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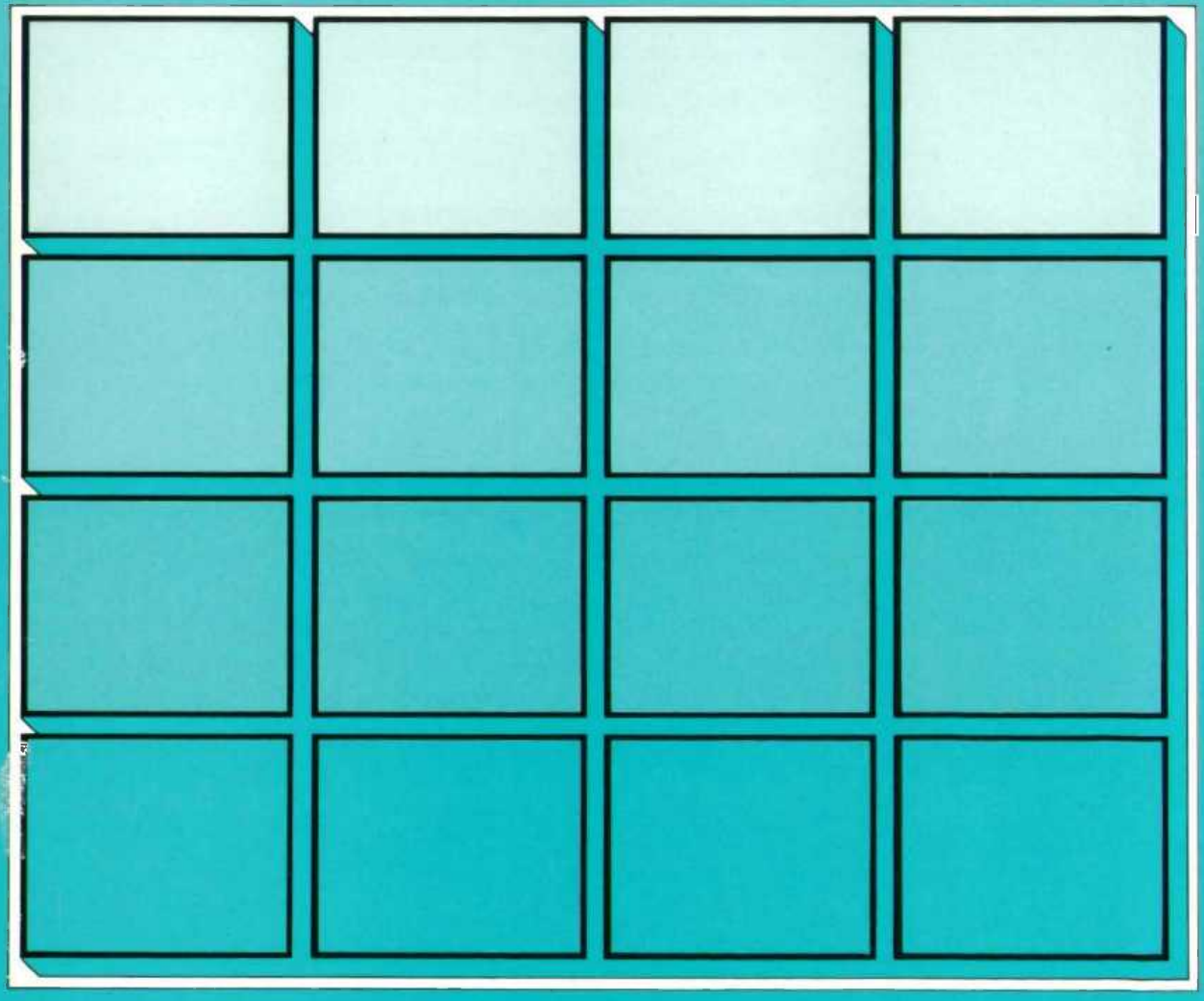

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RAF/87/030

SUB-SAHARAN AFRICA HYDROLOGICAL ASSESSMENT

(GROUP I COUNTRIES)

INTERIM REPORT

JULY 1988

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in association with
BRITISH GEOLOGICAL SURVEY
and
INSTITUTE OF HYDROLOGY

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INTERIM REPORT

Table of Contents

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INTERIM REPORT

1 OBJECTIVES OF THE STUDY

The purpose of the study is to evaluate the status of all existing hydrological data, networks and collection systems in East Africa and to make recommendations for the filling of important gaps, the upgrading of the quality of data collection and for the general enhancement of the capability to measure, retrieve, process and publish hydrological data and information. The ultimate aim is to assist the IGADD countries in the creation and/or improvement of a sound hydrometric base for the purposes of planning and evaluating water resource development programs and projects. The studies apply to surface water resources, hydrometeorological data and surveys, and groundwater.

The study is being carried out in three main steps:

(a) Preparation of inventories of the present status of data collection, processing and publication including the listing of bibliographies;
(b) Identification of the more important gaps that exist in present hydrological data collection and assessment programmes;
(c) Formulation of recommendations on priority data collection and assessment programmes to fill the gaps, including institutional and training aspects.

For the assessment of meteorological and surface water data, samples of data have been collected and their quality assessed by analysis and comparison. Not only rainfall but also net rainfall (rainfall less actual evaporation) is being assessed on a regional basis, and both variables are to be presented in the form of maps based on recent data. Sample tests are being carried out on river flow records to establish their quality by examination of rating curves and processing methods for a number of stations, and by using double mass and correlation tests between records; trends in river flows are being examined. The measurement of sediment load is also being reviewed.

Groundwater data is also being assessed in terms of availability and quality, and the information presented not only in tabular form but also in the form of hydrogeological maps to a scale of 1:1,500,000 (except for Djibouti) and using the standard UNESCO legend. A greater variety of types of information - aquifer locations, geological features, aquifer characteristics, borehole development, and water quality - are being investigated than in the surface water studies.

2. SUMMARY OF PROGRESS

2.1 General

The country visits have been completed for those countries where approval for the project has been received and most of the reports on the different subjects for these countries have been drafted. The hydrogeological maps have been drafted and their production has been started following the preparation of a pilot map.

2.2 Meteorology

Details of the meteorological networks have been obtained for Djibouti, Kenya, Sudan and Uganda and sample basic data from these countries. Analysis was started on Sudan data in order to develop techniques for application in the other countries.

2.3 Surface Water

Examination of the flow gauging network has been completed in Djibouti and Sudan; quality control of the data was carried out during field visits, and draft reports have been written. In the case of Somalia, where access to flow records was not permitted, a note is being prepared using as the principal source an FAO/UNDP report on the hydrometric network. In Uganda, where recent flow records were missing, basic data processing is being carried out as part of the study.

2.4 Groundwater

Field visits to Somalia, Sudan and Uganda have been made and hydrogeological maps and draft reports have been prepared for these countries. A map and draft report have been prepared for Djibouti on the basis of an existing report; it is hoped eventually to combine a field visit with a visit to one of the other countries.

2.5 Sediment

Virtually no measurements of sediment are being carried out at present in the countries visited. A report on measurement of sediment yield in East Africa has been prepared from a review of available information and maps.

2.6 Mapping

Hydrogeological maps have been drafted on base maps at 1:1,500,000 scale for Somalia, Sudan and Uganda and at 1:500,000 scale for Djibouti. These maps have been compared for consistency and are being prepared for map production; a pilot sheet of part of the Somalia map has been produced.

3. PRELIMINARY FINDINGS BY TOPIC AND COUNTRY

3.1 Meteorology

3.1.1 General

The meteorological assessment of water resources depends on comparison of maps of rainfall and actual evaporation. In terms of national or regional planning the data need averaging over a number of years, but it is essential to consider the pattern within the average rainy season and therefore calculate net rainfall on a monthly, if not shorter, basis.

The evaluation of runoff from rainfall must be based on isohyetal maps, which may be derived either subjectively or using a numerical procedure, taking due account of data outside the area and large scale topographic features. A major concern in water resource planning is the extrapolation of past events to the future in the light of the well-documented decrease in rainfall in Africa in recent decades. We do not think it reliable to extrapolate downward trends but believe it right to assume that the average over recent years is more relevant to the next decade than the 1931-60 average; we have chosen to use data since 1970 to ensure an adequate data set.

Maps of potential evaporation from limited numbers of stations are smoother than those of rainfall, and it is known that potential evaporation varies less than runoff from year to year. A simplified model relating actual to potential evaporation has been developed to assess hydrological net precipitation, which can be compared with runoff measurements.

Given the accuracy required of the rainfall and runoff figures the density of network required in any area can be specified in terms of the number of climatological stations to estimate evaporation and the number of rainfall stations. However, it will probably be more cost effective in the

future to use fewer raingauges and supplement them with rainfall estimates derived from satellite data; such methods are already available. Estimates of actual evaporation may also be improved with the help of satellite data, but more research is needed before the methods can be considered operational.

3.1.2 Individual Countries

The methodology used in the meteorological studies has been developed using Sudan data, so that Sudan records are being used to study the recent history of the network and the climate, and also to provide a framework within which other countries may be studied.

Historical analyses of the raingauge and meteorological network for Sudan have been based on annual reports from 1950. Some 840 raingauges have been in operation during that period; their durations range from a few months to many decades. The analysis indicates the extent of incomplete and missing data. The number of raingauges reporting reached a maximum of 589 in 1969, while in recent years data have been particularly difficult to obtain with only 152 stations apparently reporting in 1986, concentrated in the centre of the country. Similar analyses relate to meteorological stations and recording raingauges.

Graphs of annual precipitation for long-term stations show not only great annual variability but also the general decline persisting since the late 1960's. Using a selection of the longer and more complete records, mean annual isohyetal maps have been produced for the wetter and drier periods of 1950-67 and 1968-86. These isohyets, produced by an objective computer interpolation procedure, show a southward shift in the last 18 years and a general decrease in precipitation totals of more than 10%. Double mass curves for selected pairs of stations across the country show no breaks in consistency.

A procedure for the calculation of hydrological net precipitation (HNP) has been selected. Monthly potential evaporation estimates, using a modified Penman equation with meteorological records from a large number of stations, have been interpolated to rainfall stations. These estimates are used within a model to estimate HNP by relating actual evaporation from bare soil and different vegetation types to potential evaporation by taking account of available water. The sensitivity of this model to the various parameters has been tested; the dry season soil evaporation is critical and in dry years makes the difference between significant and zero HNP. Comparisons are being made with measured runoff records.

A similar historical analysis has been performed on the Djibouti raingauge network, where the maximum number of stations was 24 in 1975/76. At present monthly rainfall data are available for some Kenya stations, but more information has been requested on both rainfall and meteorological networks. Some information has been received from the Ugandan Meteorological Service and from other sources which have been contacted.

3.2 Surface Water

3.2.1 General

The quality of surface water records has been studied in each country by examination of data collection and processing and the organisations responsible for this. The main tool was the analysis of rating curves and processed flows using the HYDATA suite of programs. Some observations and recommendations are given for individual countries, but two general points can be emphasised here.

A shortage of equipment, and in particular transport, has meant that field calibration of gauging stations has deteriorated in recent years. This is largely due to the fact that the collection of basic hydrological data does not receive high priority in the spending plans of governments. The allocation of specific funding to recurrent expenditure of this type,

without the need to set up an expensive project team, could greatly assist the status of this work. Relatively modest financial assistance could produce very significant improvements in the hydrological records to support development.

The computerised processing of hydrological data is now feasible with the use of modern micro computers. The software for this processing now exists, and it is now opportune to install standardised analytical procedures and equipment for this purpose. Comparatively small numbers of staff, with limited qualifications, can be trained to undertake the routine work, leaving qualified hydrologists free to carry out analyses and investigations in addition to supervising the processing.

Plans for regional comparisons of flow data have been delayed by the lack of key data from certain countries. The material has been assembled for the analysis of flows of different Nile tributaries, but comparisons on a wider regional basis are not yet possible.

3.2.2 Djibouti

Surface water resources in Djibouti are mainly of importance as a source of aquifer recharge and they were studied in 1979/82 by Ruhr University, Bochum as part of a hydrogeological cooperation programme. The studies have been continued by ISERST (Institut Superieur d'Etudes et de Recherches Scientifiques et Techniques); in particular the gauging of wadi flows has been maintained in spite of problems of flood damage, transport and access. Earlier studies have shown that basin recharge is negligible over much of the country and that recharge from wadi flow is important. This depends markedly on the duration of flow, which varies greatly from site to site. Records of two sites on Wadi Ambouli, near Djibouti town, show that much of the runoff at the upper site does not reach the lower site; thus recharge can be estimated by differential gauging.

Although rating curves have been based on hydraulic calculations and require confirmation by float or flow measurements, it is as important to maintain the continuity of record as well as the accuracy of individual

records and if possible to extend the gauging network from the present six sites. Support in the form of transport and possibly further short-term hydrological assistance would facilitate this extension. Liaison with the ground-water authorities is clearly important and is reasonable at a working level; the formation of a liaison committee is encouraging.

3.2.3 Somalia

Although the hydrologist who undertook the field visit was responsible for setting up the computer system to analyse hydrometric records he was not able to obtain any recent records. However, permission has been received to use a report prepared for FAO, which enables us to record the hydrometric network. This network is concentrated on the two main rivers, the Juba and Shebeelle, but there is a need to re-establish the computer based processing of hydrometric records and to maintain discharge measurement and rating curves. We are aware that a project for this purpose is currently being funded by ODA. No recommendations are being made on institutional matters because of the discontinuation of the project by the Government of Somalia.

3.2.4 Sudan

The majority of the flow gauging stations in Sudan are on the Nile and its tributaries, and many of these stations were established early this century to make the Nile one of the world's best documented large basins. The responsibility for these stations is shared between the Egyptian Irrigation Department (EID) and the Sudan Ministry of Irrigation (SMI). Some 200 flow measurement stations have been listed as having had records at some time. Gauging stations outside the Nile basin are the responsibility of the National Rural Water Corporation (NRWC), and 45 out of 60 stations are operational at present.

Liaison between EID and SMI is through the Permanent Joint Technical Commission (PJTC), which also cooperates with the countries of the upper Nile, Kenya and Uganda. There is a need for greater contact between SMI and NRWC, but efforts are being made to improve this.

In order to assess the quality of the flow records and how these might be improved, 25 stations were selected for detailed assessment. These records were selected to give a reasonable geographical coverage of long-term stations on the main tributaries. Field and office procedures were reviewed for both SMI and NRWC, and a number of detailed recommendations are made in our draft report.

For the 25 selected gauging stations, discharge measurements and rating curves were assessed over a perind of years to test stability. It is not possible to generalise the results of this analysis, as the reliability of the rating curve depends greatly on the individual site, and in particular on its stability or dependence on shifting bed or downstream control. In general the processing procedures are reliable and the publication policy based on 10-day flows is reasonable for most purposes.

Detailed recommendations made on maintenance and calibration of current meters should result in improved record quality but the main recommendation is for comprehensive computerisation of office procedures at SMI, including past data, with the reorganisation of record filing which this entails. At NRWC stations the need is for checking rating curves, where these are based at present on float measurements and a standard factor of 0.7, together with bed surveys. Although the stations in the south are not operational at present, the network is in general adequate, but additional stations are needed away from the Nile and improved records are needed on the Gash and Baraka.

3.2.5 Uganda

The gauging network has suffered severely from recent events, but by concentrating on a selection of 20 stations our hydrologists were able to establish that most of the level records up to the early 1970's could be recovered and most discharge measurements were also available for these stations. These records were collated with the assistance of local staff,

and discharge measurements were entered on the HYDATA system to establish rating equations. Sample stage data were entered to compile flow records for some years at the 20 stations. Because no flow records exist with which these calculations can be compared, the original concept of this work as a check on flow processing procedures was irrelevant.

As a relatively small amount of work, involving level data entry and subsequent processing and compilation, could provide valuable records for 20 stations which are not available in Uganda, approval was sought and granted for additional work. This work is well advanced and will provide flow records for a number of years for these key stations, which can form the basis for water resources studies in Uganda. It could also provide a framework on which the processing of other records in Uganda could be based.

The preparation of a detailed report on Uganda will follow the completion of this flow processing programme. The elements exist for a successful rehabilitation of the hydrological survey for Uganda.

3.3 Groundwater

3.3.1 General

The approach in each country has been based on the study of geological maps and reports, hydrogeological data bases and reports derived from these and the representation of information on hydrogeological maps. Some general points may be made.

The hydrogeological maps being prepared are individual country maps and not regional maps but a basically similar legend is being used so comparisons can be made. There are advantages in country maps since local geological formation names can be used which allows additional interpretation using background geological knowledge.

Hydrogeological maps have been produced in recent years in three of the countries concerned - Sudan, Somalia and Djibouti. None has been prepared in accordance with a UNESCO legend and mainly with regard to the

importance of a particular feature - water quality in the case of Djibouti and Somalia. In the present instance the importance of this feature has been emphasised by use of appropriate ancillary maps.

A programme to produce hydrogeological maps of Africa at a scale of 1:5 million is presently being carried out by the African Association for Cartography (AAC) under the leadership of the Organisation for African Unity. Contact has been made with this programme through the International Association of Hydrogeologists and efforts have been made to involve the local correspondants of the AAC programme during country visits.

The data bases in all countries studied to date are manual systems which are time consuming to manipulate or analyse statistically. There has been insufficient time to carry out any such work and assessments are based on appraisals of existing reports etc. Archival data in Provincial offices have not been accessible for the country visitor either because of time constraints or security. The archival records of ground water data are standardised and basic and show no particular correlation with the special needs of individual aquifer types. Prior to computerisation, some additional data inputs could usefully be incorporated, either by reference to original borehole completion records or topographic maps where location in respect to relief could be of significance. Pumping test data are frequently inadequate in respect to drawdown, duration of testing and other essential facts which may be available in the original records.

Routine hydrogeological monitoring is rarely being undertaken in the countries visited. This monitoring is essential if groundwater recharge is to be estimated in semi-arid regions. However, the constraints of funding and in particular the difficulties of meeting recurrent expenditure, compounded by shortages of transport, make this monitoring difficult to achieve. Hydrogeological monitoring requires careful planning and detailed justification if sufficient priority is to be allocated to it by developing countries.

3.3.2 Djibouti

With half the population in the capital, the water requirements of the country are dominated by urban water supply, but supply for rural communities and small-scale irrigation supplies are provided by boreholes, hand-dug wells and springs. Three types of aquifer can be identified - extensive aquifers in the recent basalts and stratoid series over the west of the country and near Djibouti, local aquifers in regions of Dalha basalt, Mahla rhyolite and the sediments of the Arta region, and intergranular aquifers in Plio Pleistocene to Recent sediments. A hydrogeological map at 1:500,000 scale has been adapted from the interpreted data in the BGR report and map annexes. The stratigraphy of the country's geology is summarised in a draft report and the hydrogeological characteristics of the aquifers deduced from available information. Over much of the country rainfall is inadequate to provide regional recharge to aquifers except in areas of thin soil, which also induce runoff. The main recharge occurs from direct infiltration of wadi flood water to underlying aquifers; this underlines the importance of wadi flow measurements described above. Some transmissivity estimates are provided by pumping tests but these were of very short duration. Water quality varies with aquifer and location; the areas where normal limits for human consumptions are exceeded have been delimited, taking into account that such water has been used without apparent problems. In addition to recommendations made by BGR for hydrogeological data collection and exploration, we consider that routine water level measurements would be invaluable in confirming recharge and flow processes.

3.3.3 Somalia

Although it was not possible to complete the field visit with a study of all the reports available, a hydrogeological map has been prepared following the UNESCO recommendations on International Legend. However, an intermediate classification has been found necessary where both intergranular and fissured aquifers coexist. Emphasis has also been given to water quality classification in view of its importance. The geological features of the country are described briefly in the draft report with emphasis on hydrogeological factors.

Groundwater occurs in the Basement Complex in fissures which are better developed in the north and in channel alluvium. Although Jurassic limestones and sandstones appear to have reasonable potential, the part of the formation in which groundwater occurs and the variation in quality with depth are important; similar considerations affect Cretaceous sediments. The Eocene sediments are water-bearing with porosity ranging from intergranular to fissured, while Oligocene Miocene sediments underlying basalt have water of reasonable quality. Quaternary sediments of alluvial and coastal origin can be particularly productive where recharge from rivers occurs.

The sources of water for different communities are summarised. Hydrogeological investigations in Somalia led to a first hydrogeological map in 1973 after a UNDP - funded study which resulted in an extensive inventory of wells; a project funded by GTZ from 1983-87 resulted in a comprehensive assessment of surface water and groundwater quality after a major data collection programme. These data are currently being collated on a computer data base at the National Water Centre.

The structural evolution of the various geological formations is described in the report and each formation is discussed in terms of its productivity, depth to water and water quality. The text is intended to supplement the 1:1,500,000 hydrogeological map which has been produced as part of the current project. This map, which is at present with the publishers, presents the available information in a format which is uniform between the countries studied.

3.3.3 Sudan

Sudan possesses vast groundwater resources. In general, knowledge of the main aquifers is fairly well advanced as a result of some 40 regional and local studies, which provide the best source of quality controlled data. We have produced a map at a scale of 1:4 million showing where these studies have been undertaken and also where regional hydrogeological maps have been produced. A bibliography of some 400 references relating to the groundwater sub-sector has also been prepared.

Borehole data prior to decentralisation in 1979 are held in a file archive in Khartoum. Data since then are still retained by the regional offices. These data sets are presently being collated and transferred to a computerised national archive. The borehole data, particularly non-project data collected during the Anti-Thirst Campaign of the 1970's when borehole construction was rather unsupervised, have a number of limitations. The most important of these include a lack of reliable pumping test data, poor lithological logs, and lack of elevation and coordinates. Borehole data for the Gneiss Complex area of South Sudan collected during rural water supply development schemes are also believed to have similar deficiencies, although information collected by UNICEF in this area was not available for assessment.

The 1:1,500,000 hydrogeological map and accompanying report are well advanced. These summarise present knowledge and are largely based on a hydrogeological interpretation of the geology linked with published and unpublished sources of regional information.

Activities in the groundwater sub-sector are reliant on external funds, particularly from Dutch aid. These have provided computing facilities, staff training, and equipment support as well as chemical, bacteriological, and isotope laboratories. Recent groundwater studies have concentrated on the important alluvial aquifers but the potential of the Nubian Sandstone Formation is now being studied in more detail as a possible source to combat desertification and to supplement surface water irrigation.

The collection of field data by the regional offices and analysis of information for the development and management of the groundwater resources on a national scale are hampered by a restricted recurrent budget. This has delayed the formation of a national monitoring network for both water levels and water quality, although a national network is being planned incorporating the few regional monitoring programmes. Agricultural and urban development may be causing a deterioration in shallow groundwater supplies and this needs to be evaluated.

About 100 water level recorders are available but the collection of routine data is restricted by lack of transport and fuel, limited staff training in the installation of equipment and by difficulties of access. Equipment facilities available to the regional offices also appear to be very inadequate for the collection of reliable data.

3.3.5. Uganda

Groundwater sources form an essential component of the rural water development strategy in Uganda. There are no major regional aquifers; some 90% of existing boreholes use weathered or fractured metamorphic rock aquifers, which occur extensively but mainly only yield supplies suitable for hand-pump rates of abstraction. There are about 7000 boreholes but spring sources, which are abundant, are also important sources of supply.

Only a small proportion of the rural population (perhaps less than 10%) have access to safe and reliable water supplies. Consequently, a high priority has been given by the Government of Uganda to the rehabilitation of existing sources and the development of new supplies. The rural water supply development programmes are supported by external funds, in particular by UNICEF. The need to provide many dispersed local water supplies tends to override the collection of routine scientific hydrogeological data, which is considered to be the responsibility of central government. The available data have been assessed mainly as to whether they can assist the planning of these development programmes.

Comparatively little work has been undertaken in Uganda to assess the groundwater resources, partly because of the local extent of the metamorphic rock aquifers but also because of abundant alternative supplies over a large part of the country, the type of water requirement, and as local recharge generally greatly exceeds the rate of abstraction.

The UNDP groundwater survey of Karamoja in 1968 remains the most detailed analysis of groundwater occurence and conditions in the metamorphic rock aquifers. However, a new study of such aquifers in southwestern Uganda by the Water Development Department with external assistance will provide

further important information and also includes training in field data collection techniques. The routine collection of groundwater data is constrained by shortages of staff, transport and equipment, although the situation is improving as the economy recovers and external funds obtained.

The borehole archive is located at Soroti which was inaccessible due to the security situation. It is understood to contain records on some 5000 boreholes. These are rather incomplete and of limited reliability, but are particularly deficient in drawdown data with which to assess aquifer characteristics. The records, together with information on water quality and springs, need to be transferred to a central computerised data system with appropriate application programs in order to support future well-siting programmes. We believe that the transfer and initial analysis of these data, together with support for the WDD and local staff training, would require an external consultant for a period of six months initially.

Literature on the hydrogeology of Uganda is relatively limited but a bibliography of some 60 references has been assembled. An important source of general reference is the Atlas of Uganda prepared in 1969 and now also available on the UNEP global environmental data base. These sources of information have been used to compile a hydrogeological map at a scale of 1:1,500,000. Whilst we believe that this map presents a useful summary of present knowledge, the available data do not permit a detailed quantitive assessment of the local hydrogeological conditions. Information on the coarse deposits which occur in areas of the Western Rift Valley is particularly lacking.

3.4 Sediment

Of the countries for which surface water investigations have been carried out in this study - Djibouti, Somalia, Sudan, Uganda - few recent sediment measurements are available, and these have been carried out by consultants in Sudan for specific projects.

A review of measurement requirements and network design has been based on published information including maps, and regional knowledge. It is proposed that networks should be concentrated on areas of steep relief and high rainfall, bearing in mind population densities and projected development of water resources and intensive agriculture. Such areas where erosion will present problems have been indicated using soil and physiographic maps and related to key river systems.

Existing sediment monitoring is at present concentrated in Kenya and Ethiopia, and relationships between sediment yield and basin size and yield have been derived in these areas. These relationships are used to put forward a conceptual framework for a network of sediment measurement sites, which requires greater understanding but should provide a more economical approach than a simple recommendation of a major extension to existing networks. Analysis of the factors causing sediment load based on information already collected would lead to a more rational network. Techniques for measurement of sediment and bed load, suitable for the conditions of the region, are also discussed.

4. CONCLUSIONS AND FUTURE PROGRAMME

4.1 Project Review

In those countries where it has been possible to work, the overall aims of the project are being achieved and excellent cooperation has been received from the respective authorities. Inventories of data are being compiled, their quality is being assessed by detailed study of samples and an overall view of data availability is being obtained not only within individual countries but also between different countries in the region.

Gaps in networks, in data processing methods and in publication are being identified and a number of detailed recommendations are being prepared. In the case of groundwater, the status of knowledge of the various aquifer characteristics is being examined through incorporation on hydrogeological maps.

4.2 Preliminary Recommendations

In the course of our studies a number of recommendations have been formulated for the improvement of hydrological data collection and analysis. Some of the more urgent of these recommendations have been included in this Interim Report, in advance of their presentation in final form, to give an indication of the findings of the project. These are presented in Annexes 1-7.

It will be noted that there is emphasis on computerisation of data collation and that rehabilitation of networks in Uganda is an urgent priority. Where possible, an indication of the cost of these recommendations is included, but in some cases, where for example a programme of multidisciplinary investigations is suggested, the scope and cost of the study will require detailed discussion and analysis.

4.3 Future Programme

For all the countries where it has been possible to work, analyses have been carried out and draft reports prepared. These are now being reviewed internally prior to finalisation. The report for Uganda depends on the completion of data processing. The hydrogeological maps for four countries have been prepared and are being successively handed to the mapping sub-contractor. It is planned to produce the final country reports for Uganda, Sudan and Djibouti by the end of November 1988, together with hydrogeological and hydrological maps.

It is now assumed that no work will be undertaken in Ethiopia but it is still hoped that it will be possible to commence work in Kenya in the near future.

ANNEXES

PRELIMINARY RECOMMENDATIONS

Annexe 1	Meteorology
Annexe 2	Hydrology:Djibouti
Annexe 3	Hydrology:Uganda
Annexe 4	Hydrology:Computer facilities and training
Annexe 5	Hydrology:Assistance to NRWC, Sudan
Annexe 6	Groundwater:Sudan
Annexe 7	Groundwater:Uganda

ANNEXE 1

Meteorology

Because the meteorological analysis is still in progress, our main recommendations for action are not yet formulated. However, we consider that there is a need for the WMO initiative in introducing the CLICOM system on a worldwide scale to be extended not only to meteorological services but also to other national organisations which acquire and archive rainfall and meteorological data for their own needs.

CLICOM is an IBM PC based management system for meteorological data and several African countries, including the Sudan meteorological service, already have such a system. Because other national organisations concerned with water resources and agriculture, for example will wish to operate their own networks and archives, they should be encouraged to use the CLICOM systems for their meteorological data.

It is recommended that a start should be made in one country - e.g. Uganda - to implement this recommendation. Financial provision would be needed for an initial consultation mission of 2 - 3 weeks; hardware, software and training; then a 6 month consultation mission plus the time of two trained local operators to enter the past data for all or selected stations. The cost could be about $100,000 per system per country.

Certain shortcomings of the present CLICOM system should be noted. There is a need for assistance to users in maintenance of the hardware. The system should have within it a suitable statistics package and a geographical information system.

ANNEXE 2

Hydrology: Djibouti

The surface water runoff of Djibouti is an important source of groundwater recharge, and it can best be measured by a small network of gauging stations. The present network of six sites was initially set up as part of a German aid programme. There is a need to extend the network and to improve the calibration of the present gauging stations by a programme of measurements. Although the measurement programme is being continued by ISERST, we believe that the expansion of the network and the improved calibration could best be expedited by assistance from a hydrological expert, possibly from Ruhr University, Bochum, where the original study was conceived. Because staff exist at ISERST, such assistance could be provided by periodic visits at relatively small cost. Equipment would be required to increase the network to the planned twelve stations. The installation of a computer and associated software may be necessary when the network is increased, but is not urgent in view of the small number of gauging stations and the short duration of flows.

ANNEXE 3

Hydrology:Uganda

We believe that there is an urgent need for assistance to the Hydrological Service in the Water Development Department of Uganda. The hydrological network in Uganda, first established by the Egyptian Government and then extended by the Hydrological Survey Department and subsequently by the Hydrometeorological Survey, was transferred to the national hydrological service in 1982. However, the network was virtually destroyed during the disturbances around 1979 and at present lack of equipment and transport means that the small amount of data being collected at present cannot be systematically calibrated. Furthermore, lack of computing facilities makes it impossible to process present and past hydrological records.

As an extension of the present project we have been able to establish that much of the past basic hydrological information - levels, discharge measurements - is still available in the office filing system and we believe that by processing the records for a selection of stations with the help of local hydrologists we are showing that it is possible to rehabilitate the records as well as surveying the requirements for rehabilitating the stations. However, it is clear to us that a sustained effort is needed to enable the Hydrological Service to reestablish the hydrometric network, process past and present data and contribute to water resources development within the country and through regional projects.

We believe that there is a strong case for introducing an experienced operational hydrologist as an expert to assist the Head of the Hydrological Service in preparing a detailed plan to rehabilitate the network in terms of stations and equipment, supervising its installation, and to plan and put into operation a computer processing system for past and present records.

In addition to the need for expertise there is a great need for instruments and equipment, data processing equipment and transport. This need applies not only to initial provision but also to maintenance of equipment in an operational state.

A problem specific to Uganda is that professional staff are paid extremely low salaries, and any project must take realistic account of this, possibly by means of allowances. For example, a gauge reader currently receives 24 Uganda Shillings per month, which is less than US $0.50 at the official exchange rate.

We believe that a duration of 2 - 3 years would be appropriate for the appointment of the hydrological expert, and a provisional estimate of costs is of the order of $100,000 per year, with equipment costs of the same order.

This does not include the provision of computer facilities and training, which is discussed in Annexe 4.

ANNEXE 4

Hydrology:Computer Facilities and Training

Introduction

Although water is a scarce resource throughout East Africa, there are great variations between countries in data collection, processing, archiving and publication. In some countries, such as Kenya, the responsible government departments have a body of trained technical staff and have access to computing facilities for data processing and storage. In Somalia two projects are currently underway to provide personal computers and staff training for the processing of both hydrogeological and hydrological data. In Uganda and Sudan, there is a clear need to provide improved computing facilities and staff training for the processing and archiving of data. The example of Somalia may provide a model for Uganda and Sudan. Until recent years the major problem was a lack of computing facilities. Although a number of organisations have been collecting rainfall, climate, river flow and hydrogeological data for many years, these data have not been processed in a consistent manner and checks on the quality and internal consistency of these data have generally not been undertaken. This is largely because of a shortage of trained technical staff, but the problem is compounded by the need to process and archive data by hand.

Modern personal computers are relatively cheap, are robust and reliable, and yet offer very powerful computing capabilities. When combined with suitable software packages, such computers are capable of carrying out all the data processing, archiving and publication of results for countries such as Somalia, Uganda and Sudan. Somalia in fact has two such computers, one within the newly formed National Water Centre (NWC), and a second within the Department of Hydrology of the Ministry of Agriculture.

The Institute of Hydrology, Wallingford has provided the software for both of the existing archives in Somalia, utilising the HYDATA and GRIPS software packages. HYDATA, designed for processing all types of hydrometeorological data, was originally conceived and developed for use in Somalia and first installed in 1982. It has subsequently been improved and expanded, and following its successful application in 16 other countries, the modified software is currently being installed on a new personal computer within the Department of Hydrology. Staff of the Department will receive further training in the application of the software. The GRIPS software was developed for the storage, processing and publication of all types of hydrogeological data. It was installed on a computer at the National Water Centre in November 1987 and preliminary staff training provided.

These software packages contain the full range of data processing and publication options required by hydrologists or hydrogeologists. The software is easy to use and staff with no previous computing experience can become proficient after two or three weeks training. Users do not need to understand either the computer operating system or the structure of the data files or programmes; the systems use a series of "menus" or lists of options from which users make selections.

Example Proposal for Uganda

During the study visits to Uganda, it became apparent that the present data collection and processing situation is far from ideal. Whilst the field and office staff are enthusiastic, a significant backlog of collected data currently awaits processing. Data processing and checking must be undertaken by hand and this system is both slow and error prone.

As an extension to the present studies, the backlog of data from 20 key stations are being processed using HYDATA and printouts of the computed discharges are being given to the appropriate authorities in Entebbe. Copies of all data will also be made available in computer compatible form on floppy disc. Whilst this work will be of considerable value, there still remains a significant backlog of data which requires checking, processing and publication.

It is suggested that an IBM compatible personal computer plus associated printer and plotter is required in Uganda in order to maintain the data processing and archiving. The computer should be provided with the HYDATA and GRIPS software packages (or similiar) together with a number of other standard software products such as a word-processor, spreadsheet and statistical package. The cost of such hardware and software (approximate only) is estimated to be

Hardware	
IBM PS-2 Model 70 Personal Computer or similar	
Dot-matrix printer (Epson or IBM)	
Hewlett-Packard HP7475A pen plotter or similar	
Miscellaneous sundries (paper, floppy-discs, plotter pens, cables, printout folders etc)	
Back-up power source	
	$ 17,000
Software	
HYDATA plus associated analysis software	
Word-processor (e.g. Wordstar, Word-Perfect)	
Spreadsheet (e.g. LOTUS 1-2-3, Quattro etc)	
Statistical software plus other utilities	
	$ 11,000
Contingency (to cover inflation, currency fluctations, unforeseen items etc)	2,000
OVERALL TOTAL	$ 30,000

It is suggested that some funding should also be provided for staff training. We believe that local training courses would be preferable to long term training assignments in either Europe or the U.S.A. Whilst individual staff undoubtedly benefit from such training, there is often only partial transfer of this training to colleagues on return to post. With a small number of staff, the relevant government departments very often cannot provide cover for staff overseas on training assignments and consequently a large backlog of work accumulates.

A better solution to staff training is believed to be that adopted in Somalia. Expert European or American staff with the requisite skills could be seconded to the Ministry of Water in Uganda for a period of months to work with local staff and to provide training. Such an approach avoids the problem of a backlog of work developing and ensures that not just one, but all staff receive training in the new computer skills. It is suggested that specialist expert staff should be provided, in addition to the hydrometric data collection expert (referred to above) who would be responsible mainly for the field programme. The specialist expert should be experienced in computers and office data processing. While the hydrometric field expert should be sufficiently familiar with the computer and associated software to provide continued training to staff, the computer expert should have a number of shorter inputs, of say three weeks to one month, and local staff should be left to undertake data processing and checking between such visits.

A preliminary cost estimate based upon 2 visits of 1 month by a computer specialist is $30,000.

Proposal for Sudan

There is a similar need for improved computer facilities in Sudan, both in the Sudan Ministry of Irrigation and in the National Rural Water Corporation. The discussion on data requirements for Uganda is in many ways applicable to Sudan, and the costs of facilities and training would be comparable. However, we feel that the need of Uganda for computer facilities is the more urgent, and we also believe that initial assistance to the National Rural Water Corporation should take the form of advice on flow measurement. This proposal is outlined in annexe 5.

ANNEXE 5

Hydrology: Assistance to NRWC Sudan

The National Rural Water Corporation (NRWC) of Sudan is responsible for the collection and processing of hydrological data for rivers that are not part of the Nile basin. The NRWC have a number of problems maintaining and processing data from the discharge measuring stations for which they are responsible. Comments on these problems will be discussed fully in the final report.

Because measuring flows in wadis and rivers in these arid and semi-arid regions of Sudan is difficult, the NRWC asked Dr. J.R. Meigh of the Institute of Hydrology, who undertook the field visit to Sudan, for advice on how the data collection procedure could be improved. Dr Meigh was able to give some preliminary advice, and has undertaken a literature review on this topic note will be incorporated in the final report. This note will be of necessity rather brief and is somewhat theoretical, because Dr. Meigh was unable to visit any of these remote stations. The problem seems to be worthy of more detailed study involving visits to representative stations and the provision of advice and training.

It is recommended that a visit should be made by an experienced hydrometric engineer to give advice on methods of flow measurement in wadis with sporadic floods. If necessary he should also prepare terms of references for a further more detailed programme of assistance. The cost of this visit would be relatively modest and is estimated to be $20,000 for 1.5 month visit.

ANNEXE 6

Groundwater:Sudan

The Groundwater Division of the Research and Water Resources Department of the National Corporation for Rural Water Development (NCRWD) is the organisation primarily responsible for the collection and analysis of hydrogeological information in Sudan.

Computerisation of groundwater data for a national archive, training of local staff at professional and technical levels, and the provision of equipment, are supported by external funding, in particular by a joint programme being undertaken with the Dutch. This support is directed at headquarters staff and facilities and to studies of selected areas. Major studies have been undertaken with assistance from external consultants in most areas in Sudan over the past 20 years.

Immediate support is required to strengthen the work being undertaken at a national level and to support data collection by the regional offices. Both aspects suffer from constraints in recurrent expenditure and long term improvements require that such expenditure is directed to best effect. The following recommendations are intended to indicate how this might be achieved.

(a) National Programmes

1. Water balance studies in three areas of different geology and recharge conditions selected to typify conditions over a much wider area. Each of these representative areas or catchments would be studied in detail with a high density data collection network for a minimum of two years and the results extrapolated to areas with similar conditions but with a low density network. A new multi-disciplinary team should be created within NCRWD for these studies, which would require appropriate levels of transport and hydrometeorological field equipment as well as computing facilities.

Priority areas would include the Gneiss Complex areas of Kordofan-Darfur and South Sudan. Training of field technicians in the installation of equipment and in data collection could be usefully included in such programmes.

2. A programme of borehole construction and testing to provide more detailed information on the aquifer characteristics of the major sedimentary formations and to provide a basic national monitoring network in conjunction with NRWDC research wells and regional networks.

3. Groundwater quality surveys to examine possible contamination of the shallow aquifers underlying the major agricultural areas and the main urban centres. Initially, this would be as reconnaissance surveys for problem identification with a view to carrying out more detailed studies in selected areas, such as Gezira and Khartoum, and for water quality monitoring networks. This will require support to the new NCRWD laboratory, the provision of field chemistry and sampling equipment and the means to undertake analyses for more unusual elements such as pesticides. Training should be included and the programmes could usefully involve cooperation with the University of Khartoum.

4. A national programme is required to prepare hydrogeological maps at a scale of 1:250,000 by grid square beginning with those areas having detailed information and economic importance, such as the major agricultural areas along the Nile. This will require new up-to-date topographical maps. A new mapping section within NCRWD could be established to carry out the routine preparation of these hydrogeological maps in an ordered priority. The national computerised archive, backed by improved plotting facilities and linked to remote sensing applications, could be used to prepare hydrogeological maps. This would also need to be supported by overseas training in the preparation of such maps and the application of modern techniques.

These recommendations are presented in general terms at this stage, and will be discussed in more detail in our final report. However, certain of the proposals, for instance where sites for water balance studies need to be selected, will require further investigations, preferably by a multi-disciplinary team, in consultation with national and regional staff.

ANNEXE 7

Groundwater:Uganda

The Hydrogeological Section of the Water Development Department is responsible for the collection and analysis of groundwater data. The level of staffing has been increased and external funds are supporting a new programme of work designed to assist well siting and overcome limitations of earlier data collection. There is still the need, however, to strengthen the Hydrogeological Section to enable WDD to fulfill its responsibilities and sustain the improvements that are being made. Recommended immediate needs are as follows:-

(a) Transfer all groundwater data (boreholes, springs, water quality) to a central, computerised system appropriate to the storage, analysis and presentation of such data. This should be based at Entebbe and should consist of at least the following hardware:-

IBM PS-2 Model 70 Personal Computer
Dot matrix printer (Epson or IBM)
Plotter to A3 size (Hewlett-Packard HP7475A or similar,
Back-up power source

In addition to hydrogeological software like GRIPS, commercially available software will be required to allow the analysis and presentation of spatial and time-varying data, word processing and spreadsheet applications. Three staff will need to be trained in the operation of the system.

It is important that this installation and training should be integrated with the hydrogeological proposals for Uganda. A nominal additional cost for training has been included.

(b) Appoint an external hydrogeological consultant for a period of initially six months to a year to provide support to the WDD, including the following duties:-

initiate and supervise the transfer of groundwater data to the computerised system and carry out preliminary statistical analysis appropriate to the planning of well-siting programmes.

assist the WDD to identify and prepare proposals that would attract external funding.

prepare a detailed inventory of the equipment and material needs of the Hydrogeological Section.

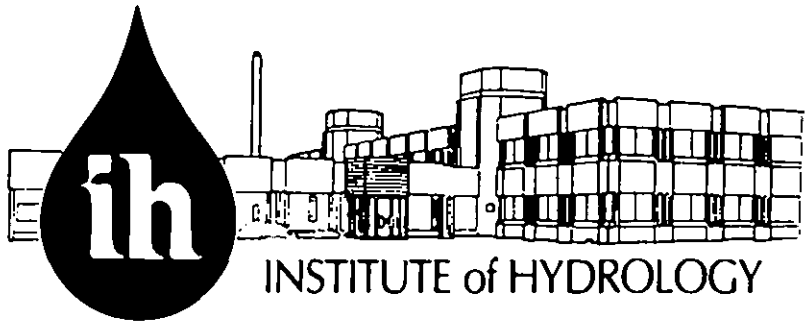
provide training to the hydrogeological staff.

Consideration should be given to attracting funds from a donor country to support longer-term programmes of training and technical assistance and to undertake groundwater studies linked to development priorities.

(c) The ongoing Mbarara study is providing valuable training in data collection techniques and project management. Nonetheless, it is recommended that senior staff should be given additional training in data analysis techniques relevant to the occurrence and use of groundwater in Uganda. It would be preferable for this training to be undertaken in the country as part of (b) above or in conjunction with Makerere University.

Preliminary Cost Estimates (£UK)

(a)Computing		
Hardware (including backup power source)		17,000
Software		10,000
Training		8,500
	Total	$ 35,000
(b) External Consultant		
(6-month period appointment)		$ 50,000 (fees only)
(c) Training (provisionally included in item (b)		



The **Institute of Hydrology** is a component establishment of the UK Natural Environment Research Council, grant-aided from Government by the Department of Education and Science. For over 20 years the Institute has been at the forefront of research exploration of hydrological systems within complete catchment areas and into the physical processes by which rain or snow is transformed into flow in rivers. Applied studies, undertaken both in the UK and overseas, ensures that research activities are closely related to practical needs and that newly developed methods and instruments are tested for a wide range of environmental conditions.

The Institute, based at Wallingford, employs 140 staff, some 100 of whom are graduates. Staff structure is multidisciplinary involving physicists, geographers, geologists, computer scientists, mathematicians, chemists, environmental scientists, soil scientists and botanists. Research departments include catchment research, remote sensing, instrumentation, data processing, mathematical modelling, hydrogeology, hydrochemistry, soil hydrology, evaporation flux studies, vegetation-atmospheric interactions, flood and low-flow predictions, catchment response and engineering hydrology.

The budget of the Institute comprises £4.5 million per year. About 50 percent relates to research programmes funded directly by the Natural Environment Research Council. Extensive commissioned research is also carried out on behalf of government departments (both UK and overseas), various international agencies, environmental organisations and private sector clients. The Institute is also responsible for nationally archived hydrological data and for publishing annually HYDROLOGICAL DATA: UNITED KINGDOM.