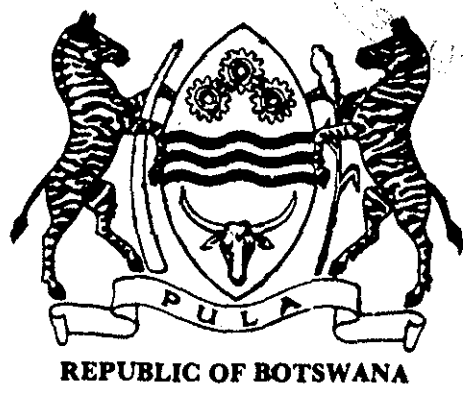


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ANNUAL REPORT

OF THE

GEOLOGICAL SURVEY

DEPARTMENT

FOR THE YEAR

1990

PRICE: P3,00



GEOLOGICAL SURVEY DEPARTMENT

(Director : T.P. Machacha)

ANNUAL REPORT
OF THE
GEOLOGICAL SURVEY DEPARTMENT
FOR THE YEAR
1990

Published by

*The Director
Geological Survey Department
Private Bag 14, Lobatse, Botswana.*

*With the authority of
The Ministry of Mineral Resources and Water Affairs
Republic of Botswana.*

1. GENERAL

The Geological Survey remained within the Ministry of Mineral Resources and Water Affairs and continued with its main functions of gathering, assessing and disseminating all data related to the rocks, mineral deposits and groundwater resources of Botswana.

The departmental organisational structure continued to consist of the Directorate, four operational divisions of Regional Geology, Economic Geology, Hydrogeology and Geophysics together with an administrative division. Support to the main divisions was provided by the Drawing Office, Technical Records and Library, Chemistry and Mineral Dressing laboratories.

The staffing position within the department was not satisfactory. The two posts in the Records and Library Section continued to be vacant. Dr. Norman Lock resigned from the Civil Service at the end of his local contract. Drs. R. Kreimeyer and M. von Hoyer left the department at the end of December, 1990. Their posts were localised in January, 1990, but they stayed on as advisors until the end of the year.

Mr. John Dowsett who had been holding the two posts of Deputy Director and Principal Geophysicist resigned the former post to concentrate his duties on the latter as per agreement with CIDA as from August, 1990. This post was still vacant at the end of the year.

Within the Economic Geology division work continued to be directed towards the evaluation and review of industrial minerals occurrences. A study on the potential precious metals mineralisation associated with copper-nickel deposits at Selebi-Phikwe and elsewhere continued. Work on the compilation of a monograph on gold deposits in Botswana was started during the year.

Mineral exploration by the private sector continued at a high level throughout the year. Two hundred and sixty prospecting licences and one reconnaissance permit were in force at the beginning of the year. During the year two were converted to mining leases and twenty-five were terminated, relinquished or surrendered. Fifty-seven new licences were issued during the year so that by year end, there were two hundred and ninety active prospecting licences. Two hundred and twenty-three of these were for precious stones, fifty-three for base and precious metals and fourteen for others.

Within the Hydrogeology Division a number of groundwater investigation projects were started, some after long delays. These include Letlhakeng-Botlhapatlou, phase II of the Mmamabula groundwater project and the programme of TGLP Groundwater surveys. The Letlhakeng-Botlhapatlou project began in February, 1990 and has a duration of eighteen months. Work on the other projects involved preparation of tender documents which meant that the contracts would be awarded in 1991. The Matsheng Area Groundwater Investigation project has been shelved due to manpower constraints. The contract for the Borehole Records Archive and Data Base project was awarded early in the year and started in July with a duration of eight months.

Projects carried out within the Hydrogeology Division include reassessment of the Seleka Wellfield groundwater resources, the evaluation of the groundwater resources within the Kanye Northern Wellfields and the interpretation of SPOT imagery from northwest Ngamiland.

Research into groundwater recharge mechanisms continued as a joint venture with the University of Botswana and the Free University of Amsterdam.

In the Regional Geology Division a volume of data appendices was published to accompany Bulletin 23, the geology of the Molopo Farms Complex. The geological maps to accompany Bulletins 33 (Kanye) and 35 (Shashe) were sent to the printer but had not been printed at year end. Bulletin 36 describing the geology of the Metlobo and Mabule areas was being printed as the year ended.

Mapping projects were carried out in three areas; Magogaphate (QDS 2128C), Mosetse (QDS 2026D) and Ghanzi (QDS 2121B,C,D and 2122A,B,C). The last conducted jointly by the department and the West German Geological Survey (BGR) under an intergovernment technical cooperation agreement.

The results of geological mapping in the Mmamabula-Dibete (QDS 2326C,D) Marico River (QDS 2426B) and Topisi (QDS 2226A) areas are currently being prepared for publication.

In the Geophysics Division two foreign aid projects continued in 1990. A PetroCanada International Assistance Corporation (PCIAC) supported stratigraphic drill hole in the Nosop Basin of western Botswana which started in 1989 was completed in April. Field geophysical data were collected to provide information for a Groundwater Geophysics Methodology Handbook.

Work began on a major project to produce a catalogue of the geophysical signatures of kimberlite and lamproite pipes in Botswana and a considerable amount of time was spent on professional consultation to the Hydrogeology Division on groundwater evaluation projects.

One CIDA project, the localisation of the Geophysics Division, continued throughout the year. Under this project, CIDA seconds Canadian geophysicists to the Geological Survey Department while Botswana students continue to pursue degree and post graduate degrees at various Canadian institutions.

5. HYDROGEOLOGY DIVISION

5.1 Introduction

The Hydrogeology Division is charged with responsibility for the investigation and exploration of the groundwater resources of the country as well as for carrying out applied research intended to advance groundwater science in Botswana. The exploration of groundwater resources involves the assessment of their potential for development and utilisation with water quality being of prime importance. The research projects are undertaken within the Division or as technical cooperation joint ventures with the University of Botswana and overseas institutions. Detailed research studies include the understanding of recharge phenomena in our semi-arid climate, regional groundwater flow and its chemical evolution and investigations involving the application of remote sensing to hydrogeological studies.

A further major responsibility of the Division is to gather data on groundwater levels from established monitoring networks, to monitor water abstractions and water quality evolution and to receive borehole data and water samples from both government and privately drilled boreholes. All this information is stored in the National Borehole Records Archive and Groundwater Computer Data Bank. Rock chippings from water borehole drilling are held in the Core and Sample Store. To deal with the large back log of data which has accumulated over the years the Division engaged a consultant whose major task has been to update the National Borehole Archive Data base.

As in previous years, training and localisation remained a central concern. This involved specialist training at overseas institutions on, for example, groundwater modelling; basic courses offered at the University of Botswana in geology and hydrogeology as well as attendance of introductory computer courses offered by the Institute of Development and Management.

The long-term divisional support from BGR, Germany, was concluded towards the end of the year when Dr. von Hoyer, who had been acting as Adviser to the Division, completed his contract and returned home. Hydrogeological support from other organisations in particular SIDA and ODA continued throughout the year.

The posts of Principal and Senior Hydrogeologists were localised early in January with the appointment of Mr. E. Selaolo and Mr. P. Phofuetsile respectively. Mr. M. Morosini joined the Department in March as a project hydrogeologist from Sweden and in July Mr. K. Mokokwe joined the Department after graduating from the University of Botswana. A Technical Trainee, L. Keareng, was recruited in late February while G. Gabaake, hydrogeologist, left the Department on transfer to the Department of Water Affairs in early September.

5.2 Development Projects

5.2.1 *Evaluation of Underground Water Resources (GS10).*

5.2.1.1 Letlhakeng - Botlhapatlou Groundwater Investigation Project (GS10).

Project duration: 15th February, 1990 to the 30th August, 1991.

Total project cost: Pula 6.161.992.

Consultant: Bureau de Recherches
Geologiques et Minieres
(BRGM), Orleans, France.

Drilling Contractor: Geotest (Pty) Ltd., Gaborone.

Commencement of project: 15th February, 1990.

This project officially commenced on the 15th February, 1990 after long delays in the signing of the financial package between the French and Botswana governments. Although the drilling programme which was scheduled to commence at the beginning of August, was delayed by three weeks, the project was almost on schedule by the end of the year.

The Consultant has implemented regional geological and geophysical studies as well as more detailed ground geophysics. The geophysical siting programme has concentrated on distinct targets such as significant fractured zones caused by block faulting of Karoo rocks into horst and graben structures. Some boreholes have been sited in undisturbed areas. Preliminary results from the drilling activities indicate that the highest yielding boreholes are located on the step faulted zones between horsts and graben where fractured coarse and medium sandstones within the Mmamabula formation of the Ecca Group have been encountered.

Costs for the consulting services are funded from a soft loan and partly as a grant from France to Botswana.

5.2.1.2 TGLP Groundwater Potential Survey (GS03)

The Tribal Grazing Lands Policy (TGLP) was formulated by Government in 1975 with the intention of allocating specific areas of land to be developed and utilized for commercial or semi-commercial cattle ranching. The policy sought to conserve the range resources of the nation whilst encouraging greater productivity in the livestock sector and a more equitable distribution of income.

Large tracts of land have been allocated as ranches in many districts but the demarcation of ranches has been based primarily on land availability and rangeland carrying capacity with too little cognisance of the need for adequate supplies of good quality water. As a result, there is a growing reluctance amongst cattle farmers to take up TGLP ranches in regions where water supply may be difficult to obtain and, in some areas, considerable development capital has been lost.

In order to revitalise the TGLP programme, Government has instigated a series of projects designed to examine the groundwater potential of designated TGLP areas prior to land allocation. The implementation of these groundwater studies has been hampered by the shortage of professional hydrogeologists. Only in March, 1990, when the Geological Survey recruited a project hydrogeologist from Sweden, did it become possible to initiate studies of the TGLP area southeast of Toteng in Ngamiland District and to prepare terms of reference for a commercial consultancy.

The project area is underlain mainly by metasedimentary and metavolcanic strata belonging to the Upper Proterozoic Ghanzi Group which is largely obscured by variable thicknesses of Kalahari sands, clays and calcretes and, in the east of the area, by the lacustrine and alluvial deposits of the Makgadikgadi.

The Toteng/Sehitwa consultancy is scheduled to commence early 1991 and will be carried out within a period of sixteen months for a total estimated cost of about P4 million. Implementation of the other TGLP areas which include the areas north of Middlepits, southeast of Ghanzi and Tshane will depend on the recruitment of additional hydrogeologists.

5.2.1.3 Matsheng Area Groundwater Investigation (GS10)

This project is presently dormant because no manpower is available for its implementation. Nonetheless there are four ranch zones within the Matsheng area for which the groundwater potential has to be assessed. This project will be an integrated study examining not only groundwater resources but the potential for forestry and horticultural activities thus enabling a better land use programme to be prepared.

The project was offered to donor agencies and in August 1989 DANIDA expressed an interest in funding the project. Long delays in the negotiations between DANIDA and the Botswana government have been experienced and the project will most likely be taken up during the course of 1991.

5.2.1.4 Mmamabula Groundwater Investigation Project, Phase II, Khurutshe Area (GS10).

The consultancy for this project went to tender in June and tender documents were received from five international companies by the end of September. The project will investigate the groundwater resources potential of the country around Dibete. It is scheduled to commence in the first quarter of 1991 for a period of two years. The total estimated project cost is P10 million.

5.2.2 *Groundwater Resources Monitoring and Recharge Studies (GS04)*

5.2.2.1 Groundwater Recharge Evaluation Study.

Project duration: July 1987 to December 1990 (including a 6 months extension).
Total project cost: Pula 766 000

This project is carried out as a joint venture between the Geological Survey Department, the University of Botswana and the Free University of Amsterdam. The project has been designed and implemented in order to investigate the mechanisms of water replenishment to the aquifers of eastern Botswana. A report on the findings of the investigations was compiled during the second half of the year and will be completed during the first quarter of 1991. Preliminary results indicate that recharge does take place within the groundwater basins that have been investigated i.e the Pitsanyane/Nnywane basins, Molepolole east and the Kanye wellfields. Different recharge routes - river bed infiltration, diffuse infiltration and through-flow from colluvial fans - have been identified in the Pitsanyane/Nnywane basins while in the Molepolole and Kanye catchments the predominant recharge mechanism is diffuse infiltration. For further details refer to the list of publications.

The financial assistance for this project has been largely provided by the Dutch government while some domestic development funds have been used to cover the balance.

5.2.2.2 Groundwater Resources Monitoring.

Project duration: August 1987 to March 1991.
Total project costs: Pula 566 000.
The project is financed from domestic development funds.

The Pitsanyane/Nnywane monitoring network was expanded by the drilling of 5 monitoring boreholes, by the Geological Survey and a further 11 boreholes, including production wells, by Water Utilities Corporation.

5.3 Departmental Groundwater Exploration projects

5.3.1 *Groundwater Potential Assessment in the Waterberg North of Molepolole.*

The cored borehole near Medie was abandoned at a depth of 669.85 metres after the drill bit was lost in the hole. The last cores recovered are of coarse sandstones and conglomerates of the Gagobakwe formation (Waterberg Group). The Regional Geology and the Hydrogeology Divisions will prepare a full log of the borehole and a short technical report.

5.4 Groundwater Basin Monitoring

Water level fluctuations, water abstraction, water quality changes, precipitation and rainwater chemistry were recorded monthly in the following groundwater basins: Serowe wellfield, Palapye wellfield, Malotwane wellfield northwest of Mochudi, south of Mochudi, Molepolole east wellfield, Metsemotlhaba valley, Ramotswa wellfield, Nnywane-Pitsanyane wellfield north of Lobatse, Kanye wellfield. Monitoring in connection with pollution prevention was carried out in the Lobatse sewerage treatment plant area. Each month, water levels were recorded from 200 observation boreholes and 57 production boreholes.

No new monitoring networks were introduced during the course of the year. Installations in the networks now comprise a total of 30 automatic water level recorders and 18 automatic rain gauges.

5.5 Borehole Records Archive and Data Base, Drill Sample Store

During the year, work concentrated on the input of additional data into the expanded data base and considerable progress was made in the incorporation of borehole data for additional map sheet areas. The index map shows the status of data computerisation at the end of 1990.

During 1989 it became evident that the small staff in the Borehole Records Archive would take years to complete the input of borehole data and achieve country wide coverage of borehole location maps. Meanwhile requests for readily available hydrogeological data are increasing from both government and the public. For these reasons it was decided to employ a consultant to assist with the completion of the data base. The overall objectives of the project are to provide new borehole location maps for areas of the country where they are currently not available; to update existing maps; to update existing computerised data and to complete the input of borehole and water chemistry data to the National Archive Database. This project started in July 1990 and is scheduled for completion in February 1991.

During the year 242 private boreholes and 108 government boreholes were registered. The decrease in the drilling of government boreholes from previous years is a result of the ending, around April 1990, of the Consolidated Emergency Programme, which was implemented by Department of Water Affairs.

Drill samples continued to be received at the Drill Sample Store. Samples were filled into containers, labelled and listed. At the end of the year the core shed contained 103 536 samples from private boreholes and 150 886 government borehole samples.

5.6 Consulting Services for Government and the Public, Membership on Committees and Boards

Professional advice has again been provided to the Public. Consultants have made extensive use of the Borehole Records Archive, largely in connection with the setting up of data bases for the various districts, groundwater exploration projects and the National Water Master Plan Study. The following government institutions received consulting services.

- Department of Water Affairs: Input to the National Water Master Plan Study. Geological Survey chaired the Sub-Committee Groundwater Resources throughout the year. Assistance with the supervision of the Molepolole-Mochudi Groundwater Exploitation Project continued at a low key.
- Ministry of Local Government and Lands: Hydrogeological advice has been given in connection with the Self-Help Environmental Programme-Pit Latrine Construction. In

consideration of water resources quality protection recommendations for the construction of pit latrines have been prepared for Chadibe, Gambule, Jackalas II, Mambo, Mapoka, Mathangwane, Matsiloje, Molepolole, Nlaphwane, Tati Siding, Tlhalogang and Zwenshambe.

- Ministry of Industry and Commerce: A pre-feasibility study continued to investigate geological and hydrogeological factors related to the possibility for underground storage of mineral oil near Gaborone.

- Water Apportionment Board: Geological Survey is a board member. Technical advice was provided, in particular with the control of wellfield monitoring at Jwaneng, Orapa, Paje, Seleka Farm and Ramotswa.

- Lobatse Sewerage Scheme: An assessment was carried out of the potential pollution hazard near the Lobatse Treatment Plant area as a result of uncontrolled disposal of sewerage.

- The Geological Survey has been a member on the following project steering groups: "Okavango Integrated Water Resources Development" (DWA), "Consolidated Water Supply Emergency Programme" (DWA), "National Water Master Plan Study" (DWA), "Ramotswa Wellfield Operation Procedure and Monitoring" (WUC). It is also represented on the "Interministerial Water Supply and Sanitation Committee" and the "Debswana Water Supply Committee".

5.7 Hydrogeological Research Programmes

In addition to the Groundwater Recharge Evaluation Study being conducted jointly with the University of Botswana and the Free University of Amsterdam (see section 5.2.2.1) the following research projects were undertaken:

5.7.1 *Seleka Wellfield - Reassessment of Groundwater Resources*

This project, which started in October 1989, continued throughout the year. The main project objective is to develop a computer groundwater model for the Seleka Farm aquifer: aquifer geometry will be studied; an attempt to simulate aquifer response to different abstraction scenarios will be made and an investigation into the impact of irrigation on groundwater flow and water chemistry will be carried out. Throughout the year the project concentrated mainly in establishing a monitoring network, literature search, carrying out of geological and geomorphological field mapping activities. It is planned that this work will be compiled in the form of an MSc. thesis by Mr. G. Nkala.

5.7.2 *An Evaluation of the Groundwater Resources within the Kanye Northern Wellfield*

The presently operating Kanye wellfield is situated within a valley near Dinaka Hills west of Kanye village. The northern catchment in which the wellfield is located, is believed to be the extreme northern part of the main dolomite complex south of Kanye. Recharge mechanisms and hydraulic characteristics within the northern catchment and their relationship to the main dolomite complex are still not fully understood. It is thought that the replenishment to the main aquifer comes from the Waterberg rocks of the Dinaka Hills but the lack of information between the northern and main dolomite complexes prohibits any firm conclusions to be drawn concerning hydraulic continuity and replenishment mechanisms. Indeed, the northern catchment could be independent of the main dolomite aquifer. This project is designed to address these problems. During the later part of the year the project concentrated on establishing a monitoring network and fieldwork involved soil sampling, geophysical surveys and familiarisation with the project area. The project is designed as MSc. training for Mr. K. Mokokwe.

5.7.3 *A Summary Report on the Interpretation of SPOT Imagery from Northwest Ngamiland, Botswana.*

This brief report, by Gabaake, continues his earlier work compiled in an MSc. thesis entitled "A report on an investigation of the hydrogeological and hydrochemical conditions in northwest Ngamiland". The report involves the use of SPOT imagery for hydrogeological investigations within an area of approximately 26 000 km² in northwestern Botswana. The conclusions from this report are that: (a) groundwater occurrence in the area investigated is below the root zone and hence has no influence on the vegetative growth, (b) the vegetation cover distribution gives some ideas about soil type, salinity and drainage pattern and hence could be considered useful in soil mapping, (c) the Kalahari sand cover in the bulk of the investigation area effectively obscures bedrock geology and tectonic structures, and (d) it is quite clear that the Okavango Delta has developed through a number of stages and that they may have been significant breaks in time between the development of some of the stages.

It is also concluded that the groundwater occurrence and, in particular, its flow behaviour is complex and there is a need to launch a more rigorous and systematic investigation if we are to understand the complex hydraulic behaviour of the Delta's groundwater resources.

5.8 Staff and Staff Training

5.8.1 *Staff Assignment and Movements*

Dr. M. von Hoyer who acted as Adviser to the Division during the course of the year, returned to BGR, Hannover, Germany on the 15th November, 1990 at the end of his contract.

Dr. von Hoyer came to Botswana in 1982 under a technical cooperation agreement between BGR and the Geological Survey and was the Principal Hydrogeological from 1982 to 1989. He reorganised the Hydrogeology Division, started an intensive training programme and was instrumental in the advancement of water science in Botswana. His services are indeed greatly acknowledged.

The posts of Principal Hydrogeologist and Senior Hydrogeologist were localised in January 1990 by E.T. Selaolo and P. Phofuetsile respectively. G. Gabaake who returned from the University of London late 1989 after successfully completing his MSc. studies transferred from the Geological Survey to the Department of Water Affairs in early September. G. Nkala continued his research work on the Seleka Farm aquifer. Further academic training at an overseas university is planned for late 1991. K. Mokokwe joined the Hydrogeology Division on the 6th July, 1990 and received training in the Kanye groundwater resources evaluation project. Further overseas training will most likely take place during 1992. M. Morosini (SIDA) joined the Hydrogeology Division on the 27th March 1990 and has been responsible for the planning and implementation of the TGLP project southeast of Toteng/Sehitwa. Further planning of the TGLP potential surveys is envisaged during 1991 and thereafter. H. Timje (SIDA) continued his contract as hydrogeologist with work mainly in connection with project planning and supervision. His contract has been extended by one year to the 31st January, 1992. R. Hargreaves (ODA) has been in charge of the groundwater monitoring programme; in addition, she has been in charge of the guidance and supervision of the consultants engaged for the Borehole Archive Project. There are indications that she will be willing to extend her contract once again in order to set up the National Monitoring Network Unit. T. Kgole, Technical Officer, has been responsible for the Borehole Records Archive, Data Base and Drill Sample Store. To this Unit were also assigned the Technical Assistants B. Mohamadi and N. Ramotsoko, the Senior Administration Assistant, J. Marks and the Senior Technical Assistant, T. Ntesang. The following Senior Technical Assistants continued the routine groundwater monitoring programme within the established national network as well as in the Groundwater Recharge Evaluation Study: J. Keakile, K. Leetile. Technical Assistants J. Setlhomo, N. Ramotsoko and J. Phiri and the Trainee L. Keareng, who joined the

Hydrogeology Division on the 28th February, 1990, have also been involved in monitoring activities.

5.8.2 Staff Training

Mr. G. Nkala continued his research project on the Seleka Farm aquifer under the guidance of Dr. von Hoyer. He also attended an international course on "Modelling for Groundwater Management" in Delft, The Netherlands, from the 20th August to the 30th September, 1990.

K. Mokokwe was introduced to the Kanye project and will receive training under the guidance of E.T. Selaolo.

A. Mogotsi completed his academic training in geotechnical engineering at Sir Sandford Fleming College, Canada in June and is now receiving further training in the Letlhakeng/Botlhapatlou Groundwater Investigation Project together with L. Keareng. N. Ramotsoko is receiving practical training in the Molepolole-Mochudi Exploitation project. He also attended an IDM course in Data Base III PLUS. Further academic training at an overseas institution is planned for late 1991. J. Setlhomu and L. Keareng attended the course "Basic Groundwater" from the 21st May to the 3rd August, 1990 at the University of Botswana financed by the European Community.

5.9 Reports and Publications

During the course of the year a number of reports and publications were prepared mainly as a result of the research investigations from the Groundwater Recharge Evaluation Study:

Gieske, A. and de Vries, J.J. 1990. Note on the analysis of moisture-depth curves obtained by the hot air method for the determination of soil moisture diffusivity. J. Hydrology 115, 261-268.

De Vries, J.J. and Gieske, A., 1990. A simple chloride balance routing method to regionalise groundwater recharge: a case study in semi-arid Botswana. Int. Symp. on Regionalisation in Hydrology, IAHS, Yugoslavia, April 23 - 26.

Gieske, A., Selaolo, E. and McMullan, S. 1990. Groundwater recharge through the unsaturated zone of southeastern Botswana: a study of chlorides and metal isotopes. Int. Symp. on Regionalisation in Hydrology, IAHS, Yugoslavia, April 23 - 26.

Gieske, A. and De Vries, J.J., in press. Conceptual and computational aspects of the mixing cell method to determine groundwater recharge components. J. Hydrology

Van der Lee, J., Gieske, A. and Gehrels, J.C., 1989. "Earth": Extended Lumped Parameter Model to Simulate Aquifer Recharge and Moisture Transport in Semi-arid Conditions. GRES Report. University of Botswana in collaboration with the Geological Survey and the Free University Amsterdam.

Gehrels, J.C. and Van der Lee, J., 1990. Rainfall and recharge: A critical analysis of the atmosphere-soil-groundwater relationship in Kanye, semi-arid Botswana. GRES report. University of Botswana in collaboration with the Geological Survey and the Free University Amsterdam.

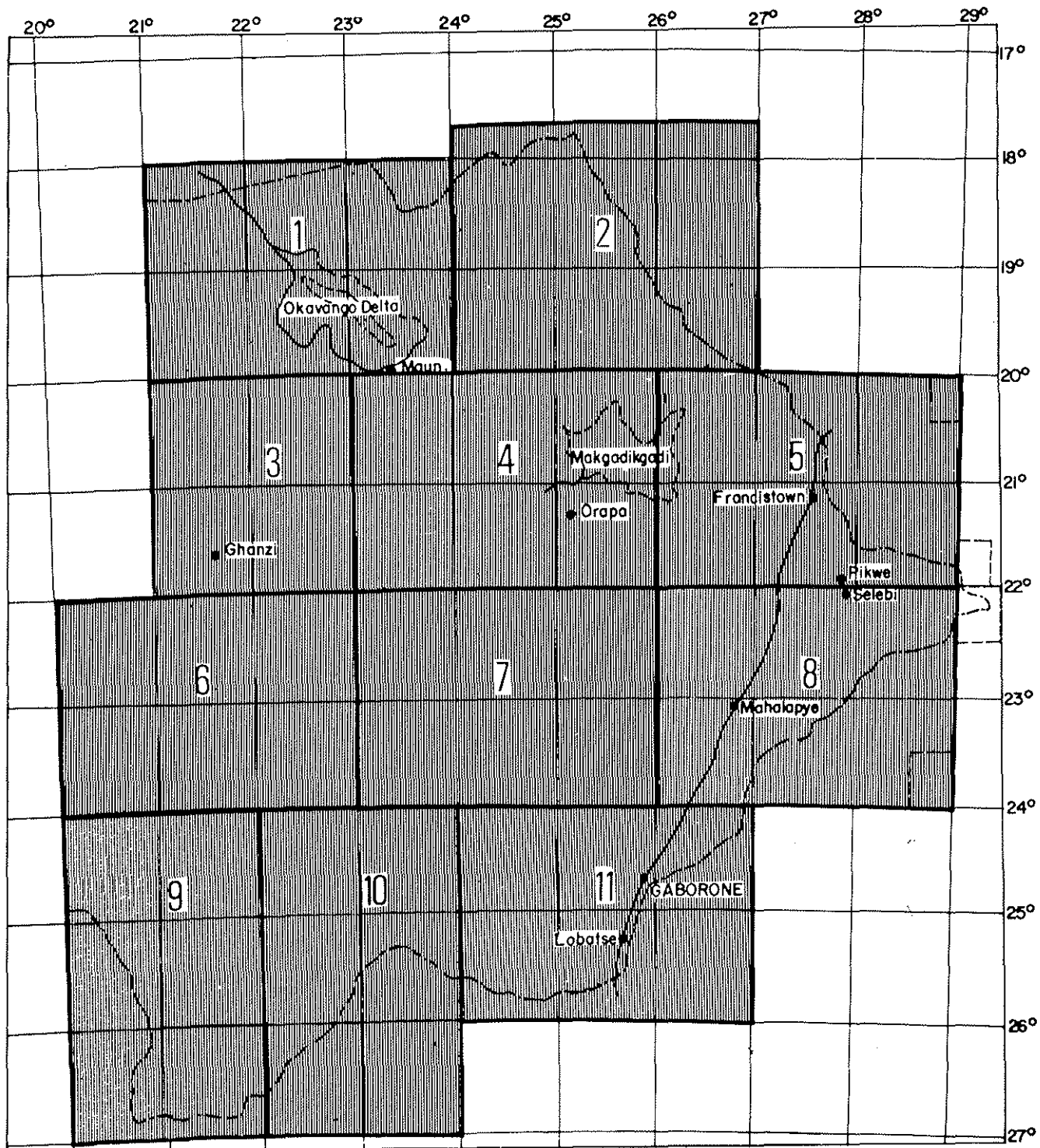
Sloots, R.R. and Wijnen, M.M. 1990. Groundwater recharge to a fractured aquifer in SE Botswana: Results of a survey of the Molepolole-East Wellfield. GRES Report. University of Botswana in collaboration with the Geological Survey and the Free University Amsterdam.

Spaans, S. and van Haren, I., 1988. Aspects of recharge in a small basin in SE Botswana. GRES Report. University of Botswana in collaboration with the Geological Survey and the Free University, Amsterdam.

Gieske, A. and Selaolo, E.T., 1990. A study of deep moisture infiltration in southeastern Botswana by means of soil moisture balance, chloride and environmental isotope methods. First scientific conference. SADCC Land and Water Management Research Programme. Gaborone, 8 - 10 October, 1990.

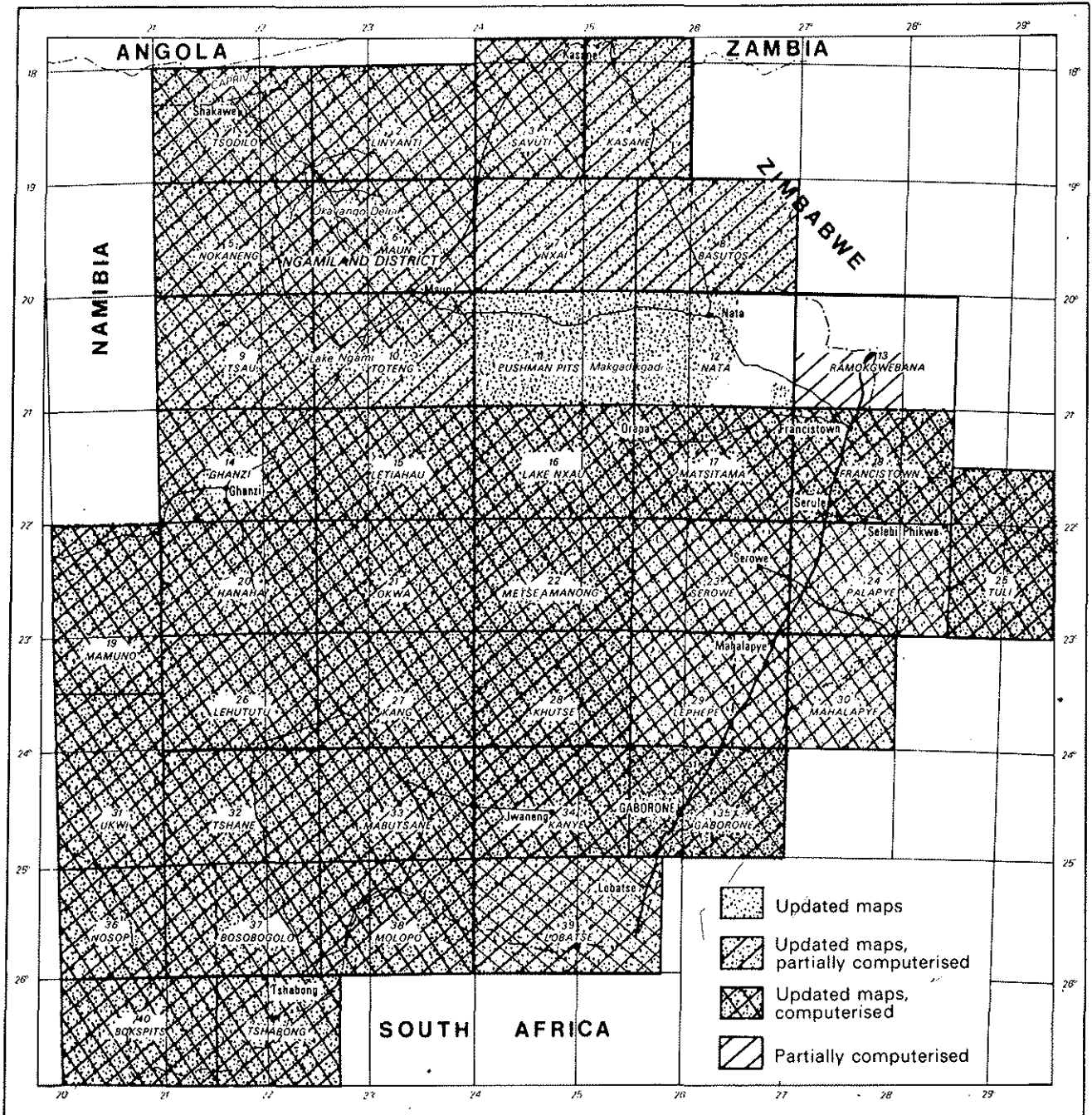
Phofuetsile, P., 1990. Hydrochemistry of the groundwater of the Kalahari - Southwestern Botswana. International Conference on Groundwater in Large Sedimentary Basins. University of Western Australia. 9 - 13th July, 1990.

HYDROGEOLOGICAL RECONNAISSANCE MAP OF THE REPUBLIC OF BOTSWANA
AT SCALE 1 : 500 000
SHEET INDEX

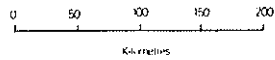


GEOLOGICAL SURVEY DEPARTMENT

PROGRESS IN COMPUTERISATION OF HYDROGEOLOGY WELL RECORDS AS AT 1.1.91



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6. GEOPHYSICS DIVISION

6.1 Summary

Two foreign aid projects were continued in 1990. A Petro-Canada International Assistance Corporation (PCIAC) supported stratigraphic drill hole in the Nosop Basin of western Botswana was started in 1989 and completed in April 1990, and field geophysical data were collected to provide information for a Groundwater Methodology Handbook.

In addition, work was started on a major project to produce a catalogue of geophysical signatures over kimberlite and lamproite pipes in Botswana and a considerable amount of time was spent on professional consultation to the Hydrogeology Division on groundwater evaluation projects.

6.2 Staff

Management and direction of the Geophysics Division continued to be supplied by three Canadian geophysicists provided by the Canadian International Development Agency (CIDA) under project No. 200/11011. This project terminated in mid-1990 but agreement was reached for a second phase (CIDA project No. 200/15360), again of five years duration, to commence on the first of June, 1990.

In May 1989 K. Mosikare completed a three year technology course in geological engineering at Cambrian College in Canada. In May 1990 he successfully completed the third year of a three year technology course in geophysics at the same College and assumed duties in the Geophysics Division. At year end the geophysics staff (excluding the Canadians) consisted of, 5 geophysicists, 4 technicians, 1 technical assistant, field assistants and drivers.

At the end of the year an electrical engineer (C. Smit) was in his final year of a B.Sc. at Memorial University in Canada and is expected to join the Geophysics Division in May 1991.

6.3 Development Projects

6.3.1 *Stratigraphic Drill Hole - Western Botswana*

A stratigraphic drill hole, designed to help assess the petroleum potential of Botswana, was started in November 1989 and completed at a depth of 4007 meters, on 14th April 1990. The hole was jointly funded on a 50/50 basis by PCIAC and the Government of Botswana the final cost being about 28 million Pula.

The hole was located about 95 kilometres west-north-west of Hukuntsi. The site was chosen on the basis of a detailed interpretation of the 1987/88 PCIAC reflection seismic survey with the objective of revealing as much pre-Kalahari geology as possible. During the drilling of this hole a Vertical Seismic Profile survey was carried out under the supervision of Geophysics Division staff; A report on this survey was produced.

All data and reports on the stratigraphic hole and the 1987/88 PCIAC seismic survey are classified as confidential; However, on 17th December 1990 Cabinet decided to make the data and reports available for purchase by the public.

6.3.2 *Airborne Electromagnetic Survey - Magogaphate Area*

The European Community funded an airborne electromagnetic and magnetic survey in the Magogaphate area of northeastern Botswana to aid in the exploration for metallic mineral deposits.

The survey was contracted to Compagnie Generale de Geophysique (CGG) of Massy, France, using the GEOTEM EM system. The Geophysics Division provided logistical support and monitored data quality during the survey.

CGG completed flying the GEOTEM survey in November 1989, and final reports were released to the private sector in September 1990.

The GEOTEM survey identified several electromagnetic and magnetic anomalies which could indicate metallic mineralization. Private sector exploration activities were stimulated so that the entire survey area is now held under reconnaissance permits and prospecting licences.

6.3.3 Professional Consultation to Hydrogeology Division

A considerable amount of time was spent on professional consultation and advice to the Hydrogeology Division in connection with groundwater evaluation projects. The projects included Molepolole-Mochudi, Letlhakeng-Botlhapatlou, Mmamabula Phase II, the Tribal Grazing Land Project, the Groundwater Recharge Evaluation Study, and a few smaller projects.

6.3.4 Groundwater Methodology Handbook

A two and a half year project funded by the CIDA with input from the Geophysics Division of the Geological Survey was initiated in 1989. The objective of the project is to produce for hydrogeologists and technicians a handbook which assesses the use of geophysics in the search for groundwater resources in the semi-arid portions of southern Africa. The handbook will be based on case histories developed in Botswana.

A considerable portion of the resources of the Geophysics Division were devoted during June, July and August to collecting field geophysical data for this project. Data were collected over previously existing boreholes in the Kopong, Sirinane, Kgagodi, Tshane and Ghanzi areas.

6.3.5 Ghanzi/Chobe Project

The majority of the resources of the Geophysics Division were devoted to collecting magnetic, electromagnetic and spectrometer data in the Toteng, Kuke and Ghanzi areas to support geological mapping and mineral exploration being carried out within the technical cooperation project operated jointly by the GSD and the West German Geological Survey (BGR). Project activities are described more fully in section 7.2.3. below.

6.4 Internal Projects

6.4.1 Kimberlite Methodology

The purpose of this project is to compile an atlas of geophysical signatures of various types of kimberlite and lamproite pipes in Botswana. Such a reference would assist in the exploration for precious stones in Botswana. To date all company reports have been examined and field work has been carried out over five kimberlites in the Jwaneng area and three lamproites in the Mabuasehube area. Various geophysical techniques have been used including magnetics, gravimetrics, electromagnetics, resistivity and radon emanometry. Results indicate distinct gravity, magnetic and radon responses. The results from the Jwaneng area were presented at the European Association of Exploration Geophysicists annual meeting in Copenhagen. This work, which will continue in 1991, is being carried out in collaboration with Molopo Botswana (Pty) Ltd.

6.4.2 Mabuasehube Gravity Survey

The 1972/73 National Gravity Survey revealed a strong but poorly defined gravity low (40

The Principal and Senior Chemists attended meetings with staff of the Hydrogeology Division (Department of Geological Survey), Hydrogeology and Chemistry Laboratory divisions (Department of Water Affairs) intended to improve co-operation and to reduce the duplication of work between GSD and DWA laboratories.

During 1990, the Chemical Society of Botswana was formed with the participation of professional staff of the Chemistry Laboratory. The Senior Chemist was nominated to be a member of the advisory committee of the Chemistry Department of the University of Botswana and attended its first semi-annual meeting in September.

The Senior Chemist attended a seminar entitled "Studies in Water Pollution in Botswana and the Principal Chemist attended a seminar entitled "Chemical Studies of seed oils of Botswana". Both meetings were organised by the Chemistry Department of the University of Botswana.

8.1.6 *Assistance to projects*

8.1.6.1 Groundwater Recharge and Evaluation Study

GRES, jointly undertaken by the Department of Geological Survey (Hydrogeology Division), the University of Botswana and the Free University of Amsterdam continued during 1990. A total of 214 water samples with 1498 anion determinations and 10 cation determinations were analysed for the project.

8.1.6.2 Botswana Meat Commission Effluent

The quality of effluent emanating from the abattoir's operations was monitored. However, only 4 samples were analysed with 20 cation determinations as the B.M.C.'s chemical laboratory has since taken this up.

8.1.6.3 Letlhakeng/Botlhapatlou Groundwater Project

Analytical support was provided to BRGM (France), the consultants undertaking this project. The moisture content of 76 soil samples was determined and 167 water samples were analysed with 2049 determinations. A temporary employee, payed by BRGM, was engaged to assist the soil moisture analyses.

8.1.6.4 Borehole Records Archive Project

This project will computerise water borehole records and include the water chemistry data from the Chemistry Laboratory.

The Principal Chemist attended monthly progress meetings of this project undertaken by the consultant Knight-Piesold. The Senior Chemist attended in the principal's absence.

8.1.6.5 Desalination

The Chemistry Laboratory continued to provide assistance to RIIC in Kanye and ARADP in Southern Kgagalagadi by analysing saline water samples.

The library maintained subscriptions for the periodicals listed below. Problems, reported last year, with the UK supplying agent were corrected and most missing journal issues were received.

The Analyst	International Jnl of Coal Geology
Analytical Abstracts	Jnl African Earth Sci.
Analytical Proceedings	Jnl Contaminant Hydrology
Analytical Chemistry	Jnl Geochemical Exploration
Bulletin Geol. Soc. America	Jnl of Geology
Earth Science Reviews	Jnl of Hydrology
Economic Geology	Jnl of Petrology
Geobyte	Jnl of Structural Geology
Geodrilling	Mining Journal
Geoexploration	Nature
Geological Magazine	Precambrian Research
Geological Society Journal	Quarterly Jnl Engineering Geology
Geology	South African Jnl Geology
Geophysical Prospecting	Tectonophysics
Geophysics	Water Resources Research
Groundwater	
Industrial Minerals	

Consultants reports received during the year were as follows:

Sir Alexander Gibb & Partners	Review of the temporary groundwater supply for Selebi-Phikwe May 1971. GC4/1/5a.
Wellfield Consulting Services Ltd.	Consolidated emergency village water supply programme. Selolwane, Tobane, Mogapi, Mogapinyana/Kgagodi, Diloru. Inception Report June 1988. GC10/14/3.
Anglo American Corporation of South Africa.(Pty) Ltd.	De Beers Botswana Mining Co. (Pty) Ltd., Orapa Mine. Report on long term water supply to Orapa Mine and the Wellfield extensions during 1988 Vol.1: Summary Technical report and drawings. Report No. CED/030/89. April 1989. GC14/7/1.
	De Beers Botswana Mining Co. (Pty) Ltd., Orapa Mine. Report on Long term water supply to Orapa Mine and the Wellfield extension during 1988 Vol. 2: Appendices. Report No. CED/030/89. April 1989. GC14/7/2.
	De Beers Botswana Mining Co. (Pty) Ltd. Orapa Mine. Modelling of groundwater resources. Report No. CED/018/90. March 1990. GC14/7/3.
	De Beers Botswana Mining Co. (Pty) Ltd. Jwaneng Northern Wellfield. Computer modelling calibration and prediction of future behaviour. Report No. CED/076/89. December 1989. GC14/6/5.
Debswana (De Beers Botswana)	Orapa Wellfields groundwater monitoring report No. 12 for the period 30th June to 31st December 1989 12:1 Executive summary. February 1990. Report OGD/001/90. GC18/3/3f.
	Orapa Wellfields monitoring report No. 12 for the period 30th June to 31st December 1989 12:2 Technical data. February 1990. Report OGD/001/90. GC18/3/3g.

- Jwaneng Mine Northern Wellfield groundwater monitoring report 19. July to December 1989 19.1 Executive summary. GC18/3/1g.
- Jwaneng Mine Northern Wellfield groundwater monitoring report 19 July to December 1989. 19.2 Data compilation. GC18/3/1h.
- De Beers Botswana Mining Company (Pty) Ltd. Jwaneng Mine. Introductory notes on the exploration history and geology of the Jwaneng kimberlites. GC18/2/4.
- Watermeyer, Legge
Piesold and Uhlmann
- Mahalapye dam feasibility/preliminary design study feasibility report. Vol. I Main report. February 1989 Report No. 7823/R5284/SAC. GC27/9/2.
- Mahalapye dam feasibility/preliminary design study feasibility report. Vol. II Appendices. February 1989. GC27/9/3.
- Mahalapye dam feasibility preliminary design study final report on preliminary design Vol. V Site investigation report. December 1989 No. 7823/R564/ABM. GC27/9/5.
- Mahalapye dam feasibility preliminary design study. Environmental issues report. February 1989. GC27/9/6.
- Morupule Power Station pollution monitoring report March 1990. GC27/8/2.
- Botswana National Water Plan Study Interim report Vol.I Main Report February 1990. GC27/12/1.
- Botswana National Water Plan Study Interim report Vol. II Appendices February 1990. GC27/12/2.
- Botswana National Water Plan Study Draft Final Report Vol. II Agricultural aspects May 1990.
- Swedish Geological Co.
- Experimental geochemical exploration programme in Indonesia Vol. I text. In 5/8/011 UN technical report. GC30/7/1.
- Experimental geochemical exploration programme in Indonesia Vol. 2 illustrations INS/8/011 UN technical report. GC30/7/2.
- Integrated exploration using multivariate modelling of geochemical and petrophysical data. GC30/8/1.
- SMEC(Snowy Mountain
E n g i n e e r i n g
Corporation)
- Feasibility/preliminary design study Lower Shashe dam. Environmental impact study. Final report March 1990. GC35/4/5.
- Feasibility/preliminary Design Study Lower Shashe dam. Engineering and economics. Final Report Vol. III Figures April 1990. GC35/4/6.
- Southern Okavango integrated water development Sakwane dam and pipeline to Mopipi feasibility/preliminary design study inception report April 1990. GC35/5/1.

Geological & Geodetic Services (Botswana) Pty Ltd.	Consolidated emergency programme project: Sefare Valley. Sefare drilling and test pumping supervision. Final report February 1990. GC39/2/1.
	Department of Water Affairs project: Mhalatswe river. Mahalapye test pumping supervision August/September 1989. GC39/3/1.
	Department of Water Affairs consolidated emergency programme project: Serowe wellfield. Serowe drilling supervision October to December 1989 Final Report. GC39/3/2.
	Department of Water Affairs project: Mhalatswe River. Mahalapye Test pumping supervision August/September 1989 Final Report. GC39/3/3.
CIDA	Report of the CIDA Groundwater technical mission to Botswana October 16-30 1976. GC42/2/1.
Hydromin Consulting (Pty) Ltd.	Consolidated emergency water supply programme: Final report Vol. I. Maun Sehitwa road Kachikau Parakarungu/Satau March 1990. GC49/2/1.
	Consolidated emergency water supply programme: Final report Vol. 2A. Maun Sehitwa Road, Kachikau-Parakarungu Satau, March 1990. GC49/2/1A.
	Consolidated emergency water supply programme final report Vol. 2b. Maun/Sehitwa road, Kachikau-Parakarungu-Satau. March 1990. GC49/2/6b.
Botswana Power Corporation	Morupule Power Station 1989 report on Paje wellfield borehole monitoring. GC50/1/2.
Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)	Technical cooperation project No. P.N 78-2091-3. Sudanese German exploration project. Reconnaissance of groundwater and surface water resources in the coastal area of Sudan (Eastern Red Sea province). March 1980. GC55/3/1.
	Technical cooperation project No. 78-2250.5. Ground geophysical, geochemical and geological investigations in selected areas of the Kalahari. Final report July 1980. GC55/4/1.
	Technical cooperation project No. 78-2250-5. A ground follow up survey conducted in selected areas of the Tsabong (Kheis) district. Interim Report August 1983. GC55/4/2, GC55/4/3.
	Technical cooperation project No. 78-2250-5. Mineral Exploration of the Kalahari GS17 project: further results from geophysical investigation of the Ngami, Tsabong (Kheis) and Tshane areas 1980-1983 supplementary report 1985. GC55/4/4.
	Technical cooperation project No. 78-2250-5. Mineral Exploration Kalahari GS17 project: Further results from geophysical investigations of the Ngami, Tsabong (Kheis) and Tshane areas 1980-1983 supplementary report annex 1985. GC55/4/4a.

Technical cooperation project No. 84-2071-3. Mineral Exploration in the Vumba schist belt of Northeastern Botswana: Final report October 1989. GC55/6/1.

Technical cooperation project 84-2071.3. Mineral Exploration in the Vumba belt. The Vumba Schist Belt of Botswana, a model of its gold mineralization and its relationship to metamorphism. Field season 1984-1985. GC55/6/2.

Technical cooperation project No. 84-2053-2. Assessment of hydrocarbon prospectivity in graben and basins of Zimbabwe, Botswana, Zambia. Final report February. GC55/5/1.

Technical cooperation project No. 82-2024-6. The establishment of a cement industry in Botswana using small-scale cement plant technology. 1989. GC55/7/1.

Technical cooperation project No. 83-2024-2. Pilot project: Contributions to the prospecting for and exploration of groundwater in hard rock areas. Technical Report: Application of remote sensing in the investigation of fractured aquifers in Eastern Botswana. 1989. GC55/1/1.

Lahmeyer International
Consulting Engineers

Botswana energy master plan inception report January 1986. GC56/2/1.

JICA/MMAJ

Report on geological survey of Northeastern Botswana Phase V No. 23 February 1983. GC57/1/1.

Report on geological survey of the Northeastern area, Northeastern Botswana Phase I No. 29 February 1980. GC57/1/2.

TTCS Groundwater
Consulting Services

Consolidated emergency programme: Sekoma, Maralaleng, Werda and Sekoma-Makopong road. Draft final report Vol. I. December 1989. GC58/1/1.

Consolidated emergency programme: Makopong, McCarthy's Rust, Draihok, Vaalhoek and Bray. Final Report Vol. 2 September 1989. GC58/1/2.

Consolidated emergency programme: Vaalhoek, McCarthy's Rust, Draihok, Makopong and Bray. Field geophysics data & pump Test Data. GC58/1/3.

Consolidated emergency programme: Makopong, McCarthy's Rust, Draihok, Vaalhoek and Bray. Final report Vol. I September 1989. GC58/1/4.

TRRL Overseas Unit, UK

An evaluation of route alternatives for the Jwaneng-Ghanzi road in Botswana. Part 2 Morwamosu - Takatshwane. August 1982. GC59/1/1.

ARUP Botswana

Lotsane Dam feasibility study. Inception report TB10/3/14/89-90 March 1990. GC60/1/1.

L G W B u s i n e s s Consultants Ltd.	A joint mid-report evaluation of the CIDA project of technical assistance to the Botswana department of Mines. Final report October 1980. GC61/1/1.
PRACK Consult	Three major village water supply Serowe water supply: Final design engineering report. Vol. I. February 1989. GC62/1/1.
Geotechnical Consulting Services (Pty) Ltd.	Consolidated emergency programme: Drilling, construction and pumping test works at Tswaaneng, Goodhope, Pitsane-Goodhope road, Metlojane, Diphuduhudu, Mochudi-Sikwane road Hebron, Sorilatholo, Molengwane, Sefhare-Chadibe Malotwane and Oodi. Final report Vol. I. January 1990. GC63/1/1.
	Consolidated emergency programme: Supervision of drilling, construction and pumping test works at Tswaaneng, Goodhope, Pitsane-Goodhope road, Metlojane, Diphuduhudu, Mochudi-Sikwane road, Hebron, Sorilatholo, Molengwane, Sefhare-Chadibe, Malotwane and Oodi Final report Vol. II Raw data January 1990. GC63/1/2.
	Consolidated emergency programme: Borehole siting, supervision of drilling construction and pumping test works at Metsemotlhaba, Gakutwe, Ngwapa, Dutlwe, Tswanne and Moshupa villages. Final report Vol. I. March 1990. GC63/2/1.
	Consolidated emergency programme: Borehole siting, supervision of drilling construction and pumping test works at Metsemotlhaba, Gakutwe, Ngwapa, Dutlwe, Tswanne and Moshupa villages. Final report Vol. II March 1989. GC63/2/2.
Water Utilities Corporation	Lobatse water supply refurbishment: Township and Woodlands wellfields design report. (undated) GC64/1/1.
International GmbH	Major village water supply and sanitation planning study: Maun long-range plan. January 1989. GC65/1/1.

8.4.2 Reports and publications

The following report and maps were published during the year:

Report:

Bulletin 23: The Geology of the Molopo Farms Complex. Volume 2 - Appendices. by D Gould, P A Rathbone and GS Kimbell.

Maps:

Areas held under reconnaissance permits, prospecting licences and mining leases as at 1 January 1990 (1:2 000 000).

Areas held under reconnaissance permits, prospecting licences and mining leases as at 1 July 1990 (1:2 000 000).

Progress in geological mapping as at 31 December 1989 (1:2 000 000).

Sales of departmental publications realised approximately P9200 while several hundred publications were distributed free of charge or on exchange.

The following internal technical reports were filed during the year:

Farr, J L, Neumann-Redlin, C, Gabaake, G G and Mokokwe, K.	Bibliography of hydrogeology in Botswana. Volume 1: Unpublished Reports. Revised 1990. KM/1/90.
Gehrels, J C and van der Lee, J.	Gres Report: Rainfall and recharge. A critical analysis of the atmosphere-soil groundwater relationship in Kanye, semi-arid Botswana. July 1990. JCG/2/90.
Gehrels, J C and van der Lee, J.	Gres Report: Hydrological report; Modelling aquifer recharge. Introduction to the lumped parameter model EARTH. July 1990. JCG/3/90.
Gehrels, J C and van der Lee, J.	Gres Report: Rainfall and recharge. Appendix II: Data book. July 1990. JCG/1/90.
von Hoyer, M.	Lobatse sewerage scheme treatment plant area - Lobatse Estates groundwater monitoring 1984 - 1990. MvH/4/90.
Sloots, R R and Wijnen, M M.	Groundwater recharge to a fractured aquifer in S-E Botswana: Results of survey of the Molepolole east wellfield. Final report, April 1990. RRS/1/90.
Sloots, R R and Wijnen, M M.	Groundwater recharge to a fractured aquifer in S-E Botswana: Results of survey of the Molepolole east wellfield. Final report; Appendices. April 1990. RRS/2/90.

8.5 Drilling Section

8.5.1 Staff

The Drilling Section, which has the responsibility for providing drilling services to all field divisions of the Geological Survey Department, became fully localized in August when D.L. Allen's 18 months contract expired. Mr. T. Sekgopa was promoted to the second post of Senior Technical Officer (Drilling). This now leaves the division with two Senior Technical Officer posts. In future one of the posts will be upgraded to Chief Technical Officer.

The staff situation of the Drilling Division at the end of 1990 is as follows:

Senior Technical Officers	-	Mr. C.K. Mpelege Mr. T.B. Sekgopa
Technical Officers	-	Mr. M. Ntloedibe Mr. R. Raditladi Mr. M. Molatlhegi
Technical Assistants	-	Mr. K. Babitse Mr. I. Ludick

8.5.2 Drilling Projects

8.5.2.1 Tone rigs I & II; Matsitama.

The two tone rigs continued drilling at Matsitama to assist Regional Geology Division

mapping work. A month's work was lost due to poor ground conditions during the rainy season. Twenty boreholes were sited and seventeen drilled to the required depth of about 40m. Three boreholes could not be mud cored; these will be air cored by the Edson rig when it becomes available.

After completing work at Matsitama, the two tone rigs were employed by the Economic Geology Division at Mmathethe where they drilled 10 boreholes of 50m each. The objective being to provide information on the calcretes in the area.

From Mmathethe, the tones moved to Ghanzi to drill ten 100m angle holes for the Regional Geology Division. The rigs failed to reach the required depth and were removed from site.

8.5.2.2 Longyear Rig; Mabuasehube

After drilling of the Medie borehole for the Hydrogeology Division was terminated, the rig moved to Headquarters for a major service before leaving to drill a geophysical anomaly 70 km southeast of Hukuntsi.

Drilling started in late March. The first borehole had to be abandoned at 128 m when the drilling rods became stuck. The rig was moved 15 m away and a second borehole started. No core samples were collected until the depth of 128 m and by the end of the 1990 field season the borehole was down to 172 m.

8.5.2.3 Edson 6000W Rig.

The arrival of this Australian donated multipurpose drilling rig brought some changes to the Drilling Section's annual drilling production. Commissioning of the rig started in early February with the drilling of a borehole at the Lobatse Estates for the Economic Geology Division. The hole was hammered from surface to 118 m with a 5 1/2" bit. The borehole was then cased and cored to a final depth of 390 m. The hole was completed within six weeks. After completing the commissioning hole, the rig moved to Lobatse Sewage ponds where 3 boreholes were drilled to the following depths:- Borehole 1 - 63 m 5 1/4", borehole 2 - 63 m 5 1/2" and borehole 3 - 69 m 5 1/4". The borehole were drilled to allow the Hydrogeology Division to monitor groundwater pollution from the sewerage ponds.

The rig then moved to Seleka Farms to drill a total of nine boreholes for the Hydrogeology Division. These boreholes were drilled to the following depths: - 111 m with 5 3/4" bit, 21 m with 5" bit (after being flushed from 0 - 16 m), 56 m with 5" bit, 81 m with 5 1/2" bit, 75 m with 4 1/4" bit, 81 m with 5" bit, a 60° angle hole to 81m with 6" bit and two more vertical holes of 81 m each with 6" bit.

A total of three boreholes were then drilled at Dukwi for the Economic Geology Division. These boreholes were drilled to depths of about 30m to investigate potential gypsum and bentonite deposits. After completion of this project, the rig moved to Kanye to drill ten groundwater monitoring boreholes for the Hydrogeology Division. One borehole was completed to the depth of 97m but a broken water well head drive shaft prevented further progress. A replacement was ordered from Australia and while waiting for the ordered shaft, a coring head drive shaft was fitted. The rig then proceeded to Ghanzi to replace the Tone rigs to drill cored angle boreholes for the Regional Geology Division.