Palaeontological specialist assessment: desktop scoping study

Proposed Tshivhaso Coal-fired Power Plant near Lephalale, Waterberg District Municipality, Limpopo Province

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EXECUTIVE SUMMARY: HERITAGE STATEMENT

Cennergi is proposing to construct a coal-fired power station of capacity of up to 600 MW in Phase-1, with the site being brought up to a maximum of 1200-MW in Phase-2on a site some 20 km to the northwest of Lephalale, Waterberg District Municipality, Limpopo Province. Several site options for the Tshivhaso Coal-fired Power Plant and associated ash-dump have been identified on the farms Graafwater 456, Goedehoop 457, Eendragpan 451, Gelykbult 455, Vooruit 449, Kalkvlakte 256, Elandsvley 453, Appelvlakte 448 and Jackhalsvley 309.

The great majority of the study area for the proposed Tshivhaso Coal-fired Power Plant and associated ash-dumps is underlain by sedimentary rocks of the Karoo Supergroup (Eendragtpan and Clarens Formations) as well as volcanic rocks of the Lebombo Group (Letaba Formation) that are all of low palaeontological sensitivity. Significant impacts on local fossil heritage resources are not anticipated here and there are no preferred sites for the power plant or ash-dump on fossil heritage grounds. This assessment applies to adjoining farms Graafwater 456, Goedehoop 457, Eendragpan 451, Gelykbult 455, Vooruit 449, Kalkvlakte 256, Elandsvley 453 and Appelvlakte 448. It is noted that farm Eendragtpan 451 may be of special geological (stratigraphic) heritage significance as the probable type area of the eponymous Eendragtpan Formation. The power plant two grid connection options under consideration are both short with a small anticipated footprint (*i.e.* pylon footings). Although they traverse potentially fossiliferous Karoo Supergroup rocks, direct impacts on subsurface bedrocks are rated as negligible.

The isolated portion of the study area on Jakhalsvley 309, to the west of the Grootegeluk opencast mine, overlies bedrocks of the Grootegeluk and Swartrant Formations (Karoo Supergroup). These sedimentary successions are correlated with the Ecca Group of the Main Karoo Basin and are likewise known to be associated with rich plant fossil assemblages of the *Glossopteris* Flora of Gondwana. Substantial excavations into, or sealing-in of, the bedrocks on Farm Jakhalsvley 309 may have significant negative impacts on possible fossil-rich horizons in the subsurface (*e.g.* coal seams and associated sedimentary partings). Should Jakhalsvley 309 be selected for the proposed ash dump, a field-based palaeontological assessment would be required prior to development in order to determine if any fossiliferous surface exposures will be impacted. Specialist palaeontological mitigation may then be required during the construction phase of the ash dump. *Provided that* the recommended mitigation measures are carried through, it is likely that negative impacts of the proposed mining on local fossil

resources will be substantially reduced. Furthermore, they will be partially offset by the *positive* impact represented by increased understanding of the palaeontological heritage of the coal measures of Limpopo.

1. INTRODUCTION AND BRIEF

The company Cennergi is proposing to construct a coal-fired power station of capacity of up to 600 MW in Phase-1, with the site being brought up to a maximum of 1200-MW in Phase-2 on a site some 20 km to the northwest of the small town of Lephalale, Waterberg District Municipality, Limpopo Province (Fig. 1). The project is to be known as the Tshivhaso Coal-fired Power Plant. Various options regarding siting of the power station and associated infrastructure are being investigated. It is proposed to source coal from Exxaro Coal's Thabametsi Coal-Mine development which is to be located in the vicinity of the sites under investigation. The electricity generated from the power station will be fed into the Eskom electricity grid. Two grid connection options are being considered (Fig. 2).

The main infrastructural components of the proposed Tshivhaso Coal-fired Power Plant include the following (specifications will be decided based on the technology selected):

- Access roads;
- Power plant production unit/s (boilers / furnaces, turbines, generators and associated equipment,);
- Raw-Water Pipeline, Treatment and Storage;
- Waste-Water Storage and Treatment;
- Storm-water and polluted-water facilities, treatment and storage;
- Coal Transfer-House, Strategic Stockpile, Working Stockyard, Silos and Conveyors;
- Limestone Rail/Road Offloading, Storage, Silos and Conveyors;
- Ash-Handling Conveyors, -Silos, -Disposal and Dump Facilities;
- Workshops, Offices, Warehouses and Control Rooms
- Hazardous and Non-Hazardous Waste, Disposal Facilities and Logistics;
- Heavy Fuel Oil (HFO), Diesel, and Liquid Petroleum Gas (LPG) Logistics and Storage;
- Rail-head extension from Grootgeluk Mine, Rail-Spur to power station, and Tippler facilities;
- High-Voltage Yards, substations and overhead power lines to connect into the Eskom grid, and
- Temporary facilities for construction, including workshop facilities, laydown areas, water-supply, electricity-supply and logistics.

Cennergi has identified a number of farms which could be options for the placement of the power station and ash dump, depending on issues identified. These are indicated in Figures 1 & 2 below. Savannah Environmental (Pty) Ltd has been appointed by Cennergi to undertake the desktop scoping study for the Tshivhaso Coal-fired Power Plant (Contact details: Ms Jo-Anne Thomas**.** Savannah Environmental (Pty) Ltd**.** 1st Floor, Block 2, 5 Woodlands Drive Office Park, Woodlands Drive, Woodmead, 2191. Tel: +27 11 656 3237. Fax: +27 86 684 0547. Cell: +27 74 882 8746. Email: joanne@savannahsa.com. Postal address: P.O. Box 148, Sunninghill, 2157). The purpose of this study will be to identify issues associated with the proposed project and determine whether there are any fatal flaws from an environmental perspective. Following this study, the client will decide whether to proceed with the full process or not.

1.1. Scope of this palaeontological heritage study

The study area for the Tshivhaso Coal-fired Power Plant is underlain by potentially fossiliferous sedimentary rocks of the Karoo Supergroup of Permian to Jurassic age in the Ellisras Basin, Limpopo Province, South Africa. This desktop palaeontological specialist report provides an assessment of the observed or inferred palaeontological heritage within nine land parcels that are under consideration, with recommendations for further specialist palaeontological studies and / or mitigation where considered necessary. These land parcels are indicated in Figures 1 & 2 below and include:

- Two site options for the power plant itself: Graafwater 456 / Goedehoop 457 or Eendragpan 451 / Gelykbult 455 / Vooruit 449;
- Five site options for the ash-dump: Kalkvlakte 256 / Elandsvley 453, Vooruit 449, Appelvlakte 448, Goedehoop 457 and Jackhalsvley 309.

1.2. Legislative context for palaeontological assessment studies

The present combined desktop and field-based palaeontological heritage report falls under Sections 35 and 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999), and it will also inform the Environmental Management Plan for this project.

The proposed road development is located in an area that is underlain by potentially fossil-rich sedimentary rocks of Permian to Jurassic age as well as Late Caenozoic superficial sediments (Sections 2 and 3). The construction phase will entail substantial excavations into the superficial sediment cover and also into the Karoo Supergroup bedrocks. These developments may adversely affect known or potential fossil heritage at or beneath the surface of the ground within the study area by destroying, disturbing or sealing-in fossils that are then no longer available for scientific research or other public good.

The various categories of heritage resources recognised as part of the National Estate in Section 3 of the National Heritage Resources Act include, among others:

- geological sites of scientific or cultural importance;
- palaeontological sites;

- palaeontological objects and material, meteorites and rare geological specimens.

According to Section 35 of the National Heritage Resources Act, dealing with archaeology, palaeontology and meteorites:

(1) The protection of archaeological and palaeontological sites and material and meteorites is the responsibility of a provincial heritage resources authority.

(2) All archaeological objects, palaeontological material and meteorites are the property of the State.

(3) Any person who discovers archaeological or palaeontological objects or material or a meteorite in the course of development or agricultural activity must immediately report the find to the responsible heritage resources authority, or to the nearest local authority offices or museum, which must immediately notify such heritage resources authority.

(4) No person may, without a permit issued by the responsible heritage resources authority—

(a) destroy, damage, excavate, alter, deface or otherwise disturb any archaeological or palaeontological site or any meteorite;

(b) destroy, damage, excavate, remove from its original position, collect or own any archaeological or palaeontological material or object or any meteorite;

(c) trade in, sell for private gain, export or attempt to export from the Republic any category of archaeological or palaeontological material or object, or any meteorite; or

(d) bring onto or use at an archaeological or palaeontological site any excavation equipment or any equipment which assist in the detection or recovery of metals or archaeological and palaeontological material or objects, or use such equipment for the recovery of meteorites.

(5) When the responsible heritage resources authority has reasonable cause to believe that any activity or development which will destroy, damage or alter any archaeological or palaeontological site is under way, and where no application for a permit has been submitted and no heritage resources management procedure in terms of section 38 has been followed, it may—

(a) serve on the owner or occupier of the site or on the person undertaking such development an order for the development to cease immediately for such period as is specified in the order;

(b) carry out an investigation for the purpose of obtaining information on whether or not an archaeological or palaeontological site exists and whether mitigation is necessary;

(c) if mitigation is deemed by the heritage resources authority to be necessary, assist the person on whom the order has been served under paragraph *(a)* to apply for a permit as required in subsection (4); and

(d) recover the costs of such investigation from the owner or occupier of the land on which it is believed an archaeological or palaeontological site is located or from the person proposing to undertake the development if no application for a permit is received within two weeks of the order being served.

Minimum standards for the palaeontological component of heritage impact assessment reports (PIAs) have recently been published by SAHRA (2013).

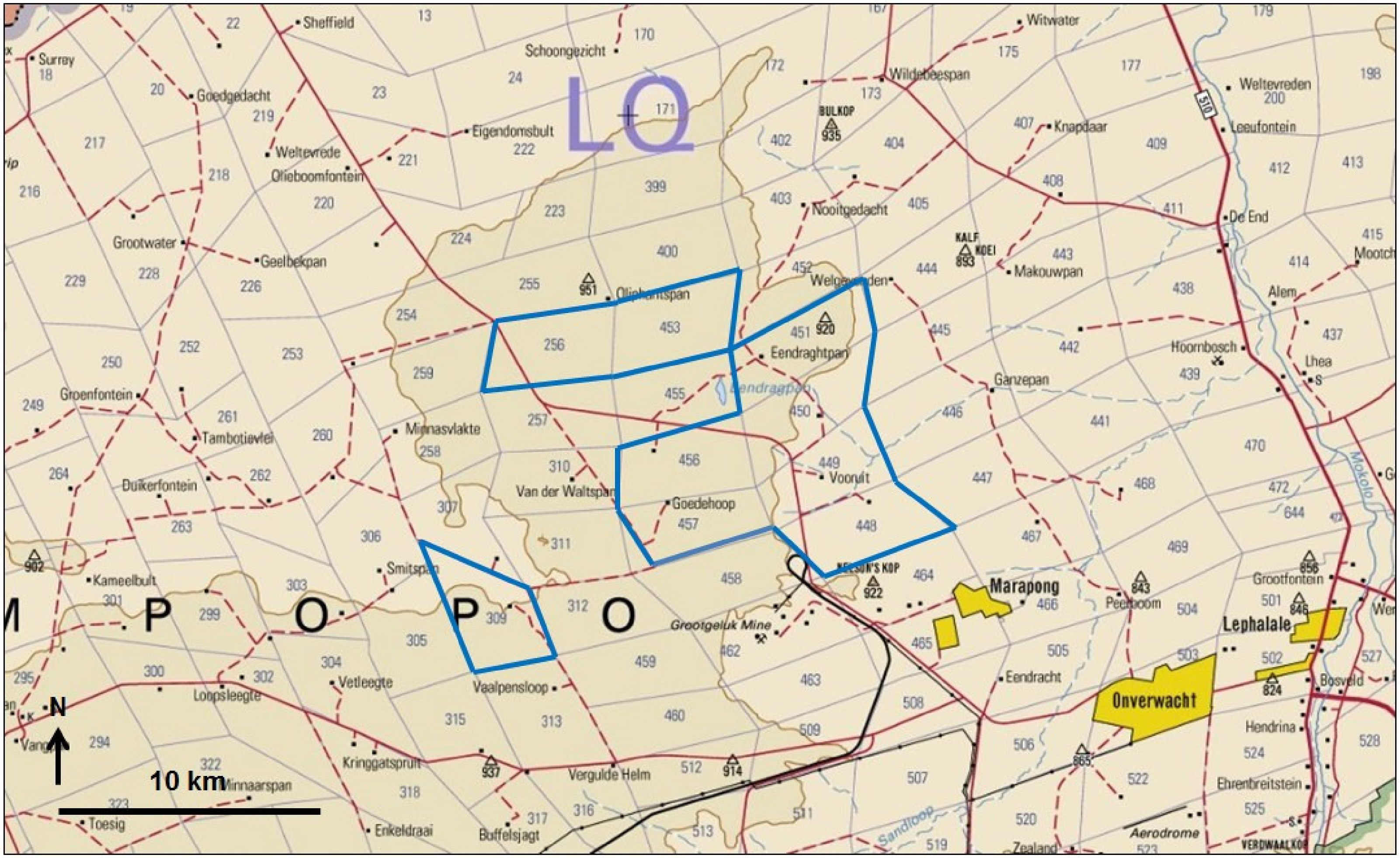

Figure 1. Extract from the 1: 250 000 topographical sheet 2326 Lephalale (Courtesy of the Chief Directorate: National Geospatial Information, Mowbray) showing the outline of land parcels considered for the proposed Tshivhaso Coal-fired Power Plant and associated infrastructure, located *c*. 20 km northwest of Lephalale, Limpopo (blue polygon).

Figure 2. Google earth© satellite image of the Tshivhaso Coal-fired Power Plant study area *c.* 20 km to the NW of Lephalale, Limpopo (land parcels outlined in white) to the north of the existing Grootegeluk opencast mine. Land parcels under consideration for the power plant are outlined in orange; those beung considered for the ash-dump are shown in white. Grid connection options are indicated in blue.

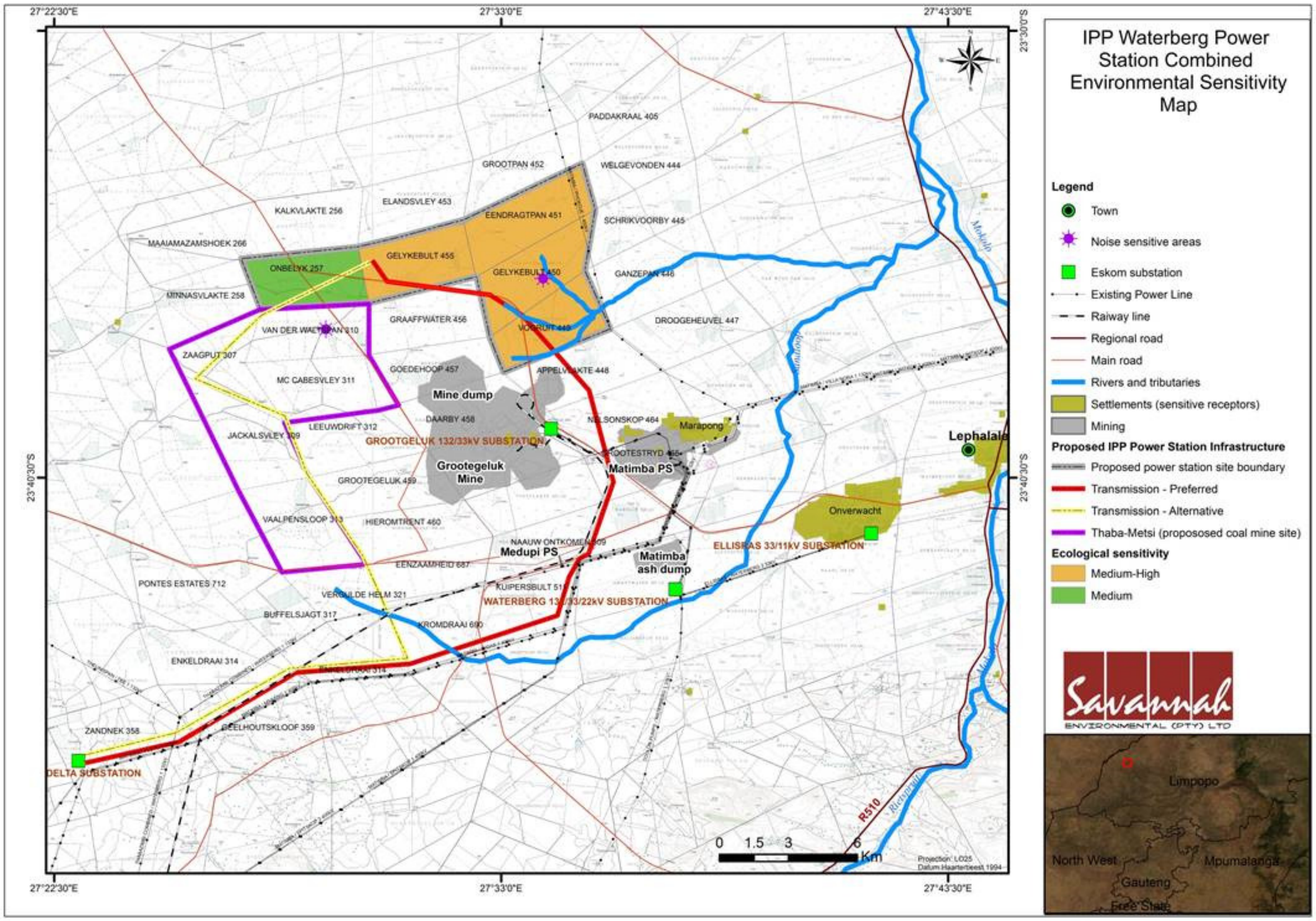

Figure 3. Contextual map for the proposed Tshivhaso Coal-fired Power Plant near Lephalale (Image kindly provided by Savannah Environmental (Pty) Ltd).

1.3. Approach to the palaeontological heritage study

The approach to this palaeontological heritage study is briefly as follows. Fossil bearing rock units occurring within the broader study area are determined from geological maps and satellite images. Known fossil heritage in each rock unit is inventoried from scientific literature, previous assessments of the broader study region, and the author's field experience and palaeontological database. Based on this data as well as field examination of representative exposures of all major sedimentary rock units present, the impact significance of the proposed development is assessed with recommendations for any further studies or mitigation.

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area are determined from geological maps and satellite images. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following field assessment during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development (provisional tabulations of palaeontological sensitivity of all formations in Limpopo have already been compiled by J. Almond (unpublished database). The likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature and scale of the development itself, most significantly the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a Phase 1 field assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any mitigation required before or during the construction phase of the development.

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authority, SAHRA (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za). It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

1.4. Assumptions & limitations

The accuracy and reliability of palaeontological specialist studies as components of heritage impact assessments are generally limited by the following constraints:

1. Inadequate database for fossil heritage for much of the RSA, given the large size of the country and the small number of professional palaeontologists carrying out fieldwork here. Most development study areas have never been surveyed by a palaeontologist.

2. Variable accuracy of geological maps which underpin these desktop studies. For large areas of terrain these maps are largely based on aerial photographs alone, without ground-truthing. The maps generally depict only significant ("mappable") bedrock units as well as major areas of superficial "drift" deposits (alluvium, colluvium) but for most regions give little or no idea of the level of bedrock outcrop, depth of superficial cover (soil *etc*), degree of bedrock weathering or levels of small-scale tectonic deformation, such as cleavage. All of these factors may have a major influence on the impact significance of a given development on fossil heritage and can only be reliably assessed in the field.

3. Inadequate sheet explanations for geological maps, with little or no attention paid to palaeontological issues in many cases, including poor locality information;

4. The extensive relevant palaeontological "grey literature" - in the form of unpublished university theses, impact studies and other reports (*e.g*. of commercial mining companies) - that is not readily available for desktop studies;

5. Absence of a comprehensive computerized database of fossil collections in major RSA institutions which can be consulted for impact studies. A Karoo fossil vertebrate database is now accessible for impact study work.

In the case of palaeontological desktop studies without supporting Phase 1 field assessments these limitations may variously lead to either:

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

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

Since most areas of the RSA have not been studied palaeontologically, a palaeontological desktop study usually entails *inferring* the presence of buried fossil heritage within the study area from relevant fossil data collected from similar or the same rock units elsewhere, sometimes at localities far away. Where substantial exposures of bedrocks or potentially fossiliferous superficial sediments are present in the study area, the reliability of a palaeontological impact assessment may be significantly enhanced through field assessment by a professional palaeontologist. In the case of the Waterberg Coalfield area near Lephalale bedrock exposure is usually very poor due to soil and vegetation cover. Fossiliferous beds are mainly available for study only within artificial excavations such as mines, borrow pits and trenches made for infrastructure such as pipelines. However, some useful palaeontological data (*e.g.* palynology) has also been obtained from numerous borehole cores

1.5. Information sources

The information used in this desktop study was based on the following:

1. A short project outline provided by Savannah Environmental (Pty) Ltd ;

2. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations as well a limited number of desktop and field-based palaeontological assessment studies in the broader study region (*e.g.* Karodia & Higgitt 2013, Bamford 2014, Almond 2015);

3. The author's unpublished palaeontological database and previous field experience with the formations concerned and their palaeontological heritage.

2. GEOLOGICAL OUTLINE OF THE STUDY AREA

The Ellisras Basin comprises a comparatively small outlier of Karoo Supergroup (Carboniferous to Jurassic) sedimentary rocks in Limpopo Province that forms an easterly extension of the extensive Kalahari Basin of Botswana (Catuneanu *et al.* 2005, Johnson *et al.* 1996, 2006, Mtimkulu 2009) (Fig. 4). The basin presently extends about 80 km north-south and 35 km east-west. In structural terms the basin has the form of a west-east orientated half-graben and is of Karoo age (Fig. 5). It is bounded by the Zoetfontein Fault Zone in the north. Here the Karoo Supergroup succession is thickest (*c*. 550 m, though some estimates are much higher) and faulted against Archaean basement rocks of the Limpopo Belt. The Karoo sedimentary wedge thins gradually towards the south where it abuts against Proterozoic sediments of the Waterberg Group along the Eenzaamheid Fault Zone (Fourie *et al.* 2014). Waterberg rocks form the basement to the Karoo succession throughout the central and southern portions of the Ellisras Basin.

In general, the levels of surface exposure of the Karoo Supergroup sediments within the Ellisras Basin are very poor; most stratigraphic information has been obtained from boreholes, supplemented recently by airborne geophysical surveys (Brandl 1996, Johnson *et al.* 2006, Fourie *et al.* 2014 and references therein). Late Carboniferous to Early Jurassic correlatives of the Dwyka, Ecca, Beaufort and Stormberg Groups of the Main Karoo Basin have been recognised here (Fig. 6; see also Bordy *et al.* 2010). The wide spectrum of depositional settings represented in the Ellisras Basin include glacio-lacustrine and glacio-fluvial towards the base through prodelta and delta platform, braided and meandering rivers, alluvial fans as well as desert aeolianites towards the top. The Karoo sedimentary succession is capped by basaltic lavas of the Letaba Formation, dated *c*. 180 Ma, which are placed within the Lebombo Group and also correlated with the Early Jurassic Drakensberg Group (Duncan & Marsh 2006). Coal deposits are well-developed within the lower portion of the Karoo Supergroup succession and these are likely to prove a major source of minable coal in future, with possibly over half of the RSA's remaining coal reserves. Displacement along the post-Karoo Daarby Fault has generated separate blocks of coal at shallow depths that are suitable for open-cast mining. Currently the only large-scale exploitation of coals from the Ellisras (= Waterberg) Basin is at Grootegeluk Mine, situated just to the south of the present study area and *c*. 20 km west of Lephalale (See satellite image Fig. 2).

Four sedimentary subunits of the Karoo Supergroup within the Ellisras Basin are mapped within the present study area (See geological map Fig. 7 and stratigraphic column Fig. 6) underlying basaltic volcanic rocks of the Letaba Formation (Lebombo Group). These are the Swartrant and Grootegeluk Formations that are correlated with the Early to Middle Permian Ecca Group, the Eendragtpan Formation that is correlated with the Beaufort Group and the Clarens Formation within the Stormberg Group. The sedimentology and environmental interpretation of these formations have been outlined in the Ellisras geology sheet explanation by Brandl (1977; see earlier references therein) and summarized by Johnson *et al.* (2006).

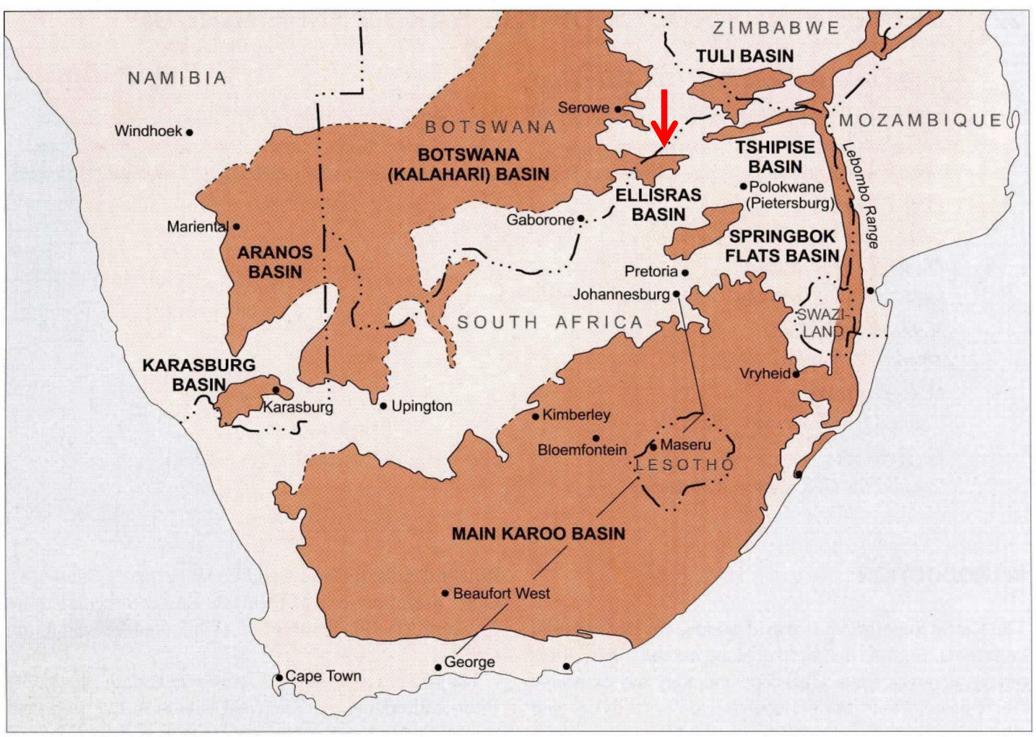

Figure 4. Map showing the Karoo Supergroup basins of southern Africa, including the Ellisras Basin in Limpopo (red arrow), an eastward extension of the Kalahari Basin of Botswana (From Johnson *et al.* 2006).

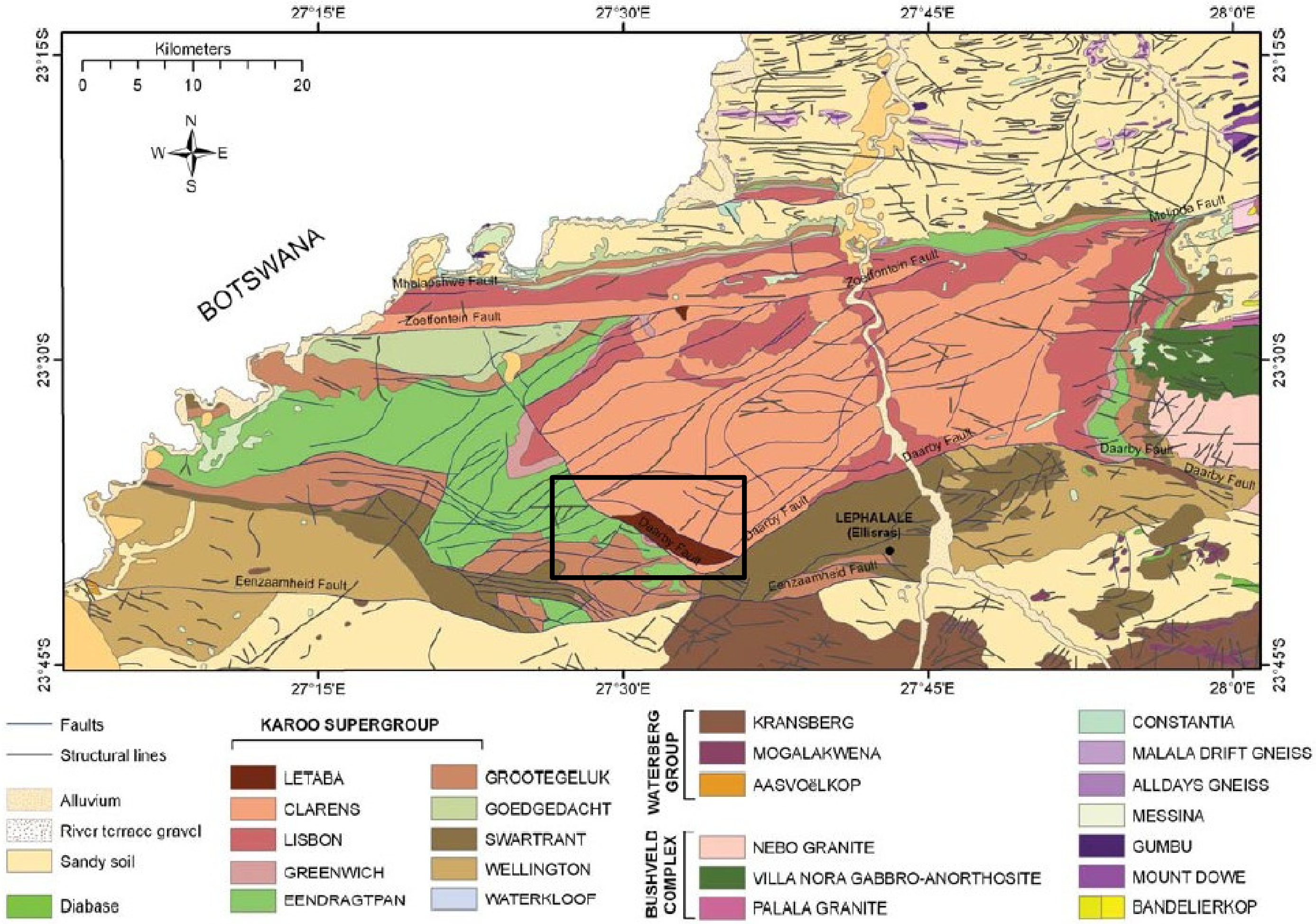

Figure 5. Geological map of the Ellisras Basin, Limpopo Province (From Fourie *et al.* 2014). The *approximate* location of the present study area towards the southern basin margin is shown by the black rectangle (See also Fig. 7).

Karoo stratigraphy in the Lephalale (Ellisras) area

Thickness (m)	Stratigraphy column	Formation	Group
>125		Letaba	Drakensberg
130		Clarens	
100-110		Lisbon	
7-33		Greenwich	
40-110		Eendragtpan	Beaufort
10-110		Grootegeluk	Ecca
0-80		Goedgedacht	Ecca
2-130		Swartrant	Ecca
20-160		Wellington	Ecca
26		Waterkloof	Dwyka
		Pre-Karoo Basement	

Figure 6. Stratigraphy of the Karoo Supergroup within the Ellisras Basin (From Fourie *et al.* 2014, based on Johnson *et al*. 2006). Rock units represented within the Tshivaso Coal-Fired Power Plant study area are indicated by the red bars. The Letaba Formation lavas are now placed within the Lebombo Group (Duncan & Marsh 2006).

2.1. Swartrant Formation

The basal zone of the Swartrant succession consists of interbedded sandstone and siltstone overlain by coarser, cross-bedded sandstones and then a 1-meter thick coal seam with a seat earth at the base. These lower beds are interpreted in terms of a prograding delta prism with delta-top swamp deposits at the top. The middle zone has a laterally-extensive transgressive sandstone at the base followed by laminated mudrocks with dispersed dropstones attributed to suspension deposition in a glacio-lacustrine lake setting. The lacustrine mudrocks are overlain by prograding delta front sediments followed by delta-top deposits comprising thinly-interbedded coals and mudrocks. Coarse-grained, cross-bedded sandstones of the upper zone in the south of the basin containing thin coals and plant rootlet horizons are interpreted as fluvial deposits on the delta top or paralic floodplain. The Swartrant Formation has been correlated with the Lower to Middle Ecca Group of the Main Karoo Basin.

2.2. Grootegeluk Formation

This formation is built up of cyclically-repeated facies including laminated to massive mudstone, carbonaceous shale and coal. It has been correlated with the Vryheid Formation (Middle Ecca) of the Main Karoo Basin. A two metre-thick tonstein (kaolinitic mudstone) – possibly a palaeosol or tuff - lies at the base of the formation and constitutes an important chronostratigraphic marker. Thick, mineable seams of coal are found within the lower part of the formation and constitute the main target of coal exploitation in the Ellisras Basin. A well-developed, fine-scale micro-cyclicity within the middle part of the Grootegeluk Formation features interlaminated sub-millimetric layers of bright coal (vitrinite), dull coal (inertinite), pollen-rich exinite and carbonaceous shale. The depositional pattern is attributed to a phase of delta abandonment in a tectonically stable setting. Tundra-type peats repeatedly flourished within poorly-drained floodplain swamps under the influence of a fluctuating water table and oxygenation levels. Most of the Grootegeluk coals are regarded as autochthonous, with subordinate allochthonous coals derived from transported plant debris. Low sulphur contents as well as the abundance of concretionary siderite suggest the coals formed in freshwater settings with low ambient oxygen levels (*cf* Faure *et al.* 1996).

2.3. Eendragtpan Formation

This unit is correlated with the Permo-Triassic Beaufort Group of the Main Karoo Basin and is dominated by fine-grained variegated mudrocks, ranging from greyish towards the base with an increasing proportion of reddish-purple hues towards the top. Coloration reflects increasing oxidation levels during deposition as well as variable redox conditions during diagenesis. Pale reduction spots are ubiquitous while coalified material is absent. The depositional setting is interpreted as a well-drained floodplain. On the basis of geochemical and mineralogical data the mudrocks were deposited in a freshwater setting and once contained organic matter that has been subsequently degraded (Faure *et al.* 1996).

2.4. Clarens Formation

The Clarens Formation represents a geographically widespread succession of arid desert aeolian sands of Early Jurassic age and constitutes the final depositional phase within a number of Karoo sedimentary basins in southern Africa (Johnson *et al.* 2006 and refs. therein, McCarthy & Rubidge 2005). In the Ellisras Basin the Clarens sandstones reach a thickness of *c*. 130 m and are moderately well-exposed compared with most of the underlying Karoo Supergroup succession, locally forming prominent hills and ridges; most of the outcrop area is mantled in pale, fine-grained sand, however (Brandl 1996). The creamy to pinkish sandstones are typically massive, well-sorted and fine-grained, with occasional coarse sands and pebbly horizons. Sand grains are well-rounded but typical large-scale aeolian dune cross-sets are rarely preserved. Coarser facies are interpreted as deposited by small ephemeral streams feeding inland sebkhas.

2.5. Letaba Formation

The Letaba Formation is a thick succession of picritic (olive-rich) mafic lavas within the lower part of the Early Jurassic Lebombo Group that is recognised widely within the northern portion of the RSA as well as Zimbabwe, Botswana and Zambia (Duncan & Marsh 2006). They crop out in a small area of the Ellisras Basin, to the northeast of the Grootgeluk coal mine (Fig. 7) where borehole data indicates a thickness of 125 m (Brandl 1996). Bedrock exposures in shallow excavations here indicate purplish and greenish-grey amydaloidal lavas with flow units of about one meter thick.

2.6. Superficial deposits

Google earth© satellite imagery shows that the present study area some 20 km to the northwest of Lephalale is situated in flat-lying to gently undulating terrain between 880 and 950 m amsl (Fig. 2). The area is dominated by typical dry Kalahari bushveld with occasional small pans but no major water courses. The large Grootegeluk open cast coal mine and Medupi power station (currently under construction) lie just to the south. Due to the easily-weathered and –eroded nature of the Karoo Supergroup bedrocks, and especially the mudrock-dominated portions of the succession, there is very little topographic relief in the region and the bedrocks are largely or entirely mantled by a surface sands (*cf* Almond 2015). According to Brandl (1996) the extensive surface sands were largely emplaced by sheetwash processes subjected to limited aeolian reworking, with a secondary contribution from weathering of local Karoo Supergroup sandy lithologies. Small, shallow water courses are associated with fine alluvial sands, silts and dispersed fine gravels of Quaternary of younger age. The alluvium as well as pan deposits are usually extensively calcretised, with the formation locally of a massive subsurface calcrete hardpan. According to Netterberg (1969) the calcretisation is mainly a Mid-Pleistocene phenomenon. Calcrete-dominated areas are typically dominated by *Acacia* thornveld (darker green in satellite images) while arid bushveld with tree genera such as *Terminalia*, *Combretum* and Maroela predominates elsewhere. Between the trees there are tall grasses and reddish-brown or greyish sandy soils (Almond 2015). The various late Caenozoic superficial deposits in the study region are not shown on geological maps at 1: 250 000 scale

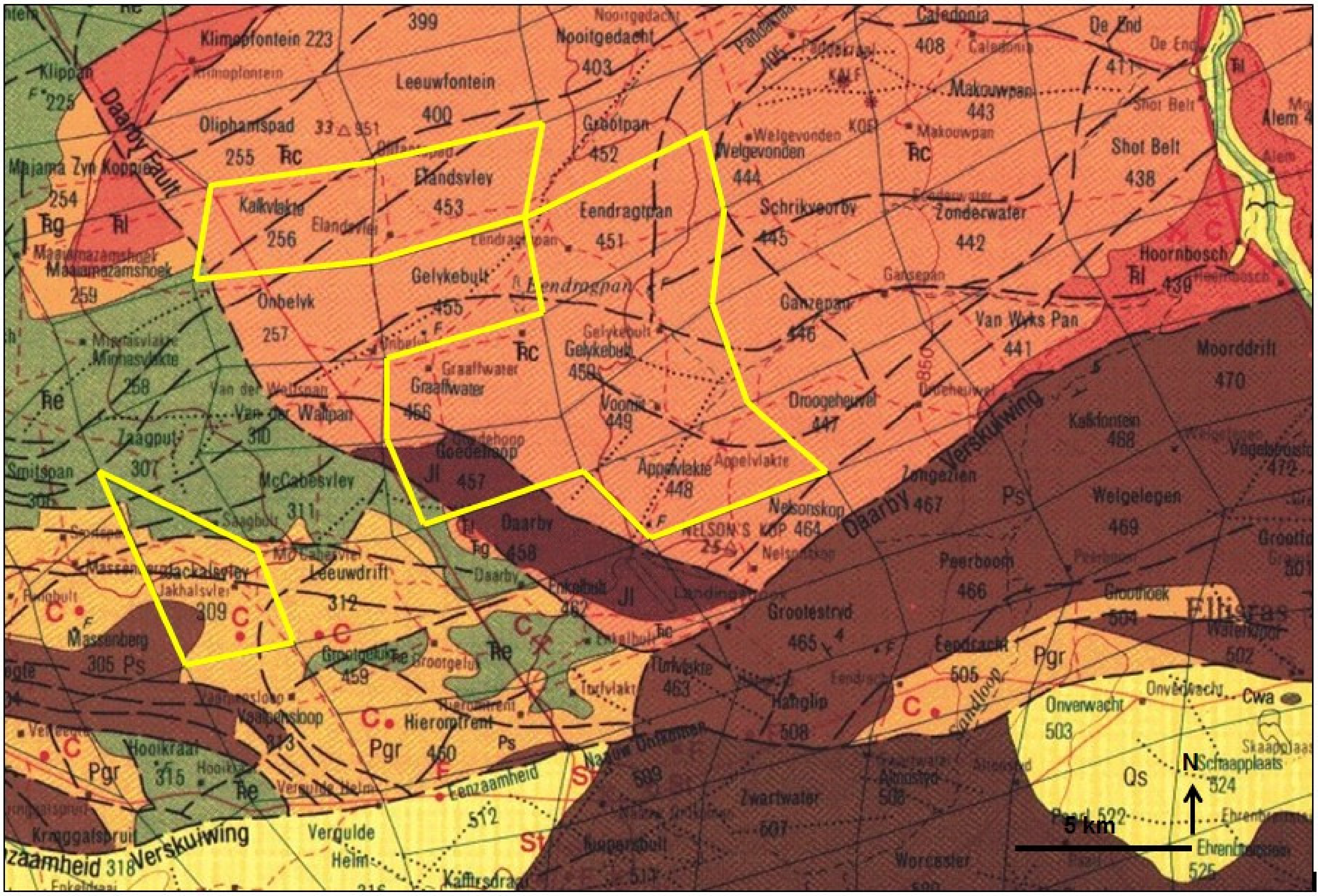

Figure 7. Extract from 1: 250 000 geology sheet 2326 Lephalale (Ellisras) showing the outline of the land parcels involved in the proposed Tshivhaso Coal-fired Power Plant study area (yellow polygon). The red "C" symbols refer to identified coal occurrences associated with the Grootegeluk Formation (Note C marked in Jakhalsvley 209). The main subunits of the Karoo Supergroup represented here include: Swartrant Formation (Ps, brown); Grootegeluk Formation (Pgr, beige); Eendragtpan Formation (Tre, grey-green); Clarens Formation (TRc, pink); Letaba Formation (Jl, dark brown); Late Caenozoic superificial sediments (soils, alluvium, gravels) are not mapped at this scale with the exception of Tertiary calcrete (Tc) to the north.

3. PALAEONTOLOGICAL HERITAGE WITHIN THE STUDY REGION

The palaeontology of the Karoo Supergroup succession of the Ellisras Basin of Limpopo Province is very poorly known, largely due to the very low levels of bedrock exposure here (Almond 2015). A brief summary of fossil heritage resources associated with various constituent formations is presented below in Table 1.

Plant macrofossils of the Permian *Glossopteris* Flora, including compression or impression fossils of leaves as well as plant roots ("*Stigmaria*") in seat earths, are well represented within the lower part of the Ellisras Basin succession comprising Ecca Group equivalents, namely the Swartrant, Goedgedacht and Grootegeluk Formations. To the author's knowledge, there have been no published systematic studies of these coal floras, although good exposures are now available in the Grootegeluk Mine west of Lephalale. Future open cast mining of the Ellisras Basin coals should provide excellent opportunities to sample and study these poorly known Limpopo palaeofloras. The palynology (pollen, spores *etc*) of portions of the Ellisras Basin has been described in a monograph by MacRae (1988). Dinosaur remains and various invertebrate trace fossils have been reported in the area since the 1920s. They include possible representatives of the Late Triassic "*Euskelesaurus*" Assemblage Zone and Early Jurassic *Massospondylus* Assemblage Zone found in the upper part of the Ellisras Basin Karoo succession (Lisbon Formation) that is correlated with the Elliot Formation of the Main Karoo Basin. Sparse dinosaur remains (bones, teeth, trackways) of the *Massospondylus* Assemblage Zone might also be expected within the Early Jurassic desert deposits of the overlying Clarens Formation and fossilised plant roots have been recorded here (Brandl 1996).

The volcanic Letaba succession is not known to be fossilferous in the Ellisras Basin. It is noted that significant fossil plant assemblages are known, however, from sedimentary intercalations between lava flows of the correlated Drakensberg Group of Lesotho (Anderson & Anderson 1985, p. 44) and similar palaofloras might likewise be present within the Lebombo Group succession.

No fossil remains were recorded from the very poorly-exposed Karoo Supergroup bedrocks or the overlying Late Caenozoic superficial sediments (*e.g.* calcrete hardpans, calcretised alluvium) to the west of the present study area during a recent field assessment by Almond (2015).

Table 1: Stratigraphy and palaeontology of the Karoo Supergroup in the Ellisras Basin

		FORMATION	SEDIMENTOLOGY	FOSSIL RECORD & CORRELATION	COMMENTS
LEBOMBO GROUP	ELLISRAS BASIN	**Letaba Formation**	Basaltic lavas	No fossils recorded. Plant fossils might occur in sediments between lava flows.	Correlated with the Drakensberg Group
KAROO SUPERGROUP (Late Carboniferous to Early Jurassic)		**Clarens Fm (TRc)**	Aeolian sandstone, minor ephemeral stream deposits	Dinosaur remains and trackways can be expected. Plant root traces (rhizoliths).	Exposure levels generally very poor. Early records of dinosaur remains from 1920s.
		Lisbon Fm (TRl)	Red mudrocks with calcareous concretions, minor sandstones	Trace fossils ("*Cruziana*", "*Skolithos*", extensive bioturbation, possible fossil termitaria, rhizoliths) Large sauropodomorph dinosaurs (possibly "*Euskelesaurus*" and / or *Massospondylus*) Probably Elliot Fm. equivalent	
		Greenwich Fm (P-TReg)	Sandstones, grits, conglomerates & thin mudstones of braided streams	No coals Probably Beaufort Group and/or Molteno equivalents.	
		Eendragtpan Fm (P-TReg)	Variegated mudrocks of arid floodplains		
		Grootegeluk Fm (Pg)	Cycles of thick coals, carbonaceous mudrocks	Glossopterid coal flora abundant associated with thick coal seams Probably Ecca Group equivalents (*e.g.* Vryheid Formation)	Also known as Waterberg Coalfield Important coal reserves for future mining – high impacts may be anticipated. Ellisras floras very poorly known.
		Goedgedacht Fm (Pg)	Mudstones, sandstones, coals of proglacial alluvial fans, braided streams	Glossopterid coal flora	
		Swartrant Fm (Pg)	Deltaic sandstones, mudrocks, with coals, glacio-lacustrine, fluvial and swamp sediments	Glossopterid coal flora	
		Wellington Fm	Laminated mudrocks, sandstones, dropstones	Probable Dwyka equivalents.	Palynology studies on Waterberg Basin by C. MacRae (1988)
		Waterkloof Fm	Diamictite, mudstone, rhythmitite, congloms		

KEY: Units in red = HIGH palaeosensitivity. Units in blue = LOW palaeosensitivity.Units in black = V. LOW palaeosensitivity

4. ASSESSMENT OF IMPACTS AND IDENTIFICATION OF MANAGEMENT ACTIONS

4.1. Assessment of impact significance

Construction of the proposed Tshivhaso Coal-fired Power Plant and associated infradstructure near Lephalale, Limpopo Province, will involve substantial excavations into the underlying bedrocks as well as large-scale ground clearance (*e.g.* for access roads). The great majority of the study area to the north of the existing Grootegeluk opencast mine overlies Karoo Supergroup sedimentary rocks (Eendragtpan and Clarens Formations) as well as Lebombo Group volcanics that are of low palaeontological sensitivity (Geological map Fig. 7 and Table 1). Significant impacts on local palaeontological heritage resources are not anticipated here. This assessment applies to adjoining farms Graafwater 456, Goedehoop 457, Eendragpan 451, Gelykbult 455, Vooruit 449, Kalkvlakte 256, Elandsvley 453 and Appelvlakte 448. It is noted that farm Eendragtpan 451 may be of special geological (stratigraphic) heritage significance, however, as the probable type area of the eponymous Eendragtpan Formation (supporting documentation not available). The two power plant grid connection options under consideration (Fig. 2, blue lines) are both short with a small anticipated footprint (*i.e.* pylon footings). Although they traverse potentially fossiliferous Karoo Supergroup rocks, direct impacts on subsurface bedrocks are rated as negligible.

The isolated portion of the study area on Jakhalsvley 309, to the west of the Grootegeluk opencast mine, overlies bedrocks of the Grootegeluk and Swartrant Formations. These sedimentary rocks are correlated with the Ecca Group of the Main Karoo Basin and are likewise known to be associated with rich fossil assemblages of the *Glossopteris* Flora of Gondwana (See 'C" for coal on Jakhalsvley 309, geological map fig. 7). Despite the history of major coal mining in the region, the Permian palaeofloras of Limpopo remain very poorly sampled and studied. As a rule, the best-preserved and most informative coal measure floras are preserved within the fine-grained sediments associated with the coal-bearing sedimentary packages, rather than within the coal seams themselves. The potential ash-dump on Jakhalsvley 309 may cause significant loss of palaeontological heritage - notably plant macrofossils - for example due to subsurface excavations or sealing-in of subsurface fossils during the construction and operational phases.

Given the large scale of proposed as well as current mining in the region, the cumulative impacts entailed on local fossil heritage are probably high. Loss of fossil heritage resources through coal mining and associated developments can be partially mitigated through constructive collaboration between the palaeontological community and developers, including mine management, as outlined in the following section of the report. Residual negative impacts from loss of fossil heritage would then be partially offset by an improved palaeontological database for the study region as a direct result of appropriate mitigation. This is a *positive* outcome because any new, well-recorded and suitably curated fossil material from this palaeontologically under-recorded region would constitute a useful addition to our scientific understanding of the fossil heritage here.

4.2. Recommended mitigation and management actions (Jakhalsvley 309 *only*)

Proposed mitigation and management actions regarding anticipated impacts on fossil heritage in the potentially coal-bearing portions of the Tshivhaso Coal-fired Power Plant study area (Jakhalsvley 309) are largely based on the document *Protection and conservation of South African coal-associated fossil floras* authored by Dr Rose Prevec (2013) of the Albany Museum, Grahamstown, who has considerable expertise in the field of South African palaeobotany. Following Dr Prevec's initiative, the following recommendations (dated 9 October 2013) with reference to coal mining applications were proposed by Ms Jenna Lavin of SAHRA's Archaeology, Palaeontology and Meteorites Unit.

- If an area is deemed palaeontologically sensitive, a field-based assessment is required prior to development in order to determine if any fossiliferous surface exposures will be impacted.
- One site inspection should be done by a suitably qualified palaeontologist during preliminary excavations, once mining has commenced and overburden has been removed. At this stage, the partings (the layers of siltstone and mudrock between the coal seams) are visible for inspection for significant fossil material.
- Should the site yield significant palaeobotanical specimens, further site inspections must be arranged between the on-site geologist and palaeontologist.
- A Section 35 permit application is required for the removal of any palaeontological material from the site. However, issuing a collections permit prior to any evidence of a heritage resource is not possible in terms of Section 35 of the National Heritage Resources Act (NHRA).

These recommendations should apply equally to any large-scale excavations directly impacting coal-bearing strata in the study area, such as those for power plants and associated infrastructure. They should be incorporated into the Environmental Management Programme (EMPr) for the Tshivhaso Coal-fired Power Plant project if farm Jakhalsvley 309 is chosen as the site for the ash-dump.

Provided that the recommended mitigation measures are carried through, it is likely that any potentially negative impacts of the proposed development on local fossil resources will be substantially reduced. Furthermore, they will be partially offset by the *positive* impact represented by increased understanding of the palaeontological heritage of the coal measures of Limpopo.

Please note that:

- All South African fossil heritage is protected by law (South African Heritage Resources Act, 1999) and fossils cannot be collected, damaged or disturbed without a permit from SAHRA or the relevant Provincial Heritage Resources Agency;

- The palaeontologist concerned with mitigation work will need a valid fossil collection permit from SAHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection);

- All palaeontological specialist work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies recently developed by SAHRA (2013).

5. CONCLUSIONS AND RECOMMENDATIONS

The great majority of the study area for the proposed Tshivhaso Coal-fired Power Plant and associated ash-dumps is underlain by sedimentary rocks of the Karoo Supergroup (Eendragtpan and Clarens Formations) as well as volcanic rocks of the Lebombo Group (Letaba Formation) that are all of low palaeontological sensitivity. Significant impacts on local fossil heritage resources are not anticipated here and there are no preferred sites for the power plant or ash-dump on fossil heritage grounds. This assessment applies to adjoining farms Graafwater 456, Goedehoop 457, Eendragpan 451, Gelykbult 455, Vooruit 449, Kalkvlakte 256, Elandsvley 453 and Appelvlakte 448. It is noted that farm Eendragtpan 451 may be of special geological (stratigraphic) heritage significance as the probable type area of the eponymous Eendragtpan Formation. The two power plant grid connection options under consideration are both short with a small anticipated footprint (*i.e.* pylon footings). Although they traverse potentially fossiliferous Karoo Supergroup rocks, direct impacts on subsurface bedrocks are rated as negligible.

The isolated portion of the study area on Jakhalsvley 309, to the west of the Grootegeluk opencast mine, overlies bedrocks of the Grootegeluk and Swartrant Formations (Karoo Supergroup). These sedimentary successions are correlated with the Ecca Group of the Main Karoo Basin and are likewise known to be associated with rich plant fossil assemblages of the *Glossopteris* Flora of Gondwana. Palaeofloras of the Waterberg Coalfield are still very poorly known, despite a history of large-scale mining here. Substantial excavations into, or sealing-in of, the bedrocks on Farm Jakhalsvley 309 may have significant negative impacts on possible fossil-rich horizons in the subsurface (*e.g.* coal seams and associated sedimentary partings). Should this site be selected for the proposed ash dump, a field-based palaeontological assessment would be required prior to development in order to determine if any fossiliferous surface exposures will be impacted. Specialist palaeontological mitigation may then be required during the construction phase of the ash dump (See Almond 2015). *Provided that* the recommended mitigation measures are carried through, it is likely that negative impacts of the proposed mining on local fossil resources will be substantially reduced. Furthermore, they will be partially offset by the *positive* impact represented by increased understanding of the palaeontological heritage of the coal measures of Limpopo.

Please note that:

- All South African fossil heritage is protected by law (South African Heritage Resources Act, 1999) and fossils cannot be collected, damaged or disturbed without a permit from SAHRA or the relevant Provincial Heritage Resources Agency (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za);

- The palaeontologist concerned with mitigation work will need a valid fossil collection permit from SAHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection);
- All palaeontological specialist work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies developed by SAHRA (2013).

6. ACKNOWLEDGEMENTS

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8. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

Dr John Almond has an Honours Degree in Natural Sciences (Zoology) as well as a PhD in Palaeontology from the University of Cambridge, UK. He has been awarded post-doctoral research fellowships at Cambridge University and in Germany, and has carried out palaeontological research in Europe, North America, the Middle East as well as North and South Africa. For eight years he was a scientific officer (palaeontologist) for the Geological Survey / Council for Geoscience in the RSA. His current palaeontological research focuses on fossil record of the Precambrian - Cambrian boundary and the Cape Supergroup of South Africa. He has recently written palaeontological reviews for several 1: 250 000 geological maps published by the Council for Geoscience and has contributed educational material on fossils and evolution for new school textbooks in the RSA.

Since 2002 Dr Almond has also carried out palaeontological impact assessments for developments and conservation areas in the Western, Eastern and Northern Cape, Limpopo, Mpumalanga, Free State and Northwest Province under the aegis of his Cape Town-based company *Natura Viva* cc. He is a long-standing member of the Archaeology, Palaeontology and Meteorites Committee for Heritage Western Cape (HWC) and an advisor on palaeontological conservation and management issues for the Palaeontological Society of South Africa (PSSA), HWC and SAHRA. He is currently compiling technical reports on the provincial palaeontological heritage of Western, Northern and Eastern Cape for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHP (Association of Professional Heritage Practitioners – Western Cape).

Declaration of Independence

I, John E. Almond, declare that I am an independent consultant and have no business, financial, personal or other interest in the proposed development project, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

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