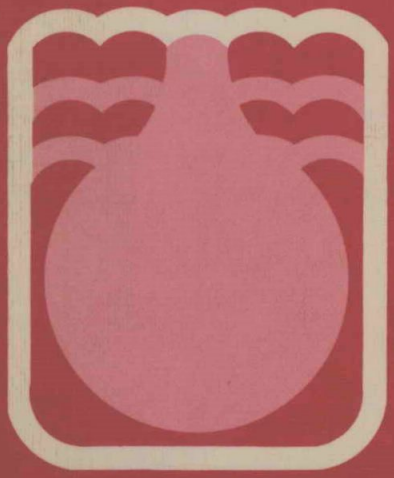

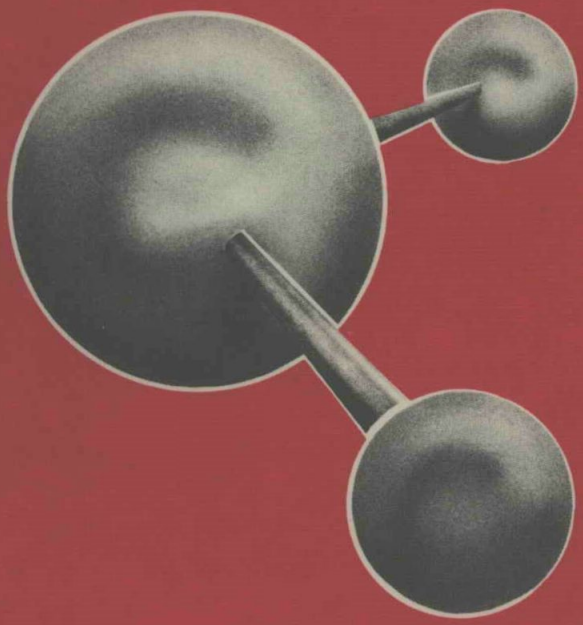

water research commission

ANNUAL REPORT

1 January 1975 to 31 December 1975

WATER RESEARCH COMMISSION

CONTENTS

WATER RESEARCH COMMISSION

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Water Research Commission
P O Box 824
PRETORIA
0001
23rd January, 1976

Dear Sir

We take pleasure in submitting to you, herewith, the report of the Water Research Commission. This report covers the period 1st January 1975 to 31st December 1975.

Balance sheets and statements of revenue and expenditure for the financial year 1st January 1975 to 31st December 1975, as certified by the Auditor-General, are furnished in chapter 11 of this report.

Whilst the compilation of this report was in progress, it was announced that you had exchanged the portfolios of Water Affairs and Forestry for those of Labour and Mines. Through this medium the members and personnel of the Commission wish to express their appreciation for your support and competent leadership since the establishment of the Commission.

Yours respectfully

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Chapter 1

The Commission's Programme of Activities

After slightly more than four years since the establishment of the Water Research Commission, it is advantageous to review the progress made with the Commission's programme of activities, with specific reference to:

(i) The progressive widening and implementation of priority research programmes relevant to specific problem areas within the framework of the Commission's tentative National Master Research Plan (See Chapter 2, 1973/74 Annual Report of the Commission), and research priorities as expounded in the report RP 34/1,70 of the Commission of Enquiry into Water Affairs (Water Plan Commission);

(ii) Fulfilling the Commission's functions of promoting and co-ordinating water research, financing meritorious projects, endeavouring to effect the application of research results, utilizing overseas expertise and publishing and distributing information.

In order to place the progress made in true perspective it is important:

Firstly, to obtain a clear picture of the Republic's water balance and of the lines of research that have been recommended in the report of the Water Plan Commission for maintaining the equilibrium between water supply and demand.

Secondly, to review the fields of research in which the Commission's Co-ordinating Research and Development Committees (CRD Committees) and Study Groups are engaged, in addition to the co-ordination, publication and dissemination of knowledge.

The water balance of the Republic

Water in the soil and run-off in rivers are the two main components of the Republic's water credit. The fact that this volume of water is limited and over the short term extremely variable and yet has to satisfy the increasing demands of socio-economic development, necessitates a critical evaluation of the water balance of the Republic as based on information contained in the report of the Water Plan Commission, and as supplied by the Department of Water Affairs.

Water credits

River run-off

Approximately 8,6 per cent – on average 52,5 milliard m^3 per year – of the Republic's rainfall reaches our rivers. In the report of the Water Plan Commission it was envisaged that the percentage of this run-off which could be made available for use could be improved (by thorough investigation, research and *planning and the necessary financial investment) from 40 to* slightly more than 50 per cent to amount together with groundwater resources, to 27,5 milliard m^3. Since then the Department of Water Affairs has found that with the improved planning currently being applied (see Table 1), it would indeed be possible to utilize advantageously approximately 60 per cent of the mean annual run-off to yield a reasonable assured supply of 31,5 milliard m^3 per year. This represents the *credit side in respect of our distributable water* – it must satisfy the requirements of domestic and recreational uses, industries, irrigation, and stock watering.

TABLE 1

METHODS FOR INCREASING THE ASSURED YIELD OF WATER IN SOUTH AFRICA

Method	Increase (milliard m^3 p.a.)
Improving the exploitation of groundwater sources	1,2
Desalination of sea water (coastal areas only)	0,5
Coupling of river systems	2,3
TOTAL	4,0

Water in the soil

More than 90 per cent of the Republic's rainfall, i.e. more than 10 times the total river run-off, remains in the soil. Of this, less than 10 per cent penetrates deeply enough to augment groundwater and the remainder is lost to surface evaporation or to assimilation and transpiration by natural vegetation, agronomic crops, pastures and trees.

Water debits

On the debit side of our water balance, the total water requirements by the year 2000 will be approximately as follows:

A greater portion of the population will be concentrated in towns and cities – approximately 80 per cent as against the current 48 per cent. The expected water requirements of cities, towns, industries, mining and power generation are 16,7 milliard m^3 per year. The demand for agriculture, mainly irrigation farming, is estimated at 12,8 milliard m^3 per year.

The total annual demand for distributable water in all consumer sectors will thus be 29,5 milliard m^3, i.e. only 2,0 milliard m^3 less than the total estimated *distributable water* of 31,5 milliard m^3 – 2,0 milliard m^3 being less than two years' increment at the current rate of growth in water consumption. Measures could be applied, however, to reduce water demand and the following estimates are based on information contained in the report of the Water Plan Commission:

(i) Savings through improved utilization of irrigation water 1,5 milliard m^3 p.a.

(ii) Savings through water reclamation and reuse 7,2 milliard m^3 p.a.

Total reduction in demand 8,7 milliard m^3 p.a.

From the foregoing it is clear that the measures envisaged will in fact assure a water credit of 10,7 milliard m^3 per year by the end of this century; however, this will be eliminated within the following ten years by increased consumption.

The realization of these measures, aimed at increasing the assured supply and reducing demand, necessitates the development and application of new knowledge and to this end intensive and sustained research will be essential. Water research will have to anticipate requirements in order to ensure that the Republic's growth will not be limited by a shortage of water. It is therefore of the utmost importance that the research potential of state departments, statutory organizations, universities, municipalities and industries be mobilized to develop measures which will be of critical importance to the long term maintenance of an equilibrium between water supply and demand.

Priority research areas

The Commission has to allocate high priority to certain research areas and consequently to research and development in respect of difficulties and problems within these areas in order to accelerate priority research within the tentative National Master Research Plan (see Chapter 2 of the Annual Report 1973/74). The identification of the priority research areas listed below and at which the Commission's work programme is aimed, resulted from its survey of water research at various organizations in the Republic and from the activities of its CRD Committees and Study Groups.

1. Soil conservation

Soil is not only fundamental to food production, but it is also an important reservoir for recharging groundwater and for maintaining river flow.

The destruction of soil productivity by erosion, within the catchments and flood plains of rivers and the detrimental effect of siltation on the storage capacity of existing and future storage dams, necessitate hydrological research on catchments and flood control. In this regard the Commission supports hydrological investigations of catchments at the Universities of Natal, Rhodes and Zululand and research on flood damage at the Universities of Stellenbosch and the Orange Free State.

2. Increasing the assured supply

Coupling of river systems

Since suitable and economic dam sites in the Republic are limited in number, half of the annual river flow of 52,5 milliard m^3 cannot be utilized. The coupling of river systems by means of pumping schemes offers possibilities for the partial recovery of this 'lost' water. By this means, it is estimated that the assured supply can be increased by 2,3 milliard m^3.

It is obvious that the intensification of research and development in this direction holds great promise. Practical proof of this is the pioneering work done by the Department of Water Affairs which led to the development and commissioning of the Tugela-Vaal water scheme for augmenting water supplies in the Vaal triangle.

As new knowledge is developed, the assured supply can be increased even further than envisaged by the Water Plan Commission. It is thus essential that research and development on the coupling and management of the country's river systems into an integrated national network receive in-depth attention. The Hydrological Research Unit of the University, the CSIR and the Commission, could, in close collaboration with the Department of Water Affairs, play a very important role in this regard.

Flood control

An in-depth study of the cost-benefit factors of flood control is necessary in order to determine to what extent it would be economically justified to incorporate 'lost' water, by means of flood control works, as a component in increasing the safe yield of storage dams. In addition to the supply of additional water and the control of erosion problems, these factors also include the prevention of damage to communications and transport connections, buildings, crops, etc. These were the motivations for the two research projects on flood damage allocated to the Universities of Stellenbosch and the Orange Free State, and which were referred to under 'Soil conservation'. (See 'Flood Damage', Chapter 10).

Exploitation of groundwater resources

Research and surveys relating to the development of groundwater resources were until recently mainly directed at investigations of a local nature to comply with specific requirements. During the past few years, the key role that groundwater may play in the Republic's water economy has become increasingly clear, as has our inability to determine completely the exploitation potential of these sources as a whole. Pertinent recommendations on research required to increase the safe yield of the Republic's groundwater resources were therefore made in the report of the Water Plan Commission.

Against this background the Water Research Commission has established a Study Group for Groundwater Research with objectives as described in Chapter 2.

The Study Group has already submitted a Master Research Plan for Groundwater to the Commission, and is in the process of compiling a priority research programme. To this end the activities, both in the laboratory and in the field, of various organizations are being examined and discussed.

3. Water reclamation and re-use and pollution control

In terms of the proposed measures to decrease water demand, as expounded earlier in this chapter, water reclamation and re-use will contribute approximately 70 per cent to the estimated water credit of 10,7 milliard m^3 per year at the end of the century. It is furthermore the key to preventing water pollution and protecting the utilization value of water.

Realizing the importance of water reclamation and re-use, the Commission has deemed it essential that research and development be accelerated and directed at those aspects which could play a decisive role in the formulation of a policy in respect of reclamation and re-use on a national basis and as an integrated part of the Republic's water economy.

Research projects

By means of surveys, the Commission has determined the key objectives of the various research fields that should be accorded preference and has initiated active research and development in specific problem areas, as described in Chapter 10. Information generated by these research projects will find practical application in a wide range of water reclamation and re-use schemes for urban, industrial and agricultural development. The projects are briefly:

(i) Construction and operation of three pilot scale water reclamation plants, each with a capacity of 4 500 m^3 per day:

- At *Windhoek,* domestic water supply is being studied, especially with reference to hygienic quality, epidemiological aspects and toxicological monitoring.
- At *Daspoort, Pretoria,* attention is focussed on the development and formulation of design and operational criteria of water reclamation plants and especially those which have to produce water according to quality requirements for various industrial and domestic uses and for the control of water pollution and eutrophication.
- On the *Cape Flats,* all aspects relating to the reclamation, underground storage and withdrawal of purified sewage effluent in the Cape Peninsula, are being studied.

(ii) Construction and operation of a 300 m^3 per day pilot plant at the Athlone sewage works, Cape Town, for studying the reclamation of purified sewage effluent, mainly of industrial origin, for various industrial uses.

(iii) Improvement of the activated sludge process for sewage purification and for the removal of phosphates and nitrogen in order to prevent or control the problems of eutrophication and toxic aquatic plants.

(iv) Recirculation of water and reclamation of chemicals in the textile industry. Results derived from this work should have a wide application in industry.

(v) Desalination of seawater, brackish water, purified industrial effluents and drainage from irrigation schemes. Desalination is of key importance in optimizing the re-use of water. The discharge of mineralized industrial effluents and drainage from irrigation schemes into the aquatic environment constitutes the Republic's largest pollution problem because it has a serious detrimental effect on the utilization value of our fresh water resources. Valuable information is generated through research projects being financed by the Commission, namely:

- Treatment of sewage effluents by means of ion exchange
- Desalination of sea and brackish water

(vi) Research on removal of metal ions from effluents in the metal industry.

(vii) Research on the eutrophication of rivers and dams and the role of aquatic plants in maintaining trophic conditions in Swartvlei (Wilderness).

As far as these two aspects are concerned, emphasis falls on the role of effluents in enriching the water environment with phosphorus and nitrogen and the resulting detrimental secondary pollution, and on measures to prevent and control this, as well as on the role and possible utilization of aquatic plants in the assimilation of nutrients.

(viii) An investigation into the hygienic quality and epidemiological aspects of reclaimed water from the water reclamation plants at Windhoek and Daspoort, Pretoria.

Health aspects of water reclamation

Dr E Windle-Taylor, a former Director of the London Metropolitan Water Board, visited the Republic in 1974 as a specialist consultant (under contract to the Commission), to study research requirements in South Africa relating to the health aspects of water re-use and the utilization of water from polluted sources. He held discussions with various research organizations and interested government departments such as the Departments of Health and Water Affairs, and also attended with the Chairman of the Commission, an international meeting of specialists in Amsterdam in January 1975. The purpose of this meeting was to make an in-depth evaluation of the current status of knowledge on health aspects of water re-use and to identify problem areas that require priority research.

The report submitted by Dr Windle-Taylor to the Commission's Study Group for Health Aspects of Water Use contains several recommendations relating to the situation in the Republic. As a result of the recommendations, attention is now being given to the following aspects:

- *Water quality networks* in urban and industrial complexes where water pollution and re-use are becoming of critical importance. The Commission has established an *ad hoc* Study Group to investigate the matter with special reference to the Pretoria-Witwatersrand-Vereeniging-Sasolburg complex, the Umgeni River complex, the Buffalo-Nahoon River complex and the Berg River complex.
- *Epidemiological* aspects of water re-use and pollution.
- *Micro concentrations* of specific organic residues in sewage effluents and in the water environments of urban and industrial complexes, which may have health implications.
- *Water and effluent purification* processes to remove detrimental substances to satisfactory limits.
- *Codes of operation and monitoring procedures* for water reclamation and pollution control installations.

Based on Dr Windle-Taylor's report and on that of the above-mentioned international meeting of specialists, the Study Group for Health Aspects of Water Use is currently compiling a priority research programme. In this regard Dr R J Wells, Senior Adviser to the Commission, made an overseas study tour during the year and held discussions with various organizations. Accompanied by Dr W Hattingh, Senior Chief Research Officer of the CSIR's National Institute for Water Research he also attended, on behalf of the Commission, an international symposium on health aspects of water re-use at the Water Research Centre, London.

Discharge of industrial effluents in sewage networks and in the aquatic environment

Control of industrial effluents is a determining factor in optimizing water reclamation and re-use and in protecting the utilization value of water in the environment.

Specialist consultants from England, commissioned by the Commission to study the problem in the Republic, have emphasized in their report those aspects that necessitate research and development and administrative measures in the Republic. The Liaison Committee which supervised these investigations on behalf of the Commission made specific recommendations (as indicated elsewhere in this report) which were approved and will be implemented by the Commission.

During the year under review, special attention was focussed on the water and effluent problems of abattoirs, tanneries and related industries. In order to facilitate the work of the relevant Co-ordinating Research and Development Committee in identifying priority research projects and keeping abreast of the latest developments overseas, the Commission contracted the specialist services of Dr A L Downing, former Director of the Water Pollution Research Laboratories in England. Dr Downing is connected with a well-known London firm of consulting engineers which is associated with a similar firm in South Africa. He held discussions with various organizations

and accompanied by a representative of the local firm visited a broad range of industries in the Republic. As a result of his preliminary recommendations, it will be possible for the Commission to allocate early priorities to certain problem areas. This matter is discussed at length in Chapter 4.

4. Agricultural uses of water

Through the ages it has often been proved beyond any doubt that soil, vegetation and rainfall, as an integrated whole, constitute the largest single factor contributing to the prosperity of communities; in fact, their appreciation, conservation and effective utilization are essential to the progress and continued existence of mankind.

Agriculture is undoubtedly one of the most rewarding and important fields for the application of sound conservation and utilization practises concerning soil and water, especially because of its importance for essential and sustained food production. Modern thinking tends not to view the utilization of the natural resources of soil, water and vegetation as separate entities. Environmental factors determine the nature of the specific complexes, the components of which, with the exception of water, cannot physically be transferred from one locality to another. In other words, the rational approach is to utilize resources in harmony with nature.

Exceptional work in this field is being done by the Departments of Agricultural Technical Services, Water Affairs and Bantu Administration and Development and the Commission regards it as its responsibility to promote, stimulate and assist the work of these organizations where possible, thus fulfilling its co-ordinating function. Facets of water utilization in agriculture that currently receive the attention of the Commission are irrigation, the production of fresh water fish as an agricultural activity and the desalination of brackish water for human and animal consumption.

Irrigation

As agriculture is currently responsible for approximately 75 per cent of the total water consumption in the Republic, it is clear that water should be utilized as efficiently as possible in this large consumer sector.

To promote this objective, the Commission has established a Study Group for irrigation; is financing projects at the University of the Orange Free State; will initiate additional projects early in 1976 at the Universities of Pretoria and Fort Hare; will investigate the possibility of importing researchers from overseas on a contract basis in order to strengthen the research force. More details of these activities are given in Chapter 7.

Fish production in inland waters

At the request of the Department of Water Affairs the Commission has given considerable attention during the past year to the question of utilizing water for commercial fish production.

Against the background of an increasing demand for food and the possible supplementation of the protein requirements of a large part of the population, it has become essential that urgent attention be given to the utilization of inland waters for this purpose.

The utilization of inland waters for fish production should be regarded as an effort to establish multi-purpose and more efficient use of the water used for irrigation and for domestic, industrial and recreational purposes without creating quantitative competition for this purpose. Fish production may assist in combating eutrophication problems in impoundments. Discussions held with interested organizations (the Departments of Water Affairs, Agricultural Technical Services and Planning, Agricultural Economics and Marketing, Provincial Administrations, the Bantu Investment Corporation, the Fish Industries Research Institute, the Fisheries Development Corporation of SA Ltd (Fishcor), the Fresh Water Fish Co-operative Ltd., and the National Food Research Institute of the CSIR), showed, however, that the establishment of a viable fresh water fish industry is a complex undertaking that should take cognizance of the utilization of water sources, pollution aspects, economics, food technology, marketing and sport and recreation.

In the meantime, the Department of Agricultural Technical Services has decided to recognize fish farming as an agricultural activity, and will in future be the organization responsible for promoting the fresh water fish industry. In future, the Commission will involve itself only in those aspects of fish farming which require research. Two aspects to which attention will possibly have to be given are the yield per unit of water lost in fish ponds and the evaluation of the raceway system in irrigation farming.

Water for domestic use and stock watering in rural areas

In this regard investigations are being undertaken in close co-operation with the National Institute for Water Research of the CSIR into the desalination of underground brackish water in order to produce water which would be suitable for human and animal consumption. Several pilot plants have been erected in certain areas of the country where large quantities of brackish water occur and the economic and practical aspects of desalination in these localities are being studied. These projects are being financed by the Commission.

5. Creation of new water sources

As shown in this and other chapters in the report, the main objective of the Commission's research priorities is to ensure a sustained water credit. Accordingly, the research and development work initiated by the Commission is largely aimed at the realization of the full potential of our water resources and the efficient utilization and re-use of water. It is, however, equally important that the creation of new water sources should

be included in a priority research programme, especially with a view to long term water requirements.

Developments in science and technology have already suggested possibilities for the creation of new water sources. The Commission has, therefore, taken specific action to promote research in this direction.

Desalination of water

Apart from the key role that desalination may play in optimising water re-use and pollution control, the development of large scale desalination plants may convert sea and brackish water into important new fresh water sources, especially in the Republic's coastal areas and in arid regions where large quantities of brackish water occur, but which are not suitable for man, beast or plant.

Progress already made with research on the desalination of sea and brackish water, financed by the Commission, has accentuated the need to compile and implement a master research plan and priority research programme for the desalination of water, aimed at the Republic's short, medium and long term requirements. For this purpose the Commission has established a Study Group for Research on the Desalination of Water and also acquired the specialist services of Mr K D B Johnson of the United Kingdom Atomic Energy Agency. Details concerning the activities of the Study Group and the recommendations of the specialist consultant are given in Chapter 5, whilst progress in the projects supported by the Commission is reported on in Chapter 10.

Stimulation of rainfall and the withdrawal of moisture from the atmosphere

The Commission is financing a project, undertaken by the Chemical Engineering Department of the University of Pretoria, on the withdrawal of moisture from the atmosphere by means of hygroscopic chemicals. The specific potential of this process will become clear only when additional research information becomes available from other projects being financed by the Commission, *inter alia* on water desalination and the development of dry cooling processes. (See Chapter 10).

The artificial stimulation of rainfall is a field of research which has already received considerable attention from the Departments of Water Affairs and Transport. In 1971 these Departments, through the Weather Bureau, commenced a programme at Bethlehem where favourable conditions prevail. Bethlehem is situated in the catchment of the Vaal Dam and positive results from these experiments would also cause additional inflow of water to this important reservoir. Originally, the project was planned and initiated under the control of an interdepartmental committee of the Departments of Water Affairs and of Transport.

Since then much basic information has been collected and a stage has been reached where the sophisticated instrumentation and equipment required as well as the infrastructure for the implementation of the work are now available. Progress with this work, however, has been restricted by a shortage of adequately trained professional and technical staff. During the past year the Commission has negotiated with the Department of Transport on contracting researchers from overseas and seconding them to the Department in order to accelerate the project. These negotiations have now reached an advanced stage and it is envisaged that the first nucleus of trained overseas researchers will be recruited for the project early in 1976.

6. Water conservation and optimal utilization by municipalities and industry

Realizing the important role of water conservation in the optimal utilization of the Republic's limited water resources, the Commission has already initiated several research projects in this regard, *inter alia* on:

- Water losses in pipe networks
- Water consumption patterns in urban areas
- Disposal of sludge and wash water at water purification works
- Dry cooling at power stations
- Recycling of water and reclamation of chemicals in the textile industry.

However, during the year a new dimension was given to the Commission's activities in this field by the recommendations of the Water Conservation Committee for Urban Areas of the Honourable the Minister of Water Affairs. In terms of these recommendations, the Commission should support additional, purposeful research to enable proposals and advice submitted to the Committee to be implemented.

After a preliminary investigation of the recommendations, the Commission established a Co-ordinating Research and Development Committee for Water Conservation Measures in Urban Distribution Systems. The Committee has already progressed well in compiling a priority research programme and in programming specific research projects. The activities of the Committee are fully reported on in Chapter 9.

Promotion of co-ordination, publication and information transfer

Co-ordination

The establishment of *Study Groups* and *Co-ordinating Research and Development Committees* covering clearly demarcated areas of related research, proved to be a very successful procedure for identifying research priorities, determining problem areas which should be researched and ensuring co-ordination. This procedure, furthermore, has a stimulating effect with regard to the following:

(i) Objective and frank discussions of mutual problems within specific study areas, in that individuals from different sectors and disciplines are brought together.

(ii) Specific action taken by the Commission concerning recommendations made by specialist consultants from overseas; research projects that are initiated; the extension of new directions in existing research programmes; financing the attendance of overseas conferences; contracting overseas expertise; and assisting overseas scientists to work in the Republic or to address congresses.

(iii) The operation of steering committees and exchanging research information. The Commission is an autonomous organization that does not undertake water research itself but has the necessary means and statutory authority to carry out co-ordination in a practical manner and at the level of the research workers, by means of its steering committees. A steering committee is established for projects financed by the Commission, and represents a broad spectrum of scientific and statutory interests in the relevant problem area. Each organization has free access to research results and can participate in or contribute to the working programme if they so wish.

Publications

"Water SA"

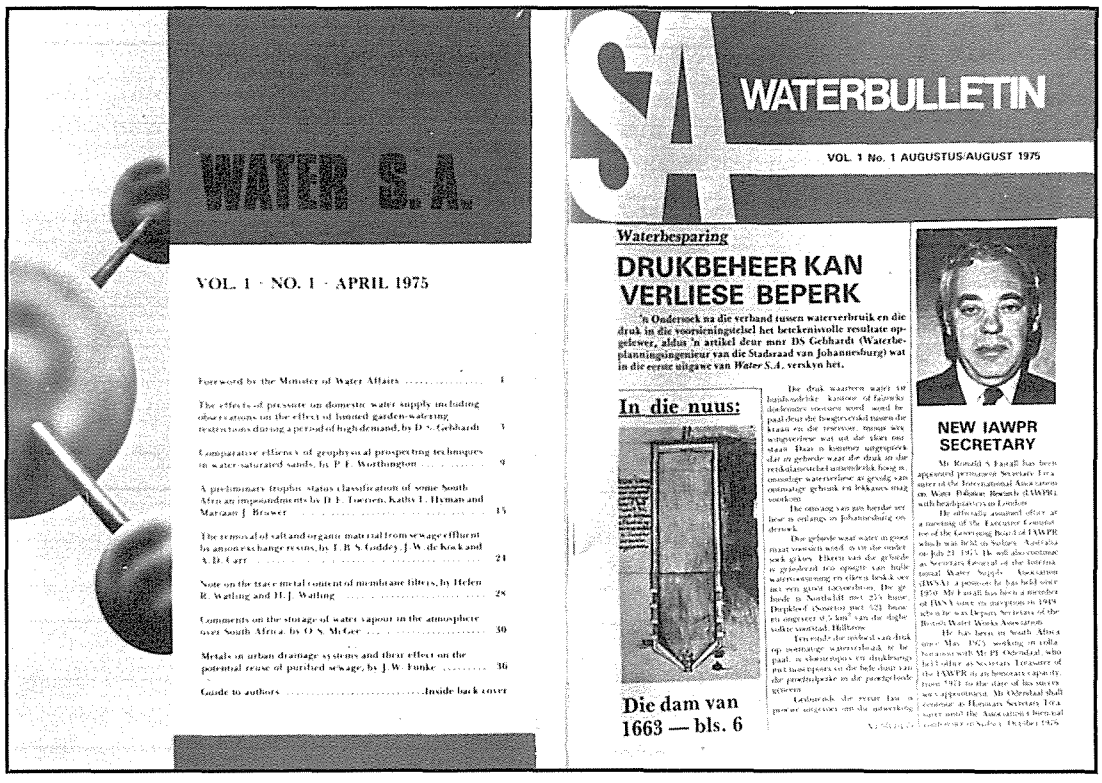
As was envisaged in Chapter 3 of the previous Annual Report, the Commission has launched South Africa's first scientific journal on water, with the April 1975 edition of *Water SA*. The journal is issued quarterly and publishes original research and review articles on all aspects of water science.

Reaction to the publication of the journal has been very encouraging and favourable comments have been received from various quarters, including from abroad.

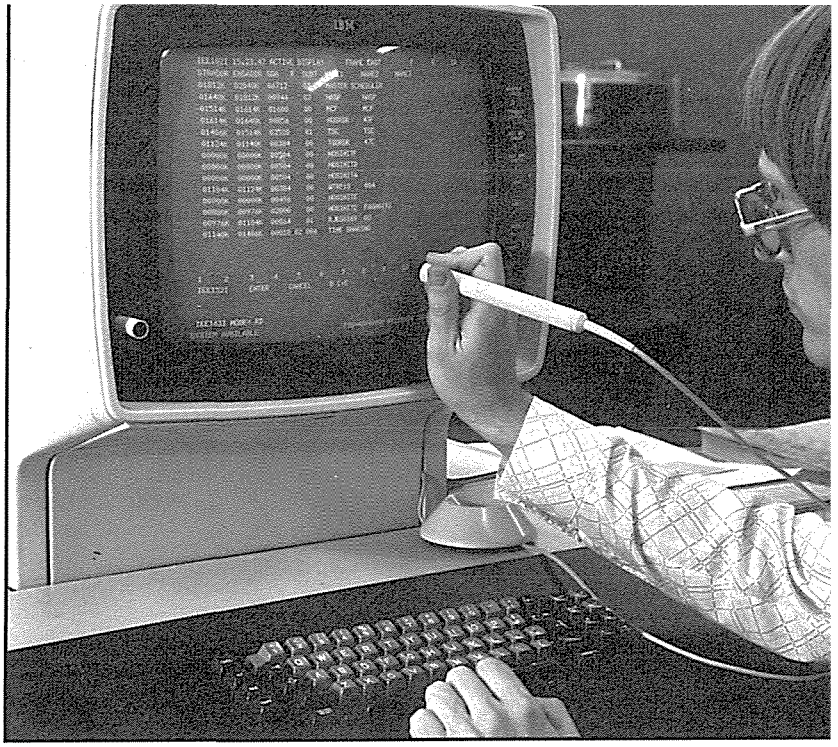
Subscriptions are being received daily and attention is now being given to active expansion of the already substantial overseas distribution list. Apart from its obvious function of disseminating research results, the journal will also serve to promote the image of the South African water scientist abroad and in this way facilitate liaison with overseas scientists.

"SA Waterbulletin"

It was also announced in Chapter 3 of the previous Annual Report that the Commission intended publishing a bi-monthly newsletter on water and thus to contribute to a 'water consciousness' at all levels of South African society. The first issue of the newsletter *(SA Waterbulletin)* appeared in August 1975 and contains articles, news items and items of general interest on many aspects of water in this country and overseas. Good co-operation has been obtained in acquiring articles from other



The first edition of Water SA *(a scientific journal on water) and* SA Waterbulletin *(a newsletter on water) were published during 1975.*



The SA Water Information Centre utilizes modern techniques in data storage and retrieval. With a minimum loss of time, information is projected on a screen after a search has been entered into the system.

organizations involved with water. The newsletter has also been well received.

Municipalities, industries and the manufacturers and distributors of equipment have been invited by way of circulars to contribute information for use in *SA Waterbulletin,* and it is envisaged that the Bulletin will play a valuable role in promoting contact and the exchange of information between readers.

National Water Information Centre

The South African National Water Information Centre is operated by the CSIR's Information and Research Services Division under contract to and on behalf of the Commission.

The first task of the Centre was to determine, by means of literature studies, the functioning of similar centres elsewhere. Subsequently the requirements of South African users were ascertained and analysed through direct contact and their needs, which are not covered by existing information systems, were identified. Various new services have been planned to satisfy these needs.

The Centre already publishes a current awareness bulletin, *Selected Journals on Water* (SJOW). The bulletin consists of the index pages of a number of the most important journals in the field of water. There is a great need for a suitable computerized bibliographical data base for those involved with water resources. To meet the demand, the Centre is in the process of establishing a magnetic tape data base known as *'Waterlit'.* Through the offices of the SASDI service of the CSIR this base will become accessible to all interested persons. Input to the base will to a great extent be supplied by the centre, but various other organizations, such as the Departments of Water Affairs and of Agricultural Technical Services, and individual scientists, will eventually co-operate to produce a comprehensive data base on a national basis. The bibliographical data base will be available on a coupled computer terminal for retrospective literature searches.

In a previous Annual Report mention was made of the other aspect of the activities of the Centre, namely the development of information sources. This activity is undertaken in co-operation with various other organizations and is progressing well.

Technology transfer

Technology transfer must be seen as a purposeful activity – within the wider framework of the dissemination of information – to effect the practical application of existing knowledge. This will become increasingly important in the Commission's future programme.

Technology transfer must be promoted by various means, and the basis for such a broad promotion programme has already been established:

- The Commission's Co-ordinating Research and Development Committees are eminently suitable for the promotion of technology transfer in specific problem areas. The Committees serve to identify clearly problems and to collect the information required for their solution. These are ideal condi-

tions for channelling technology transfer since the Committees are directly associated with bodies that could apply the information.

- As mentioned elsewhere in this report, the Commission has already brought several overseas specialists to the Republic to examine – in consultation with local experts and consultants – specific problem areas in the country's water economy and to make recommendations on relevant research. An additional advantage accruing from this procedure is that these specialists also make recommendations on the application of existing knowledge, and in this way technology transfer is actively promoted.
- The Commission's steering committees also constitute routes for promoting technology transfer, as members often represent organizations which can implement the relevant research results in practice.

With the basis already established, the time has now come for the development of a comprehensive and purposeful programme to promote the transfer of water technology in South Africa. Overseas, specially in the USA, this aspect is already receiving active attention, and it is intended to send one of the Commission's advisers overseas in 1976 in order to obtain information which may be incorporated in the South African programme.

Chapter 2

Groundwater Resources

It is envisaged that effective development and utilization of the Republic's underground water resources will substantially contribute towards maintaining the country's water balance.

At this stage the order of magnitude of our groundwater potential cannot be accurately predicted because insufficient data are available. It is therefore of paramount importance that a concerted effort be made to obtain this information as soon as possible, so that timely steps can be taken for the effective integration of these sources with existing water supplies. The specific nature and occurrence of groundwater in the Republic, however, calls for a drastic intensification and expansion of surveys and research.

More than half a million boreholes for water have already been drilled in the Republic. An analysis of a large number of these boreholes indicates that more than 90 per cent were drilled into formations that are inherently impervious. Such holes yield no, or very little, water even though the rock formations below the water table level may be saturated with water. Groundwater in these formations, therefore usually occur in secondary water-bearing structures – that is in zones of weathering, joints, zones in close proximity to dolorite dykes, faults, joints, cleavage zones and solution cavities and channels in dolomites. Many of these aquifers are composed of narrow linear structures and are often referred to as 'water veins'. The storage capacity and specific yield of secondary aquifers are relatively small when compared with primary aquifers which could store and yield immense volumes of water.

Primary aquifers, as occur in America, Australia and many parts of the world, do not occur generally in the Republic, and are mainly restricted to alluvial deposits along certain river flats, particularly in the northern Transvaal, the Quarternary sand deposits along the coastline of the Republic as well as lenses of sandstone or gravel in Tertiary deposits in various parts of the country. In these formations, groundwater is normally evenly distributed and does not occur in linear structures.

In America, Europe and some other countries the development of groundwater resources has already reached an advanced stage and the major aquifers with exceptionally large storage capacities have been developed intensively. Methods for tracing and optimally exploiting these specific types of aquifers have already been developed and applied overseas.

Development of new techniques

On account of the diversity in the hydrogeological characteristics of the waterbearing formations in the Republic, and in their mode of occurrence combined with the variability of the climatological conditions, it is exceedingly difficult to acquire adequate information for the determination of the exploitation potential of the groundwater resources. Although specific procedures and techniques have already been developed for field investigations, their applicability is restricted under South African conditions. Similar limitations apply to the techniques developed for the interpretation of the results.

Since the majority of the techniques which are currently used in hydrogeological studies were developed in Europe and the U.S.A., their application is mostly restricted to primary and artesean aquifers, which do not occur generally in South Africa. Recognizing these deficiencies, the Water Research Commission had already initiated several projects in 1973, aimed at the development of applicable techniques for the determination of the Republic's groundwater potential.

Submissions to the Water Research Commission during its survey of water research in the Republic, and subsequent activities in this regard, showed that only a small number of the groundwater sources of the Republic has been determined with any degree of accuracy and that the tempo of some surveys and of research must be accelerated drastically to keep abreast of the country's development and requirements. These findings concur with those of the Commission and from these and from submissions received from the Geological Survey of the Department of Mines, the South African Council for Scientific and Industrial Research and the Universities of the Orange Free State, Witwatersrand and Stellenbosch it appeared

clearly that investigations and research should be thoroughly co-ordinated and undertaken in a planned way.

To attain this objective it became essential to intensify groundwater research through:

(i) Formulation of a National Master Research Plan;
(ii) Development of a National Priority Research Programme aimed at generating new knowledge and creating new horizons;
(iii) Compilation of development programmes supported by planned services and surveys as an effective research-related activity which forms an integral part of the Priority Research Programme;
(iv) Training of personnel;
(v) Effective employment of the Republic's groundwater experts; and
(vi) Importing expertise from overseas.

Study group for groundwater research

With these objectives established, it was deemed of the utmost importance to obtain the expert advice of all interested organizations. A Study Group for Ground Water Research was therefore established by the Commission and comprises representatives from the Department of Water Affairs, the Geological Survey of the Department of Mines, the Weather Bureau of the Department of Transport, the Department of Agricultural Technical Services, the Department of Forestry and the Water Research Commission. Additional members may also be co-opted as the need arises.

The first meeting of the relevant Study Group was held on 21st February, 1975 and it was agreed that the Study Group would endeavour specifically to:

(i) Compile a Master Research Plan in respect of underground water, taking into account the recommendations of the "Commission of Enquiry into Water Matters in the Republic of South Africa" as well as those of the "Committee of Investigation into The Groundwater Situation in the Republic of South Africa". The establishment of the latter Committee resulted from the recommendations of the forementioned Commission of Enquiry.

(ii) Compile a Priority Research Programme in order to meet immediate requirements and to alleviate problems.

(iii) Establish directives for the planning and implementation of the Priority Research Programme, namely –
  (a) identification of priority problems and the determination of task areas, disciplines and organizations involved;
  (b) effective co-ordination of research activities by –
    - appointing and integrating research organizations on a co-operative basis
    - allocating research projects and tasks to organizations which could pursue these purposefully
    - integrating overseas expertise
    - establishing work groups
  (c) budgeting for and programming and financing of research;
  (d) continuous conducting of research and feedback;
  (e) publication and dissemination of information;
  (f) implementation of findings; and
  (g) advice to governmental and other organizations.

(iv) Submit recommendations to the Water Research Commission which will promote the implementation of groundwater research in the Republic.

As a result of the diligent and enthusiastic co-operation of members of the Study Group it has already been possible to submit a National Master Research Plan and Priority Research Programme to the Water Research Commission which was accepted and approved by the Commission at its meeting of 17th November 1975. A broad outline of the National Master Research Plan and of the Priority Research Programme is presented below.

National master research plan

The Master Research Plan presents a framework of different disciplines and aspects which require research and development, and is aimed at the following:

(i) Determining the basic physical and chemical aspects of groundwater especially in relation to the application and validity of the existing formulae for the movement of water through the earth's crust and the relationship of the various factors which influence it;

(ii) determining the applicability of existing geophysical groundwater exploration techniques, their modification to suit South African circumstances, and developing new techniques for tracing groundwater;

(iii) improving drilling techniques and the application of mechanical methods to increase the yield of boreholes;

(iv) determining the applicability and modification of existing formulae for the determination of storage coefficiencies, transmissibility and safe yield of the various types of aquifers in the country;

(v) refining remote sensing techniques such as aerial photography, infrared photography, false colour techniques and EROS photography to identify water-bearing structures and formations;

(vi) developing computer techniques for the analysis of pump test results, for the development of mathematical models and for the establishment of a data bank for groundwater;

(vii) the effective application of isotope, dye and chemical tracer techniques in order to determine the movement and recharge of groundwater;

(viii) developing model and analogue systems in order to simulate and control mathematically and electrically the behaviour of the aquifer under operational conditions;

(ix) determining the extent of aquifers and developing techniques for tracing groundwater in different representative structures and geological formations in the country with specific reference to the Karroo formation, the sand deposits along coastal areas and rivers, the Cape Folded area, the Kalahari sands, the dolomites, rocks with few water-bearing characteristics and crystalline, metamorphic and igneous rock;

(x) compiling groundwater quality and temperature maps for the Republic; determining the influence of irrigation, geology and evaporation on the quality of the water; developing techniques for the desalination of brackish water and the removal of undesirable toxic mineral salts such as nitrates and fluorides;

(xi) developing techniques for determining the hydrological characteristics of groundwater and the extent of groundwater compartments in the various geological formations in the country;

(xii) studying the groundwater cycle with a view to: determining the influence of afforestation and deforestation and of phreatic vegetation on groundwater; determining the surface run-off, groundwater recharge and losses under varying geological, pedological, climatic and topographical conditions, developing techniques for the artificial recharge of groundwater and determining the influence of groundwater utilization on the availability of surface water;

(xiii) determining the quantitative and qualitative effect of changes in land utilization on groundwater and the effect of dewatering groundwater compartments;

(xiv) establishing the required organizational structure to allow groundwater to take its rightful place in the optimal utilization of all water sources, backed by suitable legislation and control;

(xv) promoting publication and dissemination of data; and

(xvi) establishing the required facilities which will promote the training of groundwater scientists and technicians, the creation of careers and the recruitment of researchers.

Priority research programme

In compiling the Priority Research Programme, it was realized that the programme had to be dynamic in order to be adaptable to changing circumstances and requirements of the country. The programme therefore presents a broad outline of task areas that will have to receive attention in the near future. Research activities relating to specific task areas may be organized in such a way that one or more of the task areas may be covered simultaneously by one or more research projects.

The Priority Research Programme provides for the processing of all existing data on groundwater in the country in order to outline insufficiencies in available information relating to the conservation, exploitation and utilization of groundwater. In this regard, an attempt will be made to compile a groundwater atlas containing processed data and serving as a basic reference in the determination and development of future research and development programmes.

In developing various techniques used for tracing groundwater sources and selecting borehole sites more successfully, projects will be undertaken in selected areas which represent as closely as possible the idiosyncrasies of areas as a whole.

Specific projects will be undertaken to: compile a contour map of potential evapotranspiration in the various areas of the country; prepare a groundwater quality map of the Republic; investigate possibilities of artificially recharging aquifers; determine the effect of the country's development and the utilization of groundwater or groundwater sources; identify areas with possible large groundwater potential, such as, inter alia, the dolomitic area of the Transvaal and the Northern Cape, the Cape folded area and the cristalline and metamorphic formations of the Karroo and other parts of the country.

In implementing this programme and in order to afford members of the Study Group the opportunity of acquainting themselves with local problems, arrangements for visits to various problem areas have been made.

Projects supported by the Commission

The Commission has initiated four projects which will require expenditure of R2,5 million over a period of six years with a view to developing techniques for the tracing and determination of the groundwater resources of the Republic. The areas where research is being undertaken will benefit greatly because the results will promote the development of the groundwater sources in those areas. The projects are the following:

(i) Storage of river run-off, stormwater and reclaimed water in the sand deposits of the Cape Peninsula (University of Stellenbosch and the CSIR).

(ii) Determination of the exploitation potential of groundwater sources in the Southern Free State and in the North Western Cape (University of the Orange Free State).

(iii) Determination of the exploitation potential of groundwater sources along the Doornberg fault zone (CSIR) – see map on page 40.

(iv) Geohydrological studies in the Gamagara catchment (in the Sishen area) by means of environmental isotopes and supplementary techniques (University of the Witwatersrand).

Details of these projects are presented in Chapter 10.

Chapter 3

Water Pollution and Effluent Reclamation in the Pretoria-Witwatersrand-Vereeniging-Sasolburg Complex

In the previous Annual Report, attention was drawn to the importance of the Pretoria-Witwatersrand-Vereeniging-Sasolburg complex, being the most densely populated and industrialised region in the Republic. It was emphasised that, with the water utilization of this complex increasingly becoming a closed system, the question of water pollution and effluent reclamation assumes a most important rôle. This is a matter of considerable concern to the local authorities situated within the areas, who are faced with the problem of coping with large flows of sewage and industrial wastes at their treatment works.

Co-ordinating Research and Development Committee

Appreciating this position, and to assist these local authorities, the Commission has established a Co-ordinating Research and Development Committee to systematically programme and co-ordinate all current and envisaged research into the problems of water pollution and effluent reclamation within the complex, which is carried out by collaborating institutions. This Committee operated at high level, and comprises representatives from the following state departments, provincial administrations and individual organisations:

Water Research Commission
Department of Water Affairs
Department of Health
Department of Planning and the Environment
Department of Agricultural Technical Services
Department of Bantu Administration and Development
Transvaal Provincial Administration
O.F.S. Provincial Administration
Chamber of Mines of South Africa
Rand Water Board

The scope of the Committee will embrace the collection, collation, and examination of existing knowledge, and its supplementation where necessary, in regard to the following:

(a) The hydrological pattern of the rivers and vleis of the areas.

(b) A survey of all existing wastewater purification facilities, as well as any proposals for new works and/or extensions of existing works.

(c) Sources and degree of pollution of the waters of the area, with particular reference to –
- mineral pollution
- organic pollution of wastewater origin
- organic pollution from surface run-off
- nutrient addition from wastewater works
- siltation

(d) Detailed ecological and biological studies of the area, with a view to establishing:
- Background data against which to assess changes in effluent flows and quality
- a composite biological index of the present pollution status of the rivers of the area
- the value of existing aquatic macrophytes in controlling pollution

- the impact of future pollution loading of the vleis
- the effect upon the vleis of steady slime encroachments, and other deleterious occurrences

(e) Assessment of water quality factors, both in relation to effluent discharge standards and necessary water quality criteria for:

- alternative reclamation requirements.
- protection of impoundments against enrichment and other deleterious occurrences.

(f) Integration of chemical, biological, hydrological and engineering data, either abstracted from existing sources, or derived from current basic research.

(g) Development of the necessary mathematical models to enable the mass of information bearing on the subject to be sifted, evaluated and optimised.

(h) Evaluation of the cost factors involved, especially the cost of outfall sewers; pumps and rising mains; wastewater purification to alternative standards; water reclamation to specific requirements; delivery of reclaimed water for various purposes.

(i) Formulation of the basis for the optimum planning of regional schemes.

Priority areas

The Co-ordinating Research and Development Committee decided that it would be advantageous to divide the project area into three subdivisions, in order of priority, as follows:

(i) First priority

The Vereeniging-Vanderbijlpark-Sasolburg area

This area will include the towns of Vereeniging, Vanderbijlpark, Meyerton, Sasolburg and Sebokeng. It comprises the entire catchment areas of the Taaiboschspruit, and the Rietspruit, with those sections of the catchments of the Vaal River, the Klip River and the Suikerbos River situated in the south western vicinity of the project area.

(ii) Second priority

The Witwatersrand area

This area includes the remainder of the catchment of the Vaal River lying to the south of the Witwatersrand Ridge, and draining to the Vaal River Barrage below the Vaaldam. It includes those parts of Johannesburg and other towns draining to the Vaal River within this catchment area.

(iii) Third priority

The Pretoria area

The remainder of the project area consists of the section which lies north of the Witwatersrand Ridge, and which is supplied with water from the Vaal River by the Rand Water Board. All discharges from cities and towns, or portions thereof, which flow northwards are included in the consideration of this section.

In order to establish the existing conditions within the first two priority areas a firm of consulting engineers were appointed in November, 1974, to carry out the initial investigation, which included the examination and an appreciation of all geographical, topographical, and engineering features, with details of water supply undertakings, sewage and wastewater treatment plants, and major stormwater systems. Good progress has been made with this work, and much of the information upon which further work will be built for the first priority area, was submitted to the third meeting of the Committee, on 29th November, 1975.

Work had also been commenced early in the year by the Hydrological Research Unit of the University of the Witwatersrand, on the formulation of a simulation model of the water circulation in the first two priority areas. The Unit was also responsible (through the Urban and Regional Research Unit of the University) for the determination of the present distribution, composition and future trends of the population throughout the complex. In addition, the Unit was responsible for a geological description of the whole project area, as well as the hydrology of the complete river system.

Research projects

The Committee has established the following avenues of research which would be required to solve the problems, and arrangements are being made for the work to be undertaken as soon as possible.

(a) Complete in-depth studies of the Vaal River Barrage

The Vaal River Barrage system is of major importance in consideration of the project area. There are two major types of input – firstly, the Vaal Dam outflow of high quality and secondly, the lower tributaries of much poorer quality (the former flow is regulable, and the latter is not). The phenomena in the system which are of importance, are:

(i) The hydraulics of the Barrage, including reverse flow conditions when the possibility exists that effluents discharged below the Rand Water Board intakes might be drawn into these intakes.

(ii) The marked variations in quality which occur, affecting in turn the quality of water abstracted and processed by the Rand Water Board.

(iii) The periodical subjecting of the Barrage to the growth of blooms of algae – this problem may become aggravated with the passage of time, leading to acute operational problems in the water purification processes and/or the emergence of toxic or taste- and odour producing algae in the water source.

(iv) The accumulation of silt – firstly, that resulting from impoundment and secondly, that derived from the purification processes of the Rand Water Board.

(v) Stratification and mixing of the disparate water quality inputs. For example, it is known that vertical stratification between the purer water of lower density and the tributary water of high density can persist for many kilometres under certain conditions.

(b) The present pollution status of rivers and streams in the project areas

As indicated under (a), the inflow to the Barrage from the several tributaries of the river is of a much poorer quality than the Vaaldam outflow, and a comprehensive study of the present pollution status of these tributaries is required. The Rand Water Board carries out a regular programme of analyses of the streams in the catchment area, and it will be necessary to determine the extent to which this reflects the overall picture.

(c) Hydrobiological patterns of vleis

This is envisaged as a project comprising chemical, hydrobiological and hydraulic aspects. The following points illustrate the purpose and importance of this project:

(i) *Purification capacity* – it is recognised that the vleis play an important rôle in the self-purification capacity of a river, especially in those streams which are found on the southern slopes of the Witwatersrand, which receive considerable volumes of treated effluents. The vleis appear to exert a favourable effect on phosphate and nitrogen concentrations. The nature of this effect, in regard to domestic and industrial effluents is little known and requires research. The work should be correlated with other projects, especially those on eutrophication of rivers and dams.

(ii) *Sensitivity to pollution* – the extent to which these vleis can continue to handle increasing volumes of pollution should be investigated, as also their sensitivity to damage by toxic discharges, and by the invasion of silt from mine dumps.

(iii) *The degree of evaporative loss* which takes place in the vlei areas as they exist compared to that which would occur if they were to be canalised or otherwise modified.

(d) Migration of silt from mine dumps and slimes dams

The loss of silt from mine dumps and slimes dams in the Witwatersrand area to the streams is a well-known phenomenon, deriving from earlier mining days when such dumps were not well designed, and were both too steep and too near the natural streams. Many of the latter have been irretrievably damaged as a result of the inflow of this enert and biologically hostile material. This has contributed to the extermination of many forms of life in those upper tributaries, while the extent of this effect upon the ecology of the vleis downstream is uncertain.

(e) Salinity Studies

Although the work carried out on other projects within the Complex will include certain aspects of salinity, it was considered that an overall study of this phenomenon should be undertaken. One aspect which is of importance and on which information is lacking is the economic impact upon the community of an increase in total dissolved solids and hardness, as well as indirect damages caused by corrosion and deposits in pipe networks and other equipment. This is becoming increasingly important as many industries are changing over to full ion exchange processes instead of mere softening in the treatment of the water because of high salinity.

(f) Eutrophication and its prevention

The problem of eutrophication is well-known and has received attention in other selected catchments by the National Institute for Water Research, under contract to the Water Research Commission, but little work has been done in the catchment of the Vaal river Barrage up to the present. There are many sources of pollution giving rise to eutrophication within the project area, and attention will be directed to this aspect.

(g) Agricultural practice in relation to the use of effluents in irrigation schemes

Vereeniging and Sebokeng at present discharge all their effluents to irrigation, and it is advantageous to know:

- how effective this is as a pollution control measure
- the degree and quality of any flows reaching the rivers
- the maximum amount that can be economically irrigated on available land
- the economic aspects of irrigation and the viability of greater use of irrigation for the control of pollution.

It would be of value to collate information on the extent to which irrigation is at present being practised within the project area, in order to determine the degree to which sewage and mining effluents could be exploited profitably in local agricultural activity. This is important in the light of the fact that irrigation is a consumptive use of water and that mineralised effluents which have a detrimental effect on natural water, may be perfectly acceptable for irrigation.

(h) Economic evaluation of major outfall sewers and other engineering aspects

The economic feasibility of water supply schemes and associated distribution systems, and of sewerage systems for waste water purification works, is mainly determined by the water supply requirements of a specific area or region. The cost of treating a unit volume of water depends to a large extent on the operational cost which decreases exponentially with the size of the installation. These factors should be thoroughly considered when implementing large-scale water and wastewater treatment in order to obtain maximum cost benefit from the economics of scale. The annual cost per person of a works for 500 000 contributors might well be one-half that of a works for 50 000. Many local authorities are prevented from cooperating with their neighbours in combined schemes, because of the extremely high cost of outfall sewers. A thorough study of the economic evaluation of all these factors would be advantageous when the further development of the area is considered. This study should include the cost of installing

outfall sewers; costs of purifying waste water according to alternative standards; costs of water reclamation to sub-potable and to potable standards; and the cost of delivering reclaimed water to potential bulk consumers, or direct to raw water sources.

When the projects outlined above have been successfully concluded, their results will contribute immeasurably to the solution of many pressing problems that the local authorities of the Pretoria-Witwatersrand-Vereeniging-Sasolburg complex (PWVS complex)- and its industrial and other undertakings – are facing, and which cannot be delayed any longer. Without the knowledge that will flow from the research work which has been described, the various bodies concerned could be forced to make decisions which may create irreversible situations, but which would not give the most suitable answer.

The whole approach of the Commission to this type of problem will be clarified and streamlined as a result of its experience with the PWVS complex and it is proposed to apply the refined approach to similar problems throughout the country where intensive development is taking place. In this regard, attention is given specifically to the Umgeni River Catchment, which serves the highly-developed areas on the Pietermaritzburg-Durban axis; the Buffalo and Nahoon River Catchments, serving East London and the Berg River Catchment serving the Western Cape, and generally to other areas such as Port Elizabeth, Bloemfontein and Kimberley.

Chapter 4

The Discharge of Industrial Effluents into Sewerage Systems and the Environment

The efficient treatment and disposal of industrial effluents and their proper management is of cardinal importance to control pollution effectively and to conserve water in the Republic. It is also important for local authorities, in that the acceptance of industrial effluents into their sewerage systems often causes problems in sewers and at treatment works. This could seriously prejudice the ability of even well-designed works to comply with the general standards for effluents, and also the possible re-use of the water.

Direct discharge of industrial effluents into the environment causes problems in water purification, and in the maintenance of uniform water quality. There are at the moment no clearly defined and uniform criteria or technical requirements against which the acceptability of industrial effluents for discharge into sewers may be measured. It is, therefore, of prime importance to both the local authority and the industry that this whole matter should receive early attention.

This position has been appreciated by the Water Research Commission, who, in May, 1973, engaged the services of British consultants, who have had extensive experience of this problem in England and on the European Continent.

In order to ensure that the interests of all organizations concerned with industrial effluents would be taken into account, and to facilitate discussions with the consultants, a Liaison Committee was formed consisting of representatives from:

The Water Research Commission
The Department of Water Affairs
The Department of Health
The United Municipal Executive
S.A. Federated Chamber of Industries
Steel and Engineering Industries Federation of S.A.
National Institute for Water Research
The Institute of Water Pollution Control

The report of the consultants, together with the recommendations of the Liaison Committee were submitted to the Commission at its meeting on 3rd September, 1975 and approved.

These documents comprise a comprehensive and valuable background to the whole problem, including applicable recommendations and many useful comments on current practices in South Africa, as compared to overseas, in regard to industrial effluents; due notice will be taken thereof in future consideration of the many facets of these problems.

It was clear from these investigations that there are several factors, which, while not falling within the field of research *per se,* nevertheless have an important bearing upon the success of achieving optimum results when dealing with the technical aspects of industrial effluent control. These factors refer to the general infrastructure within which local authorities must perforce operate in applying control, and, unless this framework is comprehensive and adequate, successful application of the results of research on the technical side will be adversely affected. For this reason, the Commission has drawn attention to the defects in the present system, and recommended the appointment of a Ministerial *ad hoc* committee to investigate the matter.

On the research side, the whole field in relation to industrial effluent control has been covered in the reports, and the directions into which research must be channelled clearly indicated. These may be divided into six categories, and the Commission has approved of the establishment of a Co-ordinating Action Committee, whose prime function will be the active prosecution of research and the co-ordination of the work within these six groups. The Commission has requested the Committee to take the necessary steps to implement recommendations for research, with due regard to priorities and to the necessity of co-ordinating relevant activity programmes of established Study Groups, Research and Development Committees and Steering Committees of the Commission, as well as of the CSIR, and of departmental committees dealing with aspects relating to the problem areas covered in the report. In this way, the Commission will avoid duplication and overlapping of the research work necessary, and ensure its co-ordination and continuity.

The six categories of research that have been decided on are as follows:

(a) Industrial wastes management

This group comprises the technical control measures to be applied to the management of industrial wastes, and includes the following sub-groups;

(i) Regulations and tariff rates
Existing technical control measures for the discharge of industrial effluents are in many instances not clearly defined, while the present regulations governing the concentration of pollutants in these effluents merely encourage the wastage of water in that concentrations are diluted with pure water to the required level. Similarly, tariff rates applicable to industries for the acceptance of their effluents show considerable diversity among the local authorities throughout the Republic, in the formulae on which these tariffs are based. New technological information will have to be acquired in order to establish practical formulae. The need for research in these fields is manifest, and should show avenues for economy in water usage, and assist local authorities in their responsibility for control.

(ii) Guidelines for industries
There is a clear need for the establishment of guidelines for industries in relation to methods for complying with the quality standards of effluents, and these should be drawn up for each particular type of industry. Such guidelines would be of immeasurable aid to industries, since many of them have difficulty in complying with present requirements.

(iii) Good housekeeping
In order to reduce wastage of water and loss of material, and to promote the re-use of water, good housekeeping within and outside the factory is essential. There are many aspects of factory processes which should be investigated to achieve this aim. Research in this field will result in considerable economic advantage accruing to the industry itself, while easing the treatment problems of the local authority, apart from saving water in the national interest.

(iv) Process design and equipment
Among other aspects of industrial wastes management which will be investigated from the technical angle is the examination of various process designs and equipment, which should aim at the minimum wastage of materials and products, the minimum of effluent and the maximum re-use of water – such standards are not being achieved at present.

(v) Safety regulations
A matter for concern at the moment is the danger to the health and safety of workers in sewers and at purification works owing to the discharge of certain toxic industrial effluents into sewers. It is essential that local authorities should prohibit the discharge of any substance that singly, or in combination with others, may cause objectionable conditions in sewers, and research is necessary to establish such requirements.

(b) Solid and toxic wastes

An urgent problem exists in this country in respect of the disposal of industrial sludges, waste oils, solvents, paint residues, strong solutions of waste chemicals and similar solid, toxic and intractable wastes – many of which are presently illegally dumped into sewers, or into ditches, or on vacant premises. These give rise to health hazards, public nuisance, and to difficulties in the receiving waters of sewers and at treatment works and prejudice the utilization value of the effluents. The possible use of municipal refuse dumps, sanitary landfills or other methods of disposal will be investigated.

(c) Special problems

The discharge into sewers and the natural aquatic environment of industrial effluents containing high concentrations of nutrients such as nitrates and phosphates, can cause serious eutrophication problems in river and dams. As this problem also occurs in other circumstances, advantage will be taken of the work that has already been done in those fields to be applied wherever possible to these special industrial problems. This category comprises the work on eutrophication, denitrification and phosphate removal – the latter will include work on phosphorus-containing detergents. This field of special problems will also embrace problematic effluents from certain specific industries, such as dyestuffs, pharmaceuticals, explosives and toxic substances. Research would cover the pollution significance of these substances, and the extent to which they are removed during tertiary treatment.

(d) Water quality protection

Although a Study Group has already been established by the Commission (See Chapter 1) to investigate the health aspects of wastewater reclamation for direct re-use and the purification of water from polluted sources, it is inevitable that a consideration of industrial effluent problems would also touch on health aspects. These will be discussed with the abovementioned Study Group to ensure that research will cover the aspects that concern industry and its effluent problems. These include the following:

(i) Potentially harmful chemicals
There are certain well-known chemical substances that may over the long and the short term, adversely affect human health and that may reach the water cycle during manufacturing processes (e.g. in the manufacturing of insecticides and pharmaceutical products). Discharge of the effluents of such process cycles into sewerage systems must be totally phohibited and special techniques must be developed for its treatment and disposal. With this in view, lists of these chemical sub-

stances must be compiled and distributed to industrialists with instructions to the effect that these substances should under no circumstances be allowed to reach the factory effluent. Research must be done to ensure the isolation of water cycles in which these substances occur.

(ii) Organic pollution and water quality networks

Natural waters contain organic constituents resulting from contact with soil and vegetation – these constituents present no health hazards. In areas of intensive industrial, agricultural and urban development, such water resources are subject to gradual and progressive organic pollution which should be monitored thoroughly since it may adversely affect water utilization and the ecology of the aquatic environment. Water quality in these environments must at all times meet requirements for its utilization. The progressive collection of information by maintaining water quality networks will indicate the extent to which sewage and industrial effluents should be purified for reclamation and discharge into the aquatic environment, and the extent to which the use of agricultural chemicals should be controlled.

This study is being undertaken by the Commission through the existing Study Group on Health Aspects, who will keep in close touch with current investigations into the discharge of industrial effluents.

(e) Analytical techniques and instrumentation

In view of the key rôle of analysis at all stages of any critical investigation into the discharge of industrial effluents, it is essential that analytical techniques should be brought to a high level of efficiency. The Commission proposes to convene a group of interested persons to examine these techniques and to consider their adaptation to local conditions. Consideration will also be given to methods of investigation to be adapted for the concentration, identification and quantitative determination of specific compounds with known harmful effects, when present in low concentrations in sewage and industrial effluents and in the aquatic environment. establishing the best available analytical techniques will result in considerable saving of time in these and other investigations.

(i) Information booklet on the design of experimental equipment

One of the difficulties in regard to independent research on the various problems associated with industrial effluents is that laboratory and pilot scale work is often carried out by inexperienced researchers who are unfamiliar with approved procedures. Through this lack of knowledge, opportunities to make the best use of the resources, and of the results, are wasted and the value of the work minimised. To obviate this, it is proposed that an information booklet, giving all the essential details of design for equipment for laboratory scale and pilot scale experimental work, be compiled for general distribution to all research workers in these fields.

(ii) Automatic monitoring

One of the problems of ensuring adequate control in respect of the discharge of industrial effluents is the provision of suitable monitoring equipment, particularly in outdoor and remote situations. A unit will therefore be established to develop, test and recommend automatic monitoring equipment for measuring and controlling water and effluent quality.

(f) Technology Transfer

Valuable data and technological information will undoubtedly flow from the work that has been described in this and other chapters, and it is of vital importance that this knowledge should be available and transferred to all quarters where it is needed and where it can be used to considerable advantage. This aspect was discussed more extensively in Chapter 1.

Reference is made elsewhere in this report of the other activities initiated by the Water Research Commission in connection with various industries – these concern the mining industry; the meat, hides and skins, leather and allied industries; the fruit and vegetable canning industry and the textile industry. Work associated with these and other industries will be closely allied to general work on the discharge of industrial effluents into sewerage systems and the environment, and a close liaison will be maintained between all these activities.

Chapter 5

Water Pollution and Effluent Control in Specific Industries

Fruit and vegetable canning industry

This industry is an important sector of the national economy with a total employment figure approaching 30 000 persons, and an annual total turnover in excess of R120 000 000, of which some two-thirds is derived from overseas markets. The bulk of the industry – represented by some 20 large factories – operates in the Western Cape, with other factories in the Eastern Cape, Natal and Eastern Transvaal.

In the canning industry, a great deal of water is used, mainly in the washing of fresh fruit and vegetables; in the fluming and pumping system used for the conveyance of these products through the various process stages; and in the removal of waste material, both in the processing stages and in the subsequent washing of floors and in the cooling of cans.

The industry consumes an aggregate of some 45 000 m^3 of water per day in the peak of the season – this figure is considerably reduced in the off-season, although efforts are being made to extend the harvesting period through scientific methods. About 70% of the flow becomes effluent for disposal, and this gives rise to considerable difficulties. In two cases, factories have recently been given time limits by the relevant local authority, to comply with the effluent standards laid down. The problems arise from high biological loadings, low pH, excessive suspended solids, and high sucrose content. The industry also has special problems in relation to the peeling processes and washing.

In view of their difficulties, the Fruit and Vegetable Canners Association requested the Commission to investigate the matter on a national basis. A Study Group was established, and met in January and in May 1975 to examine the position and to prepare a situation statement and a motivation for research. A document comprising this information was submitted to the Water Research Commission in June, 1975, when it approved the establishment of a Co-ordinating Research and Development Committee to investigate the problems of water usage, wastewater management, pollution control and effluent re-use in the fruit and vegetable canning industry. This Committee has since been constituted, with representation as follows:

Water Research Commission
Department of Water Affairs
Department of Health
Department of Agricultural Technical Services
Department of Agricultural Economics and Marketing
S.A. Fruit and Vegetable Canners Association
- Western Province: six representatives
- Eastern Province: two representatives
- Natal: one representative
- Transvaal: one representative

The Committee held its first meeting in Cape Town on 7th November, 1975, and is now engaged in drawing up a detailed programme of research into the industry's problems associated with water and effluent management.

Meat, hides and skins, leather and related industries

For many years the problems of water pollution and effluent control in abattoirs, hide curing, tanneries and related industries have been viewed with considerable disfavour by local authorities who have to cope with these difficult effluents in their sewerage systems. In fact, there are several such undertakings in the Republic which are presently under notice to effect drastic improvements in the standard of their effluents within a specified time limit or to cease operations. As a result of the serious deterioration in the position, the S.A. Tanners Association called together several kindred associations, and decided to support the formation of an Environmental Research Unit at the Leather Industries Research Institute.

At a meeting in February, 1974, at which the various parties were represented, and to which the Chairman of the Commission was invited, it was finally decided to form a Study Group to define the problems and their various inter-relationships, and to assess the present position of research in these fields, with a view to an approach being made to the Commission for assistance.

As a result of these representations the Water Research Commission approved the formation of a Co-ordinating Research and Development Committee to investigate the problems of water and effluent management in the meat, hides and skins, leather and related industries. This Committee comprises representatives of the following:

Water Research Commission
Department of Water Affairs
Department of Health
Department of Agricultural Technical Services
(a) Division of Agricultural Engineering
(b) Division of Veterinary Services
(c) Veterinary Research Institute
The Abattoir Commission
Livestock and Meat Industries Control Board
National Institute for Water Research
Leather Industries Research Institute
S.A. Bureau of Standards
S.A. Tanners Association
S.A. Fellmongers Association
S.A. Curers Association
Wattle Bark Industry of S.A.

At its meeting on 21st April, 1975 the Committee recommended that the services of a specialist consultant be obtained, in order that a comprehensive situation statement of the water and effluent management problems associated with the various industries of the group should be compiled. As a result, arrangements were made to obtain the specialist services of Dr A L Downing, who is attached to a well-known firm of consulting engineers in London, which is associated with a similar firm in South Africa. Dr Downing is the former Director of the Water Pollution Research Laboratory of the United Kingdom, and has extensive experience of pollution control aspects.

Dr Downing visited South Africa during August/September, 1975, and accompanied by a representative of the local firm on a comprehensive inspectional tour, visited feedlots, abattoirs, meat processers, hide curers, fellmongers, wool pulleries, and tanneries. He also held discussions with several Government Departments and research organisations.

The main report from Dr Downing is now awaited, but in an interim report, he has recommended a programme of pilot plant studies for certain aspects of fellmongery and tannery effluents which represent an urgent problem as far as these industries are concerned. These studies relate to new systems to avoid the use of large quantities of salt which cause serious pollution problems through discharge of the effluents into the aquatic environment. Furthermore, the effluents contain high concentrations of organic substances and other inorganic components such as chromium which have to be recovered before the effluents can be discharged into the natural aquatic environment. This work will commence as soon as possible.

The textile industry

It has been recognised that one of the foremost industries in the Republic which has many problems in the field of water and effluent management is the textile industry. This fact had been recognised by the Water Research Commission at an early stage, and it has already initiated two research projects in this field. The first is the research being carried out by the Chemical Engineering Department of the University of Natal on the recycling of water and the recovery of chemicals in textile processes; the second is the treatment of wastewater from wool textile industries, with particular reference to the recovery of wool grease from wool scouring effluents – this research was commenced by the S.A. Wool Textile Research Institute of the CSIR.

Research is also in hand at the University of Natal, in conjunction with one of the large textile organisations, into the treatment and re-cycling of dyehouse effluents. In addition there are many independent research projects in connection with effluent problems being actively pursued in several of the larger textile undertakings in the Republic – these relate to decolourisation, sodium contamination, removal of fibres, conservation of chemicals and the replacement of water-based operations by solvent-based operations.

It is clear from the position outlined above that some attention is indeed being given to water and effluent problems in the textile industry, but it was equally clear that there was a need for co-ordination between the various research projects being undertaken by different agencies. To maintain adequate liaison with these bodies with a view to proper problem identification, and the elimination of unnecessary duplication of work, it was essential that there should be some central co-ordinating body that would supply unified direction to all research activities in this field.

With this object in view, the Water Research Commission has authorised the establishment of a Study Group to investigate the position and to report on the desirability of establishing a Co-ordinating Research and Development Committee, who could act in the national interest and to the advantage of the textile industry as a whole. This Study Group comprises representatives of the following:

The Water Research Commission
S.A. Wool Board
S.A. Wool Textile Research Institute
University of Natal
S.A. Wool Combers Trade Association
National Association of Woolwashers and Carbonisers of S.A.
S.A. Cotton Textiles Manufacturers Association
S.A. Worsted Manufacturers Trade Association
National Textile Manufacturers Association
S.A. Dyers and Finishers' Association

This Study Group met on 30th June, 1975, and is presently engaged in the compilation of a basic situation statement and problem identification report and the development of a National Master Research Plan and a National Priority Research Programme for submission to the Water Research Commission, with a view to the early establishment of the essential co-ordinating body to direct research into the problems of water usage and effluent reclamation in the textile industry.

The mining industry

Serious pollution problems are encountered in the gold and coal mines, principally owing to the mineralization of ground and surface water.

This mineralization is caused by the interaction of sulphuric acid and notably the lime-bearing rock in the mine, and in the sand, stone and waste dumps in the vicinity of the mine. Large quantities of sulphuric acid are produced in mines and mine dumps as a result of pyrite oxidation, and cause the formation of calcium sulphate that dissolves in the drainage water and reaches rivers.

In view of the position, particularly on the Witwatersrand, where the magnitude of the problem is appreciable, representations were made to the Water Research Commission for the establishment of a Co-ordinating Research and Development Committee to investigate the water pollution problems of the mining industry. This proposal was duly approved by the Commission, and the Committee was then constituted, with representatives of the following:

Water Research Commission
Department of Water Affairs
Department of Mines
Department of Agricultural Technical Services
Chamber of Mines of South Africa
Natal Coal Owners' Society
S.A. Iron and Steel Corporation (ISCOR)
National Institute for Water Research
S.A. Bureau of Standards

The inaugural meeting of the Committee was held on 14 May, 1975, and it was decided that the first step would be the compilation of a comprehensive background statement on the present position and the actual water pollution problems facing the mining industry. Statements are now being prepared by the Chamber of Mines, the National Institute for Water Research, Iscor, and the Departments of Water Affairs and of Agricultural Technical Services. The Department of Mines will assist in the contacts with mines that are not members of the Chamber of Mines or of Mining Associations, and will co-operate with the Department of Water Affairs in the case of derelict mines, which also contribute to these problems.

Chapter 6

Research on Eutrophication

During the recent period of increased public awareness of environmental pollution, one aspect which has not escaped the attention of the public is eutrophication and its secondary pollution problems, although the phenomenon and its problems have been a commonplace to biologists working in the water environment for many years.

The word 'eutrophication' denotes in general an increase in the nutrient status of a water body and is a natural process in the history of water impoundments. However, intensive urban and industrial development of catchments leads to an acceleration of the eutrophication process as a result of effluents and run-off containing nitrogen and phosphorus reaching water bodies, leading to increased plant growth and indeed increases in all biological forms including fish.

Mild eutrophication is often welcomed, especially for example by anglers but continued increase in growths can lead to serious problems. Excessive algal growth causes toxic or aesthetically objectionable conditions and hampers water purification processes, while excesses of plant growth seriously affect the recreational value of water. South African impoundments are in many ways particularly sensitive to potential eutrophication problems, especially in view of the limited volume of water available for dilution.

Research needs

The problem calls for a wide range of investigations at this stage, aimed at practical measures for –

- preventing the eutrophication of currently unpolluted impoundments in the face of intensified developments in their catchments
- rehabilitating impoundments that are already eutrophied
- controlling acute symptoms of eutrophication when rehabilitation will be a long-term process or is in fact economically unjustifiable.

Short-term measures for controlling the symptoms of eutrophication may include mechanical management strategies, biological control of aquatic weeds, chemical treatment or mechanical harvesting of weeds or algal growth. Another possibility that must not be overlooked is the utilization of this enriched status, for example, through the extensive harvesting of fish from such impoundments.

A multi-disciplinary approach is required to attain the research objectives outlined above, and this calls for co-ordinated investigations by a variety of institutions.

Research supported by the Water Research Commission

Eutrophication of rivers and dams

Research by the National Institute for Water Research (NIWR) into the eutrophication of rivers and dams (under contract to the Commission) concentrates on seeking a fuller understanding of the limits which should be imposed on nutrient inputs to lakes in order to prevent or minimize eutrophication problems. This work is commented on in Chapter 10, but briefly consists of intensive studies of selected impoundments covering a range of eutrophication conditions, in an attempt to correlate their nutrient budgets with the degree of eutrophication nuisance encountered. This is being supplemented by studies of the effects of artificial enrichment on small selected impoundments.

The work seeks to include both clear water lakes, corresponding more closely to those overseas on which much of the original work has been done, and silty lakes, typical of many South African impoundments. The programme also includes investigations into the economic implications of eutrophication problems for water purification processes, and a collation of present methods for nutrient removal from effluents. This work has now reached the stage where manuals may be compiled to serve as guidelines when developing catchments, in order to limit eutrophication to a minimum.

The role of aquatic plants

It has often been observed that eutrophied streams passing through dense plant growth, as in vleis, undergo a marked reduction in phosphorus levels. This kind of natural control of eutrophication is one of obviously great importance. The project being carriekd out at Swartvlei by the Institute of Fresh Water Studies of Rhodes University is directed to seeking a fuller understanding of the effect of aquatic growths on trophic levels (i.e. levels of plant nutrients). Whereas this fundamental study is being carried out on a non-eutrophied impoundment, it

is envisaged that what is learned there of the mechanisms of these processes can be exploited and applied to the management of other water bodies – possibly by means of artificial establishment of plant growth as a means of phosphate removal.

Removal of nitrogen and phosphorus from effluents

For some years now in various parts of the world attention has been given to maximising the biological removal of nitrogen and phosphorus (the main eutrophying elements) from wastewaters. A number of South African workers are making considerable contributions in this field and encouraging progress has been made. One example is the Commission's contract with the NIWR for research on biological denitrification and phosphate removal reported in Chapter 10 of this report. This work is being co-ordinated with related work done at the University of Cape Town, much to the benefit of both groups. Several other groups of experts including municipal and consulting engineers are making great strides in this direction. While these processes may not provide a final solution it can be predicted that in a very short time this work will give rise to possible standard approaches to the design of sewage works to ensure effluents with significantly lower phosphate and nitrogen content than is usual at present. Technology for the removal of nitrogen and phosphates from effluents has already progressed sufficiently to permit the compilation of manuals on design criteria for the relevant unit processes.

Integrated catchment studies

The Commission is interested in extensive and integrated studies of effluent disposal and water reclamation in selected catchments (such as is outlined in the Chapter 3 of this report dealing with the Pretoria-Witwatersrand-Vereeniging-Sasolburg complex), where intensified development is bringing potential effluent problems into prominence. In another of these important catchments, the Umgeni River catchment in Natal, concern is already being expressed at the possible eutrophication both of existing dams and those yet to be built in this extremely important catchment and it is increasingly evident that vital planning decisions will have to be made soon if the creation of irreversible harmful situations is to be avoided. The same applies to a third area of great interest and importance, the catchment of the Buffalo River near East London, with the associated catchment of the Nahoon River.

Work in progress in other institutions

Around the country there is a considerable amount of work being carried out relevant to this problem, and in many cases this is still to be co-ordinated.

One such project is the experimental aeration of sections of Hartebeespoortdam that is being carried out by the Department of Water Affairs and in which the NIWR is also involved. The work is directed to maintaining healthier oxygenated conditions in the water and to investigating the conditions under which phosphate will remain insoluble in the bottom sediments rather than becoming resolubelised and therefore available for fresh plant growth.

A number of workers in the country, both at universities and in the Natal Regional Laboratory of the NIWR, are given attention to the role of sediments in phosphate release and/or absorption. This is obviously of great importance in view of the silty nature of so many South African rivers and it is still obscure whether the presence of this suspended clay and similar materials acts to improve or aggravate eutrophicated conditions.

Control measures

Mention has already been made of control measures that can be applied either to deal with emergency situations or under conditions where rehabilitation measures will be long-term or impossible. These approaches should be seen side by side with possibilities for exploitation of the eutrophied status, e.g. by fish harvesting.

As was indicated above, a number of possibilities present themselves and it is the intention that in the coming year greater attention should be given to the need for research and development projects in one or more of these fields. Tentative guidelines for the control of eutrophication are in the course of preparation, emerging from the contract with NIWR on eutrophication. While these mention some of the control measures that can be applied, it is clear that further investigation is necessary on the technical and economic feasibility of these measures under varying physical conditions.

Chapter 7

Research on Irrigation

The application of water for irrigation purposes plays an important strategic role in food production and currently represents approximately 75 per cent of the total water consumption in the Republic. It is estimated that water consumed for irrigation purposes will increase at the rate of 3 per cent per annum and industrial consumption with approximately 7 per cent which will entail that agriculture, by the year 2000, will probably be allocated only 45 per cent of the total consumption. To resolve this situation, research on the improvement of irrigation techniques and more efficient production per unit of water is urgently required.

Study group for irrigation

As was reported in the previous Annual Report, the Commission, in pursuing its task of co-ordinating and promoting research on the agricultural uses of water, established a Study Group for Irrigation Research. The Study Group comprises representatives of the Water Research Commission, the Departments of Agricultural Technical Services, Agricultural Economics and Marketing, Water Affairs and the South African Sugar Association Experiment Station at Mount Edgecombe.

Investigations undertaken during the past year by the Study Group for Irrigation Research indicated that irrigation practice and water management will have to improve greatly in order to realize increased production per unit of water.

The first task of the Study Group was to identify the restraints and specific problems in detail in order to compile a Master Research Plan and a Priority Research Programme. To this end the group undertook a number of visits to important irrigation schemes and irrigation areas as well as research organizations for in-depth and critical discussions with farmers and research officers. Professor P J C Vorster, Senior Adviser of the Commission undertook an overseas study tour and visited various centres of expertise in a number of countries.

With the collected information as basis, the Study Group compiled a report in which those aspects which require urgent research were classified under the following headings:

1 Overhead considerations in irrigation.
2 Irrigation water: sources, storage, supply and distribution.
3 Soil aspects.
4 Climatological factors: agricultural-meteorology aspects.
5 Aspects relating to crops.
6 Engineering aspects.
7 Specific problems in respect of irrigation and drainage systems.
8 Agricultural economic aspects.
9 Irrigation extension and training.

The investigations of the Study Group again indicated very clearly that irrigation research requires in most cases an interdisciplinary approach; moreover, that it is essential that a high degree of co-operation should exist between the Departments of Water Affairs and Agricultural Technical Services and other organizations in order to attain the common objective.

Priority research programme

The Study Group is currently in the process of compiling a Priority Research Programme and of formulating the essential requirements for its implementation. Even at this stage it is evident that high priority should be accorded to the following specific problems:

- The insufficiency of data and information in respect of the water requirements of crops under widely divergent condition of crops, climate and soils.
- Inefficient scheduling of water applications during the growth seasons.
- Inadequacies in existing irrigation techniques and equipment.
- The lack of management expertise and haphazard approaches to economic and water conservation aspects.
- Ineffective irrigation extension and guidance to farmers in respect of irrigation.
- Scarcity of trained manpower in the field of irrigation research.

Research supported by the Commission

Against the background of the abovementioned restrictions which have already been clearly identified, the Commission has already taken action and currently finances research projects in connection with water requirements of agronomic and horticultural crops at the Universities of Pretoria, the Orange Free State and Fort Hare. At Fort Hare in the Transkei certain soil factors which influence optimal utilization of irrigation water are being investigated, whilst an investigation was commenced at Vaalhartz on soil compaction which has a deleterious effect on efficient irrigation. These projects are closely related to similar important work being done by the Soils and Irrigation Research Institute (Department of Agricultural Technical Services), the Hydrological Research Institute (Department of Water Affairs) and by other organizations in various localities and it is envisaged that within the next four years a considerable volume of new information will become available for more accurate determination of the water requirement of crops.

Further information on the projects financed by the Commission appears in Chapter 10.

As far as the manpower problem is concerned, the Commission is currently negotiating with the Departments of Agricultural Technical Services and Water Affairs in connection with the acquisition of the services of overseas contract researchers for the promotion of work relating to the water requirements of plants and the instrumentation and automation of equipment.

Chapter 8

Desalination Research

As mentioned in Chapter 1, the Water Plan Commission had recommended the desalination of sea water as one of the measures to increase the assured yield of fresh water in South Africa.

Although desalination research has been proceeding on a worldwide basis, economic considerations still constitute a barrier to the large scale desalination of sea water. A definite breakthrough in this field can probably not be expected and it is rather a case of research gradually lowering the real cost of desalination and placing it in a more favourable position compared to the ever growing cost of developing other sources of supply.

In South Africa especially, the greatest immediate potential of desalination techniques seems to lie in the desalination of naturally occurring brackish waters and mineralized waters originating from agricultural, industrial, mining and domestic use.

The occurrence of mineralized waters in South Africa

Various sources of mineralized water occur in South Africa, which may require desalination in the foreseeable future. These are discussed below:

- Most natural *surface water* resources in the Republic are of good quality, having total concentrations of dissolved solids below 500 mg/ℓ; however, in certain parts of the country, notably the Western Cape, the salinity of the runoff may exceed this value during periods of low flow.
- In the high rainfall areas the quality of *groundwater* is normally good but it usually deteriorates in the drier areas where some very brackish waters are encountered.
- Drainage waters from irrigation schemes are in most cases severely mineralized, and lead to a considerable deterioration in the quality of river waters.
- An increase in the recycling of water is leading to increases in the dissolved solids concentration of effluents being returned to the water environment.
- The mineralisation of waters during industrial and domestic use and as a result of mining activities is one of the most serious problems affecting the quality and reuse potential of these waters.

Processes for the desalination of water

The following are the most feasible unit processes which can be applied to the desalination of water on a large scale and which are of importance for the South African scene:

Distillation	Electrodialysis
Reverse Osmosis	Ion Exchange

In *distillation* heat is applied to the water and the resultant vapour is condensed to give pure water. This is the process most widely applied to sea water thus far.

Reverse osmosis is a process which is being widely developed and applied overseas for the desalting of sea water and other saline waters. In this process, water is separated from a salt solution by applying a pressure across a semi-permeable membrane.

In the *electrodialysis* process, water is pumped through an electrolytic cell and the various ions are separated by passage through cation and anion selective membranes, leaving fresh water behind.

Ion exchange is a process in which the various anions and cations present in water are absorbed reversibly on the resinous materials in the form of small beads.

Desalination research in South Africa

An awareness of the limited water resources of the country and of the serious effect of mineralisation on the reuse potential of water, has led to a good deal of research into desalination over the past two decades. This research was initially concentrated on electrodialysis while in recent years increased attention has been given to reverse osmosis and ion exchange. Tests on a vapour recompression distillation unit were completed in 1974.

The application of *electrodialysis* to a number of different saline waters has been studied. These waters include particularly the mine drainage waters of the Orange Free State goldfields which were desalinated on a large scale for a time and also brackish water for stock watering. Studies were also carried out on the development of selective membranes for electrodialysis from Kraft paper.

As reported in the previous annual report, an experimental *reverse osmosis* plant, comprising five different types of unit, was commissioned towards the end of 1974 in the Beaufort West district to evaluate its field application. Progress on this project, being sponsored by the Commission, is reported in Chapter 10 of this report.

The *ion exchange* research into desalination sponsored by the Commission is being conducted at two centres, namely the National Institute for Water Research of the CSIR, Pretoria and the Department of Chemical Engineering at the University of Cape Town. The WAT process for the desalination of sea water is being studied at the former while desalination of saline treated sewage effluent, which includes the removal of some dissolved organic matter, is being studied at the latter. Further information on these projects is given in Chapter 10.

Basic research on the synthesis of membranes for reverse osmosis and ultrafiltration (a process similar to reverse osmosis) is being done at the University of Stellenbosch.

Finally, it can be mentioned that promising results have been obtained at the University of Natal in the application of *ultrafiltration* to certain liquid effluents from the textile industry. This work is proceeding and is also being sponsored by the Commission.

Co-ordination of desalination research

In addition to sponsoring various desalination research projects, the Commission has also taken action to promote the co-ordination and rational planning of desalination research in South Africa. Steps taken so far, were to enlist the services of a specialist overseas consultant and to establish a Study Group for Desalination Research.

Visit by specialist consultant

A contract was negotiated with the Atomic Energy Research Establishment at Harwell in the United Kingdom, for the services of Mr K D B Johnson. Mr Johnson's terms of reference were to review the status of current research and development work on desalination in South Africa and to make recommendations with respect to its extension, programming and implementation as an integral part of water resources planning and exploitation. During his visit, Mr Johnson, accompanied by an expert of the National Institute for Water Research, visited various government departments, research establishments, statutory bodies and industries having an interest in desalination research and the application of desalination techniques.

Mr Johnson's final report has been completed, and some of his recommendations and conclusions are as follows:

- South Africa should coordinate its desalination research with work which is being done in other countries and should concentrate on applications and field trials and the development of equipment which operates reliably in the hands of relatively unskilled operators.

- A substantial portion of this work should be research and development of reverse osmosis and ultrafiltration techniques because of their wide range of application to South African problems.

- The combination of reverse osmosis with water reclamation processes should be considered.

- A detailed examination should be made of many of the potential sites for the medium-scale use of desalination, to identify the characteristic problems of each individual site.

- A central, field trial team should be established which could evaluate selected desalination equipment in the field in respect of adaptability and minimum technical supervision.

- The programme should also include studies on electrodialysis and ion exchange processes while a watching brief should be kept on distillation and freezing desalination developments.

- Suitable attention should be given to the development of brine disposal by means of solar evaporation pans, both natural and artificial, as brine arises in every desalination process.

Study group for desalination research

At a joint meeting of the Steering Committees for the WAT process and the Brackish Water Desalination research projects, it was decided to form a Study Group for Desalination Research. The primary function and purpose of this Study Group is to prepare a Master Plan for Desalination Research together with a Priority Research Programme, to meet the needs of South Africa in this field. This Master Plan is being prepared, taking into account Mr Johnson's recommendations, and significant progress has already been made.

The membership of the Study Group comprises representatives of the Department of Water Affairs, the Department of Agricultural Technical Services, the National Institute for Water Research, three universities conducting desalination research and the Water Research Commission.

At its first meeting during December, 1975, the Study Group decided that, in order to make recommendations regarding priorities for desalination research, it would first be necessary to examine a number of potential priorities in more detail. Some of these are:

- Brackish waters from selected boreholes
- Underground waters pumped from mines in the Witwatersrand.
- Treated saline sewage effluent of industrial origin.
- Reclaimed water derived from sewage in the Rand Water Board area of supply.
- Water from the Diep River or Berg River in the Cape Province.
- The Orange River Project area at Komiteesdrif.
- Saline water at Port Elizabeth and East London
- Selected effluents from major industries

These and other aspects are to be considered by a subcommittee of the Study Group.

Once the Study Group has completed a Master Plan and Priority Research Programme, these will be submitted to the Water Research Commission for approval. The intention is subsequently to form a Co-ordinating Research and Development Committee consisting of high level representation of interested bodies in order to give effective implementation to the programme and to review it on a continuing basis.

Chapter 9

Water Economy Measures in Distribution Systems in Urban Areas

Following the Water Year of 1970, the Honourable the Minister of Water Affairs and Forestry (the Honourable S P Botha MP) indicated that it should be possible to effect great savings in the use of water, and in October, 1973, he appointed a Water Economy Committee to investigate the possibilities of incorporating water-saving measures in domestic and industrial water supply systems.

This Committee, which operated under the aegis of the Secretary for Water Affairs and his Department, considered many suggestions for water saving devices, and decided that there was considerable scope for research in this matter. This was brought to the attention of the Water Research Commission, so that further investigation and research into the possibilities of these and other water saving devices could be instituted.

At the same time, the Water Research Commission was carrying out an extensive survey of the water supply systems provided by local authorities. This survey, carried out by means of interviews, inspections and questionnaires, helped to build up comprehensive background information, highlighting the problems which are being encountered by these authorities. One of the aspects clearly brought out is the relatively high consumption of water per capita in many instances, and the excessive losses which generally take place in the distribution of potable water to consumers.

It was clear, therefore, from the results of these surveys and from the recommendations of the Ministerial Committee on Water Economy, that research and development on aspects of water economy would be rewarding and fully justified. The Commission thereupon appointed a Co-ordinating Research and Development Committee (CRD-Committee) to initiate and direct the necessary research; the following State Departments and other organisations being represented:

Water Research Commission
Department of Water Affairs
Department of Public Works
Department of Health
Building and Construction Advisory Council
National Building Research Institute
S.A. Bureau of Standards
The Institution of Municipal Engineers
The S.A. Institution of Civil Engineers
The S.A. Institute of Architects
Building Industries Federation of S.A.

The CRD-Committee held its first meeting on 30th May, 1975, and arranged for the compilation of a comprehensive programme of research, for its consideration. At its meeting on 13th November, 1975, the Committee approved in general the following fields of investigation:

(a) Losses at purification works

This is a substantial source of wastage. The survey carried out by the Commission indicated losses of the order of 8 to 10 per cent of the water passing through the purification works, mainly in the desludging of settling basins, and in the backwashing of filters. Methods to reduce these losses will be investigated.

(b) Losses in distribution

The Commission's survey revealed that considerable losses of water also occurred in distribution systems – in some cases as high as 14 per cent of the water supplied. An investigation into this problem had been instituted by the Commission prior to the establishment of the CRD-Committee, when in August, 1974, a contract was concluded whereby the Department of Chemical Engineering of the University of Pretoria would investigate the loss of water from pipe networks. Good progress is being made on this work, which consists of two phases – firstly, to determine the causes and extent of the water losses, and secondly, to investigate methods of preventing and controlling these losses.

(c) Consumption of water

Reference has been made to the relatively high consumption of water per capita in urban areas, and it is essential to establish standards for various usages. This problem was also recognised by the Commission at an earlier stage and a contract was awarded to the Department of Chemical Engineering of the University of Pretoria, in August, 1974, to determine the water consumption patterns in the domestic and industrial sectors. Attention is being paid to the effect on water consumption of varying sizes of erven; of various income groups; and of diffe-

rential water tariffs, each in the context of different population groups. The water requirements of sewage in sewerage systems, and the possible use of sea and brackish water in sewerage systems and in fire-fighting are also being investigated. Good progress is also being made with the preliminary stages of this study.

Another aspect of the consumption of water that is to receive attention is the subject of metering, particularly in regard to high-rise buildings, where difficulties have been encountered. Effective metering means good control of consumption, and the merits of various types of meters will be investigated.

Other fields of water consumption included in the research programme are urban garden watering, private swimming pools, and the collection and usage of casual water, for example, the run-off from roofs into rainwater tanks. The use of water for public purposes and for parks and open spaces will also be examined.

(d) Water fittings

A prolific source of wastage in water supply systems is leakage from water fittings, particularly those installed in consumers' premises. The aim of this research will be to investigate and recommend designs and control devices which are more economical in water usage, while still maintaining acceptable standards of hygiene. Included in this group, in addition to the standard items of washhand basins, baths, waterclosets and urinals, will be such appliances as hot-water heaters, garbage grinders, dishwashers, washing machines, air conditioning installations and the like – all potential sources of wastage of water, which in the aggregate means the loss of large amounts of water.

(e) Training and supervision

The Committee proposes to give some attention to the question of ensuring that persons concerned with the distribution of water should be adequately trained in its efficient use, so that they will be capable of exercising proper control over the distribution of water. It is envisaged that this approach will involve university and technical training colleges, and will comprise lectures in this field to students of civil engineering, architecture and building science, while seminars would be organised for all building and drainage inspectors and allied technicians to bring to their notice the efficient use of domestic water and its importance in water usage.

(f) Technology transfer

It is important that advantage should be taken of all available knowledge in this field, especially overseas where recently a conference was held on this very subject. Steps will be taken to obtain this information, to be used in the research being supported by the Commission.

Finally, attention will be given to getting the positive results flowing from this research over to the consumer of water. Adequate and effective publicity for this purpose must be obtained through the media of television, radio, cinema and press, and also in schools. Additional transfer of knowledge will be obtained by means of symposia, seminars and lectures. The public can contribute much to the cause of water economy and its aid must be enlisted in the endeavour to save water.

Chapter 10

Research and Development Projects

The Commission grants research appropriations in terms of Section 3(1)(c) of the Water Research Act by way of formal contracts previously approved by the Honourable the Minister of Water Affairs. Each project is carried out under supervision of a Steering Committee representing the Commission, other interested organizations and personal expertise. Steering Committees have to consider and approve, inter alia, working programmes, progress reports and projects.

Five new contracts were awarded during the year under review, bringing the total number of research contracts in which the Commission is envolved, to 33. In addition, the Commission has approved a further two projects for the next financial year. One project *viz* 'The treatment of waste water from wool textile industries' was completed during the year under review.

Projects financed by the Commission, are the following:

WATER RECLAMATION

Reclamation of Water at the Athlone Sewage Works

(Existing project: Contract with the Municipality of Cape Town and the CSIR – National Institute for Water Research)

As a result of intensive investigations carried out in the Cape Peninsula on the feasibility of reclaiming purified sewage effluents for unrestricted reuse, it was found that the concentration of mineral salts in the purified sewage effluents was of the order of 600 to 800 mg/ℓ, which is an unusually high level. This meant that an additional stage for the demineralisation of the effluent would have had to be incorporated in the reclamation system, in order to meet an acceptable drinking water standard of 500 mg/ℓ of total dissolved solids.

Subsequent investigations, however, showed that the major portion of the mineral load was derived from a relatively small flow of highly mineralised industrial effluents which were discharged into the sewers. The obvious solution to this problem was therefore to segregate the effluents of predominantly industrial and domestic origin.

In replanning the sewage conveyance systems and the sewage purification works in the Cape Peninsula, the Cape Town Municipality commendably decided to utilize the existing sewage purification works at Athlone for the treatment of the predominantly mineralized industrial effluents and to construct separate treatment facilities for the effluents of predominantly domestic origin. Since the segregation of the industrial and domestic effluents greatly enhances the possibilities of reclaiming purified sewage effluents for unrestricted reuse, this is a principle which should be adopted wherever practical. There still remains the question of dealing with the highly mineralised industrial effluents.

The feasibility of reclaiming the purified industrial sewage effluents for industrial reuse cannot be disregarded and for this purpose the Commission has entered into an agreement with the Cape Town Municipality to investigate this aspect. As a result of these negotiations it was agreed to erect a pilot reclamation plant with a capacity of 300 m^3d at the Athlone sewage treatment works. The water produced from this plant will be evaluated as to its suitability for industrial use.

The construction of the pilot plant was commenced in October, 1975, and is due to be completed in the third quarter of 1976. Research work on the pilot plant will be carried out by the Cape Town Municipality in collaboration with the National Institute for Water Research of the CSIR and the University of Cape Town, the latter of whom will undertake studies on the demineralisation of the effluents as part of their project with the Commission on the 'Treatment of Waste Water by Ion-exchange'.

The design of the pilot plant is based on the latest research information made available by the National Institute for Water Research of the CSIR. The plant will include a biological stage

after lime treatment and ammonia stripping, to ensure improved quality and higher efficiency in the removal of organic carbon.

Adaptation of the Windhoek water reclamation plant to the latest research data and technological development

(Existing project: Contract with the Windhoek Municipality and the CSIR – National Institute for Water Research)

This project entails modernising the Windhoek Water Reclamation Plant according to the latest research data generated by the National Institute for Water Research (NIWR). An evaluation of these data during practical and large scale operation will be very valuable in implementing water reclamation systems in the Republic.

Construction of the modified plant is the responsibility of the Municipality and is expected to be complete by March 1976. Thereafter a start will be made to evaluate the performance of the plant and to optimize the operation of the units before reclaimed water is again incorporated into the water distribution system.

In the meantime a thorough investigation into the hygienic quality and epidemiological aspects of water in the Windhoek area has been proceeding. In this way useful background information has been generated which will serve as a basis of comparison when continuing the hygienic and epidimiological studies after the reclaimed water has been incorporated into the water supply network.

Since the quality of the reclaimed water must at all times rigorously comply with the microbiological and chemical quality requirements for potable water, controlling investigations are being conducted by four separate organizations viz. the NIWR, the Municipality of Windhoek, the S.A. Institute for Medical Research (SAIMR) and the Department of Water Affairs (SWA Branch). The results of the various organizations are correlating well, which signifies that the analytical techniques being applied are suitable to detect unacceptable deviations.

In order to obtain a clear picture of the quality variations of the different sources of water supply to Windhoek, provision has been made for sampling and analysing the separate sources according to a regular and irregular time schedule. In pursuing this monitoring procedure it has been possible to exercise control over the quality of all water sources and to establish measures to prevent pollution of the individual supply sources.

The epidemiological studies in Windhoek have been extended considerably by the establishment of the SAIMR's properly equipped virological laboratory at the Windhoek hospital. Thus far the epidemiological studies have indicated that disease patterns in the Windhoek area show no relation to the quality of water supply in Windhoek.

Technological development of water reclamation and pollution control

(Existing project: Contract with the CSIR – National Institute for Water Research)

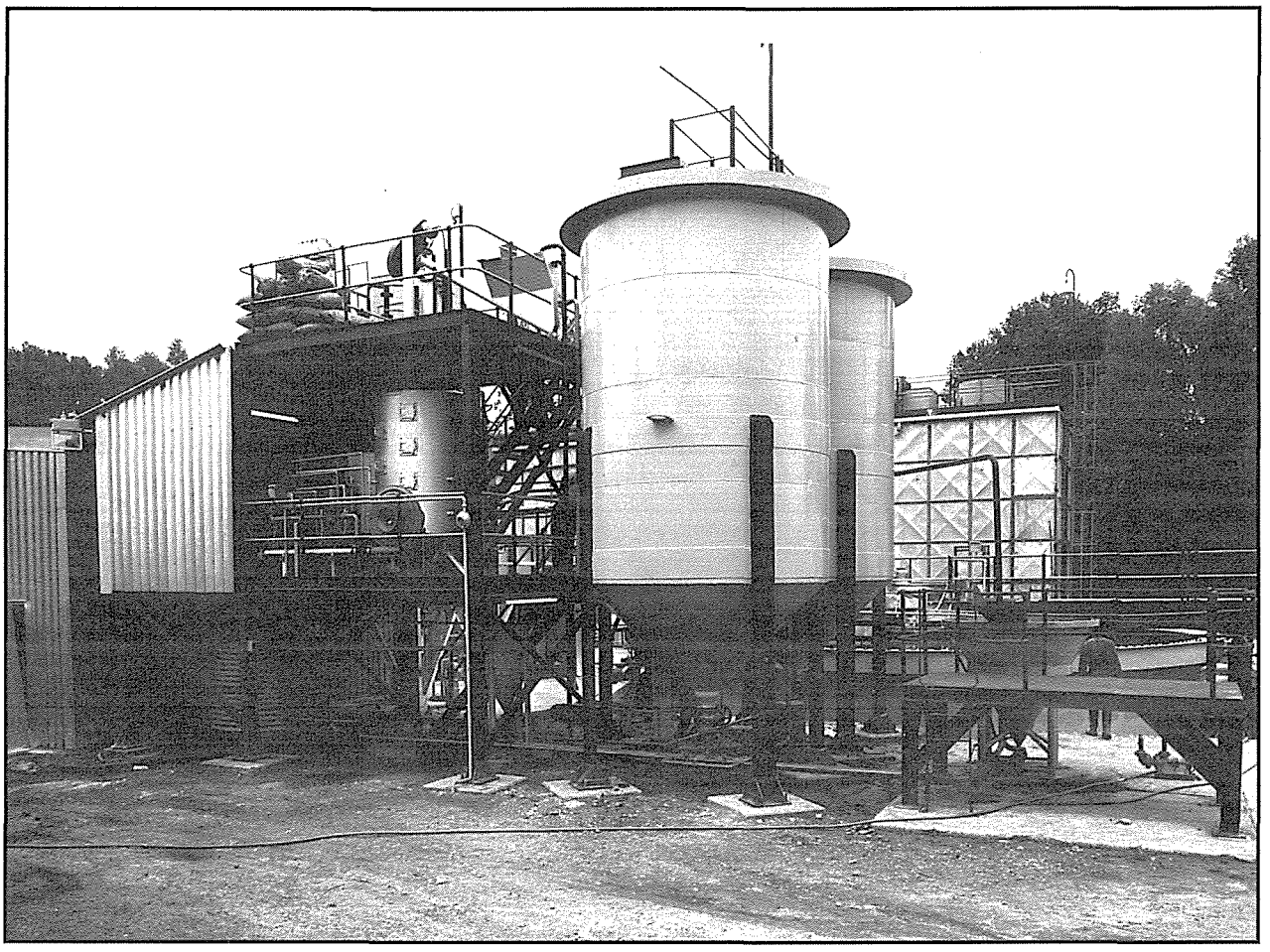
The Stander Water Reclamation Plant at Daspoort, Pretoria, has during the past year been in continuous operation for nine months, and has consistently produced water of excellent quality. The main objective was to develop design and operational criteria for full-scale application of water reclamation. Concurrently, various process units were refined in respect of their performance within the reclamation system. A further objective of continuous operation was to enable intensified evaluation of health aspects of water reclamation.

During the past year, the water reclamation system was subjected unintentionally to possibly its most strenuous test to date. As a result of toxicity in the raw sewage influent to the conventional sewage works, the secondary biological processes were inactivated to such a degree that the feed to the reclamation plant was of extremely poor quality for a period of some two months. Even under these adverse conditions the plant produced reclaimed water of Class A quality throughout.

Problems associated with lime dosing as previously reported were greatly alleviated by the use of an improved closed-loop pH control system. This system now effectively controls the pH within the specified limits. The use of air for mixing the added lime as was practised initially, had a serious drawback in that the lime reacted with the carbon dioxide in the air. This constituted a 28 per cent wastage of lime at pH 11,2 and further caused the formation of additional sludge. The air agitation system was subsequently replaced by a mechanical mixer effecting savings in both chemicals and electricity as well as in sludge disposal.

Calcium carbonate and magnesium hydroxide precipitation in the lime reactor and primary clarifier were studied for a number of different modes of plant operation. Increasing the lime dosage resulted in increasing dissolved calcium and decreased dissolved magnesium in the primary clarifier effluent. The incorporation of the lime reactor resulted in more complete magnesium hydroxide precipitation. The recirculation of primary clarifier sludge upstream of the reactor resulted in an even more complete precipitation of both calcium carbonate and magnesium hydroxide. The final mode of operation effected an average suspended hardness carry-over of the order of 10 mg/ℓ (as $CaCO_3$) from the primary clarifier.

The introduction of an equalization pond in the sequence of process stages resulted in a significant degree of ammonia and pH quality equalization. This facilitated the downstream control of breakpoint chlorination as well as carbon dioxide and alkali dosing. A system comprising a surface aerated equalization pond followed by stripping towers yielded superior ammonia stripping characteristics. In addition scale formation in the stripping tower was reduced by 26 per cent while the cost of recarbonation was significantly lowered due to the uptake of carbon dioxide in the surface-aerated pond.



The carbon regeneration plant at Daspoort (in Pretoria) used by the National Institute for Water Research in researching technological development of water reclamation and pollution control.

The surface-aerated pond was found to act as a microbiological barrier and considerable reductions in coliform, presumptive *E. coli* and polio virus II counts were observed. The advantages gained by the inclusion of the surface-aerated equalization pond justify its incorporation into the design of future water reclamation plants.

Various modes of split treatment chlorination were evaluated with a view to possible chemical savings. Partial or complete replacement of carbon dioxide by chlorine reduced the consumption of both carbon dioxide and sodium hydroxide, but certain inherent disadvantages of split treatment chlorination was found to offset the cost benefit.

The running costs for the activated carbon treatment is one of the most expensive of all the individual processes involved in water reclamation. This can, however, be substantially reduced by thermal regeneration of the spent carbon for re-use. To evaluate the feasibility and economic advantages of regeneration and re-use of the granular activated carbon a thermal regeneration plant was commissioned during the past year. It is estimated that the capital outlay for the regeneration plant will be offset by one year's savings in running costs for the replacement of the spent activated carbon.

Phase one of the development programme envisaged under the initial contract between the National Institute for Water Research and the Water Research Commission was concluded at the end of 1975. Comprehensive documentation of design criteria for future water reclamation systems and of quality parameters is currently in progress, and the final document will be made available to the Commission and published by the Commission for distribution to consulting engineers, local authorities and government institutions who may be interested in the implementation of water reclamation for the production of water for various industrial uses. This phase has clearly indicated that sewage may be purified to such an extent that it may be applied for industrial purposes, and may replace fresh water.

The current contract with the Water Research Commission, which drew to a close at the end of 1975, has been extended for a further five years in order to ensure a thorough evaluation of the suitability of reclaimed water for unrestricted re-use from a health point of view.

To this end, a joint programme is being undertaken by the S.A. Medical Research Institute and the NIWR. The investigation is being integrated with the Windhoek studies and the programme entails intensive monitoring. In addition the NIWR

has entered into a contract with the Department of Health with regard to the determination of chemical residues.

Advantage will also be taken of this opportunity to: determine the efficiency of ozonation as a means of sterilization as opposed to chlorination; carry out a cost-benefit analysis of the thermal regeneration of activated carbon; assess the performance of the plant to an influent feed from an activated sludge sewage purification plant instead of that from a conventional biological filter treatment plant; and make use of the facility during this period for demonstration and training purposes. In the latter regard specific steps will be taken to acquaint state departments, local authorities and consulting engineers with the processes involved and the applicability of the system to serve as a supplementary water supply source.

Reclamation, underground storage and abstraction of purified sewage effluent in the Cape Peninsula

(Existing project: Contract with the CSIR – National Institute for Water Research)

This project comprises reclamation and storage of purified sewage effluent in the sand deposits of the Cape Flats, and to this end the construction and operation of a module reclamation plant is envisaged.

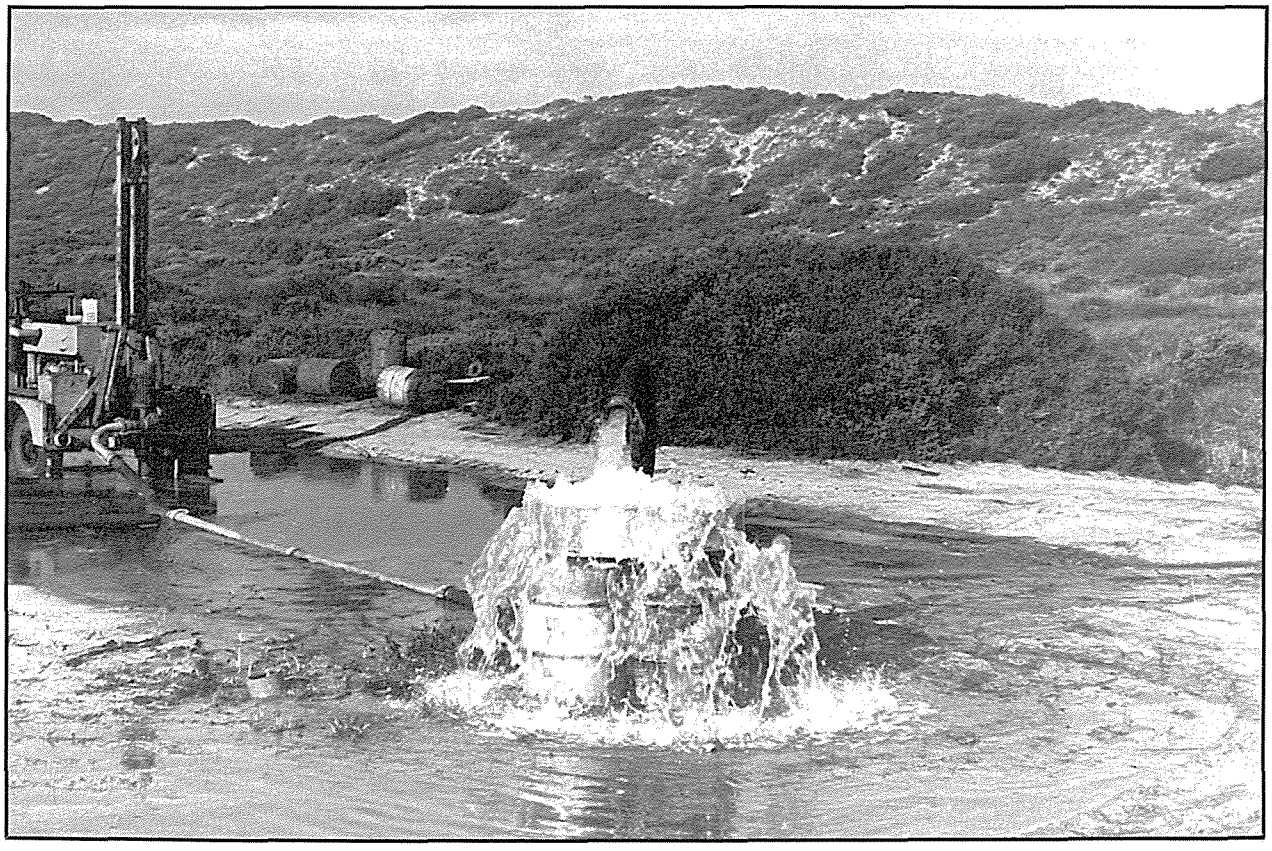
This plant provides complete purification of secondary purified sewage effluent for direct and unrestricted re-use. Furthermore, the water will be partially treated for artificial recharge and storage in the sand, from where it may be abstracted according to demand and integrated into the distribution system for direct re-use after further treatment.

Tenders for the erection of the module plant have been awarded and construction will commence during 1976. In the meantime tenders have been invited for a supply main and pump station which will deliver oxidation pond effluent to the reclamation plant. In this instance construction is expected to be completed by July 1976.

A study of the hydrological characteristics of the aquifers

A set of 15 prototype production boreholes were completed in geologically representative areas and three or four observation holes drilled in the immediate vicinity of each. Water was subsequently withdrawn continuously during periods of ten to fifteen days whilst the rates at which the water level was lowered at the various observation points in the vicinity were measured.

Results were correlated with particle sizes as determinated on sand samples from the production and observation holes in order to determine the mechanism of water discharge and re-



Water being abstracted at a high rate from a borehole in the Cape Flats during a test run. The possibility of storing purified sewage water in the sand deposits of the Flats is currently being investigated.

charge. A mathematical equation was developed to determine the behaviour of the aquifer under virtually arbitrary conditions of recharge and abstraction. It was found *inter alia* that water in some places were readily released to such an extent that abstraction at a rate of 100 m^3 per hour, even if continued uninterruptedly for a period of one year would have no discernible effect over a distance of 500 meters.

In other instances, where layered sediments with low permeability occur, the drop in the water level may be as much as 2,5 meters over a distance of 1 km. In instances where such points occur close to the sea, preventative measures must be taken to prevent salination of the groundwater, especially when they are subject to the accumulated influence of abstraction systems consisting of a large number of boreholes. Preliminary calculations indicate that at least 100 abstraction boreholes will be required fully to utilize the eventual capacity of the underground reservoir and approximately the same number to transport the expected volume of purified sewage water underground.

Monitoring of underground water quality

In the area selected for the storage and abstraction of the purified sewage effluent reasonably intensive vegetable farming has been in progress for many years whilst town development has only been undertaken on a limited scale. It was therefore essential that a monitoring programme in respect of the quality of the underground water be established. Results acquired over a period of 21 months indicate that the groundwater is free from faecal pollution and harmfull virusses. Most of the heavy metals occur in such small concentrations that they cannot be determined without prior concentration of the elements. The use of insecticides and fertilizers over an extended period in agricultural activities has also had no significant effect on the quality of the underground water.

Studies are being conducted at two refuse dumps on the Cape Flats to determine the possible pollution of underground water as a result of the dumping of domestic and industrial wastes. No significant pollution occurred during the past year in the area where the water level was between 15 and 20 meters from the ground surface, in spite of the penetrating rains which fell in the area during this period. Where the water level is situated within a few meters of the refuse and where no protective line strata occur in the intermediate sand deposits, discernible pollution was observed. These findings indicate that in future the position at both sites will merit careful attention in order to protect the underground water sources.

Monitoring of microbiological quality of drinking water

(New project: Contract with the South African Institute for Medical Research)

Careful monitoring of micro-biological quality has always constituted an essential part of the reclamation studies at Windhoek and at Daspoort, and the results of such work have made a significant contribution to world knowledge of the safety of water produced by such processes.

The importance of reclamation processes increases from year to year with increasing likelihood of their use on a wider scale. At the same time there is a growing world-wide consciousness of the importance of further study on the health aspects of water use and this has prompted the Commission to contract the South African Institute for Medical Research to undertake an intensive bacteriological, virological and epidemiological study, both of water produced by the reclamation processes in Windhoek and Daspoort and of the conventional drinking water supply.

This project has proceeded smoothly so far and apart from providing further evidence of the safety of these waters according to microbiological standards, has provided extremely valuable liaison between a number of laboratories working in the field of drinking water microbiology and especially on methodology, etc.

It must be emphasised that the value of this project lies not only in the acquisition of further information on the quality of water generated by advanced reclamation processes, as well as from polluted sources. It has also compelled researchers critically to review conventional purification methods and their efficiency to produce safe water from these sources.

GROUNDWATER RESEARCH

Utilization of water from the Eerste River by means of storage in sand beds or other methods

(Existing project: Contract with the University of Stellenbosch – Department of Civil Engineering)

This project entails an investigation into the possibility of storing water from the Eerste River – which would normally flow unutilized to the sea – in the sand deposits of the Cape Flats or by other means and to allow its abstraction for utilization.

During the year under review the collection of existing information was commenced on the quantity and quality of the water available for this purpose, as well as relevant characteristics of the sand deposits involved and of their water content. Information was also collected on the land use envisaged for this area.

Early during 1976 holes will be drilled in the eastern part of the Flats where few boreholes exist, with a view to studying the sand and groundwater more intensively. Sampling and analysis of water from the Eerste River and from the Kuils River (which flows through the relevant part of the Cape Flats) will also commence during 1976.

Investigations have indicated that a considerable portion of the water of the Kuils River which flows through shallow pans in

the eastern part of the Flats, infiltrates the sand mass and probably reaches the sea subterraneously; furthermore, especially during floods, a reasonably large quantity of water reaches the Eeste River on the surface and in this way eventually the sea. It would seem therefore that provision will have to be made to store water from both the Eerste River and the Kuils River in the area.

Based on the results, details will be compiled during the final stage of the project for the design, construction and operation of a proposed water supply scheme.

Development and evaluation of techniques for determining the exploitation potential of groundwater resources in the Southern Orange Free State and North Western Cape

(Existing project: Contract with the University of the Orange Free State – Department of Geohydrology)

The Southern Free State

The Southern Free State is known as an area where little perennial surface waters occur. Consequently, most towns and farming communities in the area depend on groundwater sources. These sources are normally low-yielding, not very reliable, and difficult to locate. It is therefore essential that additional techniques be developed to determine the potential of the groundwater sources of this area.

Dolorite basin structures are fairly common in the whole area, but in the past very little attention has been paid to these structures as possible aquifers. Their particular basin-like structures constitute natural subterranean impoundments in which groundwater can accumulate. However, very little knowledge about these structures is available, and during the year under review special attention was paid to the development of techniques for determining their geohydrological characteristics. The structures were investigated geologically in order to determine the gradients of the basin walls, joint directions and densities, weathering of the basin structures and the structural and age relationships between the basin structures and other rock formations.

During 1976 the basin structures will be further investigated geologically as well as geophysically in order to select suitable localities for the siting of test boreholes.

North Western Cape

Potentially one of the largest aquifers in South Africa is to be found in the dolomitic rock formations in the northern Cape Province. Owing to its location, this aquifer has been relatively poorly exploited and will undoubtedly play an important role in future development of the area. Research, therefore, is at this stage aimed at the evaluation of existing techniques and, if required, to develop new techniques for the evaluation of the global potential of the groundwater sources of the dolomites.

Groundwater in the dolomitic rock formations is apparently mainly associated with dolorite intrusions, joints and other linear structures cutting through the dolomites. In order to obtain a clearer picture of the occurrence of groundwater in the area, work was commenced in order to interpret the area as a whole with the aid of aerial and LANDSAT photographs, to measure and collect data in connection with water levels, temperatures, borehole yields and water samples for chemical analysis. These data will be used to select areas where intensive tests may be carried out.

Vryburg is one area selected in this way and where promising results have been found. Routine observations there have largely been completed and a mathematical model for modelling of the Vryburg aquifer is currently being developed, whereafter it will be tested by means of a digital computer.

Development and evaluation of techniques for determining the exploitation potential of groundwater resources along the Doornberg fault zone

(Existing project: Contract with the CSIR – National Physical Research Laboratory and the University of the Orange Free State – Department of Geology)

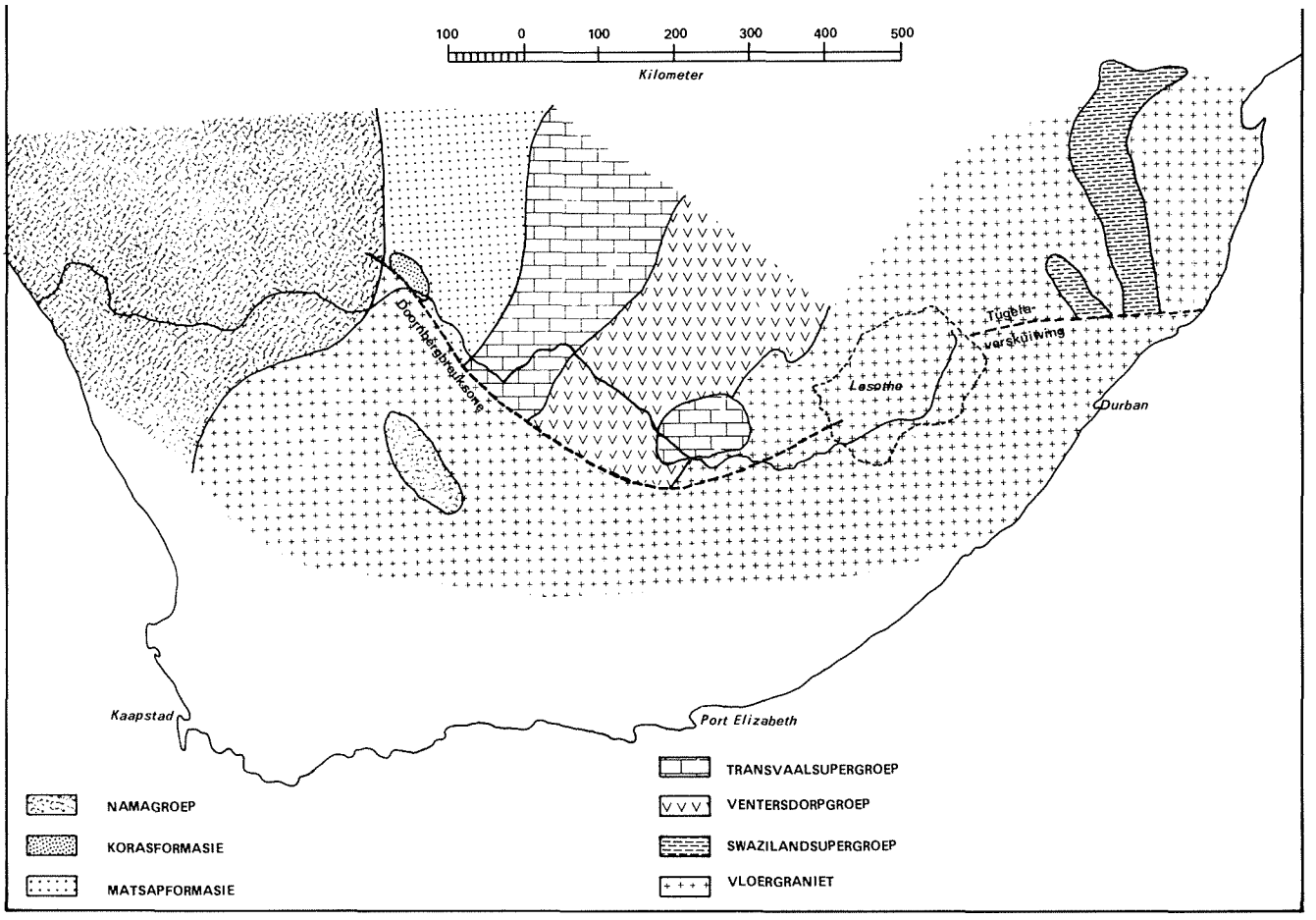
Although the Doornberg fault zone is exposed only in the area between Prieska and Koegas, it has in the past given rise to much speculation that the zone continues under the Karroo sediments, subsequently turning eastwards to join the Tugela fault along the Natal coast (See map). This project, consequently, does not entail only the development and evaluation of techniques for determining and tracing the exploitation potential of the fault zone in those areas where it is overlaid by the Karroo sediments, but also determining the exploitation potential of groundwater sources in the exposed area.

Geological and geohydrological aspects of the investigation are handled by the University of the Orange Free State and the geophysical work by the CSIR.

The geological implications of the continuation of the Doornberg fault zone, should it in fact join the Tugela fault, may be discussed with reference to the map. North of the latter fault, rock formations of up to 2 700 million years of age occur whilst the oldest formations south of the fault zones are 1 000 million years old.

Investigations during the past year were limited mainly to an area south of the Hendrik Verwoerd Dam where flooding occurred during construction of the Orange-Fish River Tunnel. One theory posited is that the position where the water was found in the tunnel corresponds roughly with a line connecting the Doornberg fault zone and the Tugela fault and water found in the tunnel is associated with joints caused by movement along the fault zone. The relevant area was investigated both geologically and geophysically in order to test this theory.

Geologically there is very little evidence present supporting the abovementioned theory. The joints systems in the area



The Doornberg Fault Zone with its possible continuation to the Tugela Fault and its relationship to the Karroo Basement Formations, according to Visser 1974 (Trans. geol. Soc. S. Afr., *77, 229-237).*

admittedly show a very prominent orientation preference which corresponds well to the direction of the joints in the tunnel, but evidence of linear structures which would indicate the presence of the fault zone, is absent.

The distribution of thermal springs in the area corresponds well with the possible continuation of the Doornberg fault zone up to Aliwal North. Water from these sources is rich in sodium and chloride in contrast to other groundwater in the area which contains large quantities of calcium, magnesium and bicarbonate. Should these thermal springs in fact relate to the continuation of the Doornberg fault zone the difference in the chemical composition of the water could serve as a very important criterium in following the fault zone laterally.

In the meantime a structural analysis and geohydrological mapping of the exposed area of the Doornberg fault zone in the Prieska area was also undertaken.

Geohydrological studies in the Gamagara catchment using environmental isotopes and complementary techniques

(Existing project: Contract with the University of the Witwatersrand – Nuclear Physics Research Unit)

The Gamagara catchment in the north western Cape is important for its agricultural potential as well as its mining development. This area on the edge of the Kalahari has no perennial surface water and apart from imported supplies via the Vaal-Hotazel pipeline is vitally dependent on groundwater. Borehole yields are generally low; in contrast, vast amounts of groundwater are found in the Sishen mining area, in the south.

The rain water that infiltrates largely in the outcrop areas to the south, south west and east of the catchment is from the observed rest level contours, assumed to be flowing generally northwards underneath increasing thicknesses of Kalahari beds – recent sands, gravels and clays – concentrating into troughs, cut into the pre-Kalahari formations.

The extent of the areas of recharge and the percentage infiltration; the nature and magnitude of the subsurface flow; the magnitude of the infiltration through the Kalahari beds and the influence of the occasional flow of the dry river beds on the groundwater balance could previously at best only be estimated.

Environmental isotopes are being employed in the study of these different problems in an attempt to obtain more quantitative information. Radiocarbon is employed to delineate areas of rain water recharge and to investigate regional flow patterns. Tritium is used as a tracer for studying short-term flow and infiltration through the unsaturated zone. The stable isotopes deuterium and oxygen-18 serve as indicators of the source of the waters and assist in the identification of distinct water bodies.

The results of the isotope study are being supplemented by, and correlated with, hydrological and hydrochemical observations in an attempt to build up a complete picture of the subsurface drainage of the area and to develop a test bench for the quantitative interpretation of environmental isotope measurements in the hydrology of this semi-arid environment. Close co-operation is therefore maintained with existing borehole drilling programmes in the Sishen and Black Rock areas as well as with a programme of drilling borehole profiles across the Kalahari trough. Samples are thus obtained from first waters struck, from different depths and geological strata.

Results thus far indicate rapid and significant recharge in some outcrop areas around Sishen Mine; the heterogeneous nature of the recharge and flow patterns; and the limited extent of recharge from ephemeral river flow. Active infiltration of rain is shown to occur into the first 6 metres or so of Kalahari sands and methods are being devised to extend these observations to greater depths. In the Sishen mining area itself there is growing evidence that the ground waters are influenced by the regional hydrology.

Facilities for this study have been expanded. Field staff has been appointed and special field equipment developed. The staff and facilities – in particular for stable isotope determinations – of the environmental isotope laboratory at the Nuclear Physics Research Unit have been increased to cope with the work load of this project.

WATER SAVING MEASURES

Research on dry cooling

(Existing project: Contract with the CSIR – National Mechanical Engineering Research Institute)

Investigations are at present being undertaken into the optimisation of heat exchangers for dry cooling systems at power generating stations. With this system there is no direct contact between the cooling air and the water to be cooled, thereby preventing water losses.

The work carried out in terms of this contract is aimed at developing a dry cooling system in which the initial capital costs are more comparable with conventional water-consuming wet systems. This entails *inter alia,* performance tests of a particular heat exchanger developed by a private company and selected for further investigations as a result of test results obtained from a smaller model.

The pressure drop and heat transfer characteristics of this heat exchanger under various operating conditions were determined, the work being done in the Institute's temperature and humidity controlled wind tunnel in which the various conditions under which heat exchangers operate in practice, can be simulated.

A method, developed by the Institute, to evaluate the performance of dry cooling heat exchangers was used to predict the performance of the laboratory prototype unit under dry cooling conditions.

The problems originally experienced with manufacturing techniques were solved and a cost evaluation is being undertaken to determine the manufacturing costs of full size heat exchanger panels of this type.

Water losses in pipe networks

(Existing project: Contract with the University of Pretoria – Department of Chemical Engineering – Water Utilization)

A questionnaire to determine the magnitude of water losses in pipe networks was sent to the ten big municipalities in 1968 and it was found that only one of them kept a complete quantitative record acquired through maintaining an accurate leak detection programme.

Lack of information, economics and a scarcity of water were the main motivating factors for initiating this investigation into water losses in pipe networks. It was agreed by the Water Research Commission and the University of Pretoria that this project would consist of two phases:

- Determination of the order of water losses in pipe networks
- Prevention and control of water losses in pipe networks

Research on phase I of this project commenced in April 1975, with water metering being the first assignment.

Accurate water metering is essential from basically three points of view;

- to distribute the costs of supplying water evenly amongst all consumers – a consumer must pay only for the actual quantity of water he receives
- the quantity of "lost" water can only be determined by means of accurate metering at both ends of the pipe network system
- intermediate bulk metering for a volume of ca 500 m^3/d can pinpoint invisible underground leaks quickly.

Studies concerning the accuracy of meters are in progress and it is hoped that the components of unaccounted water can then be identified quantitatively. These components could be classified as:

- actual water losses because of broken pipes
- unavoidable losses due to pipe permeability
- unmetered draw-offs mostly through fire hydrants and unmetered connections
- under-registration of consumer meters

Investigations concerning pipe materials, construction specifications and installation methods for various pipe types have progressed considerably. Centres for leak detection by means of sonic apparatus have been decided upon. No field work has been done up to date but this will commence early in 1976.

EFFLUENT TREATMENT

Treatment of waste water from wool textile industries

(Completed project: Contract with the CSIR – South African Wool and Textile Research Institute)

This project – aimed at the reclamation of wool grease from wool scouring effluent and the simultaneous conservation of water through recycling – has been concluded during 1975.

Following the laboratory-scale development of a solvent process for the recovery of wool grease from wool scouring effluent, the S.A. Wool Textile Research Institute (SAWTRI) tested the process on a pilot scale rising-and-falling film evaporator at one of the largest wool scouring firms in the country.

The main results flowing from the project are the following:

- By operating on grease levels of 1 per cent or lower in wool scouring effluents, high recoveries of grease cannot be expected.
- The higher the oxidised fraction of the wool grease, the poorer the recovery. The indications are, in fact, that the *unrecoverable grease* fraction is most likely associated with the degree of oxidation of the wool grease.
- From the grease recovery figures found during the pilot scale investigations, the solvent process cannot be recommended as economically viable. (A 100 per cent increase in the price of benzine over the past two years is partly responsible for this).
- The method developed by SAWTRI may, however, find application in the removal of oils, other than wool grease, from industrial effluents, and in the de-watering of the "cream" produced from the centrifugal treatment of unconventional scouring liquors. Further work in the latter regard is currently being undertaken by SAWTRI.

Recycling of water and recovery of chemicals in the textile industry

(Existing project: Contract with the University of Natal – Department of Chemical Engineering)

Detailed surveys of the main effluent problems of the textile industry – the wool scouring, desizing, dyeing, mercerising and kiering effluents – all of which contain substantial organic and inorganic loadings, have indicated that these may be solved by the application of advanced waste water treatment technology. The most advantageous effluent treatment system, which is particularly applicable to textile effluents, is the one of closed loop recycling of the water and recovery of the chemical 'pollutants', rather than end-of-line effluent treatment. This gives benefits both to the country in terms of reduced water usage and effluent discharges, which are difficult to treat in the conventional manner, and to the individual factory, who gains from water and effluent savings, reuse of expensive process chemicals, and increased and more controlled production.

The Department of Chemical Engineering of the University of Natal, under contract to the Commission, has developed strong links with the textile industry to ensure that this research and development project on closed loop recycle systems is integrated with the factory manufacturing operations. The first phase of the work, involving surveys of material balances, water quality requirements and applicability of chemical and water reuse has been successfully completed and many simple recommendations have been made for reducing water usage and effluent discharge by emphasising good housekeeping methods, water quality requirements and process modifications. Laboratory scale investigations on desizing and wool scouring effluents, and with an associated project in the Department on dyehouse liquors, have shown that reclamation of the water to a suitable quality and recovery of process chemicals is both technologically and economically feasible in these three cases.

The nature of textile effluents, the systems engineering approach to recycle operations, and the applicable technology needed to solve these problems are illustrated for the desizing effluent: One of the main stages during the manufacture of cotton and/or synthetic cloth is weaving; the wet processing operations associated with this dry process are the application of a sizing solution, normally starch or a synthetic polymer, to strengthen the warp threads and a wax solution prior to weaving, and subsequent to weaving the enzymatic removal of these chemicals with hot water in the desizing bowl. This effluent is high in organics and suspended solids and contains about 0,5 per cent on a weight basis of the sizing chemical. If it is possible to use synthetic sizes completely, and a trial weaving programme of this nature has just been completed by a large mill, then recovery of the size is technologically feasible. A closed loop recycling system for this effluent has been proposed, consisting of:

(a) screening to remove lint
(b) dissolved air flotation to remove waxes
(c) ultrafiltration using high temperature membranes (90°C) to concentrate the sizing solution to 10 per cent and recover water of a suitable standard.

This system will recover both water and heat needed in the desizing stage and allow reuse of the process chemicals, size and wax for sizing. Laboratory experiments have shown excellent recovery efficiencies in the flotation and ultrafiltration stages and long term evaluation of the ultrafilter membrane performance is under way.

Research will continue on the development of these closed-loop recycle operations for particular manufacturing process effluents with the installation of pilot plants to demonstrate the systems at the factory site, affording opportunities for actual reuse of the reclaimed water and process chemicals.

Treatment of waste water by ion exchange

(Existing project: Contract with the University of Cape Town – Chemical Engineering Department)

This project was initiated by the Water Research Commission in order to establish a means by which highly mineralized industrial sewage effluents could be reclaimed for industrial reuse. As a result of the decision of the Cape Town Municipality to segregate and treat the effluents separately at the Athlone Sewage Purification Works, ideal conditions were created for the required research to be carried out locally by the University of Cape Town. The research work carried out by the University is therefore conducted in close collaboration with the project on "The Reclamation of Water at the Athlone Sewage Works".

Part of this research has been concerned with laboratory testing of various anion exchange resins to observe their capability for removing salt and residual organic compounds. Effluent from the Milnerton sewage works was used in the work. The most suitable resins have now been selected.

The ion-exchange system for desalinating a municipal waste-water for ultimate reuse, has been extended to give simultaneous removal of the residual organic material in the water. As the undesirable nitrates and phosphates, and the colouring matter in the water, are also removed in the course of operation, the system has considerable promise as a complete tertiary treatment process.

The two major problems in the process are the recovery of regenerant chemicals so as to give economic viability, and the possibility of the fouling of the ion-exchange resins by the organics in the water. These two areas have been examined using small laboratory-scale columns operating on a batch basis and the results are now being extended to a five-column continuous ion-exchange unit of larger size.

The problem of economic regenerant chemical recovery is being dealt with in a novel manner by using a separate cation-exchange column through which both regeneration streams are passed in turn. The resulting effluent is a concentrated brine which is a saleable chemical product – ammonium nitrate. By using the continuous ion-exchange system this chemical can be obtained at a desired purity and concentration.

The organic material in the waste-water is taken up by the anion exchange column and investigations have centered on determining the best anion resin for use, for both the salt removal and the organic fouling points of view. Longterm tests have been conducted and have led to the choice of a resin which shows virtually no permanent fouling effect.

Based on the results of the laboratory work, a small pilot-scale facility, with a capacity of 5 m^3/d, has been designed and built and is in the course of erection. This five-column continuous ion-exchange unit has between 6 and 12 stages per column and each column has separate time-cycle control. The ion-exchange resin moves down one column, is automatically washed and dewatered, and is returned to the top of the next column.

Initial work on a continuous column has given stage efficiencies and these and other results are being developed in a mathematical model, so that the design of larger units can be undertaken and the economics of the full-scale process evaluated.

The programme will continue using the five-column unit to test the complete tertiary treatment of local municipal wastewaters.

Removal of metal ions from dilute solutions in an electrolytic precipitator

(Existing project: Contract with the University of the Witwatersrand – Department of Chemical Engineering)

Excessive concentrations of metals such as zinc, iron, copper, manganese, nickel, tin, lead and chromium in effluents may adversely affect the performance of sewage purification works. These metals can normally be removed by the addition of chemicals – a costly process.

The Department of Chemical Engineering of the University of the Witwatersrand, under contract to the Commission, is investigating the efficiency of removing these metals in dilute solutions by electrolytic precipitation – a process which does not require the addition of chemicals.

The efficiency of fixed and fluidized bed electrode systems are being investigated in order to select the most suitable geometric configurations. Important variables in the system were found to be the concentration of the various ionic species in solution, current density, bed expansion and cell geometry. The effect of these parameters on the performance of the process has been experimentally determined and a mathematical model of a particulate bed electrode has been developed to fit this data.

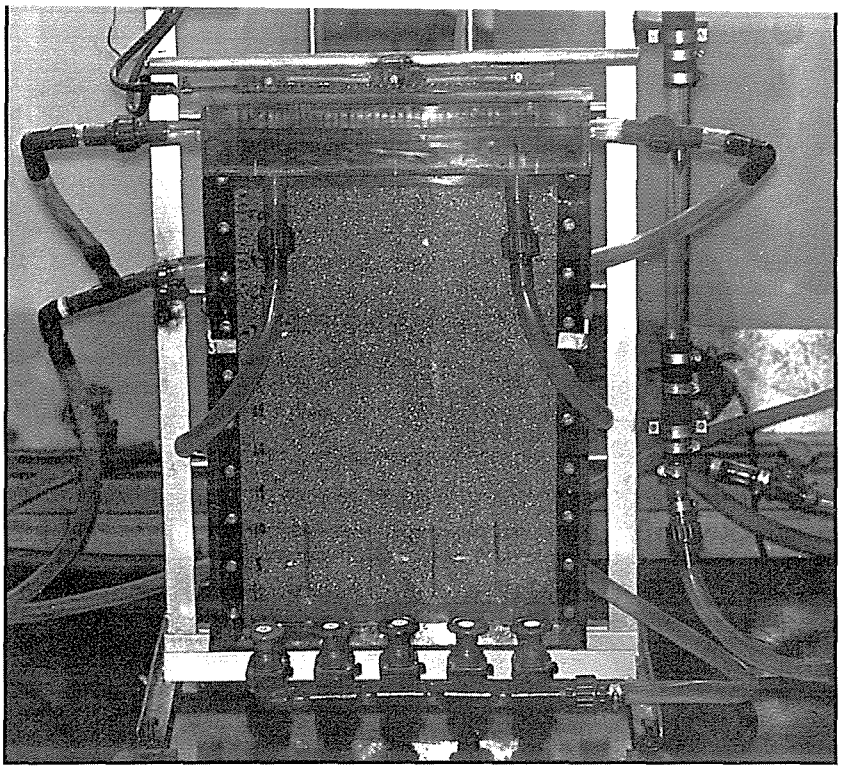
A pilot-scale fluidized bed cell has also been constructed and tested. Initial results indicated that the current efficiency of metal removal was about half that obtained on the laboratory cells. The mathematical model, however, has indicated areas where the design may be improved to enable the system to be scaled-up to much larger units without loss of current efficiency.

A joint investigation on the removal of metal ions from an industrial effluent, has recently been initiated between the University and the factory concerned. For this purpose a pilot unit is being designed to test the performance of the electrolytic precipitator for removing the metal constituents to a level which will make the water acceptable for internal reuse.

Research on the activated sludge process

(Existing project: Contract with the University of Cape Town – Department of Civil Engineering)

The activated sludge sewage purification process, besides



An 0,2m³ fluidised electrolytic bed cell used for the removal of heavy metal ions from a solution.

removing organic constituents from wastewater, is effective in removing the eutrophication elements nitrogen and phosphorus. Since the optimum conditions for removal of each element do not necessarily coincide, it is necessary to investigate each aspect thoroughly to produce design criteria giving optimum overall removal.

The Department of Civil Engineering of the University of Cape Town is currently studying the following aspects of the process.

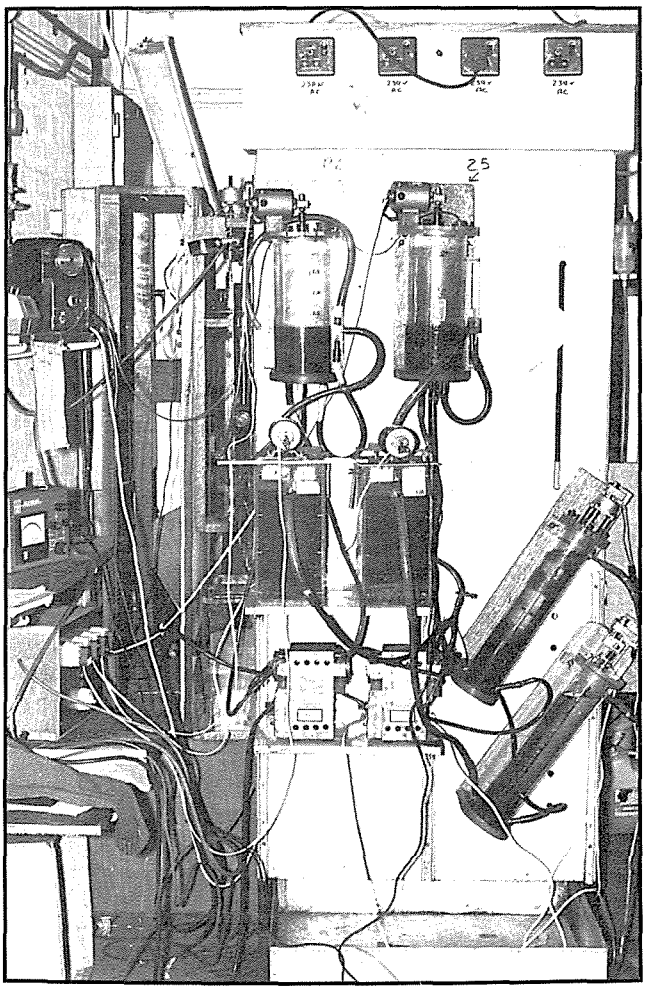
Solid-liquid separation by flotation

Under the terms of the existing contract this aspect of study is complete. Studies have been directed towards optimising saturator performance and determining the inter-relationships between process parameters. By means of an economic analysis it has been possible, for a range of mixed liquor concentrations and flow rates, to optimise the relevant parameters to give lower total cost (capital plus capitalised running costs). A design manual has been prepared which sets down principles gleaned during the contract period in a form useful to design engineers. It includes practical considerations for design based on the performance of a pilot plant flotation system.

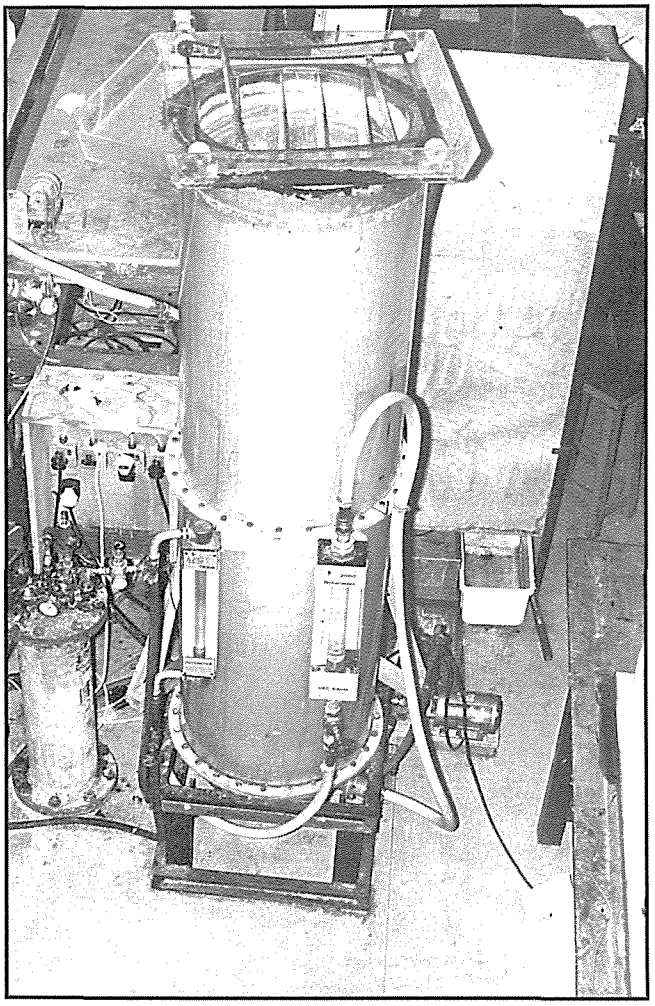
Phosphorus removal

Investigations into biological phosphate removal to date have shown that:

- Luxury uptake of phosphate may be induced by the presence of an anoxic zone;
- There is an optimum actual retention time in the primary anoxic zone for maximum phosphate removal. This coincides with the condition where there is no nett release of phosphate in the anoxic zone;



Experimental units used in investigating the removal of phosphates from waste water by means of the activated sludge process.



The experimental flotation unit used to study the clarification of effluents from activated sludge plants.

- Presence of nitrates in the mixed liquor does not inhibit phosphate removal, i.e. true "anaerobic" conditions are not necessary;
- The degree of phosphate removal is independent of the influent phosphate concentration and
- Phosphate removal appears to be a function of the COD utilized, sludge age and primary anoxic retention time.

Activated sludge kinetics

From a study of the dynamic behaviour of the completely mixed activated sludge process it was found that the COD is utilised in a two stage mechanism:

(1) COD is absorbed by the organisms (storage of COD) and
(2) stored COD is metabolised.

From the study it is suggested that the influent nitrogen is split into three fractions:

- an unbiodegrable fraction,
- a fraction which is slowly biodegradable (probably proteinaceous nitrogen) and
- a fraction of nitrogen immediately available for nitrification and synthesis (probably free and saline ammonia).

Denitrification – dynamic behaviour

Experiments investigating the dynamic behaviour of denitrification have been carried out under two feed modes:

(1) a cyclic flow incorporated with a base flow and
(2) a complete cyclic flow where the units were fed for 12 hours followed by a 12 hour no-feed period.

It was found that the change in nitrate concentration through a plug flow anoxic reactor decreases with increasing cyclic flow severity. From the experiments it is apparent that the first phase of denitrification is an adsorption mechanism and is proportional to the COD utilised. It is further apparent that the secondary phase of denitrification is linked to the rate of change of stored COD.

Development of criteria for removal of nitrogen and phosphorus from sewage effluents by means of improved biological treatment processes

(Existing project: Contract with the CSIR – National Institute for Water Research)

An activated sludge pilot plant (100 m^3/d), providing for flexible and well controllable operation, has been constructed at Daspoort, Pretoria, to study the various parameters involved in the biological removal of carbon, nitrogen and phosphorus from sewage effluents. The design is such that the plant can operate in a completely mixed or plug-flow mode in all three stages of the process, i.e. the primary anoxic stage, the main aerobic stage and the second anoxic stage. Hydraulic retention time in any of the stages can also be varied.

The plant was commissioned in November, 1974, and results have proved the potential of the process for nutrient removal. The removal of total nitrogen and chemical oxygen demand was of the order of 85 per cent, even during winter conditions. This process is also able to remove phosphorus to the extent of 50 per cent of the influent concentration, without chemical addition. The optimum operating parameters required to induce and maintain a high degree of phosphorus removal are still obscure, but work is continuing on this aspect.

The research programme also made provision for investigating the effect of lime pretreatment of sewage prior to biological purification, the major advantages to be gained by lime pretreatment being the removal of toxic substances which may inhibit biological treatment and the removal of phosphate. Laboratory studies have demonstrated the value of this mode of pretreatment and further pilot plant experiments are in progress to verify these findings.

Research has also been carried out on the use of dissolved air flotation for solids separation, instead of sedimentation. A pilot plant has been constructed for this purpose and opera-

TABLE I

RANKING OF IMPOUNDMENTS ACCORDING TO THEIR MODIFIED ALGAL GROWTH POTENTIALS†

Rank No.	Impoundment	AGP (mg/ℓ)	Rank No.	Impoundment	AGP (mg/ℓ)	Rank No.	Impoundment	AGP (mg/ℓ)
1.	Gubu	4,3	34.	Nagle	16,5	67.	Gamkapoort*	45,4
2.	Paul Sauer	4,4	35.	Churchill	16,8	68.	Bellair	45,5
3.	Njelele	4,4	36.	Douglas Weir	17,2	69.	Leeuw Gamka	46,6
4.	Magoebaskloof	4,6	37.	Wagendrift	17,3	70.	Erfenis	48,6
5.	Bulshoek	4,7	38.	Jericho	18,1	71.	Maselspoort*	49,1
6.	Groendal	4,9	39.	Maden	18,5	72.	Allemanskraal	53,1
7.	Korinte Vet	5,1	40.	Vergelegen*	18,6	73.	Malelane Weir*	53,5
8.	Ebenezer	5,2	41.	Henley	18,9	74.	Kromellenbogen	55,0
9.	Albasini	5,7	42.	Rustfontein	20,5	75.	Tonteldoos*	55,1
10.	Buffeljagts	6,1	43.	Glen Alpine	20,6	76.	Verwoerd*	56,2
11.	Rooikrantz	7,3	44.	Krugersdrift	23,6	77.	Koppies*	57,9
12.	Vlugkraal	8,1	45.	Nwanedzi	23,7	78.	Kosterrivier	58,4
13.	Midmar	8,7	46.	Westoe	24,0	79.	Lindleyspoort	60,0
14.	Settlers	9,3	47.	Buffelspoort	25,0	80.	Da Gama*	60,6
15.	Calitzdorp	9,7	48.	Klein Maricopoort	25,3	81.	Marico Bosveld*	64,9
16.	Kalkfontein	10,0	49.	Howisonspoort	25,7	82.	Laing	70,1
17.	Craigieburn	10,4	50.	Mkuzi Weir	26,9	83.	Rooikraal*	74,0
18.	Phalaborwa	10,5	51.	Stompdrift	27,4	84.	Beervlei*	77,0
19.	J.G. Strydom	11,1	52.	Brandvlei (Lake Marais)	28,7	85.	Vaalharts Weir*	84,6
20.	Klipkopje	11,1	53.	Loskop	29,5	86.	Wolmaransstad*	86,2
21.	Ohrigstad	12,3	54.	Kafferskraal*	32,1	87.	Floriskraal*	94,1
22.	Pongola Weir	12,3	55.	Bloemhof*	32,3	88.	Doornpoort*	103,0
23.	Gamka	12,6	56.	Rust der Winter	32,5	89.	Vaaldam*	104,2
24.	Clanwilliam*	12,9	57.	Mockes*	32,8	90.	Loxton*	128,6
25.	Loerie	13,0	58.	Smithfield*	34,4	91.	Armenia	136,4
26.	Stettynskloof	13,0	59.	Bronkhorstspruit*	34,5	92.	Egmont*	146,6
27.	Primkop	13,6	60.	Hluhluwe	35,5	93.	Shongweni*	265,0
28.	Kamanassie	14,5	61.	Klaserie	36,1	94.	Vaal Barrage*	300,0
29.	Katrivier	14,5	62.	Wemmershoek*	36,9	95.	Johan Neser*	452,2
30.	Nahoon	14,5	63.	Nooitgedacht	37,3	96.	Roodeplaat*	491,4
31.	Buffelskloof	15,5	64.	Bethulie*	42,1	97.	Hartbeespoort*	549,1
32.	Steenbras	16,4	65.	Boegoeberg	42,5	98.	Rietvlei*	660,4
33.	Premiermyn	16,4	66.	Chelmsford*	44,9			

*Impoundments with N as primary growth limiting nutrients

† TOERIEN, DF, *et al;* (1975). A preliminary trophic status classification of some South African impoundments. *Water SA, 1,* 1, pp 15-23.

tional criteria have been established for both sludge thickening and clarification. The rapid separation of solids in a flotation unit will enable activated sludge plants to operate at higher sludge concentrations which will improve the degree of both nitrification and denitrification and is also expected to enhance phosphate removal.

Further research and process development continues, aimed at establishing design criteria for full-scale implementation. A broad front of objectives will be achieved if nitrogen and phosphorus can be satisfactorily removed in a biological unit process.

This work is being closely co-ordinated with the related work being done by the Department of Civil Engineering at the University of Cape Town, with resultant benefit to both projects.

WATER POLLUTION

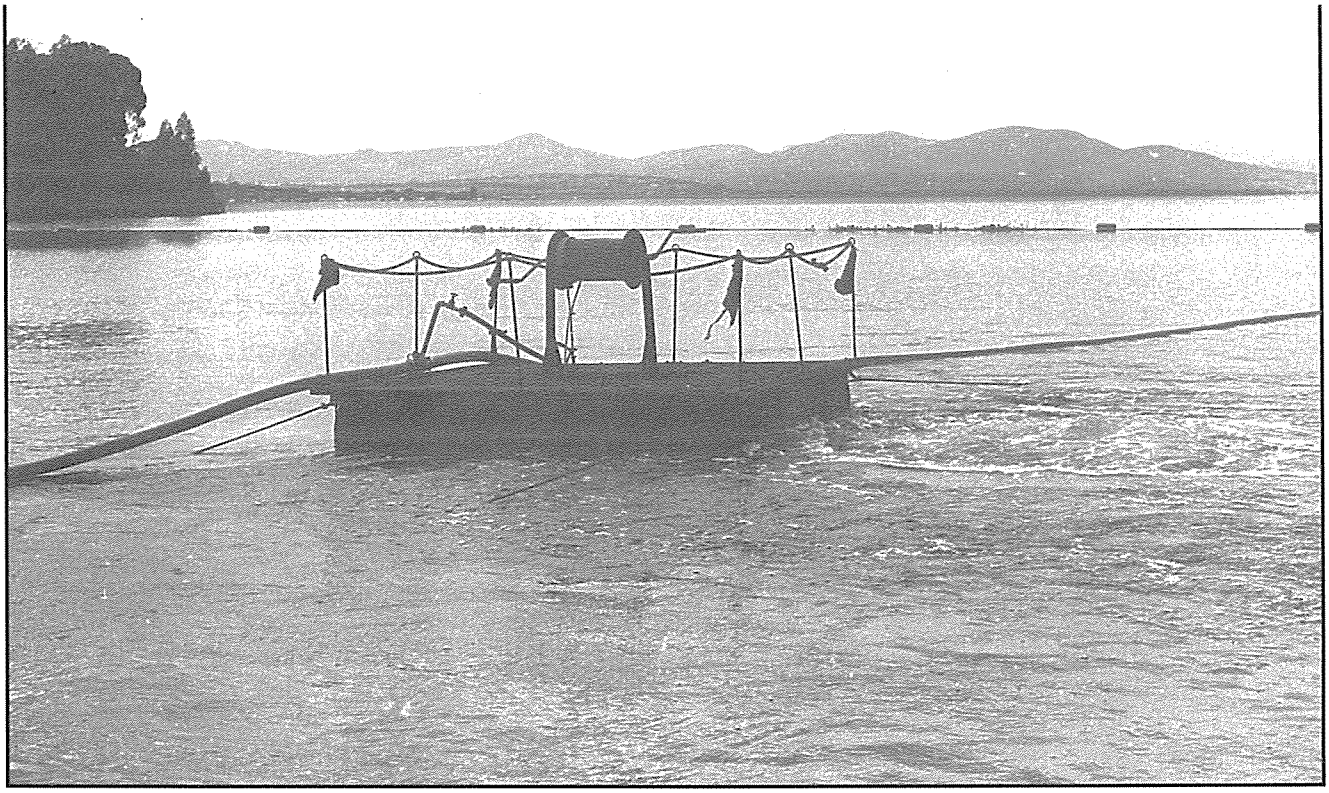
Eutrophication of rivers and dams

(Existing project: Contract with the CSIR – National Institute for Water Research)

Work has continued on the determination of nutrient loading levels of dams and impoundments under South African conditions at which nuisance growths and other effects of eutrophication can be expected. (See Table 1). Although extensive work has been done in this area overseas most of it has been in countries with clear water lakes of long residence time. Results obtained to date in South Africa are consistent with models proposed overseas, but further work needs to be done in order to refine the permissible values of nutrients for local conditions. This is being done by extension of the studies to certain impoundments in the East London-King William's Town area and by artificial enrichment studies on small selected impoundments.

A number of publications have been completed during the year or are in the course of preparation. These include research papers prepared for publication in scientific journals and a global review of eutrophication, its nature, origin and control. A report presently in course of preparation contains interim guidelines of a practical nature for control of eutrophication problems. These are intended to constitute practical advice for authorities bearing responsibility for the supervisional control of water bodies: tentative guidelines are given for the prevention of eutrophication as well as outlines for the rehabilitation of eutrophied impoundments and practical measures which while not effecting a permanent solution may be necessary as emergency measures for dealing with acute nuisance growths.

An experimental aeration system was installed at Har-



This experimental aerator was installed at the Hartbeespoort Dam by the Department of Water Affairs in an effort to prevent oxygen in the bottom layers of water being exhausted. The work relates to a project on eutrophication undertaken by the NIWR under contract to the Commission.

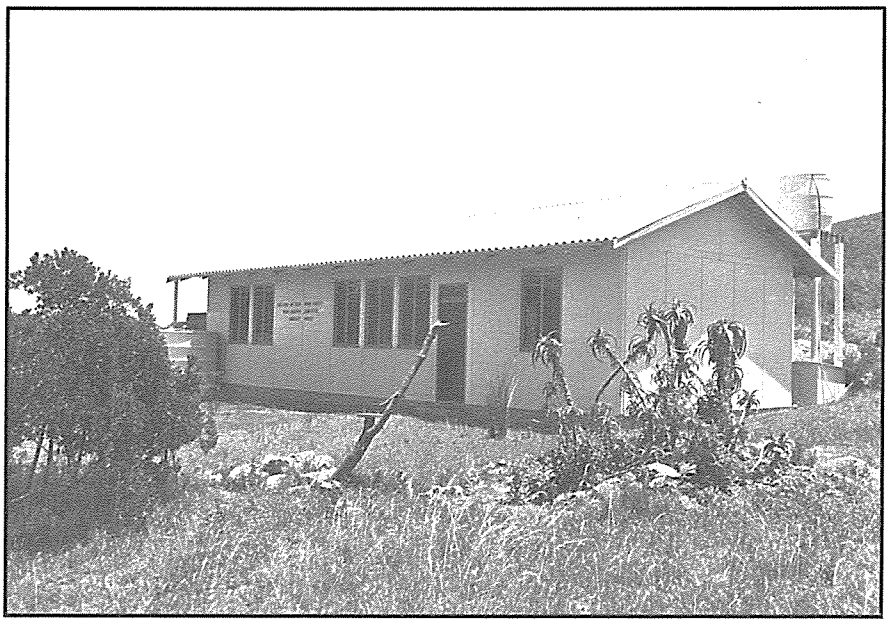
tebeespoortdam by the Department of Water Affairs and the effects of aeration are being monitored by the National Institute for Water Research. However, the short duration of the experiment precludes any firm conclusions re beneficial effect at this stage.

It is clear that while valuable and necessary information is being obtained, illuminating fundamental mechanisms of eutrophication and how it should be controlled in the long term, knowledge of short term emergency measures such as chemical and biological control and mechanical removal of nuisance growths urgently need extending.

The role of aquatic plants in maintaining trophic conditions at Swartvlei, Wilderness

(Existing project: Contract with Rhodes University – Institute for Fresh Water Studies)

The ecosystem of Swartvlei – one of the six Wilderness lakes – presents an exceptional opportunity for investigating the role of aquatic weeds in the maintenance of trophic conditions in shallow water masses.



The laboratory established on the banks of Swartvlei for studying the rôle of macrophytes in maintaining trophic conditions in the lake.

The Institute for Fresh Water Studies of Rhodes University has continued research (in terms of a contract with the Commission) to determine the precise contribution of these weeds in purifying estuarine water, since the results may have an important bearing on maintaining trophic conditions in other lakes and natural purification systems.

Since the installation of the Swartvlei Project Laboratory on the shores of Swartvlei in late 1974, research has been centred both on the main lake and on the littoral zone. Physico-chemical surveys of the open lake at all depths are made about every ten days. The results now give a detailed picture of how the lake behaves during the seasons with respect to salinity, oxygen, temperature, and a number of nutrient elements. With the current interest in lakes and estuarine management in this region of the Cape, this study will go a long way towards providing data necessary to know when and whether the estuary mouth should be artificially opened each year.

Swartvlei is exceptional in having very low levels of dissolved inorganic phosphate so particular attention is now being paid to the phosphate cycle in the lake. Studies to date have shown that the sediments act as the largest reservoir of phosphate with the aquatic macrophytes being the next largest reservoir. The inflowing rivers are particularly low in dissolved phosphate so it appears at this stage that Swartvlei would be very susceptible to phosphate pollution.

Studies are also under way on the growth rates and seasonal growth cycles of the aquatic macrophytes in Swartvlei, with a view to determining their contribution to the carbon budget of the lake, as well as to providing basic data for calculating the rates of accumulation and release of mineral elements in the littoral zone.

DESALINATION

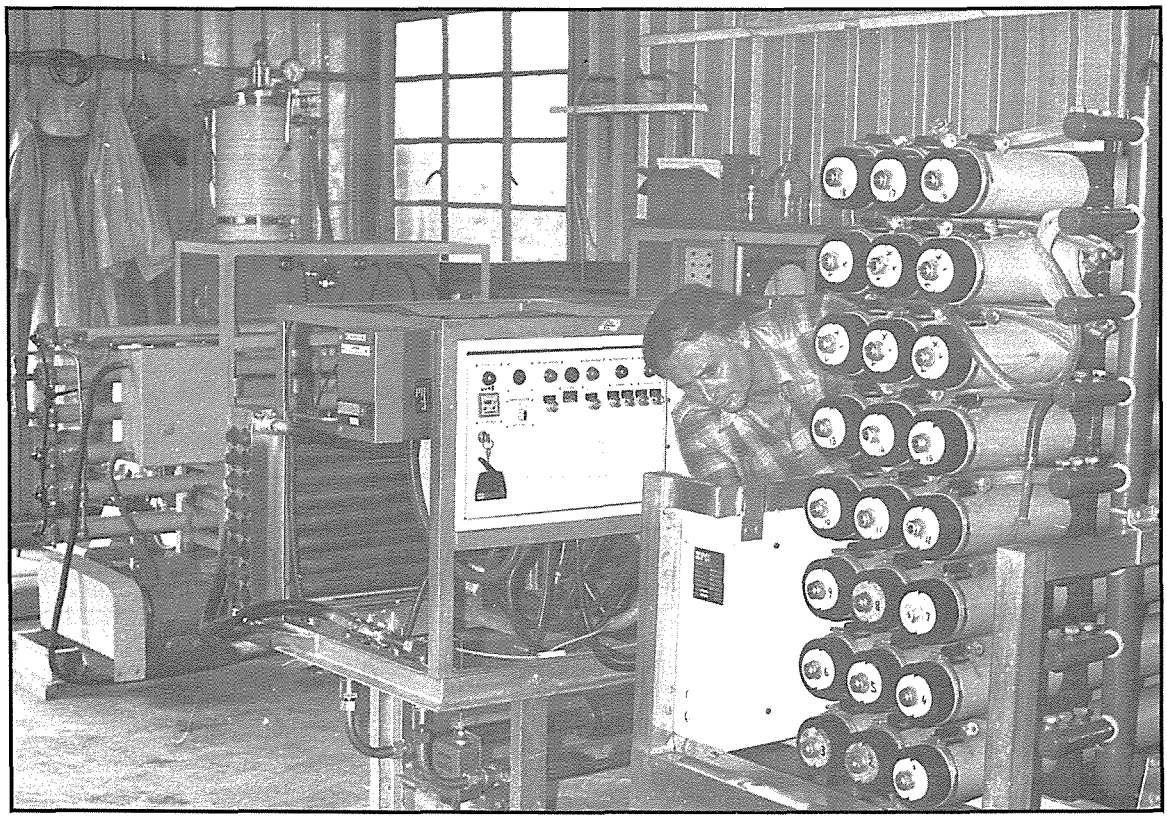
Desalination of brackish water

(Existing project: Contract with the CSIR – National Institute for Water Research)

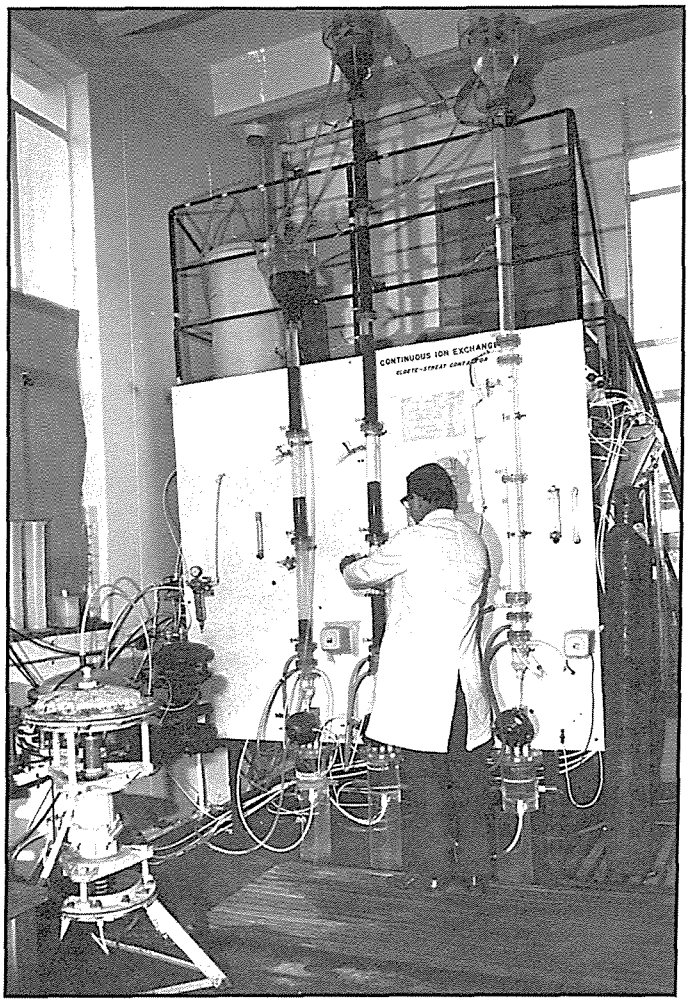
The National Institute for Water Research is continuing its evaluation studies of commercially available desalination equipment and assessing their applicability under field conditions.

As mentioned in the previous annual report, tests with the vapour recompression process have been completed, and investigations are now focussed on the reverse osmosis process. Test facilities for reverse osmosis desalination units were commissioned on the farm Vetkuil, in the Beaufort West district, during November and December, 1974, where a strong source of brackish water is available (4 000 mg/ℓ dissolved solids).

For a proper evaluation of the test units, continuous runs of at least twelve months are required. To date this could be achieved with only one of the five test units. Operating problems have been experienced with the other units – mainly associated with the high pressure feed pumps which are essen-



A general view of the desalination test facilities erected and operated by the National Institute for Water Research in the Beaufort West district.



The small-scale pilot plant used for research on the WAT process for the desalination of sea water.

tial for the operation of reverse osmosis systems. The suppliers of the units have been most helpful in overcoming these difficulties and have provided replacement pumps of more robust design.

Desalination performance of the units has been reasonably good, but meaningful assessment is not possible until extensive continuous runs are completed. The fact that operating problems have been experienced emphasizes the value of the current programme of evaluation which provides the knowledge and experience required when large-scale desalination becomes necessary.

It is anticipated that the investigation will be completed during 1976.

The WAT process for the desalination of sea water

(Existing project: Contract with the CSIR – National Institute for Water Research)

This process was devised in an attempt to reduce the cost of desalting sea water and, at the same time, to recover valuable chemicals from the concentrate produced by the desalination process. The salt recovery section was based on special ion exchange techniques which had hitherto not been applied on the scale envisaged nor at such high feed concentration. A number of technical problems were solved and a techno-economic feasibility study has been completed.

Following this study, the ion exchange section was referred to Permutit-Boby, of London, for evaluation and comment. They have reported that the multi-unit fixed bed system (the so-called "carousel" system) of contacting would, for technical reasons, be more suitable for this application than the continuous ion exchange system proposed by the National Institute for Water Research. Their report shows the two systems to be similarly priced.

Although the WAT process in its present form and under prevailing market conditions has, as previously reported, failed to meet the objectives of providing a new and cheap source of fresh water from the sea, a considerable amount of new and valuable technical and scientific knowledge has been generated.

This information, together with the techniques developed during the study, may find application in the treatment of sea water prior to distillation and in the treatment of a variety of chloride and sulphate-containing effluents. In particular, the novel damp bed system developed during this study for carbonating the ion exchange resin at atmospheric pressure, holds promise of improving the economics of the Desal desalination process and of widening its field of application.

Laboratory investigations on this project have been terminated and a detailed report, which will be available in 1976, is being prepared.

WATER CONSUMPTION PATTERNS

Research on water consumption patterns in urban areas

(Existing project: Contract with the University of Pretoria – Department of Chemical Engineering – (Water Utilization))

In order to promote the effective utilization of water, it is essential that the engineer/designer be aware of how water sources will be utilized and for what purpose.

This research is aimed at the collection of more information on water consumption by means of a thorough investigation into the water consumption patterns in urban areas. The quantity of water proportionally used for domestic and industrial purposes, as well as the water requirements for drinking, cooking, sanitation, gardening and car washing purposes must be determined. The water requirements for sewerage, the development of systems which could utilize the recycling of purified effluent and the use of seawater and brackish water in sewerage systems and for fire fighting are also important. A wider knowledge of the tendencies of water consumption will hopefully lead to the optimization of water systems in order to promote more efficient water utilization.

The research takes cognizance of the relationship between water demand and water requirements. Aspects of water saving will, therefore, also be investigated.

Information is currently being collected in respect of consumption by various private users and this will be followed by the application of statistical methods to determine tendencies. Aspects currently being investigated are:

- Water consumption patterns in respect of dwellings, apartment buildings and industries.
- Water consumption per capita on residential stands of varying sizes and for varying income groups, in both dwellings and apartments.
- Water consumption patterns in the domestic sector.
- Consumption patterns in Bantu townships.

SOLID WASTES

Removal of sludge and wastewater at water purification installations

(Existing project: Contract with the University of Pretoria – Department of Chemical Engineering – (Water Utilization))

The high turbidities of South African surface waters necessitate the addition of high coagulant dosages during water purification processes. The production of sludge per unit volume of water purified is consequently extremely high. Surface water in the Republic afford little dilution but are, nevertheless, used for sludge disposal – the most economic method.

Technological guidelines and criteria for the establishment of treatment facilities are lacking. Overseas results can be correlated with South African conditions only with difficulty especially since some of these results are based on climatic factors such as temperature and humidity.

In South Africa, therefore, a need exists for research on the pollution potential of water works sludges and the development of applicable technology and criteria for the economic treatment and disposal of sludge.

A project in this regard was initiated by the Department of Chemical Engineering of the University of Pretoria under contract with the Water Research Commission. The first three tasks comprise:

- carrying out a situation study in order to determine the pollution potential of waterworks effluents and their biological, ecological and economic implications
- identifying significant relationships between sludge concentration and sludge volume for sludges produced by different purification methods
- identifying sludge volumes and sludge characteristics according to simple parameters and as a function of raw water quality.

The situation study has indicated that much has been published about disposal methods for water works sludge. Little information, however, is available about the effect of water works sludge on the water environment. Throughout the history of water purification this sludge has escaped the stigma of pollution. The water treatment plant is a pollutor however, since it concentrates solid materials and because it may import foreign material into the aquatic environment which could have a detrimental effect. It is necessary to have a knowledge of the effluents and the receiving waters to determine if pollution has occurred or could occur and it is this knowledge that the department is trying to obtain.

The second and third tasks are currently being undertaken. The next phase will comprise a study of the settling kinetics of water works sludge in thickeners.

IRRIGATION

An investigation of soil compaction at the Vaalhartz irrigation scheme

(New project: Contract with the University of the Orange Free State – Department of Soil Science)

The potential root depth of the most important crops cultivated under irrigation on the deep, structureless and sandy soils of the Vaalhartz Irrigation Scheme is 1 500 mm and more. Current irrigation systems, and especially flood irrigation, are aimed at wetting the total potential root zone. In practice, however, it has been found that different compacted zones and an inherent soil resistance of the subsoil limit the root distribution mainly to the upper 250–300 mm. This phenomenon gives rise

to inefficient utilization of applied irrigation water by crops and a resultant lower crop yield per unit of water.

The Department of Soil Science of the University of the Orange Free State was contracted by the Commission to undertake research on this subject.

The research programme of the Department can be divided into four aspects and comprises:

- A field investigation at Vaalhartz to determine the extent of the problem and the degree of compaction
- field tests to determine the effect of different cultural practicxes and of synthetic soil ameliorants on the degree of compaction
- laboratory studies to establish the relationships between the degree of compaction, hydrological characteristics and soil strength
- hothouse pot tests for determining the effect of increasing soil strength values on root development, nutrient intake and yields of various crops.

An automatic system for the pot experiments has been designed whereby a constant soil moisture and degree of aeration is maintained for each separate pot. This system was designed and constructed on the basis of results obtained with a pilot plant. The specially designed pots enable the investigator to determine soil strength and root development at varying depths after the growth period. In addition, roots are quantitatively and qualitatively measured and physiologically examined.

Six to seven tonnes of each of the three most important soil series of the scheme, viz Mangano, Shorrocks and Annandale are used in a complete series of experiments.

The pot and laboratory investigations have already been initiated and field trials will be undertaken during 1976.

The effect of internal plant moisture stresses on the growth and production of certain agronomic crops

(New project: Contract with the University of the Orange Free State – Department of Agronomics)

The quantity of available soil moisture does not reflect the water economy of a plant. In the summer rainfall areas atmospheric requirements may often be very high whilst there may be ample or little moisture in the soil. Demand easily exceed moisture supply causing internal plant moisture stresses which give rise to a decrease in the growth and yield of the plant. It is also known that there are periods during which agronomic crops are more resistant to internal moisture stresses than in other periods.

The duration of the sensitive periods – the flowering or fruit set stages – has thus far not been determined accurately. To achieve this the whole term must be investigated over short periods and in such a manner that the relative importance of the different sensitive periods in relation to each other can be determined. From this it will be possible to establish the most important stage for irrigation and when irrigation should next be applied. In this way maximum results can be obtained with the minimum of irrigation.

To obtain more information on this problem the Commission has entered into an agreement with the University of the Orange Free State, in terms of which the University's Department of Agronomics will undertake a project to determine the extent to which vegetative growth and yield are influenced by moisture supply and internal moisture stress in the various growth and development stages.

This research will be done at the Vaalharts Agricultural Research Station. This station was chosen not only because it is one of the most important irrigation areas, but also because the soil readily releases moisture to plants at low suction. During the project the following will be determined:

- The desorption or drying curve of the soil (by watering undisturbed samples for each thirty centimeters of the soil profile and by measuring moisture over a range of 0,1–15,0 bar in a pressure pot and pressure membrane apparatus.
- The relationship between evaporation from an American class A evaporation pan and the soil moisture stress for each separate crop to be tested.
- The discrimination curve for each separate crop to be tested.
- The growth and development pattern for the root system throughout the growth season.
- The evapotranspiration of each crop against the evaporation from a class A evaporation pan during the course of one season for each separate test crop.
- Correlation for each five day period of moisture consumed and moisture stress days, with vegetative growth, with yield and with total yield of dry material.

FLOOD DAMAGE

Research on flood damage

(New project: Contract with the University of the Orange Free State – Institute for Social and Economic Research; and the University of Stellenbosch – Bureau for Economic Research)

On average once every two years floods occur in South Africa which cause losses on a relatively large scale. In South Africa the best irrigation land is often situated within the flood plains of rivers whilst urban and industrial developments as well as communication and transport connections also occur in flood plains. Flood damage, therefore, affects the decisions of the authorities at two levels. Flood damage in the first place often requires special relief and preventative measures. Secondly, authorities are involved indirectly as a result of damage to works, and installations and general disruption of essential services. There is therefore a need to establish guidelines for the rational planning of flood plains by authorities, and this requires reliable information on the extent of flood damage.

As considerable differences can occur in the economic physical situations within the flood plains of different rivers, knowledge which already exists in the United States of America, Australia and England cannot readily be used in the Republic.

The total economic impact of floods in this country has not previously been researched.

Motivated by these constraints, a project on the determination of flood damage in certain river sections has been initiated by the Institute for Social and Economic Research of the University of the Orange Free State and the Bureau for Economic Research of the University of Stellenbosch under contract to the Commission. The two organizations are working closely together in these investigations.

The first objective of the project is to develop a methodology for the identification and evaluation of flood damage which will include primary, secondary and intangible damage; secondly the methodology will be applied to specific river sections and damage relating to the floods of March 1974 will be determined for each section.

Bureau for Economic Research (BER)

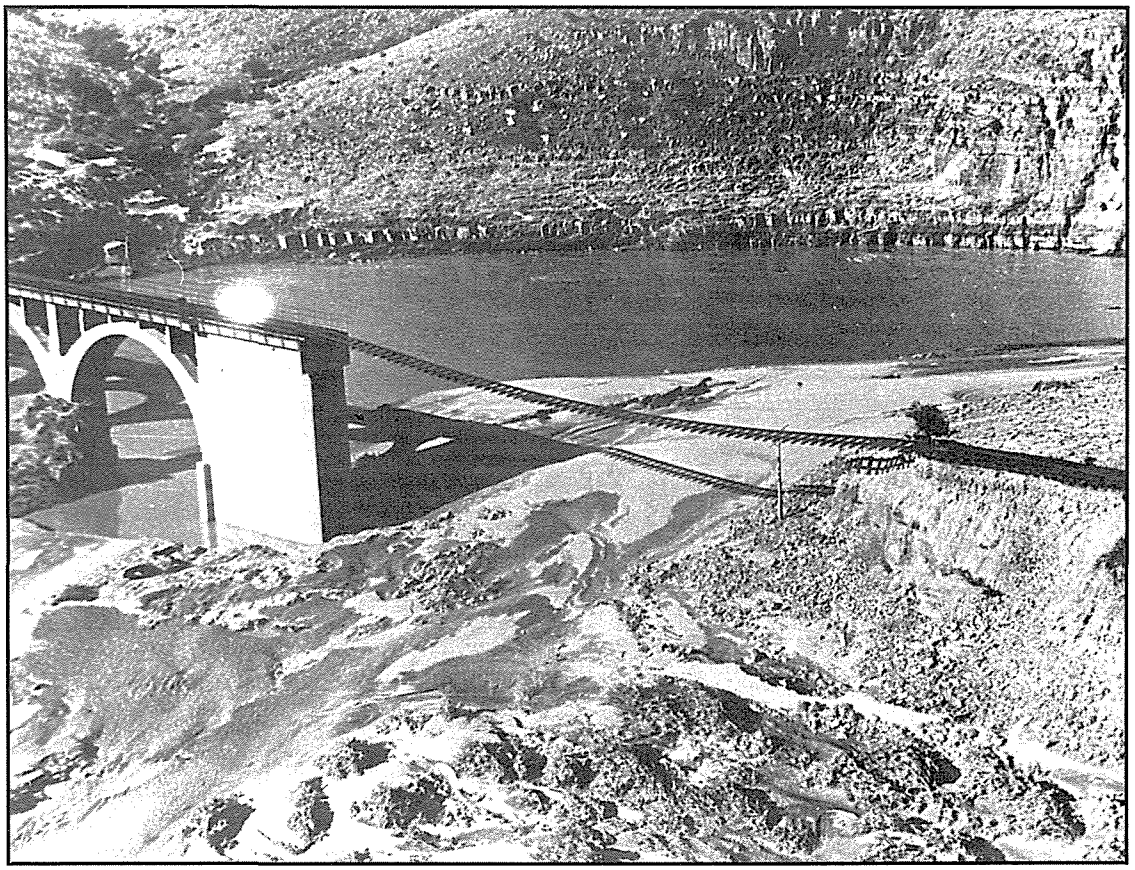
The BER is responsible for surveys in respect of the Sak River in the Karroo and the Sundays River, Fish River, Little Fish River and Koonap River in the eastern Cape. The project commenced with the collection, study and indexing of the literature, including overseas information, on flood damage.

Existing information was collected from central organizations such as the Department of Agricultural Technical Services, Department of Agricultural Economics and Marketing, Department of Agricultural Credit and Land Tenure, Department of Community Development, provincial and other authorities and was tabulated. In a similar manner, entities were identified on 1:18 000 and 1:50 000 topocadastral maps in order to allocate costs to specific points within river sections. On the spot investigations were planned and undertaken during the year under review in the upper reaches of the Sundays River and in the Sak River area. It is estimated that the survey phase of the investigation will be completed during 1976.

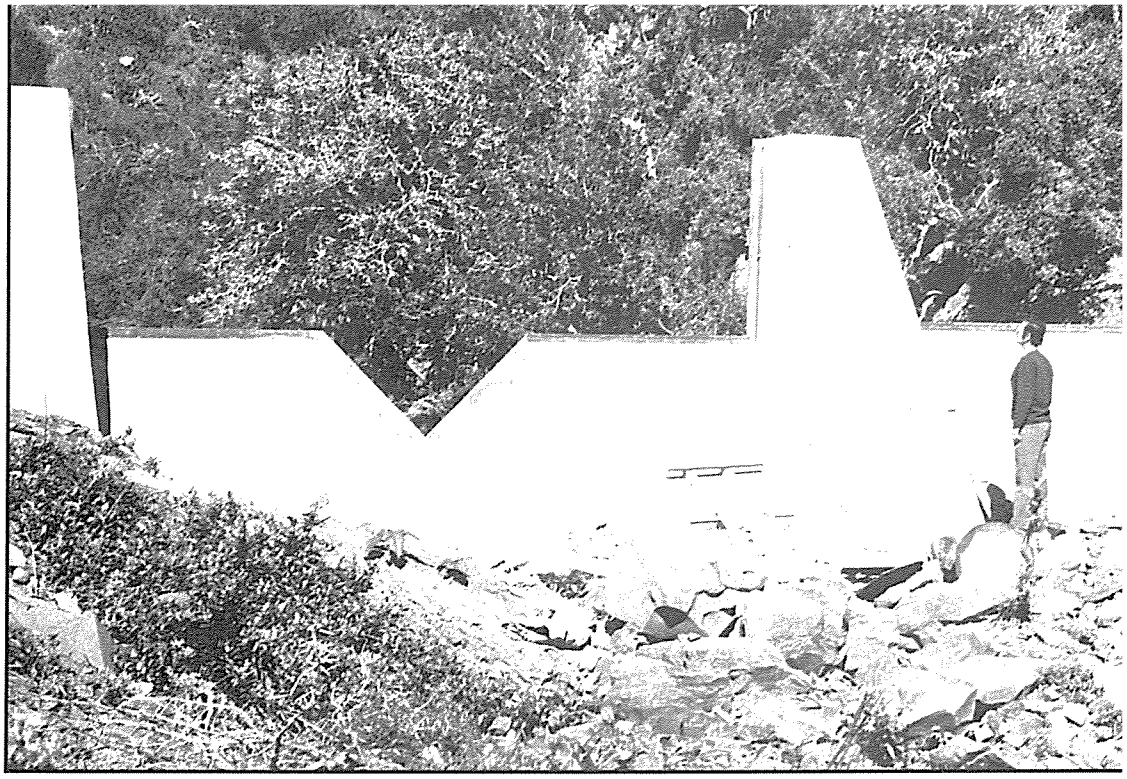
The Institute for Social and Economic Research (ISER)

The ISER is responsible for research in respect of certain sections in the Orange River, the Vaal River and the Hartbees and Seekoei Rivers in the Karroo.

An extensive investigation into existing data sources as well as a literature study were undertaken during the year and subsequently all interested parties in the flood plains were contacted in order to identify damages. Good progress has been made in determining agricultural damage, and surveys of some of the river sections have already commenced. A questionnaire was designed for this purpose and specific information on damages suffered by authorities and private institutions is being received.



Floods regularly occur in the Republic and cause extensive disruption and financial losses. The photograph shows the approach to a railway bridge between Cradock and Cookhouse washed away by the force of the flood of March, 1974. The extent of losses incurred during the 1974 floods is currently being investigated in respect of specific river sections.



The project on hydrological investigations of small catchments comprises inter alia *the erection of gauging weirs in the relevant areas. The photograph shows the V-notch in weir no 5 which has been completed in the Grahamstown area.*

In view of the fact that the Department of Water Affairs has a close interest in the planning and control of land utilization in the flood plains, close co-operation is being maintained with this Department during the course of investigation.

SURFACE HYDROLOGY

Hydrological investigations of small catchments

It is estimated that the annual run-off of rivers in the Republic is in the region of 55 000 x 10^6 m^3, i.e. approximately 8,5 per cent of the mean annual rainfall. Due to the fact that almost 90 per cent of the Republic's water consumption is derived from river flow, it is of the utmost importance to study the relationship between rainfall and run-off more intensively.

Data on precipitation/run-off relationships for a large number of catchments are continuously being collected by the Departments of Water Affairs and of Forestry and from these mathematical simulation models have been developed for the prediction of river flow in large catchments from meteorological data. These models, however, have to be modified and refined through further studies, chiefly of small catchments, where more complete observation by means of superior instrumentation is possible.

The Commission has deemed it desirable that research should include different catchments. Projects financed at the Universities of Natal and Zululand and Rhodes University have resulted in studies of catchments varying in mean rainfall, vegetation, land utilization, soil type, topography and geography.

Investigations in the Grahamstown area

(Existing project: Contract with Rhodes University – Department of Geography.)

The construction of weirs and flumes for the measurement of run-off in the Ecca River catchment has formed the major component of the research programme this year. A contract for the construction of two Robinson flumes and three rectangular weirs was awarded early during the year under review and construction commenced. The measurement of rainfall and evaporation has continued and the data storage and control systems have been improved.

The research programme has also included the formulation and refinement of a number of models for simulating the rainfall-runoff process in the small catchments. These models require an assessment of the physical environment, and thus maps depicting slope categories, morphological units and geology have been compiled. The Botanical Research Institute is assisting with an ecological survey of the catchments. As an aid to the development and calibration of the model, a geographical interpolation programme has been obtained from the United States.

The programme for 1976 will comprise:

- Collection and analysis of rainfall, runoff and evaporation data.
- Reorganisation and further development of digitizer and data storage systems.
- Calibration and further development of simulation models suited to small catchment conditions.
- Development and application of the interpolation programme to the analysis of catchment shape.
- Mapping of vegetation cover and soil depth.

Investigations in the Natal Midlands

(Existing project: Contract with the University of Natal – Department of Agricultural Engineering)

Erection of five gauging weirs at the outlets of selected catchments at the Cedara Experiment Station is expected to be completed by mid-1976. The five catchments, varying in area from 20 to 800 hectares, show the characteristic vegetation of the Natal midlands and are exposed to normal farming practices. Each weir will be equipped with a stage recorder and ten autographic rain gauges will be placed at selected points in the catchment.

A minicomputer-digitiser has been programmed to digitise all data to enable its storage on paper tape. This equipment is currently used to extract data from surveys done in the De Hoek – Tabamhlope experimental catchment. These data are then used to test the rainfall runoff models – work which will later be extended to include the Cedara catchments.

Investigations in the Natal Coastal area

(Existing project: Contract with the University of Zululand – Department of Geography)

Research in the catchment of the Ntuze River (a tributary of the Umlalazi River in the Mtunzini district) comprises, apart from testing and refining existing models, an investigation into the effect of catchment management, conservation and farming practice, afforestation and burning on runoff.

During the year under review, a network of autographic and regular rain gauges were erected in the catchment. Five class A evaporation pans, one Symons pan and one Scheepers pan were also installed. A complete meteorological station at the University is used to obtain daily records, as opposed to weekly readings in the research areas.

During the year the planning for the weirs was completed and it is estimated that construction will be complete by mid-1976. Recording apparatus has been received and will be installed after completion of the weirs.

Good progress has also been made in selecting simulation programmes in order to study the rainfall/runoff relationship in small catchments.

The research programme for 1976 comprises:

- construction of weirs and installation of recording apparatus;
- completion of field surveys relating to the morphology, morphometry, vegetation and soils;
- collection of data in respect of rainfall, evaporation and river flow, and of other relevant climatological data;
- processing of rainfall, runoff and other data obtained in the catchment, as well as the processing of historical data obtained from the Weather Bureau and the Department of Water Affairs on other catchments;
- further selection of simulation models, their adaptation to the computer and the development of new models.

Development of the concept of the runhydrograph in the analysis of flood hydrographs

(Existing project: Contract with the University of Natal – Department of Civil Engineering)

A hydrograph is a curve which graphically depicts flow rate against time. For each watershed there exists a family of hydrographs for the same return period (the return period of a flood indicates the probable regularity of similar floods). Normally the civil engineer focusses his attention on the hydrograph with the highest instantaneous discharge in designing structures for water conservation or flood control purposes.

In many practical applications other hydrographs may be of greater value to the engineer. Although a hydrograph may have a low instantaneous discharge rate, it may reflect a larger total volume of runoff and floods of longer duration. Extraction of such hydrographs from the flow record of the river will allow the engineer to select those of most value for a particular purpose. It will allow the optimisation of solutions to flood problems with regard to the whole family of hydrographs with the desired return period.

Work done by the Department of Civil Engineering of the University of Natal on the flow records of the Vaal River at Standerton has led to the development of a theory for the "Runhydrograph', a concept based on the mathematical and statistical processing of existing hydrographs. From such hydrographs it may be possible to identify important parameters in the runhydrograph for gauged catchments and to develop synthetic runhydrographs for ungauged catchments. To attain this objective, it will be necessary to extract continuous hydrographs over as long a period as possible.

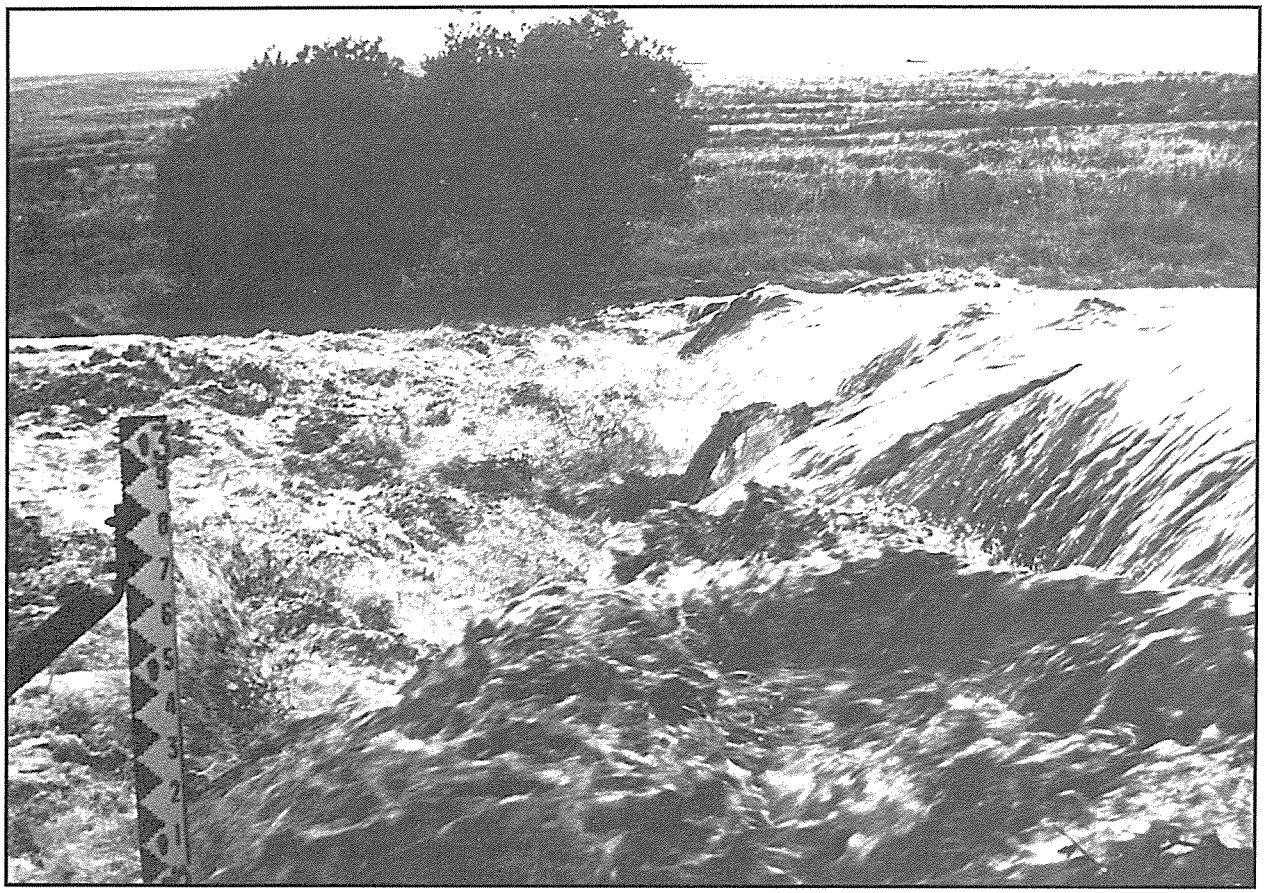
The Department of Water Affairs has kindly approved the use of their extensive flow records by the Department of Civil Engineering. A contract has been awarded to a commercial firm for processing of data.

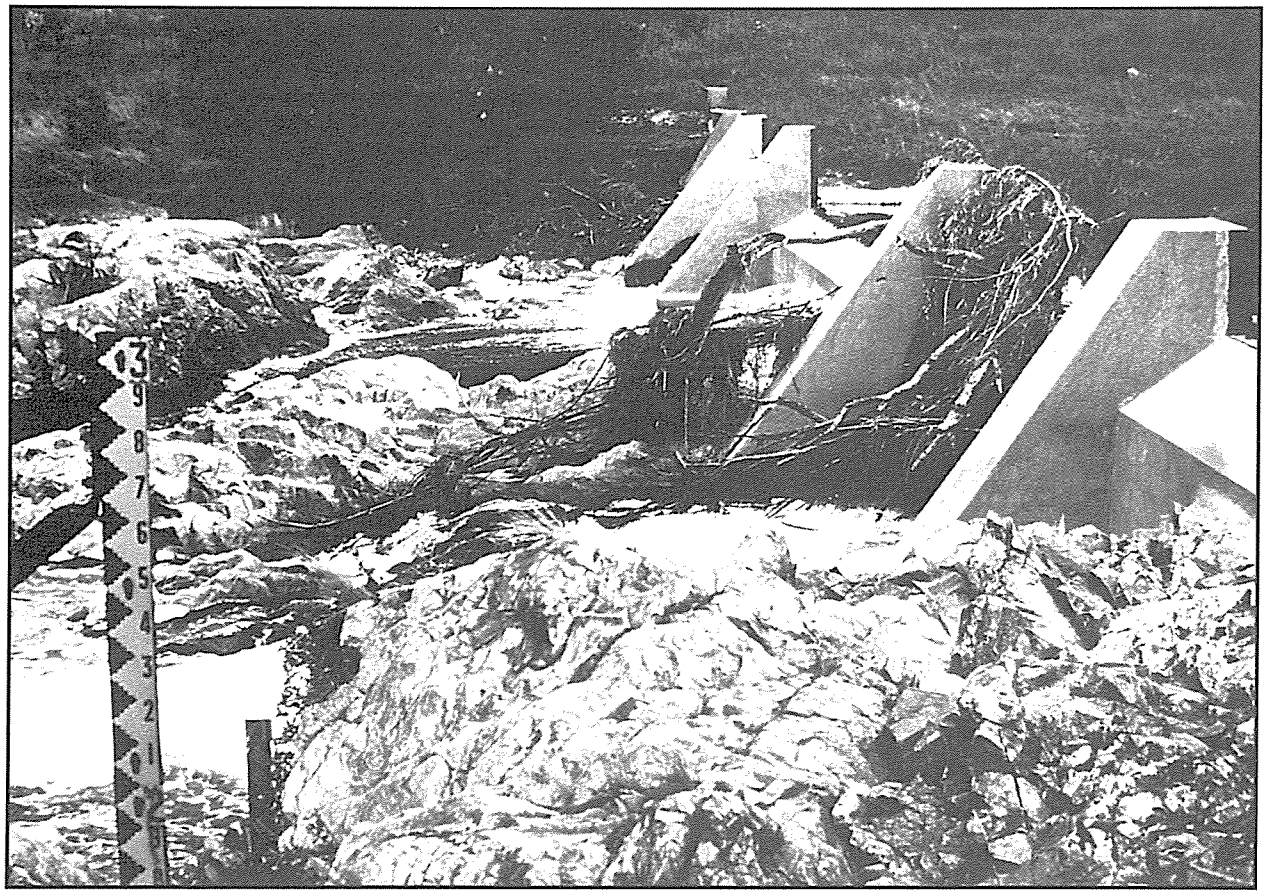
Financial support for hydrological research

(Existing Project: Joint CSIR-Witwatersrand University Council Hydrological Research Unit)

The Unit continues to receive a block grant in accordance with its undertaking to prosecute research in fields of interest to the Commission.

Some of the more important projects are reviewed below.





A gauging weir in the Jukskei Rivier – during and after a flood – used by the Hydrological Research Unit of the University of the Witwatersrand for flood studies and in watershed modelling.

Watershed modelling

The Unit's most valuable contribution to hydrological knowledge is in the field of the development and application of watershed models.

The 12-parameter mathematical model for generating monthly hydrographs of streamflow from monthly rainfall and evaporation input, supplemented by data that can readily be abstracted from maps, has been in wide use for some time.

A more sophisticated model that operates with daily input data has recently been satisfactorily tested. It will facilitate the handling of problems, the solution of which depends on knowledge of the flow frequency distribution (duration curve), e.g. run-of-river diversions, estimation of legal "normal flow", etc. It should prove a powerful aid in the routing of floods through large reservoirs, for spillway design and gate operation and for studying the effects on water resources of upstream land-use and water-use changes, e.g. afforestation, irrigation, urbanisation, effluent disposal, pollution and so on.

The model, like its predecessor, will aid estimation and appraisal of water resources, simulation of the performance of complex water supply and hydro-electric development projects and systems optimization processes. Sub-projects in all these fields are being undertaken.

Flood studies

Tests of the Stanford Watershed Model for use in South Africa for flood hydrograph synthesis are proceeding.

Numerical models to aid flood plain management, including economic aspects, are being developed.

Swamp, lake, river and estuary modelling

With the aid of the mathematical models that have been developed and calibrated for simulating water level, discharge and salinity regimes, all feasible ameliorative measures for the St Lucia system have been systematically tested. Results confirmed that the most promising measures are those that entail transfer of fresh water to the system, e.g. from the Mfolozi or Pongola rivers.

After suitable calibration the models have been applied to a study of the behaviour of the nature reserve portion of the Richards Bay development. The results demonstrate that unless the estuary now under construction is stabilized as a relatively narrow channel, the lagoon bed will be exposed during most tidal cycles. On the other hand, high salinity problems such as experienced at St Lucia will not arise.

The models have been applied to several other studies in South Africa and in neighbouring countries and will doubtless find increasing use as coastal development intensify.

Pretoria-Witwatersrand-Vereeniging Complex: Water circulation study

Charged with the task of setting up a mathematical model of the system, the Unit has largely established the hydrology of all the relevant streams and identified the trends associated with the introduction of effluent. The hierarchy of models has been structured and work is proceeding on several submodels simultaneously.

EXPLOITATION OF ATMOSPHERIC MOISTURE

Production of water by abstracting moisture from the atmosphere by means of hygroscopic materials

(Existing project: Contract with the University of Pretoria – Department of Chemical Engineering)

The first phase of the research which comprises a strictly technical investigation, is divided into two parts of which the first has already been completed.

During the first part, basic mass transfer studies were undertaken with a view to determining the most suitable process (wet or dry), a suitable absorption material and finally determining mass transfer data and design parameters. This work was done by means of a small laboratory set-up.

During the second part larger, more practical, apparatus capable of handling larger stream flows will be used. It is envisaged to test the data obtained at laboratory scale, to correct the proposed scale-up data, and to identify some of the problems which may occur during the design and commissioning of a large plant. Work already completed on laboratory scale has indicated that:

- The researchers are of the opinion that a wet process, operated continuously, is preferable.
- A concentrated solution of LiCl (Lithium chloride) in water (approximately 44 per cent LiCl per weight) is the most practical absorption medium.
- The absorption capacity of the LiCl does not decrease with use. Corrosion products in the plant will more probably have an effect on the performance of the plant, e.g. the clogging of pipes and packing material.
- An independent investigation has already commenced for determining the most practical corrosion-proof construction materials.
- Mass transfer data and design parameters as well as preliminary scale-up factors have been determined on laboratory scale.

The second part of the first phase of the research has already commenced. The larger apparatus has already been designed, and the required units purchased and construction is currently in progress.

Chapter 11

Financial Statements

The Statement of Income and Expenditure and the Balance Sheet have been drawn up in terms of Section 14(2) of the Water Research Act, 1971 (Act No 34 of 1971), as amended, and certified by the Auditor-General and cover the period 1st January, 1975 to 31st December, 1975.

The Commission derives its income from rates and charges on water usage. In terms of section 11 of the Water Research Act, the Minister of Water Affairs has announced the following rates and charges for the Republic in respect of the 1975 financial year in Government Notice No 2362 of 20 December 1974:

"(1) Forty (40) cents in respect of each hectare of land scheduled in terms of section 63 (7) or, where applicable, section 88 of the Water Act, 1956 (Act 54 of 1956), to be irrigated at any time during the period 1 January 1975 to 31 December 1975 with water supplied or made available from a Government dam and distributed by means of a canal, irrespective of whether or not such canal belongs to or is controlled by the Government, an irrigation board or other statutory body. This rate shall be recovered by or on the instruction of the Secretary for Water Affairs simultaneously with any rate which the Minister may levy in respect of the land concerned during the said period in terms of section 66 or section 56 (3) of the said Water Act, or, if no such rate is levied, the rate levied hereby shall be payable to the Secretary for Water Affairs upon demand.

"(2) Twenty (20) cents in respect of each hectare of land scheduled as in paragraph (1) but where the water supplied or made available is not distributed by means of a canal. This rate shall be recovered in the manner described in paragraph (1).

"(3) Twenty (20) cents in respect of each hectare of land scheduled in terms of section 88 of the afore-mentioned Water Act, to be irrigated at any time during the 1975/76 or, as the case may be the 1975 financial year of any irrigation board or other statutory body with water supplied or made available from a waterwork belonging to such irrigation board or other statutory body. This rate shall be recovered by the irrigation board or other statutory body concerned and shall be remitted to the Secretary for Water Affairs within thirty (30) days of the close of the financial year of the said irrigation board or other body.

"(4) Two-tenths of a cent (0,2c) per cubic metre in respect of metered water supplied or made available during the period 1 January 1975 to 31 December 1975 from a Government waterwork for purposes other than the irrigation of land. This charge shall be recovered by the Secretary for Water Affairs simultaneously with any charge the Minister may levy in terms of section 56 (3) or section 66 of the afore-mentioned Water Act in respect of the supply of such water during the said period.

"(5) Two-tenths of a cent (0,2c) per cubic metre in respect of the quantity of water used, supplied or made available for use for urban, industrial or domestic purposes during the period 1 January 1975 to 31 December 1975 by the Rand Water Board, by any regional water supply corporation established in terms of the Water Supply Ordinance, 1945 (Ordinance 21 of 1945), of Natal, by the Western Transvaal Regional Water Company (Pty) Ltd., by any water board or irrigation board established in terms of the aforementioned Water Act and by any local authority serving a White population in excess of 2 000 according to Report 02-05-01 published by the Secretary for Statistics: Provided that there shall be deducted from the total quantity of water used, supplied or made available by an above-mentioned public supplier during the said period of the quantity of water supplied or made available from the Government waterwork in terms of paragraph (4) or the quantity obtained from any other such public supplier during that period. The total amount payable in terms of this paragraph in respect of water used, supplied or made available shall be remitted by the supplier concerned to the Secretary for Water Affairs, Private Bag X313, Pretoria, as follows:

(a) In respect of the period 1 January 1975 to 30 June 1975, not later than 30 September 1975; and

(b) in respect of the period 1 July 1975 to 31 December 1975, not later than 31 March 1976."

In terms of section 11 of the Water Research Act as amended, the Minister of Water Affairs has announced the following rates and charges for South West Africa in respect of the 1975/76 financial year in Government Notice No 1074 of 6 June 1975:

"(1) Forty (40) cents in respect of each hectare of land to be irrigated at any time during the period 1 July 1975 to 30 June 1976 with water supplied or made available from a Government water work. This rate shall be recovered by or on instruction of the Secretary for Water Affairs and shall be payable simultaneously with any rate which may be levied in respect of the supply of such water.

"(2) Two-tenths of a cent (0,2c) per cubic metre in respect of metered water supplied or made available during the period 1 July 1975 to 30 June 1976 from a Government water work for purposes other than the irrigation of land. This charge shall be recovered by or on the instructions of the Secretary for Water Affairs simultaneously with any charge that may be levied in respect of such water supplied.

"(3) Two-tenths of a cent (0,2c) per cubic metre in respect of the quantity of water used, supplied or made available for urban, industrial or domestic purposes during the period 1 July 1975 to 30 June 1976 by the mining companies of Oranjemund and Tsumeb. The rates shall be recovered by the said companies and paid over to the Director of Water Affairs, Private Bag 13193, Windhoek –

(a) in respect of the period 1 July to 31 December 1975, not later than 31 March 1976; and

(b) in respect of the period 1 January 1976 to 30 June 1976, not later than 30 September 1976."

WATER RESEARCH COMMISSION

STATEMENT NO. 1

BUDGET 1976

INCOME		
Estimated revenue from rates and charges in terms of Section 11 of the Water Research Act		2 800 000
Estimated interest on investments		150 000
		2 950 000
Estimated appropriation from accumulated funds		1 756 150
TOTAL		4 706 150
ESTIMATED EXPENDITURE		
Administrative expenses:		
Salaries	321 700	
Subsistence and travelling expenses	99 700	
Postal, telegraph and telephone	13 000	
Printing, stationery, advertisements and publications	49 000	
General Expenditure	73 800	
		557 200
Research Projects:		
4/1 Development of research on the reclamation of water at the Athlone Sewage Works, Cape Town	209 950	
5/1 Technological development of water reclamation on the basis of the Windhoek plant	18 000	
6/1 Eutrophication of rivers and dams	119 800	
7/1 Technological development of water reclamation and pollution control – Daspoort	339 000	
8/1 Research on desalination of brackish water	29 000	
9/1 Reclamation, storage and abstraction of purified sewage water in the Cape Peninsula	871 000	
11/1 Natural draught dry cooling heat exchangers	2 750	
12/1 Financial support of the University of the Witwatersrand Hydrological Research Unit	60 000	
14/1 Research on recycling of water and recovery of chemicals in the textile industry	26 200	
15/1 Research on the treatment of waste water by ion exchange	71 000	
16/1 Research on the activated sludge process	109 200	
17/1 The removal of metal ions from dilute solutions in an electrolytic precipitator	20 250	
18/1 The role of aquatic macrophytes in Swartvlei, Wilderness, in maintaining trophic conditions	37 700	
19/1 Hydrological investigation of small catchments in the Grahamstown area	17 170	
20/1 Hydrological investigation of small rural catchments with specific reference to flood events	59 060	
21/1 Hydrological investigation of small catchments in the Mtunzini district	126 600	
22/1 Biological denitrification and the removal of phosphate	56 500	
23/1 An investigation on the optimal utilization of water in the Eerste River by storage in sandbeds or by other means	106 300	
24/1 Development of the WAT-process for the desalination of sea water	70 000	
25/1 South African Water Information Centre	97 400	
26/1 Research on production of water by abstraction of water vapour from the atmosphere by means of hygroscopic materials	16 600	
27/1 The development and evaluation of techniques for the determination of the exploitation potential of ground water resources in the Southern Free State and Northern Cape	167 470	
28/1 The development and evaluation of techniques for the determination of the exploitation potential of ground water resources along the Doornberg fault zone and in the Kalahari	234 850	
29/1 Research on water consumption patterns in urban areas	28 000	
30/1 Research on the removal of sludge and wash water at water purification installations	25 300	
31/1 Research on water losses in pipe networks	17 000	
32/1 Geohydrological studies in the Gamagara catchment using environmental isotope and complementary techniques	68 680	
33/1 The development of the concept of the runhydrograph in the analysis of flood hydrographs	37 000	
34/1 Research on flood damage – BER	49 700	
35/1 An investigation into soil compaction under irrigation at the Vaalharts State Irrigation Scheme	14 730	
36/1 An investigation into the influence of internal plant moisture stress on the growth and production of certain agronomic crops	8 240	
37/1 Research on flood damage – ISER	49 500	
38/1 Research project dealing with the microbiological quality of reclaimed water with particular reference to health aspects	75 000	
39/1 Research on the soil factors effecting the optimal utilization of irrigation water in the Bantu Homelands	28 000	
40/1 Water requirements of certain agronomic and vegetable crops	35 000	
		3 301 950
Other possible projects		400 000
Contracting of overseas researchers		307 000
Research and other grants		20 000
Specialist and Consultation Services		120 000
TOTAL ESTIMATED EXPENDITURE		4 706 150

WATER RESEARCH COMMISSION

STATEMENT 2

INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD 1st JANUARY 1975 TO 31st DECEMBER 1975

1974	Expenditure		1975
R		R	R
93 238	Salaries and allowances		210 172,87
3 412	Subsistence		8 962,48
1 944	Motor transport		1 634,82
22 823	General transport		29 370,21
462	Postal and telegraph services		4 810,52
2 696	Telephone services		6 261,71
3 846	Printing and stationery		5 793,30
3 070	Advertisements		4 719,34
6 486	Publications		17 420,25
1 074	Lease and maintenance of office equipment		3 610,80
1 374	Entertainment		3 056,93
6 784	Office rental		14 627,17
2 720	Maintenance of and alterations of offices		3 993,40
204	Electricity		514,42
3	Maintenance of and lease of furniture		5,32
2 085	Depreciation		4 233,62
194	Typing services		—
826	Insurance and licences		919,99
15 651	Collection fees		31 978,89
250	Audit fees		958,00
—	Legal costs		879,85
—	Registrations and subscriptions		1 147,17
1 970	Miscellaneous petty expenses		948,63
	Research projects:		
16 366	Technological development of water reclamation on the basis of the Windhoek plant	14 609,24	
48 493	Development of the WAT-process for the desalination of sea water	52 257,51	
145 521	Reclamation, storage and abstraction of purified sewage water in the Cape Peninsula	104 358,28	
329 253	Technological development of water reclamation and pollution control – Daspoort	396 140,21	
90 032	Research on desalination of brackish water	78 065,31	
84 789	Eutrophication of rivers and dams	43 813,21	
25 110	Development of mathematical models for the optimisation of systems for the development of water resources	42 000,00	
13 976	Natural draught dry cooling heat exchangers	815,70	
23 000	*Research on the treatment of effluent of the textile industries*	—	
3 042	Development of research on the reclamation of water at the Athlone Sewage Works, Cape Town	2 132,17	
6 836	Research on the treatment of waste water by ion exchange	77 766,47	
35 827	Research on the activated sludge process	78 197,46	
6 941	The removal of metal ions from dilute solutions in an electrolytic precipitator	6 484,33	
4 185	South African Water Information Centre	36 188,99	
62 571	*Biological denitrification and the removal of phosphate*	78 500,00	
30 520	The development and evaluation of techniques for determination of the exploitation potential of ground water resources in the Southern Free State and Northern Cape	77 336,13	

1974	Revenue		1975
R		R	R
	Rates: Government irrigation schemes with canal systems:		
	Received	17 900,88	
	Outstanding 1975	57 452,97	
78 153			75 353,85
	Rates: Government irrigation schemes without canal systems:		
	Received	430,98	
	Outstanding 1975	2 565,59	
4 952			2 996,57
	Rates: Irrigation board schemes:		
	Received	24 358,07	
	Outstanding 1975	4 824,18	
16 310			29 182,25
	Charges: Metered water from Government schemes:		
	Received	1 733 886,34	
	Outstanding 1975	158 482,49	
1 150 899			1 892 368,83
	Charges: Municipalities:		
	Received	912 006,19	
	Outstanding 1975	13 539,94	
392 390			925 546,13
	Charges: S.W.A.:		
	Received	4 620,24	
	Outstanding 1975	14 823,45	
—			19 443,69
—	Rates and charges prior to 1.1.75		22 977,06
109 146	Interest on investments		221 380,43
87	Sundry Revenue		139,76

—	Research on recycling of water and recovery of chemicals in the textile industry	57 486,73			
—	The role of aquatic macrophytes in Swartvlei, Wilderness, in maintaining trophic conditions	26 173,09			
—	Hydrological investigation of small catchments in the Grahamstown area	17 713,71			
—	Hydrological investigation of small rural catchments with special reference to flood events	54 302,78			
—	Hydrological investigation of small catchments in the Mtunzini district	18 693,73			
—	Research on production of water by abstraction of water vapour from the atmosphere by means of hygroscopic materials	11 956,19			
—	The development and evaluation of techniques for the determination of the exploitation potential of ground water resources along the Doornberg fault zone and in the Kalahari	91 192,75			
—	Research on water consumption patterns in urban areas	5 697,75			
—	Research on the removal of sludge and wash water at water purification installations	11 824,49			
—	Research on water losses in pipe networks	9 904,86			
—	Geohydrological studies in the Gamagara catchment using environmental isotope and complementary techniques	7 477,44			
—	The development of the concept of the runhydrograph in the analysis of flood hydrographs	3 225,20			
—	Research on flood damage – BER	52 785,93			
—	An investigation into soil compaction under irrigation at the Vaalharts State Irrigation Scheme	13 496,91			
—	An investigation into the influence of internal plant moisture stress on the growth and production of certain agronomic crops	15 586,26			
—	Research on flood damage – ISER	23 049,73			
			1 509 232,56		
4 195	Research and other grants		17 000,00		
62 056	Specialist and consultation services		73 360,73		
588 112	Excess of revenue over expenditure		1 233 775,59		
R1 751 937			R3 189 388,57	R1 751 937	R3 189 388,57

WATER RESEARCH COMMISSION

STATEMENT 3

BALANCE SHEET AS AT 31 DECEMBER 1975

1974	Liabilities		1975	1974	Assets			1975
R		R	R	R		R	R	R
	Sundry Creditors:				Capital assets:			
7 833	Revenue paid in advance		11 812,05		Land		5 000,00	
	Fund Account:				Motor vehicles	13 964,91		
4 751 555	Balance as 31.12.74	4 751 554,90			*Less* depreciation	2 299,15		
	Add Excess of Income over			5 194			11 665,76	
	expenditure, 1975	1 233 775,59			*Office equipment*:	20 166,85		
			5 985 330,49		*Less* depreciation	1 008,34		
				10 131			19 158,51	
					Office furniture	18 522,58		
					Less depreciation	926,13		
				14 717			17 596,45	
								53 420,72
					Current assets:			
				2 912 813	Investments		4 394 193,51	
				396	Advance payments		65,70	
					Sundry Debtors:			
					Outstanding Revenue:			
					Prior to 1975	18 679,67		
					1975	251 688,62		
				408 785		270 368,29		
				706 014	Project advances	*1 101 498,82		
				835	Subsistance and			
					Transport Advances	—		
				—	Deposits	50,00		
							1 371 917,11	
				50	Cash on hand		50,00	
				700 453	Cash in Bank		177 495,50	
								5 943 721,82
R4 759 388			R5 997 142,54	R4 759 388				R5 997 142,54

*Vide annexure

Pretoria, 8 April 1976

(Sgd) G J Stander
Chairman (Chief Executive Officer)

The above Balance Sheet has been audited in accordance with the provisions of Section 42 of the Exchequer and Audit Act, No. 66 of 1975 as read with section 14(1) of the Water Research Act, No. 34 of 1971, and in my opinion it has been drawn up so as to reflect a true and fair view of the financial affairs of the Water Research Commission.

Department of the Auditor-General

Cape Town, 29 April 1976

(Sgd) F G Barrie
Auditor-General

ANNEXURE

PROJECT ADVANCES

	PROJECT	R	
4/1	Development of research on the reclamation of water at the Athlone Sewage Works, Cape Town.	67 313,74	
5/1	Technological development of water reclamation on the basis of the Windhoek plant	545 786,97	
6/1	Eutrophication of rivers and dams	6 314,59	
8/1	Research on desalination of brackish water	22 489,42	
14/1	Research on recycling of water and recovery of chemicals in the textile industry	4 003,27	
15/1	Research on the treatment of waste water by ion exchange	57,00	
16/1	Research on the activated sludge process	3 909,00	
17/1	The removal of metal ions from dilute solutions in an electrolytic precipitator	22 360,10	
18/1	The role of aquatic macrophytes in Swartvlei, Wilderness, in maintaining trophic conditions	28 976,91	
19/1	Hydrological investigation of small catchments in the Grahamstown area	58 095,29	
20/1	Hydrological investigation of small rural catchments with specific reference to flood events	22 647,22	
21/1	Hydrological investigation of small catchments in the Mtunzini district	56 706,27	
22/1	Biological denitrification and the removal of phosphate	8 828,88	
23/1	An investigation on the optimal utilization of water in the Eerste River by storage in sandbeds or by other means	61 950,00	
26/1	Research on production of water by abstraction of water vapour from the atmosphere by means of hygroscopic materials	2 433,81	
27/1	The development and evaluation of techniques for the determination of the exploitation potential of ground water resources in the Southern Free State and Northern Cape	77 648,92	
29/1	Research on water consumption patterns in urban areas	1 122,25	
32/1	Geohydrological studies in the Gamagara catchments using environmental isotope and complementary techniques	104 036,56	
33/1	The development of the concept of the runhydrograph in the analysis of flood hydrographs	3 584,80	
35/1	An investigation into soil compaction under irrigation at the Vaalharts State Irrigation Scheme	1 008,09	
36/1	An investigation into the influence of internal plant moisture stress on the growth and production of certain agronomic crops	6 358,74	
37/1	Research on flood damage – ISER	10 647,27	
38/1	Research project dealing with the microbiological quality of reclaimed water with particular reference to health aspects	35 175,00	
			1 151 454,10
	Less excess expenditure over advances for projects:		
7/1	Technological development of water reclamation and pollution control – Daspoort	14 525,71	
9/1	Reclamation, storage and abstraction of purified sewage water in the Cape Peninsula	9 688,69	
24/1	Development of the WAT-process for the desalination of sea water	2 750,66	
25/1	South African Water Information Centre	9 832,19	
28/1	The development and evaluation of techniques for the determination of the exploitation potential of ground water resources along the Doornberg fault zone and in the Kalahari	2 542,75	
30/1	Research on the removal of sludge and wash water at water purification installations	4 164,49	
31/1	Research on water losses in pipe networks	4 064,86	
34/1	Research on flood damage – BER	2 385,93	
			49 955,28
			R1 101 498,82