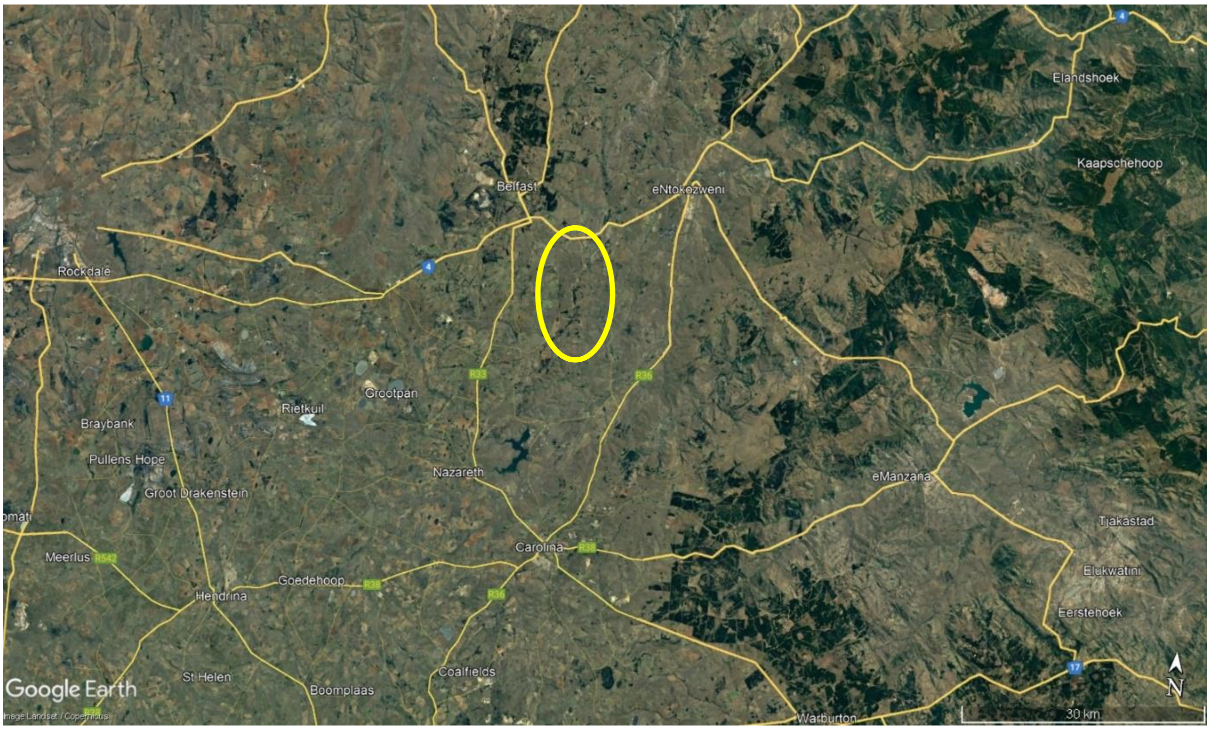

Figure 1: Google Earth map of the general area around the Dalmanutha WEF project (yellow oval) with the nearby towns and main roads.

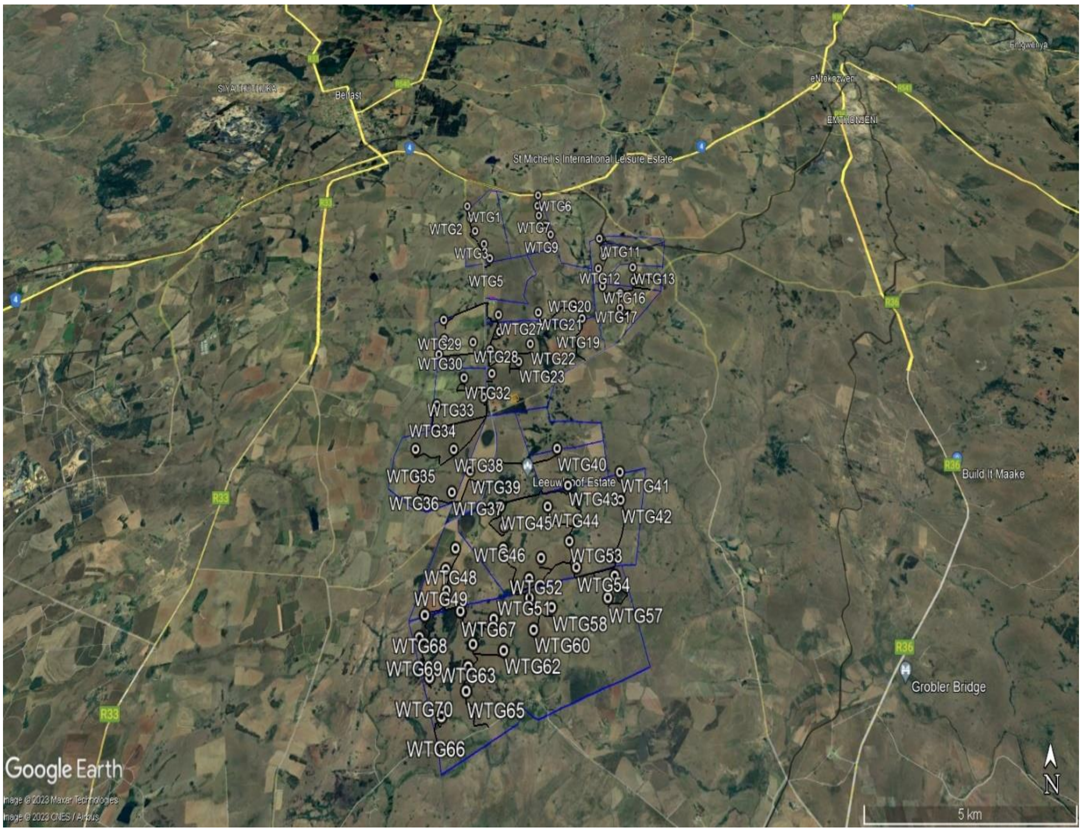

Figure 2: Dalmanutha WEF Alternative 1 comprising up to 70 turbines (WTG1 – WTG70).

Dalmanutha WEF Alternative 2 – Hybrid

The proposed Dalmanutha Wind and Solar Energy Facility (Figures 3-4) will be developed with a capacity of up to 300 megawatts (MW), and will comprise the following key components:

WIND TURBINES

- Up to 44 turbines, each with a foundation of approximately 25m^2 in diameter (500m^2 area and requiring ~2 500m^3 concrete each) and approximately 3m depth;
- Turbine hub height of up to 200m;
- Rotor diameter up to 200m; and
- Permanent hard standing area for each wind turbine (approximately 1ha per turbine).

SOLAR FIELDS

- Solar PV array comprising PV modules (solar panels), which convert the solar radiation into direct current (DC);
- PV panels will be up to a height of 6m (when the panel is horizontal) and will be mounted on fixed tilt, single axis tracking or dual axis tracking mounting structures. Monofacial or bifacial Solar PV Modules are both considered;
- Footprint: ~160 ha; and
- Inverters, transformers and other required associated electrical infrastructure and components.

IPP PORTION ONSITE SUBSTATION AND BATTERY ENERGY STORAGE SYSTEM (BESS)

- IPP portion onsite substation of up to 4ha. The substation will consist of a high voltage substation yard to allow for multiple up to 132kV feeder bays and transformers, control building, telecommunication infrastructure, access road, etc.; and
- The Battery Energy Storage System (BESS) storage capacity will be up to 300MW/1200 megawatt-hour (MWh) with up to four hours of storage. It is proposed that Lithium Battery Technologies, such as Lithium Iron Phosphate, Lithium Nickel Manganese Cobalt oxides or Vanadium Redox flow technologies will be considered as the preferred battery technology; however, the specific technology will only be determined following Engineering, Procurement, and Construction (EPC) procurement. The main components of the BESS include the batteries, power conversion system and transformer which will all be stored in various rows of containers.

OPERATION AND MAINTENANCE BUILDING INFRASTRUCTURE

- Operations and maintenance (O&M) building infrastructure will be required to support the functioning of the WEF and SEF and for services required by operations and maintenance staff. The O&M building infrastructure will be near the onsite substation and will include:
- Operations building of approximately 200m^2;
- Workshop and stores area of approximately 150m^2 each;
- Stores area of approximately 150m^2; and
- Refuse area for temporary waste and septic/conservancy tanks with portable toilets to service ablution facilities.

The total combined area of the buildings will not exceed 5 000m^2.

CONSTRUCTION CAMP LAYDOWN

- Temporary laydown or staging area -Typical area 220m x 100m = 22000m^2.
- Laydown area could increase to 30 000m^2 for concrete towers, should they be required.
- Sewage: septic and/or conservancy tanks and portable toilets.
- Temporary cement batching plant, wind tower factory & yard of approximately 7ha, comprising amongst others, a concrete storage area, batching plant, electrical infrastructure and substation, generators and fuel stores, gantries and loading facilities, offices, material stores (rebar, concrete, aggregate and associated materials), mess rooms, workshops, laydown and storage areas, sewage and toilet facilities, offices and boardrooms, labour mess and changerooms, mixers, moulds and casting areas, water and settling tanks, pumps, silos and hoppers, a laboratory, parking areas, internal and access roads - Gravel and sand will be stored in separate heaps whilst the cement will be contained in a silo. The maximum height of the silo will be 20m.

ACCESS ROADS

- The Project site can be accessed easily via either the tarred R33 or the N4 national road that run along the northern and western boundaries of the site.
- There is an existing road that goes through the land parcels to allow for direct access to the project development area.
- Internal and access roads with a width of between 8m and 10m for the WEF, which can be increased to approximately 12m on bends. The roads will be positioned within a 20m wide corridor to accommodate cable trenches, stormwater channels and bypass /circles of up to 20m during construction. Length of the internal roads will be approximately 60km. For the SEF, internal gravel roads will be established between the arrays and will be up to 4m wide.

ASSOCIATED INFRASTRUCTURE

- For the WEF, the medium voltage collector system will comprise of cables up to and including 33kV that run underground, except where a technical assessment suggest that overhead lines are required, within the facility connecting the turbines to the onsite substation. The SEF will comprise low and medium voltage cabling between components (above or below ground as needed).
- Over the fence 132kV cable to connect the onsite IPP substation to the Common Collector Switching Station.
- Fencing of up to 4m high around the construction camp and lighting.
- Lightning protection.
- Telecommunication infrastructure.
- Stormwater channels.
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- Offices.
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- Operation and Maintenance Area / Warehouse/workshop.
- Ablution facilities.
- A gatehouse.
- Control centre, offices, warehouses.
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- Substation building.

The proposed development footprint (buildable area) for the Dalmanutha Wind and Solar Energy Facility is approximately 400ha (subject to finalisation based on technical and environmental requirements), and the extent of the project area is approximately 9 197ha. The development footprint includes the turbine positions, solar PV array, and all associated infrastructure as outlined above.

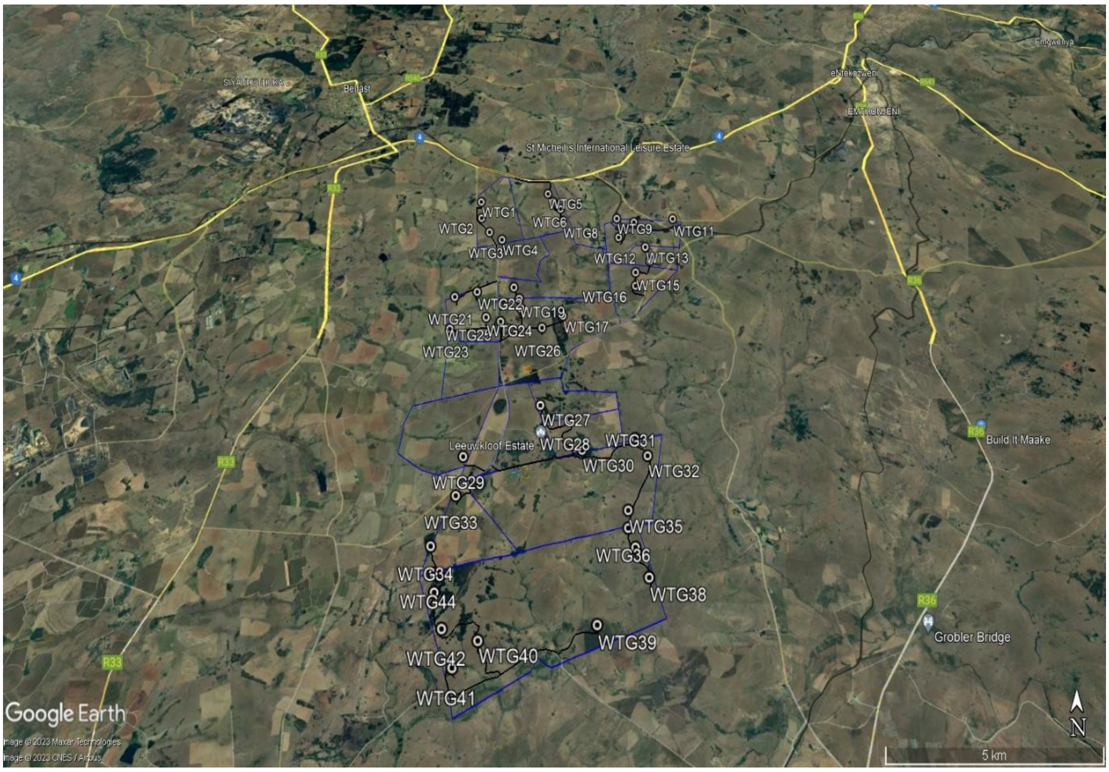

Figure 3: Google Earth map of Dalmanutha Wind and Solar Facility (Alternative 2) to show the wind turbines WTG1 – WTG44.

Figure 4: Google Earth map of the Dalmanutha Wind and Solar Facility (Alternative 2) with the proposed solar fields shown by the orange polygons.

A Palaeontological Impact Assessment was requested for the two alternatives for the Dalmanutha WEF project. To comply with the regulations of the South African Heritage Resources Agency (SAHRA) in terms of Section 38(8) of the National Heritage Resources Act, 1999 (Act No. 25 of 1999) (NHRA), a site visit or phase 2 Palaeontological Impact Assessment (PIA) was completed for the proposed development and is reported herein.

Table 1: National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) and Environmental Impact Assessment (EIA) Regulations, 2014 (as amended) - Requirements for Specialist Reports (Appendix 6).

	A specialist report prepared in terms of the Environmental Impact Regulations of 2017 must contain:	**Relevant section in report**
ai	Details of the specialist who prepared the report,	Appendix B
aii	The expertise of that person to compile a specialist report including a curriculum vitae	Appendix B
b	A declaration that the person is independent in a form as may be specified by the competent authority	Page 1
c	An indication of the scope of, and the purpose for which, the report was prepared	Section 1
ci	An indication of the quality and age of the base data used for the specialist report: SAHRIS palaeosensitivity map accessed – date of this report	Yes
cii	A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 5
d	The date and season of the site investigation and the relevance of the season to the outcome of the assessment	N/A
e	A description of the methodology adopted in preparing the report or carrying out the specialised process	Section 2
f	The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Section 4
g	An identification of any areas to be avoided, including buffers	N/A
h	A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	N/A
i	A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 5
j	A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Section 4

	A specialist report prepared in terms of the Environmental Impact Regulations of 2017 must contain:	**Relevant section in report**
k	Any mitigation measures for inclusion in the EMPr	Section 8, Appendix A
l	Any conditions for inclusion in the environmental authorisation	N/A
m	Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 8, Appendix A
ni	A reasoned opinion as to whether the proposed activity or portions thereof should be authorised	Section 6
nii	If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Sections 6, 8
o	A description of any consultation process that was undertaken during the course of carrying out the study	N/A
p	A summary and copies of any comments that were received during any consultation process	N/A
q	Any other information requested by the competent authority.	N/A
2	Where a government notice gazetted by the Minister provides for any protocol or minimum information requirement to be applied to a specialist report, the requirements as indicated in such notice will apply.	N/A

2. Methods and Terms of Reference

The Terms of Reference (ToR) for this study were to undertake a PIA and provide feasible management measures to comply with the requirements of SAHRA.
The methods employed to address the ToR included:

1. Consultation of geological maps, literature, palaeontological databases, published and unpublished records to determine the likelihood of fossils occurring in the affected areas. Sources include records housed at the Evolutionary Studies Institute at the University of the Witwatersrand and SAHRA databases;
2. Where necessary, site visits by a qualified palaeontologist to locate any fossils and assess their importance (*applicable to this assessment*);
3. Where appropriate, collection of unique or rare fossils with the necessary permits for storage and curation at an appropriate facility (*possibly applicable to this assessment*); and
4. Determination of fossils' representivity or scientific importance to decide if the fossils can be destroyed or a representative sample collected (*possibly applicable to this assessment*).

3. Geology and Palaeontology

i. Project location and geological context

The project lies in the south-eastern part of the Transvaal Basin of the Transvaal Supergroup, where the basal Karoo Supergroup rocks from a younger basin unconformably overlie the Transvaal Supergroup (Figure 5).

The Late Archaean to early Proterozoic Transvaal Supergroup is preserved in three structural basins on the Kaapvaal Craton (Eriksson et al., 2006). In South Africa are the Transvaal and Griqualand West Basins, and the Kanye Basin is in southern Botswana. The Griqualand West Basin is divided into the Ghaap Plateau sub-basin and the Prieska sub-basin. Sediments in the lower parts of the basins are very similar but they differ somewhat higher up the sequences. Several tectonic events have greatly deformed the south western portion of the Griqualand West Basin between the two sub-basins

The Transvaal Supergroup comprises one of world's earliest carbonate platform successions (Beukes, 1987; Eriksson et al., 2006; Zeh et al., 2020). In some areas there are well preserved stromatolites that are evidence of the photosynthetic activity of blue green bacteria and green algae. These microbes formed colonies in warm, shallow seas.

In the Transvaal Basin the Transvaal Supergroup is divided into two Groups, the lower Chuniespoort Group and the upper Pretoria Group (with ten formations; Eriksson et al., 2006). Making up the lower Pretoria Group are the Timeball Hill Formation and the Boshoek Formation. The Hekpoort, Dwaalheuwel, Strubenkop and Daspoort Formations form a sequence as the middle part of the Pretoria Group, Transvaal Supergroup, and represent rocks that are over 2060 million years old. The Hekpoort Formation is a massive lava deposit and is overlain by the Dwaalheuwel conglomerates, siltstone and sandstone (not present here). A hiatus separates the Strubenkop Formation slates and shales from the overlying quartzites of the Daspoort Formation. Upper Pretoria Group formations are the **Silverton, Magaliesberg, Vermont,** Lakenvalei, Nederhorst, Steenkampsberg and Houtenbek Formations.

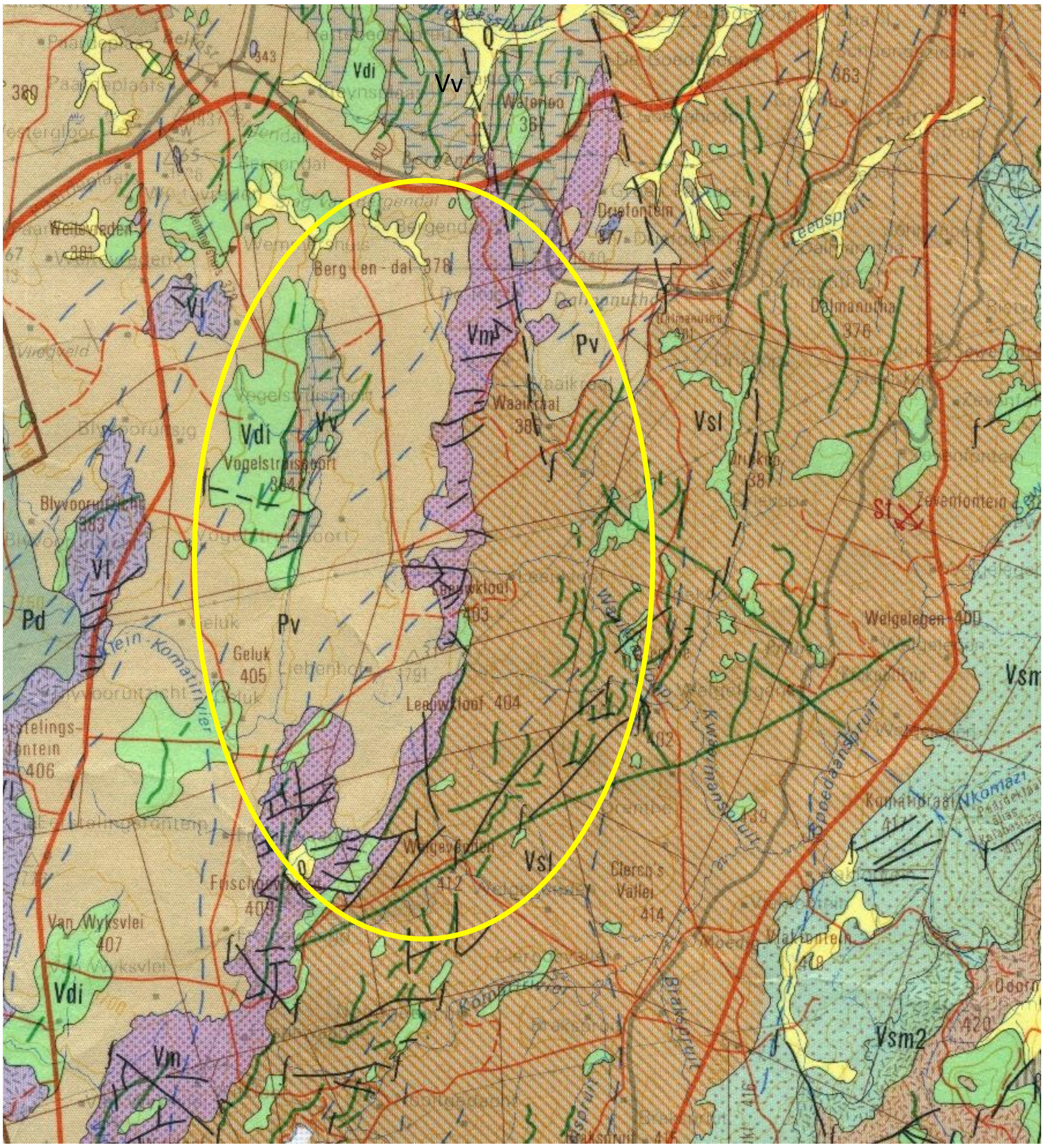

Figure 5: Geological map of the area around the Dalmanutha WEF project area. The location of the proposed project is indicated within the yellow rectangle. Abbreviations of the rock types are explained in Table 2. Map enlarged from the Geological Survey 1: 250 000 map 2530 Barberton.

Table 2: Explanation of symbols for the geological map and approximate ages (Eriksson et al., 2006. Johnson et al., 2006; Zeh et al., 2020). SG = Supergroup; Fm = Formation; Ma = million years; grey shading = formations impacted by the project.

Symbol	Group/Formation	Lithology	Approximate Age
Q	Quaternary	Alluvium, sand, calcrete	Quaternary, ca 1.0 Ma to present
Pv	Vryheid Fm, Ecca Group, Karoo SG	Shale, siltstone, sandstone, coal	Early Permian Ca 290-280 Ma
Pd	Dwyka Group, Karoo SG	Diamictites, tillites, mudstone	Late Carboniferous to Early Permian

Symbol	Group/Formation	Lithology	Approximate Age
			Ca 310 – 290 Ma
Vdi	Diabase	Intrusive volcanic dykes and sills	Post Transvaal SG
Vl	Lakenvalei Fm, Pretoria Group, Transvaal SG	Quartzite, feldspathic quartzite, arkose	Palaeoproterozoic <2212 Ma
Vv	Vermont Fm, Pretoria Group, Transvaal SG	Hornfels, minor quartzite, limestone, chert	Palaeoproterozoic <2112 Ma
Vm	Magaliesberg Fm, Pretoria Group, Transvaal SG	Quartzite, minor hornfels	Palaeoproterozoic <2080 Ma
Vsi, Vsl, Vsm, Vsb	Silverton Fm, Pretoria Group, Transvaal SG Lydenburg Mbr; Machadadorp Mbr Boven Mbr	Shale, carbonaceous in places, hornfels, chert; Vsl – shales, tuffaceous; Vsm – pyroclastic rocks, basalt	Palaeoproterozoic Ca 2202 Ma
Vr	Rooihoogte Fm, Pretoria Group, Transvaal SG	Quartzite, mudrock, conglomerate	Palaeoproterozoic <2240 Ma

The Transvaal sequence has been interpreted as three major cycles of basin infill and tectonic activity with the first deep basin sediments forming the Chuniespoort Group, the second cycle deposited the lower Pretoria Group, and the sediments in this area are from the interim lowstand that preceded the third cycle. These sediments were deposited in shallow lacustrine, alluvial fan and braided stream environments (Eriksson et al., 2012).

The Pretoria Group is approximately 6-7km thick and is composed mostly of mudrocks alternating with quartzitic sandstones, significant interbedded basaltic-andesitic lavas and subordinate conglomerates, diamictites and carbonate rocks. These have been subjected to low grade metamorphism (Eriksson et al., 2006). The Bushveld Complex intrusion has affected the layering of the formations.

The model of Eriksson et al., 2006, 2012 and collaborators shows the Transvaal Basin to have experienced three major tectonically controlled transgressive-regressive sequences. The first shallow seaway with a carbonate and a BIF platform is represented by the Chuniespoort Group followed by an 80 Ma gap. The second shallow embayment with clastic sediments is represented by the Rooihoogte and Timeball Hill Formations, and the third shallow embayment is represented by the Daspoort, Silverton and Magaliesberg Formations.

The basal **Rooihoogte Formation** overlies a deeply weathered palaeotopography that developed on the carbonates of the Chuniepoort Group. Composition of the rocks of this formation vary locally but generally comprise chert conglomerate, chert-rich sandstones, mudrocks and sandstones. An alluvial fan and fluvial braid-plain depositional setting has been interpreted from the conglomerates and sandstones, and a shallow lacustrine basin has been interpreted for the mudrocks and dolomites (Eriksson et al., 2006).

Within the **Silverton Formation** are the lower Boven Shale Member, Machadorp Volcanic Member and upper Lydenburg Shale Member. The lower shales are alumina-rich and best represented in the eastern part of the Transvaal Basin. Shallow subaqueous eruptives formed the tholiitic basalts and then the tuffaceous shales that are high in CaO-MnO-MgO formed the Lydenburg Member (Eriksson et al., 2006). The Silverton Formation has been interpreted as a high-stand facies tract that reflected the advance of an epeiric sea onto the Kaapvaal Craton from the east, so the Daspoort Formation would represent a lowstand facies tract or a transgressive systems tract (ibid).

There are five formations in the **post-Magaliesberg group** (or upper Pretoria Group) in the eastern part of the Transvaal Basin and they are composed of alternating quartzitic sandstones and shales with subordinate carbonate rocks, tuffs and lavas. These formations are the basal **Vermont Formation** (mudrock), the **Lakenvalei Formation** (sandstone), the Nederhorst Formation (mudrock and sandstone), the Steenkampsberg Formation (sandstone) and the topmost Houtenbeck Formation (mudrock, sandstone and limestone) (Eriksson et al., 2006). In contrast, in the central and western part of the Transvaal Basin only the Rayton and Woodlands Formations, respectively, have been recognised.

Long after the Transvaal Basin had been filled with sediments, another foreland arc basin formed over the central part of South Africa, the Karoo Basin. The **Karoo Supergroup** rocks cover a very large proportion of South Africa and extend from the northeast (east of Pretoria) to the southwest and across to almost the KwaZulu Natal south coast. It is bounded along the southern margin by the Cape Fold Belt and along the northern margin by the much older Transvaal Supergroup rocks. Representing some 120 million years (300 – 183Ma), the Karoo Supergroup rocks have preserved a diversity of fossil plants, insects, vertebrates and invertebrates.

During the Carboniferous Period South Africa was part of the huge continental landmass known as Gondwanaland and it was positioned over the South Pole. As a result, there were several ice sheets that formed and melted, and covered most of South Africa (Visser, 1986, 1989; Isbell et al., 2012). Gradual melting of the ice as the continental mass moved northwards and the earth warmed, formed fine-grained sediments in the large inland sea. These are the oldest rocks in the system and are exposed around the outer part of the ancient Karoo Basin, and are known as the Dwyka Group. They comprise tillites, diamictites, mudstones, siltstones and sandstones that were deposited as the basin filled (Johnson et al., 2006).

Overlying the Dwyka Group rocks are rocks of the Ecca Group that are Early Permian in age. There are eleven formations recognised in this group but they do not all extend throughout the Karoo Basin. In the central and eastern part are the following formations, from base upwards: Pietermaritzburg, **Vryheid** and Volksrust Formations. All of these sediments have varying proportions of sandstones, mudstones, shales and siltstones and represent shallow to deep water settings, deltas, rivers, streams and overbank depositional environments.

ii. Palaeontological context

The palaeontological sensitivity of the area under consideration is presented in Figure 6. The site for development is in the Vryheid Formation (red: very highly sensitive), Silverton, Magaliesberg and Rooihoogte Members (orange: highly sensitive) and non-fossiliferous Jurassic dolerite (grey).

The Transvaal Supergroup sequence of sedimentary and volcanic rocks has been interpreted as having undergone three cycles of tectonically controlled basin subsidence and infilling with clastic deposits from the west and northwest. The first cycle (Chuniespoort Group) was a shallow seaway in a marine environment where the carbonate platform (Malmani Subgroup) was deposited and has a variety of limestones and dolomite (Erikson et al., 2012). The different lithofacies represent different depths of formation of carbonates, for example, intertidal zone, high energy zone and shallow subtidal deposits are limestone and dolomite, with flat domes and columnar stromatolites being formed in the intertidal zone. In the high energy zone oolites, oncolites and ripples were formed, while in the deep tidal zone elongated stromatolitic mounds were formed (Truswell and Eriksson, 1973; Eriksson and Altermann, 1998).

After a hiatus of about 80 Myr, the second cycle (Duitschland, Rooihoogte and Timeball Hill Formations) occurred under glacial influence. The stromatolites in the Timeball Hill Formation are questionable but they are present in the Duitschland Formation (Schröder et al., 2016).

The third cycle after a brief hiatus, represented by the rest of the Pretoria Group, was deposited in a shallow embayment. Carbonates (not necessarily stromatolites) are reported from the upper Silverton Formation, the Houtenbeck and Vermont Formations. From the Magaliesberg Formation there have been several reports of microbial features. No fossils are recorded from the Rayton Formation, and the upper Pretoria Group rocks are not listed in the Palaeotechnical report for Gauteng (Groenewald et al., 2014), however the rocks are quartzites and shales like the underlying members of the Pretoria Group. Since Parizot et al., (2005) first recorded microbial mat features from the Magaliesberg Formation north of Pretoria, a number of other occurrences have been reported in this formation (Bosch and Eriksson, 2008; Eriksson et al., 2012).

Bosch and Eriksson (2008) described crack-like features, vermiform structures and circular imprints resembling concretions or, possibly oncolites, that occur on sand sheet surfaces within the uppermost beds of the **Magaliesberg Formation**. They indicated two localities, one north of Pretoria, on the farm Baviaanspoort 330 JR and the other on the farm Rietvlei 518 JR, east of Pretoria. Leeuwpoort is northeast of Pretoria. The presence of such microbial mat-like features are found in epeiric marine tidally dominated coastline. The rhythmic alternation of water levels inherent in such settings can explain desiccation of microbial mats growing on the sandy substrates formed within the palaeoenvironment. In addition, the shifting loci of deposition were probably also related to braided fluvial inputs, through the medium of braid deltas (Bosch and Eriksson, 2008).

Stromatolites are the trace fossils that were formed by colonies of green algae and blue-green algae (Cyanobacteria) that grew in warm, shallow marine settings. These algae were responsible for releasing oxygen via the photosynthetic process where atmospheric carbon dioxide and water, using energy from the sun, are converted into carbon chains and compounds that are the building blocks of all living organisms. The released carbon dioxide initially was taken up by the abundant reducing minerals to form oxides, e.g. iron oxide. Eventually free oxygen was released into the atmosphere and some was converted into ozone by the bombardment of cosmic rays. The ozone is critical for the filtering out of harmful ultraviolet rays.

Stromatolites are the layers upon layers of inorganic materials that were deposited during photosynthesis, namely calcium carbonate, magnesium carbonate, calcium sulphate and magnesium sulphate. These layers can be in the form of flat layers, domes or columns depending on the environment where they grew (Beukes, 1987). Some environments did not form stromatolites, just layers of limestone that later was converted to dolomite. The algae that formed the stromatolites are very rarely preserved, and they are microscopic so they can only be seen from thin sections studies under a petrographic microscope.

Microbialites (sensu Burne and Moore, 1987) are organo-sedimentary deposits formed from interaction between benthic microbial communities (BMCs) and detrital or chemical sediments. In addition, microbialites contrast with other biological sediments in that they are generally not composed of skeletal remains. Archean carbonates mostly consist of stromatolites. These platforms could have been the site of early O2 production on our planet. Stromatolites are the laminated, organo-sedimentary, non-skeletal products of microbial communities, which may have included cyanobacteria, the first photosynthetic organisms to produce oxygen. Another type of trace fossil has been termed Microbially-induced sedimentary structures (MISS sensu Noffke et al., 2001) or simply 'fossil mats' (sensu Tice et al., 2011). These include swirls, rip-ups, crinkled surfaces and wrinkles that were formed by the mucus extruded by littoral algae or microbes and bound together sand particles. Davies et al. (2016) caution against the assumption that all such structures are microbially induced unless there is additional evidence for microbes in the palaeoenvironment.

Nonetheless, stromatolites and microbialites are accepted as trace fossils of algal colonies. MISS could be microbially or abiotically formed. The oldest stromatolites have been recorded from the Barberton Supergroup that was deposited between 3.55 to ca. 3.20 Ga, and stromatolites still form today in warm, shallow seas (Homan, 2019).

The **Vryheid Formation** lies on the uneven topography of pre-Karoo or Dwyka Group rocks in the northern and northwestern margins but lies directly on the Pietermaritzburg Formation in the central and eastern part. The lithofacies show a number of upward-coarsening cycles, some very thick, and they are essentially deltaic in origin. There are also delta-front deposits, evidence of delta switching, and fluvial deposits with associated meandering rivers, braided streams, back swamps or interfluves and abandoned channels (Cadle et al., 1993; Cairncross, 1990; 2001; Johnson et al., 2006). Coal seams originated where peat swamps developed on broad abandoned alluvial plains, and less commonly in the backswamps or interfluves. Most of the economically important coal seams occur in the fluvial successions (ibid). In the east (Mpumalanga and northern KwaZulu Natal), the Vryheid formation can be subdivided into a lower fluvial-dominated deltaic interval, a middle fluvial interval, and an upper fluvial-dominated deltaic interval again (Taverner-Smith et al., 1988).

Fossil plants of the *Glossopteris* flora occur in the Vryheid Formation. This flora includes *Glossopteris* leaves, seeds, fructifications, roots and wood, as well other groups such as the lycopods, sphenophytes, ferns, cordaitaleans and early gymnosperms (Plumstead, 1969; Anderson and Anderson, 1985; Bamford, 2004).

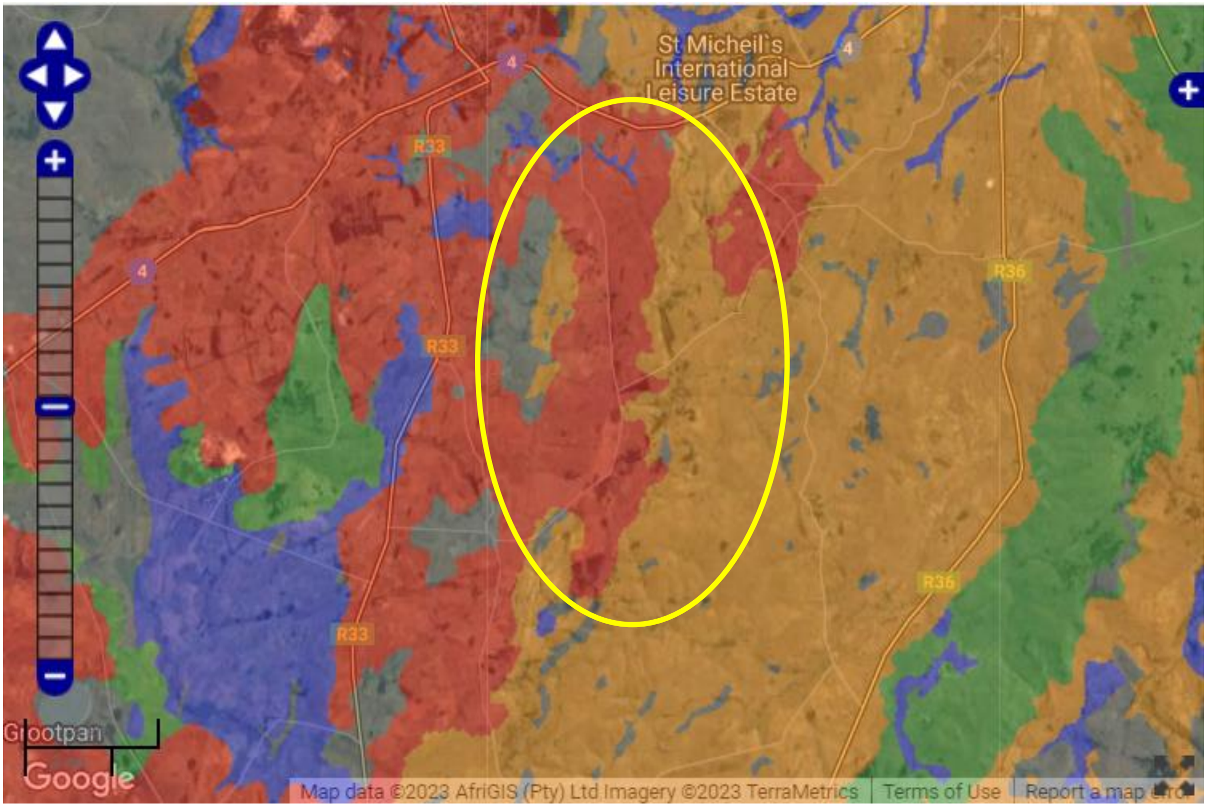

Figure 6: SAHRIS palaeosensitivity map for the site for the proposed Dalmanutha WEF two alternatives shown within the yellow rectangle. Background colours indicate the following degrees of sensitivity: red = very highly sensitive; orange/yellow = high; green = moderate; blue = low; grey = insignificant/zero.

iii. Site visit Observations

The area was visited in December 2022 and February 2023 and where the roads and field were dry enough for access, the turbine sites were inspected. There had been heavy rains prior to the site visit so not all locations were accessible. The project area consists of a largely agricultural landscape consisting of various farms with mixed farming activities that include cattle, sheep and goat farming as well as the cultivation of various crops. The surrounding landscape consists of rolling hills covered in a thick growth of ground vegetation. The soil is fairly rocky around these hills with reddish sandy soil situated on the flatter areas. Scattered thickets of trees are situated across the landscape. These include 'black wattle', 'eucalyptus', 'conifer' and a shrublike tree that tends to grow in thickets on the various packed stone features across the landscape. The landscape becomes progressively mountainous towards the southern portions of the project area.

Figure 7: Site visit photographs for Dalmanutha WEF. A - General view of the landscape showing the rolling hills towards the southern edge of the project area. B - Image showing the mountainous terrain throughout the southern parts of the project area.

Figure 8: Site visit photographs for Dalmanutha WEF. A - General view of the landscape facing south from a rocky hilltop. B - General site conditions of the flatter areas towards the centre of the project area showing the fair grass cover. C - Image showing the large open fields towards the centre of the project area. D - Large scale farming activities take place across the project area - Image showing a newly ploughed field

Figure 9: Site visit photographs for Dalmanutha WEF. A - View of the general landscape as seen from a central location showing the terrain becoming gradually mountainous towards the southern edge. B - Large open fields situated towards the central areas of the project area. C - General site conditions surrounding the eastern parts of the project area showing wide open fields. D - Image showing newly ploughed fields towards the eastern edge of the project area.

Figure 10: Site visit photographs for Dalmanutha WEF. A - Large cultivated crops are scattered across the project area. B - Large scale farming activities taking place along the western edge of the project area. - Image showing a newly ploughed field.

4. Impact assessment and Mitigation

The assessment of impacts and mitigation evaluates the likely extent and significance of the potential impacts on identified receptors and resources against defined assessment criteria, to develop and describe measures that will be taken to avoid, minimise or compensate for any adverse environmental impacts, to enhance positive impacts, and to report the significance of residual impacts that occur following mitigation.

Following the mitigation sequence/hierarchy of five levels:

a) Avoid/prevent significant impact
b) Minimise
c) Rehabilitate/restore
d) Off-set
e) No-go,

mitigation in the form of removing any important fossils (steps a and b) will reduce realty the impact of this project on the palaeontological heritage.

The key objectives of the risk assessment are to identify any additional potential environmental issues and associated impacts likely to arise from the proposed project, and to propose a significance ranking. Ranked criteria listed in Table 3 and the scores for the palaeontological impact are given in Table 3b.

Table 3a: Impact Assessment and Scoring according to WSP protocols.

CRITERIA	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Impact Magnitude (M) The degree of alteration of the affected environmental receptor	Very low: No impact on processes	Low: Slight impact on processes	Medium: Processes continue but in a modified way	High: Processes temporarily cease	Very High: Permanent cessation of processes
Impact Extent (E) The geographical extent of the impact on a given environmental receptor	Site: Site only	Local: Inside activity area	Regional: Outside activity area	National: National scope or level	International: Across borders or boundaries
Impact Reversibility (R) The ability of the environmental receptor to rehabilitate or restore after the activity has caused environmental change	Reversible: Recovery without rehabilitation		Recoverable: Recovery with rehabilitation		Irreversible: Not possible despite action
Impact Duration (D) The length of permanence of the impact on the environmental receptor	Immediate: On impact	Short term: 0-5 years	Medium term: 5-15 years	Long term: Project life	Permanent: Indefinite
Probability of Occurrence (P) The likelihood of an impact occurring in the absence of pertinent environmental management measures or mitigation	Improbable	Low Probability	Probable	Highly Probability	Definite
Significance (S) is determined by combining the above criteria in the following formula:	$[S = (E + D + R + M) \times P]$ $Significance = (Extent + Duration + Reversibility + Magnitude) \times Probability$				
IMPACT SIGNIFICANCE RATING					
Total Score	**4 to 15**	**16 to 30**	**31 to 60**	**61 to 80**	**81 to 100**
Environmental Significance Rating (Negative (-))	**Very low**	**Low**	**Moderate**	**High**	**Very High**

CRITERIA	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Environmental Significance Rating (Positive (+))	**Very low**	**Low**	**Moderate**	**High**	**Very High**

Table 3b: Impact Assessment score and significance for Palaeontology for the Dalmanutha WEF project (Alternative 1 and Alternative 2).

Criteria (from table above)	Scores			
Project:	Alt 1 – 70 turbines		Alt 2 – turbines + solar	
Action	Pre-mitigation	Post-mitigation	Pre-mitigation	Post-mitigation
Impact Magnitude (M)	3	1	3	1
Impact Extent (E)	1	1	1	1
Impact Reversibility (R)	3	1	3	1
Impact Duration (D)	1	1	1	1
Probability of Occurrence (P)	3	1	3	1
Significance (M+E+R+D) x P	24	4	24	4
Significance Rating	Low	Very low	Low	Very Low
Negative / Positive	Neg	Neg	Neg	Neg

Mitigation

The site visit and verification confirmed that there are no fossils on the surface in the project footprint. Any further impact on the palaeontological heritage can be reduced greatly by the environmental officer or contractor checking the excavations for fossils, photographing and putting aside any possible fossils, and seeking the opinion of a palaeontologist as to whether the possible fossils are of any scientific value. The palaeontologist can then remove any scientifically important fossils with the relevant SAHRA permit. (See the Fossil Chance Find Protocol in Section 8 and Appendix A that should be added to the EMPr).

Positive/Negative Impact

The discovery and removal of fossils as a direct result of this project has a positive impact because prior to this the particular fossils or fossil deposit were unknown to science.

Additional Environmental Impacts

As far as the palaeontology is concerned, there are no additional impacts because the fossils are inert and inactive.

Cumulative Impacts

As far as the palaeontology is concerned, there are no cumulative impacts because each site is unique and may or may not have fossils. Fossil bones may be scattered over the landscape but their distribution is erratic and unpredictable. If a bone-bed or plant outcrop occurs this would be an aerially small concentration of fossils and very unlikely to extend beyond tens of metres. Therefore, projects on adjacent land parcels are unlikely to add any impact on this project.

No-Go areas
There are no-go areas because the fossils, if present, can be removed ad curated in a recognised institution such as a museum or university that has the facilities to store and research the fossil material.

5. Assumptions and uncertainties

Based on the geology of the area and the palaeontological record as we know it, it can be assumed that the formation and layout of the dolomites, sandstones, shales and sands are typical for the country and only some contain trace fossils or fossil plants. The soils and sands of the Quaternary period would not preserve fossils. The site visit and walkthrough confirmed that there are NO fossils of any kind visible on the ground surface. It is unknown what lies below the ground until excavations commence.

6. Recommendation

Based on site visit verification and walkdown, as well as the lack of any previously recorded fossils from the area, it is extremely unlikely that any fossils would be preserved in the overlying soils and sands of the Quaternary period. The site visit and walkthrough in February 2023 confirmed that there were NO FOSSILS (stromatolites or fossil plants) on the surface. There were very few rocky outcrops that could potentially preserve fossils. There is a very small chance that fossils may occur below ground in the dolomites or quartzites, if present, or in the below-ground shales of the early Permian Vryheid Formation so a Fossil Chance Find Protocol should be added to the EMPr. If fossils are found by the contractor, environmental officer, or other responsible person once excavations for foundations, amenities, infrastructure or underground cables have commenced then they should be rescued and a palaeontologist called to assess and collect a representative sample. The impact on the palaeontological heritage for both Alternative 1 and Alternative 2 would be low pre-mitigation and very low post-mitigation . There is no cumulative impact. There are no no-go areas.

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8. Chance Find Protocol

Monitoring Programme for Palaeontology – to commence once the excavations / drilling activities begin.

1. The following procedure is only required if fossils are seen on the surface and when drilling/excavations commence.
2. When excavations begin the rocks must be given a cursory inspection by the environmental officer or designated person. Any fossiliferous material (plants, insects, bone or coal) should be put aside in a suitably protected place. This way the project activities will not be interrupted.
3. Photographs of similar fossils must be provided to the contractor to assist in recognizing the trace fossils such as stromatolites or microbially features (trails, curls, rip-ups, mudcracks) trace fossils in the dolomites, limestones, shales and mudstones, or fossil plants (for example see Figure 11-13). This information will be built into the EMP's training and awareness plan and procedures.
4. Photographs of the putative fossils can be sent to the palaeontologist for a preliminary assessment (Appendix A).
5. If there is any possible fossil material found by the contractor /environmental officer then a qualified palaeontologist should be appointed by the developer to conduct a site visit to inspect the selected material and check the dumps where feasible.
6. Fossil plants or vertebrates that are considered to be of good quality or scientific interest by the palaeontologist must be removed, catalogued and housed in a suitable institution where they can be made available for further study. Before the fossils are removed from the site, a SAHRA permit must be obtained. Annual reports must be submitted to SAHRA as required by the relevant permits.
7. If no good fossil material is recovered then no site inspections by the palaeontologist will be necessary. A final report by the palaeontologist must be sent to SAHRA once the project has been completed and only if there are fossils.
8. If no fossils are found and the excavations have finished then no further monitoring is required.

9. Appendix A – Examples of fossils from the Karoo Supergroup and the Transvaal Supergroup

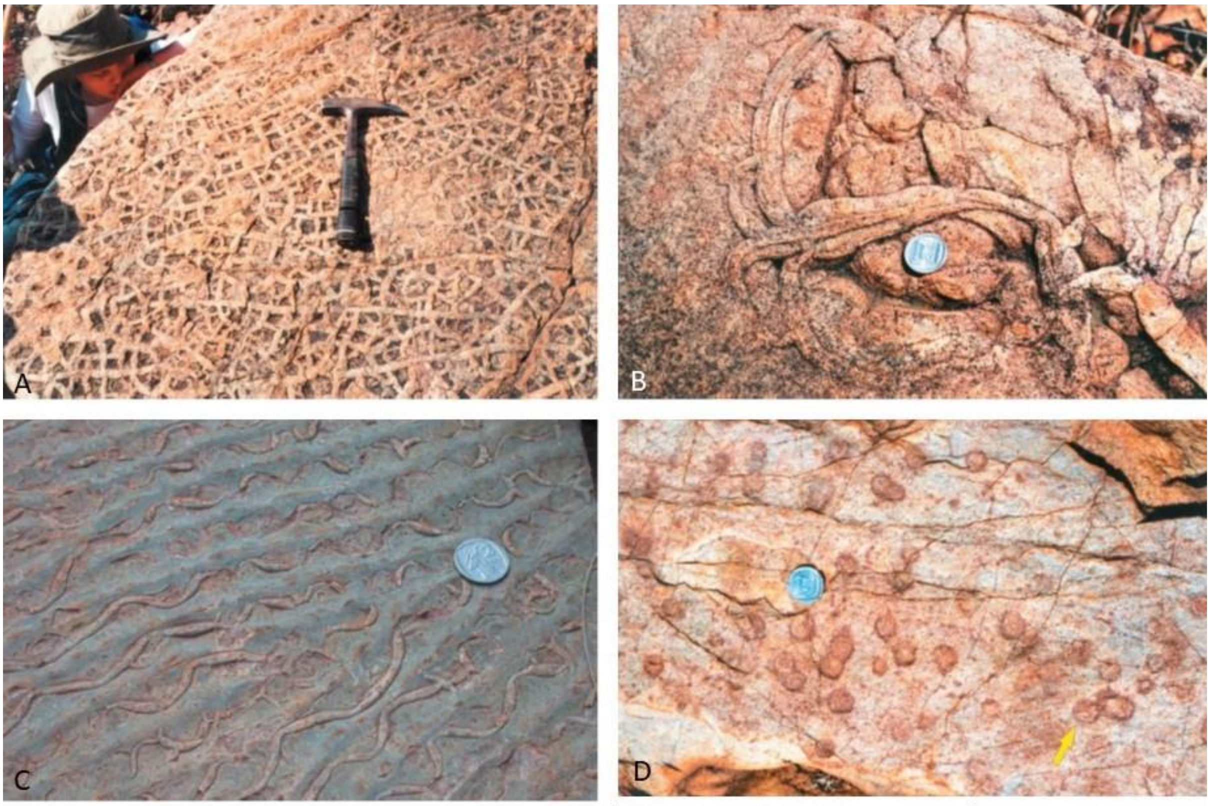
Weathering of dolomite

Small domal stromatolites

Side view of a stromatolite

Surface view of domal stromatolites

Figure11: Photographs from the Malmani Subgroup of different types of stromatolites in dolomite.



Magaliesberg Fm trace fossils, near Pretoria (all from Bosch & Eriksson, 2008): A – cracks,.
B – sinuous structure, C – *Manchuriphycus*, D – circular structures. R1 coin for scale.

Figure 12: Photographs of microbial features from the Magaliesberg Formation (in Bosch and Eriksson, 2008).

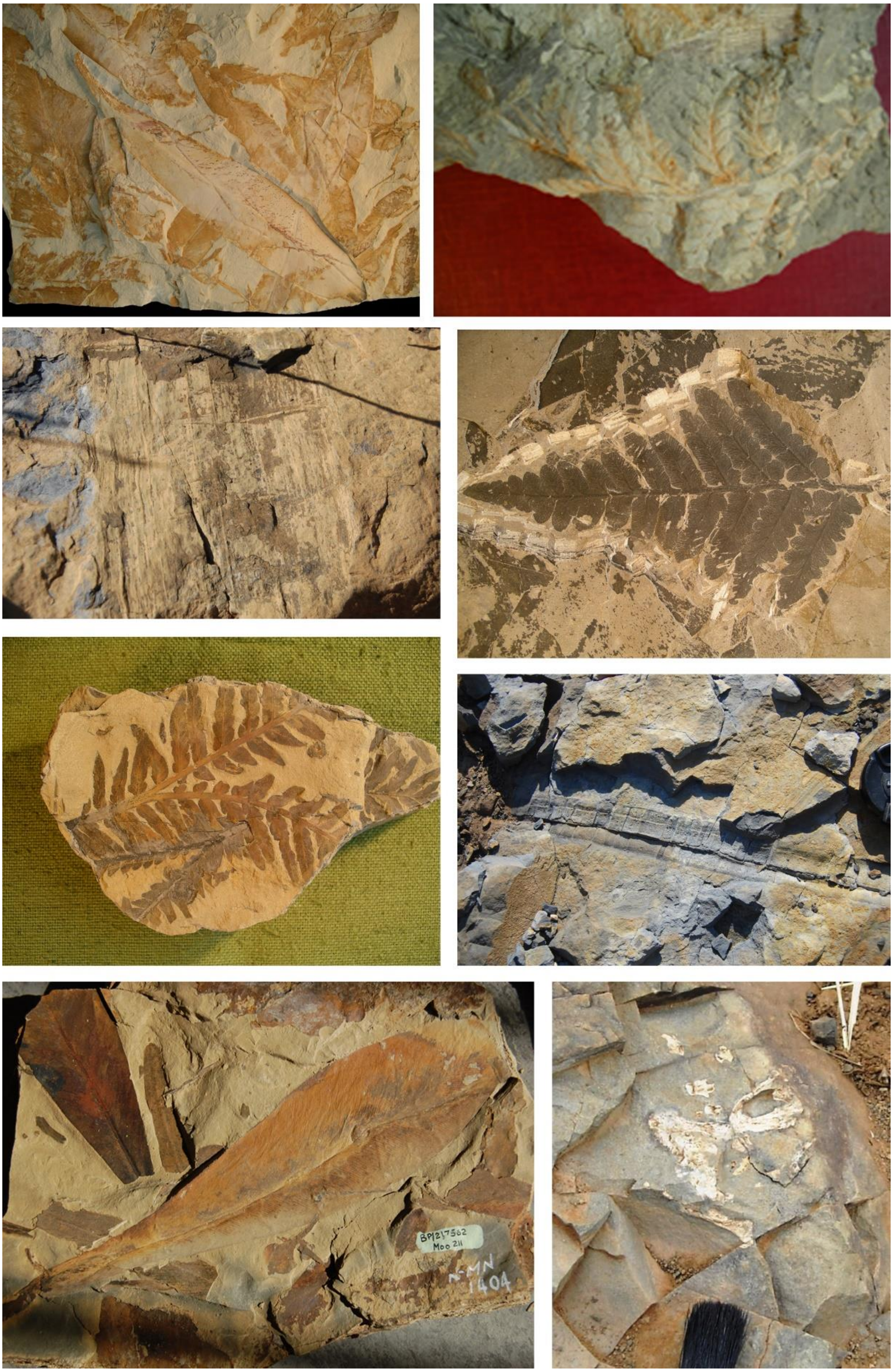


Figure 13: Photographs of fossil plants from the Vryheid Formation with *Glossopteris*, lycopods and ferns. Bottom right shows fossil bones in the field.

10. Appendix B – Details of specialist

Curriculum vitae (short) - Marion Bamford PhD
January 2023

Present employment: Professor; Director of the Evolutionary Studies Institute. Member Management Committee of the NRF/DSI Centre of Excellence Palaeosciences, University of the Witwatersrand, Johannesburg, South Africa
Telephone : +27 11 717 6690
Cell : 082 555 6937
E-mail : marion.bamford@wits.ac.za ; marionbamford12@gmail.com

ii) **Academic qualifications**
Tertiary Education: All at the University of the Witwatersrand:
1980-1982: BSc, majors in Botany and Microbiology. Graduated April 1983.
1983: BSc Honours, Botany and Palaeobotany. Graduated April 1984.
1984-1986: MSc in Palaeobotany. Graduated with Distinction, November 1986.
1986-1989: PhD in Palaeobotany. Graduated in June 1990.

iii) **Professional qualifications**
Wood Anatomy Training (overseas as nothing was available in South Africa):
1994 - Service d'Anatomie des Bois, Musée Royal de l'Afrique Centrale, Tervuren, Belgium, by Roger Dechamps
1997 - Université Pierre et Marie Curie, Paris, France, by Dr Jean-Claude Koeniguer
1997 - Université Claude Bernard, Lyon, France by Prof Georges Barale, Dr Jean-Pierre Gros, and Dr Marc Philippe

iv) **Membership of professional bodies/associations**
Palaeontological Society of Southern Africa
Royal Society of Southern Africa - Fellow: 2006 onwards
Academy of Sciences of South Africa - Member: Oct 2014 onwards
International Association of Wood Anatomists - First enrolled: January 1991
International Organization of Palaeobotany – 1993+
Botanical Society of South Africa
South African Committee on Stratigraphy – Biostratigraphy - 1997 - 2016
SASQUA (South African Society for Quaternary Research) – 1997+
PAGES - 2008 –onwards: South African representative
ROCEEH / WAVE – 2008+
INQUA – PALCOMM – 2011+onwards

v) **Supervision of Higher Degrees**

All at Wits University

Degree	Graduated/completed	Current

Honours	13	0
Masters	13	3
PhD	13	7
Postdoctoral fellows	14	4

vi) **Undergraduate teaching**
Geology II – Palaeobotany GEOL2008 – average 65 students per year
Biology III – Palaeobotany APES3029 – average 25 students per year
Honours – Evolution of Terrestrial Ecosystems; African Plio-Pleistocene Palaeoecology; Micropalaeontology – average 12 - 20 students per year.

vii) **Editing and reviewing**
Editor: Palaeontologia africana: 2003 to 2013; 2014 – Assistant editor
Guest Editor: Quaternary International: 2005 volume
Member of Board of Review: Review of Palaeobotany and Palynology: 2010 –
Associate Editor: Cretaceous Research: 2018-2020
Associate Editor: Royal Society Open: 2021 -
Review of manuscripts for ISI-listed journals: 30 local and international journals

viii) **Palaeontological Impact Assessments**
25 years' experience in PIA site and desktop projects

- Selected from recent projects only – list not complete:
- Skeerpoort Farm Mast 2020 for HCAC
- Vulindlela Eco village 2020 for 1World
- KwaZamakhule Township 2020 for Kudzala
- Sunset Copper 2020 for Digby Wells
- McCarthy-Salene 2020 for Prescali
- VLNR Lodge 2020 for HCAC
- Madadeni mixed use 2020 for Enviropro
- Frankfort-Windfield Eskom Powerline 2020 for 1World
- Beaufort West PV Facility 2021 for ACO Associates
- Copper Sunset MR 2021 for Digby Wells
- Sannaspos PV facility 2021 for CTS Heritage
- Smithfield-Rouxville-Zastron PL 2021 for TheroServe
- Glosam Mine 2022 for AHSA
- Wolf-Skilpad-Grassridge OHPL 2022 for Zutari
- Iziduli and Msenge WEFs 2022 for CTS Heritage
- Hendrina North and South WEFs & SEFs 2022 for Cabanga
- Dealesville-Springhaas SEFs 2022 for GIBB Environmental
- Vhuvhili and Mukondeleli SEFs 2022 for CSIR
- Chemwes & Stilfontein SEFs 2022 for CTS Heritage
- Equestria Exts housing 2022 for Beyond Heritage
- Zeerust Salene boreholes 2022 for Prescali
- Tsakane Sewer upgrade 2022 for Tsimba
- Transnet MPP inland and coastal 2022 for ENVASS
- Ruighoek PRA 2022 for SLR Consulting (Africa)
- Namli MRA Steinkopf 2022 for Beyond Heritage

ix) **Research Output**
Publications by M K Bamford up to January 2022 peer-reviewed journals or scholarly books: over 170 articles published; 5 submitted/in press; 14 book chapters.
Scopus h-index = 30; Google Scholar h-index = 39; -i10-index = 116 based on 6568 citations.
Conferences: numerous presentations at local and international conferences.