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PRELIMINARY GEOTECHNICAL SITE INVESTIGATION REPORT FOR TOWNSHIP DEVELOPMENT IN PARTS OF RE/720 IN BRANDFORT, MASILONYANA LOCAL MUNICIPALITY, FREE STATE PROVINCE

Report No.: 421-07-2020 Date: July 2020

PREPARED FOR: Free State Province Department of Human Settlements

human settlements
Department of Human Settlements
FREE STATE PROVINCE

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TITLE : **PRELIMINARY GEOTECHNICAL SITE INVESTIGATION FOR TOWNSHIP DEVELOPMENT IN PARTS OF RE/720 IN BRANDFORT, MASILONYANA LOCAL MUNICIPALITY, FREE STATE PROVINCE.**

Project Team : Mr. Sandile Khumalo Cand.Sci.Nat

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Mr. Tshwaro Mogadime Pr.Sci.Nat

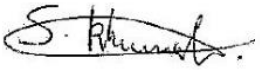
Client : Free State Province Department of Human Settlements

Thoka Geo Report No : 421-07-2020

Status of the Report : Preliminary

Date of the Report : 09 July 2020

For Thoka Geo

	Initials & Surname	Signature	Date
Compiled By	S Khumalo Cand.Sci.Nat		03 July 2020
Reviewed By	W Khumalo BSc Hons. Geology		09 July 2020
Approved By	ME Mogadime Pr.Sci.Nat		

Client

Received by : _____ _____ _____

Initials & Surname Signature Date

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1 INTRODUCTION

1.1 TERMS OF REFERENCE

Thoka Geosciences Pty Ltd was appointed to undertake preliminary geotechnical site investigation for the site selected for the proposed township development as requested by the Free State Province Department of Human Settlements.

This report addresses findings of the undertaken preliminary geotechnical site investigation for the proposed township development, and it is intended solely for the associated engineering applications as stated under Report Provisions.

1.2 PROPOSED DEVELOPMENTS

The proposed development is understood to be the formalization of Majwemasweu Informal Settlements into a Township. The proposed infrastructure and service developments for this site includes, residential units, business units, schools, church buildings, municipal offices, special units, electrical powerlines, sports & recreation, roads, underground works etc. (refer to Appendix II).

1.3 OBJECTIVES

The objectives of the investigation were to:

- Identify specific geology of the site and potential geotechnical restraining factors
- Assess the exposure and vulnerability of the site with respect to Geo-hazards
- Establish possibility of existence or non-existence of any groundwater and abnormal water table level challenges
- Provide the geotechnical basis for safe and appropriate land use planning

1.4 REPORT PROVISIONS AND EXCLUSIONS

Information gathered during this investigation is considered suitable for the site assessment purposes, and once the proposed development is approved, Phase 1 Geotechnical Site Investigation will be required to provide guidance to designing engineers.

1.5 SCOPE

The scope of the preliminary geotechnical site investigation involves consultation of existing information about the site and/or surrounding environment, this includes geological maps, geotechnical reports, mining reports, aerial photographs, climatic conditions, temperature variability, vegetation, topography, and seismic zoning maps.

1.6 SOURCES OF INFORMATION

An attempt was made to collect as much information as possible for the site. For this purpose, the following sources of information were studied as part of the investigation:

- 1: 250 000 Geological Map - Sheet 2826 Winsburg, Copyright Geological Survey of South Africa (Council for Geosciences)
- 1: 500 000 Hydrogeological Map - Series 2726 Kroonstad, Department of Water Affairs and Forestry
- Lejweleputswa District Municipality. Integrated Development Plans.
- Masilonyana Local Municipality. Integrated Development Plans.
- Google Earth Satelite Imagery

2 SITE DESCRIPTION

2.1 GEOGRAPHIC DESCRIPTION

The site proposed for the township development is located within farm RE/720 in Brandfort within Masilonyana Local Municipality, Lejweleputswa District Municipality, Free State Province (refer to Appendix I: Map 1). The site is located on geographic coordinates 28°41'27.52"S, 26°26'41.93"E with surface elevation ranging from 1392m above mean sea level (amsl) in the west to 1403m amsl in the east.

The site investigated is approximately 50 hectares in extent and is bounded by informal settlements in east and agricultural farms on other sides (refer to Appendix I: Map 3).

2.2 TOPOGRAPHY

Topographically, the site is charaterised by slightly inclined terrain predominantly towards the east. Hence, it is considered naturally stable as far as slope instability is concerned.

2.3 CLIMATE

Brandfort normally receives about 670 mm of rainfall annually, with most rainfall occurring mainly during summer. The region is the coldest during July when the mercury drops to -3 °C on average. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for Brandfort ranges from 14 to 26 °C.

According to the Thornwaite's moisture index, the area falls in the region of -20 to 0 which interprets a sub-humid condition (Schultze, 1958). The Weinert N-value for the area is less than 5 which indicates that chemical weathering predominates over mechanical weathering processes (Weinert, 1980).

2.4 DRAINAGE

The sufficiency of drainage is an important aspect of geotechnical stability, especially in karst formation prone land. Inefficient drainage may result to ponding of surface water during heavy rain seasons which could ultimately result into flooding and concentrated surface water ingress into groundwater which could result into mobilisation of soluble rock/soil and create ground instability in the form of subsidence and sinkhole formation in dolomitic land.

The site drains by means of sheet-wash towards the west and subsequently into Aardoringspruit River and Keeromspruit River flowing towards the south west.

2.5 VEGETATION

According to Acocks **(Ref.1)**, the region is characterised by *Dry Cymbopogon-Themeda Veld*. The site is covered mainly by grass with isolated trees towards the southern boundary.

2.6 LAND-USE

The proposed development is located on farm portion RE/720, which is previously disturbed land within informal settlements and is understood to be municipally owned property. Aerial photographs showed that the site was used for agricultural activities dating from 2013 backwards. Lately, from 2014 to 2020 the site is used as residential community by informal settlement dwellers as agricultural uses fades out. Refer to Appendix II for a drawing of the proposed township.

2.7 MINING ACTIVITIES

There are no mining operations within the radius of 30 km from the site that may have a negative impact on the proposed township development.

3 PRELIMINARY GEOTECHNICAL INVESTIGATION PROCEDURE

The approach adopted was to acquire as much information as possible about the proposed site and surrounding environments in accordance with the published Site Investigation Code of Practice, published by The Geotechnical Division of the South African Institution of Civil Engineering (SAICE), 2008. The GFSH-2 and SANS 634 were also consulted.

3.1 DESKTOP STUDY

Desktop studies have entailed the examination of available published geological maps, a study of site geomorphology using satellite imagery and the reading of existing geological, engineering geological, hydrogeological reports, municipal integrated development plan and/or web-sourced technical reports, within the immediate area.

4 SITE GEOLOGY & HYDROGEOLOGY

4.1 GENERAL

In general, geological material may be described as follows:

- **Transported soils** - These are soils which have been transported by a natural agent (imported fill, alluvium, hillwash etc.) during relatively recent geological times and which have not undergone lithification into a sedimentary rock or cementation into a pedogenic material.
- **Residual soils** – Soils derived from the weathering of the underlying rock and have not moved from the place of origin as with transported soils.
- **Rock** – Semi-hard to hard mass of natural material composed of one or more minerals commonly classified into three groups according to their modes of origin. They are sedimentary rock, metamorphic rock, or igneous rock.

4.2 REGIONAL GEOLOGY

According to the Geological Map-Sheet 2826 Winsburg at a scale of 1:250 000, the site is regionally characterised by the Karoo Supergroup rocks (Appendix I: Map 2). This includes grey to black shale, and subordinate light grey sandstone of the Adelaide Subgroup of the Beaufort Group. Adelaide Subgroup underlying rocks were later intruded by Jurassic Period dolerite which occur as dykes and sills.

The red and grey aeolian dune sand overlain by the calcified alluvium and river gravel all deposited in Quaternary Period provides the cover for Karoo Supergroup.

4.3 LOCAL GEOLOGY

The site is covered by red and grey aeolian dune sand deposited in Quaternary Period.

As could be seen from the map and satellite image, there are no geological features such as faults, and lineaments within the immediate vicinity of the site (refer to Appendix I: Map 2).

4.4 REGIONAL HYDROGEOLOGY

The site is located within the Upper Orange Water Management Area on C52 Tertiary Drainage Region which is regionally characterized by the fractured aquifer of Ecca Group belonging to the Karoo Supergroup. Groundwater occurrence in the predominantly argillaceous beds of the Ecca Group is associated with dolerite contact zones, joints (often the result of mechanical weathering) and bedding planes. A borehole yield analysis indicates that the overall median yield range for this unit falls in the 0.5 *l/s* to 2.0 *l/s* category.

5 POTENTIAL GEOHAZARDS

5.1 ERODABILITY OF SOIL

In general, four major categories of parameters are normally used in the qualitative assessment of soil erosion risk, namely: (1) slope: slope gradient, length, form; (2) soil/geology: soil depth, texture, surface sealing; (3) vegetation/ land use: vegetation cover, rainstorm frequency, conservation practices; (4) erosion and mass movement: rating of wind erosion, sheet erosion, rill/gully/ravine erosion, mass movement. Such a detailed study is beyond the present scope of investigations. However, according to van Zuidam (1969) slopes in excess of 4 to 6 degrees will become susceptible to soil erosion, particularly when the surface cover is degraded and poor ploughing practices are employed.

The GFSH-2 (2002) document and recently, the National Building Code issued by the Department of Human Settlements (DHS, 2009), defines two categories of erodibility that qualify for an additional subsidy. Both qualify the soil type, slope and dispersivity conditions to be present. The site is located within the region of medium (value= 9-15) to high (value= 1-8) erodibility potential, according to the national erodibility map provided in the DHS Building Code document. However, the site may be classified as Category 2 and 3 (medium to high risk), in terms of erodibility (refer to Appendix IV: Figure 2).

5.2 SINKHOLE FORMATION

Information received from the Council for Geosciences indicates that the site and its immediate environs is not characterised by soluble rocks such as dolomite or limestone (Plate 1). Therefore, the formation of karst-related subsurface topography leading to the formation of sinkholes and subsidences is unlikely (refer to Appendix IV: Figure 3).

5.3 SLOPE INSTABILITY

The probabilities of any mass movement events (landslides, mudslides, debris flows, rock falls, rock slides etc.) occurring within farm portion RE/720 are remote. This is primarily due to the low relief present on site and for 3 - 4 km radius.

5.4 UNDERMINED GROUND

There are no mining activities nearby that may have a negative impact on or endanger the community. It should however be noted that mining activities in the region are located far to the north of the site, hence, no negative impact will be encountered by the community and its surrounds. Therefore, no subsidence may be associated with mining activity around the site (refer to Appendix IV: Figure 6).

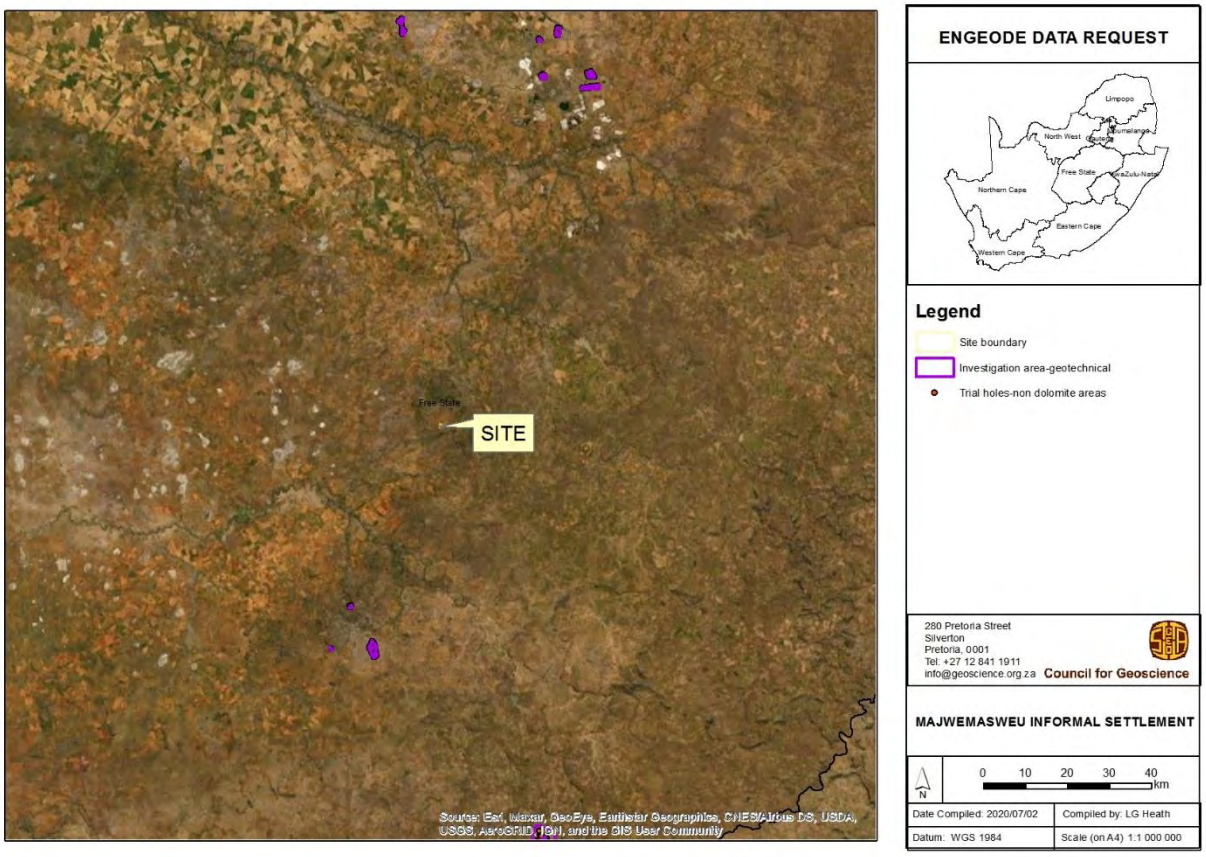

Plate 1: Historical Investigations by the Council for Geosciences.

5.5 AREAS SUBJECT TO FLOODING

The site is bordered by a watercourse along the eastern boundary, consequently, during seasons of abnormal rainfall, floods may be anticipated in those areas. By law, residential developments below the 1:50-year flood lines areas are prohibited. This is due to the risk of flooding leading to property damage, health and life hazards, inconveniences, etc.

A 1:50-year flood line implies that an area below that line has a high probability of being flooded at least once in every fifty-year period. A similar contextual definition applies for the 1:100-year flood line. Calculated flood lines for all nearby watercourses and streams should be available from the Local and/or District Municipality Town Planning Department. If not, a hydrologist should undertake this determination.

The site is not located on known floodplains, and there is no evidence of flooding history within the site.

5.6 LIQUEFACTION

Liquefaction occurs when loose, cohesionless, water- saturated soils (generally fine-grained sand and silt) are subject to strong seismic ground motion of significant duration. These soils essentially behave similar to liquids, losing much of its shear strength. Developments constructed on these soils may buckle, tilt or settle when the soils liquefy. Liquefaction more often occurs in earthquake-prone areas underlain by young sandy alluvium where the groundwater table is less than 15 m below the existing ground surface.

Liquefaction Hazard Map prepared by the Council for Geosciences shows that the site is not located within a potential liquefaction zone (refer to Appendix IV: Figure 7).

5.7 SEISMIC ACTIVITY

The peak ground acceleration (PGA) is the maximum acceleration of the ground shaking during an earthquake. The seismic hazard map of South Africa **(Ref.3)**, indicates that the site generally lies within an area where there is a 10% probability that Peak Ground Accelerations of 0.15 g will be exceeded in 50 years, which corresponds to a seismic intensity of VI on the Modified Mercalli Scale (MMS) (Plate 2). The physical impacts of such earthquakes are outlined hereunder:

- Felt by all.
- Many frightened and run outdoors.
- People walk unsteadily.
- Windows, dishes, glassware broken.
- Knickknacks, books, etc., off shelves, Pictures off walls.
- Some heavy furniture moved or overturned.
- Weak plaster and masonry D cracked, some chimneys broken.
- Small bells ring (church, school).
- Trees, bushes shaken visibly, or heard to rustle.

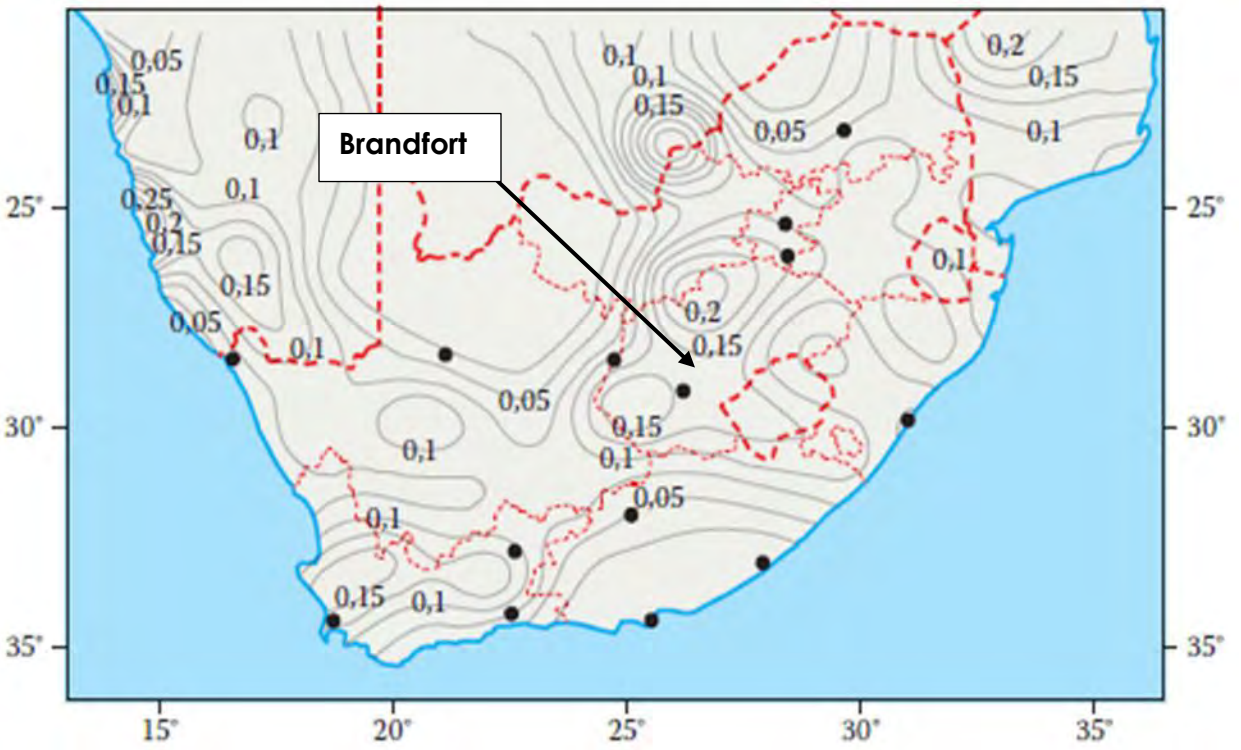

Plate 2: Seismic Hazard Map showing the Peak Ground Acceleration (gravity acceleration) with 10% probability of being exceeded in a 50-year period.

6 PRELIMINARY ENGINEERING & MATERIAL CHARACTERISTICS

6.1 GENERAL

The following findings are based on our review of existing data. Phase 1 geotechnical site investigations should be conducted for the proposed township development to provide recommendations for safe excavation procedures, foundation designs, and construction material availability.

6.2 POTENTIALLY EXPANSIVE SOILS

Damage to structures erected on potentially active soils occurs where the expansiveness has not been determined and necessary remedial measures not employed. The potential expansiveness of a soil depends upon its clay content, the type of clay mineral present, its chemical composition and mechanical character. A material is potentially expansive if it exhibits the following properties (van der Merwe, 1964):

- Clay content of more than 12 %
- Plasticity index of more than 12 %
- Linear shrinkage of more than 8 %

According to the information published by the Council for Geosciences, the site soils are characterised by expansive clays. Therefore, the potential expansiveness for this clay soil is anticipated to be “severe”. The possibility of structural distress resulting from cyclic drying shrinkage in dry seasons and swell after wetting is therefore anticipated to be high (refer to Appendix IV: Figure 4).

6.3 COLLAPSIBLE AND COMPRESSIBLE SOILS

Collapsible soils can withstand relatively large imposed stresses with small settlements at low in situ moisture content, but this can increase rapidly when saturation wetting occurs under loaded (house) conditions. It can occur in any open-textured, clayey to silty sandy soils, with a high void ratio and generally low *in-situ* dry density.

According to the information published by the Council for Geosciences, the site soils possesses the potentially collapsible fabric (refer to Appendix IV: Figure 5). In addition Aeolian sand deposits are generally expected to be compressible throughout the entire depth.

6.4 AGGRESSIVE SOILS

Dispersion can occur in any given soil with a high percentage of exchangeable sodium percentage (ESP). A dispersive soil is prone to desegregation or separation of clay particles from the soil mass upon contact with water. These soils can be identified by the presence of erosion gullies, soil piping and areas of stunted growth and ponds of cloudy water. The Emmerson Crumb test is used to identify the dispersivity of soil samples by determining the tendency of soil particles to deflocculate and go into suspension.

The site geology is mainly Karoo Supergroup which is well known to be the source of dispersive clays. However, the majority of these occur in areas of relative water scarcity. In addition, satellite images showed south west to north east trending small scale gully erosions around the area of study. It is apparent from aerial photographs observation that the site soils may be classified as slightly dispersive.

6.5 CORROSIVENESS

Corrosive soils contain chemical constituents that may cause damage to construction materials such as concrete and ferrous metals. One such constituent is water-soluble sulphate, which, if high enough in concentration, can react with and damage concrete. Electrical resistivity, chloride content and pH level are indicators of the soil's tendency to corrode ferrous metals.

Based on our preliminary investigation, the soil on site is expected to be slightly corrosive towards metals. Therefore, testing of the soils should be conducted in order to identify the corrosiveness of the earth materials on site.

Table 1: Preliminary Geotechnical Site Characterization

Letter	Constraint	Site Condition	Class
A	Collapsible soil	Low potential collapse anticipated	1 / 2
B	Seepage	Permanent or perched water table more than 1.5 m.	1
C	Active soil	Severe soil heave anticipated	1 / 2
D	Highly compressible soil	Moderate to high soil compressibility anticipated	1 / 2
E	Erodibility of soil	Low to medium	1 / 2
F	Difficulty of excavation to 1,5 m depth	Rock or hardpan pedocretes more than 40% of the total volume.	1
G	Undermined ground	Not undermined	1
H	Instability in areas of soluble rock	Not characterised by dolomitic bedrock	1
I	Steep slopes	Near horizontal natural slopes (Between 2 and 6 degree).	1
J	Areas of unstable natural slopes	Low risk	1
K	Areas subject to seismic activity	10 % probability of an event less than 100 cm/s² within 50 years	1
L	Areas subject to flooding	Not adjacent to floodplains, however, flood line investigation required	1

7 CONCLUSIONS

Thoka Geosciences (Pty) Ltd was appointed to undertake preliminary geotechnical investigation for the site selected for the proposed township development as requested by the Free State Province Department of Human Settlements.

The site proposed for the township development is located within farm RE/720 (~50 ha, 28°41'27.52"S, 26°26'41.93"E) in Brandfort within Masilonyana Local Municipality, Majwemasweu District Municipality, Free State Province.

The approach adopted was to acquire as much information as possible about the proposed site and surrounding environments in accordance with the published Site Investigation Code of Practice, published by The Geotechnical Division of the South African Institution of Civil Engineering (SAICE), 2008. The GFSH-2 and SANS 634 were also consulted.

The site is regionally characterised by the Karoo Supergroup rocks. This includes grey to black shale, and subordinate light grey sandstone of the Adelaide Subgroup of the Beaufort Group. Adelaide Subgroup underlying rocks were later intruded by Jurassic Period dolerite which occur as dykes and sills. The red and grey aeolian dune sand overlain by the calcified alluvium and river gravel all deposited in Quaternary Period provides the cover for Karoo Supergroup.

The preliminary geotechnical site investigation indicate that the site may be located on potential expansive soils and collapsible soils. The land was previously used for agricultural activities where different chemicals are used to fertilize soils; for these reasons soil corrosiveness must be tested.

The conditions prevailing at the site suggest that no problems are foreseen for the land to be released for further geotechnical investigations.

It is recommended that Phase 1 Geotechnical Site Investigations for the site be conducted to confirm and/or enhance the findings of this preliminary report. The investigation should focus on confirming soil characteristics at founding depth.

8 REFERENCES

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15) Weinert, H.H. (1980). *The Natural Road Construction Materials of Southern Africa*. H & R Academia Publ., Pretoria, 298 pp.

9 APPENDICES

Appendix I

Map 1: Locality Map

Map 2: Geological Map

Map 3: Site Map

Appendix II

Site Development Drawings

Appendix III

Seismic Classification Tables

Appendix IV

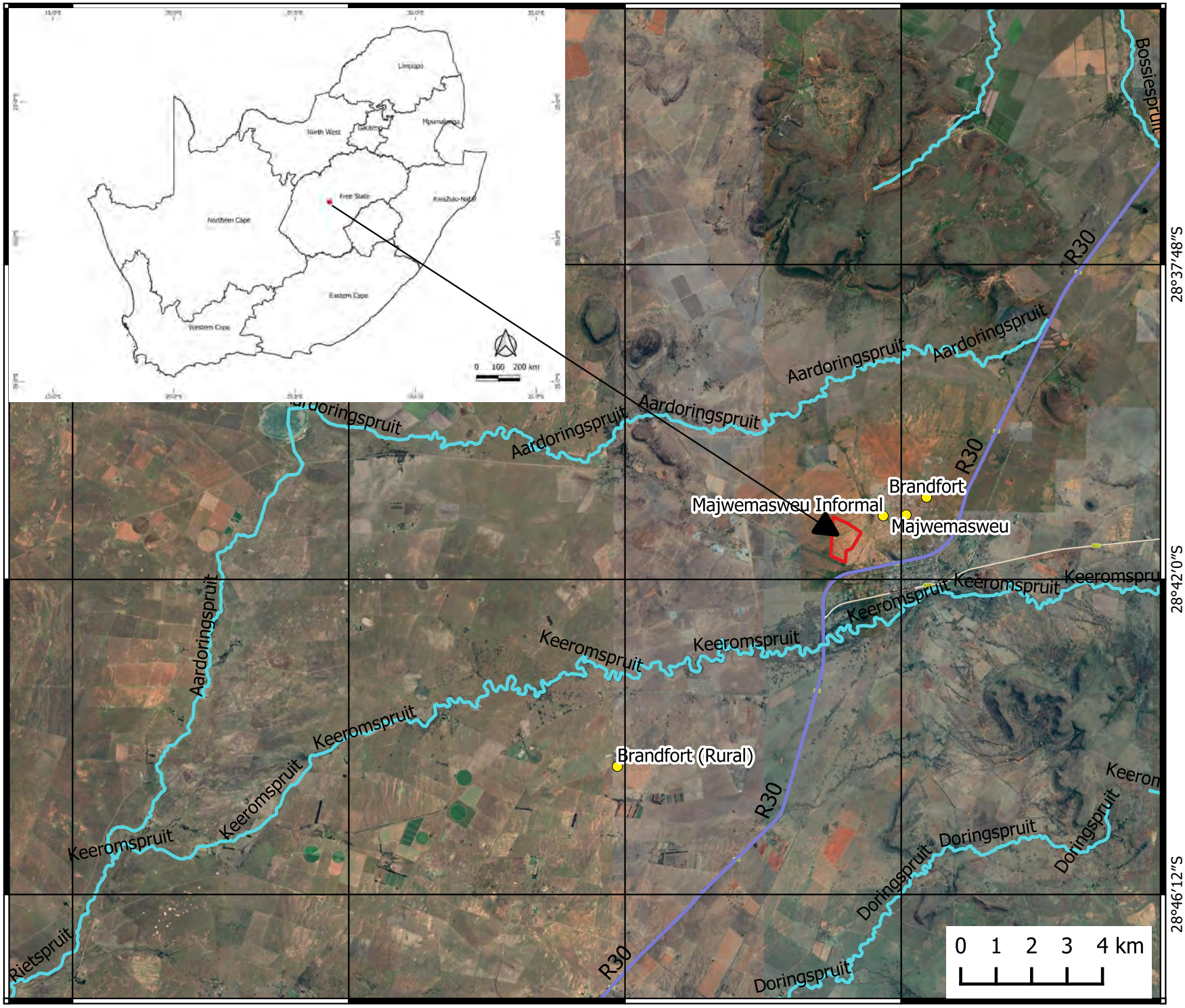
Council for Geosciences Maps

Appendix I:

Map 1: Locality Map

Map 2: Geological Map

Map 3: Site Map



Map 1: Proposed Township Development Locality Map
Title: Geotechnical Investigation
Site: Farm RE720, Brandfort, Free State Province
Client: Free State Province Department of Human Settlements
Company: Thoka Geosciences (Pty) Ltd

N

Legend

- Place Name
- River

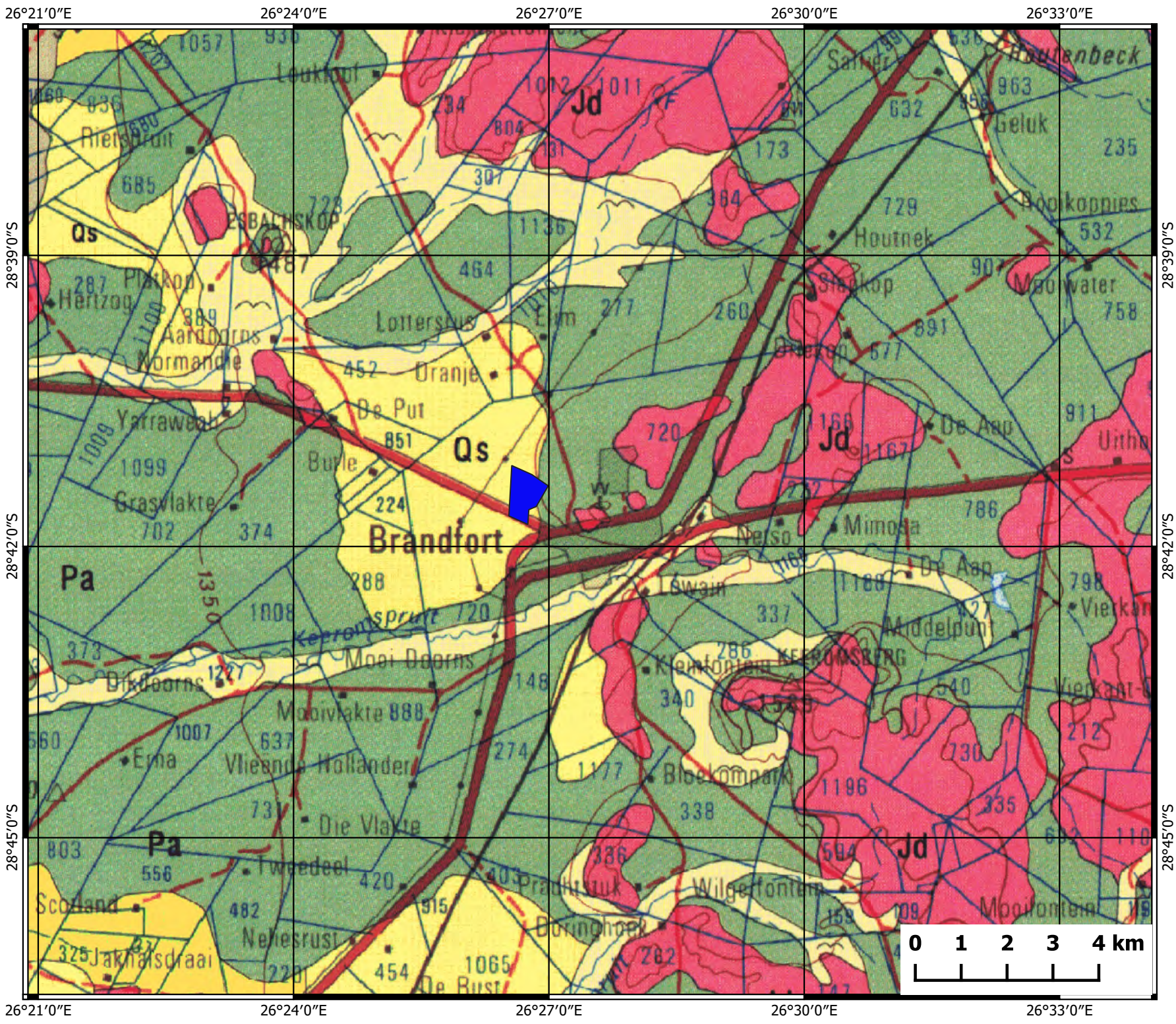
South Africa_Roads

- R30
- Proposed Joe Slovo Township Development

human settlements
Department of Human Settlements
FREE STATE PROVINCE

THOKA GEOSCIENCES PTY LTD

Map Datum: WGS84
Date: July 2020



Map 2: Abstract of 2826 Winsburg Geological Map
Title: Geotechnical Investigation Site: Farm RE720, Brandfort, Free State Province
Client: Free State Province Department of Human Settlement
Company: Thoka Geosciences (Pty) Ltd

N

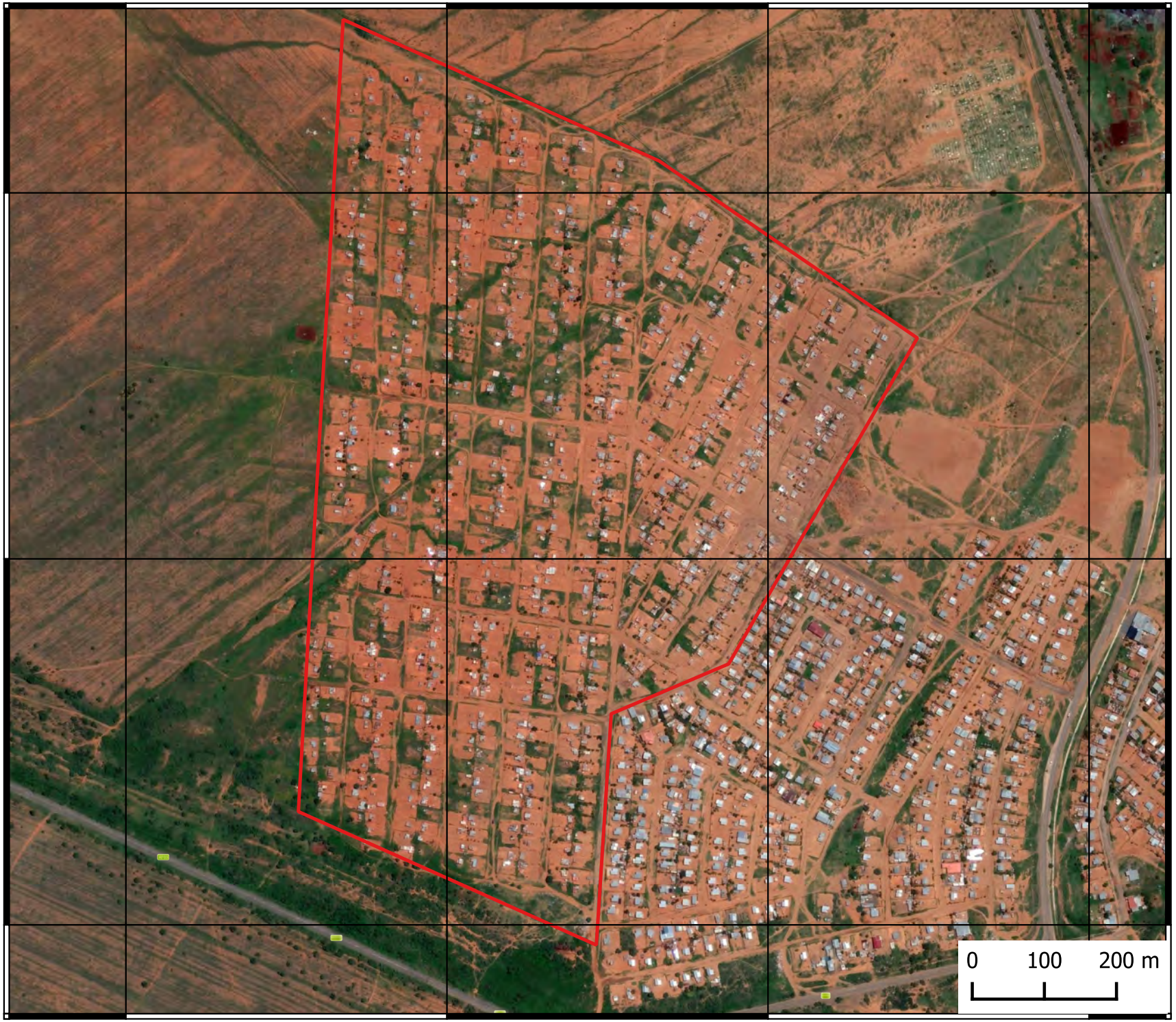
Legend

- Study Site
- Alluvium
- Qs (Aeolian sand deposits)
- Jd (Dolerite)
- Pa (Shale, sandstone)

human settlements
Department of Human Settlements
FREE STATE PROVINCE

THOKA GEOSCIENCES PTY LTD

Map Datum: WGS84
Date: July 2020



Map 3: Site Map
Title: Geotechnical Investigation
Site: Farm RE720, Brandfort, Free State Province
Client: Free State Province Department of Human Settlements
Company: Thoka Geosciences (Pty) Ltd

N

Legend

Proposed Township Development

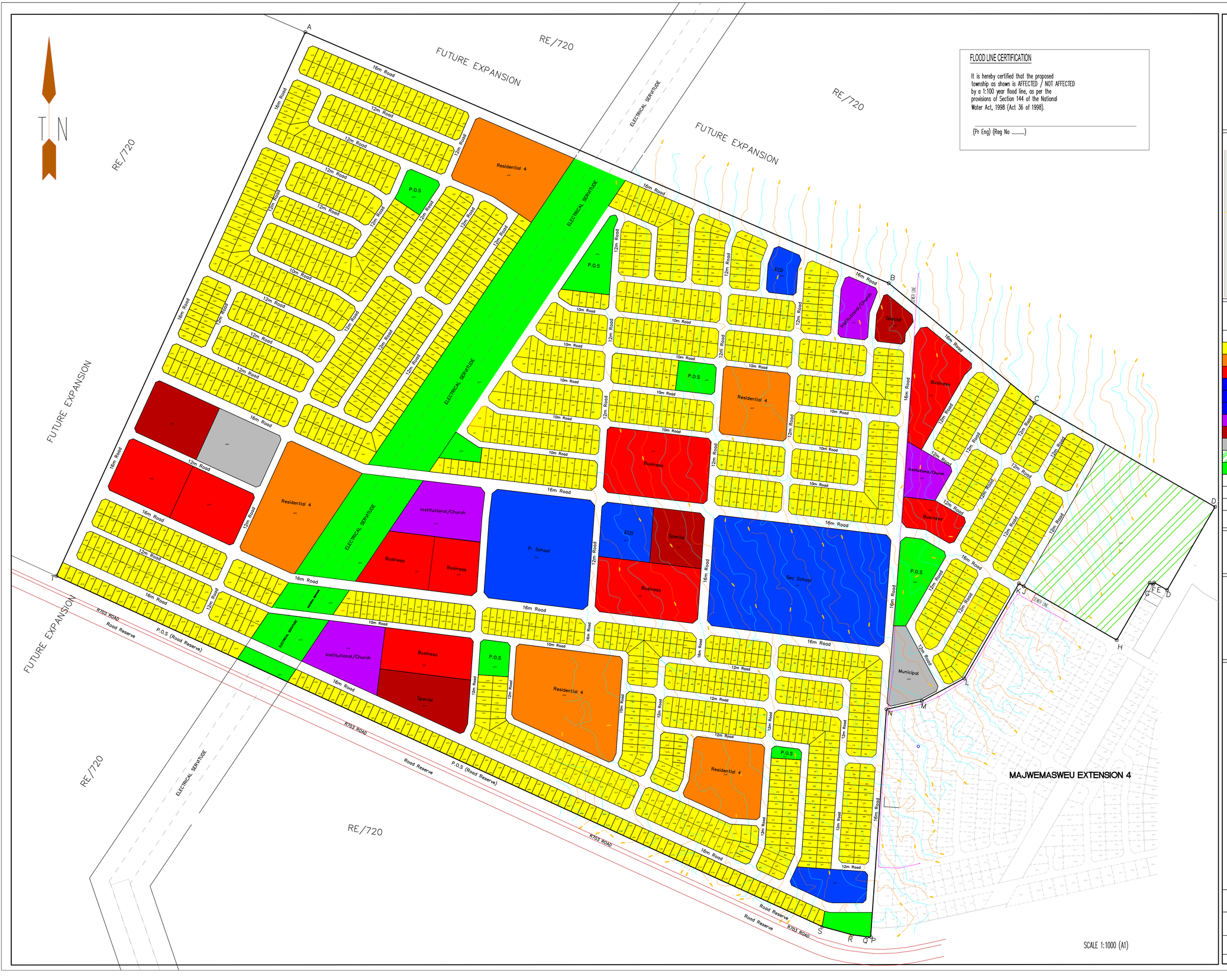
human settlements
Department of Human Settlements
FREE STATE PROVINCE

THOKA GEOSCIENCES PTY LTD

Map Datum: WGS84
Date: July 2020

Appendix II:

Site Development Drawings



FLOOD LINE CERTIFICATION

It is hereby certified that the proposed township as shown is AFFECTED / NOT AFFECTED by a 1:100 year flood line, as per the provisions of Section 144 of the National Water Act, 1998 (Act 36 of 1998).

(Pr Eng) (Reg No .....)

PROPOSED TOWNSHIP

PROPOSED TOWNSHIP TO BE SITUATED ON THE PORTION OF THE REMAINDER OF THE FARM BRANDFORD TOWNLAND NO. 720

LOCALITY

LEGEND

	ZONING	ERF NO.	NO. OF ERVEN	AREA [HA]	% OF AREA
	Residential	1 - 2036	2036	62,3651	41.75
	Residential 4	2037 - 2041	5	9,6886	6,49
	Business	2042 - 2050	9	9,9812	6,68
	Secondary School	2051	1	5, 4732	3,66
	Primary School	2052	1	3, 1503	2,11
	Nursery School	2053 - 2055	3	1,7483	1,75
	Church	2056 - 2059	4	3,3657	2,25
	Special	2060 - 2063	4	3,3906	2,27
	Municipal	2064 - 2065	2	1,8906	1,27
	Sports & Recreation	2066	1	5,3966	3,61
	P.O.S	2067 - 2078	12	11,6259	7,78
	ROADS			31,3505	20,99
	TOTAL		2 078	149, 3966	100

LOCAL AUTHORITY

MASILONYANA LOCAL AUTHORITY

CLIENT

human settlements
Department of Human Settlements
FREE STATE PROVINCE

GENERAL NOTES

The Figure ABCDEFGHJKLMNPQRSTA represents the proposed township to be 149, 3966 in extent

RESIDENTIAL 1 SITES

THE MAXIMUM SIZE OF RESIDENTIAL SITES = +/- 588sqm
THE MINIMUM SIZE OF RESIDENTIAL SITES = +/- 300sqm
THE AVERAGE SIZE OF RESIDENTIAL SITES = 12m * 25m [300sqm]
TOTAL NUMBER OF UNITS = 2 036 UNITS

RESIDENTIAL 4 SITES

TOTAL DEVELOPABLE SITE AREA = 96 886sqm – 40%
= 58 131 sqm /60sqm [Unit size]
= 969 Units * 2 Storeys
TOTAL NUMBER OF UNITS = 1 938 UNITS

TOTAL NUMBER OF RESIDENTIAL UNITS = 2 036 + 1 938
= 3 972 UNITS

ROADS

RESERVE WIDTHS OF ALL INTERNAL STREETS ARE INDICATED ON THE PLAN
SPLAYS ON ALL STREETS ARE HALF THE WIDTH OF THE STREETS
MAXIMUM SLOPE ON ROADS IS : 1:40
MINIMUM SLOPE ON ROADS IS: 1:90

DATE: April 2020

DRAWING NO. Brandfort/04/20

SCALE 1:1000 (A1)

Drawn by: B.M Phahlamohlaka

VEXOCOM
REDEFINING INNOVATION

Appendix III:

Seismic Classification Tables

Classification of Earthquakes in terms of Modified Mercalli Scale Table

Intensity / Scale	Description of Outcome of Quake	Approximate Peak Ground Acceleration (g)
I	Not felt, except by a very few under, especially favourable circumstances. Marginal and long-period effects of large earthquakes.	**0.001 g**
II	Felt by a few persons at rest, especially on upper floors of buildings, or favourable places. Suspended objects may swing slightly.	**0.001 g–0.002 g**
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it is an earthquake. Hanging objects swing. Vibration like passing of light trucks. Standing motor vehicles may rock slightly. Duration estimated. May not be recognized as an earthquake.	**0.002 g–0.005 g**
IV	During the day felt indoors by many, outdoors by few. At night some awakened. Hanging objects swing. Vibrations like passing of heavy trucks, or sensation of a jolt like a heavy ball / truck striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frame make creaking sound.	**0.005 g–0.01 g**
V	Felt by nearly everyone indoors and outdoors, many sleepers awakened.Direction estimated. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Disturbances of trees, poles and other tall objects sometimes noticed. Pendulum clocks stop, start, change rate.	**0.01 g–0.02 g**
VI	Felt by all. Many frightened and run outdoors. People walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Some heavy furniture moved or overturned. Weak plaster and masonry D cracked, some chimneys broken. Small bells ring (church, school). Trees, bushes shaken visibly, or heard to rustle.	**0.02 g–0.044 g**
VII	Everyone runs outdoors. Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices, unbraced parapets and architectural ornaments. Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damage.	**0.044 g–0.094 g**
VIII	Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B, none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers and elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Sand and mud ejected in small amounts. Cracks in wet ground and on steep slopes.	**0.094 g–0.202 g**
IX	Damage considerable in specially designed structures, well designed frame structures thrown out of plumb, great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.	**0.202 g–0.432 g**
X	Some well-built wooden structures destroyed, most masonry and frame structures destroyed with foundations, ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water slashed (slopped) over banks.	**>0.432 g**
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slump and land slips in soft ground. Rails bent greatly.	
XII	Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.	

Masonry A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together using steel, concrete, etc.; designed to resist lateral forces.

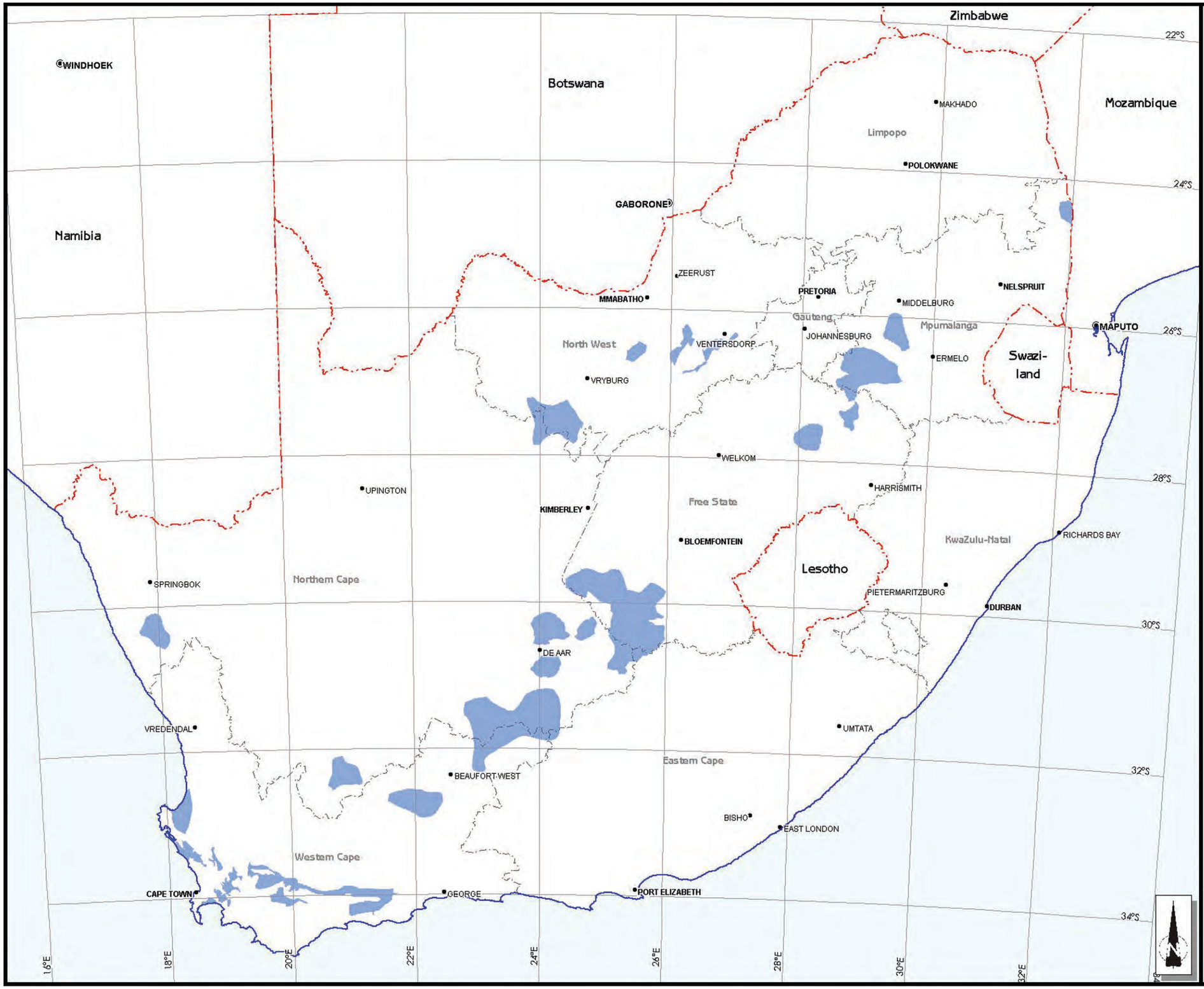
Masonry B. Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.

Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

Appendix IV

Council for Geosciences Maps



LEGEND

Boundaries

- Coastal
- International
- Provincial

Groundwater less than 10m

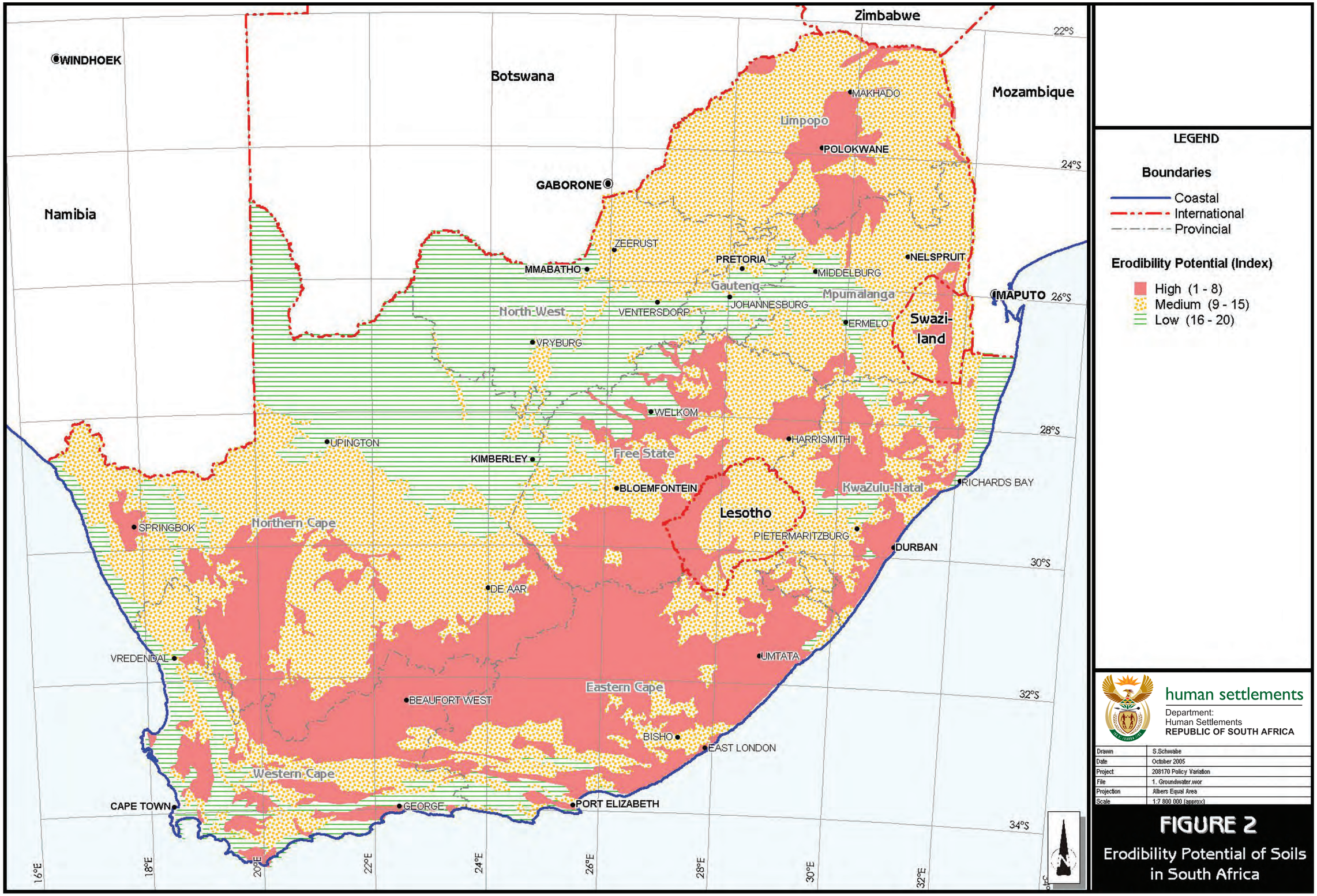
human settlements

Department:
Human Settlements
REPUBLIC OF SOUTH AFRICA

Drawn	S.Schwabe
Date	October 2005
Project	208170 Policy Variation
File	1. Groundwater.wor
Projection	Albers Equal Area
Scale	1:5 500 000 (approx)

FIGURE 1

Shallow Groundwater in South Africa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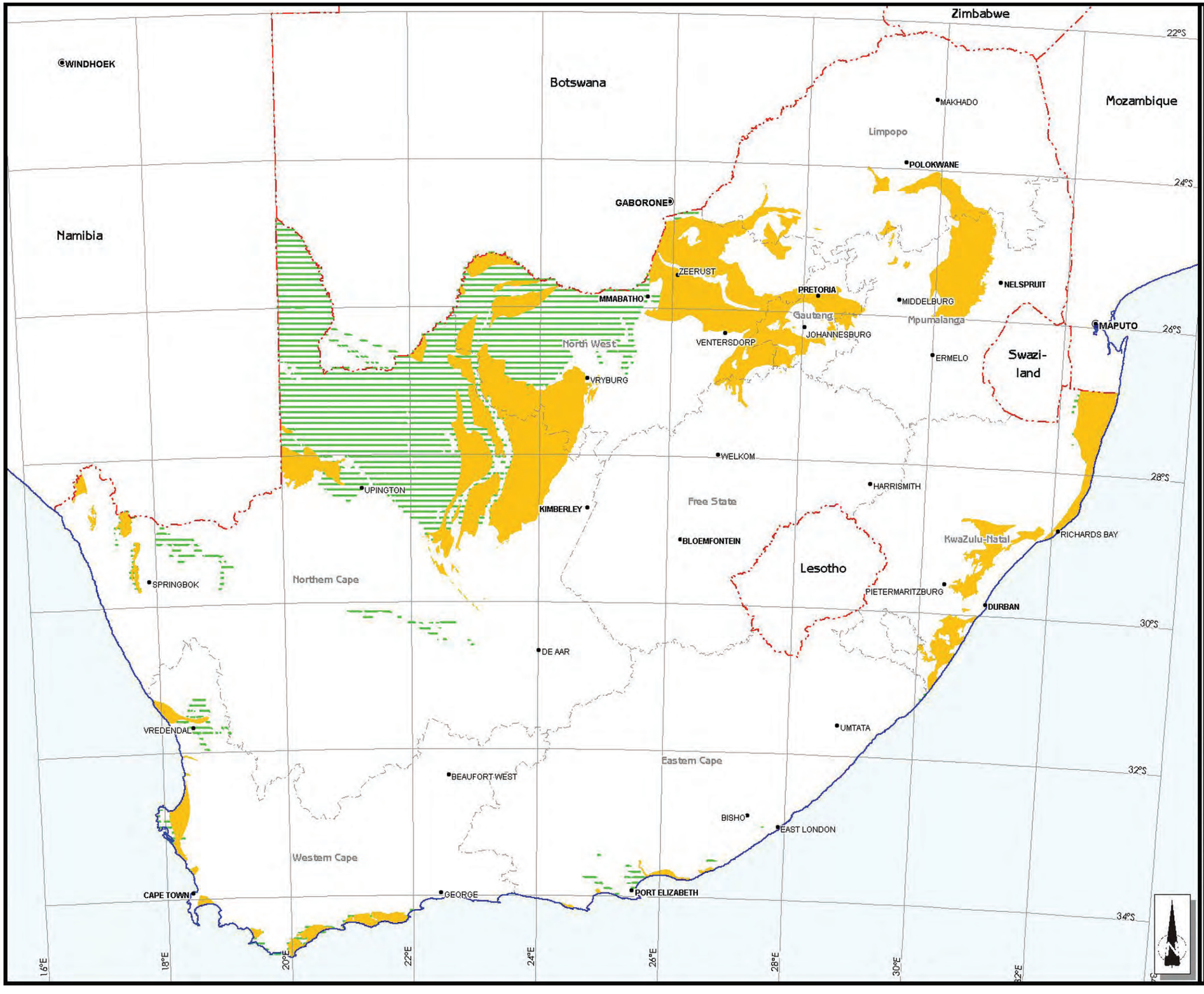
Botswana
Mozambique
Namibia
Lesotho
Swazi-land
WINDHOEK
GABORONE
MAKHADO
POLOKWANE
Limpopo
ZEERUST
MMABATHO
PRETORIA
NELSPRUIT
MIDDELBURG
Gauteng
Mpumalanga
JOHANNESBURG
VENTERSDORP
North-West
ERMELO
MAPUTO
VRYBURG
WELKOM
HARRISMITH
UPINGTON
KIMBERLEY
Free State
BLOEMFONTEIN
KwaZulu-Natal
RICHARDS BAY
SPRINGBOK
Northern Cape
PIETERMARITZBURG
DURBAN
DE AAR
VREDENDAL
UMTATA
Eastern Cape
BEAUFORT WEST
BISHO
EAST LONDON
Western Cape
CAPE TOWN
GEORGE
PORT ELIZABETH
22°S
24°S
26°S
28°S
30°S
32°S
34°S
16°E
18°E
20°E
22°E
24°E
26°E
28°E
30°E
32°E
34°E
N
LEGEND
Boundaries
Coastal
International
Provincial
Erodibility Potential (Index)
High (1 - 8)
Medium (9 - 15)
Low (16 - 20)
human settlements
Department:
Human Settlements
REPUBLIC OF SOUTH AFRICA
Drawn S.Schwabe
Date October 2005
Project 208170 Policy Variation
File 1. Groundwater.wor
Projection Albers Equal Area
Scale 1:7 800 000 (approx)
FIGURE 2
Erodibility Potential of Soils in South Africa



LEGEND

Boundaries

- Coastal
- International
- Provincial

Lithology

- DOLOMITE
- LIMESTONE

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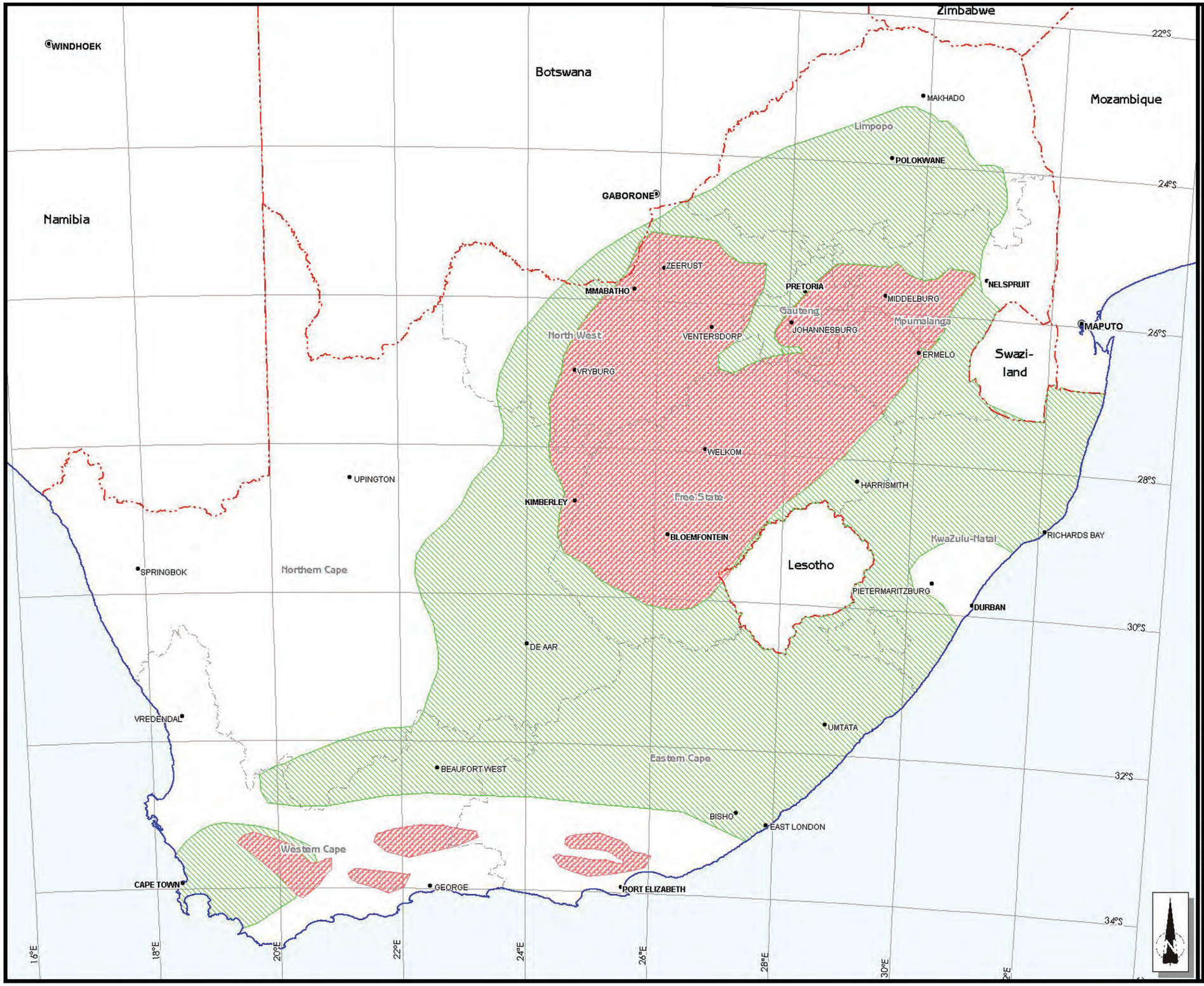
Drawn	S.Schwabe
Date	July 2005
Project	208170 Policy Variation
File	3. Dolomites.wor
Projection	Albers Equal Area
Scale	1:5 500 000 (approx)

FIGURE 3
Predominantly Dolomite and Limestone Deposits in South Africa



LEGEND

Boundaries

- Coastal
- International
- Provincial

Soils

- Expansive - some movement
- Expansive - severe movement

Data Source: Council for GeoSciences

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Drawn	S.Schwalbe
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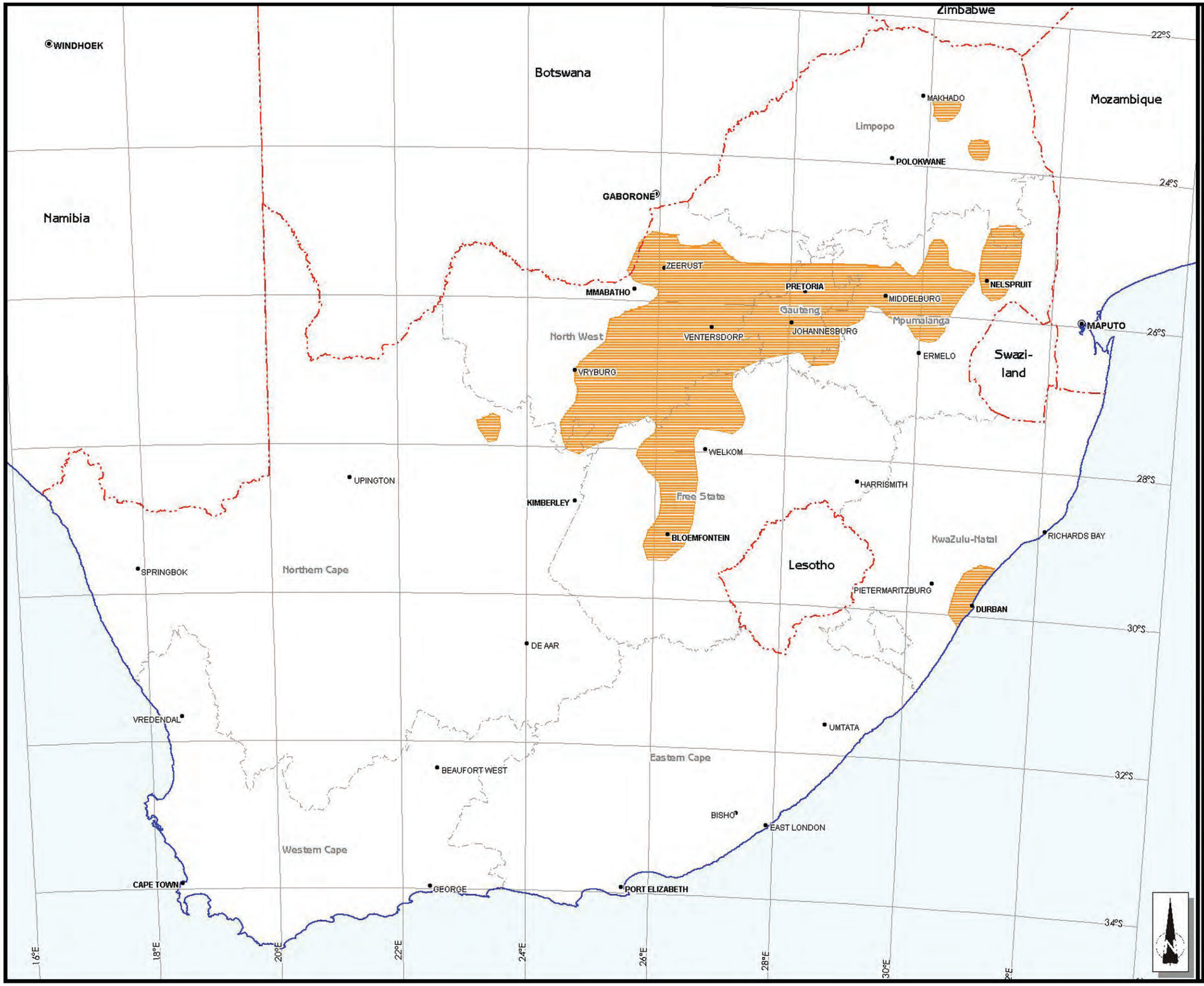
Project	208170 Policy Variation
File	4. Exp Soils.wor
Projection	Albers Equal Area
Scale	1:5 500 000 (approx)

FIGURE 4

Expansive Soils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Botswana
Namibia
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MAKHADO
Limpopo
POLOKWANE
GABORONE
ZEERUST
MMABATHO
PRETORIA
NELSPRUIT
MIDDELBURG
Gauteng
Mpumalanga
North West
VENTERSDORP
JOHANNESBURG
MAPUTO
ERMELO
Swazi-
land
VRYBURG
WELKOM
UPINGTON
HARRISMITH
KIMBERLEY
Free State
BLOEMFONTEIN
KwaZulu-Natal
RICHARDS BAY
Lesotho
SPRINGBOK
Northern Cape
PIETERMARITZBURG
DURBAN
DE AAR
VREDENDAL
UMTATA
Eastern Cape
BEAUFORT WEST
BISHO
EAST LONDON
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GEORGE
PORT ELIZABETH
22°S
24°S
26°S
28°S
30°S
32°S
34°S
16°E
18°E
20°E
22°E
24°E
26°E
28°E
30°E
LEGEND
Boundaries
Coastal
International
Provincial
Soils
Potentially Collpasible
Data Source: Council for GeoSciences
human settlements
Department:
Human Settlements
REPUBLIC OF SOUTH AFRICA
Drawn S.Schwalbe
Date July 2005
Project 208170 Policy Variation
File 5. Coll Soils.wor
Projection Albers Equal Area
Scale 1:5 500 000 (approx)
FIGURE 5
Collapsing or
Compressible Soils

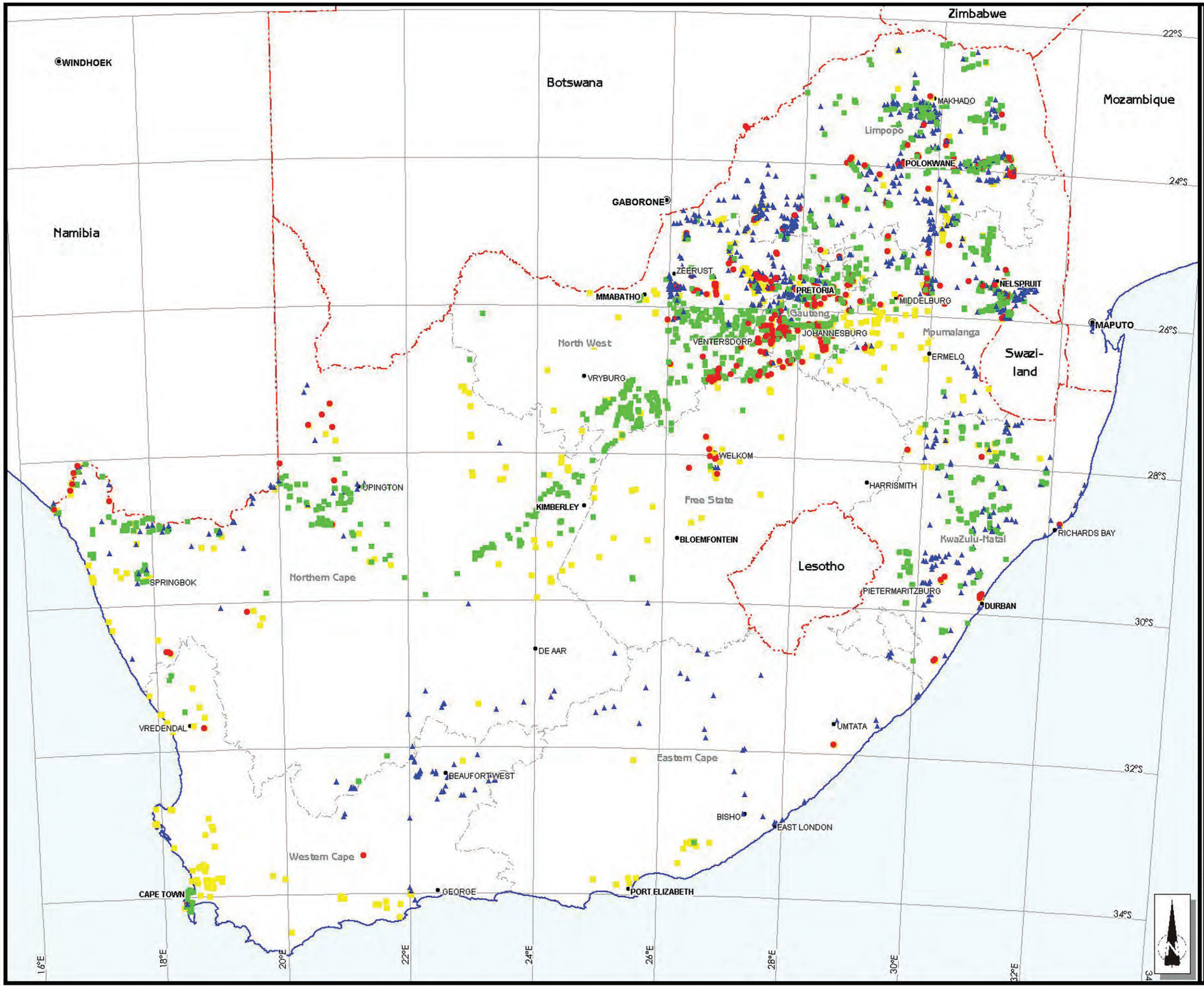
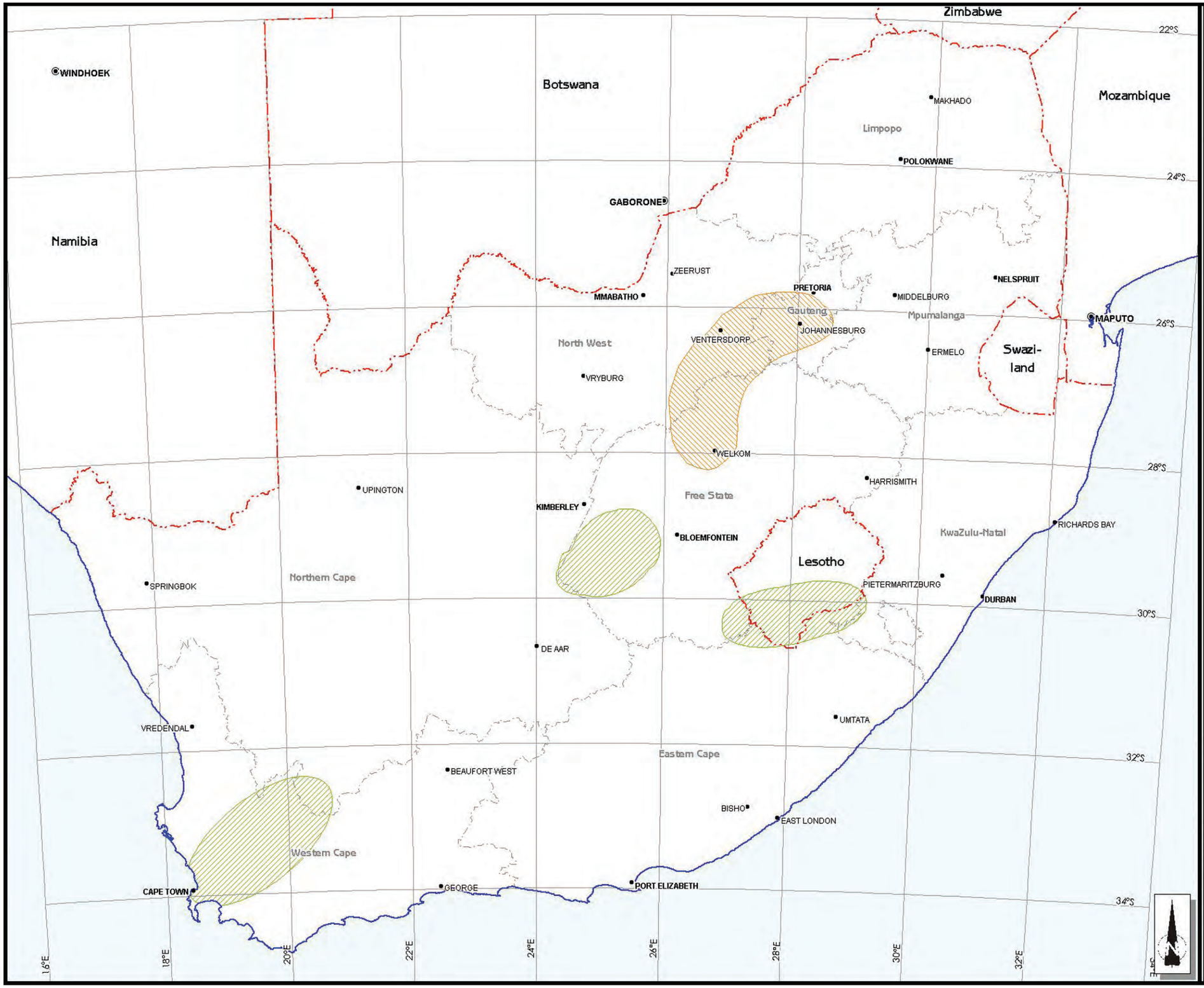


FIGURE 6
Areas of Possible Subsidence due to Mining Activity in South Africa



LEGEND

Boundaries

- Coastal
- International
- Provincial

Seismic Hazard Zones

- Low Natural Activity
- Mining Induced Activity

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Drawn	S.Schwalbe
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Project	208170 Policy Variation
File	7. Liquefaction.wor
Projection	Albers Equal Area
Scale	1:5 500 000 (approx)

FIGURE 7

Liquefaction Hazard Map of South Africa

FIGURE 8

Southern Cape Coastal Condensation Problem Area