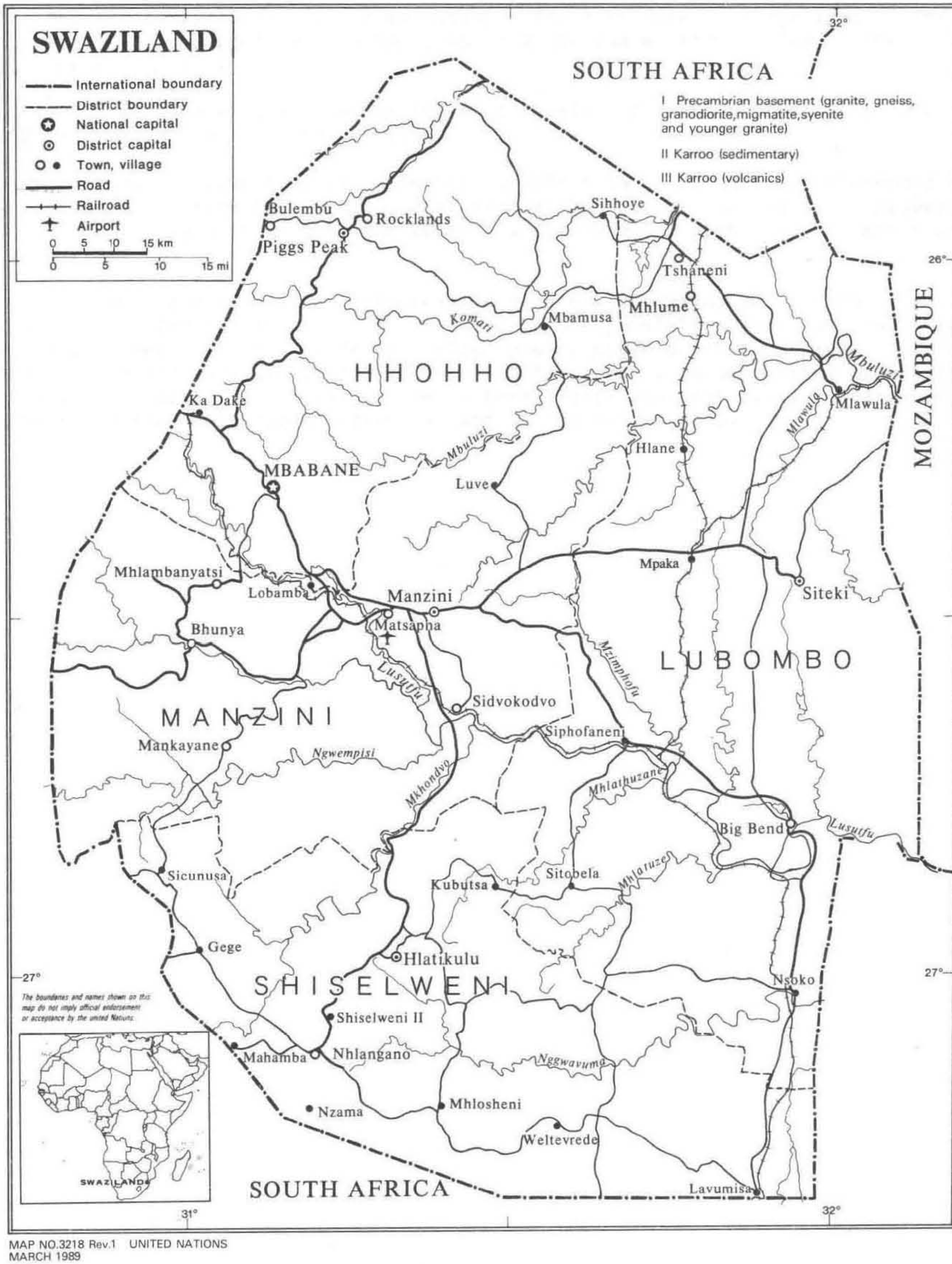
MAP 25. SWAZILAND – GENERAL MAP



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SWAZILAND

Area: 17,360 km^2
Population: 600,000

I. BACKGROUND

Swaziland is a landlocked country situated between the Republic of South Africa in the west and Mozambique in the east. It can be divided into four regions on the basis of physiographical criteria:

The Highveld (or "Inkangala") which covers about 29 % of the country. This is a mountainous area consisting mainly of large granitic masses, with very ancient metamorphic rocks in the north-west with a few high peaks such as Bulembu (1,862 m) and Ngwenya (1,828 m). The watercourses of this region have cut deep valleys in the massif.

The Middleveld ("Live") which is an intermediate area between the Highveld and the Lowveld. It occupied 26 % of the country and is the most densely populated area. This is gently undulating terrain resting on a granitogneiss rock mass, with open plains and low hills. The altitude is between 300 and 1,050 m. Tall grasses are the main natural vegetation. Agriculture is well developed here.

The Lowveld ("Lihlanze") is the largest area of the country (covering 37 %); it is of low altitude and consists of Karroo sedimentary rocks. The altitude varies from 150 to 300 m and there are some ranges of hills.

The vegetation is typical of the Bushvels with thornbushes and grasses. Sugar cane plantations are undergoing considerable development in areas where ground water can be used for irrigation. The Lubombo mountains cover 8 % of the country in a narrow strip along its eastern edge. These mountains are in fact a steep-sided plateau rising from the Lowveld and consist of volcanic rocks of the Upper Karroo. The altitude increases from the Lowveld up to 777 m and then gradually declines towards the east. The main watercourses have cut deep gorges in these mountains. There is a degree of oceanic influence on the vegetation.

Climate and rainfall

The country has a good network of meteorological stations. The Manzine and Stegi stations were established in the last century. About 60 pluviometric stations have been in operation for more than 20 years.

Maximum and minimum temperatures have been recorded at 25 stations for more than 20 years. Additional less abundant but adequate weather data are available.

Swaziland's climate is of the subtropical type. The capital, Mbabane, is situated 300 km south of the Tropic of Capricorn. The rainfall is strongly influenced by the relief; it increases by 25 mm a year for each additional 30 m of altitude.

The summer rains are brought by the prevailing winds. The Lowveld, to which rain is brought only by convection currents, receives 500-600 mm.

The Highveld, where the warm wet air is forced upwards by the topography and convection, receives 1,600 mm on average.

In the Middleveld and Highveld the rain falls in heavy showers which can sometimes be rendered torrential by Indian Ocean cyclones. The three cyclones this century occurred in 1925, 1966 and January 1984; the last one (Cyclone Domonia) was the most violent in living memory and caused considerable damage everywhere.

The average annual rainfall for the whole country is about 890 mm, 710 mm falling in summer and 180 mm in winter. This standard pattern can vary. For example, during the summer of 1977-1978 the average was 50 mm, as against 560 mm during the winter of 1943. The largest amount of rainfall recorded in a calendar year was 3,300 mm at Nottingham near Piggs Peak, and the smallest amount was 200 mm at Lavumisa in 1935. There seem to be alternating wet and dry periods.

Temperatures

Like the rainfall, the average air temperatures are influenced by the relief, with a maximum of 22 °C in the eastern Lowveld and a minimum of 16 °C in the Highveld; this represents a drop in temperature of half a degree for every 100 m of altitude. The highest recorded maximum was 49 °C in the east of the country, but only 36 °C at Bulemba at the western frontier. The lowest recorded minimum was -6 °C at Mbabane.

In winter the zone of the south-east prevailing winds shifts northwards and Swaziland comes under the influence of an east-west high-pressure front. This usually brings clear dry weather with wide daily temperature ranges, cool nights and hot days. In spring and autumn cold fronts preceding masses of polar air push the warm tropical air upwards and bring rain and cold.

Losses of water through evaporation from the soil, plants, watercourses and lakes are higher at low altitude where the sky is clearer. In winter, losses of water through evaporation are higher owing to the clearer skies and the presence of masses of dry continental air.

Surface water

While most of Southern Africa has climatic conditions of the arid or semi-arid type, Swaziland is benefited from the standpoint of resources by the large rivers which cross the country. A volume of 144 m^3/s, i.e. about 45 billion m^3 a year, leaves the country; this is a considerable amount for Africa.

The flows of the watercourses are diminished by drawoffs both in South Africa where some of these rivers rise and during their passage through Swaziland. At present Swaziland uses almost 50 m^3/s, i.e. about one-third of the volume of water which leaves the country.

Almost all the watercourses of the Highveld are perennial, owing to the fairly high rainfall and the presence of permeable strata which can absorb and then transmit the water to the watercourses. In contrast, the watercourses of the Lowveld, except for the big rivers, flow only after heavy local storms. Even in the permanent streams the flow varies considerably owing to the seasonal nature of the rainfall. The maximum flows occur a the end of summer, i.e. in January, February and March, with the minimums in July or August. The main rivers rise in the Highveld. They are the Mlumati, Komati, Mbuluzi, Lusushwena, Lusutfu, Ngwempisi, Mkhondvo and Ngwavuma, which flow eastwards towards the Indian Ocean.

Of these rivers the Lusutfu, which rises in the Transvaal, has the largest flow: it crosses the Lubombo mountains in a dramatic gorge before reaching the sea. Next in size is the Komati but its flow is less than half that of the Lusutfu. The Mbuluzi and the Ngwavuma rise in Swaziland, but the Ngwavuma dries up un very dry years.

The total flow of Swaziland's watercourses is equivalent to 150 mm of the rainfall, i.e. 17 % of the total rainfall of 882 m for the drainage basins in Swaziland and South Africa. In the Highveld the flow coefficient can be 10 times higher than in the Lowveld. For example, the Komati's flow upstream of the Vergelegen measuring station is 329 mm (20 % of the rainfall), while the Mbuluzi's flow in its lowest reaches (station 20) is about 25 mm (4 % of the rainfall).

According to a number of chemical analyses, the total mineral content (dry residue) of the river water is usually below 150 ppm and even below 30 ppm in the streams in the granitic formations of the Highveld.

II. GEOLOGY

Most of the country consists of Archean granites and gneiss of the western part of the Kaapvaal crater. These rocks, together with the ancien metamorphic rocks of the Swaziland and Angola supergroups, constitute the high plateaus in the west and centre of the country. Further east are found the Karroo volcanic and sedimentary rocks of Permian to Jurassic age which form the eastern side of the crater in the Lowveld and the Lubombo mountains.

Swaziland has sedimentary rocks which are among the oldest in the world - the Swaziland group. The oldest belong to the Onverwacht group and are 3,400 million years old. This group is overlain by the Fig-Tree and Moodies groups which contain argillaceous schists, cherts and quartzites. The Fig-Tree group also contains ferrous strata which have been worked at Ngwenya. All these rocks are very resistant to erosion, and this is the reason for the rugged relief in the north-east of the country.

The predominant rocks of the Middleveld are ancient granites and gneiss. These are Archean rocks more than 2,000 million years old. Owing to their varying chemical composition these rocks are differently marked by erosion; this factor produced the hills and valleys of the Middleveld. The Karroo rocks were formed from a long sequence of shallow terrestrial or marine sediments. At the base are found tillites more than 300 million years old and glacial sediments; at that period Southern Africa was centered over the South Pole. Overlying these rocks there are various argillaceous schists and sandstones with coal seams which are being worked at present. At the summit are found volcanic rocks: basalts and rhyolites which spread over the soil about 200 million years ago in the period immediately preceding the splitting of the southern supercontinent known as Gondwanaland. These Karroo rocks are traversed by many doleritic dykes and sills.

Swaziland has few unconsolidated or partially cemented sediments of Cenozoic to Recent age. They are found only in a few valleys and flood zones of the main rivers. In fact, most of the rivers flow directly over the rocks, which they have deeply incised in places.

III. GROUND WATER

The lack of drilling rigs prevented Swaziland's Geological Service from making accurate studies of the country's ground-water potential until very recently; but a short time ago the arrival of two rigs from Canada lead to the initiation of systematic studies, with test pumping basin by basin. At present reports are available on brief reconnaissance exercises, together with reports prepared by United Nations/United Kingdom consultants on short missions.

An inventory has been made of all the country's springs, the majority of which are found in the Highveld and the upper Middleveld. A total of 161 springs have been mapped, with yields from 01. to 6 l/s. A ground-water development section was set up in 1974 in the Geology and Mines Service with the main task of digging and drilling wells in the rural areas of the Lowveld. This section is also responsible for advising the Government and the public on the sitting of boreholes and their installation. The successes obtained in the installation of productive boreholes have gradually reduced the use of water-diviners in the government services.

The number of boreholes currently in use is estimated at 300 but the exact figure is not known, for drilling for water is not yet subject to declaration with details of dimensions and yield.

The hydrogeological studies are based mainly on examination of geological maps (1:50,000) and interpretation of aerial photographs. In many cases the ground water is contained in fracture and breccia zones which can be detected on aerial photographs.

Electrical geophysical prospecting (resistivity method) has been used with great success in ground-water exploration in Swaziland. The Geological Service is making studies at several sites. A Canadian prospecting team recently obtained promising results in the Lowveld using electromagnetic techniques which identified structures saturated with water. Doleritic dykes have also been located by magnetometric methods. However, many of the dykes are non-magnetic, especially if they are unaltered. Dykes are known to be a favourable indicator of the presence of ground water.

Ground water in the pre-Karroo formations

With the exception of the Insuzi and Mozaan series, these formations consist of massive crystalline rocks with very poor primary permeability. The most productive boreholes are those which penetrate the joints (secondary permeability) or are located adjacent to dykes or basic intrusions, although some boreholes find water in altered zones. Clays produced by intense alteration can impair the yields in certain areas. In many cases small perennial streams are found in the areas of contact with dolerites.

The data studied by Robins in 1978 indicated that 39 % of the holes bored in gneiss and 46 % of those in granites furnished less than 0.5 l/s, with an average yield of 1.1 l/s. However, yields are often obtained from boreholes drilled close to villages, health centres and schools which are in many cases situated near the summits of the mountain chains (Versey, 1977). This may be due to the fact that these chains were shaped by differential erosion and thus the degree of alteration and fracturation of the rock is less developed than in the valleys where the drilling sites are more promising.

Many boreholes in the Ezulwini valley and the Malkerns Farmlands draw their water from the permeable altered zone overlying the solid rock. The Ezulwini test hole identified a three-metre layer of red clays with poor permeability overlying 20 metres of permeable sands produced by the alteration of granites and gneiss. This alteration developed in situ, for traces of quartzitic veins are found in the clays. A similar red clay is present in the Malkerns valley at a depth of 30 m. One of the wells of the Swazi Spa Hotel has a yield of 6.9 l/s. The hydrogeological properties of the Insuzi and Mozaan series are unknown. However, it is probable that the lavas and argillaceous schists have poor primary permeability. The ground water can also be exploited when secondary permeability is present.

The holes bored in granites give slightly higher specific yields (0.046 l/s/m) than those in the Ancient gneiss complex (0.033 l/s/m) but this is to be expected in the light of the clearly higher yields obtained in the altered granite basins of the Malkerns and Ezulwini valleys.

Ground water in the Karroo rocks and Recent sediments

A uniform shallow aquifer is situated at the base of the Karroo system and in the altered upper part of the underlying Archean rocks. This aquifer gives generally poor yields. However, it is used to supply a coal mine and a refugee camp in the Mpaka area.

The Karroo sediments are well cemented, with porosity in the order of 0.5 to 2,5 %. It is not surprising that the granulometry of the deltaic sediments should be variable and in all cases below 0.5 mm. Secondary porosity is therefore essential if large yields are to be obtained. Joints are found only in the argillaceous schists and coal seams and they yield water of poor quality.

In the light of the exploratory diamond coring carried out by the Geological Service under the new coal project at Mpaka, it seems certain that below a depth of 80 m there is little permeability associated with fractures or alteration. There are few joints in the volcanic rock either. The open joints cease to yield water a few metres away from the deep dykes and faults. Only when they are altered and situated in low zones do they furnish water in any quantity. Some of the faults are blocked by red clays. The best conditions are found in the contact zones in the vicinity of doleritic dykes. In these zones 80 % of the boreholes are productive. The fractures are open to a depth of 20 m. Below that level they have been closed by compaction. It has been established that the best yields are obtained at less than a metre from the contact with the dyke and the compact rock. A dyke may contain some water in its alteration zone.

There are several types of basalt in the Lowveld:

- Amygdaloid basalts which are found only in the Lubuli area; they are easily altered and rarely outcrop. The amygdules include quartz, carbonates, zeolites, epidotes and chlorites;

- The porphyritic basalts have not been accurately delimited. Most of the altered basalts are good aquifers;

- The interstratified agglomerated basalts in the acid volcanic rocks are also good aquifers in the Lowveld. The productivity of the aquifers in the basaltic formations is determined by their physical properties such as porosity and permeability, the size and distribution of the vesicules, the number and spacing of the joints, and the extent of the alteration.

Of the 92 boreholes inventoried in the Karroo, 21 are barren and 56 yield under half a litre per second. Similar results have been obtained in South Africa. However, in the Lowveld of Swaziland the density of the dykes is higher in the south and the ground-water potential is therefore greater. In the Karroo system the boreholes in the Ecca sediments have slightly higher specific yields (0.028 l/s/m) than the boreholes in the lavas (0.023 l/s/m).

Little water is extracted from the alluviums, for they are generally thin and occur in narrow strips in the valleys. They play an important role only when constituting a natural filter for water pumped from the bed of the watercourse.

Water quality

In most cases Swaziland's ground water has low concentrations of dry residue and is neutral to slightly acid, with pH of 6 to 7. The lowest concentrations are due to leaching through the shallowest aquifers. For example, in the Highveld and Middleveld the steep slopes and heavy rainfall hold the dry residue below 500 mg/l. However, the ground water in the Lowveld and Lubombo mountains in eastern Swaziland is more saline, with a dry residue often in excess of 1,000 mg/l.

The granitogneiss regions of the Highveld and Middleveld furnish the country's best ground water. The four holes drilled in the metamorphic granites and schists of the Lowveld have a dry residue below 80 mg/l and usually closer to 30 mg/l. The surface water in the west of the country has a similar dry residue. In the Middleveld the metamorphic rocks and some of the Karroo sedimentary rocks have a slightly higher mineral content: 100-500 mg/l and up to 1,000 mg/l. The water is slightly acid (pH 6 to 7) owing to the presence of carbonic acid in the recharge zone and the lack of calcite sediments in the cations. The dominant element is sodium or calcium, sometimes with magnesium present in similar or higher concentrations. Bicarbonate is the commonest anion owing to the incorporation of atmospheric or organic CO_2. The concentration of CO_3H may also result from the dissolution of hydrothermal carbonated minerals in the metamorphic rocks. The chlorine content is usually 10 mg/l with up to 200 mg/l in exceptional cases. The sulphate content is usually below 5 mg/l. In the Lowveld and the Lubombo mountains the ground water of the Karroo sediments and the volcanic rocks has undergone more intensive interaction with the water-bearing rocks and therefore has a higher mineral content. Samples taken from the boreholes indicate concentrations often in excess of 1,000 mg/l. This water usually has a low chloride content and a fairly low sulphate content. As in the case of the Highveld and Middleveld, there is no truly dominant cation. On the basis of the limited number of analyses of the water of the region, it seems possible to conclude that the water quality is up to the standards of the World Health Organization.

Current studies

In 1986 the Geological Service in co-operation with the Canadian Government began a five-year programme of ground-water exploration. The project covers the whole country and it dealt first with the Lowveld and the Lubombo plateau. The aim is to recognize the accessible ground-water resources and determine their potential and the quality of the water, as well as increasing the capacity of the staff of the Geological Service to undertake future ground-water exploration programmes and data analysis. A terminal report will be presented on the conclusion of the project in 1990.

IV. EXPLOITATION OF THE GROUND WATER

The Geological Survey and Mines Department is the only government service in possession of drilling equipment: two combined rotary/down-the-hole hammer rigs supplied by Canada for the hydrogeological study of the country, and a lighter rotary rig supplied by UNDP for a village water-supply project; this latter rig is used only for utilitarian and humanitarian purposes with little associated hydrogeological research. All the workers are Swaziland nationals and by the end of the programme they will have the necessary technical capacity to conduct the studies and operate the rigs. There is also a second, somewhat older, cable rig. Some drilling is carried out by private firms with compressed-air rigs.

There are eight qualified national drillers, and the drilling capacity of the Government's boreholes section is estimated at about 5,000 m per year.

The ground water is usually used to supply rural areas, including social infrastructures, schools and health and community centres. It is thought that it might also be used to supplement surface water in the supply of the large rural centres which experience periods of water shortage.

Livestock-raising is confined to the Lowveld where there is little surface water. The development of ground water is therefore of great interest in this region. Furthermore, ground water is the only water resource available to State and private enterprises, and the quantities extracted are steadily increasing.

Data collection, drilling for water and installation of wells will be continued at sites with good potential under the auspices of the Geological Service, but it will also be necessary to establish hydrogeological and hydrochemical centres and improve the design of the installations. A better correlation must also be achieved between the geophysical and the geological data.

Since the ground water has not been extensively exploited so far, there are no problems with respect to the effects of pumping on the environment.

V. REFERENCES

CIDA/WHO, Survey of springs in Swaziland. Unpublished report prepared for the Rural Water Supply Board, 1981.

Cleverly, R.W., The structural and Magmatic evolution of the Lubombo monocline, Southern Africa, with particular reference to Swaziland. D. Phil. Thesis, University of Oxford, 1977.

Davies, D.N., Annual report for the Geological Survey Department. Mbabane, 1966.

Enslin, J.F., Geophysical Methods of Tracing and Determining Contacts of Dolerite Dykes in Karroo Sediments in Connection with the Sitting of boreholes for Water. Trasn. Geol. Soc. of S. Africa, 1950.

Frommurze, H.F., The water bearing properties of the more important geological formations in the Union of South Africa. Geological Survey Memoir, Pretoria, 1937.

Hunter, D.R., The Geology of Swaziland. Geological Survey and Mines Department, Mbabane, 1961.

Navarro, A., Report on a mission to Swaziland. Unpublished report UNOTC/CNRET, New York, 1976.

Robins, N.S., The new water borehole (No. 13/18) at Mpisi Government Farm. Unpublished report, Geological Survey and Mines Department, Mbabane, 1977.

Van Wyk, V.L., Ground-water Studies in Northern Natal, Zululand and Surrounding Area. Geological Survey, Pretoria, 1963.

Versey, H., Terminal report, 1976. Unpublished report, Institute of Geological Sciences, London, 1977.

Vilakati, A.M., Hydrogeological Branch - 1978 annual report. Swaziland Geological Survey internal report, 1979.

__________, A.M., Hydrogeology study of Manyonyameni cattle ranch. Internal report for Swaziland Geological Survey, 1983.

Visser, D.J.L., The Geology of the Barberton Area. Geological Survey, Pretoria, 1956.

Visser, Krige and Truter, The Geology of the Country South of Ermelo. Geological Survey, Pretoria, 1947.