APPENDIX I: SPECIALIST PALAEONTOLOGICAL IMPACT ASSESSMENT

Palaeontological Impact Assessment for the proposed EIA318 drill sites (Target Areas 1-3) for the Rhino Oil and Gas project, Kroonstad to Lindley, Free State Province

Desktop Study (Phase 1)

For

SLR Consulting (Pty) Ltd

19 March 2023; Revised 24Mar2023

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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 SLR Consulting (Pty) Ltd, Johannesburg, 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 drill sites between Kroonstad and Lindley, central Free State Province, for Rhino Oil and Gas ER318 project and associated three target areas.

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.

Target Areas 1 and 2.
The drill sites are on Quaternary sands, mostly on ploughed fields so any rocks (or fossils) would have been removed. One site is on non-fossiliferous Jurassic dolerite.

Target Area 3.
The proposed site lies on the very highly sensitive Adelaide Subgroup (Beaufort Group, Karoo Supergroup) that might preserve vertebrate bones Therefore, 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 drilling commences. From the site visit photographs (from SLR), the occurrence of any fossils is highly unlikely because the farmlands have been cleared of all rocks.

The significance / impact on the palaeontology is low pre-mitigation and insignificant post-mitigation. There is no cumulative impact; there is no residual impact and there is no no-go area.

Contents

1. Introduction

i. Project Background

Rhino Oil and Gas Exploration South Africa (Pty) Ltd. (Rhino Oil & Gas) is a South African registered subsidiary of Rhino Resources Ltd. Rhino Resources Ltd is a technology driven, independent oil and gas exploration and development company focused on Africa. Rhino Oil & Gas has been granted an Environmental Authorisation and Exploration Right, permitting their exploration for natural gas using non-invasive techniques on various farms in the Magisterial District of Bultfontein, Wesselsbron, Welkom, Odendaalsrus, Wolmaransstad, Bothaville, Viljoenskroon, Kroonstad, Koppies and Heilbron, Free State and North-West Provinces (ER reference: 12/3/318). Exploration was to be undertaken in terms of an approved Exploration Work Programme (EWP), over an initial period of three (3) years.

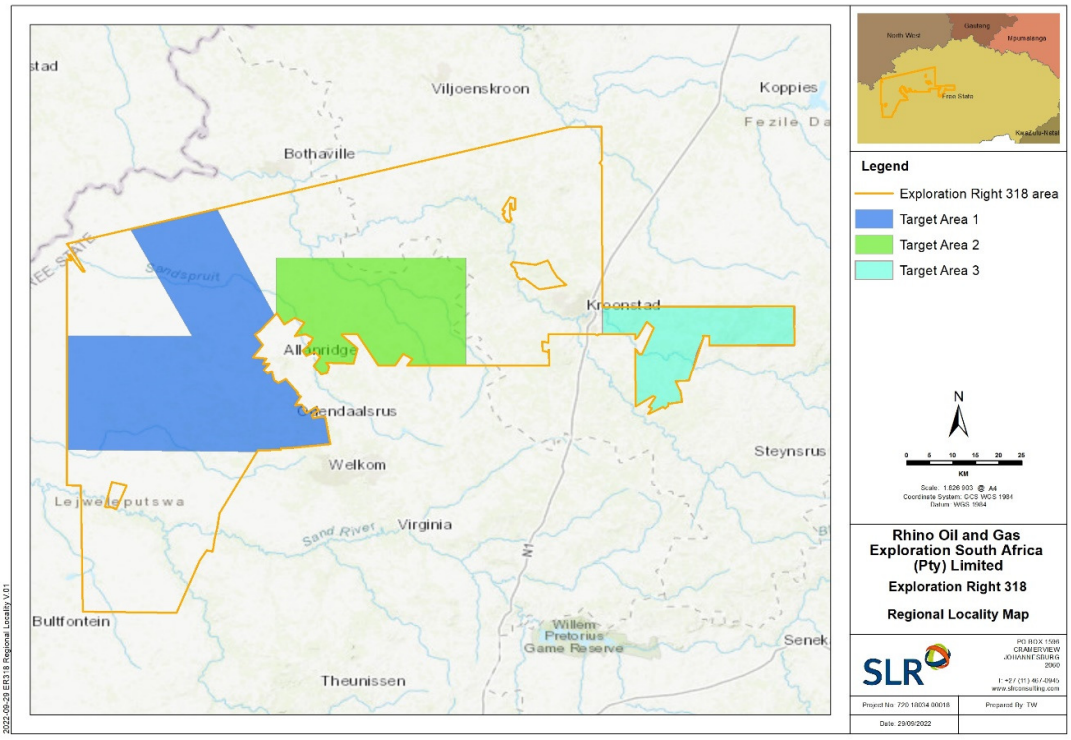

Figure 1-1: Locality Map showing extent of 318

Source-SLR Consulting

ii. Requirements for Specialist Reports

The National Environmental Management Act, 1998 requires for specialists reports to contain certain information in order to be credited. Information regarding the requirements for specialist reports is tabulated below.

Table 1: Requirements for Specialist reports

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 **Error! Reference source not found.**
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 0
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;	Section 3
I	A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 0
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 **Error! Reference source not found.**
K	Any mitigation measures for inclusion in the EMPr	Section 8, Appendix A
L	Any conditions for inclusion in the environmental authorisation	Section 8 Appendix A
M	Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 8, Appendix A

	A specialist report prepared in terms of the Environmental Impact Regulations of 2017 must contain:	**Relevant section in report**
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. Project Description

i. Project Location

The extent of ER 318 includes ~ 3 000 properties (farms and portions) over an area of approximately 600 000 ha).

Rhino Oil and Gas has identified three (3) Target Areas within which the updated well drilling EWP intends to focus. The Target Areas include (See Figure 1-1):

- **Target Area 1** is approximately 200 km^2 in extent and is located approximately 4 km west of Allanridge and 5 km north of Welkom. The Target Area includes ~ 680 properties;
- **Target Area 2** is approximately 450 km^2, approximately 4 km northeast of Allanridge and 20 km west of Kroonstad. The Target Area includes ~ 324 properties; and
- **Target Area 3** is approximately 138 km^2 in extent in the eastern portion of ER 318, with Steynsrus located 38 km south and Kroonstad to 2 km west. The target Area includes ~ 228 properties.

The location of well drilling sites is subject to a process of geological review, landowner consent and environmental considerations. Areas that are unsuitable are eliminated from further consideration. Rhino Oil and Gas is currently busy with the well site identification process.

ii. Main project components

The main project components, include the following:

- Onshore Drill Rig;
- Exclusion Zone;
- Local logistics base;
- Supply trucks;
- Personnel;
- Crew transfer; and
- Infrastructure and services.

A Palaeontological Impact Assessment was requested for Target Area 1, 2 and 3 of the ER318 section of the Rhino Oil and Gas 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 desktop Palaeontological Impact Assessment (PIA) was completed for the proposed development and is reported herein.

3. 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 included 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 (*not 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 (*not 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 (*not applicable to this assessment*).

4. 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 fossil plant, insect, invertebrate and vertebrate material. The sands of the Quaternary period would not preserve fossils.

5. Legal Requirements

i. Minerals and Petroleum Resources Development Act, 2002

The MPRDA is the principal legislation governing prospecting and mining and the exploration and production of oil and natural gas. The Act provides for the equitable access to and sustainable development of mineral and petroleum resources. The MPRDA Regulations (GN R527 of 2004) provide for the application for and issuing of Reconnaissance Permits, Prospecting Rights, Exploration Rights, Mining Rights and Production Rights. The MPRDA also provides for the renewal of rights and permits. Rhino Oil and Gas currently holds an Exploration Right 12/3/318 and have made application to renew the ER in terms of Section 81 of the MPRDA.

ii. National Environmental Management Act, 1998

Chapter 5, Section 24 of the NEMA provides a framework for the granting of an Environmental Authorisation. Section 24(4) provides the minimum requirements for procedures for the investigation, assessment and communication of the potential impact of activities.
EIA Regulations 2014 (as amended) promulgated in terms of Chapter 5 of NEMA, provide for the control of certain listed activities. These activities are listed in GN No. R983 (Listing Notice 1), R984 (Listing Notice 2) and R985 (Listing Notice 3) of 4 December 2014 (as amended) and are prohibited until an Environmental Authorisation has been obtained from the competent authority.
The proposed exploration project triggers activities contained in both Listing Notice 1 – 21D and Listing Notice 2 - 18, thus an EIA process must be undertaken for PASA and DMRE to consider the application. Rhino Oil and Gas have made application for an EA in terms of Section 24 of the NEMA.

iii. National Heritage Resources Act, 1999

The National Heritage Resources Act, 1999 (No. 25 of 1999) (NHRA) provides for the identification, assessment and management of the heritage resources of South Africa. The NHRA requires that a person who intends to undertake a listed activity notify the relevant provincial heritage authority at the earliest stages of initiating such a development. The relevant provincial heritage authority would then, notify the person whether a Heritage Impact Assessment (HIA) should be submitted.

Section 38(1) of the NHRA lists development activities that would require authorisation by the responsible heritage resources authority. The proposed well drilling activities in the updated EWP do not trigger any activity set out in this section of the NHRA and thus there is no requirement for approval from the heritage authority.

6. Description of the Baseline Environment

i. Project location and geological context

The project lies in the central part of the main Karoo Basin where the Ecca Group sediments are exposed (Figures 6.1-6.3). A few rare outcrops of the underlying and older Ventersdorp Supergroup lavas occur near Odendalsrus. Much younger Quaternary sands and alluvium unconformably overlie most of the Karoo Supergroup rocks that have not been extensively eroded.

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.

Overlying the basal 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.

Overlying the Ecca Group are the rocks of the Beaufort Group that has been divided into the lower Adelaide Subgroup for the Upper Permian strata, and the Tarkastad Subgroup for the Early to Middle Triassic strata. As with the older Karoo sediments, the formations vary across the Karoo Basin.

Minor exposures of Jurassic dolerite dykes occur throughout the area. These intruded through the Karoo sediments around 183 million years ago at about the same time as the Drakensberg basaltic eruption.

Quaternary Kalahari sands cover large parts of the rocks in this region, especially to the west. This is the largest and most extensive palaeo-erg in the world (Partridge et al., 2006) and is composed of extensive aeolian and fluvial sands, sand dunes, calcrete, scree and colluvium. Periods of aridity have overprinted the sands, and calcrete and silcrete are common. Most geological maps indicate these sands simply descriptively (aeolian sand, gravelly sand, calcrete) or they are lumped together as the Gordonia Formation because the detailed regional lithostratigraphic work has not been done, Nonetheless, these sands have eroded from the interior and have been transported by wind or water to fill the basin. Reworking of the sands or stabilisation by vegetation has occurred. Probable ages of dune formation are around 100 kya (thousand years), 60 kya, 27-23 kya and 17-10 kya (in Botha, 2021).

Along many of the rivers and watercourses are fluvially-transported sands and gravels that too are difficult to date. This sand is derived from the meandering channels and

terraces and has been reworked in the past from rivers and re-captured rivers as the tectonic uplift has changed drainage patterns (de Wit, 1999; Botha, 2021). Human activities have also impacted the rivers and their sediment source.

Target Area 1

Figure 6-1: Geological map of the area around the Target area 1 indicated within the blue oval. Abbreviations of the rock types are explained in Table 2. Map enlarged from the Geological Survey 1: 250 000 map 2726 Kroonstad.

Table 2: Explanation of symbols for the geological map and approximate ages (Eriksson et al., 2006. Johnson et al., 2006; Partridge et al., 2006). 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
Jd	Jurassic dykes	Dolerite dykes, intrusive	Jurassic, approx. 183 Ma
Pa	Adelaide Subgroup, Beaufort Group, Karoo SG	Mudstones, sandstones	Late Permian Ca 27-251 Ma
Pvo	Volksrust Fm, Ecca Group, Karoo SG	Grey-black fine-grained mudstone, sandstone	Late Permian, ca 260 - 257 Ma
Ra	Allanridge Fm, Pniel Group, Ventersdorp SG	Mafic lava, tuff; amygdaloidal at base	2664 – 2654 Ma

Target Area 2

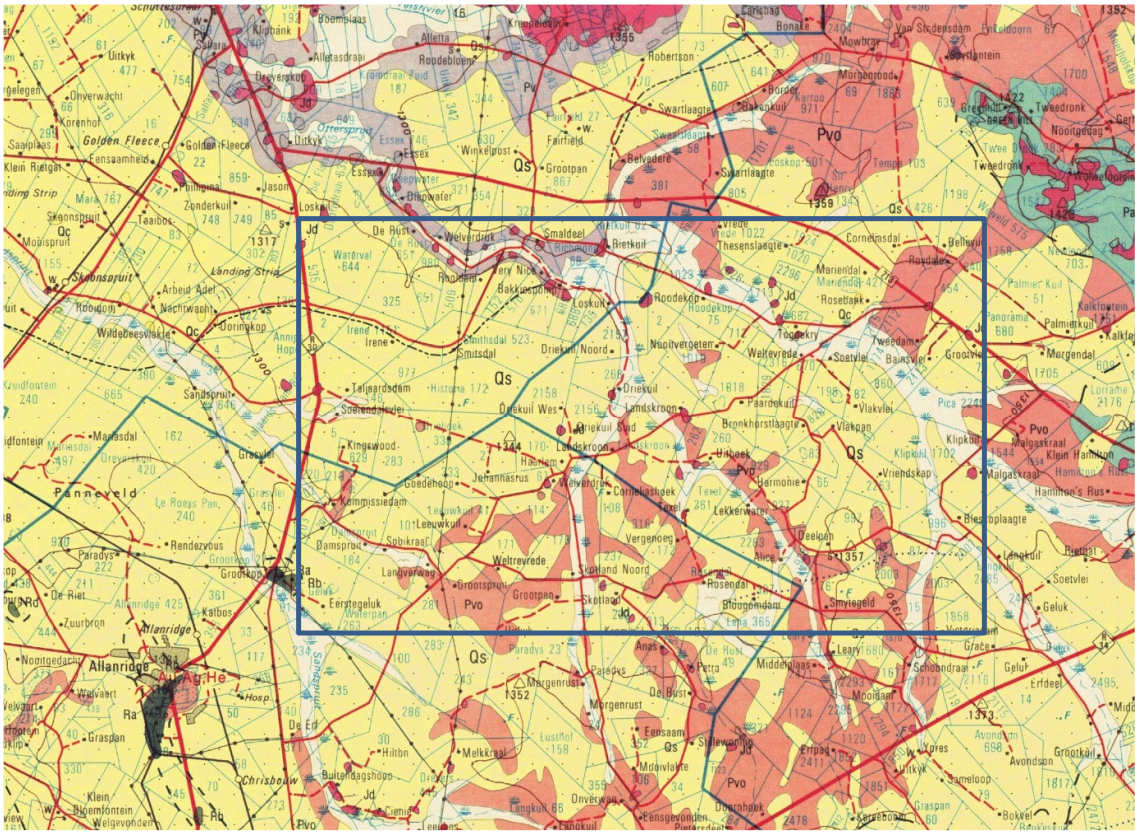

Figure 6-2: Geological map for the area around Target area 2. Abbreviations of the rock types are explained in Table 2. Map enlarged from the Geological Survey 1: 250 000 map 2726 Kroonstad.

Target Area 3

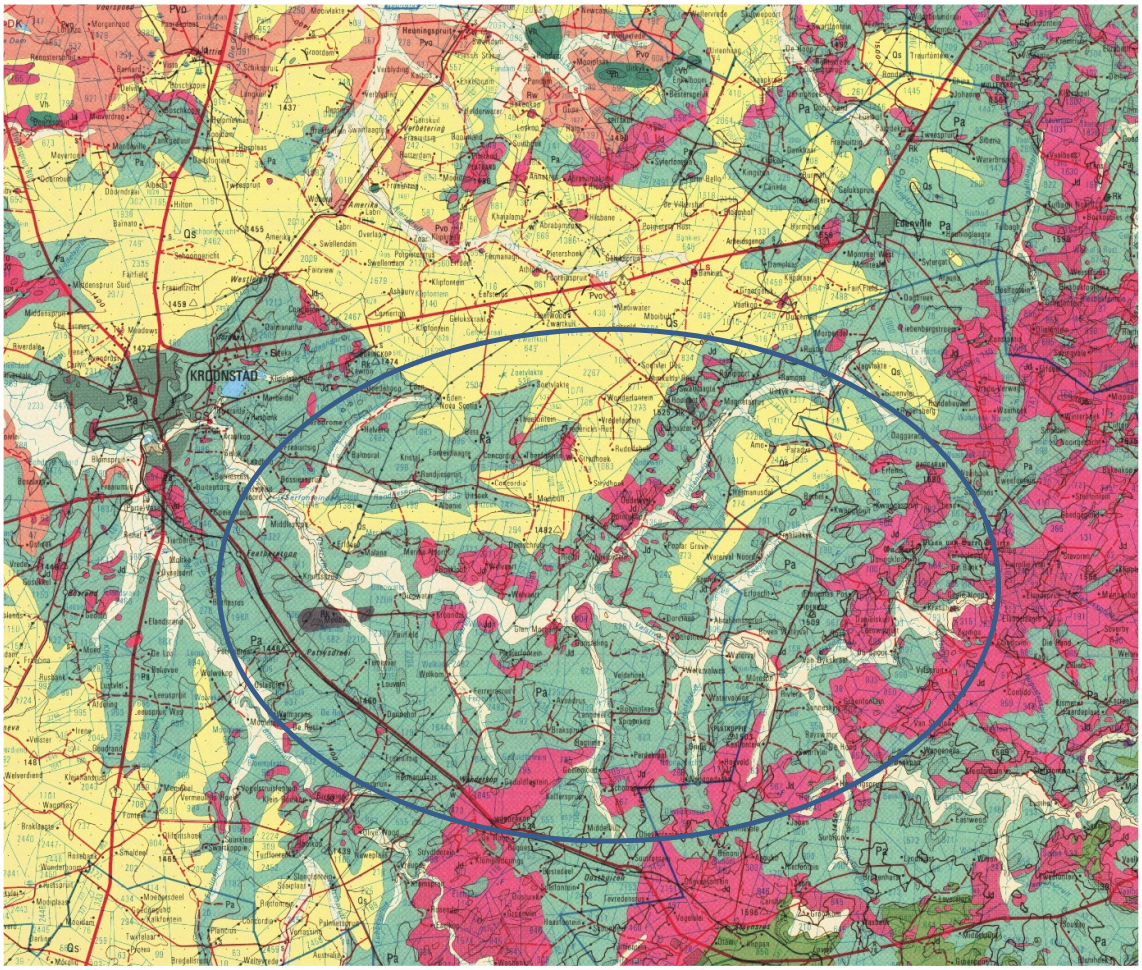

Figure 6-3: Geological map of the area around the Target area 3 indicated within the blue oval. Abbreviations of the rock types are explained in Table 2. Map enlarged from the Geological Survey 1: 250 000 map 2726 Kroonstad.

ii. Palaeontological context

Although there are no mapped outcrops of the various formations that comprise the Adelaide or Tarkastad Subgroups in the central part of the basin, detailed mapping has been done for the southern and western parts of the Karoo Basin and vertebrate fossils have been used to recognise the different formations. Note, in the field it is very difficult to recognise the different animal species but bones will appear as white structures in the mudstones.

The **Adelaide Subgroup** is part of the eastern foredeep basin and was deposited in the overfilled or non-marine phase (Catuneanu et al., 2005) and so comprises terrestrial deposits. There are numerous fining-upward cycles, abundant red mudrocks and sedimentary structures that indicate deposition under fluvial conditions (Johnson et al., 2006). Some of the lower strata probably represent a subaerial upper delta-plain

environment and the generally finer grained materials are typical of meandering rather than braided rivers. Channel deposits are indicated by sandstones while overbank deposits are indicated by the mudstones (Johnson et al., 2006).

The **Koonap Formation** (lower Adelaide Subgroup) has been divided into the *Eodicynodon* and *Tapinocephalus* Assemblage Zones based on the dominant basal therapsid genera.

Typical fossils of the *Eodicynodon* Assemblage Zone are fish, amphibians, dinocephalians, anomodonts (including *Eodicynodon*), gorgonopsians, therocephalians, invertebrate trace fossils and molluscs (Rubidge and Day, 2020). Plants are not common but there are leaves of *Glossopteris* and *Schizoneura* (sphenophyte) (Plumstead, 1969; Anderson and Anderson, 1985; Bamford, 2004).

Typical fossils of the *Tapinocephalus* Assemblage Zone are fish, amphibians, parareptiles, eureptiles, biarmosuchians, dinocephalians (including *Tapinocephalus*), anomodontians, therocephalians, vertebrate and invertebrate trace fossils and molluscs (Day and Rubidge. 2020). There is a low diversity of fossil plants from this assemblage zone but they include glossopterids, sphenophytes and gymnosperm woods (Plumstead, 1969; Anderson and Anderson, 1985; Bamford, 2004).

The **Middleton Formation** (Adelaide Subgroup) has been divided into the *Endothiodon*, and lower *Cistecephalus* Assemblage Zones based on the dominance of various vertebrate taxa. Fauna of the ***Endothiodon* Assemblage Zone** include the co-occurrence of the dicynodonts *Endothiodon, Emydops, Pristerodon* as well as the gorgonopsian *Gorgonops* (Day and Smith, 2020). Other vertebrates are fish, amphibians, biarmosuchains, anomodontians, other gorgonopsians, therocephalians and vertebrate and invertebrate traces. Plants include glossopterids, lycopods and sphenophytes (Plumstead, 1969; Anderson and Anderson, 1985; Bamford, 2004).

The ***Cistecephalus* Assemblage Zone** is characterised by the co-occurrence of the *Aulacephalodon, Oudenodon* and *Odontocyclops*, which are medium- to large-sized dicynodonts, as well as *Diictodon, Pristerodon* and *Cistecephalus* which are smaller dicynodonts (Smith, 2020). Important components are the diverse, gorgonopsians *Aelurognathus, Cyonosaurus* and *Lycaenops*. The therocephalians *Theriognathus, Ictidosuchoides* and *Ictidosuchop*s are rare components, as is the early cynodont *Cynosaurus*. Of the parareptiles, *Pareiasaurus* is most common taxon. The much rarer small-bodied pareiasaurs *Anthodon, Nanoparia*, and *Pumiliopareia* make their first and last appearances in the upper *Cistecephalus* Assemblage Zone (ibid). Fossil plants are rare and include glossopterids, lycopods and sphenophytes (Plumstead, 1969; Anderson and Anderson, 1985; Bamford, 2004).

The **Balfour Formation** is represented by the *Daptoccephalus* Assemblage Zone
The **Daptocephalus Assemblage Zone** is recognised by the co-occurrence of the dicynodontoid *Daptocephalus leoniceps*, the therocephalian *Theriognathus microps*, and the cynodont *Procynosuchus delaharpeae* (Viglietti, 2020). This has been further divided into two subzones, the lower *Dicynodon -Theriognathus* Subzone (in co-occurrence with *Daptocephalus*), and the upper *Lystrosaurus maccaigi – Moschorhinus kitchingi* Subzone

(ibid). Other taxa include fish, amphibians, parareptiles, eureptiles, biarmosuchians, anomodontians, gorgonopsians, therocephaleans, cynodonts and molluscs. The flora is more diverse than the older Assemblage Zones and comprises glossopterids, mosses, ferns, sphenophytes, lycopods, cordaitaleans and gymnosperm woods (Plumstead, 1969; Anderson and Anderson, 1985; Bamford, 2004).

The **Volksrust Formation** is the upper part of the Ecca Group (and lower Beaufort according to Smith et al., 2020) and is predominantly argillaceous and the grey to black silty shale with thin, usually bioturbated siltstone or sandstone lenses and beds that occur mostly in the upper and lower boundaries. The very thick and fine-grained sediments represent an open shelf environment where muds were deposited from suspension with (Johnson et al., 2006) in a deepwater environment. It is not known if this was an inland sea or open marine setting but the discovery of the marine bivalve, *Megadesmus*, (albeit one instance) about 25km west southwest of Newcastle in Volksrust Formation shales, points to a marine influence for at least part of the sequence (Cairncross et al., 2005).

Some sites for drilling are on Quaternary sands. Six formations are recognised in the Kalahari Group but they are not often indicated on the geological maps. A more recent review by Botha (2021) attempts to correlate the Quaternary sediments but they are difficult to date or to determine their source. In this part of the Free State the Hoopstad Aeolian sands are present. According to Harmse (1963, in Botha, 2021) this extensive red and grey sandy soil cover is associated with three generations of aeolian sand sheets. Moreover, these generations of aeolian sand form the soil substrate in the heart of the nation's maize cultivation region, yet their geological origin and age remains understudied (Botha, 2021, p. 825).

Quaternary sands and alluvium do not preserve fossils because they are transported and porous. For preservation of fossils, a low energy deposit with sedimentation of fine grained silts or muds that exclude decomposing organisms such as bacteria, fungi and invertebrates is required to maintain a highly reducing environment (Cowan, 1995). Only if there are traps such as palaeo-pans or palaeo-springs that provide traps for water and fine sediments, would plants or bones be preserved and fossilised. No such features are visible in the satellite imagery in the project footprint.

Each site was checked at high resolution and their palaeosensitivity maps are given below after the table summarising the geology.

Target Area 1

The palaeontological sensitivity of the area under consideration is presented in Figure 6-4. The 12 sites for drilling are all in the Quaternary sands and alluvium (green coding in the SAHRIS map) but some are close to the Volksrust Formation (orange coding in the SAHRIS map).

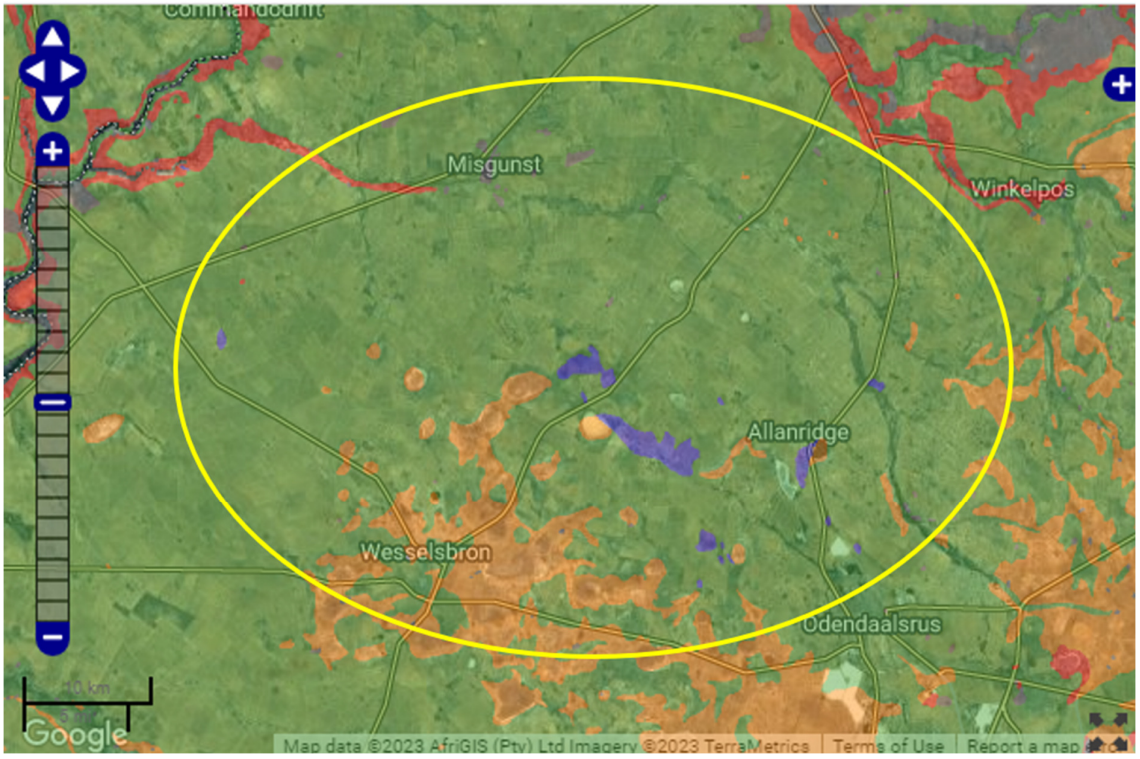

Figure 6-4: SAHRIS palaeosensitivity map for the site for the proposed drill sites for the ER318 target area 1 shown within the yellow oval. Background colours indicate the following degrees of sensitivity: red = very highly sensitive; orange/yellow = high; green = moderate; blue = low; grey = insignificant/zero.

Each site was checked at high resolution and ALL sites lie on Quaternary sands with none on the Volksrust Formation. Summary of drill sites and geology are provided in Table 4 below.

Target Area 2

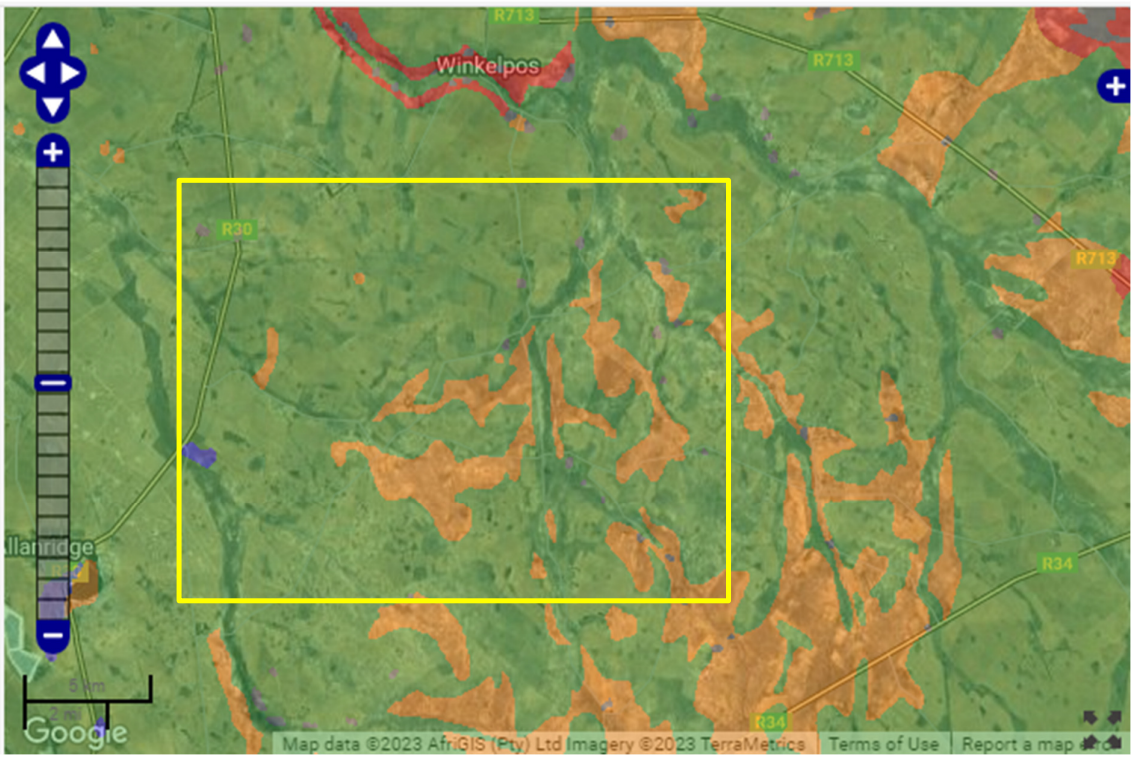

Figure 6-5: SAHRIS palaeosensitivity map for the site for the proposed drill sites for the ER318 target area 2 shown within the yellow rectangle. Background colours as for previous map.

The two sites in Target Area 2 lie on moderately fossiliferous Quaternary sands. Summary in Table 4 below.

Target Area 3

The palaeontological sensitivity of the area under consideration is presented in Figure 6-6. The single site for drilling is in the Adelaide Subgroup (red for very highly sensitive).

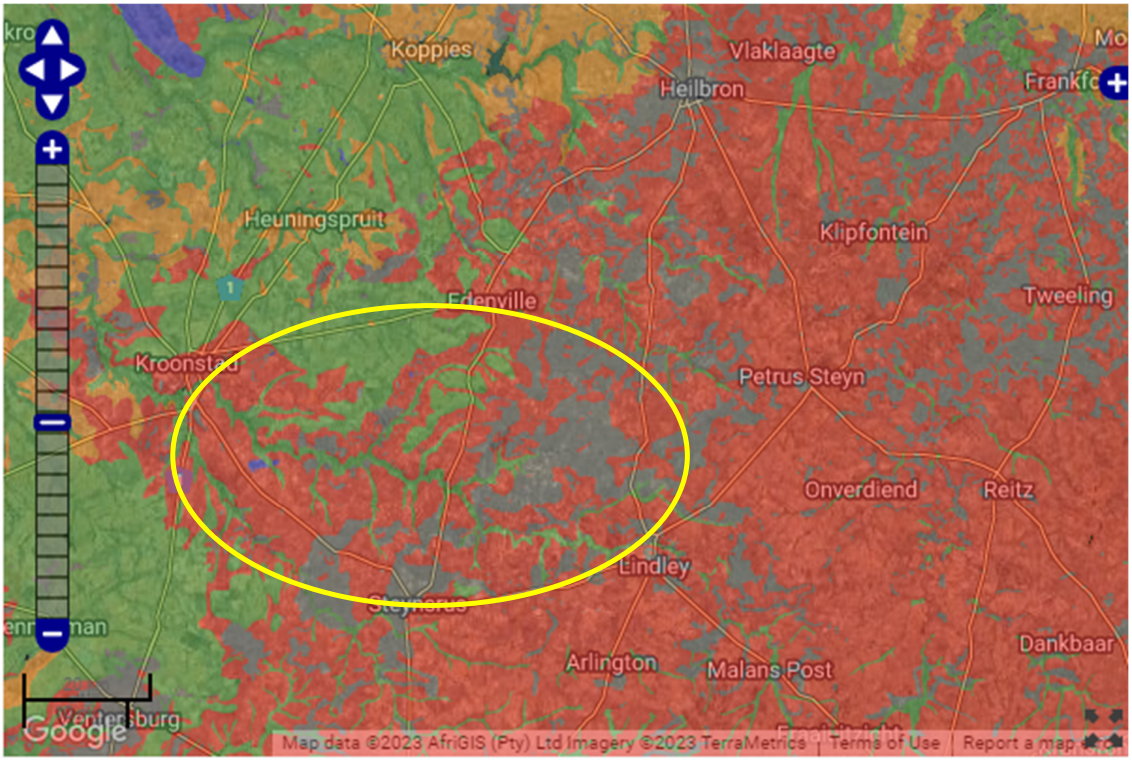

Figure 6-6: SAHRIS palaeosensitivity map for the site for the proposed drill sites for the ER318 Target area 3. shown within the yellow oval. Background colours indicate the following degrees of sensitivity: red = very highly sensitive; orange/yellow = high; green = moderate; blue = low; grey = insignificant/zero.

Table 4: Drill sites in the three Target Areas with (SAHRIS) palaeosensitivity coding and geology.

Target Area	Drill Site No	Surveyor General Code	Geology and palaeosensitivity
Target Area 1	Drill Site - 01	F00500000000010200000	Quaternary sands Transported fragments
	Drill Site – 02	F00500000000024100000	Quaternary sands Transported fragments
	Drill Site – 03	F04100000000025200000	Quaternary sands Transported fragments
	Drill Site – 04	F04100000000021300000	Quaternary sands Transported fragments
	Drill Site – 05	F04100000000015600000	Quaternary sands Transported fragments
	Drill Site – 06	F04100000000032800000	Quaternary sands Transported fragments
	Drill Site – 07	F04100000000022000000	Quaternary sands

			Transported fragments
	Drill Site – 08	F04100000000033300000	Quaternary sands Transported fragments
	Drill Site – 09	F04100000000008900000	Quaternary sands Transported fragments
	Drill Site – 10	F02400000000015400000	Quaternary sands Transported fragments
	Drill Site – 11	F04100000000021000000	Jurassic dolerite No fossils
	Drill Site – 12	F02400000000011500000	Quaternary sands Transported fragments
Target Area 2	Drill Site – 01	F02400000000045800000	Quaternary sands Transported fragments
	Drill Site – 02	F02400000000004600000	Quaternary sands Transported fragments
Target Area 3	Drill Site – 01	F02000000000074800000	Adelaide Subgroup Vertebrate fossils

Figures 6-7 to 6-10 below are site photographs supplied by SLR and linked to the kml in Figure 2. Not all these sites will be drilled but it provides an indication of the general areas. They all show grasslands that have been used for agriculture and no rocky outcrops are visible and so no fossils would be visible on the land surface even if present.

Figure 6-7: Site photograph No 3916 on the Adelaide Subgroup. No rocky outcrops visible,

Figure 6-8: Site photograph 3891 on the Adelaide Subgroup. No rocky outcrops visible.

Figure 6-9: Site photograph 3894 on Adelaide Subgroup but no rocky outcrops.

Figure 6-10: Site photograph 3897 on the Adelaide Subgroup but no rocky outcrops.

All (except for one on dolerite) of the sites in Target Area 1 and Target Area 2 are on moderately sensitive sands of the Quaternary that might have transported fragmentary fossils or fossils trapped in pans. No palaeo-pans however, remain in the agricultural areas. In Target Area 3 the single site is on potentially very highly sensitive rocks of the Adelaide Subgroup that might preserve fossil vertebrates. This is very unlikely as the area has been cleared and ploughed.

7. Methodology

An assessment of the potential impacts to possible palaeontological resources considers the criteria encapsulated in **Error! Reference source not found.**:

PART A: DEFINITIONS AND CRITERIA*		
Definition of SIGNIFICANCE		**Significance = consequence x probability**
Definition of CONSEQUENCE		**Consequence is a function of intensity, spatial extent and duration**
Criteria for ranking of the INTENSITY of environmental impacts	**VH**	Severe change, disturbance or degradation. Associated with severe consequences. May result in severe illness, injury or death. Targets, limits and thresholds of concern continually exceeded. Substantial intervention will be required. Vigorous/widespread community mobilization against project can be expected. May result in legal action if impact occurs.
	H	Prominent change, disturbance or degradation. Associated with real and substantial consequences. May result in illness or injury. Targets, limits and thresholds of concern regularly exceeded. Will definitely require intervention. Threats of community action. Regular complaints can be expected when the impact takes place.
	M	Moderate change, disturbance or discomfort. Associated with real but not substantial consequences. Targets, limits and thresholds of concern may occasionally be exceeded. Likely to require some intervention. Occasional complaints can be expected.
	L	Minor (Slight) change, disturbance or nuisance. Associated with minor consequences or deterioration. Targets, limits and thresholds of concern rarely exceeded. Require only minor interventions or clean-up actions. Sporadic complaints could be expected.
	VL	Negligible change, disturbance or nuisance. Associated with very minor consequences or deterioration. Targets, limits and thresholds of concern never exceeded. No interventions or clean-up actions required. No complaints anticipated.
	VL+	Negligible change or improvement. Almost no benefits. Change not measurable/will remain in the current range.
	L+	Minor change or improvement. Minor benefits. Change not measurable/will remain in the current range. Few people will experience benefits.
	M+	Moderate change or improvement. Real but not substantial benefits. Will be within or marginally better than the current conditions. Small number of people will experience benefits.
	H+	Prominent change or improvement. Real and substantial benefits. Will be better than current conditions. Many people will experience benefits. General community support.
	VH+	Substantial, large-scale change or improvement. Considerable and widespread benefit. Will be much better than the current conditions. Favourable publicity and/or widespread support expected.

Criteria for ranking the DURATION of impacts	**VL**	Very short, always less than a year. Quickly reversible
	L	Short-term, occurs for more than 1 but less than 5 years. Reversible over time.
	M	Medium-term, 5 to 10 years.
	H	Long term, between 10 and 20 years. (Likely to cease at the end of the operational life of the activity)
	VH	Very long, permanent, +20 years (Irreversible. Beyond closure)
Criteria for ranking the EXTENT of impacts	**VL**	A part of the site/property.
	L	Whole site.
	M	Beyond the site boundary, affecting immediate neighbours
	H	Local area, extending far beyond site boundary.
	VH	Regional/National

PART B: DETERMINING CONSEQUENCE							
			EXTENT				
			A part of the site/property	Whole site	Beyond the site, affecting neighbours	Local area, extending far beyond site.	Regional/ National
			VL	**L**	**M**	**H**	**VH**
INTENSITY = VL							
DURATION	Very long	**VH**	**Low**	**Low**	**Medium**	**Medium**	**High**
	Long term	**H**	**Low**	**Low**	**Low**	**Medium**	**Medium**
	Medium term	**M**	**Very Low**	**Low**	**Low**	**Low**	**Medium**
	Short term	**L**	**Very low**	**Very Low**	**Low**	**Low**	**Low**
	Very short	**VL**	**Very low**	**Very Low**	**Very Low**	**Low**	**Low**
INTENSITY = L							
DURATION	Very long	**VH**	**Medium**	**Medium**	**Medium**	**High**	**High**
	Long term	**H**	**Low**	**Medium**	**Medium**	**Medium**	**High**
	Medium term	**M**	**Low**	**Low**	**Medium**	**Medium**	**Medium**
	Short term	**L**	**Low**	**Low**	**Low**	**Medium**	**Medium**
	Very short	**VL**	**Very low**	**Low**	**Low**	**Low**	**Medium**
INTENSITY = M							
DURATION	Very long	**VH**	**Medium**	**High**	**High**	**High**	**Very High**
	Long term	**H**	**Medium**	**Medium**	**Medium**	**High**	**High**
	Medium term	**M**	**Medium**	**Medium**	**Medium**	**High**	**High**
	Short term	**L**	**Low**	**Medium**	**Medium**	**Medium**	**High**
	Very short	**VL**	**Low**	**Low**	**Low**	**Medium**	**Medium**
INTENSITY = H							
	Very long	**VH**	**High**	**High**	**High**	**Very High**	**Very High**
	Long term	**H**	**Medium**	**High**	**High**	**High**	**Very High**

DURATION	Medium term	**M**	**Medium**	**Medium**	**High**	**High**	**High**
	Short term	**L**	**Medium**	**Medium**	**Medium**	**High**	**High**
	Very short	**VL**	**Low**	**Medium**	**Medium**	**Medium**	**High**
INTENSITY = VH							
DURATION	Very long	**VH**	**High**	**High**	**Very High**	**Very High**	**Very High**
	Long term	**H**	**High**	**High**	**High**	**Very High**	**Very High**
	Medium term	**M**	**Medium**	**High**	**High**	**High**	**Very High**
	Short term	**L**	**Medium**	**Medium**	**High**	**High**	**High**
	Very short	**VL**	**Low**	**Medium**	**Medium**	**High**	**High**
			VL	**L**	**M**	**H**	**VH**
			A part of the site/property	Whole site	Beyond the site, affecting neighbours	Local area, extending far beyond site.	Regional/ National
			EXTENT				

PART C: DETERMINING SIGNIFICANCE							
PROBABILITY (of exposure to impacts)	Definite/ Continuous	**VH**	**Very Low**	**Low**	**Medium**	**High**	**Very High**
	Probable	**H**	**Very Low**	**Low**	**Medium**	**High**	**Very High**
	Possible/ frequent	**M**	**Very Low**	**Very Low**	**Low**	**Medium**	**High**
	Conceivable	**L**	**Insignificant**	**Very Low**	**Low**	**Medium**	**High**
	Unlikely/ improbable	**VL**	**Insignificant**	**Insignificant**	**Very Low**	**Low**	**Medium**
			VL	**L**	**M**	**H**	**VVH**
			CONSEQUENCE				

PART D: INTERPRETATION OF SIGNIFICANCE	
Significance	**Decision guideline**
Very High	Potential fatal flaw unless mitigated to lower significance.
High	It must have an influence on the decision. Substantial mitigation will be required.
Medium	It should have an influence on the decision. Mitigation will be required.
Low	Unlikely that it will have a real influence on the decision. Limited mitigation is likely to be required.
Very Low	It will not have an influence on the decision. Does not require any mitigation
Insignificant	Inconsequential, not requiring any consideration.

8. Impact Assessment

i. Impact Assessment for Palaeontology

Issue: PALAEONTOLOGY
Description of impact: Destruction of fossils that might be present in the drill site and laydown area.
Impact Assessment

Issue: Palaeontology		
Phases: Laydown of drill site and operation (drilling)		
Criteria	Without Mitigation	With Mitigation
Intensity	High	Low
Duration	Permanent	Permanent
Extent	Site	Site
Consequence	Medium	Low
Probability	Conceivable	Unlikely
Significance	Low	Insignificant
Additional Assessment Criteria		
Degree to which impact can be reversed	Irreversible impact.	
Degree to which impact may cause irreplaceable loss of resources	Fossils are irreplaceable. However, the implementation of a chance finds protocol will enable the monitoring and where required documentation of such resources.	
Degree to which impact can be avoided	High.	
Degree to which impact can be mitigated	**High:** implementation of a chance finds protocol will enable the monitoring and where required documentation of such resources	
Cumulative Impacts		
Nature of cumulative impacts	General loss of fossils and scientific knowledge to national palaeontological record.	
Extent to which a cumulative impact may arise	Negligible because each site is unique	
Rating of cumulative impacts	Without Mitigation	With Mitigation
	Insignificant	Insignificant
Residual impacts	None	
Mitigated outcome	With mitigation (removal of any fossils) the impact will be insignificant	

Mitigation actions

The following measures are recommended (see Fossil Chance Find Protocol in Appendix A):

Monitoring

The following monitoring is recommended (see EMPr):
When the drill core has been extracted and while it being logged, the geologist should look for fossil plants in the shales and photograph and retrieve them if possible. Noting that the drill core diameter is 135mm no complete fossils are likely to be retrieved.

Based on the nature of the project, surface activities may impact upon the fossil heritage if preserved in the development footprint. The geological structures suggest that the rocks are the wrong kind (transported sands) to contain fossils. Since there is an extremely small chance that fossils from covered or obscured palaeo-pans or palaeo-springs by the overlying Quaternary sands may be present and may be disturbed, a Fossil Chance Find Protocol has been added to this report. Taking account of the defined criteria, the potential impact to fossil heritage resources is extremely low.

9. Recommendation

Based on experience and the lack of any previously recorded fossils from the area, it is extremely unlikely that any fossils would be preserved in the overlying sands and alluvium of the Quaternary. There is a very small chance that features that trap fossils, such as palaeo-pans and palaeo-springs might be obscured by the sands. This is the case for all the drill sites in Target areas 1 and 2.

The drill site in Target Area 3 is on potentially very highly fossiliferous mudstones of the Adelaide Subgroup that might preserve fossil vertebrate bones, are on flat fields that have been cleared for agriculture (grazing or previously for crops) and no rocky outcrops remain on the surface. Therefore, no fossils would be visible on the surface. However, 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 drilling has commenced then they should be rescued and a palaeontologist called to assess and collect a representative sample. The impact on the palaeontological heritage would be insignificant pre-mitigation and insignificant post-mitigation. There is no residual impact and no cumulative impact. There is no no-go area as far as the palaeontology is concerned.

10. References

Anderson, J.M., Anderson, H.M., 1985. Palaeoflora of Southern Africa: Prodromus of South African megafloras, Devonian to Lower Cretaceous. A.A. Balkema, Rotterdam. 423 pp.

Botha, G.A., 2021. Cenozoic stratigraphy of South Africa: current challenges and future possibilities. South African Journal of Geology 124, 817-842.
Doi: 10.25131/sajg.124.0054.

Cairncross, B., Beukes, N.J., Coetzee, L.L., Rehfeld, U., 2005. The Bivalve *Megadesmus* from the Permian Volksrust Shale Formation (Karoo Supergroup), northeastern Karoo Basin, South Africa: implications for late Permian Basin development. South African Journal of Geology 108, 547-556

Isbell, J.L., Henry, L.C., Gulbranson, E.L., Limarino, C.O., Fraiser, F.L., Koch, Z.J., Ciccioli, P.l., Dineen, A.A., 2012. Glacial paradoxes during the late Paleozoic ice age: Evaluating the equilibrium line altitude as a control on glaciation. Gondwana Research 22, 1-19.

Johnson, M.R., van Vuuren, C.J., Visser, J.N.J., Cole, D.I., Wickens, H.deV., Christie, A.D.M., Roberts, D.L., Brandl, G., 2006. Sedimentary rocks of the Karoo Supergroup. In: Johnson, M.R., Anhaeusser, C.R. and Thomas, R.J., (Eds). The Geology of South Africa. Geological Society of South Africa, Johannesburg / Council for Geoscience, Pretoria. Pp 461 – 499.

Plumstead, E.P., 1969. Three thousand million years of plant life in Africa. Geological Society of southern Africa, Annexure to Volume LXXII. 72pp + 25 plates.

Smith, R.M.H., 2020. Biostratigraphy of the Cistecephalus Assemblage Zone (Beaufort Group, Karoo Supergroup). South African Journal of Geology 123, 181-190.

Smith, R.M.H., Rubidge, B.S., Day, M.O., Botha, J., 2020. Introduction to the tetrapod biozonation of the Karoo Supergroup. South African Journal of Geology 123(2), 131-140.

Taverner-Smith, R., Mason, T.R., Christie, A.D.M., Smith, A.M., van der Spuy, M., 1988. Sedimentary models for coal formation in the Vryheid Formation, northern Natal. Bulletin of the Geological Survey of South Africa, 94. 46pp.

Visser, J.N.J., 1986. Lateral lithofacies relationships in the glacigene Dwyka Formation in the western and central parts of the Karoo Basin. Transactions of the Geological Society of South Africa 89, 373-383.

Visser, J.N.J., 1989. The Permo-Carboniferous Dwyka Formation of southern Africa: deposition by a predominantly subpolar marine icesheet. Palaeogeography, Palaeoclimatology, Palaeoecology 70, 377-391.

11. Appendix A - 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 and discard 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 developer to assist in recognizing the fossil plants, vertebrates, invertebrates or trace fossils in the shales and mudstones (for example see Figures 9-10). 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.
5. If there is any possible fossil material found by the developer/environmental officer then the qualified palaeontologist sub-contracted for this project, should visit the site 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.

12. Appendix B – Examples of fossils from the Quaternary sands.

Figure 9: Photographs of fragmented and transported fossils that can be found in Quaternary sands and alluvium.

Figure 10: Photographs of fossil vertebrates from the Beaufort Group. Bottom left is what bones would look like in the field – indeterminate white structures in the darker mudstone.

13. Appendix C – 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 Mukondelei 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 = 31; Google Scholar h-index = 39; -i10-index = 116 based on 6568 citations.
Conferences: numerous presentations at local and international conferences.