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A HYDROGEOLOGICAL ASSESSMENT
OF THE
UITENHAGE - COEGA ARTESIAN SYSTEM

by

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Submitted in partial fulfillment of the
requirements for the degree of Master of Science
in the Department of Geography
Rhodes University
Grahamstown

January 1985

SYNOPSIS

The Uitenhage artesian aquifer north-west of Port Elizabeth in South Africa, is one of the few artesian groundwater systems in Southern Africa. The Uitenhage - Coega, and Kruis River areas, are the most important portions of the Uitenhage Artesian System in terms of water abstraction and water use. This study concentrates on the Uitenhage - Coega area and in particular, on the Coega Ridge where the Table Mountain Sandstone (TMS) aquifer occurs at relatively shallow depths.

The investigation is aimed at assessing the geological, hydrogeological and hydrochemical characteristics of the TMS and any other aquifers present, with the object of providing quantitative data for use in future decisions on the water resource management of the area.

In order to achieve these objectives, field work, involving a hydrocensus, geological mapping, geophysical exploration, drilling, aquifer testing and hydrochemical sampling was carried out. Analysis of these data provided information on the extent of the aquifers, their hydrogeological characteristics and the chemical nature of the various groundwater types.

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Acknowledgements

I would like to express my thanks to the following:

- My supervisor, Mr A.W. Stone, for his assistance and encouragement throughout the period of study.

- The Division of Geohydrology, Directorate of Water Affairs, for finance and logistical support

- Tony Barbour and Nelson Sweetnam for proof-reading the script.

CHAPTER 1

STUDY AREA, AIMS AND HYPOTHESES

1.1 Introduction

The Uitenhage Artesian System (U.A.S.), situated in the Cape Province between latitudes 33°30'S and 35°55'S and longitudes 25°15'E and 25°45'E, covers an area of about 3700 square kilometres and is the only artesian system of practical importance in the Republic of South Africa (Mountain, 1955). See Fig. 1 for locality.

The artesian system has been studied previously (see section 1.3, p 3), although these early investigations were of a rather general nature. This study is aimed at gaining a thorough understanding of the geological, hydrogeological and hydrochemical processes, operating in the northern portion of the artesian system. This northern area is known as the Coega Compartment (Marais, 1964) and forms a discrete hydrogeological unit within the U.A.S.

The study is principally concerned with the Table Mountain Sandstone (TMS) aquifer, in the area between the Uitenhage Springs and the sea. Attention will, however, be paid to the other major rock units present - the Bokkeveld and Uitenhage Groups.

1.2 Historical Background

From the establishment of the town of Uitenhage in 1804, until the early 1900's, water requirements were supplied almost exclusively from the nearby Springs, (Fig. 2) Since that time, however, many artesian boreholes have been drilled and the increased abstraction rate has led to a drop in yield from both the Uitenhage Springs, and from boreholes in the area as a whole. The completion, shortly after 1950, of flowing artesian boreholes on the farms Coegakop and Wells Estate, led to a halving of the water available to Uitenhage from the Springs (Marais, 1964).

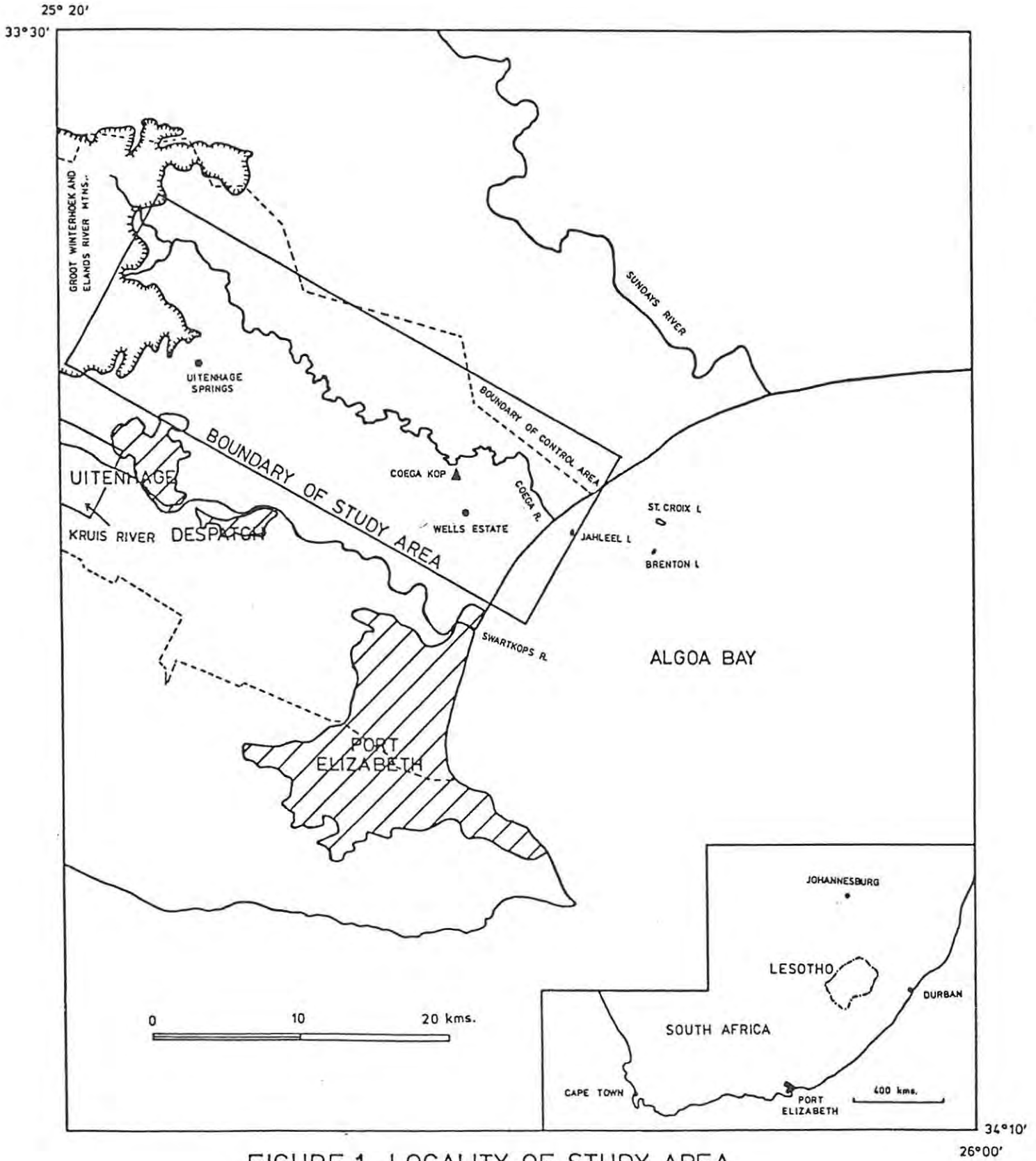


FIGURE 1 LOCALITY OF STUDY AREA

In 1957, in terms of Government Proclamation 260, controls on drilling and groundwater abstraction were implemented in the Uitenhage Groundwater Control Area. In 1964, Proclamation 266 was issued. This increased the size of the Control Area to approximately 1125 km² (see Fig. 2).

1.3 Previous Work

Geohydrological studies of the entire Uitenhage Artesian Area were carried out by Enslin in 1962, and Marais in 1964, under the auspices of the South African Geological Survey. A gravity survey over the onshore portion of the Algoa Basin was undertaken by the South African Geological Survey in 1964. As part of the national programme of oil exploration, a detailed seismic reflection survey was carried out in 1976. More recently, hydrochemical analyses, and isotope work in particular, were undertaken by Talma, Vogel and Heaton (1983), of the C.S.I.R.

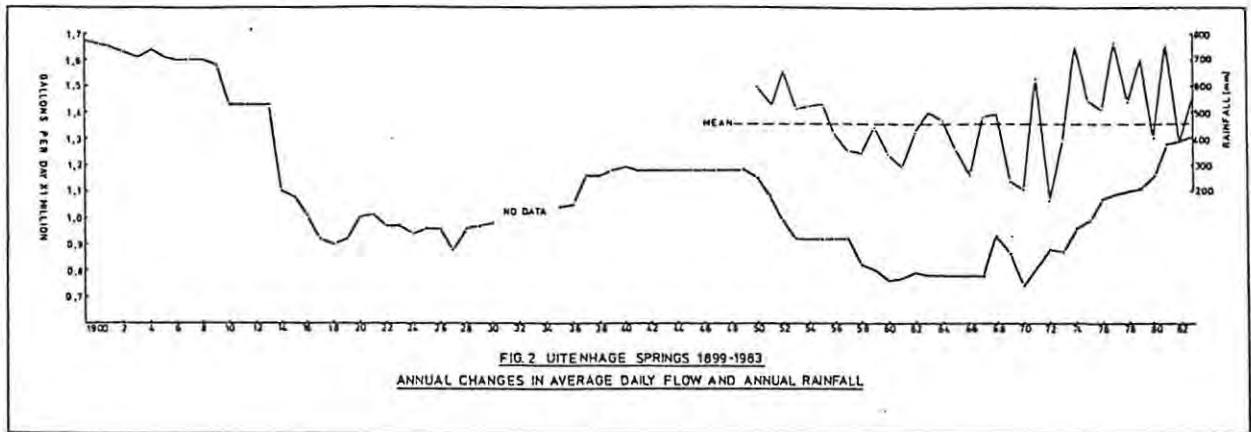
1.4 The Study Area

1.4.1 Location

The Study Area extends from north of the town of Uitenhage in an east-south easterly direction to the coast (Fig. 1). It encompasses most of the northern section of the Uitenhage Underground Water Control Area (U.U.W.C.A.). This northern section is known as the Coega Compartment (Marais, 1964). The total area covered is approximately 470 square kilometres.

1.4.2 Climate and Vegetation

The region experiences a temperate climate with warm, humid summers and mild to cold winters. The annual rainfall at Uitenhage Springs averages 460mm and is concentrated in the summer months (Fig. 2). The potential annual evaporation varies from about 1 400mm near the coast to 600mm near the Groot Winterhoek mountains in the west of the study area (Marais, 1964). The vegetation in the area is principally dense bush and shrub comprising mainly thorn trees and prickly pear bushes. Following Acocks' (1975) definition of veld types, the vegetation is classified as Karoo Valley Bushveld.



1.4.3 Physiography

The study area is bounded to the east by Algoa Bay. The country rises to the west in a series of steps corresponding to marine transgressions and regressions. These "steps" are known as the Bontrug Plateau, the Salt Pan Terrace and the Grassridge Plateau respectively (Ruddock, 1968; Marker, 1984). The "steps" stretch in an arcuate fashion parallel to the coast and dip at low angles (1 to 1,5°) towards the sea. Westwards the relief becomes progressively more rugged towards the Groot Winterhoek and Eland's River mountain ranges. These are composed of predominantly Table Mountain Sandstone with lesser pre-Cape quartzites and phyllites, and probably form the principal recharge area for the artesian system.

Surface drainage is effected primarily by the Coega River in the north and Swartkops River in the south. Near the coast both of these rivers show mature features such as meanders and flood plains. Further inland a dendritic pattern of drainage is established, with the landscape having a dissected appearance as the streams cut their way through the resistant quartzites of the Table Mountain Group.

The Uitenhage-Coega Fault lies within the southern portion of the study area. It is exposed at the extreme western end of the area but is obscured by Cretaceous sediments further east. It is this fault, which downthrows to the south, that separates the Coega Compartment from the rest of the artesian system. North of the fault the so-called Coega Ridge extends from the mountains in the west and culminates in three small islands in Algoa Bay. Although, in the east, the Coega Ridge is mostly obscured by Cretaceous sediments, its presence is manifested on the surface by small inliers of Table Mountain Sandstone the most prominent of which is Coega Kop (Fig. 1).

1.5 Aims and Objectives of the Study

The objective of the study is to identify the factors influencing the hydrogeology and hydrochemistry of the northern portion of the Uitenhage Artesian System, (the Coega Compartment) and to provide information to serve as the basis for effective management decisions enabling maximum exploitation of the water resource.

The specific aims are;

- (a) To determine the geometry and geohydrological characteristics of the principal aquifer - The Table Mountain Group.
- (b) To evaluate any other subsidiary aquifers in the project area.
- (c) To redefine the boundaries of the Control Area in terms of geohydrological rather than cadastral criteria.
- (e) To assess the factors influencing the quality of groundwater water both laterally and vertically, throughout the project area.

1.6 Hypotheses

Based on theoretical hydrological concepts and the work of Enslin (1962), Marais (1964), and Bush (1982), the following hypotheses are proposed for the study area.

Aquifer Geometry and Geology

1. The principal aquifer comprises the quartz-arenites of the Table Mountain Group.
2. The argillaceous rocks of the Kirkwood and Sunday's River Formations act as an effective aquiclude.
3. The pre-Cretaceous relief is extremely irregular.
4. The Uitenhage-Coega Fault, by juxtaposing impermeable with permeable strata, forms the southern boundary of the Coega Compartment.

Geohydrology

5. The Table Mountain quartz-arenites form an inhomogeneous aquifer with secondary permeability being governed by the degree of jointing, fracturing and faulting.
6. The direction of groundwater flow is predominantly from the WNW to the ESE.
7. Water derived from the Table Mountain Group quartz-arenites is less mineralised than that from the Bokkeveld and Uitenhage Groups.

1.7 Thesis Structure

The thesis has been structured in much the same way as the investigation of the study area was carried out. After the desk study and literature search, a hydrocensus, or borehole survey was conducted, the results of which are included as Appendix 1. Thereafter, the study involved geology, geophysics, drilling, aquifer testing, and hydrochemistry. These aspects are discussed in Chapters 2-6 respectively. Chapter 7 examines whether the aims and objectives proposed in section 1.5 (p 5) have been fulfilled, as well as testing the hypotheses (section 1.6, p 5) for validity. The thesis is concluded with a short section on conclusions and recommendations.

CHAPTER 2

GEOLOGY

2.1 Geological Mapping

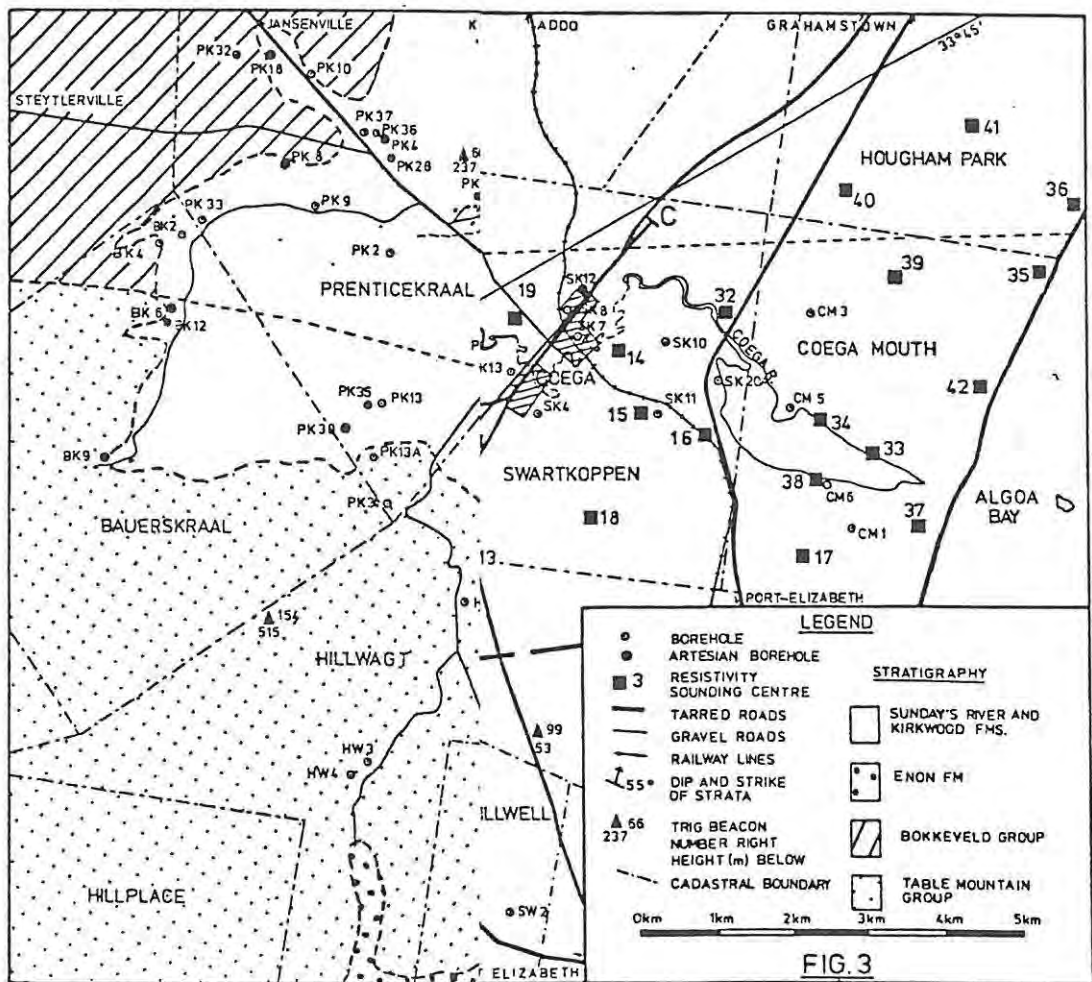
The compilation of a geological map for the study area was accomplished using three techniques:-

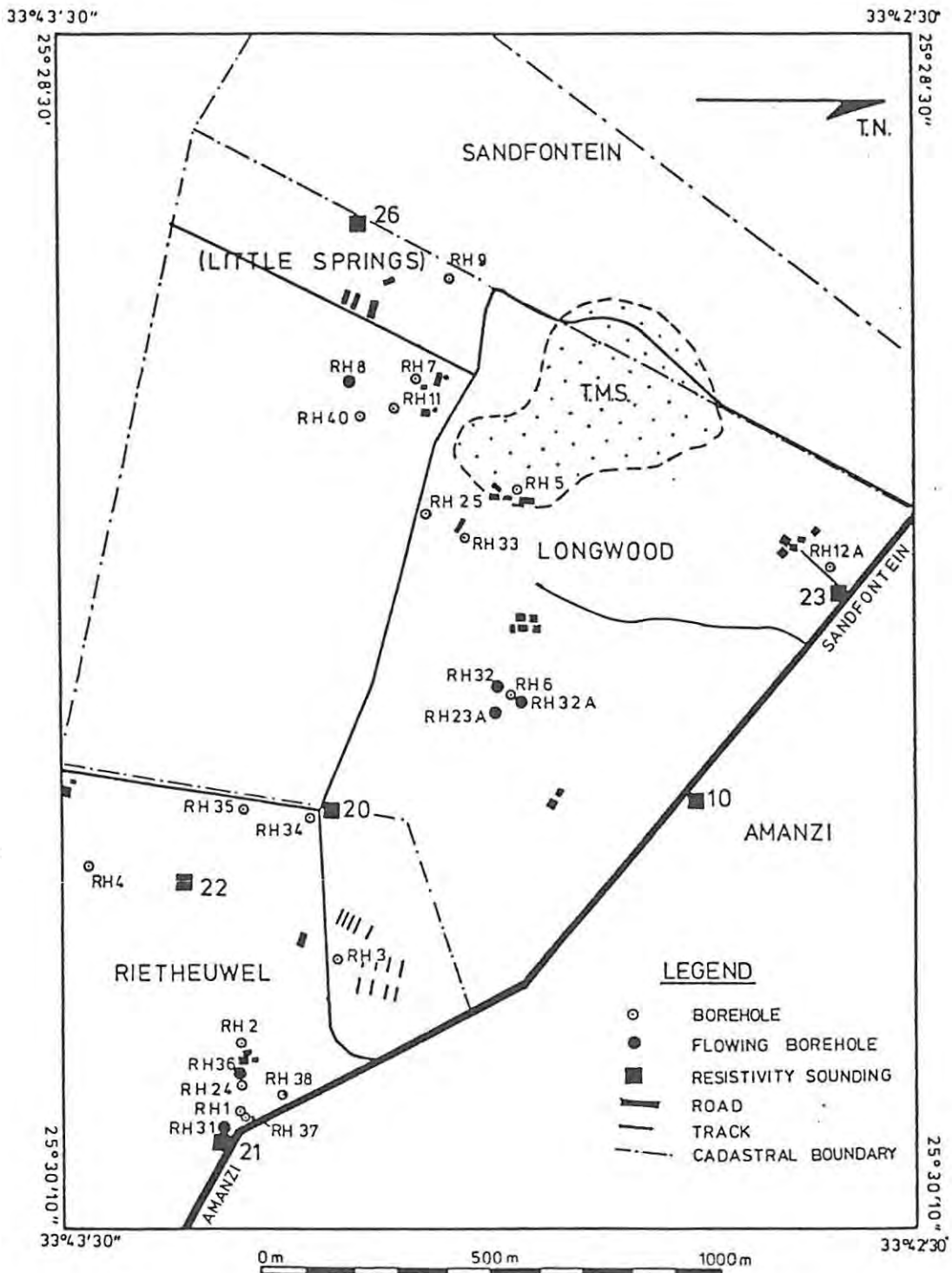
1. Use of existing geological maps, notably that of Marais (1964).
2. Field mapping, involving the tracing of contacts and the measurement of various structural parameters such as dips, strikes, joint orientations and fracture densities.
3. Interpretation of aerial photographs. This was facilitated by the use of stereoscopic apparatus.

An understanding of the sub-surface geology was gained by making use of geophysical methods and by the drilling of exploration boreholes for both stratigraphic information and geophysical correlation. These aspects are discussed in Chapters 3 and 4 respectively.

The surface geology of the study area has been incorporated into the base map (Fig. 3) which, in addition, shows cadastral boundaries, topography, borehole positions and electrical resistivity sounding sites. Geological sections, A-A', B-B', C-C' and D-D' are presented in Figs. 4 A-D.

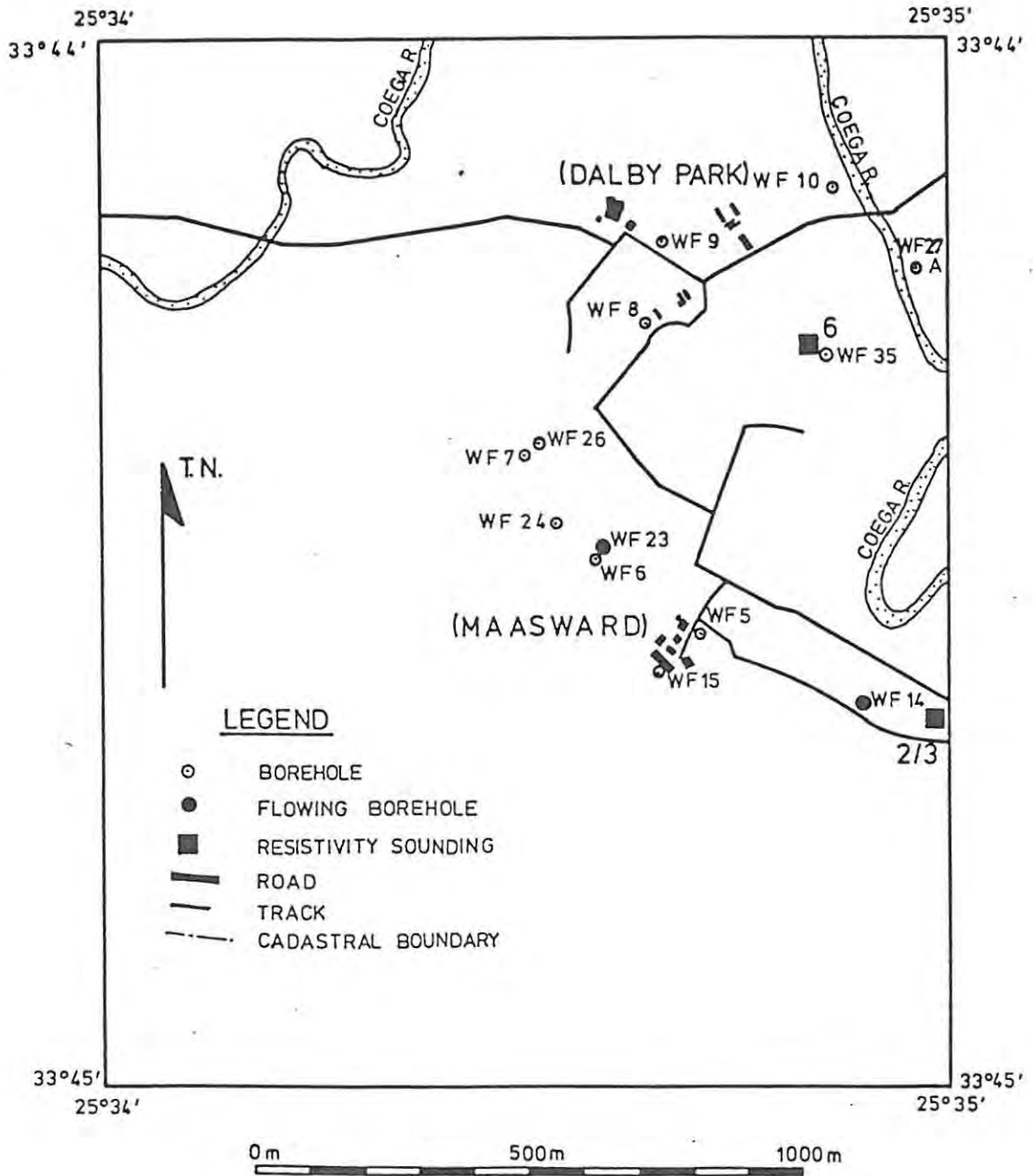
There has been no attempt to differentiate between the Kirkwood and Sunday's River Formations of the Uitenhage Group, as hydrogeologically they represent a single unit. This would also have been an extremely time-consuming task and beyond the scope of this investigation which is principally concerned with the Table Mountain Group, (also referred to as the Table Mountain Sandstone or TMS).





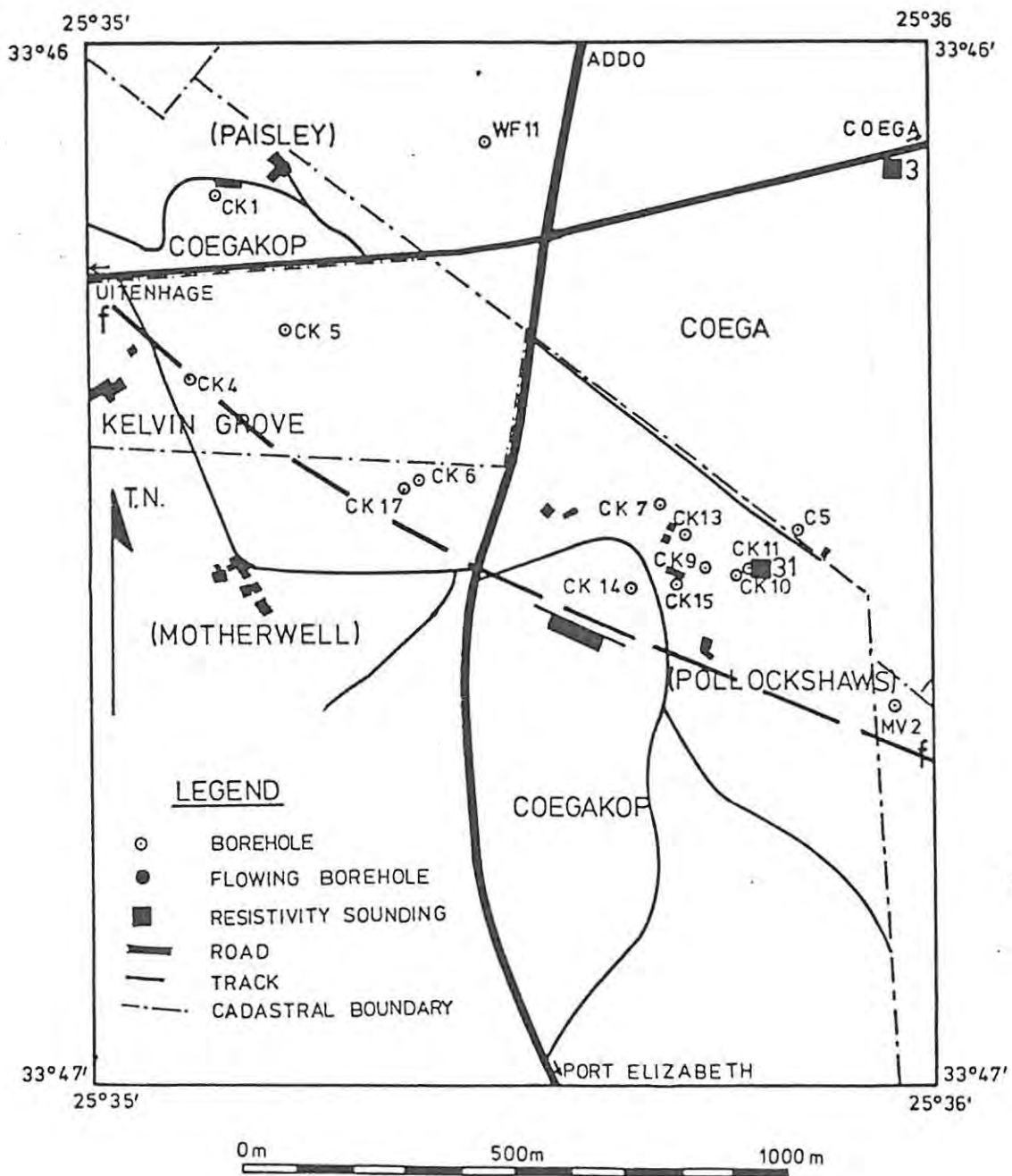
INSERT A-RIETHEUWEL

FIG. 3A ENLARGEMENT OF INSERT A (FIG. 3)



INSERT B - WELBEDACHTSFONTEIN

FIG. 3B ENLARGEMENT OF INSERT B (FIG. 3)



INSERT C - COEGAKOP

FIG. 3C ENLARGEMENT OF INSERT C (FIG. 3)

2.2 Stratigraphy

The following geological units are present in the study area:

<u>Period</u>	<u>Age (Ma)</u>	<u>Stratigraphic Units</u>	
Quaternary	0-18	Recent deposits	
<hr/>			
Tertiary	18-65	Alexandria Fm.	
<hr/>			
Cretaceous	65-141	Uitenhage Group	- Sunday's River Fm. - Kirkwood Fm. - Enon Fm.
<hr/>			
Palaeozoic	330-450	Cape Supergroup	- Bokkeveld Gp. - Table Mountain Gp. (Peninsula Fm)
<hr/>			
Late Pre-Cambrian	+450	Pre-Cambrian Basement - Gamtoos Gp.	
<hr/>			

Table 1 - Stratigraphy of the Uitenhage-Coega area (After S.A.C.S., 1980)

2.2.1 The Pre-Cambrian Basement - The Gamtoos Group

Areally these rocks comprise a very small portion of the study area, occurring for a short distance on the upthrown side of the Uitenhage-Coega Fault. Lithologically they consist of quartzites with interbedded phyllites, shales and limestones. The Gamtoos Group is considered to be conformable with the overlying Table Mountain Group (Amm, 1934). The Pre-Cape rocks are of little geohydrological importance for two reasons:

- (a) The area they cover is very small;
- (b) They are lithologically similar to the T.M.S. although Amm (1934), maintains that because of their more plastic nature (by virtue of higher argillite content) they are better able to accommodate stress. This implies that these rocks are not as fractured as the

2.2.2 The Cape Supergroup

2.2.2.1 The Table Mountain Group (TMS)

Outcrop is confined to the western portion of the study area, and isolated inliers in Mesozoic sediments on the upthrown side of the Coega Fault. Three small islands in Algoa Bay are also composed of sediments of the Table Mountain Group.

The Group is thought to range from Early Ordovician to Early Devonian in age and consists primarily of quartz arenites with minor conglomerate and mudstone beds (Tankard et al., 1982). Sedimentation and facies stacking patterns appear to have been controlled by pronounced basement subsidence accompanied by faulting.

Although, in the Eastern Cape, the Group can be divided into 5 formations (Tankard et al, 1982), only the lowermost, Peninsula Fm. is thought to be present in the study area. Estimates for the thickness of this formation vary greatly, with figures of 2000m (Visser, 1974) and 4600m (Marais, 1964) being proposed.

Lithologically and sedimentologically, evidence is consistent with a high-energy deposition model. The quartz-arenites comprise medium to coarse-grained sandstones with pebbles of well-rounded quartz and quartzite. Individual quartz grains are cemented with silica cement. Medium to large-scale cross-bedding is the dominant sedimentary structure. Visser, (1974) considers this to be a consequence of a barrier-beach, shallow-shelf environment with the maturity of the sequence being ascribed to high-energy current and storm winnowing processes on a stable, but slowly subsiding shelf.

Four different sandstone facies have been described by Rust (1973), Visser (1974) and Hobday and Tankard (1978), but further stratigraphic discussion is beyond the scope of this report.

2.2.2.2 The Bokkeveld Group

Rocks of the Bokkeveld Group outcrop in the north-western portion of the study area and represent the most dynamic phase of Cape Supergroup deposition. The model applied by Tankard et al., (1982) is that of a southward thickening sedimentary prism constructed largely by fluvial and shoal-water delta processes. The succession contains five of six

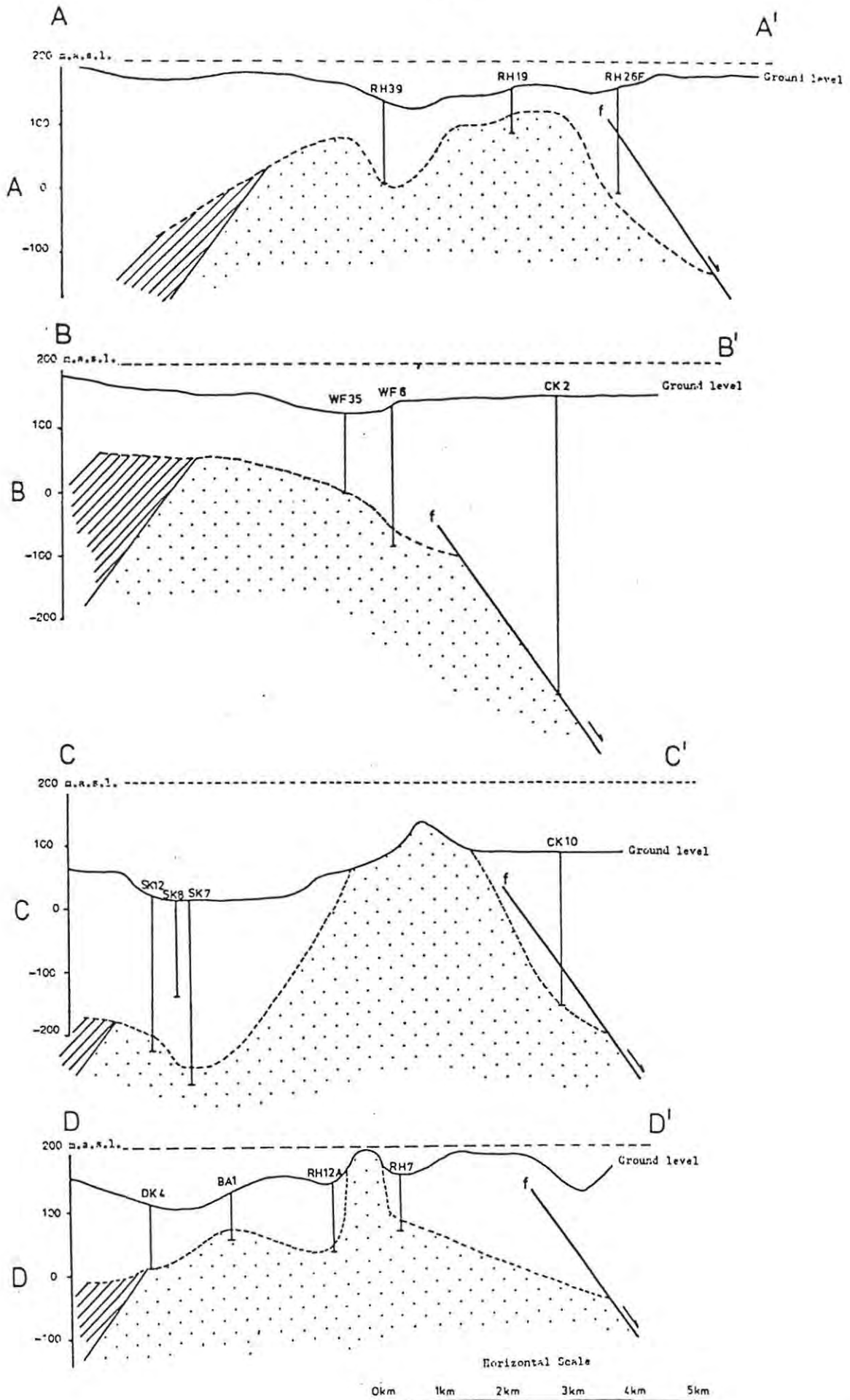


FIG. 4 A-D GEOLOGICAL SECTIONS ACROSS THE CCEGA RIDGE
(see Fig. 3 for locations and stratigraphic symbols)

interrupt the lower two but become progressively thicker in the upper three. The substantial thicknesses of fine-grained prodelta sediments are attributed to continuous deposition, while the quartz arenites are a result of lengthy periods of reworking.

The basal, Gydo Fm., is the only one of importance in the study area reaching a thickness of 600 m (S.A.C.S. 1980). The lithology comprises black shale, siltstone and lenses of fine-grained sandstone.

2.2.3 The Uitenhage Group

Regional stress patterns, produced by early Cretaceous shearing along the southern continental margin, caused tensional displacements on southward-dipping normal faults in the Cape Fold Belt (Lock, 1978). This resulted in numerous fault-controlled basins, developed with an elongation parallel to the structural grain and sub-parallel to the present coast. In each of the Southern Cape basins, sedimentation was partially controlled by boundary faulting, resulting in accumulations of conglomerates and finer-grained terrigenous clastics.

The largest of the onland Mesozoic basins is the Algoa Basin which covers $\pm 4000 \text{ km}^2$ and comprises two major depositories bounded along their northern margins by the Coega and Suurberg faults. Field evidence suggests that igneous activity, (the Suurberg volcanics) took place contemporaneously with the deposition of the lowermost unit - the Enon Conglomerate. The volcanics have been dated at 162 Ma (Mclachlan and Mcmillan, 1976), suggesting that Enon deposition may have commenced in the Early or Middle Jurassic.

2.2.3.1 The Enon Formation

The Enon Formation is of relatively minor importance in the study area as it is confined to a small occurrence in the west and does not appear to have any significant hydrogeological importance.

Where present, the Enon Fm. rests unconformably on folded pre-Mesozoic rocks and represents braided alluvial fans formed in response to faulting along basin margins. Lithologically it comprises poorly sorted conglomerates with subordinate sandstone, siltstone and mudstone lenses. Clasts are generally well-rounded and less than 50 cm in diameter. The conglomerates are predominantly clast-supported with a silty matrix.

Individual units are poorly bedded and are separated by subarkosic sandstones. Crude bedding and imbrication are interpreted as being the result of deposition as longitudinal bars in a braided stream environment. Deposition during low-river stage is reflected in the lenses of finer-grained material.

As the distance from basin margins increases, the Enon suite interfingers with the finer grained Kirkwood Fm. The upper contact of the Enon Formation is defined as the top of the massive conglomerate facies although, in the field, this may sometimes be difficult to identify.

2.2.3.2 The Kirkwood Formation

The Kirkwood Fm. outcrops over a large portion of the study area, notably just north of the Coega Fault and abutting against the Table Mountain Group in the west. The base of the Kirkwood Fm. may constitute the floor of the Mesozoic sediments or it may be in contact with the Enon Fm.

The lithology of the Kirkwood Fm. comprises mainly fine-grained clastics of the valley-flat environment (Winter, 1973). The clays are predominantly reddish-brown, silty mudstones but characteristically show patches of greenish-grey and grey resulting from local reducing conditions. Grey shale beds are also present, favouring positions close to sandstones. The silty sands are reddish-yellow to yellow in colour and the coarse sands yellow, white and pale grey. Most of the coarse sands are massive to cross-bedded, fluvial point-bar facies, fining upwards, and often contain pebble-washes, clay pellets, or pieces of fossilised wood, especially near the base.

Although the Kirkwood Fm. does attain thicknesses of up to 2200 metres in the Algoa Basin (Winter, 1973), in the study area, the range is from 0-800 metres north of the Fault, to over 1000 m south of it.

2.2.3.3 The Sunday's River Formation

The Sunday's River Formation outcrops south of the Coega Fault and towards the north-eastern portion of the study area. Although the Kirkwood-Sunday's River contact is gradational, the Sunday's River Fm. is considered to be the most distal of the Uitenhage Group and is made up of shallow-water marine and estuarine facies.

"Progradational deltaic and shelf sedimentation is reflected in thick sequences of mudstone and siltstone which commonly display upward-coarsening tendencies" (Tankard et al., 1982, p 414).

Lithologically, the Sunday's River Fm. consists of grey clays, silts and sands, weathering to a greenish-grey colour and containing secondary limestone and gypsum. The sandstones are commonly shell-bearing and lenticular, with scoured channels up to 3 m deep (Shone, 1978).

The thickest borehole intersection of the Sunday's River Formation is 1860 metres but occurs far to the north of the study area. Within the study area, the range is from 0 to less than 1000 m (Winter, 1973).

2.2.4 The Alexandria Formation

A major, 100 million year unconformity, separates the Tertiary, Alexandria Fm. from the underlying Uitenhage Group which is of Cretaceous age.

The Alexandria Fm. is of both marine and aeolian origin and comprises sporadic conglomerate, shelly gravel, skeletal limestone and calcareous sandstone (Siesser, 1972). The Formation does attain thicknesses of 50 m but is generally thinner than 10 m.

2.2.5 Recent Deposits

These comprise partially consolidated aeolian deposits, fluvial gravels and alluvium, and estuarine sediments, marine terraces and recently stabilised coastal dunes. Recent deposits are of little importance to this study and will not be discussed further.

2.3 Structure

The Algoa Basin, of which the Coega Compartment forms a part, owes its existence to a sequence of tectonic events, commencing with intense and complex folding of the Cape Fold Belt, and culminating in large scale subsidence and faulting, accompanied by basin infilling.

2.3.1 Folding

Petrographic and field evidence, such as elongation and flattening of conglomerate clasts and the almost total destruction of sedimentary structures, suggests that the pre-Cape rocks were subjected to a period of deformation before deposition of the Cape Supergroup.

Deformation of the Cape Supergroup occurred during four tectonic paroxysms spanning the period 278 ± 2 Ma to 230 ± 3 Ma. (Söhnge and Hälbich, 1983). In the Port Elizabeth area the four episodes have been identified by Bell (1980) as;

1. F_1 folds with fold axes parallel to mineral orientation. These are accompanied by the presence of low grade, regional metamorphic minerals.
2. F_2 folds with near horizontal axes, accompanied by prominent axial plane cleavage.
- * 3. F_3 folds with low angle fold axes and associated with crenulation cleavage.
4. Rare isolated kink bands.

The effects of the second phase tend to mask the others especially in the massive quartz-arenite accumulations of the Cape Recife Formation (= Peninsula Formation). Deformation events 1, 3 and 4 have only been identified in less competent strata (Bell, 1980), suggesting that these horizons acted as zones of shearing during overthrusting.

The overall effect of the four deformation phases has been to imprint on the Cape Fold Belt the following general characteristics.

1. Major asymmetrical folds.
2. Curved axial surfaces.
3. Gently inclined southern limbs.
4. Sleepily inclined or overturned northern limbs with gravity induced parasitic folds.
5. A scarcity of visible fold closures in the more competent formations because of the intensity of brecciation in the hinge zones.

With primary porosity and permeability low because of pressure solution and syntaxial cementation of individual grains, the over-riding geohydrological effect of the episodic folding, has been the creation of cleavages and joints which permit passage of fluids, especially in the massive quartz-arenite sedimentary pile of the Peninsula Formation.

2.3.2 Faulting

In the Southern Cape a number of major dislocations such as the Worcester, Congo, Gamtoos and Uitenhage Faults form the boundaries of tilted fault blocks composed of folded sediments. These faults therefore postdate the folding. The faults are aligned along the trend of Cape folding (WNW - ESE) and downthrow normally to the south. Seismic evidence (section 3.2, p 36) indicates that the fault angles are of the order 35°-40°. This is considered fairly low for gravity faulting (Winter, 1973).

The rift-type basins derived by the faulting have extremely complex floor structures for the following reasons;

1. An irregular pre-Mesozoic topographical relief.
2. The presence of tilted fault blocks, some of which have subsided at faster rates than other.
3. Later epeirogenetic movements such as those which tilted the Alexandria Formation.

In the Uitenhage - Coega area of the Algoa Cretaceous Basin, the prominent feature of geohydrological importance is the Coega Ridge, composed of Table Mountain Sandstone. This Ridge extends from the Winterhoek Mountains to three small islands in Algoa Bay. The TMS outcrops in windows along the ridge which has a relatively steep northern flank and is bounded to the south by the Coega Fault. To the north the floor levels off before dipping in under the Bokkeveld Group.

Although the Coega Fault is the major displacement feature in the study area, borehole information in the form of abnormally high core dips, suggests that there could be many small faults affecting both Palaeozoic and Mesozoic sediments and which were not detected by seismic surveys (Winter, 1973). It is unlikely that the faulting plays nearly as important a role as a fracturing agent as the folding does, although it may give rise to local zones of increased transmissivity. The high yields from boreholes CK2 and SV3, situated on, or very close to the Coega Fault suggest this. (See section 7.1.1.2, p 93).

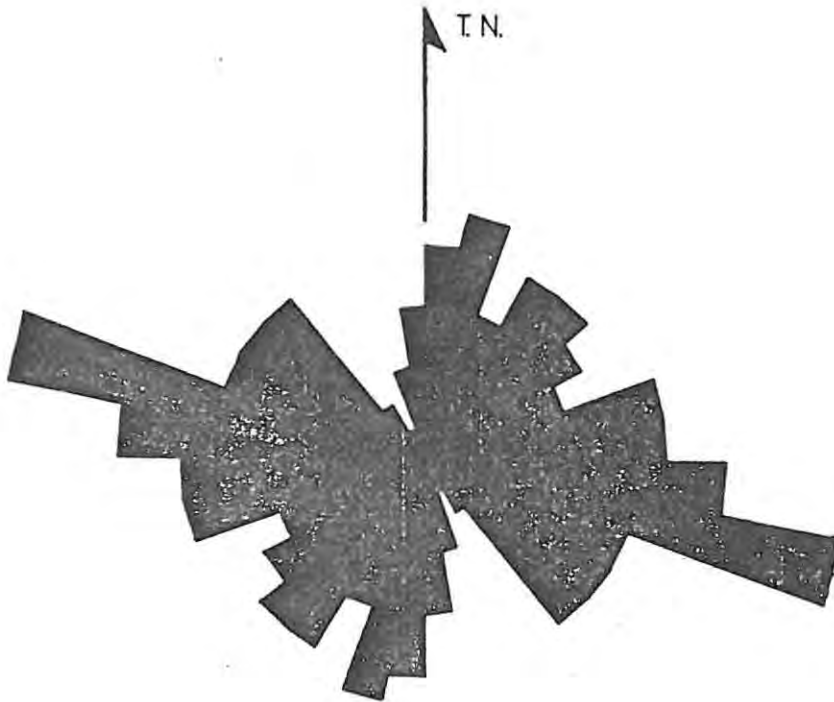


FIG. 5 ROSE DIAGRAM SHOWING FRACTURE ORIENTATION
IN TABLE MOUNTAIN SANDSTONE.

An analysis of fracture orientations was made on outcropping TMS strata at over 200 localities along the Coega Ridge. The results are plotted as a rose-diagram, (Fig.5) which clearly shows a dominant fracture orientation in a WNW - ESE direction. A subordinate fracture system, although not as clearly defined, can be seen at right angles to this orientation. Fracture dips are generally very high, mostly greater than 75° with few less than 60° . The orientation of the dominant fracture system is coincident with the trend of the Cape Fold Belt, the strike of the major faults and the dominant grain of folding - the F_2 episode. More attention is devoted to this aspect in the section on groundwater flow directions and zones of high transmissivity. (p 92)

CHAPTER 3

GEOPHYSICS

In order to determine the nature of the subsurface geology of an area the investigator has two choices open to him; either drilling a borehole or utilizing one or more geophysical techniques.

While a borehole is usually preferable in that it provides unequivocal data regarding stratigraphy, lithology and depths to water, and provides material samples of water or rock, or both, the costs of drilling have steadily increased to become almost prohibitive for all but the most deserving cases. Geophysical techniques, on the other hand, are comparatively inexpensive and rapid, and, as such, make it possible for far larger areas to be studied than would be the case with drilling.

In this chapter, attention is given to the three geophysical techniques which have been employed in the Algoa Basin and in the study area in particular.

3.1 Electrical Resistivity

A number of recent investigations such as on the Cape Flats, (Meyer and de Beer, 1981) in the Omaruru Delta, (de Beer et al, 1981) and in Zululand (Worthington, 1978) have demonstrated the worth of utilizing electrical resistivity methods in the search for groundwater and the delineation of aquifers. During this project, 54 electrical resistivity soundings were carried out in an attempt to define the surface of the Table Mountain Group where it is buried under younger sediments.

3.1.1 Resistivity Theory

The principle of electrical resistivity is based on Ohms Law, mathematically defined as;

$$R = \frac{V}{I} \dots \dots \dots \text{Eq. 1}$$

- where R = resistance (SI unit = ohm)
- V = potential difference (SI unit = volt)
- I = current (SI unit = amp)

In order to apply this relationship to physical conditions it is necessary to consider a semi-infinite solid medium with a uniform resistivity (ρ). If a measured current (I) is introduced at two points, (A and B) on its surface; and the potential difference, (V) associated with this current, is measured across two other points (M and N) on the same surface, the potential at M will be;

$$V_M = (I\rho / 2\pi) \times (1/r_1 - 1/r_2) \dots \dots \dots \text{Eq. 2}$$

and the potential at N will be;

$$V_N = (I\rho / 2\pi) \times (1/R_1 - 1/R_2) \dots \dots \dots \text{Eq. 3}$$

- where r_1 = the distance from M to A
- r_2 = the distance from M to B
- R_1 = the distance from N to A
- R_2 = the distance from N to B

The potential difference, V , measured across M and N is simply $V_M - V_N$.

By subtracting Eq. 3 from Eq. 2 and solving for ρ , the following relationship is obtained;

$$\rho = \frac{2\pi V}{I} \times \frac{1}{1/r_1 - 1/r_2 - 1/R_1 + 1/R_2} \dots \dots \dots \text{Eq. 4}$$

This can be diagrammatically illustrated as in Fig. 6.

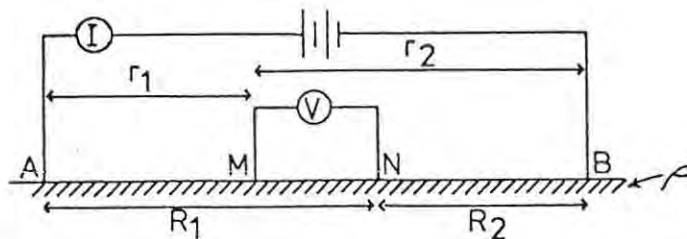


FIG. 6 ELECTRODE CONFIGURATION - SCHLUMBERGER ARRAY

Eq. 4 will give a true resistivity only if the medium is homogeneous. If different layers are present, (as is almost always the case) an apparent resistivity will be obtained.

If the electrodes are laid out along a line and the separation between the current electrodes is increased in a systematic manner, the depth to which the resistivity is measured will increase accordingly. In a situation where layers of different resistivity are present, the value of the apparent resistivity will vary as the electrode spacing is changed (Dobrin, 1960). The apparent resistivity is a measure of the effects of all the layers between the maximum depth of current penetration and the surface (Davis and de Wiest, 1966).

There are a number of drawbacks associated with the execution and interpretation of the electrical resistivity method.

1. Electrolytic conduction (Davis and de Wiest, 1966), which is the conduction of current by interstitial water within the rock unit, may give rise to changes in apparent resistivity when a change in the conductivity of the water is encountered. This may have nothing to do with a change in lithology.
2. Use of the method is confined to areas away from influences such as powerlines, fences, railways, pipelines etc. These will preferentially conduct the current and give erroneous results.
3. In terrestrial geoelectrical prospecting, precision decreases rapidly with depth (Heiland, 1946). Accuracy can be maintained to a degree if, at wide electrode separations, the current supply is increased. For portable instruments the maximum depth of penetration is about 500m (Davis and de Wiest, 1966).
4. High contact resistances between the electrode and the ground may occur in areas of dry sand cover. In these cases it may become necessary to resort to copper-sulphate pots, increasing the number of electrodes, and moistening the sand with salt-water. All these operations make the programme less portable and consequently, more expensive.

The two most common electrode configurations are the Wenner and Schlumberger arrays. During this project the latter was used as only the current (AB) electrodes have to be moved after each reading (Fig.6). This reduces electrode effects and allows clearer subsurface definition (Van Zijl, 1977; Smith, 1982).

3.1.2 Data Collection

The principal aim of the electrical resistivity programme was to determine the depth to the top of the Table Mountain Group. In order to achieve this, 54 soundings were carried out. (For locations, see Fig. 3). Selection of sounding sites was largely dependent upon the availability of roads and fence lines, as the dense thornbush vegetation is virtually impenetrable. This restriction may have led to a number of data errors, as the current may have travelled preferentially along the fence wires rather than through the earth.

Maximum AB separations achieved were 1 500 metres with the majority 1 000 metres or less. In most cases the sounding was deemed complete when the ascending, final portion of the curve was defined by four points. In some cases, however, this was impossible due to either;

(a) Cable limitations. Initially two 750 metre cables were available. After a number of cable breaks and suspected current leakage, these were replaced with two 500 metre cables.

(b) Impassable terrain. Occasionally one of the electrode extensions ran up against an obstacle such as dense thornbush or a game-fence and the sounding had to be curtailed.

(c) Insufficient current. At large distances, and especially when the contact resistance was high, the two 12 volt batteries seemed incapable of delivering enough amps for a potential difference to be measured across the MN electrodes.

In all cases, the data obtained were entered onto the pre-prepared tabulated sheets in the field. The apparent resistivity was then calculated and the data plotted on standard 62,5mm bilogarithmic graph paper with the apparent resistivity on the Y-axis and the distance AB/2 on the X-axis. This enabled a qualitative estimate of the geoelectric nature of the earth at that sounding point to be made, and provided information on whether to increase the AB separation or not.

The calculations were subsequently checked and the points plotted neatly and accurately. Interpretations were made following the procedures outlined by Smith (1982). The theoretical and field data were then compared using a computer modelling technique (Ghosh, 1971), and suitable adjustments made until a satisfactory fit, agreeing with geological data, was obtained.

Typed field-data sheets and the computer-modelled curves with interpretations are included as Appendix 2.

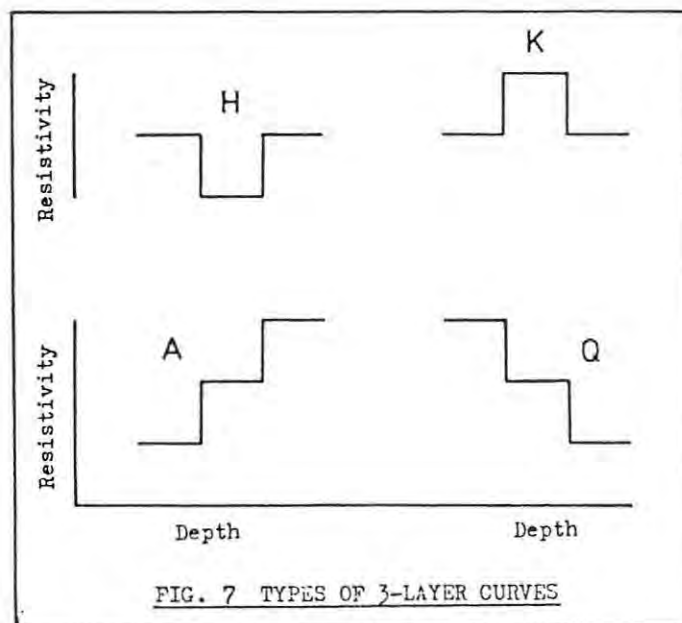
3.1.3 Data Interpretation

Interpretation of the Schlumberger electrical resistivity curves, centres around the matching of the field curves to a set of standard curves in order to arrive at values for the relevant Dar Zarrouk parameters. The parameters are longitudinal conductance, (S) where the layer in question has a lower resistivity than those above and below it and transverse resistance, (T) when the opposite is the case. The variables can be expressed as functions of layer thickness and resistivity in the following manner;

$$S = \text{thickness} / \text{resistivity}$$
$$T = \text{thickness} \times \text{resistivity}$$

(de Beer et al., 1981; Van Zijl, 1977)

Each of the standard curves represents, at the most, three layers. The first step, therefore, is to divide the field curve into 3-layer segments. Each of these segments will be one of four types; (Fig. 7)



- (a) H - type curve. In this case the middle layer has a lower resistivity than both the layers above and below it.
- (b) K - type curve. Here, the opposite is true, where the middle layer has a higher resistivity than those above and below.
- (c) A - type curve. The middle layer has a resistivity higher than the layer above it, but lower than the one below it.
- (d) Q - type curve. The middle layer has a lower resistivity than the one above, but higher than the one below.

Each 3-layer segment of the sounding curve is then matched to one of the theoretical curves in Joubert, (1977), and the relative S or T value calculated for each layer.

As both S and T are dependent on resistivity and thickness, it is necessary to know one of these values if an accurate estimate of the other is to be obtained. The resistivity can normally be estimated to a fair degree from the graph and the thickness then calculated. This, however, is not the optimum solution as factors such as equivalence and suppression can provide problems which cannot be resolved without the drilling of correlation boreholes. The principle of equivalence concerns those formations which are either conductive or resistive in relation to the over and underlying formations while suppression relates to formations possessing intermediate resistivities compared to the adjacent formations, (Worthington, 1978).

The drilling of a number of correlation boreholes is necessary so that a value for one of the variables (thickness or apparent resistivity), is obtained. This is normally thickness, although when a borehole only partially penetrates a geoelectric horizon, the use of downhole logging instruments may yield a value for apparent resistivity, enabling the thickness of the relevant formation to be calculated.

3.1.4 Discussion of Results

The interpreted curves are presented, along with the field data as Appendix 3. A rather large variety of eleven different curve types was encountered although four multilayer curves accounted for 74% of the soundings. The different curve types are presented in Table 2 along with the number of layers and the frequency of occurrence.

<u>Curve Type</u>	<u>Number of Layers</u>	<u>Frequency (out of 54)</u>
QHA	5	12
HA	4	11
QH	4	9
HKH	5	8
HAA	5	4
QHKH	6	3
H	3	2
KH	4	2
KQH	5	2
HKHA	6	1
QQH	5	1

Table 2. Frequency of Occurrence of Curve Types

Of the 54 soundings carried out, the interpretations reveal that 30 have a final layer with an apparent resistivity of greater than 100 ohm - metres. With a few exceptions this has been accepted by the author as indicative of a Table Mountain Sandstone basement ie. highly resistive quartz arenite. The remaining 24 soundings have the resistivity of the final layer ranging in value from 12 to 70 ohm - metres. In most cases this is ascribed to a very deep basement where the current electrode spacing was too small. In other situations, the basement is thought to be the rocks of the Bokkeveld Group and in a few instances, it appears as if the apparent resistivity of the TMS is lower than normal. This may be due to weathering or intense fracturing. Table 3 lists the soundings with low final-layer resistivities and attempts to justify them on the basis of geology and/or limitations in field - procedure.

<u>Sounding Number</u>	<u>Reason for low, final layer apparent resistivity</u>
1/3 (12)	Basement is Bokkeveld, not Table Mountain Sandstone.
1/4 (20)	Basement is Bokkeveld, not Table Mountain Sandstone.
2/1 (20)	Basement is Bokkeveld, not Table Mountain Sandstone.
1/11 (15)	On downthrow side of Uitenhage Fault.
2/6 (30)	On downthrow side of Uitenhage Fault.

15	(40)	TMS too deep for available electrode spacing.
16	(30)	TMS too deep for available electrode spacing.
17	(30)	TMS too deep for available electrode spacing.
19	(20)	TMS too deep for available electrode spacing.
25	(22)	TMS too deep for available electrode spacing.
32	(20)	TMS too deep for available electrode spacing.
36	(12)	TMS too deep or Bokkeveld basement.
40	(15)	TMS too deep or Bokkeveld basement.
41	(14)	TMS too deep or Bokkeveld basement.
8	(35)	800m AB Separation. Possibly too short.
3	(35)	Final layer is low resistivity TMS.
5	(18)	Final layer is low resistivity TMS.
6	(70)	Final layer is low resistivity TMS.
7	(25)	Final layer is low resistivity TMS.
14	(20)	Final layer is low resistivity TMS.
20	(50)	Final layer is low resistivity TMS.
24	(30)	Final Layer is low resistivity TMS.
29	(30)	Final Layer is low resistivity TMS.
31	(50)	Final Layer is low resistivity TMS.

(Numbers in brackets are apparent resistivities in ohm - metres.)

Table 3. Possible reasons for low apparent resistivity of final layer

Near the coast, and particularly in the vicinity of the Coega Saltworks, the validity of some of the interpretations has come into serious doubt. Sounding nos. 33, 34, 37 and 38 with final-layer resistivities of 200, 100, 200 and 200 ohm-metres respectively, and with interpreted depths to basement of 124, 93, 47 and 60 metres, are now considered to have given data leading to erroneous conclusions. The presence of salt-saturated clays with extremely low apparent resistivities of the order of 1,0 ohm - metres is almost certainly responsible in that the relative resistivity of the underlying layers is greatly exaggerated (principle of equivalence). Borehole No. CM 6 which is currently being drilled on the site of Sounding No. 38 has reached a depth of 250 metres without intersecting basement, which, according to the geophysical interpretation should be at a depth of around 47 metres. For the rest of the study area, from Coega westwards, the resistivity survey has yielded fairly good results as a comparison of the geological and geophysical sections and Cretaceous isopach maps will indicate (Figs. 8-11 and 12 and 13).

One possible exception is Sounding No 2/5 where the interpreted depth to the final layer which has an apparent resistivity of 100 ohm metres, was 258m. This value does not appear possible as the sounding is sited on the downthrow side of the Uitenhage - Coega Fault where the depth to TMS is in the order of 1000 metres (see section on seismic reflection, p 36). There could be an error in data collection, interpretation, or the value for the final layer could be a geological phenomenon related to the fault.

Two exploration boreholes were drilled on Sounding Sites 6 and 9 for, among other things, correlation between geology and geophysics. The results were very encouraging with borehole WF 35 (on Site 6) intersecting TMS at 125 metres (geophysical depth was 110m). Borehole RH 39 (on site 9) intersected TMS at 137 metres (geophysical depth was 130 metres). From these figures and data from other sites with boreholes fairly close by, it was deduced that, on average, a correction factor of 1,1 should be applied to the geophysically interpreted depths.

For the purpose of this investigation little attention was paid to the correlation between geology and the various geoelectrical boundaries within the Cretaceous sediments. The reasons for this are twofold.

1. The study is primarily concerned with the Table Mountain Group although the geohydrological properties of the Cretaceous, principally as an aquiclude are appreciated.
2. The discontinuous nature of the sandstone horizons in the Cretaceous, their relative thinness, the large distances between sounding sites and the lack of sufficient reliable borehole data makes correlation difficult, if not impossible.

A comparison between the geophysical interpretation and geological log of borehole RH 39 (Sounding No 9) does reveal that there is an increase in apparent resistivity at about 30 metres - roughly the base of the boulder and sandy horizons and the top of the clays. A similar correlation can be made with borehole WF 35 and Sounding No 6. Here, there is an increase in apparent resistivity at about 27 metres from 10 to 15 ohm - metres. This coincides with the base of a 7 metre thick sandstone horizon at 30 metres. In these instances, the relationship between geology and geophysics suggests that geoelectric methods could be used to map the Cretaceous sediments. In the author's opinion, however, the sounding density would have to be drastically increased, (to the order of about 100 metres between sounding sites) and geological control (by means of boreholes) would have to be greatly intensified.

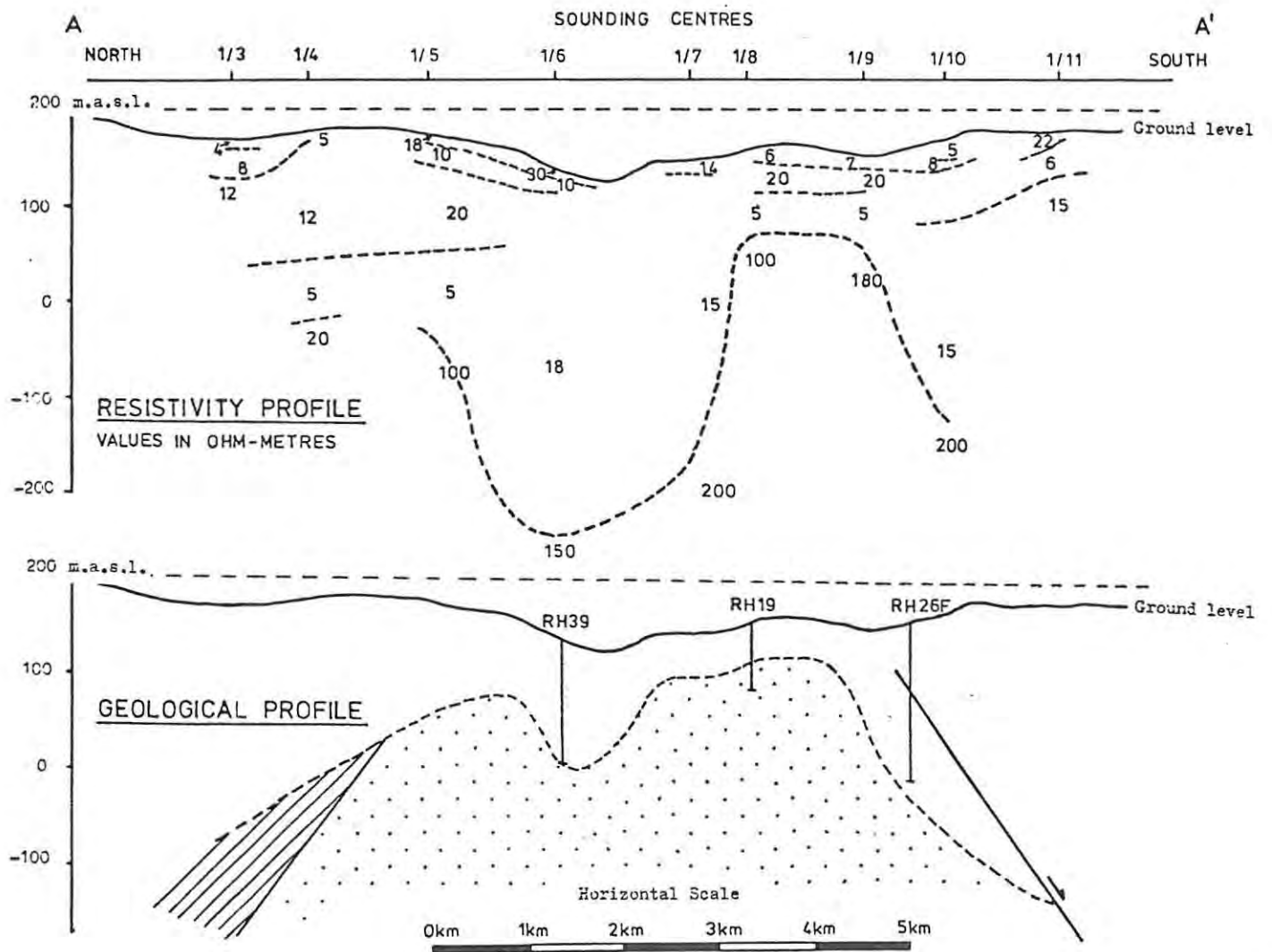


FIG. 8 CORRESPONDING RESISTIVITY AND GEOLOGICAL PROFILES
ALONG SECTION A - A'

(see Fig. 3 for locations and stratigraphic symbols)

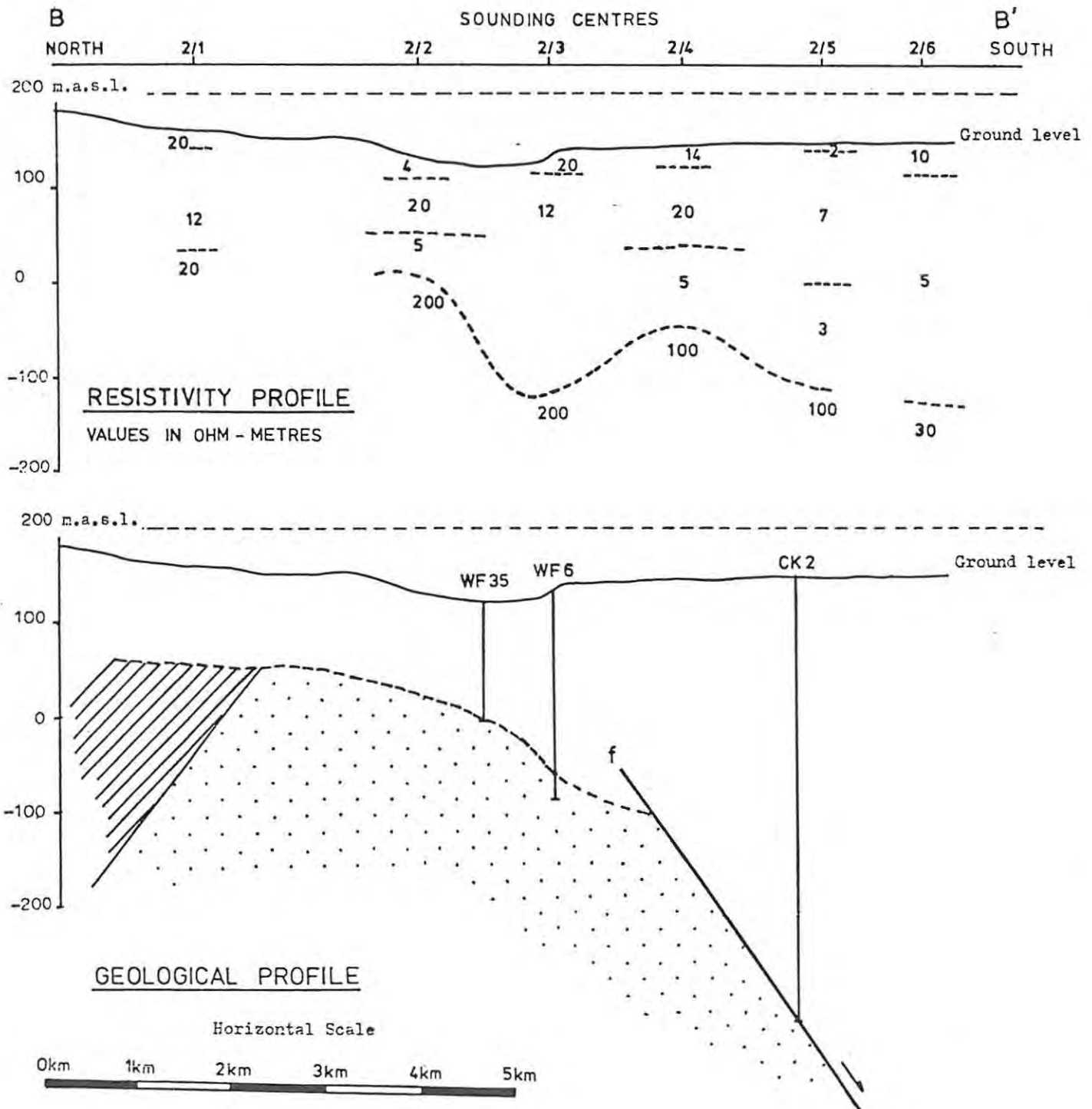


FIG. 9 CORRESPONDING RESISTIVITY AND GEOLOGICAL PROFILES
ALONG SECTION B - B'

(see Fig. 3 for locations and stratigraphic symbols)

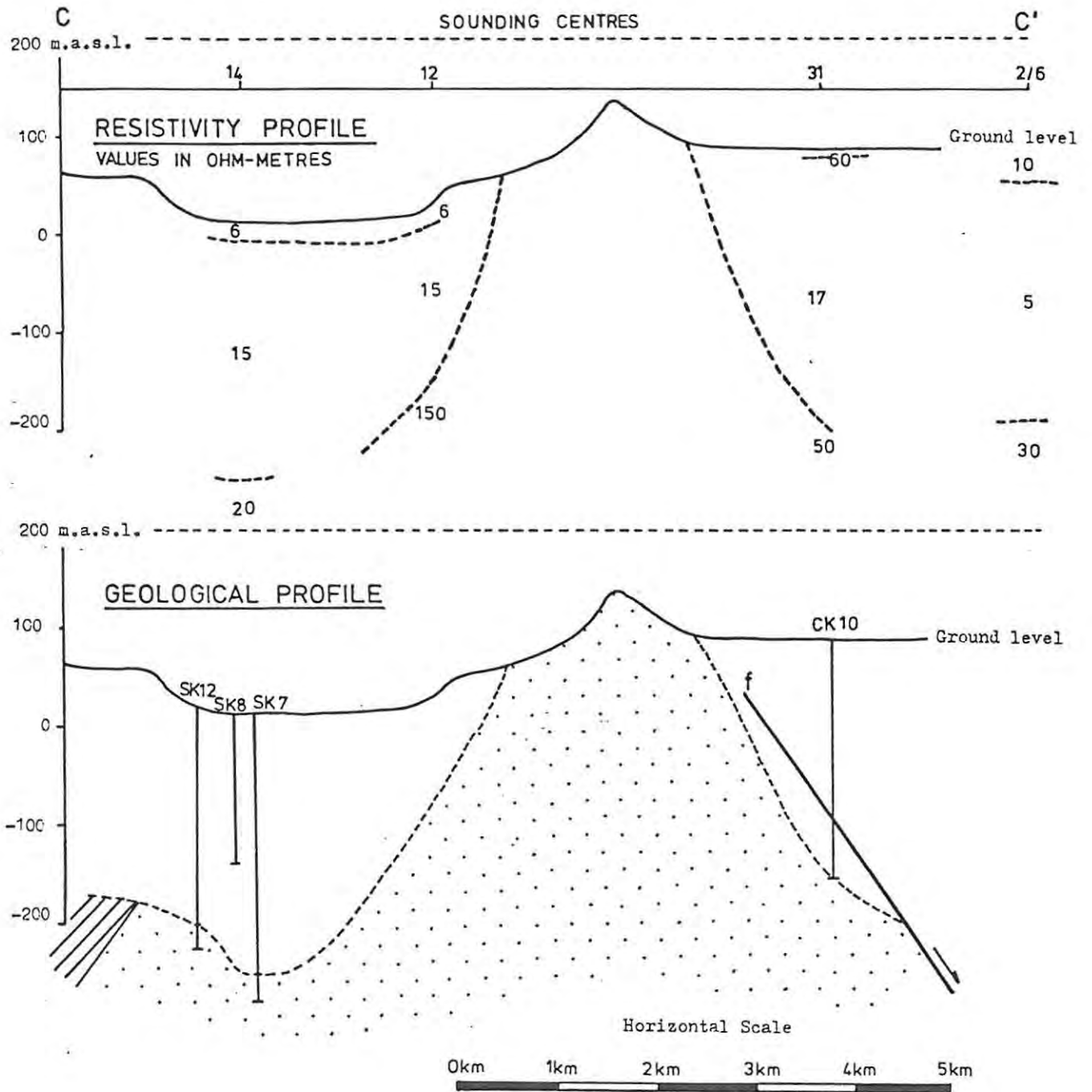


FIG. 10 CORRESPONDING RESISTIVITY AND GEOLOGICAL PROFILES
ALONG SECTION C - C'

(see Fig. 3 for locations and stratigraphic symbols)

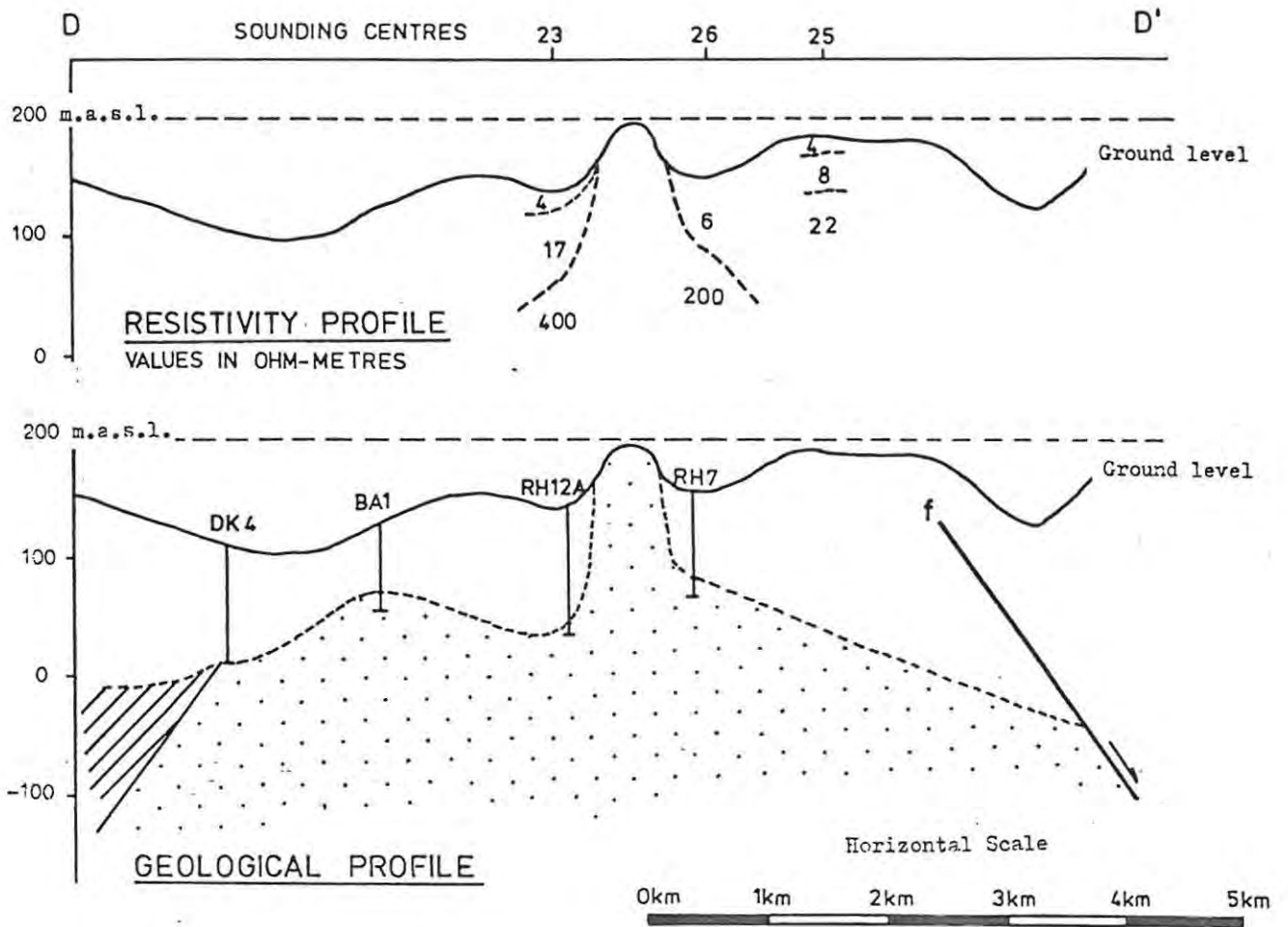
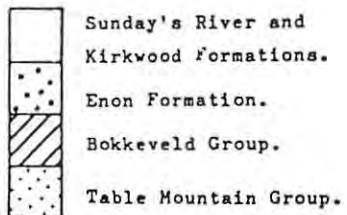
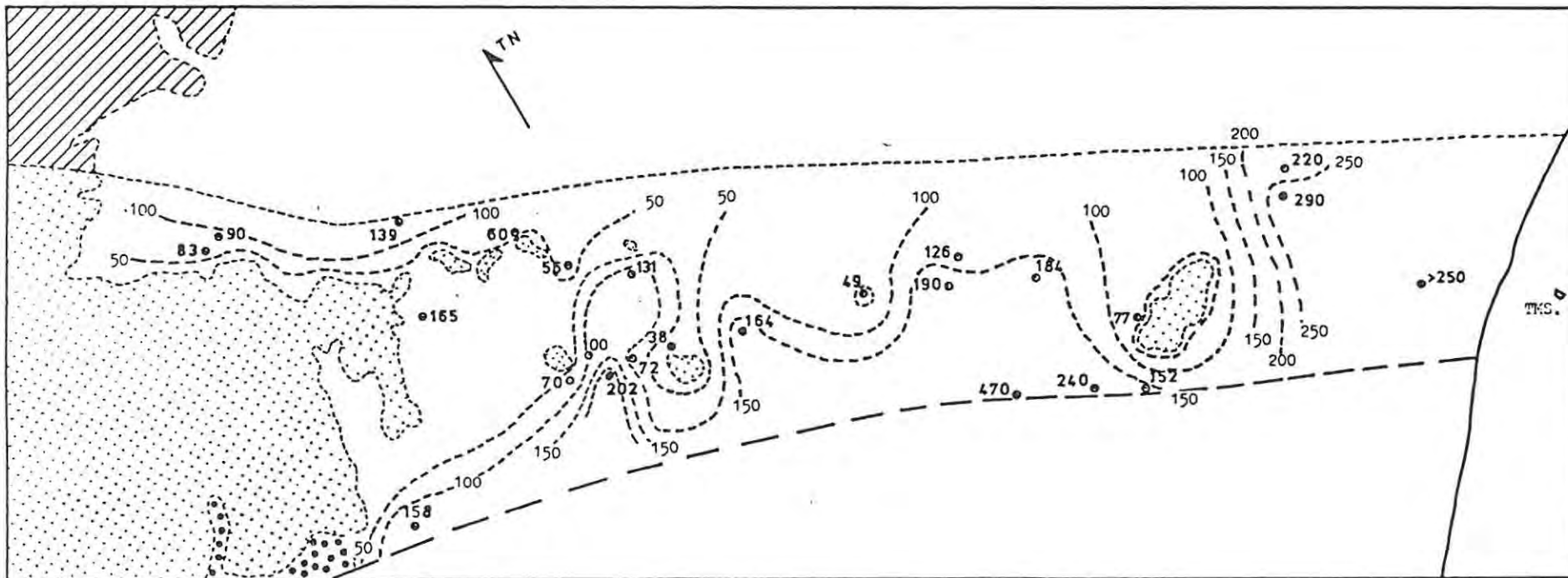


FIG. 11 CORRESPONDING RESISTIVITY AND GEOLOGICAL PROFILES
ALONG SECTION D - D'

(see Fig. 3 for locations and stratigraphic symbols)

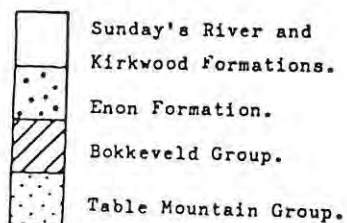
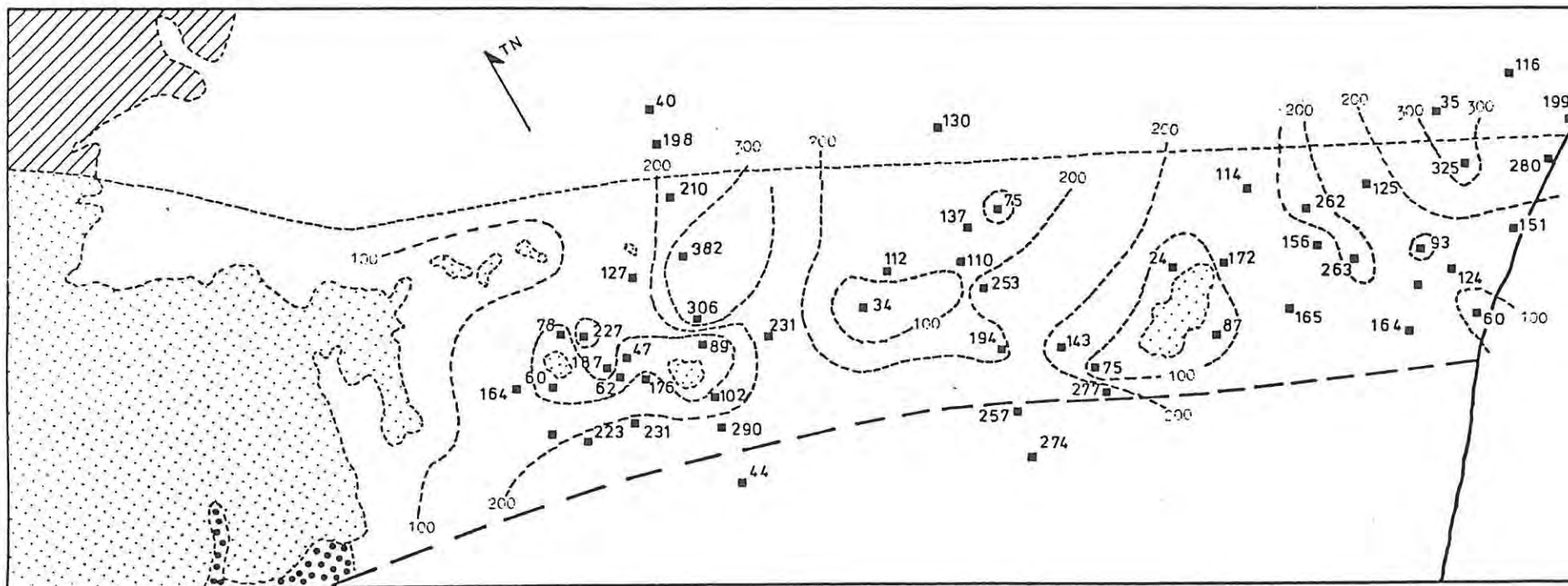


• 90 Borehole with depth to TMS.

— Isopach line



FIG. 12 ISOPACH MAP OF THE CRETACEOUS. (BASED ON GEOLOGY)



■ 60 Resistivity sounding site with depth to deepest interpreted layer in metres.

— Isopach line



FIG. 13 ISOPACH MAP OF THE CRETACEOUS. (BASED ON RESISTIVITY)

The geological/geophysical sections, and isopach maps of the Cretaceous, (Figs. 8-13) are self-explanatory and reveal a good degree of correlation except for the abovementioned coastal section.

Finally, it is important to note that most of the interpretations reveal the existence of a thin top layer of highly resistive material. This is probably dry sand, or topsoil with little or no moisture content, and could be responsible for a number of small data errors, where the high contact resistance between electrode and earth led to erroneous current and voltage measurements.

3.2 Seismic Reflection

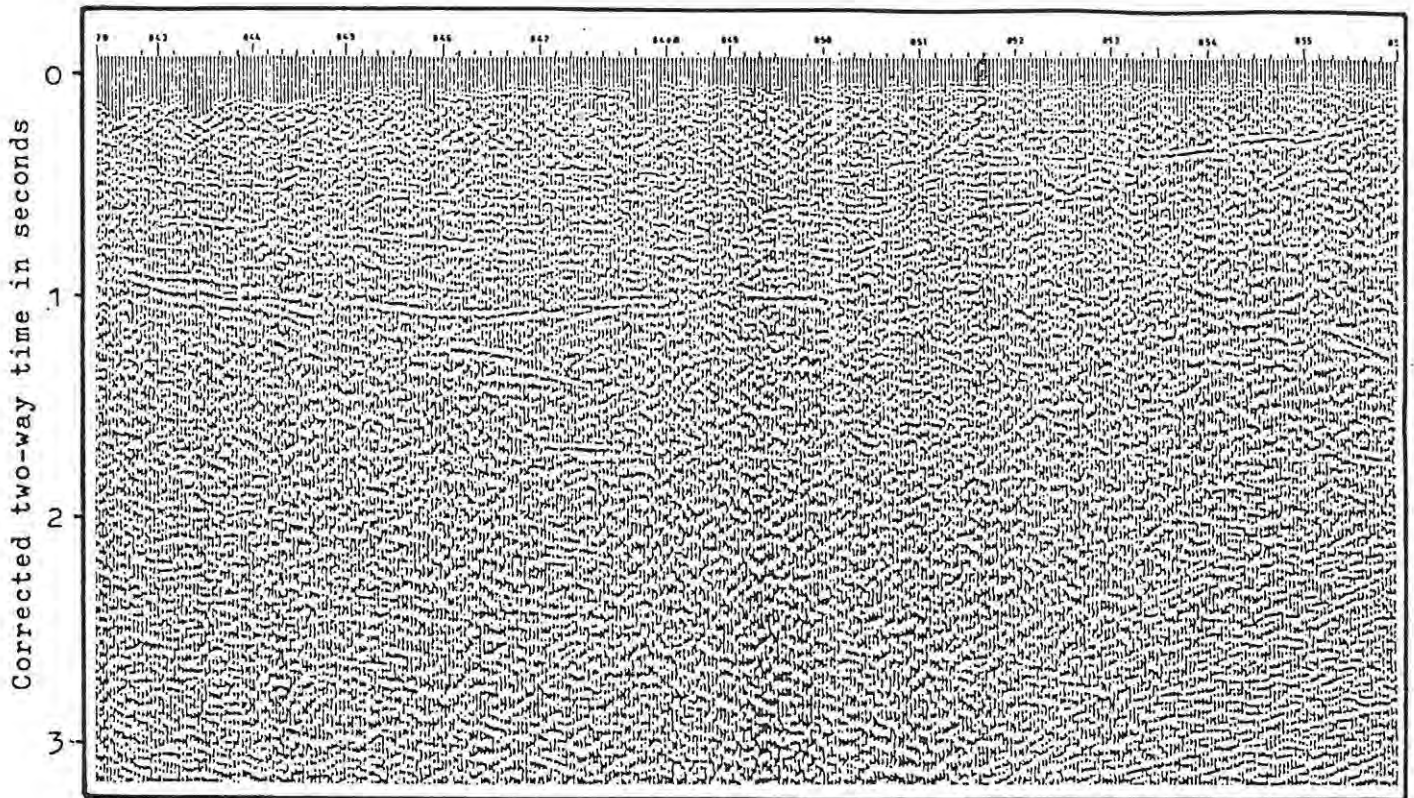
Seismic reflection is based upon the propagation of elastic waves in the earth and their reflection due to changes in the earth's velocity - density distribution (Sengbush, 1983).

Elastic waves travel with different velocities in different rocks. The principle of seismic reflection is to initiate such waves at a point and to determine, at a number of other points, the time of arrival of the energy reflected by the discontinuities between different rock formations. This then enables the position of the discontinuities to be calculated (Parasnis, 1972).

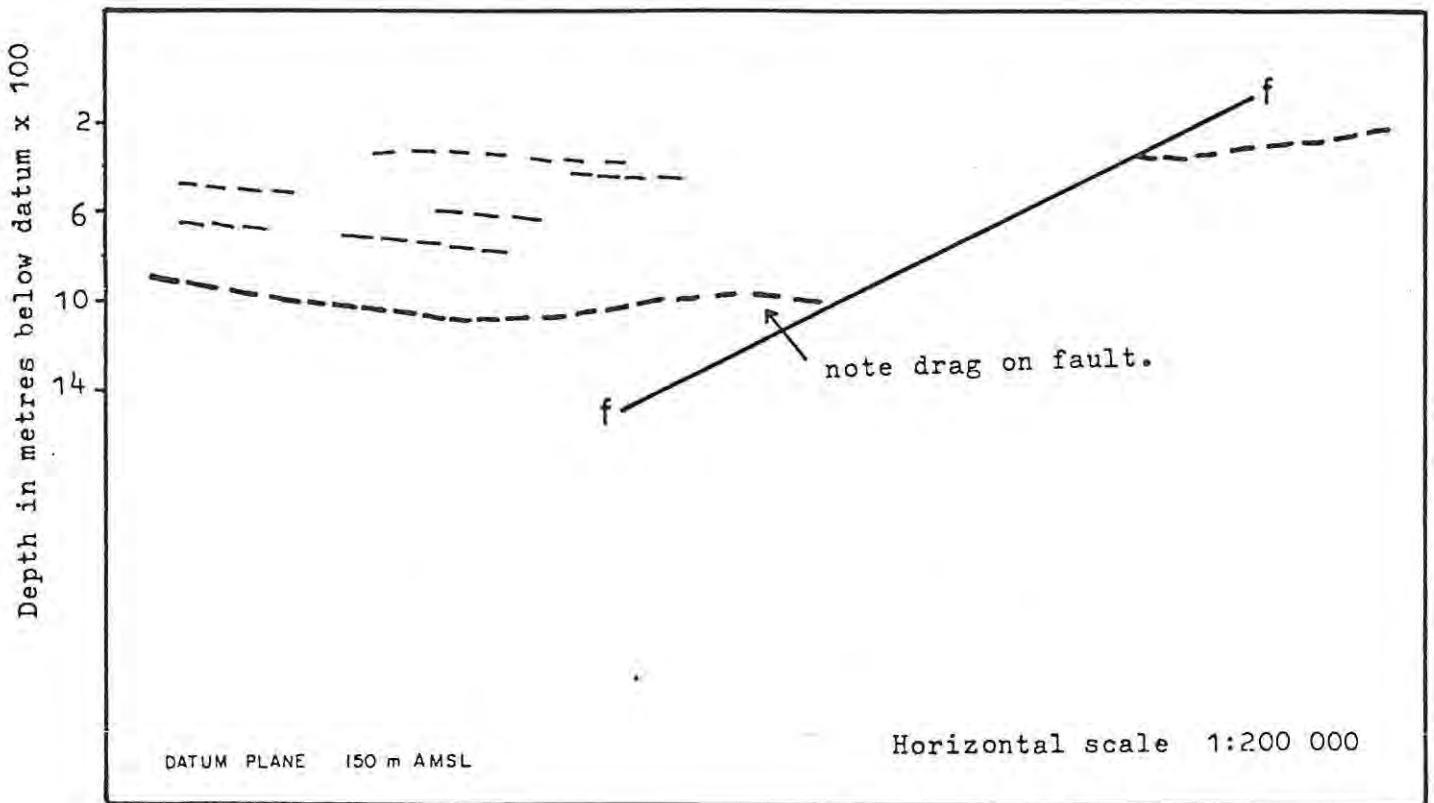
The seismic record comprises a series of "wiggles" running vertically, each corresponding to one sampling point. In the VAR (Variable Area) display depicted on Fig.14A, one side of each wiggle has been blacked out. Reflection signals are recognised by the lining up of troughs and crests on the adjoining traces across the record.

A detailed seismic reflection survey was carried out over the entire Algoa Basin onshore area by SOEKOR in 1976. A portion of the basement contour map covering the Uitenhage - Coega area is presented on Fig.15. Line A-17 was chosen to illustrate the nature of a seismic section (Fig.14 A) and a partial interpretation of this section is shown on Fig. 14 B. Here, the displacement of a major reflective horizon, (the top of the TMS) can be clearly seen across the Coega Fault. Discontinuous horizons, probably representing sandstone beds within the Kirkwood Fm. can be seen above the TMS.

The seismic data suggest a south-downthrow of about 1000 metres for the Coega Fault. This, however, is not substantiated by data from borehole ST 1/71, which intersected TMS at 1753 metres below the seismic datum, effectively giving a downthrow of about 1500 metres. Bearing this in mind, the basement contours on Fig. 15 may be an underestimate of the true depth to basement.



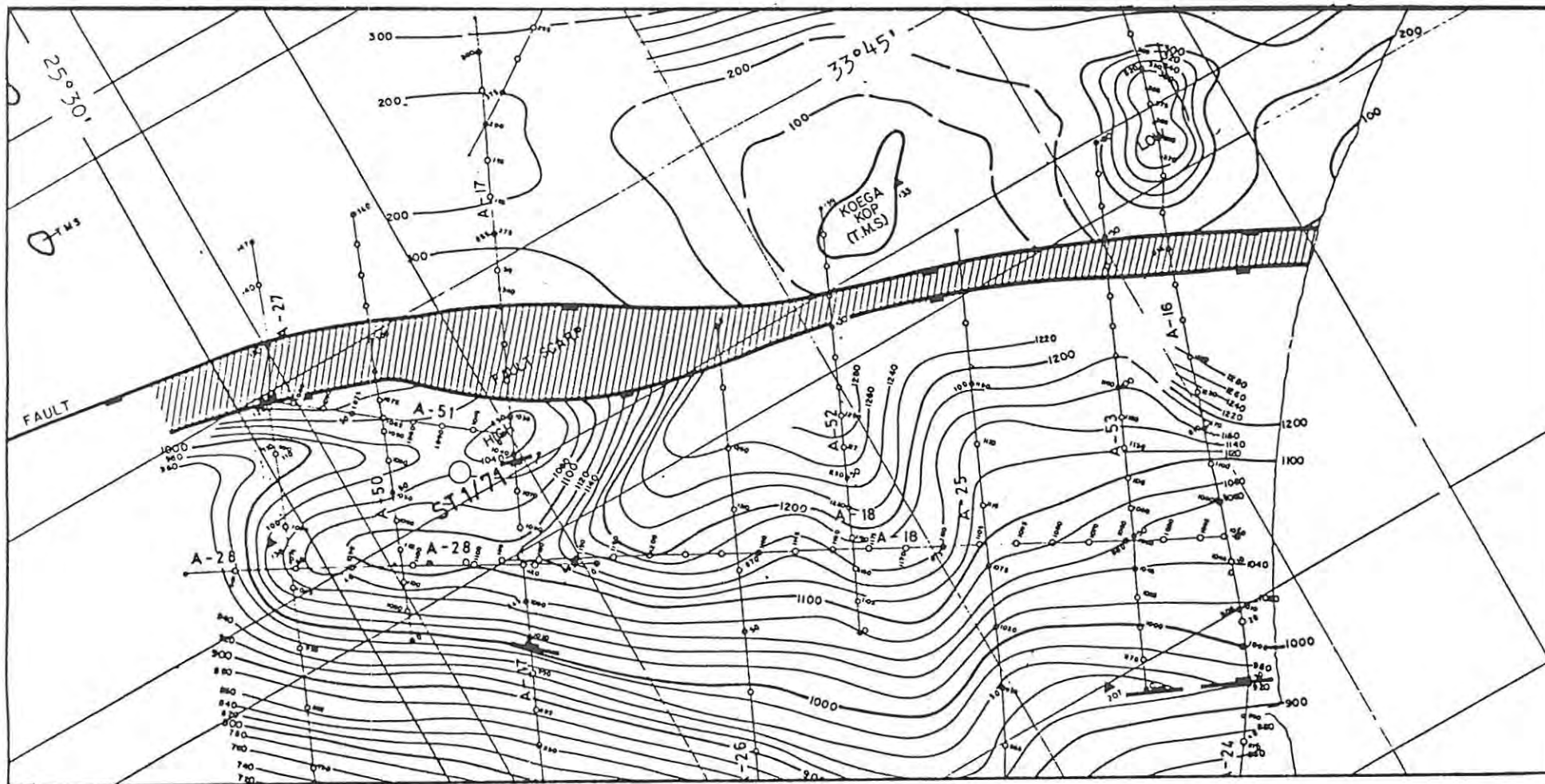
A.



B.

FIG. 14A PART OF THE SEISMIC RECORD FOR S.C.E.K.O.R. AIGCA, LINE A-17 SOUNDING POINTS 862B - 856. (File No 10 C 14)

FIG. 14B ROUGH INTERPRETATION OF THE ABOVE SHOWING DISPLACEMENT OF A MAJOR REFLECTIVE HORIZON - THE TOP OF THE TMS. (Other less reflective horizons probably represent sandstone beds within the Kirkwood Formation.)



CONTOUR INTERVAL . 20 AND 100 ms DATUM PLANE 150 m AMSL

FIG. 15 TWO WAY TIME CONTOUR MAP OF BASEMENT (TMS & BOKKEVELD)



Data from SOEKOR Algoa Basin Onshore Project,
File No. 10 C 14

The contour data south of the fault indicate a fairly uniform dip of about 5° to the north, for the top of the TMS. North of the fault, the shallow-lying Coega Ridge is clearly recognisable by the contours.

3.3 Gravity

Gravimeters give the gravity difference (Δg) between an observation point and a base point. Appropriate corrections involving latitude, topography and elevation must be applied to reduce these differences to standard conditions. The corrected Δg - values are called Bouguer anomalies and are expressed in the unit milligals (Parasnis, 1972).

A detailed gravity survey of the entire onshore portion of the Algoa Basin was conducted by the Geological Survey in 1968. A residual gravity contour map of the study area and surrounding region is presented on Fig. 16. Two geophysical profiles, (X-X' and Y-Y') along with the respective models of the basement geometry are also included (Fig. 17).

The area of shallow-lying and outcropping TMS is clearly represented by relatively high gravity contours, (above - 8 milligals). To the north-east, where the basin deepens considerably, the residual gravity drops to -18 milligals, and, beyond the borders of Fig. 16, to -26 milligals.

This reflects the higher density of the consolidated Table Mountain and Bokkeveld Groups, as compared with that of the Uitenhage Group and provides a useful means for delineating the extent and depth of the basin.

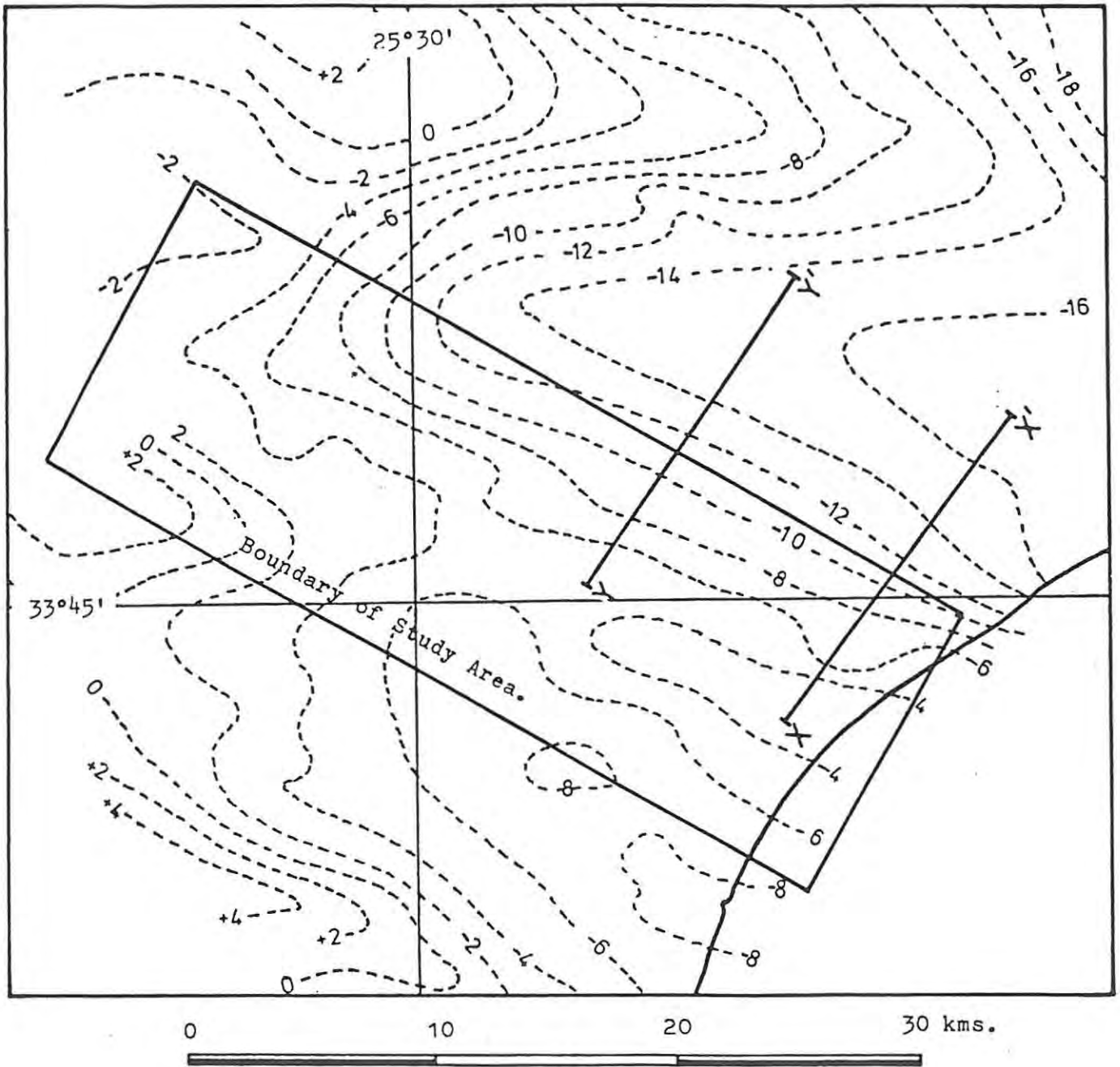


FIG. 16 RESIDUAL GRAVITY CONTOURS (in milligals)

X-X' & Y-Y' are section lines

Data from Geological Survey.
Compiled by R.J.Kleywegt, (1968).

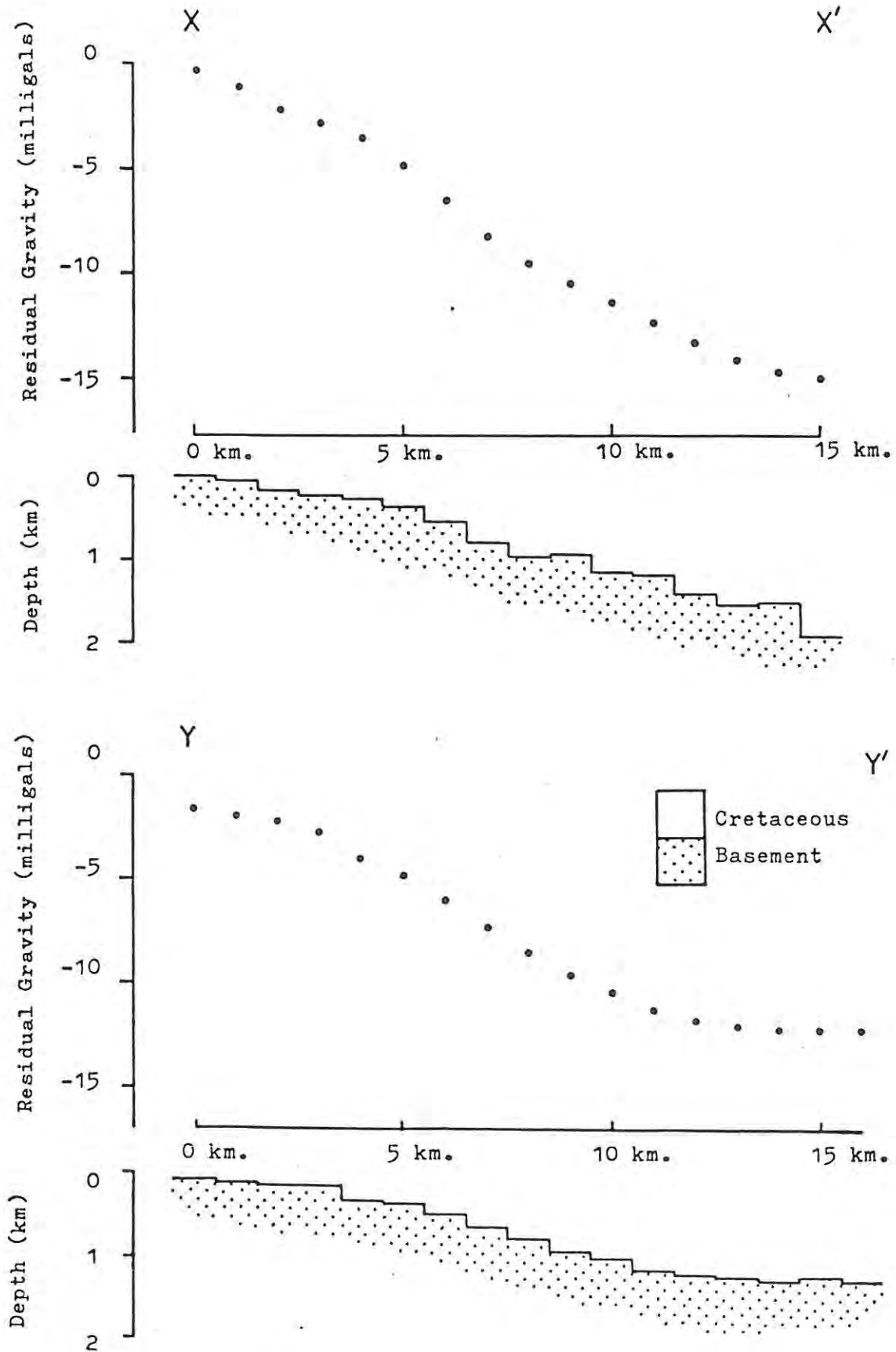


FIG. 17 SECTIONS X-X' & Y-Y'. RESIDUAL GRAVITY AND
MODELLED BASEMENT GEOMETRY

Interpretation by G. Welch (1983, pers. comm.)

CHAPTER 4

Drilling

4.1 Reasons for Drilling

"The surest way to learn the character of the formations beneath the earth's surface, is to drill through them, obtain samples while drilling and record a log of the borehole" (Johnson, 1972, p 159). Although a large number of boreholes have been drilled throughout the study area, very few have reliable borehole logs regarding stratigraphy, water-bearing formations, water yields or hydrochemical changes. In addition, most are located in positions which are unfavourable for the execution of resistivity work, a factor which makes very few suitable for correlation between geology and geophysics. For these reasons, the Division of Geohydrology gave permission for three exploration boreholes to be drilled within the study area. These boreholes, RH 39, WF 36 and CM 6 were sited on resistivity sounding centres Nos.9,6 and 38 respectively. Sites 9 and 6 were chosen for two main reasons;

- 1) The conditions for resistivity work were thought to be very favourable with relatively large AB electrode spacings possible, and little interference from fence wires and other conductive materials. The geological/geophysical correlation was therefore hoped to be as true as possible.
- 2) Both sites were relatively close to the middle of the Coega Ridge with site 9 some 7 kilometres from the Uitenhage Springs and site 6 about 14. Both holes were expected to intersect TMS at a little over 100 metres which is reasonably shallow for the area, and in both cases access for the drilling rig was no problem. With borehole CM6 being 24 kilometres from Uitenhage Springs it was planned that the available boreholes would give as much information as possible on the Coega Ridge, from recharge area to the sea. The relative shallowness and accessibility of RH39 and WF35 were important in terms of time and money.

Borehole CM 6, (sounding centre No. 38) was sited for somewhat different reasons;

- 1) Although previous seismic reflection work suggested a basement low in the area between Coega Kop and the sea (Fig. 15), the resistivity work gave some very strange results with an apparent resistivity of 200 ohm-metres for the final layer of Sounding no.38. This, as is discussed in section 3.1.4 has now been ascribed to the effect of salt-saturated clays. It was hoped that the borehole would help explain this phenomenon.
- 2) No borehole drilled between hole no. SK7 and the sea has ever intersected TMS and it was hoped that this one would do so. Apart from providing valuable samples for hydrochemical analysis, and especially for isotope dating, a TMS intersection would fix the basement depth between the outcrops of Coega Kop and Jahleel Island.

In addition to the three exploration boreholes allocated to the project, valuable information was gained by utilising data gleaned from boreholes drilled for private individuals. Of particular importance here are the four holes drilled on Portions 13 and 14 of Rietheuwel (see Fig. 3A). Geological logs for these seven holes are included as Appendix 4 along with data regarding borehole construction, water quality and yields.

4.2 Methods Employed for Drilling and Sampling.

All three of the exploration boreholes were drilled by means of the cable-tool percussion method. This involves the regular lifting and dropping of a heavy string of tools in the borehole. The drill-bit breaks or crushes the rock into fragments. These are then naturally or artificially mixed with water to form a slurry which is periodically removed by bailing.

Sampling was carried out in the following manner: Rock samples were taken by the driller at one metre intervals and placed in labelled packets to await the geologist. Wherever possible, a washed and unwashed sample was taken to facilitate accurate identification, as washed samples tend to underestimate the amount of fine material originally present. Contamination did cause a few problems but was generally of little concern. Water samples were collected at regular intervals (normally 5 or 10 metres) and the TDS calculated from the electrical conductivity. It is feared that contamination played a more important role here and dissolved solids contents should be viewed with some circumspection.

The four private boreholes were drilled using the rotary air percussion method. This technique employs compressed air as the drilling fluid and for delivering rapid piston-like blows to the down-hole hammer bit. The bit chips and crushes the rock which is then blown to surface by the released compressed air (Johnson, 1972). This method is far quicker than the cable tool method but can only be used in hard, consolidated formations where caving of the hole does not occur.

Rock and water samples were collected, not by bailer as previously, but by sampling the material blown out of the top of the hole. Rock samples were collected every metre but water samples only where measurable water was struck.

On completion of the various boreholes, those that were to be used for production were fitted with PVC casing and the dry holes were allowed to collapse. Two of the exploration holes (RH 39 and WF 35) will be fitted with permanent water level recorders and CM 6 (when it is completed), will be sealed with cement to prevent any further leakage of artesian water.

4.3 Results of the Drilling

4.3.1 Borehole WF35 (G 35739) See Appendix 4 for Log

Resistivity data indicated a depth of 110 metres to the top of TMS which was actually intersected at 125 metres. The lithology of the Cretaceous rocks, comprised predominantly multicoloured clays with three sandstone horizons (maximum thickness was 7 metres) and a boulder horizon. Very weak water was intersected at 25 metres. This was of poor quality (3300mg/l). A stronger flow was encountered in the TMS (1,2 l/sec.), but the quality remained poor even after 2 hours pumping. As the hole was drilled primarily as a stratigraphic and correlation borehole, no attempt was made to drill deeper into the TMS to increase the yield.

4.3.2 Borehole RH 39 (G35740) See Appendix 4 for Log

TMS was intersected at 137 metres, slightly deeper than the interpreted resistivity depth of 130 metres. The geology once again comprised mainly clays of the Kirkwood Formation (86%), with two narrow sandstone horizons and two boulder beds (one of 8 metres). Both sandstones yielded very weak water and no increase was recorded when the TMS was intersected. As with borehole WF 35, the yield and quality could probably be drastically improved by deepening the hole and sealing off the water from the overlying Cretaceous sediments.

4.3.3 Borehole CM 6 (G 36201) See Appendix 4 for Log.

Resistivity interpretations of sounding no.38 indicated the presence of a geoelectric horizon with a high apparent resistance of 200 ohm-metres some 47 metres below surface. The hole is at present incomplete, but at 250 metres has still not intersected TMS. As this borehole is situated immediately adjacent to the Coega Saltpan, it has been suggested (section 3.1.4), that the salt-saturated clays near the surface may have acted as a zone of extremely high conductivity, exaggerating the resistance of the deeper horizons where fresh water is present.

Lithologically the borehole consists mainly of clay with many thin, interbedded sandstone bands. The quality of the water intersected up till 150 metres was extremely bad, reflecting inflow from the salt brine. At 150m, however, fresh artesian water was intersected and the overall quality improved dramatically. Chemical analysis of this artesian water indicates that, in all probability, it is derived from the TMS. It is suspected that the water entered the borehole through a system of interconnected, permeable sandstone horizons within the Cretaceous after being forced upwards under artesian pressure.

Drilling continued to 250m where it was temporarily suspended because of severe sidewall caving. An attempt was made to cement the section below the casing but this was unsuccessful when the cement failed to harden.

The hole is at present flowing at about 0,2 l/sec. and the water quality is good. For these reasons it is considered by the author to be important to determine the origin of the water and drilling should continue. In the meantime the valuable geological information so far obtained has indicated that all the resistivity results in this part of the study area should be viewed with suspicion. A comparison between the isopach maps drawn up on the basis of resistivity and geology (Figs. 12 and 13 respectively), reveals the great disparity in this area.

4.3.4 Private Boreholes - RH 31, RH 34, RH 35, R 36 See Appendix 4 for logs

Borehole RH 31 was drilled as a replacement for RH 1 - a badly leaking borehole which had to be sealed with cement from top to bottom. This was intersected at 71 metres after a sequence of clays mudstones and siltstones. The borehole is at present flowing at 1,2l/sec. and has been yield tested at 8,9 l/sec. PVC casing has been grouted in and the borehole has been fitted with a control valve in case it becomes necessary to restrict the flow of

Boreholes RH 34 and RH 35 were dry holes which had failed to intersect TMS at their final depths of 98 and 202 metres respectively. All the casing has been removed and both have collapsed.

Borehole RH 36 was drilled to replace RH 24 and was successful in that TMS was intersected at 108 metres, and a good yield of good quality water obtained. This borehole is currently flowing at 1,9 l/sec and has also been cased with PVC.

CHAPTER 5

Aquifer Testing

5.1 General Theory

A pumping test may serve two main objectives;

- a) It may be performed in order to determine the hydraulic characteristics of the aquifer. These may include variables such as Transmissivity (T), Storage (S) and Permeability.
- b) It may provide information about the well itself. This may facilitate decisions on pump type to be used, depth of pump inlet, optimum discharge rate and pumping duration.

Theoretically, the execution of a pump test is rather simple, involving the measurement of factors such as yield, drawdown with time, and distance of observation point from abstraction point (Kruseman and de Ridder, 1970). In practice, however, problems, (particularly mechanical ones) frequently occur, making interpretations difficult.

5.1.1 Constant Rate Pump Tests

Constant rate tests are performed by pumping a borehole at a constant discharge rate and measuring the amount of drawdown in the pumped hole as well as in neighbouring observation holes. The appropriate time-discharge data are plotted along with the discharge rate and a variety of techniques are employed to arrive at values for the hydraulic properties mentioned above. On cessation of pumping the recovery of the water level is also measured, and is used as a check on the drawdown data.

As the aquifer in question, the Table Mountain Sandstone, is confined by the Cretaceous sediments and the flow is in an unsteady state, the methods of analysis of the constant rate pump test data are based on the work of Theis (1935), who developed the classic unsteady-state or Theis equation;

$$s = (Q/4 \pi T) W(u) \dots \dots \dots \text{Eq.5}$$

where $u = r^2 S/4Tt$

s = drawdown measured at a distance r from the pumped well

Q = discharge

S = coefficient of storage

T = transmissivity

t = time in days since pumping started

W(u) is read as the well-function of u or Theis well function and is an exponential integral which varies with u. Values for W(u) are obtained from tables once u is known.

The Theis solution is based on the following assumptions, (Kruseman and de Ridder, 1970);

- The aquifer is infinite in extent.
- The aquifer is isotropic and of uniform thickness (over the area affected by pumping).
- Prior to pumping, the piezometric surface is horizontal.
- The discharge rate remains constant.
- The pumped well penetrates the entire aquifer.

In addition the following conditions should be met:

- The aquifer is confined.
- The flow to the well is in an unsteady state.
- The water removed from storage is discharged instantaneously with decline of head.
- The diameter of the pumped well is very small i.e. the storage in the well is negligible.

These ideal conditions are extremely rare (if not absent) in nature and the TMS aquifer is no exception. Although for the purpose of the pump test, the aquifer may be considered to be of infinite extent, it certainly is not isotropic. The piezometric surface is considered to be virtually horizontal and the discharge rate is as far as possible kept constant. The aquifer is confined, but the well in no case fully penetrates the aquifer. However, the well diameter is small, flow is in an unsteady-state and for all intents and purposes, the water removed from storage is discharged instantaneously with decline of head.

In spite of the limitations imposed by the Theis assumptions, in the opinion of the author, an idea of the hydraulic characteristics of the aquifer could still be gained. Hantush, (1962) has devised a solution for partially penetrating aquifers, based on the Theis equation, but this method requires a knowledge of total aquifer thickness and hydraulic conductivity of the aquifer, variables which at this stage are unknown. One severely limiting factor in the analysis of the data was the lack of observation boreholes. Only in the case of CK10-CK11 was there an observation borehole present, and in this case the distance between the holes was probably too small for accurate results.

With all these factors in mind, four different methods, all based on the original Theis equation were used in an attempt to analyse the data.

5.1.1.1 Theis's Method

This technique involves curve matching, where a "type curve" of $W(u)$ is plotted against $1/u$ on double logarithmic paper. On another sheet of the same scale, drawdown (s) is plotted against t/r^2 . The data plot is then placed on top of the type curve and the position of best match is located. An arbitrary match point (A) is then selected (normally where the co-ordinates of the type curve are $W(u) = 1$ and $1/u = 10$). These values are then substituted into the following equations to solve for T and S.

$$T = (Q/4 \pi s)W(u) \dots \dots \dots \text{Eq.6}$$

$$S = 4T (t/r^2) u \dots \dots \dots \text{Eq.7}$$

This method can only be employed where there is an observation hole available as it is dependent on the determination of values for t/r^2 , where r is the distance between the pumped and observation hole(s).

5.1.1.2 Chow's Method

Chow (1952) developed this method, based directly on the Theis equation and subject to the same assumptions and conditions. The technique has advantages in that it avoids curve fitting and enables values for T to be calculated even when no observation borehole is present.

For the borehole in question, whether it be the pumped or observation hole, drawdown is plotted against time with time on the log scale of single logarithmic paper. A point, A, is selected on the curve through the plotted points and a tangent to the curve is drawn through A. Three values are now

- s_A = the drawdown value for point A
- Δs_A = the drawdown difference per log cycle
- t_A = the time value for point A.

The variable $F(u)$ is now calculated according to the formula:

$$F(u) = s_A / \Delta s_A$$

Knowing the value for $F(u)$ the corresponding values for $W(u)$ and u are read from tables. The values along with those for s, Q, t and r are then substituted into Eqs. 6 and 7 to solve for T and S .

5.1.1.3 Jacob's Method

The Jacob method (Cooper and Jacob, 1946) is also based on the Theis equation, avoids curve fitting and allows T to be calculated without observation holes. This technique is applicable only when the value for u is small i.e. less than 0.01. In the equation,

$$u = r^2 S / 4Tt \dots\dots\dots \text{Eq.8}$$

it is apparent that u will decrease as r is decreased and t is increased. The Theis equation (Eq. 5) can be rewritten as;

$$s = (2.30 Q / 4 \pi T) \log (2.25 Tt / 4r^2 / s) \dots\dots\dots \text{Eq.9}$$

A plot, therefore of s vs. $\log t$ should form a straight line. This line is extended till it intersects the time axis where $s = 0$ and $t = t_0$. Substitution of these values into equation 9 gives the following:

$$T = 2.30 Q / 4 \pi \Delta s \dots\dots\dots \text{Eq.10}$$

where Δs is the drawdown per log cycle of t , and

$$S = 2.25 Tt_0 / r^2 \dots\dots\dots \text{Eq.11}$$

To check for the validity of this method (i.e. u less than 0.01) the values are substituted into Eq. 8 and a minimum pumping time, t , is calculated. A pump test must be of longer duration than this calculated time if the Jacob method is to be applicable.

5.1.1.4 Theis's Recovery Method

The rise of water level on cessation of pumping can be measured as residual drawdown s'' , i.e. as the difference between the original water level prior to pumping and the actual water level measured at a time, t'' since pumping stopped (Kruseman and de Ridder, 1970). For calculation purposes, the rate of recharge, Q is taken to be equal to the rate of discharge Q during pumping. Once again the assumptions and conditions of the Theis method should be satisfied. Where S is constant and u is sufficiently small, the residual drawdown is given by;

$$s'' = (2.30 Q/4 \pi T) \log t/t'' \dots\dots\dots \text{Eq.12}$$

For an observation hole or the pumped hole, s'' is plotted against t/t'' where t = time in days since pumping started and t'' = time in days since pumping stopped. A straight line is fitted through the plotted points and, since the slope of the line is equal to $2.30 Q/4 \pi T$, the value of, $\Delta s''$, the residual drawdown difference per log cycle of t/t'' can be substituted into Eq. 9 as follows:

$$T = 2.30 Q/4 \pi \Delta s''$$

It should be noted that, with this method, no value for S can be obtained.

5.1.2 Variable Rate Pump Tests (Step Tests)

"A step drawdown pumping test is one in which the drawdown in a borehole is observed while the discharge rate is increased in steps" (Clarke, 1977, p 125). The step test was devised by Jacob (1946) in order to solve the equation;

$$s_w = BQ + CQ^n \text{ (n approximately = 2)}$$

where s_w = drawdown
 Q = discharge
 B = aquifer loss factor
 C = well loss factor

The step drawdown test can also be used to determine the transmissivity (T) of the aquifer and to estimate the storage coefficient (Eden and Hazell, 1973).

During the pump-testing programme, three methods were used in determining the well loss factor (C), the aquifer loss factor (B) and the transmissivity (T).

5.1.2.1 Jacob's Method

Jacob (1946) recognised the following general relationship between B and C, the two components of drawdown mentioned above;

$$s_w = BQ + CQ^2 \dots\dots\dots Eq.13$$

He also developed the following general equation for the well loss factor C:

$$C = \frac{\frac{\Delta S_w^i}{\Delta Q^i} - \frac{\Delta S_w^{i-1}}{\Delta Q^{i-1}}}{\Delta Q^{i-1} + \Delta Q^i} \dots\dots\dots Eq.14$$

This equation can be solved graphically as depicted in the Jacob analyses in Appendix 5. The increments of drawdown are determined by plotting drawdown versus time on semilog paper with time on the log axis. The line through the data of each step is extended forward to the end of the succeeding step and the incremental drawdowns and discharge rates from adjacent steps are substituted into the general equation to evaluate C (Clark, 1977).

5.1.2.2 Bierschenk and Wilson's Method

By dividing Eq. 13 throughout by Q, Bierschenk and Wilson (1961) derived the equation;

$$s_w/Q = B + CQ \dots\dots\dots Eq 15$$

The arithmetic plot of s_w/Q (specific drawdown) against Q (discharge) will, therefore, be a straight line with a slope of C and a Y-intercept of B. The increments of drawdown are determined in the same way as for Jacob's method and the total drawdown for each discharge rate is the sum of the incremental drawdowns for all the discharge rates up to and including that step. A good example of this method is provided by the data for borehole RH 31 presented in Appendix 5.

The Bierschenk and Wilson specific drawdown - discharge plot can also be used to estimate transmissivity (T) by utilizing the Thiem (1906) equation;

$$T = (2.3Q/2 \pi s_w) \log r_i/r_w \dots\dots\dots Eq.16$$

where r_i = radius of influence of the well
 r_w = effective well radius

As Q and sw can be measured, an estimate must be made of ri/rw. Experience has shown (Clark, 1977), that log ri/rw is about 3.3. The Thiem equation will therefore reduce to:

$$T = 1.22 Q/sw \dots\dots\dots Eq.17$$

$$As B = sw/Q, \dots\dots\dots Eq.18$$

combining Eqs. 17 and 18;

$$T = 1.22/B \dots\dots\dots Eq.19$$

5.1.2.3 Hazell's Method

Hazell's (1973) analysis requires the reconstruction of the true drawdown discharge-rate curve for each step. This is accomplished by plotting the data on semi-log paper and using the incremental drawdown data to plot each point for each succeeding step.

The transmissivity is calculated by substituting the mean values for discharge (Q) and incremental drawdown per log cycle (Δ sw) into Eq. 9 as follows:

$$T = 2.3Q/4r\Delta sw$$

5.2 Results

The results of the pump test programme are presented in Table 4. In order to evaluate both the well and aquifer characteristics, the various parameters will first be discussed individually. Attention will then be paid to a number of tests where the results were unsuitable for detailed analysis. A synthesis of all the results will complete the chapter. The graphical solutions to the pump test data are presented in Appendix 5.

5.2.1 Aquifer Loss Factor (B)

"The aquifer loss is that part of the drawdown caused by resistance to laminar flow within the aquifer" (Clark, 1977, p 125). Calculated results for B were generally disappointing with only borehole RH 31 yielding satisfactory values. The Bierschenk and Wilson (B & W) method enables the value for B to be read directly from the plot (the Y-intercept of the best-fit straight line), while the Jacob method requires substitution of values into Eq. 13 to solve for B.

Bh. No.	Method of Analysis	B	C	T
RH 31	Jacob steps 1 & 2	$1,95 \times 10^{-2}$	$7,18 \times 10^{-5}$	63 m ² / day
		$2,24 \times 10^{-2}$	$6,70 \times 10^{-5}$	54 m ² / day
		$3 \& 4$	$-2,56 \times 10^{-1}$	$4,40 \times 10^{-4}$
	Hazell	---	---	67 m ² / day
	B & W	$2,00 \times 10^{-2}$	$7,06 \times 10^{-5}$	61 m ² / day
	CK 10	Jacob steps 1 & 2	$6,60 \times 10^{-4}$	$2,50 \times 10^{-6}$
$4,39 \times 10^{-3}$			$-0,90 \times 10^{-6}$	278 m ² / day
$3 \& 4$			$-1,75 \times 10^{-1}$	$1,49 \times 10^{-4}$
Hazell		---	---	114 m ² / day
B & W		$6,80 \times 10^{-4}$	$2,45 \times 10^{-6}$	1794 m ² / day
CK 11		Jacob steps 1 & 2	$-1,90 \times 10^{-4}$	$4,10 \times 10^{-6}$
	$-9,09 \times 10^{-3}$		$1,11 \times 10^{-5}$	-134 m ² / day
	$3 \& 4$		$-2,07 \times 10^{-2}$	$1,88 \times 10^{-5}$
	Hazell	---	---	69 m ² / day
	B & W	invalid - negative Y-intercept		
	BA 1	Jacob steps 1 & 2	$-1,98 \times 10^{-2}$	$2,43 \times 10^{-5}$
$2,02 \times 10^{-2}$			$-7,50 \times 10^{-6}$	60 m ² / day
$3 \& 4$			$1,80 \times 10^{-1}$	$-1,52 \times 10^{-5}$
Hazell		---	---	59 m ² / day
B & W		invalid - negative Y-intercept		

Constant Rate Tests

Borehole No.	Method of Analysis	T	S
RH 31	Theis Recovery	5,4m ² / day	---
CK 10(p)	Jacob	34m ² / day	---
	Chow	33m ² / day	---
CK 10(o)	Jacob(1)	176m ² / day	$1,50 \times 10^{-2}$
	Chow(1)	174m ² / day	$1,62 \times 10^{-2}$
	Jacob(2)	33m ² / day	$2,56 \times 10^{-2}$
	Chow(2)	24m ² / day	$2,48 \times 10^{-2}$
CK 11(p)	Jacob	26m ² / day	
	Chow	24m ² / day	
CK 11(o)	Jacob	186m ² / day	$1,50 \times 10^{-2}$
	Chow	183m ² / day	$1,56 \times 10^{-2}$
	Theis	227m ² / day	$1,07 \times 10^{-2}$
BA 1	Jacob	33m ² / day	
	Chow	33m ² / day	
	Theis Recovery	27m ² / day	
RH 17	Jacob	382m ² / day	
	Chow	382m ² / day	

B = Aquifer loss factor

C = Well loss factor

T = Transmissivity

S = Storage coefficient

B & W = Bierschenk and Wilson

(p) = Data from pumped hole

(o) = Data from obs. hole

Table 4 Aquifer test results

Borehole RH 31 shows good agreement between the values derived by the B & W method and those obtained during the first three steps of the step drawdown by the Jacob method. The negative value of -2.56×10^{-1} obtained for the last step has been attributed to pump inefficiency at high discharge rates and discarded. This can be seen graphically on the discharge versus specific drawdown plot (Fig. 18) where the last point falls well away from the straight line through the others.

The pump test data from borehole CK 10 exhibit good agreement between the B & W analysis and the Jacob analysis for the first two steps. The values, however, are considered to be too low, leading, as will be seen later, to excessively high values for T. The Jacob analyses of the 2nd, 3rd and 4th steps resulted in widely differing values and are considered unreliable.

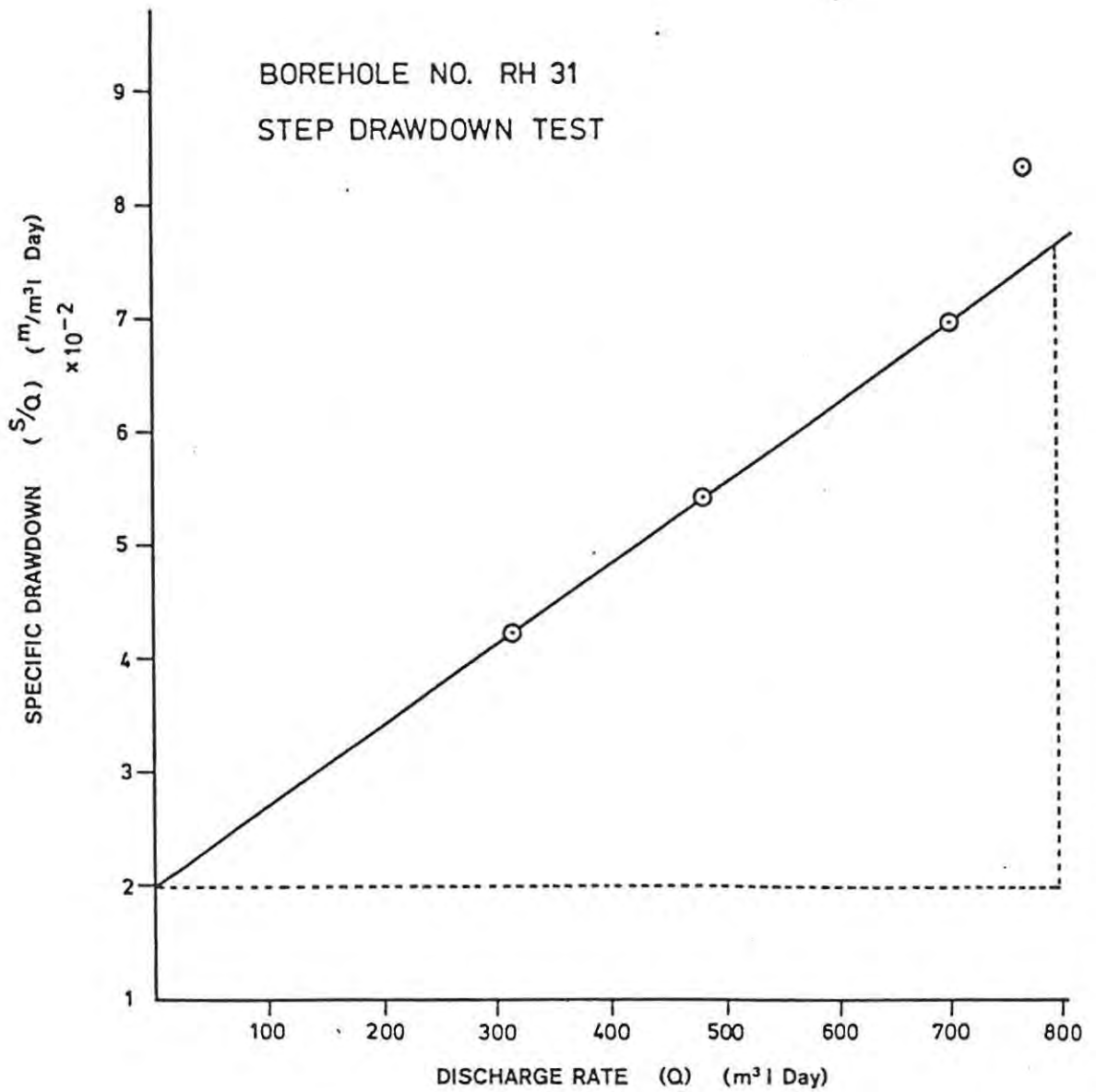
The analyses of the CK 11 pump test data are characterised by all the values for B being negative. The B & W method was not utilized as the Y-intercept of the straight line fell at -2.4×10^{-3} . The negative values may possibly be explained as follows;

Let Eq. 13 be rearranged to solve for B.

$$B = sw/Q - CQ$$

As Q is constant, a negative value for B can arise only if sw is too small or if C is too large. C is computed from values for Q and sw (Eq. 14). It is therefore apparent that too little drawdown for the corresponding abstraction rate is the cause of the negative B-value. Boreholes CK 10 and CK 11 are both artesian in nature and have a history of leakage into the overlying formations and, on occasions onto the surface. Neither of the holes has been cased from the TMS aquifer to the surface and it seems likely that this upward leakage is continuing. On commencement of pumping, the level of water within the borehole drops and the water contained in the upper layers flows, under gravity, back into the hole. This inflow of water results in an underestimation of the drawdown and correspondingly, a negative value for B. In time this water becomes used up and natural conditions prevail. This is substantiated by chemical analysis; after 10 minutes pumping of CK11, the water had a TDS content of 205mg/l. After 30 minutes this had dropped to 118mg/l. A similar phenomenon was noted at CK10. The recharge via the borehole itself will be further discussed in the section on transmissivity, (p 60).

The data from borehole BA1 has also resulted in some strange values for B. The Jacob analysis of steps 2 and 3 leads to a reasonable figure of 2.02×10^{-2} . This is in close agreement with steps 1 and 2 except that the



BIERSCHENK AND WILSON ANALYSIS

Well loss factor (C) = Slope = $7,06 \times 10^{-5}$

Aquifer loss factor (B) = Y intercept = 0,02

Drawdown (S_w) = $0,02 Q + 7,06 \times 10^{-5} Q^2$

Transmissivity (T) = $1,22 / B = 61 \text{ m}^2 / \text{day}$

FIG. 18 BH. RH31 SPECIFIC DRAWDOWN - DISCHARGE PLOT

latter is negative. The analysis of steps 3 and 4 gives rise to a B-value which is considerably higher than most of the others although similar to those at higher pumping rates in RH 31 and CK 10. The initial negative value may once more, be the result of water flowing back into the borehole. At borehole BA 1, some downhole flow is known to occur although the degree to which the drawdown was affected was, until now, not fully appreciated. With the first step being affected by return flow and the fourth by the effects of pump inefficiency, the value for B as derived from the 2nd and 3rd steps will be accepted.

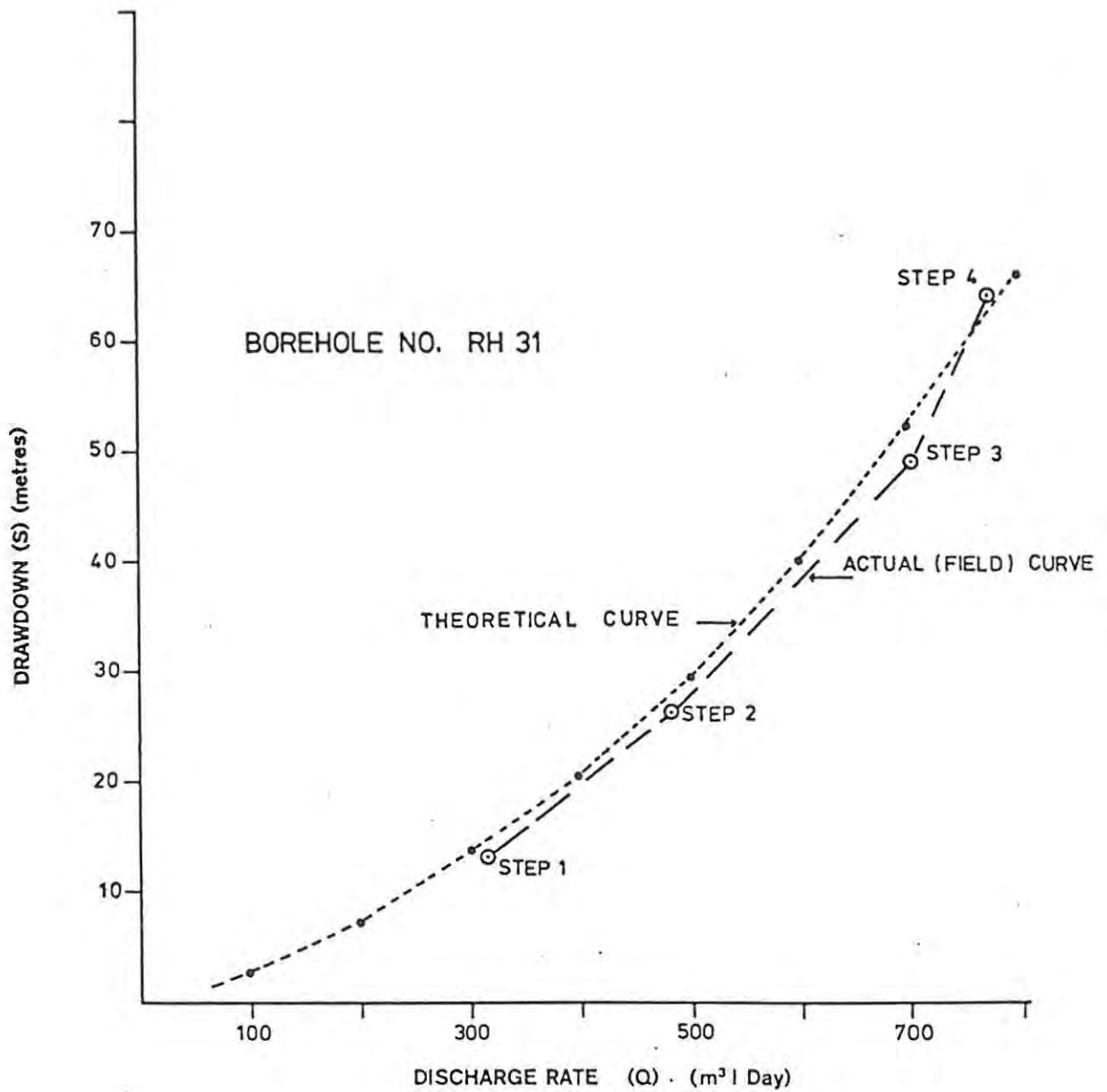
5.2.2 Well Loss Factor (C)

"The well loss results from resistance to turbulent flow in the zone adjacent to the well, and through the screen" (Clark, 1977, p 125). In deep wells, an additional component of well loss is the frictional head loss during flow up the well. C was calculated in two different ways; by substitution of values into Eq. 13, (Jacob Method) and by determining the slope of the straight line in the sw/Q versus Q plot (Bierschenk and Wilson method). The results are presented in Table 4.

As with the determination of B, borehole RH 31 yielded the best results, with a convincing value for C of about $7,00 \times 10^{-5}$. Using this value (actually $6,92 \times 10^{-5}$) and a value of 2.0×10^{-2} for B, a theoretical curve of drawdown versus discharge was constructed (Fig. 19). This compared very well with the actual field data proving that, in this case the Jacob relationship (Eq. 13) is applicable, and that the turbulent component is a second order function of well discharge (Miller and Weber, 1983). Once again, at higher discharge rates, the results deteriorated and the value for C calculated for the final step should be ignored.

Table 5 illustrates how the efficiency of borehole RH 31 decreases with increased discharge, i.e. as the flow becomes more turbulent and C begins to play a greater role.

Analysis of the CK 10 data once again provided some contrasting results. Those from the 1st and 2nd steps and the B & W analysis agreed well and it is these that will be accepted as valid. A negative value for the 2nd and 3rd step data and a high, $C = 1,49 \times 10^{-4}$ for the 3rd and 4th steps has resulted in these being ignored.



Theoretical curve derived from the equation;

$$S_w = BQ + CQ^2$$

B = 0,02 (derived from the Bierschenk and
Wilson analysis)

C = 6,92 × 10⁻⁵ (mean of Jacob and B & W values)

FIG. 19 DRAWDOWN - DISCHARGE CURVES FOR BOREHOLE RH 31

<u>Discharge Q (m³/day)</u>	<u>Well Efficiency</u>
100	74%
200	59%
400	42%
600	32%
800	26%
1000	22%
2000	13%
5000	5%

Table 5 Well Efficiency - Bh. RH 31

It is suspected that casing recharge with water from upper level strata has affected the determination of C for borehole CK 11. There is, however, a measure of agreement among the values derived from the different steps and a mean value of $1,13 \times 10^{-5}$ will be accepted for this borehole.

The borehole BA 1 data has led to a wide range of values for C. In their present state these results are of little value and corrections will have to be made if any use is to be made from them. The disparity in values from BA 1 may once again be the result of flow of water into the well from the surface or it may be a reflection of the non-validity of the Jacob equation in this particular case.

In spite of some of the calculated values for C being obviously incorrect, most are sufficiently similar for there to be a general figure for boreholes in this area pumping from a similar depth. As all these tests were conducted with the pump at 60 metres, it is suggested that for similarly constructed boreholes, a value of $C = 6,5 \times 10^{-5}$ be utilized. This compares favourably with a figure of $1,2 \times 10^{-5}$ for a borehole in the neighbouring Kruis River area (Bush, 1983).

The calculation of the well loss factor is vital in those cases where no observation holes are present and where transmissivity is calculated from the drawdown in the pumped well. As the drawdown comprises well loss and aquifer loss, the effect of the well loss must be calculated and the data corrected to yield the true drawdown. Ignoring well losses leads to an underestimation of T (Clark, 1977). Assuming that all the boreholes and the aquifer obey the Jacob equation, corrections may be made in the following manner.

Example 1 RH 31

$$\begin{aligned}sw &= 26,4 \text{ m} \\Q &= 485 \text{ m}^3/\text{day} \\C &= 7,2 \times 10^{-5} \\ \text{Well loss } CQ^2 &= 16,9 \text{ m} \\ \text{True drawdown} &= 26,4 \text{ m} - 16,9 \text{ m} = 9,5 \text{ m}\end{aligned}$$

Example 2 CK 11

$$\begin{aligned}sw &= 5,52 \text{ m} \\Q &= 1169 \text{ m}^3/\text{day} \\C &= 4,2 \times 10^{-6} \\ \text{Well loss } CQ^2 &= 5,74 \text{ m} \\ \text{True drawdown} &= 5,52 \text{ m} - 5,74 \text{ m} = - 0,22 \text{ m}\end{aligned}$$

The true drawdown (BQ) can also be calculated for RH 31 as follows:

$$\begin{aligned}BQ &= 0,02 \times 485 \\ &= 9,7 \text{ m}\end{aligned}$$

This is close enough to the previously calculated value, and a mean value of 9,6 m is accepted.

The calculated true drawdown for CK 11 is obviously false as the resultant drawdown is negative. This may be due to either:

- a) Incorrect determination of C. As mentioned previously (section 5.2.1), inflow of upper level water will affect the measured drawdown and upset the correct calculation of C from Eq. 14.
- b) Non-applicability of the Jacob relationship. It has been suggested, (Rorabaugh, 1953), (Miller and Weber, 1983) that treatment of discharge as a second order variable in the turbulent component was overrestrictive. In this case it may be necessary to raise the discharge to a power of slightly less than 2 in the term (CQ^2) for the relationship to hold true.

5.2.3 Transmissivity (T)

"Transmissivity is the rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient" (Lohman, 1972, p 6). Various methods, employing both variable and constant rate pump tests were utilized in determining T. Mechanical problems with the pump prevented the execution of a

constant rate test at RH31 and the very low T as calculated by the Theis recovery method reflects the non-constant nature of the test. The constant rate test was not repeated at RH31 because of time constraints and because the results of the step tests were so conclusive in evaluating T. Ignoring the Jacob analysis of the 3rd and 4th steps, the mean of the other calculated values was $61\text{m}^2/\text{day}$ with a standard deviation of 4,7.

The determination of T from the CK10 pump test data has been complicated by the very large spread of values. The Hazell method, which has been very reliable, especially with regard to the RH31 and BA1 data, provided a value of $114\text{m}^2/\text{day}$. The very high values determined by the B & W analysis and the Jacob method for steps 1 and 2, are considered to be erroneous because of doubtful results for B and C. The value for the Jacob method (steps 2 and 3) is also viewed with distrust because of the negative C-value assigned to this calculation. The constant rate test analyses of Jacob (1946) and Chow (1952), although agreeing closely for any particular segment of the drawdown-time curve, do show marked differences when different portions of the curve are used.

It is a characteristic of both CK10 and CK11, that the drawdown-time curves show an initial, slow drawdown, followed after a few hours by comparatively rapid drawdown. This is attributed, as were some of the strange step-drawdown results, to flow of water into the borehole from the saturated upper layers. In time this inflow would cease and normal pumping conditions would commence. Unfortunately this fact was not recognised in time and pumping was stopped before conditions approaching equilibrium were met. For this reason, Jacob and Chow analyses conducted on the steeply-rising, rapid drawdown portions of the curves, should be accepted as providing minimum T-values only. The analyses, Jacob (1) and Chow (1), giving T-values of 176 and $174\text{m}^2/\text{day}$ respectively, should be ignored. These are interpretations of the drawdown-time conditions prevailing when inflow into the well was occurring and do not represent the transmissive qualities of the aquifer at all.

The calculated value for T from the CK11 pump test data should be similar to CK10 as the two holes are only 4,40 metres apart. From the results it is apparent that CK11 must be even more prone to downhole return-flow than CK10. Not only are all the T-values calculated by the Jacob step-test method negative, but the drawdown-time, constant rate plot, takes considerably longer to start reacting to pumping conditions and observing normal drawdown patterns.

Although forced by time factors to curtail the test early, the data from the pump test on CK11 with CK10 as an observation borehole possibly provides one

of the most satisfactory values for T in this area. This figure of $186\text{m}^2/\text{day}$ is almost three times that derived by the Hazell method ($69\text{m}^2/\text{day}$) but it must be remembered that the latter, like all the step-test analyses, was affected by water inflow. The Theis solution to this data arrives at a value of $227\text{m}^2/\text{day}$ for T and is also considered to be reliable. Bearing all these factors in mind, a transmissivity of $T = 200\text{m}^2/\text{day}$ is thought to be reasonable for the TMS aquifer in this area.

Interpretation of T-values from the BA1 pump test data is also complicated by negative values for B and C. The Jacob analysis of steps 1 and 2 of the step test has led to a negative T of $-62\text{m}^2/\text{day}$. This is, without doubt, also due to return flow, a feature which can be detected at the beginning of the constant rate drawdown - time graph. The figure derived from steps 2 and 3 ($60\text{m}^2/\text{day}$) is probably not greatly in error as it matches that obtained by the Hazell method. As was the case with CK10 and CK11, the constant rate analyses of Jacob and Chow, as well as the Theis recovery method, probably result in underestimations of T as equilibrium conditions had not yet been obtained. A value of $T = 60\text{m}^2/\text{day}$ is considered reasonable for the TMS aquifer in the vicinity of BA1.

The constant rate pump test at RH17 - the Edwards borehole, yielded a value for T of $382\text{m}^2/\text{day}$. As the curve was beginning to flatten off, this must also be considered a minimum value and a figure of $400\text{m}^2/\text{day}$ will be accepted. Unfortunately it was not possible to throttle down the submersible pumps used for the test, and as such, a step test was not carried out.

5.2.4 Storage Coefficient (S)

"The storage coefficient is defined as the volume of water released or stored per unit surface area of the aquifer per unit change in the component of head normal to that surface" (Kruseman and de Ridder, 1970, p 21). The storage coefficient is designated the symbol S and is dimensionless.

In order to calculate the value for S, it is necessary either to have at least one observation borehole or to have some knowledge of the radius of influence of the pumping well (Clark, 1977).

Observation boreholes were only available in the CK10 - CK11 system and here, seven determinations of S were made using the Jacob, Chow and Theis methods (see results in Table 4). Agreement was very good and resulted in a mean of

$1,76 \times 10^{-2}$ with a standard deviation of $0,51 \times 10^{-2}$. Although the anisotropic nature of the aquifer makes estimation of the radius of influence risky, and errors are squared in the calculation, an attempt was made to calculate S with the RH31 data. Using 100 metres as the radius of influence of the well, a value of $S = 1,98 \times 10^{-4}$ was obtained.

According to Johnson (1972), values of S for artesian aquifers range from $1,0 \times 10^{-5}$ to $1,0 \times 10^{-3}$. The values for the CK10 - CK11 system fall outside this range and must be viewed with some circumspection as the influence of water flowing down the well could have upset the calculations. The value obtained for RH31 falls neatly into the middle of the abovementioned range but once again it must be emphasized that an arbitrary figure was used for the radius of influence.

5.2.5 Other Pump-Test Results

5.2.5.1 Borehole RH1

Before sealing this leaking borehole with cement, a short constant rate test was carried out. It took only 30 minutes to draw the water level down to the pump inlet at 53 metres. The measured discharge was $51\text{m}^2/\text{day}$. Recovery was then allowed to commence with full recovery not being obtained after 400 minutes. The shape of the recovery curve is shown in Fig. 20.

The rapid drawdown may be explained as follows: During cleaning of the hole prior to sealing, it is suspected that some of the old casing was forced downwards until it formed a plug which effectively blocked off the TMS water. The water in the hole was then a mixture of TMS and Cretaceous water (supported by chemical analysis). When pumping commenced, the drawdown was rapid because there was no replenishment from the TMS. During pumping it was noticeable that a large amount of clayey material was discharged with the water, possibly resulting in a large number of cavities in the borehole and near the pump in particular. When recovery commenced, these cavities filled first so that there was little rise in water level. When the cavities were filled, normal recovery took place - rapid at first and gradually slowing. The transmissivity calculated from the recovery data was very low with a value of $5\text{m}^2/\text{day}$.

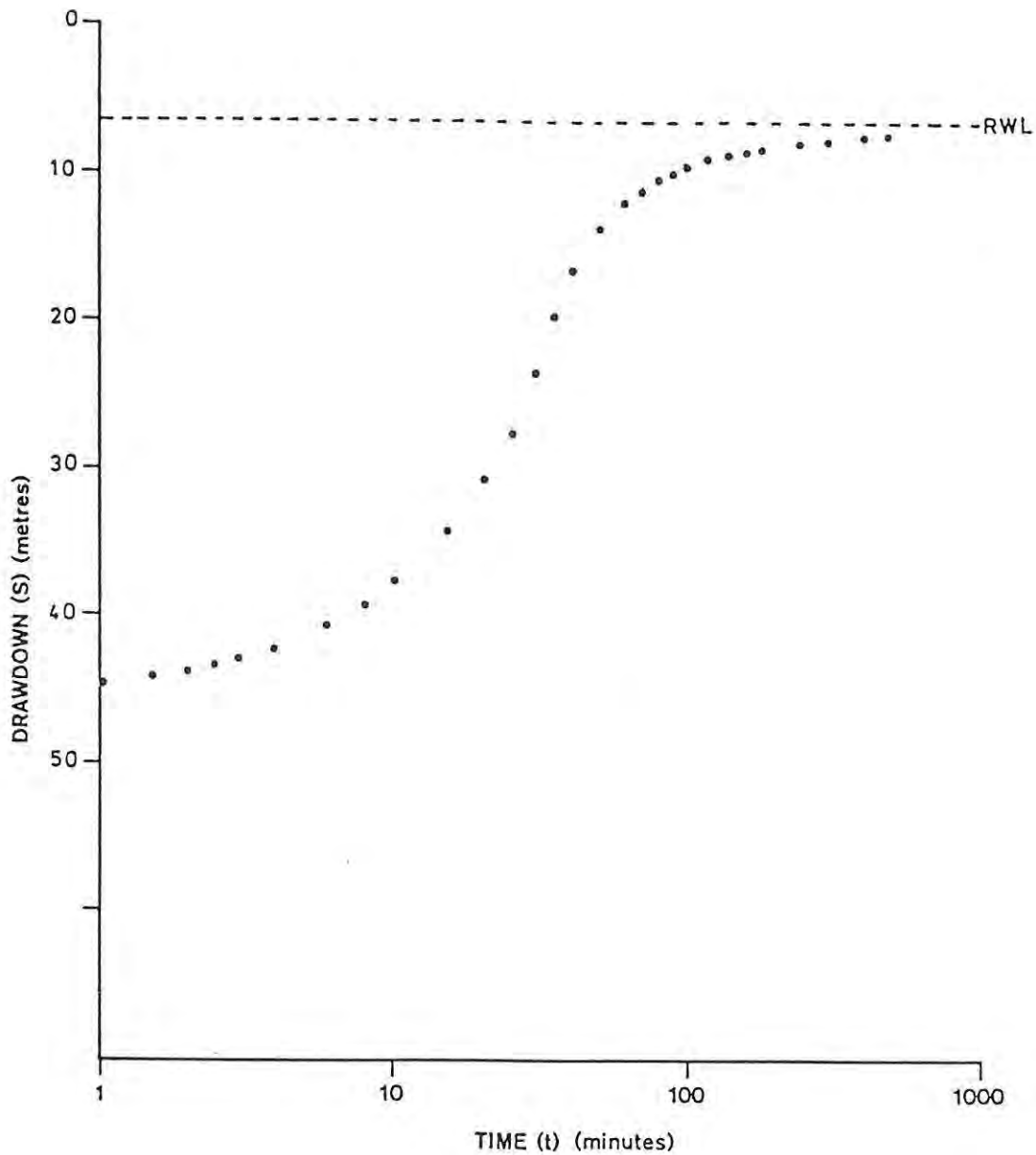


FIG. 20 BOREHOLE RH 1 - RECOVERY CURVE

5.2.5.2 Borehole RH38

This hole was tested by bailing shortly before sealing with cement. The average discharge was calculated and the Theis method utilized to calculate T from the recovery. Although by no means accurate, a value for T of $1,2\text{m}^2/\text{day}$ which compares favourably with RH1, was obtained.

5.2.5.3 Borehole WF35

The pump on the cable tool drilling rig was used to test this borehole. The pump inlet was located at 115 metres. Drawdown after 100 minutes reached the

The discharge rate decreased from 2,5 l/sec to 1,2 l/sec when the water level reached 115 metres. The pump was then switched off and the hole was allowed to recover. Full recovery had not been reached after 24 hours. Analysis of the recovery results by the Theis and Sternberg (1968) methods yielded very low values for T of 0,14 and 0,27m²/day respectively.

It is suspected that, although this borehole intersected TMS, no water was obtained from this aquifer and all the water in the borehole was of Cretaceous origin. This theory is supported by the chemistry of the pumped water which had a mean T.D.S. content of 2000mg/l.

5.2.5.4 Borehole RH39

This borehole, like WF 35, was an exploration borehole drilled principally for stratigraphic information and geophysical correlation. It was never intended to be a production borehole and as such, drilling was terminated as soon as TMS was intersected.

A step-drawdown test was carried out with the turbine pump, but was stopped soon after commencement of the 4th step, when the drawdown reached the level of the pump inlet at 56 metres. The test was of little use, as maximum discharge (2,77 l/sec) was obtained during the 2nd step, the effect of increased head counteracting the higher pump revolutions during the 3rd step. The data from the first step, however, was used for analysis by the Jacob and Chow methods. Both gave values for T of 17m²/day at a discharge rate of 230m³/day. The water quality throughout the test was extremely poor with an average TDS content of 11500 mg/l, conclusive evidence that the water was of Cretaceous origin and that the low transmissivities should not be ascribed to the TMS.

5.2.5.5 Borehole CK9

This borehole is located close to boreholes CK10 and CK11 and was also cleaned in preparation for sealing with cement. Pump testing was considered important because observation boreholes were available at suitable distances, a criterion lacking in the other tests. Step tests were attempted on three occasions but all had to be curtailed, when, after about 20 minutes pumping, the discharge decreased rapidly and the water level began to rise in the borehole. The reason for this was found to be the blocking of the pump screen by small lumps of clay. The borehole was not cased and these clay pellets

were drawn against the screen by the sucking action of the pump. After a period of time, the flow of water to the pump was impeded and discharge dropped. This was accompanied by a rise in water level. The only ways in which this problem could have been circumvented were either to remove the screen, something that drillers were loth to do in case of damage to the pump, or to insert casing, an expensive operation not really justified by the expected results.

5.2.6 Summary of Results

Of all the boreholes tested, data from RH31 was undoubtedly the most reliable with good agreement among all the methods of analysis employed. Strange results from the CK10-CK11 pair may probably be explained by inflow of water into the well. In spite of this, however, valuable data was extracted and a reasonable idea of the prevailing aquifer and well characteristics obtained. Borehole BA1 was also affected by water inflow although not to the same extent as CK10 and CK11 and it was possible to calculate minimum values for T. The Edwards borehole (RH17) was tested at a constant rate, and yielded satisfactory results. Three of the tests undertaken on wells discharging water of Cretaceous origin had to be curtailed early because of rapid drawdown. Average transmissivities for the Cretaceous aquifers were low - in the order of $5\text{m}^2/\text{day}$.

Transmissivities for the TMS ranged from about $50\text{m}^2/\text{day}$ to about $400\text{m}^2/\text{day}$. A possible high value of $1800\text{m}^2/\text{day}$ for CK10 has been discounted as improbable in light of the other results, although this figure does compare with those obtained in the Australian artesian basin where values ranging from $1-2000\text{m}^2/\text{day}$ were recorded (Habermehl, 1983). The transmissivities may also be compared with those obtained by Kohut et al., (1983) in fractured granitic terrain, conditions not dissimilar to those experienced in the Uitenhage area. Their study, carried out in British Columbia, gave transmissivities of about $74\text{m}^2/\text{day}$. Of interest in this investigation of an anisotropic aquifer, was the fact that T varied with the orientation of fractures, a feature which doubtless occurs in the TMS aquifer but which will require a great deal of drilling and pump testing to quantify.

Figures for the storage coefficient are scarce owing to the lack of observation boreholes. High values of $1,76 \times 10^{-2}$ were obtained from the CK10 - CK11 system although it is suspected that these have been influenced by inflow of water into the borehole. A reasonable value of $1,98 \times 10^{-4}$ was calculated from an estimate of the radius of influence of borehole RH31.

CHAPTER 6

HYDROCHEMISTRY

In order to obtain stable isotope hydrochemical data for the study area aquifers, 66 water samples were collected and submitted to the Hydrological Research Institute at Roodeplaat for analysis. Of these samples, 64 were from pumping or flowing boreholes, one was taken from the Uitenhage Springs and one, (SV7) was taken from a large diameter well. Each sample was analysed for 12 different ionic concentrations and the pH and electrical conductivity were measured. Analytical data are tabulated in Appendix 3.

The principal aims of the hydrochemical analyses were;

- (a) To determine the range in ionic concentrations for waters derived from different aquifers, where a direct, uncontaminated relationship between sample and source aquifer was ensured.
- (b) To use the concentration limits calculated in (a) to determine the source aquifer(s) of waters whose origin was unknown.
- (c) To enable detection of anomalies where the chemical data was not compatible with data from other sources (geology, geophysics, etc.)

Parsons (1983) used a number of graphical methods to distinguish between water types, in his study on the Coega Kop area. With these, he was able to recognise water derived solely from the TMS or Cretaceous aquifers, as well as defining those boreholes which delivered water of mixed origin. This latter phenomenon, Parsons maintained, was the result of upward flowing TMS water mixing with Cretaceous water entering the borehole through holes in the corroded casing. Verhagen (1984, pers. comm.), suggests that this mixing method will be of importance mainly in weakly artesian boreholes as the pressure of the TMS water in strong holes would tend to force this water out through the corrosion holes without allowing entry of Cretaceous water.

In this discussion the 14 chemical variables will be discussed individually, the total dissolved solids (TDS) and pH as discrete sections, and the individual ionic concentrations as another. Ionic concentrations are expressed in mg/l except for a few cases where equivalent parts per million (epm) are used. This is a method utilised for comparing the concentrations of

Total alkalinity, (TAL) is expressed in equivalent amounts of bicarbonate, carbonate and hydroxide ions. Hem (1959) states that alkalinity reported as hydroxide is normally absent from natural waters and that the carbonate phase is absent at pH values below 8,2.

Various graphical and statistical methods will be employed to distinguish between waters derived from different groups. Anomalous samples will be discussed, and a summary including a tabulation of samples with source aquifers will be presented. The chapter will be concluded with a discussion on isotopes and age dating.

6.1 Hydrochemical Classification of the Uitenhage Groundwaters

6.1.1 Electrical Conductivity and Total Dissolved Solids (TDS)

Electrical conductivity is defined by Hem (1959, p37) as "The ability of a substance to conduct a current." The units are millisiemens per metre (mS/m) which can be related to a salt concentration (TDS) in mg/l, by multiplying by a conversion constant. For the Uitenhage groundwaters this constant was calculated at 5,9 by adding the concentrations of the constituent ions and comparing with the measured electrical conductivity.

The TDS of a sample may also be calculated;

- a) By evaporation and weighing
- or b) By determining the specific gravity (approximate)

The most accurate method, however, is by the addition of the concentrations of the component anions and cations, and the simplest is multiplying the electrical conductivity by the conversion constant.

After calculation of the mean TDS values for waters of known origin, it was possible to designate samples of unknown origin into one of the four groups. Statistical analysis of all the samples then gave the following means and standard deviations.

<u>Aquifer</u>	<u>Mean TDS</u>	<u>Std. Deviation</u>
TMS	170 mg/l	18 mg/l
Cretaceous	5070 mg/l	357 mg/l
Bokkeveld	3294 mg/l	188 mg/l
Mixed	704 mg/l	56 mg/l

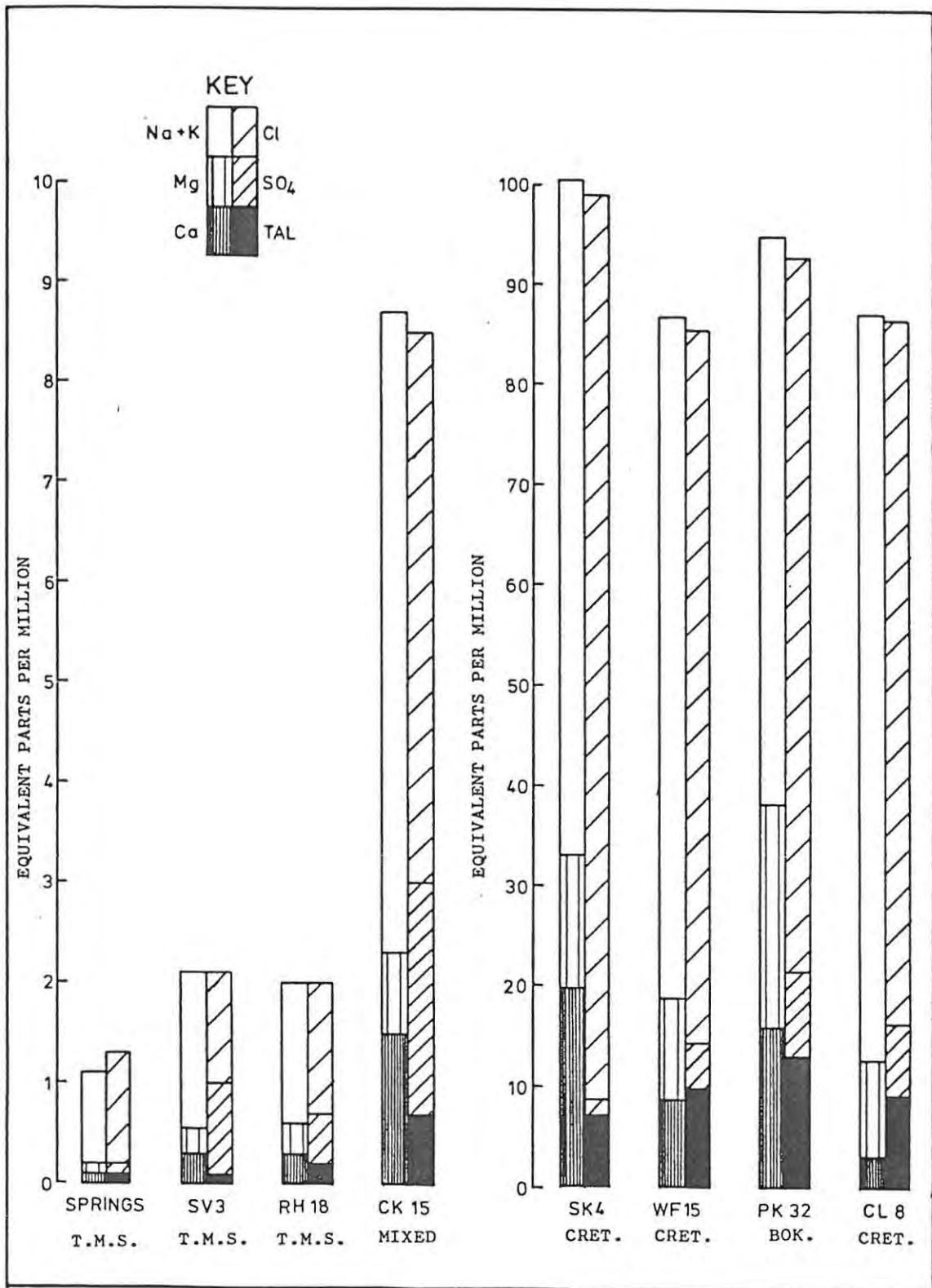


FIG 21 BAR GRAPHS OF CHEMICAL ANALYSES IN
EQUIVALENT PARTS PER MILLION

Fig. 21 is a presentation by means of bar graphs, of the relative differences in TDS contents for the four different water types. The tendency for the mixed water to have a chemical nature fairly close to the TMS water is interpreted as being a function of the greater amounts of TMS being involved in the mixing process. The reasons for the large differences in TDS among waters of different formations will be explained by the probable origin of their major ions and will be discussed in the section on individual ionic concentrations (p 71)

6.1.2 Hydrogen Ion Concentration (pH)

Mean laboratory measured pH values for the different waters, as measured at Roo-deplaat are shown below:

TMS	7,1
Cretaceous	7,7
Bokkeveld	8,0
Mixed	7,6

TMS - derived groundwater in the Uitenhage - Coega area is found to be slightly acidic. The rapid corrosion of steel borehole casing confirms this. It is suspected that the pH value of 7.1, which was derived from measurements made some time after the sample was taken, is too high for the following reasons;

According to Hem (1959, p 46) "The loss of CO₂ is most important in sampling water from confined underground sources, as, upon the release of confining pressure, CO₂ will be lost from the solution until the amount equals that which will remain under the partial pressure of this gas in the atmosphere." This will result in an increase in measured pH. Data from Verhagen (pers. comm.) verifies this. Five boreholes were sampled and pH values determined in the field. Table 6 illustrates how the field and laboratory values vary.

<u>Bh. No</u>	<u>pH (Field)</u>	<u>pH (Laboratory)</u>
WF 3A	6,4	7,5
WF 23	6,4	7,2
RH 15	6,3	7,2
SK 12	6,9	7,2
SK 18	6,5	6,9

Table 6 Differences in pH measurements made in the field and laboratory

The higher pH values of the Cretaceous and Bokkeveld water are probably caused by the buffering action of dissolved alkaline salts such as calcium or magnesium bicarbonate. The low value for borehole SK 20A (6,1) is not properly understood but may be related to the total absence of carbonate and bicarbonate in the sample.

6.1.3 Individual Ionic Concentrations

A general relationship exists between mineral composition of a natural water and that of the solid minerals with which the water has been in contact (Hem, 1959). A study carried out by Johnstone (1982) in the neighbouring Kruis Rivier area, revealed that distilled water in contact with rocks of the Kirkwood Fm., Enon Fm., and TMS, showed, even after 2 months, chemical characteristics similar to those of the relevant rock type.

The bar graphs (Fig. 21), and the scatter plots (Figs. 22, 23, 24 and 25), as well as the analyses in Appendix 3, indicate that TMS - derived waters have low mineral contents whereas those waters from Cretaceous and Bokkeveld sediments are high in dissolved solids. As would be expected, mixed water have intermediate values.

Low ionic concentrations in the TMS water are easily explained by the composition of the rock itself. As mentioned earlier in the section on geology (p 13) the TMS is composed almost exclusively of quartz grains with a matrix of silica cement. Because of its resistance to attack by water, quartz can probably be ignored as a source of silica in groundwater (Johnson, 1972).

In contrast, the Bokkeveld and Cretaceous formations have a high percentage of clay minerals contributing to their argillaceous lithologies. Clay minerals are defined by Drever (1982, p 65) as follows. "Fine-grained, crystalline, hydrous silicates with structures of the layer lattice type. They are the most common products of water-rock interactions under earth-surface conditions. As a consequence of their structures, clays are efficient ion exchangers."

Chemical and geological evidence suggest that high TDS contents in waters from the Cretaceous and Bokkeveld Sediments can be attributed to three main factors;

- (a) The readiness with which the clay minerals will give up metals such as sodium, to base exchange. When water flows through a porous medium, exchange relations take place between ions in the water and ions absorbed on the medium. The cation-exchange capacities of most media are sufficient to have a significant influence on the composition of waters flowing through them (Drever, 1982).
- (b) The small pore spaces in the clay minerals result in slow movement of water through these sediments and thus, a longer time is available for the water to remove ions from the particular silicate lattice.
- (c) In some instances, (particularly with regard to the Cretaceous Formations) the sediments were either laid down in a marine environment or may have suffered periodic incursions of salt water. Some of this saline water and its dissolved matter would have remained in the pore spaces or attached to the mineral grains.

	<u>TMS</u>	<u>Cretaceous</u>	<u>Bokkeveld</u>
Na	50	1590	940
K	7	33	14
Ca	7	130	102
Mg	5	120	111
SO ₄	8	417	310
Cl	65	2570	1500
TAL	59	210	306
NH ₄	0,0334 (A)	0,0827 (B)	0,0291
NO ₃	0,057	0,330	0,064
F	0,555	1,053 (C)	0,811
Si	8	6	0,007
P	0,030	0,006	0,007

Table 7 Mean Ionic Concentrations (in mg-l) for the different waters

A - Anomalous value for PK 30 omitted from calculation

B - Anomalous value for SK 20A omitted from calculation

C - Anomalous value for KG 2 omitted from calculation

Reference to the scatter plots (Figs. 22, 23, 24 and 25) and to the mean ionic concentrations (Table 7) indicates that, with the exception of TAL in the Bokkeveld, all the major ions have the highest concentration in the Cretaceous Sediments.

The chemistry, coupled with the geological and palaeontological evidence shows conclusively that these formations were subjected to marine influences at one or another time. The connate water introduced to the sediments would, by virtue of the small pore spaces, be removed very slowly and result in a high T.D.S. content.

In the following discussion the concentrations of the major ions will be dealt with individually. The values for the ammonium, nitrate, phosphate and silica ions do not appear to be diagnostic and are too low to warrant further attention.

6.1.3.1 Sodium Ion Concentration

The sodium ion is the most abundant cation in all three waters. Sodium is a highly soluble element and may be incorporated into groundwater in a variety of ways (viz.)

- (a) By leaching from sodium-containing minerals (esp. feldspars).
- (b) By base-exchange of calcium or magnesium already in solution, for sodium. (This is particularly important in the clay minerals).
- (c) By the groundwater coming into contact with evaporites or sediments containing trapped sea water.

The comparatively low sodium concentration in the TMS-water, can be explained by the fact that none of the above three cases apply in what is essentially a cemented quartz - arenite lithology.

The differences between the mean sodium concentrations of the Bokkeveld and Cretaceous waters, (940 and 1590 mg/l respectively) is almost certainly due to a greater marine influence on the latter. Marine incursions into the fresh water deltaic environment would serve to deposit layers of halite as well as conceivably allowing saline water to be trapped within the sediments. This theory is supported by the fact that the most important anion is chloride - also a product of marine influences.

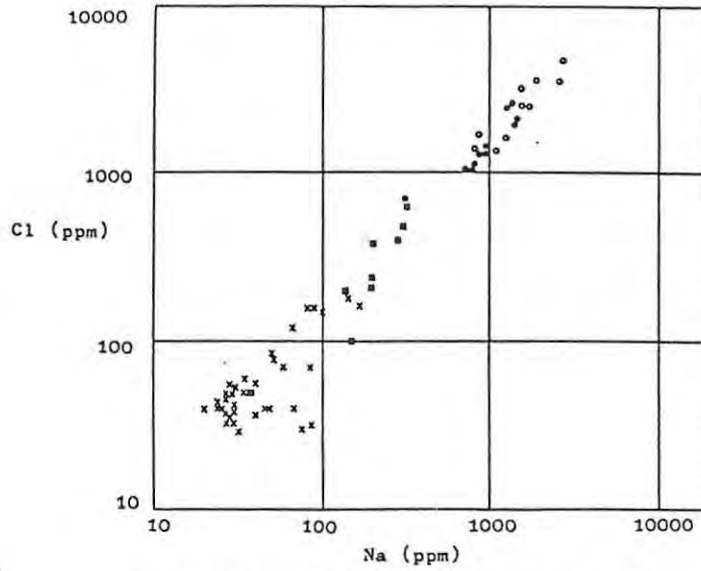


FIG. 22 SCATTER PLOT OF Na vs Cl

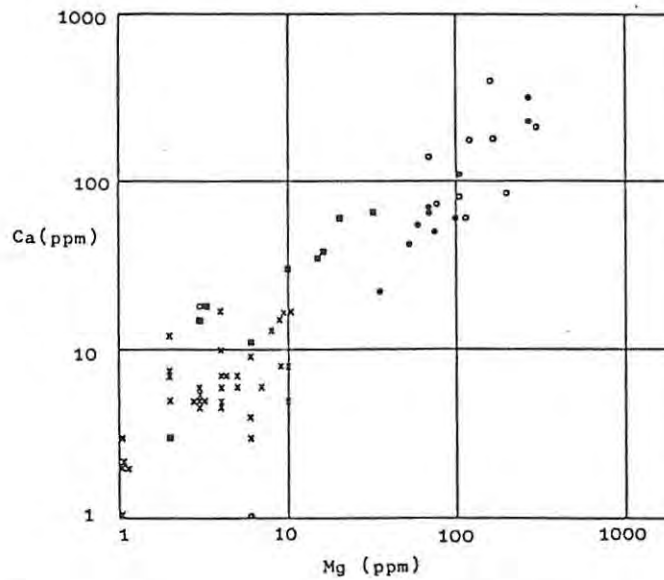


FIG. 23 SCATTER PLOT OF Mg vs Ca

- * TMS WATER
- o CRETACEOUS WATER
- BOKKEVELD WATER
- MIXED WATER

LOG-LOG SCALE

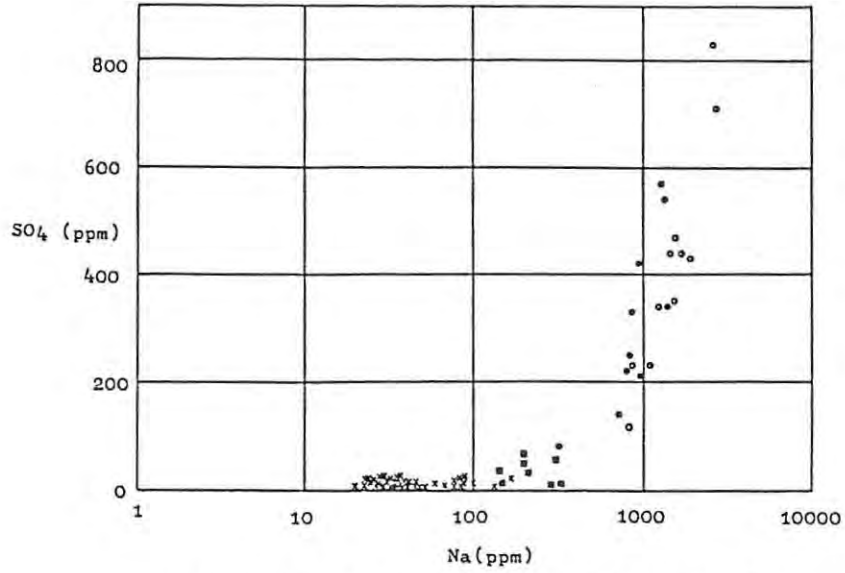
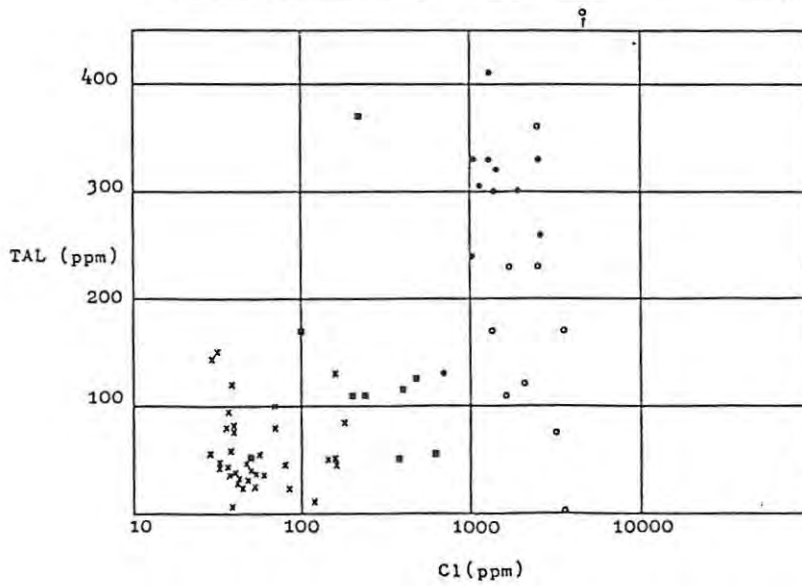


FIG. 24 SCATTER PLOT OF Na vs SO₄



- * TMS WATER
- o CRETACEOUS WATER
- BOKKEVELD WATER
- MIXED WATER

FIG. 25 SCATTER PLOT OF Cl vs TAL

SEMILOG SCALE

6.1.3.2 Potassium Ion Concentration

Sodium tends to remain in solution when leached whereas potassium combines easily especially with the clay minerals (Hem, 1959). This could possibly explain the low concentration of potassium in the waters. (7, 14 and 33 mg/l for the TMS, Bokkeveld and Cretaceous waters respectively.) The relatively high concentration for the Cretaceous water is once again probably attributable to the influences of marine water.

6.1.3.3 Calcium Ion Concentration

Dissociated calcium is normally present in natural waters as the bivalent ion Ca^{2+} . Because of its widespread occurrence in rocks and soils and its ready solubility, calcium is present in nearly all waters. Very high concentrations of calcium suggest solution of gypsum or anhydrite whereas low concentrations may indicate either;

- (a) An absence of readily soluble calcium minerals.
- (b) The action of base exchange whereby calcium originally in the water has been exchanged for sodium.

The TMS waters have very low calcium concentrations reinforcing the theory that interstitial cement is almost exclusively quartz. The samples from the Bokkeveld and Cretaceous sediments (mean concentrations, 102 and 130 mg/l respectively) also have high sulphate concentrations suggesting that some of the calcium may have been derived from gypsum beds. Base exchange where dissociated potassium ions replace calcium ions on the exchange sites is probably responsible for adding calcium to these waters.

It is important to note that carbon dioxide has a critical effect on the solubility of calcium. If CO_2 is added to a system, solution of calcium continues, if CO_2 is removed, deposition occurs.

This may serve as proof that the TMS associated groundwater has a very low calcium concentration. If concentrations were high it would be expected that calcium mineral deposits such as travertine, should, on drop of confining pressure, be deposited at springs and borehole collars. No deposits of this nature have been recorded from this area.

6.1.3.4 Magnesium Ion Concentration.

"In most waters of low to medium T.D.S., the magnesium concentration is considerably less than calcium even when computed on the basis of concentrations expressed in equivalents per million" (Hem, 1959, p 82). The ratio of calcium to magnesium for natural water ranges from about 5:1 to 1:1. For the Uitenhage groundwaters, the ratio is low (approximately 1;1.5), and, although the Cretaceous and Bokkeveld waters can hardly be described as having low to medium TDS, the relatively high magnesium content is unusual. Hem (1959) suggests that the low values may arise from dissolution of magnesium silicate minerals or dolomite, or from contamination by sea water. As the first two options are absent in this area, sea water contamination is probably the cause. A possible contributing factor to the low ratio, may be precipitation of calcium on loss of CO₂ (discussed in section 6.1.3.3).

6.1.3.5 Sulphate Ion Concentration

Mean sulphate concentrations for the TMS, Bokkeveld and Cretaceous waters are; 8, 310 and 417 mg/l respectively. There may be two possible sources of sulphate in the latter two formations:

- (a) From gypsum and anhydrite (Freeze and Cherry, 1979)
- (b) From bacterial reduction of organic matter.

The presence, (particularly in the Cretaceous) of waters with high concentrations of calcium suggest that the former is the case.

6.1.3.6 Chloride Ion Concentration

"When porous rocks are submerged by the sea at any time after their formation, they are impregnated with soluble salts" (Hem, 1959, p 104). Chloride may also be present as a result of inclusion of connate water and is to be expected in any incompletely leached deposit laid down under the sea or in a closed basin when chloride was present.

When base exchange is of minor importance, it is to be expected that the source of ions is essentially from dissolution of soluble minerals. As the most common of these is normally halite, the concentration of Na, or Na + K will be practically equal to that of Cl when expressed in equivalent parts per million. When the concentrations of Na + K are recalculated to epm and expressed as a percentage of Cl, the mean values for the three waters are;

TMS	129%
Bokkeveld	97%
Cretaceous	98%

The percentages for the Bokkeveld and the Cretaceous indicate that base exchange is a fairly minor process and the concentration of these ions is primarily the result of the influence of sea water. The percentage for the TMS can be discounted as evidence for base exchange, for the reasons proposed in section 6.1.3. Although the mean chloride content for TMS waters is low (65 mg/l) it must be noted that concentrations range from 29-180 mg/l and it is principally due to this spread that the TMS samples plot over such a wide field in the Piper diagram (Fig. 26).

6.1.3.7 Total Alkalinity (TAL)

Mean TAL values are: TMS 59, Bokkeveld 306, and Cretaceous 210 mg/l.

As mentioned in the introduction to this chapter, the carbonate phase is absent at pH values below 8.2. Taking the pH values in Appendix 3 as correct, in all but 9 analyses the TAL refers only to bicarbonate concentration. The doubt surrounding some of the pH values could mean that less than 9 sample have a carbonate phase present. (see section 6.1.2).

TAL values seldom exceed 800mg/l and are most common in the 50-400 mg/l range (Davis and De Wiest, 1966). As indicated in Appendix 3, the waters analysed fit neatly into these limits with some slightly low TMS analyses and a very anomalous zero value for sample SK 20A. It is suspected that this may be analytical error.

6.1.3.8 The Piper Diagram

Piper (1944) developed a trilinear diagram which is convenient for graphically displaying large numbers of analyses (Freeze and Cherry, 1979).

TRILINEAR PLOT
OF HYDROCHEMISTRY

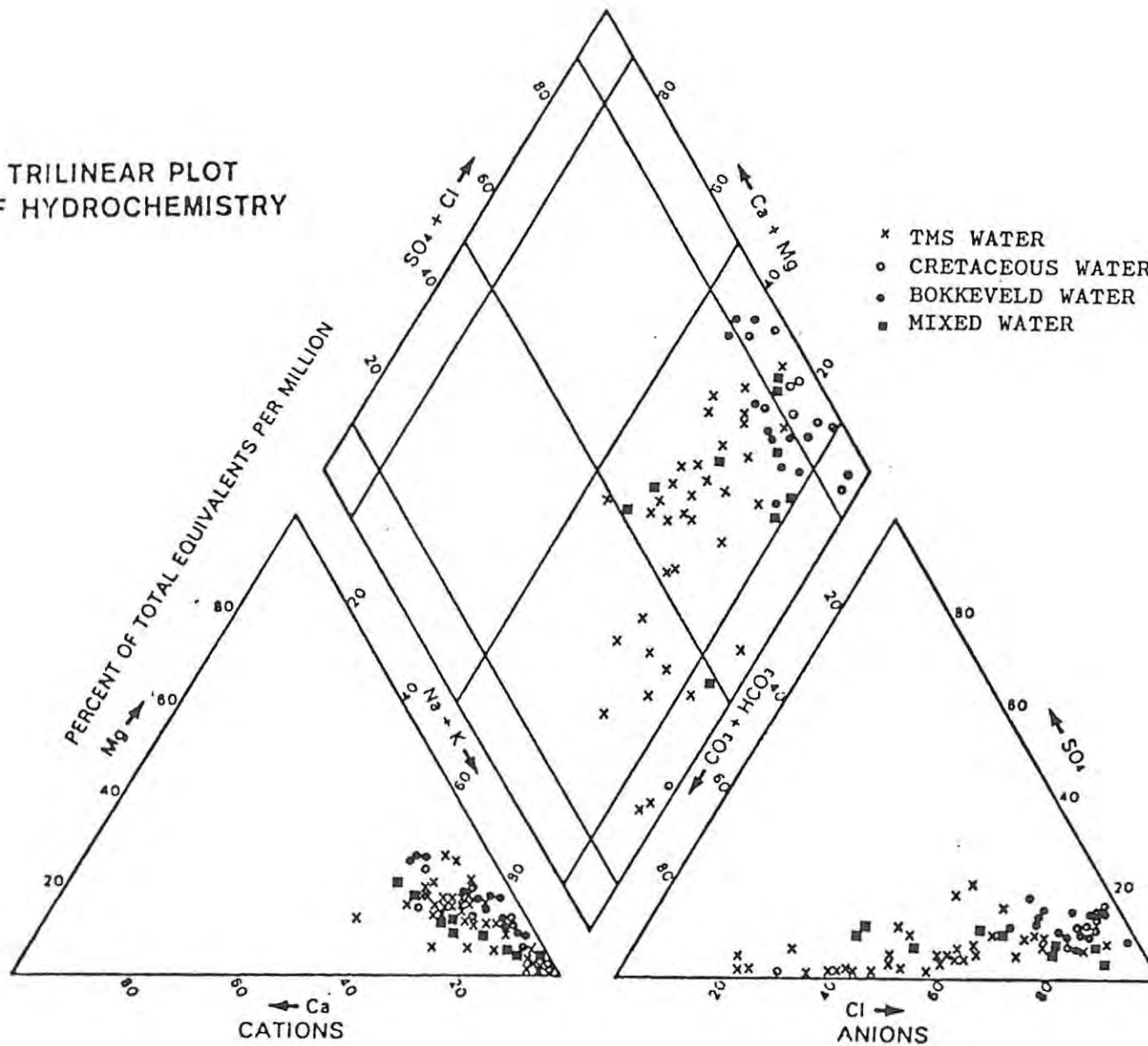


FIG. 26 PIPER DIAGRAM PLOTS FOR THE 4 GROUNDWATER TYPES

This diagram (Fig. 26), permits the representation of cation and anion compositions on a single graph in which major groupings and trends in the data can be discerned visually. Because the compositions are represented as percentages and the analysis by a single point, waters with widely differing total concentrations may have identical representations on the diagram.

In Fig. 26, the relative cation and anion proportions are presented in the triangles, and the major ion composition in the diamond-shaped field. From the diagram it is apparent that;

- (a) The proportions of cations remain fairly constant with a pronounced clustering in the high Na-K portion of the triangle. The different waters do not show any tendency to group together thus negating cation proportions as a method for differentiation among these waters.
- (b) The waters are all low in sulphate ion concentration and the Bokkeveld and Cretaceous waters tend to cluster in the high Cl portion of the anion triangle. The TMS waters on the other hand show a marked variation in chloride content accompanied by reciprocal changes in the concentrations of carbonates and bicarbonates. As would be expected mixed waters plot in intermediate positions.
- (c) All the Cretaceous and Bokkeveld waters, (with the exception of the anomalous sample from KG2) plot in the diamond shaped field as sodium chloride brines. The wide variation in chloride and TAL content of the TMS waters results in some of these plotting as dynamic waters (Johnson, 1972), while the majority plot in the NaCl field - the word brine hardly described waters with TDS values as low as 80mg/l.

It appears therefore, that the Piper diagram is of little use as a basis for distinguishing the source of a particular water sample. All that can be claimed with any degree of certainty is that samples whose analyses indicate chloride contents of less than 70% and TAL contents of greater than 30% are derived from the TMS.

6.1.4 The KG2 and MV3 anomalies

Samples from these two boreholes are considered anomalous on the basis that their geological situation and hydrochemical characteristics are incompatible.

6.1.4.1 KG2

This borehole is situated on the downthrown side of the Uitenhage-Coega fault where a substantial thickness of Cretaceous sediments overlies the TMS. The water would be expected to show typical Cretaceous characteristics such as high cation and anion concentrations, high conductivity and a pH of about 7.7. Instead, the water contains only three of the major ions, namely, sodium, chlorine and TAL., the pH is very high (8.8) and it has a high fluoride concentration of 5.8mg/l. In addition the Cl:TAL ratio which averages about 12:1 for the other Cretaceous waters is 1:3.5 for this sample. The e.p.m. values for the sodium and chloride ions and for TAL are as follows:

Na	7.83
Cl	2.26
TAL	5.40

This indicates that the principal salt is not halite as in the other waters but sodium carbonate or bicarbonate. On the basis of these chemical anomalies, it is apparent that the water from KG2 is not typical of the Cretaceous but has been affected by some factor not yet understood.

6.1.4.2 MV3

Borehole MV3 is also situated on the downthrown side of the fault yet, chemically, the water exhibits all the characteristics of TMS-water. The pH (6.7) and the TDS (153 mg/l) are low and individual ionic concentrations compare very favourably with those waters of definite TMS origin. There are two possible explanations for this:

- (a) The borehole could be situated on a TMS-high of pre - Cretaceous relief and has actually penetrated the TMS.

- (b) A situation such as at borehole CM6 (exploration borehole) may have arisen. In this case there appears to be hydraulic connection between the TMS and the overlying sediments possibly through a system of overlapping and interfingering sandstone horizons within the Cretaceous. (See section 4.3.3 p 45)

Either of the above is possible especially when it is borne in mind that MV3 is situated quite far to the south, well away from the fault and where geological information is, at best, scanty.

6.1.5 Summary

On the basis of hydrochemistry, it appears possible to distinguish between waters derived from different lithologies. By utilizing graphical and statistical methods a water may be classified with a high degree of confidence as originating from the TMS or not. Some difficulty arises when attempting to differentiate between Cretaceous and Bokkeveld waters although generally, Cretaceous waters are of poorer quality. Mixed waters, derived chiefly through contamination of TMS water by leakage through corroded casing, have ionic concentrations intermediate between TMS on the one hand, and Cretaceous and Bokkeveld on the other.

The good quality of the TMS water is attributed to the fact that the lithology essentially comprises non-reactive quartz grains cemented with amorphous silica cement. The argillaceous formations on the other hand, have suffered marine invasion with the probable precipitation of halite and gypsum beds, as well as having a high proportion of clay minerals available for the base-exchange process.

The mixed waters have intermediate ionic concentrations but are skewed towards the lower side, almost certainly a function of greater yields and therefore greater dilution from the TMS.

The groundwater/source aquifer classification for the various boreholes is presented on Table 8.

<u>Bh. No.</u>	<u>Source</u>	<u>Bh.No.</u>	<u>Source</u>	<u>Bh.No.</u>	<u>Source</u>
SK 1	Mix.	WF 14	Mix.	PK 4	Bok.
SK 4	Cret.	WF 15	Cret.	PK 6	Bok.
SK 7	TMS.	WF 16	TMS.	PK 8	Bok.
SK 8	Cret.	WF 17	TMS.	PK 9	Bok.
SK 10	Cret.	WF 23	TMS.	PK 10	Bok.
SK 12	Mix.	BR 1	Cret.	PK 13A	TMS.
SK 18	TMS.	RH 1	TMS.	PK 18	Bok.
SK 19	TMS.	RH 8	TMS.	PK 30	TMS.
SK 20A	Cret.	RH 11	TMS.	PK 31	Bok.
CK 2	TMS.	RH 15	TMS.	PK 32	Bok.
CK 13	Mix.	RH 18	TMS.	PK 34	TMS.
CK 15	Mix.	RH 22	TMS.	PK 35	TMS.
SV 1	TMS.	RH 23A	TMS.	UC 1	TMS.
SV 3	TMS.	RH 28	TMS.	BK 6	TMS.
SV 7	Mix.	PH 32	TMS.	BK 9	TMS.
MV 2	TMS.	RH 32A	TMS.	CL 1	Bok.
MV 3	TMS.	KG 1	Cret.	CL 2	Bok.
C 2	Mix.	KG 2	Cret.	CL 3	Cret.
C 5	TMS.	BA 1	TMS.	CL 6	TMS.
C 9	Mix.	GR 1	Cret.	CL 8	Cret.
WF 3A	TMS.	GR 11	TMS.	AB 1	Cret.
WF 5	Mix.	DK 1	TMS.	Springs	TMS.

TMS - Table Mountain Sandstone

Cret. - Cretaceous Formations

Bok. - Bokkeveld Group

Mix. - A mixture of TMS with Cretaceous or possibly, Bokkeveld.

Table 8 Classification of Borehole Waters with Respect to Source Aquifer

6.2 Isotopes and Age Dating

Previous isotopic studies on the waters of the Uitenhage area were carried out by Talma et al., (1983). This work principally involved the determination of relative concentrations of ^{13}C , ^{14}C , and tritium (T). From these results the water was dated and flow rates calculated. Further research was later carried out by Professor Verhagen of the University of the Witwatersrand, assisted by the author. In the latter case, in addition to the three isotopes mentioned above, the samples were analysed for deuterium (D) and ^{18}O . The results of all the analyses are presented in Table 9.

6.2.1 Tritium

The concentration of the tritium isotope (^3H), which has a half-life of 12.3 years, was radically increased in the atmosphere after nuclear-weapons testing in the mid 50's. As a result, waters exposed to the atmosphere after this time will have measurable concentrations of tritium. For those samples analysed for this isotope, only three fall into this category. An examination of Fig. 27 reveals that these samples originate from boreholes either in the recharge area or from a phreatic hole (WF7) where recent water could be expected. All the samples from the confined waters had zero tritium concentrations, indicating that no measurable addition of recent water has taken place.

6.2.2 Deuterium (D) and ^{18}O

Deuterium occurs in natural waters as the molecule HOD (ie. hydrogen - oxygen - deuterium) at concentrations of about 320 ppm, and ^{18}O as H_2^{18}O at about 2000 ppm (Mandel and Shifan, 1981). During phase changes, the heavy isotopes tend to concentrate in the liquid phase with the result that the lightest values are found in polar ice and the heaviest in terminal lakes.

^{18}O values, in conjunction with those for D may assist in determining recharge areas and identifying palaeoclimates where different temperatures have resulted in different evaporation rates. For the Uitenhage waters, although analyses for D and ^{18}O were carried out on only 6 and 4 samples respectively, the values are extremely constant and do not show any regional trend.

Bh.No.	Collection Date	Collected By	Cond. (nS/m)	Tritium T.U.	D ‰	¹³ C ‰	¹⁴ C (pmc)	¹⁴ C Model Age (years)	¹⁸ O ‰
BA1	8/78	T,V&H	35,5	---	---	-19,5	43,0±0,3	4920	
BK9	8/78	T,V&H	45,5	0	---	-19,5	30,5±0,3	8950	
C2	3/69	T,V&H	188,0	---	---	-19,4	3,87±0,1	23400	
CK2	3/69	T,V&H	26,5	---	---	-19,5	3,67±0,2	23500	
CL5	11/81	T,V&H	73,1	---	---	-18,4	7,51±0,2	15000	
HV1A	8/78	T,V&H	34,5	0	---	-19,7	86,7±0,5	350	
RW3	11/81	T,V&H	73,6	---	---	-12,8	77,7±0,5	recent	
PK8	3/69	T,V&H	520,0	1,3	---	-13,2	2,92±0,2	25100	
PK13	11/81	T,V&H	26,5	---	---	-11,9	4,70±0,4	21100	
PK34	11/81	T,V&H	64,2	---	---	-15,8	39,6±0,4	5590	
RH1	3/69	T,V&H	22,0	---	---	-18,9	28,2±0,3	8190	
RH14	8/78	T,V&H	28,0	---	---	-19,9	28,6±0,2	7850	
"	12/83	V&V	25,0	0,2±0,2	-26	---	---	---	-5,1
RH18	3/69	T,V&H	22,0	---	---	-17,2	31,8±0,3	7100	
RH23A	11/81	T,V&H	20,6	---	---	-19,7	37,5±0,3	4770	
RH31	12/83	V&V	22,0	0,0±0,2	-25	-20,1	32,2±0,5	8000	-5,2
SF1	3/69	T,V&H	---	0	---	-18,1	62,6±0,6	3000	
SK7	11/81	T,V&H	24,0	---	---	-18,0	1,98±0,2	28000	
SK12	11/81	T,V&H	70,4	---	---	-16,0	1,76±0,2	27800	
"	12/83	V&V	115,0	0,1±0,2	-28	-16,5	6,9±0,4	20000	
SK18	12/83	V&V	87,0	0,2±0,2	-24	-18,9	25,7±0,5	10000	
SV3	11/81	T,V&H	31,7	---	---	-18,8	10,5±0,2	15100	
WF3A	8/78	T,V&H	24,0	---	---	-18,8	7,42±0,2	18200	
"	12/83	V&V	22,0	0,1±0,2	-28	-22,9	12,7±0,4	15000	-5,3
WF7	8/78	T,V&H	237,0	2,1	---	-11,9	13,1±0,3	10850	
WF23	8/78	T,V&H	22,0	---	---	-19,2	4,95±0,2	21200	
"	12/83	V&V	23,0	0,3±0,2	-23	-21,6	6,40±0,4	21000	-5,6
UC1	11/81	T,V&H	27,8	---	---	-19,9	5,22±0,3	20800	
US	3/69	T,V&H	---	17,4	---	---	---	recent	
"	8/78	T,V&H	11,5	0	---	-21,7	81,5±0,4	1560	
"	11/81	T,V&H	13,9	---	---	-21,5	78,5±0,5	1840	
"	11/81	T,V&H	12,6	---	---	-21,4	83,8±0,6	1350	

T,V&H Talma, Vogel and Heaton
V&V Verhagen and Venables
US Uitenhage Springs

Table 9. Isotope analyses for some boreholes and the Uitenhage Springs.

6.2.3 ¹³C

The stable isotope, ¹³C, is particularly useful for distinguishing between carbon derived from organic matter (light carbon) and that derived from carbonate minerals (heavy carbon). The erratic distribution pattern and small range in values, however, makes further deductions from these data impossible.

8.2.4 ^{14}C

The radioisotope, ^{14}C , decays to ^{14}N and has a half-life of 5730 years. Accordingly, when groundwater is isolated from the atmosphere, the concentration of ^{14}C will diminish with time, making it possible to arrive at an age for the water. This assumption presupposes that no "dead" carbon, (no detectable ^{14}C) is added to the water and that no precipitation of carbon minerals has taken place. The former process will lead to an increase in the calculated age and the latter to a decrease. Naturally, mixing of old water with younger will give rise to intermediate ages.

In the confined section of the Uitenhage Artesian System, it has been shown by Talma et al., (1983) that there is a gradual down-flow increase in pH and alkalinity, reflecting the gradual dissolution of rock carbonate in an environment where there is no carbon exchange with the atmosphere. This facilitates interpretation of the ^{14}C data, as carbon dissolution usually proceeds fairly rapidly in nature.

Modelled ages for waters from various sample locations are plotted on Fig. 27. The central section of the area, from Uitenhage Springs, through Amanzi and Welbedachtsfontein to the coast, exhibits a clearly recognisable increase in ages in a south-easterly direction. These ages range from recent, in the recharge area to 29 000 years at borehole SK12 suggesting an average flowrate of 0,76 metre/year (Talma et al., 1983)

The picture is not as clear when samples taken north and south of the central profile are considered. To the north, samples from boreholes BK9, PK34, CL6, PK13 and PK8 have ages ranging from 6000 - 25000 years despite the fact that they are all situated close to the recharge area. Borehole PK8 is situated in Bokkeveld sediments where flow rates may be greatly retarded in the fine grained, less fractured shales but the other four boreholes all penetrate TMS.

Talma et al., (1983), suggest that the higher ages could imply, either;

- (a) A different, more distant recharge area for these samples, or
- (b) A slower rate of flow in a northerly/north-easterly, as opposed to south-easterly, direction. This may be valid, as the dominant fracture orientation (see section 2.3.2, p 19) is WNW - ESE.

Verhagen (pers. comm.), suggests that there may be a number of flow "loops," carrying water from different recharge points instead of a single, simple system of downdip flow.

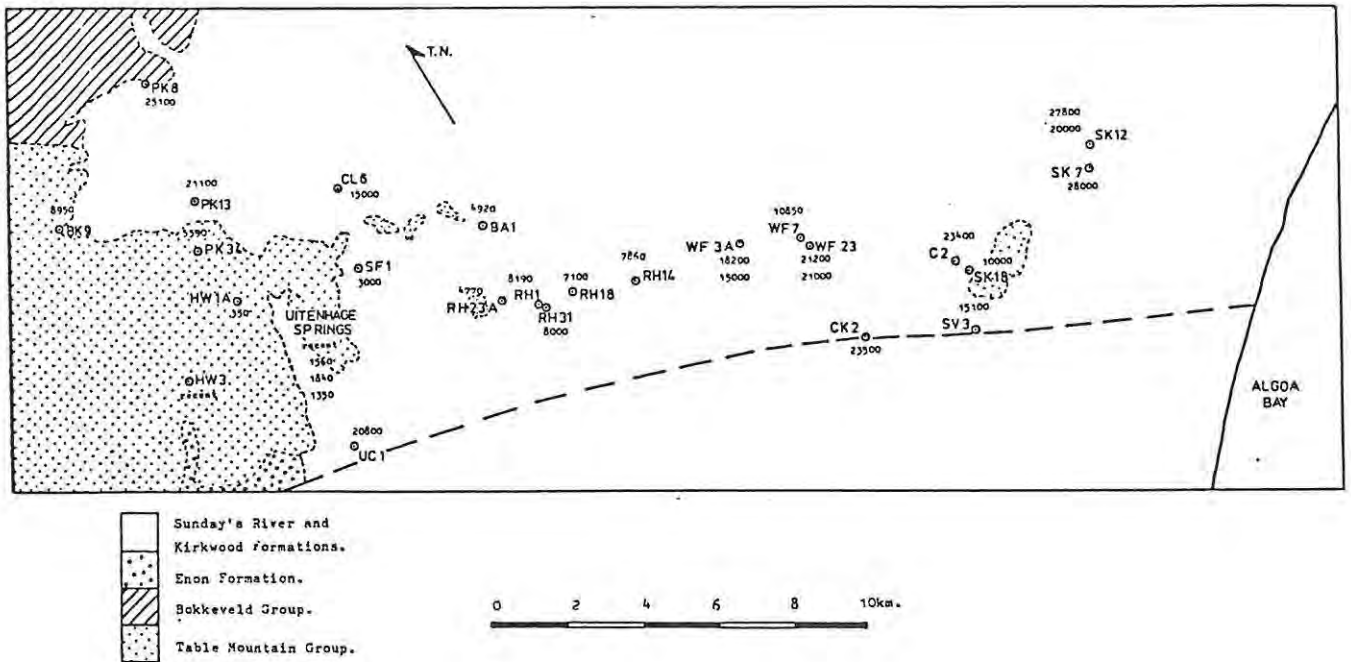


FIG. 27 AGES (in years) OF GROUNDWATERS ALONG THE COEGA RIDGE

Of the three southerly sample points, only borehole CK2 yielded an age consistent with that expected. The water from UCI was anomalously old, possibly due to the same factors influencing CL6 and PK13 etc. The comparatively young age of the SV3 water may reflect a higher flow rate along the Coega Fault although the evidence from CK2 tends to refute this.

The fairly low age for WF7 is of little consequence, as this borehole does not penetrate TMS and is thus not part of the confined system. Borehole SK18 is thought to have corroded casing, resulting in mixing of "old" TMS - water with younger groundwater.

The large difference in the two ages measured for SK12 may be the result of either;

(a) Differences in sampling techniques.

The hole was pumped and a sample taken from the depth of the pump inlet in 1981. In 1983 a sample of the water flowing from the mouth of the casing was collected.

(b) Deterioration of the casing.

The corrosive action of the water may have resulted in a greater amount of mixing between TMS - water and younger water when the borehole was sampled for the second time.

CHAPTER 7

DISCUSSION AND TESTING OF HYPOTHESES

In the introductory chapter, the study area was briefly described, the aims and objectives of the investigation were outlined and a number of study hypotheses were proposed. Chapters 2-6 described the collection and analysis of data, the methods used, and the results obtained. This chapter serves to check whether the aims of the study have been fulfilled and to examine if the proposed hypotheses are validated. The chapter is divided into two parts; section 7.1 dealing with the aims and objectives and 7.2 with the hypotheses. Because there is common ground between the two sections cross-referencing is extensively used.

7.1 Fulfillment of the Aims and Objectives of the Study

The aims and objectives of the study are presented in Chapter 1, p 4. The discussion follows the framework of these stated aims.

7.1.1 The TMS Aquifer

7.1.1.1 Geometry

The discussion of aquifer geometry is primarily concerned with the delineation of the confined portion of the TMS aquifer in the Coega Compartment. In terms of exploitation of the groundwater resource, only those parts of the aquifer which are within reach of the more common drilling rigs (say, a maximum of 300 metres) are considered. Bearing this in mind it is clear that the Uitenhage - Coega Fault which downthrows the TMS approximately 1000 metres to the south forms the southern boundary of the confined Coega Compartment. To the west the TMS is exposed in outcrop, and to the east, the Indian Ocean may be classed as a boundary as no groundwater exploitation is feasible offshore. To the north the TMS dips under the Bokkeveld Group at about 50° (See sections in Figs. 4 A-D). Because of the high dip angle there is little chance of drilling through the Bokkeveld and intersecting TMS at a reasonably shallow depth, except very close to the sub-outcrop.

The edge of the TMS outcrop area was defined by geological mapping assisted by previous work (Marais, 1964), and aerial photographs. The subsurface fault boundary and TMS - Bokkeveld contact were inferred from borehole information, surface geophysics, and in some instances, from hydrochemical results. The greater amount of information available in the south of the area made the positioning of the fault an easier task than accurately locating the sub-outcrop. Difficulties with some of the geophysical results have been discussed in section 3.1.2 p 24. It is apparent from the geology on the base plan, that the portion of confined TMS which is available for groundwater exploration is restricted to a narrow strip, some 6 x 26 kilometres, extending from the Uitenhage Springs to the coast. Within this area the TMS has an extremely irregular surface, a result of pre-Cretaceous erosion following tectonic uplift. The irregular surface is reflected in the number of "koppies" of TMS which rise above the surrounding Cretaceous sediments. Between these inliers of TMS, deep pre-Cretaceous valleys occur (see Cretaceous isopach maps, Figs. 12 and 13), as demonstrated at Coega Kop, where boreholes CK 9, 10, and 11 intersected TMS at a depth of 240 meters only 1500 metres from the outcrop. Another example of pre-Cretaceous erosion is from borehole CM6, which was sited midway between the TMS outcrops of Coega Kop and Jahleel Island. These outcrops are about 8 kilometres apart. To date (Jan. 1985), this borehole is 250 metres deep without intersecting TMS, and records show that the Cretaceous sediments have never been penetrated in this area. The seismic reflection work (Fig. 15) also reveals an area of deep TMS basement near the coast in this vicinity.

It is considered that the the geometry of the confined portion of the TMS in the Coega Compartment has been adequately defined, especially in the area from the Springs to Coega Kop. To the north, an accurate positioning of the TMS-Bokkeveld contact was not possible due to scanty borehole information and limited geological data. Analysis of resistivity data could not accurately define layer boundaries because of high contact resistances between electrodes and the ground. East of Coega Kop, the TMS appears to have been eroded to a very deep level and the depth, combined with geoelectrical interference from salt-saturated clays, has made estimates of the thickness of the Cretaceous virtually impossible.

7.1.1.2 Hydrogeology

Prior to performing detailed geological and geophysical exploration, a census of all available groundwater abstraction points was calculated. For this purpose 175 boreholes and the Uitenhage Springs were visited (often on more than one occasion).

In each case as much information as possible was obtained from the landowner and measurements were made at the borehole itself. These data included information on depths, stratigraphy, yield, water quality, water use, rest and pumping levels, pump types and capacities, and borehole construction. All the data are presented in tabulated form in Appendix 1. The hydrogeological characteristics of the TMS aquifer were determined by utilizing the hydrocensus data, by drilling and aquifer testing, and by interpretation of groundwater chemistry (this latter aspect will be more fully dealt with in section 7.1.4). In the hydrogeological discussion, attention is paid to porosity permeability, transmissivity, storage, flow directions, rates of flow, and to the abstraction of groundwater from the TMS.

As mentioned previously, (Chapter 2 p 13) the quartz grains constituting the clastic component of the TMS have been cemented together in a matrix of silica. This syntaxial cement has rendered the TMS very low in primary porosity and permeability (Johnstone, 1982). Any capacity the rock may have possessed for storing or transmitting water, must therefore, be the result of secondary processes which formed voids in the forms of joints, fissures, faults and cleavages. These porous and permeable zones appear to be controlled strongly by directional factors related to regional stress patterns within the Cape Supergroup.

The directional component in porosity and permeability has resulted in calculated values for transmissivity and storage, for any aquifer test, being influenced by the relative positions of pumping and observation boreholes. In testing an anisotropic aquifer such as the TMS, great care should be exercised with the planning of test holes (pumped and observation) "as fracture anisotropy has a pronounced effect on the magnitude of drawdown" (Kohut et al., 1983, p 564)

In spite of the drawbacks in not having enough available boreholes to pump, even less to use as observation holes, and no say in the positioning of the latter, it was possible to arrive at a number of values for T (section 5.2.3), which it is felt, approximate the transmissivity for different areas of the Coega Compartment. The situation was not as fortunate for the determination of S (section 5.2.4), which is far more reliant on observation boreholes than T. In spite of close agreement among a number of calculated results, the mean value, (according to the range given by Freeze and Cherry, 1979), is far too high for a confined aquifer. A separate determination (performed on data from borehole RH31), gave a realistic value but was reliant on an estimate for one of the unknowns, any error being squared in the calculation.

According to Darcy (1856), one can assume that the underground flow is in the direction of pressure gradient and at right angles to pressure contours or isopotential lines.

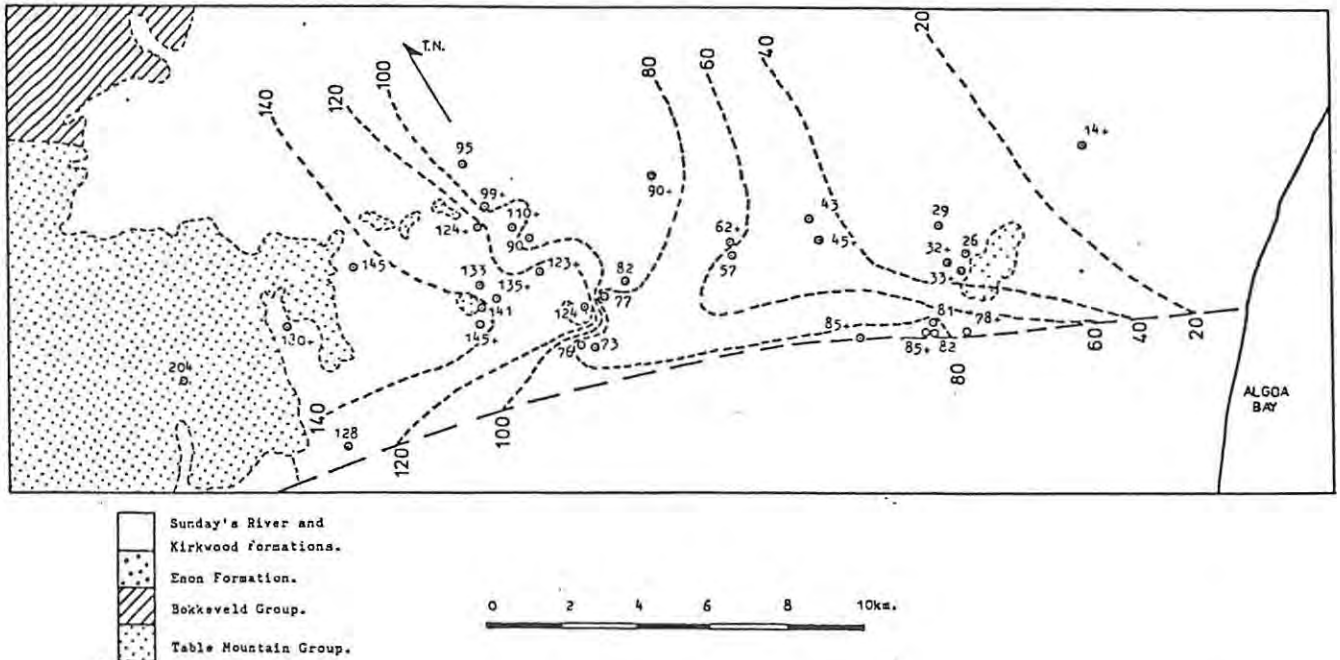


FIG. 28 PIEZOMETRIC SURFACE CONTCURS (in metres above sea level)

It is well illustrated in Fig. 28 that the piezometric contours are generally orientated north-south with the inference that groundwater flow should be from west to east. Naturally, any direction of increased transmissivity in an anisotropic aquifer will also play an important part in determining groundwater flow directions. Measurement of secondary permeability features, such as joints, cleavages and cracks, and graphical representation on a rose diagram (Fig. 5), has revealed a dominant fracture direction in a WNW - ESE direction with a secondary orientation at right angles to it. Mountain (1955) noted the general rough alignment of the chief artesian boreholes and suggested that there may be a system of joints associated with the Uitenhage-Coega Fault, and running parallel with it. This seems a fair assumption as the regional grain of Cape folding in the Southern Cape, is in a WNW - ESE direction.

Talma et al., (1983) undertook an isotopic study of TMS groundwaters in the Uitenhage area and found that modelled ages increase from recent, at the Uitenhage Springs, to about 26000 years old near Coega (Fig. 27). This increase confirms that the flow direction along the central portion of the Coega Ridge is WNW - ESE.

Anomalous results north and south of the central profile do tend to confuse the issue, but may be explained by slower flow rates in northerly and southerly directions or may be the result of more rapid flow along the Coega Fault. That the latter consideration has merit, is substantiated by the fact that some of the strongest boreholes in the area, SV3 (20,5 l/sec), CK 2 (4, 54 l/sec originally), CK 10 (13,95 l/sec) and CK 11 (16,69 l/sec), are located on, or close to the Fault. Borehole CK2 intersected TMS at 470 metres which strongly suggests that the intersection was made within the fault zone (see Fig. 4 B for cross-section).

Assuming that the Fault is a zone of high transmissivity, it would be expected that groundwater ages from boreholes on or near the Fault should be lower than for water derived from sources an equal distance from the recharge area, but away from the Fault. This is true for SV3 where the water is about 8000 years younger than from C2 which is roughly the same distance from recharge. Unfortunately the same is not true of CK2 where the water was dated at a similar age to nearby sample points away from the Fault. The reason for this is not, as yet, fully understood, although it may have something to do with the greater depth from which the water originates.

In the Coega Compartment, groundwater is abstracted from the TMS in four ways:

- a) By free-flowing boreholes and springs, where the groundwater reaches the surface and is either stored and used, or is wasted by being allowed to flow away uncontrolled.

As far as water usage is concerned, artesian flow is by far the most important method, as two of the strongest abstraction points are the Uitenhage Springs (63,5 l/sec), and borehole SV 3 (20,5 l/sec).

- b) By pumping non-flowing holes or attempting to increase the yield of flowing holes by pumping. With the exception of the Edwards Group on Amanzi Estate (27,9 l/sec), none of the pumped boreholes average more than 5,0 l/sec for more than 10 hours at a time. The total abstraction for the TMS for pumped and free flowing holes was calculated at 150 l/sec. This figure was obtained by recalculating pump rates per hour to l/sec for 24 hours. Windpumps were allocated an arbitrary value of 0,1 l/sec.
- c) By leakage, through corroded casing into slightly permeable layers within the Cretaceous. Groundwater loss by this method is impossible to quantify although those boreholes suspected of leaking have, to a large degree, been identified by hydrochemistry (Table 8, p 83).

The group of boreholes on Coega Kop (CK 9, 10, and 11), which are suspected to be amongst the worst offenders in terms of groundwater leakage, have been cleaned out in preparation for sealing with cement. An insight into the effects of sealing these holes will possibly be gained at a later date, if local piezometric levels rise, and if the nearby pans, thought to be in existence only due to inflow of artesian water, dry up.

- d) By natural gravity flow into the sea, with the TMS groundwater probably emerging somewhere offshore in Algoa Bay.

Reference back to Fig. 2 reveals that since water control regulations were instituted in 1957, a period of constant flow lasting till about 1967 was experienced. Thereafter the flow at the Springs increased steadily, suggesting that the controls were working. This increased flow, however, appears to be confined to the Springs, as little or no increase in piezometric level has been recorded in areas more distant from the recharge area. The reason for this may be found in the increased rainfall which has been consistently above the mean since 1974, and which would naturally affect the Springs long before the more easterly water points.

It is felt by the author that there is more work to be undertaken on the hydrogeology of this area. This is especially important with regard to well planned and executed aquifer tests, with properly situated and constructed observation boreholes, so that accurate values for T and S may be obtained.

7.1.2 Evaluation of Subordinate Aquifers

Within the Cretaceous Uitenhage Group, no aquifers of any exploitable importance were discovered. This may be due to the scarcity of the Enon Fm. in the study area, as Bush (1983) found this unit to be a very good water carrier in the Kruis River Compartment. The Kirkwood and Sunday's River Fms. comprise mainly impermeable clays with only thin discontinuous sandstone horizons. During exploratory drilling small amounts of water were intersected in the sandstones (maximum yield = 0,25 l/sec), but were of very poor quality. The one exception was the intersection in borehole CM6 of fresh water at 150 metres. This, however is attributed to water originating from the TMS (discussed in section 4.3.3., p 45).

The Bokkeveld Group does possess sandstone aquifers interbedded among the shales. The highest recorded yield in the study area was 2,8 l/sec for PK 32. The duration of the test was not given. Water qualities are slightly better than for the Upper Cretaceous formations (refer to section 7.1.4 below). In some cases (eg. PK4 and PK8) the Bokkeveld shows artesian characteristics where it is confined by the Cretaceous aquiclude. The Bokkeveld Group is the principal aquifer in the northern and north-western portion of the study area where the TMS is too deep for economical drilling.

7.1.3 Redefining the boundaries of the Control Area

It is the author's opinion that the Uitenhage Underground Water Control Area (U.U.W.C.A.), as it exists since Government Proclamation 260 in 1957, is far too large and could be trimmed down to cover the only three areas of real importance, - the recharge area, the Coega Ridge and Kruis River. The latter are the only two areas where large scale irrigation is carried out, and both are reliant on TMS-derived artesian water for their irrigation requirements. It can serve no useful purpose to continue imposing drilling and abstraction limitations on those areas where the TMS is way beyond the reach of a drilling rig, such as south of the Coega Fault east of Uitenhage. The boundaries of the Control Area in Kruis River will be reassessed on the basis of the report by Bush (pending).

7.1.4 Lateral and Vertical Water Quality Variations

Groundwater derived from the TMS aquifer tends to show a small increase in TDS content from the recharge area towards the sea (Talma et al., 1983). This is particularly noticeable for the ions Na + K and HCO₃, and is probably a result of dissolution of these ions during passage of water through the rock. Overall, however, the quality of TMS water remains very good except where it becomes mixed with quantities of Cretaceous water. This mixing is thought to occur through corroded casing where the slightly acidic TMS water has dissolved the steel.

The water derived from the overlying Cretaceous sediments is of very poor quality possibly resulting from the deposition of salts when the rocks were first laid down (section 6.1.3 , p 71).

Bokkeveld waters, although of limited importance in this investigation are also of poor quality, although slightly better than the Cretaceous. There appears to be very little mixing between Bokkeveld and TMS waters. Mixing between Bokkeveld and Cretaceous waters does probably occur, but because of their similar chemistries this is extremely difficult to detect.

7.2 Testing of Hypotheses

7.2.1 Aquifer Geometry and Geology

Hypothesis 1. The principal aquifer comprises the quartz-arenites of the Table Mountain Group.

The sheer weight of evidence in the form of abstraction rates, water quality and water use, ensure that this hypothesis is accepted. Notwithstanding the groundwater lost by leakage to the sea, the approximate average daily abstraction from the TMS in the study area is about 150 l/sec. This is compared with approximate values of 3,9 l/sec and 7,1 l/sec for the Cretaceous and Bokkeveld waters respectively.

The hypothesis is accepted

- Hypothesis 2. The argillaceous rocks of the Kirkwood and Sunday's River Formations act as an effective aquiclude.

The fact that the TMS aquifer does have artesian characteristics requires that there must exist a confining layer or aquiclude. The geology of the area as deduced by mapping, geophysics and drilling has indicated that, where the TMS aquifer is artesian, it is overlain by the Cretaceous rocks of the Kirkwood and Sunday's River Fms. It has been established (section 7.1.2 p 94), that minor aquifers do occur within the Cretaceous, but these narrow sandstone bands constitute only a small portion of the succession, which comprises mainly impermeable clays.

This hypothesis is accepted.

- Hypothesis 3. The Pre-Cretaceous Relief is extremely irregular.

Reference to the evidence quoted in section 7.1.1.1 reveals that the surface of the TMS is very irregular. It can, with justification be compared to the present day Groot Winterhoek Mountains which are highly dissected and which represent the exposed portion of the TMS which in the study area is covered by Cretaceous sediments.

This hypothesis is accepted.

- Hypothesis 4. The Uitenhage-Coega Fault, by juxtaposing impermeable with permeable strata, forms the southern boundary of the Coega Compartment.

The Uitenhage - Coega Fault which downthrows the TMS about 1000 meters has been fairly accurately located in the subsurface by geological, resistivity and reflection seismic techniques (see section p). The + 1000 meters succession of virtually impermeable Cretaceous sediments on the south side of the Fault, will act as a barrier to southward groundwater flow, although the fault may itself act as a zone of transmission (section 7.1.1.2 p).

Because of the lack of direct evidence regarding the Fault as a barrier to groundwater flow, the hypothesis is accepted with reservations.

7.2.2 Geohydrology and Hydrochemistry

Hypothesis 5. The Table Mountain quartz - arenites form an inhomogeneous aquifer with secondary permeability being governed by the degree and orientation of jointing, fracturing and faulting.

As discussed in section 2.2.2.1, p 13, and section 7.1.1.2 p 91, the TMS has a very low primary porosity and permeability. Any storage, or water carrying capacity possessed by the TMS must necessarily be provided by secondary features such as those mentioned above. The degree of permeability is governed by the width, and frequency of occurrence of the cracks and joints. The directions of maximum and minimum permeability are determined by the orientation and degree of interconnection between fractures. In borehole RH36, for instance, although the TMS was intersected at 76 metres, the hole had to be deepened to 108 metres before a water-carrying fracture was struck and an artesian flow established. A further example of inhomogeneity was provided by the drawdowns in boreholes CK9 and CK11 respectively. When CK11 was pumped there was virtually no effect on the artesian flow of CK9. When CK9 was pumped, there was an almost immediate drawdown in CK11, and this increased steadily with pumping time. The hypothesis is accepted.

Hypothesis 6. The direction of flow is predominantly from the WNW to the ESE.

Data from the orientation of the piezometric contour lines (Fig. 28), isotope studies, geology and hydro-chemistry all indicate a predominant flow direction of WNW-ESE (section 7.1.1.2, p 92). Lesser flow loops (Verhagen pers. comm.) may occur locally, and there are almost certainly, northerly and southerly flow components in the vicinity of the recharge area. In general, however, the available evidence all suggests a WNW-ESE direction of flow.

The hypothesis is accepted.

Hypothesis 7. Water derived from the Table Mountain Group quartz arenites is less mineralised than that from the Bokkeveld and Cretaceous sediments.

The superior quality of the TMS-groundwater is amply demonstrated by the graphical and statistical techniques utilized in Chapter 6 (Fig. 21 - 25). As an example, the mean TDS contents for the three groundwaters are 170 mg/l, 3294 mg/l and 5070 mg/l for the TMS, Bokkeveld and Cretaceous respectively.

The hypothesis is accepted.

7.3 Recommendations

It is the opinion of the author that a few aspects of the investigation are worthy of more attention and/or follow up work. These are;

- a) Additional aquifer tests are required to quantitatively assess the transmissivity and storage of the TMS aquifer. These tests should involve a number of observation boreholes at pre-determined directions and distances from the pumped hole in order to maximise the data retrieved from any single test.
- b) The drilling at borehole CM6 should be continued in order to obtain a fix on the depth to TMS in the coastal area. The deeper drilling may also help to explain the origin and movement of the artesian water struck in this hole.
- c) The artesian water from CM6 should be sampled and analysed for ^{14}C so that an age determination may be made. This is particularly important as CM6 is the borehole furthest from the recharge area to tap water derived from the TMS.
- d) The boundaries of the Control Area should be redefined to include only those areas in which controls are necessary, ie. the recharge area, the Coega Ridge and Kruis River.
- e) The controls on borehole construction, especially with regard to the compulsory use of PVC casing, should be retained and, if possible, more strictly enforced.

7.4 Conclusions

In the Coega Compartment, the TMS forms the principal aquifer of the artesian system. The confined section of the TMS which is available for exploitation, extends from the mountains in the west to the sea in the east, and from the Coega Fault in the south, to the Bokkeveld sub-outcrop in the north. The buried surface of the TMS is extremely irregular forming inliers rising above the Cretaceous sediments. The predominantly argillaceous rocks of the Cretaceous form an effective aquiclude, and contribute to the artesian nature of the area.

The predominant direction of groundwater flow is from WNW to ESE although minor flow loops and secondary flow directions may exist locally. Movement of groundwater is controlled by the orientation and dimensions of secondary fractures in the TMS, reflecting the inhomogeneous nature of the aquifer. The quality of the TMS - derived groundwater is vastly superior to that of the Bokkeveld. The Bokkeveld in turn provides groundwater of slightly better quality than the Cretaceous.

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APPENDIX 1

UITENHAGE-COEGA BOREHOLE SURVEY DATA

Abbreviations used.

Stratigraphic

TMS. - Table Mountain Sandstone.
Bok. - Bokkeveld Group.
Cret. - Cretaceous Sediments.

Lithological

t.s. - topsoil
sst. - sandstone
sltst. - siltstone
cl. - clay
sh. - shale
cong. - conglomerate
b.b. - boulder bed
cc. - calcrete
grav. - gravel
lat. - laterite

Equipment

w.p. - windpump
p.h. - power-head
m.p. - mono-pump
s.p. - submersible pump
c.p. - centrifugal pump
rec. - recorder
h.p. - horse-power
kW. - kilowatt

Water use

dom. - domestic
stock. - stock watering
irr. - irrigation
ind. - industrial

Other

n.m. - not measured
r.w.l. - rest water level
art. - artesian

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Eqipt.	Water use	T.D.S. (mg/l)	Remarks
<u>CADASTRAL FARM: ALWYN BALMORAL</u>											
<u>Portion: Rem. Local name-Woodlands Owner: Mr Saayman</u>											
AB1	1930	500'	----	sh.	34,44m	----	0,6 l/s	p.h.+5h.p. elec.motor	Stock	4413	Permit No. 348/3/2/(551) Max for AB 1&2 1,095,000g/yr.
AB2	1930	----	----	----	----	----	50g/hr.	broken w.p.	----		
<u>Portion: Rem. Local name-Alwynhoek Owner: Mrs C. Stumke</u>											
RH26		392'	----	----	61,15m	----	100g/hr.	p.h.	dom.& stock	----	Permit No. 348/3/2 (536) Hole to be sealed. New on. 3305000g/yr.
RH26A	11/6/79	137,5m	47,2m 118,3m	0,12,2m cl. -95,5m sh. -130,8m sst -137,5m sh.	----	----	not tested	----	----	----	v. salty Filled in.
RH26B	30/7/79	153,5m	11,3m 140m	0-21,3m cl. -109,7m sh. -111,3m gr. -158,5m sh.	31,75m	----	0,75 l/s	p.h.	----	----	Not in use.
RH26C	16/11/79	162,8m	73,2m 112,8m 137,2m	0-162,8m cl.	----	----	not tested	----	----	----	Salty. Filled in.
RH26D	9/10/79	33,53m	dry	0-33,53m cl.	----	----	not tested	----	----	----	No water. Filled in.
RH26E	10/1/80	70,1m	51,8m 64,0m	0-15,2m cl.& sh. 0-70,1m sst.	37,12m	----	30g/hr	p.h.	----	----	Not in use.
RH26F	4/2/80	123,1m		0-30,5m cl. -70,1m sst. -106,7m cl. -121,9m sst. -123,1m sh.	23,34m	----	0,2 l/s.	m.p.	dom.& stock	----	

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Eqipt.	Water use	(mg/l) T.O.S.	Remarks
RH27	----	600'	----	----	----	----	200g/h.	m.p.	dom. & stock	----	Permit No. 348/3/2(336) /30,000g/yr.

NOTE The above boreholes with the prefix "RH" have been incorrectly numbered as they do not fall within the Rietneuwel cadastral boundary. They should be numbered with the prefix "A8". To avoid confusion and because the "RH" numbers have been used in all correspondence and reports—the original numbers will be retained for the present.

CADASTRAL FARM: ANANZI

Portion: Rem. of Balmoral Annex. Owner: Mr P.N.F. Niven

BA1	1912	235'	196' 205'	0-185' cl. -235' FMS	flow	Total for BA1,2,3= 5,6 l/sec.	15 l/sec	----	irr.	225	Bhs. BA1,2,3 comprise the "Main Group" Permit No. 343/3/2(190) 430,000g/day.
BA2	1927	196'	----	----	flow	----	----	---	irr.	225	Flow from BA1&2 meas. over V-notch.
BA3	1947	68m	----	----	-----	-----	----	-----	----	----	Collapsed.

Portion: Rem. Owner: Mr P.N.F. Niven

RH21	----	----	----	----	flow	10g/hr.	----	----	----	----	Alfred's bh.
RH22	----	----	----	----	flow	133g/hr	----	----	----	153	Zinka bh.
RH39	3/4/34	140m	21m-60g/hr. 44m-200g/hr. log 140m-2,66 l/s	see bh.	13,60m	----	2,66 l/s	-----	research	11000	Exploration bh. Drilled for strat. info. & geophys. corr.

NOTE The above 6 boreholes have been incorrectly numbered. They should have the prefix "A4" (Ananzi) before the number.

Bn.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Eqipt.	Water use	f.D.S. (mg/l)	Remarks
<u>CADASTRAL FARM: BAUERSKRAAL 234</u>											
<u>Portion: 1. Local name-Bouwerskraal Owner: Mrs S.S.A.M.Botha</u>											
BK2	1962	300'	25' 220'	sh.	6,25m	----	800g/hr.	2"m.p.	dom. & stock	----	Permit No. 348/3/2(50d)
BK4	1956	250'	30' 100'	sh.	8,30m	----	1000g/hr	m.p.	dom. & stock.	----	Total abstraction from Ptn. 1 not to exceed 6,000,000g/yr.
<u>Portion: 2. Local name-Bouwerskraal Owner: Mr Z.J.de B.Slabbert</u>											
BK6	15/5/63	386'	40' 190' 380'	TMS.	flow	0,57 l/s	9750g/hr.	c.p.+25 h.p. diesel	stock	242	Permit No. 348/3/2(544) 1,587,500g/yr.
BK12	----	----	----	cl.&TMS	flow	?	----	-----	----	-----	Sealed with a steel plate.
<u>Portion: Rem. Local name-Glensomers Owner: Mr M.C. Ranger</u>											
BK9	----	350'	----	TMS	flow	0,12 l/s	2000g/hr	----	dom,irr & stock	277	Permit No. 348/3/2/(545) 3,095,000g/yr.
<u>CADASTRAL FARM: BONTRUG 301</u>											
BK1	----	500'	200'	cl.	----	----	200g/hr	w.p.	stock	7200	
<u>CADASTRAL FARM: CENTLIVRES 231</u>											
<u>Portion: Rem. Owner: Mr H.L.C. Kleynhans</u>											
CL1	1960	200'	120'	gr. & sh.	----	----	80g/hr	w.p.	dom & stock	3200	

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Equip.	Water use	T.D.S. (mg/l)	Remarks
CL2	27/4/65	217'	130	gr. & sh.	17,89m	----	450g/hr	w.p.	stock	3200	
CL3	1964	330'	150'	gr. & sh.	----	----	150g/hr	w.p.	stock	8850	
CL6	16/10/70	520'	455'	cl. & TMS	----	----	1000g/hr	m.p.	dom. & stock	484	Permit No. 343/3/2/(506) 3000g/hr. was weak art. 442' x 6" casing cemented in.
<u>Portion: Centlivres West Outspan 232 Owner: Uitenhage Divisional Council</u>											
CL5	1957	660'	----	cl. & sh.	----	----	150g/hr	w.p.	stock	2570	No permit. was weak art.
<u>Portion: 1. Owner: Mr.J.N. Pieterse</u>											
CL8	30/10/73	231,8m	77,1m 131,1m	0-77,1m sh -82,3m sst. -231,6m sh.	77,11m	----	120g/hr 6h.p.eng	p.h.+ stock	5000		Permit No. 343/3/2/(532) 437dm ³ /yr. 400' x 5" pvc. casing.
<u>Portion: 2. Owner: Mr.S.C.J. Bosch</u>											
CL9	7/5/80	140m	91m	0-4,9m t.s -57,9m cl. -76,2m sst. -88,4m sh. -90,8m sst. -103,0m sh. -115,2m sst. -140,0m sh.	85,55m	----	1500 l/hr	----	----	----	Permit No. 343/3/2/(559) 5000m ³ /yr. Max. 13,1m ³ /day

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Equipmt.	Water use	T.D.S. (mg/l)	Remarks
<u>CADASTRAL FARM: COEGA</u>											
<u>Portion: Rem. Owner: Mr A. Mattheus</u>											
C1	----	400'	----	----	6,29m	----	200g/hr.	----	----	----	Downpipes still in hole.
C2	----	500'	----	cl. & TMS	flow	122g/hr.	3600g/hr.	----	stock	1300	Casing prob. corroded.
C4	1928	500'	----	cl/ & TMS	2,34m	----	1440g/hr	3"m.p.+ electric motor	dom. & stock	322	
<u>Portion: 8 Owner: Mr Amersfoort</u>											
C5	----	770'	----	----	2,81m	----	1200g/hr	s.p.	dom. & stock	165	
C6	----	650'	----	----	----	----	----	----	----	----	Bh. sealed at collar.
<u>Portion: 2. Local name-Glen Graham Owner: Mr H.H. Maasdorp</u>											
C10	----	250'	----	cl. & sst	20,40m	----	60g/hr	w.p.	stock	9200	Was bh. no. WF11
<u>Portion: 7. Owner: Mr D. Mattheus</u>											
C9	----	460'	----	cl. & sst.	flow	weak	----	p.h.	dom. & stock	825	
<u>Portion: Rem. of Ptn. 3. Local name-De Rust Owner: Mr H.H. Maasdorp</u>											
C7	1944	450'		cl. & sst.	flow	0,2 l/s	800g/hr.	----	stock	----	

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Eqipt.	Water use	T.D.S. (mg/l)	Remarks
<u>CADASTRAL FARM: COEGA'S RIVER MOUTH</u>											
<u>Portion: 1. Local name-Coegasmond Owner: Mr S. Potgieter</u>											
C41	----	495'	----	----	----	----	300g/hr.	p.h.	stock	----	
C46			151m-0,21/s	see bh. log				research			Exploration on. Drilled for strat. info. & geophys. correlation.
<u>Portion: 2. Local name-Sonop Owner: Mr C. J. Ferreira</u>											
C43	----	430'	----	----	24,30m	----	200g/hr	broken w.p.	----	----	
<u>Portion: 4. Local name-Saltworks Owner: Cerebos Food Corporation</u>											
C45	----	700'	----	----	4,97m	----	400g/hr.	p.h.+7.5 h.p.motor	ind. & dom.	----	
<u>CADASTRAL FARM: COEGAS KOP 316</u>											
<u>Portion : 4. Local name-Paisley Owner: Mr E. M. Ferreira</u>											
CK1	----	405'	----	blue cl.	15,10m	----	200g/hr.	----	----	----	Open dh.
CK2	25/1/57	1541'	1541'	0-1540-cl -1541-sst	flow	0,18 l/s	3600g/hr.	----	stock	136	Art. flow was orig. 5,4 l/sec. Poss. situated on Coega fault.

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Equipt.	Water use	T.D.S. (mg/l)	Remarks
<u>Portion: Rem. Local name-Kelvin Grove Owner: Mr C J Mattheus</u>											
CK4	----	432'	----	----	----	----	----	----	----	----	Filled in.
CK5	----	600'	----	----	6,53m	----	350g/hr.	----	----	----	Open on.
CK6	----	170'	----	----	3,05m	----	250g/hr.	p.h.3h.p.	----	----	Not in use.
CK17	----	150'	125'	----	----	----	100g/hr.	----	----	----	Filled in.
<u>Portion: Local name-Pollockshaws Owner: Mr C.J. Mattheus</u>											
CK7	----	300'	----	----	4,64m	----	800g/hr.	p.h.	----	----	Not in use.
CK9	----	796'	----	----	flow	----		----	----	148	Cleaned for sealing.
CK10	Sept.1950	808'	156'-in sst. 354' 791'-w.l. rose to 93' 792'-w.l. rose to 73' 804'-w.l. rose to 18' 805'-flow.	Cret.to 790'	3,65m	----	1205m ³ /d	----	----	135	Cleaned for sealing. Orig. art. flow was 18500g/hr @ 08'
CK11	26/353	782'	----	Cret.to 781'	3,88m	----	1442m ³ /d	----	----	124	Bh. stopped flowing in 1962. Cleaned for sealing in 1984.
<u>Portion: Rem. of Ptn 1. Local name-Pollockshaws Owner: Mr C. J. Mattheus</u>											
CK13	1940	200'	----	cc.,cl.,TMS	8,87m	----	900g/hr.	s.p.3.6. h.p.	dom & stock	189	
CK14	1949	315'	95'	cc.,cl.,TMS	----	----	1200g/hr.	m.p.	---	---	Not in use.

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	EQUIPT.	Water use	T.D.S. (mg/l)	Remarks
CK15	----	204'	----	----	----	----	1200g/hr	s.p.	dom.	530	Prob.leaking.
Portion: 7. Local name-Kelvin Grove Owner: Mr Rossouw Booysen											
CK16	---	127m	----	----	32,83	----		p.h.driven by tractor	dom. & stock	----	
Portion: 13 Owner: SOEKOR											
CK19	Nov.1968	150m	----	weath.sh	35,87m	----	120g/hr.	----	----	----	hole used for instr. calibration
CADASTRAL FARM: DOORNKOM 229 Owner: Mr C J Pieterse											
DK1	1945	500'	----	cc.,cl.,TMS.	flow		20g/hr.	----	stock	165	v. weak art.
DK2	14/5/1947	254'	53' 197'	----	----	----	1440g/hr.	w.p.	stock	----	Permit no. 343/3/2(180)
DK4	14/2/45	331'	90' 135'	cc.,cl.,TMS.	15,59m	----	2000g/hr	m.p.	dom. & stock	----	Total abstraction from DK2,4&6 not more than 1,095,000g/yr.
DK6	1967	700'	----	----	----	----	100g/hr	----	----	----	
DK7	19/1/82	89,7m	82,3m	0- 5m cc. -14 cl. -19 sst. -23 sltst. -29 cl. -33 sst. -90 cl.	70,58m	----	0,38 l/s	w.p.	stock	----	
CADASTRAL FARM: GRASSRIDGE 228 Owner: Tregathlyn Farms (Pty) Ltd.											
GR5	----	182m	----	----	64,87m	----	----	----	----	----	Open hole.
GR10	----	----	----	----	2,10m	----	----	broken w.p.	----	----	

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Equipt.	Water use	T.O.S. (mg/l)	Remarks
GR11	----	----	----	----	flow	v weak	----	----	----	177	
<u>CADASTRAL FARM: CRASSRIDGE 226 Owners: Mrs de Beer and Miss Rautenbach</u>											
GR1	1932	250'	----	----	19,58	----	80g/hr.	w.p.	stock	2950	Permit No. 348/3/2/(539)
GR2	1945	500'	----	----	----	----	200g/hr.	p.h. 7h.p.	stock	----	Total abstraction 4378m ³ /yr.
GR3	----	500'	----	----	29,43m	----	30g/hr.	w.p.	stock	----	
GR13	16/10/72	403'	210'	0-150' cc. -210' cl. -213' sst. -403' cl.	----	----	725g/hr. 75 g/hr	w.p.	stock	----	
<u>CADASTRAL FARM: HILLWAGT 289</u>											
Portion: 1 Local name-Leliekran's Owner: Mr van Vuuren											
HW1	1965	332'	228'	TMS.	66,50m	----	210g/hr.	----	----	----	Open bh.
HW1A	13/8/71	426'	360-380'	0-25' cl. -426' TMS	----	----	1126g/hr	p.h.	dom. & stock	----	
HW2	7/7/74	351'	210'	cl. & TMS	----	----	24g/hr.	w.p.	stock	----	
Portion: Rem Local name-Hillwacht Owner: Mr G.V. Naude											
HW3	1960	300'	----	----	39,66m	---	900g/hr.	m.p.	dom. & stock	----	
HW4	----	600'	----	----	42,66m	----	----	broken w.p.	----	----	
<u>CADASTRAL FARM: KLEINE GRASS RUG. Owner: Mr Saayman</u>											
KG1	----	----	----	----	38,16	----	----	w.p.	stock	3700	
KG2	----	----	----	----	----	----	----	hand p.	dom.	454	

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Equip.	Water use	T.D.S. (mg/l)	Remarks
<u>CADASTRAL FARM: LONGWOOD 295</u>											
<u>Portion: Rem. of Ptn. 4. Local name-Longwood Owner: Mr H.M. van der Merwe</u>											
RH5	1958	320'	----	----	38,72m	----	200g/hr.	----	----	----	Permit No. 348/3/2(557) 547,500g/yr.
RH25	27/8/76	102m	74m	0-70m c1. -102m TMS.	16,00m	---	1,8 l/s	m.p.	dom. & stock	----	547,500g/yr.
RH33	8/6/71	454'	423'	0-195' c1. -454' TMS.	----	----	634g/hr.	----	----	----	547,500g/yr.
<u>Portion: 7. Local name-Little Springs Owner: Dr Rossouw</u>											
RH7	1940	290'	240'	----	----	----	400g/hr.	hand p.	----	----	Not in use.
RH8	----	----	----	----	flow	v weak	2,86 l/s	m.p.+ 4kw motor	irr., dom stock	136	Permit No. 348/3/2(579) RH7 0,51 l/sec RH8 2,34 l/sec RH9 0,63 l/sec
RH9	1951	450'	300'	----	----	----	0,14 l/s	w.p.	dom. & stock	----	
<u>Portion: 3. Local name-Longwood Owner: Mr M.J.J. van Rensburg</u>											
RH23A	6/10/71	483'	457'	0-381' c1. -483' TMS.	flow	0,24 l/s	1290g/hr.	m.p.	dom. & stock	124	Permit No. 348/3/2(432) 300g/hr. 1,095,000g/yr.
<u>Portion: 2. Local name-Longwood Owner: Mr E.J. Meiring</u>											
RH6	1958	310'	300'	c1. & TMS.	flow	v weak	----	----	stock	----	Permit No. 348/3/2(431) RH6 0,075 l/sec. RH32 to be sealed. RH32A 663m ³ /yr. 0,51 l/sec.

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Equipt.	water use	T.O.S. (mg/l)	Remarks
RH32	2/6/70	433'	350' 416'	0-280' cl. -290' sst. -338' cl. -354' sst. -368' cl. -433' TMS.	flow	weak	1014g/hr.	w.p.	dom. & stock	130	To be sealed.
RH32A	5/10/79	108m	102m	0- 93m cl. -103m TMS.	flow	30g/hr.	1,8 l/s.	w.p.	dom. & stock	165	
<u>Portion: 1. Local name-Longwood Owner: Mr J. S. Rudman</u>											
RH12A	----	348'	315'	0-150' cl. -348' TMS.	8,84m	----	630g/hr.	1.5"m.p.	dom. & stock.	----	Permit No. 348/3/2(177) 1,095,000g/yr.
<u>Portion: 6. Owners-Mrs Thompson & Mrs Beneke</u>											
RH11	1960	110'	60'	cl. & TMS.	----	----	300g/hr.	hand p.	dom. & stock	212	Permit No. 348/3/2(576) 4926m ³ /yr.
RH40	21/4/82	62m	42m	0-41m cl&sst -62m TMS.	flow	200g/hr.	1980g/hr.	---	---	162	w.l. of RH40 greatly aff. by pumping of RH8.

NOTE: The boreholes listed under Longwood above have been incorrectly numbered. They were originally thought to be situated within the Rietheuwel cadastral boundaries and were allocated the prefix "RH". The numbers should be changed to contain the Longwood prefix "LW" but because the RH numbers have been used so frequently in correspondence and reports they will be retained for the present to avoid confusion.

CADASTRAL NAME: MORMONSVLAKTE 562 Now part of the Motherwell Township-Administered by the E.C.A.B.

AV2	----	400'	----	----	----	----	400g/hr.	w.p.	stock	212	Not in use.
AV3	----	300'	----	----	----	----	120g/hr	----	----	153	Filled in.

CADASTRAL NAME: PAPENKUILSVLEI Owner: Mr P.N.F. Niven

PV2	27/5/82	117m	104m	0- 42m cl. -117m mdst.	36,0m	----	1 l/sec.	w.p.	stock		Permit No. 348/3/2(183) 4972m ³ 3yr.
-----	---------	------	------	---------------------------	-------	------	----------	------	-------	--	---

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Eqipt.	Water use	T.O.S. (mg/l)	Remarks
<u>CADASTRAL NAME: PRENTICEKRAAL 233</u>											
<u>Portion: 20. Local name-Rondalia Owner: Mr D.J. Louw</u>											
PK2	1960	300'	140' 240'	sh.	20,09m	----	600g/hr	Recorder	Research	----	
PK30	9/12/68	325'	80' 310' 325'	0-25' bb.,cl -90' sst. -270' cl.,sst -325' TMS.	flow	90g/hr	2,7 l/s.	----	stock	142	Permit for PK30&35 348/3/2(499) 5000m ³ /yr.
PK35	16/11/81	106m	103m	0- 90m cl. -106m TMS.	24,0m		0,7 l/s.	w.p.+p.h. 2,2kw.	stock	472	
<u>Portion: 7. Owner: Mr P.J. du Pisanie</u>											
PK4	1959	420'	100'	cl.&sh.	flow	90g/hr	100g/hr	1,5"m.p.	irr.& stock	2800	Permit No. 348/3/2(573) PK4-2,400,000g/yr.
PK6	1963	320'		cl.&sh.	11,66m	----		w.p.	stock	1560	PK6-300,000g/yr
PK7	1963	380'	100' 260'	cl.&sh.	9,31m	----		----	----	----	PK7-1,095,000g/yr.
PK28	17/1/69	437'	25' 130' 430'	sh&sst.	flow	v weak	1200g/hr	2"m.p. 6h.p.	irr.& stock	----	Art.flow orig 124g/yr.
<u>Portion: 11. Owner: Mr E.M. Saayman</u>											
PK8	1962	250'	150'	sh.	flow	200g/hr.	720g/hr	----	stock	3000	
<u>Portion: 17. Local name-Harmonie Owner: Mr J.F. Sauders</u>											
PK9	1963	250'	150'	sh.	40,44m	----	150g/hr	w.p.	stock	4000	Permit 348/3/2(555) 3000g/day 1,095,000g/yr.

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Equipt.	water use	T.O.S. (mg/l)	Remarks
<u>Portion: 16. Owner: Mr P. Grewar</u>											
PK10	1958	220'	170'	cl.&sh.	10,88m	----	300g/hr	w.p.	stock	2500	Permit No. 348/3/2(509) 3000g/day 1,095,000g/yr.
<u>Portion: 6. Local name-Eureka Owner: Mr D.S. Vermaak</u>											
PK13	----	268'	----	----	21,53m	----	800g/hr.	----	----	----	Open hole
PK13A	30/9/77	50m	----	TMS.	16,57m	----	1 l/sec	w.p.+p.h	dom & stock	136	Permit No. 348/3/2(514) 4378m ³ /yr.
<u>Portion: 13. Owner: Mr C.P. Ferreira</u>											
PK18	1956	230'	212'	----	----	----	----	----	----	----	
PK32	11/8/75	48m	27m 43m	0-22m cl. -48m sh.	----	6,22m	2,8 l/s	w.p.	stock	5200	Permit No. 348/3/2(528) 4980m ³ /yr. 0,3d l/s
<u>Portion: Rem. Owner: Mr J. Kitching. Alsas (Pty) Ltd.</u>											
PK22	28/9/65	620'	----	0- 84' sst. -620' cl&sh.	11,81m	----	500g/hr	----	----	----	Monthly water-level meas.
<u>Portion: 8. Owner: Mr S.J. Rudman</u>											
PK31	11/4/69	363'	340'	0- 62' cl. - 70' bb. -240' cl. -255' sst. -340' sh. -363' sst.	----	----	150g/hr	w.p.	dom. & stock	2240	Permit No. 348/3/2(501) 3000g/day 1,095,000g/yr.

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Equipt.	Water use	T.D.S. (mg/l)	Remarks
<u>Portion: 21. Owner: Mr C. van Antwerpen</u>											
PK34	30/3/79	144,0m	140,0m	0- 98m sst. -144m T/S	----	----	0,64 l/s	w.p.	dom. & stock	384	Permit No. 348/3/2(587) 4978m ³ /yr. 0,33 l/s.
<u>Portion: 12. Local name-Ruimte Owner: Mr F.L. Louw</u>											
PK33	12/8/75	94,5m	24,4m 64,0m	0-21,0m cl,sst -94,5m sh.	32.33m	----	0,29 l/s	w.p.	stock	----	Permit No. 348/3/2(532) 4978m ³ /yr. 0,38 l/s.
<u>Portion: 25-A Ptn. of Ptn 7. Owner: Mr J.J.D. Williamson</u>											
PK36	19/4/73	553'	305'	0- 80' cl. -182' sh. -184' sst. -304' sh. -305' sst. -553' sh.	1,84m	----	----	c.p.	dom. & stock	----	Permit No. 348/3/2(572) 1 successful pn. 1,035,000g/yr. 300g/hr.
PK37	12/8/74	302m	180m	----	3,12m	----	3,2 l/s	s.p.	dom. & stock	----	
<u>CADASTRAL FARM: 290 UIT.Q.15.3.</u>											
<u>Local name-Glen Mere Owner: Mr D.J. Welgemoed</u>											
PK14	1927	500'	450'	cl.&TMS.	flow	240g/hr	6000g/hr	----	stock	----	

NOTE: This borehole is prob. incorrectly numbered as it does not fall within the Prenticekraal cadastral boundary.

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Equipt.	Water use	T.D.S. (mg/l)	Remarks
<u>CADASTRAL FARM: RIETHEUWEL 296</u>											
<u>Portion: 14. Owner: Mr L.J. Mulder</u>											
RH1	----	243'	240'	cl.&TMS	----	was 2,52 1/s		----	----	130	Sealed with cement.
RH31	1983	75m	75m	see bh. log	flow	1,2 1/s	9,0 1/s	----	dom. & stock	124	Permit No. 343/3/2/(186) 1500g/day Repl. for RH1
RH37		60m	dry	cl.	----	----	----	----	----	----	Sealed with cement.
<u>Portion: 8. Owner Mr N.P. Smith</u>											
RH4	1957	779'	----	----	----	----	360g/hr.	----	----	----	Collapsed.
<u>Portion: 13. Owner: Mr N.P. Smith</u>											
RH2	----	240'	----	cl.	----	----	----	----	----	----	Salty, collapsed.
RH24	19/1/74	83,8m	49m 82m	0-72m cl. -83,8m TMS.	----	was 0,5 1/s	not tested	----	----	140	Sealed with cement.
RH34	1983	98m	dry	see bh. log.	----	----	----	----	----	----	Collapsed.
RH35	1983	202m	dry	see bh. log.	----	----	----	----	----	----	Collapsed.
RH36	1983	108m	108m	see bh. log.	flow	1,9 1/s	9,0 1/s	----	irr. & stock.	130	Permit No. 343/3/2(184) 4927.5m ³ /yr.
RH38	1973	76,2m	48,8m 55,8m	0-55,8m cl. -76,2m TMS.	----	----	400g/hr.	----	----	----	was weak art. Sealed with cement.

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Eqipt.	Water use	T.D.S. (mg/l)	Remarks
Portion: 7 Owner: Rietheuwel Farm Fare-Epol (Pty) Ltd.											
RH3	1956	483'	----	----		----	----	s.p.	poultry	----	Permit no. 348/3/2(183) 5,595,000g/yr.
Portion: 4. Local name-Amanzi Estates Owner: Mr P.N.F. Niven.											
RH14	1955	863'	----	0-120' cl. -175' sst. -538' cl. -863' TMS.		flow	Total flow for RH14,15,16 =2300g/hr	----	irr.	136	RH14, 15 & 16 known as the Foxcroft Group Permit no. 348/3/2(188) 144,000g/day. RH14 orig. yielded 7000g/hr.
RH15	1959	1036	----	----		flow	"	w.p.	dom.	"	RH15 orig. yielded 8140g/hr.
RH16	----	----	----	----		flow	"	----	irr.	"	
RH17	1956	55m					with both pumps on, total yield for RH 17&18 =22,100g/hr	s.p. 15h.p.	irr. & dom	130	RH17, 18&19 known as the Edwards group. Permit no. 348/3/2(189) 480,000g/day.
RH18	1916	158m(?)	----	----		10,65m	"	s.p. 15h.p.	irr. & dom	"	Flow stopped 1954.
RH19	1951	227'	170'-176' 209'	0- 19' lat. -126' cl. -227' TMS.		10,58m	----	recorder	research	"	Also called "Naude" borehole.
Portion: Rem Owner: Mr N.P. Smith											
RH28	1910	300'	----	----		33,35m	----	300g/hr	w.p.	dom. & stock.	270 Permit No. 348/3/2(93) All 3 boreholes 100g/hr. 365,000g/yr.
RH29	1910	250'	----	----		13,57m	----	100g/hr	w.p.	----	RH29 not in use.
RH30	1963	550'	500'	cc.,cl.,sst.		59,33m	----	60g/h.	w.p.	stock	----

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Eqipt.	Water use	T.O.S. (mg/l)	Remarks
--------	--------------	-------	----------	--------	--------	-----------	--------------	--------	-----------	---------------	---------

NOTE: Borehole RH30 is incorrectly numbered. It falls within the Grass Rug 297 cadastral boundary and should have number prefixed by the letters "GG".
Other RH numbers may be found under Longwood, Amanzi or Alwyn Balmoral.

CADASTRAL FARM: SANDFONTEIN 291

Portion: 2. Owner: Mr J.J.H. Claase

SF1	13/3/1916	592'	----	0-542'cl -592' TMS.	flow	v. weak	----	----	----	----	Orig. yield 10,000g/hr.
-----	-----------	------	------	------------------------	------	---------	------	------	------	------	----------------------------

CADASTRAL FARM: STILLWELL

Portion: Rem. Owner: P E Municipality, E.C.A.B.

S#2	----	685'	----	----	----	----	----	----	----	----	Filled in.
-----	------	------	------	------	------	------	------	------	------	------	------------

Sutton Vallance-see Wells Estate

CADASTRAL FARM: SWARTKOPPEN 302

Portion: Rem. of Ptn. 1 Owner: Mr A. Mattheus

SK1	----	300'	----	----	----	----	200g/hr.	----	----	1100	Not in use.
-----	------	------	------	------	------	------	----------	------	------	------	-------------

Portion: 17 Owner: Mr Pienaar

SK4	----	250'	----	----	23,04m	----	100g/hr.	w.p.	stock	5500	
-----	------	------	------	------	--------	------	----------	------	-------	------	--

Portion: 20 Local name-Reading Owner: Algoa Brick and Tile

SK7	----	960'	----	----	----	was weak	400g/hr. 13hrs/day	s.p.	ind.	177	Permit no. 348/3/2(442) 65,8m ³ /day 24,000m ³ /yr.
-----	------	------	------	------	------	----------	-----------------------	------	------	-----	--

SK8	----	500'	----	----	----	----	100g/hr	s.p.	dom.	3360	
-----	------	------	------	------	------	------	---------	------	------	------	--

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Eqipt.	Water use	T.D.S. (mg/l)	Remarks
<u>Portion: 27. Owner: Sainova Salt</u>											
SK10	----	692'	----	----	----	----	850g/hr.	m.p.5h.p.	dom.	2950	
SK11	----	684'	----	----	24,53m	----	50g/hr.	----	----	----	Not in use.
SK20A	----	18m	----	0-10m sand -17m sst. -18m cl.	0,35	----	6,7 l/s.	----	----	6300	Not in use.
<u>Portion: Rem. of Ptn. Reading Owner: Algoa Brick and Tile</u>											
SK12	----	790'	720'	cl.,bb.,TMS.	flow	40g/hr	2000g/hr.	s.p. 3h.p.	dom.	625	Prop. leaking.
<u>Portion:5. Owner: Mr A. Mattheus.</u>											
SK13	----	----	----	----	6,08m	----	----	w.p.	stock	6260	
<u>NOTE:</u>	Bhs. SK18 and SK19 below are incorrectly numbered. They fall within the Coegakop cadastral boundary and should be prefixed with the letters "CK".										
SK18	17/5/28	276'	----	0-254' cl. -276' TMS.	flow	40g/hr	2000g/hr	----	dom. & stock.	390	Orig. art. flow. 2580g/hr.
SK19	----	----	----	----	flow	50g/hr	----	----	dom. & stock	390	Orig. art. flow 5000g/hr.
<u>CADASTRAL FARM: UITENHAGE COMMONAGE</u>											
UC1	1919	520'	----	----	flow	0,15 l/s	----	----	stock	177	
<u>CADASTRAL FARM: WELBEDACHTSFONTEIN 300</u>											
<u>Portion: Rem. Local name-Greenhills Owner: Mr C. Muller</u>											
WF1	----	170'	---	----	3,28m	----	----	----	----	----	Monthly w.l.meas
WF1A	1976	122m	21m 40m 116m	0-21m bb.,cl. -43m sst. -49m cl. -122m sst.	----	----	7,5 l/s	4"m.p. 50h.p.	irr., dom stock	----	Permit No. 348/3/2(433) 1,65 l/s 11881m ³ /yr.

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Equipt.	Water use	f.D.S. (mg/l)	Remarks
WF3A	1976	111m	----	0- 37m Cret. -11m TMS.	flow	200g/hr.	5000g/hr	----	dom. & stock	148	1,0 l/s 7200m ³ /yr.
<u>Portion: 7. Local name-Maasward Owner: Mr H.H. Maasdorp</u>											
WF5	----	----	----	----	11,35m	----	200g/hr.	w.p.	dom. & stock	407	Permit No. 348/3/2(385) WF5 12,000g/day
WF6	1953	720'	620' 720'	0-620' cl. -720' TMS	6,74m	----	6000g/hr	09 p.h. 4,5hp.	irr. & stock		WF6 150,000g/day
WF14	1955	730'	250'	----	flow	0,4 l/s	3,8 l/s	012 p.h. 4,6kW.	irr. &	885	WF14 100000g/day
WF15	1954	400'	100'	No TMS.	13,04m	----	100g/hr	w.p.	stock	5,000	
WF23	1953	700'	350'	cl.&TMS.	flow	weak	3200g/hr	2"m.p.	irr.& stock	124	
<u>Portion: 3. Local name-Dalby Park Owner: Mr H.H. Maasdorp</u>											
WF7	----	---	----	----	----	----	200g/hr	w.p.	stock	1690	Permit No. 348/3/2(175) WF7 30,000g/day.
WF8	1953	----	----	----	5,9m	----	1200g/hr	---	----	----	WF8 9,000g/day.
WF9	----	----	----	----	----	----	100g/hr	w.p.	stock	----	
WF10	----	----	----	----	7,68	----	150g/hr	w.p.	stock	----	
WF24	----	217'	----	----	----	----	75g/hr.	w.p.	stock	----	
WF26	----	154'	----	----	6,47m	----	----	w.p.	stock	----	
WF35	1984	127m	25m 60g/hr 127m 1,2 l/s	see bh.log	2,34m	----	1,2 l/s	----	research	1027	Bh. drilled for corr. & strat. info.
<u>Portion: 4. Owner: Mr H.H. Maasdorp</u>											
WF27A	----	139m	----	-----	5,50m	----	1200g/hr	1,5"m.p. 5h.p.	dom.& stock	----	Permit No. 348/3/2(381) 300g/hr. 1,095,000g/yr.

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Eqipt.	Water use	T.D.S. (mg/l)	Remarks
<u>Portion: 6. Local name-Brandwag Owner: Master Brickworks</u>											
WF12A	25/5/70	504'	140' 497'	0-497' cl. -504' sst.	flow	v. weak	660g/hr	p.h.5h.p.	ind.	salty	Permit No. 343/3/2(570) 300g/hr. 1,095,000g/yr.
<u>Portion: 13. Local name-Airedale Owner: Mr M.F. Tait</u>											
WF16	1954	920'	604'	cl. & TMS.	flow	60g/hr	1200g/hr	----	----	218	Sealed with a steel plate.
WF17	1954	750'	500'	cl. & TMS.	flow	200g/hr	800g/hr	----	dom. & stock	236	Permit No. 343/3/2/(386) 20,00g/day.
<u>Portion: 15. Local name-Airedale Owner: Mr C.C.B. Rademeyer</u>											
WF18	1938	350'	300'	cl. & TMS	---	---	800g/hr	s.p.	dom. & ind.	----	
WF33A	1975	137,7m	9,1m 45,7m 86,9m	0-9,1m sst. -54,9m cl. -86,9m sst. -137,7 cl.	4,20m	----	1,1 l/s	s.p.	dom. & ind.	----	
<u>Portion: 9. Local name-Airedale Owner: Mr H.M. Lloyd</u>											
WF19	1954	920'	720'	cl. & sst.	17,22m	----	400g/hr	s.p.	dom.	----	
<u>Portion: 10. Local name-Hillside Owner: Mr Pentz</u>											
WF21	1956	1050'	750' 1000'	----	18,64m	----	500g/hr	s.p.	dom. & ind.	----	Permit No. 343/3/2(377) 5,000g/day.

Bh.No.	Date Drilled	Depth	Water at	Strat.	R.W.L.	Art. flow	Pumped yield	Equipmt.	Water use	T.D.S. (mg/l)	Remarks
<u>Portion: Rem. of Ptn. 1 Owner: Bastia (Edms.) Bkp.</u>											
WF31	----	400'	280'	0- 22' cl. - 70' cl. - 80' sst. -260' cl. -280' sst. -400' cl.	72,48m	----	80g/hr	w.p.	stock	----	Permit No. 348/3/2(014) 0.38 l/sec. 4977m ³ /yr.
<u>CADASTRAL FARM: WELLS ESTATE</u>											
<u>Portion: 11. Owner: Quarry Sales, P E Municipality</u>											
SV1	----	200'	----	----	----	----	50g/hr.	w.p.	dom. & stock.	266	
SV3	----	1220'	850'	Cret. to 500'	flow	16,300g/h	pressure gauge.	ind. SAR.	136		v strong art.
SV4	----	1226'	----	----	1,92m	----	----	----	----	----	bn.prop.blocked.
SV7	----	10,5'	----	----	1,27m	----	----	----	----	885	Large diam.well.

NOTE: These 4 boreholes are incorrectly numbered. They fall within the Wells Estate cadastral boundary and not Sutton Vallance.

APPENDIX 2

GROUNDWATER CHEMISTRY

Sampling Point (Bh.No)	Date of Sample	H Number	pH	Conductivity (mS/m)	Na	K	Ca	Mg	SO ₄	Cl	TAL	NH ₄	NO ₃	F	Si	P
					in mg/l											
SK 1	82.08.18	82412788	7,3	187	310	18	35	15	54	480	125	0,396	0,006	0,384	6	0,006
SK 4	82.09.07	4324	7,6	940	1540	13	400	160	350	3200	75	0,125	0,138	0,889	6	0,006
SK 7	82.08.18	2796	7,3	40	40	10	12	2	1	37	96	0,037	0,141	0,679	8	0,005
SK 8	82.08.18	2801	7,6	570	1250	9	18	3	340	1620	110	0,083	0,100	1,737	6	0,003
SK 10	82.08.18	2819	8,2	500	1100	4	0	6	230	1380	170	0,109	0,097	2,429	6	0,000
SK 12	82.08.18	3263	7,2	106	200	8	15	3	45	240	110	0,052	0,089	1,088	7	0,008
SK 18	82.08.18	3271	6,9	66	85	16	17	10	20	160	50	0,044	0,091	0,570	7	0,008
SK 19	82.08.18	3289	6,8	66	90	5	17	10	24	160	50	0,048	0,094	0,497	7	0,003
SK 20A	82.08.19	3297	6,1	1070	1900	110	85	200	430	3600	0	13,486	0,097	0,308	1	0,006
CK 2	82.07.23	2649	7,7	23	32	8	6	3	0	29	55	0,024	0,078	0,495	7	0,025
CK 13	82.07.23	2657	7,7	32	37	11	11	6	6	50	52	0,039	0,022	0,376	9	0,016
CK 15	82.07.23	2665	8,1	90	140	15	30	10	35	200	110	0,026	0,019	0,422	8	0,000
SV 1	82.09.19	3221	7,6	45	59	11	15	9	9	70	100	0,044	0,102	0,828	8	0,014
SV 3	82.08.18	3239	7,1	23	27	10	6	4	6	37	44	0,044	0,105	0,604	9	0,029
SV 7	82.08.19	3247	7,4	150	200	18	65	33	63	220	370	0,048	0,523	1,236	15	0,061
MV 2	82.08.18	3255	7,6	36	68	8	5	3	9	39	120	0,052	0,139	0,736	9	0,058
MV 3	82.07.23	2712	6,7	26	31	3	10	4	15	53	25	0,034	0,212	0,186	3	0,009
C 2	82.08.18	4227	7,3	220	330	24	60	21	18	630	60	0,060	0,033	0,300	5	0,009
C 5	82.08.18	4251	7,4	28	40	9	7	2	1	36	80	0,036	0,066	0,528	7	0,013
C 9	82.08.18	4269	7,9	140	205	21	37	16	35	380	50	0,035	0,038	0,384	6	0,009
WF 3A	82.07.16	2631	7,5	25	30	11	5	4	0	33	42	0,024	0,030	0,403	7	0,060
WF 5	82.09.29	4918	8,2	69	150	2	3	2	21	100	170	0,023	0,105	0,865	5	0,026
WF 14	82.09.29	4926	7,8	150	290	5	18	3	14	400	115	0,015	0,070	0,497	7	0,008
WF 15	82.09.29	4934	8,0	850	1550	29	175	120	470	2550	230	0,033	1,426	1,018	6	0,007
WF 16	82.09.08	4332	8,1	37	77	1	3	0,6	0	30	145	0,044	0,050	0,654	11	0,079
WF 17	82.09.08	4316	7,9	40	87	2	2	0,3	2	32	150	0,045	0,135	0,712	9	0,041
WF 23	82.09.29	5304	7,2	21	27	11	5	3	3	33	46	0,022	0,000	0,360	7	0,019
BR 1	82.09.09	4243	8,2	1220	2600	18	140	70	830	3550	170	0,315	0,797	0,898	6	0,008
RH 1	82.07.22	2720	6,9	22	24	7	7	4	2	43	32	0,038	0,056	0,340	13	0,010
RH 8	82.07.22	2738	6,9	23	24	8	7	4	3	41	37	0,031	0,030	0,456	11	0,028
RH 11	82.07.22	2770	6,9	36	35	12	9	6	27	60	35	0,014	0,077	0,237	7	0,000
RH 15	82.09.22	5370	7,2	23	29	9	5	3	6	48	32	0,028	0,007	0,357	11	0,016
RH 18	82.09.22	82415354	8,2	22	27	8	5	4	8	45	24	0,032	0,005	0,349	13	0,009

Sampling Point (Bh.No)	Date of Sample	H Number	pH	Conductivity (mS/m)	Na	K	Ca	Mg	SO ₄	Cl	TAL	NH ₄	NO ₃	F	Si	P
					in mg/l											
RH 22	82.10.22	82416033	6,6	26	37	9	7	5	4	50	40	0,007	0,056	0,288	6	0,017
RH 23A	82.07.22	2704	6,9	21	24	8	5	3	2	40	37	0,067	0,028	0,241	14	0,039
RH 28	82.07.22	2699	7,6	46	85	3	0,6	0,3	19	70	80	0,033	0,000	1,520	8	0,375
RH 32	82.07.22	2681	7,2	22	30	8	5	3	17	42	29	0,036	0,000	2,295	14	0,007
RH 32A	82.07.22	2673	7,7	28	30	8	17	4	0	38	58	0,024	0,016	0,262	14	0,008
KG 1	82.09.09	4227	7,7	630	870	40	180	165	230	1700	280	0,046	0,062	0,413	9	0,009
KG 2	82.08.17	4277	8,8	77	180	0,5	1	1	0	80	270	0,042	0,039	5,796	6	0,008
BA 1	82.09.22	5401	7,0	38	50	6	6	7	12	85	24	0,030	0,043	0,272	8	0,026
GR 1	82.07.16	2623	7,9	500	830	32	80	105	115	1400	300	0,032	0,374	0,608	9	0,002
GR 11	82.08.17	4285	7,5	30	45	11	5	2	0	40	83	0,045	0,041	0,983	6	0,001
DK 1	82.08.17	4293	7,5	28	48	7	2	1	0	40	76	0,042	0,042	0,626	5	0,054
PK 4	82.09.15	4340	7,9	470	820	10	70	70	250	1140	310	0,041	0,051	0,642	6	0,014
PK 6	82.10.22	6041	7,6	265	320	8	65	70	70	700	130	0,031	0,043	0,520	10	0,008
PK 8	82.09.22	5427	7,6	520	860	11	110	105	330	1300	380	0,039	0,044	0,681	8	0,005
PK 9	82.09.22	5419	8,2	680	1400	15	55	60	350	1950	300	0,030	0,011	0,601	5	0,006
PK 10	82.09.15	4366	8,6	430	800	16	42	54	220	1050	330	0,016	0,024	0,536	6	0,008
PK 13A	82.09.29	5320	7,1	23	29	7	3	6	5	54	37	0,031	0,002	0,418	6	0,004
PK 18	82.09.15	4382	7,8	860	1330	20	230	270	540	2600	260	0,017	0,050	0,554	7	0,009
PK 30	82.07.22	2754	6,8	24	27	8	4	6	0	47	47	0,347	0,031	0,511	4	0,006
PK 31	82.09.29	5338	8,2	380	720	11	22	36	140	1020	240	0,023	0,251	0,858	8	0,000
PK 32	82.09.15	4358	7,5	880	1290	19	320	270	570	2500	380	0,041	0,000	0,953	6	0,006
PK 34	82.09.29	5388	7,2	65	100	4	8	10	20	150	55	0,029	0,007	0,368	6	0,008
PK 35	82.07.22	2746	7,2	80	145	5	8	9	12	180	85	0,045	0,031	0,604	9	0,025
UC 1	82.09.29	5362	7,4	30	40	6	6	5	3	56	52	0,028	0,039	0,590	5	0,011
BK 6	82.10.21	6083	6,8	41	51	5	13	8	16	80	45	0,010	0,048	0,293	7	0,007
BK 9	82.10.21	6075	5,7	47	67	2	5	10	14	120	11	0,010	0,050	0,365	5	0,007
CL 1	82.10.22	6067	8,0	540	945	12	50	75	210	1450	320	0,029	0,095	1,404	6	0,008
CL 2	82.10.22	6059	8,3	540	940	20	60	100	420	1300	410	0,024	0,069	1,362	5	0,009
CL 3	82.10.21	6122	7,9	1500	2720	46	210	300	710	4700	500	0,039	0,280	0,999	5	0,001
CL 6	82.10.21	6106	7,7	82	170	2	7	2	22	160	130	0,007	0,045	0,510	7	0,008
CL 8	82.10.21	6091	8,0	850	1690	37	60	115	440	2500	360	0,010	0,047	1,547	2	0,008
AB 1	82.08.17	4308	7,9	750	1450	30	73	78	440	2100	120	0,035	0,219	0,736	5	0,014
SPRINGS	82.09.22	82415396	6,2	14	20	1	2	1	3	39	6	0,029	0,107	0,300	5	0,034

APPENDIX 3

RESISTIVITY FIELD SHEETS AND

INTERPRETED CURVES

Map Ref.: 33° 40' 48"
25° 31' 58"

Survey: COEGA

Date: 14.01.83

Direction: 116°

E.S. No. 1/3

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	1165	72	95,3
1,5	0,5	13,74	546	135	55,6
2	,5	23,74	174	148	29,1
3	0,5	56,2	26,8	124	18,8
	2	12,57	187	125	18,8
5	0,5	156,7	3,42	115	4,7
	2	37,7	14,7	117	4,7
7	0,5	307,5	1,94	139	4,3
	2	75,4	7,49	137	4,1
10	2	155,5	4,37	160	4,2
	5	58,9	11,3	162	4,1
15	2	352	3,53	268	4,6
	5	137,4	8,83	267	4,5
20	2	627	2,24	278	5,1
	5	247	5,56	277	5,0
30	5	562	2,18	215	5,7
40	5	1001	1,83	297	6,2
50	5	1567	,733	176	6,5
	20	377	3,08	175	6,6
70	5	3075	1,05	436	7,4
	20	754	4,34	434	7,5
100	5	6280	,391	292	8,4
	20	1555	1,55	283	8,5
150	20	3520	,764	268	10,0
200	20	6270	,501	299	10,5
	80	1508	2,01	293	10,3
300	20	14120	,214	269	11,2
	80	3471	,848	270	10,9
400	20	25100	,147	306	12,1
	80	6220	,562	302	11,6
500	20	39250	,104	327	12,5
	80	9750	,405	325	12,1
750	80	22000	,161	298	11,9

Map Ref.: 33° 41' 10"
25° 31' 50"

Survey: COEGA

Date: 12.01.83

Direction: 130°

E.S. No. 1/4

OA	MN	K	V	I	Ω m
m	m		mV	mA	
1	0,5	5,89	1550	103,5	88,2
1,5	0,5	13,74	43,7	119,3	50,3
2	0,5	23,74	184	123,2	36,9
3	0,5	56,2	378	98,8	21,5
	2	12,57	189	99,6	23,8
5	0,5	156,7	5,05	97,6	8,1
	2	37,7	19,50	98,3	7,5
7	0,5	307,5	2,00	95,6	6,4
	2	75,4	7,16	96,3	5,6
10	2	155,5	3,90	104,8	5,8
	5	58,9	9,93	106,3	5,5
15	2	352	1,90	104,0	6,4
	5	137,4	4,66	105,2	6,1
20	2	627	1,50	123,2	7,6
	5	247	3,72	126,3	7,3
30	5	562	1,19	84,5	7,9
40	5	1001	,878	104,7	8,4
50	5	1567	,618	110,4	8,8
	20	377	2,76	111,3	9,3
70	5	3075	,394	126,6	9,6
	20	754	1,68	123,3	10,3
100	5	6280	,252	156,0	10,2
	20	1555	1,14	156,4	11,3
150	20	3520	,354	100,7	12,4
200	20	6270	,203	98,6	12,9
	80	1508	,828	99,7	12,5
300	20	14120	,125	143,3	12,3
	80	3471	,502	142,4	12,2
400	20	25100	,145	273	13,3
	80	6220	,282	143,1	12,3
500	20	39250	,217	615	13,8
	80	9750	1,09	795	13,4
	200	3770			
750	80	22000	,945	66,2	15,0

Map Ref.: 33° 41' 49"
25° 31' 35"

Survey: COEGA

Date: 11.01.83

Direction: 130°

E.S. No. 1/5

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	7253	52,3	816,8
1,5	0,5	13,74	1575	34,3	630,9
2	0,5	23,74	695	33,3	516,3
3	0,5	56,2	274	43,2	356,5
	2	12,57	1505	43,4	435,9
5	0,5	156,7	23,0	21,6	166,9
	2	37,7	187	35,8	196,9
7	0,5	307,5	6,1	33,1	56,7
	2	75,4	27,2	31,5	65,1
10	2	155,5	12,5	88,0	22,1
	5	58,9	39,2	87,8	26,3
15	2	352	1,50	34,8	15,2
	5	137,4	4,15	34,5	16,5
20	2	627	,616	26,3	14,7
	5	247	2,77	44,5	15,4
30	5	562	,960	40,6	13,3
40	5	1001	,552	37,9	14,6
50	5	1567	,415	43,2	15,1
	20	377	1,50	41,9	13,5
70	5	3075	,192	34,7	17,1
	20	754	,720	34,5	15,7
100	5	6280	,211	74,2	17,8
	20	1555	,217	22,2	15,2
150	20	3520	,157	33,9	16,3
200	20	6270	,067	26,7	15,7
	80	1508	,278	26,9	15,6
300	20	14120	,157	139,0	16,0
	80	3471	,595	138,6	14,9
400	20	25100	,020	28,6	17,6
	80	6220	,070	28,0	15,6
500	20	39250	,023	43,6	20,7
	80	9750	,078	43,9	17,3
	200	3770			
750	80	22000	,056	53,8	22,9

Map Ref.: 33° 42' 31"
25° 31' 20"

Survey: COEGA

Date: 20.01.83

Direction: 122°

E.S. No. 1/6

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	1252	70	105
1,5	0,5	13,74	623	129	66,4
2	0,5	23,74	343	176	48,2
3	0,5	56,2	124	167	41,7
	2	12,57	633	202	39,4
5	0,5	156,7	58	262	34,7
	2	37,7	211	262	30,4
7	0,5	307,5	26,5	243	33,5
	2	75,4	93,5	242	29,1
10	2	155,5	53,0	341	24,1
	5	58,9	147	342	25,3
15	2	352	10,42	192	19,1
	5	137,4	26,7	193	19,0
20	2	627	6,38	212	18,9
	5	247	30,3	402	18,6
30	5	562	7,98	258	17,4
40	5	1001	4,13	251	16,5
50	5	1567	5,51	518	16,7
	20	377	21,9	522	15,8
70	5	3075	1,17	210	17,1
	20	754	7,97	369	16,3
100	5	6280	1,33	491	17,0
	20	1555	4,69	445	16,4
150	20	3520	2,49	513	17,1
200	20	6270	0,379	134	17,7
	80	1508	1,94	184	15,9
300	20	14120	0,169	116	20,6
	80	3471	0,656	116	19,6
400	20	25100	0,295	350	21,2
	80	6220	1,13	347	20,3
500	20	39250	0,188	286	25,8
	80	9750	0,791	343	22,5
	200	3770			
750	80	22000	0,562	430	28,8

Map Ref.: 33° 43' 12"
25° 31' 06"

Survey: COEGA

Date: 18.01.83

Direction: 140°

E.S. No. 1/7

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	2925	632	27,3
1,5	0,5	13,74	506	331	21,0
2	0,5	23,74	417	550	18,8
3	0,5	56,2	118	363	18,3
	2	12,57	549	368	18,8
5	0,5	156,7	35,8	324	17,3
	2	37,7	147	313	17,7
7	0,5	307,5	24,7	469	16,2
	2	75,4	105	474	16,7
10	2	155,5	82,3	796	16,1
	5	58,9	220	803	16,1
15	2	352	12,9	315	14,4
	5	137,4	32,5	313	14,3
20	2	627	9,8	442	13,9
	5	247	25,0	447	13,8
30	5	562	14,1	579	13,7
40	5	1001	4,36	314	13,9
50	5	1567	1,27	138	14,4
	20	377	2,55	68	14,1
70	5	3075	1,35	278	14,9
	20	354	5,42	279	14,6
100	5	6280	0,840	356	14,8
	20	1555	3,37	353	14,8
150	20	3520	1,32	301	15,4
200	20	6270	0,630	262	15,1
	80	1058	2,99	289	15,6
300	20	14120	0,224	179	17,7
	80	3471	0,868	174	17,3
400	20	25100	0,574	734	19,6
	80	6220	1,28	425	18,7
500	20	39250	0,182	273	26,2
	80	9759	0,706	274	25,1
	200	3770			
750	80	22000	0,920	547	37,0

Map Ref.: 33° 43' 30"
25° 30' 59"

Survey: COEGA

Date: 25.01.83

Direction: 108°

E.S. No. 1/8

OA m	MN m	K	V mV	I mA	ρ m
1	0,5	5,89	47,45	94,8	295,0
1,5	0,5	13,74	1270	70,0	249,3
2	0,5	23,74	439	70,4	154,3
3	0,5	56,2	90	63,2	80,0
	2	12,57	483	62,3	97,5
5	0,5	156,7	12,68	75,1	26,5
	2	37,7	54,6	74,0	27,8
7	0,5	307,5	2,77	86,9	9,8
	2	75,4	11,07	86,0	9,7
10	2	155,5	2,61	83,4	4,9
	5	58,9	8,51	81,4	6,2
15	2	352	1,00	69,5	5,1
	5	137,4	2,82	69,2	5,6
20	2	627	,618	72,9	5,3
	5	247	1,81	73,5	6,1
30	5	562	1,03	78,6	7,4
40	5	1001	,465	61,4	7,6
50	5	1567	,380	76,1	7,8
	20	377	1,77	75,2	8,9
70	5	3075	,480	172,8	8,5
	20	754	2,25	176,2	9,6
100	5	6280	,258	147,7	11,0
	20	1555	1,169	148,9	12,2
150	20	3520	,214	56,7	13,3
200	20	6270	,340	168,0	12,7
	80	1508	1,63	168,8	14,6
300	20	14120	,244	185,0	18,6
	80	3471	1,045	185,0	19,6
400	20	25100	,155	175,0	22,2
	80	6220	,716	176,0	25,3
500	20	39250	,125	178,8	27,4
	80	9750	,295	98,8	29,1

Map Ref.: 33° 44' 09"
25° 30' 46"

Survey: COEGA

Date: 13.01.83

Direction: 108°

E.S. No. 1/9

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	3215	278	68,1
1,5	0,5	13,74	734	204	49,4
2	0,5	23,74	135	107	31,2
3	0,5	56,2	45,2	167	15,2
	2	12,57	253	169	18,8
5	0,5	156,7	11,0	242	7,1
	2	37,7	46,5	244	7,2
7	0,5	307,5	5,07	259	6,0
	2	75,4	19,1	256	5,6
10	2	155,5	8,17	236	5,4
	5	58,9	21,8	236	5,4
15	2	352	3,24	186	6,1
	5	137,4	8,15	185	6,1
20	2	627	1,70	154	6,9
	5	247	4,25	154	6,8
30	5	562	1,21	88,0	7,7
40	5	1001	,908	110	8,3
50	5	1567	1,33	241	8,6
	20	377	6,04	239	9,5
70	5	3075	,901	318	8,7
	20	754	4,01	323	9,4
100	5	6280	,606	426	8,9
	20	1555	2,73	432	9,8
150	20	3520	,739	244	10,7
200	20	6270	,650	349	11,7
	80	1508	3,17	351	13,6
300	20	14120	,434	429	14,3
	80	3471	2,07	436	16,5
400	20	25100	,323	457	17,7
	80	6220	1,49	464	20,0
500	20	39250	,169	425	15,6
	80	9750	1,02	423	23,5
	200	3770			
750	80	22000	,776	518	33,0

Map Ref.: 33° 44' 30"
25° 30' 39"

Survey: COEGA

Date: 17.01.83

Direction: 160°

E.S. No. 1/10

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	204	217	8,5
1,5	0,5	13,74	205	229	12,3
2	0,5	23,74	125	196	15,8
3	0,5	56,2	77,4	220	19,8
	2	12,57	300	219	17,2
5	0,5	156,7	16,1	207	12,2
	2	37,7	64,9	206	11,9
7	0,5	307,5	5,90	233	7,8
	2	75,4	27,5	228	7,4
10	2	155,5	6,55	193	5,3
	5	58,9	17,6	194	5,3
15	2	352	2,42	195	4,4
	5	137,4	6,01	195	4,2
20	2	627	1,08	146	4,6
	5	247	2,60	142	4,52
30	5	562	4,60	543	4,8
40	5	1001	2,89	545	5,3
50	5	1567	1,97	513	6,0
	20	377	8,57	515	6,3
70	5	3075	1,27	531	7,4
	20	754	5,42	531	7,7
100	5	6280	,765	570	8,4
	20	1555	3,23	552	9,1
150	20	3520	1,76	573	10,8
200	20	6270	,910	484	11,8
	80	1508	3,95	477	12,5
300	20	14120	,457	529	12,2
	80	3471	2,12	534	13,8
400	20	25100	0,290	510	14,3
	80	6220	1,26	507	15,5
500	20	39250	,177	415	16,7
	80	9750	,491	415	17,9
	200	3770			
750	80	22000	,420	402	23,0

Map Ref.: 33° 45' 06"
25° 30' 23"

Survey: COEGA

Date: 17.02.83

Direction: 120°

E.S. No. 1/11

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	535	204	15,4
1,5	0,5	13,74	183	245	10,3
2	0,5	23,74	52,0	189	6,8
3	0,5	56,2	12,3	192	3,6
	2	12,57	67,5	193	4,4
5	0,5	156,7	2,66	166	2,5
	2	37,7	11,72	165	2,7
7	0,5	307,5	3,12	352	2,7
	2	75,4	3,08	350	2,8
10	2	155,5	4,63	228	3,2
	5	58,9	9,77	215	2,7
15	2	352	4,10	416	3,5
	5	137,4	8,60	421	2,8
20	2	627	1,53	246	3,9
	5	247	2,88	224	3,2
30	5	562	3,81	561	3,8
40	5	1001	1,17	287	4,1
50	5	1567	1,93	692	4,4
	20	377	9,42	686	5,2
70	5	3075	0,37	221	5,1
	20	754	1,782	221	6,1
100	5	6280	0,62	629	6,2
	20	1555	2,97	625	7,4
150	20	3520	1,28	499	9,0
200	20	6270	,804	488	10,3
	80	1508	3,78	516	11,0
300	20	14120	,539	616	12,4
	80	3471	2,47	618	13,9
400	20	25100	,352	627	14,0
	80	6220	1,50	623	15,0
500	20	39250	,159	448	13,9
	80	9750	,690	449	15,0
750	80	22000			

Map Ref: 33° 42' 42"
25° 35' 30"

Survey: COEGA

Date: 17/2/83

Direction: 140°

E.S. No:2/1

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	6200	76	480
1,5	0,5	13,74	2620	89	404
2	,5	23,74	899	71	313
3	0,5	56,2	237	70	190
	2	12,57	1470	70	264
5	0,5	156,7	43,2	75	90
	2	37,7	228	75	115
7	0,5	307,5	7,75	56	42,5
	2	75,4	37,2	55	51,0
10	2	155,5	8,39	52	25,1
	5	58,9	21,9	52	24,8
15	2	352	3,68	59	21,9
	5	137,4	8,76	59	20,4
20	2	627	3,84	106	22,7
	5	247	8,90	105	20,7
30	5	562	2,49	64	21,9
40	5	1001	1,28	73	17,6
50	5	1567	1,120	110	15,9
	20	377	4,85	109	16,8
70	5	3075	,395	86	14,1
	20	754	1,65	86	14,5
100	5	6280	,191	91	13,2
	20	1555	,766	90	13,1
150	20	3520	,637	168	13,3
200	20	6270	,328	137	15,0
	80	1508	2,53	273	14,0
300	20	14120	,211	179	16,6
	80	3471	1,579	354	15,5
400	20	25100	,158	232	17,1
	80	6220	,310	122	15,8
500	20	39250	,30	662	17,8
	80	9750	1,09	656	16,2
750	80	22.000			

Map Ref: 33° 44' 01"
25° 35' 11"

Survey: COEGA

Date: 6/1/83 Direction: 115° E.S. No: 2/2

OA	MN	K	V	I	Ω m
m	m		mV	mA	
1	0,5	5,89	690	144,7	28,1
1,5	0,5	13,74	222	195,8	15,6
2	,5	23,74	33	78,5	10,4
3	0,5	56,2	8,36	88	5,3
	2	12,57	45,8	87,5	6,6
5	0,5	156,7	2,26	66,9	5,3
	2	37,7	8,64	66,7	4,9
7	0,5	307,5	1,46	92,0	4,9
	2	75,4	5,21	91,0	4,3
10	2	155,5	1,41	58,1	3,8
	5	58,9	4,32	57,9	4,4
15	2	352	0,236	22,5	3,7
	5	137,4	0,573	22,3	3,5
20	2	627	0,217	34,8	3,9
	5	247	0,540	34,6	3,9
30	5	562	0,488	64,0	4,3
40	5	1001	0,800	152,0	5,3
50	5	1567	0,240	69,9	5,4
	20	377	1,48	69,8	8,0
70	5	3075	,219	104,0	6,5
	20	754	1,25	105,3	10,7
100	5	6280	,106	87,1	7,6
	20	1555	,363	46,4	12,2
150	20	3520	,063	14,3	15,5
200	20	6270	,071	27,6	16,1
	80	1508	,142	16,8	12,7
300	20	14120	,172	127,4	19,6
	80	3471	,596	130,0	15,9
400	20	25100	,072	10,5	31,1
	80	6220	,024	7,4	20,1
500	20	39250	,057	86,9	25,7
	80	9750	,193	86,5	21,8
	200	3770	.		
750	80	22000	,148	114,7	28,9

Map Ref: 33° 44' 38"
25° 34' 59"

Survey: COEGA

Date: 1/2/83 Direction: 120° E.S. No: 2/3

OA m	MN m	K	V mV	I mA	ρ m
1	0,5	5,89	2340	370	37,2
1,5	0,5	13,74	528	389	18,6
2	,5	23,74	48,3	107	11,2
3	0,5	56,2	49,8	269	10,4
	2	12,57	201	276	9,2
5	0,5	156,7	28,5	349	12,8
	2	37,7	101,7	350	10,9
7	0,5	307,5	15,56	311	15,4
	2	75,4	55,3	313	13,3
10	2	155,5	30,4	309	15,3
	5	58,9	77,6	309	14,8
15	2	352	10,0	209	16,8
	5	137,4	25,4	210	16,6
20	2	627	8,17	310	16,5
	5	247	21,7	321	16,7
30	5	562	7,43	274	15,2
40	5	1001	4,64	327	14,2
50	5	1567	3,35	389	13,5
	20	377	14,17	393	13,6
70	5	3075	1,58	358	13,6
	20	754	6,66	366	13,7
100	5	6280	0,81	386	13,1
	20	1555	3,40	392	13,5
150	20	3520	1,83	462	13,9
200	20	6270	0,82	341	15,1
	80	1508	3,66	352	15,7
300	20	14120	0,47	430	15,4
	80	3471	2,16	445	17,0
400	20	25100	,153	226	17,0
	80	6220	,695	220	19,6
500	20	39250	,068	126	21,2
	80	9750	,305	124	24,0
	200	3770			
750	80	22000	,680	453	33,0

Map Ref: 33° 45' 30"
25° 34' 49"

Survey: COEGA

Date: 22/02/83

Direction: 100°

E.S. No: 2/4

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	1513	49,1	181,5
1,5	0,5	13,74	350	33,4	144,0
2	,5	23,74	136	33,3	101,0
3	0,5	56,2	27	34,7	43,7
	2	12,57	184	34,5	67,0
5	0,5	156,7	5	36,7	21,3
	2	37,7	24	36,6	24,7
7	0,5	307,5	1,64	33,7	15,0
	2	75,4	7,86	33,6	17,6
10	2	155,5	3,45	35,4	15,2
	5	58,9	8,80	33,0	15,7
15	2	352	1,19	32,8	12,8
	5	137,4	3,05	32,8	12,8
20	2	627	0,84	38,2	13,8
	5	247	2,11	38,1	13,7
30	5	562	1,22	43,9	15,6
40	5	1001	0,61	35,3	17,3
50	5	1567	0,44	37,0	18,6
	20	377	1,69	36,8	17,3
70	5	3075	0,19	31,7	18,4
	20	754	0,72	31,5	17,2
100	5	6280	0,17	55,9	19,1
	20	1555	0,59	55,4	16,6
150	20	3520	0,18	39,8	15,9
200	20	6270	0,11	46,7	14,8
	80	1508	0,32	46,1	10,5
300	20	14120	0,025	22,5	15,7
	80	3471	0,118	22,1	18,5
400	20	25100	0,045	60,5	18,7
	80	6220	0,124	60,6	12,7
500	20	39250	0,019	37,3	19,9
	80	9750	0,062	37,5	16,2
	200	3770			
750	80	22000	0,042	73.1	12.6

Map Ref: 33° 46' 15"
25° 34' 35"

Survey: COEGA

Date: 21/01/83

Direction: 082°

E.S. No: 2/5

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	7750	265	172
1,5	0,5	13,74	2408	243	136,2
2	,5	23,74	800	204	97,0
3	0,5	56,2	145	197	41,4
	2	12,57	891	196	57,1
5	0,5	156,7	13,1	236	8,7
	2	37,7	64,6	232	10,5
7	0,5	307,5	2,66	183	4,5
	2	75,4	11,0	180	4,6
10	2	155,5	8,34	304	4,3
	5	58,9	22,8	309	4,3
15	2	352	2,65	185	5,0
	5	137,4	7,00	184	5,2
20	2	627	1,97	209	5,9
	5	247	5,11	209	6,1
30	5	562	4,07	323	7,1
40	5	1001	2,86	354	8,1
50	5	1567	2,15	397	8,5
	20	377	8,42	394	8,1
70	5	3075	1,71	555	9,5
	20	754	6,67	554	9,1
100	5	6280	,796	506	9,9
	20	1555	3,07	504	9,5
150	20	3520	1,14	396	10,1
200	20	6270	3,84	534	10,6
	80	1508	,901	534	10,8
300	20	14120	,383	499	11,0
	80	3471	1,018	499	7,1
400	20	25100	,261	574	11,4
	80	6220	,701	571	7,6
500	20	39250	,177	555	12,5
	80	9750	,525	556	9,2
	200	3770			
750	80	22000	.214	378	12.5

Map Ref: 33° 46' 46"
25° 34' 15"

Survey: COEGA

Date: 18/02/83

Direction:

E.S. No: 2/6

OA m	MN m	K	V mV	I mA	ρ m
1	0,5	5,89	2840	42	398,0
1,5	0,5	13,74	396	17	320,0
2	,5	23,74	37,6	6	155,0
3	0,5	56,2	33,0	25	74,2
	2	12,57	183	25	92,0
5	0,5	156,7	4,49	28	25,1
	2	37,7	18,5	28	24,9
7	0,5	307,5	2,33	41	17,4
	2	75,4	9,34	41	17,2
10	2	155,5	2,32	30	12,0
	5	58,9	6,36	31	12,1
15	2	352	,463	14	11,6
	5	137,4	1,17	14	11,4
20	2	627	,542	29	11,7
	5	247	1,40	29	11,9
30	5	562	,400	18	12,5
40	5	1001	,383	37	10,4
50	5	1567	,084	13	10,1
	20	377	,223	13	6,5
70	5	3075	,145	45	9,9
	20	754	,365	45	6,1
100	5	6280	,072	53	8,5
	20	1555	,174	53	5,1
150	20	3520	,080	38	7,5
200	20	6270	,020	11	11,4
	80	1508	,079	22	5,4
300	20	14120	,068	20	13,7
	80	3471	,045	17	9,2
400	20	25100	,106	158	16,8
	80	6220	,090	79	7,1
500	20	39250	,052	110	18,6
	80	9750	,049	55	8,7
750	80	22000			

Map Ref: 33° 46' 06"
25° 35' 57"

Survey: COEGA

Date: 23/03/83

Direction: 077°

E.S. No: 3

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	3520	11	1885
1,5	0,5	13,74	985	7	1933
2	,5	23,74	409	5	2023
3	0,5	56,2	192	9	1199
	2	12,57	982	9	1371
5	0,5	156,7	46,6	13	562
	2	37,7	189	13	549
7	0,5	307,5	23,8	24	305
	2	75,4	89	23	292
10	2	155,5	45,2	57	123
	5	58,9	174	57	180
15	2	352	3,84	31	43,6
	5	137,4	12,85	30	58,9
20	2	627	3,65	68	33,7
	5	247	12,3	68	44,7
30	5	562	,797	47	9,5
40	5	1001	,170	18	9,5
50	5	1567	,155	25	9,7
	20	377	,656	24	10,3
70	5	3075	,215	56	9,7
	20	754	,812	55	11,1
100	5	6280	,215	114	11,8
	20	1555	,902	111	12,6
150	20	3520	,412	97	15,0
200	20	6270	,211	70	18,9
	80	1508	,715	70	15,4
300	20	14120	,120	71	23,9
	80	3471	,388	68	19,8
400	20	25100	,207	197	26,4
	80	6220	1,438	404	22,2
500	20	39250	,284	268	30,3
	80	9750	,957	361	25,8
750	80	22000			

Map Ref: 33° 45' 47"
25° 35' 39"

Survey: COEGA

Date: 23/03/83

Direction: 010°

E.S. No: 4

OA	MN	K	V	I	Ω m
m	m		mV	mA	
1	0,5	5,89	5850	97	355
1,5	0,5	13,74	2340	95	338
2	,5	23,74	760	72	261
3	0,5	56,2	222	86	145
	2	12,57	1110	84	166
5	0,5	156,7	28,9	80	56,6
	2	37,7	130	80	61,2
7	0,5	307,5	10,24	98	32,1
	2	75,4	43,0	97	33,4
10	2	155,5	17,9	119	23,4
	5	58,9	51	120	25,0
15	2	352	6,2	129	16,9
	5	137,4	16,0	131	16,8
20	2	627	4,04	179	14,2
	5	247	10,33	179	14,3
30	5	562	2,45	92	15,0
40	5	1001	1,42	98	14,5
50	5	1567	1,14	125	14,3
	20	377	,889	123	2,7
70	5	3075	,494	121	12,6
	20	754	,388	120	2,4
100	5	6280	,423	206	12,9
	20	1555	,337	199	2,6
150	20	3520	,081	139	2,1
200	20	6270	,071	158	2,8
	80	1508	,067	277	0,4
300	20	14120	,094	300	4,4
	80	3471	,069	170	1,4
400	20	25100	,065	140	11,6
	80	6220			
500	20	39250	,034	89	15,0

Map Ref: 33° 43' 57"
25° 35' 41"

Survey: COEGA

Date: 12/04/83 Direction: 016° E.S. No: 5

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	1390	24	341
1,5	0,5	13,74	125	6	286,0
2	,5	23,74	233	26	222,0
3	0,5	56,2	130	44	166,0
	2	12,57	226	21	135,0
5	0,5	156,7	32,3	54	93,7
	2	37,7	104	53	74,0
7	0,5	307,5	10,8	70	47,4
	2	75,4	33,7	70	36,3
10	2	155,5	3,80	53	11,1
	5	58,9	14,0	53	15,6
15	2	352	,688	42	5,8
	5	137,4	2,30	42	7,5
20	2	627	,306	40	4,8
	5	247	,920	40	5,7
30	5	562	,680	68	5,6
40	5	1001	,172	30	5,7
50	5	1567	,243	62	6,1
	20	377	1,176	61	7,3
70	5	3075	,110	50	6,8
	20	754	,487	50	7,3
100	5	6280	,118	102	7,3
	20	1555	1,111	206	8,4
150	20	3520	,622	229	9,6
200	20	6270	,521	313	10,4
	80	1508	1,102	156	10,7
300	20	14120	,211	240	12,4
	80	3471	,818	234	12,2
400	20	25100	,146	270	13,6
	80	6220	,654	270	15,0
500	20	39250	,074	200	14,5
	80	9750	,334	198	16,4
750	80	22000			

Map Ref: 37° 44' 17"
25° 34' 51"

Survey: COEGA

Date: 13/04/83

Direction: 095°

E.S. No: 6

OA	MN	K	V	I	Ω m
m	m		mV	mA	
1	0,5	5,89	1230	43	168
1,5	0,5	13,74	445	52	117
2	,5	23,74	147	38	95,7
3	0,5	56,2	42,0	37	63,8
	2	12,57	193	36	67,4
5	0,5	156,7	15,5	71	34,2
	2	37,7	65,3	71	34,7
7	0,5	307,5	5,04	78	19,9
	2	75,4	20,2	76	20,0
10	2	155,5	6,06	80	11,8
	5	58,9	20,4	80	15,0
15	2	352	1,04	39	9,4
	5	137,4	3,07	39	10,8
20	2	627	2,69	180	9,4
	5	247	7,48	177	10,4
30	5	562	3,22	164	11,0
40	5	1001	1,16	107	10,9
50	5	1567	,382	54	11,1
	20	377	1,78	54	12,4
70	5	3075	,165	40	12,7
	20	754	,664	38	13,2
100	5	6280	,156	70	14,0
	20	1555	1,281	138	14,4
150	20	3520	,386	74	18,4
200	20	6270	,411	129	20,0
	80	1508	1,74	128	20,5
300	20	14120	,126	73	24,3
	80	3471	,524	72	25,3
400	20	25100	,213	184	29,1
	80	6220	,878	182	30,0
500	20	39250	,056	68	32,3
	80	9750	,232	66	34,3
750	80	22000			

Map Ref: 33° 43' 52"
25° 33' 09"

Survey: COEGA

Date: 13/04/83 Direction: 065° E.S. No: 7

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	760	36	124
1,5	0,5	13,74	346	38	125
2	,5	23,74	266	57	115
3	0,5	56,2	157	85	104
	2	12,57	732	86	107
5	0,5	156,7	37,7	90	66
	2	37,7	165	92	68
7	0,5	307,5	11,13	78	43,9
	2	75,4	46,6	79	44,5
10	2	155,5	15,6	83	29,2
	5	58,9	48,6	83	34,5
15	2	352	5,97	154	13,6
	5	137,4	8,82	77	15,7
20	2	627	1,51	107	8,8
	5	247	2,04	52	9,7
30	5	562	2,87	179	9,0
40	5	1001	1,010	98	10,3
50	5	1567	1,099	169	10,2
	20	377	8,72	347	9,5
70	5	3075	,373	95	12,1
	20	754	2,93	196	11,3
100	5	6280	,084	41	12,9
	20	1555	,620	83	11,6
150	20	3520	1,66	428	13,6
200	20	6270	,621	254	15,3
	80	1508	1,290	127	15,3
300	20	14120	,145	119	17,2
	80	3471	1,146	224	17,8
400	20	25100	,206	239	21,6
	80	6220	1,126	339	20,7
500	20	39250	,111	182	23,9
	80	9750	,409	180	22,1
750	80	22000			

Map Ref: 33° 43' 46"
25° 32' 18"

Survey: COEGA

Date: 15/04/83

Direction: 120°

E.S. No: 8

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	332	168	11,6
1,5	0,5	13,74	99,6	136	10,1
2	,5	23,74	63,2	149	10,5
3	0,5	56,2	9,50	42	12,7
	2	12,57	34,6	41	10,6
5	0,5	156,7	6,49	68	15,0
	2	37,7	22,8	69	12,5
7	0,5	307,5	6,56	137	14,7
	2	75,4	23,0	142	12,2
10	2	155,5	5,06	64	12,3
	5	58,9	12,8	65	11,6
15	2	352	2,07	57	12,8
	5	137,4	5,15	56	12,6
20	2	627	1,58	78	12,7
	5	247	3,99	80	12,3
30	5	562	2,84	151	10,6
40	5	1001	,676	70	9,7
50	5	1567	1,246	193	10,1
	20	377	5,69	195	11,0
70	5	3075	,586	170	10,6
	20	754	1,27	85	11,3
100	5	6280	,225	129	11,0
	20	1555	,980	129	11,8
150	20	3520	,360	99	12,8
200	20	6270	,680	328	13,0
	80	1508	1,552	167	14,0
300	20	14120	,549	554	14,0
	80	3471	2,48	555	15,5
400	20	25100	,140	233	15,1
	80	6220	1,284	432	18,5
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33° 42' 22"
25° 30' 32"

Survey: COEGA

Date: 11/04/83

Direction: 153°

E.S. No: 9

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	1500	4	2209
1,5	0,5	13,74	1730	12	1981
2	,5	23,74	794	11	1286
3	0,5	56,2	294	13	1271
	2	12,57	2685	25	1350
5	0,5	156,7	114	27	662
	2	37,7	477	27	666
7	0,5	307,5	27	30	277
	2	75,4	114	30	287
10	2	155,5	43	78	85,7
	5	58,9	154	78	116
15	2	352	2,98	64	16,4
	5	137,4	9,06	63	19,8
20	2	627	,793	67	7,4
	5	247	2,14	65	8,1
30	5	562	1,653	133	7,0
40	5	1001	,624	82	7,6
50	5	1567	,279	50	8,7
	20	377	1,03	49	7,9
70	5	3075	,491	157	9,6
	20	754	1,77	149	9,0
100	5	6280	,269	152	11,1
	20	1555	,985	149	10,3
150	20	3520	,512	149	12,1
200	20	6270	,367	154	14,9
	80	1508	1,66	155	16,2
300	20	14120	,766	495	21,9
	80	3471	4,69	683	23,8
400	20	25100	,461	411	28,2
	80	6220	2,05	414	30,8
500	20	39250	,399	480	32,6
	80	9750	1,768	479	36,0
750	80	22000			

Map Ref: 33° 42' 47"
25° 29' 35"

Survey: COEGA

Date: 24/03/83

Direction: 130°

E.S. No: 10

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	332	344	5,7
1,5	0,5	13,74	162	342	6,5
2	,5	23,74	86,2	322	6,6
3	0,5	56,2	48,2	422	6,4
	2	12,57	213	422	6,3
5	0,5	156,7	7,46	188	6,2
	2	37,7	29,6	188	5,9
7	0,5	307,5	6,50	329	6,1
	2	75,4	25,5	328	5,9
10	2	155,5	12,3	328	5,8
	5	58,9	32,2	317	6,0
15	2	352	7,57	434	6,1
	5	137,4	19,7	440	6,2
20	2	627	2,03	206	6,2
	5	247	5,10	208	5,9
30	5	562	6,21	525	6,6
40	5	1001	3,82	553	6,9
50	5	1567	3,58	735	7,6
	20	377	15,65	740	8,0
70	5	3075	1,60	600	8,2
	20	754	6,86	602	8,6
100	5	6280	,948	684	8,7
	20	1555	7,17	1225	9,1
150	20	3520	2,34	809	10,2
200	20	6270	,347	197	11,0
	80	1508	1,570	198	12,0
300	20	14120	,571	576	14,0
	80	3471	1,379	311	15,1
400	20	25100	,448	626	18,0
	80	6220	1,169	368	19,8
500	20	39250	,433	724	23,5
	80	9750	1,444	566	24,9
750	80	22000			

Map Ref: 33° 45' 39"
25° 37' 49"

Survey: COEGA

Date: 20/04/83

Direction: 073°

E.S. No: 11

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	626	24	154
1,5	0,5	13,74	294	41	98,5
2	,5	23,74	51,9	20	64,2
3	0,5	56,2	33,1	46	40,4
	2	12,57	71,5	23	39,1
5	0,5	156,7	8,0	49	25,6
	2	37,7	30,1	49	23,2
7	0,5	307,5	3,32	52	19,6
	2	75,4	12,0	51	17,7
10	2	155,5	10,33	125	12,9
	5	58,9	27,8	125	13,1
15	2	352	2,00	70	10,1
	5	137,4	5,10	69	10,2
20	2	627	,820	60	8,6
	5	247	2,03	58	8,6
30	5	562	2,53	160	8,9
40	5	1001	3,73	325	11,5
50	5	1567	1,037	110	14,8
	20	377	3,81	108	13,3
70	5	3075	,938	135	21,4
	20	754	3,49	134	19,6
100	5	6280	,541	112	30,3
	20	1555	2,00	112	27,8
150	20	3520	1,25	113	38,9
200	20	6270	1,89	265	44,7
	80	1508	8,90	265	50,7
300	20	14120	,951	270	49,7
	80	3471	8,51	508	58,1
400	20	25100			
	80	6220			
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33° 45' 54"
25° 36' 18"

Survey: COEGA

Date: 26/04/83

Direction: 058°

E.S. No: 12

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	1570	18	518
1,5	0,5	13,74	550	15	504
2	,5	23,74	199	13	379
3	0,5	56,2	51,2	17	169
	2	12,57	290	17	214
5	0,5	156,7	10	29	54
	2	37,7	47,8	29	62
7	0,5	307,5	2,93	35	25,7
	2	75,4	26,3	71	27,9
10	2	155,5	4,65	46	15,7
	5	58,9	14,0	46	17,9
15	2	352	1,27	46	9,7
	5	137,4	3,37	45	10,3
20	2	627	1,27	96	8,3
	5	247	3,3	97	8,4
30	5	562	1,24	70	10,0
40	5	1001	,873	95	9,2
50	5	1567	1,46	197	11,6
	20	377	4,77	195	9,2
70	5	3075	,313	80	12,0
	20	754	1,10	79	10,5
100	5	6280	,275	83	20,8
	20	1555	1,18	161	11,4
150	20	3520	1,018	264	13,6
200	20	6270	,413	166	15,6
	80	1508	,748	77	14,6
300	20	14120	,297	211	19,9
	80	3471	,516	105	17,1
400	20	25100	,490	474	25,9
	80	6220	,926	252	22,9
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33°46'37"
25°37'42"

Survey: COEGA

Date: 20/4/83

Direction: 017°

E.S. No. 13

OA	MN	K	V	I	Ω m
m	m		mV	mA	
1	0,5	5,89	4260	141	178
1,5	0,5	13,74	1060	128	114
2	0,5	23,74	340	109	77,2
3	0,5	56,2	87,2	118	41,5
	2	12,57	476	119	50,3
5	0,5	156,7	9,25	100	14,5
	2	37,7	44,6	100	16,8
7	0,5	307,5	1,;68	70	7,4
	2	75,4	7,63	69	8,3
10	2	155,5	3,93	117	5,2
	5	58,9	11,88	116	6,0
15	2	352	2,44	169	5,1
	5	137,4	6,67	170	5,4
20	2	627	1,029	119	5,4
	5	247	2,79	120	5,7
30	5	562	,691	59	6,6
40	5	1001	,743	100	7,4
50	5	1567	,299	56	8,4
	20	377	1,13	56	7,6
70	5	3075	,249	79	9,7
	20	754	,988	78	9,6
100	5	6280	,141	65	13,6
	20	1555	,486	65	11,6
150	20	3520	,377	84	15,8
200	20	6270	,350	115	19,1
	80	1508	1,38	113	18,4
300	20	14120	,254	136	26,4
	80	3471	0,99	136	25,3
400	20	25100	,615	474	32,5
	80	6220	2,40	472	31,6
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33°45'44"
25°39'41"

Survey: COEGA

Date: 21/4/83

Direction: 170°

E.S. No. 14

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	515	28	108
1,5	0,5	13,74	160	28	79,0
2	0,5	23,74	79	29	67,4
3	0,5	56,2	25	29	48,4
	2	12,57	104	29	45,1
5	0,5	156,7	12,6	56	35,3
	2	37,7	23,3	28	31,4
7	0,5	307,5	6,05	66	28,2
	2	75,4	21,9	66	25,0
10	2	155,5	3,69	43	13,3
	5	58,9	10,56	43	14,5
15	2	352	,973	45	7,6
	5	137,4	2,59	44	8,1
20	2	627	,663	59	7,0
	5	247	1,75	58	7,5
30	5	562	,734	49	8,4
40	5	1001	,854	92	9,3
50	5	1567	1,24	194	10,0
	20	377	5,04	195	9,7
70	5	3075	2,15	611	10,8
	20	754	8,50	608	10,5
100	5	6280	,389	214	11,4
	20	1555	1,48	207	11,1
150	20	3520	,685	214	11,3
200	20	6270	,336	179	11,8
	80	1508	1,35	175	11,6
300	20	14120	,550	578	13,4
	80	3471	1,22	322	13,2
400	20	25100	,175	306	14,4
	80	6220	,699	303	14,3
500	20	39250	,123	290	16,6
	80	9750	,888	539	16,1
750	80	22000			

Map Ref: 33° 46' 14"
25° 39' 32"

Survey: COEGA

Date: 27/4/83 Direction: 127° E.S. No. 15

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	1077	19	334
1,5	0,5	13,74	178	14	175
2	0,5	23,74	55,3	17	80,3
3	0,5	56,2	35,5	54	37,0
	2	12,57	79,0	26	38,2
5	0,5	156,7	24,7	126	30,7
	2	37,7	100,5	125	30,3
7	0,5	307,5	5,71	70	25,1
	2	75,4	22,7	70	24,5
10	2	155,5	17,3	163	16,5
	5	58,9	49,4	162	18,0
15	2	352	3,60	140	9,1
	5	137,4	9,74	140	9,6
20	2	627	,767	62	7,8
	5	247	2,02	61	8,2
30	5	562	1,27	83	8,6
40	5	1001	,434	43	10,1
50	5	1567	,781	110	11,1
	20	377	2,86	108	10,0
70	5	3075	,479	108	13,6
	20	754	1,77	109	12,2
100	5	6280	,347	140	15,6
	20	1555	1,231	138	13,9
150	20	3520	,606	135	15,8
200	20	6270	,403	148	17,1
	80	1508	,718	71	15,2
300	20	14120	,274	193	20,0
	80	3471	,917	191	16,7
400	20	25100	,359	317	28,4
	80	6220	,315	102	19,2
500	20	39250	,106	153	27,2
	80	9750	,344	154	21,8
750	80	22000			

Map Ref: 33° 46' 43"
25° 30' 59"

Survey: COEGA

Date: 27/4/83

Direction: 018°

E.S. No. 16

OA	MN	K	V	I	
m	m		mV	mA	Ω m
1	0,5	5,89	1700	83	120
1,5	0,5	13,74	342	71	66,2
2	0,5	23,74	289	171	41,8
3	0,5	56,2	48,0	129	20,9
	2	12,57	260	129	25,3
5	0,5	156,7	7,23	116	9,8
	2	37,7	30,9	115	10,1
7	0,5	307,5	3,12	147	6,5
	2	75,4	12,5	146	6,5
10	2	155,5	5,54	159	5,4
	5	58,9	14,2	157	5,3
15	2	352	1,78	114	5,5
	5	137,4	4,7	111	5,3
20	2	627	1,081	124	5,5
	5	247	2,65	122	5,4
30	5	562	1,17	116	5,7
40	5	1001	,814	124	6,6
50	5	1567	,780	164	7,5
	20	377	3,61	163	8,3
70	5	3075	,685	247	8,5
	20	754	3,13	245	9,6
100	5	6280	1,75	1078	10,2
	20	1555	7,94	1075	11,5
150	20	3520	,920	262	12,4
200	20	6270	,508	266	12,0
	80	1508	2,35	267	13,3
300	20	14120	,239	260	13,0
	80	3471	,454	127	12,4
400	20	25100	,154	288	13,4
	80	6220	,358	145	15,4
500	20	39250	,234	597	15,4
	80	9750	1,23	717	16,7
750	80	22000			

Map Ref: 33°47'45"
25°40'06"

Survey: COEGA

Date: 18/5/83

Direction: 078°

E.S. No. 17

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	634	34	110
1,5	0,5	13,74	270	30	124
2	0,5	23,74	118	28	104
3	0,5	56,2	237	140	95,1
	2	12,57	153	140	104
5	0,5	156,7	93,5	149	98,3
	2	37,7	432	149	109
7	0,5	307,5	31	105	91
	2	75,4	142	106	101
10	2	155,5	54	80	105
	5	58,9	150	81	109
15	2	352	17,3	76	80,1
	5	137,4	46,2	76	83,5
20	2	627	11,6	106	68,6
	5	247	30,2	106	70,4
30	5	562	16,4	168	54,9
40	5	1001	8,60	217	39,7
50	5	1567	8,15	431	29,6
	20	377	18,4	223	31,1
70	5	3075	1,70	243	21,5
	20	754	7,21	245	22,2
100	5	6280	,605	287	13,2
	20	1555	2,47	288	13,3
150	20	3520	1,27	349	12,8
200	20	6270	,695	320	13,6
	80	1508	2,87	324	13,4
300	20	14120	,701	640	15,5
	80	3471	2,86	645	15,4
400	20	25100	,243	321	19,0
	80	6220	,931	732	17,4
500	20	39250	,223	444	20,6
	80	9750	,860	444	18,9
750	80	22000			

Map Ref: 33°46'47"
25°38'45"

Survey: COEGA

Date: 28/4/83

Direction: 123°

E.S. No. 18

OA	MN	K	V	I	Ωm
m	m		mV	mA	
1	0,5	5,89	326	4	480
1,5	0,5	13,74	91	4	313
2	0,5	23,74	83	9	228
3	0,5	56,2	12,4	4	174
	2	12,57	103,9	9	145
5	0,5	156,7	7,61	10	119
	2	37,7	27,6	10	104
7	0,5	307,5	2,44	7	107
	2	75,4	18	15	90
10	2	155,5	10,30	22	72,8
	5	58,9	26,9	22	72,0
15	2	352	7,23	50	50,9
	5	137,4	17,8	47	52,0
20	2	627	3,46	61	35,6
	5	247	8,36	57	36,2
30	5	562	1,43	39	20,3
40	5	1001	,376	20	18,8
50	5	1567	,292	25	18,3
	20	377	,575	11	19,7
70	5	3075	,345	62	17,1
	20	754	1,38	59	17,6
100	5	6280	,106	40	16,6
	20	1555	,403	37	16,9
150	20	3520	,209	49	15,0
200	20	6270	,094	40	14,7
	80	1508	,362	37	14,8
300	20	14120	,100	84	16,8
	80	3471	,373	79	16,4
400	20	25100	,199	133	18,9
	80	6220	,392	134	18,2
500	20	39250	,030	49	24,0
	80	9750	,107	49	22,2
750	80	22000			

Map Ref: 33° 43' 13"
25° 39' 07"

Survey: COEGA

Date: 18/4/83

Direction: 168°

E.S. No. 19

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	484	13	219
1,5	0,5	13,74	45,2	9	69
2	0,5	23,74	11,3	11	25,4
3	0,5	56,2	1,34	7	10,8
	2	12,57	16,0	14	14,4
5	0,5	156,7	1,55	22	11,0
	2	37,7	6,34	21	11,4
7	0,5	307,5	,820	21	12,0
	2	75,4	3,40	21	12,2
10	2	155,5	2,06	33	9,7
	5	58,9	5,87	32	10,8
15	2	352	,530	19	10,4
	5	137,4	1,44	19	10,4
20	2	627	,363	26	11,5
	5	247	1,16	25	11,5
30	5	562	1,023	50	11,5
40	5	1001	,501	41	12,2
50	5	1567	,363	47	12,1
	20	377	1,66	46	13,6
70	5	3075	,380	112	10,4
	20	754	,930	53	13,2
100	5	6280	,213	125	10,7
	20	1555	1,061	124	13,3
150	20	3520	,613	156	13,8
200	20	6270	,547	234	14,7
	80	1508	1,113	125	13,4
300	20	14120	,175	256	14,4
	80	3471	,594	256	14,4
400	20	25100	,180	263	17,2
	80	6220	,699	265	16,4
500	20	39250	,148	275	21,1
	80	9750	,594	279	20,8

Map Ref: 33° 43' 12"
25° 29' 36"

Survey: COEGA

Date: 16/2/83

Direction: 090°

E.S. No. 20

OA	MN	K	V	I	
m	m		mV	mA	Ω m
1	0,5	5,89	677	244	16,3
1,5	0,5	13,74	234	261	12,3
2	0,5	23,74	86,7	188	11,4
3	0,5	56,2	37	217	9,6
	2	12,57	159	217	9,2
5	0,5	156,7	13,9	275	7,9
	2	37,7	55,1	275	7,6
7	0,5	307,5	5,5	227	7,5
	2	75,4	21,0	227	7,0
10	2	155,5	10,6	239	6,9
	5	58,9	28,3	238	7,0
15	2	352	2,9	144	7,1
	5	137,4	7,49	144	7,1
20	2	627	4,31	402	6,7
	5	247	10,8	400	6,7
30	5	562	5,40	453	6,7
40	5	1001	3,62	520	7,0
50	5	1567	2,70	558	7,6
	20	377	10,48	559	7,1
70	5	3075	,770	270	8,8
	20	754	2,93	268	8,2
100	5	6280	,260	153	10,7
	20	1555	,980	150	10,2
150	20	3520	1,16	338	12,1
200	20	6270	1,07	519	12,9
	80	1508	4,75	527	13,6
300	20	14120	,182	193	13,3
	80	3471	,790	193	14,2
400	20	25100	,318	415	21,7
	80	6220	1,20	420	17,8
500	20	39250			
	80	9750			

Map Ref: 33°43'16"
25°30'00"

Survey: COEGA

Date: 13/2/84

Direction: 170°

E.S. No. 21

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	295	225	7,72
1,5	0,5	13,74	353	540	8,98
2	0,5	23,74	214	573	9,24
3	0,5	56,2	89,6	545	9,23
	2	12,57	366	545	8,44
5	0,5	156,7	23,6	534	6,93
	2	37,7	89,0	530	6,33
7	0,5	307,5	10,84	540	6,17
	2	75,4	40,00	540	5,59
10	2	155,5	15,3	436	5,46
	5	58,9	40,6	436	5,48
15	2	352	13,58	248	5,08
	5	137,4	24,8	674	5,06
20	2	627	4,21	535	4,93
	5	247	10,34	530	4,82
30	5	562	7,52	868	4,87
40	5	1001	3,14	578	5,44
50	5	1567	2,48	631	6,16
	20	377	13,69	803	6,43
70	5	3075	2,02	802	7,75
	20	754	8,61	803	8,08
100	5	6280	1,353	783	10,85
	20	1555	5,22	781	10,40
150	20	3520	2,05	459	15,7
200	20	6270			
	80	1508			
300	20	14120			
	80	3471			
400	20	25100			
	80	6220			
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33°43'21"
25°29'41"

Survey: COEGA

Date: 13/2/84

Direction: 182°

E.S. No. 22

OA	MN	K	V	I	Ω m
m	m		mV	mA	

1	0,5	5,89	193	49	23,2
1,5	0,5	13,74	113	151	10,3
2	0,5	23,74	29,5	134	5,4
3	0,5	56,2	6,60	114	3,3
	2	12,57	39,8	117	4,3
5	0,5	156,7	2,05	101	3,2
	2	37,7	10,0	103	3,7
7	0,5	307,5	1,58	128	3,8
	2	75,4	7,44	130	4,3
10	2	155,5	4,29	133	5,0
	5	58,9	11,25	136	4,9
15	2	352	4,15	271	5,4
	5	137,4	10,4	273	5,2
20	2	627	2,99	326	5,8
	5	247	7,64	332	5,7
30	5	562	3,83	338	6,4
40	5	1001	2,20	319	6,9
50	5	1567	1,91	392	7,6
	20	377	8,38	402	7,9
70	5	3075	1,66	556	9,2
	20	754	3,73	302	9,3
100	5	6280	1,23	628	12,3
	20	1555	4,98	635	12,2
150	20	3520	2,32	454	18,0
200	20	6270	1,73	448	24,2
	80	1508			
300	20	14120			
	80	3471			
400	20	25100			
	80	6220			
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33°42'35"
25°29'17"

Survey: COEGA

Date: 13/2/84

Direction: 130°

E.S. No. 23

OA	MN	K	V	I	Ω m
m	m		mV	mA	
1	0,5	5,89	403	60	39,6
1,5	0,5	13,74	255	124	28,3
2	0,5	23,74	109	145	18,6
3	0,5	56,2	29,8	175	9,6
	2	12,57	163	176	11,6
5	0,5	156,7	3,9	113	5,4
	2	37,7	17,1	114	5,7
7	0,5	307,5	1,57	121	4,0
	2	75,4	6,22	119	3,9
10	2	155,5	2,88	124	3,6
	5	58,9	22,4	361	3,7
15	2	352	1,93	183	3,7
	5	137,4	9,42	356	3,6
20	2	627	1,57	229	4,3
	5	247	3,93	231	4,2
30	5	562	1,92	214	5,0
40	5	1001	1,16	190	6,1
50	5	1567	1,15	257	7,0
	20	377	10,28	493	7,9
70	5	3075	1,01	345	9,0
	20	754	4,73	350	10,2
100	5	6280	,924	431	13,5
	20	1555	3,78	435	13,5
150	20	3520	1,33	247	19,0
200	20	6270	1,05	245	26,8
	80	1508			
300	20	14120	,698	246	40,1
	80	3471			
400	20	25100			
	80	6220			
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33°44'04"
25°33'32"

Survey: COEGA

Date: 14/2/84

Direction: 119°

E.S. No. 24

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	610	71	50,6
1,5	0,5	13,74	195	96	27,9
2	0,5	23,74	94,3	98	23,8
3	0,5	56,2	38,2	122	17,6
	2	12,57	497	340	18,4
5	0,5	156,7	14,2	114	19,5
	2	37,7	58,3	113	19,5
7	0,5	307,5	7,27	129	17,3
	2	75,4	29,1	127	17,3
10	2	155,5	15,2	147	16,1
	5	58,9	121	413	17,3
15	2	352	8,84	247	12,6
	5	137,4	8,45	86	13,5
20	2	627	7,81	445	11,0
	5	247	20,3	434	11,6
30	5	562	12,07	563	12,0
40	5	1001	6,37	490	13,0
50	5	1567	5,47	626	13,7
	20	377	19,8	612	12,2
70	5	3075	2,31	453	15,7
	20	754	8,49	452	14,2
100	5	6280	2,10	710	18,6
	20	1555	7,51	697	16,8
150	20	3520	3,72	689	19,0
200	20	6270			
	80	1508			
300	20	14120			
	80	3471			
400	20	25100			
	80	6220			
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33°43'44"
25°28'20"

Survey: COEGA

Date: 14/2/84

Direction: 31°

E.S. No. 25

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	159	35	26,8
1,5	0,5	13,74	163	134	16,7
2	0,5	23,74	54,8	91	15,0
3	0,5	56,2	9,00	49	10,3
	2	12,57	41,4	50	10,4
5	0,5	156,7	2,77	77	5,6
	2	37,7	9,63	78	4,7
7	0,5	307,5	2,60	142	5,6
	2	75,4	8,89	142	4,7
10	2	155,5	1,05	38	4,3
	5	58,9	7,73	110	4,1
15	2	352	2,57	197	4,6
	5	137,4	6,20	197	4,3
20	2	627	1,58	197	5,0
	5	247	7,46	380	4,8
30	5	562	2,98	301	5,6
40	5	1001	2,10	348	6,0
50	5	1567	1,02	243	6,6
	20	377	5,4	249	7,8
70	5	3075	1,06	410	8,0
	20	754	4,97	414	9,1
100	5	6280	,922	563	10,3
	20	1555	3,80	571	10,3
150	20	3520	1,95	601	11,4
200	20	6270	,847	380	14,0
	80	1508	3,51	437	12,1
300	20	14120	,495	449	15,6
	80	3471	1,88	462	14,1
400	20	25100	,341	469	18,3
	80	6220	1,394	470	18,4
500	20	39250	,208	426	19,2
	80	9750	,884	428	20,1
750	80	22000			

Map Ref: 33°43'10"
25°28'44"

Survey: COEGA

Date: 14/2/84

Direction: 027°

E.S. No. 26

OA	MN	K	V	I	
m	m		mV	mA	m
1	0,5	5,89	161	48	19,8
1,5	0,5	13,74	48,6	50	13,4
2	0,5	23,74	16,2	49	8,2
3	0,5	56,2	13,0	134	5,5
	2	12,57	92,2	137	8,5
5	0,5	156,7	4,26	139	4,8
	2	37,7	22,2	141	5,9
7	0,5	307,5	1,81	119	4,6
	2	75,4	9,2	119	5,8
10	2	155,5	12,4	341	5,7
	5	58,9	31,9	347	5,4
15	2	352	3,79	262	5,1
	5	137,4	9,47	268	4,9
20	2	627	2,70	311	5,4
	5	247	6,65	315	5,2
30	5	562	3,04	317	5,4
40	5	1001	1,93	350	5,5
50	5	1567	2,23	585	6,0
	20	377	10,2	595	6,5
70	5	3075	1,45	568	7,8
	20	754	5,86	580	7,6
100	5	6280	,693	470	9,3
	20	1555	2,78	477	10,0
150	20	3520	1,472	371	14,0
200	20	6270	1,004	347	18,1
	80	1508	,826	413	28,24
300	20	14120			
	80	3471			
400	20	25100			
	80	6220			
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33°43'54"
25°28'53"

Survey: COEGA

Date: 15/2/84

Direction: 031°

E.S. No. 27

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	136,7	20	40,0
1,5	0,5	13,74	90,9	63	19,8
2	0,5	23,74	19,4	57	8,4
3	0,5	56,2	9,01	118	4,3
	2	12,57	55,6	118	5,9
5	0,5	156,7	1,57	67	3,7
	2	37,7	7,54	68	4,2
7	0,5	307,5	2,14	161	4,1
	2	75,4	3,42	56	4,6
10	2	155,5	8,75	277	4,9
	5	58,9	23,9	280	5,0
15	2	352	8,26	560	5,2
	5	137,4	21,7	564	5,3
20	2	627	3,68	422	5,5
	5	247	9,59	425	5,6
30	5	562	3,42	382	5,0
40	5	1001	3,11	482	6,5
50	5	1567	1,77	415	6,7
	20	377	7,57	424	6,7
70	5	3075	0,89	375	7,3
	20	754	3,79	374	7,6
100	5	6280	,719	482	9,4
	20	1555	2,22	385	9,0
150	20	3520	1,15	379	10,7
200	20	6270	,690	343	11,9
	80	1508	2,14	365	12,1
300	20	14120	,438	375	15,7
	80	3471	1,49	385	13,4
400	20	25100	,227	281	20,3
	80	6220	,756	281	16,7
500	20	39250	,321	505	25,0
	80	9750	,800	440	17,7
750	80	22000			

Map Ref: 33° 44' 02"
25° 29' 38"

Survey: COEGA

Date: 15/2/84

Direction: 092°

E.S. No. 28

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	311	54	33,9
1,5	0,5	13,74	70	65	14,8
2	0,5	23,74	29	66	10,9
3	0,5	56,2	13,2	75	9,9
	2	12,57	57	75	9,6
5	0,5	156,7	13,07	246	8,3
	2	37,7	20,0	97	7,8
7	0,5	307,5	5,49	211	8,0
	2	75,4	20,8	213	7,4
10	2	155,5	8,00	190	6,5
	5	58,9	19,5	192	6,0
15	2	352	2,12	108	6,9
	5	137,4	5,10	110	6,4
20	2	627	5,56	469	7,4
	5	247	13,1	474	6,8
30	5	562	5,04	382	7,4
40	5	1001	2,98	371	8,0
50	5	1567	1,84	334	8,6
	20	377	12,7	587	8,2
70	5	3075	1,76	584	9,3
	20	754	7,09	588	9,1
100	5	6280	0,99	543	11,4
	20	1555	3,77	553	10,6
150	20	3520	1,31	380	12,1
200	20	6270	1,02	497	12,9
	80	1508	3,08	370	12,6
300	20	14120	,525	540	13,6
	80	3471	2,21	559	13,7
400	20	25100	,115	211	13,7
	80	6220	,55	210	16,3
500	20	39250	,184	374	19,3
	80	9750	,900	406	21,6
750	80	22000			

Map Ref: 33°43'35"
25°29'58"

Survey: COEGA

Date: 15/2/84

Direction: 102°

E.S. No. 29

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	889	135	38,8
1,5	0,5	13,74	250	136	25,3
2	0,5	23,74	118	164	17,8
3	0,5	56,2	29,9	144	11,7
	2	12,57	155	145	13,4
5	0,5	156,7	15,5	317	7,7
	2	37,7	22,8	112	7,7
7	0,5	307,5	7,23	326	6,8
	2	75,4	28,6	330	6,5
10	2	155,5	11,9	296	6,3
	5	58,9	12,3	104	6,7
15	2	352	6,94	382	6,4
	5	137,4	6,95	136	7,0
20	2	627	3,92	342	7,2
	5	247	11,4	350	8,0
30	5	562	4,87	314	8,7
40	5	1001	4,05	438	9,3
50	5	1567	1,98	318	9,8
	20	377	8,26	321	9,7
70	5	3075	1,01	295	10,5
	20	754	7,51	546	10,4
100	5	6280	,830	470	11,1
	20	1555	3,45	476	11,3
150	20	3520	1,76	522	11,9
200	20	6270	,720	355	12,7
	80	1508			
300	20	14120	,417	373	15,8
	80	3471			
400	20	25100			
	80	6220			
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33°42'52"
25°28'19"

Survey: COEGA

Date: 21/2/84 Direction: 086° E.S. No. 30

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	428	108	23,3
1,5	0,5	13,74	163	119	18,8
2	0,5	23,74	61,9	111	13,8
3	0,5	56,2	28,5	135	11,9
	2	12,57	96	135	8,9
5	0,5	156,7	6,21	9,6	10,1
	2	37,7	19,6	96	7,7
7	0,5	307,5	4,71	143	10,1
	2	75,4	14,6	144	7,6
10	2	155,5	4,75	98	7,5
	5	58,9	30,0	247	7,2
15	2	352	15,6	729	7,5
	5	137,4	13,75	267	7,1
20	2	627	8,88	732	7,6
	5	247	7,60	261	7,2
30	5	562	7,35	553	7,5
40	5	1001	6,33	795	8,0
50	5	1567	2,16	389	8,7
	20	377	17,65	792	8,4
70	5	3075	1,30	386	10,4
	20	754	5,06	387	9,9
100	5	6280	,720	384	11,8
	20	1555	2,91	386	11,7
150	20	3520	1,55	388	14,1
200	20	6270	1,02	390	16,4
	80	1508			
300	20	14120	,579	386	21,2
	80	3471			
400	20	25100	,395	364	27,2
	80	6220			
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33°46'28"
25°35'44"

Survey: COEGA

Date: 21/2/84

Direction: 172°

E.S. No. 31

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	470	5	554
1,5	0,5	13,74	250	28	123
2	0,5	23,74	12	2	148
3	0,5	56,2	12	9	74,9
	2	12,57	89	17	65,8
5	0,5	156,7	8,74	17	80,6
	2	37,7	32,0	17	71,0
7	0,5	307,5	0,73	3	74,8
	2	75,4	6,10	7	65,7
10	2	155,5	3,26	10	50,7
	5	58,9	8,4	10	49,5
15	2	352	3,11	2	49,8
	5	137,4	7,25	21	47,4
20	2	627	1,00	13	48,2
	5	247	2,14	13	40,7
30	5	562	0,85	17	28,1
40	5	1001	3,25	129	25,2
50	5	1567	1,56	104	23,5
	20	377	10,8	181	22,5
70	5	3075	0,59	76	23,9
	20	754	2,29	78	22,1
100	5	6280	0,60	153	24,6
	20	1555	1,12	79	22,0
150	20	3520	2,72	394	24,3
200	20	6270	0,86	225	24,0
	80	1508	2,75	228	18,2
300	20	14120	0,37	260	20,1
	80	3471	1,40	263	18,5
400	20	25100	,62	756	20,6
	80	6220	,73	228	19,9
500	20	39250	,38	595	25,1
	80	9750	,454	214	20,7
750	80	22000			

Map Ref: 33°46'02"
25°40'02"

Survey: COEGA

Date: 21/2/84

Direction: 060°

E.S. No. 32

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	256	136	11,1
1,5	0,5	13,74	90	148	8,4
2	0,5	23,74	38	143	6,6
3	0,5	56,2	10,98	128	4,8
	2	12,57	48,0	129	4,7
5	0,5	156,7	5,09	189	4,2
	2	37,7	20,1	190	4,0
7	0,5	307,5	6,32	433	4,5
	2	75,4	24,4	436	4,2
10	2	155,5	10,36	354	4,6
	5	58,9	28,5	355	4,7
15	2	352	3,00	210	5,0
	5	137,4	15,1	391	5,3
20	2	627	1,95	232	5,3
	5	247	5,38	238	5,6
30	5	562	2,53	256	5,6
40	5	1001	1,30	232	5,6
50	5	1567	1,18	309	6,0
	20	377	8,41	555	5,7
70	5	3075	,73	319	7,0
	20	754	1,74	203	6,5
100	5	6280	,23	177	8,2
	20	1555	,86	181	7,4
150	20	3520	,65	274	8,4
200	20	6270	,56	335	10,5
	80	1508			
300	20	14120	,30	361	11,7
	80	3471			
400	20	25100	,20	381	13,2
	80	6220			
500	20	39250	0,24	168	56,1
	80	9750			
750	80	22000			

Map Ref: 33°47'26"
75°41'09"

Survey: COEGA

Date: 23/2/84

Direction: 148°

E.S. No. 33

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	149	61	14,6
1,5	0,5	13,74	41,6	64	8,9
2	0,5	23,74	10,0	54	4,6
3	0,5	56,2	5,78	132	2,5
	2	12,57	31,1	134	2,9
5	0,5	156,7	1,5	159	1,5
	2	37,7	6,29	160	1,5
7	0,5	307,5	,69	173	1,2
	2	75,4	2,8	177	1,2
10	2	155,5	,72	100	1,1
	5	58,9	2,00	101	1,2
15	2	352	,50	185	1,0
	5	137,4	1,34	187	1,0
20	2	627	,37	242	1,0
	5	247	1,00	244	1,0
30	5	562	,48	254	1,1
40	5	1001	,83	649	1,3
50	5	1567	,53	546	1,5
	20	377	2,17	553	1,5
70	5	3075	,41	605	2,1
	20	754	1,63	607	2,0
100	5	6280	,32	688	2,9
	20	1555	1,31	702	2,9
150	20	3520	,75	691	3,8
200	20	6270	,53	673	4,9
	80	1508	1,37	395	5,2
300	20	14120	,15	325	6,5
	80	3471	,58	231	8,7
400	20	25100	,16	216	18,6 ?
	80	6220	,32	217	9,2
500	20	39250	,08	368	8,5
	80	9750	,45	380	11,5
750	80	22000			

Map Ref: 33°47'02"
25°40'52"

Survey: COEGA

Date: 23/2/84

Direction: 157°

E.S. No. 34

OA	MN	K	V	I	Ω m
m	m		mV	mA	
1	0,5	5,89	110	195	33
1,5	0,5	13,74	37,9	186	2,8
2	0,5	23,74	16,9	175	2,4
3	0,5	56,2	4,91	184	1,5
	2	12,57	21,7	182	1,5
5	0,5	156,7	0,53	76	1,1
	2	37,7	2,42	76	1,2
7	0,5	307,5	,40	120	1,0
	2	75,4	1,80	120	1,1
10	2	155,5	3,40	463	1,1
	5	58,9	9,36	465	1,2
15	2	352	,96	275	1,2
	5	137,4	2,57	275	1,3
20	2	627	,87	379	1,4
	5	247	2,26	375	1,5
30	5	562	1,48	450	1,8
40	5	1001	1,17	535	2,2
50	5	1567	1,28	813	2,5
	20	377	4,59	685	2,5
70	5	3075	,67	692	3,0
	20	754	2,88	695	3,1
100	5	6280	,42	695	3,8
	20	1555	1,75	695	3,9
150	20	3520	,60	395	5,3
200	20	6270	,24	228	6,6
	80	1508			
300	20	14120	,17	220	10,9
	80	3471			
400	20	25100			
	80	6220			
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33°46'52"
25°43'51"

Survey: COEGA

Date: 29/2/84

Direction: 056°

E.S. No. 35

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	823	51	95
1,5	0,5	13,74	522	59	122
2	0,5	23,74	311	52	148
3	0,5	56,2	220	64	193
	2	12,57	825	64	162
5	0,5	156,7	97	54	281
	2	37,7	344	54	240
7	0,5	307,5	53	52	313
	2	75,4	191	52	277
10	2	155,5	100	52	299
	5	58,9	241	51	278
15	2	352	38,1	45	298
	5	137,4	90	46	269
20	2	627	26,2	63	261
	5	247	61	63	239
30	5	562	10,9	63	97
40	5	1001	1,61	43	37,5
50	5	1567	3,36	254	20,7
	20	377	8,38	150	21,1
70	5	3075	,83	164	15,6
	20	754	1,72	92	14,1
100	5	6280	,76	338	14,1
	20	1555	2,84	338	13,1
150	20	3520	,370	107	12,2
200	20	6270	,500	198	15,8
	80	1508	1,31	136	14,5
300	20	14120	,195	196	14,0
	80	3471	,530	169	10,9
400	20	25100	,172	344	12,6
	80	6220	,710	348	12,7
500	20	39250	0,110	196	22,0
	80	9750	0,342	202	16,5
750	80	22000			

Map Ref: 33°46'31"
25°43'47"

Survey: COEGA

Date: 29/2/84

Direction: 054°

E.S. No. 36

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	495	5	583
1,5	0,5	13,74	634	12	726
2	0,5	23,74	507	18	697
3	0,5	56,2	51	6	478
	2	12,57	262	6	549
5	0,5	156,7	13	10	204
	2	37,7	69	10	260
7	0,5	307,5	5,6	14	123
	2	75,4	28	14	151
10	2	155,5	10	14	111
	5	58,9	83,6	40	123
15	2	352	1,80	13	48,7
	5	137,4	16	38	57,9
20	2	627	1,48	39	23,8
	5	247	4,12	38	26,8
30	5	562	1,40	40	19,7
40	5	1001	,37	29	12,8
50	5	1567	,29	38	12,0
	20	377	1,16	36	12,1
70	5	3075	,28	74	11,6
	20	754	1,06	74	10,8
100	5	6280	,14	90	9,8
	20	1555	,16	26	9,6
150	20	3520	,40	160	8,8
200	20	6270	,27	195	8,7
	80	1508	1,36	199	10,3
300	20	14120	,27	410	9,3
	80	3471	1,26	415	10,5
400	20	25100	,30	317	23,7
	80	6220	,33	201	10,2
500	20	39250	,05	209	9,4
	80	9750	,30	149	13,1
750	80	22000			

Map Ref: 33°44'54"
25°41'03"

Survey: COEGA

Date: 1/3/84

Direction: 024°

E.S. No. 37

OA	MN	K	V	I	Ωm
m	m		mV	mA	
1	0,5	5,89	1155	1	6803
1,5	0,5	13,74	409	1	5622
2	0,5	23,74	498	3,5	3517
3	0,5	56,2	515	27	1072
	2	12,57	2780	27	1294
5	0,5	156,7	31	24	202
	2	37,7	110	24	173
7	0,5	307,5	11,2	47	73
	2	75,4	21	26	60,9
10	2	155,5	10,4	80	20,3
	5	58,9	25,6	81	18,6
15	2	352	,863	49	6,2
	5	137,4	1,78	49	5,0
20	2	627	,113	23	3,1
	5	247	,481	41	2,9
30	5	562	,098	23	2,4
40	5	1001	,088	34	2,6
50	5	1567	,064	36	2,8
	20	377	,260	35	2,8
70	5	3075	,093	87	3,3
	20	754	,406	90	3,4
100	5	6280	,064	91	4,4
	20	1555	,269	91	4,6
150	20	3520	,240	124	6,8
200	20	6270	,187	130	9,0
	80	1508	1,94	128	12,3
300	20	14120	,129	136	13,4
	80	3471	,536	133	14,0
400	20	25100			
	80	6220			
500	20	39250			
	80	9750			
750	80	22000			

Map Ref: 33°47'21"
25°40'37"

Survey: COEGA

Date: 1/4/84

Direction: 134°

E.S. No. 38

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	88	323	1,4
1,5	0,5	13,74	45	325	1,9
2	0,5	23,74	24	323	1,8
3	0,5	56,2	9,2	327	1,6
	2	12,57	44	327	1,7
5	0,5	156,7	2,9	326	1,4
	2	37,7	14	324	1,6
7	0,5	307,5	1,5	325	1,4
	2	75,4	6,4	323	1,5
10	2	155,5	2,9	321	1,4
	5	58,9	8,2	322	1,5
15	2	352	3,1	783	1,4
	5	137,4	8,6	785	1,5
20	2	627	1,8	790	1,4
	5	247	4,8	788	1,5
30	5	562	2,2	777	1,6
40	5	1001	1,52	763	2,0
50	5	1567	0,94	780	1,9
	20	377	3,7	781	1,8
70	5	3075	,565	695	2,5
	20	754	2,2	695	2,4
100	5	6280	,175	394	2,8
	20	1555	1,34	695	3,0
150	20	3520	,94	720	4,6
200	20	6270	,65	695	5,9
	80	1508			
300	20	14120	,449	705	9,0

Map Ref: 33° 46' 21"
25° 42' 02"

Survey: COEGA

Date: 1/3/84

Direction: 160°

E.S. No. 39

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	648	10	381
1,5	0,5	13,74	248	8	426
2	0,5	23,74	89	5	440
3	0,5	56,2	43	6	403
	2	12,57	140	6	293
5	0,5	156,7	43	14	481
	2	37,7	137	15	344
7	0,5	307,5	67	40	515
	2	75,4	205	40	386
10	2	155,5	46	18	397
	5	58,9	122	18	399
15	2	352	13	11	416
	5	137,4	33	11	412
20	2	627	24	33	456
	5	247	64	34	465
30	5	562	29	97	168
40	5	1001	11,3	137	82,6
50	5	1567	5,31	143	58,2
	20	377	13,4	92	54,9
70	5	3075	2,20	160	42,3
	20	754	8,48	161	39,7
100	5	6280	,47	114	25,9
	20	1555	1,93	121	24,8
150	20	3520	,93	169	19,4
200	20	6270	,50	180	17,4
	80	1508	2,12	182	17,6
300	20	14120	,05	55	12,8
	80	3471	,70	195	12,5
400	20	25100	,130	202	16,2
	80	6220	,430	203	13,2
500	20	39250	,090	194	18,2
	80	9750	,330	194	16,6

Map Ref: 33° 45' 40"
25° 42' 00"

Survey: COEGA

Date: 2/3/84

Direction: 119°

E.S. No. 40

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	65	2	191
1,5	0,5	13,74	15	2	103
2	0,5	23,74	26	13	50
3	0,5	56,2	20	25	45
	2	12,57	278	73	48
5	0,5	156,7	9,6	58	25,9
	2	37,7	36	59	23,0
7	0,5	307,5	1,68	31	16,7
	2	75,4	12,0	62	14,6
10	2	155,5	10,8	146	11,5
	5	58,9	22	86	15,1
15	2	352	4,12	160	9,1
	5	137,4	11,3	148	10,5
20	2	627	1,99	155	8,1
	5	247	6,33	172	9,1
30	5	562	3,01	184	9,2
40	5	1001	1,77	192	9,2
50	5	1567	,71	113	9,8
	20	377	1,95	64	11,5
70	5	3075	,56	169	10,2
	20	754	1,63	105	11,7
100	5	6280	,34	197	10,8
	20	1555	1,20	144	13,0
150	20	3520	,67	188	12,5
200	20	6270	,39	172	14,2
	80	1508	1,51	172	13,2
300	20	14120	,210	200	14,8
	80	3471	,740	199	12,9
400	20	25100	,070	166	10,6
	80	6220	,390	166	14,6
500	20	39250	,090	205	17,3
	80	9750	,304	203	14,6

Map Ref: 33° 45' 41"
25° 43' 14"

Survey: COEGA

Date: 2/3/84

Direction: 043°

E.S. No. 41

OA m	MN m	K	V mV	I mA	Ω m
1	0,5	5,89	885	3	1737
1,5	0,5	13,74	300	2	2061
2	0,5	23,74	238	3	1963
3	0,5	56,2	108	3	2023
	2	12,57	401	3	1680
5	0,5	156,7	87	8	1704
	2	37,7	312	8	1470
7	0,5	307,5	36	7	1581
	2	75,4	368	21	1321
10	2	155,5	33	6	855
	5	58,9	306	17	1060
15	2	352	15	16	330
	5	137,4	99	33	412
20	2	627	19	63	189
	5	247	59	64	228
30	5	562	11,5	84	77
40	5	1001	1,80	59	30,5
50	5	1567	15,70	161	15,3
	20	377	7,9	163	18,3
70	5	3075	,38	99	11,8
	20	754	1,63	99	12,4
100	5	6280	,26	155	10,5
	20	1555	1,12	157	11,1
150	20	3520	,340	105	11,4
200	20	6270	,250	131	12,0
	80	1508	1,04	133	11,8
300	20	14120	,100	113	12,5
	80	3471	,380	114	11,6
400	20	25100	,070	123	14,3
	80	6220	,257	123	13,0
500	20	39250	,036	102	14,1
	80	9750	,139	103	13,2

Map Ref: 33° 47' 38"
25° 42' 26"

Survey: COEGA

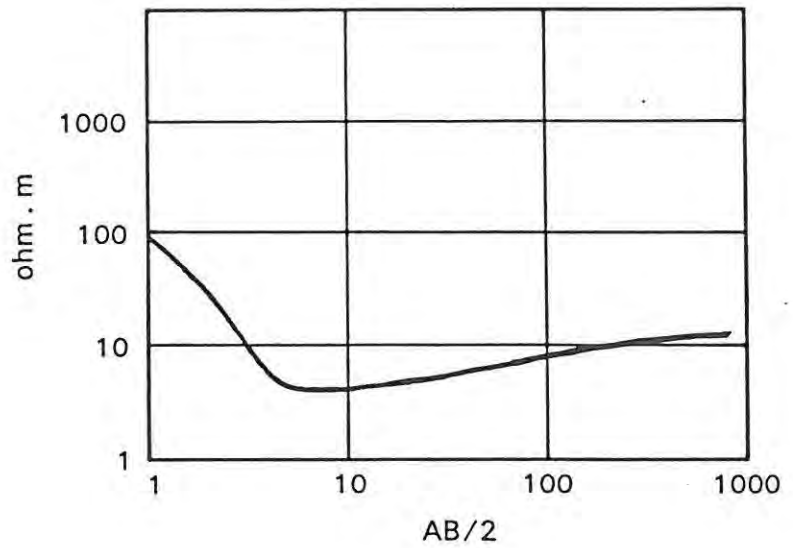
Date: 2/4/82

Direction: 037°

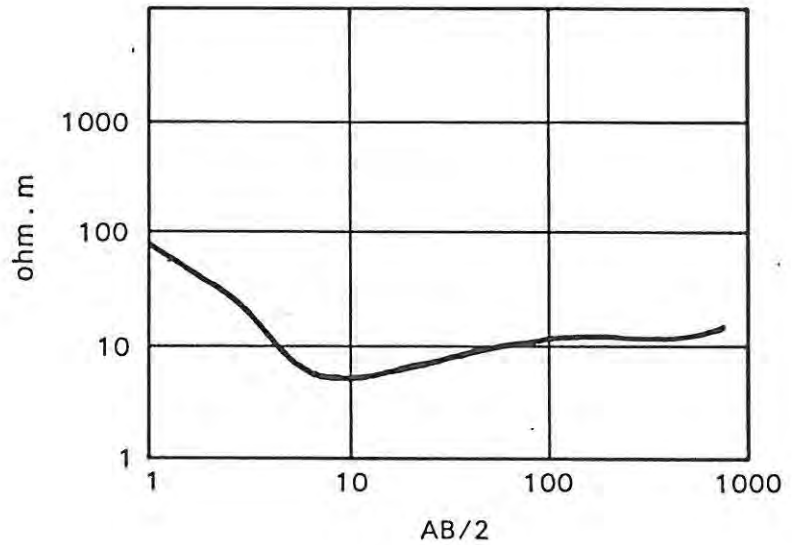
E.S. No. 42

OA	MN	K	V	I	Ωm
m	m		mV	mA	
1	0,5	5,89	516	4	760
1,5	0,5	13,74	502	11	632
2	0,5	23,74	213	11	4,78
3	0,5	56,2	60	13	260
	2	12,57	230	12	241
5	0,5	156,7	9,8	34	45
	2	37,7	34,2	30	43
7	0,5	307,5	1,37	30	14,0
	2	75,4	5,21	30	13,1
10	2	155,5	1,40	32	6,8
	5	58,9	3,40	29	6,9
15	2	352	0,94	59	5,6
	5	137,4	2,40	56	5,9
20	2	627	0,52	62	5,3
	5	247	1,41	60	5,8
30	5	562	1,08	101	6,0
40	5	1001	,501	76	6,6
50	5	1567	,326	72	7,1
	20	377	1,37	77	6,7
70	5	3075	,460	157	9,0
	20	754	1,70	158	8,1
100	5	6280	,241	144	10,5
	20	1555	,926	144	10,0
150	20	3520	,542	149	12,8
200	20	6270	,368	157	14,7
	80	1508	1,63	150	16,4
300	20	14120	,735	472	22,0
	80	3471	3,26	469	24,1
400	20	25100			
	80	6220			
500	20	39250			
	80	9750			

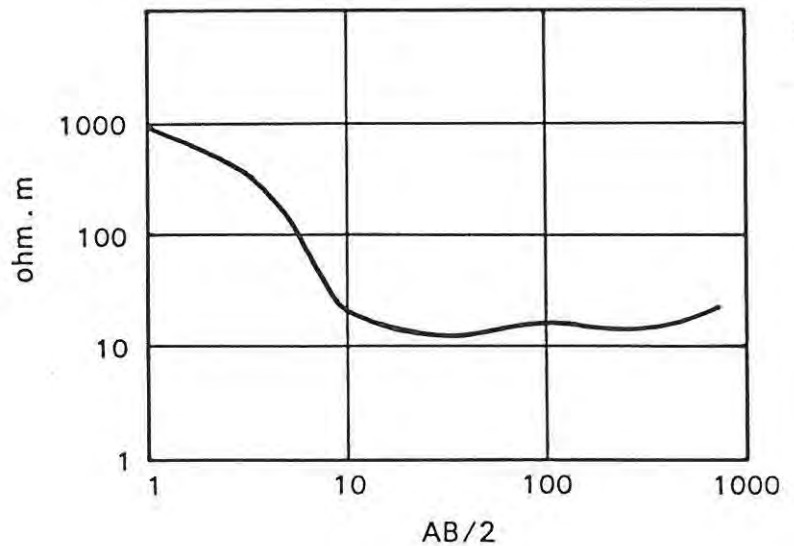
COEGA 1/3
 LAYER THICKNESS RESISTIVITY
 0,7 155,0
 8,6 4,0
 30,4 7,5
 12,0
 TOTAL S VALUE: 6,20



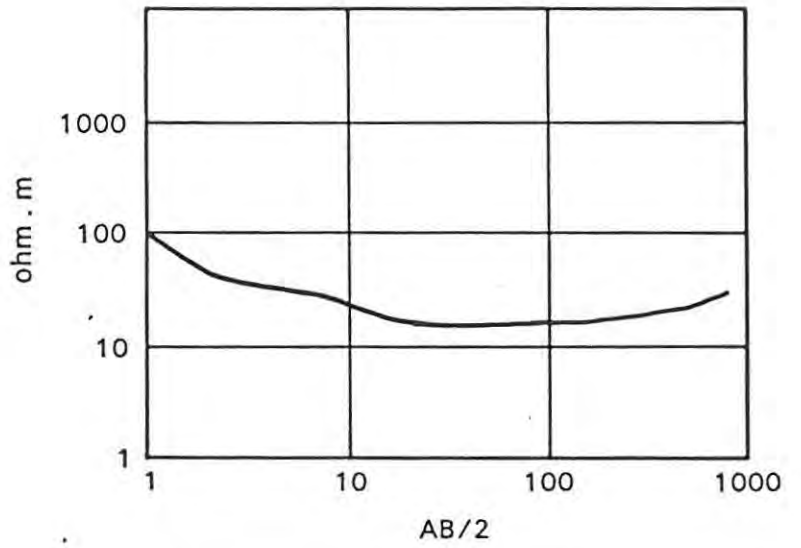
COEGA 1/4
 LAYER THICKNESS RESISTIVITY
 1,1 72,0
 8,9 5,0
 123,6 12,0
 64,4 5,0
 20,0
 TOTAL S VALUE: 24,97



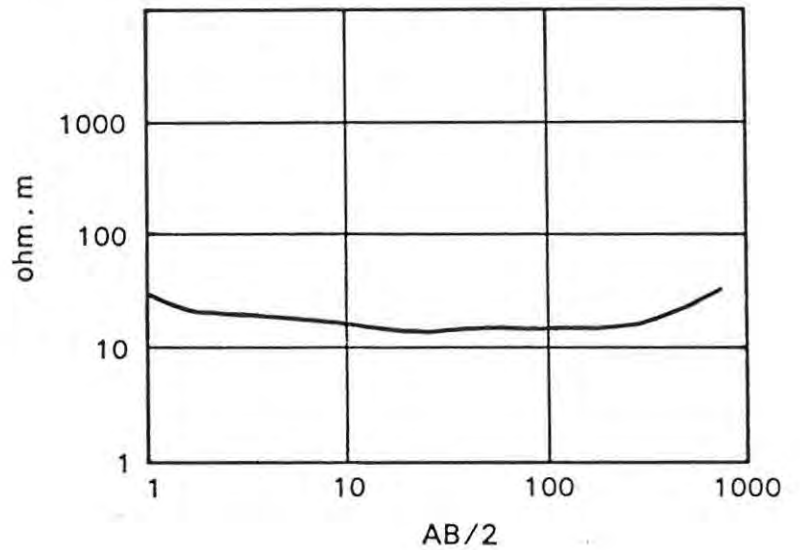
COEGA 1/5
 LAYER THICKNESS RESISTIVITY
 1,7 740
 10,5 18
 22,0 10
 90,0 20
 86,6 5
 100
 TOTAL S VALUE: 24,60



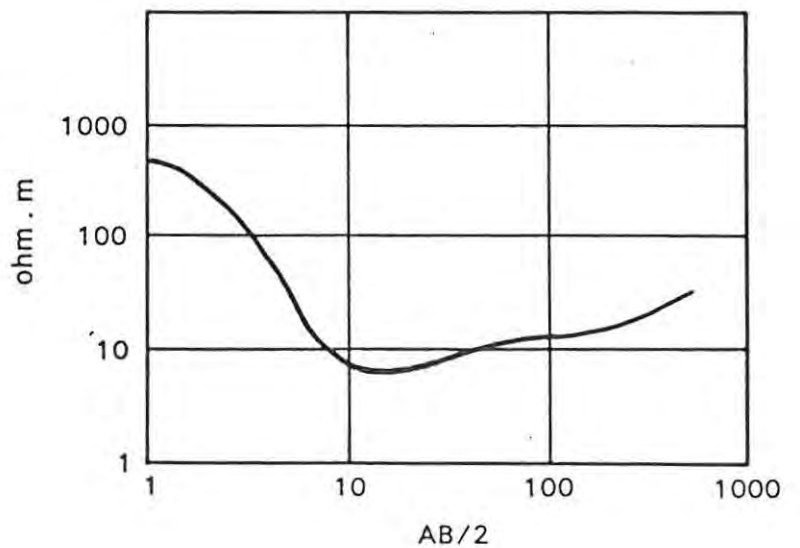
COEGA 1/6
 LAYER THICKNESS RESISTIVITY
 0,6 120
 7,8 30
 13,55 10
 360,4 18
 150
 TOTAL S VALUE: 21,64



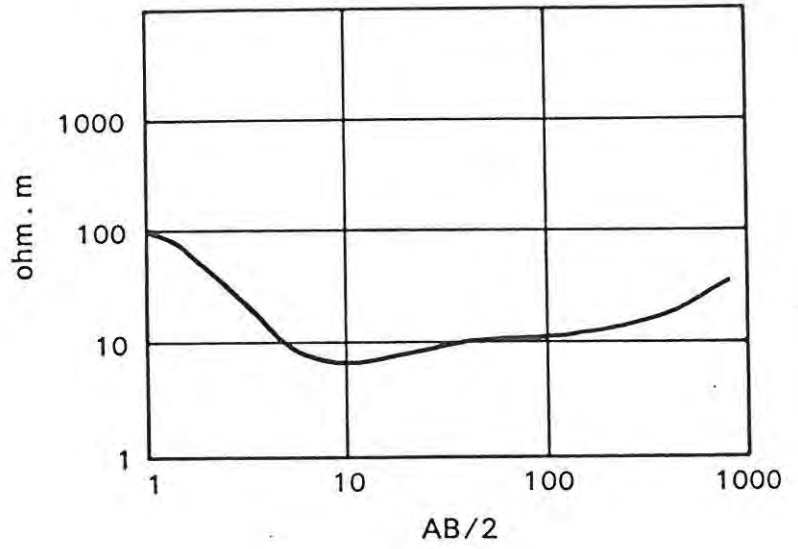
COEGA 1/7
 LAYER THICKNESS RESISTIVITY
 3,2 20,5
 14,0 14,0
 289,0 15,0
 200,0
 TOTAL S VALUE: 20,42



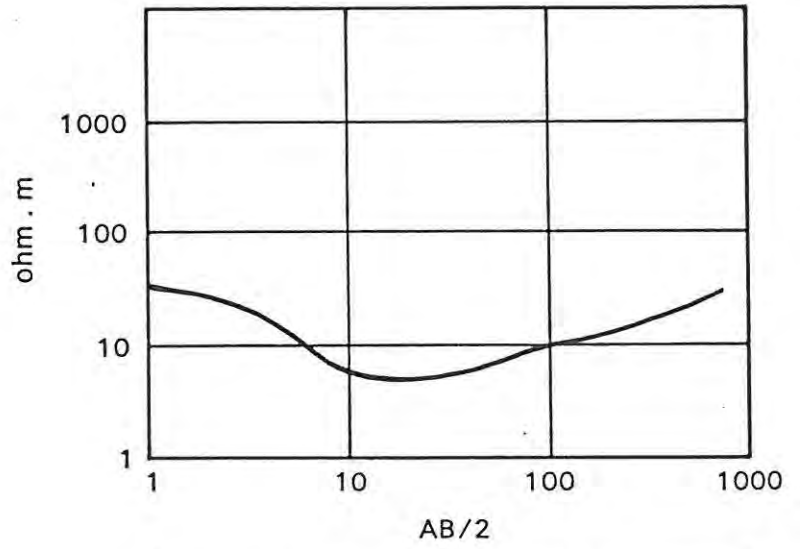
COEGA 1/8
 LAYER THICKNESS RESISTIVITY
 1,4 360
 14,4 6
 32,0 20
 41,0 5
 100
 TOTAL S VALUE: 12,20



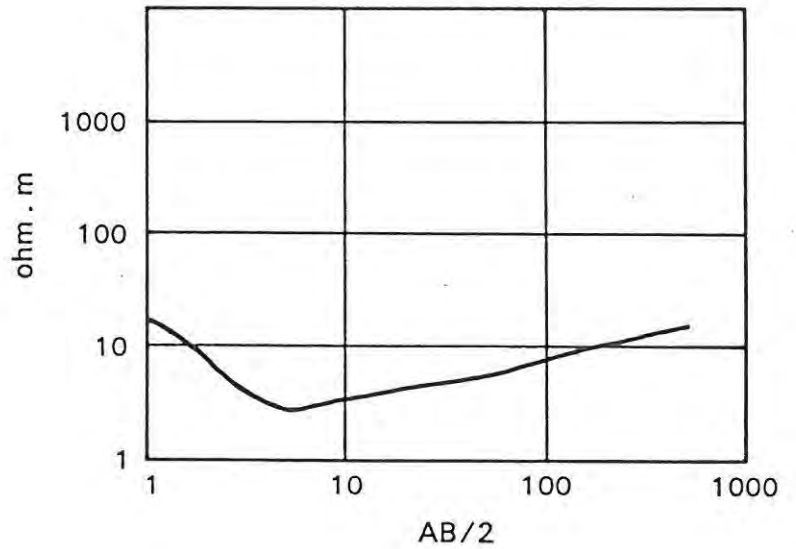
COEGA 1/9
 LAYER THICKNESS RESISTIVITY
 1,16 90
 13,1 7
 22,7 20
 64,9 5
 180
 TOTAL S VALUE: 15,99



COEGA 1/10
 LAYER THICKNESS RESISTIVITY
 2 29
 20 5
 8 8
 260 15
 200
 TOTAL S VALUE: 22,40

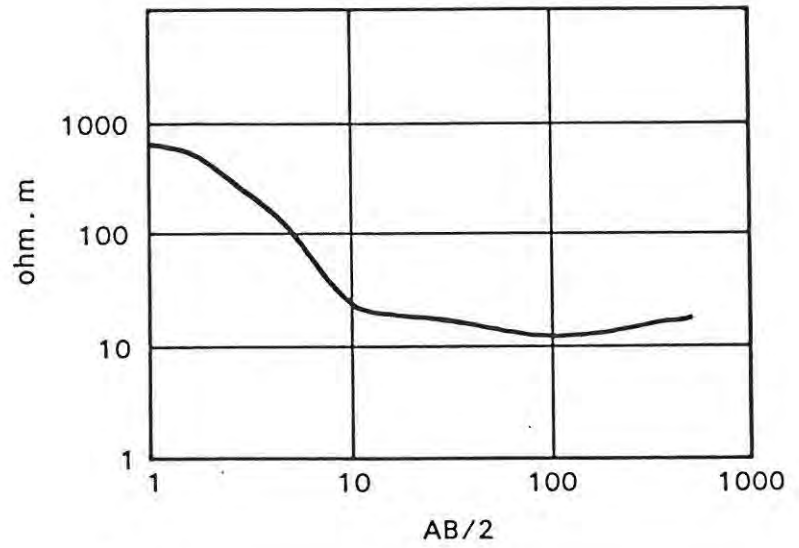


COEGA 1/11
 LAYER THICKNESS RESISTIVITY
 8,0 22
 3,8 2
 32,2 6
 15
 TOTAL S VALUE: 7,30



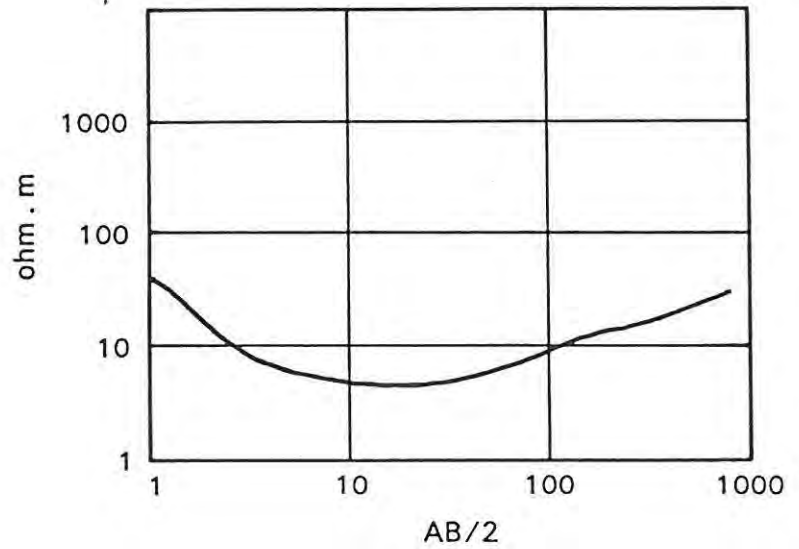
COEGA 2/1
 LAYER THICKNESS RESISTIVITY
 1,764 490
 18,0 20
 110,0 12
 20

TOTAL S VALUE: 10,07



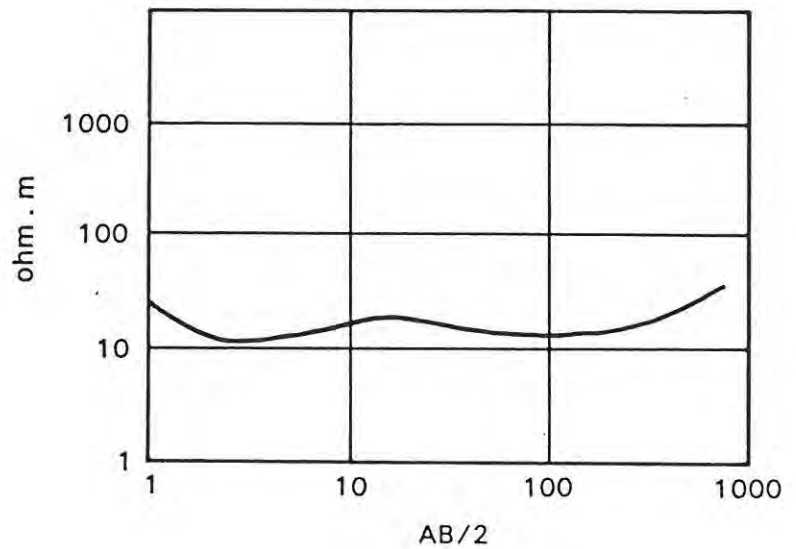
COEGA 2/2
 LAYER THICKNESS RESISTIVITY
 0,7 56
 1,4 7
 22,4 4
 56,25 20
 46,5 5
 200

TOTAL S VALUE: 17,92

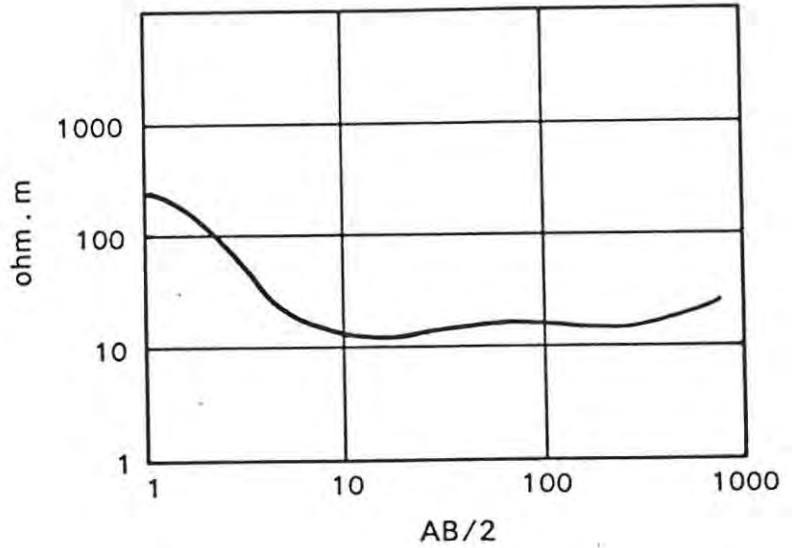


COEGA 2/3
 LAYER THICKNESS RESISTIVITY
 0,525 35,0
 3,1 10,0
 17,6 20,0
 232,0 11,5
 200,0

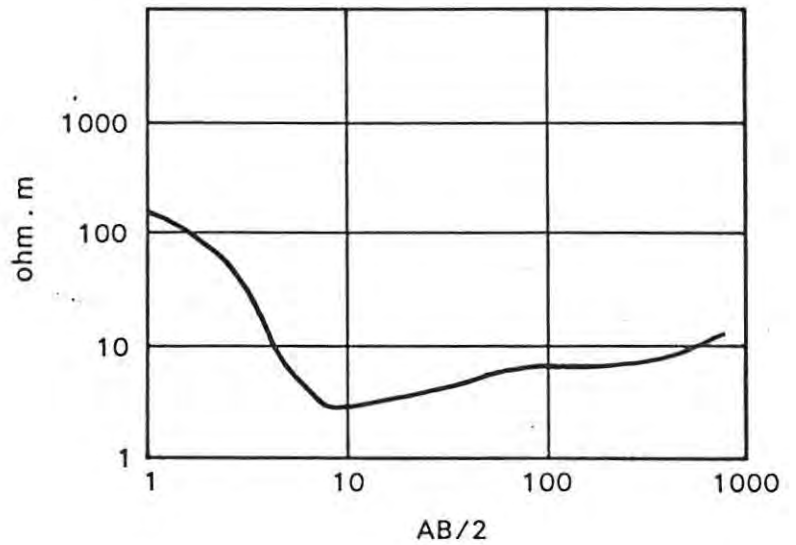
TOTAL S VALUE: 21,37



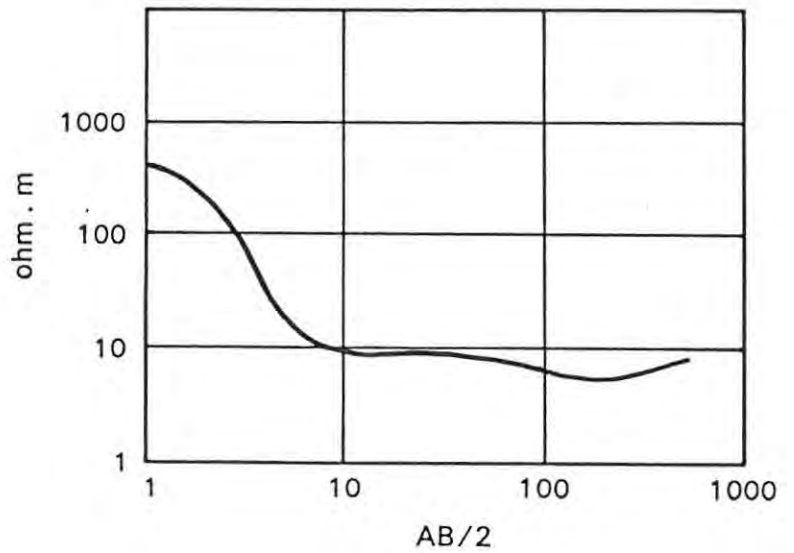
COEGA 2/4
 LAYER THICKNESS RESISTIVITY
 1,0 290
 4,5 14
 18,2 14
 84,5 20
 86,0 5
 100
 TOTAL S VALUE: 23,04



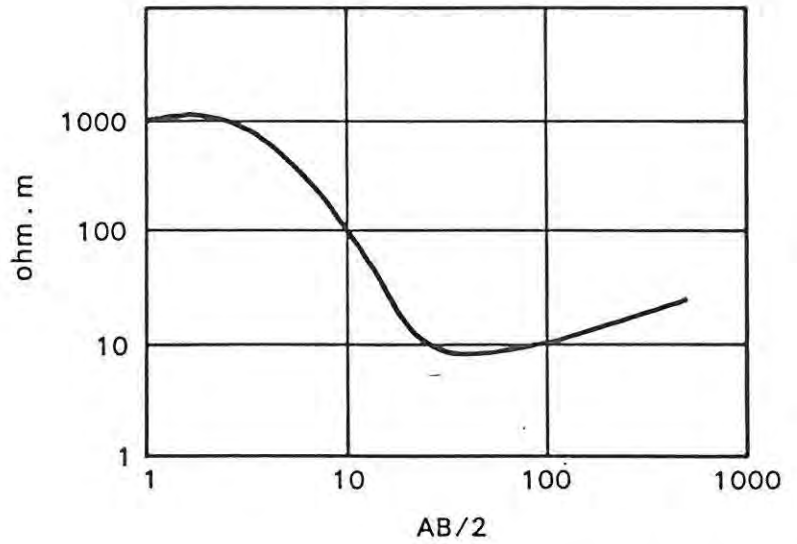
COEGA 2/5
 LAYER THICKNESS RESISTIVITY
 1,1 160
 6,5 2
 141,4 7
 109,1 3
 100
 TOTAL S VALUE: 59,82



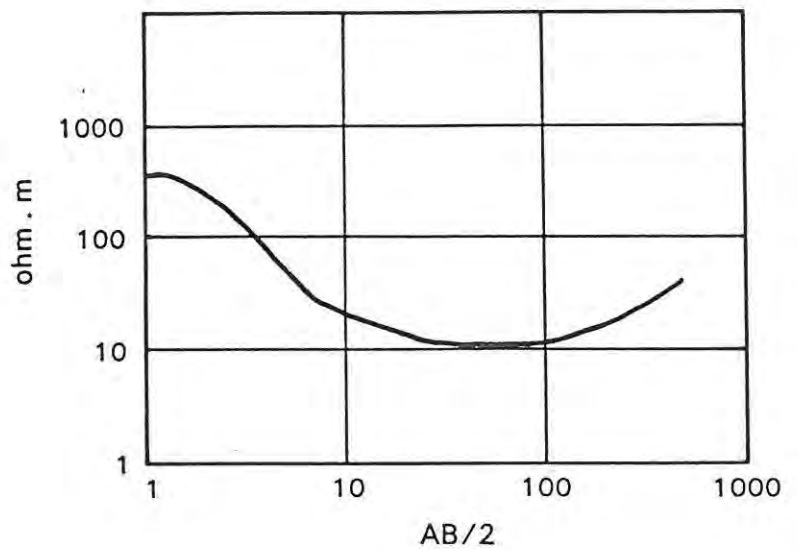
COEGA 2/6
 LAYER THICKNESS RESISTIVITY
 1,0 480
 5,0 13
 8,4 7
 20,0 12
 240,0 5
 30
 TOTAL S VALUE: 51,25



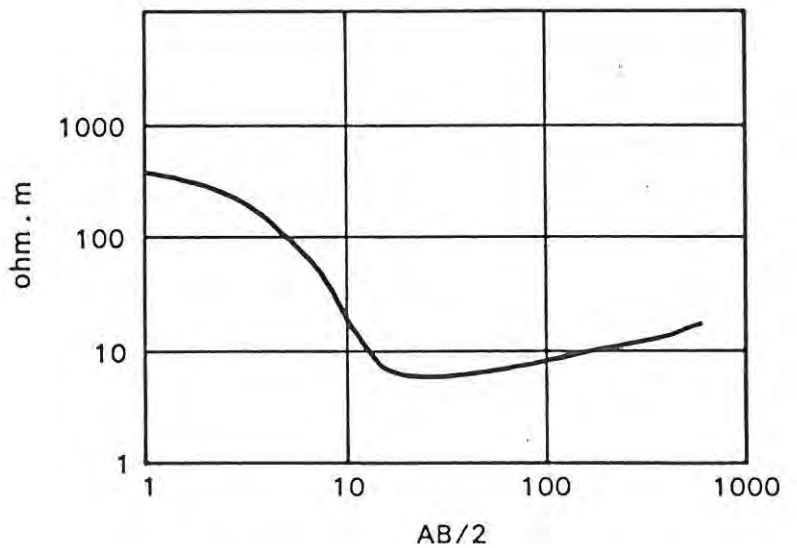
COEGA 3
 LAYER THICKNESS RESISTIVITY
 2,25 1120,0
 4,2 111,0
 68,5 8,5
 35,0 35,0
 TOTAL S VALUE: 8,09



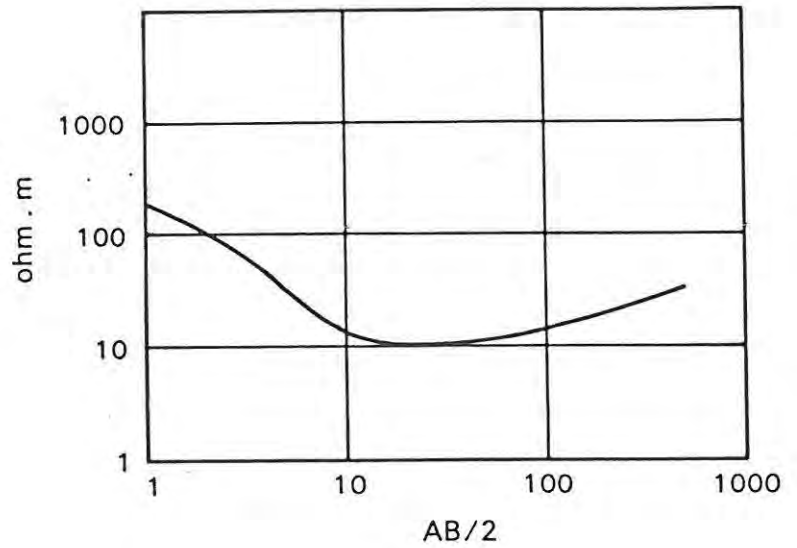
COEGA 4
 LAYER THICKNESS RESISTIVITY
 1,3 420
 6,9 25
 135,0 11
 300 300
 TOTAL S VALUE: 12,55



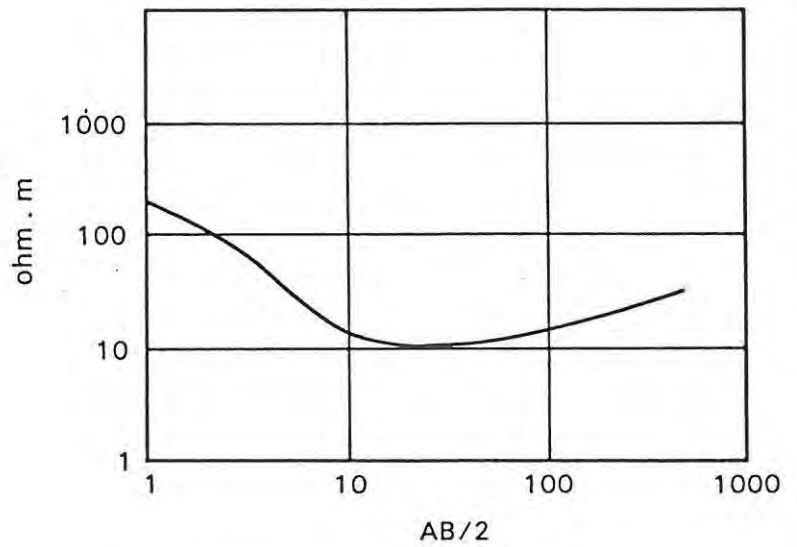
COEGA 5
 LAYER THICKNESS RESISTIVITY
 0,8 350
 1,5 300
 27,6 6
 44,1 9
 18 18
 TOTAL S VALUE: 9,50



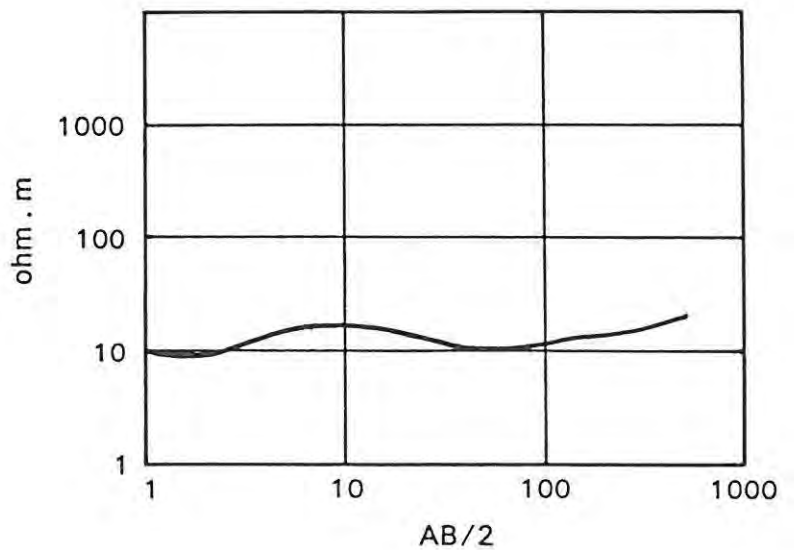
COEGA 6
 LAYER THICKNESS RESISTIVITY
 1,0 190
 1,76 55
 24,6 10
 82,5 15
 70
 TOTAL S VALUE: 7,99



COEGA 7
 LAYER THICKNESS RESISTIVITY
 2,0 150
 1,74 110
 28,6 9
 79,5 15
 25
 TOTAL S VALUE: 8,50



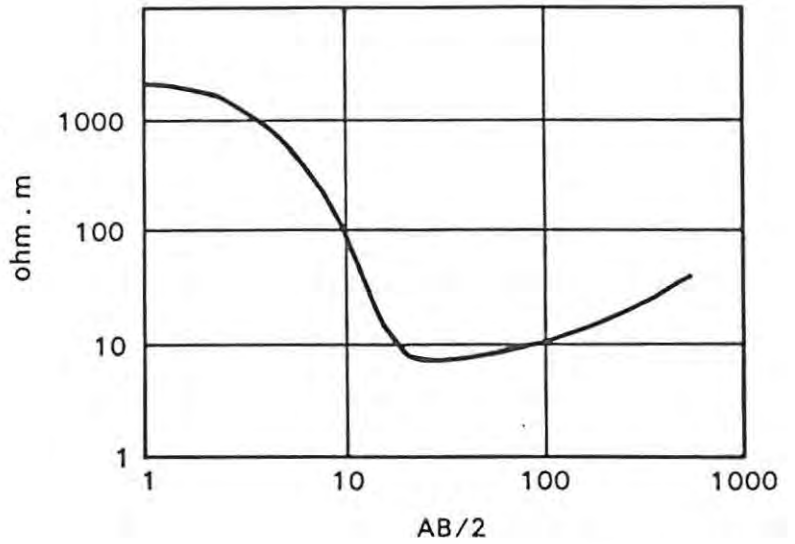
COEGA 8
 LAYER THICKNESS RESISTIVITY
 0,25 20
 2,5 10
 4,5 36
 21,0 7
 203,0 16
 35
 TOTAL S VALUE: 16,07



COEGA 9

LAYER THICKNESS	RESISTIVITY
1	2200
0,16	1400
30	8
99	15
	200

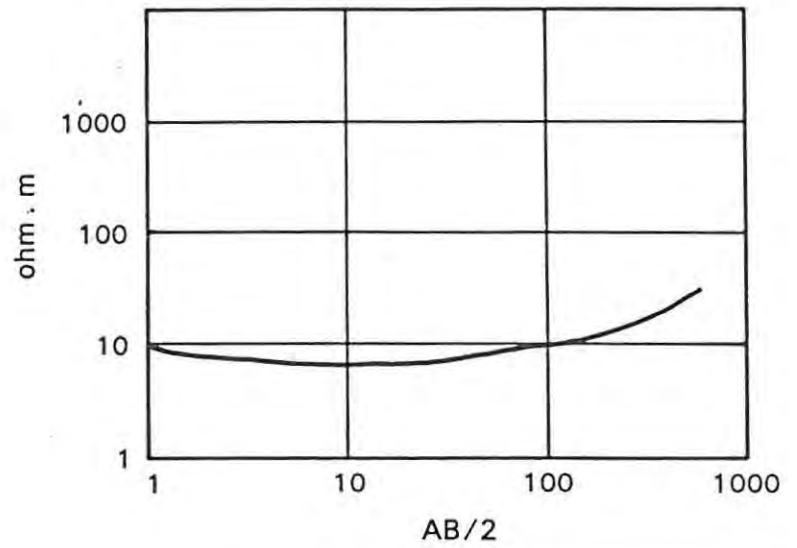
TOTAL S VALUE: 10,3



COEGA 10

LAYER THICKNESS	RESISTIVITY
0,77	10
22,2	7
204,0	12
	300

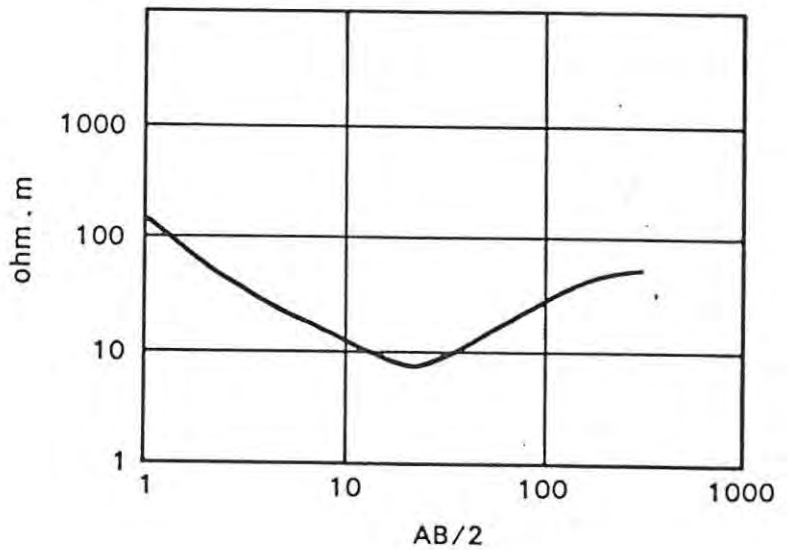
TOTAL S VALUE: 20,24



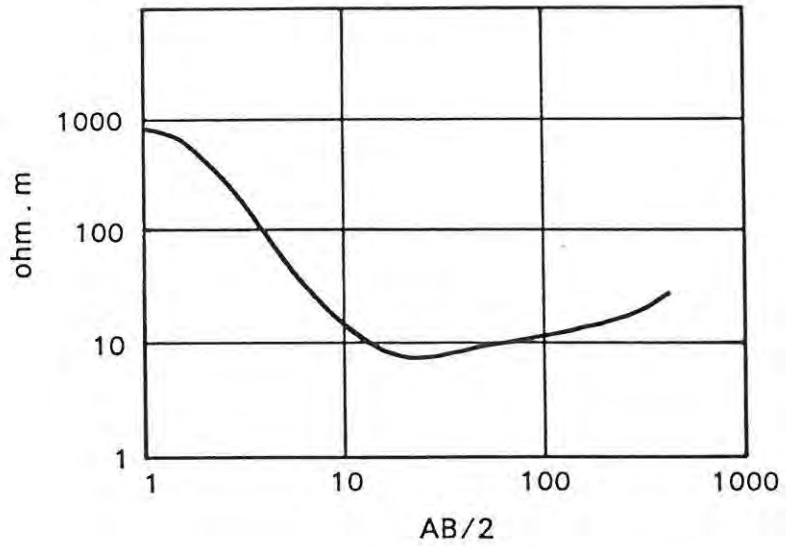
COEGA 11

LAYER THICKNESS	RESISTIVITY
6,0	250
3,54	27
18,36	6
	200

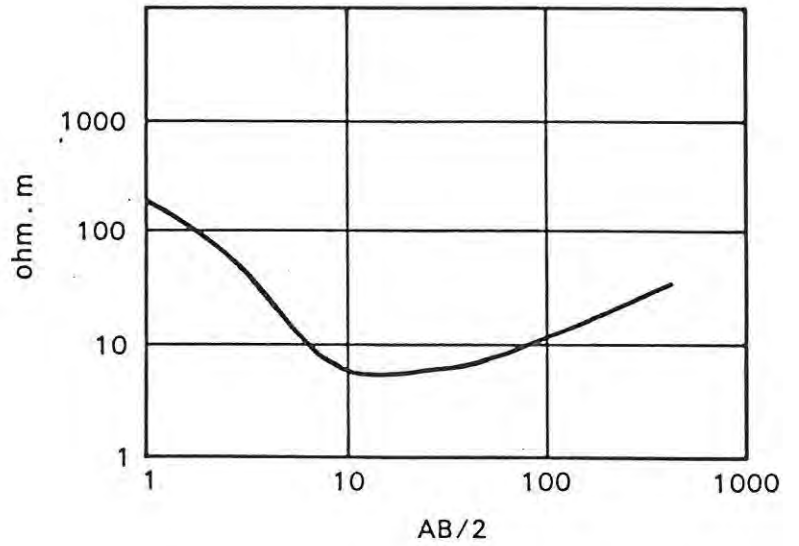
TOTAL S VALUE: 3,19



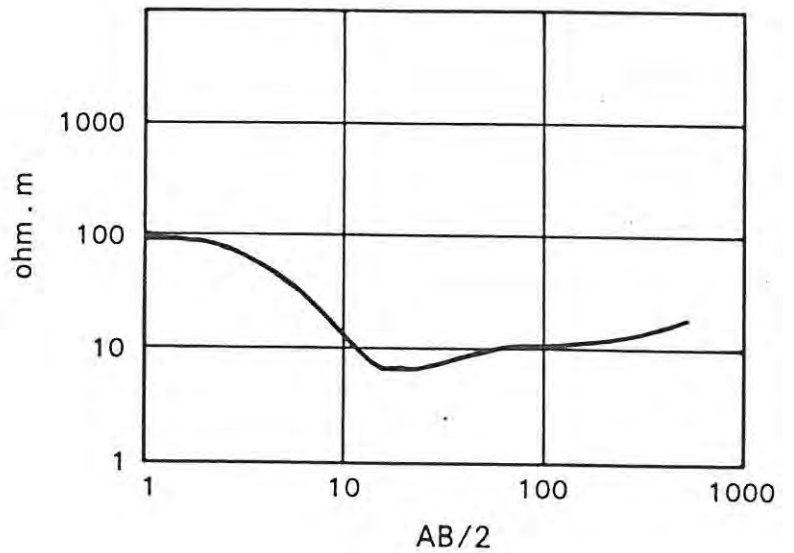
COEGA 12
 LAYER THICKNESS RESISTIVITY
 1,1 950
 3,4 37
 17,4 6
 150,0 15
 150 150
 TOTAL S VALUE: 12,99



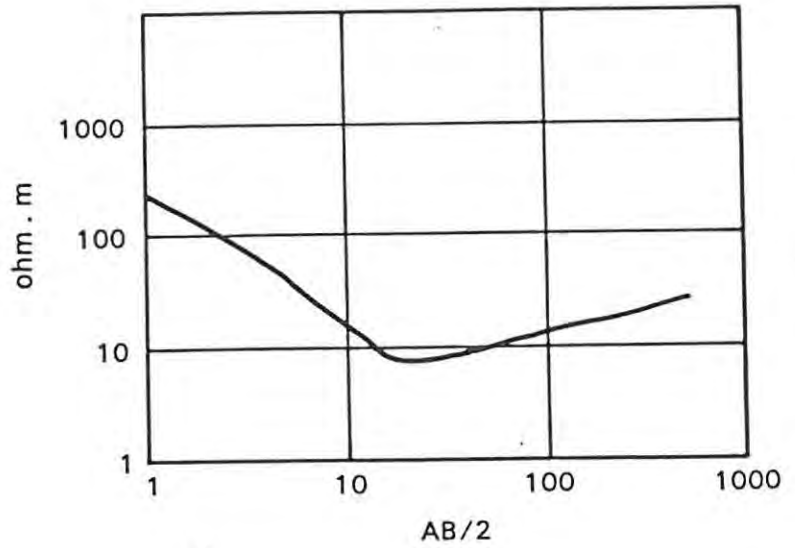
COEGA 13
 LAYER THICKNESS RESISTIVITY
 0,88 188
 1,2 35
 19,8 5
 65,0 13
 150 150
 TOTAL S VALUE: 8,99



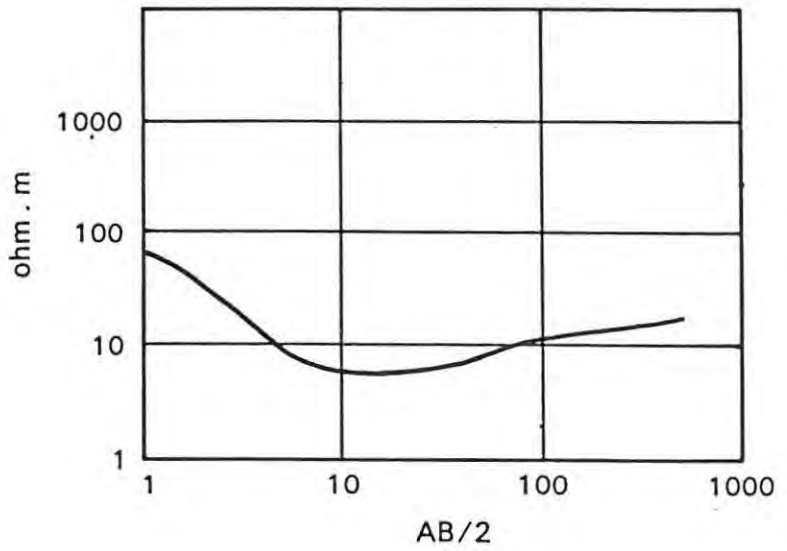
COEGA 14
 LAYER THICKNESS RESISTIVITY
 2,6 95
 19,6 6
 240,0 15
 20 20
 TOTAL S VALUE: 19,29



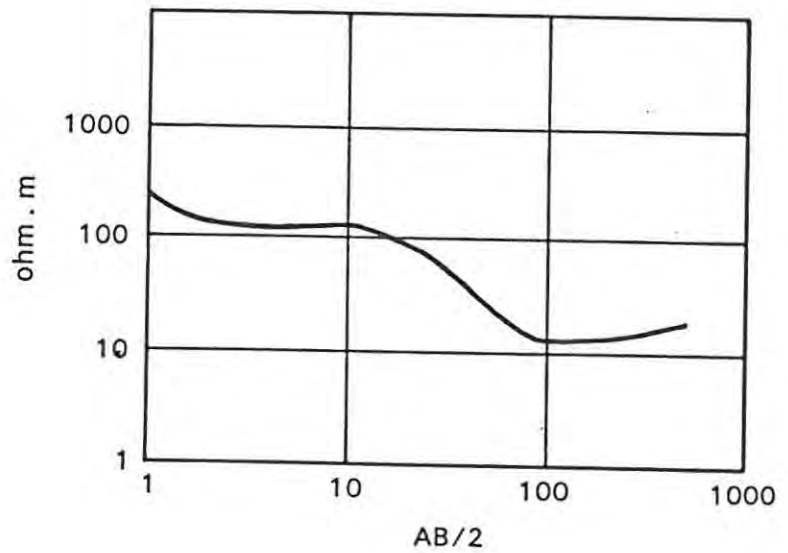
COEGA 15
 LAYER THICKNESS RESISTIVITY
 0,9 250
 3,1 55
 20,0 6
 132,0 20
 40
 TOTAL S VALUE: 9,99



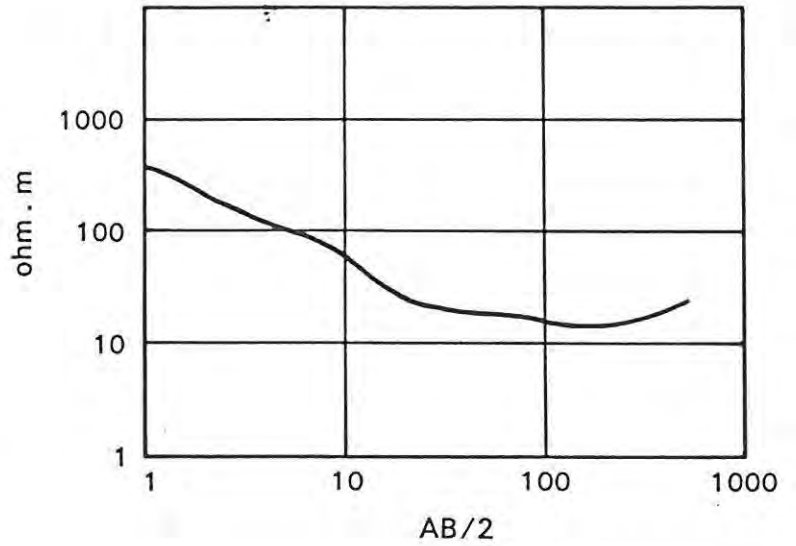
COEGA 16
 LAYER THICKNESS RESISTIVITY
 0,6 75,0
 0,7 52,0
 22,0 5,5
 240,0 15,0
 30,0
 TOTAL S VALUE: 20,02



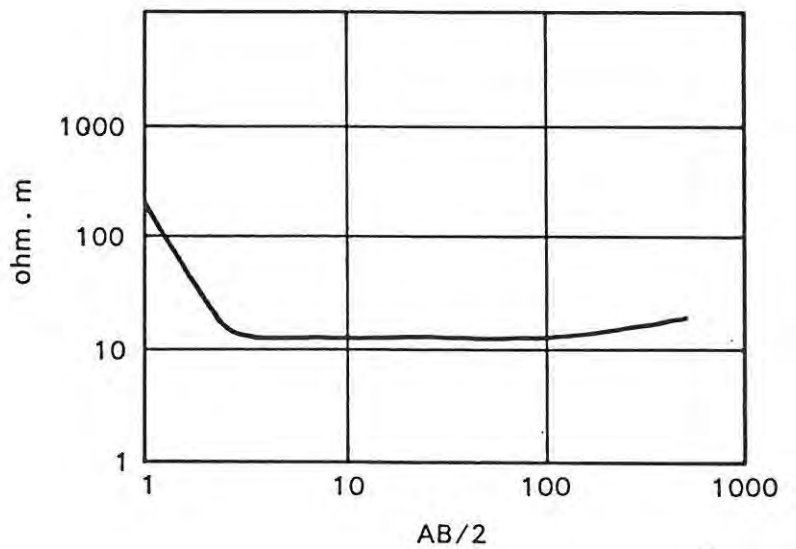
COEGA 17
 LAYER THICKNESS RESISTIVITY
 0,33 700
 3,3 110
 11,3 130
 149,0 12
 30
 TOTAL S VALUE: 12,53



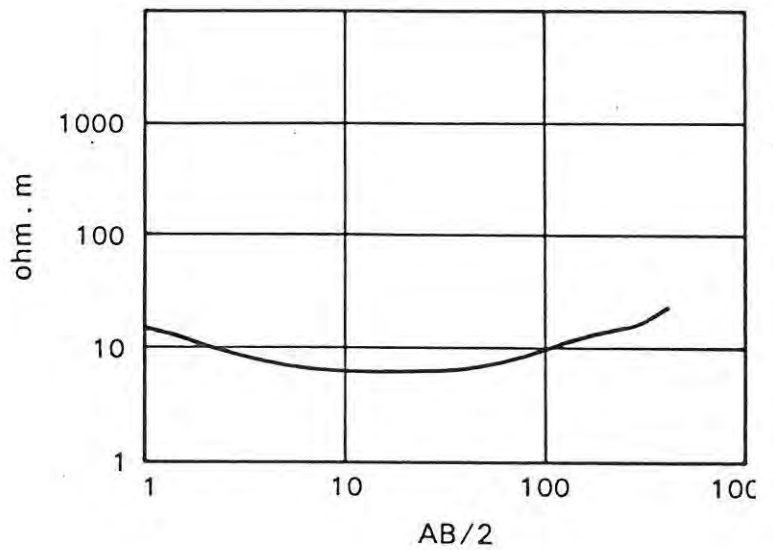
COEGA 18
 LAYER THICKNESS RESISTIVITY
 0,76 440,0
 4,94 110,0
 123,5 17,6
 35,7 3,0
 200,0
 TOTAL S VALUE: 18,96



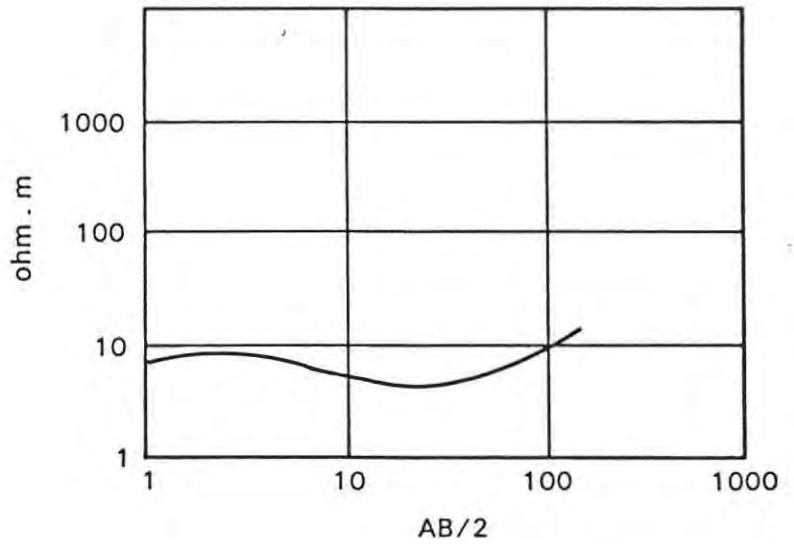
COEGA 19
 LAYER THICKNESS RESISTIVITY
 0,41 660
 114,0 12
 20
 TOTAL S VALUE: 9,50



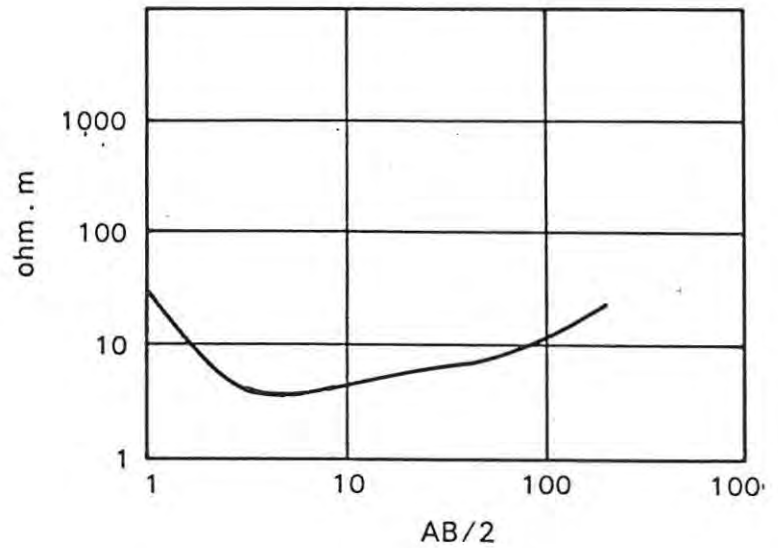
COEGA 20
 LAYER THICKNESS RESISTIVITY
 0,9 15
 13,0 7
 22,0 4
 151,0 25
 50
 TOTAL S VALUE: 13



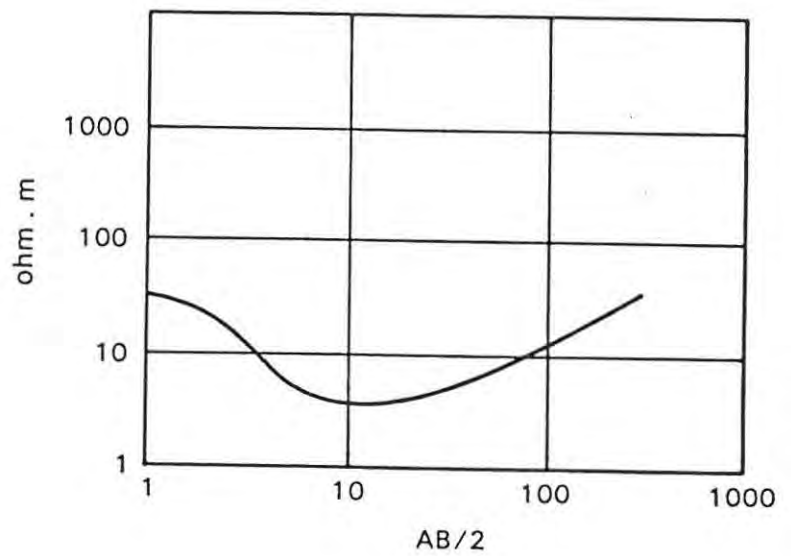
COEGA 21
 LAYER THICKNESS RESISTIVITY
 1 7
 1 15
 45 4,5
 200
 TOTAL S VALUE: 10,21



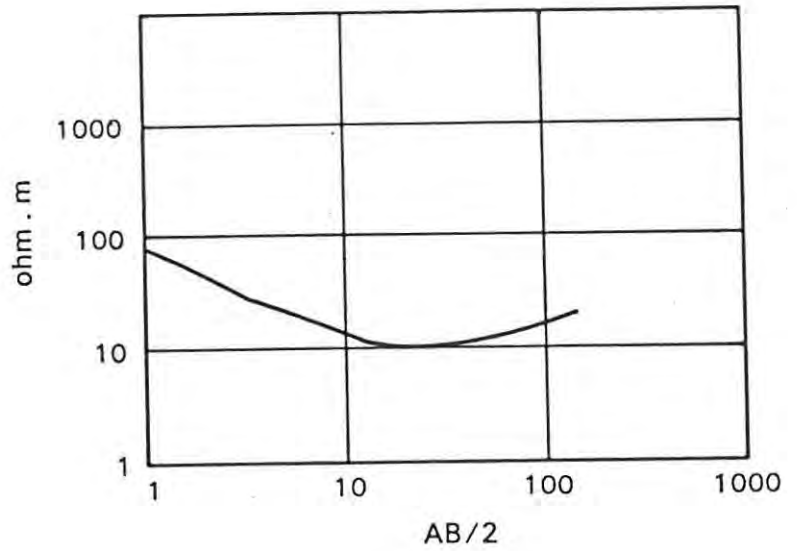
COEGA 22
 LAYER THICKNESS RESISTIVITY
 0,5 52
 5,2 3,5
 56 8
 200
 TOTAL S VALUE: 8,50



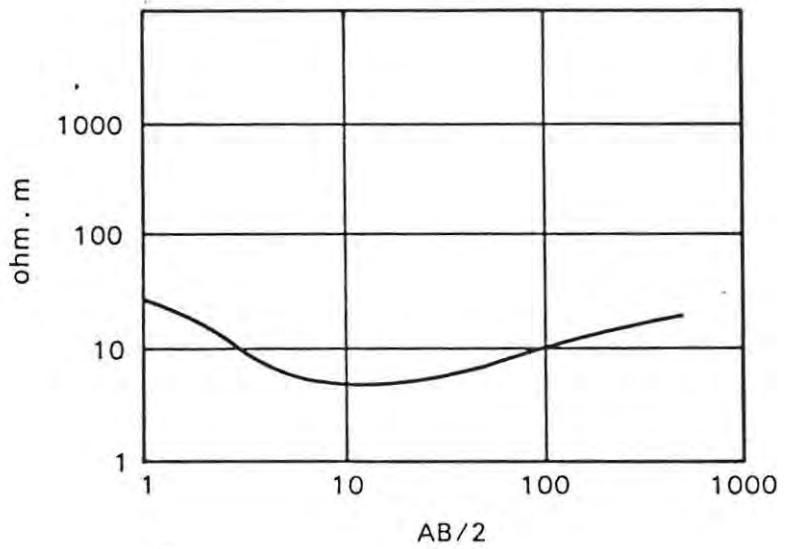
COEGA 23
 LAYER THICKNESS RESISTIVITY
 1,1 38
 15,3 3,5
 61,2 17
 400
 TOTAL S VALUE: 8,00



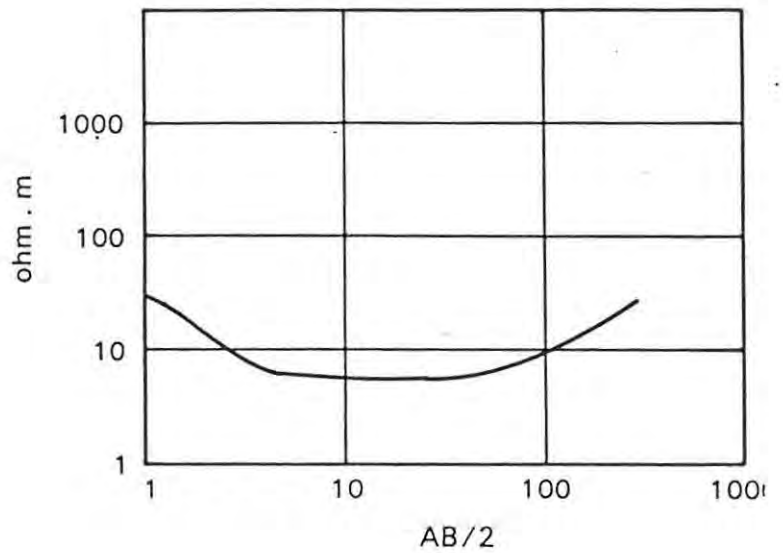
COEGA 24
 LAYER THICKNESS RESISTIVITY
 0,7 95
 3 23
 30 9
 30
 TOTAL S VALUE: 3,47



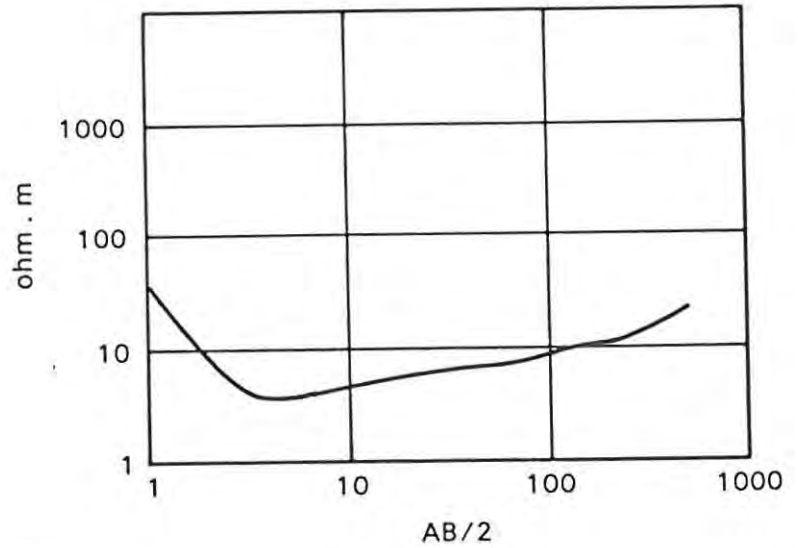
COEGA 25
 LAYER THICKNESS RESISTIVITY
 1 27
 12 4,4
 31 8
 22
 TOTAL S VALUE: 6,66



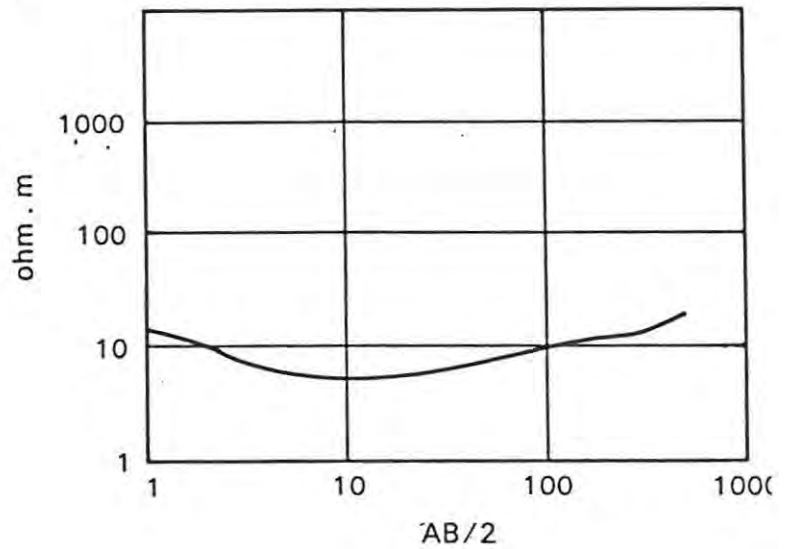
COEGA 26
 LAYER THICKNESS RESISTIVITY
 0,5 57
 0,5 14
 59 5,5
 200
 TOTAL S VALUE: 10,77



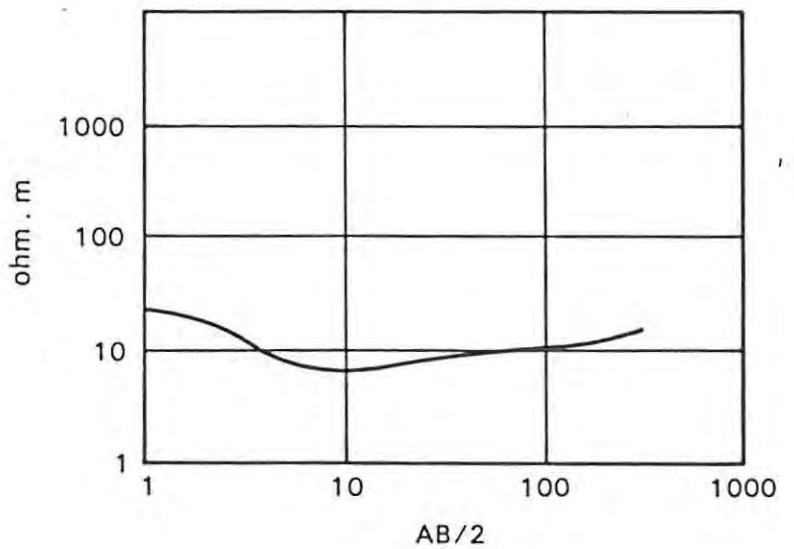
COEGA 27
 LAYER THICKNESS RESISTIVITY
 0,42 90
 0,16 23
 5,26 3,6
 30 7
 187 600
 TOTAL S VALUE: 21,34



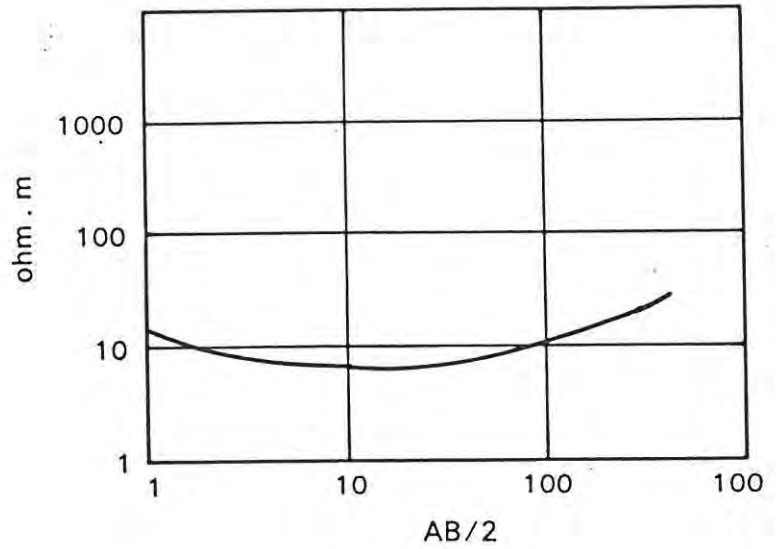
COEGA 28
 LAYER THICKNESS RESISTIVITY
 1 13
 12,1 5
 18,4 8
 200 12
 200 200
 TOTAL S VALUE: 21,46



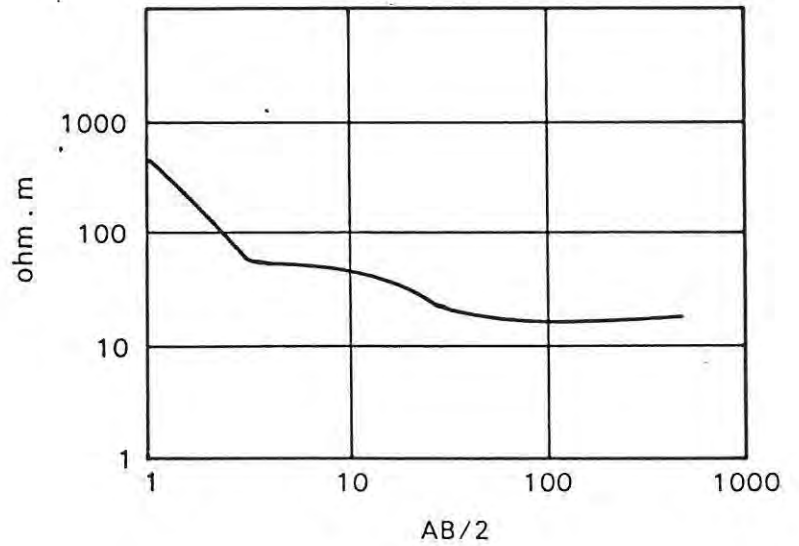
COEGA 29
 LAYER THICKNESS RESISTIVITY
 1,1 25
 11,4 6,5
 7 10
 156 12
 30 30
 TOTAL S VALUE: 15,50



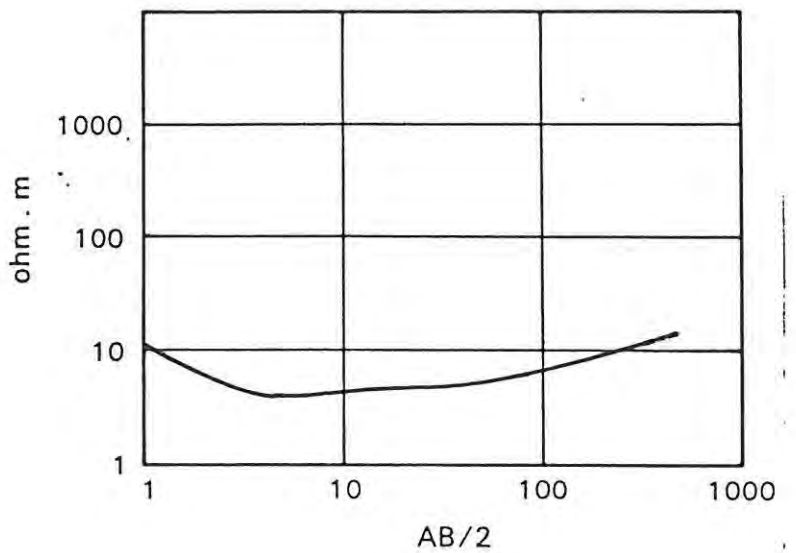
COEGA 30
 LAYER THICKNESS RESISTIVITY
 0,7 16
 35,4 7
 128 20
 100
 TOTAL S VALUE: 11,50



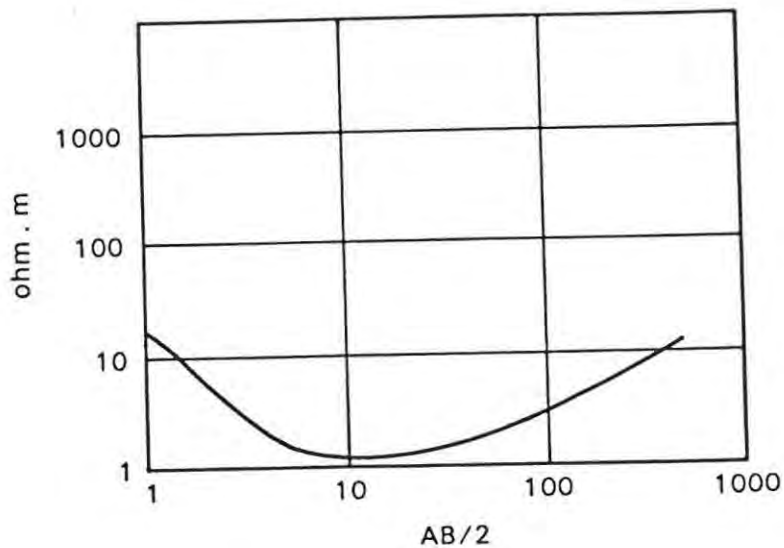
COEGA 31
 LAYER THICKNESS RESISTIVITY
 0,55 800
 3,6 50
 3 75
 270 17
 50
 TOTAL S VALUE: 16,00



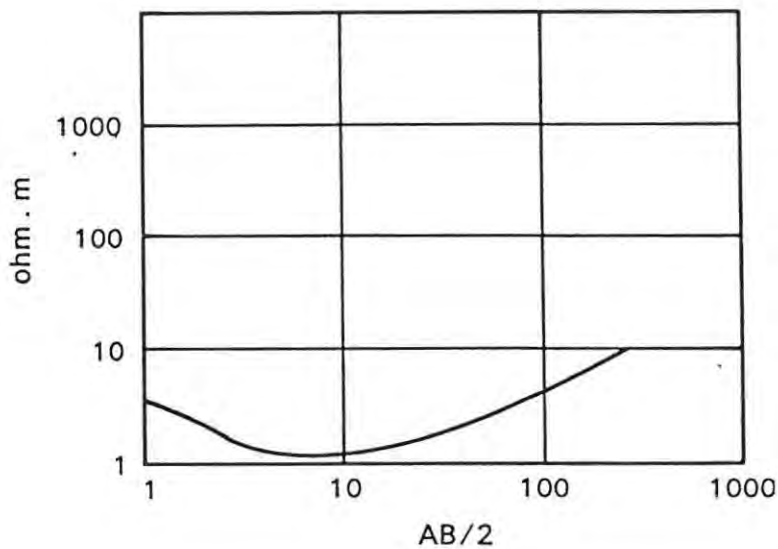
COEGA 32
 LAYER THICKNESS RESISTIVITY
 0,62 14
 6 4
 37 5
 81 12
 20
 TOTAL S VALUE: 15,69



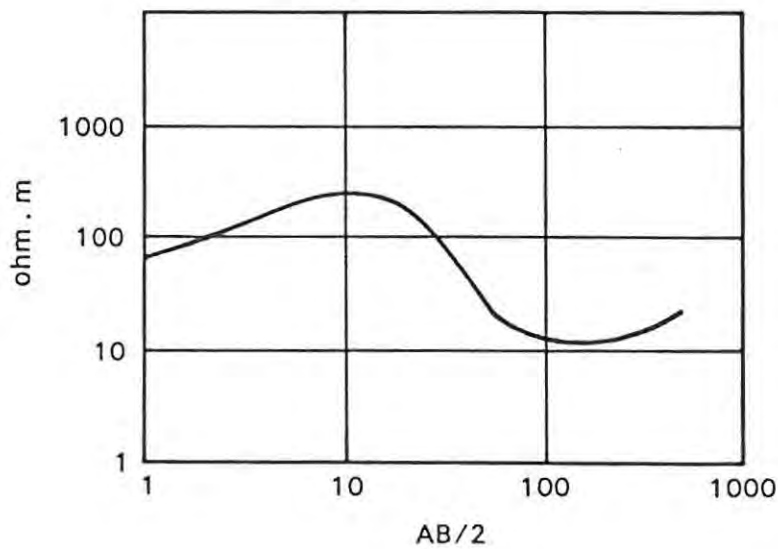
COEGA 33
 LAYER THICKNESS RESISTIVITY
 0,4 30
 1 6
 26,2 1,1
 96 8
 200
 TOTAL S VALUE: 36,00



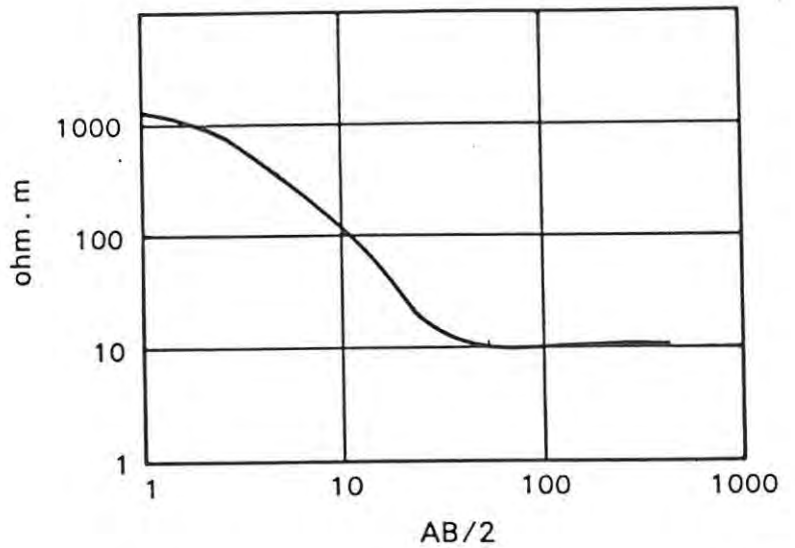
COEGA 34
 LAYER THICKNESS RESISTIVITY
 0,8 4
 15,5 1,1
 76,3 7
 100
 TOTAL S VALUE: 25,19



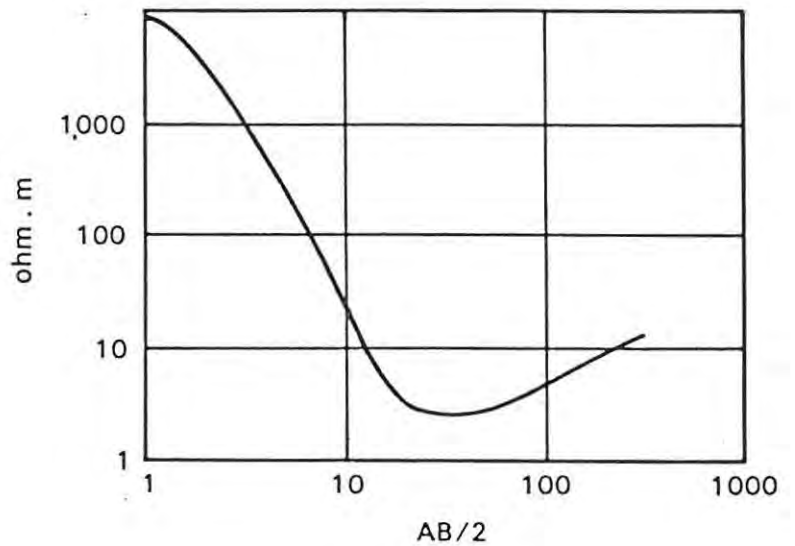
COEGA 35
 LAYER THICKNESS RESISTIVITY
 1,1 60
 3 1000
 276 12
 200
 TOTAL S VALUE: 23,02



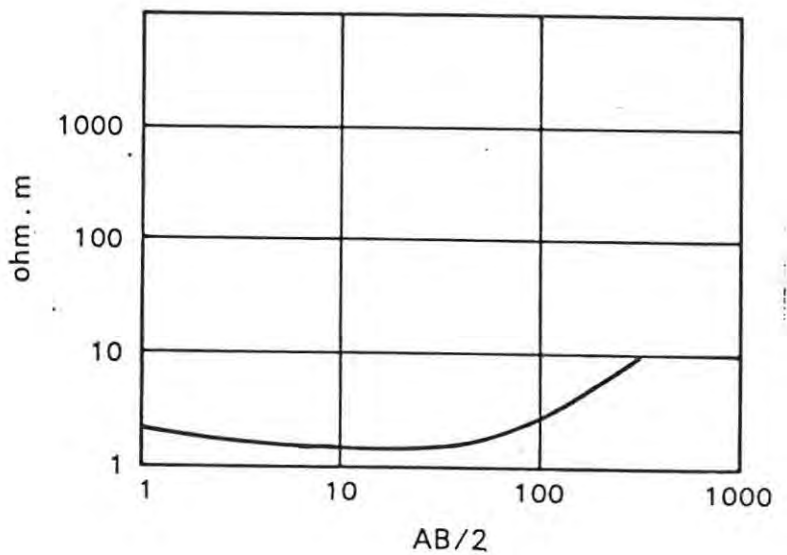
COEGA 36
 LAYER THICKNESS RESISTIVITY
 1,5 1200
 5 200
 192 10
 12
 TOTAL S VALUE: 19,23



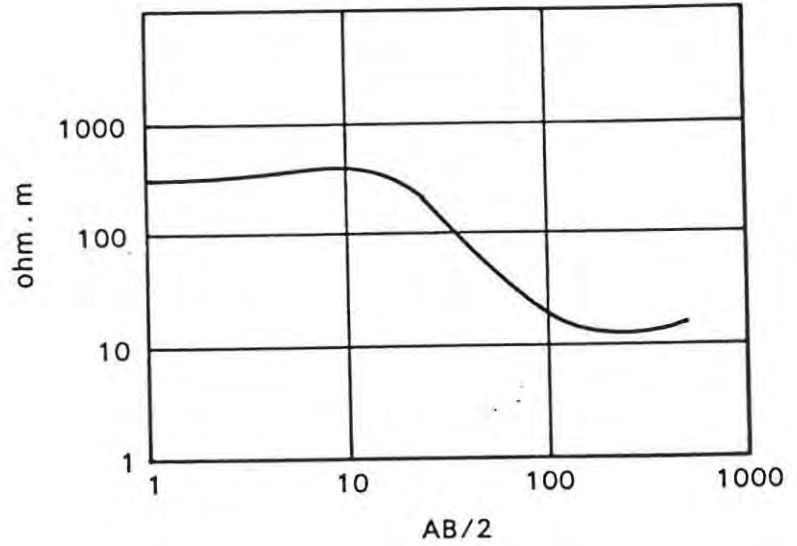
COEGA 37
 LAYER THICKNESS RESISTIVITY
 0,8 11000
 2,5 300
 57 2,5
 200
 TOTAL S VALUE: 22,81



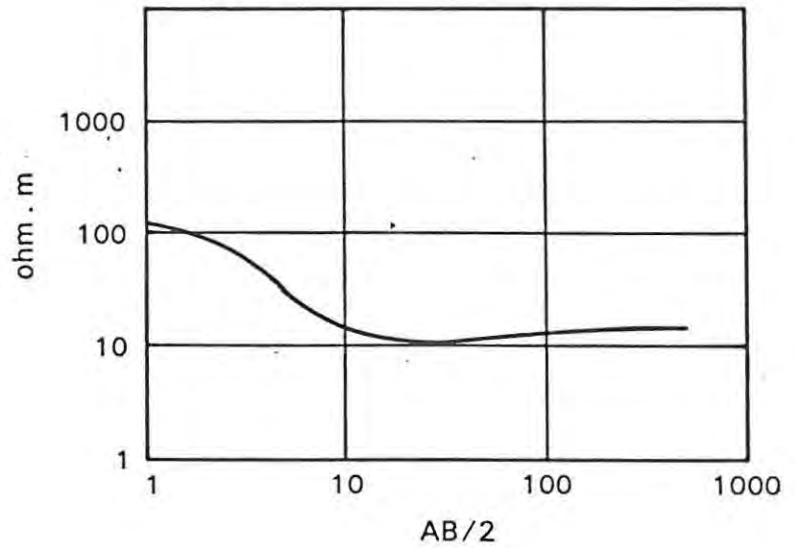
COEGA 38
 LAYER THICKNESS RESISTIVITY
 1,2 2,2
 46 1,4
 200
 TOTAL S VALUE: 33,40



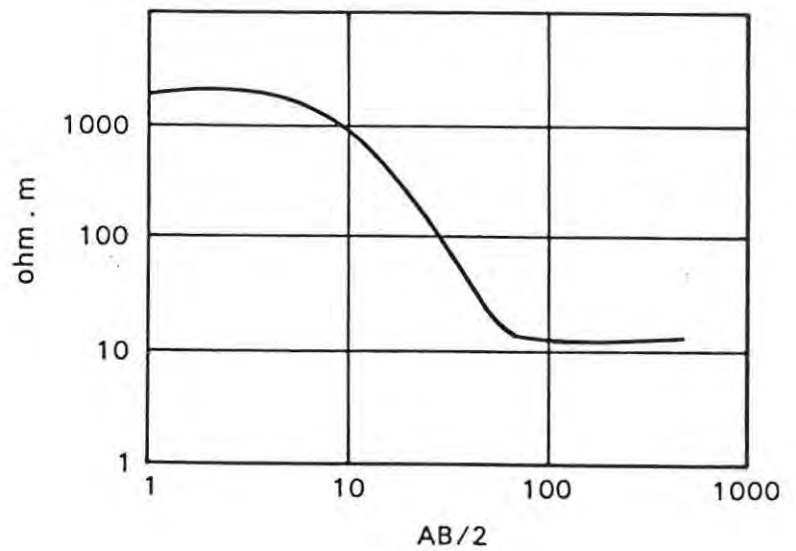
COEGA 39
 LAYER THICKNESS RESISTIVITY
 1,6 300
 10 450
 40 30
 273 10
 200
 TOTAL S VALUE: 28,66



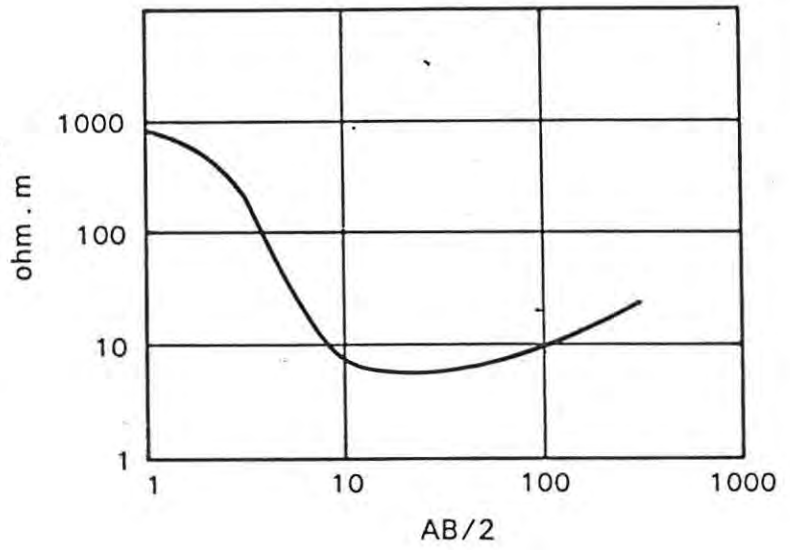
COEGA 40
 LAYER THICKNESS RESISTIVITY
 0,65 160
 1,65 70
 32,7 11
 15
 TOTAL S VALUE: 3,00



COEGA 41
 LAYER THICKNESS RESISTIVITY
 1,5 1800
 2,8 2300
 11,5 160
 100 11
 14
 TOTAL S VALUE: 9,16



COEGA_42
LAYER THICKNESS RESISTIVITY
1,2 850
35 5,5
115 18
200
TOTAL S VALUE: 12,75



APPENDIX 4

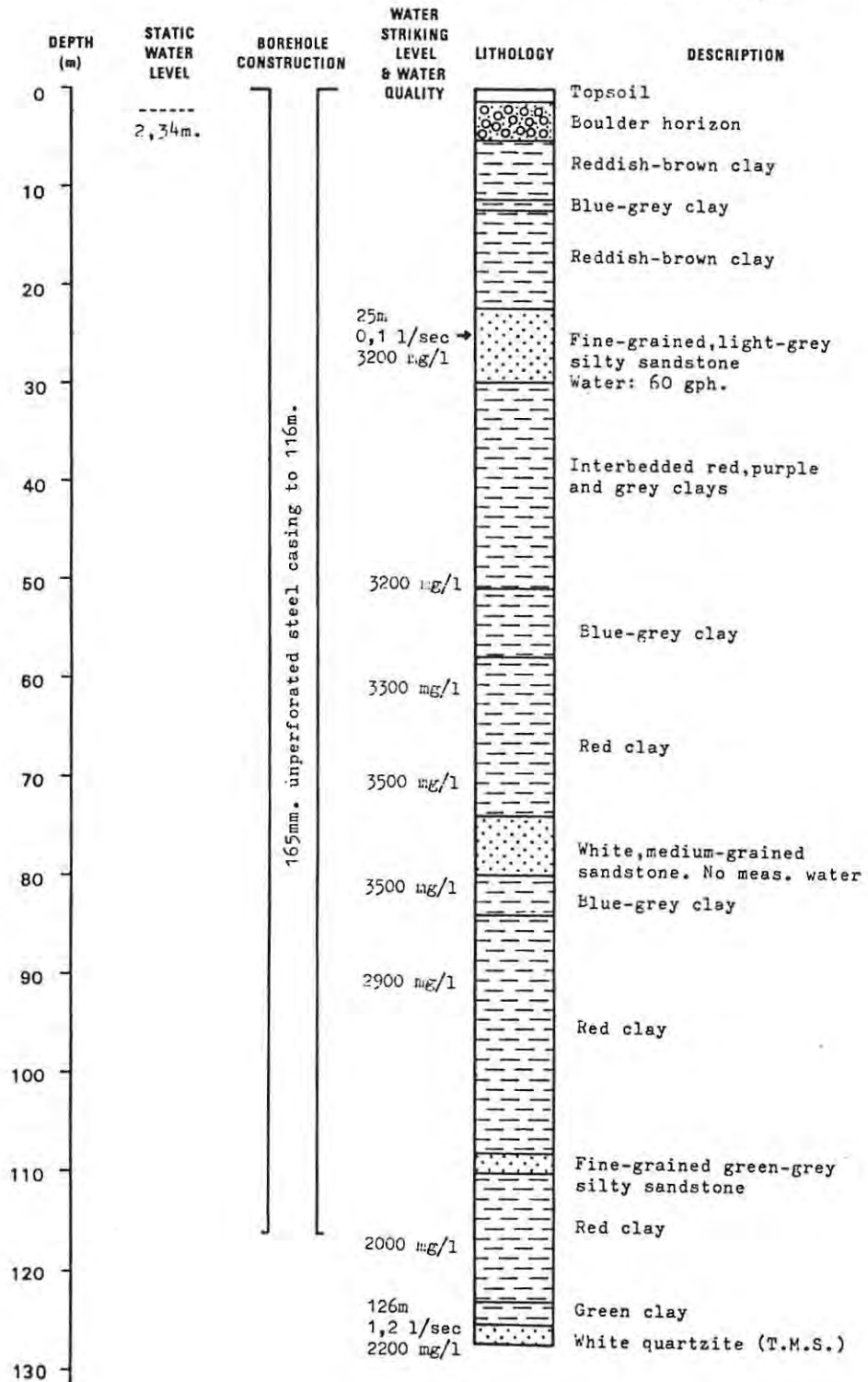
BOREHOLE LOGS

BOREHOLE NO: WF 35 (G 35739) EXPLORATION BH.

CADASTRAL FARM: WELBEDACHTSFONTEIN 300

TEST YIELD: 1,2 l/s

Cable tool percussion drilling rig.
30/1/84 - 7/3/84



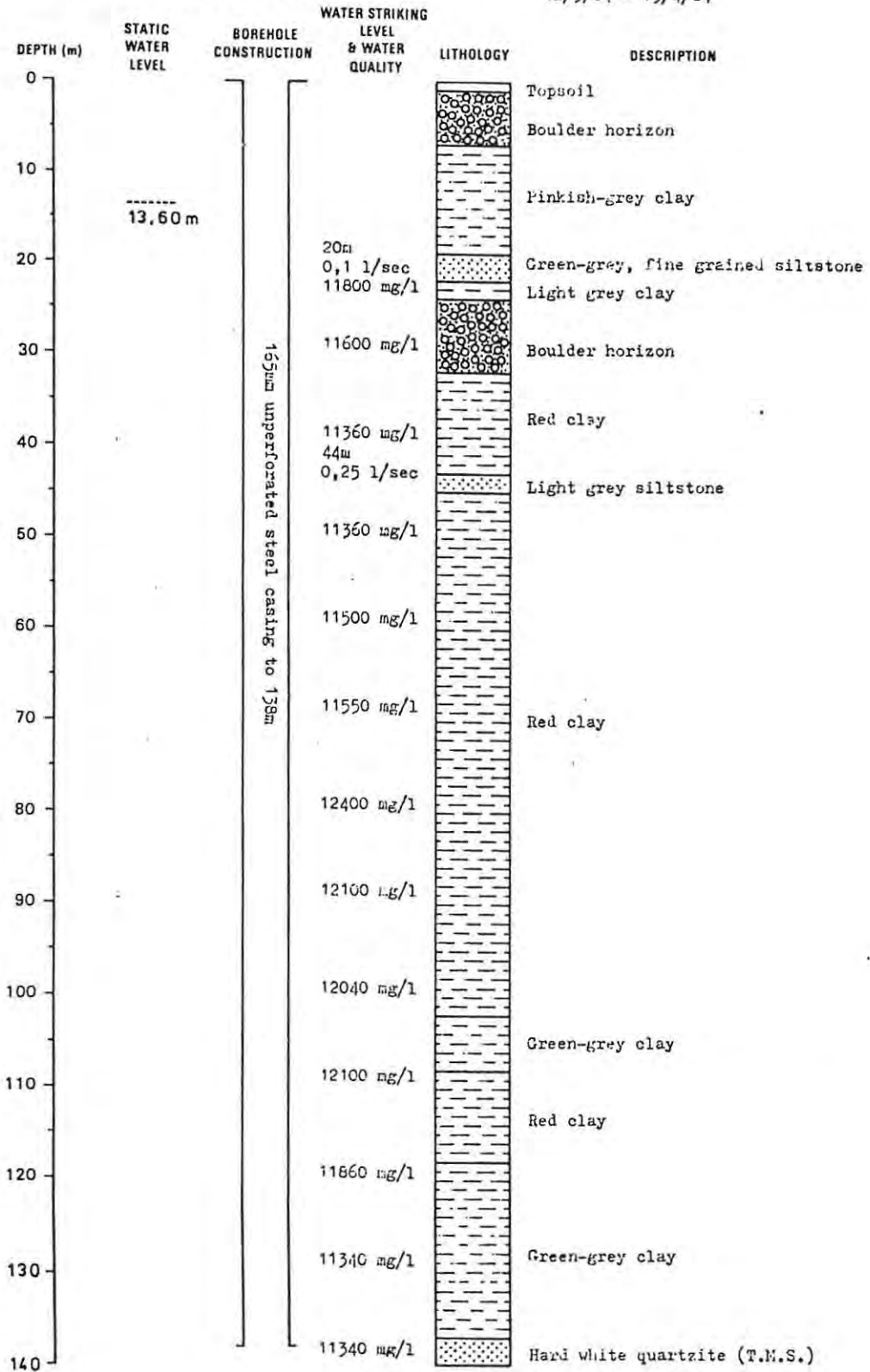
BOREHOLE NO: RH 39 (G 35740) EXPLORATION BH.

CADASTRAL FARM: AMANZI 294

TEST YIELD: 2,66 l/sec

Cable tool percussion drilling rig

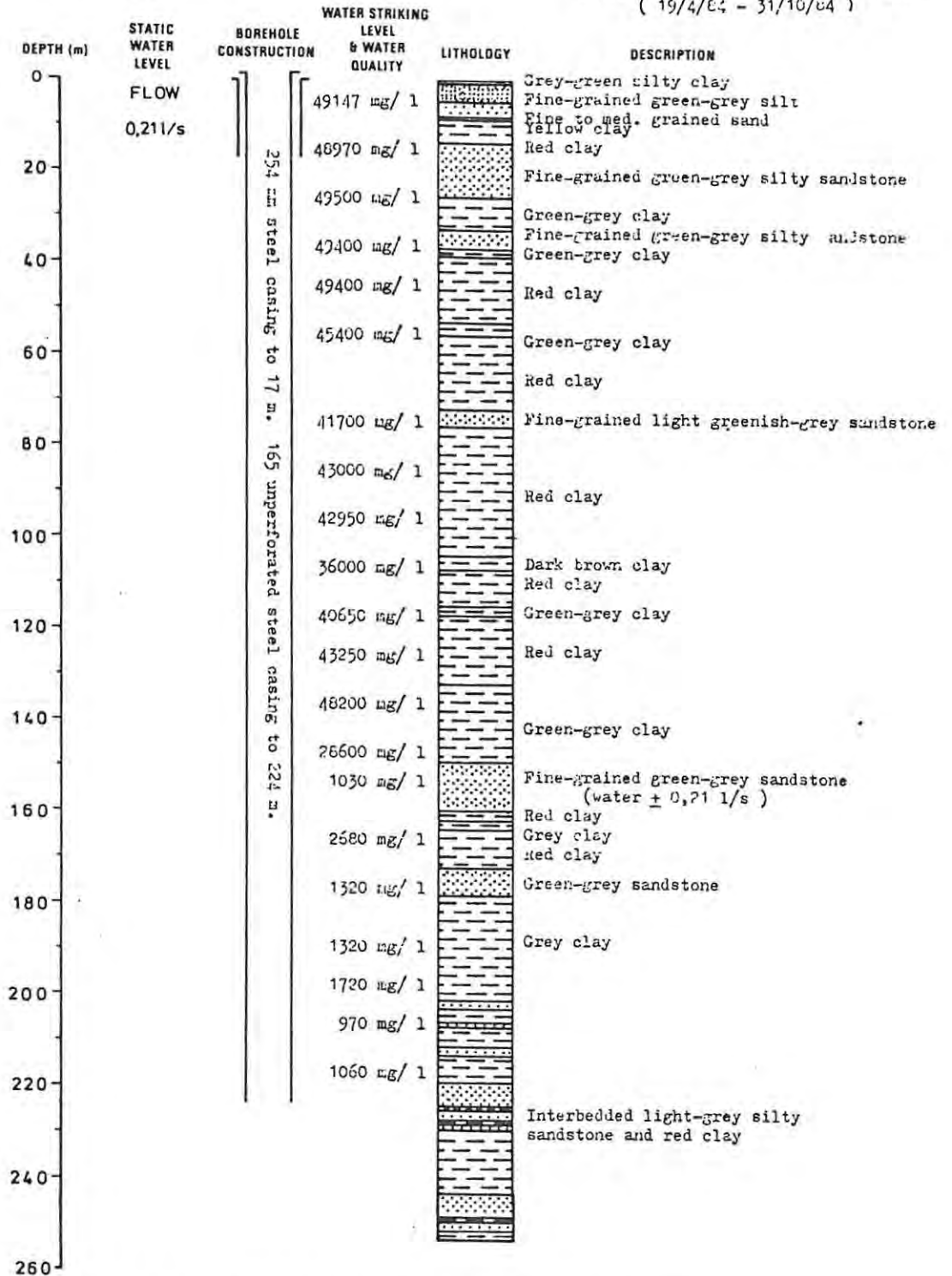
12/3/84 - 13/4/84



BOREHOLE NO: CM 6 (G 36201) EXPLORATION BH.
 CADASTRAL FARM: COEGA'S RIVER MOUTH

TEST YIELD:

Cable tool percussion drilling rig
 (19/4/64 - 31/10/64)

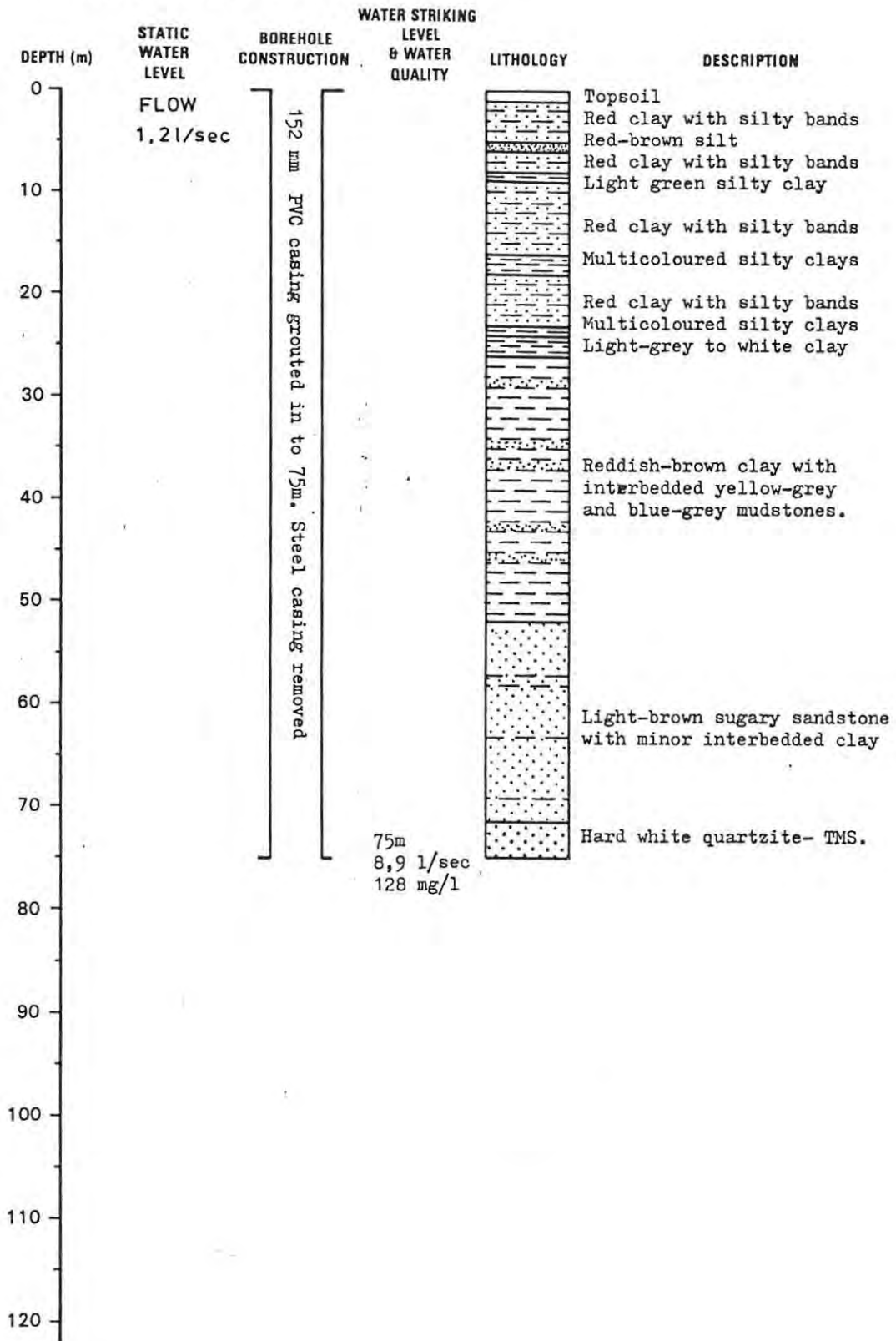


Drilling suspended at the end of October when caving made further progress impossible. Cement had been pumped into the hole in an attempt to stabilise the side-walls but failed to harden.

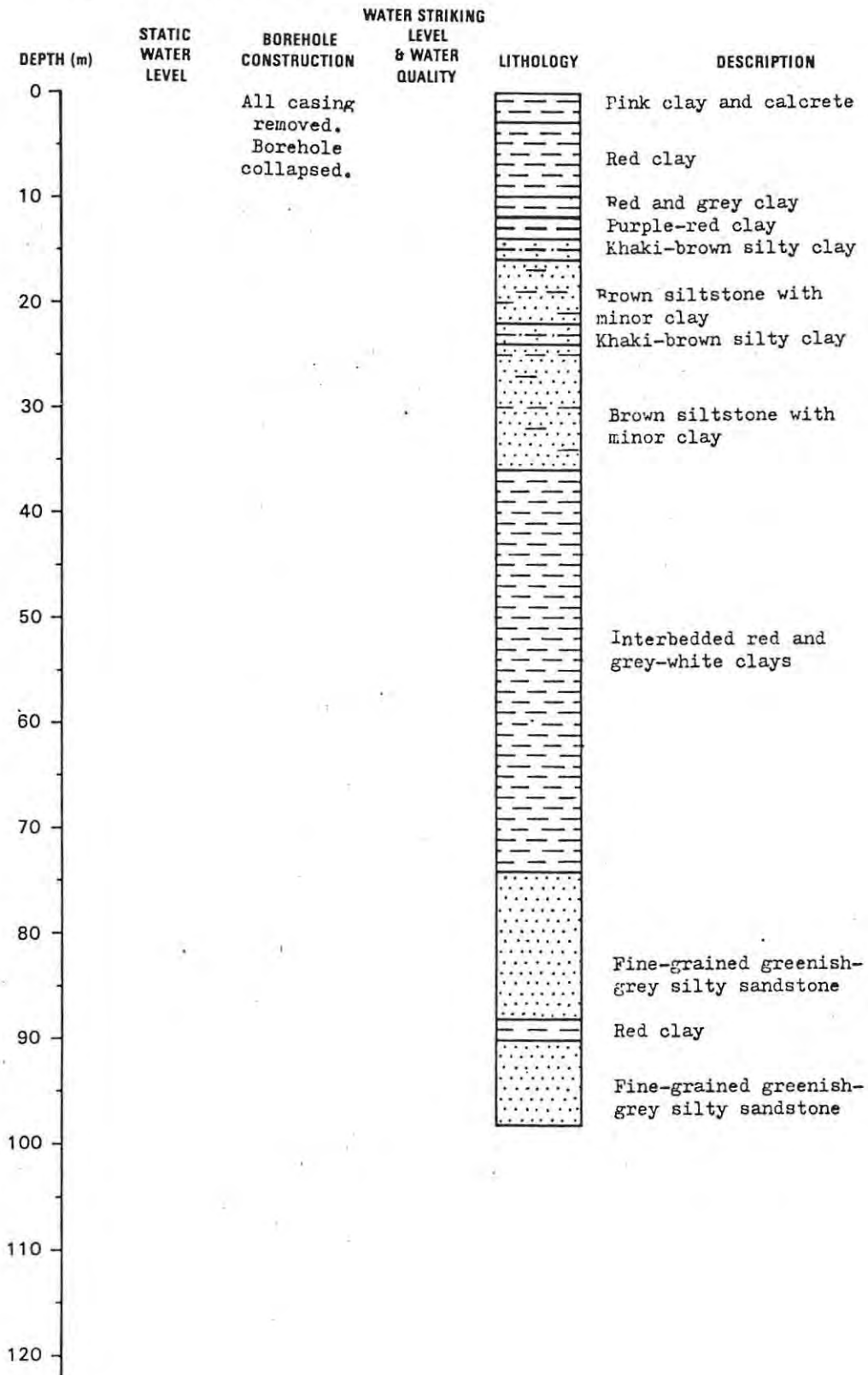
BOREHOLE NO: RH 31 (PRIVATE BH.)

CADASTRAL FARM: RIETHEUWEL 296

TEST YIELD: 8,9 l/sec



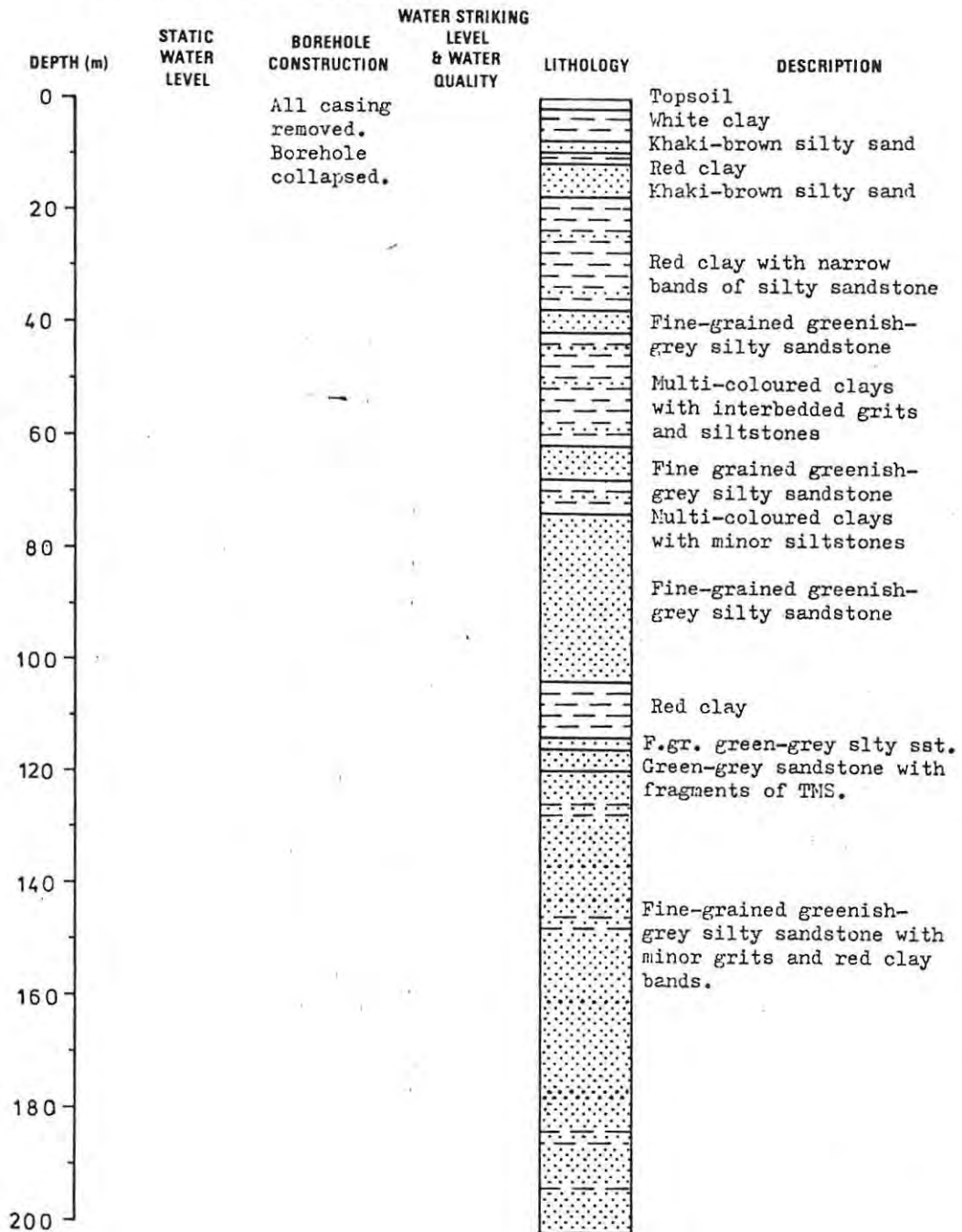
BOREHOLE NO: RH 34 (PRIVATE BH.)
 CADASTRAL FARM: RIETHEUWEL 296
 TEST YIELD: DRY HOLE



BOREHOLE NO: RH 35 (PRIVATE BH.)

CADASTRAL FARM: RIETHEUWEL 296

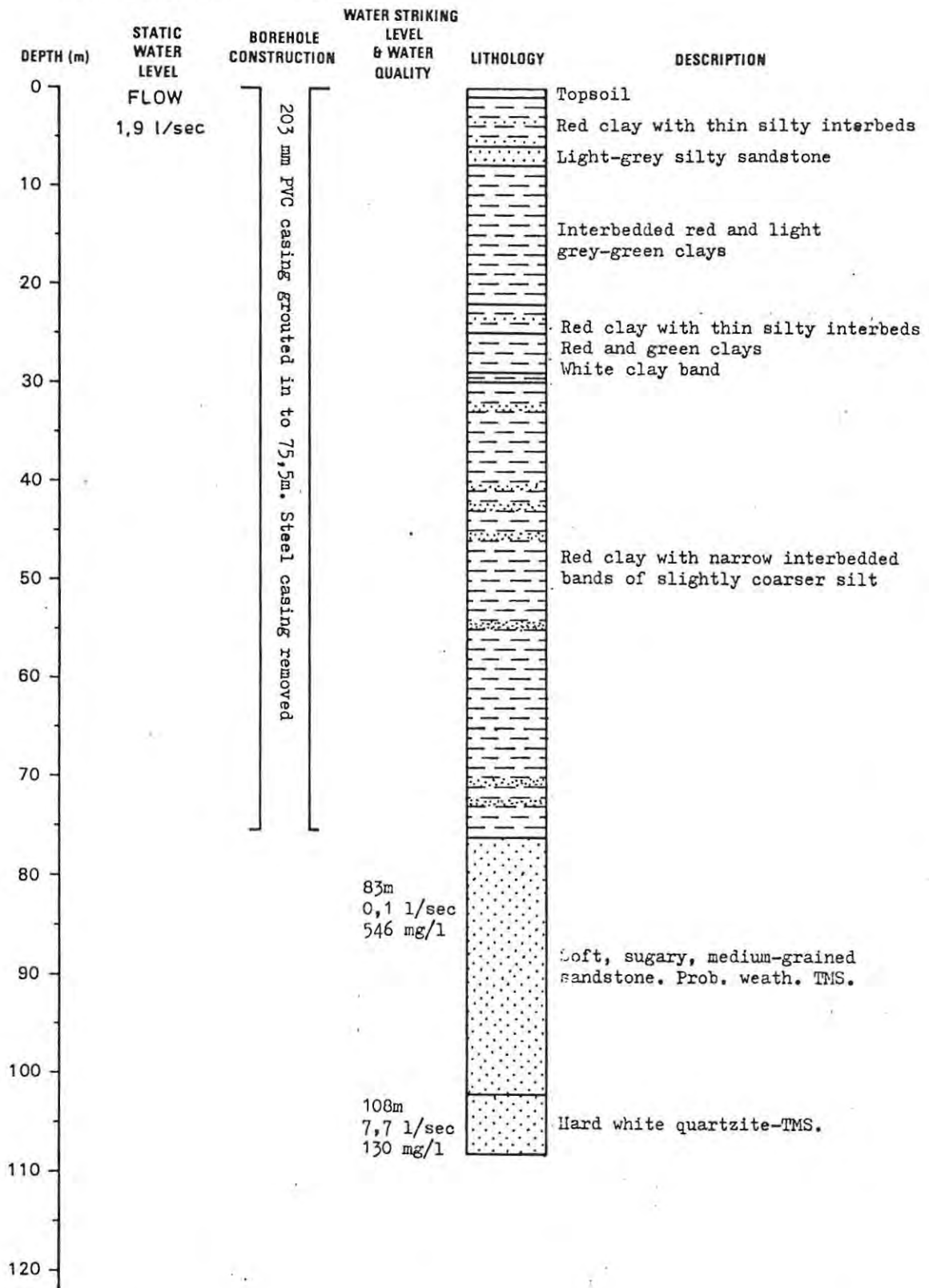
TEST YIELD: DRY HOLE



BOREHOLE NO: RH 36 (PRIVATE BH.)

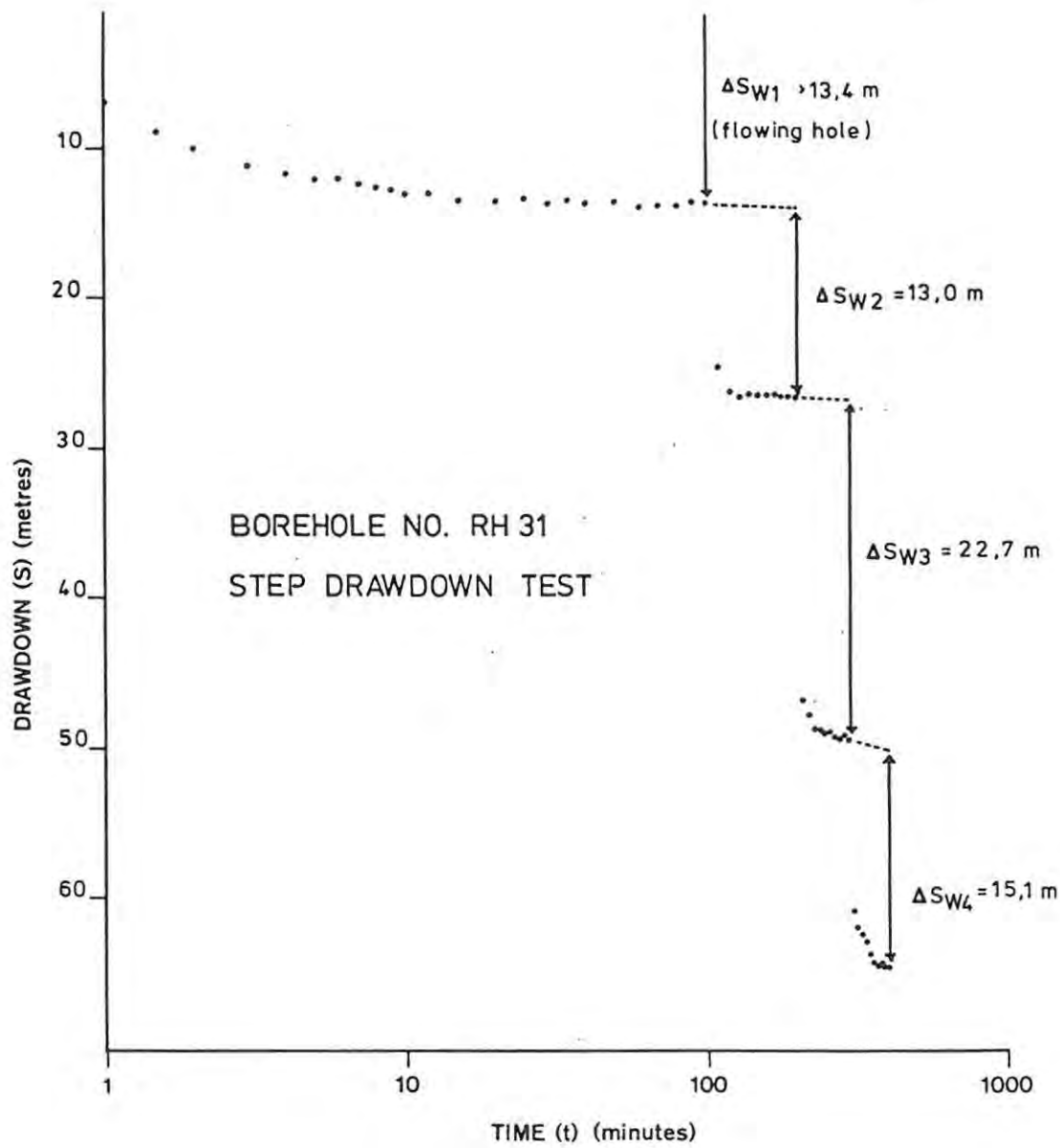
CADASTRAL FARM: RIETHEUWEL 296

TEST YIELD: 7,7 l/sec



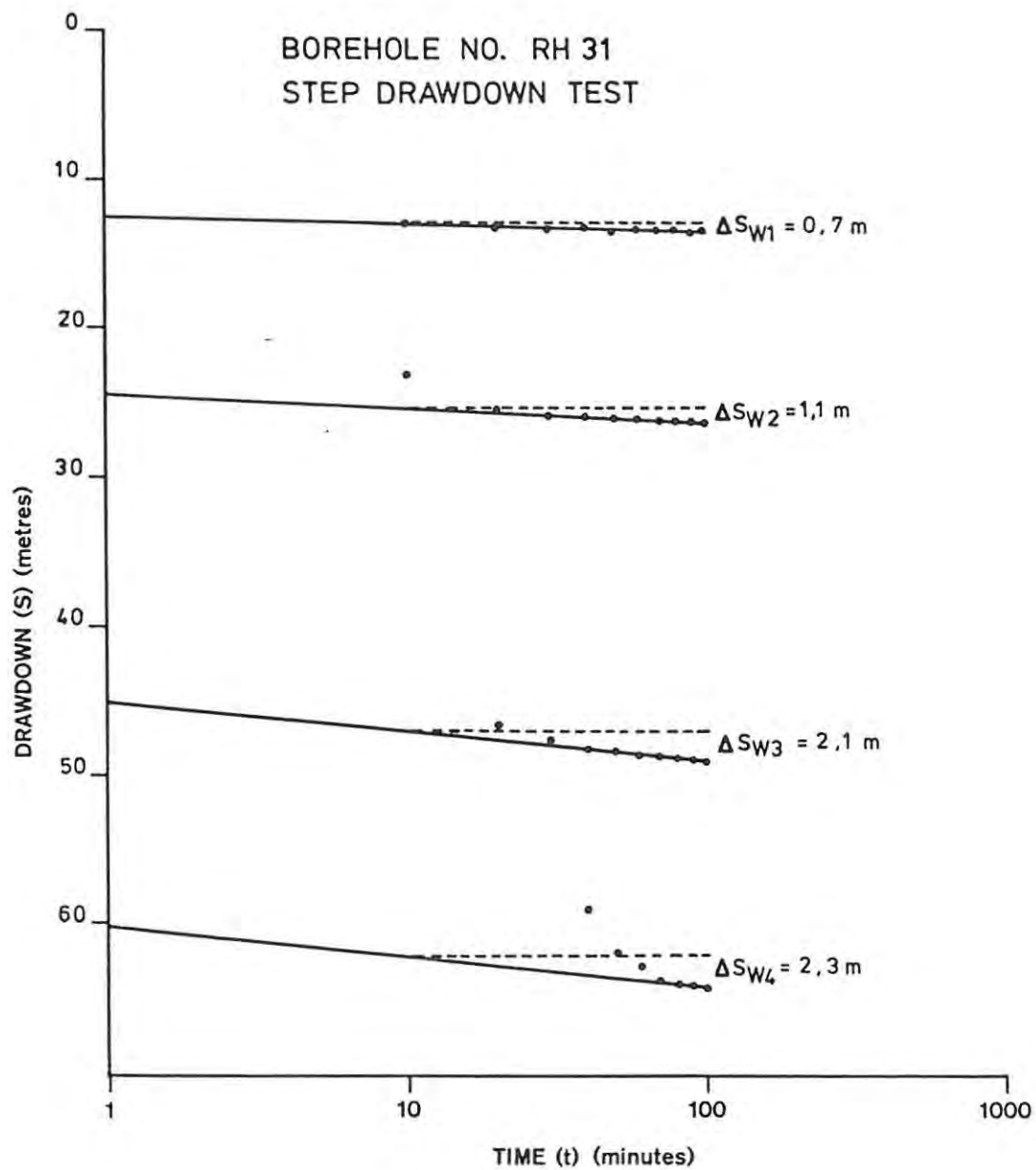
APPENDIX 5

AQUIFER TESTS



JACOB ANALYSIS

<u>Step</u>	<u>ΔSw (m)</u>	<u>ΔQ (m³ / day)</u>	<u>ΔSw/ΔQ</u> x 10 ⁻²	<u>C</u> x 10 ⁻⁵
1	13,4	317	4,2	
2	13,0	168	7,7	7,2
3	22,7	220	10,3	6,7
4	15,1	66	22,9	44,0



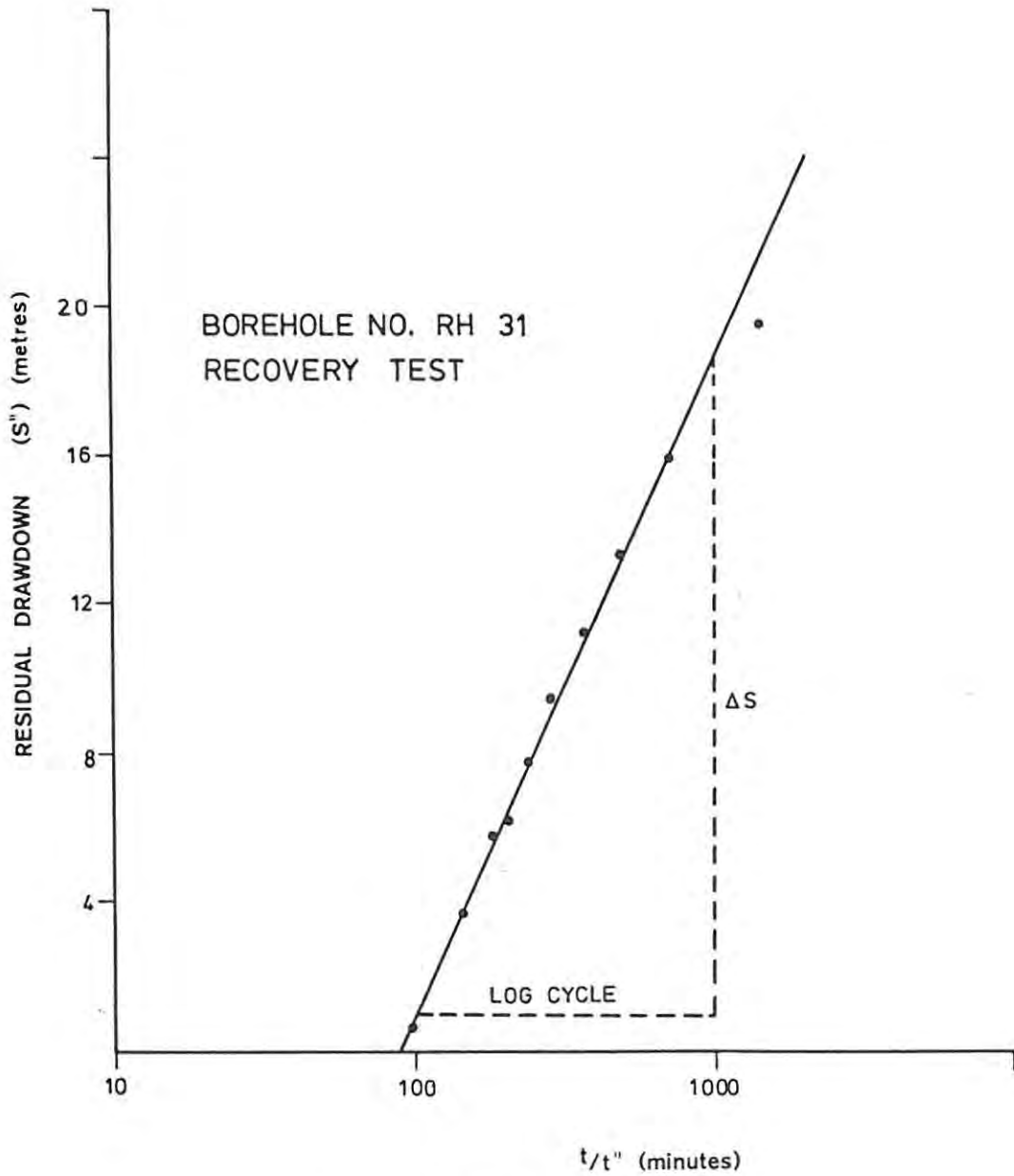
HAZELL ANALYSIS

Mean $\Delta S_W = 1,55 \text{ m}$

Mean $Q = 570 \text{ m}^3 / \text{day}$

$$T = 2,3 Q / 4\pi \Delta S_W$$

$$= 67 \text{ m}^2 / \text{day}$$



THEIS RECOVERY METHOD

t = time in days since pumping started

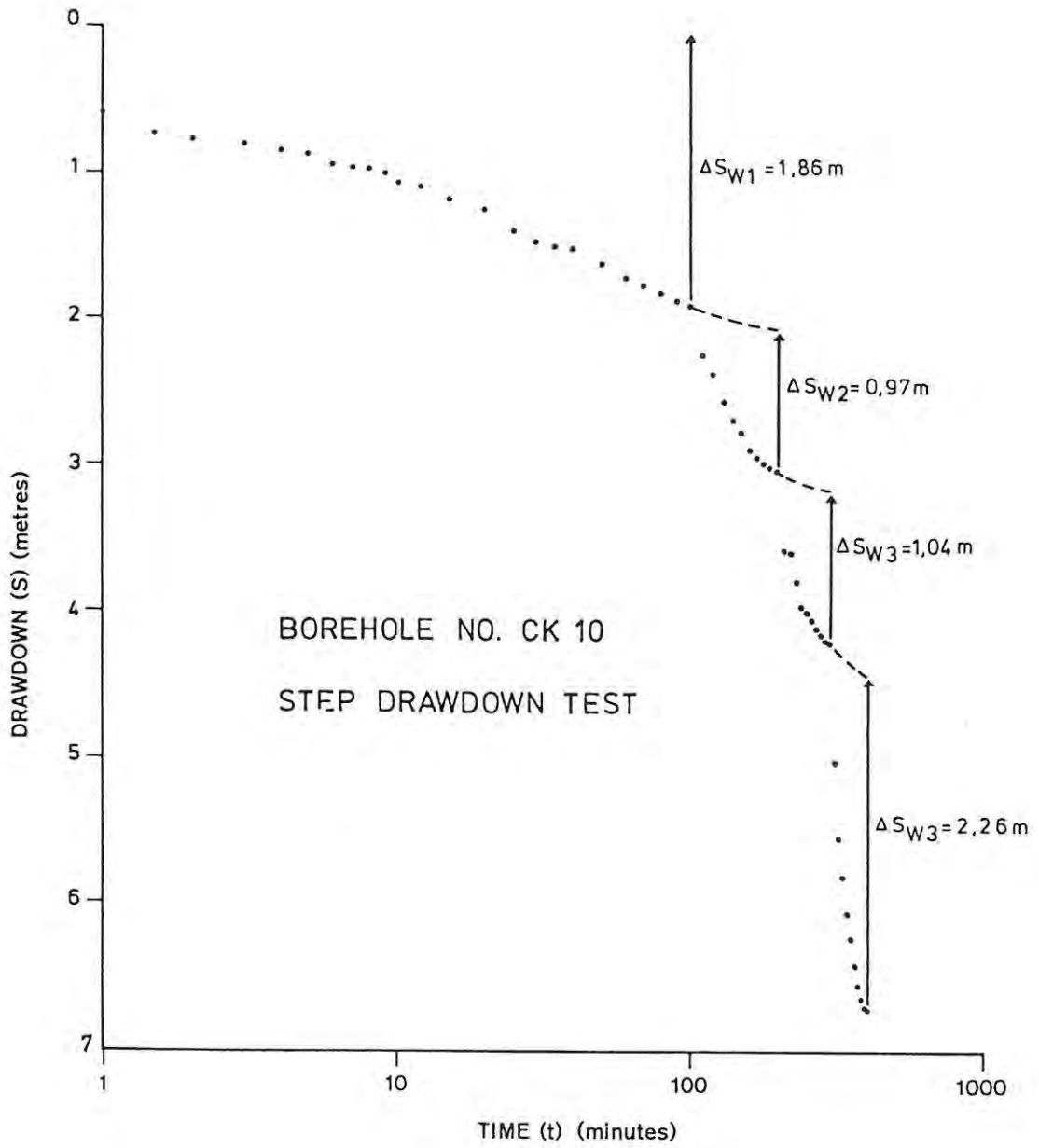
t'' = time in days since pumping stopped

Q = rate of recharge = rate of discharge
= 518 m³ / day

ΔS = Residual drawdown per log cycle of t/t''

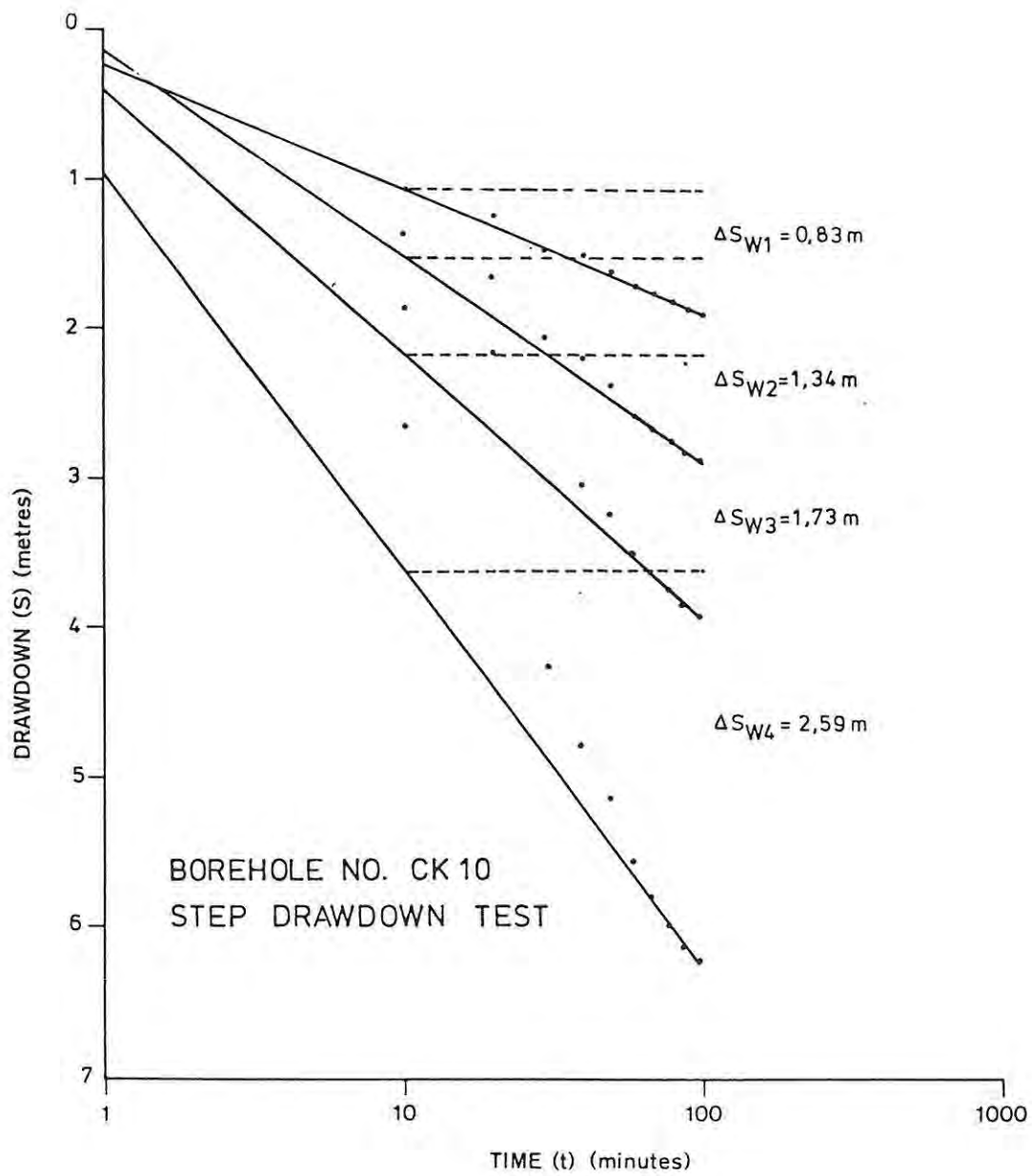
$T = 2,30 Q / 4\pi \Delta S$

= 5,4 m² / day



Step	ΔS_w (m)	ΔQ (m ³ / day)	$\frac{\Delta S_w}{\Delta Q}$ $\times 10^{-3}$	C $\times 10^{-6}$
1	1,86	740	2,50	
2	0,97	200	4,85	2,5
3	1,04	215	4,47	-0,9
4	2,26	51	44,31	149,7

Ignoring the value for step 4, mean $C = 8,0 \times 10^{-5}$



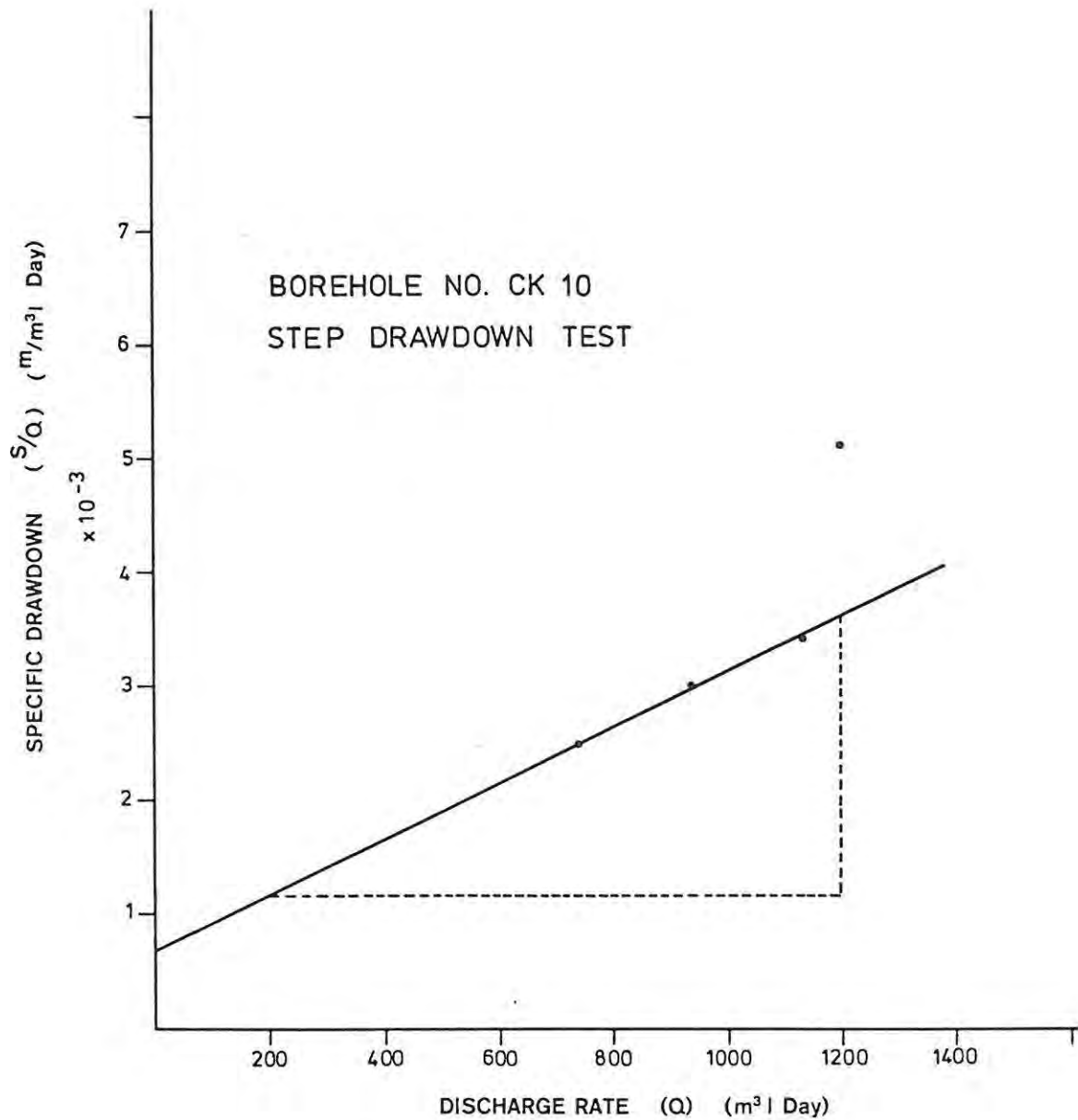
HAZELL ANALYSIS

Mean $\Delta S_w = 1,62$ m

Mean $Q = 1010$ m³

$T = 2,3 Q / 4\pi \Delta S_w$

$= 114$ m² / day



BIERSCHENK AND WILSON ANALYSIS

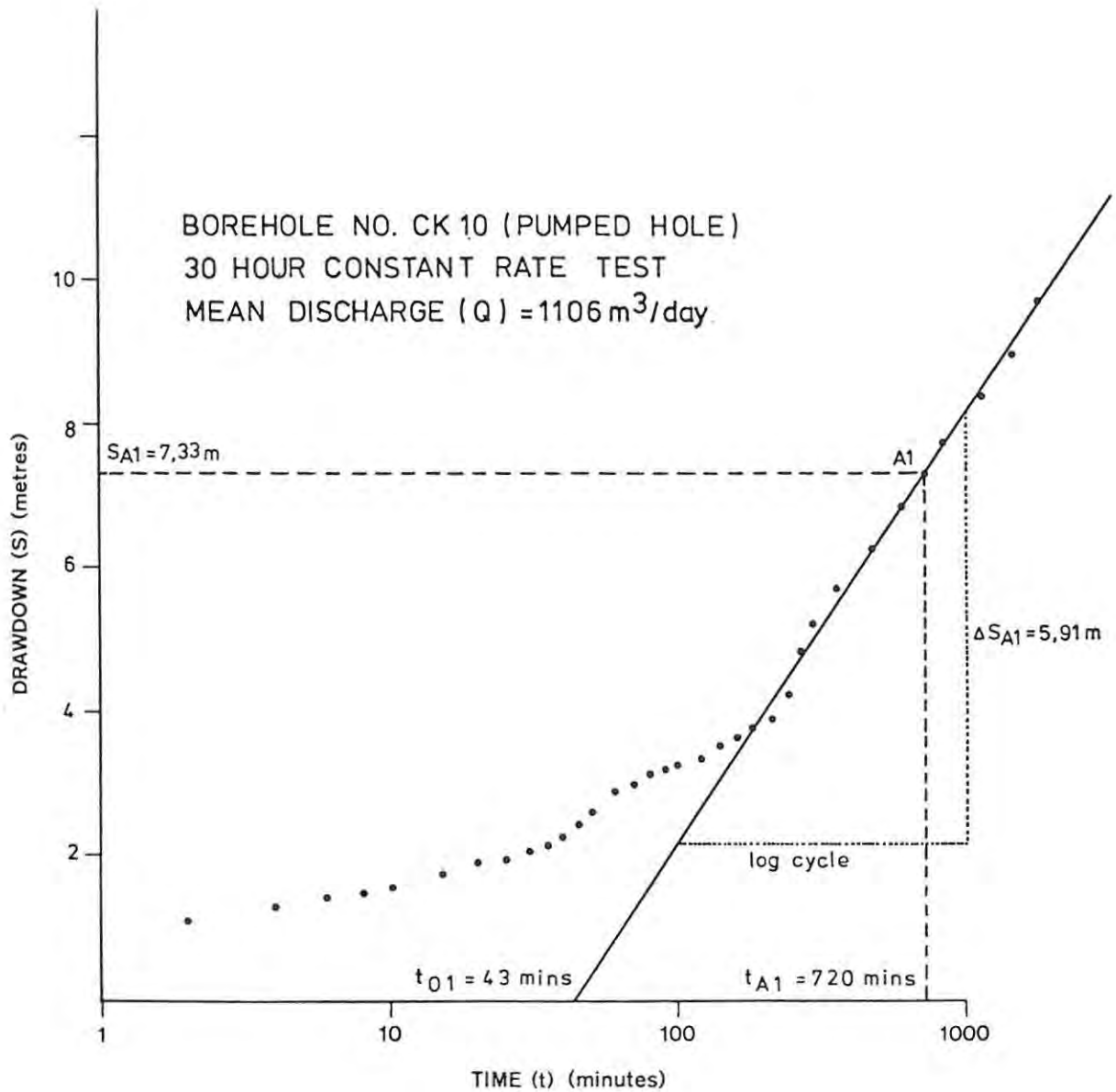
Well loss factor (C) = Slope = $2,45 \times 10^{-6}$

Aquifer loss factor (B) = Y intercept = $0,68 \times 10^{-3}$

Drawdown(S_w) = $0,68 \times 10^{-3} Q + 2,45 \times 10^{-6} Q^2$

Transmissivity = $1,22/B$

= $1794 \text{ m}^2 / \text{day}$



JACOB'S METHOD

$$T_1 = 2,3 Q / 4\pi \Delta S_{A1}$$

$$= 34 \text{ m}^2 / \text{day}$$

CHOW'S METHOD

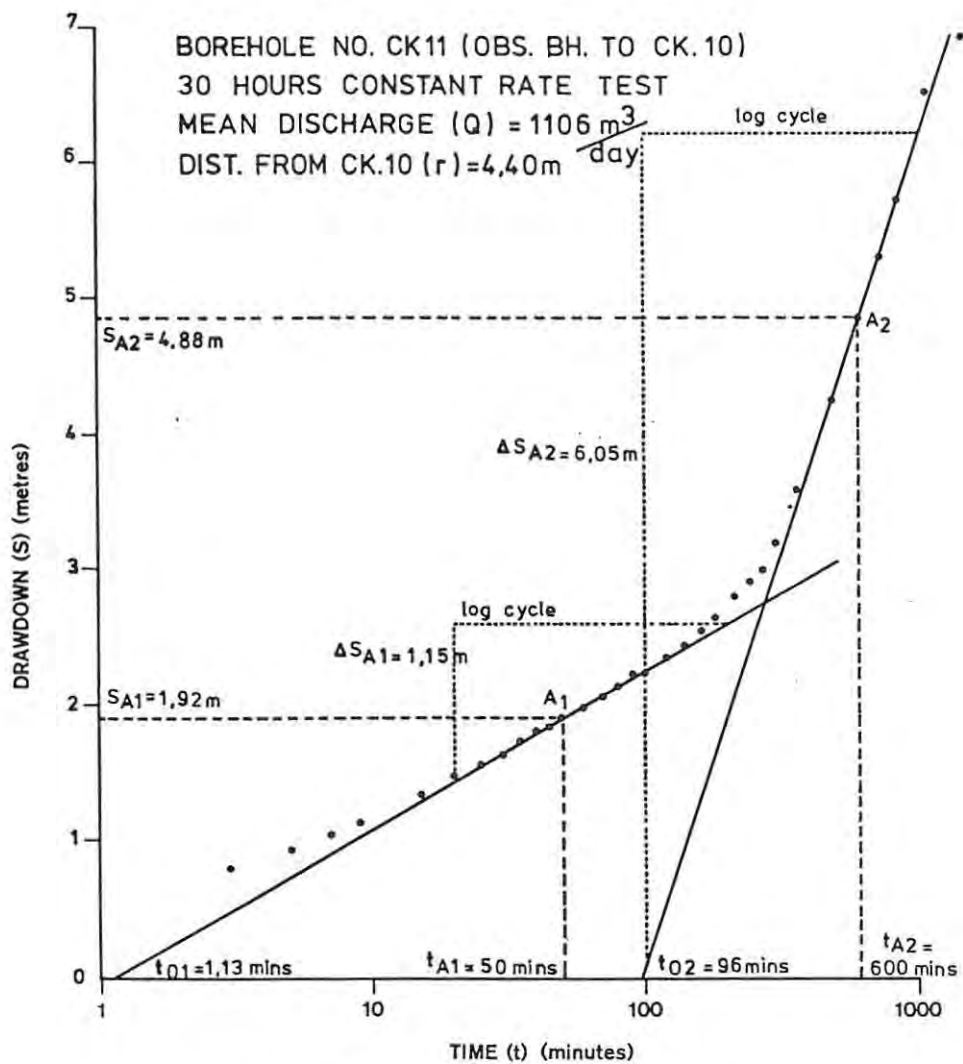
$$F(u)_1 = S_{A1} / \Delta S_{A1}$$

$$= 1,24$$

$$W(u)_1 = 2,75 \text{ (from tables)}$$

$$T_1 = Q W(u)_1 / 4\pi S_{A1}$$

$$= 33 \text{ m}^2 / \text{day}$$



JACOB'S METHOD

$$T_1 = 2,3 Q / 4\Delta S_{A1}$$

$$= 176 \text{ m}^2 / \text{day}$$

$$S_1 = 2,25 T_1 t_{01} / r^2$$

$$= 1,50 \times 10^{-2}$$

$$u_1 = r^2 S_1 / 4T_1 t$$

For validity $u < 0,01$

ie. when $t > 64 \text{ mins.}$

$$T_2 = 33 \text{ m}^2 / \text{day}$$

$$S_2 = 2,56 \times 10^{-1}$$

Valid when $t > 5406 \text{ mins}$

CHOW'S METHOD

$$F(u)_1 = S_{A1} / \Delta S_{A1}$$

$$= 1,67$$

$$W(u)_1 = 3,79 \text{ (from tables)}$$

$$u_1 = 1,30 \times 10^{-2}$$

$$T_1 = Q W(u)_1 / 4r^2 S_{A1}$$

$$= 174 \text{ m}^2 / \text{day}$$

$$S_1 = 4 u_1 T_1 t_{A1} / r^2$$

$$= 1,62 \times 10^{-2}$$

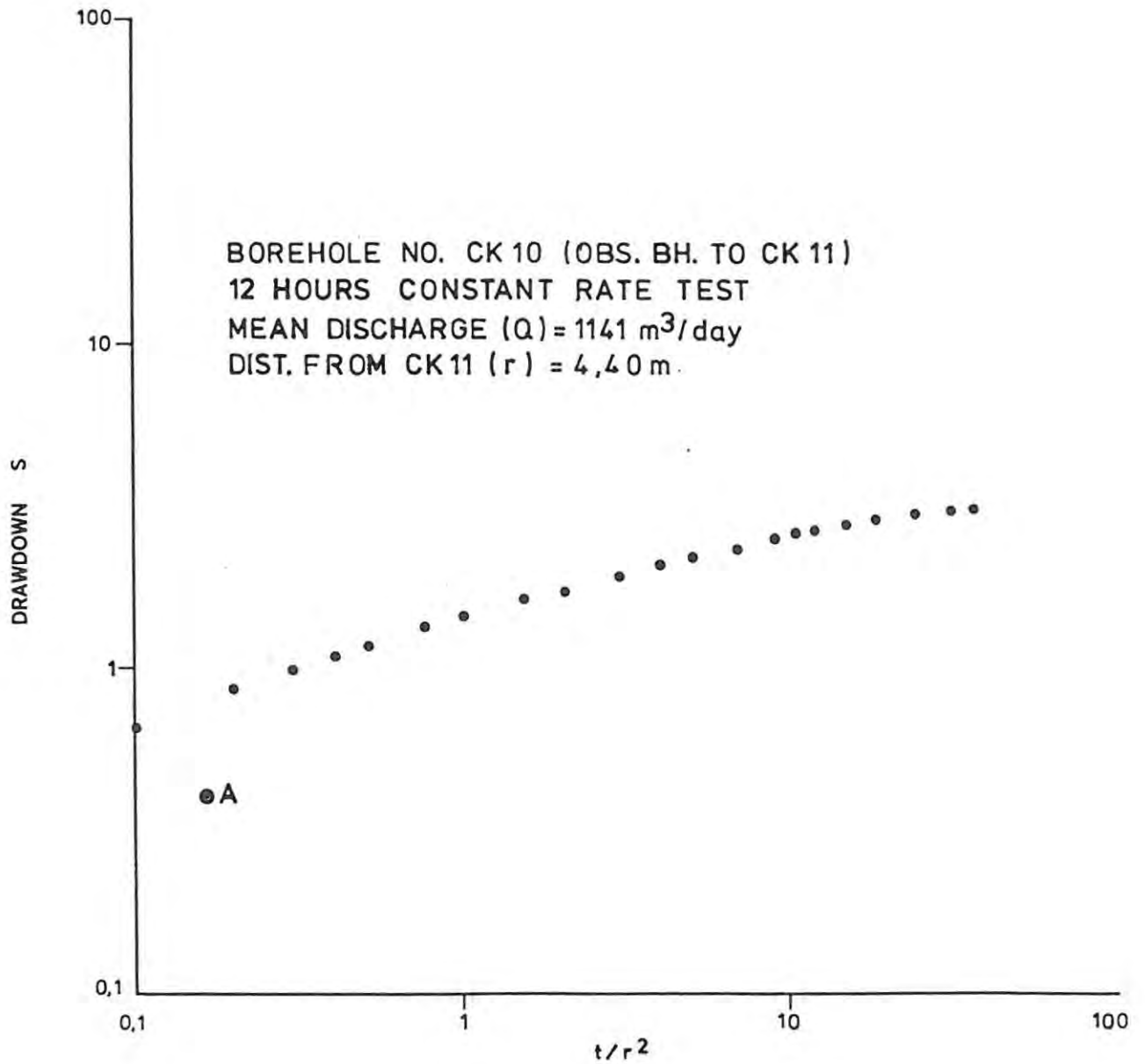
$$F(u)_2 = 0,81$$

$$W(u)_2 = 1,65$$

$$u_2 = 1,2 \times 10^{-2}$$

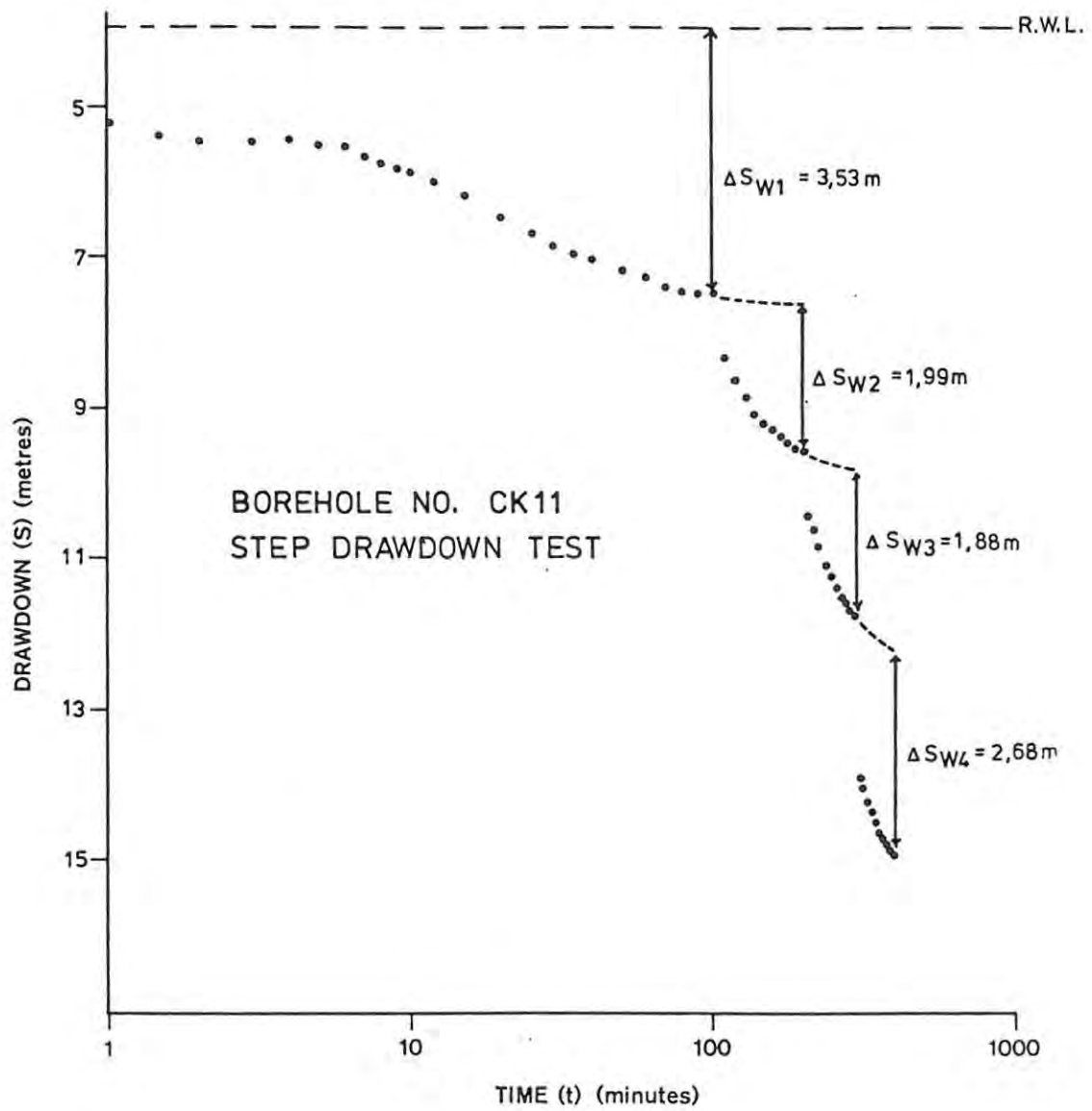
$$T_2 = 24 \text{ m}^2 / \text{day}$$

$$S_2 = 2,48 \times 10^{-2}$$



THEIS METHOD

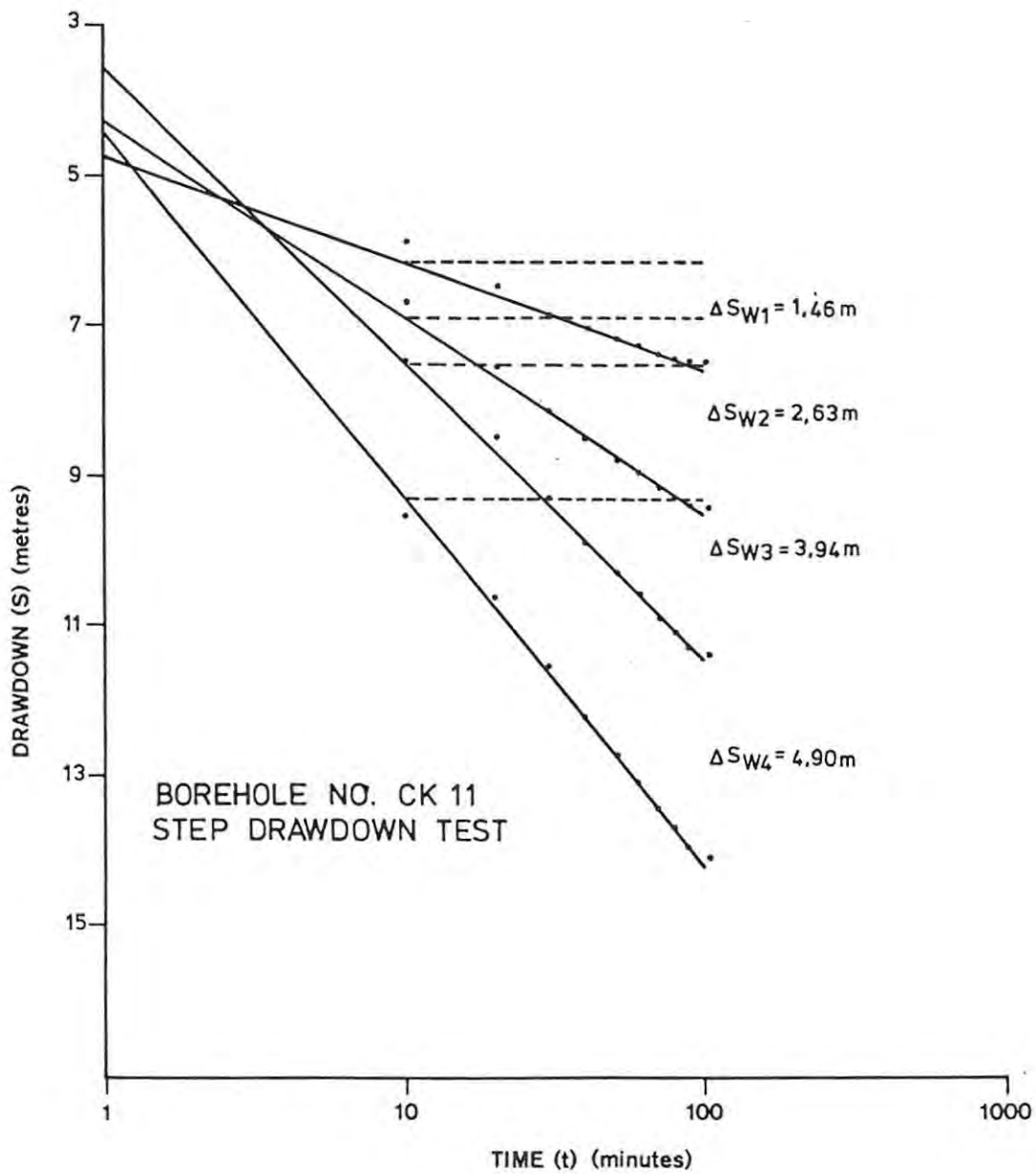
$$\begin{aligned}
 W(u) &= 1 \\
 u &= 0,1 \\
 s &= 0,4 \\
 t/r^2 &= 0,17 \\
 T &= (Q/4\pi s)W(u) \\
 &= 227 \text{ m}^3/\text{day} \\
 S &= 4T(t/r^2)u \\
 &= 1,07 \times 10^{-2}
 \end{aligned}$$



JACOB ANALYSIS

<u>Step</u>	<u>ΔSw (m)</u>	<u>ΔQ (m³ / day)</u>	<u>ΔSw/ΔQ</u> x 10 ⁻³	<u>c</u> x 10 ⁻⁶
1	3,53	942	3,7	
2	1,99	227	8,7	4,2
3	1,88	145	12,9	11,2
4	2,68	145	18,4	18,9

Mean $C = 11,4 \times 10^{-6}$



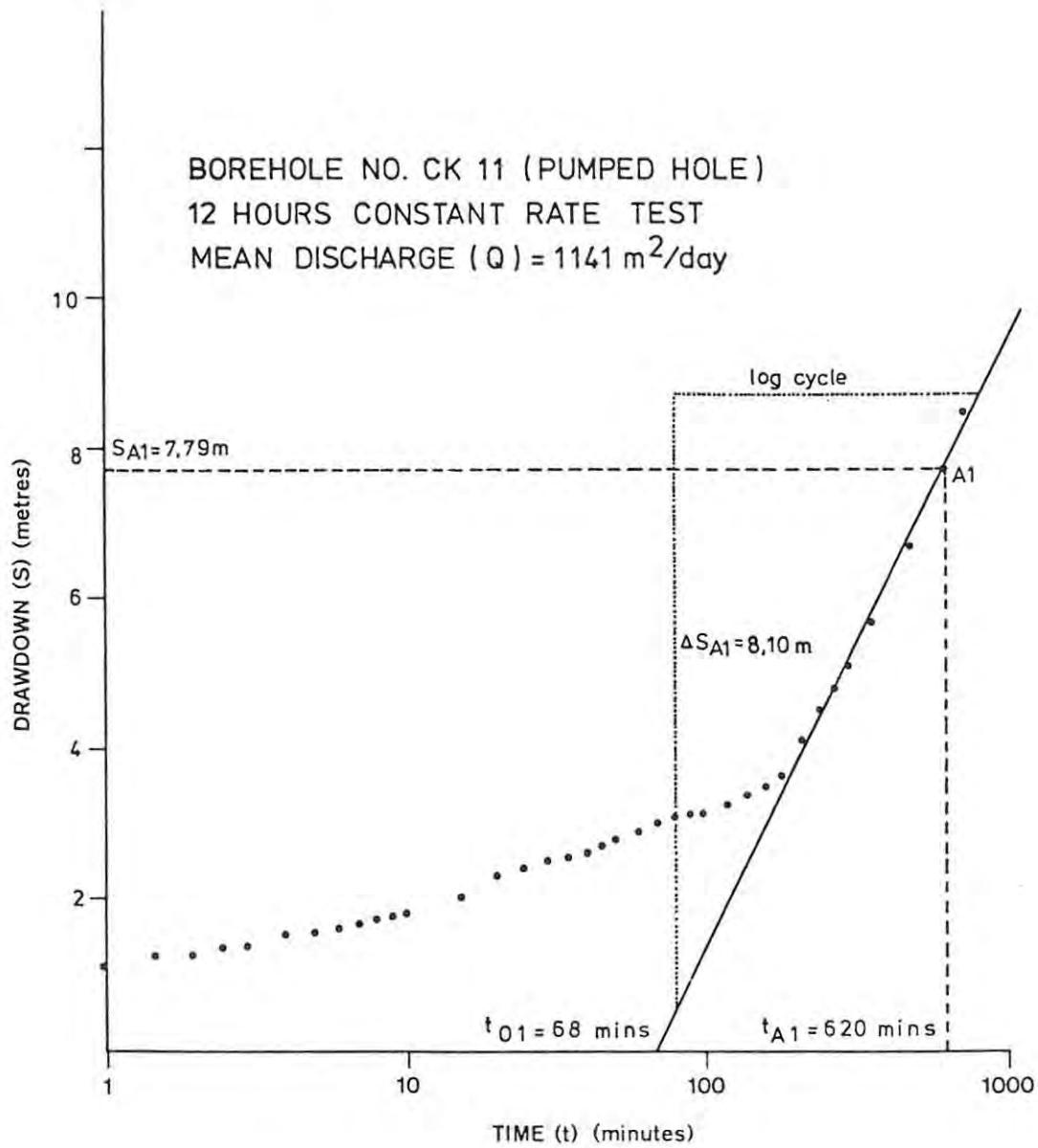
HAZELL ANALYSIS

Mean $\Delta S_W = 3,23\text{m}$

Mean $Q = 1221 \text{ m}^3 / \text{day}$

$T = 2,3 Q / 4^{\text{th}} \Delta S$

$= 69 \text{ m}^3 / \text{day}$



JACOB'S METHOD

$$T_1 = 2,3 Q / 4 \pi \Delta S_{A1}$$

$$= 26 \text{ m}^2 / \text{day}$$

CHOW'S METHOD

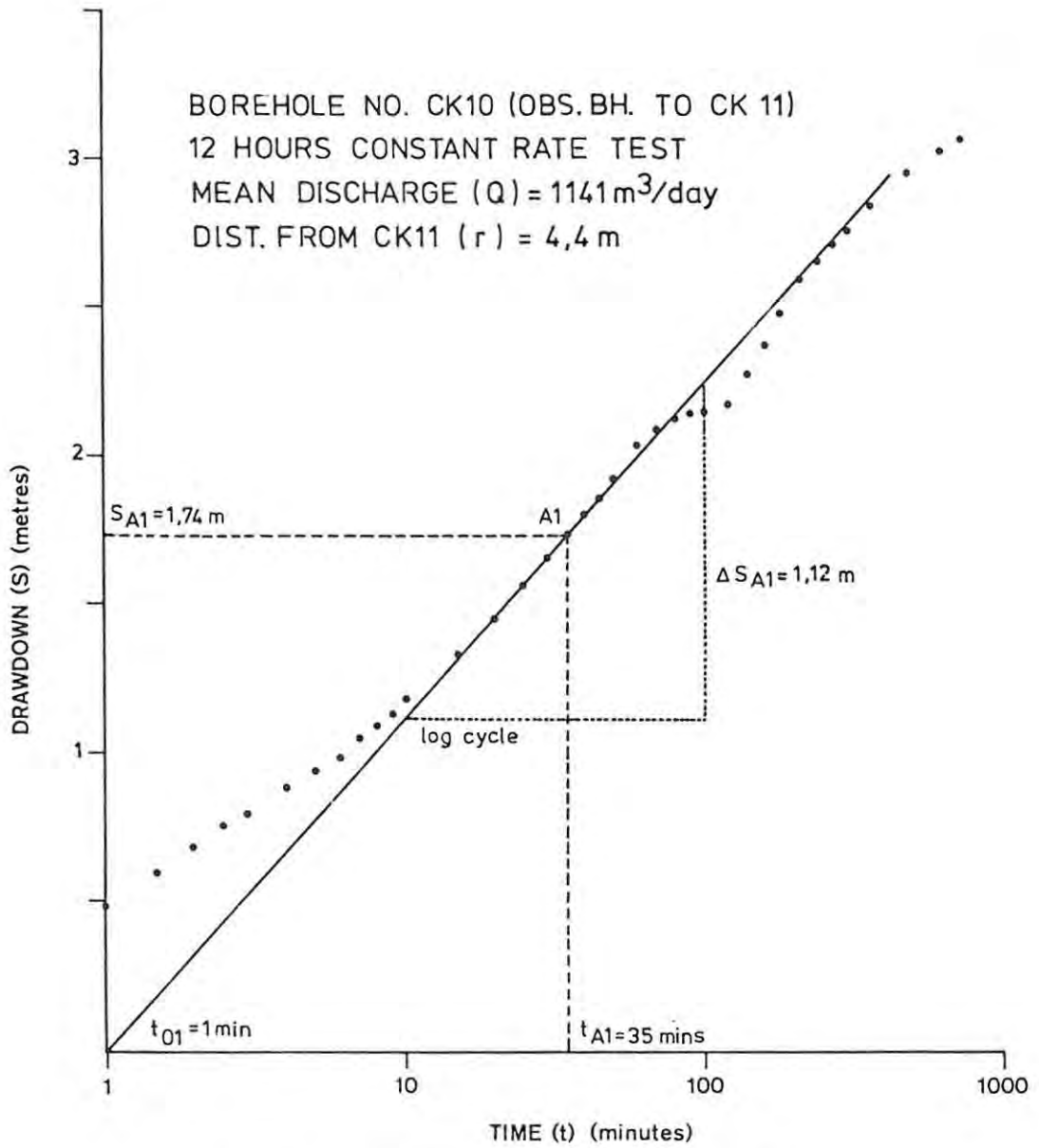
$$F(u)_1 = S_{A1} / \Delta S_{A1}$$

$$= 0,96$$

$$W(u)_1 = 2,04 \text{ (from tables)}$$

$$T_1 = Q W(u)_1 / 4 \pi S_{A1}$$

$$= 24 \text{ m}^2 / \text{day}$$



JACOB'S METHOD

$$T_1 = 2,3 Q / 4 \Delta S_{A1}$$

$$= 186 \text{ m}^2 / \text{day}$$

$$S_1 = 2,25 T_1 t_{01} / r^2$$

$$= 1,50 \times 10^{-2}$$

$$u_1 = r^2 S_1 / 4 T_1 t$$

For validity $u < 0,01$

ie. when $t > 56 \text{ mins}$

CHOW'S METHOD

$$F(u) = S_{A1} / \Delta S_{A1}$$

$$= 1,55$$

$$W(u) = 3,50 \text{ (from tables)}$$

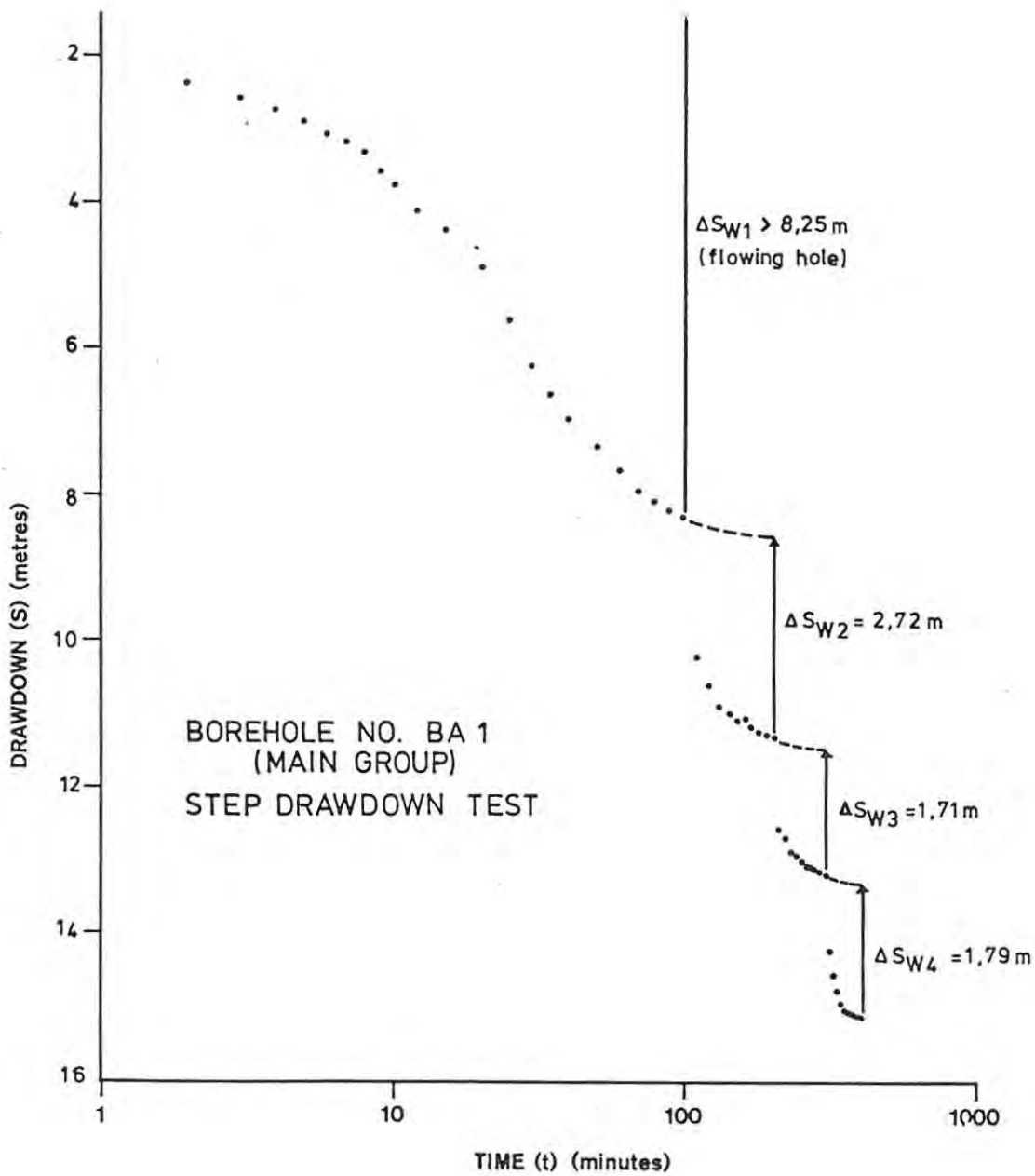
$$u = 0,017 \text{ (from tables)}$$

$$T_1 = Q W(u) / 4 \pi S_{A1}$$

$$= 183 \text{ m}^2 / \text{day}$$

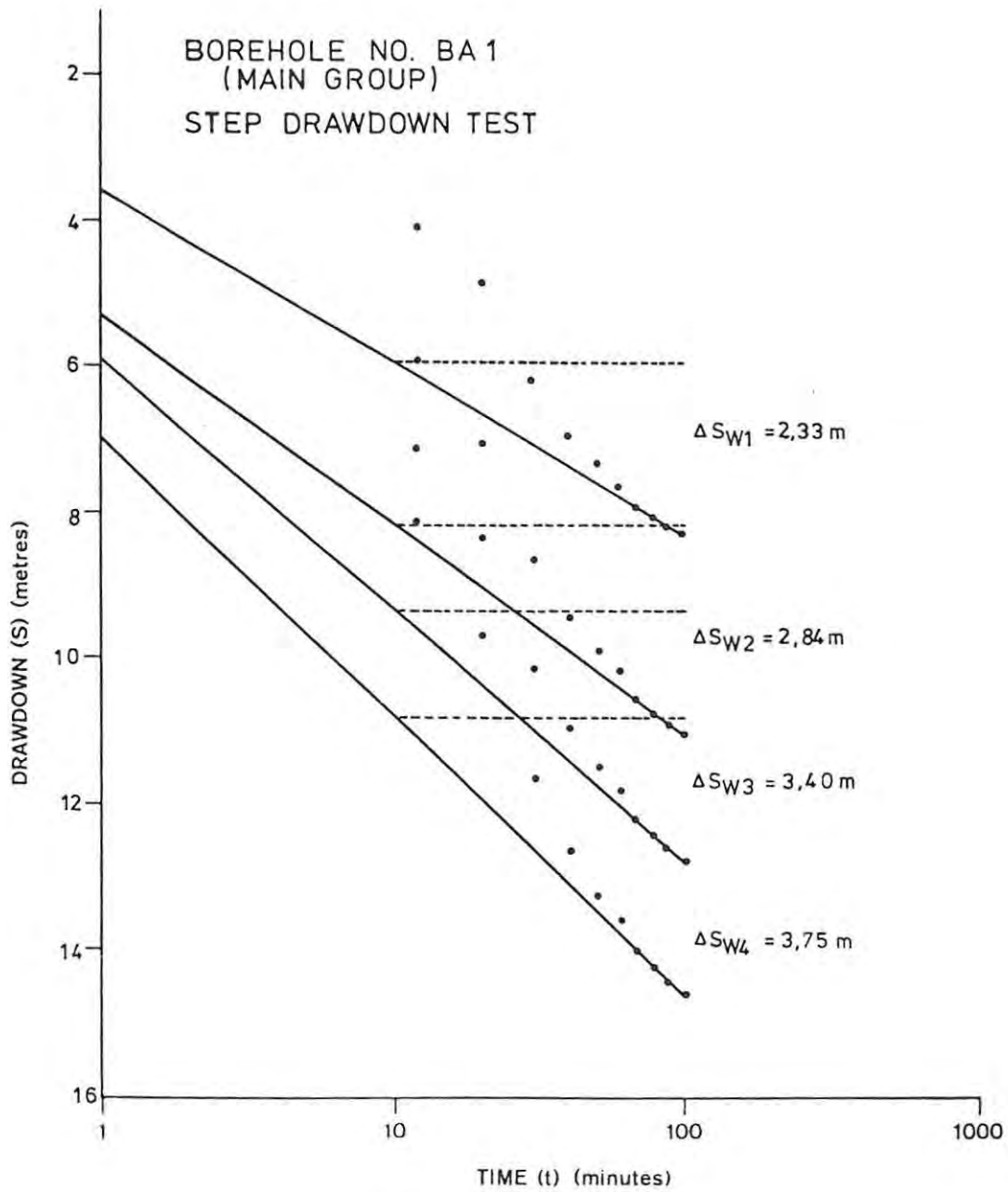
$$S_1 = 4 u T_1 t_{A1} / r^2$$

$$= 1,56 \times 10^{-2}$$



JACOB ANALYSIS

<u>Step</u>	<u>ΔS_w (m)</u>	<u>ΔQ (m³ / day)</u>	<u>ΔS_w / ΔQ</u> <u>x 10⁻³</u>	<u>C</u> <u>x 10⁻⁵</u>
1	> 8,25	890	> 9,27	
2	2,72	67	40,60	< 3,27
3	1,71	43	39,77	-0,75
4	1,79	97	18,45	-15,22



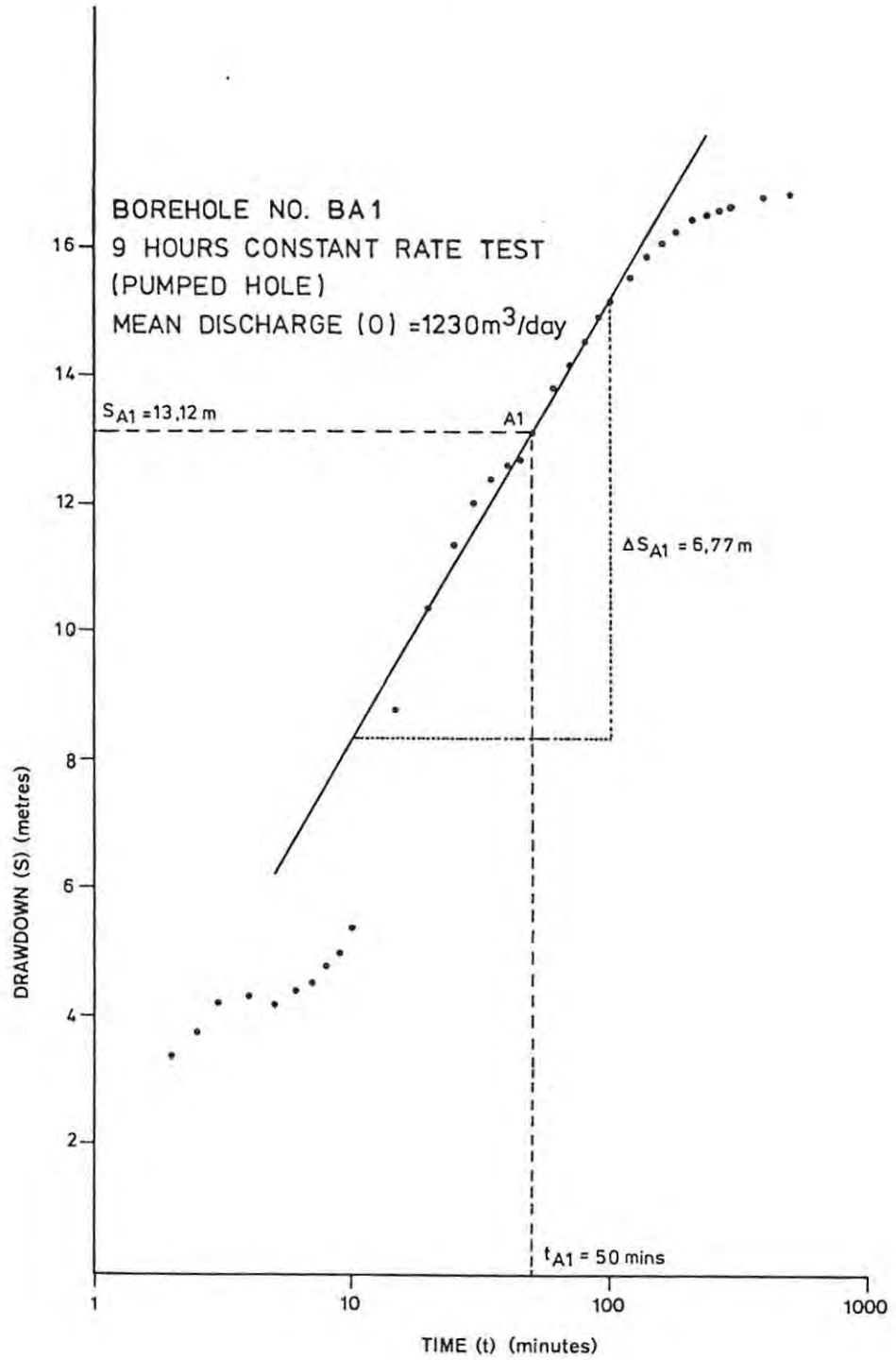
HAZEL ANALYSIS

Mean $\Delta S_w = 3,08 \text{ m}$

Mean $Q = 986 \text{ m}^3 / \text{day}$

$T = 2,3 Q / 4\pi \Delta S_w$

$= 59 \text{ m}^2 / \text{day}$



JACOB'S METHOD

$$T_1 = 2,3 Q / 4 \pi \Delta s_{A1}$$

$$= 33 \text{ m}^2 / \text{day}$$

CHOW'S METHOD

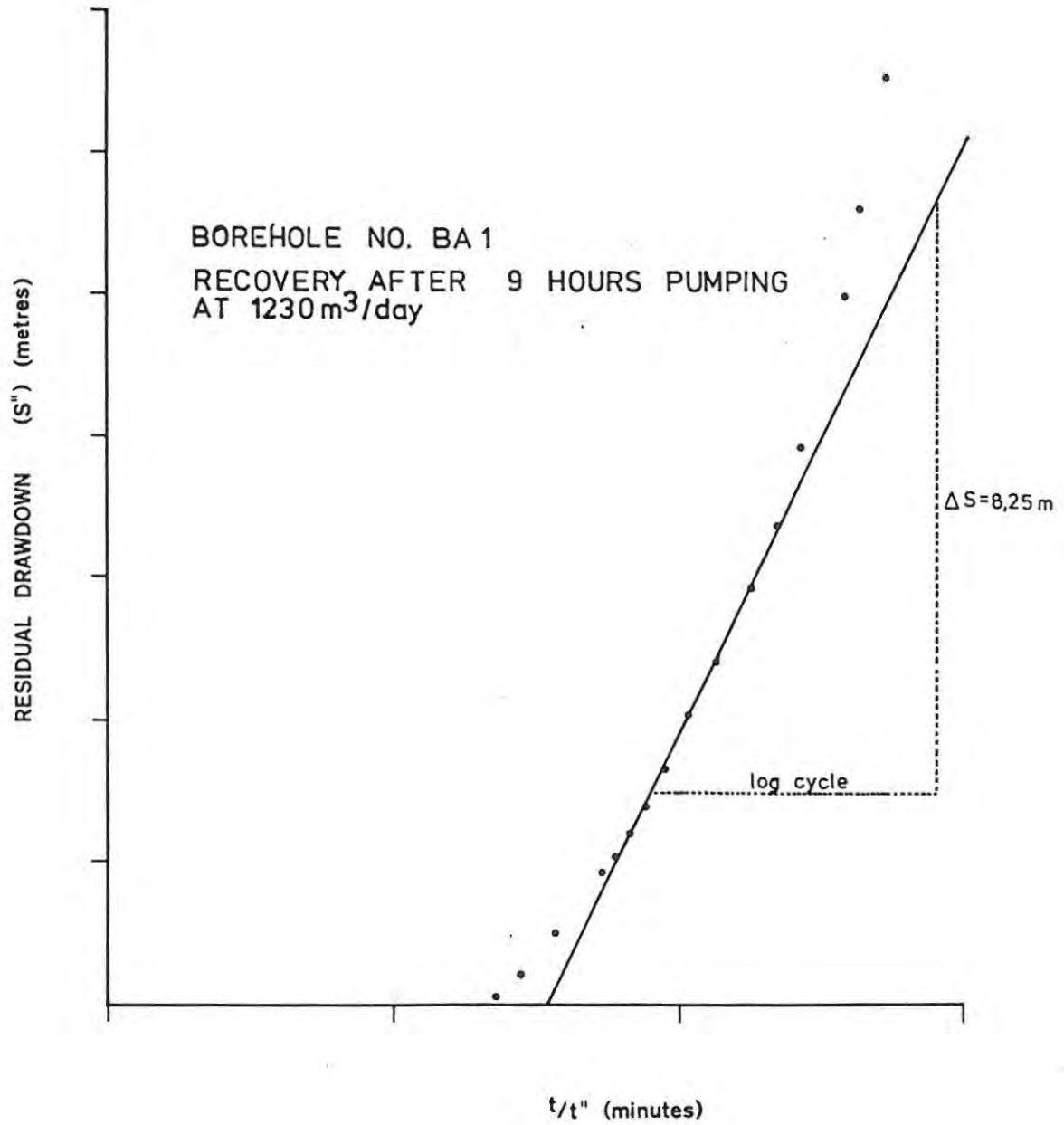
$$F(u)_1 = s_{A1} / \Delta s_{A1}$$

$$= 1,94$$

$$W(u)_1 = 4,43 \text{ (from tables)}$$

$$T_1 = Q W(u)_1 / 4 \pi s_{A1}$$

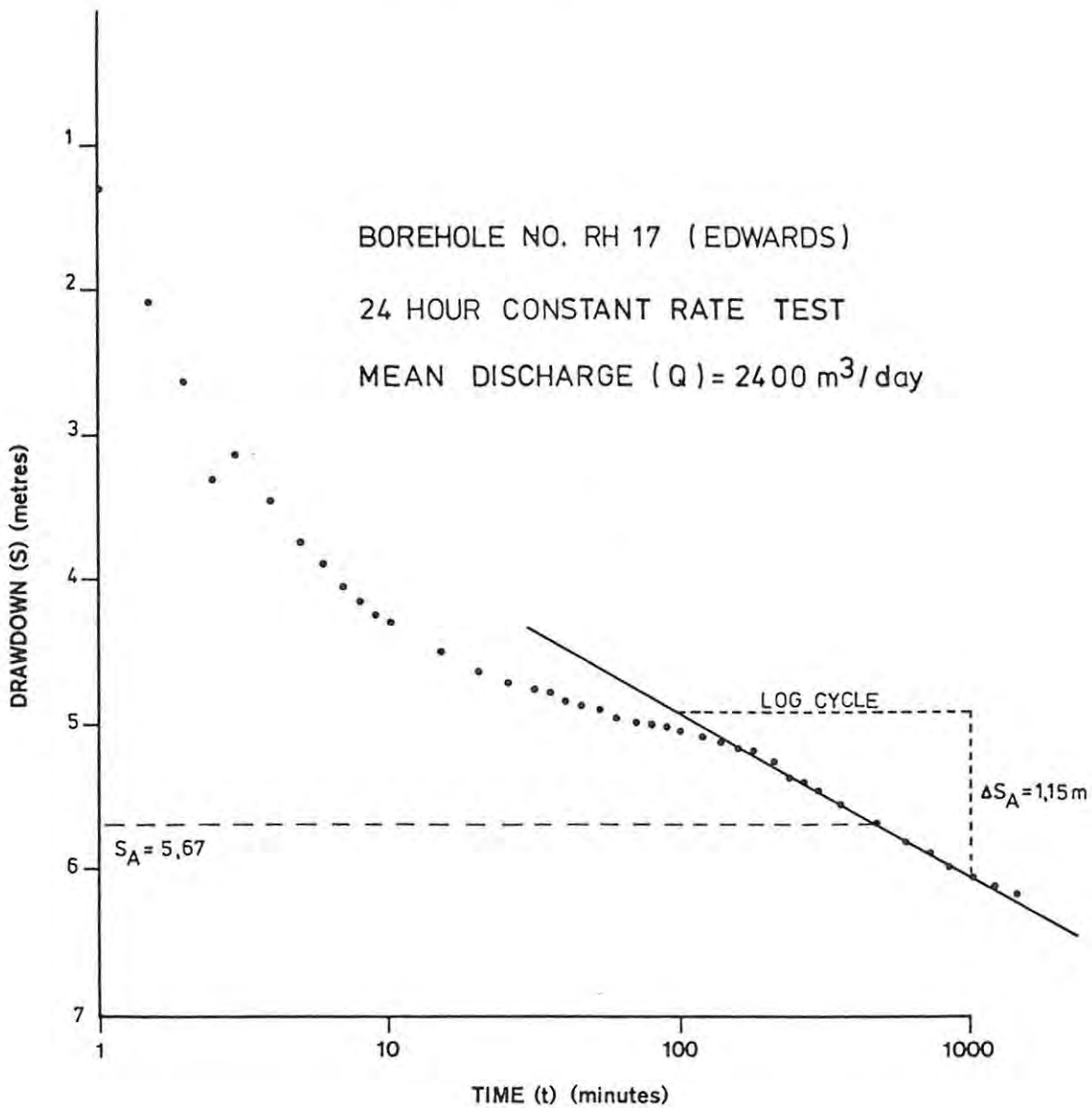
$$= 33 \text{ m}^2 / \text{day}$$



THEIS RECOVERY METHOD

$$T = 2,3 Q / 4\pi \Delta S$$

$$= 27 \text{ m}^2 / \text{day}$$



JACOB'S METHOD

$$T = 2,3 \frac{Q}{4\pi r s_A}$$

$$= 382 \text{ m}^2 / \text{day}$$

CHOW'S METHOD

$$F(u) = \frac{s_A}{\Delta s_A}$$

$$= 4,93$$

$$W(u) = 2,30 F(u)$$

$$= 11,34$$

$$T = \frac{Q W(u)}{4\pi s_A}$$

$$= 382 \text{ m}^2 / \text{day}$$