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REPORT ON A VISIT TO LESOTHO, OCTOBER 1974

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1. Introduction

The writer arrived in Maseru on 18 October and left on 23 October 1974. Arrangements during his visit were made by Mr G Bonney, ODA appointed Hydrogeologist whose hospitality is gratefully acknowledged. The purpose of the visit was to assess the programme of work, to make any relevant suggestions for improvement and to consider the need for further investigations following completion of the present contract. Mr Bonney commenced work in Lesotho on 20 March 1972 and has completed one contract period of service. His second contract is due to end about mid 1975. He is attached to the Department of Mines and Geology and the associated staff include one qualified (i.e. trained Hydrogeologist) local counterpart, a Miss Mafolo, and one Technical Assistant. The stated assignment was to make a general investigation of the groundwater potential of Lesotho and to assist the Department of Community Development in the siting of boreholes.

Lesotho is geographically subdivided into the western lowlands (approximately 20% of total area with elevations between 1500-1900 metres above mean sea level) and the eastern highlands (elevations up to 3300 metres above mean sea level). The mountains consist of an accumulation of basaltic lavas (Karroo - Stormberg Volcanics). Older Karroo sedimentary strata outcrop in the western lowlands and younger alluvium in the principal valleys.

Most of the rain falls between October and April but amounts are variable due to the effect of relief. Recorded annual averages can vary from less than 600 mm to more than 1500 mm. Run off is rapid and although there are some perennial streams, dry season flows rapidly attenuate and many streams dry up altogether.

Village water supplies are generally taken from springs. There is an increasing demand from surface or borehole supplies, particularly in the larger population developments. A UNDP Water Resources Report compiled by Binnie and Partners (1) considered groundwater potential and stated in their "conclusions".

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"The geological environment of Lesotho and neighbouring South Africa are similar and it is unlikely that any major acquifers exist within Lesotho. The alluvial deposits are silty and they are limited in extent and depth, and it is unlikely that they will be of use for major groundwater development. The sedimentary rocks have a low porosity and primary permeability and they lack the frequent jointing or solution cavities associated with good acquifers. The basalts will not provide water in any quantity as they have few joints beneath the surface, and they have few weathered layers between the lava flows. The only locations that are likely to yield water in a reasonable quantity, i.e. from 1.5 to 25 litres/sec, are where the dykes cut across the sedimentary or igneous rocks and where there are sills."

This assessment seems fairly reasonable but best may perhaps be misleading. Although major groundwater development cannot be expected, significant development seems feasible. Groundwater supplies have many advantages in terms of economy, convenience and hygiene and have particular relevance to Lesotho's population distribution. These advantages merit appreciable effort being devoted to development but it must be recognised that well siting and resources evaluation present difficulties.

2. General Assessment of Programme of Work

Mr Bonney has prepared a well conceived programme of work and has been carrying it out with considerable energy and efficiency. His background experience includes both surface and groundwater considerations which is fortunate in the present context because of the significance of both types of supply in Lesotho, and the close interrelationships between the two environments. Groundwater storage is not large and occurs mainly in fissured rocks. Mr Bonney's lack of experience in geophysical techniques of well siting in fissured rocks has inevitably proved a handicap and the deficiency could to an extent have been remedied by preliminary study prior to taking up his post in Lesotho. This is in effect one of his own proposals that preliminary studies of background geology and relevant specialist techniques should be carried out at the Institute of Geological Science in London. Related proposals are for the provision of specialist equipment as and when required, e.g. borehole logging equipment, and for visits by specialist personnel. These proposals merit consideration both in respect to this particular assignment and more generally. There are practical difficulties in these proposals and further consideration will be given in this Report and separately on these aspects.

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Considerable difficulties have been experienced in the organisation of this work programme because of inadequacies in transport supply and office accommodation and because of the numbers of agencies in Lesotho who are engaged in water supply activities. It would certainly improve efficiency if adequate arrangements for transport and office accommodation could be made in advance of such appointments. 'Pool' transport in such countries is generally unreliable. The provision of independent transport, preferably new, which is placed under the responsibility of the officer concerned is very strongly to be recommended.

Mr Bonney lists twelve agencies who are concerned as part of their activities with groundwater development. There are obvious difficulties in co-ordination of this large number but it is important that good liason is established with them in order to ensure that proper records are collected and to proffer such advice and help as may seem worthwhile. It may prove feasible in the future to organise water resources development under fewer organisations with possible improvements in scope and efficiency of operations. In the meantime, the staff of the Hydrological Department should be adequate to maintain effective liason for the reasons stated.

By the time Mr Bonney's contract will finish in mid 1975, it is to be hoped that the basic principles of data collection including those related to the hydrometric network will be well established. I understand that Mr Bonney does not intend to request a renewal of contract. I do not think that an equivalent replacement is to be recommended at the present time although it would be appropriate to seek Mr Bonney's own, more considered views on the matter. There has been a qualified local assistant working under his direction for more than two years and I consider that emphasis in the future should be placed increasingly on local involvement but providing some assistance in a variety of other ways. These might include:-

1. The appointment of a junior expatriate technical assistant (e.g. a V.S.O.) to work under the direction of Miss Mofolo.
2. Occasional visits by experienced or specialist staff.
3. Provision, possibly on a loan basis in some instances, of recommended equipment.

3. <u>Programme of Work: Technical Aspects</u>

The programme of work can conveniently be divided into two principal activities, referred to as a) site investigations and b) regional resources studies. A summary of the scope of these activities is given below with some suggestions for possible improvements.

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3.1. Site investigations including well drilling

Boreholes are sited wherever possible on the margins of dolerite dykes within the adjacent shatter zone. The practice is based on experience in similar areas in South Africa. Yields and general success rates decrease with increasing depth to the water table, presumably in consequence of fissure reduction with increasing depth. Results are variable even within comparable depth ranges (with respect to water table) and the feature is generally attributed to the narrowness of the fracture zone and the difficulties in maintaining the borehole within the limits. Analytical studies for predictive purposes are being attempted following a theory developed by Boehmer.(1)

Site selection might have improved success if the subsurface geometry of the dyke/shatter zone could be determined more accurately. Geophysical techniques, notably magnetic, electromagnetic and resistivity, are appropriate and have been used elsewhere for this purpose. The methods are to some extent complementary and in different circumstances, one or other may prove the most useful. The magnetic method will essentially relate to the dyke body and the electromagnetic to the fluid-filled fracture zone. Resistivity will be affected by a number of features in both dyke and adjacent rock. Further experimentation is to be recommended, particularly if the investigations can be closely integrated with geological data from drilling sites. A visit from a geophysicist equipped with a range of facilities could be included with advantage.

In view of the differences which are sometimes said to result from drilling a second well a very short distance (a few feet or metres) from an unsuccessful well, the use of explosives to develop unsuccessful wells might be considered. A discussion of results of 'shooting' production wells completed in sandstone in Northern Illinois is given by Walton and Csallany, 1962 in the Illinois State Water Survey Report of Investigation No 43.

Site analysis of dyke-margin conditions using the theory of Beohmer referred to above is currently being attempted by Mr. Bonney at an experimental test site in the Roma Valley Catchment. The theory has had little substantiation by practical correlation and some of the assumed boundary conditions are questionable. The test method requires fairly large numbers of observation wells. The analysis is primarily for predictive purposes (hydraulic head levels) but the information from such detailed tests with appropriate expansion,

(1) 1970 Application of the channel method for determining the hydrological characteristics of Karroo sediments tapped by a dyke/dyke-contact aquifer. Republic of South Africa Water Year 1970. Convention: Water for the future.

would have value in relation to the general patterns of dyke-controlled fissure flow, and on this account the study is to be well recommended. The observational data which is obtained can be applied to the theory referred to above but might also be incorporated into a more general model study with design and facilities provided by I.G.S.

Experience in South Africa has lead to the belief that there is little value in drilling into Karroo rocks (the principal aquifer) other than in fracture zones adjacent to dolerite dykes. Whilst this belief seems likely to be generally correct it should not be regarded as invariably so. Obvious locations which also offer chances of success include shear zones which may be unrelated, at least in surface expression, to dyke explacement. Shear zones of high angle or vertical disposition can commonly be located by ground survey, photogeological or geophysical techniques, notably electro-magnetic or resistivity.

Low angle or horizontal layers of high differential permeability within the Karroo formations in Lesotho do not appear to have been recorded but their existence must not be discounted. Whilst it is impracticable on economic grounds to carry out extensive exploratory drilling to test the likelihood, it is important to collect and analyse such basic data as can be readily derived during any relevant investigations. These include the regional resource evaluation studies which will be mentioned in more detail below which have the aim of a general water balance of the surface water - groundwater systems. These broadly based studies utilising geochemical data, hydraulic head levels, data from well logs, patterns of spring locations, run-off - drainage characteristics would provide the background information on which a limited test drilling programme would have an improved chance of success. Because of the very variable nature of the aquifers dominated by fissure flow systems, well siting on features other than those with an obvious surface expression such as high angle fault or dyke - fracture zones, can best be done on the evidence of regional flow patterns. It is most important therefore that basic data be collected as fully as possible and preferably expressed on maps. This would include the geochemistry, hydraulic head, specific capacity data etc. Data from drilling is of particular importance and every effort should be made to ensure that adequate records are maintained. Local zones of high horizontal permeability may be apparent during drilling (lost circulation, increased productivity with air-percussion methods etc.) and these should be recorded and mapped! Geophysical well logging can also be a fruitful source of information. In the present context, the most appropriate logs are likely to be electrical conductance, temperature and flow velocity. It is appreciated that logging gear is not at present available but the provision of the fairly limited facilities mentioned above would not be very expensive.

3.2. Regional Resources Studies

The programme may be summarised as follows:-

1. Basic groundwater inventory (boreholes and springs). Boreholes are relatively limited in number. There are large numbers of unrecorded springs and a comprehensive inventory is impracticable. Mr. Bonney is experimenting with infra-red photography as a means to identify and locate springs in rapid reconnaissance fashion.
2. Establishment of a hydrometric network.
3. Rainfall map of Lesotho prepared on basis of existing records.
4. Subdivision of Lesotho according to catchments and analysis of catchments by drainage patterns; analysis of surface run-off records where they exist to correlate with catchments; subsequent extrapolation to unmonitored catchments on basis of rainfall data.
5. Roma Catchment Study: detailed study of a particular catchment including test drilling.

Detailed comments on this programme are not appropriate at present other than to state general agreement with the approach, to note some limitations and to emphasise aspects of particular importance.

The standard data collection on boreholes, both existing and newly drilled, should be extended to include among other measurements :- static water levels both with respect to ground level and to a common datum, specific capacity, variations in water levels during drilling, water samples for partial or full analysis. There is also a need to collect special data on at least a selection. This special data might include:- periodic slug tests during drilling, geophysical logs of the range described, and longer and more carefully controlled pumping tests.

The surface run-off records are often rather inadequate particularly in the low flow ranges. The use of minor concrete structures to stabilise channel flow in the vicinity of a gauging site could improve data in some cases.

Improvements on total abstraction records are needed. These could be made either directly by installation of meters or indirectly on a time-discharge basis. Periodic sampling for analysis should be included in the routine collections. Electrical conductance measurements may be adequate on most occasions with more detailed chemical analyses carried out following any significant changes in conductance.

4. Summary of Conclusions and Recommendations

1. Activities can be subdivided into (i) Well Site Investigations and (ii) Regional Resource Evaluation Studies.

2. Well siting is currently limited in the large majority of cases to the vicinity of dolerite dykes. Success rate is very variable and minor differences in site location may make major difference to results.

3. Suggested improvements are as follows:-

(i) Greater use of geophysical techniques with combinations of magnetic, electromagnetic and resistivity in order to define more accurately the subsurface geometry of the dyke and the extent of the adjacent shatter zone.

(ii) The possible use of explosives to develop wells.

4. Prediction analysis is being attempted at a test 'dyke-site' in the Roma Valley Catchment using a production and several observation wells in accordance with a mathematical theory by Boehmer (op. cit). The theory assumes boundary conditions which are of uncertain validity. It is therefore suggested that I.G.S. might attempt additionally to model the situation using the raw data from this test in order to confirm the analysis.

5. Well siting away from dolerite dykes should not be precluded. Other possible locations include shear zones which are likely to have a vertical or high angle inclination, or subhorizontal zones of high permeability. The former could be detected by ground survey or by photogeological or geophysical techniques notably electromagnetic. Subhorizontal zones of high permeability in the Karroo sandstone could occur as eleswhere in Southern Africa in relation to the base of the Stormberg Volcanics or to the margins of intrusive sills. Indications of such occurrences might become apparent from the regional studies or by the correlation of suitable data recorded during drilling and well testing. The importance of plotting basic data (geochemistry head levels, specific capacity etc.) onto maps is therefore stressed and also the need to obtain and compare appropriate data from drilling and well testing. The use of logging devices, notably conductance, temperature and flow velocity is also recommended.

6. Regional evaluation studies are primarily based on rainfall-run off analysis applied to associated catchments, and extrapolated to other catchments without such records on the basis of a classification related to stream orders. Major limitations are the poor quality of some records, particularly in the low flow ranges, and the significance of spring flow which may not appear in the balance.

7. A groundwater inventory covering boreholes and springs is in progress and a regional hydrometric network has been established. More comprehensive data collection both on old and new boreholes on completion as well as part of routine sampling measurements is to be recommended (see also 5 above) but it is recognised that current availability of junior technical staff/back up facilities (office and transport) is likely to be a major restriction to implementation. The same consideration applies to making adequate liaison with the large numbers of agencies who are concerned to varying extent with groundwater development.

8. It is not recommended that an equivalent replacement of Mr. Bonney should be provided at the end of his current contract (mid 1975). Emphasis should be placed increasingly on local involvement under the direction of Mr. Bonney's qualified assistant, Miss Mafolo, and providing such additional assistance as may seem desirable. This could include:-

(a) A junior expatriate technical assistant (e.g. a V.S.O.) to work under Miss Mafolo.

(b) Occasional visits by appropriate I.G.S. personnel.

(c) Assistance with the provision or loan of equipment.

These recommendations must be regarded as a preliminary assessment and Mr. Bonney's own considered views should be sought on the matter.

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