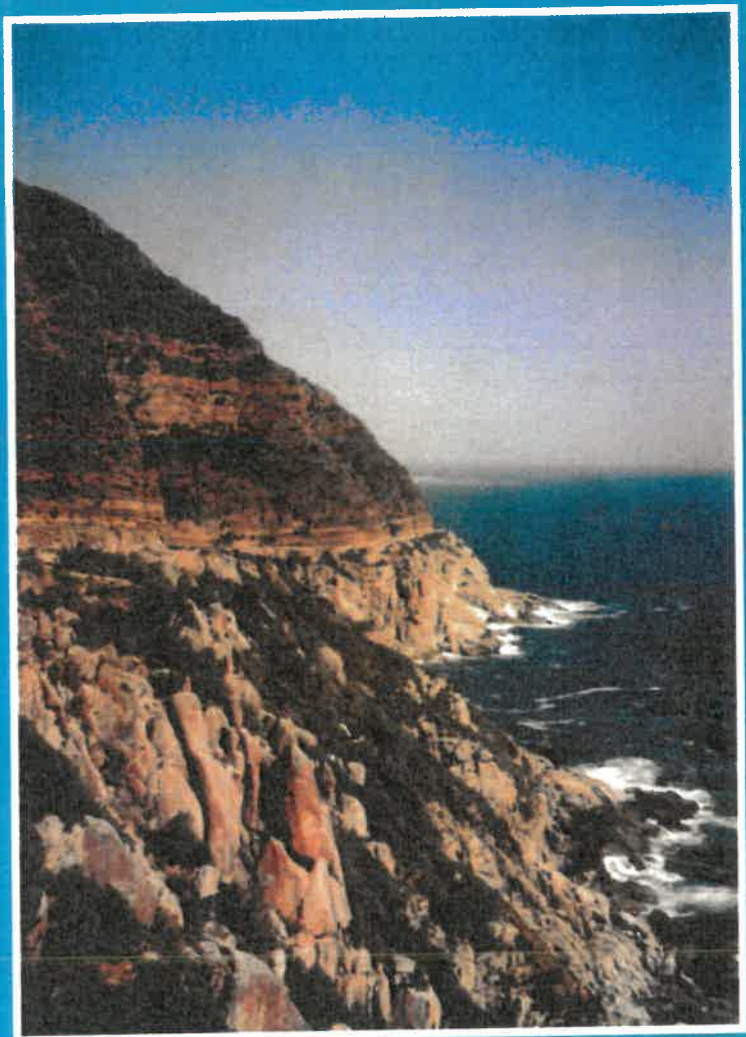
# An Explanation of the 1: 500 000 General Hydrogeological Map Cape Town 3317




**By: P.S. Meyer**


**May 2001**


DEPARTMENT: WATER AFFAIRS AND FORESTRY
REPUBLIC OF SOUTH AFRICA

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**By : Schalk Meyer**

**October 2000**

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# FOREWORD

Groundwater in South Africa as a whole is under-utilised, although some local over-exploitation does occur. Groundwater schemes can generally be implemented more rapidly and at a lower cost than comparative surface water schemes. They 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. 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.

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# PREFACE

With 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 days, but refuse him water, and death is likely to come within hours. The availability of water to even the remotest area is thus vital to maintain this indispensable force for human existence. An estimated 3% of fluid 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 Cape Town Hydrogeological Map and the accompanying explanatory brochure introduces the current state of groundwater knowledge and the basic hydrogeological 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 will impact on groundwater. Rough mountainous terrain and undulating plains, wet rainforest vegetation to dry semi-desert shrubland, old metamorphosed rocks to recently deposited unconsolidated sands and alluvium; highly competent quartzitic sandstones containing numerous fractures in contrast to dense, incompetent, fracture-free shales and mudstones and solid to weathered granitic rocks, are but a few of the diversities. Under these circumstances, various groundwater distinctives and characteristics can be expected, all of which have been referred to in the brochure.

The primary aim of a General Hydrogeological Map is to produce a synoptic overview of the hydrogeological character of an area. The main map thus features borehole yield, aquifer types, groundwater quality and groundwater use, which are superimposed against a somewhat subdued lithology background. The brochure discusses these topics in more detail, as well as issues such as geological controls on groundwater yield and quality, borehole siting, groundwater management, groundwater levels, suggestions for the future studies, etc. It is hoped that the product will be found useful by groundwater users for general planning, especially in the light of the Reconstruction and Development Programme, and that it will play a 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 environments. 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 base map for future specialised groundwater maps and groundwater studies as suggested in the brochure.

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**Cover photograph:** *Strata of the Table Mountain Group (fracture mode of groundwater occurrence), overlying granite of the Cape Granite Suite (intergranular and fracture mode of groundwater occurrence) at Chapmans Peak, Cape Peninsula.*

# ABBREVIATIONS

| | |
|---|---|
| CFB | Cape Fold Belt |
| DWAF | Department of Water Affairs and Forestry |
| CSIR | Council for Scientific and Industrial Research |
| EC | Electrical Conductivity |
| GIS | Geographic Information System |
| IWQS | Institute for Water Quality Studies |
| NGDB | National Groundwater Data Base |
| NWQDB | National Water Quality Data Base |
| SABS | South African Bureau of Standards |
| TAL | Total Alkalinity |
| TDS | Total Dissolved Solids |
| TMG | Table Mountain Group |
| UNESCO | United Nations Educational, Scientific and Cultural Organisation |
| SGWCA | Subterranean Government Water Control Area |

# SYMBOLS AND UNITS

| | |
|---|---|
| a | annum |
| amsl | average mean sea level |
| km | kilometre |
| l | litre |
| l/s | litre per second |
| m | metre |
| Ma | million years |
| m/s | metre per second |
| $m^2$ | square metre |
| $m^2$/day | square metre per day |
| $m^3$ | cubic metre |
| $m^3$/a | cubic metre per annum |
| mg | milligram |
| mg/l | milligram per litre |
| mm | millimetre |
| mS/m | millisiemens per metre |
| s | second |

abbreviations symbols and units

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Compilation of bar graphs

# 1. INTRODUCTION

## 1.1 Map Compilation

Extensive use was made of Arc/Info for cartographic compilation, data display and manipulation. Available borehole data from the National Groundwater Data Base (NGDB) was used and supplemented by field visits to areas of sparse data coverage. The delineation of the groundwater occurrence was outlined on a scale of 1:50 000 with extrapolation from hydrogeologically well defined areas into areas of data scarcity. The boundaries of groundwater occurrence types were then drawn by hand to final scale. Additional changes and minor boundary alterations were done within GIS. The same methodology was used in the compilation of the 1:1 500 000 scale groundwater quality map, using data from the National Water Quality Data Base (NWQDB). The quality parameter that is expressed, is the electrical conductivity (EC) of the groundwater. The EC intervals shown are taken from the Department of Water Affairs and Forestry (DWAF) guidelines for human and stock water consumption.

Due to a shortcoming in the NGDB, which does not distinguish between dry boreholes and boreholes with no data, dry boreholes had to be excluded from the borehole analyses. This is unfortunate, as information on dry boreholes can be helpful to determine an area's yield potential.

The map portrays the principal aquifer when more than one aquifer is present. Thus the insignificant yield of a surface sand layer would not be depicted if the underlying bedrock has a higher yield potential.

The following data limitations marred the borehole analyses:

- poor data quality,
- unscientifically sited boreholes, which often mask the true overall yield potential of a rock unit, and
- large areas of sparse data distribution.

The lithostratigraphy of the region, taken from published Geological Survey maps, was regrouped and, where necessary simplified to lithological types. These types are displayed as greyish ornaments on the map. The geological units are provided with black codes which, for reasons of countrywide uniformity, do not always coincide with the codes on the published geological maps, but are internal Departmental adaptations. The geological units and codes are explained in a chronstratigraphical column.

## 1.2 Legend Explanation

The hydrogeological map utilises an adapted international hydrogeological legend (Anon/UNESCO, 1983). The main alterations to the UNESCO legend were:

- the removal of the division of aquifers between local/discontinuous or extensive, and using only local, and
- the inclusion of fractured and intergranular as an additional mode of groundwater occurrence since this was considered to be more appropriate to South African conditions.

The definition of the borehole productivity ranges has been left by the UNESCO authors for the local mappers to define. Consideration of the local conditions resulted in the productivity ranges shown in Table 1.

The terminology adopted by the European hydrogeological map makers was used. This refers to the productivity ranges of groundwater and further subdivides according to the mode occurrence. For this map region "intergranular" was used for the porous mode of occurrence, "fractured" for the faulted, fissured and jointed, and "fractured and intergranular" for the weathered and fractured/jointed mode of occurrence. These divisions are then depicted using the colour scheme in Table 1.

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

lithological occurrences too small to carry a GIS polygon and a formation code,were omitted, lithology boundaries have in places been smoothed out and boundaries will not always correspond exactly to that of the geological maps, and where a large number of faults are concentrated some have been deleted.

A conceptual profile has been drawn to illustrate the regional hydrogeology in terms of geology and to evince target areas for groundwater development.

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

**Table 1 : Hydrogeological classification of groundwater**

| Occurrence | Intergranular | Fractured | Fractured and Intergranular |
|---|---|---|---|
| Description | Generally unconsolidated but occasionally semi-consolidated. Groundwater within intergranular interstices in porous medium. Tertiary-quaternary coastal deposits and alluvial deposits along river terraces. Covers 14,2% of the map area. | Fractured and fissured bedrock resulting from decompression and/or tectonic action. Groundwater occurs predominantly within fractures and fissures in sedimentary and metamorphic rocks with limited overlying unsaturated residual weathered products. Covers 82% of the map area. | Largely medium to coarse,grained granite, weathered to varying thicknesses, with groundwater contained in intergranular interstices in the saturated zone, and in jointed and occasional fractured bedrock. Covers 3,8% of the map area. |

| Yield (l/s) | Blue | Green | Brown-yellow |
|---|---|---|---|
| >5.0 | Dark blue | Dark green (b5) | Brown |
| 2.0 - 5.0 | Blue | Green (b4) | Light brown |
| 0.5 - 2.0 | Light blue | Light green (b3) | Pale brown |
| 0.1 - 0.5 | Pale blue | Pale green (b2) | Yellow |
| 0.0 - 0.1 | Blue tinge | Green tinge (b1) | Yellow tinge |

## 1.3 Borehole Yield Distribution and Lithological Boundaries

From the 1 : 500 000 map it can be seen that yield and lithology boundaries do not always coincide. The yield boundaries were determined from the best match to the available data, which may not always be conclusive. It may be speculated that rock competency for consolidated rock units and local recharge conditions could be major factors in the overall pattern of borehole yield distributions.

# 2. PHYSICAL ENVIRONMENT

## 2.1 Physiography

The coastal plains maintain their relatively low-lying relief of up to 300 m amsl over large areas, especially along the west coast, before the rise of the mountain ranges of the Cape Fold Belt. These mountains, which rise to up to 2 250 m, run to a large extent in a curve, parallel to the coastline. To the north-east of the mountains lies the relatively high altitude plateau of the Karoo at an elevation of between 800 m and 1 200 m.

## 2.2 Climate

The map area falls largely within the winter rainfall region, thus rain is mostly recorded between May and October. The summers are essentially dry and hot with the coastal regions being cooled by the prevailing south-westerly and south-easterly winds. Snowfalls periodically occur in the winter on the highest mountain ranges. Annual rainfall varies between 300 and 500 mm along the west and south coasts, between 200 and 300 mm in the Breede River Valley, between 100 and 200 mm in the Karoo and >1 000 mm in the mountain regions. Precipitation is clearly orographically influenced.

## 2.3 Surface Hydrology

The main drainage systems are the (drainage numbers in brackets) Breede River (H0810, H0820, H0830, H0840, H0850, H0860 and H0870), Berg River (G0710), Eerste River (G0722), Palmiet, Bot and Klein Rivers (G0740) and the Kars and Sout Rivers (G0750). The Breede, Eerste, Palmiet, Bot, Klein and Sout Rivers discharge into the Indian Ocean, while the Berg and Diep Rivers discharge into the Atlantic Ocean.

*Two major ocean current systems influence the climate of the map area, namely the Agulhas Current along the south coast and the Benguela Current along the west coast.*

*The Agulhas Current carries tropical water southwestwards. South of Algoa Bay the Agulhas Bank widens westwards and the current follows the - 200 m isobath to some 250 km offshore of Cape Agulhas. In this region the Agulhas Current is also entrained shorewards to the southern coast by cyclonic or onshore vortices. The southern coastal waters are thus characterised by complex currents and water temperature changes (Heydorn A.E.F. and Tinley K.L.,1980). At about 18°E the Agulhas Current turns back on itself and flows in an easterly direction. The water temperature of the Agulhas Current varies between 22° and 29°C and it attains a speed of up to 2 m/s.*

*The Benguela Current carries cold South Atlantic waters from the south and is most noticeable along the west coast between Cape Point and Cape Columbine. Contrary to the well-defined Agulhas Current, it can be described as a wide drift of water driven by the Southeast Trade Winds. Wind induced upwelling at least partly causes the cold temperatures of between 8° and 14°C, and it reaches a speed of between 0.6 and 1.0 m/s.*

physical environment

# 3. GEOLOGY

## 3.1 Brief Description of the Geological Units

The oldest rocks in the map area are the meta-sediments of the pre-Cambrian Malmesbury Group (Ne), which occupy the coastal plain between Saldanha and False Bay in the west, to the first mountain ranges in the east. Several erosional windows to this Group are exposed in mainly fault-controlled valleys further to the east and south, of which the Breede River valley is the most conspicuous. The Malmesbury Group consists of low grade metamorphic rocks such as phyllitic shale, quartz and sericitic schist, siltstone, sandstone and greywacke.

Various granite plutons of the Cape Granite Suite (N-Ec) have intruded the Malmesbury Group. In all, ten plutons have been identified between Saldanha and Somerset West.

The Klipheuwel Group (Ek), which is of Cambrian age, is younger than the Cape Granite Suite and consists of conglomerate, sandstone and shale.

The Cape Supergroup, which occupies most of the map area, was deposited in a trough from early Ordovician to late Devonian age (Tankard, *et al.*,1982). Three components have been differentiated namely the lowermost, predominantly arenaceous Table Mountain Group (O-St), which unconformably overlies the Malmesbury, Klipheuwel and Cape Granite rocks, is conformably followed by the largely argillaceous beds of the Bokkeveld Group (Db) and the alternating shales and sandstones of the uppermost Witteberg Group (Dw).

The Karoo Supergroup is represented by the basal glacial diamictite of the Dwyka Group (C-Pd), followed by the predominantly argillaceous Ecca Group (Pe) and the shales and subordinate sandstones of the Beaufort Group (P-Trb) in the north-eastern portion of the map area.

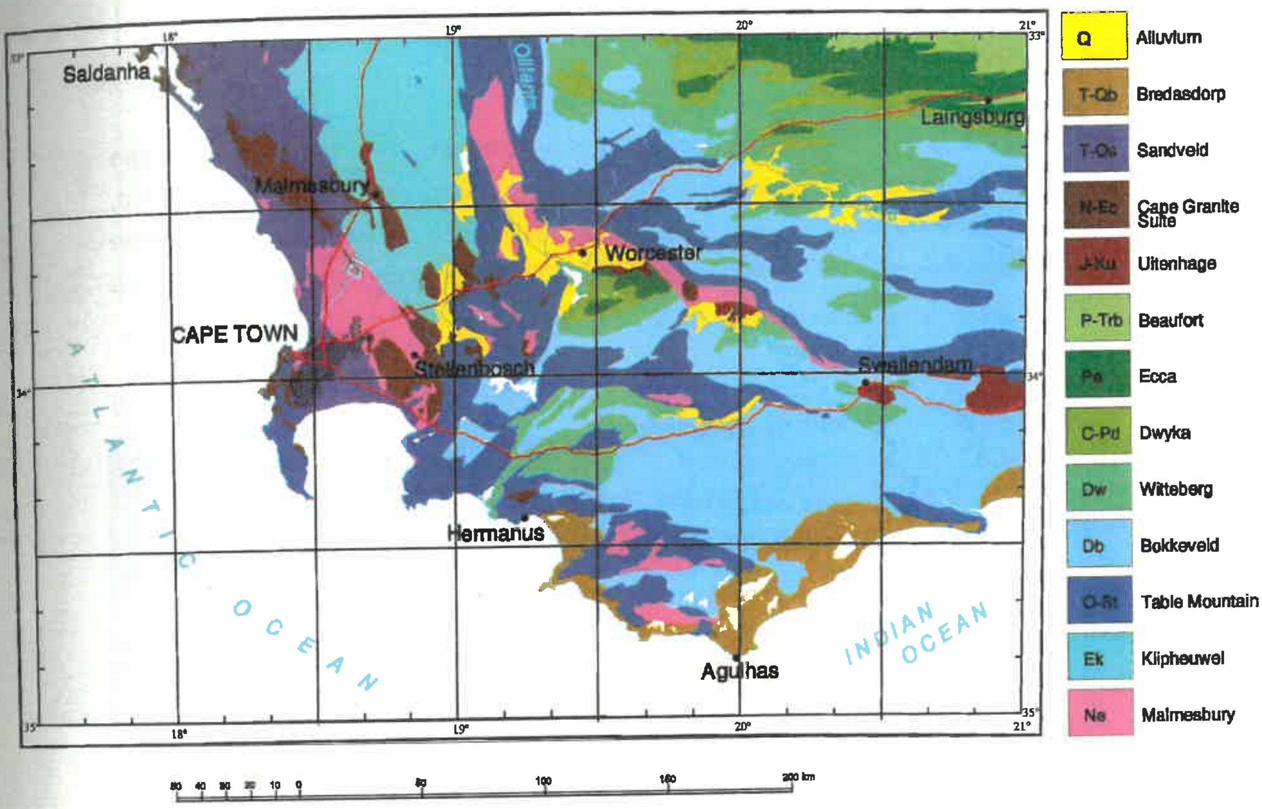
Deposits of conglomerate with interbedded sandstone lenses of the late Jurassic Enon Conglomerate Formation (J-Ku) (Uitenhage Group), occur chiefly along the Worcester Fault between Worcester and Heidelberg.

A variety of Tertiary to Quaternary deposits cover the older rocks in the area, ranging in age between 12 - 0 Ma. They consist essentially of unconsolidated to semiconsolidated shelly, calcareous sands of the Bredasdorp Group (T-Qb) and Sandveld Group (T-Qs).

Considerable deposits of alluvium (Q) consisting of clay, sand, pebbles and boulders occur in the valley of the Breede River and its tributaries, and in the Hex River valley.

Limited occurrences of Coastal Sands (Qz) were deposited mainly along the coast between Agulhas and the Breede River Mouth. All these geological units are shown in Fig.1.

**Fig. 1 : Principal geological units**




## 3.2 Structural Geology

The Cape Fold Belt (CFB) is a largely east-west striking feature located roughly south of 33°S. It consists predominantly of sedimentary and metamorphic rocks which were subjected to intense pressure, particularly from the south. This resulted in a variety of geological features and structures which produced a wide range of groundwater characteristics peculiar to the region. Two major orogenic events influenced the development of the CFB, namely the Saldanian Orogeny and the Cape Orogeny.

geology

### 3.2.1 Saldanian Orogeny

During the Saldanian Orogeny, the pre-Cape Malmesbury strata were deformed in the late pre-Cambrian to Cambrian period and the process continued until after the intrusion of the Cape Granite Suite. The pre-Cape rocks were subjected to various deformational phases, resulting in folding along mainly north-west trending axes and considerable displacement by shearing and faulting (Tankard *et al.*,1982).

### 3.2.2 Cape Orogeny

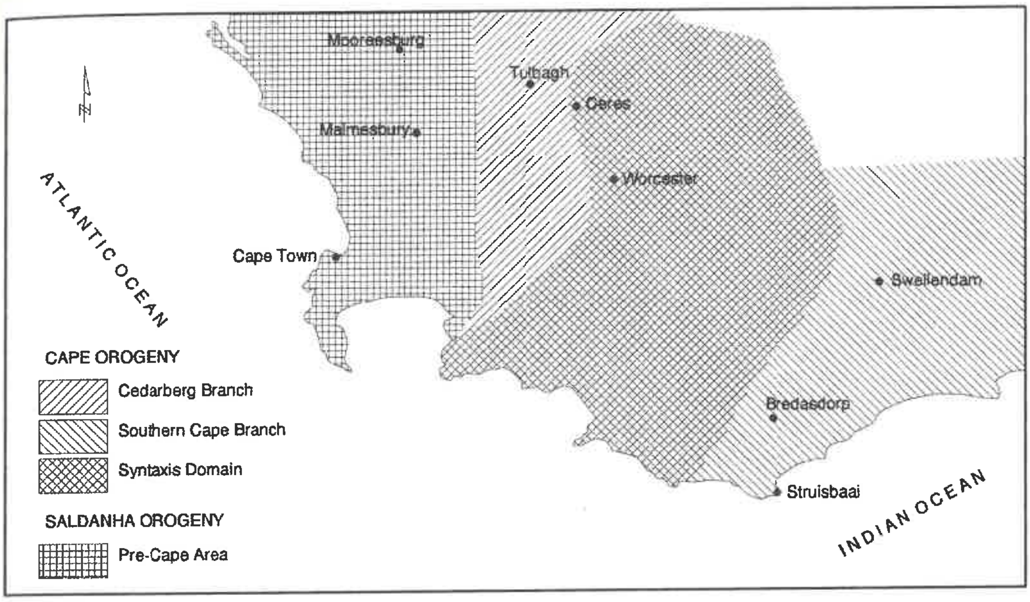
Rocks of the Cape and Karoo Supergroups were deformed by the Permo-Triassic Cape Orogeny (Söhnge and Hälbich,1983) . The outcrop pattern of the Cape Supergroup, namely parallel mega-anticlinal mountain ranges, separated by synclinal intermontane valleys, reflects the main structural features of the Cape Orogeny. Three tectonic areas (Fig. 2) can be distinguished, namely:

- The Cedarberg Branch which is characterised by open upright mega-folds, monoclines and normal north-northwest striking faults;
- The Southern Cape Branch, comprising north-verging eastwest trending folds, thrusts and normal faults, and;
- The Syntaxis Domain, which is defined as the area where the Cedarberg Branch and the Southern Cape Branch merge. This area consists of varied northeast striking faults (Gresse and Theron, 1992).

Brittle failure is often evident in the competent arenaceous units of the TMG, but to a lesser degree in the arenaceous units of the Bokkeveld and Witteberg Groups. The relatively thin interbedded sandstones of the Ecca and Beaufort Groups show the least amount of brittle failure. Numerous minor fold structures abound in the incompetent strata of the Bokkeveld, Witteberg, Ecca and Beaufort Groups.

*On 29 September 1969 an earthquake, measuring 6,5 on the Richter Scale, with its epicentre in the Skurweberg, rocked the Tulbagh Ceres area. It was felt over a wide area of the Western Cape, and even the lighthouse on Robben Island, 11 km offshore, ceased operation for half an hour due to a smashed reflector. Towns were cut off by landslides, roads and railway lines were blocked, power cuts occurred, numerous veld fires raged on the mountains and many buildings in towns like Tulbagh, Wolseley and Ceres and on numerous surrounding farms were either destroyed or seriously damaged. At least nine people were reported dead. A subsequent earthquake, measuring 6,2 on the Richter Scale occurred on 15 April 1970, causing further damage to Ceres in particular. The earthquakes had a marked impact on groundwater in the region: some boreholes suddenly dried up, while yields of other boreholes increased. New springs emerged, while springflow in others diminished or ceased altogether.*

**Fig. 2 : Sketch map: Approximate boundaries of the tectonic domains**




## 3.3 Intrusives

**A**part from the major pre-Cape granite intrusions into the Malmesbury Group, a number of mafic dykes were intruded into especially the Malmesbury Group and the Cape Granite Suite, notably in the Cape Peninsula, Worcester, Tulbagh and Wellington areas. These dykes tend to occur in swarms, often with a north-westerly to north-easterly strike direction (Gresse and Theron, 1992).

# 4. HYDROGEOLOGY OF THE DIFFERENT GEOLOGICAL UNITS

## 4.1 Fractured Aquifers

Consolidated hard rocks cover approximately 86% of the map area (Table 2). This rock mass was formed over a period of about 800 million years, experienced intrusion episodes in an early stage and subsequently endured several deformation phases. The deformation processes and succeeding orogenesis, continental uplift, weathering and erosion all aided in the development of the present groundwater environment. Competent rocks underwent brittle failure, resulting in the development of numerous fractures in rock units containing significant arenaceous material, thus furthering the formation of fracture porosity. In contrast, the incompetent rocks were more flexible and less inclined to break, thereby inhibiting the development of fracture porosity.

The existence or absence of rock fracturing and jointing and prevailing conditions of groundwater recharge thus plays a decisive role in the occurrence and characteristics of groundwater in the different consolidated rock units of the CFB.

**Table 2 : Details of the consolidated rocks within the Cape Fold Belt**

| Geological Unit | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Malmesbury Group (Ne) | 12.5 | 800 - 700 | Sedimentary and Metamorphic | 35 : 65 |
| Cape Granite Suite (N-Ec) | 3.7 | 632 - 530 | Intrusive | * |
| Klipheuwel Group (Ek) | 0.3 | 510 - 500 | Sedimentary | 60 : 40 |
| Table Mountain Group (O-St) | 20.6 | 500 - 400 | Sedimentary | 90 : 10 |
| Bokkeveld Group (Db) | 28.6 | 400 - 365 | Sedimentary | 15 : 85 |
| Witteberg Group (Dw) | 11.4 | 365 - 355 | Sedimentary | 49 : 51 |
| Dwyka Group (C-Pd) | 2.8 | 350 - 318 | Sedimentary (glacial) | * |
| Ecca Group (Pe) | 4.0 | 318 - 265 | Sedimentary | 20 : 80 |
| Beaufort Group (P-Trb) | 1.1 | 265 - 241 | Sedimentary | 30 : 70 |
| Uitenhage Group (J-Ku) | 0.9 | 160 - 80 | Sedimentary | * |

* = Not applicable.
1 = Percentage of map area covered by individual geological unit.
2 = Approximate age in million years.
3 = Geological origin.
4 = Approximate ratio of arenaceous : argillaceous material (%).

### 4.1.1 Malmesbury Group

The structural and stratigraphical features of the Malmesbury Group (Fig. 3) are complex, due to factors such as lateral facies variations and structural intricacies. Two major dislocation zones (Theron *et al.*, 1992) divide the Malmesbury Group into three northwest trending tectonic terranes, namely the south-western Tygerberg Terrane, the central Swartland Terrane and the north-eastern Boland Terrane. The Tygerberg Formation (Tygerberg Terrane) consists of phyllitic shale, siltstone, greywacke and quartzite. The Swartland Terrane is composed of the (lithology in brackets) Berg River Formation (mica schist, greywacke and subordinate limestone), the Klipplaat Formation (quartz-schist), the Bridgetown Formation (greenstone with dolomite and chert lenses), the Moorreesburg Formation (greywacke and pelite) and the Franschhoek Formation (quartzite and associated conglomerate and shale). Only the Porterville and Piketberg Formations of the Boland Terrane can be recognised in the map area. The Porterville Formation is composed of phyllitic shale, schist, greywacke and subordinate limestone, quartzitic sandstone and conglomerate. The Piketberg Formation consists of felspathic grit lenses with alternate greywacke and minor conglomerate.

*The thermal spring at Malmesbury, with a temperature of 33° C, rises from an obscure fault fracture in granite, and circulates from a depth of approximately 1 200 m (about 1 000 m below sealevel). The water has a conclusive sodium-chloride nature, and displays the same characteristics as groundwater from the Malmesbury Group argillaceous rocks. The possibility of the water originating from deep-seated Malmesbury Group rocks, and not from the granite, cannot be ruled out.*

Groundwater exploitation in the Malmesbury Group is often problematic due to the poor exposure, the largely argillaceous and thus incompetent nature of many of the lithological units and the overall structural complexities. Notable exceptions to the above statements include:

1. Areas where groundwater recharge to arenaceous units takes place from overlying alluvium. Groundwater conditions in the Wolseley area highlight this feature. The average yield of boreholes in the Breede River Valley near Wolseley, where recharge through alluvium is evident, is 15,5 l/s, as compared with the average borehole yield of 3,7 l/s in the same area where alluvium does not occur;

2. Sites in and along dislocation zones;

3. Areas where the more arenaceous units of the Malmesbury Group rocks are located in hydrogeological association with the Table Mountain Group.The presumption is

that faults and joints in the TMG beds often extend down into the Malmesbury Group beds;

4. Contact zones with granite bodies, provided favourable conditions for groundwater recharge exist.

A borehole yield analysis (Fig. 4) indicates that 32% of boreholes yield less than 0.5 l/s and 11% yield more than 5 l/s.

Groundwater quality varies considerably, probably due to the variable lithologies and recharge conditions, and ECs range between 10 and 1 000 mS/m (Table 3). The best quality groundwater can be obtained in areas where groundwater movement takes place, such as dislocation zones and areas where alluvium covers arenaceous rocks. Determinants seldom exceed recommended limits in arenaceous units where groundwater turnover takes place (A and B in Table 3). Sodium, magnesium, chloride and sulphate often exceed maximum recommended limits and even maximum allowable limits in the argillaceous units (C in Table 3). Groundwater in the Malmesbury Group is generally of a sodium-chloride-alkaline nature (Fig. 5).

**Fig. 3 : Areal location of the Malmesbury Group and position of sampling points for the chemical analyses shown in Tabel 3**

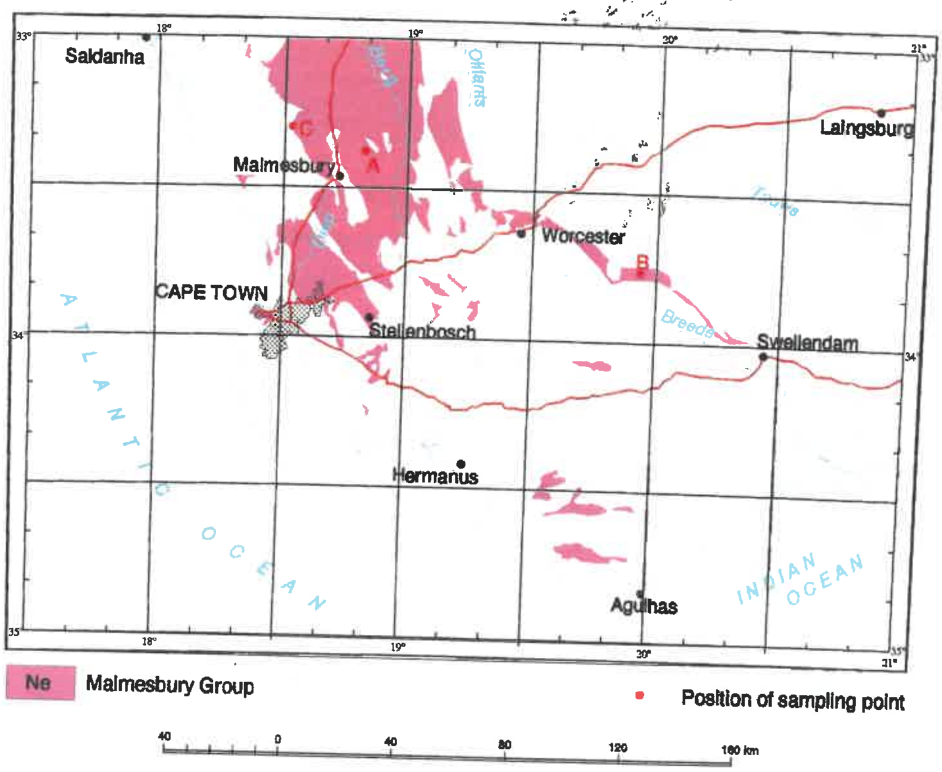


**Fig. 4 : Yield frequencies of boreholes in the Malmesbury group (770 boreholes analysed)**

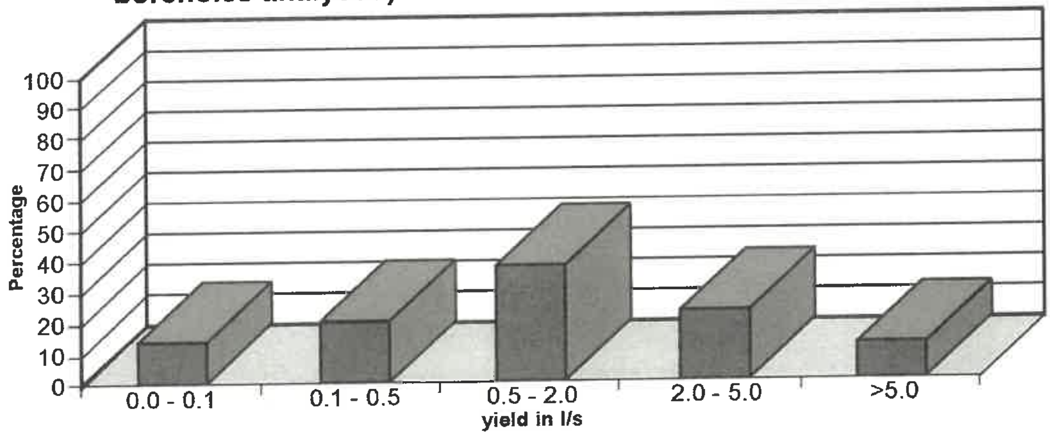
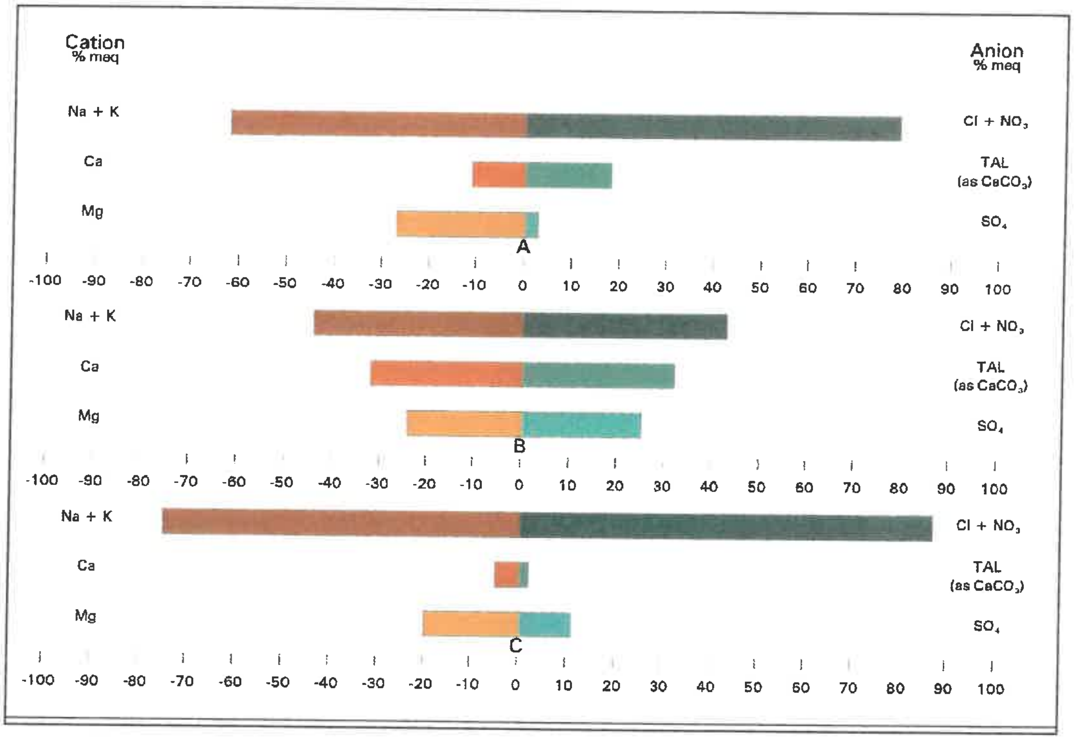



**Table 3 : Chemical analyses from different boreholes in the Malmesbury group** (Analysed by the IWQS)

| | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| EC | mS/m | 34.6 | 70.7 | 1 020.0 | 70.0 | 300.0 |
| TDS | mg/l | 172.0 | 448.0 | 6 139.0 | 1 200.0 | 2 000.0 |
| pH | | 8.0 | 7.1 | 7.6 | 6 - 9 | 5.5 - 9.5 |
| Na | mg/l | 39.0 | 67.1 | 1 830.0 | 100.0 | 400.0 |
| K | mg/l | 0.5 | 2.36 | 36.9 | 200.0 | 400.0 |
| Ca | mg/l | 6.0 | 42.4 | 106.0 | 150.0 | 200.0 |
| Mg | mg/l | 9.0 | 19.5 | 253.0 | 70.0 | 100.0 |
| Cl | mg/l | 69.0 | 95.6 | 3 196.0 | 250.0 | 600.0 |
| $SO_4$ | mg/l | 4.0 | 75.7 | 518.0 | 200.0 | 600.0 |
| TAL (as $CaCO_3$) | mg/l | 26.0 | 118.6 | 155.0 | 300.0 | 650.0 |
| F | mg/l | 0.3 | 0.61 | 1.2 | 1.0 | 1.5 |
| $NO_3$ + $NO_2$ (as N) | mg/l | 2.99 | 0.02 | 2.42 | 6.0 | 10.0 |
| $PO_4$ (as P) | mg/l | 0.016 | 0.01 | 0.009 | | |
| Si | mg/l | 14.2 | 4.75 | 8.1 | | |
| $NH_4$ (as N) | mg/l | 0.04 | 0.02 | 0.04 | 6.0 | 10.0 |
| Fe | mg/l | * | * | * | 0.1 | 1.0 |

* = Not determined.
A = Borehole; Botmas Kloof; dislocation zone; yield 1.0 l/s.
B = Borehole; Farm De Hoop; bedrock recharged by alluvium; yield 3.7 l/s.
C = Borehole; Farm Elands Vlei; massive argillaceous rocks; yield 0.2 l/s.
D = Drinking Water Quality Criteria: maximum recommended limit.
E = Drinking Water Quality Criteria: maximum allowable limit.

**Fig. 5 : Stiff diagrams of the chemical analyses in Table 3 (Malmesbury Group)**




### 4.1.2 Klipheuwel Group

The Klipheuwel Group (Fig. 6) is divided into two formations, namely the basal Magrug and the overlying Populierbos Formations. The maximum thickness of the Group is about 2 000 m. The Klipheuwel Group is limited in extent and covers only about 0.3% of the map area (Table 2).

The Populierbos Formation is an argillaceous unit and consists of shale, mudstone and sandy shale. The Magrug Formation is an arenaceous unit and consists of conglomerate, grit and coarse sandstone.

The largely argillaceous rocks of the Populierbos Formation seldom yield more than 2 l/s. The yield potential of the predominantly arenaceous rocks of the Magrug Formation is considerably better and borehole yields exceeding 2 l/s are common (Fig. 7).

ECs generally range between 200 and 1 400 mS/m in the Populierbos Formation and between 40 and 250 mS/m in the Magrug Formation (Table 4). Sodium, magnesium and chloride often exceed maximum recommended limits, and even maximum allowable limits in the Populierbos Formation (B in Table 4), but determinants seldom exceed maximum recommended limits in the Magrug Formation (A in Table 4). Groundwater in

Klipheuwel Group is generally of a sodium-chloride nature (Fig. 8).

**Fig. 6 : Areal location of the Klipheuwel Group and position of sampling points for the chemical analyses shown in Table 4**

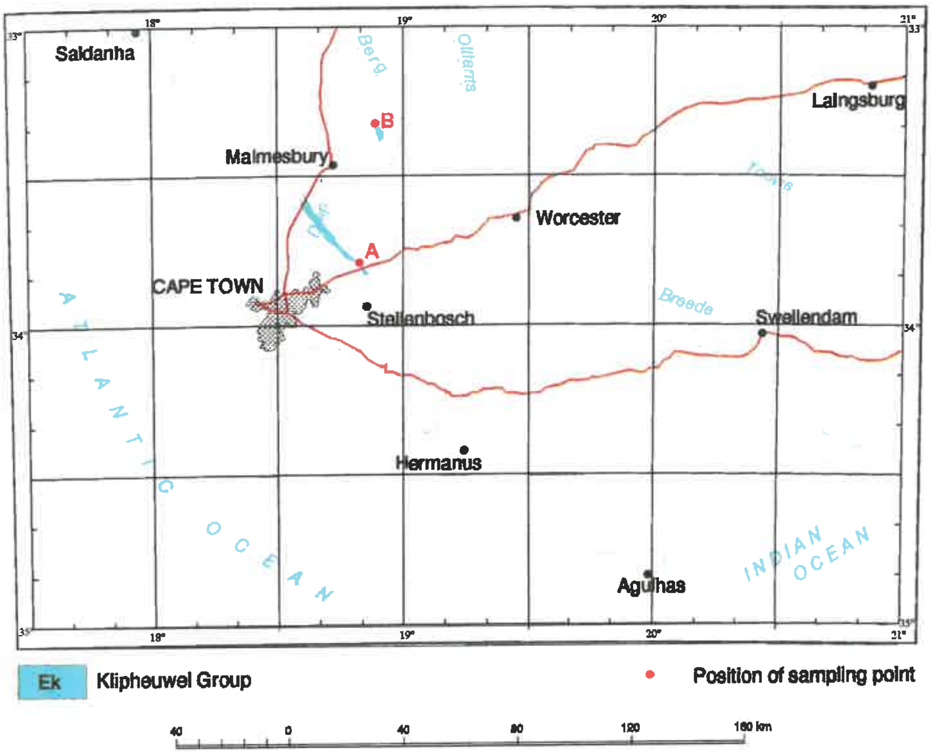



**Fig. 7 : Yield frequencies of boreholes in the Klipheuwel group (8 boreholes analysed)**

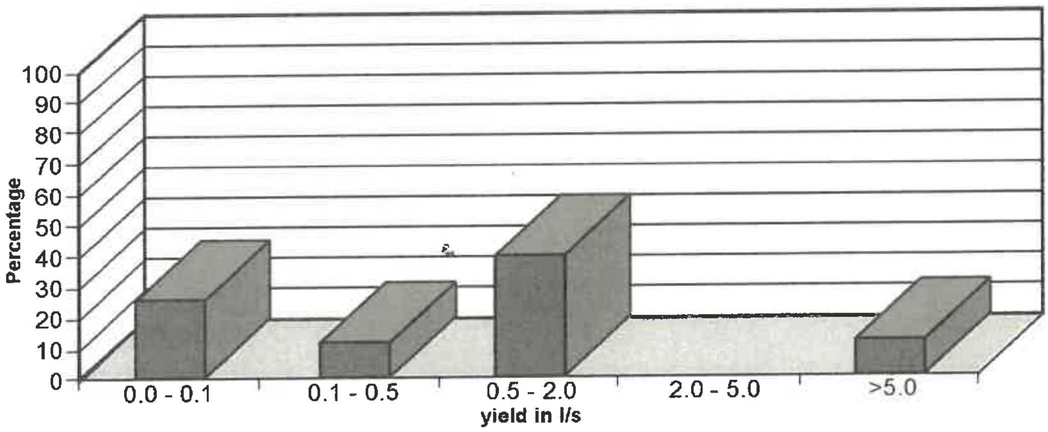
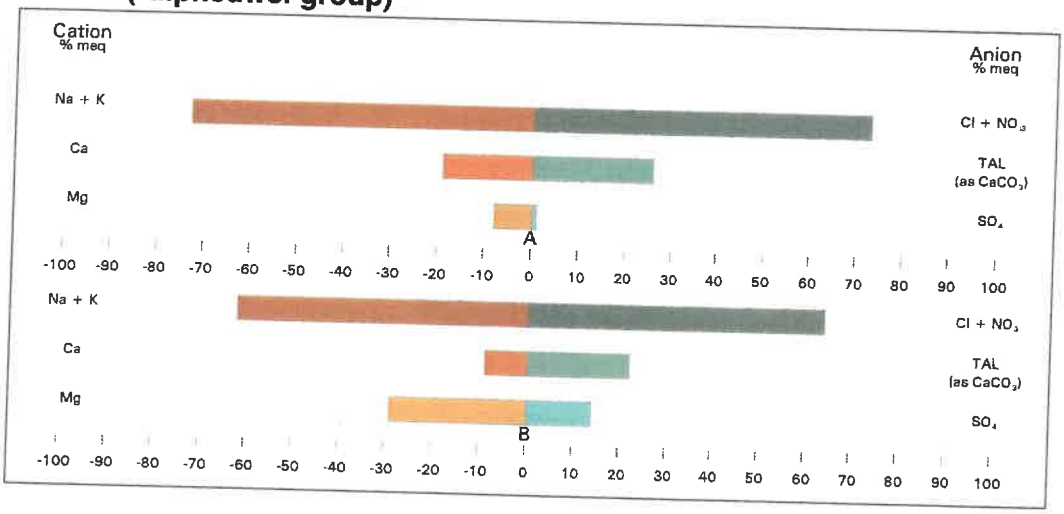


**Table 4 : Chemical analyses from different boreholes in the Klipheuwel group** (Analysed by the IWQS)

| | | A | B | C | D |
|---|---|---|---|---|---|
| EC | mS/m | 43.0 | 255.3 | 70.0 | 300.0 |
| TDS | mg/l | 275.0 | 1 475.0 | 1 200.0 | 2 000.0 |
| pH | | 8.1 | 7.6 | 6 - 9 | 5.5 - 9.5 |
| Na | mg/l | 60.0 | 332.7 | 100.0 | 400.0 |
| K | mg/l | 3.9 | 8.5 | 200.0 | 400.0 |
| Ca | mg/l | 13.2 | 39.7 | 150.0 | 200.0 |
| Mg | mg/l | 3.6 | 83.5 | 70.0 | 100.0 |
| Cl | mg/l | 91.0 | 502.7 | 250.0 | 600.0 |
| $SO_4$ | mg/l | 2.0 | 150.0 | 200.0 | 600.0 |
| TAL (as $CaCO_3$) | mg/l | 55.0 | 291.4 | 300.0 | 650.0 |
| F | mg/l | * | 0.9 | 1.0 | 1.5 |
| $NO_3 + NO_2$ (as N) | mg/l | * | 0.2 | 6.0 | 10.0 |
| $PO_4$ (as P) | mg/l | 0.2 | 0.04 | | |
| Si | mg/l | * | 8.1 | | |
| $NH_4$ (as N) | mg/l | * | 0.05 | 6.0 | 10.0 |
| Fe | mg/l | 7.4 | * | 0.1 | 1.0 |

* = Not determined.
A = Borehole; Eensaamheid SW of Paarl; Magrug Formation; yield 3.7 l/s.
B = Borehole; Weltevreden NE of Riebeeck West; Populierbos Formation; yield < 0.5 l/s.
C = Drinking Water Quality Criteria: maximum recommended limit.
D = Drinking Water Quality Criteria: maximum allowable limit.

**Fig. 8 : Stiff diagram of the chemical analyses in Table 4 (Klipheuwel group)**



### 4.1.3 Table Mountain Group

The Table Mountain Group (TGM) (Fig. 9) is divided into six units in the map area, (thickness and lithology according to Theron *et al*,1992) namely:

| Formation | Thickness | Lithology |
|---|---|---|
| Piekenierskloof Formation | 10 - 150 m | Quartzitic sandstone with coarse-grained to gritty zones and rudites |
| Graafwater Formation | 25 - 65 m | Thin-bedded sandstone, siltstone, shale and mudstone |
| Peninsula Formation | 575 - 2 000 m | Largely thick-bedded, coarse-grained quartzitic sandstone |
| Pakhuis Formation | 1 - 70 m | Diamictite, quartz-arenite and thin-bedded quartzitic sandstone |
| Cedarberg Formation | 45 - 60 m | Shale, siltstone and silty sandstone |
| **Nardouw Subgroup** (subdivided into): | | |
| Goudini Formation | 60 - 110 m | Quartzose sandstone, reddish-brown when weathered |
| Skurweberg Formation | 160 - 200 m | Light-grey, thick-bedded felspathic quartzose sandstone |
| Rietvlei Formation | 90 - 200 m | Thinly- to medium-bedded felspathic sandstone and some shale |

The TMG, notably the often fractured arenaceous components, is largely anisotropic, and thus does not display uniform aquifer characteristics. An intricate network of fissures, joints, fractures (Plate 1), and even cavities govern the infiltration, storage and transmission of groundwater in the largely competent and brittle-natured arenaceous units of the TMG. The TMG generally constitutes the mountainous areas which, in turn influence precipitation to a significant extent. Due to the fractured nature of the sandstones in generally high rainfall regions, groundwater recharge is favourable and an infiltration rate of 15% of precipitation in certain areas is not unrealistic. It would appear that the TMG thus offers by far the most favourable opportunities for groundwater development from fractured aquifers in the south-western Cape region.

An abundance of springs is a further characteristic of the TMG. Three kinds of springs can be distinguished:

1. Fault and major structure controlled, generally deep circulating springs, often with large constant supplies. The Brandvlei Hot spring, with a constant yield of 127 l/s is an example;

2. Lithologically controlled, relatively shallow circulating springs. These springs issue due to the presence of impeding shale layers such as the Cedarberg Shale Formation (Plate 2). Yields from these springs are less constant and seasonal yield fluctuations are a distinctive feature. The bulk of the perennial springs issuing from the TMG are likely to be lithologically controlled;

3. Springs seeping from numerous small fractures and joints. They are very evident during and shortly following rainy periods and are responsible for the myriad of springs in the TMG. They are however highly seasonal and cease to exist with the onset of dry weather conditions.

*Six thermal springs occur in the Cape Supergroup rocks in the map area, namely (temperature in brackets) the Goudini (37°C), Brandvlei (64°C), Caledon (38°C), Montagu (43°C ), Baden (39°C) and Warmwaterberg (45°C) hot springs. They are all fault related and are situated in a TMG sandstone-Bokkeveld Group shale relationship. Water circulates from between approximately 1600 m (1200 m below sealevel) at Caledon, to about 3800 m (3600 m below sealevel) at Brandvlei. The Brandvlei thermal spring has the distinction of being both the hottest and strongest yielding thermal spring in the country.*

The quality of groundwater from the TMG is excellent with electrical conductivities generally ranging between 5 and 70 mS/m (Table 5). However, groundwater with ECs of up to 180 mS/m can occasionally procured from boreholes drilled into interbedded shaly layers. Groundwater is generally of a sodium chloride nature (Fig. 11).

Despite the opportune groundwater potential in the TMG (Fig.10), provided proper scientific methods of borehole siting are applied, some adverse groundwater exploitation aspects should be cited:

- Permeability inhibiting material derived from microbreccia, mylonite, iron and manganese oxides (Plate 3 ) and silica were formed and deposited in many of the fractures and joints, rendering some of them less effective groundwater conduits;

- Due to the rough, mountainous terrain, large areas of the TMG are almost inaccessible. Groundwater development is thus generally limited to the foothills of mountains;

- The TMG sandstones are hard, brittle and cross-jointed and are difficult to drill into. Due to the abrasiveness of these rocks, drilling bits tend to lose gauge, resulting in a gradual narrowing of a borehole diameter with depth. If this is not heeded, considerable problems of delivering a borehole of uniform diameter can result;

- Owing to the fractured and somewhat unstable nature of structures that are often drilled into, loose rock fragments are inclined to slip into boreholes not equipped with casing, causing obstructions. As numerous boreholes have been lost this way, it has become customary to fully equip boreholes with casing, adding considerably to the cost. Effective groundwater exploitation of the TMG is costly. Deep groundwater circulation is a reality and borehole depths in excess of 200 m, drilled in a difficult and complex medium and cased off to great depths, are required for optimum results. The cost of a single borehole can thus amount to tens of thousands of Rands;

- Once a borehole is functional, the action of iron bacteria can set in under certain circumstances. Iron bacteria often occur when substantial levels of iron and manganese are present in the groundwater, as is often the case with groundwater in the TMG. Slimy material is created and may plug screen pores and perforated slotting, and may even retard fracture permeability, rendering a once productive borehole much less effective. Borehole rehabilitation is possible with chemical treatment.

**Fig. 9 : Areal location of the Table Mountain Group and position of sampling**

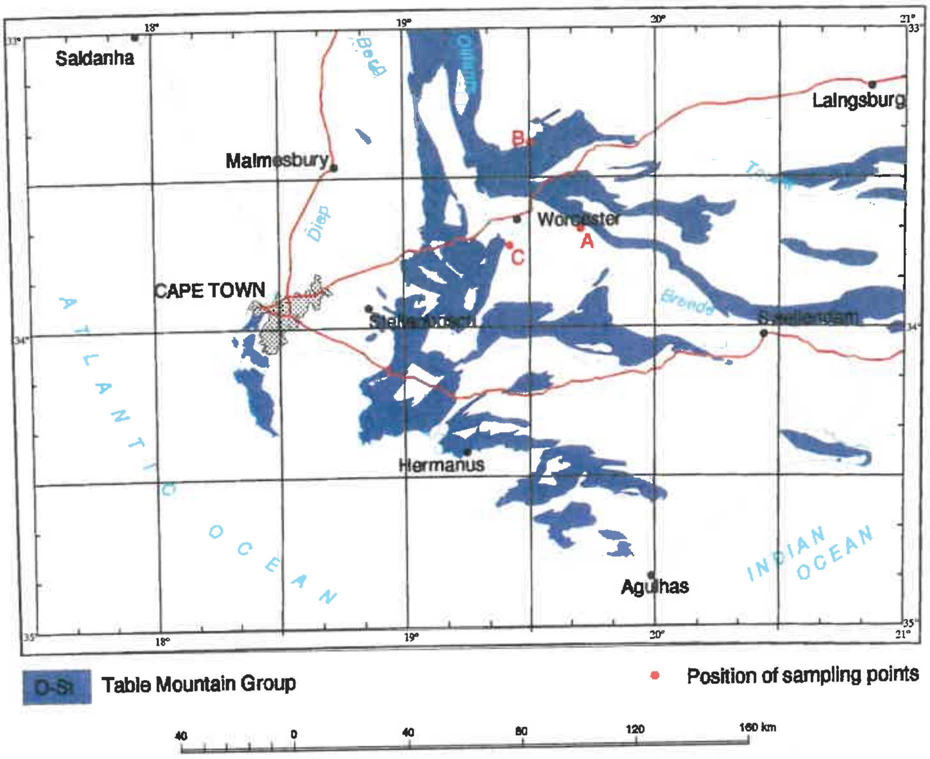



**Plate 1. Jointing and fracturing in Table Mountain Group sandstones at Hermanus.**

**Plate 2.** Cedarberg Shale Formation (smooth slope) near Rawsonville. The Cedarberg Formation has a marked impact on groundwater and is for instance responsible for most of the perennial springs in the map area. The flat-lying area in the foreground is underlain by alluvial deposits in the Breede River valley, which is one of the important intergranular aquifers in the map area.

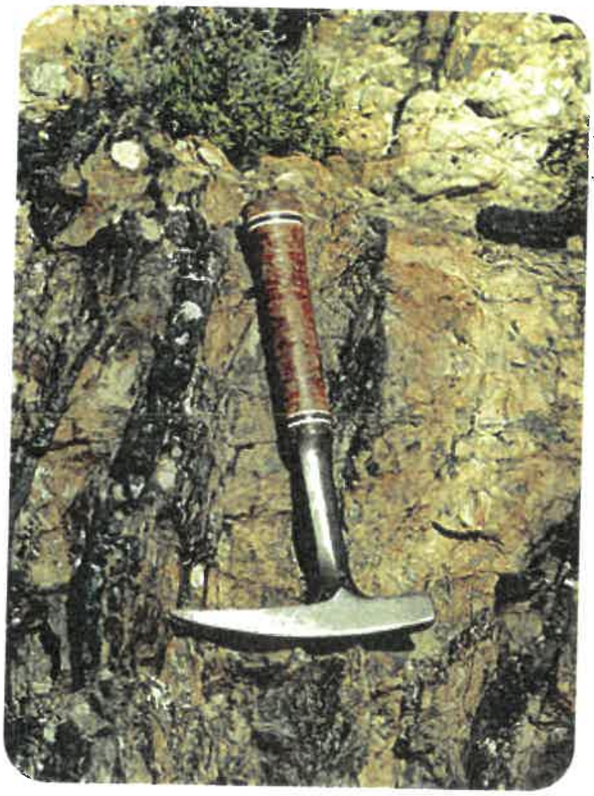
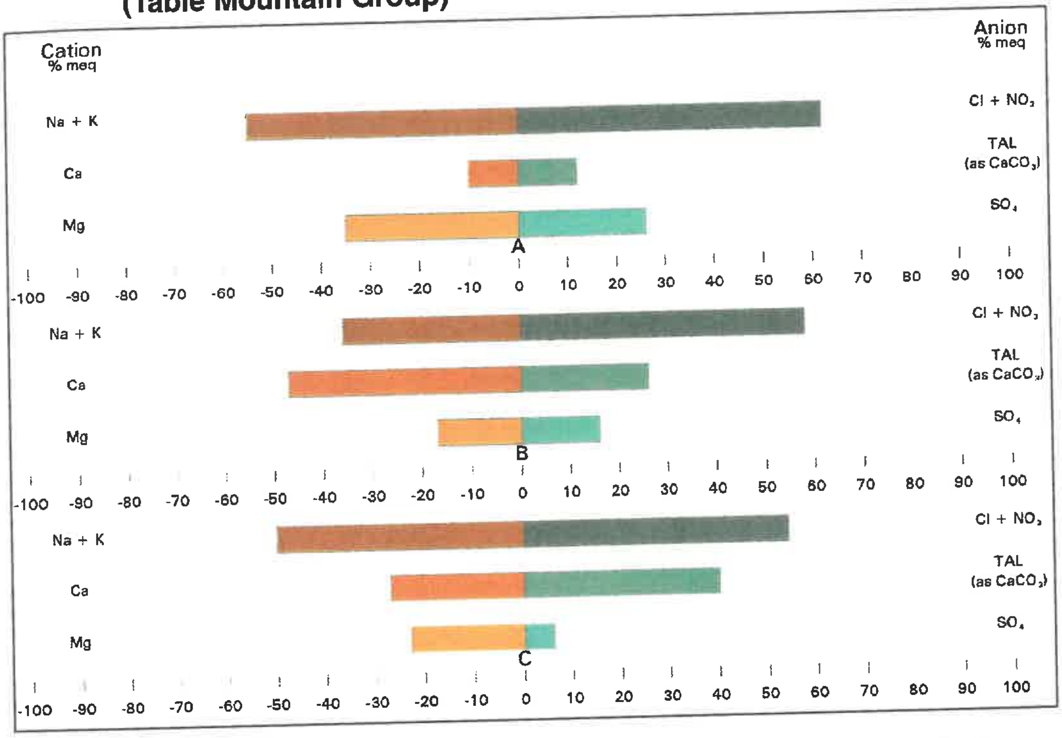


**Plate 3.** Manganese deposits in a fault between Franschhoek and Villiersdorp. The infilling of fracture openings by deposits such as iron and manganese often impedes permeability.

## Fig. 11 : Stiff diagrams of the chemical analyses in Table 5 (Table Mountain Group)

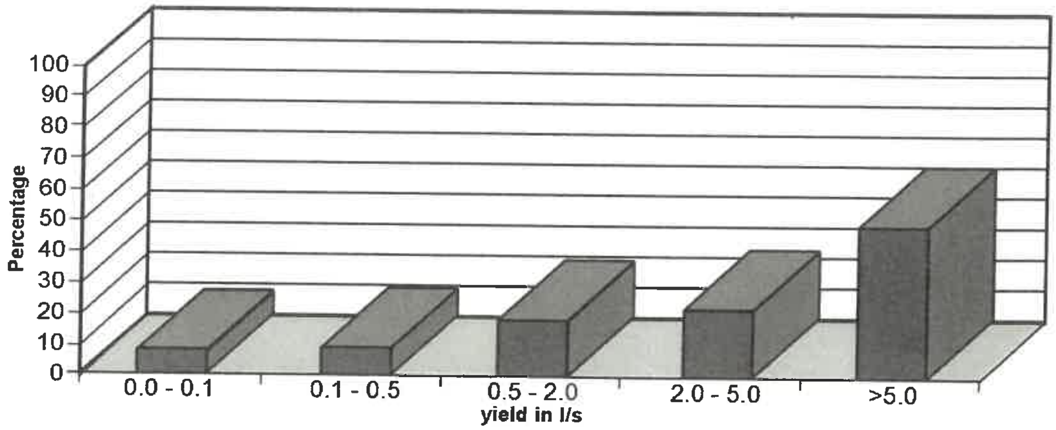



## Table 5 : Chemical analyses from different groundwater sources in the Table Mountain group (Analysed by the IWQS)

| | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| EC | mS/m | 5.0 | 36.0 | 7.8 | 70.0 | 300.0 |
| TDS | mg/l | 21.0 | 203.0 | 51.0 | 1 200.0 | 2 000.0 |
| pH | | 6.95 | 7.4 | 6.4 | 6 - 9 | 5.5 - 9.5 |
| Na | mg/l | 3.9 | 25.0 | 7.17 | 100.0 | 400.0 |
| K | mg/l | 0.31 | 2.3 | 1.93 | 200.0 | 400.0 |
| Ca | mg/l | 0.7 | 28.0 | 3.37 | 150.0 | 200.0 |
| Mg | mg/l | 1.4 | 6.0 | 1.72 | 70.0 | 100.0 |
| Cl | mg/l | 7.4 | 60.0 | 12.48 | 250.0 | 600.0 |
| $SO_4$ | mg/l | 4.2 | 22.0 | 1.73 | 200.0 | 600.0 |
| TAL (as $CaCO_3$) | mg/l | 2.4 | 48.0 | 12.83 | 300.0 | 650.0 |
| F | mg/l | 0.09 | 0.2 | * | 1.0 | 1.5 |
| $NO_3 + NO_2$ (as N) | mg/l | * | 0.09 | * | 6.0 | 10.0 |
| $PO_4$ (as P) | mg/l | 0.03 | 0.009 | 0.16 | | |
| Si | mg/l | 5.77 | 10.5 | * | | |
| $NH_4$ (as N) | mg/l | 0.01 | 0.04 | * | 6.0 | 10.0 |
| Fe | mg/l | * | * | * | 0.1 | 1.0 |

* = Not determined.
A = Borehole; Naudésberg, east of Worcester; fracture related in Peninsula Formation; yield 12.5 l/s.
B = Borehole; Farm Welvaart, northeast of Worcester; fracture related in the Nardouw Subgroup; yield 15.1 l/s.
C = Brandvlei Hotspring south of Worcester; fault related; yield 127 l/s.
D = Drinking Water Quality Criteria: maximum recommended limit.
E = Drinking Water Quality Criteria: maximum allowable limit.

**Fig. 10 : Yield frequencies of boreholes in the Table Mountain Group (325 boreholes analysed)**




### 4.1.4 Bokkeveld Group

The Bokkeveld Group (Fig.12) is composed of two subgroups in the map area, namely the basal Ceres Subgroup and the overlying Bidouw Subgroup. The following formations occur (approximate and varying thickness and lithology according to Gresse and Theron, 1992):

| Formation | Thickness | Lithology |
|---|---|---|
| **Ceres Subgroup:** | | |
| Gydo Formation | 160 m | Shale, siltstone and thin sandstone beds |
| Gamka Formation | 15 - 70 m | Felspathic sandstone and siltstone |
| Voorstehoek Formation | 200 - 300 m | Mudstone, shale and siltstone |
| Hex River Formation | 30 - 55 m | Felspathic and micaceous thick-bedded sandstone, wacke and sandy shale |
| Tra-tra Formation | 250 - 300 m | Shale, mudstone and stilstone |
| Boplaas Formation | 35 - 100 m | Micaceous and mottled sandstone, siltstone and sandy-shale |
| **Bidouw Subgroup:** | | |
| Waboomberg Formation | 200 m | Shale, siltstone and immature sandstone |
| Wuppertal Formation | 26 m | Sandstone, siltstone and shale |
| Klipbokkop Formation | 300 - 400 m | Micaceous siltstone, mudstone and argillaceous sandstone |
| Osberg Formation | 30 m | Felspathic sandstone, shale, mudstone and siltstone |
| Karoopoort Formation | 40 m | Siltstone, sandy shale and minor mudstone |

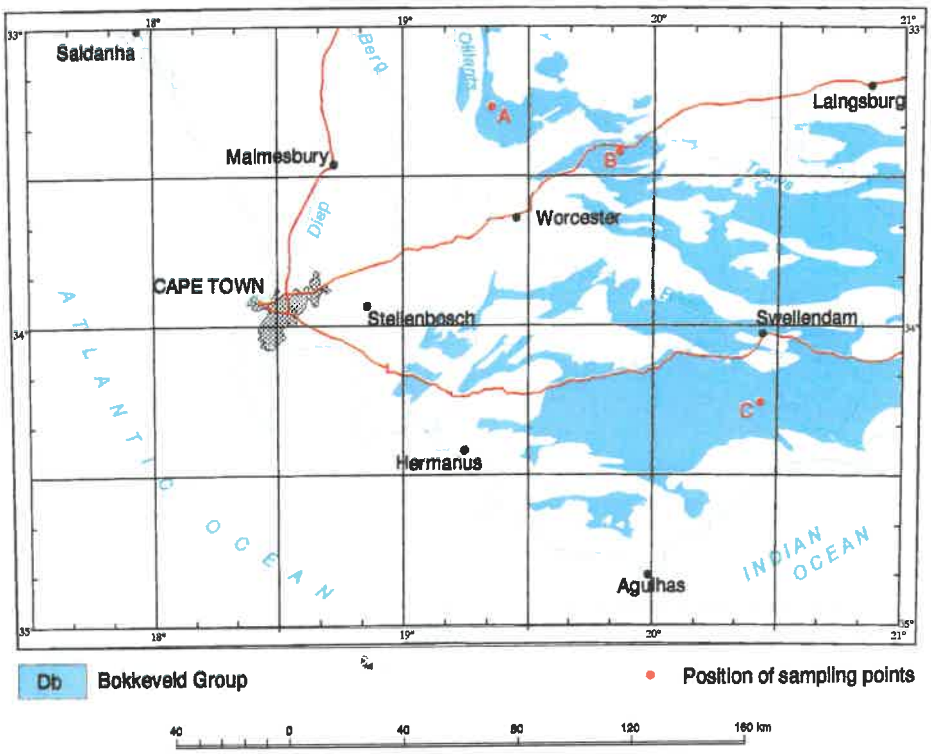
The arenaceous : argillaceous ratio of the Ceres Subgroup is approximately 23% : 77%, and that of the Bidouw subgroup is approximately 8% : 92%.

Occurrences of Bokkeveld Group rocks east of Caledon and south of the Langeberg range (the area known as the Rûensveld) are largely argillaceous.

The arenaceous : argillaceous ratio plays a noticeable groundwater role both quantatively and qualitatively. Borehole yields vary widely (Fig. 13). Yields of more than 5 l/s are common in the sandstone richer Ceres Subgroup, provided recharge conditions are favourable. Borehole yields in the Ceres Subgroup in areas where recharge conditions are not so favourable, seldom exceed 3 l/s. Borehole yields in the sandstone-poor Bidouw Subgroup seldom exceed 3 l/s, even if recharge conditions are favourable, and yields of below 1 l/s can generally be expected.

ECs of groundwater in the Ceres Subgroup vary between 30 and 400 mS/m (A and B in Table 6). Sodium, calcium, magnesium, chloride and total alkalinity often exceed maximum recommended limits and may even exceed maximum allowable limits. Sodium, calcium, magnesium, chloride, sulphate and total alkalinity commonly exceed maximum recommended limits in the Bidouw Subgroup (C in Table 6). Groundwater in the Bokkeveld Group is generally of a sodium-chloride nature (Fig. 14).

**Fig. 12 : Areal location of the Bokkeveld Group and position of sampling points for the chemical analyses shown in Table 6**




hydrogeology of the different geological units

**Fig. 13 : Yield frequencies of boreholes in the Bokkeveld Group (917 boreholes analysed)**

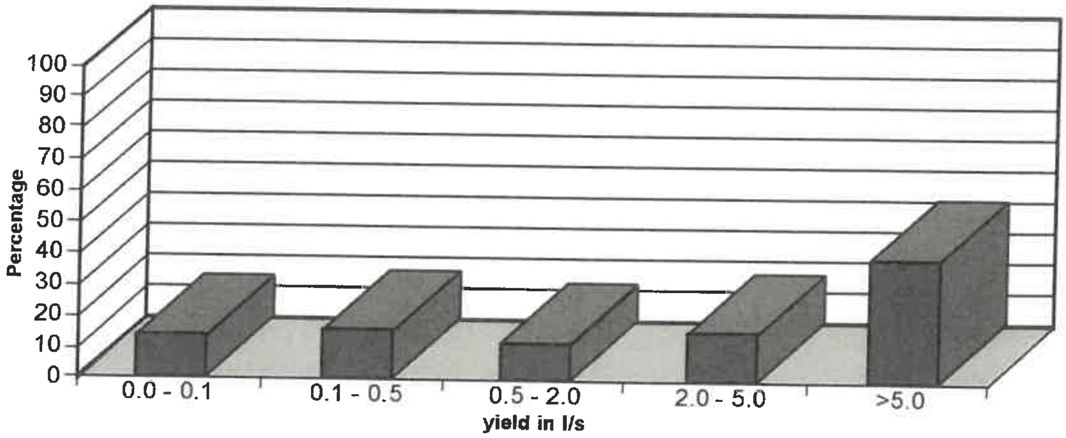


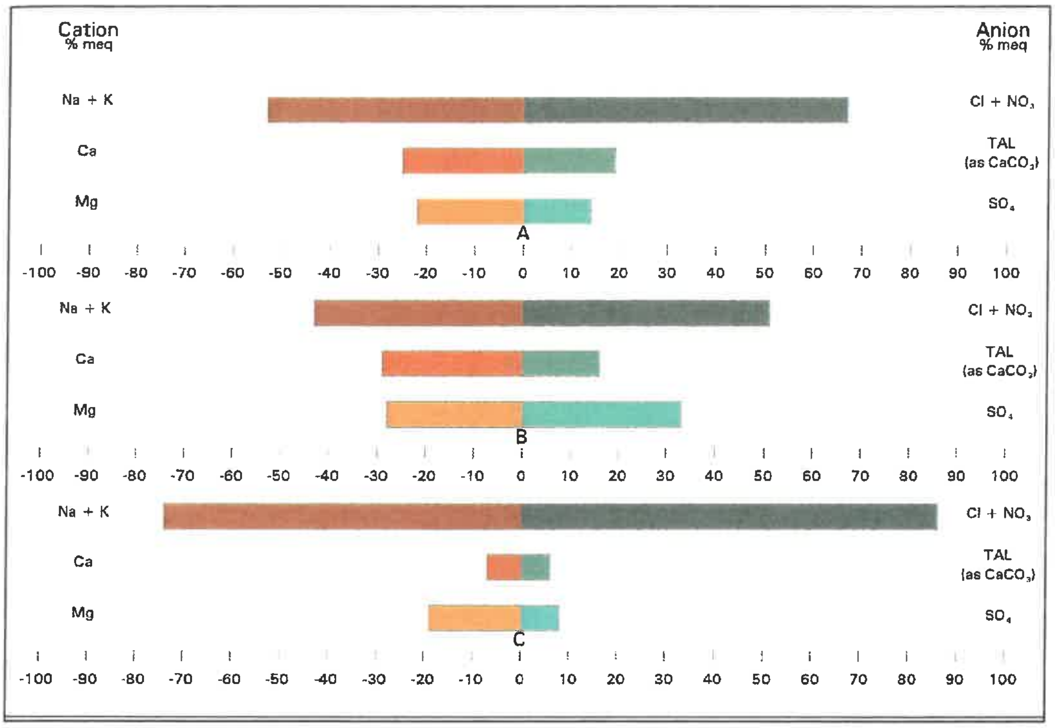

**Table 6 : Chemical analyses from different boreholes in the Bokkeveld Group** (Analysed by the IWQS)

| | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| EC | mS/m | 118.1 | 368.0 | 1 320.0 | 70 0 | 300 0 |
| TDS | mg/l | 697.0 | 2 487.0 | 8 558.0 | 1 200 0 | 2 000 0 |
| pH | | 7.2 | 7.8 | 8.4 | 6 - 9 | 5 5 - 9 5 |
| Na | mg/l | 135.0 | 386.0 | 2 505.0 | 100 0 | 400 0 |
| K | mg/l | 2.0 | 3.1 | 31.9 | 200.0 | 400.0 |
| Ca | mg/l | 55.0 | 228.3 | 203.0 | 150 0 | 200 0 |
| Mg | mg/l | 29.0 | 129.0 | 334.0 | 70 0 | 100 0 |
| Cl | mg/l | 256.0 | 726.1 | 4 393.0 | 250 0 | 600 0 |
| $SO_4$ | mg/l | 72.0 | 614.8 | 526.0 | 200 0 | 600 0 |
| TAL (as $CaCO_3$) | mg/l | 121.0 | 326.6 | 461.0 | 300 0 | 650 0 |
| F | mg/l | 0.2 | 0.5 | 1.7 | 1.0 | 1.5 |
| $NO_3 + NO_2$ (as N) | mg/l | 0.04 | 0.04 | 0.04 | 6.0 | 10.0 |
| $PO_4$ (as P) | mg/l | 0.03 | 0.01 | 0.01 | | |
| Si | mg/l | 15.9 | 10.3 | 6.1 | | |
| $NH_4$ (as N) | mg/l | 0.04 | 0.02 | 0.08 | 6 0 | 10.0 |
| Fe | mg/l | * | * | * | 0 1 | 1.0 |

* = Not determined.
A = Borehole; Elandsrivier NNE of Ceres; Tra-tra Formation; yield 3.0 l/s; recharge conditions favourable.
B = Borehole; Helpmekaar SW of Touws River, Boplaas Formation; yield 1.5 l/s; recharge conditions not so favourable.
C = Borehole; Helpmekaar (Rûensveld) south of Swellendam; Bidouw Subgroup; yield 0.1 l/s.
D = Drinking Water Quality Criteria: maximum recommended limit.
E = Drinking Water Quality Criteria: maximum allowable limit.

hydrogeology of the different geological units

**Fig. 14: Stiff diagrams of the chemical analyses in Table 6 (Bokkeveld Group)**

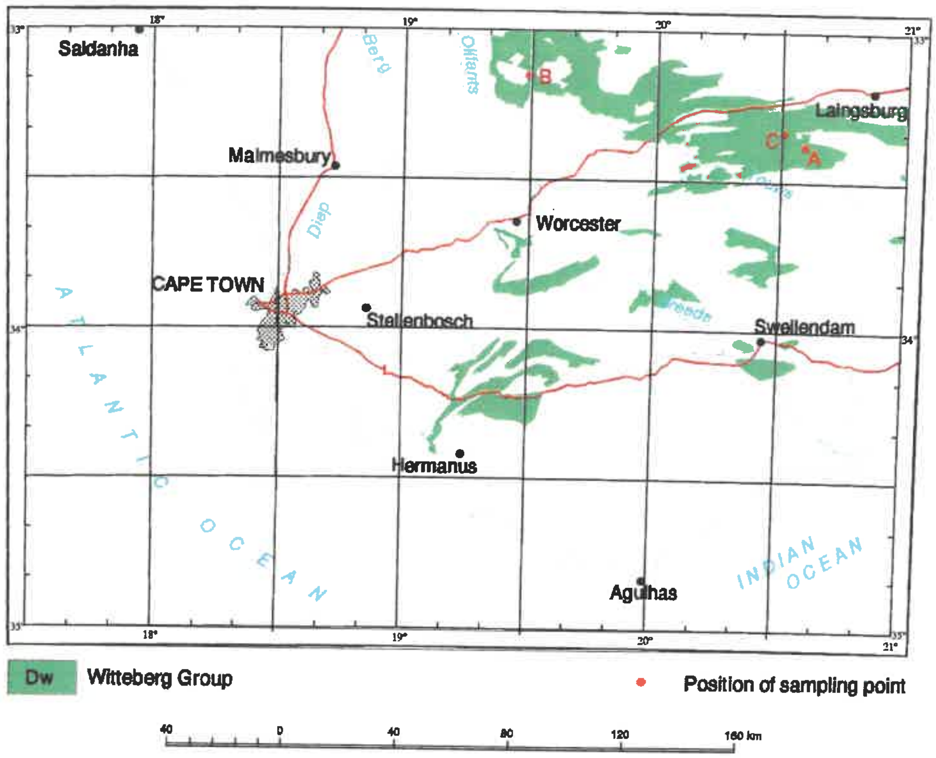



### 4.1.5 Witteberg Group

The Witteberg Group (Fig. 15) is divided into seven formations in the map area. The lower three formations, viz the Wagendrift, Blinkberg and Swartruggens Formations, form part of the Weltevrede Subgroup, which is overlain by the Witpoort Formation (which does not belong to a Subgroup). The topmost three formations, namely the Kweekvlei, Floriskraal and Waaipoort Formations belong to the Lake Mentz Subgroup. The thickness and lithology (Gresse and Theron, 1992) of individual formations are as follows:

| Formation | Thickness | Lithology |
|---|---|---|
| **Weltevrede Subgroup:** | | |
| Wagendrift | 135 - 165 m | Siltstone, sandy shale, mudstone and lithic sandstone |
| Blinkberg | 15 - 90 m | Thick-bedded quartzitic sandstone |
| Swartruggens | 300 m | Siltstone, mudstone and thin-bedded sandstone |
| Witpoort | 65 -380 m | Quartzitic sandstone, pebbly sandstone and thin conglomerate layers |
| **Lake Mentz Subgroup:** | | |
| Kweekvlei | 30 - 50 m | Micaceous shale and stilstone |
| Floriskraal | 25 - 70 m | Felspathic quartzitic sandstone, stilstone and micaceous shale |
| Waaipoort | 25 - 37 m | Shale, mudstone and stilstone |

**Fig. 15 : Areal location of the Witteberg Group and position of sampling points for the chemical analyses shown in Table 7**




The arenaceous : argillaceous ratio of the Witteberg Group in the map area is approximately 50 : 50, with the Blinkberg, Witpoort and Floriskraal Formations being predominantly arenaceous, and the other formations being predominantly argillaceous units.

The arenaceous : argillaceous ratio plays a noteworthy role in terms of groundwater yield and quality. The shale components seldom yield more than 2 l/s but the yield potential of the sandstone components is noticeably better, especially in the Witpoort Formation, with borehole yields up to 5 l/s not uncommon. A borehole yield analysis, taking boreholes from all the different units into account, indicates that 30% of boreholes yield less than 0.5 l/s, and 26% yield more than 5 l/s (Fig. 16).

Brackish groundwater with ECs ranging between 200 and 700 mS/m can be expected in the shale components. The following determinants often exceed maximum allowable limits in the shales: sodium, chloride and total alkalinity (A and C in Table 7). Groundwater from the shaly units are generally of a sodium-chloride nature (A and C in Fig. 17).

ECs of groundwater from the sandstone units generally range between 70 and 150 mS/m. Sodium, chloride and total alkalinity may occasionally exceed recommended limits. Groundwater from the sandstone units is generally of a sodium-chloride nature, but can also be of a calcium-sulphate nature (B in Fig. 17).

Positioning of boreholes on fractures in the sandstone units close to shale units often poses the danger of poor quality groundwater being drawn in from the shale units.

**Fig. 16 : Yield frequencies of boreholes in the Witteberg Group (200 boreholes analysed)**

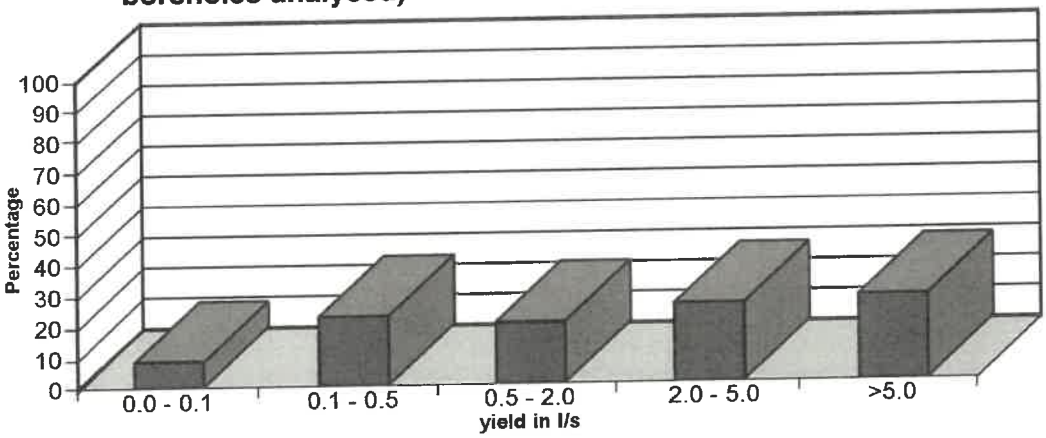



**Fig. 17 : Stiff diagram of the chemical analyses in Table 7 (Witteberg Group)**

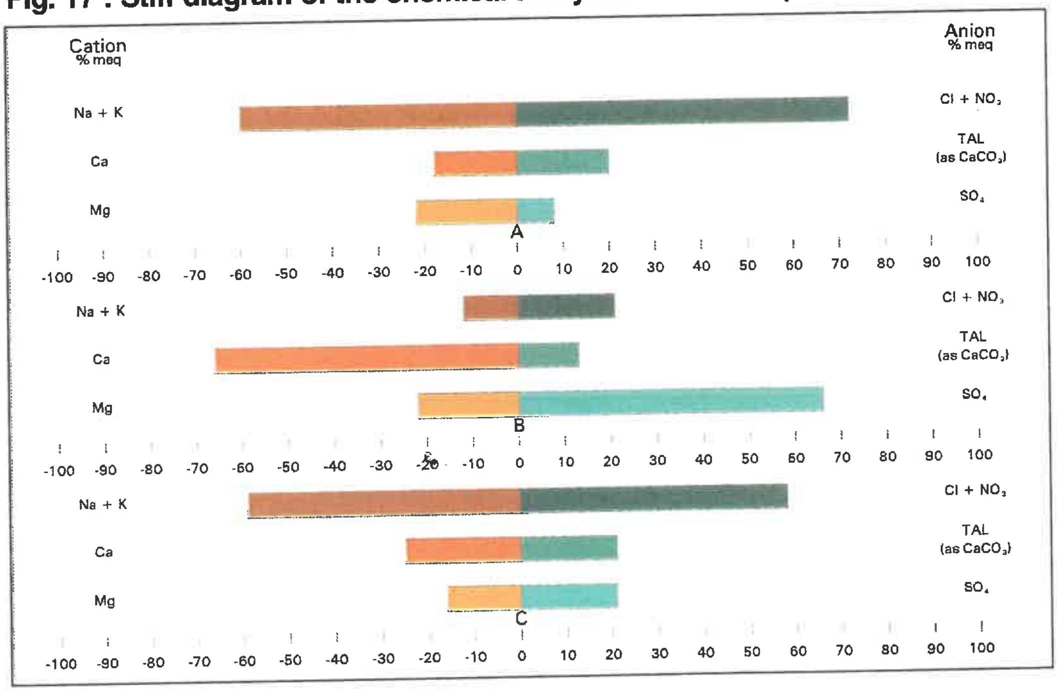


**Table 7 : Chemical analyses from different boreholes in the Witteberg Group** (Analysed by the IWQS)

| | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| EC | mS/m | 323.0 | 89.2 | 207.0 | 70.0 | 300.0 |
| TDS | mg/l | 2 049.0 | 648.0 | 1 263.0 | 1 200.0 | 2 000.0 |
| pH | | 8.3 | 7.5 | 7.8 | 6 - 9 | 5.5 - 9.5 |
| Na | mg/l | 457.0 | 27.0 | 259.7 | 100.0 | 400.0 |
| K | mg/l | 4.6 | 4.0 | 6.4 | 200.0 | 400.0 |
| Ca | mg/l | 120.0 | 129.0 | 97.4 | 150.0 | 200.0 |
| Mg | mg/l | 92.0 | 27.0 | 37.0 | 70.0 | 100.0 |
| Cl | mg/l | 796.0 | 71.0 | 375.9 | 250.0 | 600.0 |
| $SO_4$ | mg/l | 117.0 | 296.0 | 181.4 | 200.0 | 600.0 |
| TAL (as $CaCO_3$) | mg/l | 378.0 | 76.0 | 238.9 | 300.0 | 650.0 |
| F | mg/l | 0.7 | 0.3 | 1.40 | 1.0 | 1.5 |
| $NO_3 + NO_2$ (as N) | mg/l | 0.38 | 0.13 | 2.72 | 6.0 | 10.0 |
| $PO_4$ (as P) | mg/l | 0.005 | 0.018 | 0.004 | | |
| Si | mg/l | 4.8 | 9.5 | 8.01 | | |
| $NH_4$ (as N) | mg/l | 0.12 | 0.06 | 0.06 | 6.0 | 10.0 |
| Fe | mg/l | * | * | * | 0.1 | 1.0 |

* = Not determined.
A = Borehole; Kleinspreeuwfontein, south of Matjiesfontein; Lake Mentz Subgroup; yield 0.25 l/s.
B = Borehole; Wolwekloof, north of Ceres; Witpoort Formation; fracture related; yield 6.3 l/s.
C = Borehole; Elandskloof, south of Matjiesfontein; Weltevrede Subgroup; yield 2.5 l/s.
D = Drinking Water Quality Criteria: maximum recommended limit.
E = Drinking Water Quality Criteria: maximum allowable limit.

### 4.1.6 Dwyka Group

The Dwyka Group (Fig. 18), varying in thickness between 480 m and 1 000 m, consists of diamictite and occasional shale, with siltstone and sandstone lenses. Much of the material is ill-sorted, and angular fragments of varying sizes are set in a greenish-grey matrix.

The Dwyka Group rocks are generally of a massive and impervious nature, and often offer poor groundwater potential. However, due to the Group's location within the CFB, the rocks endured several deformational episodes and fracturing does occur from which strong boreholes can be developed.

A borehole yield analysis (Fig. 19) indicates that 31% of boreholes on record yield less than 0.5 l/s and 47% yield more than 2 l/s. Borehole yields exceed 2 l/s only where faults and joints occur.

Brackish groundwater, with ECs in excess of 300 mS/m can generally be expected in massive diamictite. The following determinants often exceed maximum recommended and even maximum allowable limits: sodium, calcium, magnesium and chloride (C in Table 8). Groundwater from relatively massive diamictite usually portrays a sodium-chloride character (C in Fig. 20).

ECs of groundwater from fractured and jointed Dwyka Group rocks, where significant groundwater movement and turnover takes place, range between 25 and 200 mS/m (A in Table 8). Sodium and chloride can exceed maximum recommended limits. Groundwater from fractured and jointed Dwyka Group rocks generally display a sodium-chloride nature (A in Fig. 20).

**Table 8 : Chemical analyses from different boreholes in the Dwyka Group**
(Analysed by the IWQS)

| | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| EC | mS/m | 24.8 | 138.0 | 514.0 | 70 0 | 300 0 |
| TDS | mg/l | 110.0 | 698.0 | 3 554.0 | 1 200 0 | 2 000 0 |
| pH | | 7.8 | 7.5 | 8.1 | 6 - 9 | 5 5 - 9 5 |
| Na | mg/l | 18.0 | 124.0 | 837.0 | 100.0 | 400.0 |
| K | mg/l | 1.0 | 1.0 | 10.73 | 200.0 | 400.0 |
| Ca | mg/l | 9.0 | 68.0 | 203.0 | 150 0 | 200 0 |
| Mg | mg/l | 6.0 | 36.0 | 179.0 | 70.0 | 100 0 |
| Cl | mg/l | 53.0 | 330.0 | 1 984.0 | 250.0 | 600 0 |
| $SO_4$ | mg/l | 4.0 | 12.0 | 197.0 | 200 0 | 600 0 |
| TAL (as $CaCO_3$) | mg/l | 15.0 | 104.0 | 116.2 | 300 0 | 650 0 |
| F | mg/l | 0.2 | 0.1 | 0.5 | 1.0 | 1.5 |
| $NO_3 + NO_2$ (as N) | mg/l | * | * | * | 6.0 | 10.0 |
| $PO_4$ (as P) | mg/l | 0.001 | 0.009 | 0.01 | | |
| Si | mg/l | 3.1 | 7.7 | 0.25 | | |
| $NH_4$ (as N) | mg/l | 0.05 | 0.04 | 0.09 | 6 0 | 10 0 |
| Fe | mg/l | * | * | * | 0 1 | 1 0 |

* = Not determined.
A = Borehole; Valsch Fontein north of Ceres; fault related; yield 3.8 l/s.
B = Borehole in tillite and interbedded sandstone; Odessa north of Ceres; yield 1.2 l/s.
C = Borehole in massive diamictite; Doorn Rivier south of Worcester; yield 0.8l/s.
D = Drinking Water Quality Criteria: maximum recommended limit.
E = Drinking Water Quality Criteria: maximum allowable limit.

hydrogeology of the different geological units

**Fig. 18 : Areal location of the Dwyka Group and position of sampling points for the chemical analyses shown in Table 8**

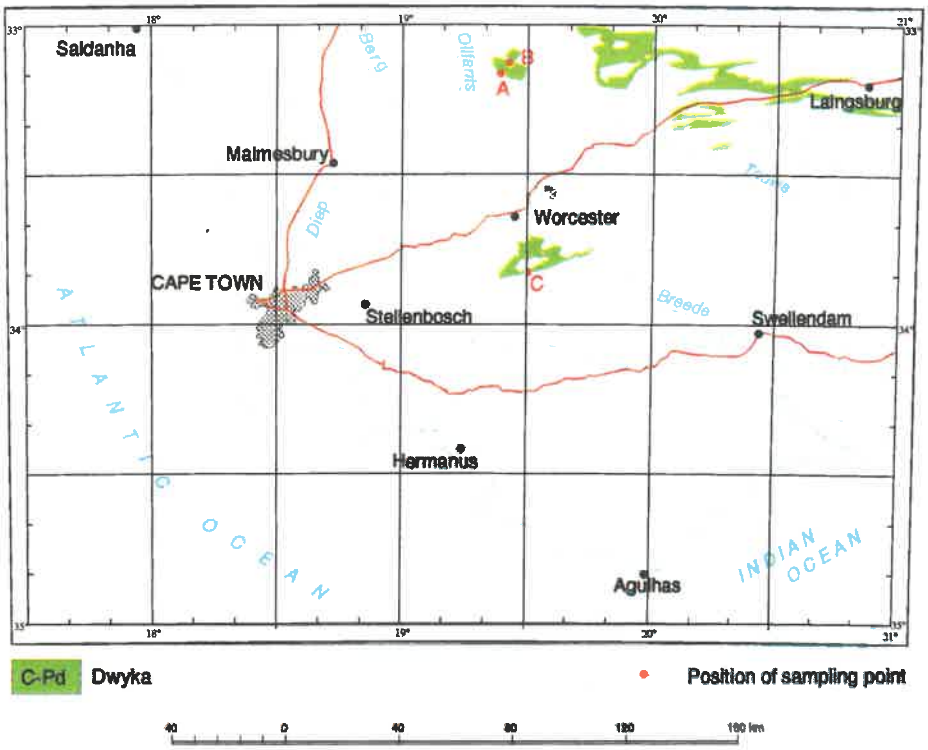



**Fig. 19 : Yield frequencies of boreholes in the Dwyka Group (80 boreholes analysed)**

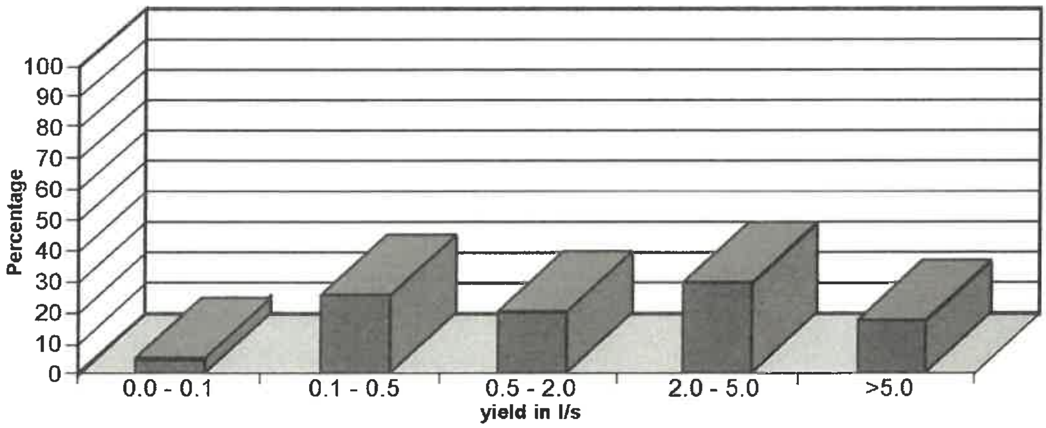
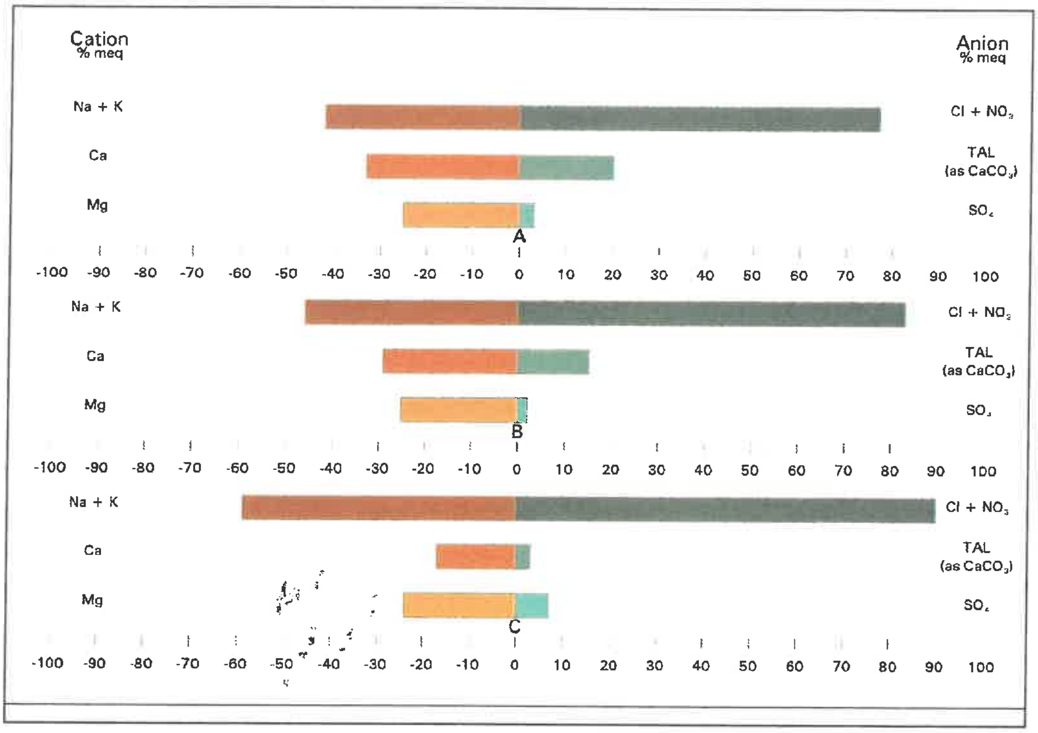


**Fig. 20 : Stiff diagrams of the chemical analyses in Table 8 (Dwyka Group)**




## 4.1.7 Ecca Group

The Ecca Group (Fig. 21) is composed of five formations in the map area, all of which are argillaceous units except the Waterford Formation. The known and inferred thickness and lithology (Gresse and Theron,1992) of individual formations is as follows:

| Formation | Thickness | Lithology |
|---|---|---|
| Prince Albert | 120m | Laminated shale with intermittent silty to cherty layers |
| Whitehill | 30m | Carbon-bearing black shale |
| Collingham | 45m | Shale, claystone, siltstone and cherty mudstone |
| Tierberg | 300m | Laminated shale, mudstone and siltstone |
| Waterford | 80m | Sandstone intercalated with pelitic units |

Due to its location within the CFB, numerous minor folds, fractures and joints can be expected in the Ecca Group beds. A borehole yield analysis (Fig. 22) shows that 44% of boreholes yield 0.5 l/s and less and 19% yield 5 l/s and more. Borehole yields of more than 3 l/s can frequently be obtained in fold, fault and joint structures where favourable recharge conditions exist (Plates 4 and 5).

Groundwater quality varies considerably with ECs ranging between 70 and 900 mS/m. About 43% of boreholes on record registered ECs of less than 200 mS/m and 6% registered values in excess of 500 mS/m. The following determinants often exceed maximum recommended limits: sodium, magnesium, chloride, sulphate and total alkalinity (B in Table 9) and may occasionally exceed maximum allowable limits. Groundwater from the Ecca Group beds generally has a sodium-chloride alkaline nature (Fig. 23).

**Fig. 21: Areal location of the Ecca Group and position of sampling points for the chemical analyses shown in Table 9**

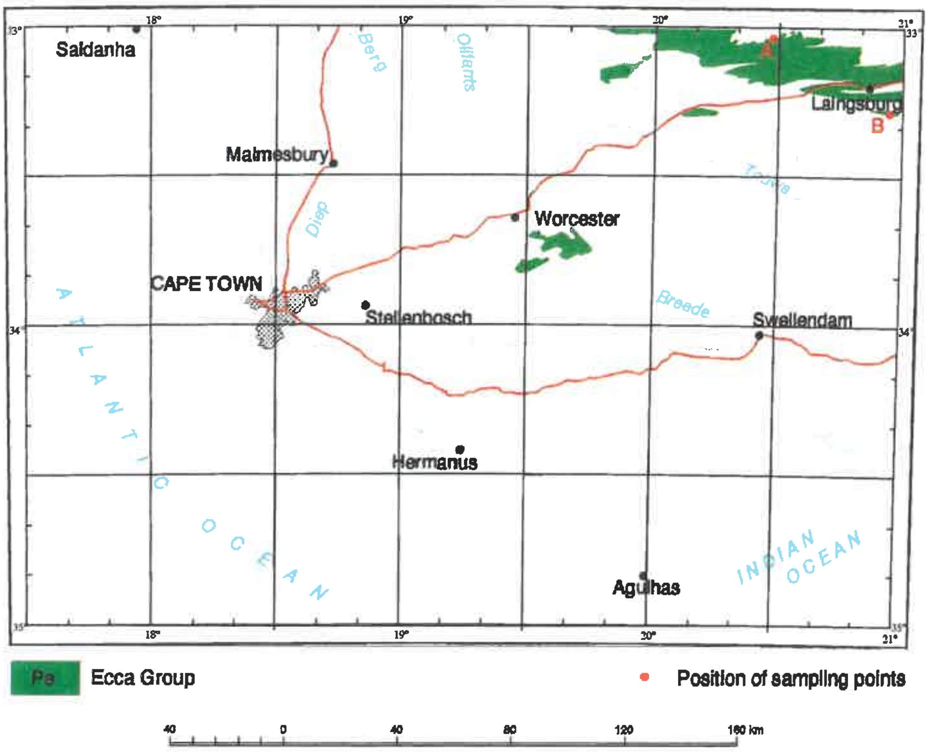



**Fig. 22 : Yield frequencies of boreholes in the Ecca Group (101 boreholes analysed)**

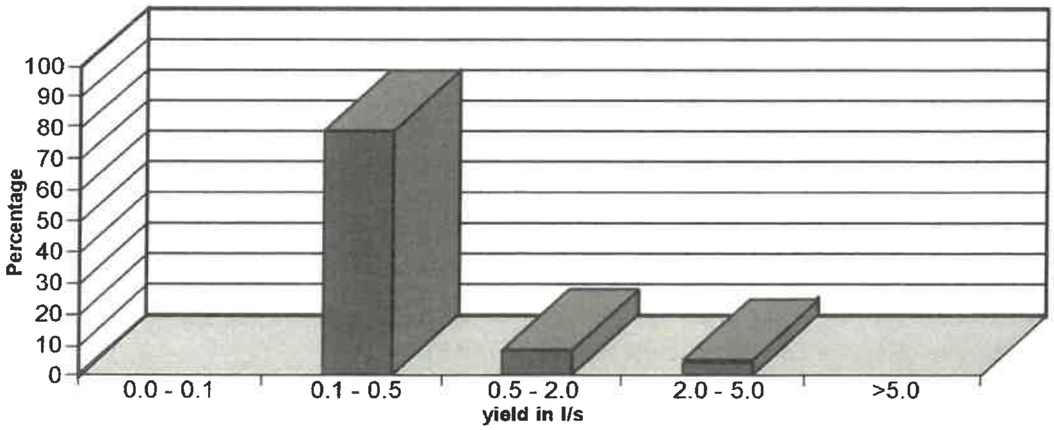
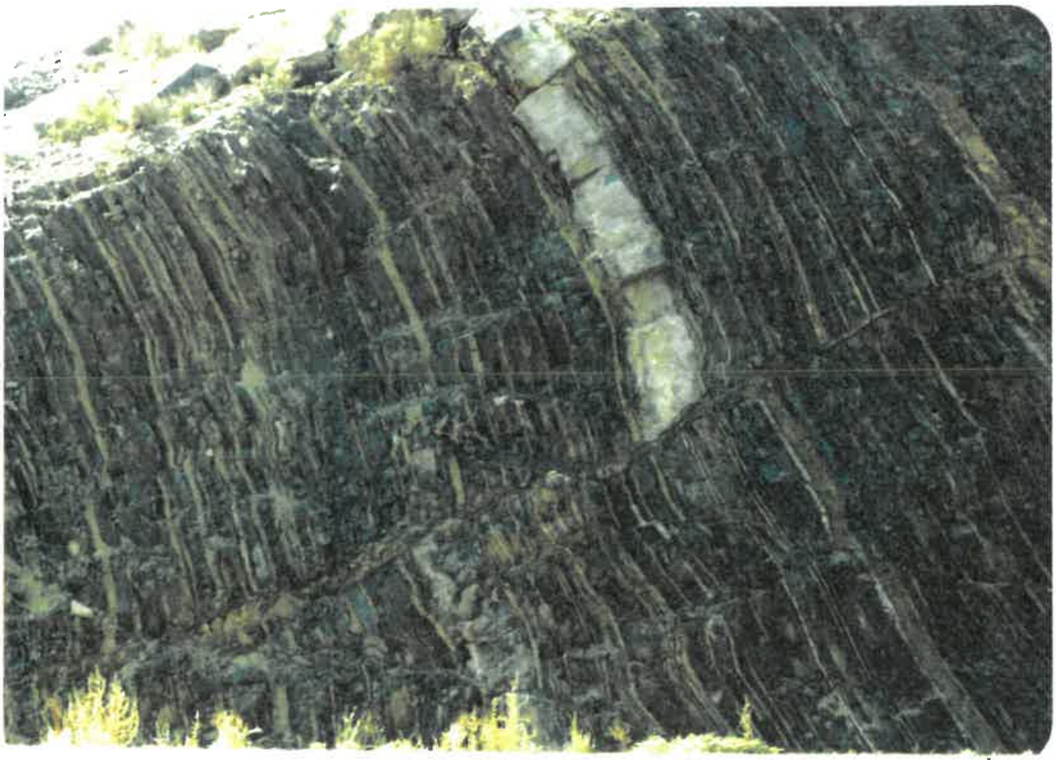
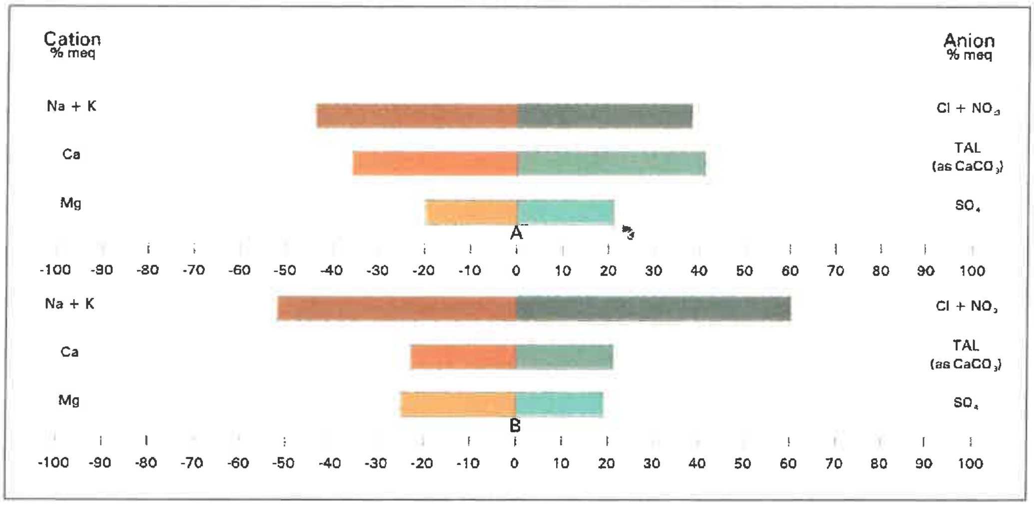


**Plate 4. Fold structures in shale of the Ecca Group west of Laingsburg.**

**Plate 5. A fault in shale of the Ecca Group west of Laingsburg. Numerous minor folds and faults occur in strata of the Dwyka, Ecca and Beaufort Groups in the map area. Yields in excess of 3 l/s can be obtained in fold structures (Plate 4) and faults, provided favourable recharge conditions exist.**



## Fig. 23 : Stiff diagrams of the chemical analyses in Table 9 (Ecca Group)




## Table 9 : Chemical analyses from different boreholes in the Ecca group
(Analysed by the IWQS)

| | | A | B | C | D |
|---|---|---|---|---|---|
| EC | mS/m | 86.9 | 286.0 | 70 0 | 300.0 |
| TDS | mg/l | 581.0 | 1835.0 | 1200 0 | 2000 0 |
| pH | | 8.3 | 8.1 | 6 - 9 | 5 5 - 9.5 |
| Na | mg/l | 84.0 | 341.4 | 100 0 | 400 0 |
| K | mg/l | 1.28 | 2.0 | 200 0 | 400 0 |
| Ca | mg/l | 60.9 | 130.1 | 150 0 | 200 0 |
| Mg | mg/l | 19.9 | 90.1 | 70 0 | 100.0 |
| Cl | mg/l | 104.0 | 592.3 | 250 0 | 600.0 |
| $SO_4$ | mg/l | 77.7 | 249.7 | 200 0 | 600.0 |
| TAL (as $CaCO_3$) | mg/l | 190.8 | 346.8 | 300 0 | 650 0 |
| F | mg/l | 0.73 | 0.64 | 1 0 | 1 5 |
| $NO_3$ + $NO_2$ (as N) | mg/l | 0.0 | 1.10 | 6 0 | 10 0 |
| $PO_4$ (as P) | mg/l | 0.0 | 0.0 | | |
| Si | mg/l | 8.59 | 7.2 | | |
| $NH_4$ (as N) | mg/l | 0.0 | 0.05 | 6.0 | 10 0 |
| Fe | mg/l | ✱ | ✱ | 0 1 | 1.0 |

✱ = Not determined.
A = Borehole drilled into a weak joint structure in sandstone and shale of the Waterford Formation; Hartjies Kraal NW of Matjiesfontein; yield 1.2 l/s.
B = Borehole drilled in massive shale of the Prince Albert Formation; Floriskraal south of Laingsburg; yield 0.25 l/s.
C = Drinking Water Quality Criteria: maximum recommended limit.
D = Drinking Water Quality Criteria: maximum allowable limit.

### 4.1.8 Beaufort Group

The Beaufort Group (Fig. 24), which is limited to the north-eastern corner of the map, is represented by the Abrahamskraal Formation in the map area. The Abrahamskraal Formation is composed of reddish mudstone, interbedded sandstone and subordinate limestone and chert.

An analysis (Fig. 25) of only sixteen boreholes on record in the map area, indicates that 81% of boreholes yield 0.5 l/s and less. Boreholes with higher yields might be obtained by targeting occasional folds, faults and joints in situations where recharge can take place.

Groundwater quality generally varies between 70 and 300 mS/m. The following determinants may exceed maximum recommended limits: sodium, chloride and sulphate (A in Table 10). Groundwater in the Beaufort Group generally displays a sodium-chloride-bicarbonate nature (Fig. 26).

**Table 10 : Chemical analyses from different boreholes in the Beaufort Group**
(Analysed by the IWQS)

| | | A | B | C | D |
|---|---|---|---|---|---|
| EC | mS/m | 194.0 | 77.3 | 70.0 | 300.0 |
| TDS | mg/l | 1 229.0 | 571.0 | 1 200 0 | 2 000.0 |
| pH | | 8.0 | 8.3 | 6 - 9 | 5 5 - 9.5 |
| Na | mg/l | 278.0 | 76.2 | 100.0 | 400.0 |
| K | mg/l | 2.0 | 1.16 | 200.0 | 400 0 |
| Ca | mg/l | 86.0 | 77.8 | 150.0 | 200.0 |
| Mg | mg/l | 29.0 | 7.3 | 70.0 | 100.0 |
| Cl | mg/l | 350.0 | 67.6 | 250.0 | 600 0 |
| $SO_4$ | mg/l | 236.0 | 72.3 | 200 0 | 600 0 |
| TAL (as $CaCO_3$) | mg/l | 203.0 | 217.4 | 300.0 | 650 0 |
| F | mg/l | 0.9 | 0.72 | 1 0 | 1.5 |
| $NO_3 + NO_2$ (as N) | mg/l | 0.08 | 0.53 | 6 0 | 10.0 |
| $PO_4$ (as P) | mg/l | | 0.005 | 0.00 | |
| Si | mg/l | 9.3 | 10.39 | | |
| $NH_4$ (as N) | mg/l | 0.09 | 0.05 | 6.0 | 10.0 |
| Fe | mg/l | ✷ | ✷ | 0 1 | 1 0 |

✷ = Not determined.
A = Borehole; Josephs Kraal NE Of Matjiesfontein;; Abrahamskraal Formation; yield 0.4 l/s.
B = Borehole; Schelm Hoek north of Laingsburg; Abrahamskraal Formation; yield 0.5 l/s.
C = Drinking Water Quality Criteria: maximum recommended limit.
D = Drinking Water Quality Criteria: maximum allowable limit.

**Fig. 24: Areal location of the Beaufort Group and position of sampling points for the chemical analyses shown in Table 10**

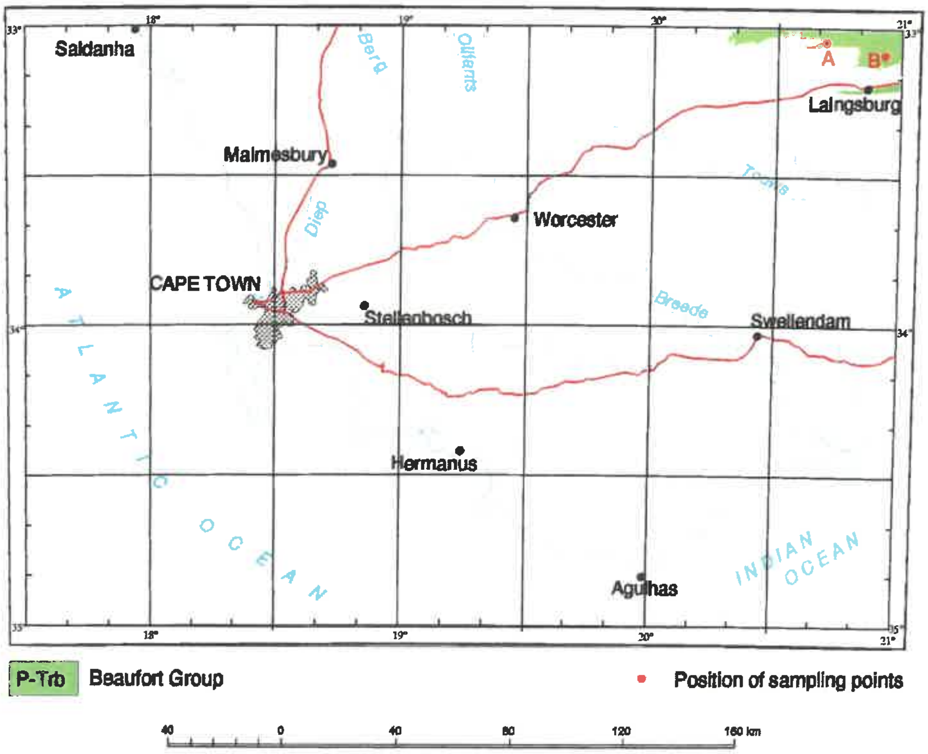


**Fig. 25 : Yield frequencies of boreholes in the Beaufort Group (16 boreholes analysed)**

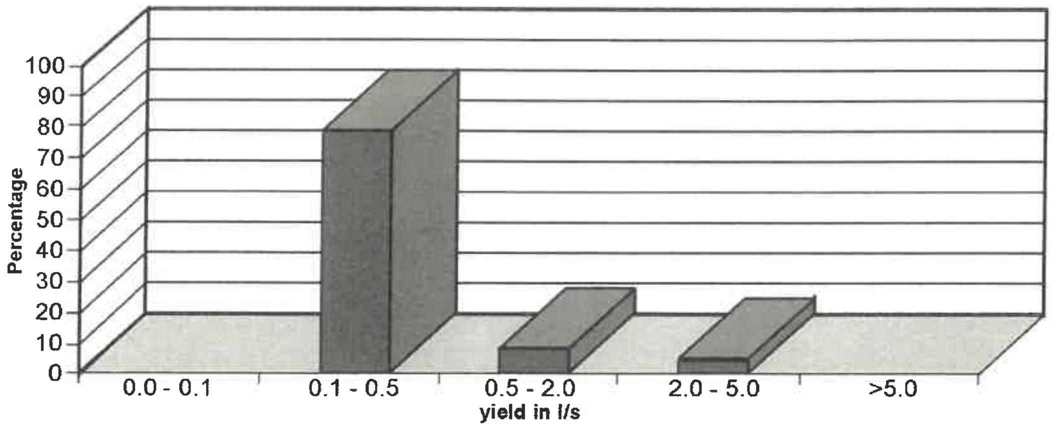
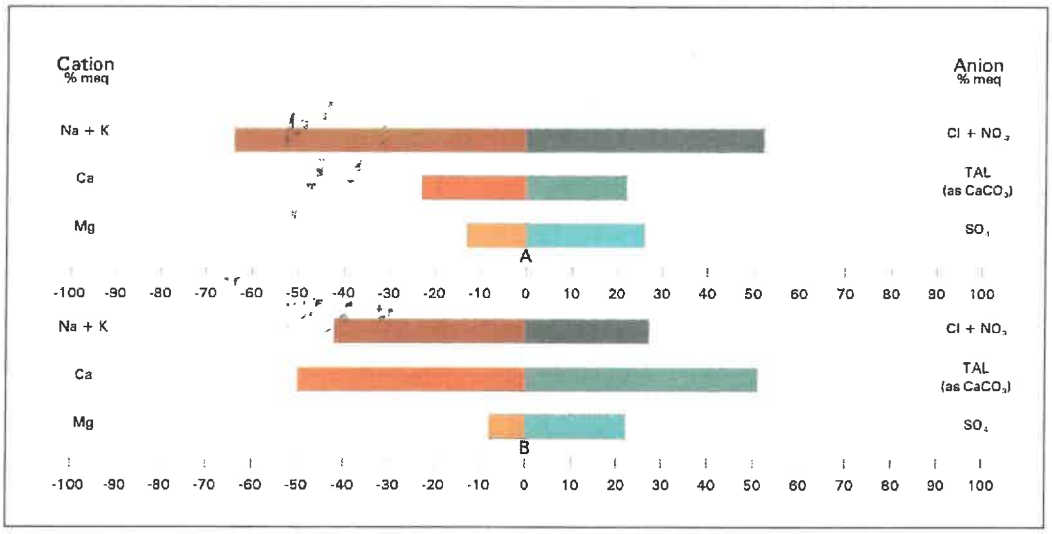



**Fig. 26 : Stiff diagrams of the chemical analyses in Table10 (Beaufort Group)**




## 4.1.9 Uitenhage Group

The Uitenhage Group (Fig. 27) is represented mainly by the Enon Conglomerate Formation, and to a lesser extent by the Kirkwood Formation. The Uitenhage Group is confined to a few scattered occurrences south of the Worcester fault at Heidelberg (where some mudstone and sandstone of the Kirkwood Formation overlies the Enon conglomerate), Swellendam, Robertson and Worcester.

The Uitenhage Group rocks are bonded into a dense impervious mass with insignificant permeability properties, and its groundwater potential is thus limited. The scantiness of boreholes is probably indicative of its lack of groundwater potential. Incomplete records of only nine boreholes are on record and 44% (4 boreholes) yield less than 0.5 l/s (Fig. 28). The accuracy of the yield data of the remaining five boreholes is questionable.

Groundwater in the Uitenhage Group beds is almost invariably of poor quality and ECs in excess of 300 mS/m are common. The following determinants are likely to exceed maximum and allowable limits: sodium, magnesium, chloride, sulphate and fluorite (Table 11). Groundwater in the Uitenhage Group is usually of a sodium-chloride nature (Fig. 29).

**Table 11 : Chemical analyses from a borehole in the Uitenhage Group**
(Analysed by the IWQS)

| | | A | B | C |
|---|---|---|---|---|
| EC | mS/m | 809.0 | 70.0 | 300.0 |
| TDS | mg/l | 4 759.0 | 1 200.0 | 2 000.0 |
| pH | | 8.3 | 6 - 9 | 5.5 - 9.5 |
| Na | mg/l | 1 281.0 | 100.0 | 400.0 |
| K | mg/l | 4.3 | 200.0 | 400.0 |
| Ca | mg/l | 104.0 | 150.0 | 200.0 |
| Mg | mg/l | 268.0 | 70.0 | 100.0 |
| Cl | mg/l | 2 537.0 | 250.0 | 600.0 |
| $SO_4$ | mg/l | 297.0 | 200.0 | 600.0 |
| TAL (as $CaCO_3$) | mg/l | 218.0 | 300.0 | 650.0 |
| F | mg/l | 1.1 | 1.0 | 1.5 |
| $NO_3 + NO_2$ (as N) | mg/l | 0.04 | 6.0 | 10.0 |
| $PO_4$ (as P) | mg/l | 0.005 | | |
| Si | mg/l | 7.4 | | |
| $NH_4$ (as N) | mg/l | 0.07 | 6.0 | 10.0 |
| Fe | mg/l | ✱ | 0.1 | 1.0 |

✱ = Not determined.
A = Borehole; De Doorn River NW of Heidelberg; Kirkwood Formation; yield 1.2 l/s.
B = Drinking Water Quality Criteria: maximum recommended limit.
C = Drinking Water Quality Criteria: maximum allowable limit.

**Fig. 27 : Areal location of the Uitenhage Group and position of sampling point for the chemical analyses shown in Table 11**

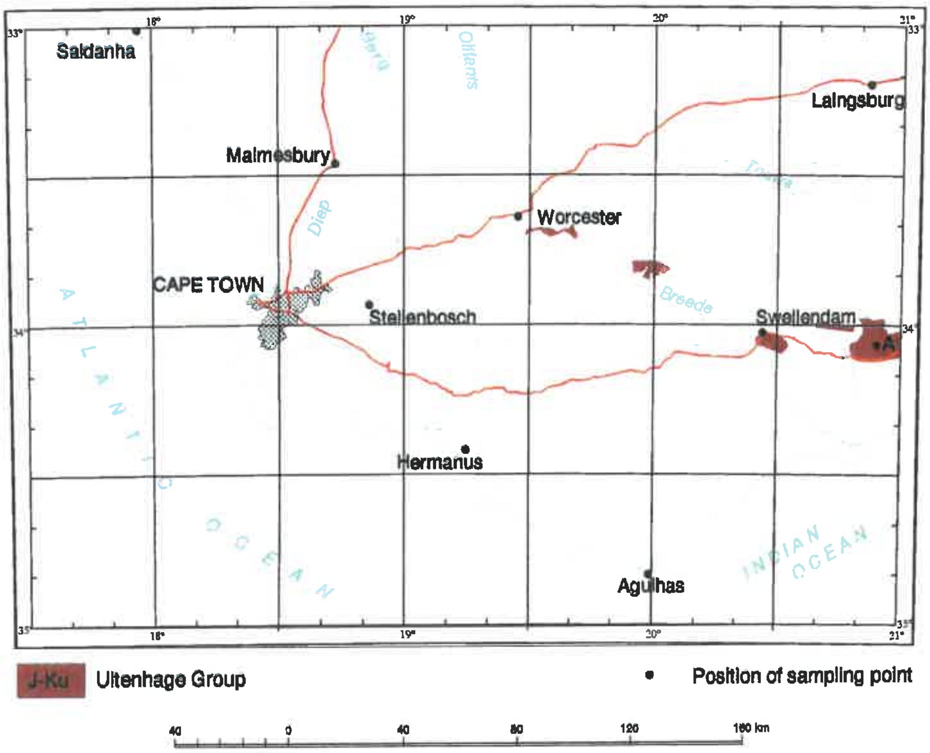


**Fig. 28 : Yield frequencies of boreholes in the Uitenhage Group (9 boreholes analysed)**

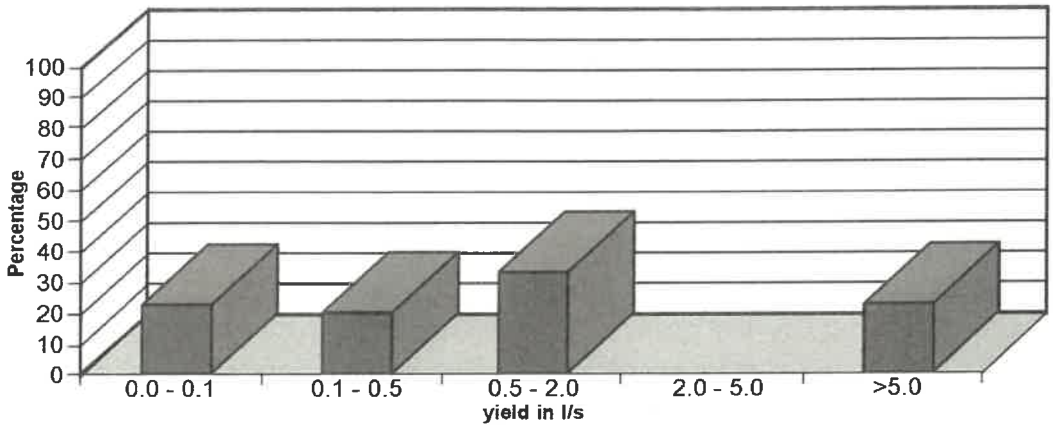
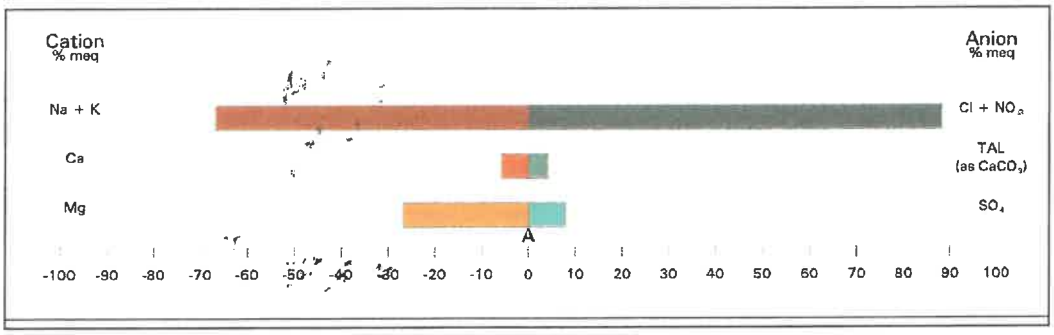



**Fig. 29 : Stiff diagram of the chemical analyses in Table 11 (Uitenhage Group)**




## 4.2 Fractured and Intergranular Aquifers

The only rocks in the map area in which groundwater occurs in both weathered rock and in jointed bedrock, and which can thus be termed fractured and intergranular, are the various granites. The granites, collectively known as the Cape Granite Suite, cover an area of 3,7% of the map area (Table 2).

### 4.2.1 Cape Granite Suite

Thirteen granite bodies (Fig. 30) are dispersed over mainly the western half of the map area, namely the Cape Peninsula, Kuils River/Helderberg, Stellenbosch, Paarl, Paardeberg, Darling, Langebaan, Wellington, Hermanus, Robertson, Greyton Plutons, the Swellendam Subsuite, and the Worcester Granite Fragment.

A distinct characteristic of almost all these granite bodies, with the exception of the Worcester Granite Fragment, is that they are composed of coarse-grained porphyritic granite, interspered with fine- to medium-grained biotite granite. Phenocrysts of feldspar, often occurring in clusters, and with individual feldspar phenocrysts up to 60 x 30 mm big (Hermanus Pluton, Gresse and Theron, 1992), are scattered in most of the plutons. Aplogranite dykes, generally less than 25 cm wide, penetrated some of the plutons. The Worcester Granite Fragment is atypical of the Cape Granite in that it is an intensely tectonised, gneissic rock which exhibits all gradations from crushed granite to mylonite (Gresse and Theron,1992).

Since fine-, medium- and coarse-grained granite with varied compositions occur, diverse weathering forms can be expected, with diverse groundwater implications. Porphyritic granite, containing abundant phenocrysts of feldspar is likely to weather to a largely clayey substance, which often impedes permeability. Weathered medium-grained granite with a more balanced composition is likely to be a better aquifer.

Features in granite that can be utilized for groundwater development are:

- zones of weathering;
- contact zones between granites and Malmesbury Group rocks;
- dyke contacts, and;
- occasional fracturing.

It is often difficult to develop boreholes with strong yields in the Cape Granite Suite, due to:

- lack of weathering;
- permeability inhibiting substances produced by weathering (Plate 6) and;
- lack of joints and fractures.

A borehole yield analysis (Fig. 31) indicates that 42% of boreholes yield 0.5 l/s and less, while 5% of boreholes yield 5 l/s and more.

Due to varied rock compositions, diverse groundwater qualities can be expected. ECs generally vary between 30 and 350 mS/m. The following determinants often exceed maximum recommended limits (B and C in Table 12) and may occasionally even exceed maximum allowable limits: sodium, chloride, sulphate and fluoride. Groundwater in the granites generally displays a sodium-chloride sulphate nature (Fig. 32).

**Table 12 : Chemical analyses from different boreholes in the Cape Granite Suite**

(A was analysed by the CSIR, B by the Dept. of Public Works and C by the IWQS)

| | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| EC | mS/m | 38.0 | 124.0 | 116.6 | 70.0 | 300.0 |
| TDS | mg/l | 243.0 | 780.0 | 760.0 | 1 200.0 | 2 000.0 |
| pH | | 6.4 | 7.3 | 7.3 | 6 - 9 | 5.5 - 9.5 |
| Na | mg/l | 55.0 | 131.0 | 187.2 | 100.0 | 400.0 |
| K | mg/l | 3.0 | 3.9 | 4.0 | 200.0 | 400.0 |
| Ca | mg/l | 2.4 | 123.0 | 26.0 | 150.0 | 200.0 |
| Mg | mg/l | 4.6 | 15.0 | 35.6 | 70.0 | 100.0 |
| Cl | mg/l | 86.0 | 214.0 | 369.2 | 250.0 | 600.0 |
| $SO_4$ | mg/l | 16.0 | 274.0 | 50.6 | 200.0 | 600.0 |
| TAL (as $CaCO_3$) | mg/l | 11.0 | 90.0 | 35.8 | 300.0 | 650.0 |
| F | mg/l | * | 1.5 | 0.57 | 1.0 | 1.5 |
| $NO_3 + NO_2$ (as N) | mg/l | 0.05 | 0.0 | 9.8 | 6.0 | 10.0 |
| $PO_4$ (as P) | mg/l | * | * | 0.22 | | |
| Si | mg/l | * | * | 28.5 | | |
| $NH_4$ (as N) | mg/l | * | * | 0.5 | 6.0 | 10.0 |
| Fe | mg/l | * | 0.9 | * | 0.1 | 1.0 |

* = Not determined.

A = Borehole; Hemel en Aarde; Hermanus Pluton; weathered granite; yield 2.7 l/s.

B = Borehole; Sir Lowrys Pass; Stellenbosch Pluton; fracture related; yield 2.3 l/s.

C = Borehole; Klipfontein north of Malmesbury; Paardeberg Pluton; largely solid granite; yield 0.08 l/s.

D = Drinking Water Quality Criteria: maximum recommended limit.

E = Drinking Water Quality Criteria: maximum allowable limit.

**Plate 6. Weathered to partially weathered porphyritic granite near Chapmans Peak, Cape Peninsula. The phenocrysts of feldspar are likely to weather to a clayey substance, which could impede permeability.**

Fig. 30 : Areal location of the Cape Granite Suite and position of sampling points for the chemical analyses shown in Table 12

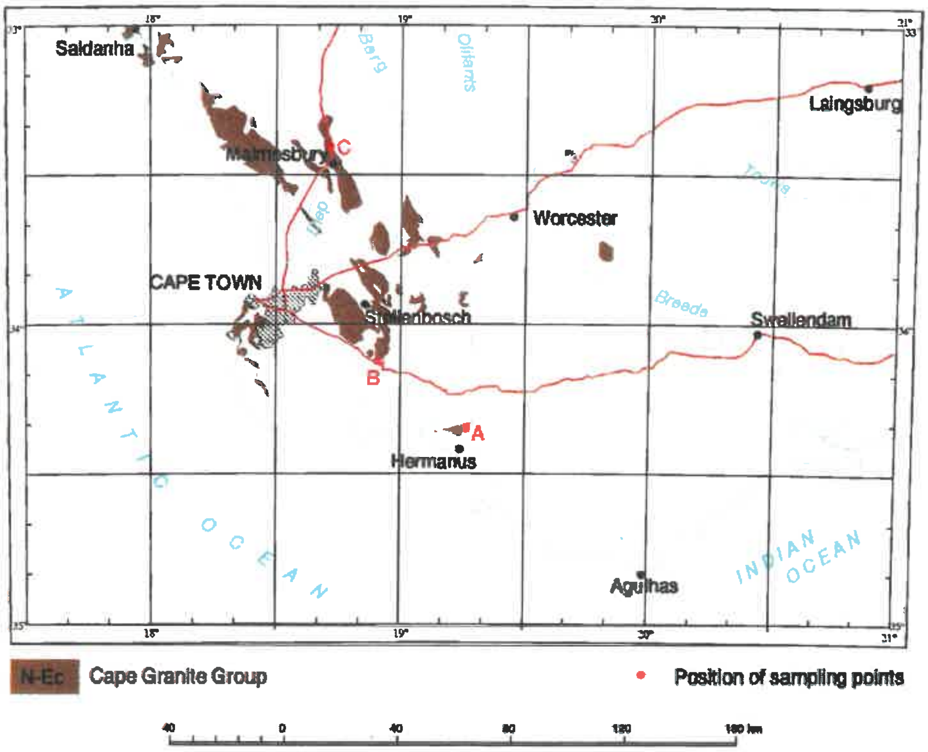



Fig. 31 : Yield frequencies of boreholes in the Cape Granite Suite (449 boreholes analysed)

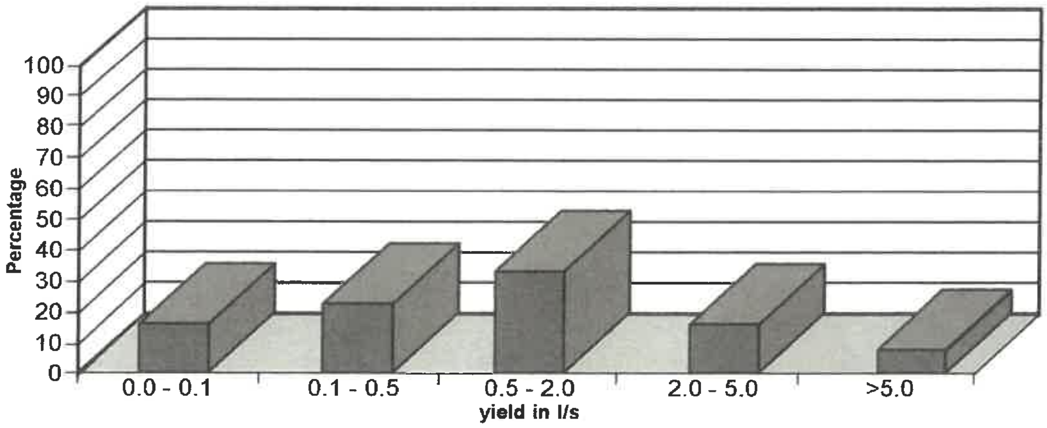
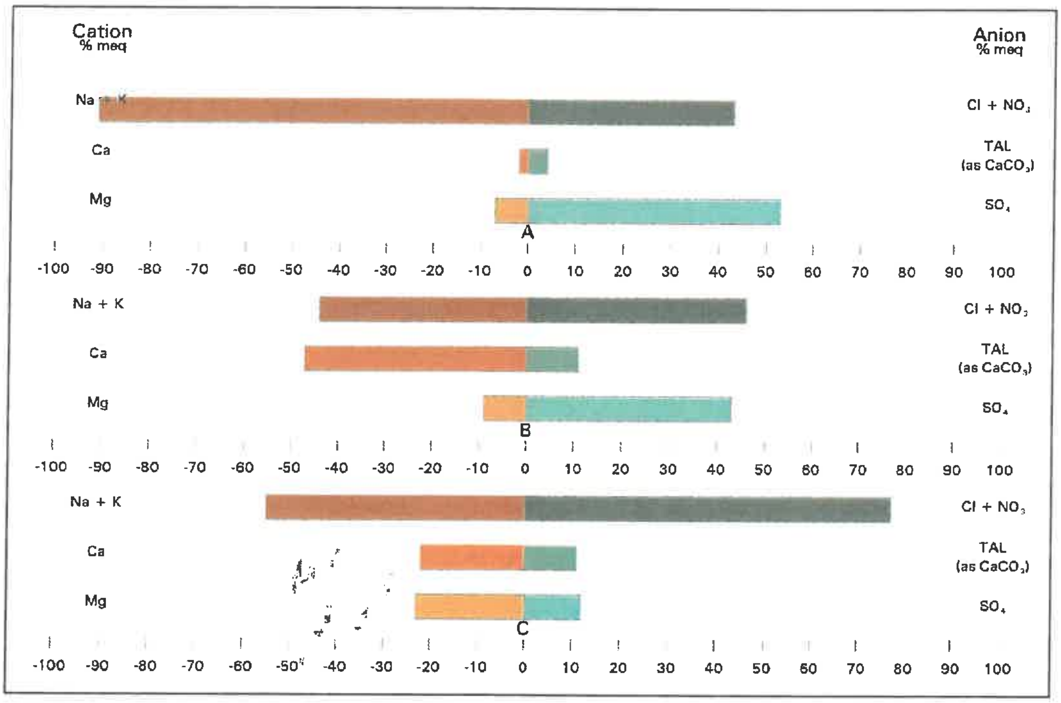


**Fig. 32 : Stiff diagrams of the chemical analyses in Table 12 (Cape Granite Suite)**




## 4.3 Intergranular Aquifers

Intergranular aquifers cover about 14% of the map area. Three intergranular aquifer types can be distinguished of which the Sandveld and Bredasdorp Groups aquifers are essentially coastal aquifers. The third comprises the Alluvial Deposits, which occur primarily along the Breede River between Wolseley and Worcester. The unnamed sands along the coast between Struisbaai and Witsand contain hardly any groundwater worth mentioning.

### 4.3.1 The Sandveld Group

The Sandveld Group (Fig. 33) consists of four formations, namely (lithology in brackets) the basal Springfontein Formation (well sorted, fine- to medium -grained quartz sand, virtually free of mud), Velddrif Formation (partially consolidated lime rich shell beds, shellcoquina to clay and sand with shell layers), Langebaan Formation (calcarenites) and the Witzand Formation (fine-to coarse-grained calcareous coastal dune sand).

The Sandveld Group, which extends along the west coast from False Bay to Saldanha is hydrogeologically divided into mainly four units, viz the Cape Flats unit, extending from False Bay to Melkbosstrand, the Silwerstroom-Witzand unit in the Atlantis area, the Grootwater unit in the Yzerfontein region and finally the Berg River unit in the Saldanha area.

A borehole yield analysis indicates that 41% of boreholes yield 0.5 l/s and less and 30% of boreholes yield 2 l/s and more (Fig. 34).

*In 1995 fossil human footprints were discovered by Dr Dave Roberts of the Geological Survey at Langebaan. The footprints were made by a human some 117000 years ago, who was descending diagonally down the face of a sand dune. The stride length of 0.51 m and the length of the feet suggest that the dunewalker was a smallish female, about 1.6 m tall. The feet had well-developed arches, and the big toe was the longest of the toes-all features of modem humans. The age relates to the critical period in human evolution when anatomically modern man had recently emerged from archaic types (Roberts D.L. and Berger L.,1997).*

**Table 13 : Hydrogeological properties of the Sandveld group aquifer**

| Aquifer Unit | EC (mS/m) | Potential ground-water yield ($10^6 m^3/a$) | Trans-missivity ($m^2/day$) | Recharge (%)* | Storage ($10^6 m^3$) | Mean annual precipita-tion (mm) |
|---|---|---|---|---|---|---|
| Cape Flats | 60 - 135 | 15 | 250 - 600 | 15 - 35 | 1500 | 91 |
| Silwerstroom Witzand | 80 - 110 | 6 | 50 - 1300 | 15 - 35 | 400 | 360 |
| Grootwater | 30 - 250 | 3.5 | 100 - 1000 | 10 | 250 | 263 |
| Berg River | < 100 | 36 | 200 - 1000 | 15 | 6000 | 294 |

✱-% of the mean annual precipitation.

ECs of groundwater vary between 30 and 250 mS/m (Table 13). Determinants seldom exceed maximum recommended limits and groundwater generally displays a sodium-chloride-calcium-alkaline nature (Fig. 35). There is concern, especially in densely populated areas, regarding the vulnerability of these aquifers to pollution (B in Table 14 where nitrate levels substantially exceed maximum allowable limits). An inherent contamination problem in coastal aquifers is a function of the porous nature of the aquifers and their proximity to the sea. The aquifer often extends below sea level, thus over-abstraction and mismanagement of the groundwater can result in saline water intrusion into the fresh water zone of the aquifer. Careful control of abstraction rates is thus essential in such circumstances to preserve the potability of

*The greater Cape Town Metropolitan Area lies on one of the most extensive sand aquifers in South Africa, and the supply potential of groundwater from this aquifer is highly significant. In line with the recently initiated National Water Conservation Campaign, aimed at reducing water usage and demand by all sectors, the exploitation of this aquifer is strongly encouraged. Groundwater can be abstracted very cheaply by means of well-points and utilised e.g. for garden irrigation, thereby reducing the huge volumes of purified fresh water resources being wasted annually for these purposes (Maclear L.G.A.,1995).*

circumstances to preserve the potability of the groundwater. In the case of the Grootwater aquifer near Yzerfontein, a 2.5 km "buffer zone" was declared along the coastline where no abstraction of groundwater is permitted, in order to protect the groundwater quality of the aquifer further inland. This aquifer was declared a Subterranean Government Water Control Area (SGWCA) in 1992 to protect the resource. Another SGWCA in the Saldanha area was declared in 1976 and is part of the Berg River aquifer unit.

**Fig. 33 : Areal location of the Sandveld Group and position of sampling points for the chemical analyses shown in Table 14**

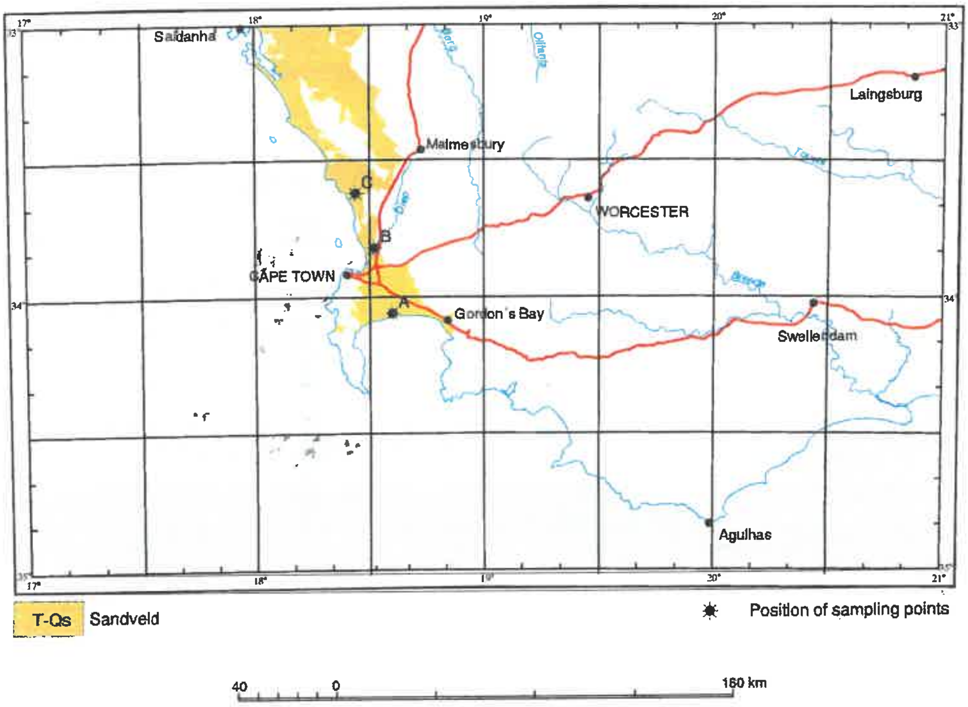



**Fig. 34 : Yield frequencies of boreholes in the Sandveld Group (497 boreholes analysed)**

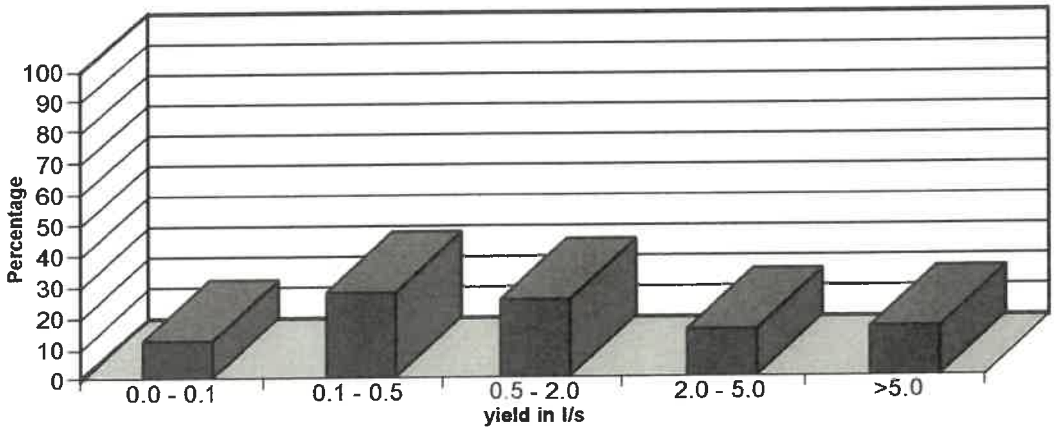


**Fig. 35 : Stiff diagrams of the chemical analyses in Table 14 (Sandveld Group)**

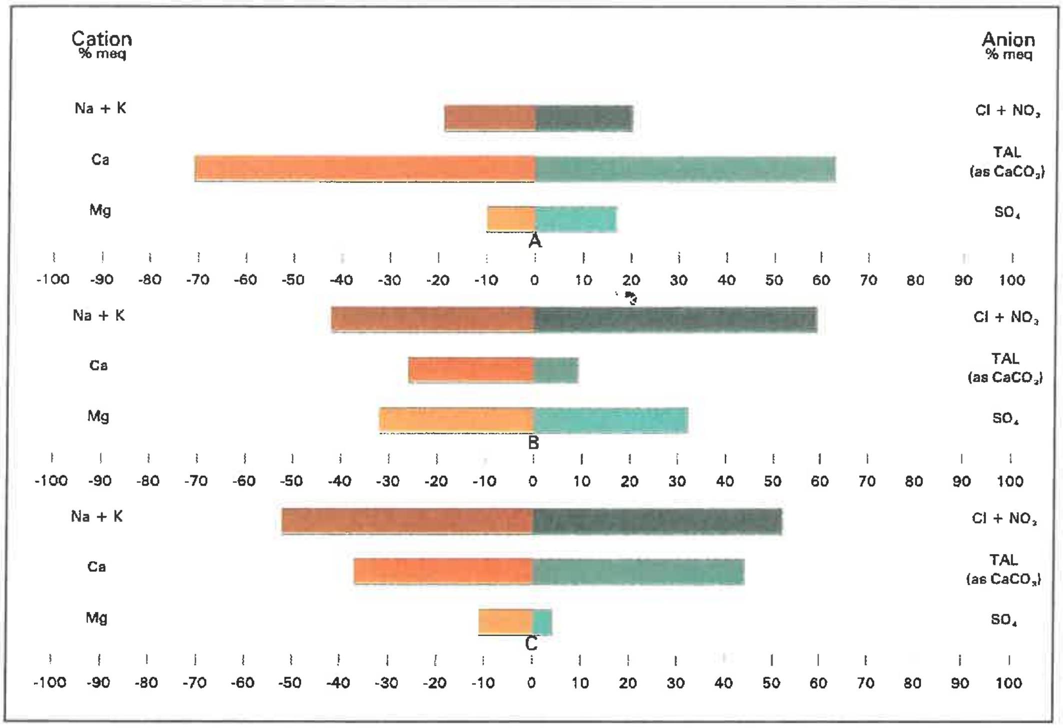



**Table 14 : Chemical analyses from different boreholes in the Sandveld Group**
(Analysed by the IWQS)

| | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| EC | mS/m | 53.5 | 82.8 | 85.4 | 70 0 | 300 0 |
| TDS | mg/l | 365.0 | 472.0 | 516.0 | 1 200 0 | 2 000 0 |
| pH | | 8.0 | 6.2 | 7.6 | 6 - 9 | 5.5 - 9.5 |
| Na | mg/l | 21.0 | 61.0 | 85.0 | 100 0 | 400 0 |
| K | mg/l | 1.5 | 8.3 | 6.9 | 200 0 | 400 0 |
| Ca | mg/l | 70.0 | 36.0 | 56.0 | 150 0 | 200.0 |
| Mg | mg/l | 6.0 | 26.0 | 10.0 | 70 0 | 100 0 |
| Cl | mg/l | 29.0 | 101.0 | 126.0 | 250 0 | 600 0 |
| $SO_4$ | mg/l | 33.0 | 75.0 | 13.0 | 200.0 | 600 0 |
| TAL (as $CaCO_3$) | mg/l | 157.0 | 26.0 | 180.0 | 300.0 | 650 0 |
| F | mg/l | 0.19 | <0.10 | 0.22 | 1 0 | 1 5 |
| $NO_3$ + $NO_2$ (as N) | mg/l | 2.86 | 30.06 | 0.04 | 6.0 | 10 0 |
| $PO_4$ (as P) | mg/l | 0.014 | 0.007 | 0.007 | | |
| Si | mg/l | 2.9 | 2.6 | 8.9 | | |
| $NH_4$ (as N) | mg/l | 0.05 | 0.04 | 0.05 | 6.0 | 10 0 |
| Fe | mg/l | ✱ | ✱ | ✱ | 0 1 | 1 0 |

✱ = Not determined.
A = Borehole; Mitchell's' Plain.
B = Borehole; Table View.
C = Borehole; Atlantis area.
D = Drinking Water Quality Criteria: maximum recommended limit.
E = Drinking Water Quality Criteria: maximum allowable limit.

### 4.3.2 Bredasdorp Group

The Bredasdorp Group (Fig. 36) consists of the following five formations in the map area (lithology in brackets): the basal De Hoopvlei Formation (calcarenite with shells and conglomerate lenses), Wankoe Formation (calcarenite with aeolian crossbedding and calcrete lenses), Klein Brak Formation (shelly sand with pebbles), Waenhuiskrans Formation (partly calcified dune sand with calcrete lenses), and the Strandveld Formation (white dune sand with finely comminuted shell material).

The Bredasdorp Group rocks occur along the south coast from Stanford to east of Witsand and overlie Bokkeveld Group and Table Mountain Group rocks.

The basal De Hoopvlei Conglomerate Formation, which is generally a discontinuous layer, is the most important formation, as groundwater can, as a rule, be found in the conglomerate only.

The Bredasdorp Group aquifer is a unique intergranular aquifer: water seeps relatively rapidly through the generally porous material to the underlying, mostly impervious pre-Bredasdorp beds. It moves in the conglomerate to lower lying outlet points, where it frequently emerges as springs. A number of such springs, issuing from the De Hoopvlei conglomerate, occur between Stanford and Gansbaai and are used by local authorities as sources of water supply to communities in that area. Unlike conventional intergranular aquifers, hardly any buildup of groundwater levels takes place, and a water interception in the conglomerate is likely to be the true piezometric level.

A borehole yield analysis shows that 34% of boreholes yield 0.5 l/s or less and 30% of boreholes yield 2 l/s and more (Fig. 37).

ECs of groundwater are generally less than 150 mS/m, provided drilling does not extend into underlying formations where poor quality groundwater can be intercepted. Sodium and chloride might occasionally exceed maximum recommended limits (Table 15). Groundwater in the Bredasdorp Group rocks often displays a sodium-chloride-alkaline-calcium nature (Fig. 38).

**Table 15 : Chemical analyses from groundwater sources in the Bredasdorp Group** (A was analysed by the IWQS, B and C by the CSIR)

| | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| EC | mS/m | 141.0 | 105.0 | 74.0 | 70.0 | 300.0 |
| TDS | mg/l | 932.0 | 682.0 | 474.0 | 1 200.0 | 2 000.0 |
| pH | | 7.8 | ✷ | 7.3 | 6 - 9 | 5.5 - 9.5 |
| Na | mg/l | 182.0 | 109.0 | 61.0 | 100.0 | 400.0 |
| K | mg/l | 4.9 | 3.2 | 1.2 | 200.0 | 400.0 |
| Ca | mg/l | 92.0 | 87.6 | 92.0 | 150.0 | 200.0 |
| Mg | mg/l | 23.0 | 12.8 | 7.2 | 70.0 | 100.0 |
| Cl | mg/l | 327.0 | 196.0 | 113.0 | 250.0 | 600.0 |
| $SO_4$ | mg/l | 34.0 | 31.0 | 10.0 | 200.0 | 600.0 |
| TAL (as $CaCO_3$) | mg/l | 212.0 | 204.0 | 208.0 | 300.0 | 650.0 |
| F | mg/l | 0.2 | ✷ | ✷ | 1.0 | 1.5 |
| $NO_3 + NO_2$ (as N) | mg/l | 2.32 | 1.54 | 2.18 | 6.0 | 10.0 |
| $PO_4$ (as P) | mg/l | 0.01 | ✷ | ✷ | | |
| Si | mg/l | 4.0 | ✷ | ✷ | | |
| $NH_4$ (as N) | mg/l | 0.04 | ✷ | ✷ | 6.0 | 10.0 |
| Fe | mg/l | ✷ | ✷ | ✷ | 0.1 | 1.0 |

✷ = Not determined.
A = Borehole; De Hoop Nature Reserve; De Hoopvlei conglomerate; yield 0.2 l/s.
B = Spring; De Kelders north of Gansbaai; De Hoopvlei conglomerate; yield > 5 l/s.
C = Spring near Stanford; De Hoopvlei conglomerate; yield > 5 l/s.
D = Drinking Water Quality Criteria: maximum recommended limit.
E = Drinking Water Quality Criteria: maximum allowable limit.

**Fig. 36 : Areal location of the Bredasdorp Group and position of sampling points for the chemical analyses shown in Table 15**

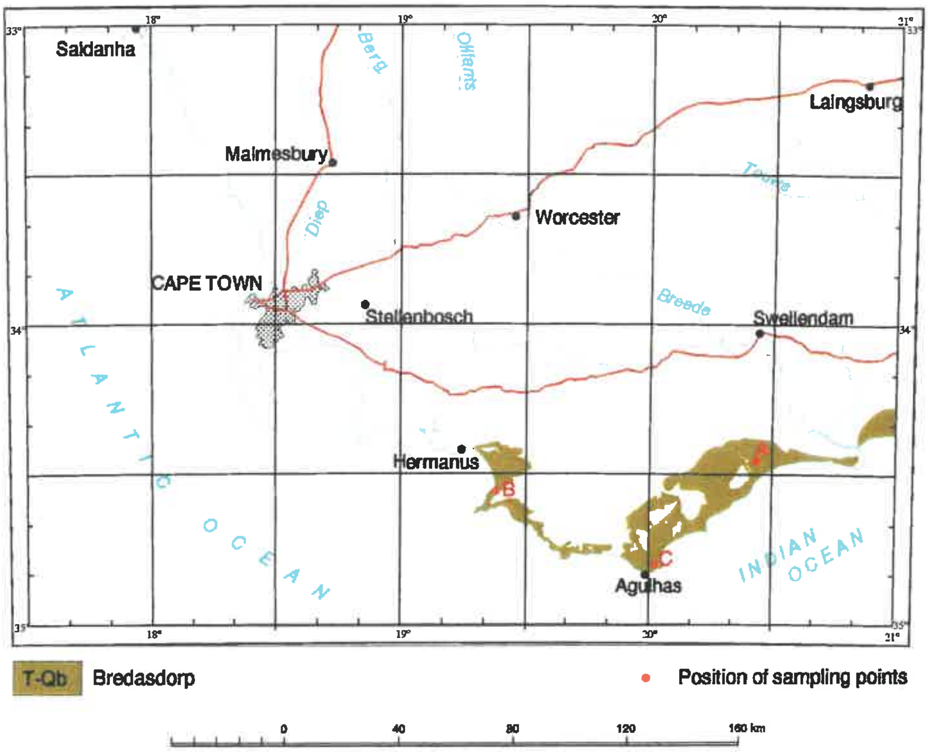


**Fig. 37 : Yield frequencies of boreholes in the Bredasdorp Group (56 boreholes analysed)**

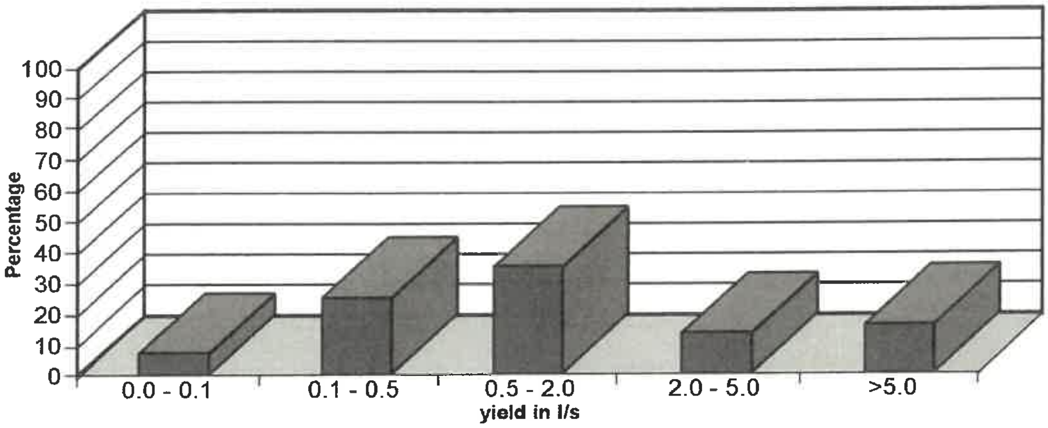
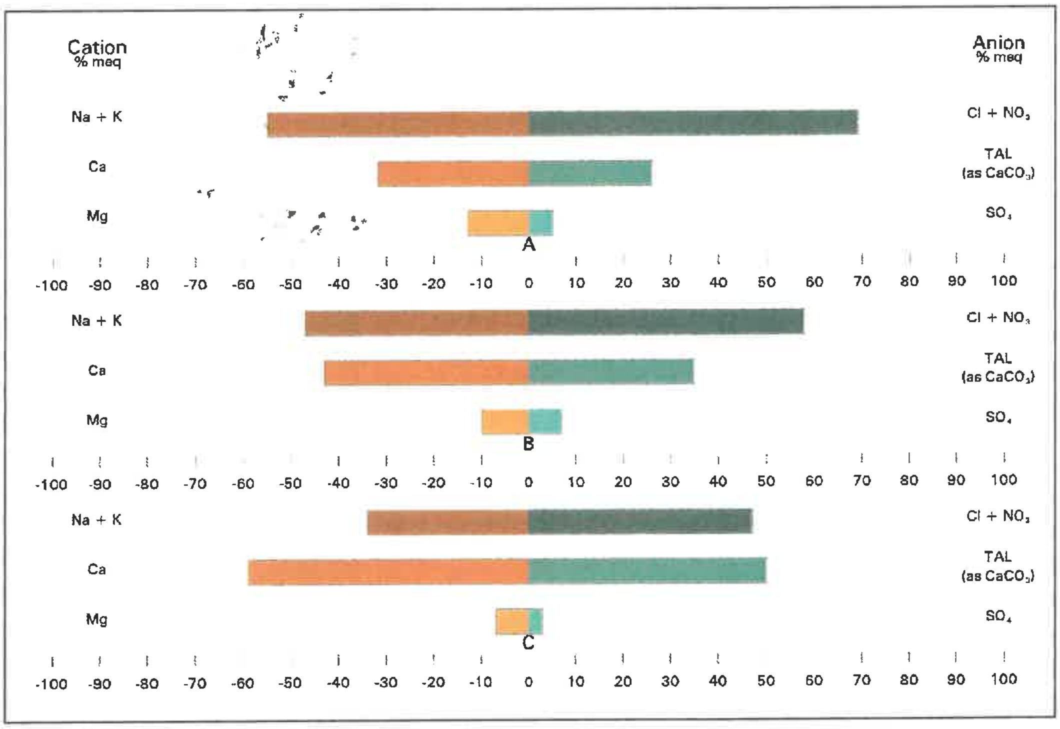



**Fig. 38 : Stiff diagrams of the chemical analyses in Table 15 (Bredasdorp Group)**




### 4.3.3 Alluvial Deposits

By far the most important, if not the only noteworthy Alluvial Deposits (Fig. 39) aquifer is the Breede River alluvial aquifer (Plate 2). The most extensively utilised portion of this aquifer is situated in the Rawsonville-Goudini region and covers an area of approximately 100 km².

The alluvium, consisting generally of an upper boulder bed overlying sand and gravel layers, attains thicknesses of 10 to 30 m in the valley floor and up to 50 m where tributaries enter the valley.

Groundwater level fluctuations are relatively limited, seldom exceeding 8 m. Groundwater levels generally vary between 0.5 and 4.5 m below surface in the winter, and between 1.5 and 8 m in the summer.

Yields vary between 0.1 and 20 l/s. A yield analysis indicates that 10% of boreholes yield less than 0.5 l/s and 17% yield 5 l/s and more (Fig. 40). Groundwater abstraction amounts to 20 x 10 $m^3$/a and is mainly utilised for irrigation.

EC values seldom exceeds 100 mS/m and generally ranges between 10 and 50 mS/m (Table 16). Individual determinants seldom exceed maximum recommended limits. Groundwater is usually of a sodium-chloride-alkaline-calcium nature (Fig. 41).

**Table 16 : Chemical analyses from different borholes in the Alluvial Deposits** (Analysed by the CSIR)

| | | A | B | C | D |
|---|---|---|---|---|---|
| EC | mS/m | 20.5 | 15.5 | 70.0 | 300.0 |
| TDS | mg/l | 131.0 | 99.0 | 1 200.0 | 2 000.0 |
| pH | | 6.8 | 6.3 | 6 - 9 | 5.5 - 9.5 |
| Na | mg/l | 17.0 | 8.1 | 100.0 | 400.0 |
| K | mg/l | 2.9 | 3.5 | 200.0 | 400.0 |
| Ca | mg/l | 8.9 | 9.1 | 150.0 | 200.0 |
| Mg | mg/l | 5.9 | 4.4 | 70.0 | 100.0 |
| Cl | mg/l | 29.0 | 16.0 | 250.0 | 600.0 |
| $SO_4$ | mg/l | 3.0 | 17.0 | 200.0 | 600.0 |
| TAL (as $CaCO_3$) | mg/l | 46.0 | 7.0 | 300.0 | 650.0 |
| F | mg/l | ✷ | ✷ | 1.0 | 1.5 |
| $NO_3$ + $NO_2$ (as N) | mg/l | ✷ | ✷ | 6.0 | 10.0 |
| $PO_4$ (as P) | mg/l | ✷ | ✷ | | |
| Si | mg/l | ✷ | ✷ | | |
| $NH_4$ (as N) | mg/l | 1.6 | 0.1 | 6.0 | 10.0 |
| Fe | mg/l | 3.38 | 0.05 | 0.1 | 1.0 |

✷ = Not determined.
A = Borehole; Wysersdrift west of Worcester (Breede River Valley); yield > 5 l/s.
B = Borehole; Oak View southwest of Worcester (Breede River Valley); yield > 5 l/s.
C = Drinking Water Quality Criteria: maximum recommended limit.
D = Drinking Water Quality Criteria: maximum allowable limit.

**Fig. 39 : Areal location of the Alluvial Deposits position of sampling points for the chemical analyses shown in Table 16**

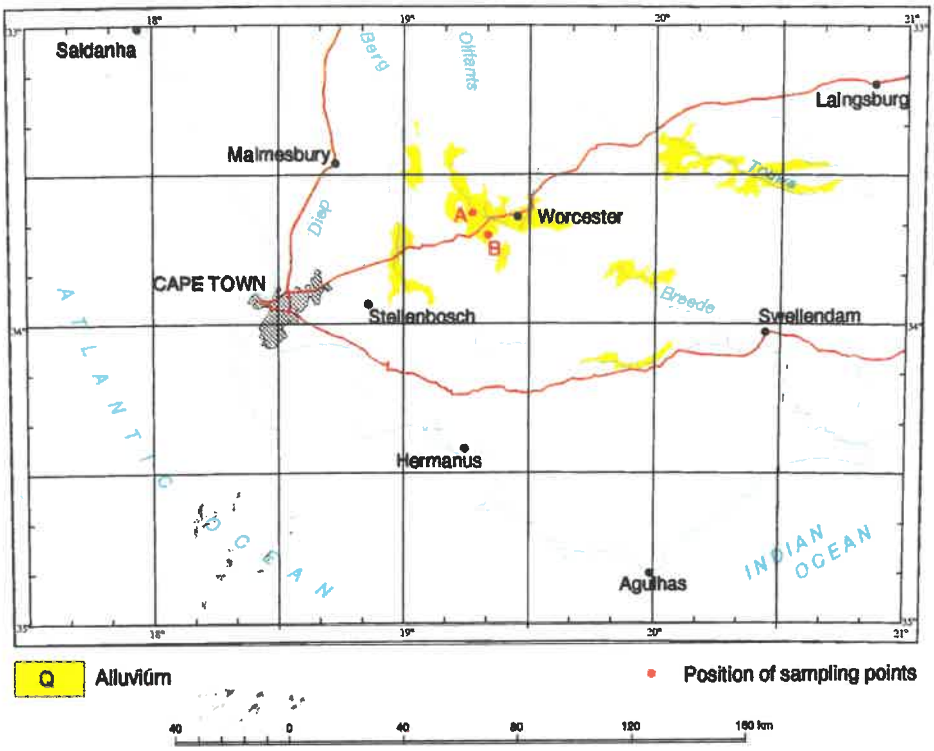



**Fig. 40 : Yield frequencies of boreholes in the alluvial deposits (210 boreholes analysed)**

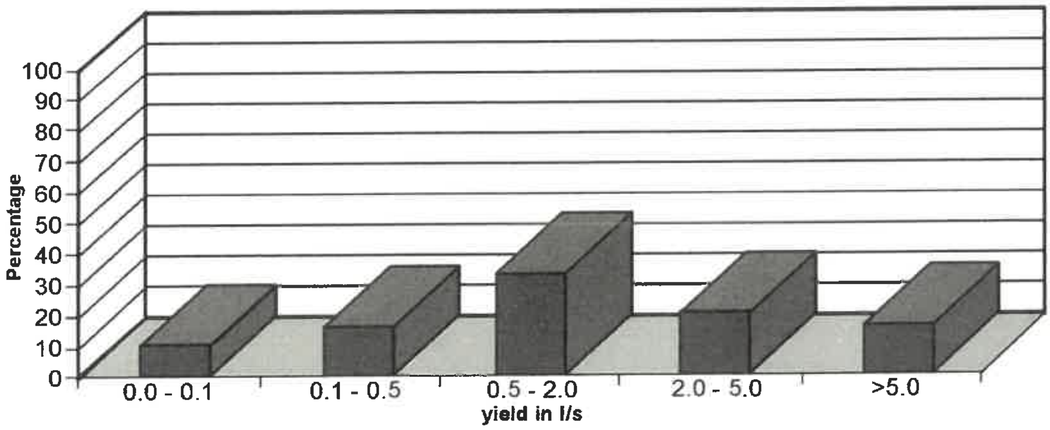
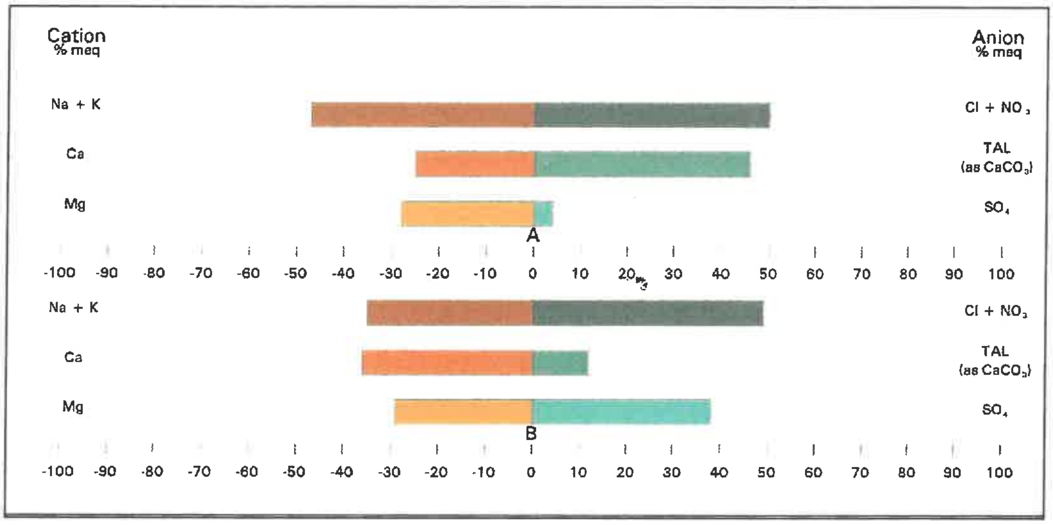
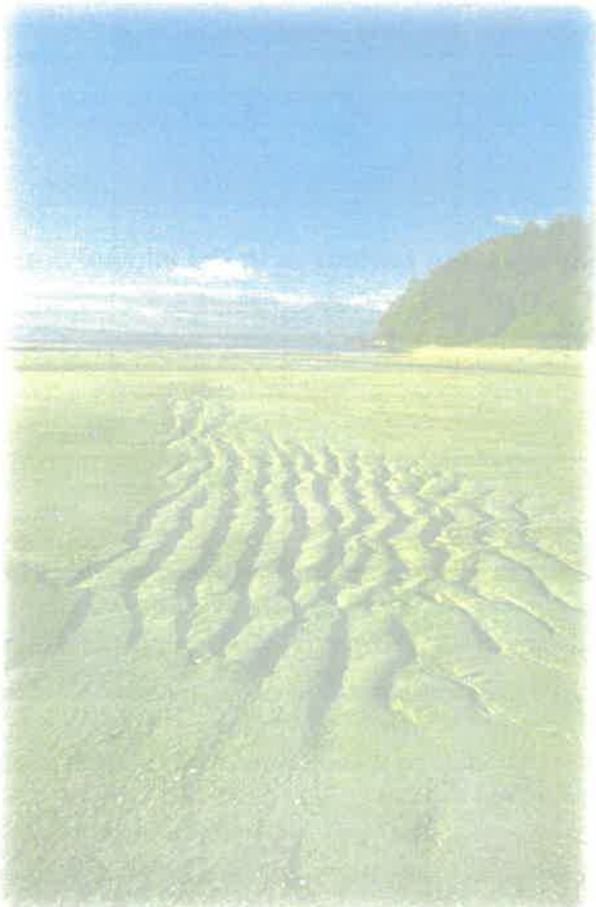


**Fig. 41 : Stiff diagrams of the chemical analyses in Table 16 (Alluvial Deposits)**



# 5. GROUNDWATER RELATED ISSUES

## 5.1 Previous Investigations

The Cape Town Hydrogeological Map and Explanatory Brochure were compiled utilising data obtained from various previous investigations and research projects. These projects were executed by the Department of Water Affairs and Forestry, various universities and a number of groundwater consultants. Investigations include amongst others, borehole sitings for farmers and groundwater exploration for municipal water supplies such as that for Hopefield, Hermanus, Agulhas, Struisbaai, Bredasdorp, Napier, Witsand, Barrydale and Touws River. Broader investigations were conducted on the intergranular aquifers along the West Coast, on the Cape Supergroup rocks in the Agter-Witzenberg and Struisbaai areas, in the Breede River valley and in the Hex River valley. A fair regional spread of data was obtained from numerous regional borehole surveys.

## 5.2 Groundwater Levels

Groundwater levels within the map area are relatively shallow. An analysis of the available groundwater level data (Table 17) indicates that the occurrence of levels shallower than 10 m below surface range between 64% in the Witteberg Group to 85% and 86% in the Klipheuwel and Sandveld Groups respectively. Percentages of groundwater levels deeper than 30 m below surface vary between 2% in the Ecca Group and 10% and 19% respectively in the Uitenhage and Witteberg Groups.

With the exception of the Struisbaai area, no abnormally deep groundwater levels, caused by over-abstraction of groundwater are found in the area covered by the map. Excluding areas of major groundwater abstraction, seasonal fluctuations of groundwater levels commonly vary between 1 and 3 m. In areas of largescale groundwater with-drawals, fluctuations of up to 30 m may occur, e.g. in the Hex River valley and in the Ceres basin. Groundwater recharge during the rainy season is usually satisfactory and groundwater levels generally recover to pre-dry season levels. This is particularly true of areas where some form of groundwater management is applied.

**Table 17 : Groundwater levels below surface for the different geological units, expressed as percentages**

| Geological Unit | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Malmesbury | 74 | 16 | 7 | 3 | 1 310 |
| Cape Granites | 81 | 11 | 5 | 3 | 770 |
| Klipheuwel | 86 | 0 | 9 | 5 | 21 |
| Table Mountain | 78 | 12 | 6 | 4 | 528 |
| Bokkeveld | 70 | 15 | 8 | 7 | 1 280 |
| Witteberg | 64 | 17 | 9 | 10 | 286 |
| Dwyka | 65 | 21 | 6 | 8 | 96 |
| Ecca | 65 | 26 | 7 | 2 | 127 |
| Beaufort | 78 | 22 | 0 | 0 | 23 |
| Uitenhage | 68 | 7 | 6 | 19 | 16 |
| Sandveld | 85 | 9 | 3 | 3 | 1 751 |
| Bredasdorp | 82 | 10 | 5 | 3 | 122 |
| Alluvial Deposits | 74 | 15 | 6 | 5 | 297 |

1 = percentage of water levels < 10 m below surface
2 = percentage of water levels > 10 m < 20 m below surface
3 = percentage of water levels > 20 m < 30 m below surface
4 = percentage of water levels > 30 m below surface
5 = number of water levels analysed

## 5.3 Borehole Siting Methods

In the Cape Fold Belt, geophysical methods of siting boreholes are relatively limited in their application and are used as an aid only when surface features are largely obscured. As fracture, joint and fold structures (Table 18) are generally the principal features to focus on when siting boreholes, the use of aerial photographs is crucial. A thorough field reconnaissance of the geology and topography, together with the collection and interpretation of hydrocensus data, is essential. Once a broad picture of conditions on the ground has taken form, obscured features can be traced geophysically, applying the electrical resistivity and electromagnetic methods, and in exceptional cases the magnetic method. Seismic and gravity methods are generally applied when more extensive regional surveys are required.

The necessity of using trained personnel to site boreholes cannot be over-emphasised.

**Table 18 : Guidelines for boreholes siting**

| Geological Unit | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Malmesbury | ·· | · | ·· | | ·· | | |
| Cape Granites | · | | | ·· | · | | |
| Klipheuwel | ··· | | | | | | |
| Table Mountain | ··· | | | | | | |
| Bokkeveld | ·· | · | · | | | | |
| Witteberg | ·· | · | · | | | | |
| Dwyka | ·· | | | · | | | |
| Ecca | ·· | | · | | | | |
| Beaufort | ·· | | · | | | | |
| Uitenhage | | · | | | | | |
| Sandveld | | | | | | ··· | |
| Bredasdorp | | | | | | · | ··· |
| Alluvial Deposits | | | | | | ··· | |

· used on limited scale  ·· moderately used  ··· widely used

1 = Targeting fracture joint and fold structures
2 = Targeting interbedded sandstone
3 = Employing alluvium as recharge medium to underlying rocks
4 = Targeting weathering zones
5 = Targeting intrusion contact zones
6 = Targeting sand/alluvium occurrences
7 = Targeting basal conglomerate

## 5.4 Groundwater Management

For the optimum development of a groundwater resource, in both the intergranular and fractured aquifers, sound groundwater management is essential in order to prevent over-exploitation and/or pollution of these resources, and in order to achieve some measure of sustainable resource yield.

A study of groundwater level fluctuations is generally the accepted method of monitoring an aquifer's response to groundwater abstraction. For this purpose monitoring boreholes are required, A thorough knowledge of the geology of the terrain and an understanding of the anticipated groundwater flow, are requirements for the correct positioning of monitoring boreholes.

Groundwater level measurements must subsequently be carried out on a regular basis and the data recorded. The results should be interpreted and related to groundwater abstractions and recharge conditions. The possible impact of groundwater abstraction on likely affected springs, should be closely monitored. Long term observations generally provide better results. In any large-scale groundwater development a strategy of establishing two or more additional hydrogeologically independent well fields should be adopted, especially

groundwater related issues

for fractured aquifers such as the TMG. The knowledge of the dimensions and storage capacity of the underground reservoir is often limited, the groundwater parameters are frequently over-estimated, and any prolonged drought can result in the exhaustion of the groundwater resource. When a well field is fully exploited, the alternative well field(s) can be brought into operation.

The most common groundwater management approach applied in the map area, which is a winter rainfall region, is the conjunctive use of groundwater and surface water. From November to April groundwater is generally used, while surface water is commonly utilised from May to October. This strategy allows for recharging of groundwater resources during the wetter winter months.

Seawater intrusion into both the coastal intergranular aquifer along the West Coast and into the TMG fractured sandstone aquifer are the most important forms of groundwater contamination in the map area. These forms of salinisation have been recorded amongst others at Gansbaai, Agulhas, Witzand and probably at Strandfontein on the West Coast. Saline water intrusion from groundwater in the Bokkeveld Group rocks into the TMG sandstones is less common. Saline 0water intrusion can, in all instances, be attributed to over-exploitation. Groundwater management by means of groundwater level monitoring, evaluation with regard to volumes abstracted, and suitable water quality monitoring should be applied where groundwater from vulnerable aquifers is developed.

Waste disposal and sewage sites should be selected with utmost care by groundwater pollution specialists in order to protect vulnerable aquifers.

A knowledge of the 1998 National Water Act, the purpose of which is to ensure that water resources are protected, used, developed, conserved, managed and controlled for the benefit of all, could prove to be advantageous with regard to aspects of groundwater management.

## 5.5 Groundwater Utilisation

As has been mentioned, an important characteristic of water utilisation in the map area is the conjunctive use of surface water and groundwater from boreholes. During the dry summer months a number of towns use groundwater to supplement surface water supplies. In the agricultural sector, surface water and groundwater are likewise being used conjunctively for irrigation and stock-watering purposes.

Despite the fact that large areas in the Moorreesburg and Malmesbury districts west of the escarpment are being supplied from regional surface water supply schemes (such as the Saldanha, Swartland and Berg River water supply schemes) for domestic and stock watering needs, groundwater is also used to augment surface water supplies. Large tracts of the Ceres, Worcester, Montagu, Laingsburg and Ladysmith districts falling within the map area, are largely dependent on groundwater for domestic and stockwatering requirements. In the area south of latitude 34, which is largely underlain by Bokkeveld Group rocks, groundwater potential is so limited that water from the Theewaterskloof Dam is distributed for the needs of the farming community, and groundwater utilisation in that area is thus insignificant.

Large-scale groundwater abstraction occurs at several localities as illustrated in Table 19.

**Table 19 : Localities where large-scale groundwater abstractions (> 100 000 m³/a) take place**

| | Approximate abstraction ($10^6$ m³/a) | |
|---|---|---|
| Locality / Area | Urban | Agriculture |
| Witzenberg Valley | | 11.0 |
| Ceres Basin | | 8.0 |
| Hex Valley | | 20.0 |
| Napier | 0.2 | |
| Bredasdorp | 0.5 | |
| Struisbaai | 0.3 | |
| Breede River Valley | | 30.0 |
| Brandvlei-Sandrif Area | | 11.0 |
| Barrydale Area | | 4.4 |
| Montague Area | | 0.3 |
| Scheepers Area | | 1.0 |
| Touws River Area | | 1.7 |
| Koo Area | | 2.0 |
| Vyeboom Area | | 4.1 |
| Stanford / De Kelders | 1.4 | |
| West Coast Primary Aquifers | 30.0 | |

## 5.6 Recommendations for Future Studies

Suggestions for more detailed groundwater related studies include the following:

- Evidence exists of deep groundwater circulation, mainly in the TMG sandstones. To elucidate this phenomenon, the tectonics of the CFB and associated fracturing of the deeper sections of the TMG and its groundwater exploitation potential should be studied comprehensively;

- The relative competency of rocks in the CFB plays a key role in the occurrence of groundwater. Relative rock competencies and associated brittle failure should be studied to target areas of promising groundwater potential;

- Core drilling on a variety of faults (Plates 7 and 8) is recommended in order to establish to what extent permeability inhibiting material occur in joints and fractures and to shed light on depth of fracture occurrence;

- Relatively little is known about groundwater parameters in rocks of the CFB, such as recharge, transmissivity, storage, etc. Isotope studies as well as more conventional study methods to gain further knowledge in this field should be encouraged;

- The influence of afforestation and deforestation on the groundwater regime is relatively unknown at present and needs further investigation;

- The distribution and mode of occurrence of springs in the CFB with particular emphasis on their occurrence in the TMG, needs to be examined.



*Southern Africa boasts at least four plants that have remained largely unaltered since the time of Gondwanaland, namely Welwitschia mirabilis, the only plant of its kind in the world, and which exists where few other plants will grow in the Namib desert; the Cycads which were very common in Gondwanaland during the Triassic period, the Baobab (Adansonia digitata), currently found in tropical areas only, and two genera of the Conifer family, namely Podocarpus (South African Yellowwood) and Widdringtonia (the Cape Cedar or Mountain Cedar). Both the Yellowwood and the Mountain Cedar are indigenous to the map area. The Mountain Cedar distinctly favours Table Mountain Group sandstone terrain (partly adopted from Plumstead E.P.,1969).*

**Plate 7. Core from a borehole in the Worcester Fault between Wolseley and Worcester. Most of the fracture openings have been in-filled by iron oxide, which is likely to hamper permeability.**

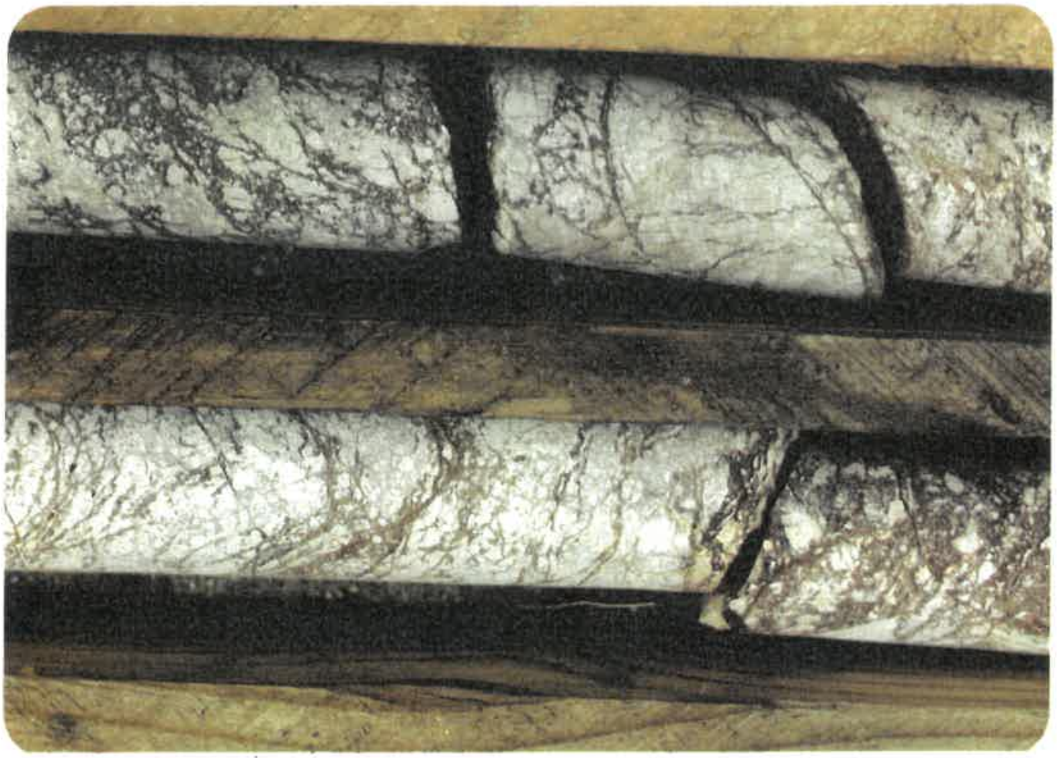
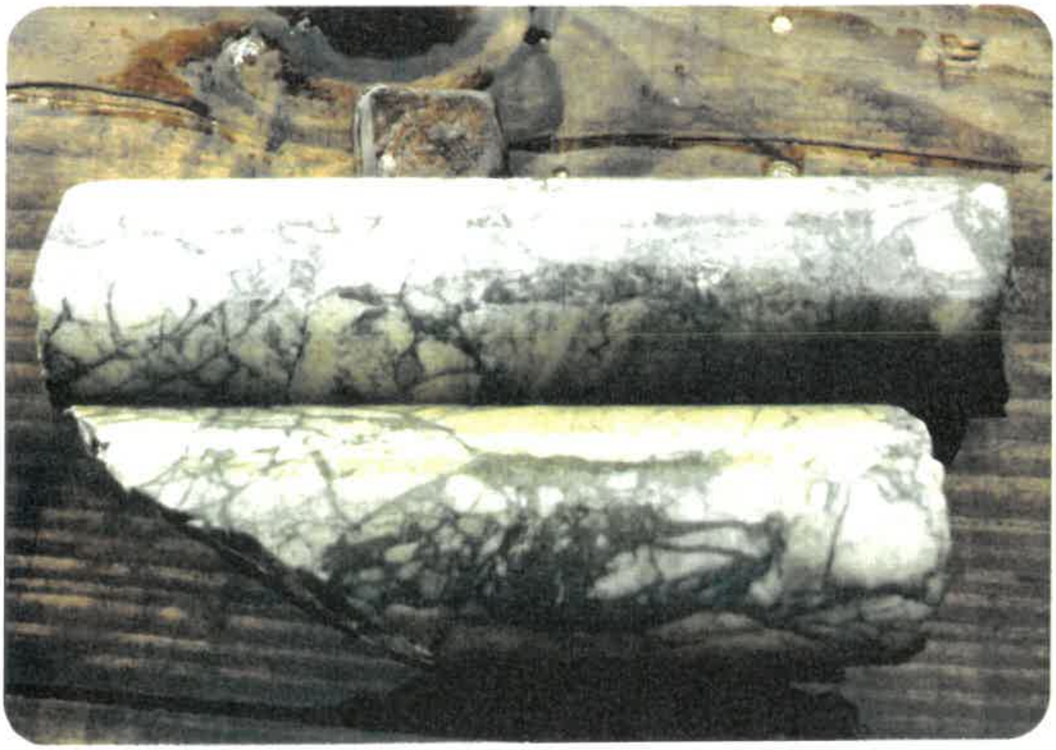


**Plate 8. Core from a borehole in the Worcester Fault south of Wolseley. Most of the fracture openings have been filled-in and blocked by sulphate. These in-fillings are likely to hamper permeability.**



# REFERENCES


**ANON/UNESCO, 1983**
International Legend for Hydrogeological Maps, Revised Edition 1983, Unesco Techn. Document, SC84/WS/7,51 p., Paris.

**GRESSE P.J. and THERON J.M., 1992**
Geology of the Worcester Area. Explanation Sheet 3318, Geological Survey of South Africa.

**HEYDORN A.E.F. and TINLEY K.L., 1980**
Estuaries of the Cape, Part I, Synopsis of the Cape Coast, Natural Features, Dynamics and Utilization.

**JOHNSON DIVISION, JOP INC., 1975**
Groundwater and Wells.

**MACLEAR L.G.A., 1995**
Cape Town Needs Water. A note on the Potential of the Cape Flats Aquifer Unit to Supply Groundwater for Domestic Use in the Cape Town Metropolitan Area. Department of Water Affairs and Forestry. Technical Report No Gh3868, August 1995.

**PLUMSTEAD EDNA P., 1969**
Three Thousand Million Years of Plant Life in Africa. Geological Society of South Africa, Annexure to Volume LXX 11, 1969. Alex L. du Toit Memorial Lectures No 11.

**ROBERTS D.L. and BERGER L., 1997**
Last Interglacial (c.117 kyr) Human Footprints, South Africa. South African Journal of Science, (93, 349-350).

**SÖHNGE A.P.G. AND HÄLBICH I.W., 1983**
Geodynamics of the Cape Fold Belt. Special Publication No.12 of the Geological Society of South Africa (Edited by A.P.G. Söhnge and I.W. Hälbich).

**TANKARD A.J., JACKSON M.B.A., ERIKSSON K.A., HOBDAY D.K., HUNTER D.R. and MINTER W.E.L., 1992**
Crustal Evolution of Southern Africa, SpringerVerlag, New York 523 p.

**THERON J.M., GRESSE P.G., SIEGFRIED H.P. and ROGERS J., 1992**
Geology of the Cape Town Area. Explanation Sheet 3318, Geological Survey of South Africa.



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