PALAEONTOLOGICAL SPECIALIST STUDY

In terms of Section 38(8) of the NHRA

Proposed Square Kilometre Array (SKA) fibre optic cable between Beaufort West and Carnarvon, Northern and Western Cape

Prepared by

Dewald Wilken

and

CTS HERITAGE

In Association with

CSIR

October 2020

CTS HERITAGE

THE INDEPENDENT PERSON WHO COMPILED A SPECIALIST REPORT OR UNDERTOOK A SPECIALIST PROCESS

I, **Dewald Wilken**, as the appointed independent specialist hereby declare that I:

• act/ed as the independent specialist in this application;

• regard the information contained in this report as it relates to my specialist input/study to be true and correct, and

• do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the NEMA, the Environmental Impact Assessment Regulations, 2010 and any specific environmental management Act;

• have and will not have no vested interest in the proposed activity proceeding;

• have disclosed, to the applicant, EAP and competent authority, any material information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the NEMA, the Environmental Impact Assessment Regulations, 2014 (as amended) and any specific environmental management Act;

• am fully aware of and meet the responsibilities in terms of NEMA, the Environmental Impact Assessment Regulations, 2014 (specifically in terms of regulation 13 of GN No. R. 326) and any specific environmental management Act, and that failure to comply with these requirements may constitute and result in disqualification;

• have ensured that information containing all relevant facts in respect of the specialist input/study was distributed or made available to interested and affected parties and the public and that participation by interested and affected parties was facilitated in such a manner that all interested and affected parties were provided with a reasonable opportunity to participate and to provide comments on the specialist input/study;

• have ensured that the comments of all interested and affected parties on the specialist input/study were considered, recorded and submitted to the competent authority in respect of the application;

• have ensured that the names of all interested and affected parties that participated in terms of the specialist input/study were recorded in the register of interested and affected parties who participated in the public participation process;

• have provided the competent authority with access to all information at my disposal regarding the application, whether such information is favorable to the applicant or not; and

• am aware that a false declaration is an offence in terms of regulation 14 of GN No. R. 326.

Signed

Name

Dewald Wilken

Date
8 October 2020

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

EXECUTIVE SUMMARY

A Palaeontological Impact Assessment (PIA) was requested for the proposed Square Kilometre Array fibre optic line connection between the Towns of Beaufort West via Loxton to Carnarvon. This PIA was conducted to comply with 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).

The trenching for this line will predominantly be carried out within the road reserve at about 1 m form the fence line. Some areas characterised complex / difficult terrain will be traversed by overhead fibre optic lines – wooden poles on which the cabling is mounted will be planted in 1.5 m deep holes. The area covers multiple palaeontologically sensitive strata. These are the Poortjie and Hoedemaker Members of the Teekloof Formation, in the Adelaide subgroup, of the Beaufort Group, in the Karoo Suppergroup, and the Abrahamskraal Formation in the Adelaide subgroup, of the Beaufort Group, in the Karoo Suppergroup. The area covers some strata of the Ecca Group of the Karoo Suppergroup, however these strata, although fossiliferous is of low concern. The area has been intruded by multiple dolerite sills and dykes of Jurassic age.

The road reserve area has been greatly degraded, and mudstones and have been highly weathered and fractured. The chance of finding a fossil in the area during trenching is low, but possible. For this reason, a Chance Fossil Find Procedure is added to the end of this report. As far as the palaeontology is concerned the project may proceed.

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

CTS HERITAGE

CONTENTS

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

1. INTRODUCTION

1.1 Background Information on Project

The South African Radio Astronomy Observatory (SARAO) spearheads South Africa's activities in the SKA Radio Telescope through engineering, science and construction. SARAO is a National Facility, managed by the National Research Foundation, which incorporates radio astronomy instruments and programmes such as the MeerKAT and KAT-7 telescopes in the Karoo, the Hartebeesthoek Radio Astronomy Observatory (HartRAO) in Gauteng, the African Very Long Baseline Interferometry (AVN) programme in nine African countries, as well as the associated human capital development and commercialisation endeavours.

Connectivity is required between the SKA core site in the Northern Cape and a data processing facility in Cape Town to transport the science data for the SKA project and its precursor, MeerKAT. Access to dark fibre is required to transport this data due to the expected data throughputs for the SKA project.

The details of the preferred and selected SKA fibre route (Route A) is as follows:

1. The fibre route starts from Beaufort West Transnet building, to a 3 m x 6 m signal repeater station at Loxton, and then on to the Carnarvon SKA Point of Presence (PoP) site (location where networking equipment may be accessed).
2. The fibre duct and cable will be laid in a 1 m deep and 300 mm wide trench and be buried by backfilling and compacting the trench.
3. The fibre route will predominantly be installed within the road reserves of roads R381 and R63, and 1 m from the fence of the private land.
4. 155 km will be underground and 25 km will be overhead due to it not being technically or financially feasible to trench on the Molteno Pass section. The total pole length is 9 m, buried 1.5 m deep, with a resultant above-ground height of 7.5 m
5. There are several streams / rivers and associated wetlands to cross. Rivers will be crossed using directional drilling 2 m below the riverbed starting 32 m away from river banks.
6. There is only one river with solid bedrock (the Brak River near Loxton) where directional drilling is not technically or financially feasible. Here the fibre cable will be attached to the existing road bridge.

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

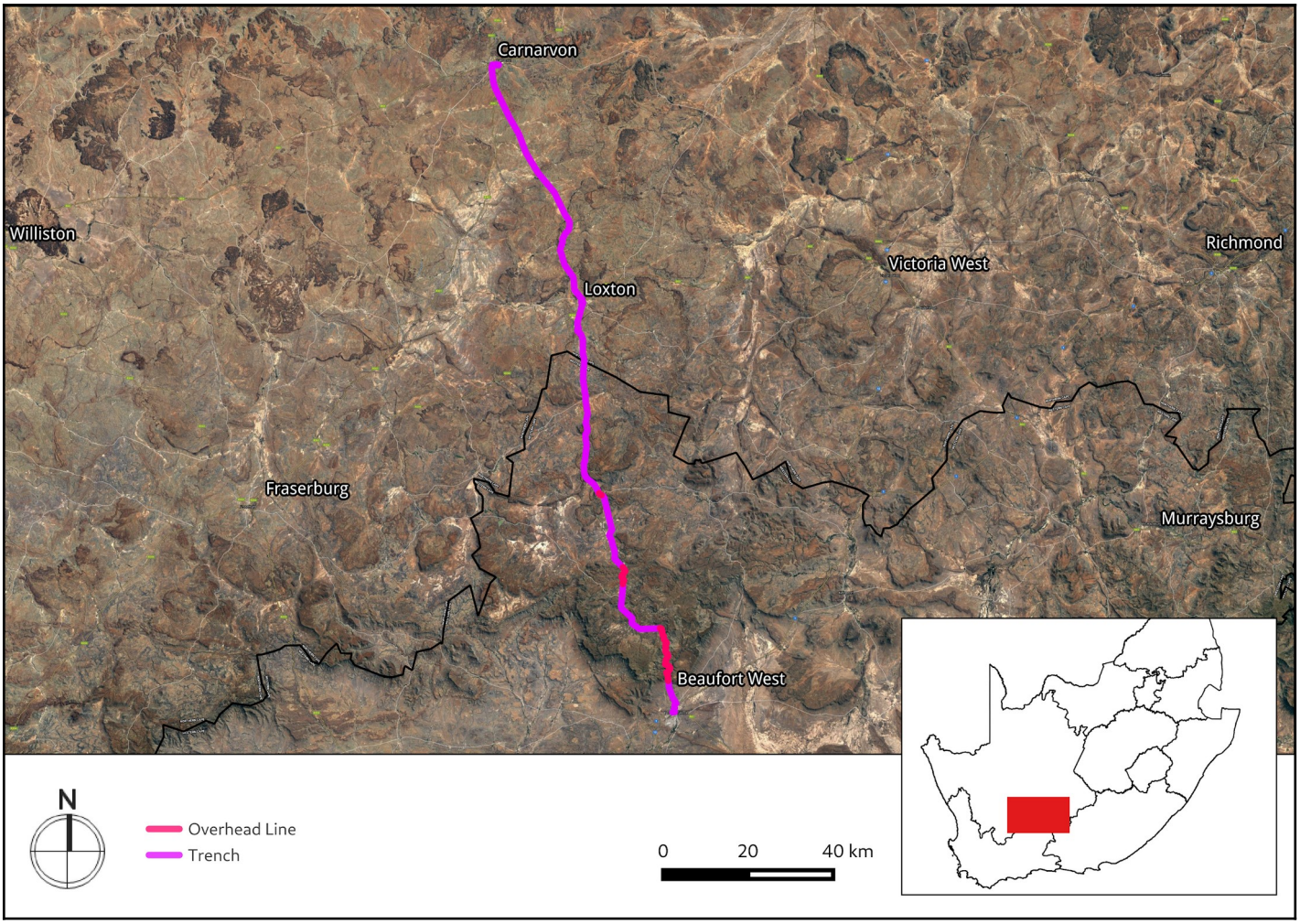

Figure 1 Google Earth© satellite image of the proposed Fibre line between Beaufort West and Carnarvon. Please see the following two figures for more detail.

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

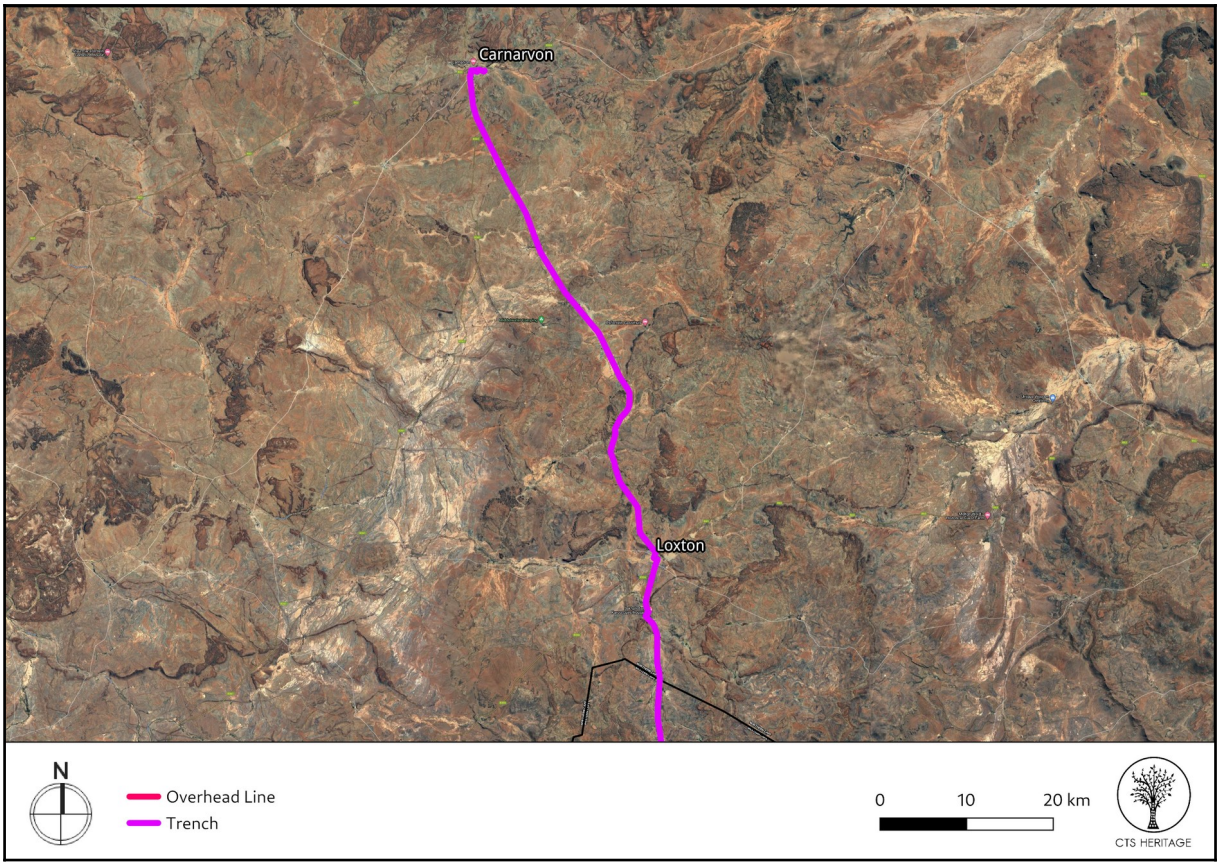

Figure 2 Google Earth© satellite image of the study area in the Northern Cape

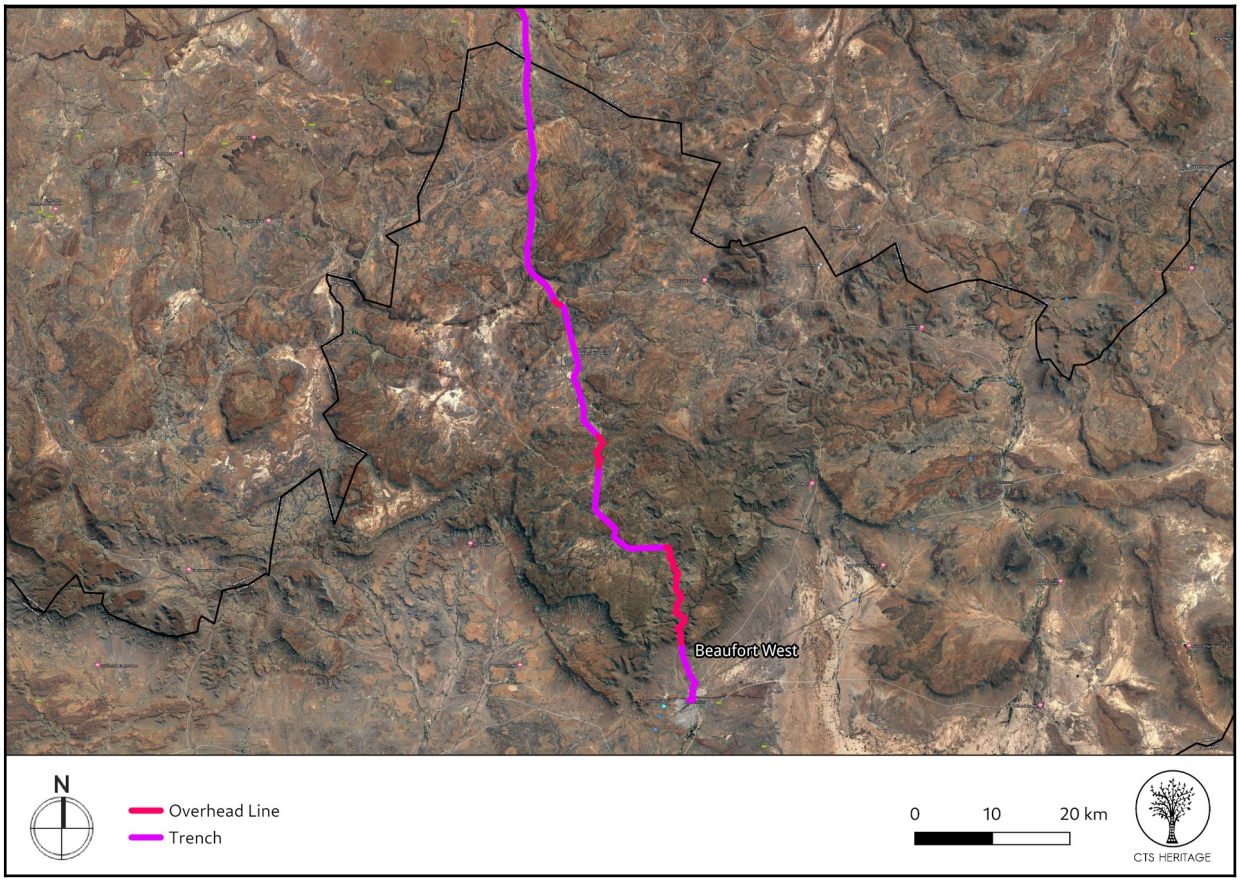

Figure 3 Google Earth© satellite image of the study area in the Western Cape

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

2. METHODOLOGY

2.1 Purpose of Palaeontological Study

The SKA fibre route project area is underlain by potentially fossiliferous sediments of the Poortjie Member and Hoedemaker Member of the Teekloof Formation, and the Abrahamskraal Formation of the Beaufort Group. It is therefore likely that any excavation conducted within this palaeontologically sensitive area is likely to negatively impact on significant palaeontological heritage. A palaeontological heritage assessment of the road project has been recommended in a recent Heritage Screener by CTS Heritage, Cape Town (CTS Heritage 2019). The purpose of this palaeontological heritage study is to satisfy the requirements of section 38(8), and therefore section 38(3) of the National Heritage Resources Act (Act 25 of 1999) in terms of impacts to palaeontological resources. It contributes to the broader environmental assessment for the road project being coordinated by the CSIR.

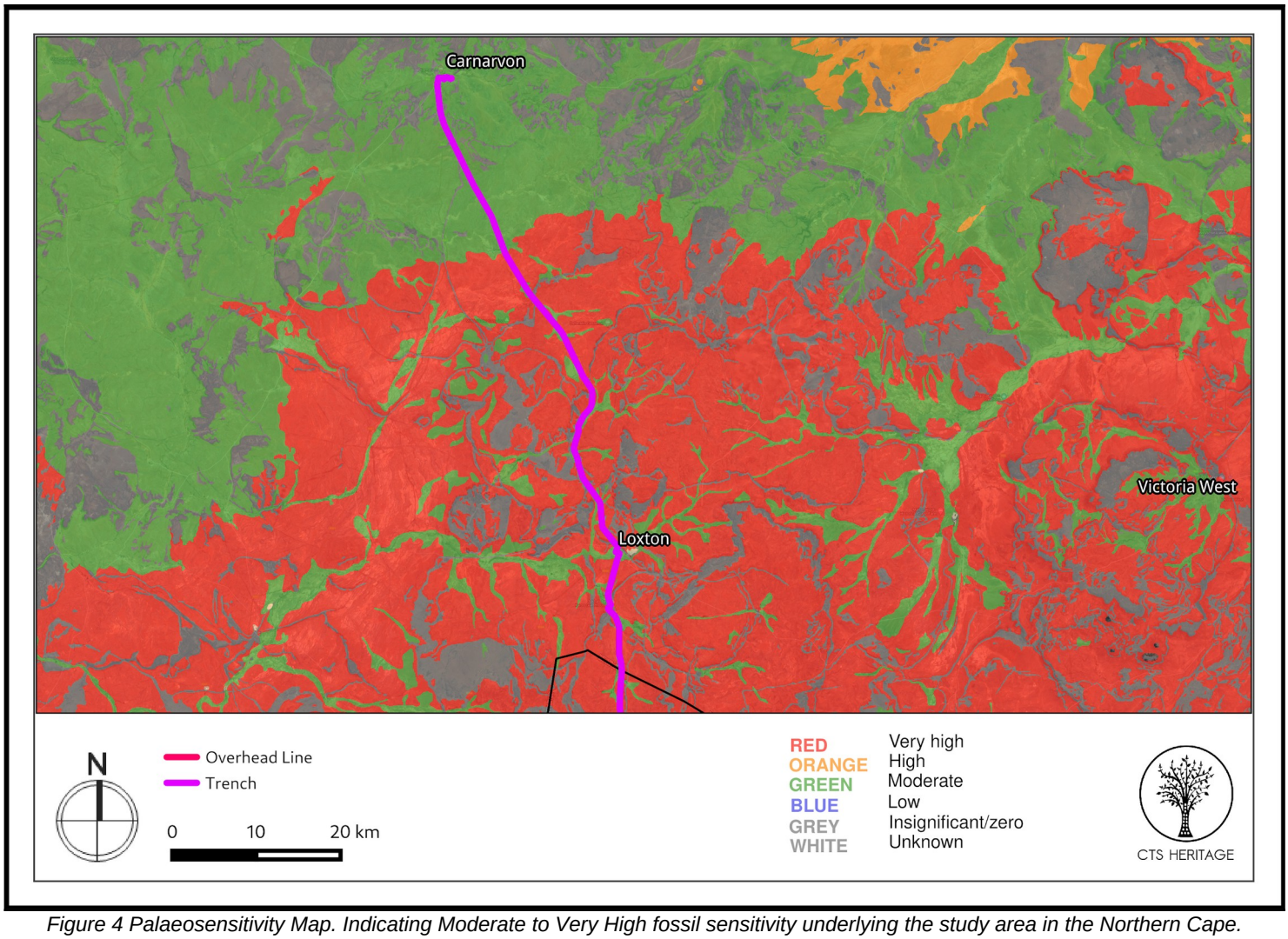

Figure 4 Palaeosensitivity Map. Indicating Moderate to Very High fossil sensitivity underlying the study area in the Northern Cape.

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

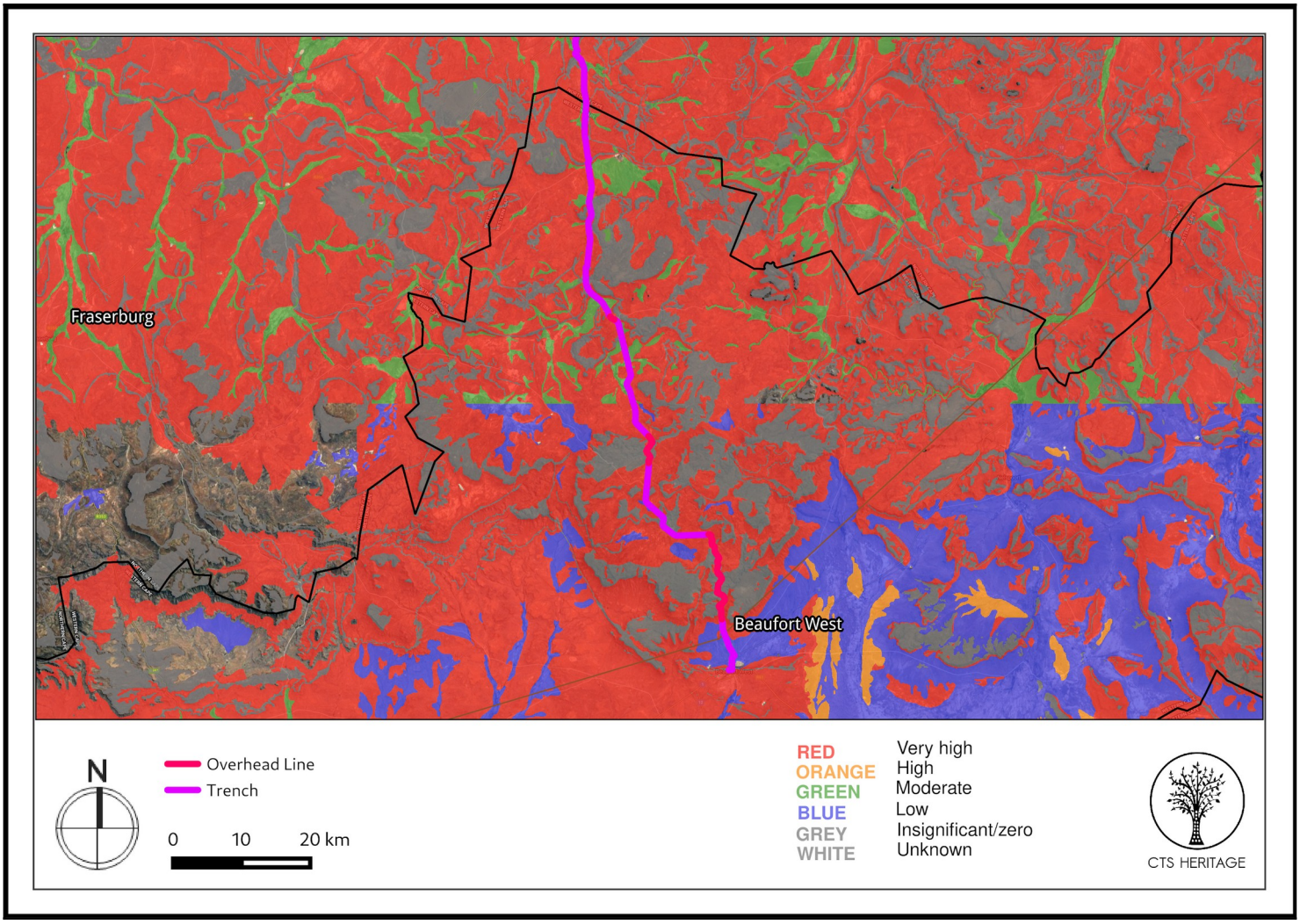

Figure 5 Palaeosensitivity Map. Indicating Moderate to Very High fossil sensitivity underlying the study area in the Western Cape.

2.2 Study approach

This Palaeontology Impact Assessment (PIA) report provides a record of the observed or inferred palaeontological heritage resources within the broader SKA fibre route project study area. The identified resources have been assessed to evaluate their heritage significance in terms of the grading system outlined in Section 3 of the NHRA (Act 25 of 1999). Recommendations for specialist palaeontological mitigation are made where this is considered necessary. The report is based on (1) a review of the relevant scientific literature, including previous palaeontological impact assessments in the broader study region (*e.g.* Almond 2016, Rossouw 2019), (2) published geological maps and accompanying sheet explanations, and (3) a palaeontological field study of the SKA fibre route project area between Beaufort West and Carnarvon, via Loxton on 28 & 29 September 2020. GPS locality data for numbered sites mentioned in the text are provided in Appendix 2.

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

3. Geological and Paleontological context of the study area

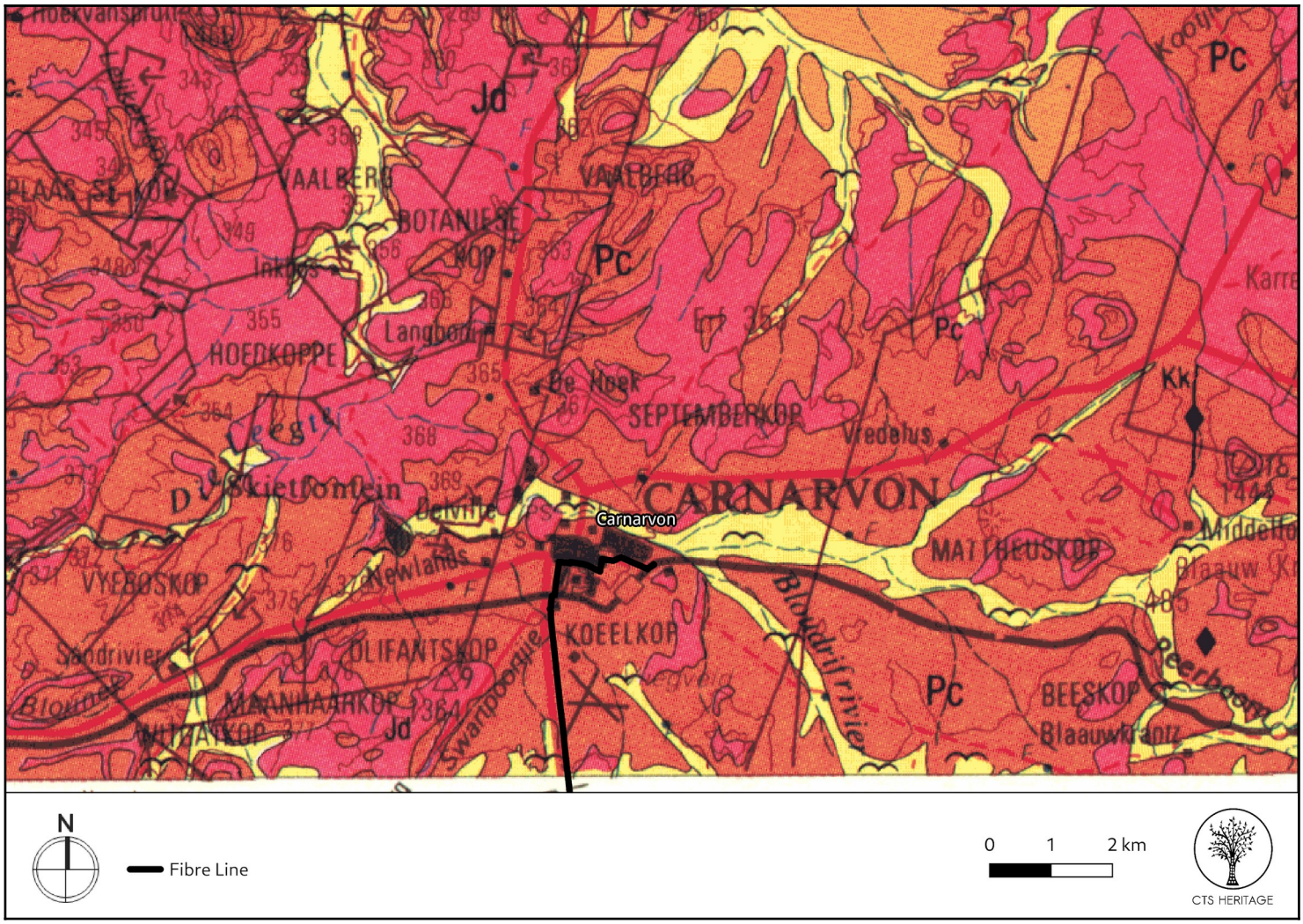

Figure 6 Extract from the CGS 3022 Britstown Map indicating that the development area is underlain by Pc: Waterford Formation previously, Carnarvon Formation of the Ecca Group, Quaternary Sands and Jd: Jurassic Dolerite

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

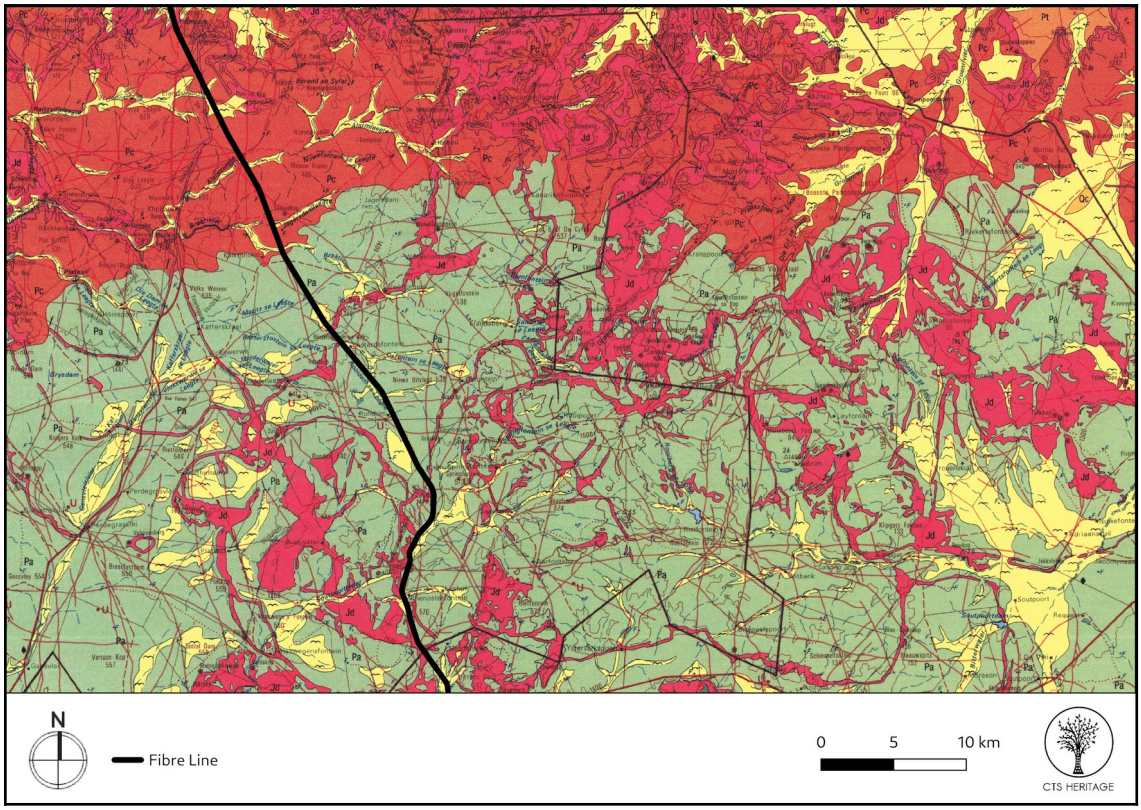

Figure 7 Extract from the CGS 3122 Victoria West Map indicating that the development area is underlain by Pa: Abrahamskraal Formation of the Beaufort Group, Pc: Waterford Formation previously, Carnarvon Formation of the Ecca Group, Quaternary Sands and Jd: Jurassic

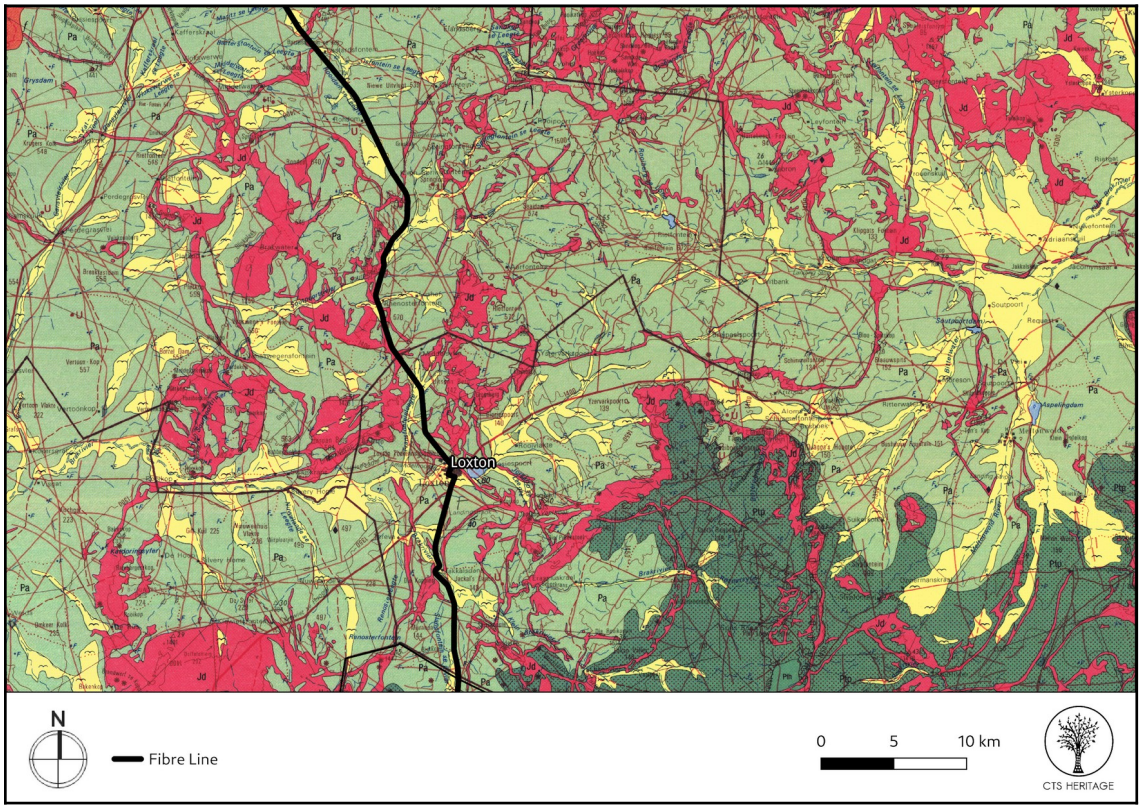

Figure 8 Extract from the CGS 3122 Victoria West Map indicating that the development area is underlain by Pa: Abrahamskraal Formation of the Beaufort Group, Pc: Waterford Formation previously, Carnarvon Formation of the Ecca Group, Quaternary Sands and Jd: Jurassic

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

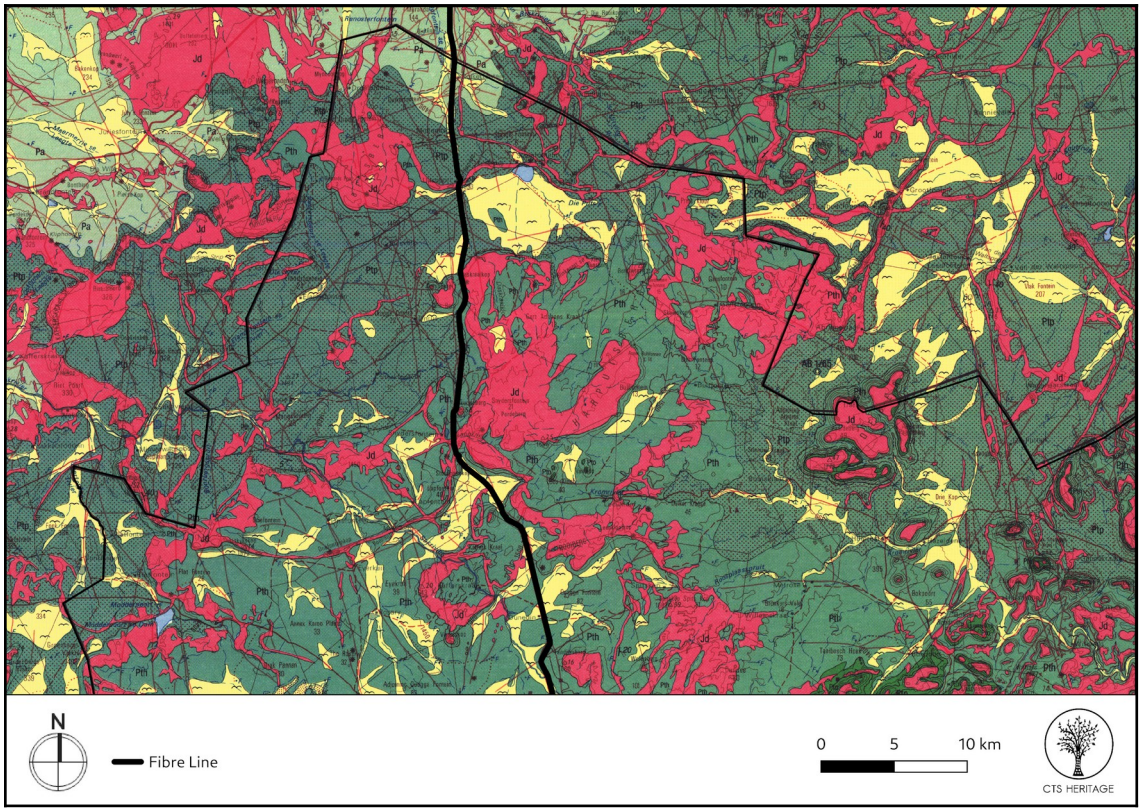

Figure 9 Extract from the CGS 3122 Victoria West Map indicating that the development area is underlain by Ptp: Poortjie Member and Pth: Hoedemaker Member of the Teekloof Formation, Pa: Abrahamskraal Formation of the Beaufort Group, Pc: Waterford Formation, previously Carnarvon Formation.

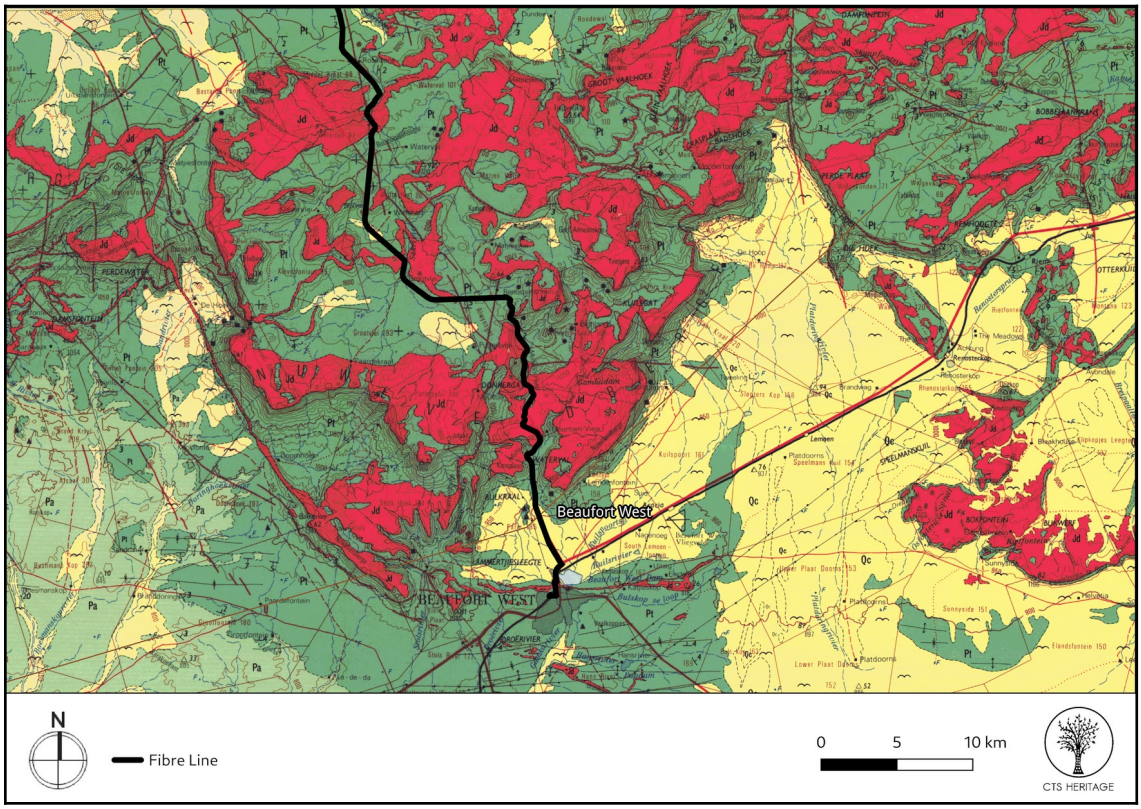

Figure 10 Extract from the CGS 3222 Beaufort West Map indicating that the development area is underlain by Ptp: Poortjie Member and Pth: Hoedemaker Member of the Teekloof Formation, Pa: Abrahamskraal Formation of the Beaufort Group, Pc: Carnarvon Formation of the Ec

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

Table 1 Explanation of symbols indicating geological strata in Figure 6 to Figure 10.

Symbol	Group	Formation	Lithology	Approximate Age	Palaeontology
Pth	Beaufort, Adelaide Subgroup	Teekloof, Hoedemaker member	Arenaceous sandstone	266 – 250 Ma	Raindrop imprints, desiccation cracks Tropidostoma Assemblage Zone
Ptp	Beaufort, Adelaide Subgroup	Teekloof, Poortjie member	Red Mudstone		Raindrop imprints, desiccation cracks Pristerognathus Assemblage Zone
Pa	Beaufort, Adelaide Subgroup	Abrahamskraal	Green to blue-grey mudstones		Bioturbation, Trance fossils ~Tapinocephalus Assemblage Zone
Pc	Ecca	Water Ford (Previously Carnarvon)		290 – 266 Ma	Trace Fossils
Pt	Ecca	Tierberg	Dark shales, yellow tuffs.		Trace fossils, fish scales, and sponge spicules
Jd	Jurassic Dolerites		Dolerite	182-183 Ma	
Qs	Quaternary Sediment		Sand/Clay/ silt	2.6Ma to present	
Ma: million years					

The following section will provide a basic review of the relevant geology and palaeontology in the study area.

3.1. Beaufort Group

3.1.1. Teekloof Formation

The Teekloof Formation overlies the Abrahamskraal Formation and is not capped by any other preserved sedimentation. There is some continuation of Beaufort Groups rocks preservation East of 24ºE, but no preservation in the western-southwestern portions of the Karoo Basin (Day (2014), Day et al. (2015), Viglietti et al. (2018))

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

The Teekloof Formation consists of five Members as seen in Table 2, however only the oldest two members occur in the study area.

Table 2 The Five Members of the Teekloof Formation from youngest to oldest

Javanerskop Member	Correlates with the Daptocephalus Assemblage Zone
Steenkampsvlakte Member	
Oukloof Member	Correlates with the Cistecephalus Assemblage Zone
Hoedemaker Member	Correlates with the Tropidostoma Assemblage Zone
Poortjie Member	Correlates with the Pristerognathus Assemblage Zone

Rocks of the teekloof Formation consist mostly of reddish (with minor green) mudstones. These are either structureless, horizontally laminated, or medium to thickly bedded. These beds can contain Pedogenic and diagenetic carbonate nodules and fossil gypsum rosettes.

The mudstones are interbedded with fine to medium sandstones which show an upward fining sequence (Johnson et al., 2006).

The depositional environment of the Teekloof Formation is thought to be a meandering river environment, showing evidence for seasonal flooding and drying (to the point of playa lake formation), as indicated by the upward fining, and occurrence of gypsum rosettes (Smith, 1989).

The Teekloof Formation contains the richest Permo-Triassic tetrapod fauna from Pangaea / Gondwana. It also provided vital evidence of mammal like characteristics developing in therapsids. This Formation also recorded two Mass Extinction Events (260 Ma and 52 Ma). The Formation also contain non-marine bivalves, phyllopod crustaceans, and trace fossils, and six successive assemblage zones.

3.1.2. Abrahamskraal Formation

The rocks of the Abrahamskraal Formation are generally green-grey to blue-grey mudstones, although grey-red, red-brown, or purple mudstones are also found. Calcareous nodules are present, these nodules tend to weather out brown. Within these mudstone layers fine grained green-grey sandstones are found, usually showing an upward fining trend. These sandstones can range from metres to tens of metres in thickness in some areas, and are important stratigraphic markers for geologists and palaeontologists. These mudstones are also interbedded with siltstone beds. These sedimentary rocks tend to reveal a depositional environment in a retro-arc foreland basin (Karoo Basin), where sediment was deposited in a low energy alluvial plain flowing to the north. As indicated by fluvial and lacustrine sediments. (Johnson et al., 2006)

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

The lower part of the Formation in seen as deltaic (green-grey, blue-grey mudstones) while the upper part of the Formation is seen as fully terrestrial (often indicated by the red mudstones).

The Abrahamskraal Formation correlates well with the Tapinocephalus Assemblage Zone. Therapsids, pareiasaur reptiles and fish fossils have been sparsely reported in this Formation. Plant material (e.g. sphenophyte ferns, fossil wood), freshwater invertebrates (principally smooth-shelled bivalves; and a range of trace fossils including tetrapod trackways (e.g. temnospondyl amphibians, therapsids) have been found.

3.2. Ecca

3.2.1. Waterford Formation (previously Carnarvon Fm /Koedoesberg Fm)

The thickness of the Waterford Formation fluctuates between 200 m and 800 m. The Formation consists of fine grained sandstones and mudrock or clastic rhythmite units. The individual sandstone units have an average thickness of 6 m, with 18 m being the maximum. These units are mostly structureless, but horizontal lamination, low angle crossbedding and ripple lamination is found in some areas. Oscillation ripples are more common. The Formation is characterised by ball and pillow structures, as well as other water escape features. Thin mud-flake conglomerates area occasionally found. Brown weathering calcareous concretions can be found in the sandstone and mudstone. Wave ripples indicate a shallow sedimentary environment, in a delta front area / storm dominated shelf. (Johnson et al., 2006)

The Formation is mostly known for petrified wood and other plant material of the Glossopteris Flora (e.g. Glossopteris, Phyllotheca). Large fossil logs (“Dadoxylon”) showing seasonal growth rings are found. Two different genera of gymnospermous woods, Prototaxoxylon and Australoxylon, have been identified (Bamford, 1999, 2004). Rolled vertebrate bone fragments, low intensity bioturbation, and trace fossils also found.

3.2.2. Tierberg Formation

The Tierberg Formation ranges in thickness form 700 m in the west to 350 m in the north east. It is a predominantly argillaceous Formation which grades upwards into the Waterford Formation. These grey mudrock and fine sandstones where deposited offshore in an inland sea, with influences of offshore fans, and distal pro-deltaic deposition. There is some occurrence of yellow tuffaceous layers of up to 10 cm thick in the lower part of the succession.

The Tierberg Formation is known for a wide range of both vertebrate and invertebrate trace fossils, these include include, fish swimming trails (Undichna), crustacean trackways (Umfolozia), arthropod feeding marks (Vadoscavichna) and resting traces (Quadrispinichna / Broomichnium). Boddy fossils are mostly found in the form of plant remains of glossopteris including fossilised wood. Some micro vertebrate remains have been reported (Prinsloo, 1989)

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

3.3. Jurassic Dolerites

Before discussing the karoo dolerite system two terms must be explained, namely, sills and dykes. Dykes are igneous intrusions that run vertically, forcing through cracks in the overlying rock, while sills are offshoot intrusions running horizontally into weaknesses between or through layers as seen in Figure 11 (Marshak, 2008).

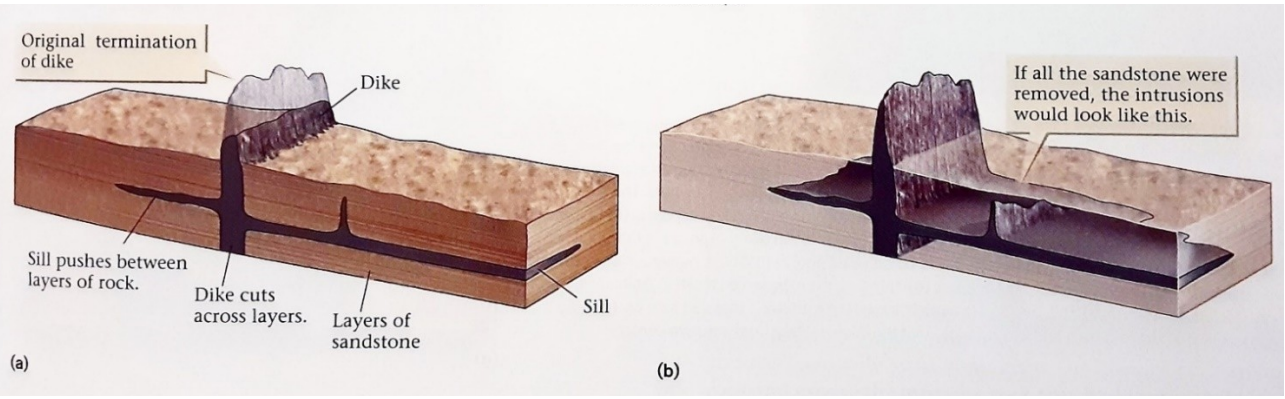

Figure 11 (a) Dykes and sills are vertical or horizontal bands of intrusive igneous rocks (b) if the surrounding rock is stripped away the igneous rock would look like vertical and horizontal planes. (Marshak, 2008)

The Karoo dolerites is an extensive interconnected network of dykes and sills (Figure 12), which intruded in between the sedimentary layers of the Karoo Suppergroup. The dolerite intrusions signify the origin of a volcanic system and is thought to be of the same age as their extrusive counterpart, the Drakensberg basaltic eruption at 183 Ma (Bamfort, 2019; Woodford and Chevallier, 2002; Molaba, 2017). Dolerites are intrusive igneous bodies which does not contain fossils and will destroy fossils they come in contact with (Bamfort; 2019)

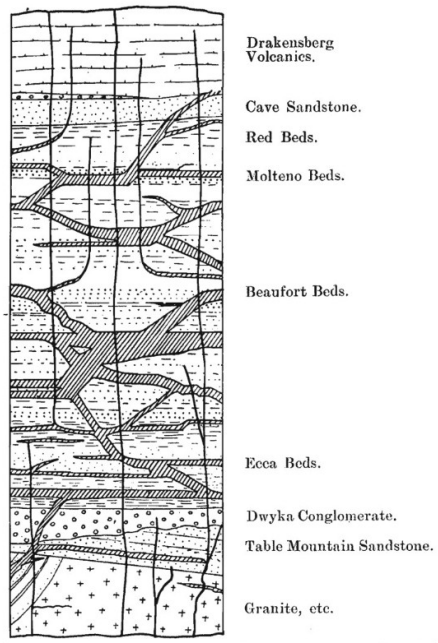

Figure 12 Diagram of basalt sills and dykes intruded into the Karoo Suppergroup (sills running horizontally, dykes running vertically) (du Toit, 1920)

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

Figure 13 Road cutting showing highly fractured mudstones, with more resistant sandstone

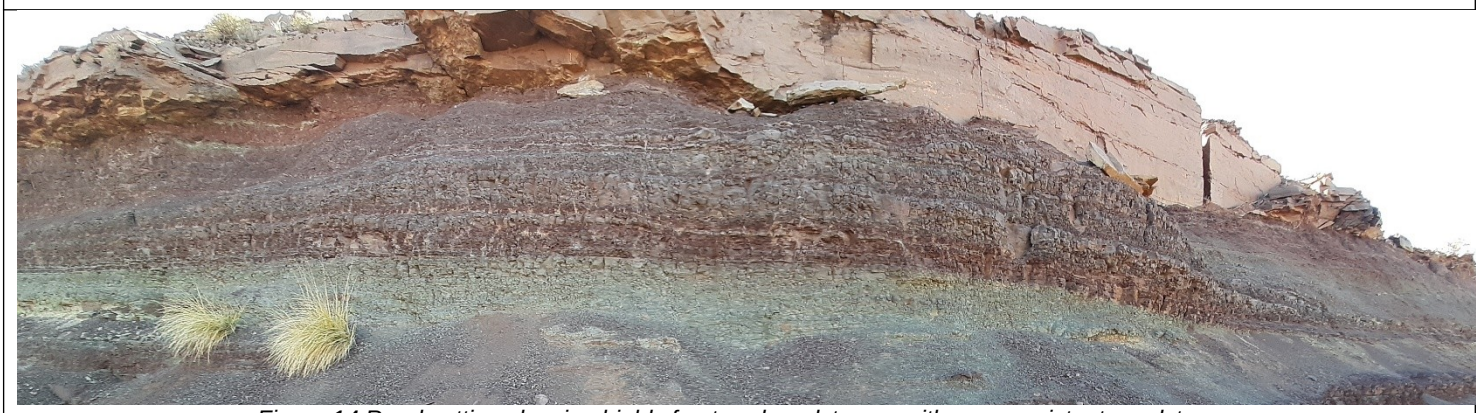

Figure 14 Road cutting showing highly fractured mudstones, with more resistant sandstone

Figure 15 Road cutting showing highly fractured mudstones, with more resistant sandstone, note how the broken sandstone sheets cover much of the finely fractured mudstones

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

Figure 16 horizontal layers of alternating mud- and sandstone (to the left) cut by a dolerite dyke.

Figure 17 Typical outcrop of dolerite forming stacked pillars.

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

Figure 18 Highly fractured mudstones

Figure 19 Highly fractured mudstones

Figure 20 Highly fractured mudstones

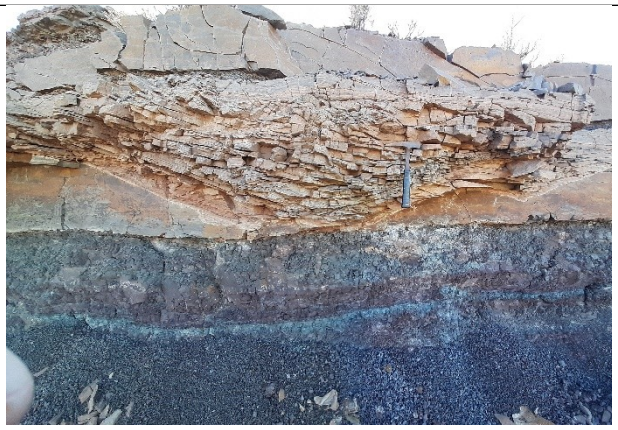

Figure 21 Ancient river channel, filed with fine grained fractured sandstone, in a more resistant sandstone bed.

4. PALAEONTOLOGICAL HERITAGE RESOURCES

4.1. Review of regional palaeontology

Most of the area proposed for development is underlain by sediments that have very high palaentological sensitivity. According to geology maps from the CGS, these sediments include the Poortjie Member and Hoedemaker Member of the Teekloof Formation, and the Abrahamskraal Formation of the Beaufort Group. According to Rossouw (2019), the study area is located within “early Permian Abrahamskraal Formation rocks of the Adelaide Subgroup (Karoo Supergroup) that is capped by severely degraded, superficial sheet wash and channel related (Quaternary) deposits bounded by Jurassic age dolerite intrusions to the north.

The Loxton area lies within the outcrop area of the Tapinocephalus Assemblage Zone (AZ) (see Figure 22) which spans the middle part of the Abrahamskraal Formation. Vertebrate fossils of the Tapinocephalus AZ are not as common as in succeeding biozones and are usually found as individual specimens in the mudrock sequences in association with, and often enveloped by, brown-weathering calcareous nodular material. This faunal assemblage is mainly represented by small dicynodonts, large dinocephalians, pareiasaurs and pristerognathid therocephalians. The dinocephalians, which consist of

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

Synapsida and Therapsida, dominated as one of the tetrapod groups in the Middle Permian. The Tapinocephalus AZ in the Main Karoo Basin holds the most abundant record these dinocephalians. The top of the Abrahamskraal Formation marks the extinction of the dinocephalians. Their disappearance is one of the criterion that marks the beginning of the Pristerognathus AZ. The Pristerognathus AZ correlated with the Poortjie member of the Teekloof Formation. This assemblage zone is folowed by the Tropidostoma Assemblage Zone which coronates with the Hoedemaker Member of the Teekloof Formation (Day et al., 2015).

Day et al. (2015) reported new specimens of the rare tapinocephalid dinocephalian Criocephalosaurus in the lower Poortjie Member, which extends the Tapinocephalus AZ from the Abrahamskraal Formation up into the Teekloof Formation.

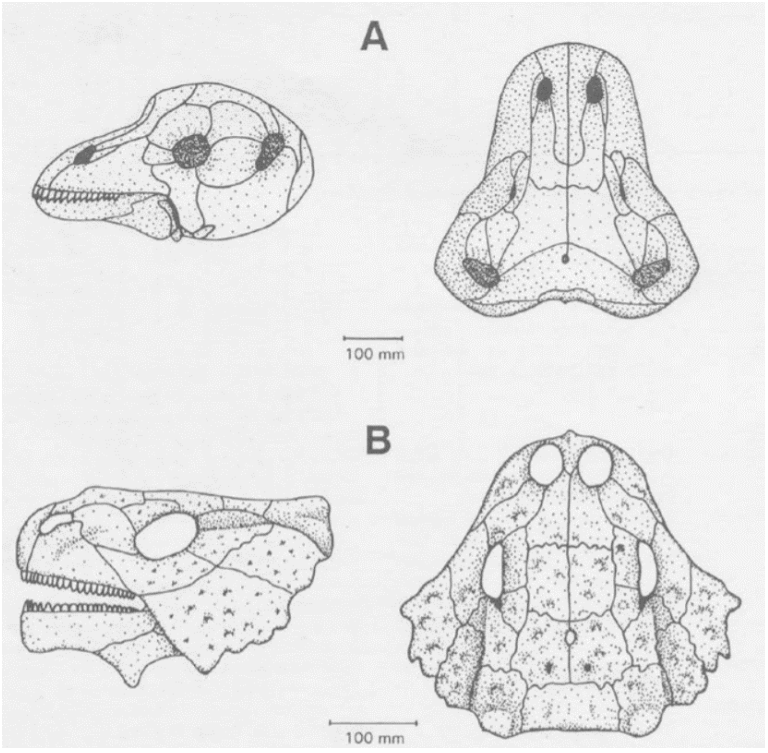

Figure 22 Lateral and dorsal views of biozons-defining fossils of the Tapinocephalus Assemlage Zone. A. Tapinocephalus; B. Bradysaurus modified after Boonstra, 1969 (Rossouw, 2019)

Table 3 sumary of Regional palaeontology, adapted from Almond (2016).

Group	Subgroup	Formation	Member	Rock type	Fossil heritage
Karoo Dollerite Suite (Jd) Early Jurassic (182-183 Ma)				Intrusive dolerites (dykes, sills), associated diatremes	NO fossils recorded
Lower Beaufort Group Middle	Adelaide Subgroup	Abrahamskraal Fm (Pa)		Fluvial sediments with channel sandstones (meandering rivers), thin mudflake conglomerates	Diverse continental biota dominated by a variety of therapsids (e.g. dinocephalians,

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

Group	Subgroup	Formation	Member	Rock type	Fossil heritage
Permian – Early Triassic (c. 266 – 250 Ma)				interbedded with floodplain mudrocks (greygreen, purplish), pedogenic calcretes, playa lake and pond deposits, occasional reworked volcanic ashes	dicynodonts, gorgonopsians, therocephalians, cynodonts) and primitive reptiles (e.g. pareiasaurs), sparse Glossopteris Flora (petrified wood, rarer leaves of Glossopteris, horsetail stems), tetrapod trackways, burrows & coprolites. Freshwater assemblages include temnospondyl amphibians, palaeoniscoid. fish, non-marine bivalves, phyllopod crustaceans and trace fossils (esp. arthropod trackways and burrows, “worm” burrows, fish fin trails, plant rootlet horizons).
Lower Beaufort Group		Teekloof Fm (Pt)	Poortjie Member. (Ptp)		
Lower Beaufort Group			Hoedemaker Member (Pth)		
Ecca Group – Middle Permian (290 – 266 Ma)		Waterford Fm (Pwa/Pw=Pko, Pc in part)		Prodelta to delta plain sediments	Low diversity non-marine trace assemblages (especially arthropod scratch burrow Scoyenia), common petrified logs (silicified/ calcified), twigs and other remains of Glossopteris Flora (e.g. horsetails), palaeoniscoid fish scales, rare rolled fragments of tetrapod bone (probably from large temnospondyl amphibians)
Ecca Group		Tierberg Fm (Pt)		Offshore non-marine mudrocks with distal turbidite beds, prodeltaic sediments	Disarticulated microvertebrate remains (e.g. fish teeth, scales), sponge spicules, spare vascular plants (leaves, petrified wood), moderate diversity trace fossil assemblages (as below plus variety of additional taxa such as large ribbed pellet burrows, arthropod scratch burrows, Siphonichnus etc)

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

4.2. Summary of palaeontological resources identified

Table 1: Summary of geology and palaeontological heritage significance

Site No.	GPS	GEOLOGY	FOSSILS OBSERVED	COMMENTS	PHOTO
BTC09	32°18'15.57" S 22°34'11.19" E	Abrahamskraal Formation	Trace Fossils	On top of road cutting on the western side of the road.	
BTC10	32°17'26.33" S 22°33'59.72" E	Abrahamskraal Formation	Mudflakes in sandstone “mud flake conglomerate”	Not in situ	

5. ASSESSMENT OF THE IMPACT OF THE DEVELOPMENT

The area in the road reserve where the fibre line will predominantly be lain is highly degraded, with large amounts of external material brought in during road construction. The mudstones in the area are also extremely fractured, decreasing the chance of fossil preservation. Only one site was identified to contain trace fossils during the field work. For this reasons it is unlikely that the trenching to lay the fibre line or digging to plant poles for overhead installation will have a significant effect on the area, provided that the chance fossil find procedure is followed in the possible case of a fossil being found.

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

Table 2: Impact Assessment Criteria

Criteria	Category	Explanation
Overall Nature	***Negative***	Possible fossils in the construction footprint could be destroyed Impact will remain negligible if the Chance Fossil Find Procedure is followed
Type	***Direct***	The development will directly impact these resources
Extent	***Site***	Impact is mainly limited to the trenching area
Duration	***Permanent***	Likely impacts will affect the heritage resources identified permanently
Severity	***Low negative***	The site is partly located on very sensitive palaeontological strata but has been bisected by Jurassic Dolerites. Impact will remain negligible if the Chance Fossil Find Procedure is followed in the case of any fossil finds.
Reversibility	***Irreversible***	The impact cannot be reversed, regardless of the mitigation or rehabilitation measures.
Irreplaceable Loss	***Resource may be partly destroyed***	Partial loss or destruction of the resource might occur but can be mitigated if the Chance Fossil Find Procedure is followed.
Probability	***low***	The site is partly located on very sensitive palaeontological strata but has been bisected by Jurassic Dolerites. Impact will remain negligible if the Chance Fossil Find Procedure is followed in the case of any fossil finds.
Mitigation Potential	***High***	If the Chance Fossil Find Procedure is followed in the case of any fossil finds.
Impact Significance	***Negligible***	Impact significance will remain negligible if the Chance Fossil Find Procedure is followed

6. ASSUMPTIONS AND UNCERTENTIES

The Jurassic dolerites (Dykes and Sills) of the Karoo will not contain any preserved fossil material.

Based on the palaeontological record and the geology of the area it is assumed that the area contains plant, invertebrate and vertebrate fossils, trace fossils should also be common. These fossils are often found as individual specimens and might have been destroyed by the Jurassic Dolerites.

The key assumption for this study is that “existing geological maps and datasets used to assess site sensitivity are correct and reliable. However, the geological maps used were not intended for fine scale planning work and are largely based on aerial photographs alone, without ground-truthing. There is also an inadequate database for fossil heritage for much of the RSA (South Africa), due to the small number of professional palaeontologist carrying out fieldwork in RSA. Most development study areas have never been surveyed by a palaeontologist.

These factors may have a major influence on the assessment of the fossil heritage significance of a given development and without supporting field assessments may lead to either:

- an underestimation of the palaeontological significance of a given study area due to ignorance of significant recorded or unrecorded fossils preserved there, or

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

- an overestimation of the palaeontological sensitivity of a study area, for example when originally rich fossil assemblages inferred from geological maps have in fact been destroyed by weathering, or are buried beneath a thick mantle of unfossiliferous “drift” (soil, alluvium etc.). (Groenewald, 2016).

7. CONCLUSION AND RECOMMENDATIONS

The proposed installation of the SKA fibre line may proceed. It is unlikely that this construction will have a great effect on the national palaeontological heritage.

Although the area has a rich occurrence of multiple fossil assemblages fossil finds are often isolated as individuals. Only one site was identified to contain some trace fossils. The trench for the SKA fibre line will predominantly run along highly disturbed and fractured (Figure 18 to Figure 21) roadside material. This decreases the chance of finding fossils dramatically. It is recommended that the responsible Environmental Control Officer (ECO) monitor the material extracted during excavation.

Should important new fossil remains - such as insects, vertebrate bones and teeth, petrified wood, plant-rich fossil lenses or dense fossil burrow assemblages - be exposed during construction, the responsible ECO should alert Heritage Western Cape (HWC) for finds in the Western Cape Province (Contact details: Colette Scheermeyer, 021 483 5959 or colette.scheermeyer@westerncape.gov.za) or SAHRA for finds in the Northern Cape Province (Contact details: Phillip Hine, 021 462 4502, phine@sahra.org.za) as soon as possible. This is so that appropriate action can be taken in good time by a professional palaeontologist at the developer’s expense. Palaeontological mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as of associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy). The palaeontologist concerned with mitigation work will need a valid fossil collection permit from HWC / SAHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection). All palaeontological specialist work should conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies recently developed by SAHRA (2013). These recommendations are summarised in tabular form in Appendix 1 (Chance Fossil Finds Procedure) and should be incorporated into the Environmental Management Programme (EMPr) for the proposed development.

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

7. REFERENCES

Almond, J. E. 2016, SKA Core And Phase 1 Development Area, Great Karoo, Northern Cape – Plaeontological Herritage, Unpublished PIA, Natura Viva

Bamford, M. 1999. Permo-Triassic fossil woods from the South African Karoo Basin. Palaeontologia africana 35, 25-40.

Bamford, M.K. 2004. Diversity of woody vegetation of Gondwanan southern Africa. Gondwana Research 7, 153-164

Bamford, M. 2019 Palaeontological Impact Assessment for the proposed construction of three residential townships in Kroonstad, Free State Province, Archaeological and Heritage Services Africa (Pty) Ltd

CTS Heritage. 2020. Desktop Heritage Screening Assessment for the Proposed Square Kilometre Array (SKA) fibre optic cable between Beaufort West and Carnarvon, Northern and Western Cape. Unpublished.

Day, M.O.; Güven. S.; Abdala; F.; Jirah; S. Rubidge, B.; Almond, J. 2015. Youngest dinocephalian fossils extend the Tapinocephalus Zone, Karoo Basin, South Africa S. Afr. j. sci. vol.111 n.3-4 Pretoria Mar./Apr. 2015 Evolutionary Studies Institute, School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

Day, M.O. 2013. Charting the fossils of the Great Karoo: a history of tetrapod biostratigraphy in the Lower Beaufort Group, South Africa ISSN 0078-8554.

Day, M. O. 2014. Middle Permian continental biodiversity changes as reflected in the Beaufort Group of South Africa: a bio- and lithostratigraphic review of the Eodicynodon, Tapinocephalus and Pristerognathus assemblage zones (PhD thesis).

du Toit, A. L. 1920 The Karoo dolerites of South Africa, a study in hypabyssal injection, Transactions of the Geological Society of South

Groenewald, G. 2016. palaeontological desktop assessment for the proposed TETRA4 development near Matjhabeng (Virginia), Matjhabeng Local Municipality, Lejweleputswa District Municipality, Free State Province. HIA Consultants.

Johnson, M.R, van Vuuren, C.J. Visser, J.N.J. Cole, D.I. de v. Wickens, H. Christie, A.D.M. Roberts, D.L. Brandl, G. 2006. Sedimentary Rocks Of The Karoo Suppergroup. In: Johnson, M.R., Anhaeusser, C.R. and Thomas, R.J., (Eds.), The Geology of South Africa, Johannesburg/Councel for Geoscience, Pretoria, 461-499 pp.

Marshak, S. 2008, Portrait of a planet. 3dr edition. W.W. Norton & Company, London, 832pp.

Molaba, G.L. 2017. Investigating the possibility of targeting major dolerite intrusive to supplement municipal water supply in Bloemfontein: a Geophysical approach, MSc thesis, Faculty of Natural and Agricultural Sciences (Institute for Groundwater Studies) at the University of the Free State 110pp.

Prinsloo, M.C. 1989. Die geologie van die gebied Britstown. Explanation to 1: 250 000 geology Sheet 3022 Britstown, 40 pp. Council for Geoscience, Pretoria.

Rossouw, L. 2019 Exemption from further Heritage Impact Assessment: Rectification in terms of Section 24G for Residential Development in Loxton, Northern Cape Province. Palaeo Field Services PIA Report

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

Smith, R. M. H. 1989. Fluvial facies, vertebrate taphonomy and palaeosols of the Teekloof Formation (Permian) near Beaufort West, Cape Province, South Africa. Unpublished PhD Thesis, UCT

Viglietti, P. A.; Smith, Roger M.H.; Rubidge, Bruce S. 2018. "Changing palaeoenvironments and tetrapod populations in the Daptocephalus Assemblage Zone (Karoo Basin, South Africa) indicate early onset of the Permo-Triassic mass extinction". Journal of African Earth Sciences. 138: 102–111 Bibcode:2018JAfES.138..102V

Woodford, A.C., and Chevallier, L. 2002. Hydrogeology of the Main Karoo Basin: Current Knowledge and Future Research Needs. Water research commission, Report No TT 179/02, 466pp.

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

Appendix 1

Chance Fossil Finds Procedure

(Adopted from the HWC Chance Fossils Finds Procedure: June 2016)

Introduction

This document is aimed to inform workmen and foremen working on a construction and/or mining site. It describes the procedure to follow in instances of accidental discovery of palaeontological material (please see attached poster with descriptions of palaeontological material) during construction/mining activities. This protocol does not apply to resources already identified under an assessment undertaken under s. 38 of the National Heritage Resources Act (no 25 of 1999).

Fossils are rare and irreplaceable. Fossils tell us about the environmental conditions that existed in a specific geographical area millions of years ago. As heritage resources that inform us of the history of a place, fossils are public property that the State is required to manage and conserve on behalf of all the citizens of South Africa. Fossils are therefore protected by the National Heritage Resources Act and are the property of the State. Ideally, a qualified person should be responsible for the recovery of fossils noticed during construction/mining to ensure that all relevant contextual information is recorded.

Heritage Authorities often rely on workmen and foremen to report finds, and thereby contribute to our knowledge of South Africa's past and contribute to its conservation for future generations.

Training

Workmen and foremen need to be trained in the procedure to follow in instances of accidental discovery of fossil material, in a similar way to the Health and Safety protocol. A brief introduction to the process to follow in the event of possible accidental discovery of fossils should be conducted by the designated Environmental Control Officer (ECO) for the project, or the foreman or site agent in the absence of the ECO It is recommended that copies of the attached poster and procedure are printed out and displayed at the site office so that workmen may familiarise themselves with them and are thereby prepared in the event that accidental discovery of fossil material takes place.

Actions to be taken

One person in the staff must be identified and appointed as responsible for the implementation of the attached protocol in instances of accidental fossil discovery and must report to the ECO or site agent. If the ECO or site agent is not present on site, then the responsible person on site should follow the protocol correctly in order to not jeopardize the conservation and well-being of the fossil material. Once a workman notices possible fossil material, he/she should report this to the ECO or site agent.

Procedure to follow if it is likely that the material identified is a fossil:

- The ECO or site agent must ensure that all work ceases immediately in the vicinity of the area where the fossil or fossils have been found;
- The ECO or site agent must inform SAHRA of the find immediately. This information must include photographs of the findings and GPS co-ordinates;
- The ECO or site agent must compile a Preliminary Report and fill in the attached Fossil Discoveries: Preliminary Record Form within 24 hours without removing the fossil from its original position. The Preliminary Report records basic information about the find including:
- The date
- A description of the discovery
- A description of the fossil and its context (e.g. position and depth of find)
- Where and how the find has been stored
- Photographs to accompany the preliminary report (the more the better):

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

- A scale must be used
- Photos of location from several angles
- Photos of vertical section should be provided
- Digital images of hole showing vertical section (side);
- Digital images of fossil or fossils.

Upon receipt of this Preliminary Report, SAHRA will inform the ECO or site agent whether or not a rescue excavation or rescue collection by a palaeontologist is necessary.

- Exposed finds must be stabilised where they are unstable and the site capped, e.g. with a plastic sheet or sandbags. This protection should allow for the later excavation of the finds with due scientific care and diligence. SAHRA can advise on the most appropriate method for stabilisation.
- If the find cannot be stabilised, the fossil may be collected with extreme care by the ECO or the site agent and put aside and protected until SAHRA advises on further action. Finds collected in this way must be safely and securely stored in tissue paper and an appropriate box. Care must be taken to remove all the fossil material and any breakage of fossil material must be avoided at all costs.

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com

No work may continue in the vicinity of the find until SAHRA has indicated, in writing, that it is appropriate to proceed.

FOSSIL DISCOVERIES: PRELIMINARY RECORDING FORM		
Name of project:		
Name of fossil location:		
Date of discovery:		
Description of situation in which the fossil was found:		
Description of context in which the fossil was found:		
Description and condition of fossil identified:		
GPS coordinates:	Lat:	Long:
If no co-ordinates available then please describe the location:		
Time of discovery:		
Depth of find in hole		
Photographs (tick as appropriate and indicate number of the photograph)	Digital image of vertical section (side)	
	Fossil from different angles	
	Wider context of the find	
Wider context of the find. Temporary storage (where it is located and how it is conserved)		
Person identifying the fossil Name:		
Contact:		
Recorder Name:		
Contact:		
Photographer Name:		
Contact:		

CTS Heritage
34 Harries Street, Plumstead
Tel: +27 (0)87 073 5739 **Email:** info@ctsheritage.com **Web:** www.ctsheritage.com