Palaeontological Impact Assessment for Proposed Extension of Tormin Mine, West Coast, South Africa

Heritage Specialist Study

SRK Project Number 507228

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EXECUTIVE SUMMARY

Mineral Sand Resources (Pty) Ltd owns and operates the Tormin Mineral Sands Mine (Tormin Mine) on the West Coast of South Africa, near Lutzville. MSR proposes to extend mining operations into the following areas (Figure 1-1):

- Ten beaches adjacent to Remainder of Graauw Duinen 152 and Portions of Farm Klipvley Karoo Kop 153, along a stretch of coastline north of Tormin Mine comprising 43.7 ha mining and ~6 ha haul road widening; and
- Inland "Strandline" mining area on the Farm Geelwal Karoo 262, inland of the existing Processing Plant comprising 75 ha mining; and
- An infrastructure / plant expansion area of 64 ha adjacent to the existing Processing Plant to accommodate additional processing plants, stockpile areas, industrial yards, parking and laydown areas.

MSR has appointed SRK Consulting (South Africa) (Pty) Ltd (SRK) to conduct the Environmental Impact Assessment (EIA) processes. ACO Associates cc, Archaeology and Heritage Specialists, have been appointed to undertake the Heritage Study of the project to inform the EIA process.

This report is the contribution to the Heritage Assessment that encompasses the palaeontological heritage of the Tormin project areas. It is based on the published scientific literature on the origin and palaeontology of the Namaqualand coastal-plain deposits and the author's comprehensive field experience of the formations involved and their fossil content.

The main assumption is that the fossil potential of a formation in the study area will be typical of that found in the region and more specifically, similar to that already observed in the study area. The discovery of diamonds spurred initial interest in the palaeontology of the West Coast deposits and fossil shells selected from exposures in the area featured in the earliest palaeontological findings about the marine deposits (*e.g.* Haughton, 1926, 1928, 1932). Subsequently interest was mainly focussed on the higher-grade diamondiferous deposits of northern Namaqualand and the palaeontological potential of the area has languished until quite recently when the systematic searches undertaken by Prof Kaye Reed and Dr Deano Stynder have revealed the promising prevalence of fossil material. The density of material is probably not unique, but the material is rendered more available and visible as it is being exposed on the extensive slopes of the eroding aeolianites present in the area, as opposed to the 2D exposures of mine open-pit sides.

The regional context of the proposed project is elucidated by way of a summary of the stratigraphy of the Namaqualand coastal plain. The stratigraphic scheme is elaborated and modified according to the author's own observations, with particular emphasis on the aeolianite formations. A brief field survey was undertaken. Its purpose was not to search for more fossil occurrences, but to commence the provision of landscape and stratigraphic context for the fossils of the area.

FINDINGS AND RECOMMENDATIONS

No palaeontological NO-GO areas have been identified within the confines of the affected Beach Mining, haul roads and Strandline Mining and infrastructure areas.

The fossiliferous coastal plain formations present in the Study Area are tabulated below, with their palaeontological sensitivities indicated. The prime concern is the fossil bones in the terrestrial formations, mainly aeolianites.

Formation Sensitivities in the Study Area

Formation	Age	Deposit type	Sensitivity	
H-Hi, M-Med, L-Low (arch. = archaeological context)			Bones	Seashells
Witzand	Holocene	pale dunes & sandsheets	H rare, arch	H arch.
Younger coastal aeolianites	Mid-late Quat.	Dorbanks, red and yellow aeolian sands (Koekenaap Fm. etc.)	H rare, arch	H arch.
Curlew Strand	mid-late Quat.	shelly marine MIS 11, LIG, Holocene Hi	H v. rare	L
Olifantsrivier	early-mid Quat.	aeolianite & pedocretes	H mod common.	H arch.
Graauw Duinen Member 2	latest Plio-early Quat.	Aeolianite, colluvia, pedocrete	H mod common	
Hondeklipbaai	late Pliocene	shelly marine	H v. rare	M
Graauw Duinen Member 1	mid Pliocene	Aeolianite, colluvia, pedocrete	H mod common	
Avontuur	early Pliocene	Shelly marine	H v. rare	M
Unnamed	late Miocene?	aeolianite	H	
Koingnaas	Oligocene-early Miocene	Kaolinitic sands & gravels. Possible fossil wood	NA	NA

BEACHES 1 – 10

The mining of loose beach sands is not anticipated to have significant palaeontological impact. Notwithstanding, screened-off material may include reworked fossils and possibly other materials of archaeological interest (*e.g.* evidence of shipwrecks).

Valuable fossil bones in both archaeological and non-archaeological contexts may be uncovered in the shallow gradings of widening the access roads. The recommended archaeological mitigation measures for the pre-construction and construction phases of the haul and access roads must be performed in order to rescue archaeological and possible fossil material.

INLAND STRANDLINE MINING

The mining will intersect surficial deposits of the Koekenaap Formation, the underlying palaeosurface which bears archaeological material, beneath of which are the pedocretes, aeolianite and colluvia of the Olifantsrivier Formation. At depth the marine Avontuur and Hondeklipbaai formations will be intersected, as well as the older Graauw Duinen Formation aeolianites.

Open-pit mine excavations are a scientific and fossil resource and have been the major contributor to the understanding of the deposits and palaeontology of the Namaqualand coastal plain. Notably, the Strandline Prospect is just inland of the portion of the coast where exposures are poor. The proposed mining should have a positive impact with respect to understanding the stratigraphy and to palaeontological heritage, providing that adequate mitigation measures are in place and duly performed over the duration of the mining.

It is impossible for a specialist to routinely monitor the mine pit and mined material. Routine monitoring can only be achieved by the co-operation of the people on the ground. By these are meant personnel in supervisory/inspection roles, such as the geologist, surveyor, pit foremen, etc., who are willing and interested to look out for occurrences of fossils. A monitoring presence is critical for spotting a major "strike" of fossils and stopping further damaging excavation. Very importantly, mine staff must be empowered to rescue the fossil material that appears sporadically, but quite routinely in the aeolianites during excavation and must be promptly rescued from loss.

There must be guidelines to be followed for finds and a reporting/action protocol in place when finds are uncovered during monitoring. A "Fossil Finds Procedure" is provided in Appendix F. This could be adapted and made more specific to the geological/fossil contexts expected. For instance, as fossil tortoises are quite common, they should be in the category of "allowed" rescue by mine staff *cf.* isolated bone finds.

<table>
<tr><th colspan="9">Loss of fossil bones from Strandline Mining and infrastructure</th></tr>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Regional
2</td><td>High
3</td><td>Long
3</td><td>V High
8</td><td>Possible</td><td>High</td><td>-ve</td><td>Medium</td></tr>
<tr><td colspan="9">Essential mitigation measures
• Identify and appoint stand-by palaeontologist should paleontological finds be uncovered by earthworks.
• Construction personnel to be alert for rare fossil bones and follow "Fossil Finds Procedure".
• Cease construction on (chance) discovery of fossil bones and protect fossils from further damage.
• Contact appointed palaeontologist providing information and images.
• Palaeontologist will assess information and establish suitable response, such as the importance of the find and recommendations for preservation, collection and record keeping.
• Exposed fossiliferous sections in earthworks recorded and sampled by appointed palaeontologist.</td></tr>
<tr><td>With mitigation</td><td>Regional
2</td><td>High
3</td><td>Long
3</td><td>V High
8</td><td>Possible</td><td>High</td><td>+ve</td><td>Medium</td></tr>
</table>

Additionally, it is recommended that the contracted palaeontologist carry out field inspections at appropriate stages during mining of the inland Strandline deposits. The aim of field inspection is to examine a representative sample of the various deposits exposed in the excavations, recording context, fossil content and to take samples. Involving a few days of fieldwork, this will take place in the event of fossil exposures.

REGIONAL HERITAGE SENSITIVITY

It is abundantly evident from the archaeological and fossil sites already discovered that the study areas are of considerable geological and palaeontological heritage importance. The main attributes are the natural exposures of coastal-plain formations of Namaqualand along the cliffs. The cliff exposures are of historical geology/palaeontology significance, being examined by geologists/palaeontologists in the early part of the 20th century, with the first fossils collected and described from West Coast coastal-plain deposits. These formations are rarely exposed elsewhere along the Namaqualand coast, where they are beneath younger aeolian coversands and are only temporarily exposed in mining pits. In addition to the natural exposures in the cliffs there are numerous artificial exposures due to previous diamond prospecting and mining.

The formations present in the area and their definitions are still mostly informal in that official names and type sections/areas are still to be designated in official South African Committee for Stratigraphy (SACS) publications. Due to the temporary nature of the mine pits, from which the formations are best known, type sections cannot be designated in them. Instead, they will have to be designated among the exposures along the stretch of coast within the study area. These type localities have the status of geoheritage sites. Similarly, the existing fossil sites, and later discoveries, must be assessed and receive appropriate protection. However, as can be inferred from discussions above, there is a lot more fieldwork required. A recommendation in the Heritage Baseline Report is that the subject of grading the sites and area be addressed in terms of the latest criteria issued by Heritage Western Cape.

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Appendix E: Palaeontological Sensitivity Rating

Appendix F: Fossil Find Procedures

ACRONYMS AND ABBREVIATIONS

AIA	Archaeological Impact Assessment..
asl.	above (mean) sea level.
BA	Basic Assessment Process.
EIA	Environmental Impact Assessment.
EMP	Environmental Management Plan.
EMP	Environmental Management Programme.
ESA	Early Stone Age. The archaeology of the Stone Age between 2 000 000 and 250 000 years ago.
Fm.	Formation.
HIA	Heritage Impact Assessment.
LIG	Last Interglacial. Warm period 128-118 ka BP. Relative sea-levels higher than present by 4-6 m. Also referred to as Marine Isotope Stage 5e or "the Eemian".
LSA	Late Stone Age. The archaeology of the last 40 000 years associated with fully modern people.
MSA	Middle Stone Age. The archaeology of the Stone Age between 40-400 000 years ago associated with early modern humans.
MSP	Mineral Separation Plant.
NEMA	National Environmental Management Act 107 of 1998, as amended.
OSL	Optically stimulated luminescence. See glossary.
PIA	Palaeontological Impact Assessment.
RO	Reverse Osmosis.
S&EIR	Scoping and Environmental Impact Reporting.
SAHRA	South African Heritage Resources Agency – the compliance authority, which protects national heritage.
SRK	SRK Consulting (South Africa) (Pty) Ltd.
SST	Sea surface temperature.
ToR	Terms of Reference.
VHM	Valuable Heavy Minerals.

GLOSSARY

~ (tilde)	Used herein as “approximately” or “about”.
Aeolian	Pertaining to the wind. Refers to erosion, transport and deposition of sedimentary particles by wind. A rock formed by the solidification of aeolian sediments is an aeolianite.
Alluvium	Sediments deposited by a river or other running water.
Archaeology	Remains resulting from human activity which are in a state of disuse and are in or on land and which are older than 100 years, including artefacts, human and hominid remains and artificial features and structures.
Baseline	Information gathered at the beginning of a study which describes the environment prior to development of a project and against which predicted changes (impacts) are measured.
Bedrock	Hard rock formations underlying much younger sedimentary deposits.
Calcareous	sediment, sedimentary rock, or soil type which is formed from or contains a high proportion of calcium carbonate in the form of calcite or aragonite.
Calcrete	An indurated deposit (duricrust) mainly consisting of Ca and Mg carbonates. The term includes both pedogenic types formed in the near-surface soil context and non-pedogenic or groundwater calcretes related to water tables at depth.
Clast	Fragments of pre-existing rocks, *e.g.* sand grains, pebbles, boulders, produced by weathering and erosion. Clastic – composed of clasts.
Colluvium	Hillwash deposits formed by gravity transport downhill. Includes soil creep, sheetwash, small-scale rainfall rivulets and gullying, slumping and sliding processes that move and deposit material towards the foot of the slopes.
Construction Phase	The stage of project development comprising site preparation as well as all construction activities associated with the development.
Coversands	Aeolian blanket deposits of sandsheets and dunes.
Cumulative Impacts	Direct and indirect impacts that act together with current or future potential impacts of other activities or proposed activities in the area/region that affect the same resources and/or receptors.
Duricrust	A general term for a zone of chemical precipitation and hardening formed at or near the surface of sedimentary bodies through pedogenic and (or) non-pedogenic processes. It is formed by the accumulation of soluble minerals deposited by mineral-bearing waters that move upward, downward, or laterally by capillary action, commonly assisted

	in arid settings by evaporation. Classified into calcrete, ferricrete, silcrete.
Environment	The external circumstances, conditions and objects that affect the existence of an individual, organism or group. These circumstances include biophysical, social, economic, historical and cultural aspects.
Environmental Authorisation	Permission granted by the competent authority for the applicant to undertake listed activities in terms of the NEMA EIA Regulations, 2014.
Environmental Impact Assessment	A process of evaluating the environmental and socio-economic consequences of a proposed course of action or project.
Environmental Impact Assessment Report	The report produced to relay the information gathered and assessments undertaken during the Environmental Impact Assessment.
Environmental Management Programme	A description of the means (the environmental specification) to achieve environmental objectives and targets during all stages of a specific proposed activity.
Ferricrete	Indurated deposit (duricrust) consisting predominantly of accumulations of iron sesquioxides, with various dark-brown to yellow-brown hues. It may form by deposition from solution or as a residue after removal of silica and alkalis. Like calcrete it has pedogenic and groundwater forms. Synonyms are laterite, iron pan or “koffieklip”.
Fluvial deposits	Sedimentary deposits consisting of material transported by, suspended in and laid down by a river or stream.
Fossil	The remains of parts of animals and plants found in sedimentary deposits. Most commonly hard parts such as bones, teeth and shells which in lithified sedimentary rocks are usually altered by petrification (mineralization). Also impressions and mineral films in fine-grained sediments that preserve indications of soft parts. Fossils plants include coals, petrified wood and leaf impressions, as well as microscopic pollen and spores. Marine sediments contain a host of microfossils that reflect the plankton of the past and provide records of ocean changes. Nowadays also includes molecular fossils such as DNA and biogeochemicals such as oils and waxes. A trace fossil is the track or footprint of a fossil animal that is preserved in stone or consolidated sediment.
Heritage	That which is inherited and forms part of the National Estate (Historical places, objects, fossils as defined by the National Heritage Resources Act 25 of 1999).
Impact	A change to the existing environment, either adverse or beneficial, that is directly or indirectly due to the development of the project and its associated activities.
Midden	A pile of debris, normally shellfish and bone that have accumulated as a result of human activity.
Mitigation measures	Design or management measures that are intended to minimise or enhance an impact, depending on the desired effect. These measures are ideally incorporated into a design at an early stage.

Operational Phase	The stage of the works following the Construction Phase, during which the development will function or be used as anticipated in the Environmental Authorisation.
Optically stimulated luminescence - OSL	Optically stimulated luminescence. One of the radiation exposure dating methods based on the measurement of trapped electronic charges that accumulate in crystalline materials as a result of low-level natural radioactivity from U, Th and K. In OSL dating of aeolian quartz and feldspar sand grains, the trapped charges are zeroed by exposure to daylight at the time of deposition. Once buried, the charges accumulate and the total radiation exposure (total dose) received by the sample is estimated by laboratory measurements. The level of radioactivity (annual doses) to which the sample grains have been exposed is measured in the field or from the separated minerals containing radioactive elements in the sample. Ages are obtained as the ratio of total dose to annual dose, where the annual dose is assumed to have been similar in the past.
Palaeontology	The study of any fossilised remains or fossil traces of animals or plants which lived in the geological past and any site which contains such fossilised remains or traces.
Palaeosol	An ancient, buried soil formed on a palaeosurface. The soil composition may reflect a climate significantly different from the climate now prevalent in the area where the soil is found. Burial reflects the subsequent environmental change.
Palaeosurface	An ancient land surface, usually buried and marked by a palaeosol or pedocrete, but may be exhumed by erosion (*e.g.* wind erosion/deflation) or by bulk earth works.
Peat	partially decomposed mass of semi-carbonized vegetation which has grown under waterlogged, anaerobic conditions, usually in bogs or swamps.
Pedocrete	A duricrust formed by pedogenic processes.
Pedogenesis/pedogenic	The process of turning sediment into soil by chemical weathering and the activity of organisms (plants growing in it, burrowing animals such as worms, the addition of humus *etc.*).
Remanié	Fossils, usually of durable nature (*e.g.* teeth or petrified) and abraded, that have been reworked from an older deposit and incorporated into a younger deposit. From French *re*- + *manier* - to handle, rearrange.
Rhizolith	Fossil root. Most commonly formed by pedogenic carbonate deposition around the root and developed in palaeosols.
Scoping	A procedure to consult with stakeholders to determine issues and concerns and for determining the extent of and approach to an EIA and EMP (one of the phases in an EIA and EMP). This process results in

	the development of a scope of work for the EIA, EMP and specialist studies.
Specialist study	A study into a particular aspect of the environment, undertaken by an expert in that discipline.
Stakeholders	All parties affected by and/or able to influence a project, often those in a position of authority and/or representing others.
Stone Age	The earliest technological period in human culture when tools were made of stone, wood, bone or horn. Metal was unknown.
Trace fossil	A structure or impression in sediments that preserves the behaviour of an organism, such as burrows, borings and nests, feeding traces (sediment processing), farming structures for bacteria and fungi, locomotion burrows and trackways and traces of predation on hard parts (tooth marks on bones, borings into shells by predatory gastropods and octopuses).

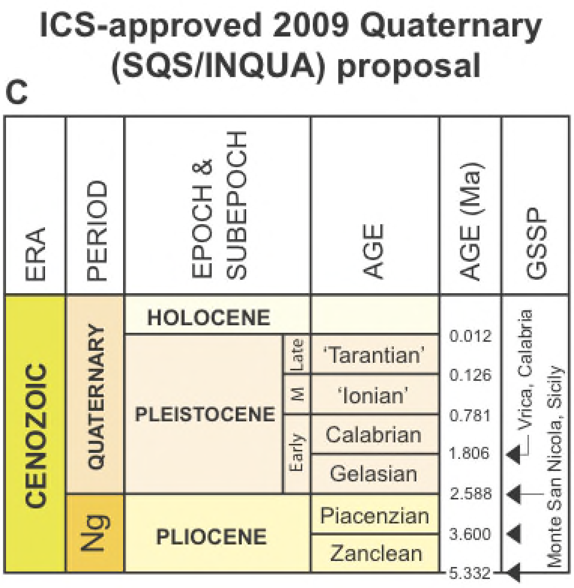
Geological Time Scale Terms.

ka: Thousand years or kilo-annum (10^3 years). Implicitly means "ka ago" *i.e.* duration from the present, but "ago" is omitted. The "Present" refers to 1950 AD. Generally not used for durations not extending from the Present. Sometimes "kyr" is used instead.

Ma: Millions years, mega-annum (10^6 years). Implicitly means "Ma ago" *i.e.* duration from the present, but "ago" is omitted. The "Present" refers to 1950 AD. Generally not used for durations not extending from the Present.

Holocene: The most recent geological epoch commencing 11.7 ka till the present.

Pleistocene: Epoch from 2.6 Ma to 11.7 ka. Late Pleistocene 11.7–126 ka. Middle Pleistocene 135–781 ka. Early Pleistocene 781–2588 ka (0.78-2.6.Ma).



Quaternary: The current Period, from 2.6 Ma to the present, in the Cenozoic Era. The Quaternary includes both the Pleistocene and Holocene epochs. As used herein, early and middle Quaternary correspond with the Pleistocene divisions, but late Quaternary includes the Late Pleistocene and the Holocene.

Pliocene: Epoch from 5.3-2.6 Ma.

Miocene: Epoch from 23-5 Ma.

Oligocene: Epoch from 34-23 Ma.

Eocene: Epoch from 56-34 Ma.

Paleocene: Epoch from 65-56 Ma.

Cenozoic: Era from 65 Ma to the present. Includes Paleocene to Holocene epochs.

Cretaceous: Period in the Mesozoic Era, 145-65 Ma.

Mid Pliocene Warm Period (MPWP): An interval of warm climate and high sea level around ~3 Ma. When this interval was referred to as "mid-Pliocene" the boundary between the Pliocene and Quaternary was set younger, at 1.8 Ma at the beginning of the Calabrian (see figure above). Now that the Pliocene/Quaternary boundary is set further back in time by international agreement to the beginning of the Gelasian at ~2.6 Ma, the MPWP at ~3 Ma is no longer "mid", but is in the late Pliocene. However, for continuity it is still being referred to as the MPWP.

1 INTRODUCTION

1.1 BACKGROUND

Mineral Sand Resources (Pty) Ltd (MSR) owns and operates the Tormin Mineral Sands Mine (Tormin Mine) on the West Coast of South Africa, near Lutzville. The mine holds two Mining Rights (MR162 and MR163), covering an area of 119.9 ha, and an approved Environmental Management Programme (EMPr) to mine Valuable Heavy Minerals (VHM) below the high-water mark adjacent to Farm Geelwal Karoo 262 (**Error! Reference source not found.**). The mine has been in operation since 2013.

MSR proposes to extend mining operations into the following areas (the "project"):

- Ten beaches adjacent to Remainder of Graauw Duinen 152 and Portions of Farm Klipvley Karoo Kop 153 (Figure 1-2), along a stretch of coastline north of Tormin Mine comprising 43.7 ha mining and ~6 ha haul road widening;
- Inland "Strandline" mining area on the Farm Geelwal Karoo 262, inland of the existing Processing Plant comprising 75 ha mining (Figure 1-1); and
- An infrastructure / plant expansion area of 64 ha adjacent to the existing Processing Plant to accommodate additional processing plants, stockpile areas, industrial yards, parking and laydown areas (Figure 1-1).

MSR has appointed SRK Consulting (South Africa) (Pty) Ltd (SRK) to conduct an Environmental Impact Assessments (EIA) process compliant with the EIA Regulations, 2014, for the project.

ACO Associates cc, Archaeology and Heritage Specialists, have been appointed by SRK to undertake the Heritage Study of the project to inform the EIA process. This report is the contribution to the Heritage Impact Assessment that encompasses the palaeontological heritage of the Tormin project areas.

1.2 TERMS OF REFERENCE

The proposed ToR for the Heritage Impact Assessment is as follows:

- Undertake a sensitivity screening study for all project areas and map sensitivity;
- Undertake site surveys to identify and analyse the heritage resources in the refined area of study and place these in a regional context, including a more detailed assessment of any specific points of interest or/and relevance;
- Formulate statements of heritage significance in terms of the heritage criteria;
- Identify and assess the suite of potential direct and indirect heritage impacts of the extension of VHM beach mining operation;
- Identify and assess the suite of potential direct and indirect heritage impacts of the expansion of operations to include conventional opencast surface VHM mining inland;
- Identify and assess the potential cumulative impacts of the project and existing mining activities at Tormin and regionally;
- Recommend mitigation measures to avoid and/or minimise impacts and enhance benefits associated with the proposed project; and
- Specify management and monitoring requirements/guidelines for use as conditions.

1.3 ASSUMPTIONS AND LIMITATIONS

The study is based on a number of assumptions and is subject to certain limitations, which should be borne in mind when considering information presented in this report. The validity of the findings of the study is not expected to be affected by these assumptions and limitations.

The main assumption is that the fossil potential of a formation in the study area will be typical of that found in the region and more specifically, similar to that already observed in the study area. A limitation on predictive capacity exists in that it is not possible to predict the buried fossil content of an area or formation other than in such general terms. The important fossil bone material is generally sparsely scattered in most deposits. Most of the fossiliferous deposits of coastal Namaqualand are covered by more recent aeolian sands, only to be exposed in excavations such as large open pits for mining. In this case, much depends on spotting the sparse fossil bone material as it is uncovered during digging, *i.e.* by monitoring excavations, but success is limited by the difficulty of seeing the bone fragments in freshly-excavated faces and spoil. They become more evident on weathering and etching of the pit faces and deflation of spoil/overburden dumps.

In contrast, the southern part of study area is unique along the Namaqualand coast in possessing natural exposures of the marine and aeolian formations in the cliffs and the backing hillside salients, with eroding expanses of slopes in which valuable fossil bone material is exposed at higher occurrence densities which more closely reflect the actual densities.

The main limitation is that this report does not purport to identify all sites of palaeontological importance. The survey and excavations carried out during the project of Prof. Kaye Reed and Dr Deano Stynder and their students serve merely to illustrate the fossil potential of the area that will be delivered by the continuation of diligent, systematic searches.

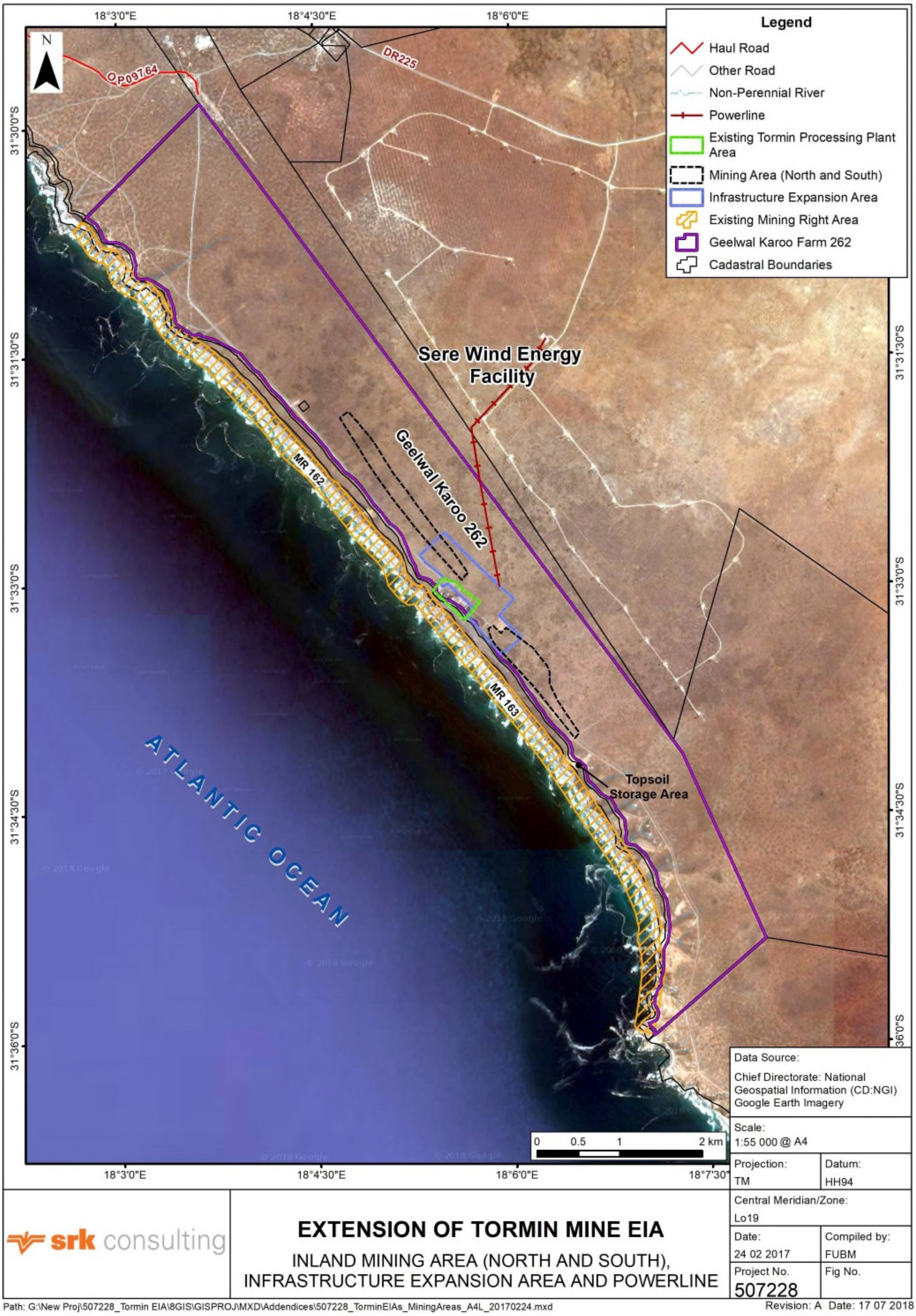


Figure 1 1: Localities map, Tormin plant, mining and infrastructure expansion areas.

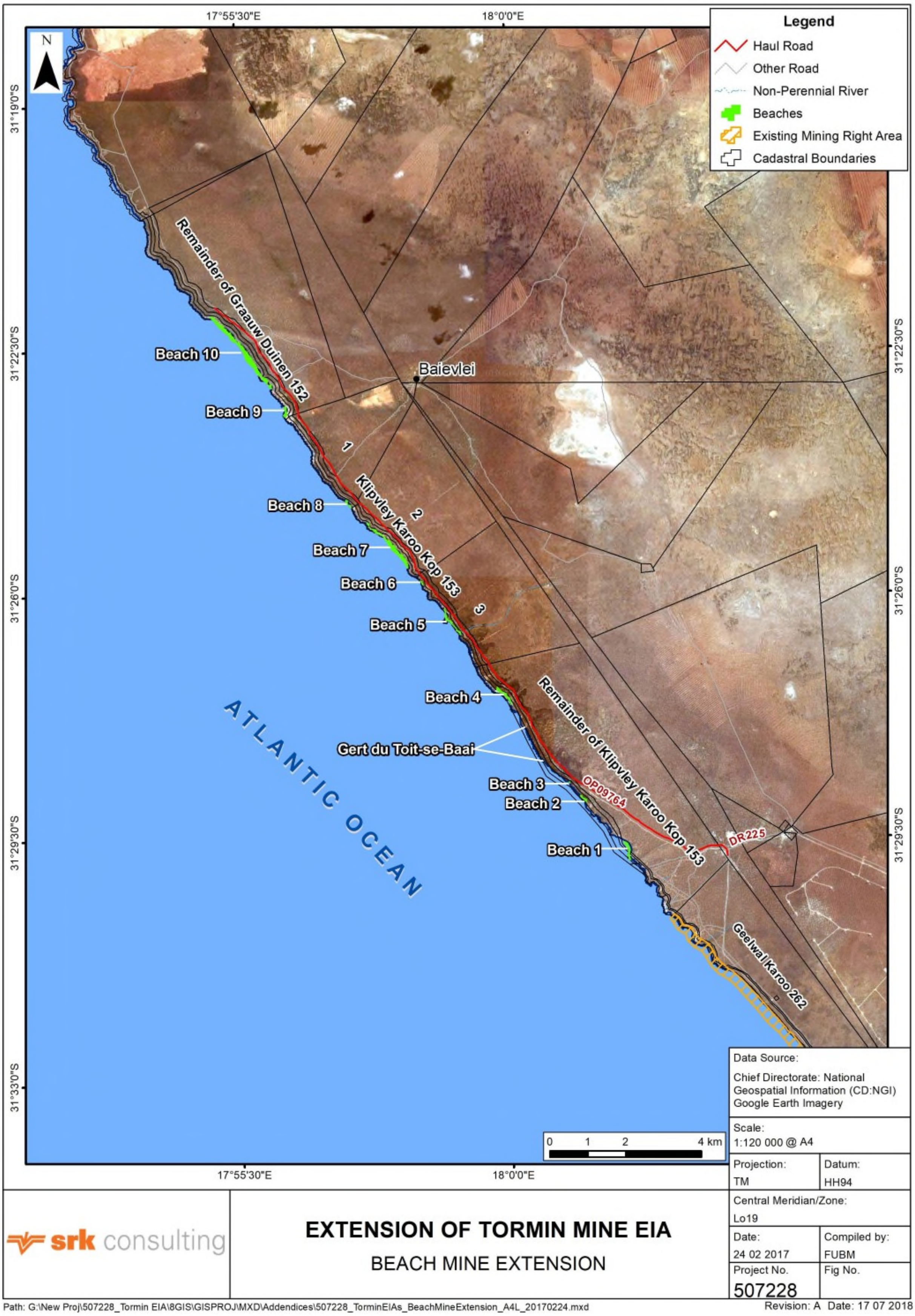


Figure 1-1: Localities map of Beaches 1 – 10 of the Beach Mine Extension.

2 METHODOLOGY

2.1 LITERATURE REVIEW

This assessment is based on the published scientific literature on the origin and palaeontology of the Namaqualand coastal-plain deposits and the author's comprehensive field experience of the formations involved and their fossil content. This includes observations of the exposures in the project area when he worked as a geologist for Trans Hex (1982) and detailed observations at Namakwa Sands mine (2006). Pertinent to the study area are parts of three geological maps and the accompanying explanations: Visser & Toerien (1969, 1971), De Beer *et al*. (2002) and De Beer (2010). Additional valuable geological detail and fossil observations have been provided by Elferink (2005) who has described and mapped the sea cliff exposures along Geelwal Karoo 262.

The regional context of the proposed project is elucidated by way of a summary of the stratigraphy of the Namaqualand coastal plain. This is in terms of the new stratigraphic terminology proposed by De Beer (2010) in the explanation for the recently issued 3017 Garies 1:250k geological map. The stratigraphic scheme is elaborated and modified according to the author's own observations at Namakwa Sands and regionally, with particular emphasis on the aeolianite formations. Other research contributions relevant to this assessment are cited in the normal manner as references in the text and are included in the References section.

2.2 FIELD SURVEY

A brief field survey was undertaken. Its purpose was not to search for more fossil occurrences, but to provide landscape and stratigraphic context for the fossils of the area.

The sites/waypoints of the survey are sequential along the tracks traversed and are labelled with the prefix JPE. Table 1 in Appendix B lists the JPE sites (1-50) and comments.

Appendix C contains Google Earth maps plotting the JPE points and tracks. Also plotted are subsets of the data provided by Webley & Halkett (in the HIA, Table 1) and by Prof. Reed for the Stynder & Reed observations, where fossil material was noticed at a site. The maps of Geelwal Karoo 262 also include the sites where Elferink (2005) made stratigraphic observations.

Appendix D is a selection of images which are also labelled according to the site number, which is preferable to a report-specific figure number. In the text below where there is reference to a site for which there is an image in Appendix D, the site label is in bold font.

3 PROJECT DESCRIPTION

MSR currently uses hydraulic excavators to mine VHM beach deposits to an average depth of 6 m, along a ~75 m wide and ~12 km long stretch of beach adjacent to Farm Geelwal Karoo 262. Sand (ore) is excavated and loaded into dump trucks. The dump trucks haul the ore to a processing plant on the elevated coastal plain. The VHM are extracted at the processing plant and the silica (beach sand) is returned to the beach as slurry by pipeline.

MSR proposes to extend mining operations to ensure the ongoing operation of Tormin Mine. The proposed project consists of the following key components:

- **Mine VHM deposits on ten isolated beaches** along a stretch of coastline north of Tormin Mine (Figure 1-1):
  - Mining will be undertaken using hydraulic excavators, slurry pumps and other ancillary equipment to position and load the ore into a mobile Primary Beach Concentrator for

processing. Dump trucks will haul the processed ore up the beach access roads to the haul road and then onward to the secondary (current) processing plant;

  - Beach mining will be conducted along the beaches between the low-water mark of the sea and the toe of the dunes / cliffs with a 10 m buffer. Mining will progress along each beach depending on tidal movements and mine schedule grade requirements;
  - Mining will be to an average depth of 6 m. Where the VHM deposit is shallow or poorly developed, mining will take place where tides allow. Where thick VHM deposits are found near the low water mark, a sand berm, wave breaker (ditch in the sand), or similar will be constructed on the seaward side of the deposit, providing temporary safety protection from the incoming tide whilst ensuring the mining process is efficient and minimising the need to return to the same area following tide retreat. Once the deposit has been mined, wave action will quickly return the beach to its former condition in a short period of time (and partly replenish VHM deposits). In some instances, a bulldozer will reshape the beach to the original profile where mining occurs above the high-water mark;
  - The Trans Hex Group (THG) has the right to mine the beaches for diamondiferous gravel below the VHM deposit. MSR will continue to coordinate mining activities with THG to ensure efficient mining of the VHM deposit and the diamondiferous gravel.

- MSR proposes to utilise existing gravel roads from the Tormin Mine entrance (off the DR2225) to the beaches to serve as haul roads for dump trucks (Figure 1-2). This includes public road OP09764 adjacent to the coast and informal beach access roads currently used by the Trans Hex Group and, previously, by Namakwa Diamond Company. MSR will widen and grade OP09764 and the beach access roads as required;
- **Mine an inland strand line** within a 100 - 300 m wide and ~4.8 km long area inland of the existing mine and processing plant but seaward of the Sere wind energy facility:
  - Strip mining will be undertaken progressively with topsoil (to a depth of 50cm) removed and stockpiled in designated areas or – where mine sequencing allows – placed directly over tailings backfilled to the preceding mine void. Topsoil from the initial box cut will be stored in the existing topsoil storage area;
  - Overburden will be removed to a depth of 2-25 m (depending on resource depth) and will immediately be backfilled into an adjacent previously mined-out area or temporarily stored in the designated infrastructure buffer areas;
  - Excavators will mine the mineralised sand layer (ore) up to a maximum depth of 30 m. The ore will be loaded into dump trucks and transported to the new ROM stockpile area in the infrastructure / plant expansion area;
  - Tailings will be returned (pumped) to the mine void as backfill and then covered with stockpiled overburden and topsoil material;; and
  - Rehabilitation will be undertaken as soon as the mining path allows. Once an area has been mined and backfilled, the backfilled material will be re-profiled to create the desired landform. The backfill material will be reseeded (if required) and the final rehabilitated area demarcated as a No-Go area;
- **Construct additional processing plants** in the infrastructure / plant expansion area:
  - A **Mineral Separation Plant (MSP)** to further beneficiate the concentrates produced and increase overall mineral recovery; and
  - A **Tailings Disposal Plant (TSP)**.

- **Install a 22 kV powerline** from the Sere wind energy facility to an electrical substation in the infrastructure / plant expansion area.

4 APPLICABLE LEGISLATION

The National Heritage Resources Act (NHRA No. 25 of 1999) protects archaeological and palaeontological sites and materials, as well as graves/cemeteries, battlefield sites and buildings, structures and features over 60 years old. The South African Heritage Resources Agency (SAHRA) administers this legislation nationally, with Heritage Resources Agencies acting at provincial level.

According to the Act (Sect. 35), it is an offence to destroy, damage, excavate, alter or remove from its original place, or collect, any archaeological, palaeontological and historical material or object, without a permit issued by the SAHRA or applicable Provincial Heritage Resources Agency.

Notification of SAHRA or the applicable Provincial Heritage Resources Agency is required for proposed developments exceeding certain dimensions (Sect. 38). If the areal scale of subsurface disturbance and exposure exceeds 300 m in linear length and 5000 m^2 (NHRA 25 (1999), Section 38 (1)), a notification must be submitted to the relevant Provincial Heritage Resources Agency upon which they will decide whether or not the development must be assessed for heritage impacts (an HIA) that may include an assessment of palaeontological heritage (a PIA).

5 THE AFFECTED ENVIRONMENT – GEOLOGY AND PALAEONTOLOGY

The geology of the region is summarised, as by convention, from the oldest bedrock to the youngest deposits. The overview stratigraphic column for the western part of southern Africa (Figure 5-1) indicates which major stratigraphic entities are represented in the project area.

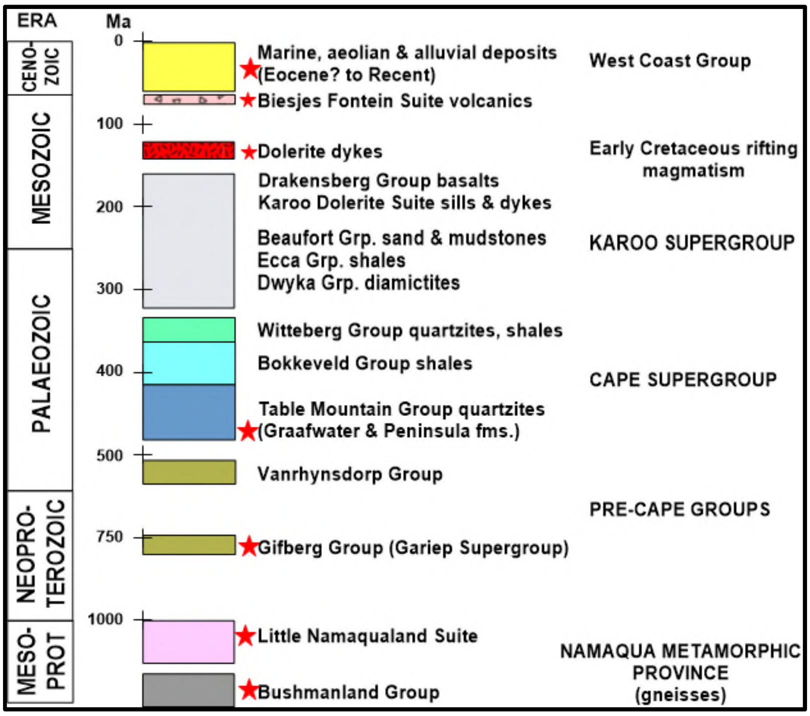


Figure 5-1: Summary stratigraphic column. Red stars indicate strata represented in the project area. Ma = Million years ago.

Notably, most of the strata of the Palaeozoic and Mesozoic eras have been eroded from the western margin of the subcontinent during and subsequent to the rifting of the Gondwana supercontinent and opening of the Atlantic Ocean, so that for the main part of the Namaqualand coast the Cenozoic deposits, overlie much older Proterozoic crustal basement bedrock. Annotated extracts from the relevant geological maps are reproduced in the figures below.

5.1 The Bedrock

A considerable variety of bedrock types of disparate ages occur along the shore of the study area, but are not of palaeontological concern in the current context.

5.1.1 The Gneisses

North of the boundary between Geelwal Karoo 262 and Klipvley Karoo Kop 153 the basement gneisses of the Namaqua Metamorphic Province crop out along the shore (Figure 5-2). These gneisses are older than 1000 Ma (Mesoproterozoic).

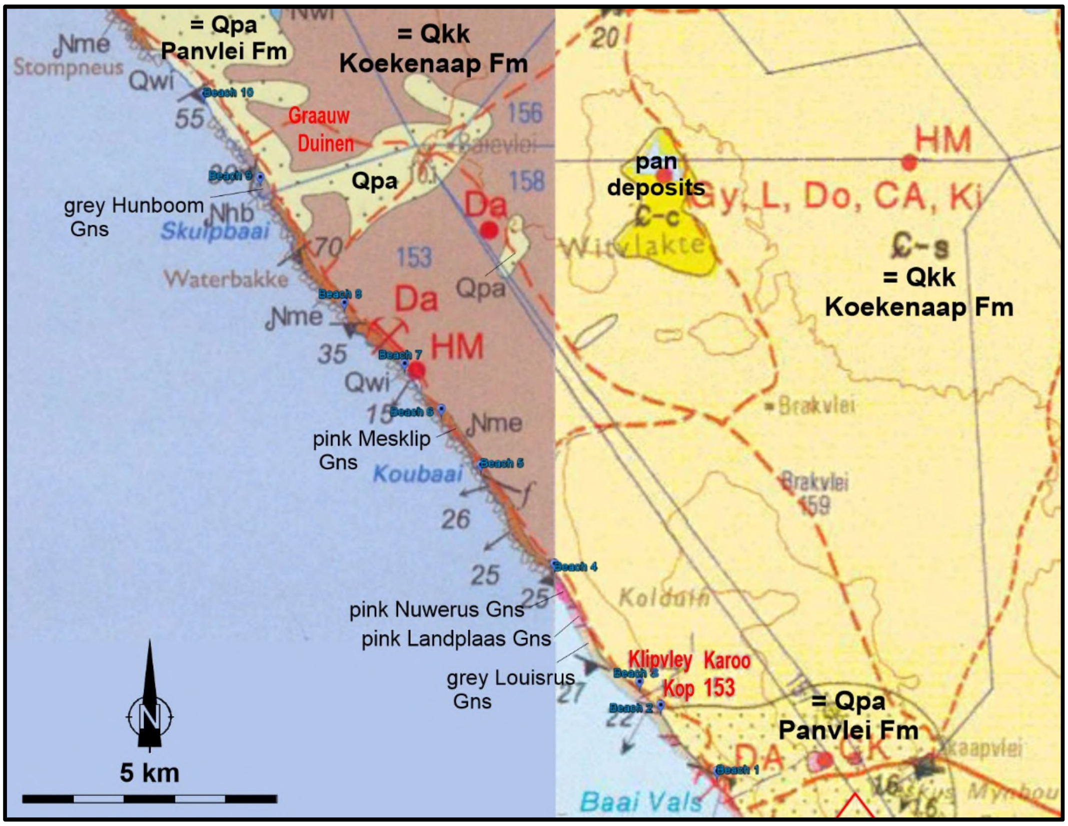


Figure 5-2: Extracts from 1:250 000 sheets 3017 Garies (LHS) and 3118 Calvinia (RHS). Council for Geoscience. Points labelled in red (DA, HM etc.) indicate mineral resources (e.g. Diamonds, Heavy Minerals).

The oldest gneiss is the pale-grey Louisrus Formation (Mlr) of the Bushmanland Group of metamorphosed ancient sediments. The grey gneisses are intruded by pink, coarse-grained, granitic gneisses of the Little Namaqualand Suite of intrusives, *viz*. the Landplaas Gneiss (Ɲlp) and the Nuwerus Gneiss (Ɲnu). Still farther north on the map 3017 GARIES the pink gneiss outcrops are mapped as the Mesklip Gneiss (Ɲme) and the grey Hunboom gneiss.

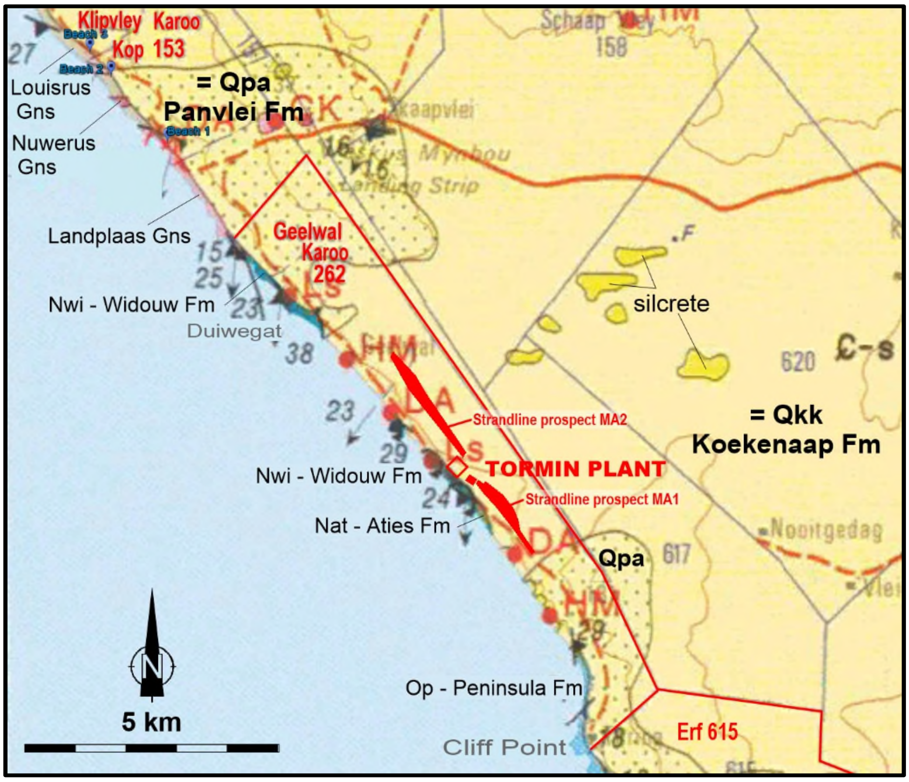


Figure 5-3: Extract from 1:250 000 sheet 3118 Calvinia. Council for Geoscience.

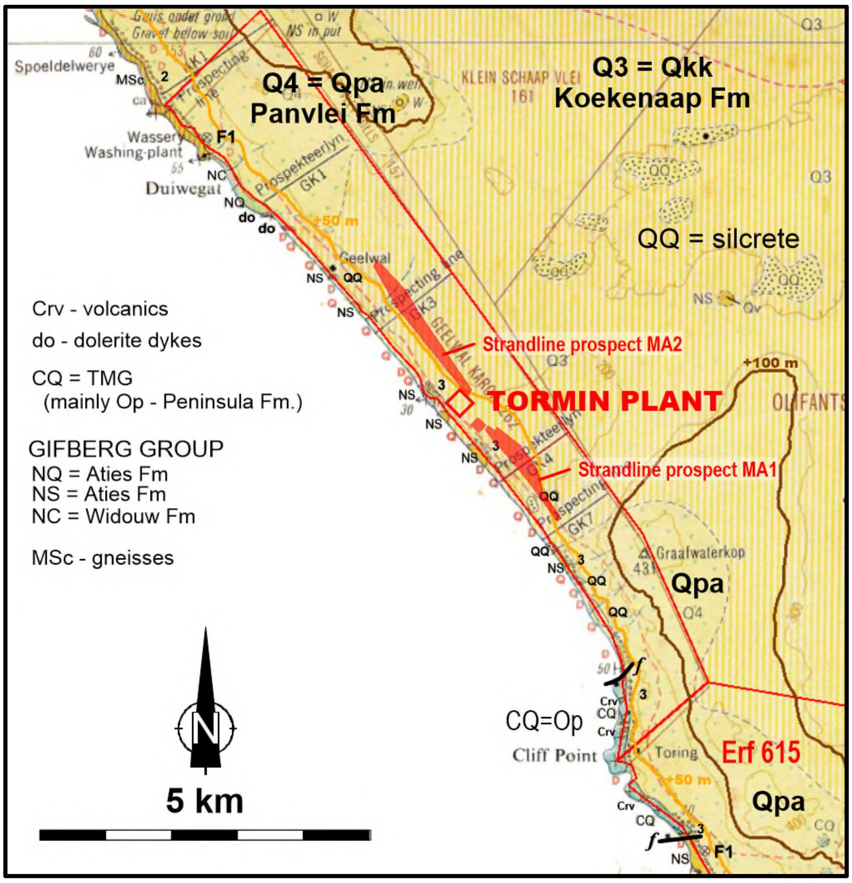


Figure 5-4: Extract from Visser & Toerien (1969), 1:125 000 Map Sheet 254: 3118C (Doringbaai) & 3218A (Lamberts Bay).

5.1.2 The Gifberg Group Metasediments

South of the boundary between Geelwal Karoo 262 and Klipvley Karoo Kop 153 the bedrock is comprised of metamorphosed and deformed sedimentary rocks (metasediments) of the succeeding Gifberg Group. Blue-grey, black and white dolomitic marbles of the Widouw Formation are exposed in limited areas in the vicinities of Duiwegat and near the Tormin Plant on Geelwal Karoo 262 (Nwi, Figure 5-3). However, most of the bedrock along Geelwal and south to the Olifants River mouth is the Aties Formation which consists of micaceous schists and flakey phyllites, with some interbedded quartzites and limestones (Nat, Figure 5-3; NS, Figure 5-4).

5.1.3 The Table Mountain Group Sandstones

The cliffs centred on Cliff Point are comprised of the Peninsula Formation quartzitic sandstones and quartz conglomerates of the Table Mountain Group (TMG), the lower part of the Cape Supergroup succession (Op, Figures 5-3, 5-4). These are the oldest rocks in the Cape wherein trace fossils (burrows and arthropod tracks) are found.

5.1.4 The Intrusions – Dykes, Pipes and Plutons

The succeeding formations of the Cape Supergroup and the Karoo Supergroup, which previously extended over the area to depths of several km, have all been removed from the coastal region by erosion during and subsequent to the breakup of the supercontinent Gondwana, when rifting initiated the separation of Africa and South America and the formation of the Atlantic Ocean. Rifting during the early Cretaceous ~140 to ~130 Ma was accompanied by widespread volcanic activity. In southern Namaqualand in particular, the rifting volcanic activity had additional counterparts at depth involving the intrusion of numerous dykes, plugs and granites of varied compositions, called the Koegel Fontein Complex (De Beer, 2010). In the study area two such dolerite dykes occur just south of Duiwegat (do, Figure 5-4). The last volcanicity affecting southern Namaqualand took place during the earliest Cenozoic ~55 Ma and involved a cluster of small volcanic pipes called the Biesjes Fontein Suite (De Beer, 2010). A small volcanic pipe and associated fissures and alteration present just north and south of Cliff Point is deemed to correlate with this last phase of volcanicity (Crv, Figure 5-4).

5.2 The Early Coastal Plain

The **West Coast Group** is the name proposed to accommodate the Cenozoic coastal deposits between the Orange River and Elandsbaai (Roberts *et al.*, 2006). The context of the West Coast Group in terms of global Cenozoic palaeoclimatic and sea-level trends is shown in Figure 5-5.

The early coastal plain would have been inundated or transgressed by the sea during times of late Cretaceous high sea-levels and transgressive Eocene events also affected the coastal plain (Figure 5-5). This earlier marine record, with palaeoshorelines that now would have been uplifted to 150-200 m asl., has been eroded from the Namaqualand coastal plain.

Deeply weathered, kaolinized (white china clay) bedrock is a feature of the older parts of the coastal plain, with silcrete cappings in places. The silcrete originally formed in poorly-drained low spots in the pre-existing landscape. The deep weathering and silcrete formation resulted from humid, tropical weathering phases during the latest Cretaceous and earlier Cenozoic (Figure 5-5).

For locations mentioned below refer to the maps in Appendix C. Site labels in bold type below refer to images in Appendix D.

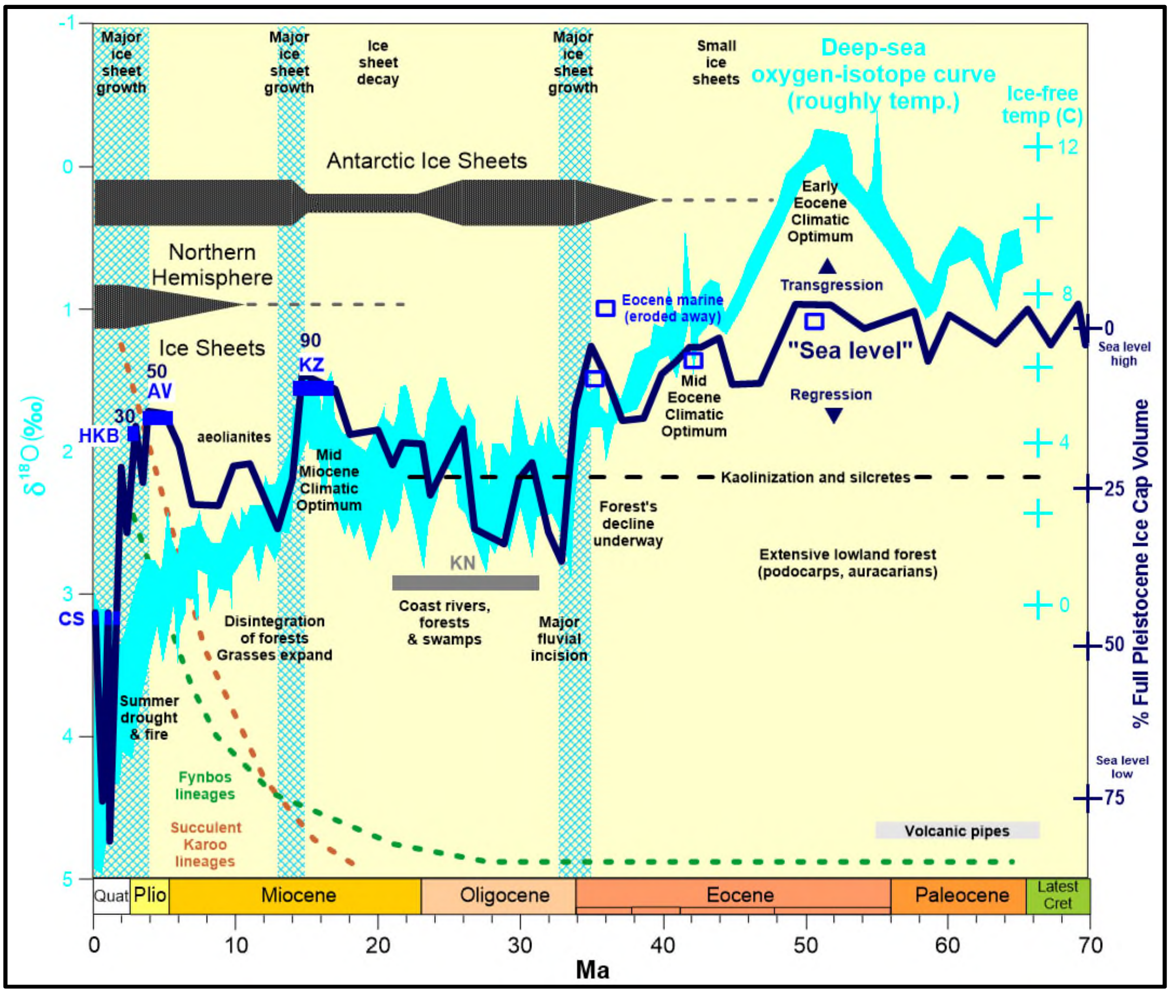


Figure 5-5: The Cenozoic Era (65.5 Ma to present) showing global palaeoclimate proxies, aspects of regional vegetation history and the context of marine formations of the West Coast Group, Alexander Bay Subgroup.

Cyan curve - history of deep-ocean temperatures, adapted from Zachos *et al*. (2008). Blue curve is an estimate of global ice volumes, adapted from Lear *et al*. (2000). Global ice volumes roughly indicate sea-level history caused by the subtraction from the sea of water as land-ice. The expansion of Fynbos and Karoo floras is adapted from Verboom *et al*. (2009).

Formations: KN – Koingnaas Fm. KZ - Kleinzee Fm. AV – Avontuur Fm. HK – Hondeklipbaai Fm. CS – Curlew Strand Fm.

5.2.1 THE KOINGNAAS FORMATION

Buried between the main Namaqualand rivers are ancient river channels that attest to the wetter climates of the early Cenozoic, when many more rivers drained the coastal plain. These palaeochannels have fluvial infills that have also been kaolinized and silcrete has formed within the upper channel deposits in places. Previously referred to as the “Channel Clays” by diamond miners, these deposits are now proposed as the Koingnaas Formation (De Beer, 2010). It is not shown on the geological maps, being covered by younger deposits. However, the white, kaolinitic quartz gravels and sands of this formation form the cliffs along most of the shore of Geelwal Karoo 262 (**JPE033, 034**) and these are the most extensive natural exposures of the Koingnaas Formation in all Namaqualand. Drilling has roughly indicated the considerable extent of the palaeochannel deposits (Figure 5-6) (Cole & Roberts, 1996).

Beds of carbonaceous, peaty material containing plant fossils occur in the Koingnaas Formation in the Koingnaas area. Similar deposits have been intersected in boreholes inland on the nearby farms Karoovlei 454 and Schaap Vley 158. Fossil wood of tropical African mahogany has been found in these deposits on Koingnaas. Silicified fossil wood of tropical trees, again including mahogany, has been found in the Olifantsrivier gravels near Vredendal and was presumably reworked from Koingnaas Fm. deposits exposed somewhere in the valley.

Figure 5-6: Palaeochannels of the Koingnaas Formation.

Fossil pollen from the organic-rich beds has provided evidence of the vegetation type present and age of the Koingnaas Formation. Yellowwood forest with auracaria conifers and ironwoods dominated the West Coast. The presence of primitive daisy pollen (Asteraceae) indicates an age not older than Oligocene (Muller, 1981) and the fossil mahogany wood also supports an Oligocene maximum age. The background of yellowwood and araucarian conifer pollen suggests that the forests were in the foothills of the hinterland, while local swamps surrounded by woodlands occurred at the coast. . The pale, kaolinitic weathering profiles, associated silcretes and Koingnaas Formation deposits are remainders of a fossil landscape when the wooded Namaqualand coast somewhat resembled the Outeniqua forests of the south coast.

5.2.1.1 Palaeontological Sensitivity

Notably, the Koingnaas Fm. pollen assemblage, with many extinct types of uncertain affinity and no analogues elsewhere, indicates that the uniqueness of the Cape Floristic Region is rooted in "deep time" (De Villiers & Cadman, 2002). Unfortunately the uniqueness makes it difficult to determine the age of the fossil floras other than very generally, with resultant controversy. The exposures of the Koingnaas Fm. along Geelwal Karoo 262 are the most extensive available on the Namaqualand coastal plain. As largely natural exposures and although eroding slowly, their longevity relative to diamond-mine pits makes for their long-term importance for study into the future. Only general descriptions exist and the detailed observations, sampling and analyses required for palaeo-environmental diagnosis in terms of modern, multi-disciplinary approaches are yet to be done.

The presence of organic-rich laminae in the Geelwal exposures is reported by Elferink (2005), but have apparently not been analysed for fossil pollen content. There is a possibility that fossil logs and other plant material may occur in the formation. The silcrete may include impressions of plants and trace fossils. The Koingnaas Fm. is accorded MODERATE palaeontological sensitivity due to the need for fossil evidence from the study area. The Koingnaas Fm. underlies Geelwal Karoo 262 beneath the marine and aeolian deposits (Figure 5-6) and may be exposed in the bottom of the Strandline mining pits. Fresh exposures in the mine pits must be inspected for fossil plant material.

5.3 THE MARINE RECORD – THE ALEXANDER BAY SUBGROUP

Three extensive marine formations containing warm-water mollusc assemblages occur beneath the aeolian coversands of the Namaqualand coastal plain. These are currently all subsumed in the Alexander Bay Formation as members (Kleinzee Member, Avontuur Member, Hondeklipbaai Member). However, these Miocene and Pliocene marine formations each occupy a specific spatial position in the stratigraphic geometry, have distinctly different fossil faunas and are of distinctly different ages. They are therefore worthy of full formation status. Close to the coast is a volumetrically much smaller formation, named the Quaternary Curlew Strand Formation, which is composed of three "raised beaches" which enclose a modern, cold-water fauna. Concomitantly herein the Alexander Bay Formation is promoted to Subgroup rank and incorporates all four marine formations.

5.3.1 THE KLEINZEE FORMATION / 90 M PACKAGE - MID-MIOCENE CLIMATIC OPTIMUM

The oldest marine formation is the Kleinzee Formation which is found up to 90 m asl. (also called the 90 m Package). Petrified teeth of extinct pigs and a hominoid tooth have been found in the basal gravels (Pickford & Senut, 1997). These were reworked from preceding terrestrial deposits of age 18 - 17.5 Ma. The deposits are decalcified and generally lack all but the most robust macrofossils such as oysters. However, a shelly, more distal marine (shelf) facies of pebbly muddy sands and clays is very locally preserved at lower elevations, beneath the younger marine deposits. Strontium isotope ages of 16-15 Ma have been obtained from foraminifera sealed in clay at one such occurrence in the Hondeklip area (Langklip), consistent with deposition during the decline from the high sea level of the warm Mid-Miocene Climatic Optimum 17 to 15 Ma (Figure 5-5). The sparse shelly fauna from the Kleinzee Formation is poorly preserved and mainly unstudied, but the curious, thick-shelled bivalve *Isognomon gariesensis* is the zone fossil for this formation.

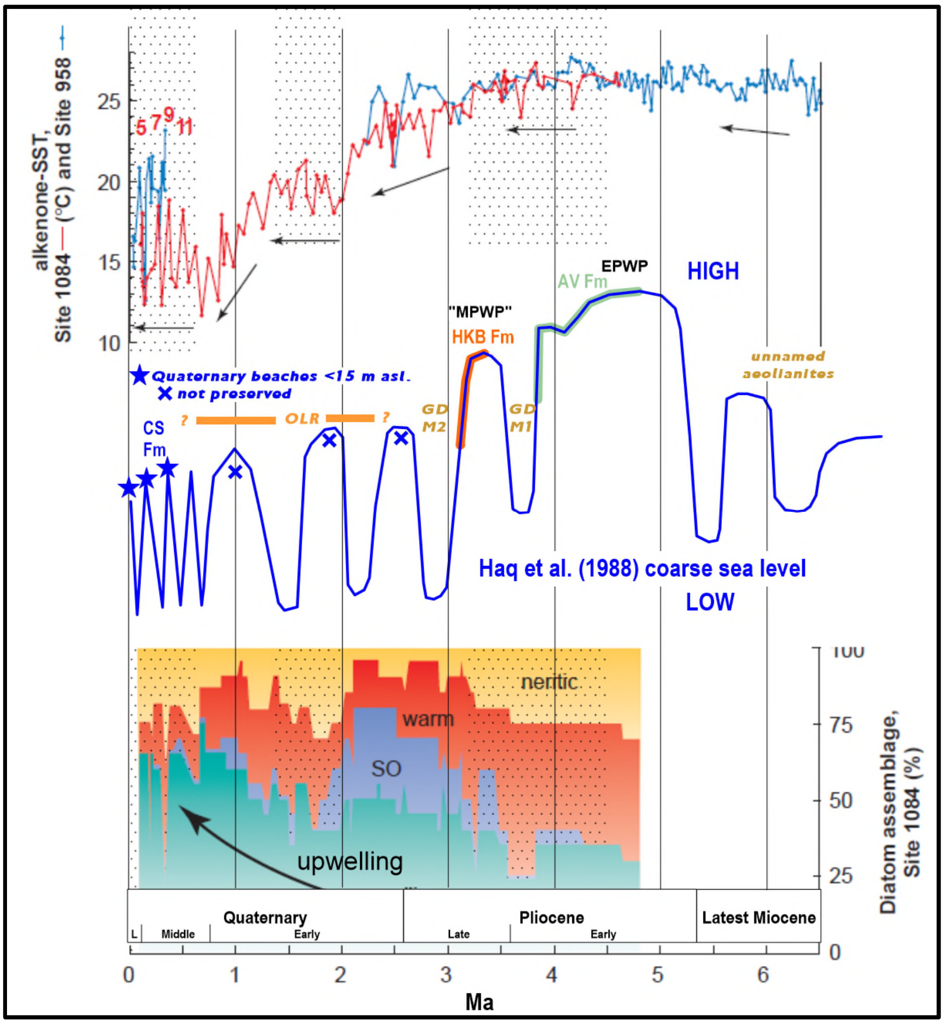


Figure 5-7: Coarse-scale sea-level history based on major margin unconformities (adapted from Haq et al., 1988), shown together with palaeoceanographic data from deep-sea core 1084 off Luderitz (from Marlow et al., 2000).

TOP: Sea Surface Temperature (SST) history showing stepwise cooling after 3 Ma.

MIDDLE: Sea Level history and Formations: AV – Avontuur Fm. HKB – Hondeklipbaai Fm. CS – Curlew Strand Fm. EPWP – Early Pliocene Warm Period. “MPWP” Mid-Pliocene Warm Period (now in late Pliocene). GD M1 – Graauw Duinen Fm., Member 1. GD M2 - Graauw Duinen Fm., Member 2. OLR – Olifantsrivier Formation.

BOTTOM: Diatom assemblages showing increase in upwelling species and decrease in warm water species during the Quaternary. SO – Southern Ocean species abundant during initial cooling transition and growth of polar ice caps.

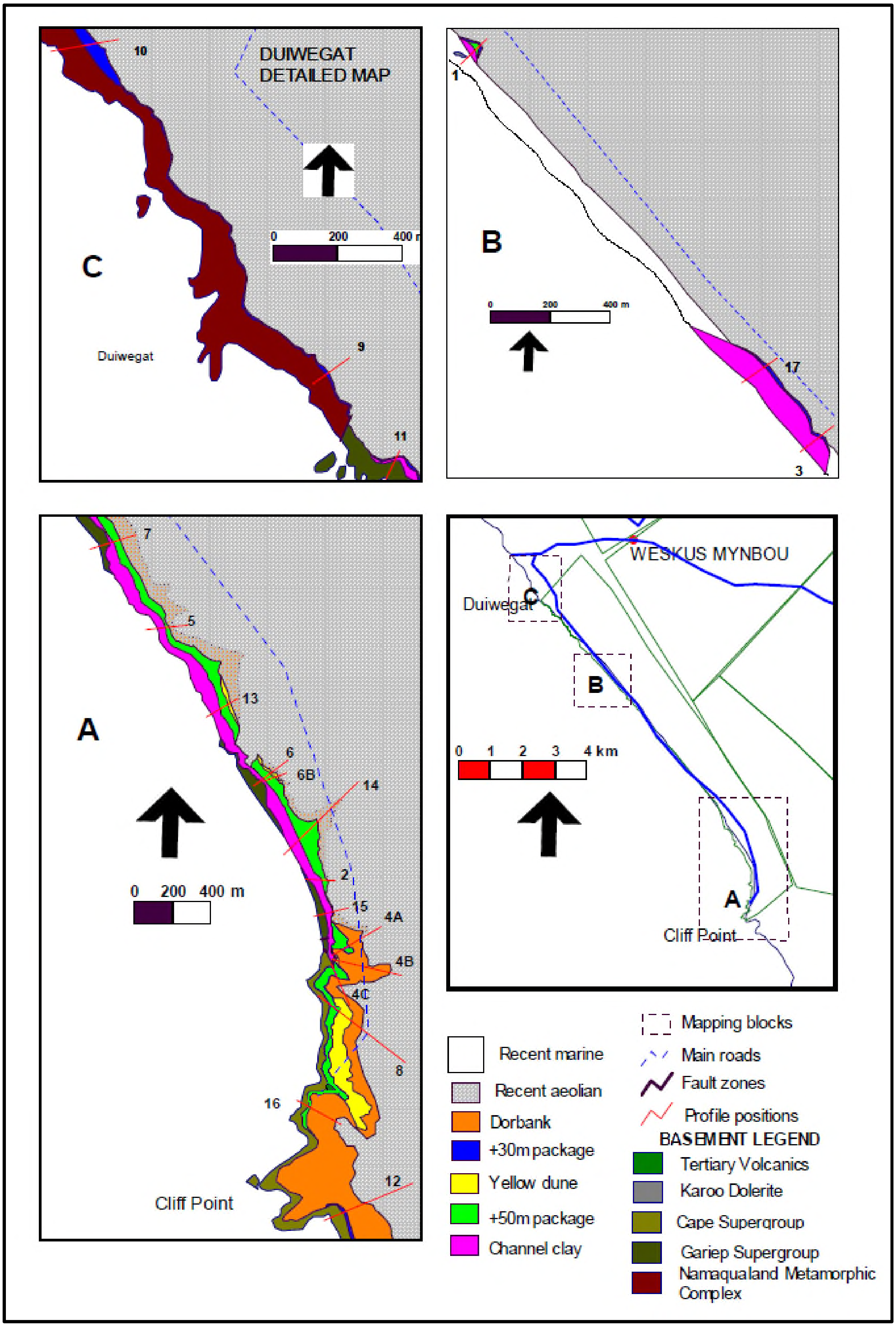


Figure 5-8: Map of formations on Geelwal Karoo 262 after Elferink, 2005. Channel clay = Koingnaas Fm. Yellow dune = Graauw Duinen Fm. Dorbank = Olifantsrivier Fm.

5.3.2 The Avontuur Formation / 50 m Package - Early Pliocene Warm Period

The previous Miocene marine beds were eroded during rising sea-level of the Early Pliocene Warm Period and the fine sands of the Avontuur Formation (the 50 m Package) were deposited 5-4 Ma as sea-level receded from the transgression maximum of about 50 m asl. (Figures 5-5, 5-7). The Avontuur Formation also contains a basal concentration of petrified and abraded vertebrate remains inherited from earlier periods. This "Basal, petrified, mixed assemblage" or remanié fauna includes shark teeth and the bones and teeth of extinct whales, proboscideans, rhinocerotids, bovids and equids.

The oldest fossils present in the basal assemblage are the bear-dog *Agnotherium* sp. (13 - 12 Ma) and the gomphothere *Tetralophodon* (12 - 9 Ma), but the age indicated by most of the material is terminal Miocene (7.5 - 5 Ma). These youngest taxa in the reworked basal assemblage constrain the maximum age of the 50 m Package. The important, unpetrified finds from within the deposits are the Langebaanian (Varswater) phocid (seal) *Homiphoca capensis* and the suid (bushpig) *Nyanzachoerus kanamensis*. This deposit is broadly contemporaneous with the early Pliocene Varswater Formation exposed at the West Coast Fossil Park near Saldanha. Much of the Avontuur Formation is also decalcified, but it must have been very shelly originally and in places shell fossils are abundant so that the shell fauna is quite well-known. The zone fossil is the extinct "surf clam" *Donax haughtoni*.

5.3.3 The Hondeklipbaai Formation / 30 m Package – "Mid-Pliocene Warm Period"

The Avontuur Formation in turn was eroded by yet another rising sea-level associated with a warm period later on during the Pliocene Epoch (*"Mid-Pliocene Warm Period") (Figure 5-7). The Hondeklipbaai Formation or 30 m Package was deposited as sea level declined from a high of about 30-35 m asl. and a substantial, prograded marine formation built out seawards (Pether, 1994; Pether, in Roberts *et al*., 2006). This formation, up to a few km wide, underlies the outer part of the coastal plains of the West Coast. (* - see Glossary)

An age-diagnostic fossil vertebrate assemblage directly associated with the Hondeklipbaai Formation has not yet been recovered and so its age is not constrained by vertebrate datums. Notwithstanding, it is the last, major formation of the coastal plain, deposited during a high sea-level never since exceeded. With its warm-water molluscan fauna, it is unlikely to postdate the inception of major cooling in the Benguela System. A core from off Lüderitz (ODP Site 1084) has provided alkenone-based Sea Surface Temperature (SST) estimates (from fossil organic matter) and diatom microfossil-assemblage records extending from 4.5 Ma. This shows a decline in temperature since ~3 Ma (Figure 5-7), from previous late Pliocene warmth (~26°C) (Marlow *et al*., 2000). Accordingly, the 30 m Package is not likely to be younger than ~3.0 Ma and corresponds with the "Mid-Pliocene Warm Period" and the second, major Pliocene sea-level highstand in the late Pliocene at ~3.0 to 3.4 Ma (Figure 5-7). The Hondeklipbaai Formation is mainly coarse-sandy and extensively decalcified and reddened. Shell fossils are quite sparse and more need to be found. The zone fossil is the large extinct "surf clam" *Donax rogersi*.

5.3.4 The Marine Mio-Pliocene Deposits in the Study Area

Visser & Toerien (1971) recorded a "27 m terrace" and an "18 m terrace", depicted in Figure 5-4 as "boulder lines" along the cliffs labelled "3" and "2", respectively. At that stage the zone fossil shells were not well known and the deposits were not distinguished on a fossil basis. This was no longer the case when De Beer *et al*. (2002) recognized that the 50 m Package zone fossil *Donax haughtoni* occurred in exposures of the "27 m terrace", while *Donax rogersi* was characteristic of the "18 m terrace".

Subsequently, Elferink (2005) mapped the marine formations on Geelwal Karoo 262 (as the 50 & 30 m Packages, Figure 5-8) in terms of a combination of the occurrence of the zone fossils, or when fossils were absent, on elevation. A map of the distribution of the marine formations abutting the coast is presented in Figure 5-9, based on the previous work and personal observations.

Figure 5-9: The Pliocene marine formations along the coast of the Study Area.

5.3.4.1 The Kleinzee Formation / 90 m Package

In situ deposits of this mid-Miocene formation have not been recognized in the study area. Notwithstanding, there may be small patches preserved in local depressions beneath the Pliocene marine deposits, as is not uncommon elsewhere on the coastal plain. Fossils derived from this formation are found in the basal gravels of the younger marine units.

5.3.4.2 The Avontuur Formation / 50 m Package

The early Pliocene Avontuur Formation is mainly exposed above the high cliffs in the southern portion of Geelwal Karoo 262 (**JPE029, 033, 034**; Map C7). Here the formation is thickest and is overlain by a particularly thick accumulation of aeolianite formations. Fossil shells are quite common.

North of these exposures the marine deposits are mainly covered by aeolianites. The exposures in some of the ramps could not be perused due to active ADT hauler traffic. In this gap stretch around the Tormin plant in the middle part of Geelwal Karoo 262 (Figure 5-9) it may be expected that the 50 m Package deposits are present in places beneath the 30 m Package gravels (*e.g.* at Profile 1, Figure 5-8 B).

5.3.4.3 The Hondeklipbaai Formation / 30 m Package

North of the "gap" along the central part of Geelwal Karoo 262 (Figure 5-9) the Hondeklipbaai Formation is continuously present beneath the aeolianites forming the coastal slope (*e.g.* **JPE025** and **026** (Map C5) and **JPE001, 002, 004** (Map C1)).

5.3.4.4 Palaeontological Sensitivity of the Pliocene Marine Formations

Most of the marine deposits on the Namaqualand coast have been decalcified and lack fossils. The fossils which remain are the robust, calcitic oysters and thick, large shells. In places more diverse assemblages with small forms may be preserved – these were originally very shelly beds that buffered themselves from dissolution by the sheer quantity of carbonate, or occur in thick deposits in upper layers where net exposure to groundwater was less than shell more permanently in the aquifer.

In the study area the fossil shell content of both Pliocene marine formations is typical of that found wider afield in Namaqualand. The gravels on the bedrock were host to aquifers in the past and rendered barren by shell dissolution, or with only oysters and other big shells remaining. Where shells occur higher in the section in thicker deposits, more delicate shells are preserved, *e.g.* at road cutting site **JPE033** and southwards to Cliff Point (Map C7).

The fossil shell fauna of the early Pliocene Avontuur Formation in central Namaqualand (Hondeklipbaai area) is fairly well sampled due to fortuitous preservation (Carrington & Kensley, 1969; Kensley & Pether, 1986). However, the sample is spatially and biogeographically restricted. Due to the poor preservation of shell in most of the Hondeklipbaai Formation (30 m Package), the sample is relatively small and biased toward robust shells. Certainly, efforts to increase the overall fossil sample size from both Pliocene formations, from wider afield along the West Coast, will inform about the nature of the coastal palaeoenvironments during of those times of extended global warmth and deglaciation.

Fossil shells selected from exposures in the study area featured in the earliest palaeontological findings about the marine deposits (Haughton, 1926, 1928, 1932) and are kept at the IZIKO South African Museum, but lack precise locations. No systematic bulk sampling of the assemblages in shelly spots in the study area has been undertaken. Thus the suspected biogeographic gradient in the fossil faunas, southwards from the central Namaqualand sites towards the Saldanha area and farther on to the Southern Cape, lacks material for study and enquiry. The Avontuur and

Hondeklipbaai formations are thus of MODERATE sensitivity with respect to shell fossils. If well-preserved shell beds are uncovered it is expected that the list of known species will be lengthened and more extinct shell species, and warm-water species, will be found, some of which are ancestral to the endemic modern fauna.

Very sparsely scattered bones occur within these marine deposits, such as bones of whales, dolphins, seals and seabirds. The abraded, petrified bones and teeth of older marine taxa, as well as those of terrestrial vertebrates, occur in basal marine gravels. The bones of terrestrial animals occur on the eroded palaeosurfaces that mark the top of the marine deposits. In these Pliocene formations the bones are of extinct species and are of HIGH palaeontological importance.

5.3.5 THE CURLEW STRAND FORMATION

Close to the seaside, the Hondeklipbaai Formation is eroded and overlain by the younger, Quaternary “raised beaches” that extend up to about 12 m asl. The name has been proposed for this composite of old beaches, equivalent to the Velddrif Formation of the SW Cape Coast. It comprises the 8 - 12 m Package (Marine Isotope Stage 11 highstand, ~400 ka), the 4 - 6 m Package (Last Interglacial (LIG) highstand ~125 ka, a.k.a. MIS 5e) and the 2 - 3 m Package (mid-Holocene highstand 6-4 ka – the “Holocene High”) (Figures 5-7, 5-10).

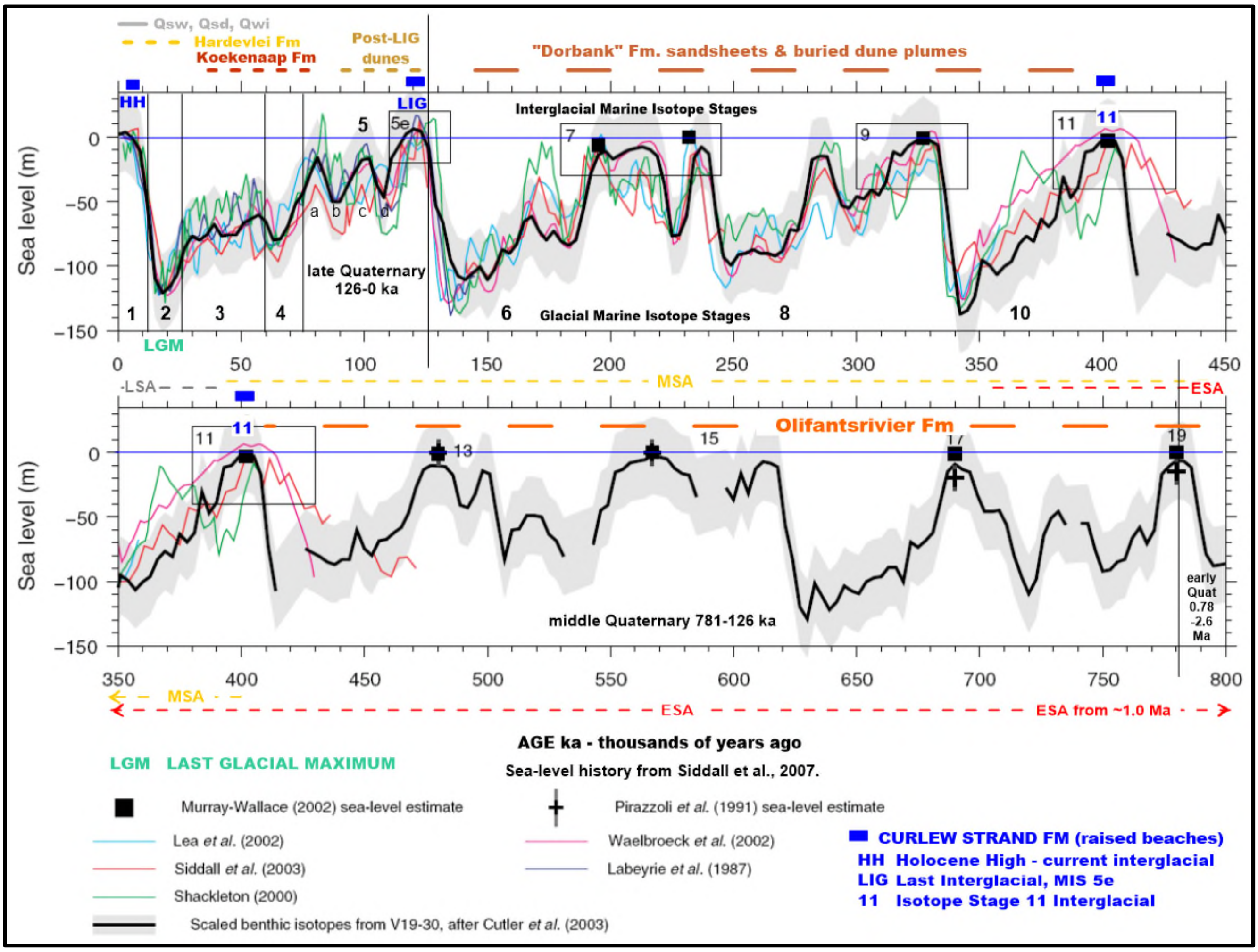


Figure 5-10: Sea-level history and the age ranges of middle and late Quaternary formations of Namaqualand.

Qwi = Witzand Fm. Qsd = Swartduine Fm. Qsw = Swartlintjies Fm.

Notably, most of the earlier Quaternary sea-level record has not been preserved and was presumably eroded away by the younger highstands (Figure 5-7). The older 8 - 12 m Package is poorly known and the few examples preserved may not always be deposits of identical age. However, it is expected that these deposits mostly relate to the MIS 11 highstand recognized globally (Figure 5-10).

The LIG beach is the best-preserved and is almost continuous along the coast, occurring within embayments and on low bedrock platforms along rocky coast. The Holocene High beach is usually preserved beneath young dunes along sandy coast, but is often eroded away along rocky coast.

5.3.5.1 The Curlew Strand Formation in the Study Area

The Quaternary raised beach deposits are effectively absent along the cliffed coast of Geelwal Karoo 262 in the southern part of the study area, where the modern beach abuts the bedrock or the Koingnaas Formation, although some vestigial deposits may be very locally preserved in gullies and ravines, beneath aeolian sand and colluvium.

The mid and late Quaternary raised beaches occur farther north where the bedrock extends inland with low gradients. Example exposures of the Last Interglacial raised beach are present at Gert du Toit se Baai (**JPE011**, Map C1) and at Skulpbaai (JPE20, Map C4). The best example of the Holocene High raised beach is also preserved along Gert du Toit se Baai, where it forms the shelly terrace above highwater mark upon which the holidaying campers set up their camps. Many of the exposures of these deposits backing the beaches have been due to mining and sampling for diamonds, otherwise they are beneath the aeolian cover. The older, mid-Quaternary, 8-12 m beach has not been recognized and if preserved, is farther back from the beaches under thicker aeolian cover.

5.3.5.2 Palaeontological Sensitivity of the Curlew Strand Formation

In open-coast settings the shell fossil content of these raised beaches is of LOW palaeontological sensitivity as the fossil shells are overwhelmingly modern species. However, along the Namaqualand shoreline, the LIG beaches are poorly examined and sampled for fossil shells. During the LIG several West African tropical taxa ranged down the coast as they are found in equivalent LIG deposits of the Southern Cape. These warm-water species evidently inhabited embayments of the inundated river mouths and are not expected along exposed coastal stretches. Notwithstanding, extinct species and subspecies occur in LIG deposits of the southern Cape (Kilburn & Tankard, 1975) and may occur in the Namaqualand LIG and MIS 11 deposits. Rare surprises have come to light in the Holocene beach deposits, such as isolated occurrences of the large South American marine snail *Concholepas* which today inhabits the coast of Chile and is an example of remarkable long-distance dispersal. The *Concholepas* shells have been found near Oranjemund and also near the Olifantsrivier mouth. The supralittoral, air-breathing small snail *Marinula tristanensis* was dispersed from the mid-Atlantic islands to the Namaqualand coast near Kleinzee. These pioneer populations evidently died out. Thus although of general low sensitivity, exposures of this formation are worthy of scrutiny for unexpected fossil finds.

The sparse fossil bones in the Quaternary Curlew Strand Formation (*e.g.* seabirds, marine mammals) are likely to be closely related or identical to modern marine species, but may include species that we would not expect nowadays and finds may be of scientific importance.

5.4 THE TERRESTRIAL RECORD

A variety of terrestrial deposits also make up the coastal plain of the Namaqualand. For the most part these are extensive aeolian dune and sandsheet deposits that overlie the eroded tops of the marine formations, the latter providing the maximum ages of overlying sequences. More locally there are colluvial (sheetwash) and ephemeral stream-channel deposits associated with nearby hillslopes; sometimes these underlie or are interbedded between the marine formations, but are more usually found interbedded within aeolian deposits. Formed within the upper parts of the marine and terrestrial sequences are pedocretes and palaeosols of a variety of types, compositions and degrees of development.

The sorting out and stratigraphic formalization of the terrestrial record of the coastal plain is still very much in its infancy and thus the formations proposed hitherto have been very broadly defined. It is quite apparent, on the basis of interleaving marine deposits of different ages, and well-developed pedocretes marking intervals of regional extent within currently-defined formations, that at this stage the formations are comprised of major units that, as fieldwork and fossil discoveries ensue, will in time become formations in their own right, in a sequence-stratigraphic framework linked to global and continental palaeoclimatic cycles and their regional outcomes.

A glance at the satellite images of the coast show that the pale swathes of modern and Holocene aeolian activity occur in specific areas, linked to antecedent topography, sea-level oscillations, locations of sandy beaches and fluvial sediment inputs. Similarly, the deeper-time aeolian record is expected to comprise buried dune fields, dune plumes and sand sheets that accumulated at different times in various areas of the coastal plain.

5.4.1 THE OLDER AEOLIANITE FORMATIONS

5.4.1.1 Later Miocene Aeolianites

The mid-Miocene, marine Kleinzee Formation has been extensively eroded and has been largely reworked into aeolian sands. These old aeolian deposits are usually quite altered by pedogenic and groundwater processes. In Namaqualand this is effectively an unnamed formation, partly due to the difficulty of diagnosis when lateral exposure is lacking. These later-Miocene aeolianites occupy the higher part of the coastal notch where they overlie residuals of the Kleinzee Formation and extend into the immediate hinterland. Locally they occur beneath the inner part of the Avontuur Formation (early Pliocene) marine wedge. The occurrence of petrified teeth of the bear-dog *Agnotherium* sp. (13 - 12 Ma) and the gomphothere *Tetralophodon* (12 - 9 Ma) in the basal gravels of the early Pliocene Avontuur Formation at Hondeklipbaai hints at the pre-existence of terrestrial deposits of this late Miocene age range.

5.4.1.2 The Graauw Duinen Formation

This name has been proposed to accommodate the aeolianites as exemplified in the Namakwa Sands excavations on Graauw Duinen 152 (Roberts *et al.*, 2006; De Beer, 2010) where the aeolianites are excellently exposed in coast-normal mining faces. However, due to ongoing mining and backfilling, these exposures are ephemeral. The more enduring natural exposures on the cliffs just north of Cliff Point on the farm Geelwal Karoo 262 have therefore been proposed as the type area (Roberts & Mthembi, 2015) and the stratotype section (Figure 5-11) is at the location of the Cliff Point 1 (CP1) hyaena lair location (Stynder, 2012). Roberts & Mthembi (2015) have proposed that the name “Graauw Duinen Formation” be restricted to West Coast Group aeolianites of Pliocene age.

Based on personal observations of the aeolianites exposed at Graauw Duinen (Namakwa Sands), the first main aeolianite unit postdates the marine early Pliocene Avontuur Formation. Also exposed at Graauw Duinen are younger aeolianites that postdate the late Pliocene Hondeklipbaai Formation. Traced inland, these younger aeolianites overlie the aforementioned aeolianites that directly overlie the Avontuur Formation. Colluvial beds, stream channel deposits and pans are locally interbedded in these aeolianites.

Accordingly, on the basis of the Graauw Duinen exposures, this formation has a lower unit (Member 1) that overlies early Pliocene marine deposits (Avontuur Formation) (Figure 5-7, GD-M1) and can be traced laterally therefrom. In the west this lower unit is transgressed and eroded beneath the marine late Pliocene Hondeklipbaai Formation where it pinches out. Its age is about 4.5 – 3.5 Ma. A younger large aeolian unit (Member 2) overlies and postdates the ~3 Ma Hondeklipbaai Formation and Member 1 (Figure 5-7, GD-M2). Other than this maximum ~3 Ma age, the age of Member 2 is not yet well constrained. However, Stone Age artefacts are apparently absent in Member 2 at Graauw Duinen/Namakwa Sands. This indicates it is older than about 1.0 Ma. The immediately overlying aeolianite unit contains rare Early Stone Age (ESA) material and is referred to the Olifantsrivier Formation (see below).

5.4.1.3 The Olifantsrivier Formation

This formation (as "Olifants River Formation") was proposed to accommodate aeolianites that contain Early and Middle Stone Age artefacts (Roberts *et al*., 2006). It is a typical, variously reddened aeolianite with palaeosols, pedocretes, abundant root casts and termite burrows, as exemplified in cliff exposures north of the Olifants River mouth and in the Namakwa Sands mine. At this stage it is an informal formation – no specific detailed descriptions have been published and stratotype sections have not yet been defined in the type area and must, of course, be identified in the clifftop exposures north of the Olifants River. An Olifantsrivier Formation or equivalent is not mentioned in De Beer *et al*., (2002) or in De Beer (2010) and in the latter work was subsumed/included in the Graauw Duinen Formation. The Olifantsrivier Fm. is thus not shown on the geological maps. However, the Panvlei Formation, indicated as Qpa in Figures 5-2 – 5-4, is pertinent to the Olifants River Formation (see below).

Isolated cobble manuports and ESA/Acheulian handaxes and cleavers are found within the formation at Namakwa Sands (pers. obs.). Middle Stone Age (MSA) artefacts are also reported, but these occur on the eroded surfaces and slopes of the formation. The ESA artefacts indicate an age range from ~1 Ma to ~350 ka (Figure 5-10). Fossils recently discovered in this formation in the study area indicate an older age range extending from the early Quaternary (see below).

5.4.1.4 The "Dorbank" Formation

There are unnamed units that post-date the capping pedocrete of the Olifantsrivier Fm. and precede the uppermost, unconsolidated formations described below. For example, thick "dorbank" comprised of several metres of reddened and semi-lithified, medium and coarse sands are typically exposed in excavations somewhat inland of the coast, overlying the eroded surfaces on Miocene and Pliocene marine deposits or older pedocreted aeolianites. This "dorbank" formation is a stack of successive sand sheets and dune bases forming beds, 0.5 to ~1 m thick, with slightly differing hues and densities of the neoformed pedogenic clays. The "dorbank" is quite hard and incipiently to variously cemented, but notably, this formation lacks the development of distinct, laterally continuous, pale pedocrete/calcrete horizons, other marked, post-depositional features and also lacks an upper, laterally-extensive calcrete capping. Evidently the palaeoclimatic and depositional conditions were not conducive to the formation of distinct, evolved pedocretes. Interestingly, in the Graauw Duinen area the top of the "Dorbank" Formation includes discrete thin lenses of calcrete that are part of fossil heuweltjiesveld-type termitaria *cf*. the pre-LIG Q2 surface of the southwestern Cape. The "Dorbank" Formation is widespread along the Namaqualand coast where it occupies a spatio-temporal context as the youngest consolidated aeolianite beneath weakly-compacted to loose surface sands. Notably, MSA artefacts occur within its upper portion and on its top surface, these suggesting that the age is in the later part of the middle Quaternary, younger than about 400 ka (Figure 5-10).

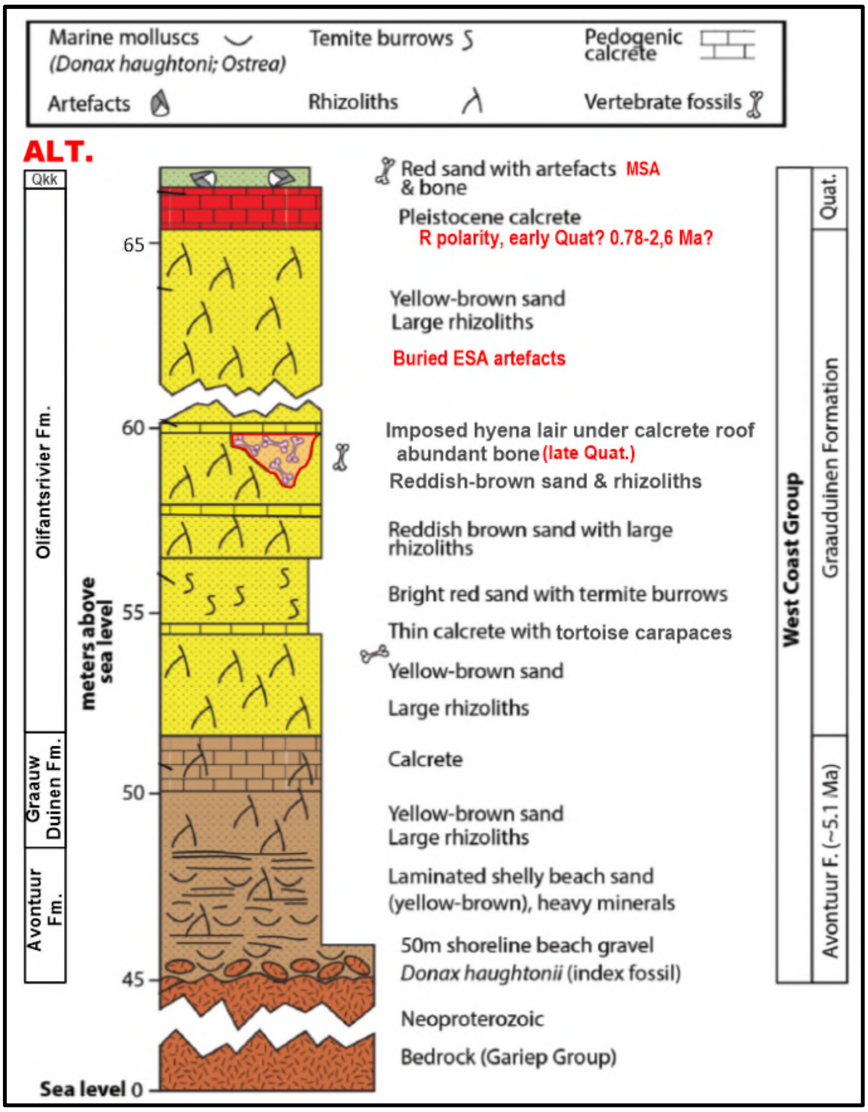


Figure 5-11: The proposed Graauw Duinen Formation stratotype. Modified from Roberts & Mthembi (2015). Alternative interpretation on LHS.

5.4.1.5 The "Panvlei Formation" Surfaces

On the geological maps are areas depicted as "calcareous soils", annotated on Figures 5-2 – 5-4 as Qpa, the proposed "Panvlei Formation" (De Beer, 2010). The Panvlei Fm. includes "sands, fluvial deposits and soils derived from bedrock erosion and reworking of Cenozoic sediments of all ages". Semi-silicified "dorbank" and calcretized and pedocreted deposits are included. The formation is overlain by "unconsolidated sands of Pleistocene to Holocene age". Its purpose is to categorize surface areas that are comprised of pedocretes and where vertical exposure is lacking. Clearly such a broad definition, based on surface outcrop, is a mapping practicality and the underlying deposits could be of differing ages. The Panvlei Fm. areas are consequently areas closely underlain by older aeolianite units, such as the pedocreted or semi-lithified tops of the preceding formations – which could be referred to instead as "Panvlei-type Surfaces".

The Panvlei Formation is depicted in areas where the overlying red sands of the Koekenaap Formation are thin and these areas encompass the eroding aeolianite hills north of Cliff Point on Geelwal Karoo 262, the slopes west of Skaapvlei homestead and on the southern part of Graauw Duinen. These areas are mostly underlain by pedocreted aeolianites of the Olifantsrivier Formation.

5.4.2 THE OLDER AEOLIANITE FORMATIONS IN THE STUDY AREA

While the aeolianite formations of the study area remain insufficiently studied only general observations can be made.

5.4.2.1 Later Miocene Aeolianites

In the study area the oldest probable aeolianite, a unit of brown and yellow sand, overlies the Koingnaas Fm. and locally underlies the Avontuur Fm. at **JPE034** (Map C7). It is thus considered to be of later Miocene age (Figures 5-5, 5-7) and not within the ambit of the post-Avontuur Fm. aeolianites of Pliocene age assigned to the Graauw Duinen Fm.

5.4.2.2 The Graauw Duinen Formation

Aeolianites of Member 1 of the Graauw Duinen Fm. occur in the area of the thick aeolianite accumulation in the south of Geelwal Karoo 262 and farther south of Cliff Point, where they overlie the Avontuur Fm. Fossil eggshells of the extinct Pliocene giant ostrich *Struthio daberasensis* are reported from aeolianites south of the study area in the vicinity of Bakoond (Roberts, in Roberts *et al*., 2006). The age range of this oospecies is 5 – 2 Ma (Pickford & Senut, 2000), confirming the presence of Pliocene – earliest Quaternary, Graauw Duinen Formation aeolianites there.

North of Cliff Point the stratotype section of the Graauw Duinen Fm. was proposed at the CP1 location (Figure 5-11, Map C7) (Roberts & Mthembi, 2015). A series of samples were taken for palaeomagnetic polarities (and pedocrete/calcrete samples for U-series dating?). At this time the only available result is that the uppermost calcrete has reversed polarity, suggesting that the calcrete and underlying sequence is in the Matuyama Chron and older than 0.78 Ma (Reed, 2012). In the meantime, until additional age constraints are available, alternative formation assignments are feasible, as suggested on the LHS of the section in Figure 5-11 (in which case the choice of this section as the stratotype for the Graauw Duinen Formation may have been too hasty).

At **JPE009** (Map C1) is a large "borrow pit" area exposing the terrestrial sequence overlying the Hondeklipbaai Formation. The lower unit exposed is dark olive-green aeolian sand with fine, black heavy minerals and abundant lithified, white, amalgamated & clumped termite-burrow "trunks" which may correlate with the Graauw Duinen Formation Member 2 (post-30 m P). The overlying yellow-brown sands with a capping calcrete are assigned to the Olifantsrivier Formation.

5.4.2.3 The Olifantsrivier Formation

The aeolianites that are attributable to the Olifantsrivier Formation are also best exposed on the hillsides in the southern part of Geelwal Karoo 262. Most of the “Panvlei Surface” areas farther north (Figures 5-2, 5-3) are likely underlain by the Olifantsrivier Fm. At places close to the coast the preceding Graauw Duinen Fm. aeolianites are eroded away and the Olifantisrivier Fm. directly overlies the late Pliocene Hondeklipbaai Fm.

Site CP537 of Stynder & Reed (2015) is a site near the northern boundary of Geelwal Karoo 262 (Map C5) where fossil bones are eroding out of a channel fill within the aeolianite succession (Figure 5-12). The marine Hondeklipbaai Fm. is basal to the sequence at CP537 (JPE026) and thus the terrestrial sequence postdates the late Pliocene, ~3 Ma. The fossils include *Numidocapra crassicornis*, a bovid found only in North Africa and Ethiopia where the age range for this fossil species is 2.5-1.7 Ma. Also found were teeth of *Dinofelis barlowi*, an extinct sabre-toothed felid, indicating an age range of 2.5-1.9 Ma. These finds suggest that the lower part of the Olifantsrivier Formation is older than ~1.7 Ma and extends from the earliest Quaternary (Figure 5-7). However, a calcrete below the channel fill has normal polarity, possibly in the Olduvai Subchron (1.95 – 1.78 Ma). This would suggest that the age of the overlying channel fill is later on in the early Quaternary and the preliminary suggested age estimate is 1.9-1.7 Ma (Stynder & Reed, 2015).

Figure 5-12: The site CP537 exposure. Courtesy Prof. K. Reed.

A notable feature of the Olifantsrivier Fm. aeolianites is the occurrence of the spherical, crudely-laminated termitaria (fungal gardens?) which seem to be a feature of the upper part of the formation.

In summary, the latest fossil finds from the area indicate that post-~3 Ma terrestrial deposits attributable to the Olifantsrivier Fm. range from the early Quaternary (<2.5 Ma), while its upper part includes ESA material of latest early Quaternary/earliest middle Quaternary age, but mainly pre-dates the appearance of MSA tools (Figures 5-7, 5-10). This broad age range constraint is reflected by the several included member units separated by pedocretes.

5.4.2.4 The "Dorbank" Formation

North of the eroded hills of thicker, old aeolianite accumulations in the south of Geelwal Karoo 262 the "Dorbank" Formation mantles the landscape, with varying thicknesses. It is exposed in prospecting trenches intersecting the rising coastal slope, typically as a massive, compact, red-brown unit, with subtle palaeosurface horizons (Figure 5-13). At places it may directly overlie the eroded Hondeklipbaai Fm. close to the coast (*e.g.* **JPE002**, **JPE004**, Map C1), or may overlie the much younger 8-12 m (MIS 11) raised beach of the Curlew Strand Fm. (Figure 5-10). It is quite likely that this "Dorbank: Formation will be encountered in the upper part of the inland "strandline" mining pits.

Figure 5-13: Typical exposure of the compact "Dorbank" Formation beneath loose sands of the Koekenaap Formation in a prospecting trench on Graauw Duinen 152.

5.4.3 THE YOUNGER AEOLIANITE FORMATIONS

Included in this category are unnamed, pale-hued, relatively-soft aeolianite units that are locally exposed along the coast and which postdate the red-brown "Dorbank Fm. and underlie the loose, surficial sands. The subsequent surficial aeolianites have a distinguishable appearances in aerial imagery, are present over wide areas and have been given formation names (Koekenaap Fm. etc.). Nevertheless, their boundaries and extents are often indistinct and their depiction on geological maps a matter of individual interpretation.

5.4.3.1 The Local Coastal Aeolianite Formations

At the coast the aeolianites overlying the Quaternary raised beaches include smaller units that reflect local permutations of aeolian deposition during the highstands of MISs 11 and 5e and at other times when sea levels were close to, but did not exceed, the present level *viz*. MISs 9, 7, 5c and 5a (Figure 5-10). Conceivably, at such times local shoreline aeolianite units were deposited at places along the coast. For example, the LIG raised beach is overlain by compact aeolian deposits, beneath the surficial, loose sands, that differ from place to place, *i.e.* rubified pink sands, or yellow sands, or grey sands, and that are apparently more locally confined to the coast and probably of different ages. These coastal units of later mid-Quaternary to earlier late-Quaternary age (Figure 5-10) exhibit variations of pale hues due to varying pedogenesis, but lack marked pedocrete horizons.

These local aeolianites are exposed in the road cuttings and prospecting excavations along the lower-lying coast north of Geelwal karoo 262. At locations where the LIG beach has been preserved (Gert du Toit se Baai/**JPE011/C1** and Skulpbaai/JPE020/C4), a very thin calcrete caps the LIG beach deposit, but the overlying yellow-brown aeolianite lacks a pedocrete. Northwards from Beach 4 the post LIG aeolianite is a different, distinct upper yellow sand unit also lacking pedocrete (**JPE012**/C2). At **JPE016**/C3 is an exposure of older, pale-grey aeolianite (early post LIG?) that underlies the yellow-brown, illustrating the complexity in the later Quaternary aeolian record close to the coast.

5.4.3.2 The Koekenaap Formation

Overlying the hard surface of the dorbank or older pedocretes are compact, but unconsolidated red sands, the "Red Aeolian Sand" or RAS that is exploited at Namakwa Sands mine, now proposed as the Koekenaap Formation (Roberts *et al*., 2006; De Beer, 2010). The red sands of the Koekenaap Formation occupy large areas of the Namaqualand coastal plain (Figures 5-2 – 5-4, Qkk) and underlie the following formations described below. These younger formations obscure surface features of the red sands over large areas, but it seems reasonable to assume that the red sands accumulated in similar modes. Where thicker, subunits can be distinguished by subtle variations in hue and grain adhesion.

The red sands are underlain by scatters of MSA material. Preliminary results of Optically-Stimulated-Luminescence (OSL) dating of reddened coversands (Chase, 2006; Chase & Thomas, 2006, 2007) indicate late Quaternary ages between ~80 ka and ~30 ka and are presumed to reflect depositional ages of the red aeolian sands (Figure 5-10).

5.4.3.3 The Hardevlei Formation

This formation is not depicted on the geological maps within the area of interest. It encompasses fields of low, relict, pale yellow dunes of complex, reticulate morphology which mainly occur inland. Dating by OSL indicates ages generally less than ~20 ka (Chase & Thomas, 2006, 2007) (Figure 5-10). Although not mapped as such, the field of complex degraded dunes called Kolduin, (between Beaches 3 and 4, Map C2) is likely a near-coastal correlate of this formation.

5.4.3.4 The Swartlintjies and Swartduine Formations

The Swartlintjies Formation is proposed for the large, pale plumes of semi-stabilized, parabolic dune ridges that extend from the beaches north of the main rivers (Roberts *et al*., 2006; De Beer, 2010). The Swartduine Formation refers to more diffuse, grey sandsheets and small dunes with a smooth vegetation texture, and to interdune areas between Swartlintjies Fm. dune ridges. Neither of these formations, of Holocene age (Figure 5-10), are mapped in the area of interest.

5.4.3.5 The Witzand Formation

This formation is extrapolated northward from the Sandveld Group of the southwestern Cape, where it accommodates sand and shell fragments blown from sandy beaches during the Holocene (Figure 5-10), in the form of partly-vegetated dune cordons backing the beach and the dune plumes transgressing inland. Along the Namaqualand coast the major dune plumes are separated as the Swartlintjies Formation and thus the Witzand Formation entails only the smaller dune plumes and cordons adjacent to the coast. In the study area the larger, modern dune accumulations along Beach 7 and Beach 10 are mapped as this formation (Figure 5-2, Qwi). Other, smaller occurrences of modern coastal foredunes are associated with headlands (Beaches 4, 5, 9).

5.4.4 Palaeontological Sensitivity of the Aeolian Formations

The fossil bones that have been found hitherto in the area attest to the fossil potential that will be delivered by the continuation of systematic searches for these sparse remains. Fossil material most commonly seen is the ambient fossil content of dune sands: land snails, tortoise shells and mole bones. Other small bones occur very sparsely such as bird and small mammal bones. The fossil content is more abundant in association with palaeosurfaces and their soils (palaeosols), formed during periods of dune stabilization and which define aeolian packages and larger formations. Importantly, the bones of larger animals (*e.g.* antelopes) are more persistently present along palaeosurfaces formed on top of marine deposits and the palaeosurfaces which separate the major aeolianite units.

The deposits on slopes adjacent to the coast have a higher content of fossil bones due to the attraction of the shoreline for foraging and scavenging. For example, jackals and hyaenas scavenge seabird, seal and other carcasses, carrying remains onto the sand slopes. The most spectacular bone concentrations found in aeolianites are due to the bone-collecting behaviour of hyaenas which store bones in and around their lairs. Hyaena bone collections are often found on the sea-facing slopes of aeolianites, noticed when some bones have been eroded out and are spilling downslope.

The fossil bone finds from aeolianites in the southwestern Cape demonstrate that this sparse material, of both small (rodents, birds) and larger animals (antelopes, carnivores), is important to on-going palaeoclimatic, palaeobiological and biostratigraphic studies. The surveys of the area indicate considerable potential for further significant fossil finds to add to the poorly-known Pliocene and early Quaternary terrestrial fossil faunas of Namaqualand. Consequently, the palaeontological sensitivity of the Graauw Duinen and Olifantsrivier formations is HIGH with respect to fossil bones.

The palaeontological sensitivity of the younger aeolian formations (Figure 5-10) is likewise HIGH with respect to fossil bones. The fossil bone potential and contexts are the same as for the older aeolianites. However, it is more likely that fossil bones occur in an archaeological context, with artefacts and shell. The fossil material in these deposits is a sample of the middle and late Quaternary fauna of the Namaqualand coast. For example, fossil bones in aeolianite near the Swartlintjiesrivier were associated with ESA artefacts and include large species (elephant, sivathere, zebra). Sivatherium maurusium was a large, heavily-built short-necked giraffid common in Africa between ~5.0 to ~0.4 Ma. In addition small species were collected (hare, squirrel, moles, snakes).

The estimated age is mid-Quaternary and the large mammals indicate that the coast was better watered than the present-day (Pickford & Senut, 1997).

A late Quaternary fauna was obtained from calcareous interdune deposits exposed between the dunes of the Swartlintjies Formation. The presence of frogs indicates a damp environment. Larger species include ostrich, zebra and steenbok and oddly, giraffe, a browser. A variety of small rodent taxa occurred. Other than the giraffe the fauna is essentially modern. The giraffe suggests that woodland still occurred in Namaqualand as recently as the late Quaternary, probably related to riverine settings and wetter conditions associated with ice age climate (Pickford & Senut, 1997).

6 IMPACT ASSESSMENT

6.1 NATURE OF THE IMPACT

In general, excavation activities result in a negative direct impact on the probable fossil content of the affected subsurface. Fossils and significant geological observations will be lost in the absence of management actions to mitigate such loss. This loss of the opportunity to recover them and their contexts when exposed at a particular site is irreversible. In the present context this applies particularly to fossil bones.

Conversely, excavations furnish the "windows" into the coastal plain depository that would not otherwise exist and thereby provide access to the hidden fossils. The impact is positive for palaeontology, provided that efforts are made to monitor for and rescue the fossils.

Table 6-1: Formation Sensitivities in the Study Area

Formation	Age	Deposit type	Sensitivity	
H-Hi, M-Med, L-Low (arch. = archaeological context)			Bones	Seashells
Witzand	Holocene	pale dunes & sandsheets	H rare, arch	H arch.
Younger coastal aeolianites	Mid-late Quat.	Dorbanks, red and yellow aeolian sands (Koekenaap Fm. etc.)	H rare, arch	H arch.
Curlew Strand	mid-late Quat.	shelly marine MIS 11, LIG, Holocene Hi	H v. rare	L
Olifantsrivier	early-mid Quat.	aeolianite & pedocretes	H mod common.	H arch.
Graauw Duinen Member 2	latest Plio-early Quat.	Aeolianite, colluvia, pedocrete	H mod common	
Hondeklipbaai	late Pliocene	shelly marine	H v. rare	M
Graauw Duinen Member 1	mid Pliocene	Aeolianite, colluvia, pedocrete	H mod common	
Avontuur	early Pliocene	Shelly marine	H v. rare	M
Unnamed	late Miocene?	aeolianite	H	
Koingnaas	Oligocene-early Miocene	Kaolinitic sands & gravels. Possible fossil wood	NA	NA

6.2 EXTENT

The physical extent of impacts on potential palaeontological resources relates directly to the extent of subsurface disturbance, *i.e.* LOCAL. However, unlike an impact that has a defined spatial extent (*e.g.* loss of a portion of a habitat), the consequences of an important fossil find are of international scientific significance. For the purposes of this report it is assumed that the vertebrate fossils (bones) that may be destroyed/lost (or found) are additions to the Pliocene and Quaternary faunas of the region, *i.e.* a REGIONAL extent. In comparison with the large vertebrate assemblages from a number of fossil sites in aeolian settings in the southwestern Cape, the Pliocene and Quaternary faunas of Namaqualand are poorly known from a few fossil bone finds only.

6.3 INTENSITY

The intensity of impact relates to the palaeontological sensitivity ratings (Appendix E) of the various formations in the study area (Table 6-1.). Due to high scientific value the occurrence of fossil bones in both the marine and terrestrial formations is of HIGH sensitivity.

6.4 DURATION

The impacts occur during mine infrastructure construction and the operational phase of mining. The impact of both the finding or the loss of fossils is permanent. The found fossils must be preserved "for posterity"; the lost, overlooked or destroyed fossils are lost to posterity. The duration of impact is thus LONG TERM.

6.5 IMPACT RATINGS

6.5.1 BEACHES 1 - 10

These beaches have existing roads and disturbed areas from the mining and prospecting activities of diamond companies since the 1960's. The upgrading of the existing ramps to the beaches is not expected to greatly exacerbate the impact on fossil resources that has already taken place. Fossil shell beds are usually at depth and should not be routinely intersected in the roads. Furthermore, the Hondeklipbaai Fm. in the area is often decalcified, with limited fossil shell content. The predominantly extant shell content of the LIG and Holocene raised beaches is of low palaeontological sensitivity.

Valuable fossil bones in both archaeological and non-archaeological contexts may be uncovered in the shallow gradings of widening the roads, but these should hopefully be spotted in the course of the archaeological mitigation.

The beach mining may encounter older deposits beneath the modern beach sands and basal gravel. Such older deposits may be preserved in larger coastal compartments where the bedrock is well below sea level (exhumed palaeochannels) and which manifest as the longer sandy beaches (*e.g.* beaches 7, 10). Examples include prograded LIG shoreface deposits, aeolianite and pedocrete attributable to MIS 7 (Figure 5-9), or yet older Quaternary marine and terrestrial deposits. Such occurrences are likely to be compacted and variously cemented and would probably be considered footwall for the beach mining.

The beach mining operation is not favourable for the spotting of fossil bones or unusual shells, but such material may appear on the screens during pre-screening of the sand.

For fossil shells the significance rating of the impact of beach mining is "very low", both without and with mitigation. Although improbable, unusual "subfossil" shells have been found before during beach mining, in which case the significance of the impact becomes High-positive.

For fossil bones the significance rating of the impact of beach mining is “high”. The possible destruction of fossil bones is a high-negative impact. With mitigation the alert for and discovery of fossil bones may produce a significant, High-positive result.

<table>
<tr><th colspan="9">Loss of fossil shells from Haul Road Upgrading and Beach Mining</th></tr>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Low
1</td><td>Long
3</td><td>Low
5</td><td>Possible</td><td>Very low</td><td>-ve</td><td>Medium</td></tr>
<tr><td colspan="9">Essential mitigation measures
• Identify and appoint stand-by palaeontologist should paleontological finds be uncovered by earthworks.
• Construction personnel and ECO to be aware that a substantial temporary exposure of marine shelly beds may require sampling and recording.
• In the event of a large exposure of shell beds, the appointed palaeontologist must be notified and provided with information and images. Palaeontologist will assess information and establish suitable response, such as the importance of the find and recommendations for sample collection and record keeping.
• Selected exposed fossiliferous sections in earthworks recorded and sampled by appointed palaeontologist.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Long
3</td><td>Low
5</td><td>Possible</td><td>Very low</td><td>+ve</td><td>Medium</td></tr>
</table>

<table>
<tr><th colspan="9">Loss of fossil bones from Haul Road Upgrading and Beach Mining</th></tr>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Regional
2</td><td>High
3</td><td>Long
3</td><td>V High
8</td><td>Possible</td><td>High</td><td>-ve</td><td>Medium</td></tr>
<tr><td colspan="9">Essential mitigation measures
• Identify and appoint stand-by palaeontologist should paleontological finds be uncovered by earthworks.
• Construction personnel to be alert for rare fossil bones and follow “Fossil Finds Procedure” (Appendix F).
• Cease construction on (chance) discovery of fossil bones and protect fossils from further damage.
• Contact appointed palaeontologist providing information and images.
• Palaeontologist will assess information and establish suitable response, such as the importance of the find and recommendations for preservation, collection and record keeping.
• Exposed fossiliferous sections in earthworks recorded and sampled by appointed palaeontologist.</td></tr>
<tr><td>With mitigation</td><td>Regional
2</td><td>High
3</td><td>Long
3</td><td>V High
8</td><td>Possible</td><td>High</td><td>+ve</td><td>Medium</td></tr>
</table>

6.5.2 Inland Strandline Mining

The mining will intersect surficial deposits of the Koekenaap Formation, the underlying palaeosurface which bears archaeological material, the “Dorbank” Formation, beneath of which are the pedocretes, aeolianite and colluvia of the Olifantsrivier Formation. At depth the Graauw Duinen Formation aeolianites will be intersected, below which are the marine Avontuur and Hondeklipbaai formations, which overlie the kaolinitic deposits of the fluvial Koingnaas Formation.

The prime concern is the fossil bones which occur in the terrestrial formations and very sparsely in the marine deposits. The mining will result in a negative impact. In the absence of effective mitigation, scientifically significant material will quite probably be destroyed. It is quite likely that scientifically valuable fossils will be lost in spite of mitigation. The negative impact is rated High.

With successful mitigation the impact should be positive. However, mitigation can only strive to obtain a sample or portion of the potential fossil content of the disturbed subsurface. This positive impact is also rated as High. If a significant find of fossils is made, such as a large assemblage of bones or ancestral human remains, the impact may translate to Very High–positive.

It is quite probable that fossil Pliocene shells will be exposed in the mine excavations. The Avontuur and Hondeklipbaai formations are of Moderate sensitivity with respect to shell fossils and hence the significance rating is Medium without and with mitigation. The unexpected occurrence of well-preserved shell beds with a diverse assemblage of species will constitute a High-positive impact.

The Koingnaas Fm. underlies Geelwal Karoo 262 beneath the marine and aeolian deposits (Figure 5-6) and may be exposed in the bottom of the Strandline mining pits. Fresh exposures in the mine pits must be inspected for fossil plant material.

Loss of fossil bones from Strandline Mining and infrastructure								
	Extent	**Intensity**	**Duration**	**Consequence**	**Probability**	**Significance**	**Status**	**Confidence**
Without mitigation	Regional 2	High 3	Long 3	V High 8	Possible	High	-ve	Medium
Essential mitigation measures • Identify and appoint stand-by palaeontologist should paleontological finds be uncovered by earthworks. • Construction personnel to be alert for rare fossil bones and follow "Fossil Finds Procedure" (Appendix F). • Cease construction on (chance) discovery of fossil bones and protect fossils from further damage. • Contact appointed palaeontologist providing information and images. • Palaeontologist will assess information and establish suitable response, such as the importance of the find and recommendations for preservation, collection and record keeping. • Exposed fossiliferous sections in earthworks recorded and sampled by appointed palaeontologist.								
With mitigation	Regional 2	High 3	Long 3	V High 8	Possible	High	+ve	Medium

Loss of fossil shells from Strandline Mining								
	Extent	**Intensity**	**Duration**	**Consequence**	**Probability**	**Significance**	**Status**	**Confidence**
Without mitigation	Local 1	Medium 2	Long 3	Medium 6	Probable	Medium	-ve	Medium
Essential mitigation measures • Identify and appoint stand-by palaeontologist should paleontological finds be uncovered by earthworks. • Construction personnel and ECO to be aware that a substantial temporary exposure of marine shelly beds may require sampling and recording. • In the event of a large exposure of shell beds, the appointed palaeontologist must be notified and provided with information and images. Palaeontologist will assess information and establish suitable response, such as the importance of the find and recommendations for sample collection and record keeping. • Selected exposed fossiliferous sections in earthworks recorded and sampled by appointed palaeontologist.								
With mitigation	Local 1	Medium 2	Long 3	Medium 6	Probable	Medium	+ve	Medium

6.5.3 Infrastructure Expansion

Excavations for the dam, foundations, pipes and cables, and haul road construction, will primarily affect the Koekenaap Formation, the underlying palaeosurface which bears archaeological material, and the pedocretes, aeolianite and colluvia of the Olifantsrivier Formation. The prime concern is the fossil bones in the terrestrial formations and the relevant rating above for Strandline Mining also applies.

6.5.4 Cumulative Impact

As mentioned, the impact of both the finding or the loss of fossils is permanent. Diligent and successful mitigation contributes to a positive cumulative impact as the rescued fossils are preserved and accumulated for scientific study. Even though just a very minor portion of the bone fossils exposed in coastal excavations has been seen and saved, the rescued fossils proved to be of fundamental scientific value.

7 FINDINGS AND RECOMMENDATIONS

No palaeontological NO-GO areas have been identified within the confines of the affected Beach Mining, haul roads and Strandline Mining and infrastructure areas.

7.1 BEACHES 1 – 10

The mining of loose beach sands is not anticipated to have significant palaeontological impact. Notwithstanding, screened-off material may include reworked fossils and possibly other materials of archaeological interest (*e.g.* evidence of shipwrecks).

Valuable fossil bones in both archaeological and non-archaeological contexts may be uncovered in the shallow gradings of widening the access roads.

The recommended archaeological mitigation measures for the pre-construction and construction phases of the haul and access roads must be performed in order to rescue archaeological and possible fossil material.

7.2 INLAND STRANDLINE MINING

Open-pit mine excavations are a scientific and fossil resource and have been the major contributor to the understanding of the deposits and palaeontology of the Namaqualand coastal plain. Notably, the proposed Inland Strandline mining area is just inland of the portion of the coast where exposures are poor. The proposed mining should have a positive impact with respect to understanding the stratigraphy and to palaeontological heritage, providing that adequate mitigation measures are in place and duly performed over the duration of the mining.

It is impossible for a specialist to routinely monitor the mine pit and mined material. Routine monitoring can only be achieved by the co-operation of the people on the ground. By these are meant personnel in supervisory/inspection roles, such as the geologist, surveyor, pit foremen, etc., who are willing and interested to look out for occurrences of fossils. A monitoring presence is critical for spotting a major “strike” of fossils and stopping further damaging excavation. Very importantly, mine staff must be empowered to rescue the fossil material that appears sporadically, but quite routinely in the aeolianites during excavation and must be promptly rescued from loss.

There must be guidelines to be followed for finds and a reporting/action protocol in place when finds are uncovered during monitoring. A “Fossil Finds Procedure” is provided in Appendix F. This could be adapted and made more specific to the geological/fossil contexts expected. For instance, as fossil tortoises are quite common, they should be in the category of “allowed” rescue by mine staff *cf.* isolated bone finds.

Additionally, it is recommended that the contracted palaeontologist carry out field inspections at appropriate stages during mining of the inland Strandline deposits. The aim of field inspection is to examine a representative sample of the various deposits exposed in the excavations, recording context, fossil content and to take samples. Involving a few days of fieldwork, this will probably take place in the event of fossil exposures.

7.3 REGIONAL HERITAGE SENSITIVITY

It is abundantly evident from the archaeological and fossil sites already discovered that the study area is of considerable geological and palaeontological heritage importance. The main attributes are the natural exposures of coastal-plain formations of Namaqualand along the cliffs. The cliff exposures are of historical geology/palaeontology significance, being examined by geologists/palaeontologists in the early part of the 20th century, with the first fossils collected and described from West Coast coastal-plain deposits. These formations are rarely exposed elsewhere along the Namaqualand coast, where they are beneath younger aeolian coversands and are only temporarily exposed in mining pits. In addition to the natural exposures in the cliffs there are numerous artificial exposures due to previous diamond prospecting and mining.

The formations present in the area and their definitions are still mostly informal in that official names and type sections/areas are still to be designated in official South African Committee for Stratigraphy (SACS) publications. Due to the temporary nature of the mine pits, from which the formations are best known, type sections cannot be designated in them. Instead, they will have to be designated among the exposures along the stretch of coast within the study area. These type localities have the status of geoheritage sites. Similarly, the existing fossil sites, and later discoveries, must be assessed and receive appropriate protection. However, as can be inferred from discussions above, there is a lot more fieldwork required.

A recommendation in the Heritage Impact Assessment Report is that the subject of grading the sites and area be addressed in terms of the latest criteria issued by Heritage Western Cape.

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APPENDICES

APPENDIX A: SPECIALIST CV

Mr John Pether, M.Sc., Pr. Sci. Nat. (Earth Science)

Geological and Palaeontological Consultant

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ID NO. 560619 5100 085. SACNASP Earth Science. Reg. No. 400094/95.

Independent Consultant/Researcher recognized as an authority with 35 years' experience in the field of coastal-plain and continental-shelf palaeoenvironments, fossils and stratigraphy, mainly involving the West Coast/Shelf of southern Africa. Has been previously employed in academia (South African Museum) and industry (Trans Hex, De Beers Marine). At present an important involvement is in Palaeontological Impact Assessments (PIAs) and mitigation projects in terms of the National Heritage Resources Act 25 (1999) (~240 PIA reports to date) and is an accredited member of the Association of Professional Heritage Practitioners (APHP). Continues to be involved as consultant to offshore and onshore marine diamond exploration ventures. Expertise includes:

- Coastal plain and shelf stratigraphy (interpretation of open-pit exposures, on/offshore cores and exploration drilling).
- Sedimentology and palaeoenvironmental interpretation of shallow marine, aeolian and other terrestrial surficial deposits.
- Marine macrofossil taxonomy (molluscs, barnacles, brachiopods) and biostratigraphy.
- Marine macrofossil taphonomy.
- Sedimentological and palaeontological field techniques in open-cast mines (including finding and excavation of vertebrate fossils (bones).

Recent Palaeontological Assessments

CLIENT	YEAR	DESCRIPTION
ACRM	2016	Palaeontological Assessment. Proposed Development Of A Sports Field Complex On Portion 12 Of The Farm Olifants Kop No. 191, Saldanha Bay Municipality, Western Cape.
ACRM	2016	Palaeontological Assessment. Proposed Low Density Self-Sustainable Residential Development on Farm 948, Paternoster, Saldanha Municipality, Vredenburg District, Western Cape.
PHS Consulting	2016	Palaeontological Assessment. Proposed Expansion Of Existing Abalone Farm 18/108, Jacobsbaai, Saldanha Bay Municipality, Western Cape.
ACO Associates cc	2016	Palaeontological Impact Assessment. Proposed Housing Development On Erf 460, St. Helena Bay, Saldanha Bay Municipality, Western Cape.
PHS Consulting	2016	Palaeontological Impact Assessment. Proposed Gouritz Abalone Farm, Farm 6 of 453, Riversdale, Hessequa Municipality, Western Cape.
SRK Consulting	2015	Palaeontological Impact Assessment. Proposed Doringbaai Aquaculture Farms, Namaqualand West Coast, Matzikama Municipality, Northern Cape Province.
SRK Consulting	2015	Palaeontological Baseline Study. Proposed Brand se Baai Abalone Farm Namaqualand, Northern Cape Province.
Abengoa Solar Power South Africa (Pty) Ltd	2015	Palaeontological Assessment Status. Proposed Construction of Paulputs 200mw Concentrated Solar Power Tower Facility, Northern Cape Province. Portion 4 of Scuit-Klip 92, Khai-Ma Municipality, Kenhardt District.
ERM SA	2015	Scoping Palaeontological Assessment (Desktop Study). Proposed Globeleq Gas-Fired Power Station, Saldanha Municipality, Vredenburg District, Western Cape. Portions of parent farms Langeberg 197 and Uyekraal 189.
ARCON Specialist Architectural and Spatial Heritage Consultants	2015	Palaeontological Assessment. Desktop Study. Proposed Development of the Paternoster Central Business Area. Saldanha Municipality, Vredenburg District, Western Cape. Farm Paternoster A No. 34 & Ptn 2 of Farm Paternoster A No. 34.

CLIENT	YEAR	DESCRIPTION
PHS Consulting	2015	Addendum Concerning Development Alternative Four. To the Palaeontological Impact Assessment (Desktop Study). Proposed Eco-Estate Development on Hoek van de Berg 572, Overstrand Municipality, Caledon District, Western Cape.
CCA Environmental	2014	Palaeontological Impact Assessment (Desktop Study). Proposed Oil and Gas Offshore Service Complex at the Saldanha Bay Industrial Development Zone, Vredenburg District, Saldanha Bay Municipality, Western Cape.
CSIR	2014	Palaeontological Impact Assessment (Desktop Study). Proposed construction of a marine outfall pipeline and associated infrastructure in Danger Bay in the Saldanha Bay region, Western Cape, South Africa. The Saldanha Regional Marine Outfall Project
PHS Consulting	2014	Brief Palaeontological Assessment (Desktop Study). Extension of Quarrying on Portion 12 of Farm Hartenbosch 217 (Maandagskop Crusher), Mossel Bay, Western Cape.
Cindy Postlethwayt - Heritage Consultant	2014	Palaeontological Impact Assessment. Proposed Sand Mining and Oakland City Urban Development, Schaap Kraal, Philippi Area, Erven 579, 580, 581, 582, 587, 588, 589, 590, 591, 637, 638, 639, 640, 641, Rem 648, Rem 650, Rem 651, 652, 653, 654, 657 & 658. City of Cape Town Metropolitan Municipality, Wynberg Magisterial District, Western Cape Province. For Cindy Postlethwayt - Heritage Consultant. For Urban Dynamics Western Cape.
SRK Consulting	2014	Palaeontological Impact Assessment (Desktop Study). Proposed Volwaterbaai Desalination Plant and Associated Infrastructure, For Zandkopsdrift Mine, Namaqualand, Northern Cape Province.

Past Clients Palaeontological Assessments

Agency for Cultural Resource Management (ACRM).	Klomp Group.
AMATHEMBA Environmental.	Megan Anderson, Landscape Architect.
Anél Blignaut Environmental Consultants.	Ninham Shand (Pty) Ltd.
Arcus Gibb (Pty) Ltd.	PD Naidoo & Associates (Pty) Ltd.
Aurecon SA (Pty) Ltd.	Perception Environmental Planning.
BKS (Pty) Ltd. Engineering and Management.	PHS Consulting.
Bridgette O'Donoghue Heritage Consultant.	Resource Management Services.
Cape Archaeology, Dr Mary Patrick.	Robin Ellis, Heritage Impact Assessor.
Cape EAPrac (Cape Environmental Assessment Practitioners).	Savannah Environmental (Pty) Ltd.
CCA Environmental (Pty) Ltd.	Sharples Environmental Services cc
Centre for Heritage & Archaeological Resource Management (CHARM).	Site Plan Consulting (Pty) Ltd.
Chand Environmental Consultants.	Strategic Environmental Focus (Pty) Ltd.
CK Rumboll & Partners.	UCT Archaeology Contracts Office (ACO).
CNdV Africa	UCT Environmental Evaluation Unit
CSIR - Environmental Management Services.	Urban Dynamics.
Digby Wells & Associates (Pty) Ltd.	Van Zyl Environmental Consultants
Enviro Logic	Western Cape Environmental Consultants (Pty) Ltd, t/a ENVIRO DINAMIK.
Environmental Resources Management SA (ERM).	Wethu Investment Group Ltd.
Greenmined Environmental	Withers Environmental Consultants.
Guillaume Nel Environmental Management Consultants.	

Stratigraphic consulting including palaeontology

Afri-Can Marine Minerals Corp	Council for Geoscience
De Beers Marine (SA) Pty Ltd.	De Beers Namaqualand Mines.
Geological Survey Namibia	IZIKO South African Museum.
Namakwa Sands (Pty) Ltd	NAMDEB

APPENDIX B: FIELD OBSERVATIONS

Table 1: Pether Observations

X	Y	Label	Date	Time	Site Name	Description	Image No.
18.01746	-31.47914	JPE1	2017-01-08	17:05	Beach 3	30mP in pit on low cliff - *Donax rogersi* frags amongst gravel. Possibly disturbed/covered during ramp construction - avoid if possible.	5444-5447
18.01823	-31.47979	JPE2	2017-01-09	10:23	Beach 2/3	Eroded 30mP in big gully in cliff. Gravel unit overlain by much younger sparsely shelly & pebbly colluvium & aeolianite. No Quat marine units.	5448-5453
18.02139	-31.48259	JPE3	2017-01-09	10:54	Beach 2	General view of slopes rotating S to N. Tailings cover S end of beach forming preferred site of ramp.	5454-5458
18.02172	-31.48242	JPE4	2017-01-09	11:05	Beach 2	Outcrop of lithified 30mP with eroded top with trace fossil *Circolites* (*Echinometra* pits) - *Ostrea* & *D. rogersi*. Boulder of older marine sst - 50mP-derived? Much bone exposed in immediate vicinity, evidently in disturbed aeolian cover (hyaena lair?). No bones seen on eroding slopes of aeolianite away from site. No Quat beach visible, but top of 30mP was submerged (*Circolites* on eroded sandstone top).	5459-5466
18.03259	-31.49249	JPE5	2017-01-09	11:56	Beach 1	30mP on cliff above track exposed in scraped area (for "porrel"), with ongoing erosion.	5467-5469
18.03309	-31.49327	JPE6	2017-01-09	12:07	Beach 1	Slabs of lithified 30mP fallen from clifftop. Slope covered with colluvium with scatd shell incl. *D. rogersi*.	5470
18.03326	-31.49369	JPE7	2017-01-09	12:11	Beach 1	Slopes of coarse colluvium.	5471-5474
18.03352	-31.49429	JPE8	2017-01-09	12:18	Beach 1	Upper pedocrete in probable pre-LIG section. View N over disturbed area behind coppice dunes. Remake ramp between wpts 7 & 8.	5475-5476
18.03023	-31.4906	JPE9	2017-01-09	12:30	Beach 1 N	Large "borrow pit" area above N end of Beach 1 exposing terrestrial sequence. Lower unit exposed is dark olive-green aeolian sand with fine, black heavy minerals and abundant lithified, white, amalgamated & clumped termite-burrow "trunks". Correlates with Graauw Duinen Formation Member 2 (post-30mP)? Overlain by yell-brown sands of the Olifantsrivier Formation with subdividing palaeosurfaces, semi-spherical termitaria and capping pedocrete. Important stratigraphic exposure. Requires scrutiny for fossil bone material.	5477-5488
18.02383	-31.48539	JPE10	2017-01-09	12:51	Beach 1/2	Large pit area exposing Olifantsrivier Formation yell-brown aeolianite with semi-spherical termitaria. Images of the top of the sequence with variably-developed pedocrete. A large burrow-fill *cf.* aardvark (5495).	5489-5496
18.00816	-31.47054	JPE11	2017-01-09	13:20	Gert du Toit se Baai	Exposure of Quat LIG beach capped by a thin pedocrete and overlain by yell-brn aeolianite lacking pedocretes, but with subtle soil-horizons. Midden on top. Also Holocene High terrace.	5497-5503
17.99977	-31.45772	JPE12	2017-01-09	13:49	Beach 4	Central backbeach area considerably disturbed. Exposures of yell-brn aeolianite lacking major pedocretes - post-LIG? Use existing ramp (D015).	5504-5515
17.98253	-31.43685	JPE13	2017-01-09	14:13	Beach 5	As previous, low-gradient slope of yell-brn, post-LIG? aeolianite behind modern dunes. Much disturbance. Upgrade of existing ramps ok. Namakwa Diamond Company (NDC) plant site on N headland of Koubaai - use site as a staging/bypass area.	5516-5518
17.97572	-31.43017	JPE14	2017-01-09	14:41	Beach 6	N part of beach bordered by low, broken gneiss cliff. Rehab-ed mine pit just inland of Hanguier headland - 30mP. Paler yellow sands now drapes slope - evidently a younger post-LIG unit. Southern slopes disturbed. No obvious palaeo-sites. Remake existing ramps.	5519-5525
17.97182	-31.42545	JPE15	2017-01-09	15:04	Beach 7	View of aeolianite slope back of modern dunes, with local eroded areas. Rehab-ed NDC mine pit just to north of Wpt 15 - the Liebenberg Bay pit, which exposed lower shorefacies facies of 30mP. N end of beach behind modern dunes disturbed by mining, where LIG beach preserved. Aeolianite slope is post-LIG.	5526-5530
17.97253	-31.42649	JPE16	2017-01-09	15:23	Beach 7 S	Aeolian sequence exposed in disturbed area. Early? post-LIG compact grey sands with termite burrows overlain by yellow-brn sand lacking pedocrete, capped by loose grey modern sand.	5531-5534
17.95663	-31.41121	JPE17	2017-01-09	15:42	Beach 8	Low gradient post-LIG yellow sand aeolianite slope - quite disturbed - view rotating S-W-N.	5535-5539
17.95759	-31.41192	JPE18	2017-01-09	15:46	Beach 8	Post-LIG yellow aeolianite with buried soil/palaeosurface exposed in scraped-out area.	5540-5541
17.95783	-31.41077	JPE19	2017-01-09	15:53	Beach 8	Prospecting pit with 30mP material in spoil - *D. rogersi*. Only compact, bedded older aeolianite exposed - pedocrete just visible ~2.5 m depth.	5542-5546

X	Y	Label	Date	Time	Site Name	Description	Image No.
17.94668	-31.40016	JPE20	2017-01-09	16:14	Skulpbaai	Shelly LIG beach with thin pedocrete capping exposed in excavation, overlain by yell-brown aeolianite with 2 units, the uppermost with buried archaeological limpet scatter. Disturbed area to S with archaeological scatter. Holocene High deposits along beach. 30mP inland (L013).	5549-5552
17.93872	-31.38805	JPE21	2017-01-09	16:46	Beach 9	View rotating S-E-N. More extensive modern dune development backing beach, with pale sand lapping onto slope of yellow, post LIG aeolianite. Suspect underlying LIG and Holocene High beaches.	5553-5557
17.92849	-31.3742	JPE22	2017-01-09	16:58	Beach 10	Aka Langstrand. View rotating S-W-N. Modern dunes in front of slope of yellow, post-LIG aeolianite, with embayments made by mining. NDC mine pits in 30mP inland of N and S ends of Langstrand.	5558-5562
17.948853	-31.40517	JPE23	2017-01-09	16:03	Waterbakke	JA Wright monument - geologist who vanished here while examining gully development 1964. Waterbakke refers to the large potholes here, formed in the gneiss, which capture rainwater.	5547-5548
18.05162	-31.51575	JPE24	2017-01-10	10:00		Site of a Weskus Mynbou plant - very disturbed with heaps of oversize and tailings. Views rotating E-N-W-S, then S-W-N & video. Eroded slope areas of aeolianite potentially with bone fossils.	5563-5572; vid 5574-5575
18.05104	-31.51422	JPE25	2017-01-10	10:16		Exposure of fossiliferous 30mP beneath thick (~20 m) yellow aeolianite (Olifantsrivier Fm.), with eroding slopes with bone potential.	5576-5584; vid 5585
18.04819	-31.51283	JPE26	2017-01-10	10:24		Fossiliferous 30mP exposure overlain by yellow aeolianite (Olifantsrivier Fm.) with semi-spherical termitaria. With midden on top and bone fragments washed out.	5586-5592; vid 5593
18.04667	-31.50979	JPE27	2017-01-10	10:55		Gully eroded into yellow-brn aeolianite - well-developed pedocrete absent. However, major pedocrete on hilltop. Borehole profiles iin Visser & Schoch (1971) show this unit beneath a unit of compact brown aeolianite with upper thick pedocrete. Taken as Olifantsrivier Fm.	5594-5597; vid 5598
18.10733	-31.56936	JPE28	2017-01-10	12:03		Deflating spur of yellow aeolianite with abundant termite burrows. Prob formed when sea level lower. Abundant tortoise bones & other bone frags. Some indication of two formations of aeolianite present by a poorly exposed pedocrete separating them. Probable Graauw Duinen Fm below, with Olifantsrivier Fm (with spherical termitaria) the upper fm.	5599-5607
18.10669	-31.56887	JPE29	2017-01-10	12:13		Marine gravel outcrop, no fossil shell (decalc.) - correlated with 50mP. Follows through to Wpt 30, with exhumed silcrete slabs.	5608-5612
18.10693	-31.56969	JPE30	2017-01-10	12:24		Cliffed fluvial Koingnaas Formation with silcrete capping.	5613-5617
18.11349	-31.57619	JPE31	2017-01-10	13:17		Views of surrounding slopes of aeolianite formations and pedocretes.	5618-5630
18.11119	-31.575	JPE32	2017-01-10	13:52		Cliffed fluvial Koingnaas Formation with silcrete capping, overlain by fossiliferous 50mP with *D. haughton*i, overlain by ~40 m of aeolianite fms.	5631-5635
18.11195	-31.57529	JPE33	2017-01-10	14:06		Exposed in road cutting - active ramp. Fluvial Koingnaas Formation overlain by fossiliferous 50mP with *D. haughtoni*. Eroded upper contact with no pedocrete and overlain by quite young yell-brn aeolian dorbank sands also lacking pedocrete.	5636-5646
18.11724	-31.58308	JPE34	2017-01-10	14:23		Cliffed fluvial Koingnaas Formation with exhumed silcrete slabs. Here locally overlain by a unit of yellow sand that appears to be of terrestrial origin - a pre-50mP aeolianite. Overlain by several m of fossiliferous 50mP with *D. haughton*i, overlain by aeolianite fms.	5647-5654

Table 2: Stynder & Reed sites with fossils

X	Y	Elev	Site	Description
226689	6501244	4	474	Micromammal Site
226750	6501573	52	Acheulean 1	Acheulean tools and cut marked bone
226786	6501606	87	CP1	Main Site (Nov 2008). (incorrect location, see note below JPE)
226746	6501825	68	CP2	Secondary Site (Nov 2008)
226794	6501625	59	CP3	Carnivores
226607	6501624	60	CP4	Large bones and tooth frags
226807	6501634	59	CP5	"Steep, long bones, dogs, not collected"
226714	6501559	55	CP6	Acheulean hand axe on spit
226747	6501836	67	CP7	Cliff Point 2 area; consolidated sands
226390	6502444	74	478	Bovid ulna frag and stone tools
225705	6503337	22	484	Stone tools nd bones (mostly reptile)
225727	6503294	34	487	Acheulean tools; equid metacarpal
226672	6500714	55	494	Tools and many bones; carnivores
237008	6482792	52	495	Recent hyena den?; cave
237329	6481672	22	497	Fossils
237378	6481426	33	502	Scattered bone

X	Y	Elev	Site	Description
237367	6481485	34	503	Scattered bone
236250	6485586	27	504	"Calcrete, termite mound, scattered bone"
219217	6510469	21	510	"Low lying cliff, hyena den, egg shell"
217277	6512737	32	512	"Bone, bovid m3, tooth roots; no clacrete"
226616	6500643	35	518	Mid-Pliocene tool in calcrete; other tools; bone
226824	6500896	76	520	Fossils coming out beneath calcrete; metatarsal; equid phalanx
226857	6500854	80	521	Scattered bone
226840	6501351	87	522	"Bones, eggshell, tools"
226736	6501317	91	523	"Fossil, tooth, "
226698	6501224	88	524	Scattered bone
220112	6509452	7	526	"Calcrete, bones, tools, Raphicerus mandible"
219772	6509841	7	528	"Hiipotrgine tooth, bovid humerus, porcupine gnawing"
220532	6508923	15	530	"Gnawed fossils, above cave/shelter"
220536	6508902	22	532	"Rhino tooth, canid mandible, ostrich egg shell (2mm)"
220571	6508866	29	533	"Articulated bovid leg, canid and verrid mandibles, measurements"
220688	6508856	42	534	Bovid calcaneus (eland)

X	Y	Elev	Site	Description
219737	6509812	25	536	Dinofelis??
219744	6509824	30	537	Bovid horn core
219675	6509794	15	538	"Egg shell, fossils, calcaneus, bovid M1/M2"
235579	6487785	2	545	Eland mandible and large canid; previously collected?
235514	6487737	0	546	"Shell midden with bone, turtle , fish"
235433	6486702	0	552	scattered bone and eggshell
235384	6486723	4	553	Elephant tusk imbedded in calcrete
235516	6486593	11	555	"Scattered bone, bovid atlas, distal radius; termite mound debris"
229574	6495359		575	Large animal
229683	6495247	43	576	"Bones, fish, carnivore, turtle, Equus"

Table 3: Webley & Halkett Draft HIA Table 1 sites with fossils

LONGITUDE	LATITUDE	LABEL	DESCRIPTION	SIGNIFICANCE
18.119917	-31.586	CP1	Chris House excavation of a presumed Hyena den in 2011. Age unsure but possibly 20-40 Kya (Hons thesis - UCT). We did not find anything when in the field as the original location we used was incorrect. The co-ordinate indicated in the Table is presumed to be correct. (Is incorrect – have changed – see note below – JPE)	
18.0488	-31.512458	CP537	"Visited by LW and DH Nov 2016. Located on high ancient dunes close to the shore. Dumps resulting from previous mining activities by Weskus Mynbou. No obvious site at co-ordinate used in the field for CP537 – see L079/D077. Referred to in permit application for CP537 (applicants Kaye Reed and Deano Stynder). In the application they state: " We noted two identifiable fossils (as well as many more eroding out of a section of channel fill). The fossils include Numidocapra crassicornis, a bovid found only in North Africa and in the Middle Awash, Ethiopia (the site where Australopithecus garhi has been found). The biochronological date ranges for this fossil are from 2.5-1.7 Ma (Million years). In addition we recorded Dinofelis barlowi teeth at the site indicating an age range of 2.5-1.9 Ma. Finally a calcrete from this area has normal polarity so preliminary estimates for the site are from ~1.9-1.7 Ma, possibly in the Olduvai subchron"."	
18.04895511	-31.51260249	CP537A	Dumps of channel fill.	
18.04903214	-31.51249604	CP537B	Channel fill.	
18.19213	-31.68528001	D024	More marine shell deposits cut by track.	
18.11997296	-31.59645002	D059	Fossil termite mound [Dave photo 3928]	
18.12024303	-31.585085	D063	A few stone flakes and fossil bone/teeth in a small blowout. Also fossil termitarium	

LONGITUDE	LATITUDE	LABEL	DESCRIPTION	SIGNIFICANCE
18.12053002	-31.58537099	D064	A few stone flakes and fossil bone/teeth in a small blowout. Also fossil termitarium	
18.12079799	-31.585344	D065	Fossil bovid long bone [Dave photo 3933]	
18.11692597	-31.57990398	D067	"Deflated area on a headland. Few MSA flakes, 1 x cobble proto biface. ! x fossil tooth seen. Many rhizoliths nearby. [Dave photo 3934-3941]"	
18.08162299	-31.54167999	D069	Fragment of adiagnostic fossil bone	
18.05984203	-31.52213699	D070	Blowout /erosion area with a few fragments of stone and fossil bone.	
18.058759	-31.52139402	D071	This is probably CP 534. A number of well preserved and identifiable fossil bones. Also rhizoliths and fossil termatarium [Dave photos 3961-3962]	
18.04852	-31.512977	D074	This may be CP 538? Exposure of a lens of white mussel-like bivalves with fossil bone associated. Cut by road. The lens extends between points D074 and D075 and beyond. [Dave photo 3970-3973]	IIIA
18.04827601	-31.51284498	D075	see D074	
17.94813599	-31.39940296	L013	Evidence for raised beach (weathered white mussels) of palaeontological interest	
18.01751803	-31.479095	L014	"Deep hole above beach with evidence of old weathered white mussels, palaeontological interest"	
18.11957901	-31.59606001	L068	Fossil bone	
18.11225901	-31.57519997	L073	Layers of shell and cobbles – old beach – palaeontological significance	

LONGITUDE	LATITUDE	LABEL	DESCRIPTION	SIGNIFICANCE
18.11383104	-31.57669899	L075	"Fossil bone, proto handaxe. Qtz chunks and flakes. Silcrete flakes. MSA? Lots of fossil bone, some diagnostic. Occasional cobble. Skull fragment."	IIIA
18.08205399	-31.54186497	L077	"Erosion area, occasional stone tool. Cobbles. Quartz chunks, quartz cores, flaked cobbles, fossilized tortoise carapace. This is CP535"	
18.04826302	-31.512747	L083	"Exposed, eroded white mussel horizon with beach cobbles – palaeontological interest"	
17.96118669	-31.41561843	LBM8	"Large quantities of stone artefacts, ostrich eggshell shell and shell (Patella granularis, Patella granatina as well as Choromytilus meridionalis) were found in tailings from a prospecting trial trench. Bone found in the tailings appears to be mineralised. This may be an indication that a buried MSA midden with preservation of shell, ostrich egg and bone may be buried in the vicinity. If this is the case, the site is extremely rare and very important. "	High (IIIA)
18.12125003	-31.59652781	PALAEO MANGROVE SITE????	Termite burrows. Same as SITE I below.	
18.12125003	-31.59652781	SITE I	Palaeontological site consisting of extensive exposure of fossil “mangroves” . (Ethembeni survey 2007). Halkett and Webley revisited the site in 2016 and identified the occurrence as fossil roots (not mangroves) which are common on the west coast. The technical term for a fossil root/stem is rhizolith. These are indicators of old land surfaces that have been exposed by wind and other erosion and usually associated with highly calcareous (shell rich) coastal dunes. (Likely to be termite burrows – JPE.)	Medium – high ethembeni

Appendix E: Palaeontological Sensitivity Rating

Palaeontological Sensitivity refers to the likelihood of finding significant fossils within a geologic unit.

HIGH: Assigned to geological formations known to contain palaeontological resources that include rare, well-preserved fossil materials important to on-going palaeoclimatic, palaeobiological and/or evolutionary studies. Fossils of land-dwelling vertebrates are typically considered significant. Such formations have the potential to produce, or have produced, vertebrate remains that are the particular research focus of palaeontologists and can represent important educational resources as well.

MODERATE: Formations known to contain palaeontological localities and that have yielded fossils that are common elsewhere, and/or that are stratigraphically long-ranging, would be assigned a moderate rating. This evaluation can also be applied to strata that have an unproven, but strong potential to yield fossil remains based on its stratigraphy and/or geomorphologic setting.

LOW: Formations that are relatively recent or that represent a high-energy subaerial depositional environment where fossils are unlikely to be preserved, or are judged unlikely to produce unique fossil remains. A low abundance of invertebrate fossil remains can occur, but the palaeontological sensitivity would remain low due to their being relatively common and their lack of potential to serve as significant scientific resources. However, when fossils are found in these formations, they are often very significant additions to our geologic understanding of the area. Other examples include decalcified marine deposits that preserve casts of shells and marine trace fossils, and fossil soils with terrestrial trace fossils and plant remains (burrows and root fossils)

MARGINAL: Formations that are composed either of volcaniclastic or metasedimentary rocks, but that nevertheless have a limited probability for producing fossils from certain contexts at localized outcrops. Volcaniclastic rock can contain organisms that were fossilized by being covered by ash, dust, mud, or other debris from volcanoes. Sedimentary rocks that have been metamorphosed by the heat and pressure of deep burial are called metasedimentary. If the meta sedimentary rocks had fossils within them, they may have survived the metamorphism and still be identifiable. However, since the probability of this occurring is limited, these formations are considered marginally sensitive.

NO POTENTIAL: Assigned to geologic formations that are composed entirely of volcanic or plutonic igneous rock, such as basalt or granite, and therefore do not have any potential for producing fossil remains. These formations have no palaeontological resource potential.

Adapted from Society of Vertebrate Paleontology. 1995. Assessment and Mitigation of Adverse Impacts to Non-renewable Paleontologic Resources - Standard Guidelines. News Bulletin, Vol. 163, p. 22-27.

Appendix F - Fossil Find Procedures

BASIC MEASURES FOR BULK EARTHWORKS EMPS

The monitoring of bulk earth works for fossils and the fossil find procedures and subsequent mitigation must be included in the EMPs for the Construction and Mining Phases.

OBJECTIVE: To see and rescue fossil material that may be exposed in the excavations for mining and infrastructure.		
Project components	Excavation of mine pits, dams, foundations pipelines, cables, spoil from excavations.	
Potential impact	Loss of fossils by their being unnoticed and/ or destroyed.	
Activity/ risk source	All bulk earthworks.	
Mitigation: target/ objective	To facilitate the likelihood of noticing fossils and ensure appropriate actions in terms of the relevant legislation.	
Mitigation: Action	**Responsibility**	**Timeframe**
Inform staff of the need to watch for potential fossil bone occurrences.	The Client, SRK, the ECO & contractors.	Pre-construction.
Inform staff of the procedures to be followed in the event of fossil bone occurrences.	ECO/specialist.	Pre-construction.
Monitor for presence of fossil bones	Contracted personnel and ECO, designated monitor.	Construction.
Liaise on nature of potential finds and appropriate responses.	ECO and specialist.	Construction.
Excavate possible finds & record and sample selected excavations.	Specialist.	Construction.
Obtain permit from HWC for fossil finds.	Specialist.	Construction
Performance Indicator	Reporting of and liaison about possible fossil finds. Fossils noticed and rescued.	

In the context under consideration, it is improbable that fossil finds will require declarations of permanent "no go" zones. At most a temporary pause in activity at a limited locale may be required. The strategy is to rescue the material as quickly as possible.

The procedures suggested below are in general terms, to be adapted as befits a context. They are couched in terms of finds of fossil bones that usually occur sparsely. However, they may also serve as a guideline for other fossil material that may occur. In contrast, fossil shell layers are usually fairly extensive and can be easily documented and sampled.

Bone finds can be classified as two types: isolated bone finds and bone cluster finds.

ISOLATED BONE FINDS

In the process of digging the excavations, isolated bones may be spotted in the hole sides or bottom, or as they appear on the spoil heap. By this is meant bones that occur singly, in different parts of the excavation. If the number of distinct bones exceeds 6 pieces, the finds must be treated as a bone cluster (below).

Response by personnel in the event of isolated bone finds

- **Action 1:** An isolated bone exposed in an excavation or spoil heap must be retrieved before it is destroyed or covered by further spoil from the excavation and set aside.
- **Action 2:** The site foreman and ECO must be informed.
- **Action 3:** The responsible field person (site foreman or ECO) must take custody of the fossil. The following information to be recorded:
    - Position (excavation position).
    - Depth of find in hole.
    - Digital image of hole showing vertical section (side).
    - Digital image of fossil.
- **Action 4:** The fossil should be placed in a bag (*e.g.* a Ziplock bag), along with any detached fragments. A label must be included with the date of the find, position info., depth.
- **Action 5:** ECO to inform the developer, the developer contacts the standby archaeologist and/or palaeontologist. ECO to describe the occurrence and provide images as soon as possible by email.

Response by Palaeontologist in the event of isolated bone finds

The palaeontologist will assess the information and liaise with the developer and the ECO and a suitable response will be established.

BONE CLUSTER FINDS

A bone cluster is a major find of bones, *i.e*. several bones in close proximity or bones resembling part of a skeleton. These bones will likely be seen in broken sections of the sides of the hole and as bones appearing in the bottom of the hole and on the spoil heap.

Response by personnel in the event of a bone cluster find

- **Action 1:** Immediately stop excavation in the vicinity of the potential material. Mark (flag) the position and also spoil that may contain fossils.
- **Action 2:** Inform the site foreman and the ECO.
- **Action 3:** ECO to inform the developer, the developer contacts the standby archaeologist and/or palaeontologist. ECO to describe the occurrence and provide images as soon as possible by email.

Response by Palaeontologist in the event of a bone cluster find

The palaeontologist will assess the information and liaise with the developer and the ECO and a suitable response will be established. It is likely that a Field Assessment by the palaeontologist will be carried out as soon as possible.

It will probably be feasible to “leapfrog” the find and continue the excavation farther along, or proceed to the next excavation, so that the work schedule is minimally disrupted. The response time/scheduling of the Field Assessment is to be decided in consultation with developer/owner and the environmental consultant.

The field assessment could have the following outcomes:

- If a human burial, the appropriate authority is to be contacted (see AIA). The find must be evaluated by a human burial specialist to decide if Rescue Excavation is feasible, or if it is a Major Find.
- If the fossils are in an archaeological context, an archaeologist must be contacted to evaluate the site and decide if Rescue Excavation is feasible, or if it is a Major Find.
- If the fossils are in a palaeontological context, the palaeontologist must evaluate the site and decide if Rescue Excavation is feasible, or if it is a Major Find.

RESCUE EXCAVATION

Rescue Excavation refers to the removal of the material from the just the “design” excavation. This would apply if the amount or significance of the exposed material appears to be relatively circumscribed and it is feasible to remove it without compromising contextual data. The time span for Rescue Excavation should be reasonably rapid to avoid any or undue delays, *e.g.* 1-3 days and definitely less than 1 week.

In principle, the strategy during mitigation is to “rescue” the fossil material as quickly as possible. The strategy to be adopted depends on the nature of the occurrence, particularly the density of the fossils. The methods of collection would depend on the preservation or fragility of the fossils and whether in loose or in lithified sediment. These could include:

- On-site selection and sieving in the case of robust material in sand.
- Fragile material in loose/crumbly sediment would be encased in blocks using Plaster-of Paris or reinforced mortar.

If the fossil occurrence is dense and is assessed to be a “Major Find”, then carefully controlled excavation is required.

MAJOR FINDS

A Major Find is the occurrence of material that, by virtue of quantity, importance and time constraints, cannot be feasibly rescued without compromise of detailed material recovery and contextual observations.

A Major Find is not expected.

Management Options for Major Finds

In consultation with developer/owner and the environmental consultant, the following options should be considered when deciding on how to proceed in the event of a Major Find.

Option 1: Avoidance

Avoidance of the major find through project redesign or relocation. This ensures minimal impact to the site and is the preferred option from a heritage resource management perspective. When feasible, it can also be the least expensive option from a construction perspective.

The find site will require site protection measures, such as erecting fencing or barricades. Alternatively, the exposed finds can be stabilized and the site refilled or capped. The latter is preferred if excavation of the find will be delayed substantially or indefinitely. Appropriate protection measures should be identified on a site-specific basis and in wider consultation with the heritage and scientific communities.

This option is preferred as it will allow the later excavation of the finds with due scientific care and diligence.

Option 2: Emergency Excavation

Emergency excavation refers to the "no option" situation wherein avoidance is not feasible due to design, financial and time constraints. It can delay construction and emergency excavation itself will take place under tight time constraints, with the potential for irrevocable compromise of scientific quality. It could involve the removal of a large, disturbed sample by excavator and conveying this by truck from the immediate site to a suitable place for "stockpiling". This material could then be processed later.

Consequently, emergency excavation is not a preferred option for a Major Find.

EXPOSURE OF FOSSIL SHELL BEDS

Response by personnel in the event of intersection of fossil shell beds

- **Action 1:** The site foreman and ECO must be informed.
- **Action 2:** The responsible field person (site foreman or ECO) must record the following information:
    - Position (excavation position).
    - Depth of find in hole.
    - Digital image of hole showing vertical section (side).
    - Digital images of the fossiliferous material.
- **Action 3:** A generous quantity of the excavated material containing the fossil shells should be stockpiled near the site, for later examination and sampling.
- **Action 4:** ECO to inform the developer, the developer contacts the standby archaeologist and/or palaeontologist. ECO to describe the occurrence and provide images as soon as possible by email.

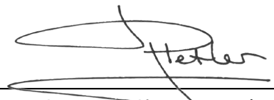
Response by Palaeontologist in the event of fossil shell bed finds

The palaeontologist will assess the information and liaise with the developer and the ECO and a suitable response will be established. This will most likely be a site visit to document and sample the exposure in detail, before it is covered up.

SPECIALIST DECLARATION

I ....John Pether.........., as the appointed specialist hereby declare/affirm the correctness of the information provided or to be provided as part of the application, and that I:

- in terms of the general requirement to be independent:
  - other than fair remuneration for work performed/to be performed in terms of this application, have no business, financial, personal or other interest in the activity or application and that there are no circumstances that may compromise my objectivity; or
  - am not independent, but another specialist that meets the general requirements set out in Regulation 13 have been appointed to review my work (Note: a declaration by the review specialist must be submitted);
- in terms of the remainder of the general requirements for a specialist, am fully aware of and meet all of the requirements and that failure to comply with any the requirements may result in disqualification;
- have disclosed/will disclose, to the applicant, the Department and interested and affected parties, all material information that have or may have the potential to influence the decision of the Department or the objectivity of any report, plan or document prepared or to be prepared as part of the application;
- have ensured/will ensure that information containing all relevant facts in respect of the application was/will be distributed or was/will be made available to interested and affected parties and the public and that participation by interested and affected parties was/will be facilitated in such a manner that all interested and affected parties were/will be provided with a reasonable opportunity to participate and to provide comments;
- have ensured/will ensure that the comments of all interested and affected parties were/will be considered, recorded and submitted to the Department in respect of the application;
- have ensured/will ensure the inclusion of inputs and recommendations from the specialist reports in respect of the application, where relevant;
- have kept/will keep a register of all interested and affected parties that participate/d in the public participation process; and
- am aware that a false declaration is an offence in terms of regulation 48 of the 2014 NEMA EIA Regulations.



Signature of the specialist:

Name of company:

1 August 2018

Date: