

**An Explanation  
of the 1:500 000  
General Hydrogeological Map  
Kroonstad 2725**



**By E. Baran**

**Z.M. Dziembowski (Consultant)**

**June 2003**



**DEPARTMENT : WATER AFFAIRS AND FORESTRY  
REPUBLIC OF SOUTH AFRICA**

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**Cover photograph:** A relatively featureless landscape so typical of large tracks of the Kroonstad map area. Windpumps, the main means of abstracting groundwater for stock-watering, dot the rural areas. (Photo: P.S. Meyer).

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**June 2003**

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DEPARTMENT : WATER AFFAIRS AND FORESTRY  
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# Foreword

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**G**roundwater in South Africa as a whole is under-utilised, although some local over-exploitation does occur. Groundwater schemes can be implemented quickly and cheaply, and are particularly effective in conjunctive use and dispersed scenarios. With increasing pressure on scarce surface water resources, and with the priority of supplying potable water to disadvantaged rural and urban communities, it is clear that groundwater will play an increasingly important role in South Africa's economic and social prosperity.

A major obstacle to the realisation of this prosperity is that insufficient information about groundwater is reaching the planners, decision-makers, users and other affected parties. In an attempt to rectify this situation, groundwater information locked away in experts' minds and computer databases is being made available on maps. The first step in this programme at the regional level is the preparation of "General Hydrogeological Maps" at the scale of 1:500 000.

The main purpose of General Hydrogeological Maps, of which the accompanying map sheet is an example, is to display in an easily understood format what is known about basic hydrogeological properties. These General Maps represent a synthesis of the most up-to-date data and geohydrologists' knowledge. Thus these maps are also very useful in identifying areas where additional data should be collected and further investigations need to be conducted.

Groundwater maps – the best available information for the best possible planning, development and management of a strategic resource – will ultimately benefit all South Africans.

EBERHARD BRAUNE  
DIRECTOR: GEOHYDROLOGY  
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# Preface

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**W**ith the exception of air, water can, with little doubt, be defined as Man's most precious resource. It is said that to deny Man food, his body can sustain life for weeks, but refuse him water and death is likely to come within a few days. The availability of water to even the remotest area is thus vital to maintain this indispensable condition for human existence.

An estimated 3% of fresh water available on Earth, occurs on the surface and 97% occurs underground (Johnson Division, 1975). To tap and develop this vast amount of underground stored water, a keen knowledge of a region's environment, and above all, its diversified geology, is of the utmost importance in order to comprehend how and where groundwater occurs.

The Kroonstad Hydrogeological Map and the accompanying explanatory brochure introduces the current state of the groundwater knowledge and the basic geohydrological characteristics of the map area. It needs to be explained that within the map's confines, dissimilar and divergent conditions occur which, to various degrees, may impact on groundwater. Under these circumstances, various groundwater distinctives and characteristics can be expected, most of which have been referred to in this brochure.

The primary aim of a General Hydrogeological Map is to produce a synoptic overview of the geohydrological character of an area. The main map thus features borehole yield, aquifer type, groundwater quality and groundwater use, which are superimposed against a slightly subdued surface lithological background. The brochure discusses these topics in more detail, as well as issues such as geological controls on groundwater yield and quality, borehole siting methods, groundwater management, groundwater levels, suggestions for the future studies, etc. It is hoped that both the groundwater scientist and the interested layman will find the product useful. The map and brochure will hopefully also be informative to planners, especially in the light of the Reconstruction and Development Programme, and it will play a constructive role in general groundwater education and groundwater awareness-building.

Groundwater has always been an important source of water supply to many people and localities in the map area, especially in the rural environment. Water consumers in many areas rely totally on groundwater for domestic and stock watering purposes and also for urban and irrigation purposes at a number of locations. It is hoped that this map and brochure will serve as a basis for future specialised groundwater maps and groundwater studies as suggested in the brochure.

The scarcity of available data in some parts of Kroonstad map area did not allow the map authors to make a more detailed analysis of borehole yield and groundwater quality.

Although groundwater is not the main source of water supply to many larger users in that area, it can always be considered as an optional supplement to surface water in a drought situation.

# Acknowledgements

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The following individuals and concerns are thanked for their assistance in data provision for the compilation of the Kroonstad hydrogeological map and the Explanatory Brochure:

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## **Various Municipalities** from the **Map Area**

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# Abbreviations

CfG	Council for Geoscience
CSIR	Council for Scientific and Industrial Research
DWAF	Department: Water Affairs and Forestry
EC	Electrical conductivity
GIS	Geographic Information System
IGS	Institute for Groundwater Studies
NGDB	National Groundwater Database
NWQDB	National Water Quality Database
SABS	South African Bureau of Standards
TAL	Total Alkalinity
TDS	Total Dissolved Solids
UNESCO	United Nations Educational Scientific and Cultural Organisation

# Symbols and units

a	annum
amsl	above mean sea level
l	litre
l/s	litre per second
m	metre
Ma	million years
meq	milli-equivalent
mg/l	milligrams per litre
m/s	metre per second
mS/m	milliSiemens per metre
m <sup>3</sup>	cubic metre
pH	logarithm of the reciprocal of the hydrogen ion concentration in moles per litre
s	second

# 1 Introduction

## 1.1 Map compilation

The sources of information and data used for the map compilation includes:

- The National Groundwater Data Base (NGDB) at the Department: Water Affairs and Forestry, Directorate: Geohydrology – borehole logs, etc.,
- The National Water Quality Data Base (NWQDB) at the Department: Water Affairs and Forestry, Directorate: Geohydrology – water analyses,
- Internal DWAF (Geohydrology) hydrogeological reports, and reports from the Institute for Groundwater Studies (IGS) – University of the Free State in Bloemfontein and the Council for Scientific and Industrial Research (CSIR) – Pretoria,
- Borehole data collected by geohydrological consultants for the Kwazulu-Natal Province section of the map area.

Extensive use was made of the Arc/Info software for data processing, display and delineation of borehole yield classes.

For some areas, revisions of the borehole yield class boundaries were made by hand, based on the knowledge of the local geohydrology and supported by the results of groundwater development reports. The alterations were subsequently digitised. Arc/Info software was also used to compile the groundwater quality inset map at a scale 1:1 500 000 in terms of its electrical conductivity (EC: mS/m) – a function of water salinity.

The EC values were contoured according to intervals categorising groundwater as fresh (0–70 mS/m), upper limit for human consumption (up to 300 mS/m), maximum salinity acceptable for stock watering (up to 1 000 mS/m) and above it, in agreement with the guidelines for human and stock consumption, as published by the DWAF (1993).

The stratigraphy of the region has been based on the 1:1 000 000 scale digital form of the Geological Map of the Republic of South Africa (1984) compiled by the Geological Survey (presently Council for Geoscience). Where it was practical, the geological units were re-grouped to simplify the map by a substantial reduction of their numbers.

An alphabetic code for the stratigraphic units was provided and explained at the chronostratigraphic column. Two schematic cross-sections illustrating the typical groundwater occurrence and drilling targets were constructed through the key areas.

The scarcity of reliable borehole data and a relative low number and erratic distribution of water analyses for the Kroonstad map area did not allow for their more detailed characterisation, hence a large degree of extrapolation was exercised.

To increase the readability of the map, the lithology and geology have been adjusted as follows:

- lithological occurrences too small to carry a polygon and a formation code were omitted,
- some of lithostratigraphical units of the Formation and Subgroup level were combined or lumped together and they appear as “Groups”,
- lithological boundaries have in places been smoothed, so that they do not always correspond exactly to those on the geological maps, especially on the larger scale.

The 1:2 000 000 scale inset maps, illustrating the distribution of borehole data, elevation above sea level and mean annual precipitation are computer generated.

**Table 1. Available borehole records and water analyses**

NATIONAL GROUNDWATER DATABASE		WATER QUALITY DATA BASE		
Borehole records	Reported borehole yield values (dry boreholes excluded)	EC values (mS/m)	Number of chemical analyses	Nitrate and Fluoride values (NO <sub>3</sub> + NO <sub>2</sub> as N) and F
11 458	5 382	561	561	101

## 1.2 Legend explanation

The hydrogeological map utilises the international legend for hydrogeological maps (UNESCO, 1983) adapted to the South African geological conditions and groundwater occurrence, especially in terms of fractured, and fractured and intergranular aquifers. These aquifers form approximately 80% of all water bearing formations in the country.

Four modes of groundwater occurrence are depicted on the General Hydrogeological Map Series, namely:

- Intergranular (a)
- Fractured (b)
- Karstic (c)
- Intergranular and Fractured (d)

**Intergranular Aquifer:** a water saturated unconsolidated sediment, such as sand and gravel, where water is stored in the intergranular pores and can be transmitted to boreholes.

**Fractured Aquifer:** associated with hard rocks, where water occurs in fractures, faults, joints or fissures.

**Karstic Aquifer:** associated with carbonate rocks such as limestone and dolomite. The groundwater is stored and transmitted through fractures and solution cavities and channels.

**Intergranular and Fractured Aquifer:** water occurs in both the upper decomposed rock zone and the fractured but fresh rock formation below. These zones are in hydraulic contact. Weathered and fractured crystalline rock can lead to the formation of this aquifer type.

Although aquifer type "a" (intergranular aquifer) is not included in the table and is not indicated on the Kroonstad map, it does occur as narrow strips of alluvium in major river valleys where its saturation thickness is limited to a few metres.

**Table 2. Aquifer types and yield classes**

YIELD RANGE (l/s)	FRACTURED AQUIFER	KARSTIC AQUIFER	INTERGRANULAR & FRACTURED AQUIFER
0.0 – 0.1			d1
0.1 – 0.5	b2		d2
0.5 – 2.0	b3		d3
2.0 – 5.0		c4	d4
> 5.0		c5	d5

## 2 Physical environment

### 2.1 Physiography and climate

The map area forms the south-eastern part of the Highveld region and straddles the Great Escarpment (Drakensberg) in the east (Schultze, 1986). The elevation varies from 1 400 m in the southwest of the map to roughly 3 300 m above mean sea level at its south-central limits. East of the Drakensberg in the Ladysmith and Colenso area the elevation decreases to 1 000–950 m and 900 m in the Tugela Valley.

The highest point is the Mount-Aux-Sources in the Drakensberg mountain range (3 282 m) at the border with Lesotho.

The rainfall increases from west to east and with elevation. The lowest mean annual precipitation occurs in the west of the area where it varies between 400 and 600 mm. The central part receives from 600 to 800 mm annually. The highest rainfall (above 1 000 mm per year) falls on the Escarpment, between Volksrust and the northern Lesotho border, and along the eastern border line.

The maximum rainfall occurs generally during summer (October – April). During winter months (May – September) snow occurs periodically in the Drakensberg.

Temperature has large daily and seasonal variations. The mean surface temperature reaches a maximum value during December – January and a minimum value during June and July. The period when frost can be expected lasts approximately

100 days (June – August). Over the most of the area, the mean annual temperature varies from 15 to 17.5°C and from 12.5 to 15.0°C on the Drakensberg. The winter temperature extreme (-11.2°C) was measured at Bethlehem (1996–97).

The mean annual pan evaporation increases across the map from 1200 mm in the southeast to 1 800–2 000 mm in the west (Figure 1). (Source: DWAF, 1993).

The vegetation occurring on the Kroonstad map area is classified by Acocks (1952) into five groups (Fig. 3):

1. **False Grassveld** – covering an area in the south-eastern part of the map;
2. **Pure Grassveld** – covering most of the map area from the southwest to the north and northeast. It is regarded as the natural vegetation, typical for the Highveld;
3. **Tropical Bush and Savanna** – covering a small part of the map from Odendaalsrus and Bothaville to the western map edge;
4. **Karoo and Karroid** – occurring around Ladysmith, Colenso and Estcourt;
5. **Temperate and Transitional Forest and Scrub** – covering a narrow strip from Phuthaditjhaba throughout Harrismith to Newcastle, along the Escarpment.

### 2.2 Surface hydrology

The Great Escarpment forms a water divide between the Indian and Atlantic Ocean catchments.

Three primary rivers drain the Kroonstad map area. These are the:

- Vaal River – (Drainage Region C),
- Orange River – (Drainage Region D) and
- Tugela River – (Drainage Region V).

Thirteen secondary Drainage Regions occur in the map area, (Figure 2).

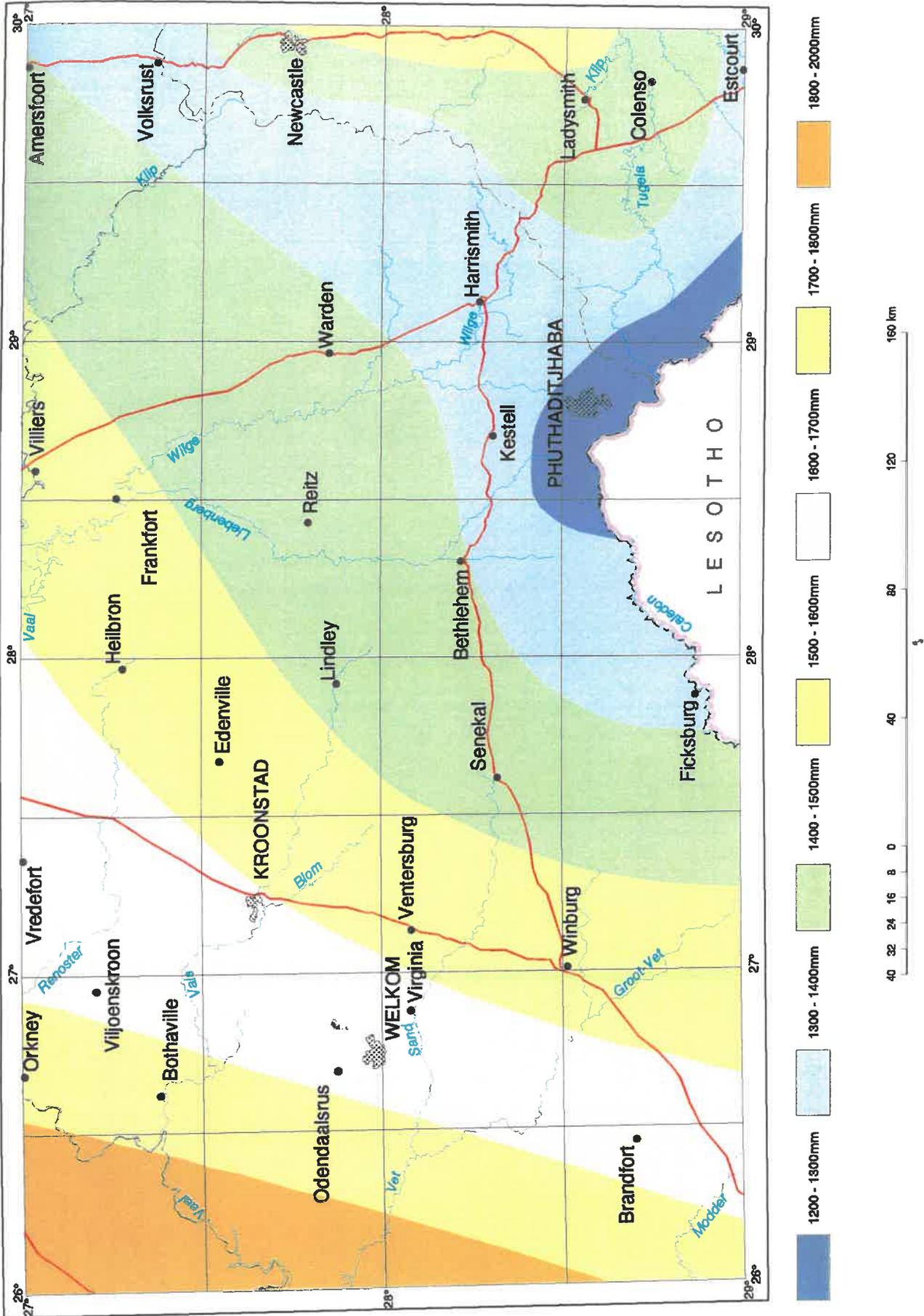
The tributaries of the Vaal River drain predominantly in the northwesterly and westerly directions. In the southeastern and eastern part of the map area, tributaries of the Tugela River drain predominantly to the east.

The Caledon River, a tributary of the Orange River, drains to the south.

**Table 3. Main dams in the Kroonstad map area**

DAM NAME	RIVER NAME	STORAGE CAPACITY (million m <sup>3</sup> )
Sterkfontein Dam	Nuwejaarspruit	2 661
Vaal Dam	Vaal	2 580
Bloemhof Dam	Vet	1 269
Woodstock Dam	Tugela	380
Spioenkop Dam	Tugela	272
Erfenis Dam	Groot-Vet	208
Chelmsford Dam	Ngagane	199
Allemanskraal Dam	Sand	175
Krugersdrift Dam	Modder	73.4
Koppies Dam	Renoster	41.2
Saulspoort Dam	Ash	17.08

Figure 1. Mean annual evaporation (Source: DWAf, 1993)



The primary and secondary rivers are perennial but some of their tributaries, especially in the west, carry water only after a period of relatively heavy rainfall.

Eleven large dams are located, or partially located, in the map area and they constitute the main source of large scale water supply for domestic, agricultural and industrial use within the Kroonstad map area, and further north, in Gauteng Province (Table 3).

There are numerous small dams built practically on all streams of the area mostly for farm water supply purposes.

Their existence seriously reduces the surface water runoff of the area. No quantitative information thereof is however available.

Two intercatchment water transfer systems were constructed in the map area. They are:

- The Lesotho Highlands Water Project
- Tugela Water Project

The objective of these projects is to improve the water supply to the Gauteng area.

**Figure 3. Vegetation types of South Africa (simplified map after Acocks, 1952)**

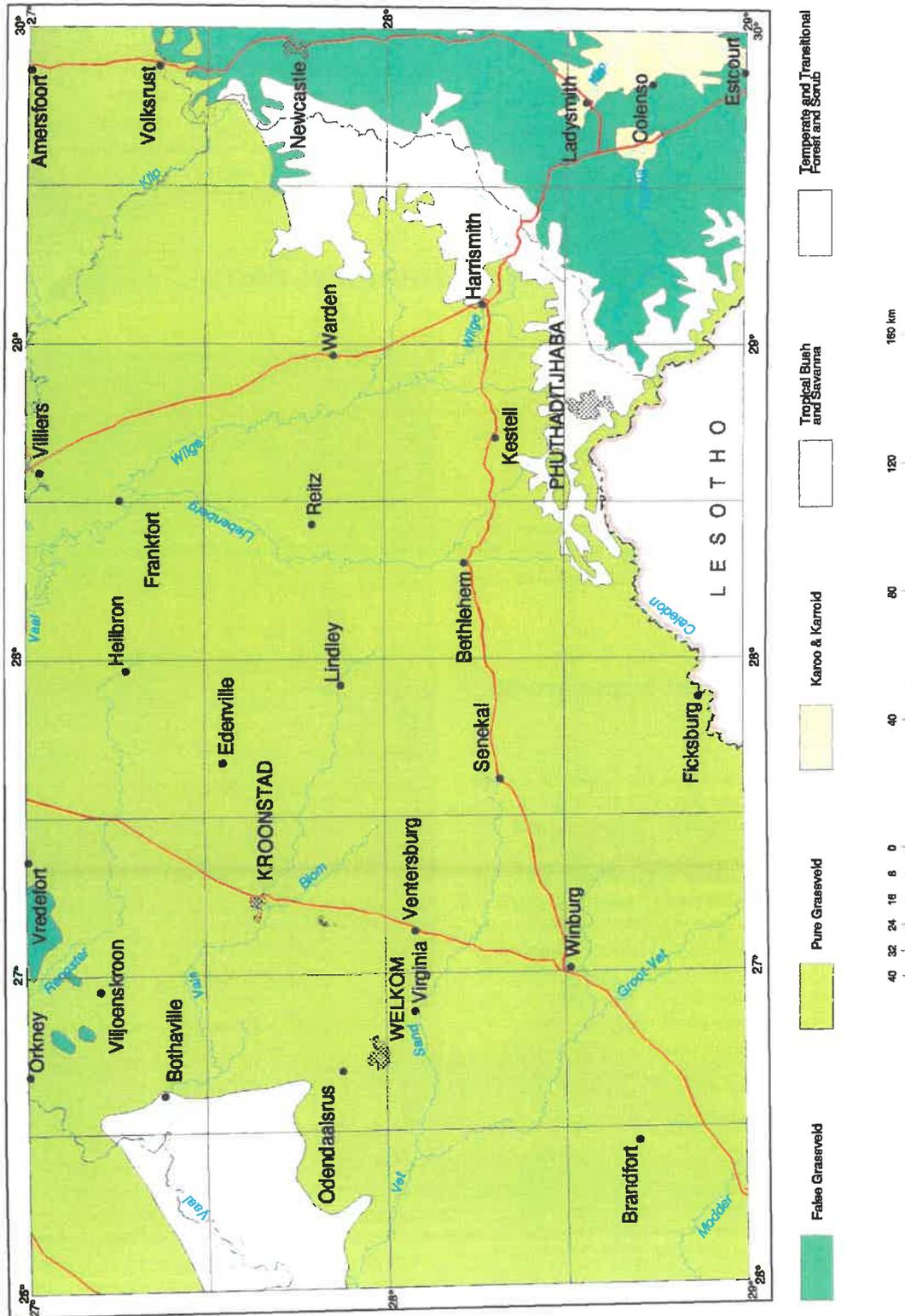
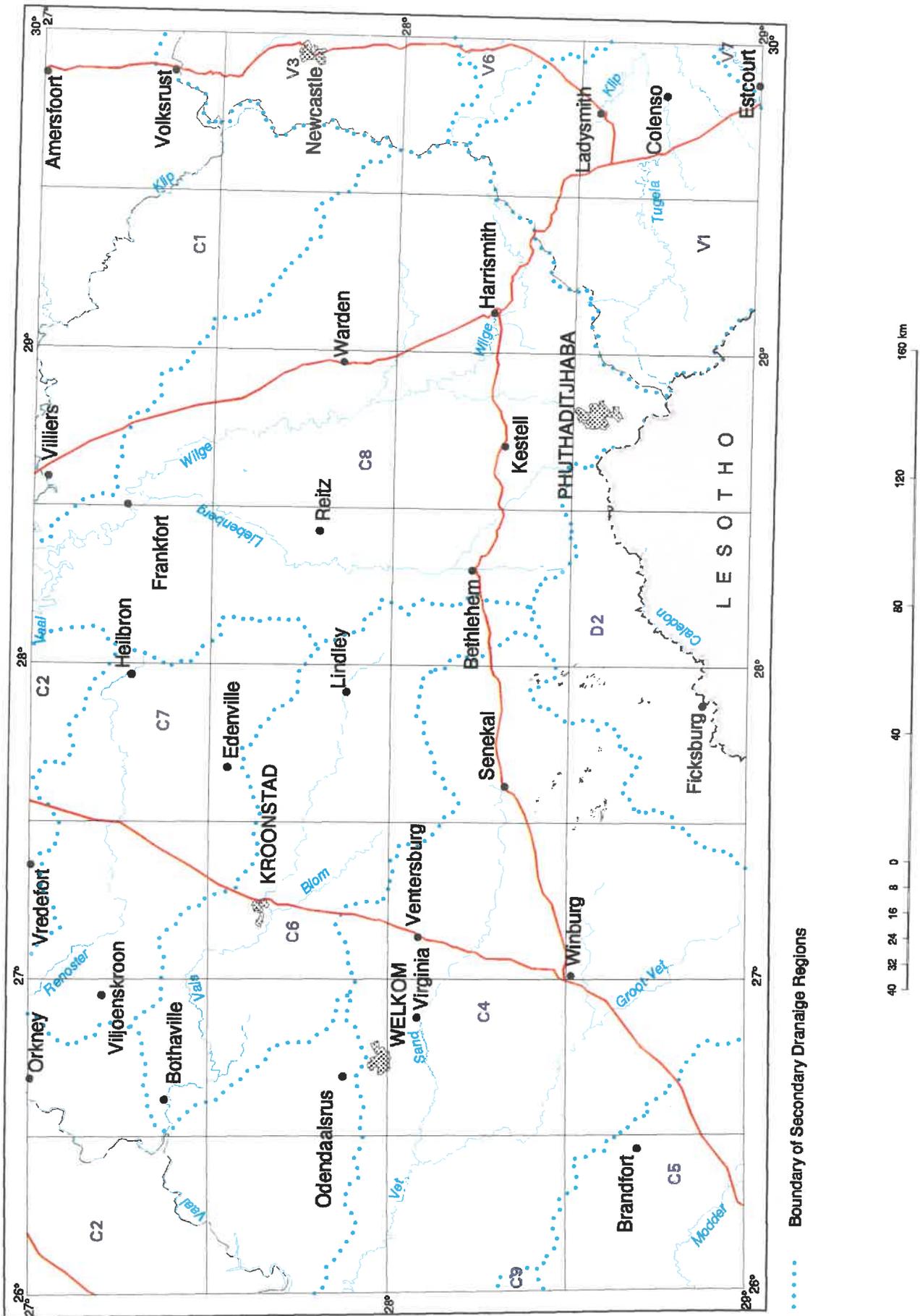


Figure 2. Secondary drainage regions



..... Boundary of Secondary Drainage Regions

The primary and secondary rivers are perennial but some of their tributaries, especially in the west, carry water only after a period of relatively heavy rainfall.

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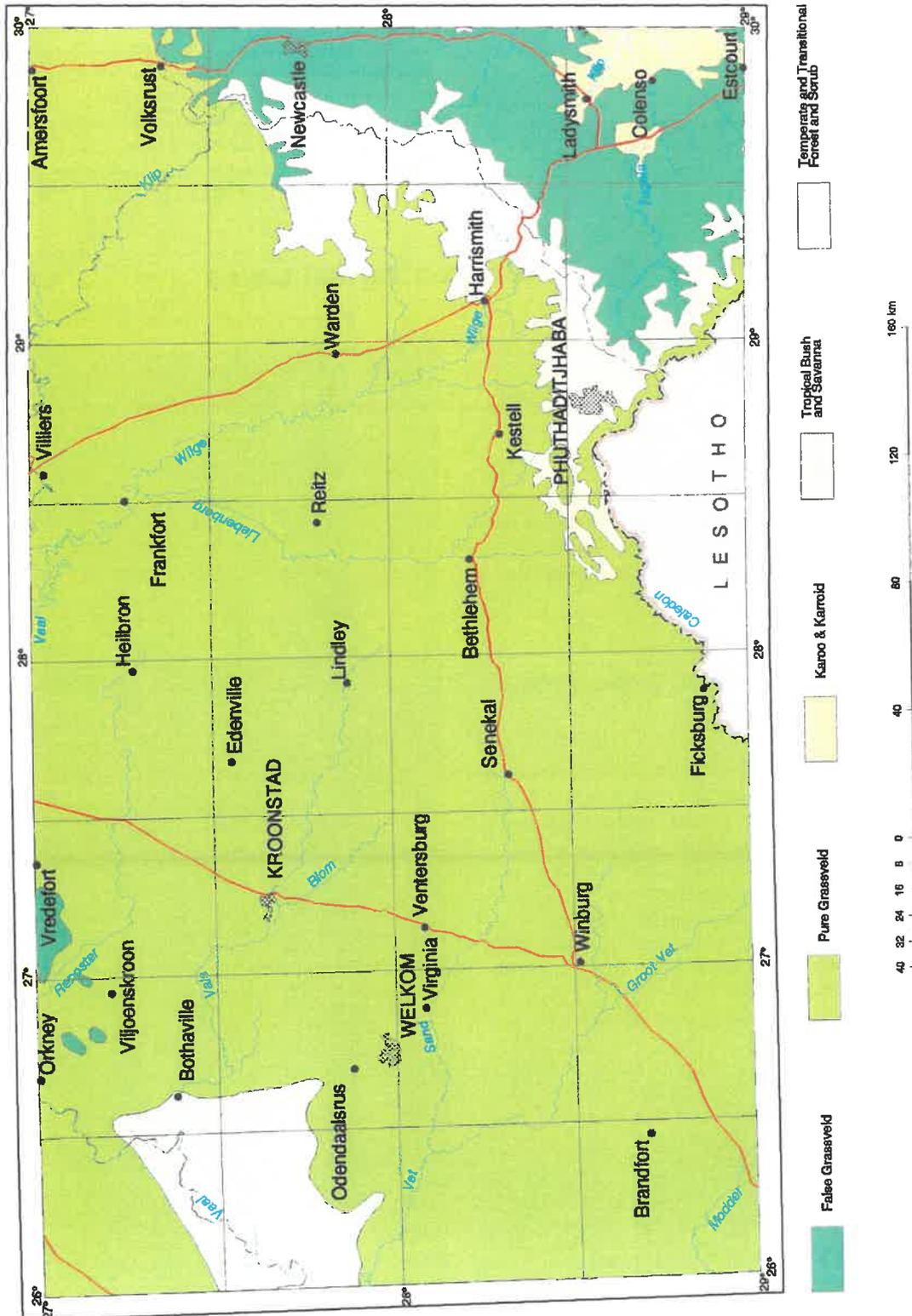
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**Figure 3. Vegetation types of South Africa (simplified map after Acocks, 1952)**



## 3 Geology

### 3.1 Structures

Nearly the entire area covered by the Kroonstad Hydrogeological Map is situated in the northeastern part of the Central Karoo Basin. The thickness of Karoo sediments increases gradually from zero in the northwest of the map area to over 2 000 m in the south. The age of the sediments decreases in the southerly direction.

The pre-Karoo bedrock in the map area consists of five main structural units:

- **Kaapvaal Craton** consisting of a variety of gneisses of the Swazian age underlies the whole map area beneath a thick cover of younger formations.
- **Witwatersrand Basin** of early Randian age, formed within the Kaapvaal Craton in the northwestern map section, roughly west of the line Villiers-Winburg. The western basin margin forms a line fluctuating between 26°15' and 26°45'.
- **Ventersdorp Basin** (Rift Zone) of late Randian age partially overlaps the Witwatersrand Basin.
- **Transvaal Basin** – The southern Basin margin forms an arch: Orkney-Kroonstad-Edenville.
- **Vredefort Dome** of post Vaalian age. The origin thereof is still debatable: a batholith type intrusion or an asteroid impact site. Only the southern half of the Dome occurs on the Kroonstad Map sheet.

### 3.2 Description of the main geological units

Figure 4 illustrates the simplified geology of the map area. \*

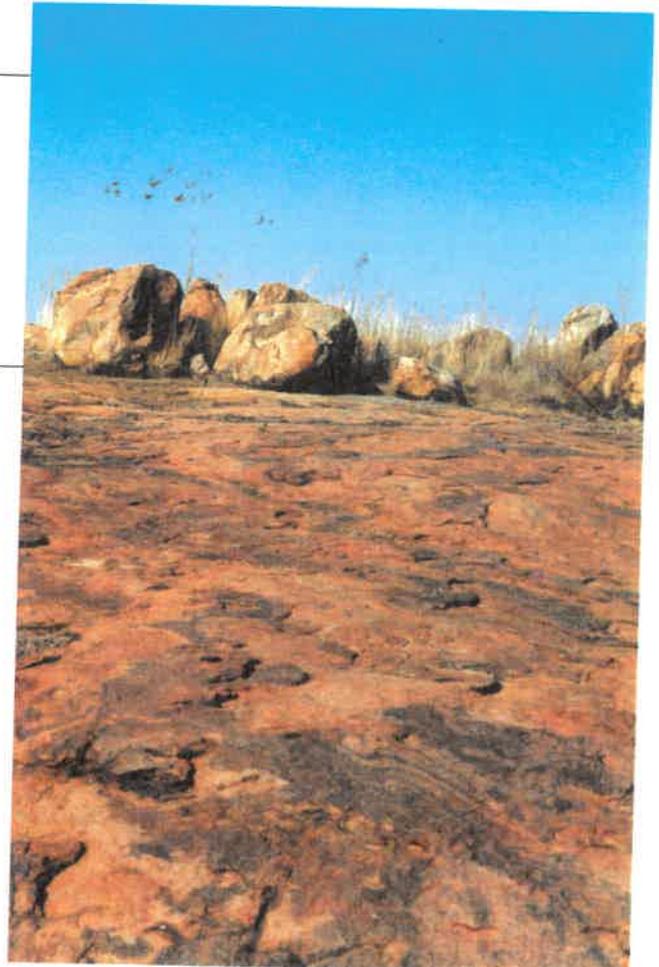
#### 3.2.1 Basement Complex (Zie and Zpa)

The oldest rocks in the map area are the Inlandsee Gneiss (Zie) and the Parys Granite (Zpa) of Swazian age. They form the Vredefort Dome, outcropping at the town of Vredefort and west and south thereof (Plate 1).

#### 3.2.2 Witwatersrand Supergroup (Rw and Rc)

The up to 200 m thick volcanic rocks of the Dominion Group occur in the Vredefort area below the Witwatersrand Supergroup sediments. Because of map scale constraints, they are not portrayed on the main map.

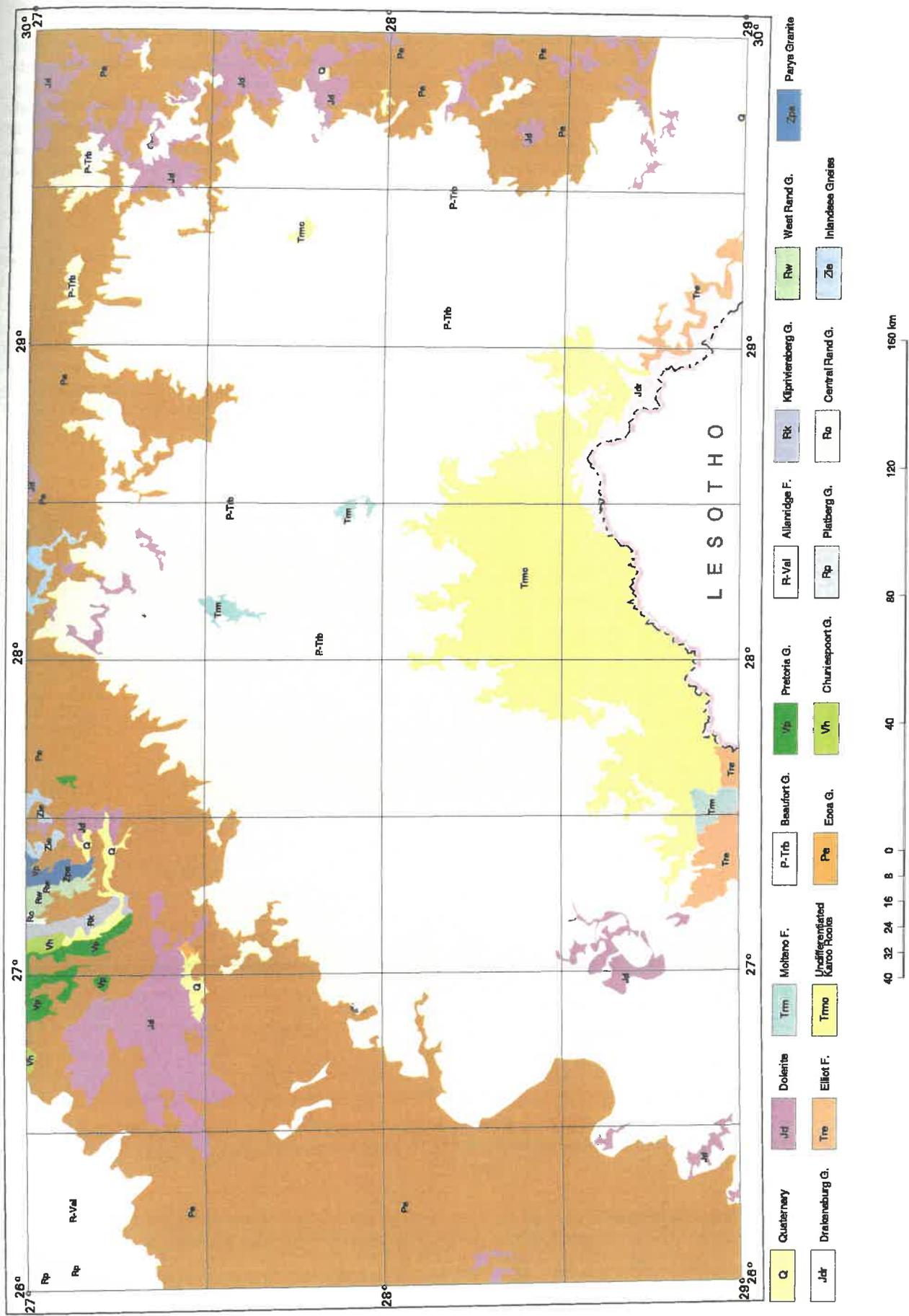
This Supergroup comprises Randian age sedimentary rocks with a total thickness of several thousand metres. It consists mainly of shale, quartzite and conglomerate. Two Groups are identified: The West Rand Group (Rw) and Central Rand Group (Rc). Outcrops of both Groups are found at the western rim of the Vredefort Dome. Further south, they occur in the Witwatersrand Basin, under cover of younger rocks.



**Plate 1.** Outcrops of solid Parys granite at Vredefort. The groundwater potential of this unit in the map area is low and yields of less than 0.5 l/s can generally be expected. The low yields can be attributed to a lack of weathering and scarcity of joints and fractures. (Photo: P.S. Meyer).

\* For the reasons of a countrywide uniformity, the lithology was based on the 1:1 000 000 scale Geological map (1984). The boundaries of the pre-Karoo rocks along the north-western edge of the Hydrogeological Map as well as boundaries of different stratigraphic and lithological units elsewhere, might differ from the more recently mapped 2726 Kroonstad Geological Map (1:250 000) and other maps published by the Council for Geoscience.

Figure 4. Simplified geology



### 3.2.3 Ventersdorp Supergroup (Rk, Rp and R-Val)

This Supergroup consists of an assemblage of sedimentary and volcanic rocks of Randian age. They are subdivided into two Groups, namely the Klipriviersberg Group (Rk) (andesitic lava) and the Platberg Group (Rp) (quartzite, conglomerate, lava, quartz-porphphy, andesite, chert and tuff.) The Bothaville Formation (not indicated on the map) consists of arkose, greywacke and sandstone, and the Allanridge Formation (R-Val) comprises andesitic lava overlying the Bothaville Formation and form the top of the Ventersdorp Supergroup.

Rocks of this Supergroup occupy the northwestern map corner area between Makwassie and Orkney and also form part of the western rim of the Vredefort Dome.

Small, isolated exposures of the Allanridge lava occur north and northwest of the Odendaalsrus and west of Koppies.

Rocks of the Ventersdorp Supergroup occur under thick Karoo cover in the Free State Goldfields where they overlay the Witwatersrand Supergroup.

### 3.2.4 Transvaal Supergroup (Vh and Vp)

The Vaalian age Chuniespoort Group (Vh) and the Pretoria Group (Vp) are present in a small area north and east of Viljoenskroon (and on the Viljoenskroon townlands) where they form the most western part of the rim of the Vredefort Dome. Two isolated small outcrops of lava of the Pretoria Group occur also northwest of Edenville and north of Koppies.

The Chuniespoort Group consists predominantly of carbonate rocks (dolomite) with intercalated chert layers. The overlying Pretoria Group is represented by shale, quartzite, siltstone, conglomerate, andesitic lava and diabase (Plate 2).



**Plate 2.** Fractured and jointed siltstone of the Pretoria Group, associated with a diabase intrusion in the northwestern environs of the map area. Yields of between 0.5 and 2 *l/s* can be anticipated in this unit. (Photo: P.S. Meyer).

### 3.2.5 Karoo Supergroup

Sediments of the Karoo Supergroup cover more than 95% of the map area. This Supergroup is represented here by the Dwyka Group, Eccca Group (Pe), Beaufort Group (P-Trb), and

by the Molteno (Trm), Elliot (Tre) and Clarens (Trc) Formations and the uppermost Drakensberg Group (Jdr).

### 3.2.5.1 Dwyka Group

The oldest Karoo unit, the Dwyka Group only outcrops in the map area at a tiny spot close to the eastern map edge on the farm Rodekop, 7–8 km east of Igogo railway station, north of Newcastle (Muntingh, 1989). Knowledge of the Dwyka is based on numerous borehole logs. The diamictite of the Dwyka Group was deposited on an uneven topography. The thickness of the Group is greatest in presumed pre-Karoo

palaeo-valleys. A thickness of up to 300 m was established from a borehole at Virginia. On the eastern margins of the map a thickness of 30 m of diamictite was reported. In general, the Group consists mainly of diamictite that grades upwards into conglomerate, mudstone and shale (Schutte, 1993).

### 3.2.5.2 Ecca Group (Pe)

A large area covering the south-western, central-northern and eastern part of the map area is occupied by sediments of the Ecca Group that consists of the Pietermaritzburg Formation (no outcrops within the map area), Vryheid Formation and Volksrust Formation. The three Formations have been lumped together as Pe on the main map, but the Vryheid and

Volksrust Formations are indicated separately on Figure 21 and their hydrogeological characteristics are also discussed separately in section 4.3.4.6.2. Their lithological differences (shale and sandstones) are more instructive from a hydrogeological point of view.

#### 3.2.5.2.1 Pietermaritzburg Formation

The Pietermaritzburg Formation in the map area is known only from coal prospecting boreholes. It consists mainly of shales. The thickness of the Formation is more than 30 m in

the eastern and southern map area but wedges out towards the north.

#### 3.2.5.2.2 Vryheid Formation (Pe)

In general, the sediments of the Vryheid Formation are of cyclic deltaic and fluvial origin. They consist of thick mudstone and sandstone with subordinate shale layers and a few coal seams. The Formation outcrops at the eastern edge of the map where it has a thickness that varies between 200 and 500 m (Johnson & Verster, 1994). It thins in the westerly direction where only 60 m was measured (Muntingh, 1989).

In the northwestern map area the total thickness of the Formation reaches a maximum of 120 m, deposited in palaeo-valleys (Schutte, 1993). In the southern and southwestern map areas the Vryheid Formation is totally covered by younger Karoo units and little or no information is available on its lithology and thickness.

#### 3.2.5.2.3 Volksrust Formation (Pe)

The Volksrust Formation, being of marine origin, is represented by shale, siltstone, mudstone and fine sandstone at the top. The belt of outcrops form an arch with its apex at the northern map edge. The thickness of the Formation in the south-east varies between 140 m and 180 m (Johnson & Verster, 1994).

In the western half of the map it reaches 260 m in boreholes (Muntingh, 1989). Nolte (1995) describes the Formation as the Tierberg Formation, that is a lateral equivalent of the Volksrust Formation, mapped further to the east.

### 3.2.5.3 Beaufort Group (P-Trb)

The Group is mostly of fluvial and deltaic origin. It is subdivided (subdivision not shown on the map) into two Subgroups:

- The older, **Adelaide Subgroup** consisting of shale, siltstone and fine sandstone, is approximately 600 m in thickness in the south-east and east of the map area (Johnson

& Verster, 1994). In the north-west mudstones and siltstones dominate with sandstones only subordinate (Schutte, 1993). In the south-west, the Adelaide Subgroup consists of alternating mudstone and sandstone layers with a total thickness of approximately 250 m (Visser *et al.*, 1989).

- The younger **Tarkastad Subgroup** consists of an assemblage of sandstone and mudstone with sandstone dominating in the south-east of the map area. The thickness given by Johnson and Verster (1994) is 250 m just south of Harrismith but it thins in a north-eastern direction.

In the north-west of the map, the dominance of sandstone increases to over 70% (Schutte, 1993). In the south-west map area the total thickness is given as 112 m (Nolte, 1995). On the main map the Tarkastad Subgroup is indicated as an argillaceous and arenaceous unit, of equal proportions.

### 3.2.5.4 Molteno Formation (Trm)

The Molteno Formation mostly outcrops around the Lesotho Highlands. (Due to its much reduced projected occurrence on the map, it has been decided to group the Molteno Formation together with the Beaufort Group (P-Trb), Elliot Formation (Tre), Clarens Formation (Trc), Drakensberg Group (Jdr) and the dolerite intrusions (Jd), and to portray them as 'Undifferentiated Rocks' (see the area between Clocolan, Bethlehem and Mafikeng). Further north there are two isolated remnants of Molteno sediments viz. north of Petrus Steyn and south-west of Reitz shown on the map as Trm. West and south of Clocolan

the Molteno Formation is also shown separately as Trm.\*

The Molteno Formation consists of sediments of fluvial origin. Sandstones form up to 80% of the sequence with the remaining 20% of mudstones. In general, the Formation material is upwards-fining. (Nolte, 1995). The thickness varies considerably over the map area. Up to 20 m is reported by Muntingh (1989) in the north, 50 m in the south-west area (Nolte, 1995) and up to 70 m at Phuthaditjhaba (Johnson and Verster, 1994).

### 3.2.5.5 Elliot Formation (Tre)

The Elliot Formation conformably overlies the Molteno Formation. In the south-central map area it is grouped together with other geological units as 'undifferentiated rocks' but to the west thereof it has been indicated separately on the map.\*

The area southeast of Clocolan and an area between Excelsior and Clocolan (both Elliot Formation (Tre) areas) were erroneously assigned the "argillaceous / arenaceous" lithology signature instead of the "predominantly argillaceous" one.

This also applies to the portrayal of the Elliot Formation (Tre) on the Drakensberg – Kestell schematic cross-section. The Formation is a product of drier climatic conditions with loess type, aeolian sedimentation of mudstones and siltstones, with fluvial, subordinate sandstones. The Formation is between 80 and 100 m thick west of Clocolan (Nolte, 1995) and up to 150 m south of Woodstock Dam (Johnson & Verster, 1994).

### 3.2.5.6 Clarens Formation (Trc)

Deposition of the Clarens Formation occurred in an arid climate with eolian transportation of fine sand and silt. The contact with the underlying Elliot Formation is gradual. South of Bethlehem the Formation is included in the hatching for 'undifferentiated rocks' due to the steep topography resulting in only narrow strips of outcrops that could not be projected on the map. In the northeast it occurs as remnants too small to be indicated on the map.\*

The Formation contains of 66% fine sandstone and 13% coarser sediment, the rest being mudstone and siltstone. The thickness of the Formation is approximately 150 m in the north-east, 145 m the south-west and 230 m in the south-east of the map area (Muntingh, 1989; Nolte, 1995 and Johnson & Verster, 1994 respectively).

### 3.2.5.7 Drakensberg Group (Jdr)

The extrusion of very large quantities of basaltic lava marked the end of the deposition of the Karoo Supergroup. Individual lava flows of up to 50 m thick contribute to the total thickness of the basalt of over 1 400 m. Thin layers of sandstone occur between some lava flows and they are more frequent in the lower segments.

The basaltic lava covers almost the whole area of Lesotho and adjoining areas of the RSA (Visser, 1998).

In the area south of Bethlehem, patches of the Group are included in the geological units grouped together as "Undifferentiated Karoo Rocks of various lithology", but the basalt of the Drakensberg Group is indicated separately on the map as a strip along the Lesotho border from just south of Clarens to the southeastern map edge. The patches of lava capping the isolated peaks that occur east of Harrismith and south-west of Memel are not shown on the map due to their small areal extent.

\* East of the FreeState / KZN border, SE of Mafikeng, the exposures of the Tarkastad Subgroup (of the Beaufort Group) are portrayed together with exposures of the Molteno, Elliot and Clarens Formations as a belt of argillaceous and arenaceous rocks (approximately equal proportions), flanked from the south by the basalt of the Drakensberg Group (Jdr). It was mistakenly assigned the stratigraphic code "Tre" instead of P-Trb, Trm, Tre and Trc indicating their grouping.

### 3.2.6 Karoo Dolerite Suite (Jd)

The large area affected by the late Karoo volcanism, the Karoo Igneous Province stretches south of the 15° latitude to the northern margins of the Cape Fold Belt (Visser, *et al*, 1998; Harzer *et al*, 1998). The intrusive dolerite sills and dykes are contemporary and younger than the basalt of the Drakensberg Group. Only large, prominent occurrences of dolerite sills of a size justified to appear on the 1:500 000 map, are

depicted. No dolerite dykes are depicted on the main map. The distribution of the dolerite intrusions in the Kroonstad map area reveals a pattern whereby the sills occur mostly in a wide belt forming an arch with its southern limit running from Brandfort in the south-west through Winburg, Lindley, Warden, Colenso to Estcourt, in the south-east. Inside of the arch dolerite dykes prevail (Figure 5).

#### 3.2.6.1 Dolerite sills (Jd)

The dolerite sills are mostly associated with the argillaceous, stratigraphically lower units of the Karoo Supergroup (Dwyka to Beaufort Group). Their thickness varies between 15 and

300 m. This undulating nature, crossing the host rock bedding at a low angle causes their discontinuous occurrence on the land surface.

#### 3.2.6.2 Dolerite dykes (Jd)

The dyke intrusions are concentrated in the younger Karoo units from the Beaufort Group up to Clarens Formation and less frequently in the Drakensberg Group. Their thickness varies from a few cm to 30 m, with an average around 3 m. Dykes 50 m thick were also reported (Johnson & Verster, 1994). Three dominant strike directions that appear to be

structurally controlled are identified: NW-SE, SW-NE and W-E. The dyke lengths vary from a few hundreds of metres up to 25 km (Johnson & Venter, 1994). They occur parallel, generally in groups. Many dykes cross the dolerite sills indicating their younger age (Muttingh, 1989).

### 3.2.7 Post Karoo Kimberlite intrusions

Kimberlite intrusions in the form of pipes and dykes occur mainly in the southern and western map area. These intrusions were not indicated on the map due to their small size and limited number. The largest number of Kimberlite pipes occur

in an area north of Theunissen and northwest of Kroonstad. A few dykes of limited length occur south of Fouriesburg, associated with a few pipes.

### 3.2.8 Cenozoic sediments

During Tertiary and Quaternary periods only terrestrial sedimentation took place over the map area. Those more important are briefly discussed here.

**Aeolian sands** cover almost 60% of the north-western map quarter with a thin, not more than a few metres thick, blanket (Schutte, 1993). In the east, sand dunes up to 20 m high were formed along larger river channels, a product of dry climatic conditions and periodical floods (Muntingh, 1989).

**Calcrete** in a modular and hardpan form occurs in and around numerous pans in the flat, north-western and western map areas, a product of groundwater evaporation and calcium carbonate precipitation. The total thickness of this lime-cemented sand and silt does not exceed 2.5 m in the north-west (Schutte, 1993) but reaches 1.5 m in places in the south-western map area (Nolte, 1995).

**Colluvial deposits** consisting of a mixture of clay and clastic local material are known from more moderate slopes of the

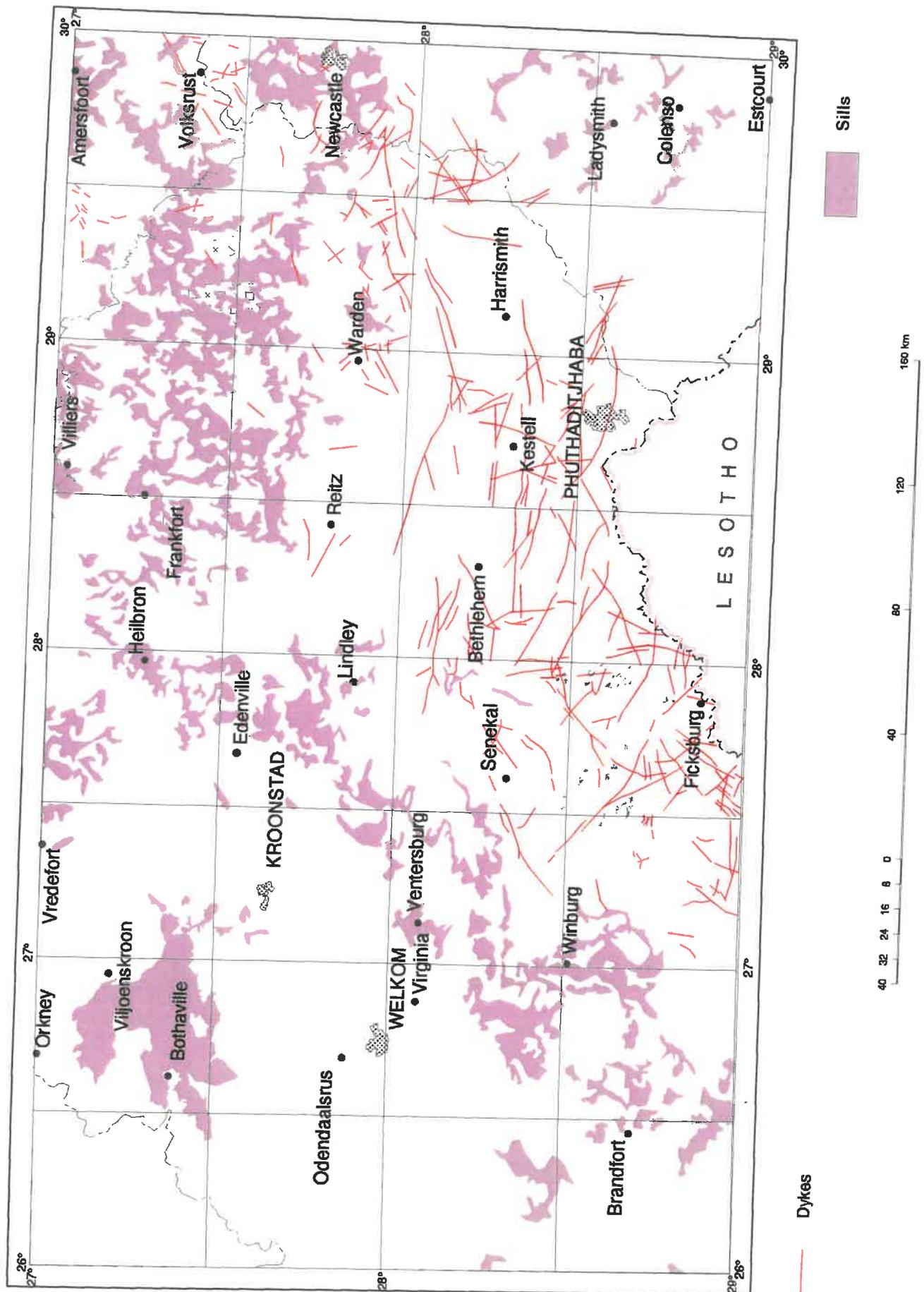
Great Escarpment, where they are named the Masotcheni Formation. The deposits rarely exceed 15 m in thickness.

**Floodplain deposits** up to 20 m thick, a clayey product of periodical erosion and flood controlled sedimentation are known from the Cornelia area.

**Alluvial sediments** are known from some sections of larger rivers, viz. Vaal, Vals, Vet, Renoster, Klip and Modder. River terraces of different levels were formed consisting of gravels, sand, silt and with a clay cover. Their thickness varies from a few metres up to 15, depending on the eroding power of the river and resistance of the rock formations. The terraces have limited areal extent, rarely exceed 6 km in width.

From all Cenozoic sediments, only small patches of alluvium at the lower Vals River, downstream from Kroonstad, and of the Klip River north of Memel are shown on the map. Other Cenozoic age geological formations have been omitted because of their limited size and geohydrological insignificance.

Figure 5. Dolerite intrusions



## 4 Hydrogeology

### 4.1 Aquifers

An aquifer can be defined as "a stratum which contains intergranular interstices, or a fissure/fracture (as such) or a system of interconnected fissures/fractures (as such) capable of transmitting groundwater rapidly enough to directly supply a borehole or a spring" (Vegter, 1995)

Water that occurs underground fills the intergranular open space in the unconsolidated sediments and in the weathered, previously consolidated rock, as well as joints and fractures in the hard rock.

However, the water saturation alone does not imply the existence of an aquifer. The gravitational mobility of water in a saturated rock formation as a result of its permeability is a pre-condition to identify the formation as an aquifer. (A water saturated layer of clay that could have a saturated porosity up to 40% of its volume, cannot be called an aquifer as its water can not be gravitationally drained by e.g. a spring or borehole).

Four aquifer types were identified in the area covered by the Hydrogeological map, sheet 2726 (Kroonstad) (see also section 1.2 "Legend explanation"):

- Intergranular (a)
- Fractured (b)
- Karstic (c)
- Intergranular and fractured (d)

The regional characterisation of the four aquifer types is given in detail in the Subsection 4.3.

The occurrence of groundwater in the unconsolidated sediments (aquifer type a) is rather a straightforward task to characterise. However, the geohydrology of the remaining three aquifer types is, due to their heterogeneity, very complex and a more detailed discussion of their origin and nature could be helpful to the map user.

### 4.2 Forming of hard rock aquifers

The aquifers originated from hard rock formations were formed by weathering processes, attacking the exposed rock and by forces and processes that were acting earlier or sometimes simultaneously to the weathering, viz.:

- tectonic forces
- intrusion of volcanic rock
- offloading

Weathering usually promotes the fracturing and jointing thereby induced, being the ultimate factor in shaping the final aquifer characteristics.

All the above processes are to be briefly discussed in the following subsections.

#### 4.2.1 Weathering

The weathering processes induced by external agents lead to fracturing, disintegration and decomposition of the exposed rock to create a mantle of weathering products (or regolith) that is formed on the site of the original rock, with fractures extending to a limited depth into the fresh rock below it.

Two main types of weathering are identified: mechanical and chemical.

- **Mechanical weathering** produces a mechanical disintegration of the rock without significant change of its mineralogical composition. Where the rock is exposed to a large and rapid temperature fluctuations (e.g. between day and night), that characterise hot and arid climate regions, fractures are produced.

The freezing of water that fills a fracture produces pressure that enlarges and deepens it. Another example of fracture forming is the pressure of plant roots that enlarges a fracture while acting as a wedge and additionally extends it to a larger depth.

Openings are frequently formed at the lithological contacts within sedimentary and metamorphic rocks of sedimentary origin due to their different physical rock properties that differentiate the scale of resistance to the weathering processes.

- **Chemical weathering** results in changing of the rock mineralogical and chemical composition and leads to rock decomposition and reduction of its mass by dissolution. The decomposition produces an overlying mantle (regolith), usually with clayey material dominating, that gradually changes with depth to a fractured only rock zone with a fresh, unweathered, solid rock below it. This type of weathering occurs mostly in warm, moist climates.

The rock dissolution takes place at the rock surface and along the fractures and joints exposed to moving water resulting in their gradual enlargement to form caves and channels. The speed of dissolution varies and is the fastest in the carbonate rocks where carbonic acid, present in groundwater, dissolves the limestone or dolomite producing karstic aquifers.

### 4.2.2 Tectonic forces

The movements by the Earth's crustal plates result in the regional scale deformation of their rock masses. The forces involved, acting on the hard rocks produce a system of rock fracturing and jointing. Of the hard rock formations, the competent rocks like sandstone, conglomerate, limestone, dolomite and crystalline rocks etc., react to form of a large number of fractures, whereas the frequency of fractures and joints occurrence in the incompetent rock (shale, mudstone, etc.) is by far lower.

Several structures are formed during the tectonical deformation of which folds and faults are the most frequent. They are to be discussed in more detail.

■ **Folds:** Competent rock formations respond to folding by forming a network of fractures and joints of different size and concentrations. Some elements of the folds such as anticlines are as a rule more intensively affected by tensional stresses and produce a network of open fractures

and joints. The synclines, where a large degree of compression occurs, have all stress related fractures closed.

■ **Faults:** These are discontinuities (large fractures) along which displacement of rock blocks took place. Two main fault types are considered:

- Normal faults (tensional) and reversed faults (compressional)

(There are however numerous fault types that describe a particular orientation of displacement, like wrench, hinge, pivot, thrust faults, etc.)

- The faults are usually associated by numerous fractures and joints produced within the rock blocks often forming zones running parallel to the bounding faults. Where compression took place, the fractures are mostly closed. Open fractures are formed by faults caused by tensional stress.

### 4.2.3 Intrusion of volcanic rocks

The intrusion of magma into discontinuities in the earth crust forms volcanic rocks. They occur in the form of vertical to sub-vertical, narrow sheets called dykes or more horizontal bodies called sills. The intrusive force and subsequent cooling of the implaced sills and dykes resulted in forming of zones of

fracturing and jointing in the intruded host rock along the intrusive body and also in the intrusive material. The intensity of this fracturing and jointing depends on the degree of competency of the intruded rock, depth of intrusion and its size.

### 4.2.4 Offloading

The erosion and denudation of rock formations leads to a gradual removal of a large volume of rock resulting in decompression of the remaining rock mass. A network of joints and

larger fractures in the solid rock below the regolith, especially in crystalline and metamorphic rocks, close to the present surface is the product of offloading.

## 4.3 Regional hydrogeological characterisation

Occurrences of the four recognised aquifer types in the area covered by the Kroonstad sheet are to be discussed in this section. The areas covered by the aquifers and the lithostratigraphical units forming them are indicated on the main map as well as on the unit Distribution Maps. The important hydrogeological features and quality of groundwater of those units are to be briefly characterised.

The median borehole yield of the four different aquifer types has been characterised on the map by the introduction of five yield classes with progressive increase in yield and related colour intensity (see "Principal Groundwater Occurrence" on the map). Each yield class has additionally been characterised

by the allocation of yield description (low, moderate, etc.) in a more generalised form:

- Median yield below 0.1 l/s – very low,
- Median yield between 0.1 and 0.5 l/s – low,
- Median yield between 0.5 l/s and 2.0 l/s – moderate,
- Median yield between 2.0 and 5.0 l/s – high,
- Median yield above 5.0 l/s – very high.

The discussion is to be carried out for every aquifer type in a chronological order from the oldest to the youngest geological formation.

### 4.3.1 Intergranular aquifers

This aquifer type is poorly represented in the map area. Unconsolidated, water saturated alluvium occurs sporadically along the Vaal, Wilge, Klip, Sand, Vet, Modder and Vals Rivers. The thickness of the alluvial sediments, consisting mainly of clay, sand and gravel at the bottom, is limited to a few metres.

Their lateral extent is usually limited to a few hundred metres. In large sections of the river course the alluvium is dry or absent as the older bedrock outcrops in the river channel and its banks. A limited number of boreholes drilled on the

alluvial terraces tap alluvium (it is usually cased-off).

Two larger alluvial areas along the lower Vet and Klip Rivers are indicated on the map. The alluvial aquifers there are thin and not directly tapped by boreholes, hence the colour of the bedrock aquifer type on the main map. Due to limitations imposed by the main map scale, other alluvial aquifers are not indicated.

The alluvial water quality could not be assessed due to the total lack of water analyses.

### 4.3.2 Fractured aquifers

Tectonic forces and to a lesser degree the weathering processes have produced a network of fractures in the highly competent mainly quartzitic rock formations of Randian age. Little or no

decomposition of the rock mass took place. The storage volume of groundwater present in this type of aquifer is therefore limited, much lower than in other aquifer types.

#### 4.3.2.1 West Rand (Rw) and Central Rand (Rc) Groups (Supergroup – Witwatersrand)

Outcrops of the older Dominion Group (volcanic rocks) occurring along the eastern edge of the West Rand Group are not shown on the map due to the map scale.

Outcrops of the West Rand and Central Rand Groups occur in a small area, just west and southwest of Vredefort (Fig. 6). They form an assemblage of quartzite and conglomerate with shale prevailing in the oldest part. Only 14 boreholes were

identified with documented yields and a few water quality analyses were found. This scarcity of data does not allow for a reliable analyses of the geohydrological rock properties such as borehole yield and water quality.

Only two of these boreholes (or roughly 14%) yield more than 2 l/s (Fig. 7). (In the adjacent sheet 2526 (Johannesburg) this figure rises slightly to 16% of 345 documented boreholes).

**Table 4. Chemical groundwater analyses from boreholes, West Rand Group**

		A	B	C	D
pH		7.17	7.64	6–9	5.5–9.5
EC	mS/m	71.3	39.0	70.0	300.0
TDS	mg/l	548.0	309.0	1 200.0	2 000.0
NO <sub>3</sub> +NO <sub>2</sub> (as N)	mg/l	13.39	1.73	6.0	10.0
NH <sub>4</sub> (as N)	mg/l	<0.04	0.06	6.0	10.0
F	mg/l	0.11	0.28	1.0	1.5
TAL (as CaCO <sub>3</sub> )	mg/l	231.3	169.5	20–300	650.0
Na	mg/l	27.5	15.9	100.0	400.0
Mg	mg/l	36.3	12.1	70.0	100.0
Si	mg/l	21.02	17.13	–	–
PO <sub>4</sub> (as P)	mg/l	0.031	<0.005	–	–
SO <sub>4</sub>	mg/l	12.8	<4.0	200.0	600.0
Cl	mg/l	58.2	13.3	250.0	600.0
K	mg/l	1.83	1.44	200.0	400.0
Ca	mg/l	70.3	47.6	150.0	200.0

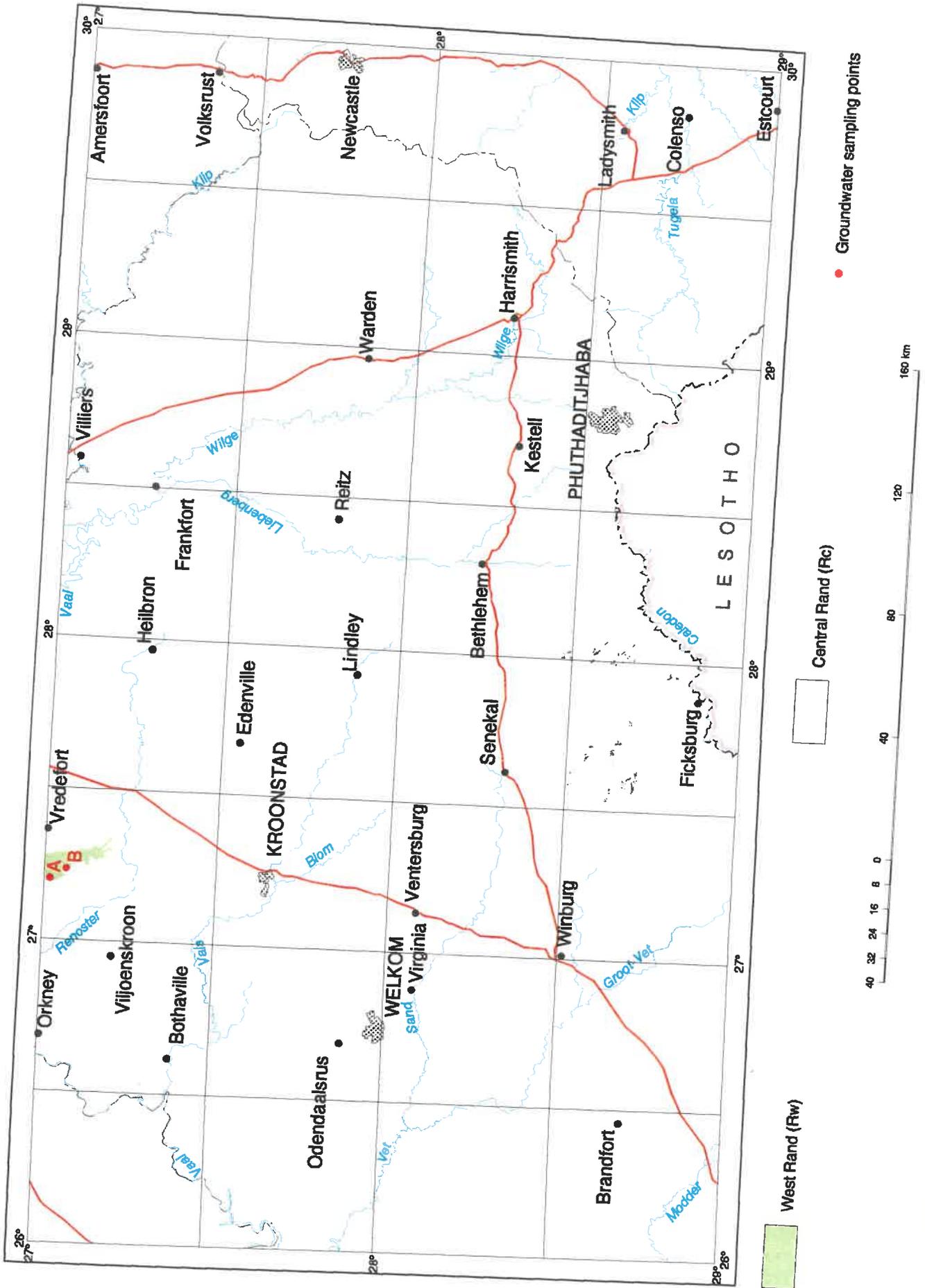
A – Borehole; Linderwestfontein, District Vredefort

C – Drinking Water Quality Criteria – Recommended Limits

B – Borehole; Mimosa, District Vredefort

D – Drinking Water Quality Criteria – Maximum Allowable

Figure 6. Distribution of the West Rand (Rw) and Central Rand (Rc) Groups with the position of Table 4 groundwater samples



The depth to the groundwater level fluctuates between 10 to 25 m and is a function of the local topography.

The chemistry of groundwater in the West Rand Group (no water analysis from the Central Rand Group was found) indicates the water to be potable (ECs around 70mS/m and less) (Table 4). It has a calcium–magnesium–bicarbonate character (Fig. 8). Pollution by nitrates occurs in places (Table 4).

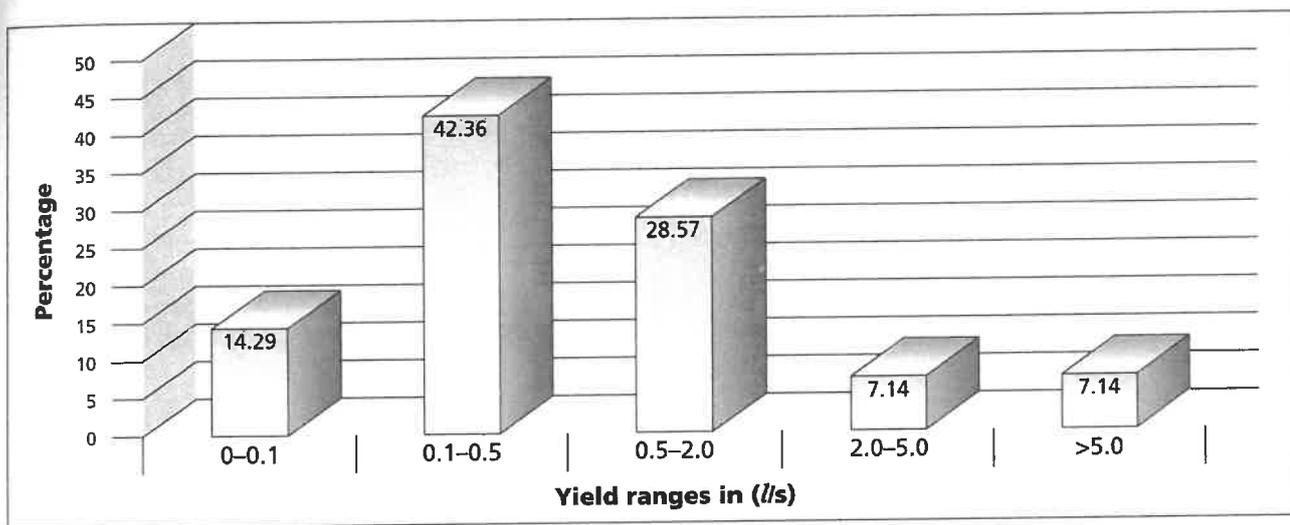
The groundwater pumped from the Free State Goldfields mines is considered to be stored in a network of interconnected fissures and fractures in the rocks of both the Witwatersrand and Ventersdorp Supergroups. It is isolated from the shallow, subsurface Karoo rock aquifer by the impermeable shales of the Ecca Group (Venter, 1968). The overall quality of the

confined water of 450 mS/m significantly differs from the water quality found in the same aquifer in the outcrops area, north of Welkom, i.e. 70 mS/m. This led Venter (1988) to a conclusion that the deep water is of a fossile character, probably of late Dwyka and early Ecca age, a result of a temporary inundation of the area by a sea and subsequent recharge by rain.

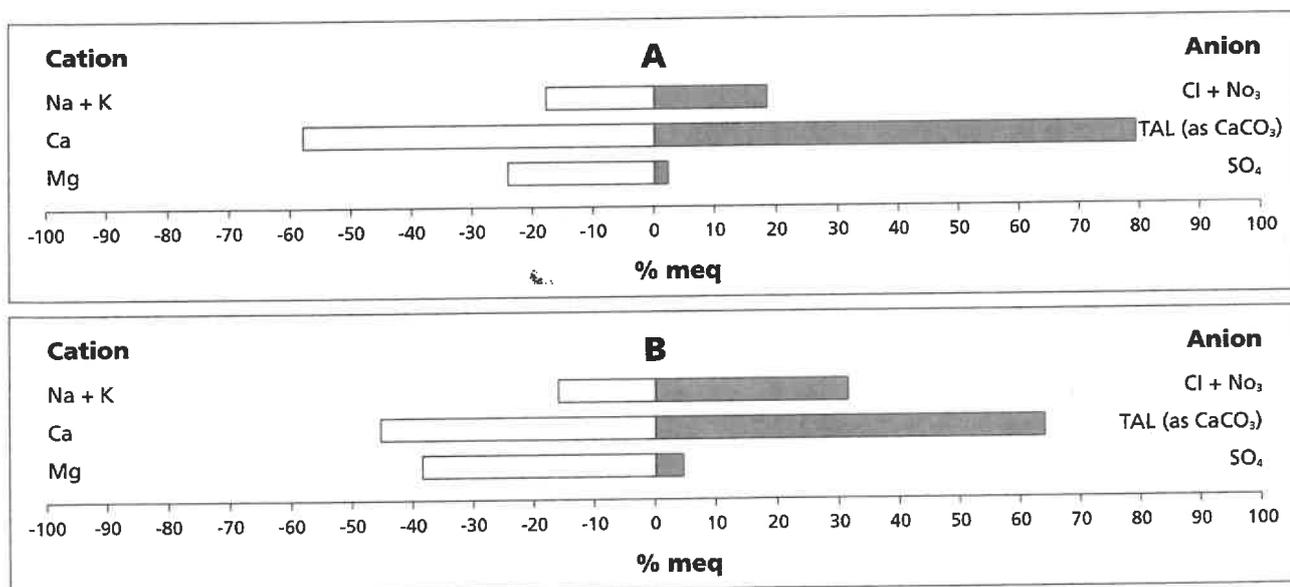
The numerical modelling of this aquifer system by Cogho at all (1992) and model simulation produced a best fit to the historical water level depth data when assuming a transmissivity value of 10m<sup>2</sup>/d, and 0.001 for the system storativity.

However, this storativity appears to be on the high side and more research of the aquifer system geohydrology is needed in order to satisfy all available observations.

**Figure 7. Yield frequencies of boreholes in the West Rand and Central Rand Groups**



**Figure 8. Stiff diagram of the chemical groundwater analyses (West Rand Group)**



### 4.3.3 Karstic aquifers

Karstic aquifers are formed by dissolution of a carbonate rock by circulating groundwater containing carbonic acid. The process takes place along the faults, fractures and joint planes resulting in their enlargement. Channels, caves and other cavities are formed which are often partially filled by permeable

residual products of chert rubble, iron and manganese oxides and hydroxides. Karstic aquifers are often characterised by high storage and high yielding boreholes, should the dissolved rock sections be penetrated.

#### 4.3.3.1 Chuniespoort Group (Vh)

Karstic aquifers have developed in the Vaalian age dolomite of the Chuniespoort Group. In the map area the rocks of the Chuniespoort Group outcrop only in two small localities, viz., at and east of Orkney and east of the Renoster River between Viljoenskroon and Vredefort (Figure 9). Under cover of the younger rock formations (the Pretoria Group and the Karoo Supergroup) the dolomite extends further south east towards Kroonstad.

Based on the information from the adjacent hydrogeological map sheet (Johannesburg 2526) the dolomite groundwater is

of good, potable quality, (average ECs of around 60 mS/m) and more than 50% of boreholes drilled yield 5 l/s and more.

No borehole information and water quality analyses from the dolomite of the two areas are available. It is thus recommended that an accurate hydrocensus be carried out in and around the two areas and further south, coupled (if needed) with exploratory geophysics and drilling in order to characterise this important aquifer and assess its groundwater development potential.

### 4.3.4 Intergranular and fractured aquifers

This aquifer system occurs practically throughout the entire map area. The action of tectonic forces together with the subsequent processes of weathering created two hydraulically interconnected zones that occur in a vertical profile:

- A shallower, weathered zone where the original rock structure has been changed to a mass of more or less loose rock fragments in a matrix of fine products of weathering, mostly sand, silt and clay.

In some other areas the rock has been transformed to an aggregate of small loose rock blocks, of up to a few cm in size, having a substantial secondary porosity. As the groundwater

level is generally at shallow depth in the map area, a large portion of this zone is saturated.

- A fractured zone, down to a depth where the rock becomes solid and fresh in appearance. The transition to this deeper zone is usually gradual.

The lateral movement of groundwater in the top zone is very slow and boreholes tapping it are very low yielding. However, the vertical water movement (leakage) is by far faster (high gradient) and therefore significant, as it recharges the fractured zone below.

#### 4.3.4.1 Inlandsee Gneiss (Zie) and Parys Granite (Zpa)

The two oldest rock formations are exposed in a diminutive area around Vredefort, close to the northern map boundary (Fig. 10). Further to the south they occur under cover of younger rocks.

Only 19 water boreholes were identified, too few to perform any meaningful statistical operations (Fig. 11). On the adjacent map (2526 Johannesburg) the median borehole yield is rated 'high' as 65% of the boreholes produced more than 2 l/s.

The yield class of the 19 boreholes identified on the Kroonstad map can be categorised as 'low' as 53% of them yield 0.1

to 0.5 l/s and only 21% fall into the 0.5 to 2.0 l/s yield range.

The groundwater level depth varies between 5 to 30m, and the influence of rock permeability and topography can be noted.

No water quality data from both rock formations are available. Extrapolating the information from the 2526: Johannesburg map one could expect that the groundwater quality should be very good, as the electrical conductivity averages 40 mS/m.

Figure 9. Distribution of the Chuniespoort Group (Vp)

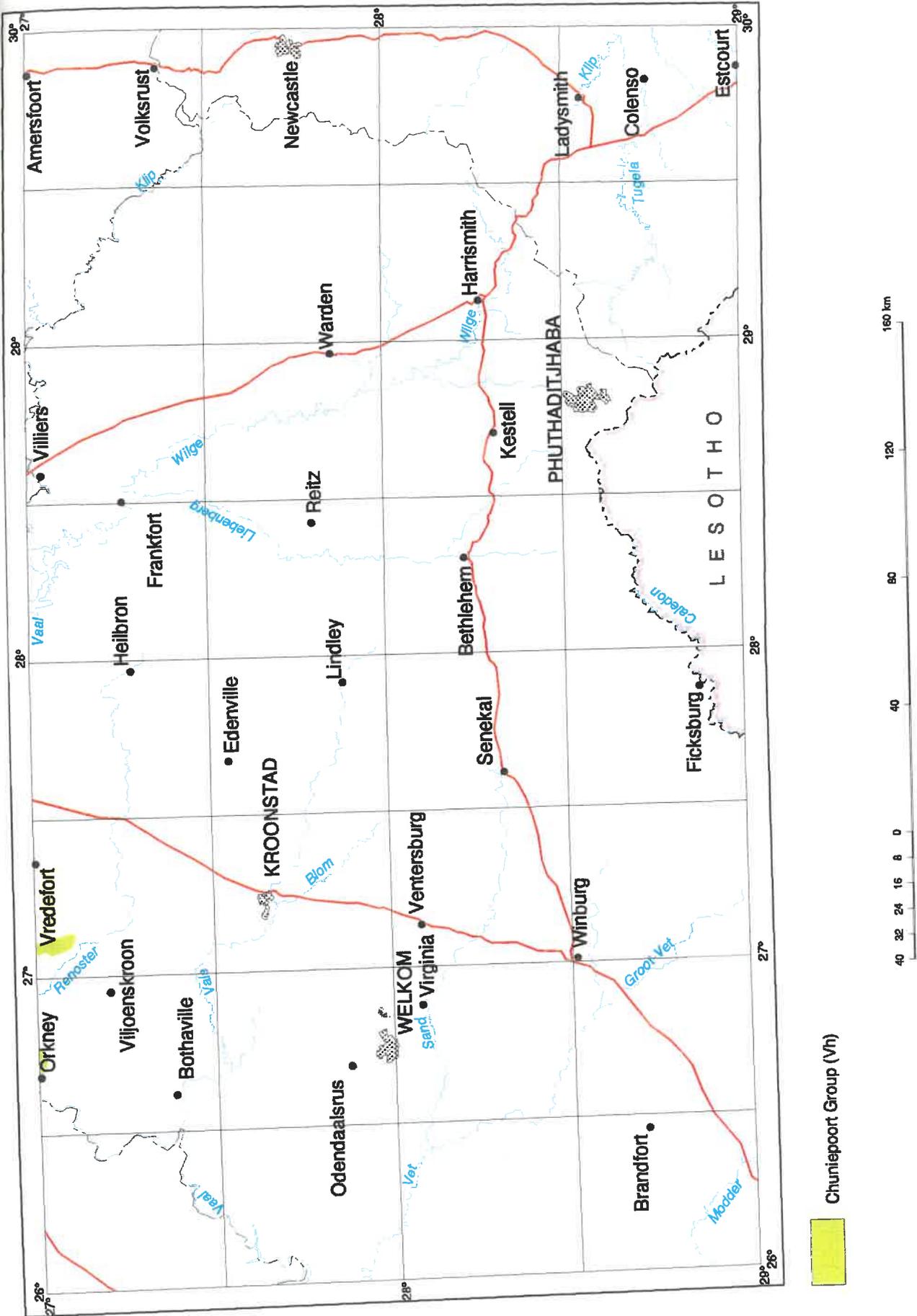
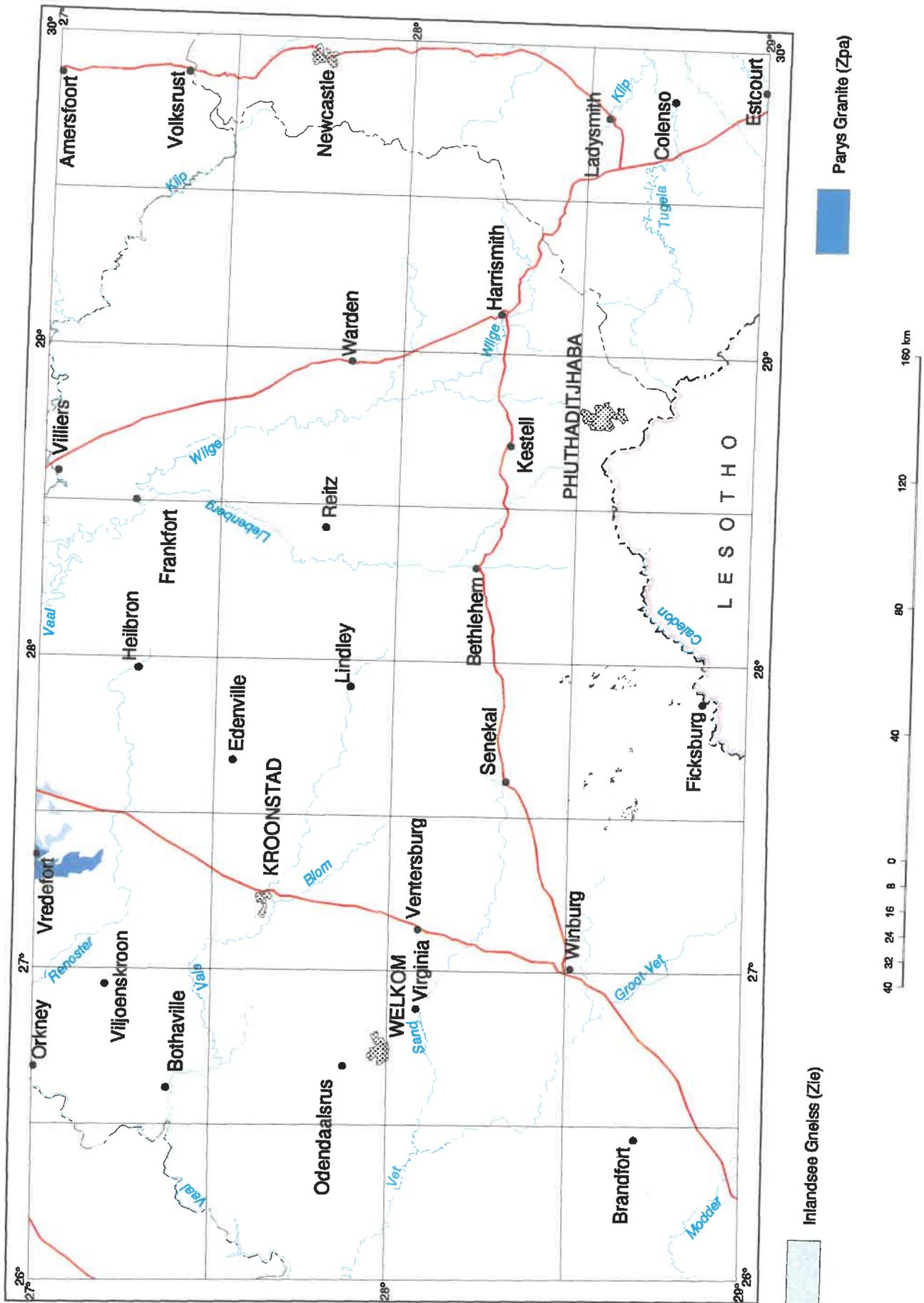
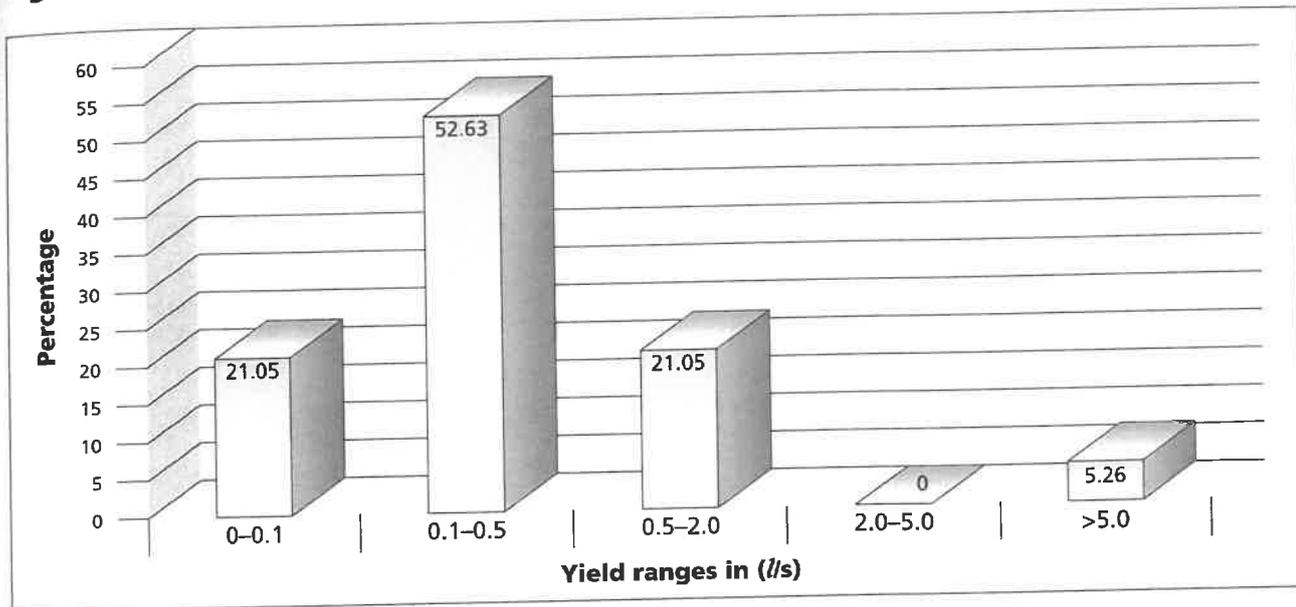


Figure 10. Distribution of the Inlandsee Gneiss (Zie) and Parys Granite (Zpa)



**Figure 11. Yield frequencies of boreholes in the Inlandsee Gneiss and Parys Granite**



#### 4.3.4.2 Klipriviersberg Group (Rk)

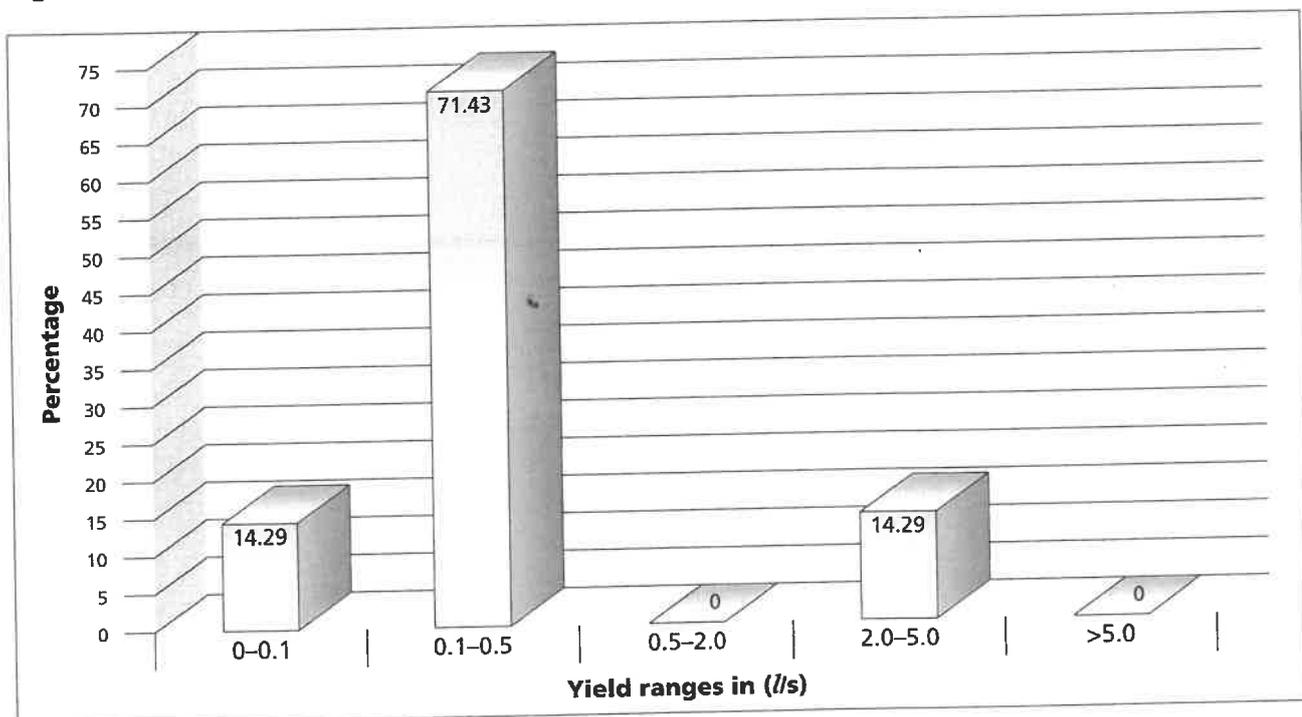
Outcrops of the Klipriviersberg Group occur as a narrow, 3 to 5 km wide strip of andesitic lava and tuff between the northern edge of the map (27°07' to 10' E) and the Renoster River in the south (Fig. 13). Two isolated inliers of the Group occur on the south-eastern extension of the strip.

Groundwater occurs in the weathered mantle of the lava and tuff, usually underlain by fractured rock; the latter forms a transition zone to the fresh, solid lava. Basins of deeper weathering are usually targeted for groundwater development.

There are yield data from only 7 boreholes and no water chemistry data are available. The borehole yield frequency diagram (Fig. 12) is attached for a general illustration only. The yield potential on the adjacent Johannesburg map is described as 'low', which was concluded from the fact that 71% of available boreholes have yields between 0.1 and 0.5 l/s.

The water quality based on data from the Johannesburg sheet can be expected to be potable with a mean EC value of 60 mS/m and average pH value of 7.6.

**Figure 12. Yield frequencies of boreholes in the Klipriviersberg Group**





## 4.3.4.3

## Platberg Group (Rp)

The Platberg Group occupies an area of the extreme north-western corner of the map and a small area at and west of Orkney and is represented by six Formations (Fig.15). Two lithological rock assemblages were portrayed i.e. the extrusive quartz porphyry and tuff, chert and lava as "various mixed lithologies".

Groundwater occurs in the weathered and fractured zone in all the lithologies present. The presence of dolerite intrusions increases the borehole yield potential.

The analysis of 79 borehole records available (Fig.14) indicates that borehole yields can be classified as 'low' to 'moderate' as 28% of the yields are between 0.1 to 0.5 l/s and 40% between 0.5 to 2.0 l/s.

Only one borehole water quality analysis is identified (Fig. 16 and Table 5) characterising the groundwater as potable with an EC value of 55 mS/m. However, an extrapolation of this analysis result to the entire Platberg Group should be avoided.

Figure 14. Yield frequencies of boreholes in the Platberg Group

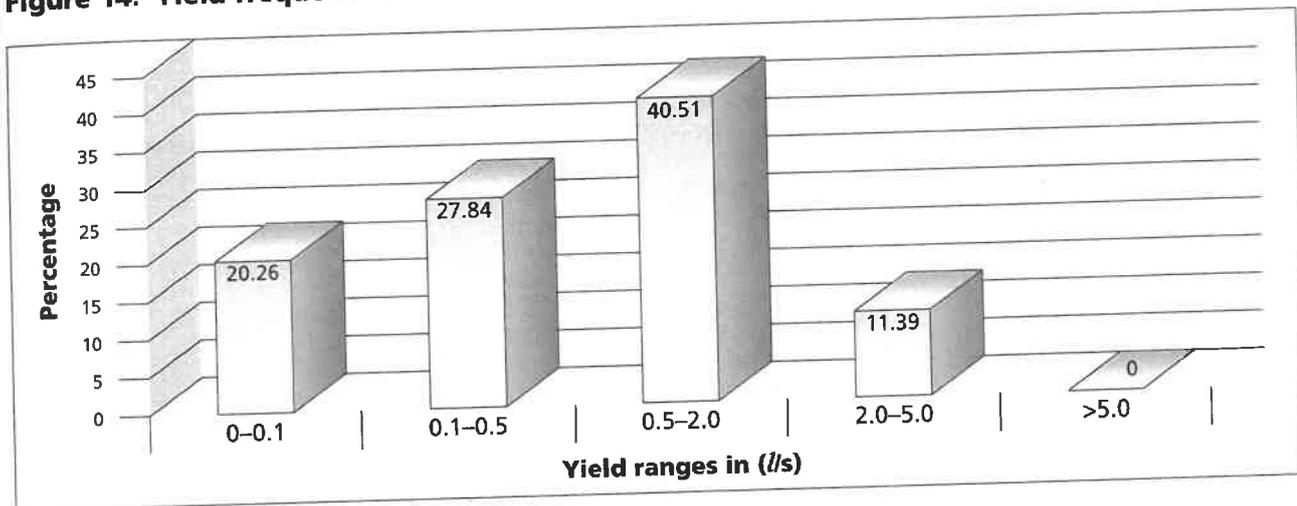


Table 5. Chemical groundwater analysis from a borehole in the Platberg Group

	A	B	C
pH	7.87	6-9	5.5-9.5
EC	mS/m 55.4	70.0	300.0
TDS	mg/l 369.0	1 200.0	2 000.0
NO <sub>3</sub> +NO <sub>2</sub> (as N)	mg/l 4.97	6.0	10.0
NH <sub>4</sub> (as N)	mg/l 0.04	6.0	10.0
F	mg/l 1.0	1.0	1.5
TAL (as CaCO <sub>3</sub> )	mg/l 182.1	20-300	650.0
Na	mg/l 18.8	100.0	400.0
Mg	mg/l 30.0	70.0	100.0
Si	mg/l 13.98	-	-
PO <sub>4</sub> (as P)	mg/l 0.026	-	-
SO <sub>4</sub>	mg/l 19.0	200.0	600.0
Cl	mg/l 14.6	250.0	600.0
K	mg/l 7.12	200.0	400.0
Ca	mg/l 34.0	150.0	200.0

A – Borehole; Kameeldoorns Formation, Platberg Group, Uital, District Wolmaransstad

B – Drinking Water Quality Criteria – Recommended Limits

C – Drinking Water Quality Criteria – Maximum Allowable

Figure 15. Distribution of the Platberg Group (Rp) with the position of Table 5 groundwater sample

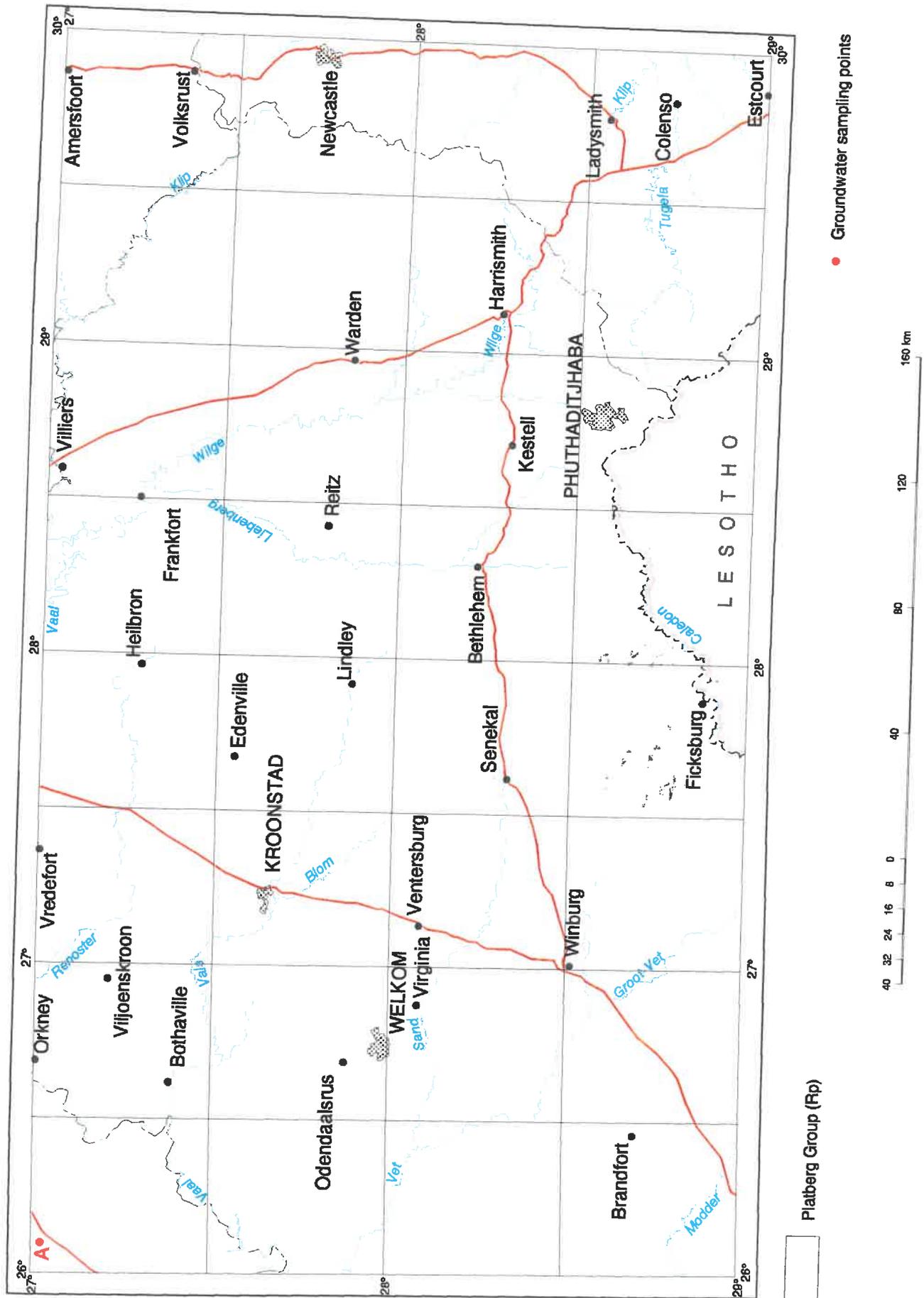
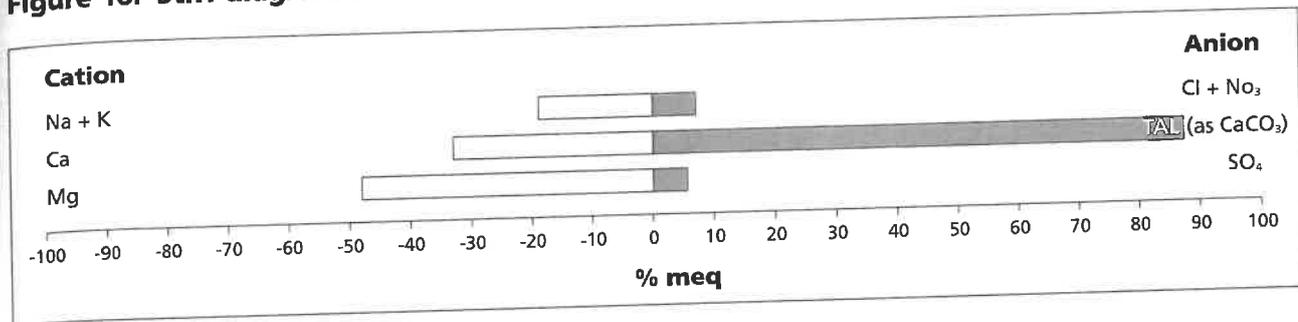


Figure 16. Stiff diagram of the chemical analysis (Platberg Group)



#### 4.3.4.4 Allanridge Formation (R-Val)

The Allanridge Formation occurs in the northwestern corner of the map area, to the east of the Rietgat volcanics (Rp) of the Platberg Group. Isolated outcrops are found in an area north and northwest of Odendaalsrus, but only two major inliers are indicated on the map (Fig. 17).

The Formation is composed of dark green amygdaloidal andesite with a thickness of up to 740 m. Because of its relative low resistance to weathering it forms a flat or slightly undulating landscape. Numerous dolerite dykes form small, wooded ridges. The Allanridge Formation is underlain by predominantly arenaceous sediments of the Bothaville Formation which consist of quartzite, conglomerate and greywacke. Their exposures form an up to 1 km wide strip along the western edge of the Allanridge Formation and were not indicated on the map. In the Welkom area the Bothaville Formation attains a total thickness of 30 m below a Karoo rocks cover. On the map the Bothaville Formation is incorporated into the

latter and not shown separately. Occurrence of groundwater is mostly associated with basins of weathering, fractured transitional zones between weathered and solid rock, and dolerite contact zones with the host rock. Some boreholes struck water on the contact of, and within, the underlying Bothaville Formation. The borehole yield analysis reveals that approximately 42% of 450 boreholes documented yield between 0.5–2.0 l/s, 46% yield less than 0.5 l/s, and only 12% are stronger than 2.0 l/s. The borehole yield can thus be classified as “moderate.” (Fig. 18).

The 14 available chemical analyses show that groundwater in the Allanridge Formation is acceptable for most uses. The EC values do not exceed 70 mS/m, the average being 42 mS/m (Table 6). The water is of slightly alkaline nature (pH 6.3–8.2) and displays a calcium-magnesium-bicarbonate character (Fig. 19).

Table 6. Typical chemical analyses from boreholes, Allanridge Formation

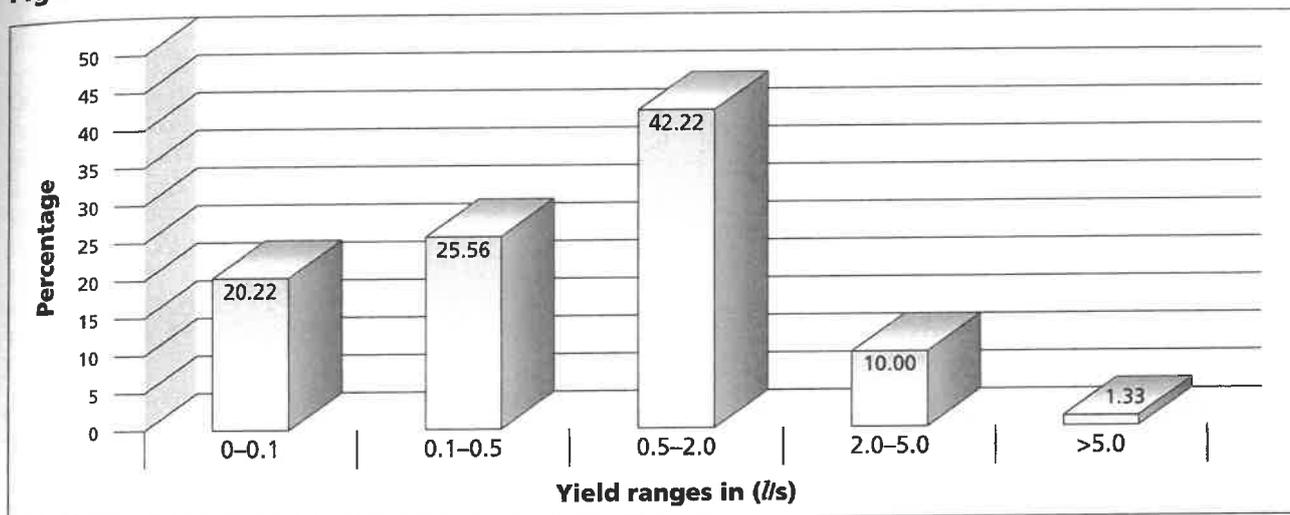
	A	B	C	D
pH	6.32	7.87	6–9	5.5–9.5
EC	16.2	56.3	70.0	300.0
TDS	122	451	1 200.0	2 000.0
NO <sub>3</sub> +NO <sub>2</sub> (as N)	1.21	0.73	6.0	10.0
NH <sub>4</sub> (as N)	<0.04	<0.04	6.0	10.0
F	0.1	0.18	1.0	1.5
TAL (as CaCO <sub>3</sub> )	46.9	260	20–300	650.0
Na	8.1	31.2	100.0	400.0
Mg	10.1	23.7	70.0	100.0
Si	7.63	16.07	–	–
PO <sub>4</sub> (as P)	0.016	<0.005	–	–
SO <sub>4</sub>	18.0	7.1	200.0	600.0
Cl	12.1	11.7	250.0	600.0
K	1.95	0.79	200.0	400.0
Ca	8.7	56.5	150.0	200.0

A – Borehole, yield 2,56 l/s; Doornplaat; District Klerksdorp  
 C – Drinking Water Quality Criteria – Recommended Limits

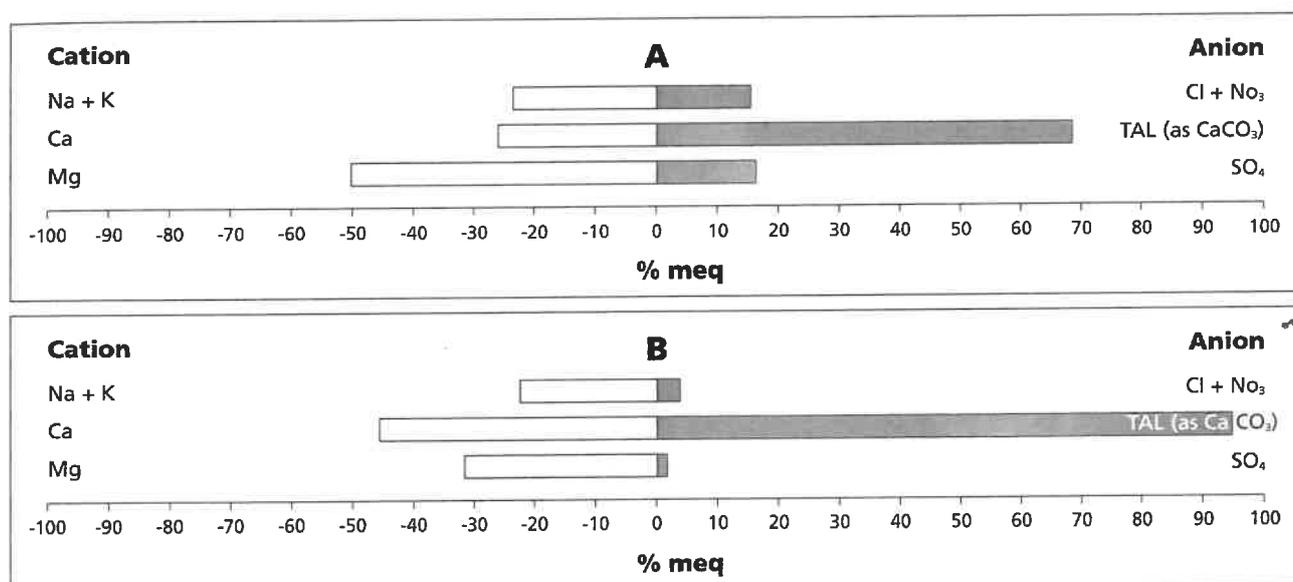
B – Borehole, yield 6,67 l/s; Wolvehuis, District Klerksdorp  
 D – Drinking Water Quality Criteria – Maximum Allowable



**Figure 18. Yield frequencies of boreholes in the Allanridge Formation**



**Figure 19. Stiff diagram of the chemical analyses (Allanridge Formation)**



**Groundwater in Mines of the Free State Goldfields**

Thirteen gold mines have been developed since the early 1950s in the west-central part of the Kroonstad sheet area, forming the Free State Goldfields. The area being mined forms a north to south extended belt approximately 60 km in length between Allanridge and a point 12 km north of Theunissen. The average width of the mining belt is approximately 12 km.

The ore occurs mainly in the conglomerate of the Witwatersrand Supergroup, that is covered by the Ventersdorp Supergroup which underlies the Karoo Supergroup. The total thickness of the Karoo cover increases towards the south to 900 m.

Groundwater occurs in two hard rock formations, viz. the upper aquifer being the intergranular and fractured type in the top section of the Karoo sediments and the lower aquifer – the fractured Witwatersrand and Ventersdorp Supergroups with a total explored thickness up to 3 400 m. Both aquifers are separated by impermeable, deeper sections of the Karoo rocks, mostly the shale of the Volksrust Formation.

The mines' dewatering operation commenced in 1952 and during the consecutive 37 years 1 240x10<sup>6</sup> m<sup>3</sup> of water from the deeper aquifer was abstracted (Cogho, et al. 1992). The dewatering could have affected a larger area than estimated by Cogho. Kent (1971) suspected that the decrease in flow of the spring at Florisbad, and of the deep artesian borehole at Glen, could be correlated with the dewatering effect of the Goldfields mines.

The average conductivity of deep groundwater is 450 mS/m and the salinity mainly of the NaCl type. The mine water has been discharged to large number of constructed evaporation dams and natural pans. Since the mining operations have begun, approximately 3.7x10<sup>6</sup> tonnes of salts have been accumulated in the evaporation dams and pans of the mining environment. The dewatering process did not affect the upper Karoo aquifer as it was sealed-off in shafts during their construction. The impermeable Volksrust shale appears to be an insulation layer that prevents vertical drainage.

The impact of the mining operations on the local groundwater quality (the Karoo aquifer) is mainly confined to the immediate vicinity of the mining dumps, slime dams and other pollution sources, mainly thanks to the preventive measures of the companies involved (Cogho et al, 1992).



#### 4.3.4.5 Pretoria Group (Vp)

Outcrops of the Pretoria Group occur along the lower Renoster River from the confluence with the Heuningspruit to the area of the northern map boundary, overlaying partially the older dolomite of the Chuniespoort Group. The andesitic lavas of the Hekpoort Formation are the most prominent lithology in the area. To the west and north of the Renoster River the more prominent occurrence of the younger formations, i.e. the Strubenkop (shale, tuff) and Daspoort (quartzite), together with large diabase bodies necessitated the intro-

duction of grouped ornament: 'undifferentiated rocks and various mixed lithologies'.

Only two boreholes penetrating the Pretoria Group aquifer were recorded. The borehole yield indicated on the map is 0.5–2.0 l/s as adopted from the adjacent Johannesburg map.

Groundwater quality data for the map are not available. Again, the extrapolation of information from the north is used, assuming that the EC (around 50 mS/m) and pH (7.5) would not change within the same lithology and rainfall zone.

#### 4.3.4.6 Karoo Supergroup

##### 4.3.4.6.1 Dwyka Group

As sediments of this Group (diamictite, conglomerate, mudstone and shale) are practically not exposed in the map area and no deep groundwater exploration was carried out, no information on their geohydrological properties is available.

##### 4.3.4.6.2 Ecca Group (Pe)

The lithology of the two Eccca Group Formations occurring in the map area differ significantly. The lower Vryheid Formation is mainly arenaceous while the overlying Volksrust Formation is predominantly argillaceous in nature. Although occur-

rences of both Formations are shown on the map, no separate borehole yield analysis is performed. The description of the large majority of the geological logs were compiled incompetently and are very vague. No confidence could be attached to

**Table 7. Typical chemical analyses from boreholes, Eccca Group**

		<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
pH		8.52	7.8	<b>6–9</b>	<b>5.5–9.5</b>
EC	mS/m	86.1	13.8	<b>70.0</b>	<b>300.0</b>
TDS	mg/l	778.0	130.0	<b>1 200.0</b>	<b>2 000.0</b>
NO <sub>3</sub> +NO <sub>2</sub> (as N)	mg/l	<0.04	0.514	<b>6.0</b>	<b>10.0</b>
NH <sub>4</sub> (as N)	mg/l	<0.04	<0.04	<b>6.0</b>	<b>10.0</b>
F	mg/l	2.6	0.16	<b>1.0</b>	<b>1.5</b>
TAL (as CaCO <sub>3</sub> )	mg/l	454.8	76.0	<b>20–300</b>	<b>650.0</b>
Na	mg/l	205.9	7.5	<b>100.0</b>	<b>400.0</b>
Mg	mg/l	<1.0	4.3	<b>70.0</b>	<b>100.0</b>
Si	mg/l	5.42	17.1	–	–
PO <sub>4</sub> (as P)	mg/l	<0.005	0.016	–	–
SO <sub>4</sub>	mg/l	5.8	<4.0	<b>200.0</b>	<b>600.0</b>
Cl	mg/l	<3.0	3.5	<b>250.0</b>	<b>600.0</b>
K	mg/l	<0.3	0.69	<b>200.0</b>	<b>400.0</b>
Ca	mg/l	5.9	15.5	<b>150.0</b>	<b>200.0</b>

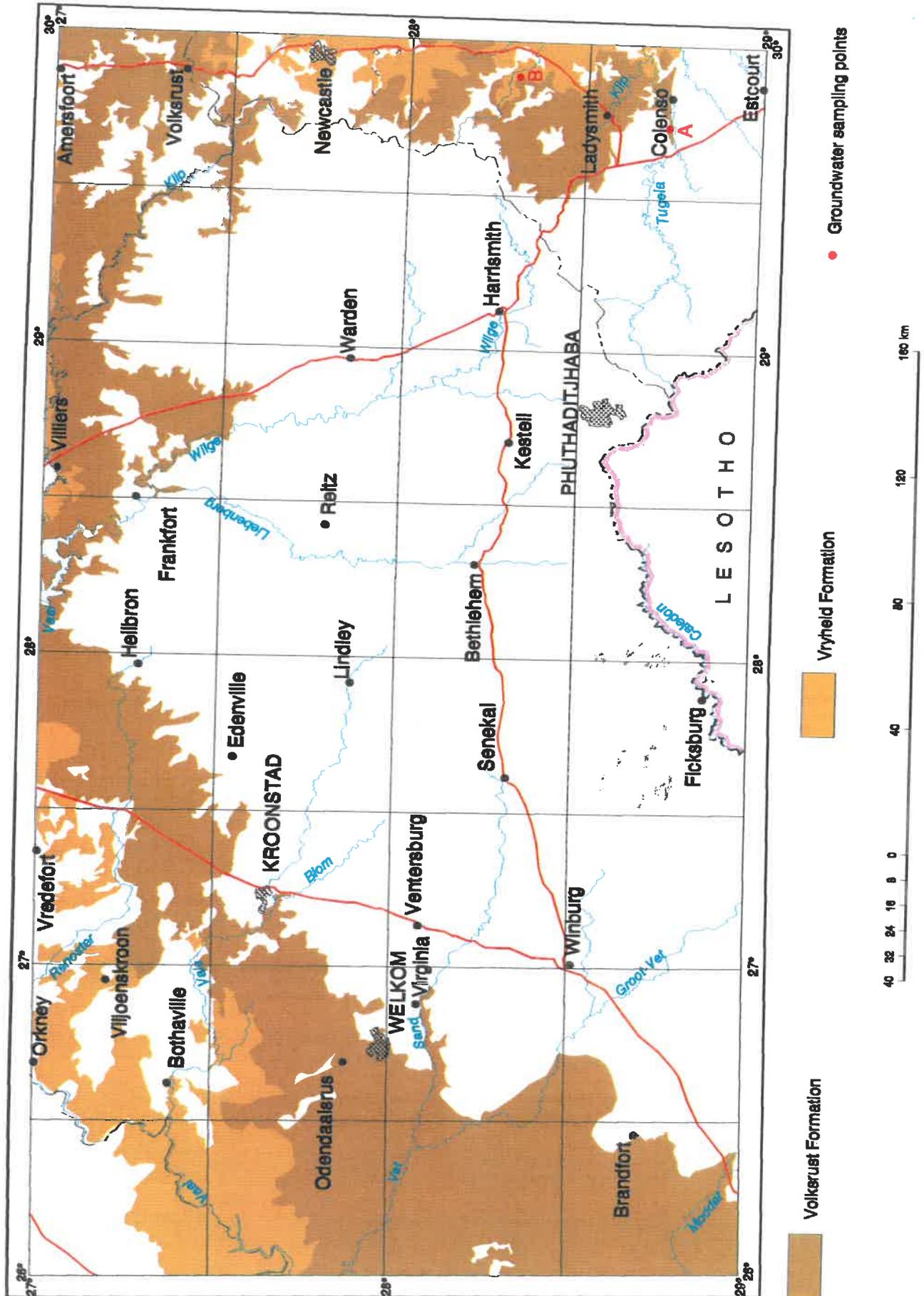
**A** – Borehole; Geluk, District Kliprivier

**B** – Borehole; Doornpoort, District Kliprivier

**C** – Drinking Water Quality Criteria – Recommended Limits

**D** – Drinking Water Quality Criteria – Maximum Allowable

Figure 21. Distribution of the Ecca Group (Pe) with the position of Table 7 groundwater samples



their stratigraphic identification. The identified 1 017 boreholes were lumped together (Fig. 22) showing the 30% of boreholes yielding 0.1 to 0.5 l/s and 40% of boreholes yielding 0.5–2.0 l/s. The performed yield analysis is not representative of the Eccca Group alone as an unspecified number of boreholes were drilled at dolerite dykes or penetrated dolerite sills. A large number of borehole logs do not specify the lithology of the rock formation penetrated and little confidence exists as to the exact borehole position with respect to dolerite intrusion. The boreholes away from dolerite intrusions were generally drilled not deeper than 35–40 m. Where dolerite intrusions were targeted the borehole depth was extended to 50–60 m.

It could be expected that weathering and fracturing within the arenaceous and more competent Vryheid Formation would be developed to a larger extent than in the argillaceous Volksrust Formation. Venter (1968) regards the Volksrust shales in the Free State Goldfields as totally impermeable, thus responsible for the artesian conditions in the fractured rocks of the pre-Karoo age. This opinion is supported by mining operations there that did not affect the overlying Karoo water bear-

ing formations of the Beaufort Group.

The water quality evaluation based on 203 analyses reveals a large fluctuation in EC. Approximately 45% of boreholes have EC values above the recommended limit for drinking water (70 mS/m) but only 2% have EC values higher than 300 mS/m (the maximum allowable limit). The mean EC value is 78.7 mS/m. According to the Stiff diagram (Fig. 23 and Table 7) groundwater in the Eccca Group is of a sodium-bicarbonate character.

An isolated area of EC > 300 mS/m northwest of Kroonstad can be attributed to local groundwater pollution of an unknown source.

The existence of a strip of poor water quality (> 300 mS/m) along the western map limit could not be explained at the present stage.

The distribution of sampling points for water analyses on the Eccca aquifer (Fig. 21) is, with exception of the KwaZulu-Natal area, rather erratic. In the western and northern map sector large areas are not sampled, giving little weight to the conclusions regarding water quality.

Figure 22. Yield frequencies of boreholes in the Eccca Group

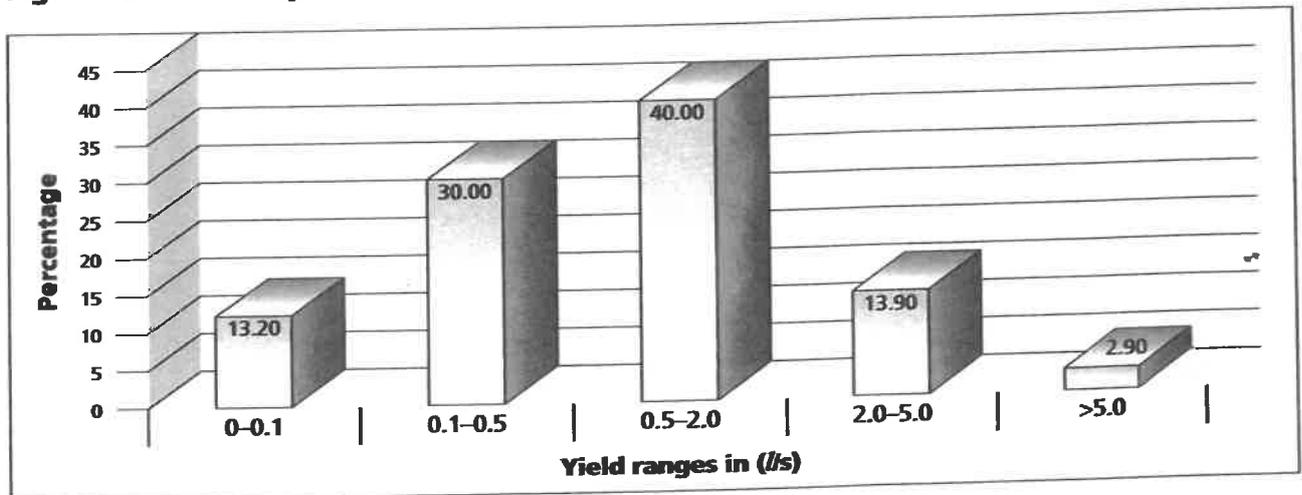
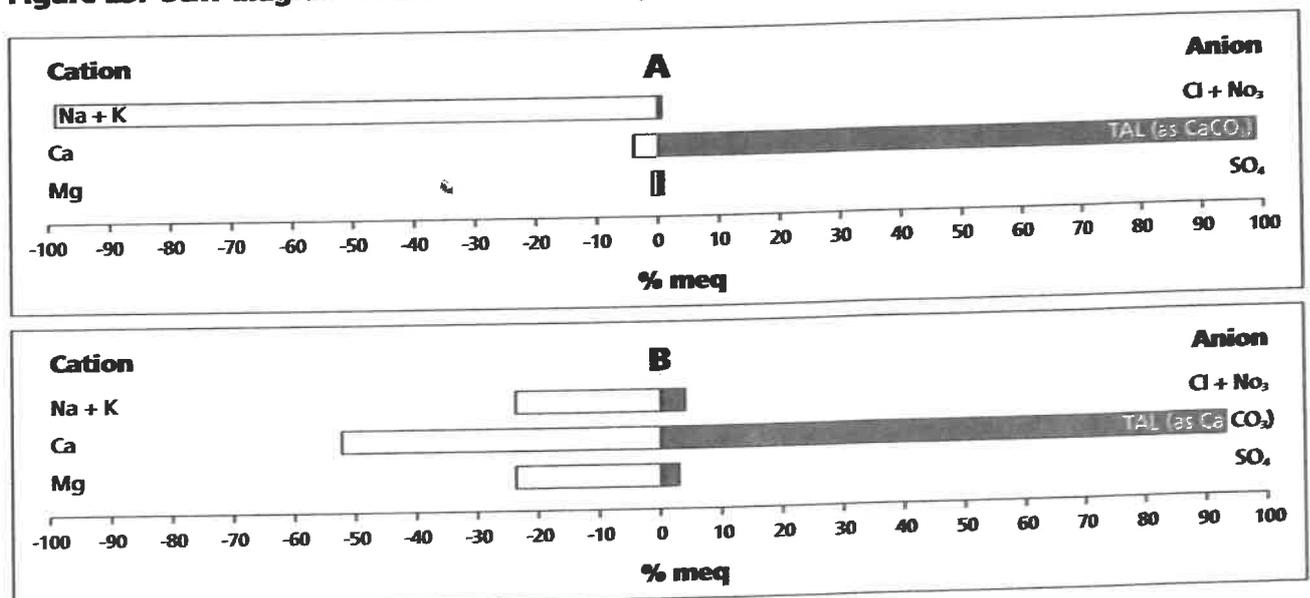


Figure 23. Stiff diagram of the chemical analyses (Eccca Group)



### Artesian thermal water at Glen, district – Bloemfontein

A deep exploration borehole was drilled next to the Glen railway station during 1968 by a private company in an effort to find oil in the Karoo sedimentary basin. Instead artesian water (35°C) was struck between 747 and 775 m in the diamictite of the Dwyka Group, just above the pre-Dwyka floor.

The artesian flow stabilised at 2.5 l/s. The water TDS was 2 034 mg/l with NaCl in the dominant position of 1 895 mg/l. Other important characteristics were: F – 5.3 mg/l, EC – 325 mS/m and pH – 7.9.

The pre-Karoo bedrock of gneiss and granite with intrusive dolerite bodies was struck at 775 m. The borehole was stopped at 1 495 m.

According to Kent (1971), the artesian flow rate was expected to weaken as a result of the dewatering effect of the Free State Goldfields mines which are situated approximately 110 km to the northeast of Glen.

The borehole still exists but is closed with a cap. A small artesian leakage appears at the casing. (Information from Mr. Piet Huysen from Glen College, December 2001).

Many other deep exploration boreholes drilled around the Goldfields were originally artesian but their flow gradually ceased when pumping from the developing mines intensified.

#### 4.3.4.6.3 Beaufort Group (P-Trb)

No subdivision of the Beaufort Group into its two Subgroups, i.e. the older Adelaide and the younger Tarkastad, was from a hydrogeological point of view regarded as useful (Fig. 24). However, the Adelaide Subgroup, consisting mainly of argillaceous sediments, is distinguished from the rest of the Group by its lithological signature: 'predominantly argillaceous rocks'. Similarly, the Tarkastad Subgroup, because of its larger arenaceous content, especially in the southwestern and southeastern map quarters, has been portrayed there as "argillaceous and arenaceous rocks (approximately equal proportions)".

The lithology of the Beaufort Group sediments appears to have little effect on the borehole yield and aquifer classifica-

tion. In general, almost the entire Group, irrespective of its lithology and presence or absence of dolerite, and with exception of a few small isolated areas, is low yielding with the median borehole yield range of 0.1–0.5 l/s. More than 50% of boreholes yield below 0.5 l/s and 33% yield 0.5 to 2.0 l/s. Almost 3 000 boreholes were identified and analysed (Fig. 25).

The depth to the solid rock is usually 30–40 m and so is the average depth of boreholes. But boreholes on sites associated with dolerite intrusions were usually drilled deeper, i.e. 45–50 m, depending on the dolerite shape, dip, thickness, etc. No evidence of the existence of deeper aquifers within the Beaufort Group has been found.

**Table 8. Typical chemical analyses from boreholes, Beaufort Group**

		A	B	C	D
pH		7.74	7.92	6–9	5.5–9.5
EC	mS/m	61.3	52.7	70.0	300.0
TDS	mg/l	462.0	423.0	1 200.0	2 000.0
NO <sub>3</sub> +NO <sub>2</sub> (as N)	mg/l	1.227	1.352	6.0	10.0
NH <sub>4</sub> (as N)	mg/l	*	*	6.0	10.0
F	mg/l	0.27	1.68	1.0	1.5
TAL (as CaCO <sub>3</sub> )	mg/l	231.4	205.5	20–300	650.0
Na	mg/l	33.6	102.0	100.0	400.0
Mg	mg/l	27.2	2.7	70.0	100.0
Si	mg/l	14.0	9.65	–	–
PO <sub>4</sub> (as P)	mg/l	0.012	0.18	–	–
SO <sub>4</sub>	mg/l	32.8	19.3	200.0	600.0
Cl	mg/l	31.4	25.3	250.0	600.0
K	mg/l	0.71	2.36	200.0	400.0
Ca	mg/l	48.3	12.4	150.0	200.0

\* – not determined

A – Zuid Wolhuterskop, District Bethlehem

B – Greenfold Plessis Lager, District Estcourt District

C – Drinking Water Quality Criteria – Recommended Limits

D – Drinking Water Quality Criteria – Maximum Allowable



The groundwater level occurs generally at a depth between 10 to 20 m below ground surface, but localities with shallower water level are also common, mostly in the wide river valleys.

The failure to strike enough water in a borehole to justify the installation of pumping equipment is quite common in the Beaufort Group aquifers. At Henneman, for example, where no DWAF assistance was rendered, the borehole success rate was only 40% (JW van Copenhagen, 1949) ( A success was defined as a borehole yielding at least 0.1 l/s).

Chemical analyses of borehole water (222 samples) indicate that fresher water is associated with the eastern and southern map areas. It appears that a positive correlation exists between the rainfall and the concentration of dissolved solids or its electrical conductivity (see inset maps on the main map). However, the erratic distribution of sampling points could also be a

factor that prohibits a more conclusive groundwater chemical characterisation.

A small isolated area of EC in excess of 300 mS/m, just north of Vrede could be an indication of localised groundwater pollution, probably by an agricultural (fertilisers) source.

Concentrations of fluoride in excess of 1.5 mg/l were found in two water samples and could be related to the deep, pre-Karoo artesian water (Table 8).

Two groundwater types occur within the Beaufort Group (Fig. 26), i.e. the (Ca-Mg-Na)-(HCO<sub>3</sub>), analysis A from the western map area and (Na)-(HCO<sub>3</sub>), analysis B, from the southeastern map margin, near Escourt. The latter composition can be accounted for by a slightly alkaline water character.

Figure 25. Yield frequencies of boreholes in the Beaufort Group

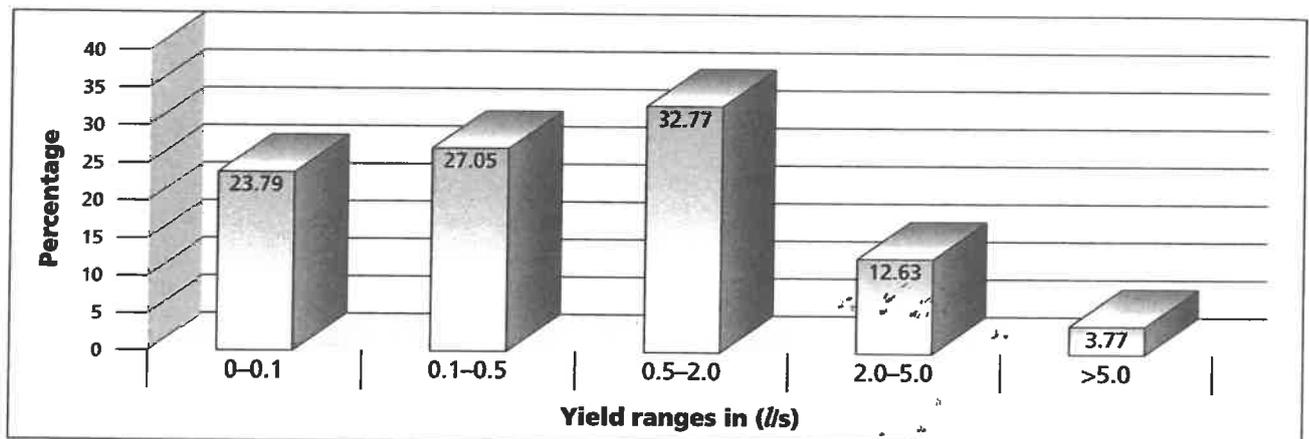
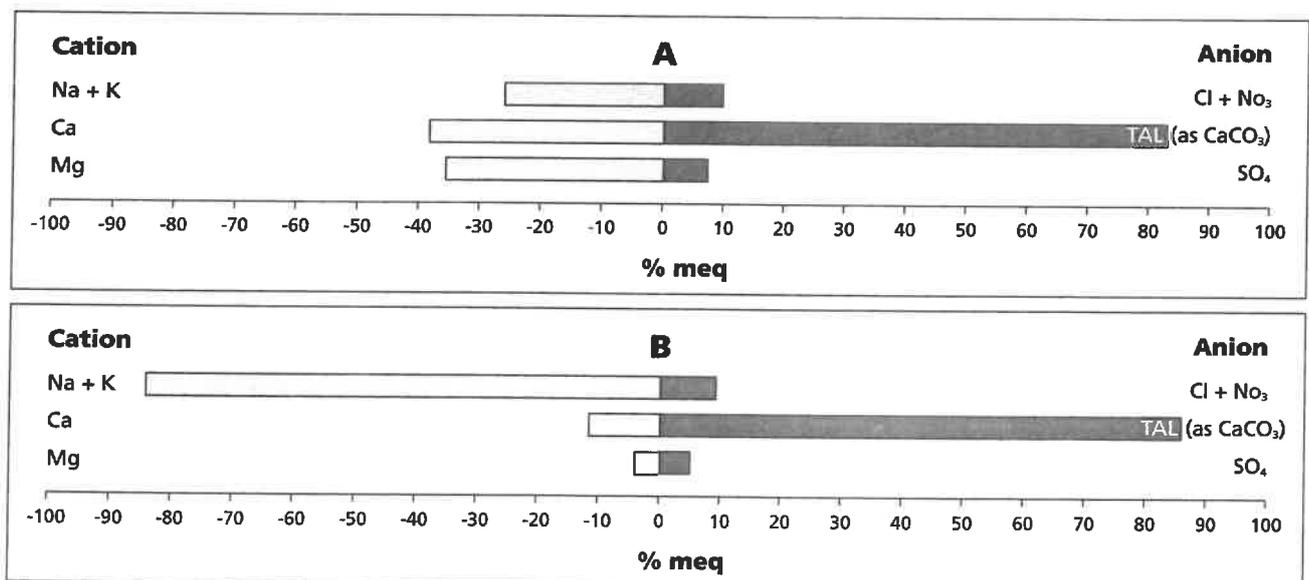


Figure 26. Stiff diagram of the chemical analyses (Beaufort Group)



### Thermal spring: Florisbad, Soutpan, district – Brandfort

The warm water spring at Florisbad had been used for recreational purposes for decades until 1980 when it was closed. The mineralised spring water has an EC value of 338 mS/m (TDS of 2360 mg/l). Sodium and chloride are the dominant determinants, while fluoride with a value of 5.5 mg/l exceeds the maximum allowable limit by a wide margin.

The water temperature of 29°C indicates a relatively deep circulation of this, originally meteoric, water down to the pre-Karoo bedrock of over 550 m below surface, where mixing with water from the Ventersdorp and Witwatersrand Supergroup takes place.

The spring is associated with a dolerite dyke intruded into rock of the Karoo Supergroup.

The surface deposits consist of sand with calcrete horizons.

The flow of the Florisbad spring was measured as early as in 1931 when 31.6 l/s was recorded. In 1953 only 14.6 l/s was recorded, followed by 2.5 l/s in 1964. The accuracy of the first record could be questionable as technical problems existed with the spring occurring as a pool with many outlets.

According to Kent (1971) the decline in spring flow rate could be linked to its artesian pressure drop caused by dewatering of the mines in the Free State Goldfields area, approximately 100 km to the northeast of Florisbad.

(The information above is based on a publication by RM Douglas: "The quality of the Florisbad spring water in relation to the quality of the groundwater and the effects of rainfall". Water SA, vol.27, No 1, January 2001:)

#### 4.3.4.6.4 Undifferentiated Karoo Rocks (Trm, Tre, Trc, Jdr)

Projection of exposures of the Molteno, Elliot and Clarens Formations, as well as of the Drakensberg Group in the area roughly between Clocolan and Phuthaditjhaba on the 1:500 000 scale map posed a cartographic problem of map readability. The steep topography and the nearly horizontal strata occurrence gave map projections in a form of a series of narrow strips, especially along the edges of deep valleys. In addition, the very low accuracy of borehole coordinates and the poor lithological description of rock formations frequently created an identification problem of the strata penetrated. Lumping of the geological stratigraphical units into an "undifferentiated Karoo rocks" composite unit was thus necessary (Fig. 28).

In localities where a larger area of an exposed Formation occurs, a separate projection of their outcrops was feasible and discussion of their water bearing characteristics and borehole yield is given in the subsequent sections.

The data from the 504 identified boreholes drilled into the "undifferentiated Karoo rocks" indicated that over 70% have a yield of more than 0.5 l/s and the yield can be characterised as 'moderate', (Fig. 27).

The depth to the groundwater level is strongly controlled by topography with dolerite dykes creating barriers, resulting in the occurrence of numerous small springs and seepages. The compartments created by the dolerite dykes are of a small size and limit the borehole or spring sustainability.

The best drilling results are achieved by drilling 9–15 m into thick dolerite dykes (average yield 3.1 l/s), dolerite sills being secondary drilling targets. Boreholes drilled outside dolerite intrusions yielded on average only 0.4 l/s, but where drilled into the indurated dolerite sediment zones, their average yield increased to 1.4 l/s (Kok & Kruger, 1976).

The water quality does not pose any problem for domestic use (EC below 100 mS/m).

Figure 27. Yield frequencies of boreholes in the Undifferentiated Karoo Rocks

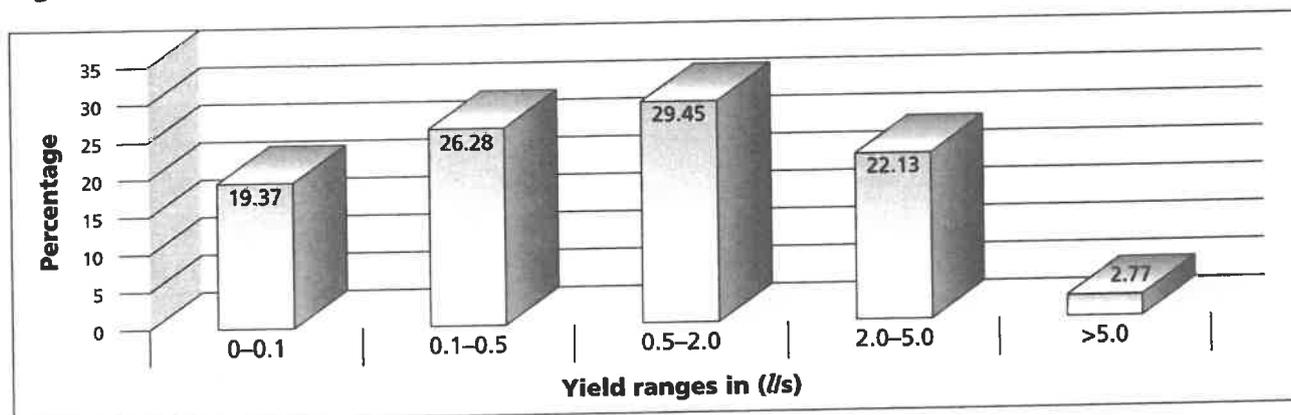
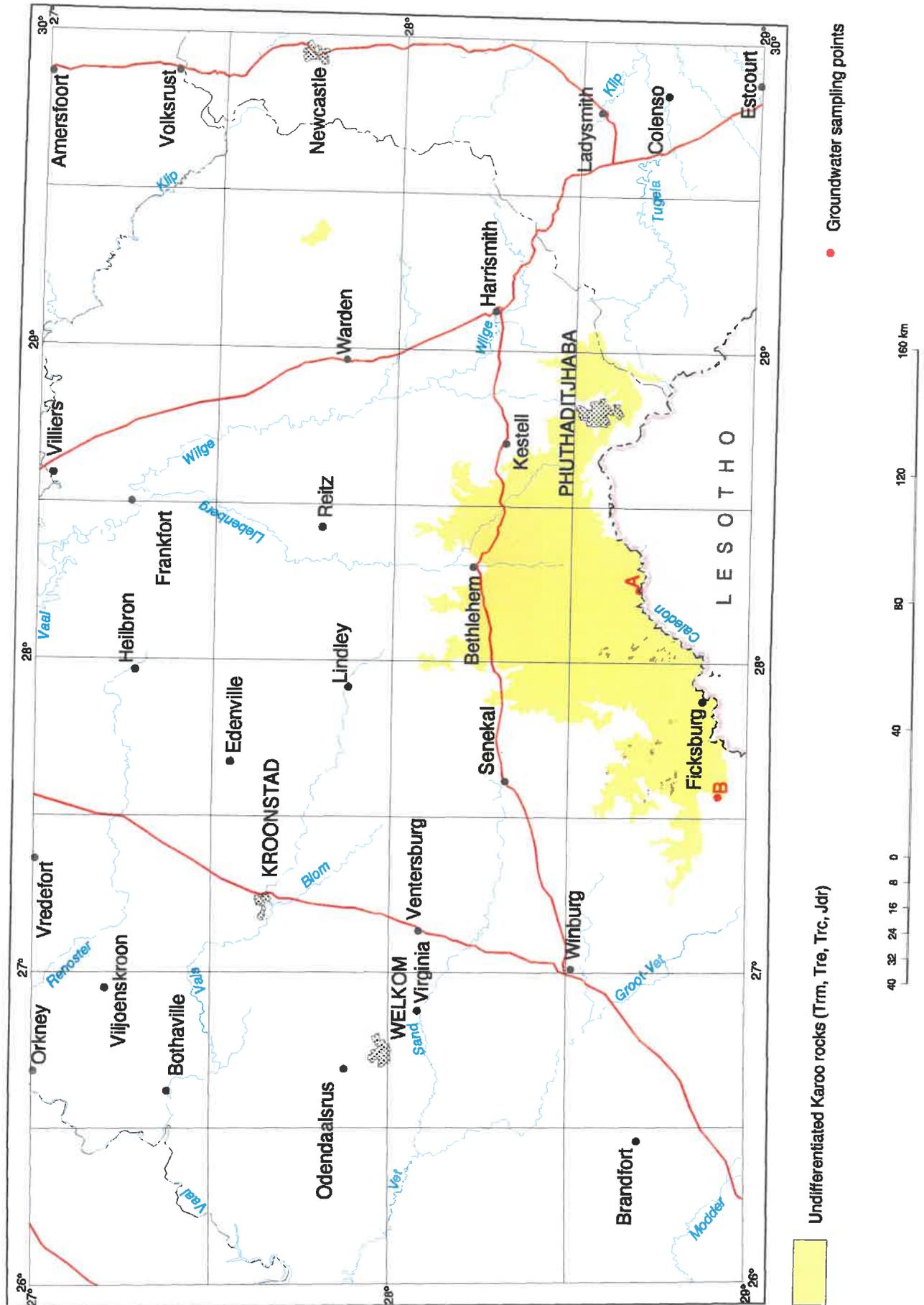


Figure 28. Distribution of the Undifferentiated Karoo Rocks with the position of Table 9 groundwater samples



#### 4.3.4.6.5 Molteno Formation (Trm)

Four areas are identified where outcrops of the predominantly arenaceous Molteno Formation are of a size to justify their appearance on the main map, i.e. around and southwest of Ficksburg, south and southwest of Reitz, and at Petrus Steyn roughly halfway between Lindley and Frankfort (Fig. 30). For the southeastern map area see Section 3.2.5.4 and the footnote.

Of the 124 boreholes identified, 67% yielded between 0.1 and 2.0 l/s and 15% less than 0.1 l/s (indicating 'low to moderate' yield) (Fig. 29).

Only one chemical analysis was found. It reveals a sodium-bicarbonate water with alkaline character. The high fluoride concentration could be an anomaly (Fig. 31 and Table 9).

**Table 9. Chemical analysis from a borehole in the Molteno Formation**

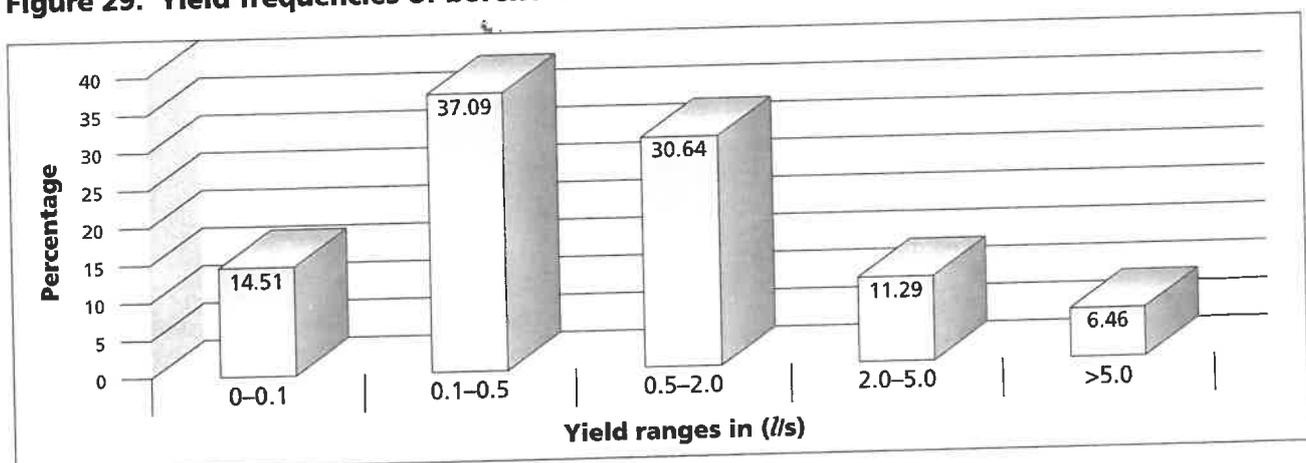
		A	B	C
pH		8.1	6-9	5.5-9.5
EC	mS/m	50.0	70.0	300.0
TDS	mg/l	522.0	1 200.0	2 000.0
NO <sub>3</sub> +NO <sub>2</sub> (as N)	mg/l	0.103	6.0	10.0
NH <sub>4</sub> (as N)	mg/l	0.082	6.0	10.0
F	mg/l	1.5	1.0	1.5
TAL (as CaCO <sub>3</sub> )	mg/l	270.2	20-300	650.0
Na	mg/l	139.2	100.0	400.0
Mg	mg/l	2.4	70.0	100.0
Si	mg/l	6.27	-	-
PO <sub>4</sub> (as P)	mg/l	0.014	-	-
SO <sub>4</sub>	mg/l	14.5	200.0	600.0
Cl	mg/l	24.0	250.0	600.0
K	mg/l	2.54	200.0	400.0
Ca	mg/l	7.9	150.0	200.0

A - Borehole; Luckhoff Allotment-Palmfontein, District Lindley

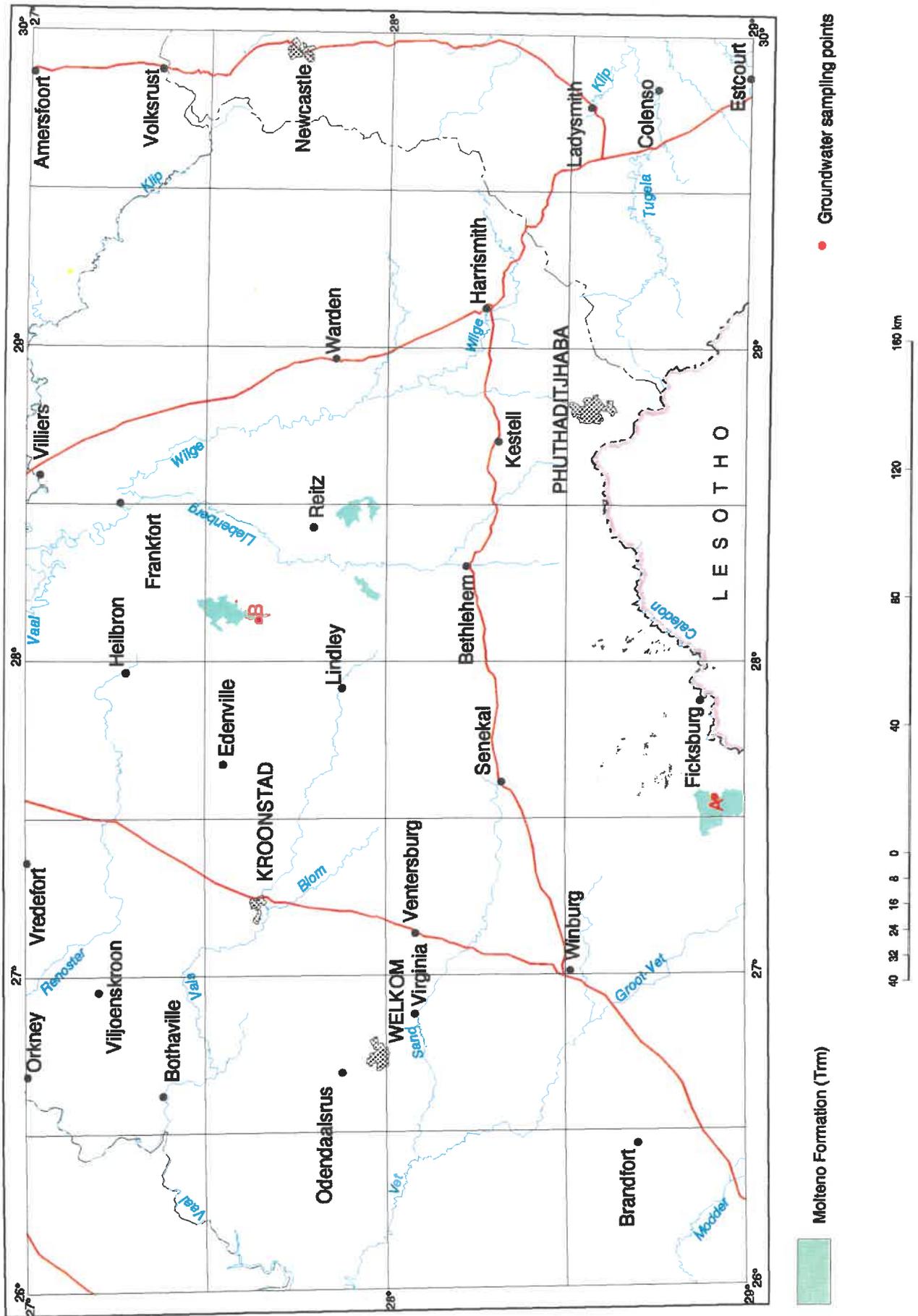
B - Drinking Water Quality Criteria - Recommended Limits

C - Drinking Water Quality Criteria - Maximum Allowable

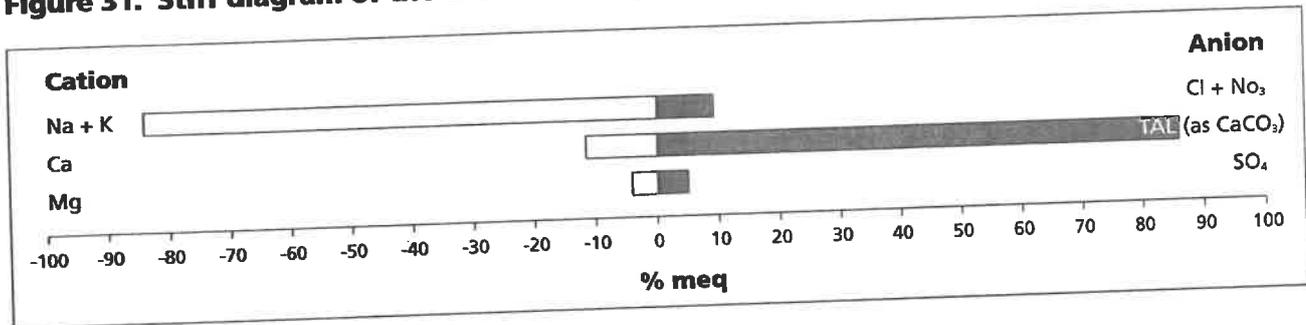
**Figure 29. Yield frequencies of boreholes in the Molteno Formation**



**Figure 30. Distribution of the Molteno Formation (Trm) with the position of Table 10 groundwater samples**



**Figure 31. Stiff diagram of the chemical analysis (Molteno Formation)**



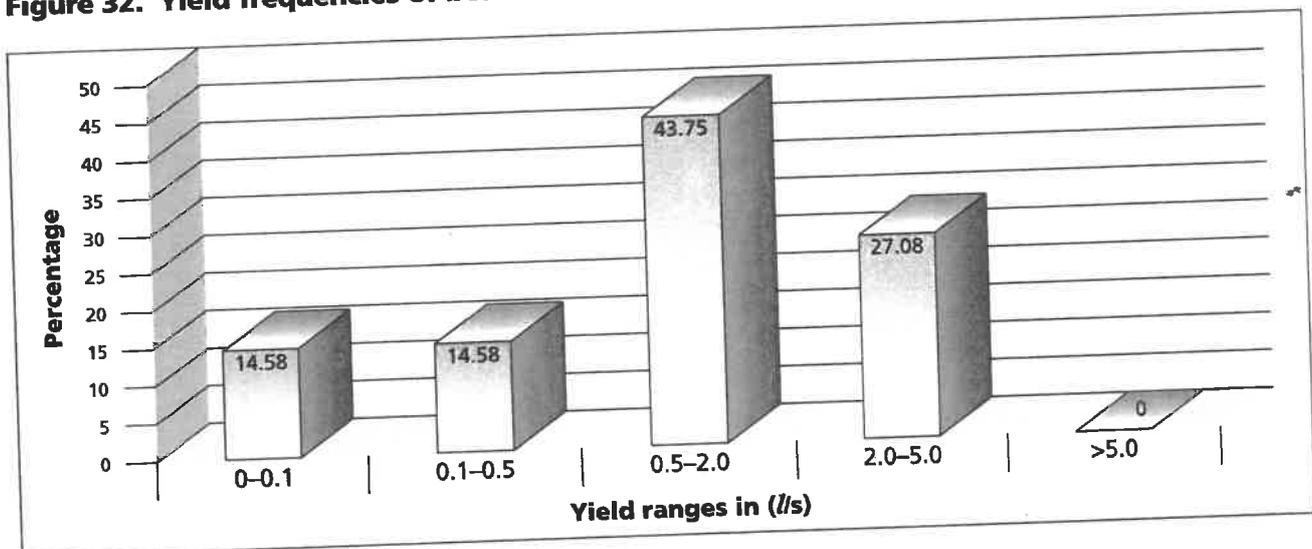
#### 4.3.4.6.6 Elliot Formation (Tre)

Larger outcrops of the mainly argillaceous Elliot Formation occur only at the border with Lesotho, southeast and west of Clocolan in the west of the map, and southeast of Mafikeng, east of Phuthaditjhaba.

Only 48 boreholes were identified. Of these, 71% yielded

between 0.5 and 5.0 l/s, indicating 'moderate to high' yield (Fig. 32). No chemical water analyses are available. The water from this Formation should in general be fit to human consumption (Bond, 1946). (See also section 3.2.5.5 and the footnote).

**Figure 32. Yield frequencies of boreholes in Elliot Formation**



#### 4.3.4.6.7 Clarens Formation (Trc)

This Formation's water bearing properties are discussed as part of the Undifferentated Karoo Rock. (Section 4.3.4.6.4). The general perception is however that this Formation offers

'moderate to low' borehole yields. (See also Sections 3.2.5.6 and the footnote). (Plate 3).

#### 4.3.4.6.8 Drakensberg Group (Jdr)

A large occurrence of this Group, south and east of Phuthaditjhaba, along the Lesotho border, appears on the main map as extrusive rocks (basalt) (Fig. 34). Because of the high elevation of the areas capped by the Drakensberg basalt (well over 2 000 m) no development of its groundwater resources has taken place, and thus no borehole information is available.

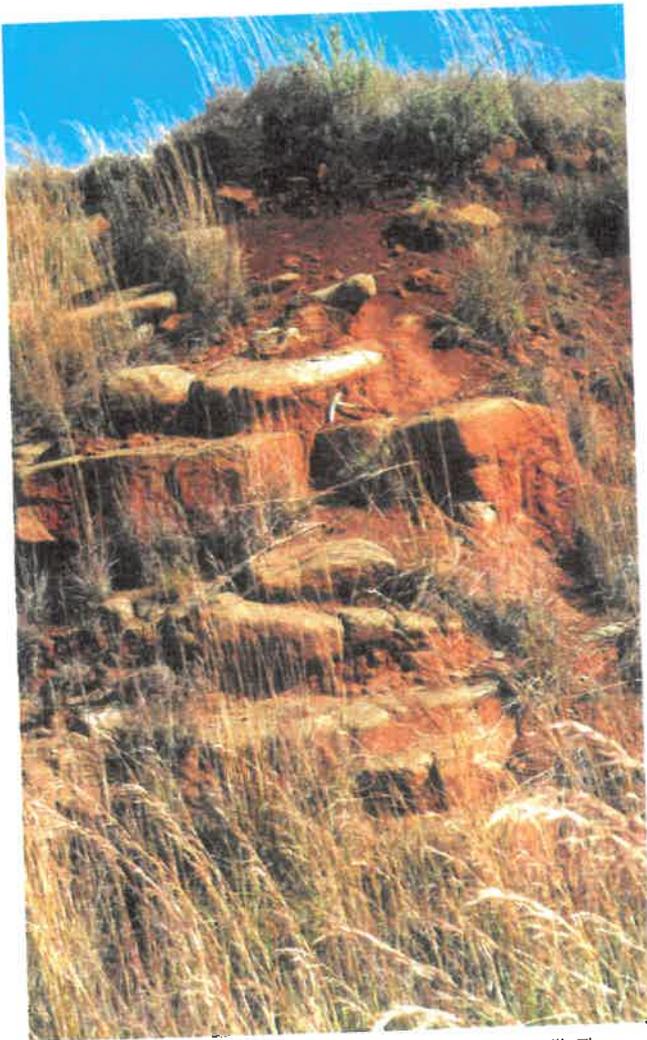
The topography is also highly dissected thus groundwater drainage appears to be fast and the rock formation offers little retention to infiltrating rain or melted snow.

No chemical analyses of groundwater from this unit is available, but it is expected to be fit for human consumption.

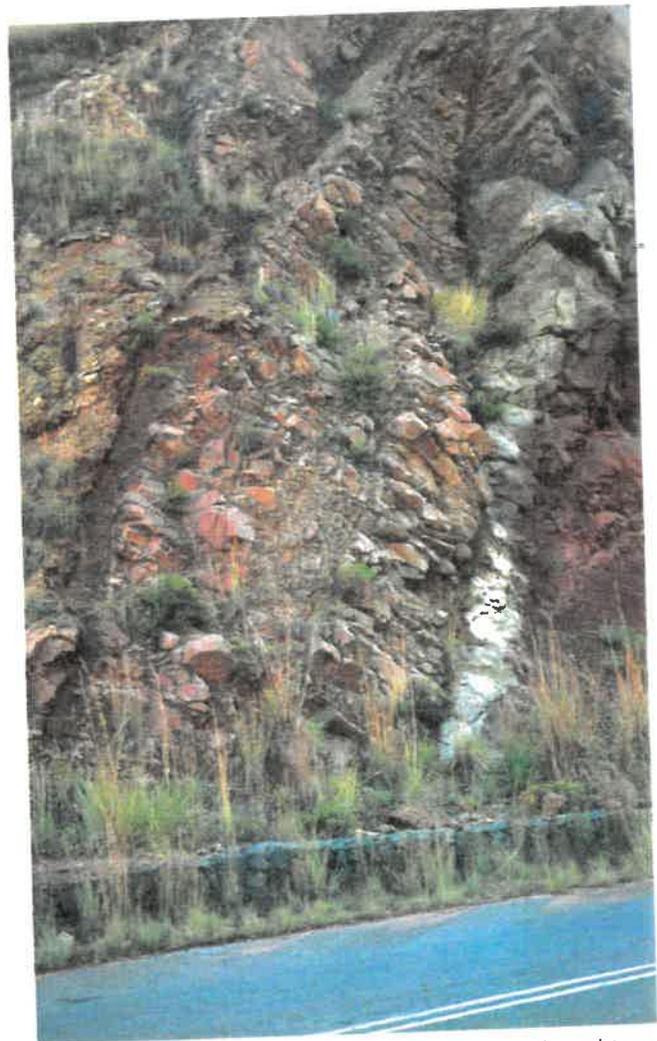




**Plate 3.** Massive fine-grained sandstone of the Clarens Formation, overlying mudstone of the Elliot Formation near Clarens. The groundwater potential of the Clarens Formation away from the dolerite intrusions is low and yields seldom exceed 0.5 l/s, while groundwater potential of the Elliot Formation seems to be somewhat higher. (Photo: P.S. Meyer).

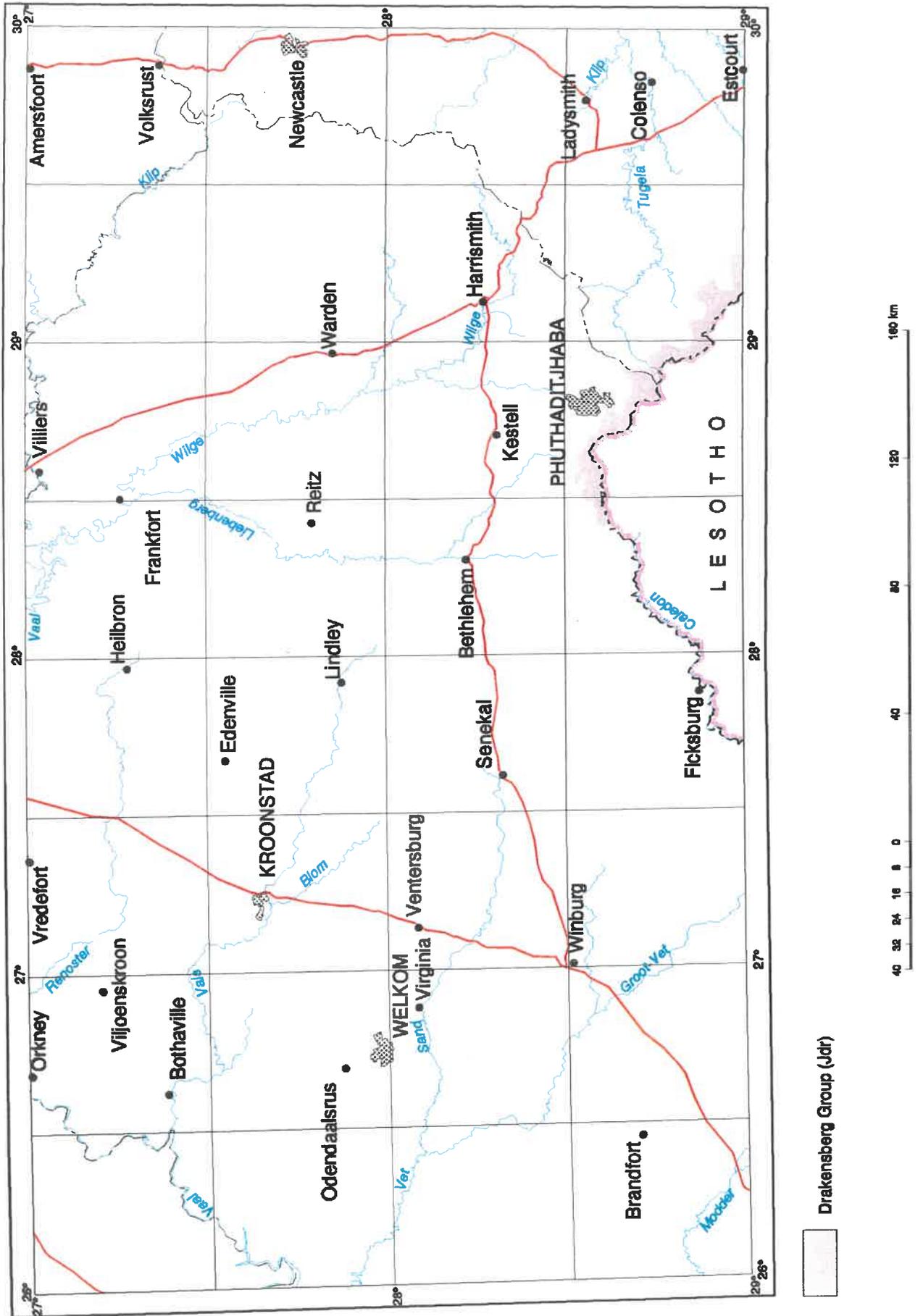


**Plate 4.** A weathered to partly weathered thick dolerite sill. The weathered and the underlying transitional jointed zones in the dolerite bodies are useful targets for groundwater development. Deep contact zones of dolerite sills with sedimentary rocks are however often devoid of jointing and offer less opportunity for groundwater strikes. (Photo: P.S. Meyer).



**Plate 5.** A fractured contact zone of a dolerite dyke with sandstone in the Tarkastad Subgroup (Beaufort Group). These contact zones are popular targets for groundwater development and yields of up to 2 l/s are not uncommon. (Photo: P.S. Meyer).

Figure 34. Distribution of the Drakensberg Group (Jdr)



#### 4.3.4.6.9 Dolerite Suite (Jd)

The processes of emplacement of dolerite bodies in host rock formations created zones of fracturing both in the host rock and in the dolerite itself. The zones of fracturing became a natural underground drainage system of groundwater stored in the weathered (fractured and intergranular) rock. Deeper fractures were also created, but to a lesser extent.

In determining the yield class of boreholes tapping different identified aquifer units, no separate provision was made for boreholes associated with dolerite intrusions. The lack of confidence in the scientific value of the geological logs documented in a majority of boreholes was the reason for this approach. However, the yield difference could be of an order of magnitude higher where intruding dolerite created the fracturing.

The dolerite related zones of fracturing usually occur on both sides of the dolerite bodies. The subsequent weathering process enhanced their permeability, thus the depth of weathering became important and could be critical to the borehole yield. At larger depths of dolerite interception, a contact zone could have a few or no open fractures (Plate 4). It has been statistically determined in the Karoo basin that the 30–40 m depth to the dolerite sill or dyke intersection is the maximum

borehole depth for obtaining usable yields. (Kok & Kruger, 1976). A map (Fig. 5) indicates the position of dolerite sills and dykes where they are of sizeable dimensions. The information utilised originates from the Council for Geoscience 1984 and 1997 Geological Maps and the 1995 Structure Map, all at a scale 1:1 000 000. There are still numerous gaps in the understanding of the relation between dolerite intrusions and groundwater occurrence. The question of depth of fracture occurrence, the degree of fracture openness, the position of a fracture with respect to the shape of the dolerite body, lithology of the host rock, and so on, remain unanswered.

A scientific evaluation of the occurrence of groundwater in fractures developed at and in dolerite and originating from the intrusive act, predominantly on the Karoo rocks in the large area covered by the Kroonstad map sheet would be extremely useful. It would bring the presently fragmented knowledge together, evaluate it, and with support of field exploration, present a comprehensive manual on exploration, evaluation, development and management of groundwater resources related to dolerite. (See section 6 "Recommendations for further studies").

##### 4.3.4.6.9.1 Dolerite sills (Jd)

The distribution of dolerite sills is illustrated in Figure 37.

Only outcrops of larger sills have been plotted on the main map. The sills prevail in the northern map sector, and dykes in the south-central part along the Lesotho border (see also Fig. 5). Yields of some 144 boreholes associated with dolerite sills were identified and analysed; 44% of borehole yields fall

in the 0.5 to 2.0 l/s category, and 28% yielded 0.1–5.0 l/s. (indicating 'low to moderate' yield) (see Fig. 35).

The groundwater quality is generally potable as ECs range between 13 and 130 mS/m, but only 26 borehole water analyses were available, thus this conclusion might not be statistically valid. (see Table 10).

**Table 10. Typical chemical analyses from boreholes in the dolerite sills**

	A	B	C	D	
pH	7.3	7.7	6–9	5.5–9.5	
EC	mS/m	76.7	46.8	70.0	300.0
TDS	mg/l	*	366.0	1 200.0	2 000.0
NO <sub>3</sub> +NO <sub>2</sub> (as N)	mg/l	<0.04	0.09	6.0	10.0
NH <sub>4</sub> (as N)	mg/l	*	0.42	6.0	10.0
F	mg/l	*	3.05	1.0	1.5
TAL (as CaCO <sub>3</sub> )	mg/l	380.6	118.8	20–300	650.0
Na	mg/l	92.0	51.1	100.0	400.0
Mg	mg/l	44.0	11.0	70.0	100.0
Si	mg/l	*	8.45	–	–
PO <sub>4</sub> (as P)	mg/l	*	1.253	–	–
SO <sub>4</sub>	mg/l	12.0	70.9	200.0	600.0
Cl	mg/l	25.0	40.0	250.0	600.0
K	mg/l	*	7.53	200.0	400.0
Ca	mg/l	20.0	32.4	150.0	200.0

\* – not determined

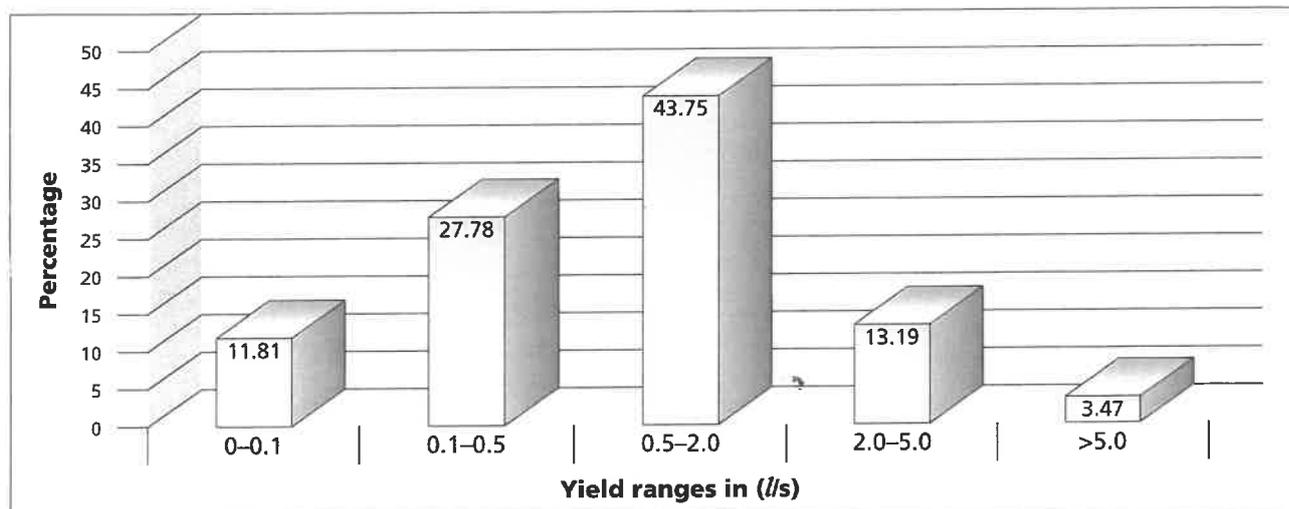
A – Utrecht, District Viljoenskroon

C – Drinking Water Quality Criteria – Recommended Limits

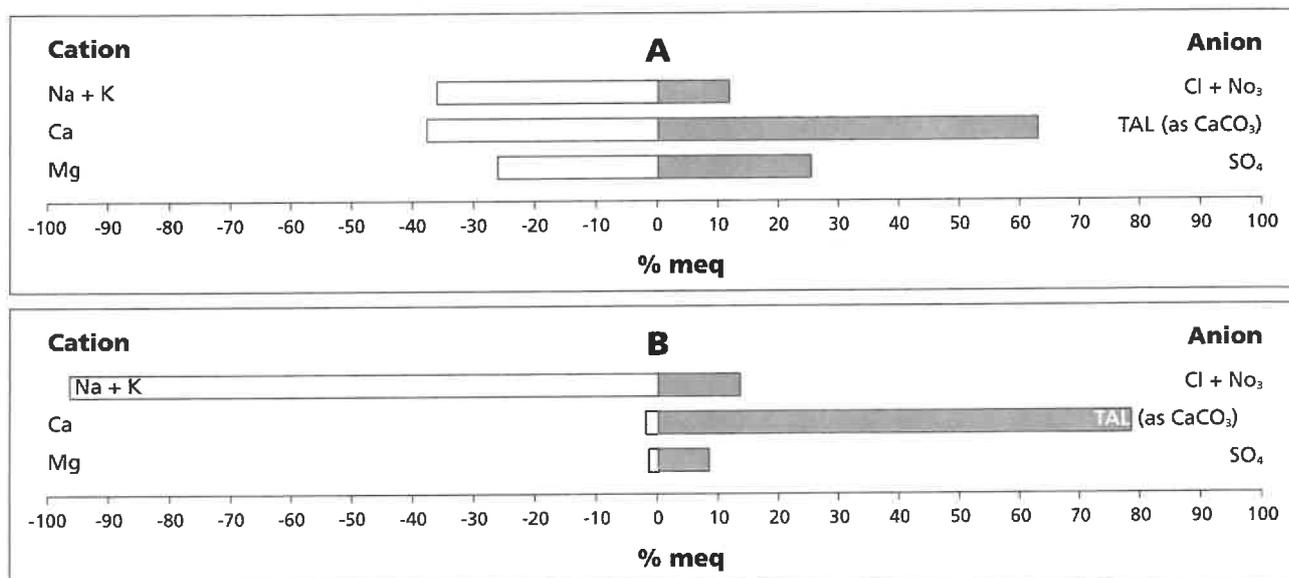
B – Newcastle Townlands, District Newcastle

D – Drinking Water Quality Criteria – Maximum Allowable

**Figure 35. Yield frequencies of the boreholes in the dolerite sills**



**Figure 36. Stiff diagram of the chemical analyses (dolerite sills)**



**4.3.4.6.9.2 Dolerite dykes (Jd)**

No yield analysis of boreholes drilled into or along dolerite dykes, i.e. those targeted at dykes, was performed for the Kroonstad area. The low quality of the geological borehole logs documented, in the great majority of cases by improperly qualified persons, could make this type of exercise of little value as it could lead to false conclusions.

However, on a small scale in the Puthaditjhaba area (the former Witzieshoek homeland, close to the northeastern part of the border with Lesotho), a yield evaluation of 96 supervised boreholes drilled into or along dolerite dykes was reported by Kok and Kruger (1976).

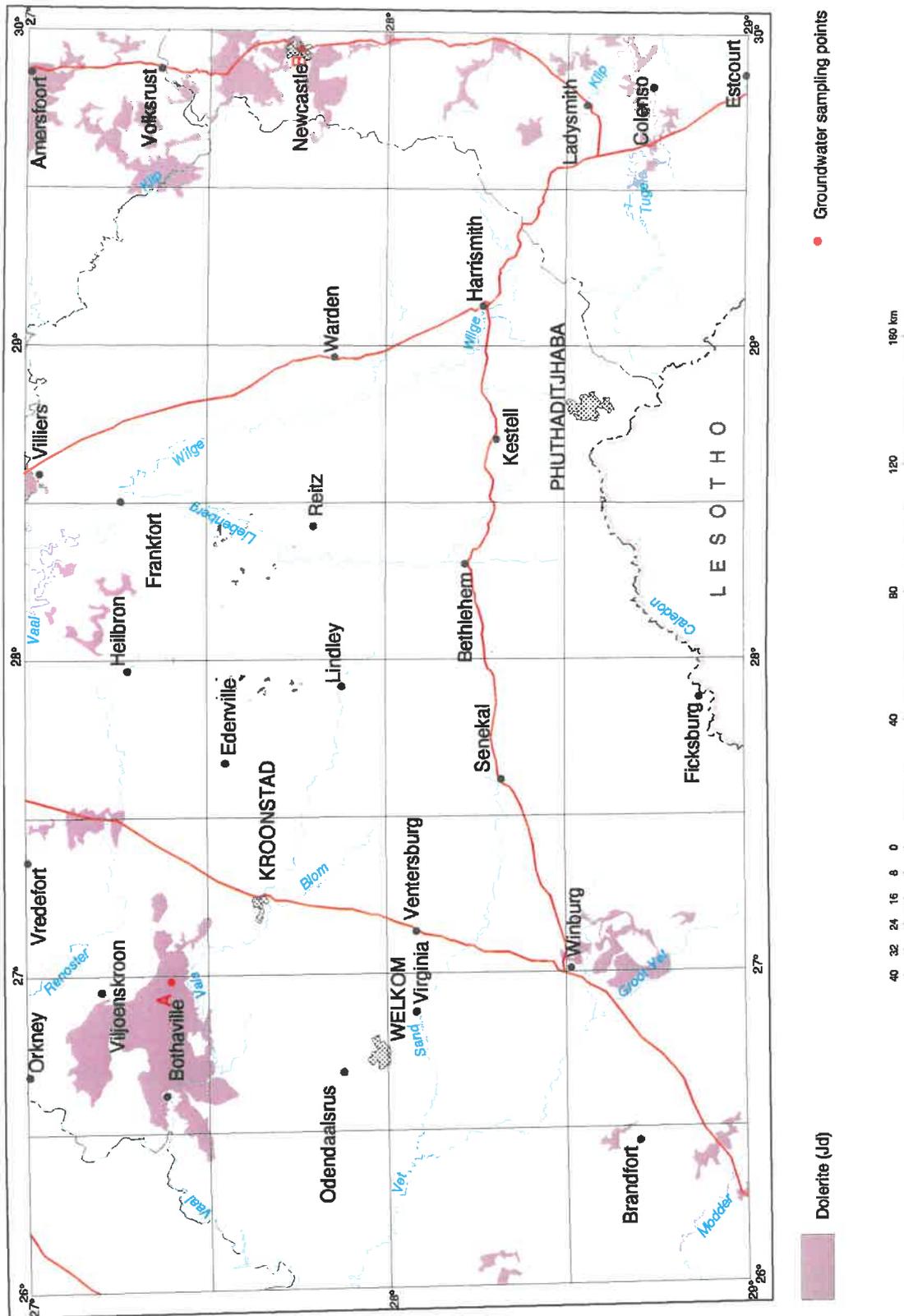
Of the 46 boreholes drilled into the dykes 40 (or 87%) were successful. (A successful hole should have a yield of 0.125 l/s or more). The average yield was relatively high (3.2 l/s) and the strongest boreholes (yields between 3.0 and 5.0 l/s) were drilled into dykes that were 9 to 15 m wide. Of the 50 bore-

holes drilled along the dykes into the fractured sediments, only 20 (or 40%) were successful and the average yield was 1.4 l/s. (By comparison, the 31 boreholes drilled into Karoo sediments on sites not affected by dolerite (Plate 5), 5 or 16% were successful, and the average yield was 0.5 l/s).

The above results clearly confirm the positive role of the dolerite dykes as groundwater drilling targets, especially when compared with the water obtained from boreholes drilled into the Karoo sediments not affected by intrusions.

However, taking into account the small size, and the lithological differences, of the Puthaditjhaba area (approximately 500 km<sup>2</sup>) in comparison to the rest of the map area, no confident extrapolation of the above results over the entire Kroonstad map or even over the area along the Lesotho border, where mostly dolerite dykes occur, would be possible without complimentary field work.

**Figure 37. Distribution of the dolerite sills (Jd) with the position of Table 11 groundwater samples**



The water quality in the Phuthaditjhaba area is of excellent quality with ECs of between 13 and 53 mS/m. The high rainfall and limited storage capacity of the rocks, allow for short water retention time. The quality of groundwater in or along dykes represents *de facto* the quality of the groundwater in the host rock formation. This is so because the size of the fractured

dyke and the associated zone of fractured sediments together with the underground reservoir they create, is diminutive when compared with the size of the aquifer they drain. Therefore no discussion of the water quality associated with the dolerite dykes is feasible.

## 5 Groundwater development

### 5.1 Previous investigations

The Kroonstad hydrogeological map and explanatory brochure were compiled utilising information and data from numerous reports on geohydrological investigations, and projects related to borehole siting and groundwater supply evaluation, mainly for municipalities, railways, roads, occasionally for individual farmers, and on a larger scale for mines of the Free State Goldfields.

The latter evaluated the effect of dewatering by the mines and future inflows (P.P. Venter, 1968) and dealt with the extent of groundwater pollution caused by mining activities (Cogho *et al.*, 1992). Numerous surveys of existing boreholes and of groundwater use were performed over decades around towns exclusively by the Groundwater Division of the Geological Survey (presently the Council for Geoscience).

The surveys were however limited to areas of less than

15 km radius around towns. In a number of cases borehole siting, exploratory drilling, test pumping and groundwater monitoring were performed to determine the aquifer properties.

The section of the map covering the western part of the KwaZulu-Natal Province was geohydrologically surveyed in 1995 by the following three consultants: VSA Earth Science Consultants, SRK, and Davies Lynn and Partners. The groundwater occurrence, quality and exploitation potential on a regional level was determined.

In total over 80 reports on groundwater investigation within the map area covering a period over 60 years were identified and studied. They were mostly compiled by Geological Survey and, since 1975, the Directorate: Geohydrology, DWAF. Only a few reports were compiled by geohydrological consultants.

### 5.2 Borehole siting

Only scientific methods of borehole siting are to be discussed. Non scientific groundwater exploration (e.g. by diviners), although popular in the map area will not be analysed and should be dissuaded. The following discussion presents briefly

the widely applied geological and geophysical methodology. For more details the reader is advised to consult the available technical literature.

#### 5.2.1 Geological methods

In open countryside, where water bearing structures like faults, dolerite dykes and sills are mostly visible, and their parameters like dip, width, nature, etc. can be determined from field observations, a borehole site can be pinpointed by a geologist or geohydrological technician with the knowledge of the region's geology and groundwater occurrence.

A borehole to be used for tapping alluvium, or unconsolidat-

ed arenaceous sediments needs to be sited carefully by a hydrogeologist/groundwater scientist as the thickness of the water saturated strata is the most critical factor. The irregular depth to the solid bedrock can disappoint many prospective water users. In areas without borehole information, the application of geophysical methods for borehole siting is strongly advised.

#### 5.2.2 Remote sensing

Geological maps, aerial photographs and satellite images are currently widely utilised for borehole siting. These are basic tools in the hands of groundwater scientists. The wider identi-

fication of target structures is possible and subsequent field application of geophysics will lead to the selection of optimum drilling sites.

#### 5.2.3 Geophysical methods

##### 5.2.3.1 Magnetic

Dolerite intrusions are in a large majority of occurrences detectable by measuring the earth's magnetic field across the expected dolerite body. The magnetic properties of the dolerite produce an anomaly on the plotted traverse lines and an

experienced person can determine the position of the dolerite, its thickness and dip. This method is the most widely used geophysical method in the Kroonstad map area.

### 5.2.3.2 Electrical resistivity

The vertical electrical sounding (VES) of apparent resistivity of the strata when plotted versus depth produces a picture of the vertical distribution of electrical resistivity that is influenced by the degree of weathering of the rock formation and presence of water. Interpretation of the results allows for the determination of the depth between the decomposed and fractured zone and to the solid rock.

The horizontal changes of the rock resistivity can be detect-

ed by an additional field technique, i.e. traversing with constant electrode separation (CES).

The electrical resistivity method is applied in support of the magnetic and other methods in the Karoo rocks region and the pre-Karoo rocks in the northwestern map area. The VES method can successfully detect basins of weathering and their deepest area for optimum borehole siting.

### 5.2.3.3 Electro-magnetic

This method is widely applied in all geohydrological environments. The measuring of the speed of decay of an electromagnetic field or electric conductivity variations using a variety of

instrumentation and arrays of field techniques enable the identification of discontinuities, faults, dykes, sills, depth of weathering, etc.

### 5.2.3.4 Other geophysical methods

Geophysical methods like seismic, gravity, radon emanation measurements, etc., are generally not applied in borehole

siting in the map area. However, their applicability needs to be tested and documented.

## 5.3 Groundwater utilisation

Underground water has always been an important source of rural water supply in the map area. It provides water for domestic needs, small vegetable gardens, and stock. Irrigation, however is normally limited to only a few ha on some farms in support of grazing in dry years.

The generally low borehole yields and low storage of the Karoo aquifers require large capital expenditure to develop a large scale supply. This in turn does not encourage farmers to develop commercial scale irrigation. No quantitative estimation of a total rural water use has been made.

Numerous towns in the map area have developed their own water supplies utilising local groundwater. Larger towns, established at rivers, had sufficient financial resources to build their own dams and water purification works. Groundwater was generally used during droughts to supplement the shrinking dam water reserves.

With the increase of urban population (the rural population has remained practically unchanged), during the last few decades, the DWAF developed an affordable subsidy system and grants for municipalities and consequently more local dams were constructed. On a larger scale the construction of the Sterkfontein dam, together with water releases to the Vaal River drainage system and water from Katse Dam in Lesotho, increased the availability of the surface water in the central part of the map area. This resulted in a gradual decrease of groundwater utilisation. Many towns switched to a conjunctive water use where municipal boreholes were used only during periods of peak seasonal demand and periodical droughts.

According to the available information (Table 11) during the late 1970s, approximately  $7.2 \times 10^6$  m<sup>3</sup>/a groundwater was used by the urban population. The municipal groundwater use has in the 1980–90s substantially decreased despite

the overall increase in the urban population because surface water resources became available. Unfortunately no figures for the current (2001) groundwater use are available.

The low degree of groundwater utilisation by the local authorities is the result of generally low aquifer permeability and storativity, coupled with low borehole yield.

Under these circumstances any large groundwater development must be expensive. The subsequent high costs of operation and maintenance of a borehole field add to the question of viability of such undertakings.

Another factor is the negative approach by potential users to groundwater development. This is based on the lack of confidence to the sustainability of the resource as result of a low degree of understanding of the groundwater regime.

A medium-scale groundwater development e.g. for a single farm, industrial plant or a small community, if based on a scientific approach can be economical and should be encouraged. Engagement of professionals in this process could reduce the usually large number of dry boreholes drilled, eliminate improper spacing of production holes and their over-pumping and secure subsequent maintenance and monitoring of the wellfield performance.

The proper application of the National Water Act (1998) can improve the confidence of the groundwater user in the developed resource and encourage its sustainable utilisation.

An illustration of the maximum groundwater utilisation potential is provided by the 'Groundwater Harvest Potential of the RSA' (Seymour & Seward, 1996). An enlarged section covering the Kroonstad map is depicted in Fig. 38. This map confirms earlier conclusions that aquifer parameters remain similar over the entire map area and thus no preferential aquifers can so far be identified.



**Table 11. Municipal groundwater use**

TOWN	POPULATION (year)	WATER USE x 10 <sup>3</sup> m <sup>3</sup> /a		SOURCE OF INFORMATION		DATE	REMARKS
		Total	Groundwater	Report No.	Author		
Vredefort	2 600 (1980)	–	202	GH3340	J. Coetzer	Oct. 1982	–
Leeudoringstad	2 900	–	249	GH1421	C.R. Opperman	Mar. 1969	Of 249 000m <sup>3</sup> /a 40% is from private boreholes
Newcastle	–	8 400	775	11/2/2/3	Town Engineer	1993	–
Newcastle–Iscor	–	–	1 040	GH3282	J.C. Kruger	Jul. 1983	–
Kroonstad	40 000 (1966)	5 000	1 643	GH1798	W.K. Boehmer	Jul. 1972	–
Cornelia	1 080 (1977)	66	66	GH2995	O. Gombar	Dec. 1977	83 000 m <sup>3</sup> /a could be abstracted safely
Cornelia	1 230 (1986)	26	26	GH3468	E.J. Nealer	Jul. 1986	26 000 m <sup>3</sup> /a can be safely supplied by existing boreholes
Steynsrus	3 750 (1974)	100–133	100–133	GH2961	O. Gombar	Sept. 1977	76 private boreholes
Petrus Steyn	2 000 (1973)	135	135	GH2953	O. Gombar & J.C. Kruger	Aug. 1977	–
Clarens	778	60	60	GH3405	C.J.H. Erasmus	Nov. 1985	Springs support water supply
Edenville	1 400 (1977)	150	150	GH3902	T.S. Kok	Jan. 1982	Private boreholes (13) are supplementing the municipal water supply
Edenville	3 860	259	–	GH1825	O. Gombar	Apr. 1973	Dam is silted, volume 4 500m <sup>3</sup> is available
Excelsior	3 750 (1979)	29–56	–	GH3125	A.F. Leskiewicz	Oct. 1979	–
Marquard	3 270 (1986)	220	58	GH3455	R.P. Parsons	June 1986	A dam on the Laaispruit 0.5 x 10 <sup>6</sup> m <sup>3</sup>
Heilbron	1 800 (1948)	150	–	GH593	C.V. Joubert	Dec. 1948	Dam water. Private boreholes are weak but are in use
Kastel	2 400 (1971)	40	40	GH1796	W.K. Boehmer & O. Gombar	1972	–
Ficksburg	10 800 (1975)	584	292	GH2816	PJ Smit & O. Gombar	Feb. 1975	Well points constructed in the Caledon river alluvium (sand) supply 50% of the town water
Soutpan	–	–	96	GH3496	G. Bekker	Nov. 1986	Borehole survey, identification of development sites
Henneman	6 200 (1949)	560	560	GH569	J.W. van Copenhagen	Oct. 1949	250 boreholes (private) 215 000 m <sup>3</sup> /a by SAR in and around the town
Witsieshoek	120 000 (1976)	4 100	1700	GH2903	T.S. Kok & J.C. Kruger	Oct. 1976	The usage of springs is not included in the groundwater consumption. Area 486 km <sup>2</sup>

Total groundwater use (1970s): 7.2 x 10<sup>6</sup> m<sup>3</sup>/a.

## 5.4 Mining activities and groundwater

The largest groundwater abstraction within the Kroonstad map takes place in the Welkom area, where mines of the Free State Goldfields are pumping approximately 33 x 10<sup>6</sup> m<sup>3</sup> annually of mine water to the surface. Unfortunately the high salinity of this water prohibits its utilisation and it is being discharged to numerous evaporation dams and pans.

The effect of the dewatering on the shallow Karoo aquifer is negligible as the mines are operating in a deep, confined aquifer. The pollution threat to local, shallow groundwater by all surface activities and structures like tailing, dumps, evaporation dams, effluents, etc. was satisfactorily addressed by the

involved mining companies (Cogho, *et al*, 1992).

Coal mining within the map area i.e. in the northern Free State and in the northwestern KwaZulu-Natal has mostly ceased. Dewatering operations of the mainly shallow coal mines removed sizeable volumes of water from the Karoo (Ecca Group) aquifers. Unfortunately, no pumping figures are available.

Other mining activities (diamonds, salt, dolerite, limestones, clay and sand) are on a small scale and intermittent in operation. Their impact on groundwater is very localised. For distribution of larger mines see Figure 39.



## 5.5 Groundwater management

The Karoo aquifers that cover nearly 95% of the Kroonstad map area have generally only a moderate development potential. Low permeability, storativity and available aquifer storage are the limiting factors. Significant water quantities can only be obtained by spreading a great number of boreholes over a large area. This seriously influences the development costs and cost of water use.

Large abstractions are an exception and the average water user is not in a position to exhaust the resource to an extent that conflicting situations between different users can appear. This is due to the low aquifer permeability and small zone of influence of individual boreholes.

From a purely groundwater science perspective the application of the National Water Act (1998) should therefore not

create many problems for the regional groundwater resource management authorities. Most of the groundwater uses will fall under the general authorisation and only a limited number of licenses will have to be issued.

The regional water authorities will thus have to concentrate on groundwater quality protection measures, especially around mining areas, a few larger scale abstractors and towns. Establishment of an effective network of monitoring boreholes will have to be created with systematic control and evaluation of monitoring results.

The development potential of the pre-Karoo aquifers in the northwestern map corner is similar to the rest of the map area and no different management measures need to be applied there.

## 6 Recommendations for further studies

More detailed investigations are suggested on the following aspects:

- Groundwater and dolerite intrusions. Study of occurrence of the fractured zones in the host rock and the dolerite body:
  - Role and depth of weathering and optimum depth to drill boreholes;
  - Role of thickness of sills and dykes in forming the fractured zones;
  - Role of the host rock lithology in the formation of fractured zones;
  - Depth of weathering and borehole yield;
  - Statistical evaluation of the yield of boreholes associated with dolerite intrusions and of those drilled in unintruded rocks.

A comprehensive study of aspects above, including collection of new information and data, supported by additional field exploration (mapping, geophysics, drilling, testing, etc.) to understand the conditions of groundwater occurrence should be undertaken. Karoo dolerite rings and sills have proven to be structures conducive to the formation of deep-seated fractured aquifers in some parts of the Karoo Supergroup (Chevallier *et al.*, 2001). Yields of up to 70 l/s were obtained at depths mostly in excess of 200 m. Similar dolerite ring-structures may occur in the Kroonstad map area, and if they do exist, they should be investigated as they could prove to be advantageous targets for groundwater development. The end product of the study could be a manual for the groundwater development in this part of the Karoo.

- Detailed research of the waterbearing characteristics of the Chuniespoort dolomite, especially in the area covered by the Karoo rocks.

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