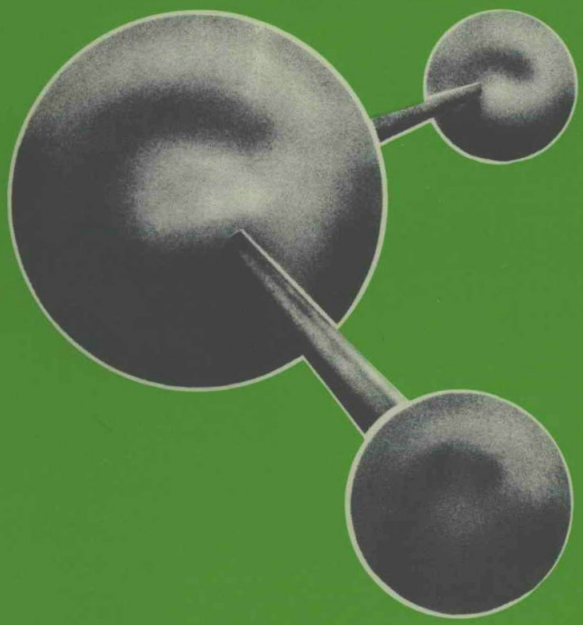

water research commission

ANNUAL REPORT

1 January 1979 to 31 December 1979

WATER RESEARCH COMMISSION

Annual Report

1 January 1979 to 31 December 1979

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Water Research Commission
PO Box 824
PRETORIA
0001

5 May 1980

Dear Sir

We take pleasure in submitting to you, herewith, the report of the Water Research Commission. This report covers the period 1 January 1979 to 31 December 1979.

The balance sheet and statement of revenue and expenditure for the financial year 1 January 1979 to 31 December 1979, as certified by the Auditor-General, are furnished in Chapter 13 of this report.

Yours respectfully

MR Henzen
CHAIRMAN

JP Kriel
VICE CHAIRMAN

The Honourable AJ Raubenheimer, MP
Minister of Water Affairs, Forestry and Environmental Conservation
PO Box 23
CAPE TOWN
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(Until 31 July 1979)

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Chairman: Noristan Ltd
(Co-opted member)

Chapter 1

Review of the year

Dr GJ Stander, Chairman and Chief Executive Officer of the Water Research Commission retired on 31 July 1979 and was succeeded by Dr MR Henzen, formerly Chief Adviser to the Commission.

With the establishment of the Commission on 1 September 1971 Dr Stander was appointed Chief Executive Officer. He was also Vice Chairman until 31 July 1974 when he was appointed Chairman in terms of the Water Research Amendment Act (Act No 16 of 1974). Under his leadership the Commission's infrastructure developed to the extent that it has been placed on a firm foundation from which the future may be faced with confidence and purpose.

On various occasions during the year, in Pretoria and elsewhere, appropriate farewell functions were held where tribute was paid to his unique contributions and achievements. It would be appropriate, however, to take this opportunity of expressing appreciation and paying tribute to Dr Stander for the almost 40 years of exceptional service in the water field.

Some of the most important contributions relate to the promotion of waste water treatment technology, waste water reclamation, his leading role in the establishment of the CSIR's National Institute for Water Research (of which he was the director) and of the Commission, manpower utilization and the development of effective programmes for the sharing of knowledge in the field of water at international level. He has authored more than 100 scientific publications.

His most notable achievements were in the field of water reclamation particularly his leadership and contributions in connection with the development of the Windhoek Water Reclamation Plant and the Stander Reclamation Plant at Daspoort, Pretoria. This work is largely responsible for his being named the 'Father of Water Reclamation.'

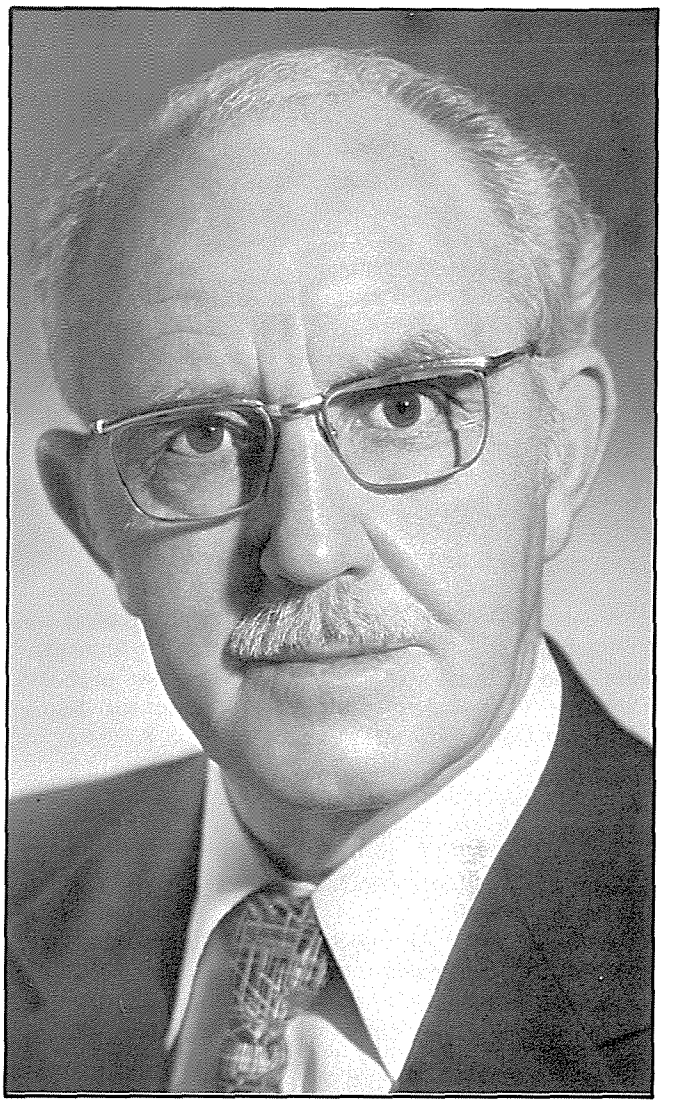
His vision, enthusiasm, drive, pioneering work

Dr GJ Stander who retired as Chairman of the Water Research Commission during the year

and the dynamic role that he played in connection with so many aspects in the water field earned Dr Stander national and international fame and several awards during his career. To single out a few: For 8 years he was President of the International Association on Water Pollution Research (IAWPR) and was accorded honorary membership of the Water Pollution Control Federation (USA) and the Abwassertechnische Vereinigung (Germany).

His successor, Dr Henzen, was previously Assistant Director of the National Institute for Water Research and has been Chief Adviser to the Commission since 1 September 1973.

Upon his retirement from the post of Secretary of the Department of Agricultural Technical Services at the end of 1978, Dr WA Verbeek also retired as a member of the Commission. The Commission wishes to take this opportunity of thanking him for his valuable advice and services rendered during his term as a member of the Commission. The vacancy left by Dr Verbeek has been filled by his successor, the new Secretary of the Department, Dr DW Immelman.



Dr MR Henzen who succeeded Dr GJ Stander as Chairman of the Water Research Commission during 1979

Promotion of water research

The principle that has evolved on which contracts are awarded was extensively reported in the 1978 Annual Report. This went hand in hand with the deployment of the Commission's coordination strategy and the growing realization of its technology transfer responsibility. As a result of this development the Commission incorporated the principle of partnership research in its financing strategy. Partnership research, i.e. research in which an operational organization is actively engaged and which contributes facilities, manpower and funds, is regarded as one of the most effective ways to effect technology transfer.

Of the 71 research projects initiated since the Commission's inception, 14 had been completed before the end of 1978 and a further 13 came to a close at the end of 1979. Serious consideration of the findings is being given in order to decide which of the results can already be applied and along which routes further research can be initiated most advantageously by means of new partnership contracts.

New research avenues in the water field will have to be developed and whenever possible the partnership principle should be incorporated. It must be realized, however, that it is not always possible to incorporate the partnership principle in research, especially in the case of new avenues of research when the work will initially be of a more fundamental nature so that operational organizations will only become involved much later during the development stage.

As a result of the sound infrastructure created by the establishment of Coordinating Research and Development Committees (CRD committees) and Study Groups, the development of centres of expertise, competent staff structure, and the strengthening of contacts between the Commission and government bodies and industry, it can be expected that the greatest part of the Commission's future contract financing will be the result of negotiations initiated by the Commission, and not the reverse, as has often been the case in the past.

Coordinating Research and Development Committees

The establishment of Coordinating Research and Development Committees and Study Groups for specific high priority problem areas still remains one of the most important and successful strategies used by the Commission to promote coordination of water research. A Study Group is appointed to investigate and report on a specific problem area, after which the group is disbanded. In contrast the CRD committee has a continuous function of identifying problems within a specific field, of compiling master research programmes, of recommending research projects on a priority basis, of coordinating research in the relevant field, of evaluating progress, and of deciding on the publication and application of research results.

Government departments, provincial and local authorities, industrial associations and research organizations with an active interest in the relevant problem areas are invited to nominate delegates for Study Groups or CRD committees.

CRD committees are currently managed by the Commission in the following fields:

- Water and effluent problems in the textile industry
- Water and effluent problems in the fruit and vegetable canning industry
- Water and effluent problems in the mining industry
- Water and effluent problems in the abattoir, tanning and related industries
- Water pollution and reclamation in the PWVS complex
- Water economy in urban areas
- Solid and toxic wastes
- Water quality networks
- Health aspects of water use
- Desalination

In addition the Committee for Inland Water Ecosystems of the CSIR's National Programme for Environmental Sciences, in terms of an agreement between the CSIR and the Commission, acts as a CRD committee. The Commission is also closely involved in another two coordinating committees, *viz* the Coordinating Research Committee for the Hydrological Cycle (CRCHC) and the Coordinating Committee for Irrigation Research (CCIR).

It can also be stated that the Commission established in 1975 a Study Group for Groundwater research. This Study Group completed its task with the compilation of a National Master Research Plan and a Priority Research Programme, which have been accepted by the Commission. For the implementation and coordination of the plan and programme, close collaboration is maintained between the Groundwater Division of the Department of Water Affairs and the Commission. As far as research on rainfall stimulation is concerned, the necessary coordination between the Commission and the Departments of Water Affairs and of Transport is effected by means of steering and sub-committees.

Technology transfer under way

The high priority accorded to technology transfer (TT) by the Commission and the various avenues along which it is promoted have already been emphasized in previous annual reports. The Commission considers it desirable that TT should be incorporated even at the planning and operational stages of research projects. In order to effect this the research has firstly to be aimed at well-defined objectives and in order to identify research requirements the Commission makes extensive use of Study Groups and CRD committees. Secondly, operational organizations should as far as possible be involved in the planning and execution of research, i.e. the partnership principle should be built into the research agreements. This will ensure that potential end users of research results are involved in the planning and execution of projects by contracting such organizations on a partnership basis in the research.

Some of the other TT techniques already used by the Commission include the publication of technical manuals and other practically orientated publications, TT seminars, demonstrations and training, utilization of overseas expertise and contact with overseas research and technology. Publication of technical manuals and other practically orientated publications received particular attention during the year. In order to promote TT it is essential that usable results should be packaged in such a form that the potential user finds it more accessible than results published in conventional scientific media.

The compilation of manuals is the responsibility of the relevant research organizations or consultants. By means of an editorial panel, the Commission has the role of critically evaluating the manual in respect of technical content and the suitability of the packaging in relation to the intended user.

In addition to these practically orientated reports, the Commission also releases interim and final project reports from time to time, and naturally some of the research financed by the Commission is often featured in papers published in scientific journals.

The following practically aimed documents have already been published by the Commission:

- *Tussentydse riglyne vir die beheer van eutrofikasie* (in conjunction with the National Institute for Water Research (NIWR) of the CSIR)
- *Manual for water renovation and reclamation* (in conjunction with the NIWR)
- *The runhydrograph — theory and application for flood predictions* (in conjunction with the University of Natal)
- *Chemical control of the water hyacinth on Hartbeespoort Dam* (in conjunction with the NIWR and the Department of Water Affairs)
- *The ecology of Swartvlei: Research for planning and future management* (in conjunction with Rhodes University)
- *A comparison of the performance of selected conceptual models of the rainfall-runoff process in semi-arid catchments near Grahamstown* (in conjunction with Rhodes University)

Practically orientated documents currently in preparation are the following:

- *A guide for the planning, design and operation of water reclamation plants* (in conjunction with a firm of consulting engineers)
- *Digitizing and routine analysis of hydrological data* (in conjunction with the University of Natal)
- *The limnology of some selected South African impoundments* (in conjunction with the NIWR)
- *Guidelines for the control of eutrophication in South Africa* (in conjunction with the NIWR)
- *Proceedings of a seminar on 'Nutrient removal from municipal effluents'* arranged by the Institute of Water Pollution Control in conjunction with the Water Research Commission, the NIWR, the South African Institution of Civil Engineers and the Institution of Municipal Engineers of Southern Africa
- *Technical guide for biological nutrient removal: the phoredox process* (in conjunction with the NIWR)
- *Design guide for biological nutrient removal* (in conjunction with the University of Cape Town)
- *The desalination of brackish water* (in conjunction with the NIWR)
- A résumé of technical information with regard to sludge handling (based on a contract report by a firm of consulting engineers and on the report of the special Study Group who studied sludge handling practices in Europe in 1978).

In order to make technology transfer as effective as possible it is essential to promote personal contact with the user. The Commission, therefore, provides in this need by holding seminars which are aimed at a specific technology and a selective audience.

The first TT seminar was held in May 1979 in Pretoria, in collaboration with the Institute of Water Pollution Control, the National Institute for Water Research, the Institution of Municipal Engineers of Southern Africa and the SA Institution of Civil Engineers, on the state of the art of the removal of nutrients from municipal waste water. The seminar was of particular importance to local authorities.

Research highlights

Projects and other activities such as Study Groups, CRD committees, etc. are reported on in the respective chapters. There are however, certain developments that occurred during the year under review that deserve brief mention here:

The treatment and disposal of sludge and solid and toxic wastes

The Commission has for some time now been aware of the problems associated with the treatment and disposal of sludges and solid and toxic wastes and of the danger it represents as a potential source of pollution of surface and groundwaters as a result of various disposal practices. The treatment, handling and disposal of sludge and solid and toxic wastes is a problem of national importance for which practical solutions must be found. Local authorities are confronted with the problem and the Commission is well aware of the need for research in this field. Such research, supported financially by the Commission, will be aimed at the scientific evaluation of new and existing treatment and disposal techniques so that environmentally and aesthetically suitable avenues of disposal might be developed, thereby assisting local authorities and eliminating the risk of water pollution.

In 1978 Dr AL Downing, former Director of the British Water Pollution Research Laboratory and currently associated with a firm of consulting engineers in the United Kingdom, was engaged as a specialist consultant by the Commission to prepare a basic background document dealing with available overseas technology relating to the treatment and disposal of municipal sludge, beneficial utilisation of sludge, disinfection techniques and health aspects associated with sludge treatment and disposal. The report was received by the Commission in 1978 and discussed with representatives of all major local authorities in the coun-

try and supplemented by information obtained during 1978 by a fact-finding mission sent abroad. The individual reports, in conjunction with a report compiled by the Commission on current sludge treatment and disposal practices in South Africa, have been studied by the Research Review Committee for Local Authorities and by the Coordinating Research and Development Committee for Solid and Toxic Wastes. Priority requiring immediate attention have been identified and a Master Plan for research in this field has been formulated.

The Master Plan includes problem areas for which a research input is necessary in the following areas: sludge processing and treatment, sludge disposal, beneficial sludge utilisation and related health aspects. The research will be aimed at eliminating the danger of pollution of surface and groundwater and establishing acceptable and economic methods for sludge disposal which do not present a health risk.

Specific research projects will therefore shortly be initiated on a partnership basis with the relevant local authorities with a view to finding solutions to the most urgent problems currently experienced by these authorities and to compile suitable codes of practice for the prevention of water pollution.

The removal of nutrients from effluents

The presence of plant nutrients such as phosphate and nitrogen in purified wastewater discharged to rivers and dams leads to the eutrophication of these water bodies. In order to prevent this problem, the Commission financially supports projects which are aimed at the development of techniques for the removal of nutrients from wastewater.

Two five-year agreements with the CSIR and the University of Cape Town respectively, on the biological removal of plant nutrients by means of modified conventional activated sludge processes recently came to a close. The research results will be published in the form of a technical guide and a design manual. Both these publications will be aimed at the needs of design engineers at local authorities and consulting firms.

There is at present an urgent need for tried and tested economical processes for the removal of nutrients since specifications for phosphate removal from effluents generated in certain critical catchments, are currently being considered by the South African Bureau of Standards (SABS) and the Department of Water Affairs. In order to ensure that such processes are available, the Commission is continuing its promotion and assistance of research on nutrient removal and has entered into two new agreements in this respect in terms of which two research projects will be undertaken. The first relates to the optimisation of the full-scale modified activated sludge process used at Goudkoppies, Johannesburg, and is being executed jointly by the City Council of Johannesburg, the CSIR and the University of Cape Town. The main objectives of this project are to ensure the effective transfer of technology developed during the previous research projects and to develop a guide for the design and operation of full-scale activated sludge plants which are capable of nutrient removal. The second project concerns nutrient removal from effluents from biological filtration type wastewater treatment plants which are the most common type of plant in the country. The project is undertaken jointly by the City Council of Pretoria and the CSIR. The main objective of the project is to develop a suitable technique for the removal of phosphate from biological filter effluents in order that existing sewage purification plants may continue to be used without the threat of polluting natural surface water supplies with nutrients. A technical guide containing design and operational criteria for the removal of a nutrient from biological filter effluents will be compiled on completion of the project. Although both projects are still in the initial stages, good progress has already been made, as reported in Chapter 5.

Water economy measures in urban areas

During the year a tripartite agreement was entered into between the CSIR (through its National Building Research Institute (NBRI), the SABS and the Commission, in terms of which research will be done on water economy measures in urban areas. The programme for this research project is embodied in the Master Plan compiled by the NBRI. The Master Plan, which is based mainly on the report of Mr M Kantor, an Israeli water economy expert and a former consultant to the Commission, has been approved by the CRD committee for Water Economy in Urban Areas.

The main objectives of the project are to achieve significant savings in water consumption by means of the design and use of water supply fittings and to establish criteria which may be used to update the relevant sections of the National Building Regulations.

Attention will be given to the standardization of fittings and appliances used in water supply installations, to the formulation of specifications of these items and to the compilation of Codes of Practice in respect of plumbing and drainage in buildings, gardens and parks, and at recreational facilities. The problem of water wastage by automatic flushing devices will also be investigated and the NBRI has already completed preliminary tests and published a report on water-closet and urinal flushing requirements.

The project envisages full participation by many of the major local authorities and those already approached have indicated their willingness to participate even in cases where water supplies *per se* do not present a problem.

The manufacturing industry has also shown great

interest and preliminary discussions have indicated that industry may even be prepared to take the lead in certain aspects, should it prove necessary.

Research on dry and wet-dry cooling

Large volumes of water are used daily for cooling purposes at power stations and high evaporation losses are experienced as a result of the use of conventional wet cooling towers. The high consumption of water can be significantly reduced by using dry or wet-dry cooling methods. Dry cooling differs from the usual 'wet' method in that cooling is effected by the movement of air over cooling elements and not by the evaporation of water. It also has the advantage that the increase in solids concentration in the water is significant.

Owing to considerably higher capital costs and lower efficiency, dry cooling has yet to be applied generally. In 1971 ESCOM installed a large dry cooling system at its Grootvlei power station, followed by a second unit in 1977, in order to gain experience with the operation of such systems.

In the light of the advantages offered by dry cooling as a result of the increasing demand for water in the Eastern Transvaal Highveld, where ESCOM's latest power stations are being erected, the Commission decided to support research on the efficiency of dry and wet-dry cooling. ESCOM, the CSIR and the Commission entered into a tripartite agreement in terms of which the Air Pollution Research Group of the CSIR will investigate the effect of atmospheric conditions on the performance of dry cooling towers, and the Corrosion Research Division of the CSIR will investigate the effect of water spraying on the physical condition of the heat exchangers.

The project will be undertaken on a partnership basis with ESCOM whereby ESCOM's input will be active participation in the execution of research and making available the required facilities. As part of the preparation for the compilation of the research programme a fact-finding mission of representatives of the relevant organizations visited the USA and Europe during the year, during which contacts with research groups overseas were also established.

Water reclamation

The original agreement between the Commission and the CSIR regarding the technological development of water reclamation and pollution control in terms of which research was done at the Stander reclamation plant at Daspoort, Pretoria, came to a close at the end of 1978. As mentioned in the previous annual report, a manual entitled *Manual for Water Renovation and Reclamation* was released jointly by the Commission and the NIWR. It is based on research done by the NIWR over the past decade and supported by the Commission for the last five years.

In order to effect a significant transfer of the technology developed, the Commission deemed it necessary to compile a supplementary guide to this manual to meet the practical requirements of planners, design engineers, scientists and operators. The guide, entitled *A Guide to the Planning, Design and Operation of Water Reclamation Plants* will be released early in 1980.

A further important example of technology transfer in the field of water reclamation came about when a tripartite agreement was entered into by the Commission, the City Council of Pretoria and the CSIR. In terms of this agreement the City Council will take full responsibility for operating the Stander reclamation plant until the end of 1981.

This project, which will be executed in close cooperation with the Department of Health, has a threefold objective. First, a local authority will be afforded the opportunity to prove that it is feasible to operate a reclamation plant as part of its normal routine. Secondly, monitoring and control programmes for the plant will be developed and maintained with a view to the formulation of requirements, should the reclaimed water be made available for human consumption. Thirdly, a programme will be developed and carried out for the control of the discharge of substances having possible health implications to the sewerage system serving the Daspoort sewage works. The latter aspect is regarded as very important, especially by the health authorities, since a thorough knowledge of specific chemical compounds which may be discharged into the sewage system may be obtained by means of such a control system. Measures may then be taken to prevent the discharge to sewer of substances which have possible detrimental health implications and which cannot be removed by sewage purification or the reclamation processes.

Research on soil compaction under irrigation

In crop production there are various factors which have a retarding effect on crop yield. Apart from factors such as the type of cultivar, different methods of fertilising, pest and weed control and satisfactory moisture supply, certain soil-physical conditions can severely limit crop yield. In this regard, soil compaction in particular, can cause an imbalance in the uptake of plant nutrients (since it limits root growth and impedes the uptake and metabolism of plant nutrients) and also has a detrimental effect on the utilization of irrigation water.

Against this background the Commission has been supporting research since 1975 on the effect of soil compaction on the soil-plant system at the Vaalharts government irrigation scheme. This research forms part of the irrigation research comprising several projects

which are financially supported by the Commission. The project has been completed and the final report, received during the year, contains several important findings:

It has been confirmed for example that root length per unit volume of soil decreases sharply with an increase in the degree of compaction for all agronomic crops, especially so for summer crops. This results in a decrease in the utilization of the available plant nutrients.

Contrary to certain beliefs, field tests have shown no difference in the degree of compaction caused by sprinkler *vis-à-vis* flood irrigation. It was clear, however, that implement traffic together with irrigation caused significantly more compaction than irrigation only. The high fine sand content of these soils together with the compaction effect of agricultural implements during primary and secondary cultivation were the main causes of soil compaction. The problem can be minimised by adopting the practice of controlled implement traffic. An agreement for a follow-up project has been entered into in order to investigate the most desirable combination of controlled implement traffic and irrigation methods, as well as the efficiency with which different root systems utilize moisture and plant nutrients when subjected to soil compaction. The project, entitled "The efficiency of water extraction from fine sandy irrigation soils by different root systems", commenced during the year.

Research on behalf of the tanning and fellmongering industry

For a number of years the Commission has been supporting research on water management and effluent problems in the hides and skins, curing, fellmongering and tanning industries.

As part of the research in this regard the Commission entered into a contract during the year in terms of which a project was successfully initiated and which led to the development of a new process for the treatment of the wastewater from a tannery in Pretoria. The application of this process will lead *inter alia* to the elimination of a difficult environmental problem caused by the tannery and which existed for many years.

In the past the tannery pumped its wastewater to evaporation ponds because the wastewater contained too high a concentration of dissolved inorganic salts for disposal by any other means, such as to municipal sewer. Associated with the use of evaporation ponds as a method of disposal are several disadvantages and these include the risk of pollution of the water environment by leakage or overflow from the ponds and the generation and release of hydrogen sulphide which causes an odour problem.

The problem of the inorganic salt concentration in the effluent being too high for acceptance in the municipal sewer can be overcome, however, by processing "green" hides instead of salt cured hides. The problem of high concentrations of sulphides in the wastewater, which can lead to the formation of hydrogen sulphide in the sewers, can also be overcome by stripping the sulphides from the wastewater with the aid of surface aerators.

The remaining component of pollution, namely a very high concentration of dissolved and suspended organic matter, has always been one of the most difficult effluent disposal problems facing the hide processing industry. The Commission, therefore, initiated a research project in conjunction with the Leather Industries Research Institute of the CSIR, the Municipality of Pretoria and a local tannery, in an effort to solve the problem. The successful use of air flotation in a pilot plant at the tannery can be regarded as a breakthrough in the treatment of the mixed liquor of tanneries. The process produces an effluent acceptable for disposal to municipal sewer.

This new development will eliminate the need for evaporation ponds at tanneries which will not only make available valuable areas of ground but will also benefit the community by eliminating an odour problem.

Research on water pollution in the Pretoria-Witwatersrand-Vereeniging-Sasolburg complex

The Pretoria-Witwatersrand-Vereeniging-Sasolburg complex (PWVS complex) is characterised by a high water demand and the fact that treated industrial and domestic effluents and stormwater runoff are being discharged to an increasing extent to the Barrage, the most important source of water supply for the area. This has resulted in a clearly noticeable deterioration in the water quality of the area over the years. As a result of these problems the Commission has been supporting research on pollution control and water reuse in the PWVS complex for several years. The research is being done by a firm of consulting engineers appointed as project manager, in conjunction with the Hydrological Research Unit of the University of the Witwatersrand. Mathematical models were developed and tested for the prediction of the daily variation of mineral salts in the system. These investigations are aimed at finding a practical solution to the problems which will curtail the increase in mineral salt content.

In addition to this research, the Commission is also investigating the cost implications to the ordinary consumer and the industrialist of a water with an increased mineral content. At this stage there are already indications that house owners and industrialists in the PWVS complex will be faced with increasing problems in future as a result of the detrimental effect of increased mineralisation of water. House owners could experience problems with piping, taps, hot water systems, washing machines, etc. as well as an increase in soap

consumption. Knowing the additional costs to the consumer resulting from increased mineralisation of water will play an important role in the evaluation of the recommendations based on the results of the study.

Briefly

1. Gold medal of the South African Institute of Agricultural Engineers

The 1979 gold medal of the South African Institute of Agricultural Engineers has been awarded to Prof PJC Vorster, Chief Adviser to the Commission. The award is in recognition of his outstanding services to agricultural engineering. Prof Vorster was previously attached to the University of Natal and joined the Water Research Commission in 1974 where, as Chief Adviser, he is responsible for the Commission's involvement in research on agricultural uses of water and hydrology.

2. Column in "IMIESA"

A monthly column on the Water Research Commission has appeared since January 1979 in *Imiesa,* the official organ of the Institution of Municipal Engineers of Southern Africa. Since its establishment in 1971 the Commission has developed a wide range of activities of direct importance to local authorities. For a long time, however, there has been a need for regular feedback of information to local authorities and this column is intended to keep local authorities informed on the activities and research done on their behalf.

3. Participation in international events

Members of staff attended certain international meetings during the year and made direct contributions in the following cases:

- The Chairman, Dr Henzen, presented a paper on *Prospects for the use of reclaimed water for drinking purposes* at the fifth world congress for engineers and architects in Israel in December 1979. Mr CF Schutte, Adviser to the Commission, co-authored the paper.

- In March 1979 Mr PE Odendaal, Chief Adviser to the Commission, presented a paper at a conference of the American Water Works Association (AWWA) on the reuse of water, in Washington, D.C. In May 1979 he also attended a meeting of the *Working Group on Future Activities of the International Association on Water Pollution Research (IAWPR)* in Copenhagen during which an in-depth study was made of the range and objectives of the Association's activities and the administrative and technical management of the Association was discussed.

Chapter 2

Water reclamation

Water reclamation and the part it plays as a supplementary water supply source in overcoming shortages in the projected demands for fresh water in certain areas, continues to enjoy high priority at the Commission which at present supports 9 research projects in this connection.

As mentioned in Chapter 1 the Commission in collaboration with the National Institute for Water Research (NIWR), published a manual entitled "Manual for Water Renovation and Reclamation" based on research into water reclamation. In order to accomplish a meaningful transfer of the developed technology into practice, the Commission also decided to publish a guide with the title "A Guide to the Planning, Design and Operation of Water Reclamation Plants" early in 1980. This guide will meet the practical needs of planners, design engineers, scientists and operational personnel dealing with water reclamation.

The year under review can to a large extent be seen as a year of consolidation in the realm of water reclamation. Consolidation of research at the Stander Water Reclamation Plant at Daspoort, Pretoria, meant that the NIWR's research activities were completed and that responsiblity for operating the plant was handed over to the City Council of Pretoria. Thus the phase has now been reached where the transfer of technology to the authority ultimately responsible for its application, has been realised. Operation of the plant by the City Council is carried out in terms of a tripartite agreement between the Commission, the City Council of Pretoria and the CSIR. Another important facet of water reclamation forming part of this project is a development and implementation programme concerning quality control in catchment areas. This aspect which is being carried out in close cooperation with the Department of Health, is regarded as being of special importance by the health authorities since, in this way, compounds which may be harmful to the health of consumers may be prevented from discharge into the sewerage system. In addition, it will be possible to determine what specific compounds may find their way into the sewer. It is envisaged that control programmes be extended in the future so as to protect those surface sources from which water for domestic use is obtained.

In the case of the project on the technological development of water reclamation on the basis of the Windhoek plant, no water was reclaimed during 1979 pending the completion of an activated sludge plant from which the effluent will be reclaimed. It is expected that this development will be of great benefit to Windhoek since a much better quality effluent will be available for reclamation, with concomitant economic advantages.

The project on the reclamation, storage and abstraction of purified sewage effluent in the Cape Flats also experienced a period of consolidation. During the year the City Council of Cape Town commissioned an activated sludge plant and the reclamation of oxidation pond effluent was only carried out for the sake of investigations in connection with infiltration studies which were performed by the NIWR.

A new contract was entered into with the University of Cape Town for research into the development and application of aspects of equilibrium chemistry and precipitation kinetics on water stability problems which are experienced in water reclamation. The purpose of this project is to provide a simple, direct, graphic procedure by means of which operators, designers and chemists can easily predict the behaviour of various unit processes in water reclamation when chemical dosing takes place. This will enable the introduction of timely measures to minimize corrosion and to prevent the formation of deposits on equipment.

Further developments have taken place with respect to the health aspects associated with the use of reclaimed water. The Commission entered into an agreement with the University of Cape Town whereby the Department of Community Health of the Medical School of the University will undertake epidemiological investigations in certain areas of Cape Town, with a view to the possible future use of reclaimed water in Cape Town and its environment. Although the community of Windhoek did not use reclaimed water during the year, epidemiological studies in Windhoek were continued by the South African Institute for Medical Research.

As mentioned in Chapter 1, the Chairman of the Commission presented a paper: "Prospects for the use of reclaimed water for drinking purposes" during December 1979 in Israel at the "Fifth World Congress of Engineers and Architects" in which the local approach to health aspects regarding water reclamation was expounded.

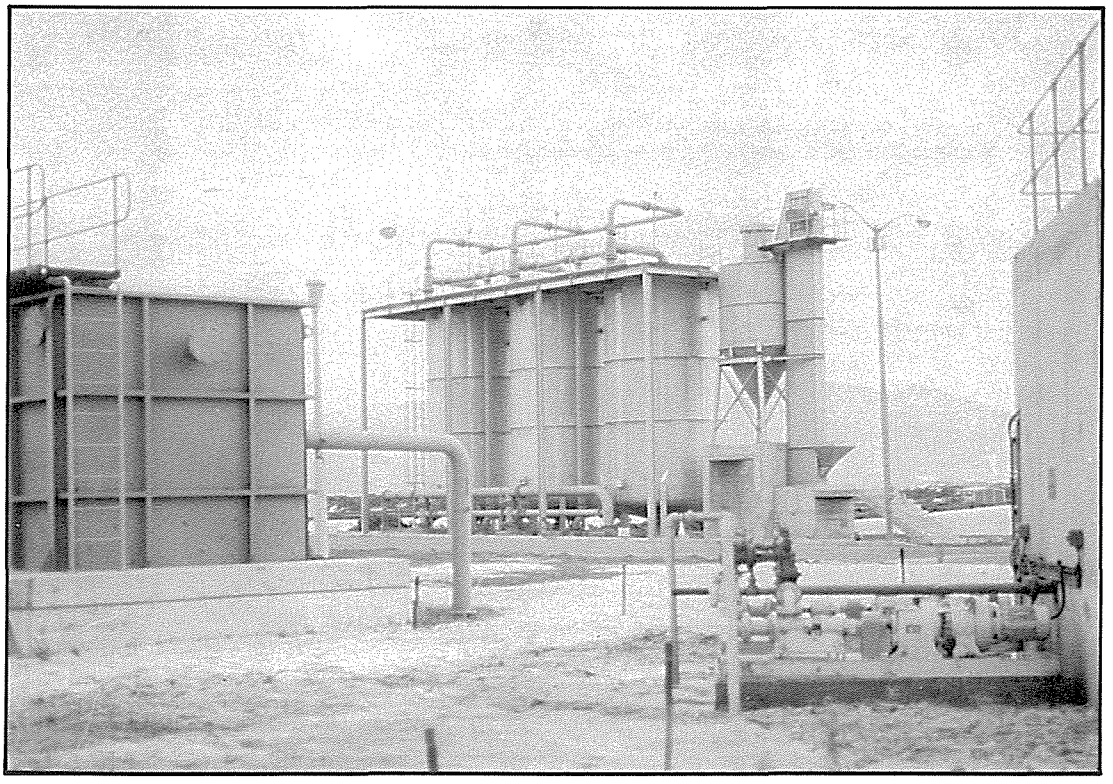
RESEARCH PROJECTS

Reclamation, storage and abstraction of purified sewage effluents in the Cape Flats

(Existing project: Contract with the Municipality of Cape Town)

The main objective of this project is the development of design and operational criteria for the full scale application of the reclamation of purified sewage of mainly domestic origin.

A part of the interim water reclamation plant which during 1979 was mainly operated to supply water of a suitable quality for infiltration studies



The original contract for this research allowed for the construction of a complete reclamation plant. The Municipality of Cape Town, however, decided to modernise its sewerage and sewage purification works and plans for the construction of the reclamation plant were held in abeyance. As a result a new contract was entered into with the Municipality for the construction of an interim reclamation plant which would form part of the final plant to be constructed at a later stage.

During 1979 the interim reclamation plant was operated mainly for the purpose of supplying water of a suitable quality for studies carried out in connection with the artificial infiltration and abstraction of purified sewage in sandbeds of the Cape Flats.

It is envisaged that a new agreement between the Commission and the Municipality will come into effect during 1980 to provide for the completion of the water reclamation plant, optimization of its performance and operation as a demonstration unit.

It is important to note that the interim reclamation plant used water from oxidation ponds on the Cape Flats, but that during 1979 the Municipality commissioned the first module of the activated sludge plant, the purified effluent from which will serve as feed water for the reclamation plant. It is envisaged that the improved quality of the purified effluent will result in very successful reclamation at lower unit cost.

The artificial recharge and abstraction of purified sewage effluent in the Cape Flats

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

An analysis of the position has indicated that the use of reclaimed water will play an important role in the future augmentation of the water supply in Cape Town and vicinity.

An infiltration pond in the sand deposits of the Cape Flats

In this connection, the sand deposits in the Cape Flats may be of great value since they contain a water storage capacity of approximately 25 per cent by volume which can be exploited for the storage and abstraction of artificially recharged reclaimed water and/or storm-water. In order to establish the recharge potential, it is essential that studies be carried out on the relevant hydraulic characteristics of the sandbeds.

During the year, various facets of infiltration by means of open ponds were examined. Divergent results were obtained for the infiltration rates of the various ponds even though all five ponds were located within 200 m of each other. Infiltration runs lasting from two to six weeks showed that the infiltration rates of the ponds varied from 2 to 15 m/d.

Factors such as uniformity and particle size of the sand, the degree of calcification and clay content of the deposits and the thickness of the unsaturated zone below the bottom of the pond, play an important role in the rate of infiltration. For full-scale application of the technique it is therefore essential to take the topography into consideration and to analize the geological material in the first few metres below the topographical surface in order to find the most suitable locations for this purpose. Maintenance of the infiltration surface is relatively easy.

On clogging, the infiltration rate can be almost completely restored simply by drying out 3 to 10 days. Alternatively the top layer (50 mm) of the infiltration surface can be removed to ensure complete restoration. Another important aspect is that no algal growth was observed in the ponds during infiltration runs with partially reclaimed water, not even during the period when no chlorine was administered. Algal growth did, however, occur during a lengthy run with groundwater but no adverse effect with respect to the speed of infiltration could be detected.

From experiments with partially reclaimed water it became clear that the presence of turbidity in the water was the single most important factor which could have a detrimental effect on infiltration.

Using the differences in chemical compositions of the natural groundwater and the infiltrated water as basis it was established that the subterranean retention time of the infiltrated water varies from 60 to 200 days. At the point of abstraction, which is located at a distance of 100 m from all the ponds, a mixture of groundwater and reclaimed water is abstracted.

It would appear that changes in the chemical composition of the water occur mainly in the unsaturated zone and basically consist of bacterial nitrification and a chemical reaction between the reclaimed water and the calciferous material present in the deposits. Microchemical analyses were performed on only a few samples since water of a considerably better chemical quality will be used in any full-scale application.

Reclamation of water at the Athlone Sewage Works, Cape Town

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

At the Athlone Sewage Works in Cape Town which treats industrial sewage containing a high salt content, research is being done on a pilot plant scale on the reclamation of water for industrial reuse.

The 300 m^3/d plant consists of a series of physico-chemical treatment processes for the removal of organic and nitrogenous contaminants and includes a biologically active aerated basin which performs an important role in the removal of organic matter, in the oxidation of ammonia and in the correction of the pH. The final process utilizes activated carbon to produce a good quality water for industrial reuse.

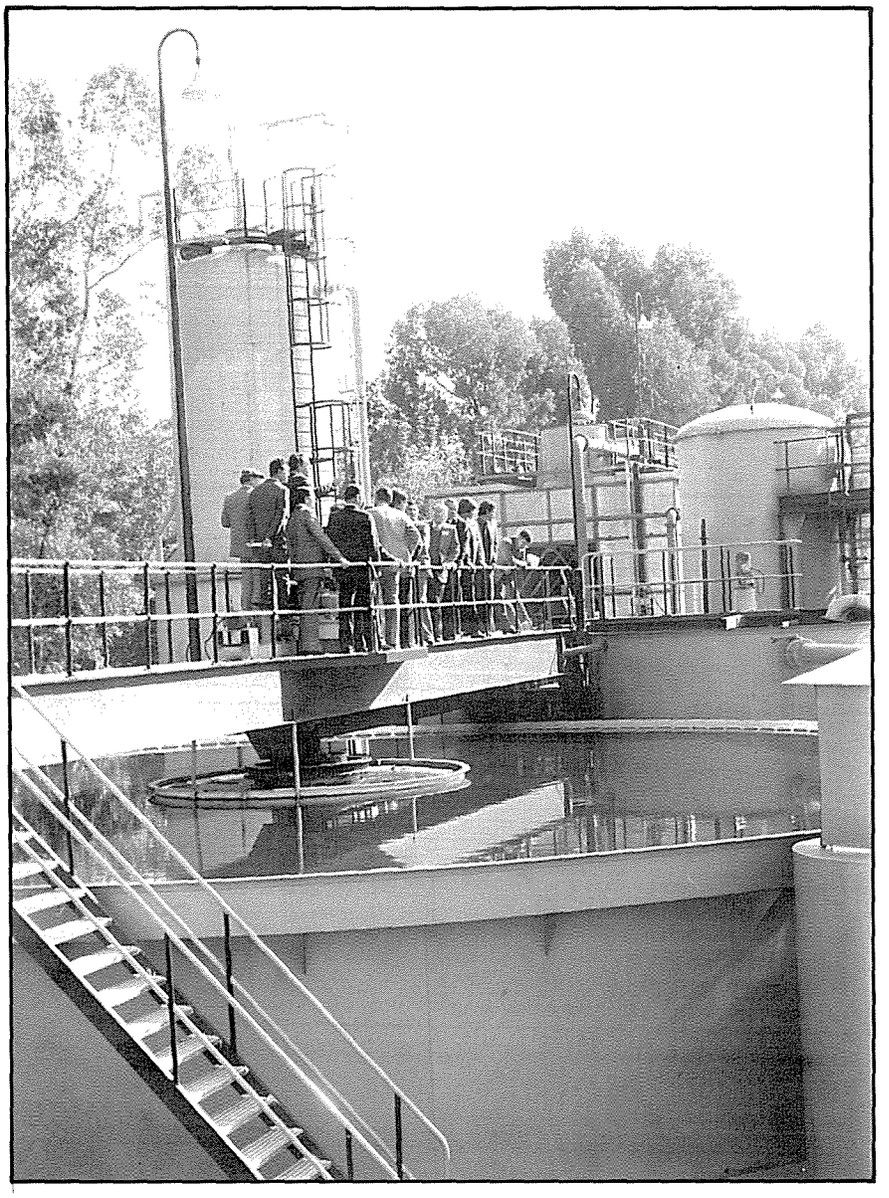
The plant was commissioned in September 1976 and steady progress was made with the optimization programme to the extent that a three month production run was undertaken using all the processes, from December 1977 to February 1978. From this exercise a great deal of useful information was acquired for assessing the costs of producing reclaimed water at Athlone.

At this stage the operation of the Athlone and Cape Flats Reclamation Plants (see report in this chapter regarding the project on reclamation, storage and abstraction of purified sewage effluents in the Cape Flats) was synchronised. The plants were operated in rotation, a few months each at a time, with significant savings in operating costs, yet still yielding the required research results.

Optimization of the unit processes at the Athlone plant continued. It was carried out by the Municipality of Cape Town under the technical guidance of the National Institute for Water Research. Particular emphasis was placed on disinfection, regeneration of activated carbon, stability of the water, control of the biologically active processes and removal of colour.

From June 1979 a second full-scale production run was made in order to gather data on operation and costs during a winter period. These figures will be used to assess the economic feasibility of large scale reclamation of the Athlone Sewage Works effluent.

Attention has also been given to assessing the industrial market for reclaimed water in Cape Town. In addition to making a survey of all industrial water users (completed in 1978), certain users in the textile industry were asked to use batches of reclaimed water during the year to test its effect on the dyeing of quantities of cloth.



The adjacent photograph shows a number of conference delegates on a visit to the Stander Water Reclamation Plant in Pretoria where research on water reclamation is being done

The reclamation project has progressed to such an extent that it has been shown that water of an acceptable quality for industrial reuse can be reclaimed from the Athlone Sewage Works effluent by applying existing technology.

Operation of the Stander Water Reclamation Plant and related investigations into certain health aspects

(New project: Contract with the CSIR — National Institute for Water Research)

The original contract between the Commission and the CSIR in connection with research on water reclamation and pollution control at Daspoort, Pretoria expired at the end of 1978 and it was envisaged that a new agreement in this connection, between the City Council of Pretoria and the Commission, would come into effect from the beginning of 1979. It was, however, not possible to finalise this agreement before 1 July 1979 and consequently an agreement was entered into between the Commission and the CSIR for the interim period of 6 months. The objectives of this agreement were to operate the plant for the production of reclaimed water which would satisfy quality requirements for direct reuse and also to continue investigations into health aspects.

The opportunity of operating the plant for six months was also exploited to evaluate the use of ferrichloride in stead of lime as primary coagulant. This was desirable as the lime process requires a great deal of maintenance, giving rise to interruptions in the operating process with related cost increases.

Results obtained confirmed the initial indications

that the clarifying action of the high-lime process can effectively be performed by ferrichloride and that the disinfection action at the high pH, by applying breakpoint chlorination immediately after primary clarification, yielded a more reliable water from a microbiological point of view.

Monitoring of the performance of ozonation, active carbon adsorption as well as the other unit processes was also continued during this period.

As a result of savings effected in operational and maintenance costs, the overall cost for reclaimed water could be reduced.

Research on water reclamation and pollution control: Operation of the Stander Water Reclamation Plant by the City Council of Pretoria, the implementation of surveillance programmes relevant to health aspects and the application of catchment quality control

(New project: Contract with the City Council of Pretoria and the CSIR — National Institute for Water Research)

In terms of this tripartite agreement entered into on 1 July 1979, the City Council of Pretoria assumes full responsibility for operating the Stander Water Reclamation Plant at Daspoort, Pretoria for the period ending 31 December 1981.

The project is being carried out in close cooperation with the Department of Health because the primary objective is to develop and maintain surveillance and control programmes for the plant aimed at formulating requirements should the reclaimed water be made available for human consumption. Furthermore, the purpose is to illustrate, by means of this project, that a local authority is capable of operating a water reclamation plant as part of its normal routine and operational procedure and on the strength of its experience to establish cost-advantage criteria for the production and possible reuse of reclaimed water.

Thirdly, a programme will be developed and implemented in order to identify and monitor the discharge of compounds, which may constitute a health hazard, into the sewerage system serving the Daspoort Sewage Works.

During the latter half of 1979 the plant was operated on a continuous basis for short periods to familiarize Council personnel with all aspects of operating the plant. The programme of catchment quality control has already been launched by provisional surveys and visits to industries in the area.

Technological development of water reclamation on the basis of the Windhoek plant

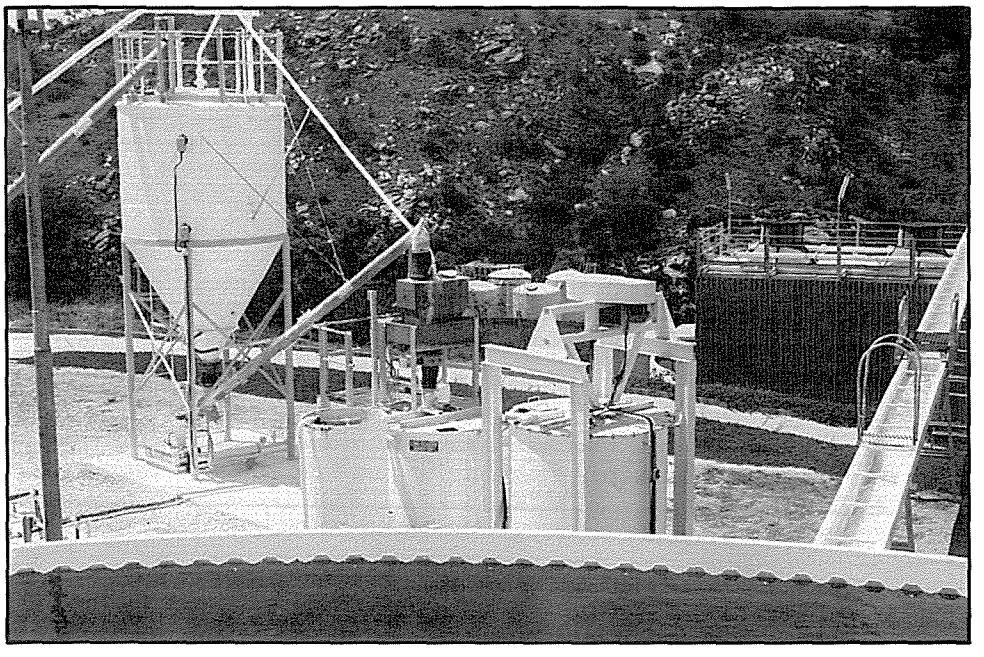
(Existing project: Contract with the Municipality of Windhoek and the CSIR — National Institute for Water Research)

The Windhoek Water Reclamation Plant has for different periods in the past played an important role in the water supply of the city since reclaimed water was integrated with the conventional supply in the distribution system.

During the year under review the Windhoek reclamation plant did not produce any water. This was due to the fact that the Municipality of Windhoek constructed a new activated sludge plant at the Gammams site and because of pipeline construction considerations, the water level of the Goreangab Dam had to be kept as low as possible. This resulted in sufficient water being available and reclaimed water was therefore unnecessary.

Because of the high quality effluent expected from the new activated sludge plant, it was decided during the year to adapt the reclamation process by replacing the high-lime process after primary clarification with alum clarification and breakpoint chlorination. This decision was made because of the high degree of maintenance required by the lime process and the concomitant production stoppages as well as the higher cost when compared to alum clarification. Furthermore, investigations at the Stander Water Reclamation Plant at Daspoort showed that lime clarification could effectively be replaced by ferrichloride and by alum clarification.

Further modifications were also made to the carbon columns by the replacement of the back-wash nozzles since the columns could no longer be efficiently back-washed.



A part of the Windhoek Water Reclamation Plant

Microbiological quality and health aspects of drinking water

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

The South African Institute for Medical Research (SAIMR), in terms of an agreement with the Commission, collaborated with the National Institute for Water Research (NIWR) of the CSIR, the Rand Water Board and the Pretoria Municipality in monitoring the microbiological quality of the water produced at the Stander Water Reclamation Plant at Daspoort, Pretoria. The water was again found to be of a high quality.

The water produced at the reclamation plant at Windhoek was monitored for its microbiological quality by the NIWR, the Department of Water Affairs, South West Africa branch (since May 1979 the Directorate of Water Affairs, South West Africa), the SAIMR and the Windhoek Municipality. Here too, the water was found to be of a consistently high standard. Although the water was not supplied to the Windhoek population during the past year (see also the report on the water reclamation project of Windhoek), epidemiological studies were nevertheless carried out as in previous years. The results showed that there is no change in the incidence of known intestinal waterborne infections when water from conventional resources was used together with reclaimed water when compared to the position when water from conventional resources only was used. So far there is no epidemiological evidence to suggest that the consumption of reclaimed water is associated with adverse effects on health.

A paper on this work was presented in London and met with great interest at the symposium sponsored by the Royal Society of Tropical Medicine and Hygiene, the International Association on Water Pollution Research and the Institution of Civil Engineers.

Research on the development and application of aspects of equilibrium chemistry and precipitation kinetics to water stability problems encountered in water reclamation

(New project: Contract with the University of Cape Town — Department of Civil Engineering)

Research projects on water reclamation at Windhoek (South West Africa), and also in South Africa at Das-

poort, Pretoria, and Athlone in Cape Town have indicated that problems with water stability, either scale formation or corrosion, may be experienced when sewage effluents are reclaimed for potable reuse. For this reason a new project has been initiated at the University of Cape Town to investigate this aspect of reclamation technology. The ultimate aim of the project is to develop a guide for the stabilization of reclaimed waters. This guide will be aimed primarily at plant operators, chemists and designers.

Prior to the commencement of the project, the University's Department of Civil Engineering had already made great strides towards the development of a suitable theory and graphical techniques for the aquatic systems involved in stability of low and high salinity waters. A major development in this regard is the development of a simple conditioning diagram which can be usefully applied for estimating chemical dosages for stabilizing waters of known composition, as well as predicting the composition of waters subsequent to chemical treatment by a variety of conditioning chemicals.

This work is being extended under the new project to include reclaimed water. Presently a single phase conditioning diagram for the carbonate-ammonia-chlorine system is being developed. Furthermore, the effects of residual organics and other foreign ions on solubility products of substances which may precipitate from reclaimed water are being investigated.

Chapter 3

Groundwater research

The Commission has supported research on groundwater for some time now and cooperates very closely with the Department of Water Affairs in this regard. The immediate objective of the research is to make the quantitative evaluation of the most important groundwater resources, with the required accuracy, a practical possibility.

The three projects in connection with groundwater research presently supported by the Commission and reported upon later, comprise the development and evaluation of techniques for determining the exploitation potential of groundwater resources in the Southern Free State and Northern Cape as well as along the Doornberg fault zone, and utilization of water from the Eerste River by means of storage in sand beds or other methods. In the meanwhile the specific research requirements of the Department of Water Affairs have been critically assessed and the stage has now been reached where decisions can be made on specific projects and adjustments so as to ensure that the programmes being pursued may be incorporated more directly into the operational programme of the Department of Water Affairs. It is envisaged that research and development programmes developed in this way will be aimed at the real problem areas in a more meaningful manner.

The Doornberg fault zone project has been completed. It has been found, inter alia, that the joints associated with the Doornberg fault zone in the Prieska area are silicified and not water-bearing. Groundwater in the Prieska and Kenhardt areas occur mainly in alluvium and weathered rock. No proof has been found that the steeply inclining joints from which large quantities of water flowed into the Orange-Fish River Tunnel during 1969 are linked to the Doornberg fault zone, or that the fault zone, at depth, is an important aquifer.

The project in respect of the Southern Free State and Northern Cape was revised and regional geohydrological and geological mapping has temporarily been shelved. Research is now being conducted on a large number of groundwater resources which are already being utilized and on which a substantial amount of work has already been done by the Geohydrological Division of the Department of Water Affairs.

During the year two special investigations into groundwater were performed with financial support of the Commission. The first assignment dealt with the groundwater supply in the Breede River Valley, in the Worcester district. In this connection the Geophysics Division of the National Physical Research Laboratory of the CSIR, with financial support from the Commission and in collaboration with the Geohydrological Division of the Department of Water Affairs, investigated the available groundwater supply of the Breede River Valley between the Brandvlei Dam in the South and Wit River Bridge in the north. The area under investigation covers approximately 300 km^2. The groundwater occurs mainly in alluvial material and a geophysical survey was conducted in order to establish the thickness distribution of the alluvium to investigate the depth and nature of the basement rock; and to deduce the hydrological properties of the alluvium from geophysical parameters and pumping tests in order to calculate the quantity of stored groundwater.

In the area under investigation five aquifers could be distinguished *viz.* those occuring in the Wolseley area of the Breede River Valley and in the valleys of the Holsloot, Molenaars, Jan du Toits and Wabooms Rivers. The thickness of the alluvium in these aquifers varies between 20 m and 50 m. A well-developed pebble layer overlies a sand layer in the Holsloot, Molenaars and Jan du Toits aquifers while the other two aquifers consist mainly of saturated sand layers.

According to a study of the quality of the groundwater in the Rawsonville Goudini area recharge occurs mainly in the upper regions of the aquifers and the

system being investigated entails linking a fish production system to an irrigation scheme by producing fish in the supply canal leading to the farmer's storage impoundment.

Further research on the water environment is indirectly sponsored by the Commission by way of an annual block grant to the Committee for Inland Water Ecosystems of the National Programme for Environmental Sciences of the CSIR. This Committee in accordance with a formal agreement with the CSIR, acts as a Co-ordinating Research and Development Committee for the Commission in the field of inland water ecosystems.

RESEARCH PROJECTS

Eutrophication of rivers and impoundments

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

Eutrophication of rivers and impoundments results in secondary pollution which detrimentally affects water utilization. The Department of Water Affairs and the South African Bureau of Standards therefore requested that research be undertaken on the causes, consequences and control of eutrophication in South Africa. This research which was initiated in 1973 by the National Institute for Water Research of the CSIR with the financial support of the Commission, was completed in 1979. The aim was to obtain information which could be used for the prevention of eutrophication in unenriched impoundments, as well as for the prevention of water systems where eutrophication problems are already experienced.

During the first two years of research the identification of the nutrient sources in the catchments of four Transvaal dams was afforded priority. It became clear that the inflow of purified sewage effluent was the greatest contributing factor causing eutrophication in these impoundments.

Most South African impoundments are turbid as a result of the presence of suspended clay material. The turbidity has an inhibiting effect on algal growth since it restricts light penetration. Full-scale experiments were conducted on a clear and a turbid impoundment in order to quantify this influence. Both were artificially enriched with fertilizer. It was established that turbid impoundments tolerate a higher nutrient loading than clear ones. On termination of the process of enrichment algal growth in both impoundments returned to original levels. The experiment also demonstrated that algal blooms can occur in turbid waters under optimum physical conditions.

The research programme also provided for an intensive investigation of 21 South African impoundments in order to establish possible relationships between nutrient loading and algal characteristics. A three year data collecting programme, which also involved research scientists from other organizations, was initiated. Analyses of the data showed that there is a statistically significant relationship between the phosphate loading of an impoundment and the quantity of chlorophyl-α in the water. From the phosphate loading it was also possible to make reliable predictions of the frequency and intensity of algal blooms in the impoundment. In addition, a new method based on the chlorophyl-α concentration, whereby South African impoundments could be classified according to their trophic status, was developed.

Details of various aspects of the research have already been published and guidelines for the control of eutrophication in South Africa, for use by planners and water management authorities, will shortly be published. The empirical relationships which appear in the guidelines have still to be thoroughly tested and improved. Further estimates are required to establish both the influence of clay material and of water retention time on nutrient uptake and primary production.

Research on intensive freshwater fish production using the raceway system

(Existing project: Contract with the Transvaal Provincial Administration — Department of Nature Conservation)

This project is being conducted at the Lowveld Fisheries Research Station, Marble Hall, in the Eastern Transvaal. The raceway system, being investigated for the production of freshwater fish species, utilizes running water forming part of an irrigation scheme and thereby eliminates water losses due to evaporation which would be the case in large impoundments. The water is used not only for the production of fish but also for the irrigation of crops.

During the year under review heavy mortalities occurred amongst the fish population in the raceway sys-

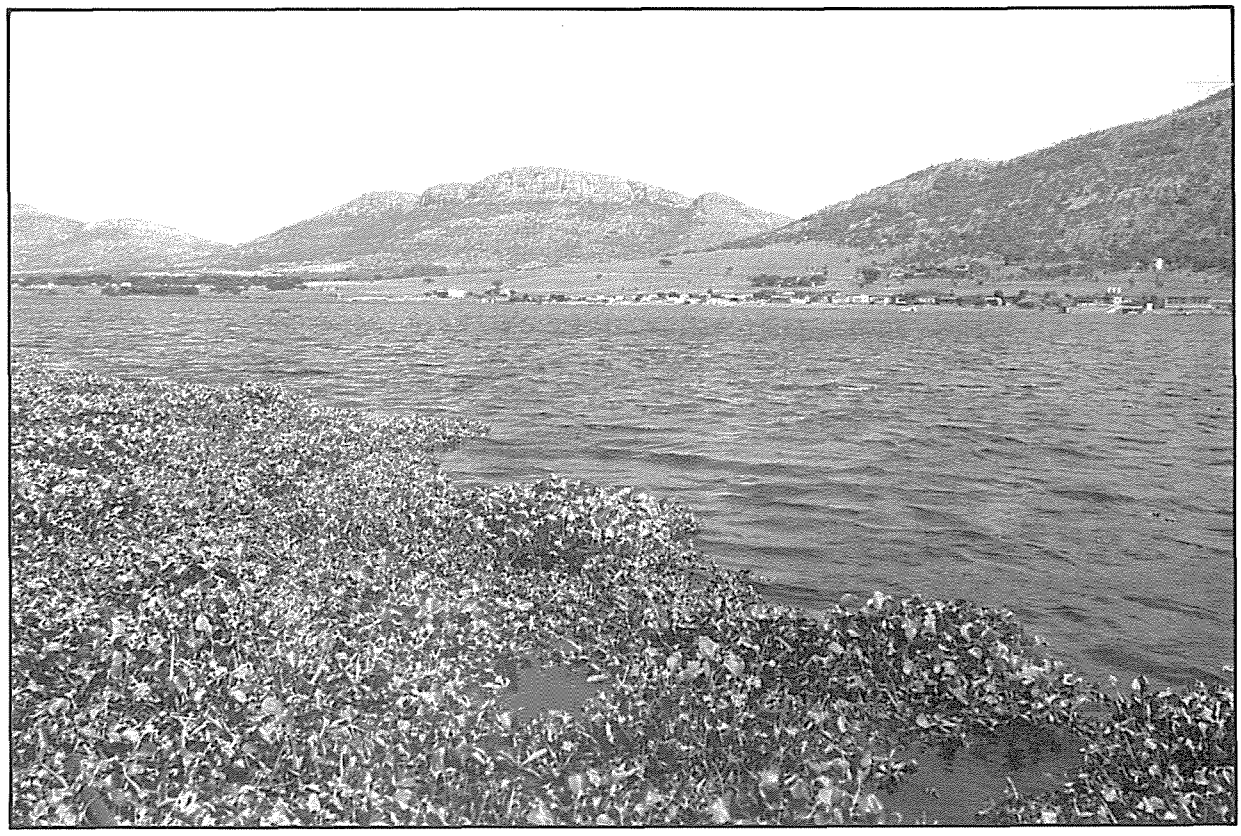
niques which have a bearing on nutrient cycles in impoundments and the development of an initial elementary model or models for nutrient cycles in the Hartbeespoort Dam. This short-term programme is regarded as a prerequisite for any further research aimed at the establishment of a scientific basis for the management strategy of eutrophic dams in South Africa.

In the 1978 Annual Report mention was made of the successful completion of a monitoring programme dealing with the effect of the large-scale application of herbicide on the water hyacinth *(Eichhornia crassipes)* in the Hartbeespoort Dam. Spraying of the hyacinths was performed by the Department of Water Affairs while monitoring was done jointly by the Department, the NIWR and several other authorities, with the financial support of the Commission. No detrimental effect was observed as a result of the spraying programme. A full description of the results of the monitoring programme was published in 1979 in the report *Chemical Control of the Water Hyacinth on the Hartbeespoort Dam* which was jointly issued by the Commission, the Department of Water Affairs, and the NIWR. The results of the programme were also used by the Department in the compilation of a guide for the use of herbicides on aquatic plants.

The final contract report by the Institute for Freshwater Studies of Rhodes University on the role of macrophytes in maintaining trophic conditions in Swartvlei was completed at the end of 1978. Guidelines for the management of the Swartvlei System are contained in the report and were accepted by the Lake Management Committee for the Knysna/Wilderness/ Plettenberg Bay area of the Department of Environmental Planning and Energy. A report, *"The Ecology of Swartvlei: Research for Planning and Future Management"*, containing the most important research findings will be released for general circulation early in 1980 as a joint publication by the Commission and Rhodes University.

The project by the Department of Nature Conservation of the Transvaal Provincial Administration, with partial financial support from the Commission, on the production of fish in a raceway system is aimed at multipurpose utilization of the water environment. The

One of the results of eutrophication is the excessive growth of algae and troublesome aquatic plants as may be seen in the picture below



Chapter 4

The water environment

The ecosystems of inland waters are particularly sensitive to changes in water quality and this can lead to symptoms which could have a detrimental effect on man's utilization of the water environment.

The dominating factor responsible for environmental water quality disturbances is human activity, e.g. the discharge of partially purified municipal and industrial effluents to streams, pollutants of human origin washed from the surface by storm water runoff, and the runoff from agricultural land which carries with it excess fertilizer from cultivated fields into the water environment.

In addition, pollutants which are discharged to the atmosphere through smoke stacks and gas exhaust systems, eventually reach the water environment through precipitation.

One of the best-known symptoms of pollution in the water environment is that of eutrophication i.e. the enrichment of water with plant nutrients (mainly nitrogen compounds and phosphates) to such an extent that the excessive growth of algae and nuisance aquatic plants occur in impoundments. This leads to restrictions in the utilization of water for recreational purposes; problems in water purification, such as accelerated clogging of filters and the generation of bad odours and tastes; the release of toxic compounds by certain types of algae; flow restriction in irrigation canals due to plant growths on canal walls; and the aesthetic disturbance of the environment generally.

In dealing with the eutrophication problem it is necessary to adopt two methods of approach. Firstly, an attempt must be made to eliminate plant nutrients at their point of origin as far as possible. As indicated in the next chapter, several projects supported by the Commission are aimed at developing and improving techniques for the removal of plant nutrients from effluents. The second approach is to develop methods for the management of the water environment in such a way as to soften the impact of eutrophication.

With regard to the latter approach, the Commission, in terms of an agreement with the CSIR, supported a long term project at the National Institute for Water Research (NIWR) which was aimed at investigating the occurrence of eutrophication in South Africa and in developing guidelines for its control. The project was concluded during 1979 and two publications will be issued jointly by the Commission and the Institute *viz. Guidelines for the Control of Eutrophication in South Africa* and *The Limnology of Selected Impoundments in South Africa.*

The former publication will be of special importance because of the fact that through the research, empirical relationships were developed which indicate the phosphate loads that can be tolerated in impoundments before eutrophication problems occur. Although these relationships must still be refined by further observations it is a valuable first approach because it applies specifically to South African impoundments.

Similar relationships which were developed abroad cannot be used locally because of factors such as the short retention time of South African impoundments and the frequently high turbidity of the water.

Although the completed project has yielded directives for the limitation of nutrient inflow to dams in order to avoid eutrophication problems, no directives exist for the management and utilization of eutrophic impoundments in South Africa. In order to give attention to this problem the Commission entered into an agreement with the CSIR whereby the NIWR will conduct a short-term investigation on eutrophication in the Hartbeespoort Dam. The programme entails a synthesis of existing information of the limnology of the Hartbeespoort Dam; a literature review of modelling tech-

permeability can only be estimated by approximation. It was also found that the permeability of the sand below the semi-permeable layer varies considerably across short distances in places. Despite these variations certain sections of the study area could be identified as being more suitable for abstraction as well as for groundwater recharge.

It will probably never be possible to determine the maximum yield from one single bore-hole with certainty and the development of production bore-holes for the long-term supply of water will always have to be preceded by at least one experimental bore-hole.

Because of the concentrations of total dissolved solids which occur in different places in the groundwater, the area can be divided into three zones where the following concentrations may be expected: 700, 1 000 and 3 800 mg/ℓ. Generally the best quality groundwater is to be found in the area having the greatest permeability in the sand deposit indicating that the speed with which the water moves through the sand mass towards the sea is a determining factor in this respect.

It is expected that the information collected from this project will be of great value in the design of a full-scale scheme for the exploitation of groundwater.

The geohydrology of the sand deposits in the Cape Flats

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

Earlier investigations into the potential of the Cape Flats aquifer as a water supply source for Cape Town indicated that the groundwater could play an important supplementary role as a local source of water. The projected safe yield from the aquifer is estimated at approximately 28 million m^3 per annum.

Exploitation of the groundwater in the Cape Flats can only be efficiently and economically carried out provided that the properties of the aquifer are fully taken into account when considering systems for abstraction. A further aspect which influences the planning of abstraction systems is the artificial recharging of groundwater (see project on "The artificial recharge and abstraction of purified sewage effluent"). It was decided, therefore, that a numerical simulation model of the aquifer had to be developed to consider all aspects regarding the abstraction and recharge of the water in order to design the most efficient systems for the utilization of the aquifer.

In an effort to refine the simulation model, monthly monitoring of water levels was continued at approximately one hundred points and in some cases increased to weekly monitoring. Furthermore, seventeen water level gauges out of a planned total of twenty have already been constructed for the purpose of obtaining continuous recordings of water level fluctuations that can be coupled to local and regional distribution of rainfall and evapotranspiration. One additional shallow borehole was drilled to ensure efficient monitoring of the groundwater level. On the strength of results obtained from this borehole it will be decided whether further shallow boreholes should be drilled.

In addition to the regular water level measurements, rainfall is recorded continuously at eight stations and evapotranspiration weekly at three stations. This information will enable the correlation of natural groundwater recharge with rainfall which is required for setting up the simulation model. The climatological data are also required for calculations of groundwater losses by evapotranspiration.

Supplementary aquifer tests, performed at two of the three sites which were previously prepared, supplied essential additional information for the simulation model. In broad outline the transmissivities of 450 and 100 m^2/d calculated for the sites at Strandfontein and Philippi respectively, agree with assumptions previously made. At Philippi the yield was less than 400 m^3/d and the aquifer can be described as semi-confined.

Large scale abstraction of groundwater incurs the potential risk of sea water intrusion. It is therefore imperative to obtain the necessary boundary conditions for the model in order to evaluate this possibility and an aquifer test is therefore being conducted at the coast to establish the position of the sea water/freshwater interface. Indications of the diffuse zone have already been found so that it is now possible to do an appraisal of the position of the interface. The aquifer test, however, is being continued in an attempt to locate the actual interface. Runs with test data have already shown that the model is functioning correctly and at present calibration of the model is being carried out with actual data.

The advantages and disadvantages of the two types of models namely the finite element and the finite difference models will be weighed up against each other in due course in an attempt to obtain the best results.

The present contract expired at the end of 1979 but for verification of the model it is essential that water level and rainfall recordings be continued for at least 5 years. The Department of Water Affairs will, however, continue the work to the extent of taking over servicing of the water level gauges. Where necessary arrangements will be made with other authorities to continue the monitoring of rainfall at 2 or 3 stations.

The Department of Water Affairs is making an important contribution to the project by supplying drilling services and equipment for the recording of water levels.

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

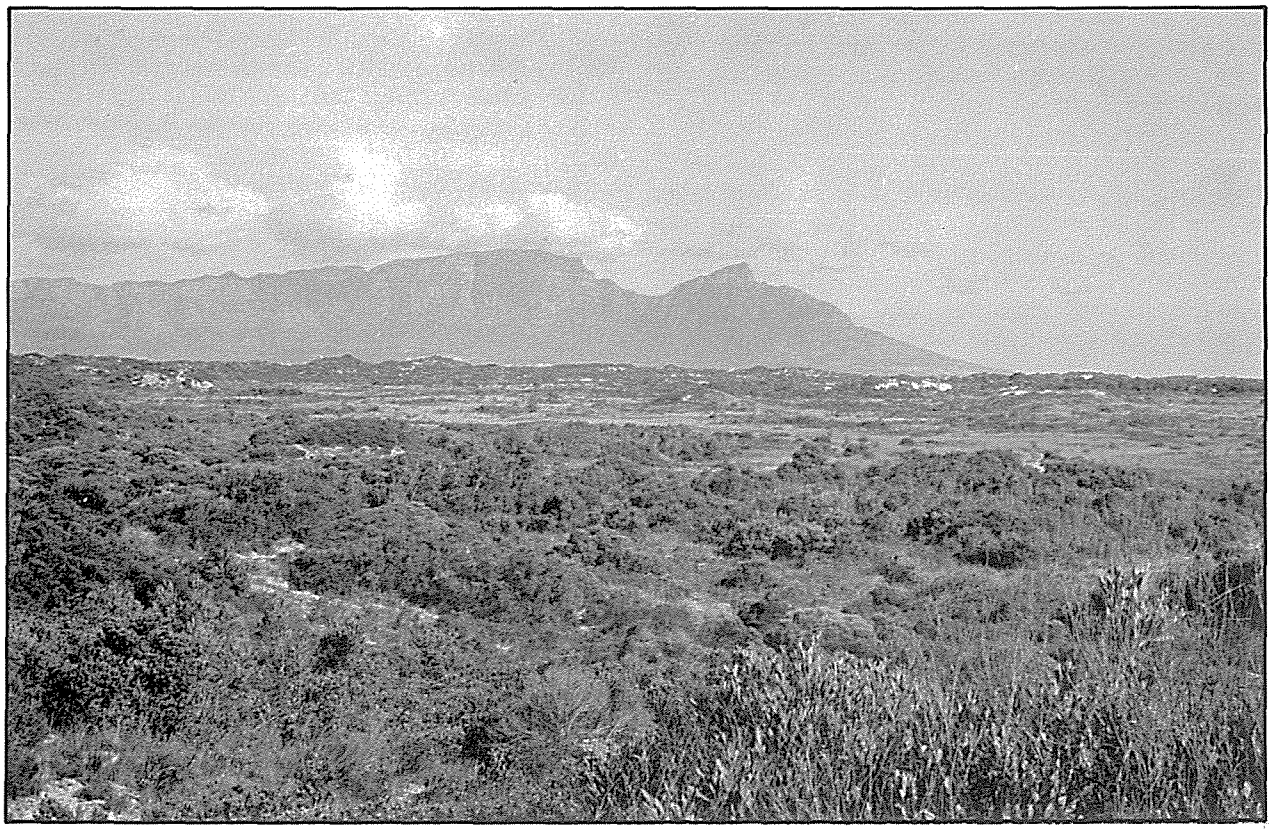
(Existing project: Contract with the University of Stellenbosch — Department of Civil Engineering)

This project entails an investigation into the feasibility of storing water from the Eerste River and its most important tributary, the Kuils River, in the sand deposits which border on the False Bay coast. The storage capacity of the section of this geological formation which occurs to the east of Swartklip Road and DF Malan Airport and to the South of the town of Kuils River is being estimated on the basis of a study of its geohydrological properties. The storage capacity of the sand deposits for water from the two rivers was studied, *inter alia,* by means of experimental dewatering, on a small scale, one bore-hole at a time. The availability of river runoff for infiltration purposes is being investigated on a daily basis taking into account current plans for diverting the water for other purposes.

A determination of the annual yield of possible water supply systems (taking the creation of storage space and recharge with surplus water from the rivers into account) may be considered the most important result of the investigation. On these grounds, decisions may be taken by water supply authorities on the possible implementation of such a system. The nature and concentration of dissolved salts which occur in the groundwater as well as in the river water are also being investigated in order to estimate the quality of the water which may be expected from such a scheme.

Information obtained during the year on the geohydrological properties of the sand deposits is in agreement with previous findings, namely that a semi-permeable layer occurs throughout the sand mass which is otherwise reasonably permeable. The permeability of this layer varies a great deal, even across distances of 30 m or less, with the result that its overall

A general view of the sand deposits of the Cape Flats where research is being conducted on the possible extraction of groundwater



the temporary postponement of the regional geohydrological surveys. More specialised research will be conducted at localities such as municipalities, where a substantial amount of work has already been done by the Department of Water Affairs. This will bring about considerable reduction in costs because a large number of calibration bore-holes are already available in this area. It is anticipated that there will be close cooperation between personnel working on this contract and the Department of Water Affairs.

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 — Institute for Groundwater Studies)

This project commenced in 1975 as a result of large quantities of groundwater found in the Orange-Fish Tunnel during excavations in 1969. The original inflow of water into the tunnel was approximately 100 ℓ/s and pumping tests indicated that the aquifer, in which steeply inclined open joints occur, has a tremendous storage capacity. The fact that the groundwater discovery is associated with a zone of positive gravitation anomalies which can be traced in a westerly direction to the so-called Doornberg fault zone near Prieska, leads to the possibility that the formation of the joints could be linked to this fault zone.

An extensive electrical sounding programme and intensive geological mapping indicated that the sudden steepening in the slope of the deep-seated dolerite sill could possibly be responsible for the formation of open joints in the tunnel area, and that the joints are therefore not necessarily associated with the supposed Doornberg fault zone.

In the vicinity of Venterstad the survey of chemical constituents of various bore-holes and fountains by the Institute for Groundwater Studies, indicated the existence of different types of water. This survey was extended by the Natural Isotopes Division of the National Physical Research Laboratory which also measured the dissolved gases and different isotopes in their natural concentrations in selected bore-holes. This indicated that recent water as well as water a few thousand years old occurred in this area. This older water was also found in the Orange-Fish Tunnel during its construction. Indications were also found that the different types of water developed relatively independently of one another and are therefore of different origins.

Subsequently the survey was extended to follow the course of the Doornberg fault zone from Prieska, where the zone is visible on the surface, eastwards beneat a cover of younger Karoo formations beyond Britstown, De Aar, Hanover and Venterstad up to the Lesotho border. A comprehensive programme of magnetic and gravitational observations and electrical sounding was also initiated. In total an area of 100 000 km^2 was covered with 8 000 magnetic and 1 500 gravitational observations and several hundred electrical soundings. The course of the Doornberg fault zone and related structures was successfully determined, especially by means of the magnetic and gravitational surveys. From this information it would appear that the fault zone is situated several kilometres to the south of the groundwater discovery in the Orange-Fish Tunnel. Although the structure of the basement rocks in which the supposed fault zone occurs could not be followed by electrical sounding because of the screening effect of the dolerite intrusions into the sediments of the Karoo cover, information was obtained on the distribution of the dolerites.

The next step was to establish whether the Doornberg fault zone, where it was exposed near Prieska, was in fact water-bearing. Geological mapping by the Institute of Groundwater Studies showed that the joints associated with the fault zone are silicified and, therefore, contain little water. Geophysical work also indicated that conditions are unfavourable for large groundwater reserves. The limited quantities of groundwater which do occur in this area are found in alluvium and weathered rock which have no direct connection with the Doornberg fault-forming episode.

It was subsequently decided to undertake a groundwater investigation near Kenhardt — firstly to determine the groundwater supply of the area and secondly to establish whether the linear structures which developed during the formation of the Doornberg fault zone are waterbearing. This phase of the project was executed in collaboration with the Geohydrological Division of the Department of Water Affairs. Once again it was found that the groundwater only occurs in alluvium and weathered rock which are not necessarily associated with the Doornberg tectonic episode. The geophysical work, drilling results and pumping tests showed that groundwater of a suitable quality occurs in sufficient quantities to provide in the needs of this area in the immediate future.

to a meaningful integration of the Commission's groundwater projects with the needs of the Department of Water Affairs so as to enable the development of a purposeful long term research and development programme. Recommendations in this regard were made and are now being considered by the Commission.

This chapter also contains a report on the research in connection with the geohydrology of the sand deposits in the Cape flats, being conducted in terms of an agreement with the CSIR. (This project stems from the research on the reclamation, storage and abstraction of purified sewage effluent in the Cape Flats). The research has as its aim the determination of the potential storage capabilities of the sand deposits and will give an indication of the quantity of natural groundwater which may be abstracted and utilized on a continuous basis from the sand beds.

RESEARCH PROJECTS

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

(Existing project: Contract with the University of the Orange Free State — Institute for Ground-Water Studies)

The existing research contract between the Water Research Commission and the University of the Orange Free State was reassessed during the year in order to establish a more purposeful research programme.

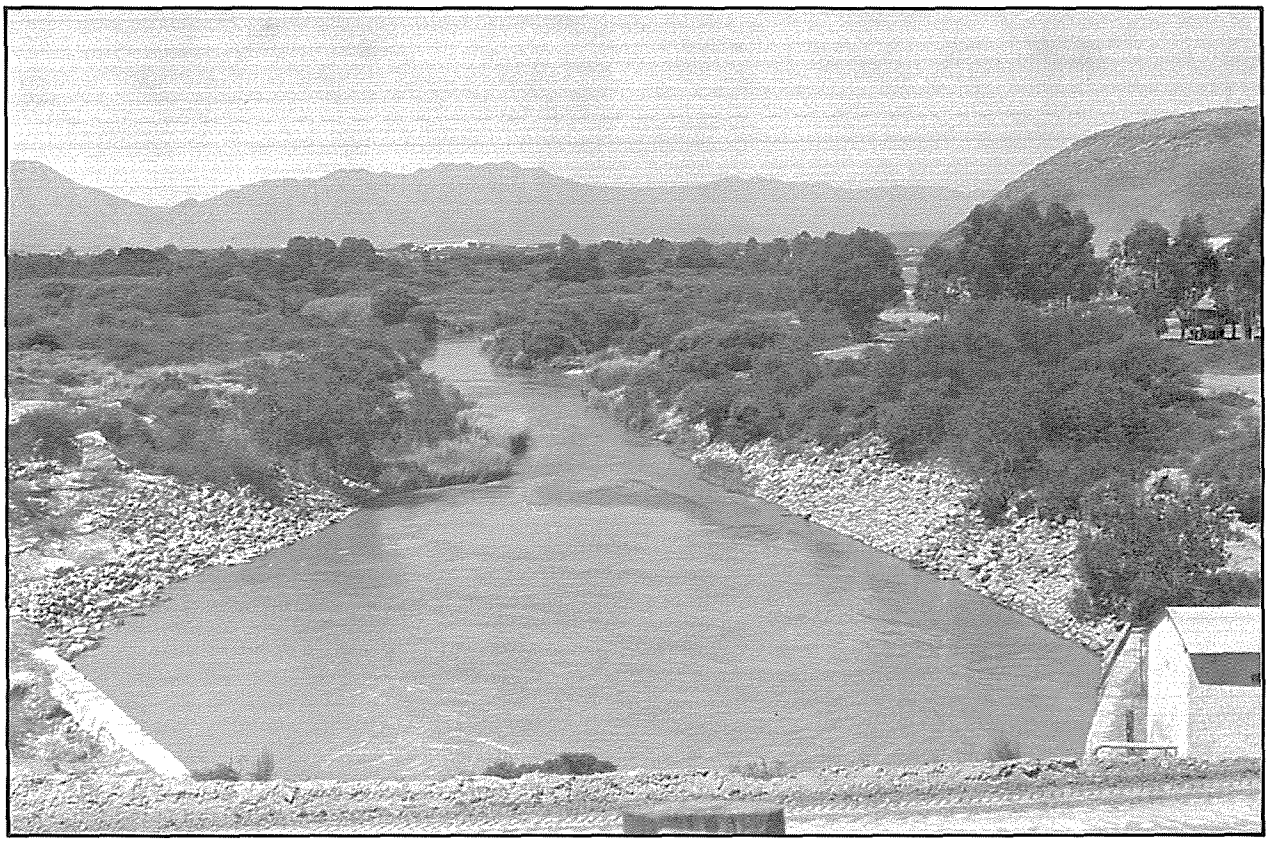
In retrospect it appears that a large body of information was collected during the first five years of this research project both in the Southern Free State and in the Northern Cape. Extensive areas were investigated and four full-colour geohydrological maps of extensive areas both in the Southern Free State and Northern Cape were published. A further map of the Vryburg aquifer and two maps of the dolomitic rock formations in the Northern Cape are currently in production and will shortly be available as full-colour publications. Several reports in the form of bulletins were published by the Institute for Groundwater Studies in connection with these maps.

Computerized data systems were designed during this period and all the information collected to date has been incorporated into and processed in the computer data bank of the University of the Orange Free State. These programs can be divided into three main units. Firstly, the Institute has at its disposal an extensive hydrochemical data bank and processing system. Any applicable diagrammatic statistical or tabular projection of chemical information so far collected, can be obtained from this within seconds. Secondly, all geophysical information generated by the Institute for Groundwater Studies is also processed and interpreted by the computer. The third category of computer programs in which the Institute is currently specialising as a continuation of this contract, involves programs which can be used to calculate the flow of groundwater and its utilization potential. Any such model, which links the reaction of the water level in the Vryburg aquifer to external influences such as rainfall and the pumping of water from boreholes, has already been published. A further model, based on advanced mathematical principles and which utilizes a finite element simulation technique was set up in order to calculate the flow of groundwater along dolerite structures in the Southern Free State. Apart from these simulation programs, the Institute also has at its disposal a large variety of other simulation programs which can, for example, be used to simulate the flow of groundwater in a coastal aquifer.

A large number of dolerite basin structures in the Southern Free State were examined and in most cases the groundwater potential of these structures is not fully utilized. A further observation is that the permeable zone along the dolerite basin structures is usually present only to a depth of approximately 60 m. Because the slope of the dolerite basin structures can readily be determined, favourable bore-hole positions can be indicated using the minimum of labour. With the aid of electrical resistance methods the depths of the basin structures can also be determined. Another important aspect of the groundwater research in the Southern Free State is the occurrence of two groundwater populations. Of special interest are the deep-seated aquifers which normally have high yield potentials and also appear to be perennial during periods of drought.

In view of the planned research activities in the Northern Free State during the next three years the research activities in the Southern Free State will be temporarily postponed. Research which is planned for the Northern Free State will be done on structures similar to the dolerite basin structures in the Southern Free State. Information generated there will aid in the interpretation of geohydrological conditions in the Southern Free State.

Revision of the existing contract contributed to



A part of the Breede River valley in the Western Cape where available groundwater resources have been investigated

valleys in which they are situated. In those regions the aquifers contain very little clayey material, permeability is best and the storage coefficient, as deduced from geophysical results is approximately 7 per cent. Lower down the aquifers become more clayey and less permeable. The quality of the groundwater in the aquifers is very good. It is, however, brackish in areas underlain by cretaceous rocks.

Weathered basement rocks are potential aquifers in regions where the Malmesbury-Klipheuwel formations occur but is probably of little value in other parts of the area under investigation.

The geophysical results and other information was utilized to map the basement rocks underlying the alluvium.

At this stage the pumping tests required to establish the hydrological parameters of the aquifers have not yet been done and neither the available water supply nor the abstraction rates can therefore, be estimated quantitatively.

The second special assignment was performed by the Division of Natural Isotopes of the National Physical Research Laboratory of the CSIR with the financial support of the Commission and is associated with an intensive study of the groundwater resources by the Department of Water Affairs in the vicinity of Beaufort West. A special bore-hole probe enabling water to be sampled from a single horizon in a bore-hole was used here for the first time. By means of this probe it was possible to establish the existence of water of recent origin on top of deeper, older water in individual bore-holes.

It was found that in addition to infiltration of rainwater along the escarpment of the Nuweveld Mountains considerable groundwater recharge occurred in the runoff area of the Plaatdoorn River. The differing isotope ratios together with other parameters gave indications of the existence of different types of groundwater in this area as well as their probable distribution.

This information is now being correlated with other results which were obtained by the Geohydrological Division and may lead to a more intensive investigation at a later stage in order to elucidate different aspects in more detail.

In the previous annual report mention was made of an investigation by a specialist consultant with a view

tem as a result of a breakdown in the water supply and the experiment had to be terminated after a mere 103 days. A second trial was attempted after restocking with fish but a satisfactory growth rate could not be established before the onset of winter.

In the light of these problems, the results which were obtained for fish production, were not mutually comparable nor could they be compared with results from the previous season. Nevertheless, certain significant observations were made; e.g. the silver carp, *H. molitrix* which were placed in some of the raceway segments together with the Aischgrund carp, performed very well by living from organic waste products in the canal. At a nominal occupation of 3,5 per cent of the total number of fish in the canal, the silver carp contributed 7 per cent towards the total fish production, amounting to an 8 per cent saving on the cost of feed. In contrast, the blue kurper, *S. Mossambicus,* contributed very little to the total production of fish and according to these tests, is therefore unsuitable for polyculture in a raceway system.

The use of demand feeders, as opposed to feeding by hand, had a remarkably stimulating effect on fish growth as well as food conversion efficiency.

From the tests it would also appear to be more advantageous to initiate fish production in the raceway system using fish larger than fingerlings.

A limited but valuable haematological investigation of the Aischgrund carp in the canal was done and it has been found that, in addition to stress from low dissolved oxygen concentrations, a build-up of carbon dioxide, ammonia and total dissolved solids in the water could act as secondary limiting factors in respect of fish production in the canal.

Chapter 5

Treatment of municipal and industrial effluents

Local authorities and industry play an important role in the optimisation of water utilization in the Republic and in this regard many of the activities of the Commission are of direct importance to these sectors. The need for extensive investigations and research to ensure adequate water supplies for the future and to protect the quality of our water resources cannot be overemphasized and, to this end, the Commission closely collaborates with local authorities and industry.

The Commission is financing essential research in specific problem areas of local authorities while at the same time utilising the expertise and facilities available at the larger cities. Recommendations for research to be undertaken in these problem areas emanate from a Research Review Committee with representation from local authorities. This Committee was established by the Commission in 1977 to consider problems concerning water supply and economy, water reuse, pollution control, the treatment of effluents and the treatment and disposal of wastes which have a pollution connotation.

As in the case of local authorities, research in the field of water management and effluent treatment sponsored by the Commission on behalf of industry, must be for the benefit of the industry as a whole. Liaison with industry, therefore, is done through its various National Associations. Several Coordinating Research and Development (CR & D) Committees have been established for the guidance of research to be done in sectors of industry. Various bodies including National Associations are represented in these Committees.

The Commission is currently supporting 11 research projects in the field of municipal and industrial effluents treatment and during the year under review significant progress has been made with several of these projects. Some of the highlights have been described in Chapter 1. Reports on these projects appear later in this chapter.

With regard to the removal of plant nutrients from effluents, two five-year projects terminated in 1979, i.e. both the agreement with the CSIR and that with the University of Cape Town on biological nutrient removal by means of the modified activated sludge process. The research results will become generally available in 1980 in the form of a technical guide and design manual respectively.

Since phosphate removal from effluents generated in critical river catchment areas will in all probability be compulsory in the Republic within the near future, an urgent need exists for the development of tried and tested economical techniques for nutrient removal. To ensure that such techniques are developed, the Commission has entered into two new agreements on nutrient removal from effluents at two different full scale plants. The first project concerns the optimization of a modification of an activated sludge process for nutrient removal and is being jointly carried out by the City Council of Johannesburg, the CSIR and the University of Cape Town. The second project concerns nutrient removal from the effluent from biological filters and is being carried out jointly by the City Council of Pretoria and the CSIR.

The Commission also supports research on pollution control and water reuse in the Pretoria-Witwatersrand-Vereeniging-Sasolburg (PWVS) complex. This area is characterized by a high demand for water and by

the fact that treated sewage and industrial effluents as well as stormwater runoff are to an increasing extent finding their way to the Barrage, which is an important source of water supply. The research has led, inter alia, to the development and testing of an extensive mathematical model for the daily variation of mineral salts in the area. The Commission has also initiated an additional investigation into the cost to the water consumer and industrialist due to the increased mineralization.

Another field in which the Commission has agreed to sponsor research is the treatment and disposal of sludges and solid and toxic wastes in view of the potential pollution hazard that these wastes pose to surface and underground waters. During the year under review a report was compiled on behalf of the Commission by a fact-finding mission that was sent overseas to investigate the possible application in South Africa of techniques used overseas. This report, together with a previous report by an overseas consultant on the current state of technology of treatment and disposal of municipal sludges and a report compiled by the Commission dealing with current sludge treatment and disposal practices in South Africa, have been studied by the Research Review Committee for Local Authorities and by the Co-ordinating Research and Development Committee for Solid and Toxic Wastes. Priority areas requiring immediate attention have been identified and a Master Plan for research in this field has been formulated.

For several years the Commission has been supporting research in connection with water management and effluent problems in the hides and skins, curing, fellmongering and tanning industries. As part of its involvement in this field, the Commission is supporting a research project undertaken by the Leather Industries Research Institute (LIRI) of the CSIR. During the year under review a second agreement was entered into with the CSIR, in terms of which LIRI has commenced investigations into the treatment of wastewater from a tannery near Pretoria. Considerable progress has been made with the research, particularly with regard to the development of a suitable technique for the clarification of the relevant tannery effluent.

A typical example of the Commission's liaison with industry through its various National Associations is to be found in the case of the textile industry. Six different National Associations are represented on the CR & D Committee for this important industry.

The textile industry with an annual gross production of more than R600 million, is a major user of water and the total consumption has been estimated to be of the order of 30 million m^3/a. The industry encounters a great deal of difficulty with water management and effluent treatment due largely to the fact that the keynote of the textile industry is variety, in terms of both the raw materials and the processing techniques used. The raw materials consist of wool, cotton and synthetic fibres which are processed into finished goods either singly or in various combinations. Each process step and each blend of raw materials generates a particular kind of wastewater treatment problem. The various effluents are to some degree biodegradable, but the conventional biological treatment systems experience many problems when dealing with these effluents. Of the 32 major textile mills in the country, only 19 discharge directly to municipal sewerage systems and several of these find it difficult to comply with the by-laws pertaining to trade and industrial effluent discharges of the relevant local authority.

In view of these problems the Commission, following requests, initiated various research projects into the effluent problems of the industry several years ago. The objective of the research is not only to reduce the pollution load from factories but also to isolate particular effluent streams within the factory, and to apply, where possible, closed loop recycle systems thereby achieving considerable savings in water consumption and recovery of chemicals. The good progress made during the year under review is reported later in this chapter.

The fruit and vegetable processing industries and the fishing industry are also fields in which the Commission is initiating investigations in order to find effective techniques for the management of water use and the disposal of effluents and solid wastes. In this respect a firm of consulting engineers has been appointed to study problems confronting these industries.

Special emphasis is being placed on the development of methods which could be of economic benefit to the industries concerned, enabling them to meet the prescribed standards for waste disposal while at the same time reducing water consumption to a minimum; many of the methods being investigated have the potential for the recovery of useful materials from the wastes making pretreatment a viable proposition.

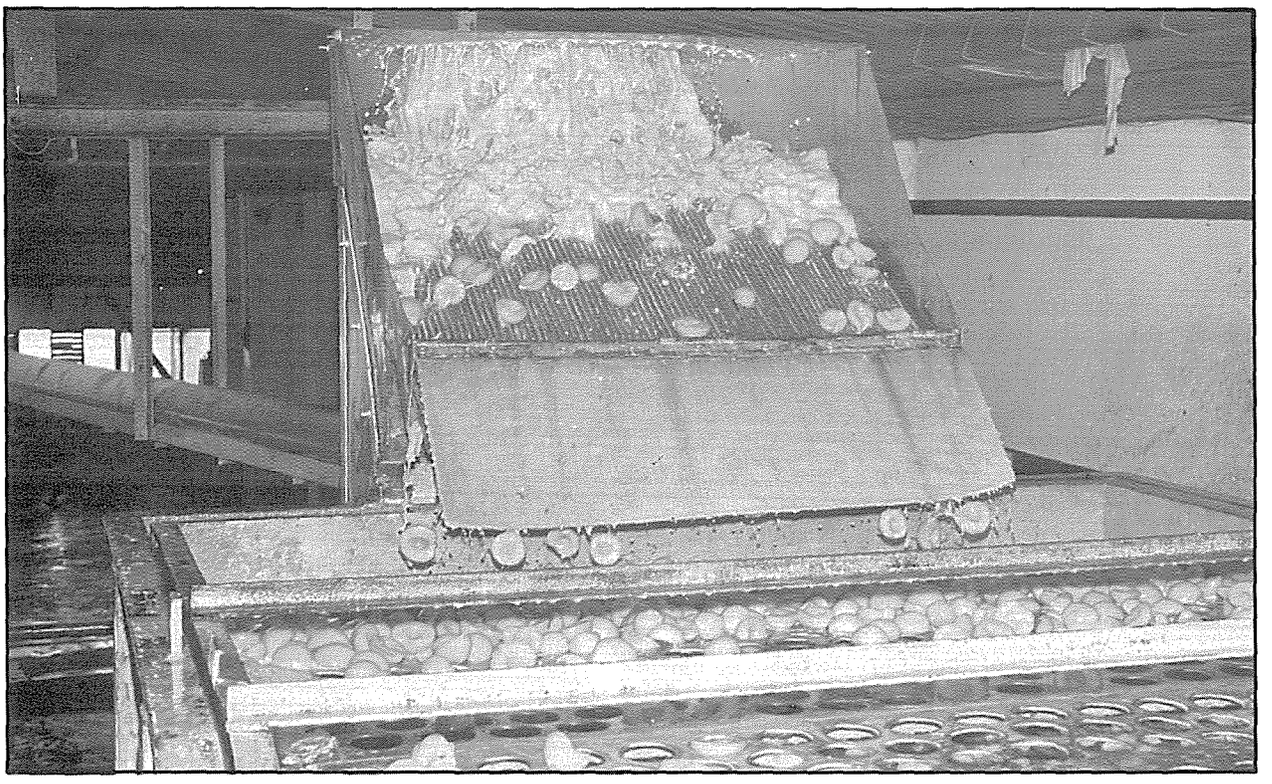
In the case of the fruit and vegetable processing industries, over 50 major fruit and vegetable processing factories are in existence in the Republic of South Africa, and which process about 830 000 t of fruit and 135 000 t of vegetables per annum, consume over 7,5 million m^3 of water and produce about 300 000 t of solid wastes per annum.

The processing techniques used for each type of fruit and vegetable are being studied and the quantity and quality of liquid and solid wastes from each commodity are being established in order to determine the scope for recovery of water and by-products from the wastes.

The investigation is being conducted in close cooperation with industry, the Department of Water Affairs and local authorities and includes an appraisal of the Codes of Practice developed in other countries.

The fish meal, oil and canning industry comprises 17 factories which process a total of approximately 315 000 t of fish meal, 30 800 t of canned fish and approximately 16 000 t of fish oil per annum.

The factories are located at the coast, from Walvis



A scene in a fruit processing factory. The Commission currently supports research on the management of water consumption and the disposal of effluents and solid wastes in the fruit and vegetable processing industry

A discharge pipe which transports effluent from a fruit processing factory to the sea

Bay to Gansbaai, and their proximity to the ocean results in the discharge of pollutants into the marine environment.

The investigations being conducted will establish the quantity and quality of all wastes generated at each of the manufacturing processes and the potential of the recovery of by-products from these wastes in order to reduce their organic strength, will be examined.

Methods for the reduction of fresh water consumption will be studied and the management of the industry in the Republic will be compared with similar industries in other countries.

RESEARCH PROJECTS

Research on the activated sludge process

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

Since the initiation of this project in 1973, the research work has been principally aimed at three aspects, i.e. investigations into the kinetics of the purely aerobic activated sludge process including nitrification under dynamic loading conditions and various process configurations; into the kinetics of biological denitrification in anoxic-aerobic activated sludge processes; and into biological and chemical phosphorus removal in the activated sludge process.

By 1978 a considerable degree of progress was made on the research into the kinetics of the aerobic activated sludge process, culminating in the development of a model capable of describing the aerobic activated sludge process under dynamic loading conditions over the range of process configurations. By that time much data on the denitrification kinetics had been collected. Although these two aspects had operated interactively on each other to a considerable degree, the interpretation of the denitrification data tended to be on an *ad hoc* basis. During the year under review, a considerable degree of success was achieved in combining these two aspects. With some minor modifications to the dynamic model describing the aerobic activated sludge process, it was found possible to integrate fully the kinetics of denitrification and to develop a general dynamic model for the anoxic-aerobic activated sludge process. This research now forms part of a cooperative research project being undertaken in collaboration with the City Council of Johannesburg and the CSIR on the optimization of the modified activated sludge process for nutrient removal (see report on project in this regard). Good correlation was found between the theoretical predictions of this generalized mathematical model compared with experimental observations on both laboratory- and pilot-scale denitrification processes.

The model now provides for the description of a range of activated sludge process configurations consisting of aerobic reactors and primary and/or secondary anoxic reactors inter-connected with the aerobic reactors and a settling tank by mixed liquor and sludge underflow recycles respectively. Once a choice is made of anoxic and aerobic reactor vessel volumes and mixed liquor and sludge underflow recycle ratios, any of the well-known nitrogen removal processes, e.g. Wuhrmann, Modified Ludzack-Ettinger, Bardenpho and Modified Activated Sludge processes, may be completely analysed. Having a general method of analysis, it was possible to derive procedures by means of which the best process and its optimal configuration can be selected for a particular effluent at a specified temperature.

Research into the third aspect, i.e. phosphate removal in the activated sludge process, was in the past principally directed towards investigating the mechanisms of enhanced biological phosphate removal. During the year research into additional phosphorus removal by in-plant addition of iron and aluminium salts was commenced. The results indicate that phosphate removal by chemical addition consists of two reactions — a fast reaction in which the phosphate is precipitated and a slow adsorption or ion-exchange reaction which is dependent on the total mass of phosphate sludge in the process. An observation of importance is that the metal salt can be added at a constant rate even under cyclic influent flow and load conditions and a near constant effluent phosphate quality can still be produced.

Biological denitrification and phosphate removal

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

The primary aim of this project, which was launched in 1974, was to develop process criteria for the biological removal of nutrients from sewage effluents, with special reference to nitrogen, phosphorus and carbon compounds. The research was initially done on laboratory scale after which the most promising findings were further evaluated and developed by means of a 100 m^3/d pilot plant at Daspoort, Pretoria.

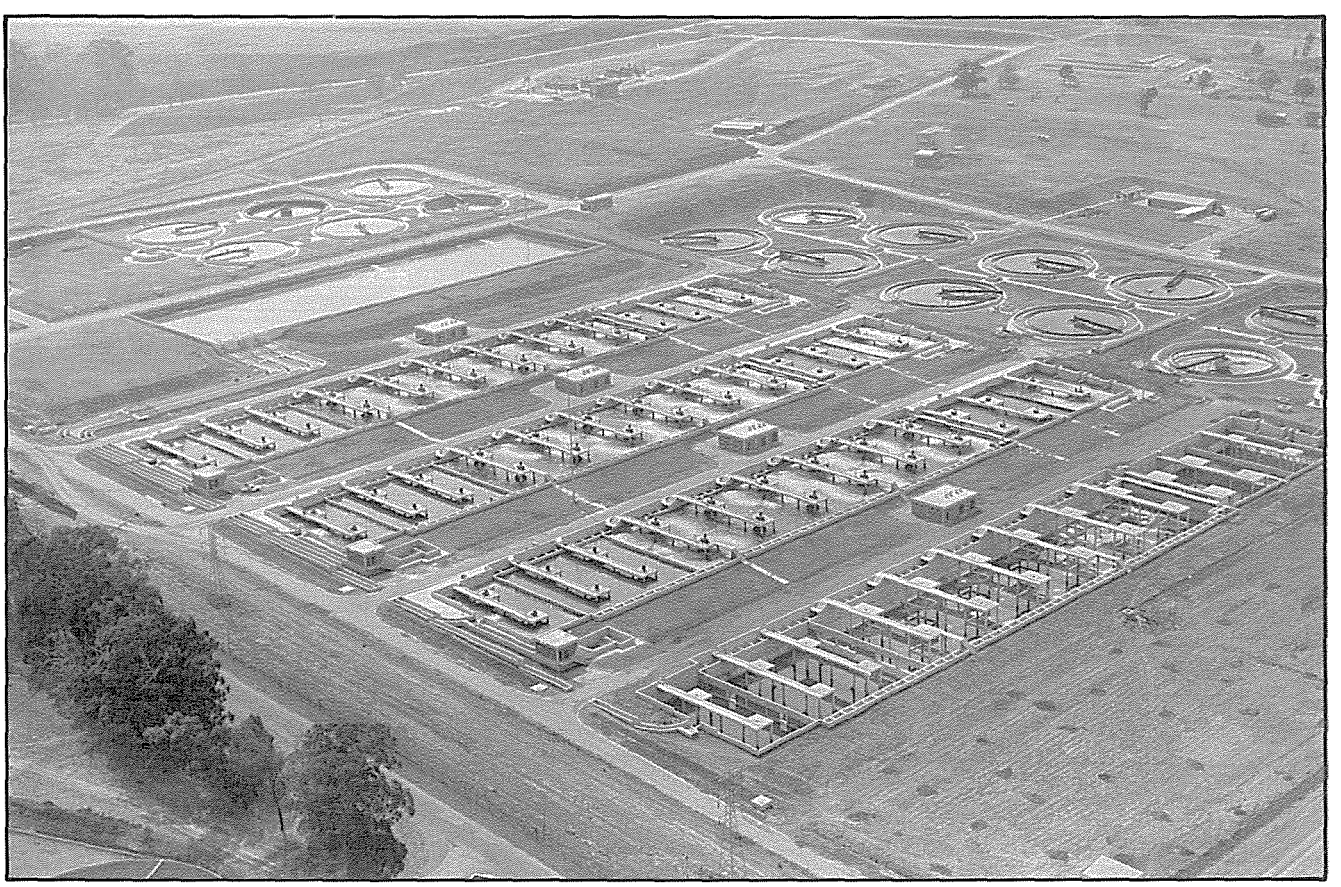
The project was completed at the end of 1978 and a start was then made with the compilation of a technical guide from the results which have ensued from the research. The content of the guide has been arranged according to the requirements of the design engineer, in order to provide a sound basis for the design of nutrient removing activated sludge plants. The guide will be published in 1980 and will be made available to all interested parties according to a distribution programme agreed to by the Commission, the CSIR and the South African Inventions Development Corporation (SAIDCOR). The latter organization is the holder of a patent on a process for biological nutrient removal, the BARDENPHO process, which was also developed by the CSIR, and has made great strides in promoting technology developed under this project both locally and overseas.

Research on the optimization of the modified activated sludge process for nutrient removal

(New project: Contract with the City Council of Johannesburg)

Research in terms of this new contract with the City Council of Johannesburg is executed in collaboration with the National Institute for Water Research of the CSIR and the University of Cape Town.

The Goudkoppie Sewage Works in Johannesburg where an important project with regard to the activated sludge process is being initiated



The investigations will be carried out at the Johannesburg Goudkoppie Sewage Works and the main objectives are to ensure the effective transfer of technology developed under previous research projects to practice and to develop a guide for the design and operation of nutrient removing activated sludge plants, based on full-scale design and operational experience. This is done in view of the fact that the phosphate removal from effluents generated in critical river catchment areas is expected to become compulsory within the near future.

The Johannesburg Goudkoppie Works with a design capacity of 150 000 m^3/d was commissioned in May 1978 and is the largest plant in South Africa to be specifically designed for biological nutrient removal. The process design includes an in-line balancing tank followed by a biological reactor consisting of a primary anaerobic zone, a primary anoxic zone, a primary aeration zone, a secondary anoxic zone and a final reaeration zone.

During the first year of operation of the plant most of the teething problems usually associated with the commissioning of projects of this magnitude were satisfactorily solved. Remaining difficulties are the control of dissolved oxygen and the prevention of wave generation by the mechanical aerators when the depth of immersion is increased.

Nutrient removal to date has been erratic and follows a cyclic pattern. Phosphate removal efficiency is generally poorest on Tuesdays and appears to be the result of low strength sewage being received over weekends. Performance had been found to be markedly better towards the end of the week when phosphate concentrations may be reduced to even trace amounts in the final effluent. The process appears to be very sensitive to the presence of nitrates and works best, as far as phosphate removal is concerned, when the plant is run in a non-nitrifying mode. Filamentous growths also made their appearance after six months operation and resulted in poor settling of the sludge.

The aforementioned problems may well occur in any of the other 27 plants of similar design now either operating or under construction in the Republic. The reasons for the erratic behaviour of the Goudkoppie Plant with regard to nutrient removal will be identified under the current investigation. Remedies to these problems will be investigated by any one or more of the three participating organizations to this project. Data produced on the plant will also be used in the further development and substantiation of a mathematical model of the process being developed by the University of Cape Town.

Research on the optimization of the modified activated sludge process for nutrient removal

(New project: Contract with the CSIR — National Institute for Water Research)

Research in terms of this contract with the CSIR is carried out in collaboration with the City Council of Johannesburg and the University of Cape Town. The investigations comprise laboratory and pilot plant studies with the main objective of serving as a back-up to the full-scale studies on the Goudkoppie works at Johannesburg. Problems with the full-scale application of the process identified at the Goudkoppie works, as well as certain other aspects which have been identified under the previous contract (see project on biological denitrification and phosphate removal) as urgently requiring research, are being investigated by the CSIR. The ultimate objective is to develop a guide for the design and operation of nutrient removing activated sludge plants, as already indicated under the subsection on the new contract with the City Council of Johannesburg.

Research in terms of the expired contract demonstrated that the employment of a biological system to remove phosphate and nitrate from sewage, was very effective. However when sewage strength varies between high during the week, and low over the weekends, the efficiency of nutrient removal varies from very good to, at times, poor. The research undertaken during the year was to determine whether carbon sources (chemicals or high strength stored sewage) could be used for maintaining process efficiency at all times.

Control of residual nutrient concentrations in effluent from the modified activated sludge pilot plant was studied using a tertiary treatment system. The results showed that effluent phosphate concentrations may be effectively controlled at acceptably low levels by the application of relatively small dosages of ferric chloride, i.e. from 25—30 mg $FeCl_3/\ell$. Furthermore, it was also demonstrated that by the additional use of sewage collected during the week, when sewage strength is at its highest, with sewage as it is normally received for treatment over weekends (usually low strength), resulted in consistently good nutrient removal. This second technique for maintaining consistently efficient nutrient removal appears to hold great promise as an economical technique for overcoming process instability with respect to nutrient removal.

The removal of nitrogen and phosphate from biofilter effluents

(New project: Contract with the CSIR — National Institute for Water Research, and the City Council of Pretoria)

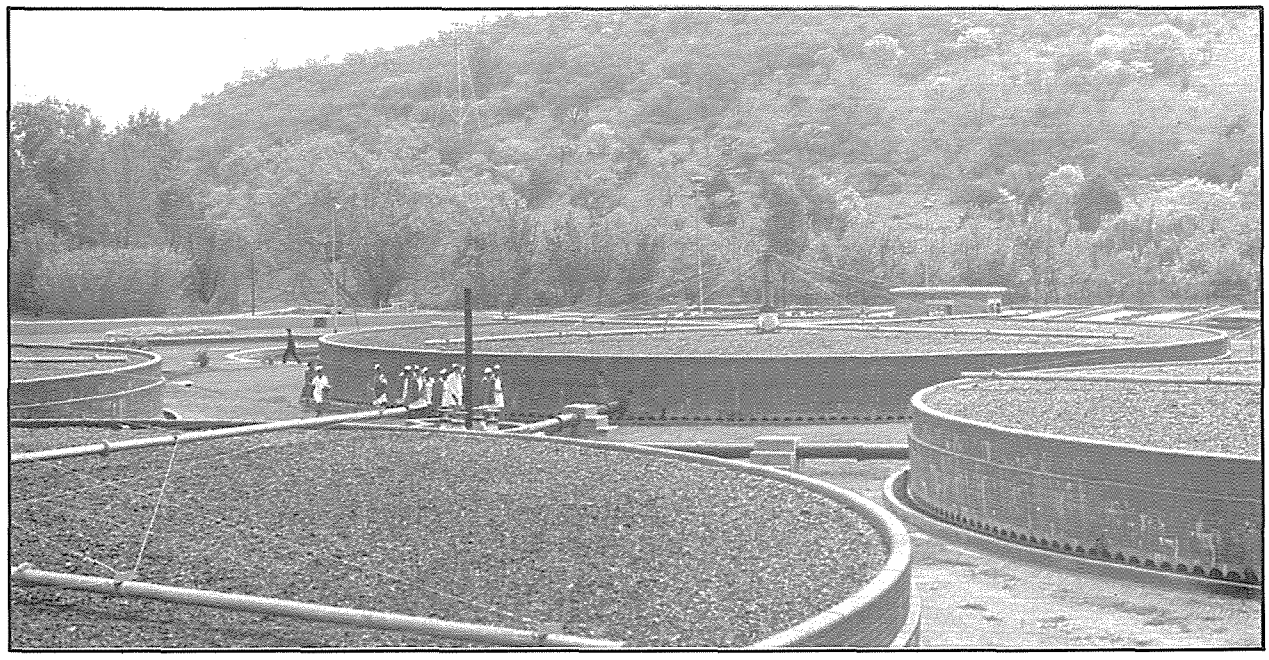
It is estimated that 65 per cent of sewage effluent generated and treated in South Africa's critical catchments is treated in sewage works of the biological filtration type. Unfortunately nitrogen and phosphate, which give rise to eutrophication of rivers and dams, are not effectively removed in biofilters. Since these filters represent a large capital investment they cannot summarily be replaced by activated sludge processes with a view to achieving the removal of nutrients. It is therefore essential that research and development work should be undertaken to develop techniques for converting these systems in such a way that nitrogen and phosphate are effectively removed from effluents. To this end a new agreement has been entered into with the CSIR and the City Council of Pretoria.

A full scale study of phosphate removal by means of ferrichloride, being undertaken by the City Council of Pretoria at the Daspoort Sewage Purification Works, Pretoria, commenced in August 1979. It entails the removal of phosphate by treating raw sewage with ferrichloride before primary sedimentation. The main objective is to reduce phosphate to a residue of 1 mg/ℓ. An additional benefit of chemical treatment is that the organic load on the biological filters can be significantly reduced — in fact, to such an extent that it allows a higher hydraulic load on the biological filters. This advantage could be a valuable asset in the chemical pretreatment of raw sewage at full scale plants, especially in instances where existing sewage purification works are already operating at maximum capacity.

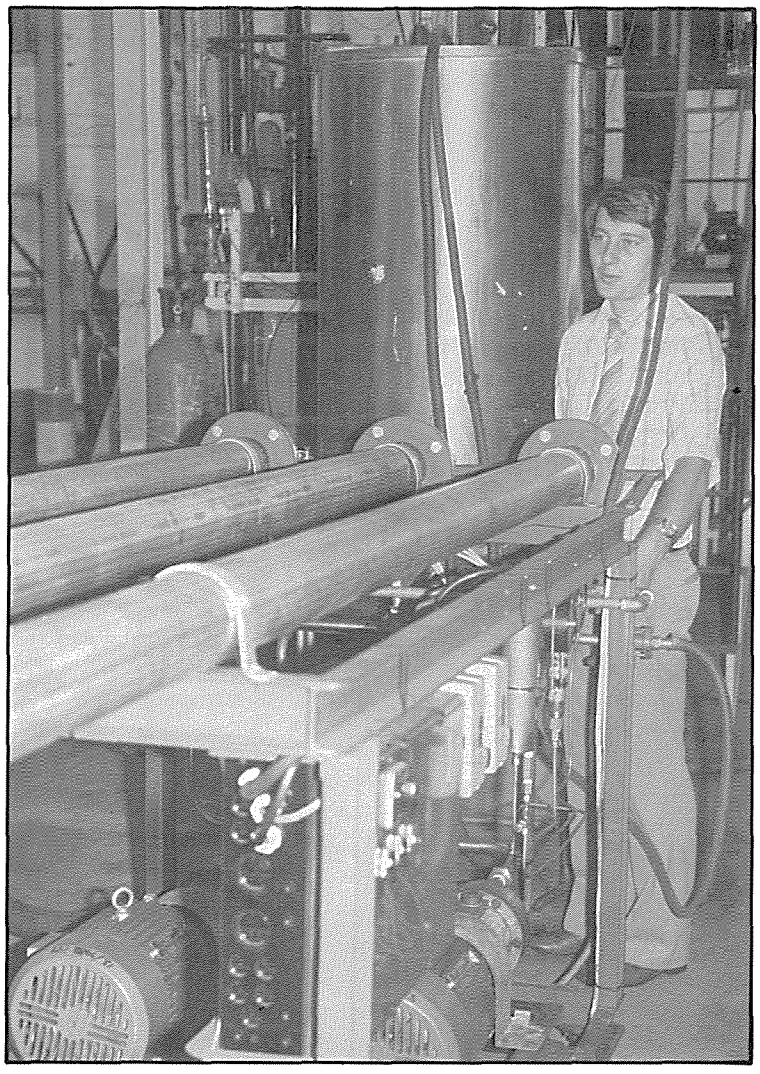
The investigation is being carried out by means of two parallel systems each with a constant flow of 2 270 m^3/d; ferrichloride is added in one system whilst the other serves as control. The two systems are evaluated simultaneously with respect to the influence of chemical pretreatment on biological sewage purification in biological filters; anaerobic digestion (which entails an intensive investigation into the digestibility of the iron rich and control sludges, the stability of the phosphate compounds, and desludging characteristics); and the maximum hydraulic load of the system.

In addition, laboratory studies of chemical-biological and purely biological methods of phosphate and nitrogen removal are being conducted by the NIWR. These investigations will take the investigation by the City Council into consideration and will entail, *inter alia,* a study of the utilization of the organic material in raw and digested sludge as a source of carbon for the purpose of biological nitrate removal. Results of the laboratory study will act as a basis for the development of a pilot plant in order to establish additional criteria for large scale application.

Biological filters at the Daspoort Sewage Plant in Pretoria. The removal of nitrogen and phosphate from these filter effluents is currently being investigated here



Membrane tubes in a laboratory of the Department of Chemical Engineering of the University of Natal where research is being conducted on effluents in the textile industry



Research into water management and effluent treatment in the textile industry

(Existing project: Contract with the University of Natal — Pollution Research Group, Department of Chemical Engineering)

This project involves the development of treatment methods to produce reusable water from the major effluent streams of the textile industry and for the recovery of chemicals. The contract between the Commission and the University also allows for agreements with textile mills in terms of which these factories contribute towards the establishment of pilot plants.

A pilot-plant programme for the closed loop recycling of desizing effluent with reuse of both water and recovered sizing agents was started this year. Further investigations have been made on the pilot-plant treatment of wool/synthetic fibre dyehouse effluents and the development of treatment processes for cotton/synthetic fibre dyehouse and wool scouring effluents.

Desizing Effluent

The results of pilot-scale ultrafiltration operating on the desizing effluent at a textile mill near Durban have indicated that polymeric sizing agents can be recovered from the effluent and be reused in sizing, and that the product water from ultrafiltration is suitable for recycling to the desize washer giving significant savings in water, and heat energy, as well as a decrease in the effluent loading.

The purpose of the pilot plant which was constructed at a factory, is to obtain information and experience which will facilitate the design and operation of a full-scale treatment plant for desizing effluents. The

pilot plant will be fully automated and the concentration of the reclaimed size solution monitored.

Wool/Synthetic Dyehouse Effluent

The dyehouse pilot plant operating at a textile mill in the Durban area at 85 m^3/d consists of the unit operations of ion exchange for auxiliary dyeing chemical recovery, electrocoagulation and sedimentation for colour and heavy metal removal and final filtration. The treated effluent has been reused by five production dyeing machines which covered the full range of the various fibres and dyeing procedures.

The ion exchange columns have removed anionic and cationic surfactants at over 90% efficiency. Electrocoagulation and clarification stages gave satisfactory removal of colour, heavy metals and organics. The colour of the product water from the treatment was consistently within design specifications. The quality of the reclaimed water has been totally acceptable to the mill management and no problems have arisen in the production dyeings.

Cotton/Synthetic Fibre Dyehouse Effluent

These alkaline effluents are highly polluted with colour, inorganic salts and a range of organic materials used in dyeing. Pilot-scale hyperfiltration tests have been carried out at a factory site to assess the flux and rejection performance of a recently introduced spiral-wrap module. This module has a poly(ether-amide) membrane which has improved characteristics over cellulose acetate types.

Rejection of salts, organics and colour by the membrane has been excellent and the permeate is of a quality suitable for reuse in dyeing. Simple prefiltration of the effluent, which contains gelatinous suspended solids and colloidal dyestuffs, has been found to be inadequate and flocculation was used. Further work is continuing to assess the long term performance of the module and to reuse the product water in test dyeings.

Wool Scouring Effluent

The development of a treatment system for wool scouring effluents to allow water reuse has continued with considerable success. The system consists of the desuinting-scouring of grease wool with treatment of the desuinting effluent by evaporation and of the scouring effluent by ultrafiltration.

Factory trials on the desuinting-scouring method have been successful with over a 20% reduction in water usage compared to normal scouring. A pilot-scale dynamic membraned ultrafilter has been constructed and this has several important advantages for the processing of an effluent which is considerably fouled. Rejection of grease and dirt is 100% and partial rejection of total dissolved solids has also been recorded. The product water from the ultrafiltration of desuinted wool scouring effluent at high water recovery is suitable for reuse in scouring. Further work is being carried out at a factory site to evaluate the long-term performance of the ultrafiltration unit.

Evaluation of the performance of a horizontal decanter centrifuge in the removal of sludge from liquid scouring wastes

(New project: Contract with the CSIR — South African Wool and Textile Research Institute)

The overall objective of the project is to evaluate the performance of a co-current horizontal decanter centrifuge in the removal of sludge from liquid scouring wastes. Due to design considerations the smallest available machine of this type has a design capacity of 4 m^3 per hour. In practice throughput may be considerably below design capacity. Nevertheless its capacity would appear to be far too large for trials to be carried out at the South African Wool and Textile Research Institute (SAWTRI). Nor is there an availability of sludge in sufficient quantity at SAWTRI for such work to be carried out in a scientific manner. A pilot plant operating during the day shift and located at a factory site was, therefore, needed for this purpose.

The contract between the Commission and the CSIR, therefore, also allows for an agreement with a wool scouring factory in terms of which the factory contributes towards the establishment and operation of the centrifugal decanter.

Pilot scale investigations into destabilisation of wool scouring waste by the magnesium-rich waste residue (known as 'bitterns') from a plant which recovers salt from sea water, showed that grease removal as high as 80 per cent and suspended solids removal of 92 per cent could be obtained with the horizontal centrifugal decanter. The quality of the centrate is good and suitable for reuse in scouring. Further work is being carried out at the factory to evaluate the long-term performance of the centrifugal decanter.

Research in connection with water management and effluent problems in the hides and skins, curing, fellmongering and tanning industries

(Existing project: Contract with the CSIR — Leather Industries Research Institute)

This project forms part of an overall study of water and effluent management in the meat, hides and skins, leather and related industries. The tanning and fellmongering industries in particular, are experiencing difficulty in the disposal of wastewaters produced by their processes. The major proportion of waste water from these industries has been disposed of hitherto by lagooning and irrigation. Problems have been experienced with these methods of disposal and research is being directed towards suitable economic treatment methods and the reuse of water and tannery chemicals.

Tanning

Combined tannery effluent has been fed to a completely mixed activated sludge pilot plant, and encouraging results are being obtained. Various operational parameters are being studied as well as the influence of individual tannery effluent components. A high rate biofilter is in operation, and initial indications are that it could be used as a pretreatment process. Beamhouse liquors will be studied in the activated sludge process in the near future.

A series of four asbestos tanks have been set up to simulate the gravity flow from four effluent ponds, and to study the changes which occur in the effluent over a long period.

A scene in a tannery near Wellington, CP, where research is being conducted on the purification of tannery effluents

The use of physico-chemical methods to purify tannery effluents is being investigated on site at tanneries in Pretoria and Wellington. In the Pretoria project, the use of dissolved air flotation after chemical addition has been successfully demonstrated. The economics of the method are currently being investigated.

At Wellington, a novel method of solids precipitation from beamhouse effluent has been developed. Initial results are encouraging and further development work is continuing.

Fellmongering

The activated sludge process has been found to be very adaptable to fellmongery unhairing effluents at high sludge loading rates. The effect on the activated sludge process of increased salinity arising from soak liquors is being investigated.

Sludge handling and dewatering experiments utilizing drying beds and filter pressing are in progress at a fellmongery in the Port Elizabeth area.

Numerous laboratory investigations are in progress at the Leather Industries Research Institute, concerning the adaptability of the activated sludge process to individual tannery wastes, since the effluent from tanneries using slightly different processes and producing different types of leather is not always the same. Laboratory studies of both primary and tertiary physico-chemical precipitation of tannery wastewater are also being done.

source of inorganic salts arises from the processing of salt cured hides.

The tannery near Pretoria was able to reduce the salt concentration in the effluent by more than 50 per cent by processing non-salt cured hides, but the overall quality still prevented it for discharge to the sewer. The Commission, therefore, initiated a new project in conjunction with the City Council of Pretoria and the tannery to find an economical method of pretreatment to achieve the standards required for sewer discharge.

It was found by laboratory scale tests that the addition of ferric chloride and a cationic polyelectrolyte to the wastewater produced a buoyant sludge. Using this information, a dissolved air flotation pilot plant was installed to treat the combined tannery wastewater. Preaeration was used to remove sulphide ion by oxidation and stripping.

Initial results have been better than expected. The system can remove up to 99 per cent chrome, 95 per cent suspended solids and 90 per cent of the dissolved organic load. The sludge produced dries within 24 h to a spadeable condition when applied to drying beds, does not readily redissolve, and would be suitable for disposal of land-fill.

The experimental work is continuing to optimise the system.

Research related to the purification and reuse of tannery effluent

(New project: Contract with a tanning company)

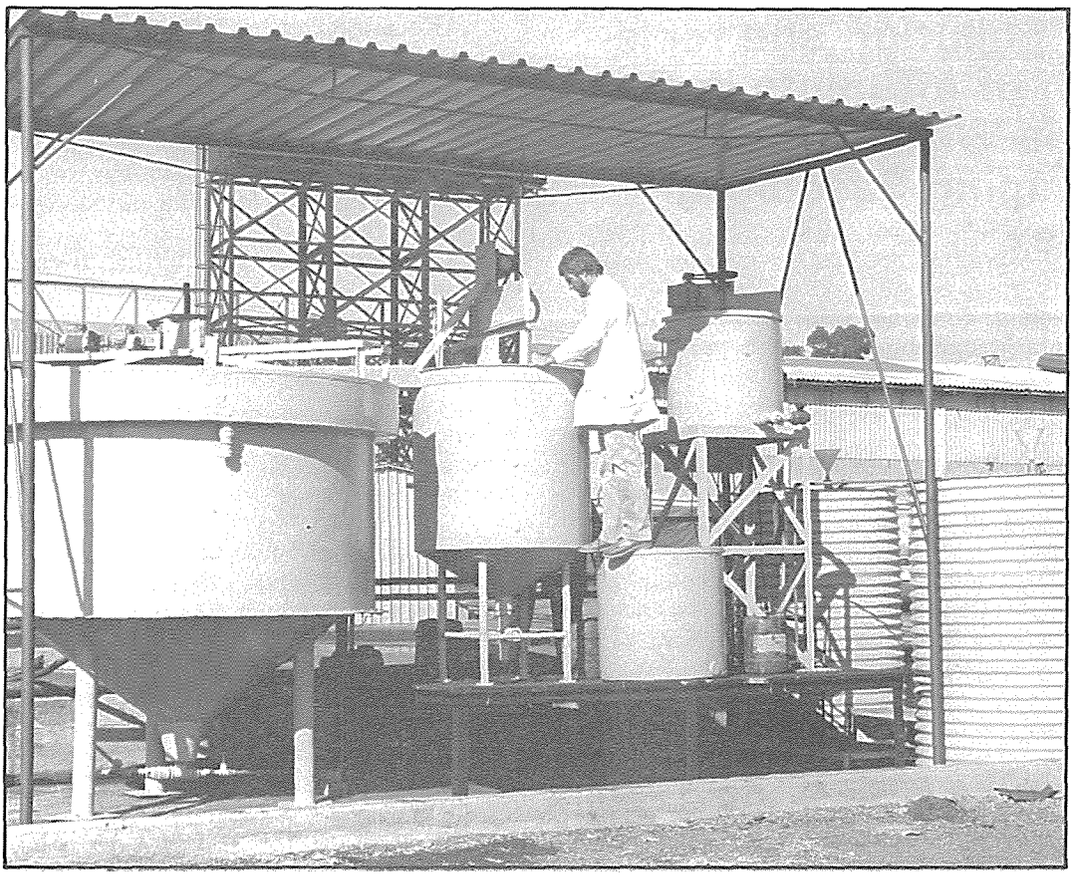
As part of the overall research concerned with the development of guidelines and a code of practice for the hide and skin processing industry, an agreement was entered into with a large tannery near Pretoria to carry out studies into, and to develop, new methods of treatment and control of a tannery effluent.

The use of evaporation ponds for disposal of tannery wastewater has become standard practice for large tanneries not only because of the high organic polluting nature of the wastewater but also because of the high inorganic salt concentrations present. However, this method of disposal leads to the generation of bad odours as well as consumptive use of water. The major

Research on the technological application of the anaerobic digestion process for the purification of spent wine residues

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

The two-year contract negotiated in 1977 and then extended for a further year was aimed *inter alia* at investigating at pilot scale operational problems being experienced with the full-scale anaerobic treatment of



The pilot plant for the treatment of effluent from a tannery near Pretoria

wine distillery waste (spent wine) at the Stellenbosch Sewage Works. The investigation was done in cooperation with the Stellenbosch Municipality and the CSIR. Results obtained proved that spent wine residues are very amenable to anaerobic digestion and that this biological process based on high volumetric load rates and low hydraulic retention times, results in efficient effluent purification. It was also demonstrated that the process is economically viable and reliable, if the system is properly designed and controlled. The research results for the project are being written up in the form of a final contract report which will be available on request from the Commission and the CSIR.

The research findings applied to the full-scale plant at Stellenbosch because of serious physical limitations of this plant, especially with respect to retention of solids in the existing sedimentation tanks (Dortmund tanks) and inadequate mixing facilities in the digester. As a result of negotiations between the respective distilleries and the Stellenbosch Municipality, agreement was reached that the distilleries would finance recommended improvements to the full-scale plant and these were carried out during 1979.

It is desirable to verify the NIWR research results obtained at laboratory and pilot scale level on the modified full-scale plant which will be commissioned during early 1980. This implies the transfer of existing technology to practice, and also allows the continued investigation into the integration of other wastes such as grain spirit distillery waste to maintain digester activity during the spent wine off-season. In view of this it was considered necessary to negotiate a new contract agreement between the Water Research Commission, the CSIR and the Stellenbosch Municipality for the period 1980 to 1982. The ultimate aim of this new project is to formulate a code of practice for the treatment of spent wine at a sewage works where the anaerobic digestion process is best applied as well as in isolated areas where irrigation is possibly the most economically attractive disposal method.

Water pollution and reclamation of effluents in the Pretoria-Witwatersrand-Vereeniging-Sasolburg complex

(Existing project: Contract with a firm of consulting engineers in collaboration with various local bodies)

The Pretoria-Witwatersrand-Vereeniging-Sasolburg (PWVS) complex is the most densely populated and highly industrialised region in the Republic and the water required by this complex (at present about 1,8-million m^3/d), is abstracted from the storage basin of the Vaal River Barrage and is pumped up against a head approximately 500 m to service reservoirs on the Witwatersrand ridge and further afield.

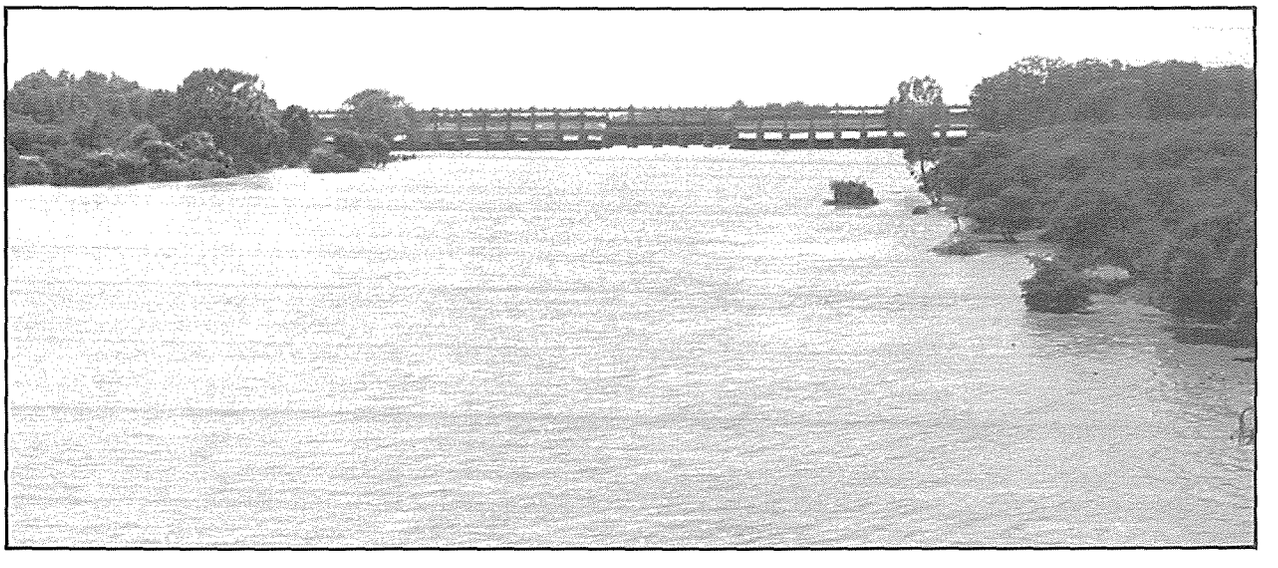
The southern catchments of this complex, which contain extensive urban, industrial and mining developments, drain back directly into the Barragestorage basin itself and the considerable pollution loads generated by these developments, either as treated effluents or as stormwater washoff, are becoming a matter of major concern to all authorities involved in the region.

This project embraces a comprehensive investigation of all aspects affecting the pollution of these southern catchments. A firm of consulting engineers was appointed by the Commission to co-ordinate the various stages of the research project, which in the main have been implemented by the Hydrological Research Unit of the University of the Witwatersrand.

The research work completed to date comprises the following:

- The assembly and collection of data relating to all existing sources of pollution.
- A detailed study of the geology of the area with particular emphasis on the permeability of the various drainage areas.
- The preparation of an atlas of the area showing all topographical features, existing and planned urban, mining and industrial developments, sewer outfalls and sewage purification works, water treatment works, bulk supply mains and reservoirs, irrigable and irrigated areas, vlei areas, together with a detailed flow diagram of the whole complex.
- A study of the present and predicted distributions of populations in the various regions.
- A preliminary study of the cost to the community of high dissolved mineral salts in the water supply.

The Vaal River in flood with the Barrage in the background. Pollution of the river and the impoundment is causing great concern and is currently being investigated



- The establishment in conjunction with the Rand Water Board of a network of monitoring stations on the various tributaries drawing into the Barrage basin.

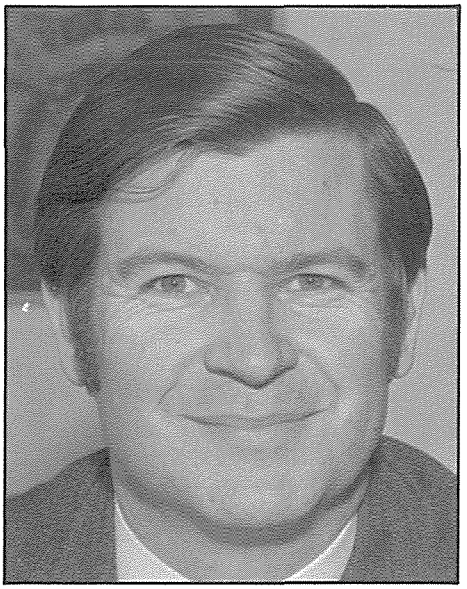
- The creation of a comprehensive suite of mathematical models of the hydrological and pollution (mineral salts) movements within the system.

- The use of the data assemblies and the mathematical models to test various management strategies for pollution control within the system.

The suite of mathematical models will be capable of predicting for various time horizons the daily variation of dissolved mineral salts at various points in the southern system. The models have for demonstration purposes been successfully utilised to predict the probabilities of further increases in pollution levels and the effect of various pollution control options such as the establishment of pollution storage dams, desalination works, etc.

It is planned to develop further models to establish the behaviour in terms of storage levels and yields of the Vaal River system itself, including all dams.

A special committee comprising representatives of all the affected authorities has considered a preliminary report (compiled by the firm of consulting engineers) dealing with the sources of mineral pollution and with strategies which could be employed for improving water quality. In this connection, Professor MJ Hamlin of the University of Birmingham, U.K., who is familiar with conditions in the PWVS area and who has wide experience of water resources management techniques and hydrological modellings, was invited by the Commission and visited South Africa as a special consultant this year. He reviewed the progress made on the project and suggested guidelines and procedures for testing the strategies proposed for the improvement of water quality.



Prof MJ Hamlin of the University of Birmingham who acted as consultant for research with regard to the PWVS complex

Chapter 6

Irrigation

In its support of irrigation research the Commission places special emphasis on those aspects of irrigation which will exert the greatest influence on optimal water utilization. The most important of these relate to water requirements of crops and, therefore, the scientific scheduling of irrigation. For this reason four of the seven irrigation research projects currently supported by the Commission, deal directly with this aspect.

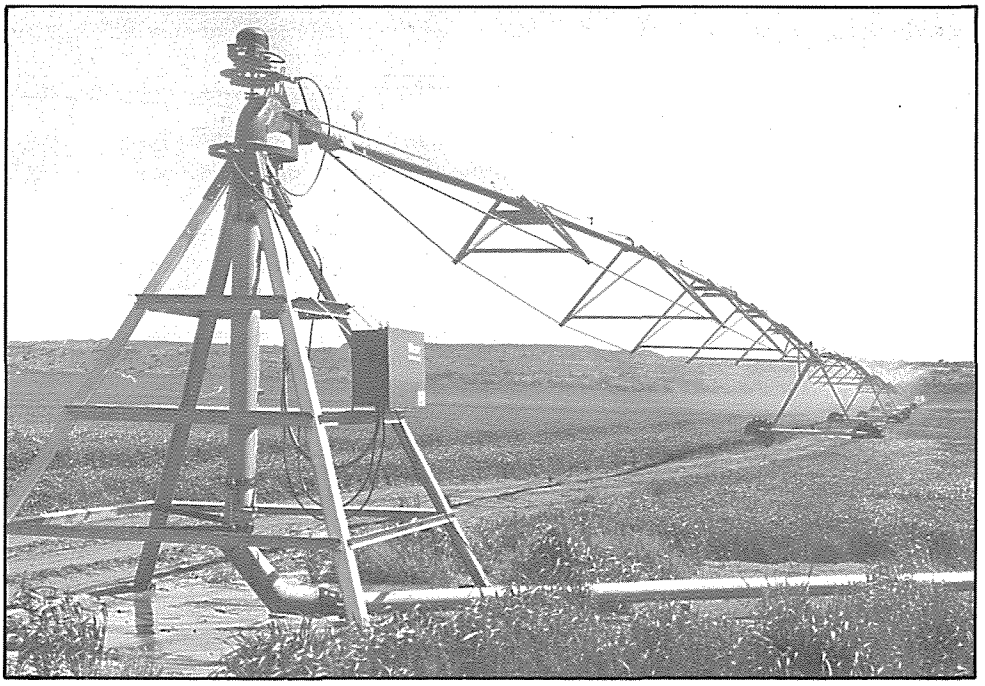
In previous annual reports the abovementioned aspects of irrigation research were often emphasized, but in the light of the energy situation have acquired a new importance. The agricultural sector, like all other sectors of the South African economy, has been seriously affected by the energy crisis. As a result, all facets of agricultural production processes have been closely scrutinized with a view to fuel savings. Consequently, energy requirements of irrigation farming have inevitably become involved.

In order to ensure optimal production per unit water under irrigation, the energy input must be evaluated in conjunction with other production factors. Overemphasizing the saving of energy at the expense of effective water utilization may lead, in the long term, to serious problems to the detriment of production and soil productivity. It is also true, however, that energy saving in some respects promotes water economy.

One method of reducing the energy requirements for irrigation is to reduce the quantity of water pumped. This approach can only be followed if it is not detrimental to the economy of crop production and consequently, an accurate knowledge of the water requirements and moisture critical growth stages of the crop is an essential prerequisite. Research of this nature should therefore continue to enjoy a high priority and for this reason the Commission, in its support of such research projects, endeavours to make a positive contribution to the available information with regard to the water requirements of crops and the effect on the yield by the quantity of water applied.

The development of this type of information, however, is very closely tied to its practical implementation. As a result scheduling techniques should be simple and reliable in practice and irrigation systems should be capable of supplying the estimated quantities at the right time and with the desired degree of accuracy. In this regard, effective extension services can play an important role and serious effort will have to be made to the cultivation and development of a positive attitude toward irrigation scheduling amongst users.

Another method of energy saving in irrigation is the reduction of pressure at which water is supplied. Energy saving in this manner however, can be both advantageous and disadvantageous with respect to water economy in irrigation. The possibility always exists that this approach will promote the use of drip irrigation, but in the case of sprinkler-irrigation the situation is more complex. A lowering from too high a pressure to the optimum is only advantageous in that distribution efficiencies are improved and evaporation losses reduced. However, when the pressure is reduced from the optimum to a substantially lower value, the attempt at energy saving can present serious problems. For example, it will be necessary to modify the sprinklers to suit the lower working pressure. If the sprinklers are not modified, larger drops are produced which break down soil aggregates which in turn leads to reduced rates of infiltration and increased runoff. In the case of centre pivot systems this phenomenon is clearly discernible and the increased runoff could even lead to erosion. If it is borne in mind that irrigation by means of the centre pivot system is expected to increase to such an extent that approximately 20 per cent of the irrigated land in South Africa will be irrigated by this method by the end of the century, it becomes clear that low pressure centre pivot systems will have to be used judiciously and



A centre pivot irrigation system in a wheat-field in the Southern Free State

with due regard to the infiltration rate of the relevant soil.

There is no doubt that these problems can be countered by various measures. The facts are however, that recommendations with respect to these counter measures are based largely on intuition and that research results which could be of help in this respect are relatively limited. With a view to future developments, this field of research will have to receive close attention.

Potential for automation of flood irrigation in South Africa

In view of the advantages incumbent in the automation of flood irrigation in respect of labour savings and increased irrigation efficiency, the Commission, at the request of the Department of Agricultural Technical Services, made funds available for an investigation into this aspect. In the previous annual report it was mentioned that Dr Howard Haise of the USA acted as specialist consultant in this regard and that he compiled a report on the potential for automation of flood irrigation in South Africa.

Dr Haise came to the conclusion that excessive water application on sandy soils with high infiltration rates were the main problem of flood irrigation systems in South Africa. The problem is compounded by the fact that many of the irrigation schemes are labour intensive and designed to utilize relatively small irrigation streams.

In these circumstances complete automation of flood irrigation is not recommended since it is only viable where large irrigation streams and beds are available. In fact, even the level basin irrigation system applied with much success in the USA, will not have the desired effect under local conditions. Alterations required to render local schemes suitable for complete automation will probably be so capital intensive that a change to sprinkler irrigation will be more economical.

However, certain equipment related to automation can be advantageously used in South Africa. One example of this is the self-regulating constant discharge valve. A prototype of this valve was built in South Africa and has functioned well. Before general use, however, it will have to be tested under field conditions.

In addition to his recommendations with regard to automation, a comprehensive research project directed at the Vaalharts irrigation scheme has also been proposed. This proposal is currently under consideration by the relevant organizations with a view to its possible implementation.

Completed irrigation research project

The first irrigation research project financed by the Commission was completed during 1979 and the ensuing report published. This project, which dealt with the soil compaction problem at Vaalharts, was undertaken by the Department of Soil Science of the University of the OFS. The final report consists of four volumes having the following titles:

Vol I: *Samevattende verslag* by R du T Burger, ATP Bennie, FJP Botha and CC du Preez

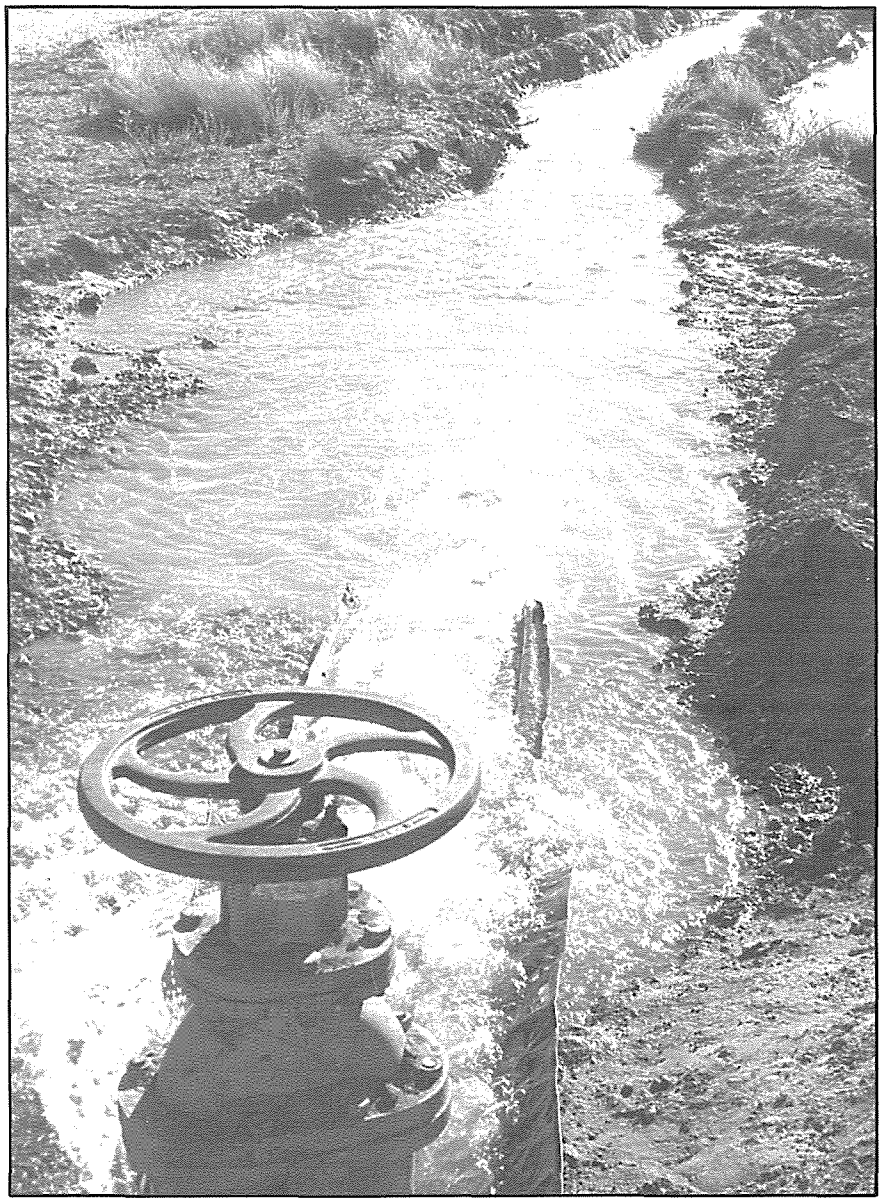
Vol II: *Die invloed van grondverdigting op die grond-plant-sisteem* by ATP Bennie and R du T Burger

Vol III: *Die oorsake en bekamping van verdigting van sanderige besproeiingsgronde,* by CC du Preez, ATP Bennie and R du T Burger

Vol IV: *Die bekamping van grondverdigting deur struktuurvormende polivinielverbindings,* by FJP Botha, ATP Bennie and R du T Burger.

During the study emphasis fell mainly on:

- The soil characteristics which render the soil susceptible to compaction under cultivation and irrigation
- The soil characteristics influenced by compaction
- The effect on agricultural crops of a change in soil characteristics such as that caused by compaction
- Possible measures which may be implemented in practice to counter compaction.



The automation of flood irrigation affords great benefits and the matter is therefore being investigated. The photograph shows a typical scene where this type of irrigation is being applied

The fine sandy soil series of the Hutton and Clovelly soil forms which comprises the largest part of the Vaalharts irrigation area has an inherent tendency to high soil density. Cultivation and irrigation aggravates the degree of compaction and this causes a serious increase in the resistance of the soil to root growth. The total length of roots per plant, the extent of branching, root area and root mass are all limited by compaction. The limitation to root growth by compaction affects the intake of water and plant nutrients in several respects. The most important is the fact that a shallow root system is unable to utilize deeper soil. Uptake of plant nutrients is affected in different ways by compaction, apparently due mainly to the uptake mechanism such as diffusion and mass flow.

Compaction layers in the soil can be related to the implements used for cultivation. The most serious is compaction under the tractor wheel. Wherever the tractor wheel travels in the furrow a compacted layer occurs which cannot be broken up by the plough. Mechanical breaking of compacted layers by deep cultivation only affords temporary relief. During the investigations soils were found which were compacted up to 98 per cent of their maximum volume density — a stage at which soil aeration is already impeded.

For the almost complete elimination of the negative effects of soil compaction, a system of controlled implement traffic, the use of furrow irrigation systems and the prevention of over-irrigation are recommended. In order to assess the practical implementation of these recommendations, further research is continuing under a new agreement.

RESEARCH PROJECTS

Water requirements of agronomic and vegetable crops

(Existing project: Contract with the University of Pretoria — Department of Plant Production)

The aim with this project is the systematic investigation of the water requirements of crops with a view to the planning and refinement of irrigation programmes. The results will be used to compile guidelines from which irrigation programmes can be adapted to apply a given volume of irrigation water in the most effective manner.

Even at the start of the project in 1976 it became clear that a real need existed for a simple technique for continuous monitoring of the effect of irrigation on the moisture status of the plants. A method has subsequently been developed whereby the relative moisture status of plants can be determined by means of the leaf temperatures of the plants. The effect of irrigation on the crop can now be monitored accurately and continuously in order to determine the minimal water application for optimal yields. The evaluation of irrigation programmes according to this method has been tried for one season only but results obtained with wheat and dwarf beans have already indicated that considerable water economy is possible, especially in the early part of the growing season. However, further tests are necessary before final recommendations can be made.

The recording of leaf temperatures of crops can replace pan evaporation as a method for irrigation programming. It has the distinct advantage that the plant itself is an irrigation programming index. This aspect is currently enjoying special attention with a view to its general use in practice.

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

(Existing project: Contract with the University of the Orange Free State — Department of Agronomy)

During the year under review two irrigation trials were undertaken at the Vaalharts Agricultural Research Station as part of the research to determine the behaviour of certain agronomic crops in moisture stress conditions which occurred during different growth stages. Wheat was once again used as test crop during the winter months and groundnuts during the summer months. The effect of moisture stresses of short duration on the yield component were used to determine the relative sensitivity of the plant to drought conditions during various growth stages.

Experimental work progressed well and although rain occurred during the winter months it did not alleviate the induced moisture stresses. These relatively favourable conditions were well utilised and valuable information with respect to the moisture content of the soil during the growth season as well as the water potential of the plant was gained. Further data gained was that in respect of the leaf area index as well as dry mass of the plant and soil moisture determinations. This provided a clear picture of the vegetative development of the plant and the effect that various treatment processes had on the plant. The data will also give an indication of the evapotranspiration-evaporation ratio E_t/E_o (i.e. the Class A pan factor) of wheat during the growth season, as well as of the discrimination curve which

distinguishes between moisture stress days and days on which the plant did not experience moisture stress.

As far as wheat is concerned, sufficient data has been collected to measure the reaction of the plant to moisture stresses in various growth stages. However, more information is required for correct calculation of moisture stress days.

During the summer months groundnuts were used as test crop for the irrigation experiment. Since rain had often in the past relieved planned moisture stress during a specific growth stage, irrigation during the past summer season was only applied when total evaporation from a Class A pan reached four different levels. As a result relatively little information was collected which could be used for the eventual determination of the drought sensitivity of the crop. Since rainy conditions in previous years also created problems, there is still a need for more data which can only be obtained by means of irrigation tests in which rain shelters are utilised.

In order to complete the research work undertaken to date, it will be necessary to undertake complementary field work under controlled conditions. Rain shelters will play an important role in these conditions.

The efficiency of water extraction from fine sandy irrigation soils by different root systems

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

This project ensued from the results obtained from the completed research project on soil compaction at Vaalharts. Research on soil compaction indicated that the roots of the commonly cultivated crops namely maize, wheat, cotton and groundnuts are affected in different ways by high soil strengths. It has been shown, for example, that wheat roots can more effectively penetrate compacted soils than the roots of the other crops. Results therefore indicate that a properly distributed root system creates an effective mechanism for the extraction of water and plant nutrients from these soils.

This new project has been designed with the aim of obtaining a clearer picture of the interaction between root and soil in the soil-water-plant-atmosphere system. This interaction will be studied by determining the following by means of a mathematical model:

- the root distribution in the various soil horizons of soils tilled according to differential cultivation methods with the crops mentioned above
- the water extraction rate within each horizon and the uptake of plant nutrients
- the effect of soil compaction on the axial and radial resistance to the flow of water and the uptake of water in roots; and
- the efficiency with which the root system of a crop utilises irrigation water.

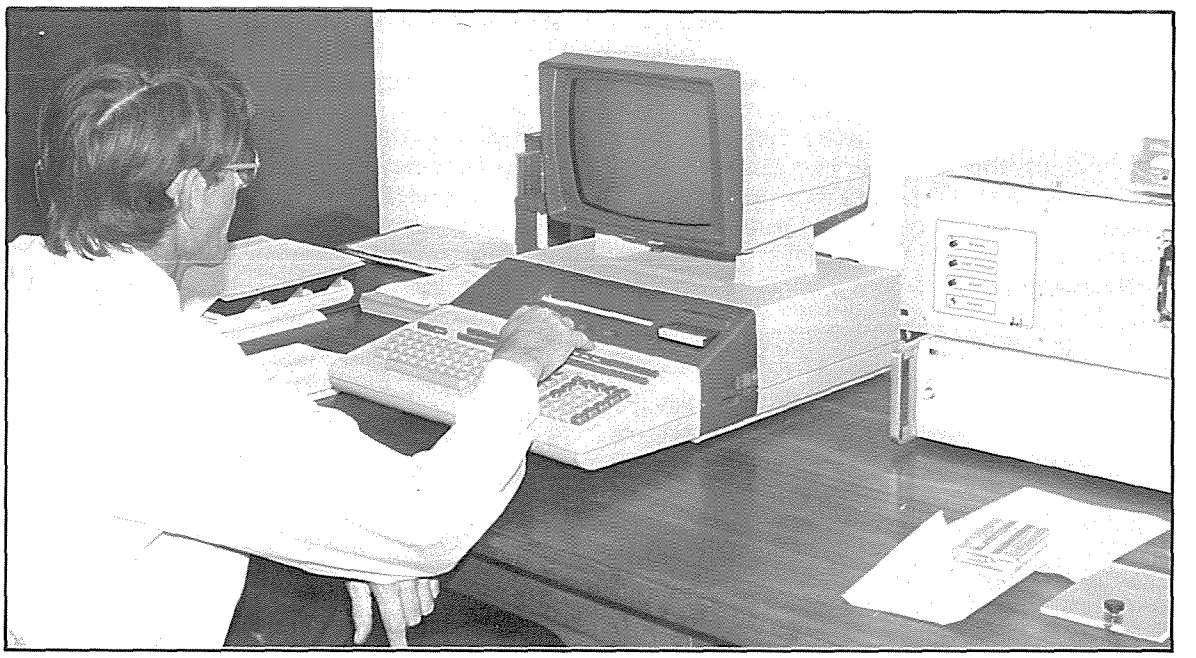
During the year under review a series of pot trials were conducted in which the effect of root thickening as a result of compaction on water extraction and on friction losses in the xylem vessels was investigated. The uptake of plant nutrients is also determined as a function of time, root length and soil strength. A series of field trials with maize and wheat as test crops will be done at Vaalharts. The effect of differential root development on water extraction will be measured as a function of time under different cultivation techniques. The hydraulic conductivity and groundwater retention will be determined on the same soil by measuring the soil moisture content continuously with a neutron moisture meter. It is expected that the results will lead to a generalised model to describe water extraction from the fine sandy soils of Vaalharts and other irrigation schemes which will be of great value from an irrigation scheduling point of view.

Research on the scheduling of irrigation of wheat in the irrigation areas of the Orange Free State

(Existing project: Contract with the University of the Orange Free State — Department of Agro-meteorology)

The objective of this project is the development of an information service in order to ensure maximum wheat production per unit of irrigation water at the Vaalharts and Jacobsdal irrigation schemes. The possibility to include other crops and areas in such an information system will be investigated at a later stage. A weekly irrigation schedule will be compiled using only weather data from the two areas and a water balance model being developed at the Agro-meteorological Observatory at the University of the Orange Free State. Information pertaining to irrigation, as well as the probability of rain during the next five days, will be released by means of press and radio to the farming industry in the relevant areas.

Although considerable attention has been paid to the development of experimental techniques and exper-



This computer equipment is used for determining the daily water consumption of wheat

The pressure bomb apparatus in the adjacent picture is used in the direct measurement of plant moisture potential

tise, as well as to techniques for the processing of data on the computer, encouraging results have been obtained. Important functions which form an integral part of the water balance model have already been developed and will be verified at the observatory during the next season. The incorporation of these functions in an existing water balance model will enjoy a high priority during the next season, whilst a programme for the statistical analysis of rainfall probability has already been developed. The applicability of the programme will be investigated thoroughly and should modifications become necessary, these will be incorporated.

Although the central theme of the project is the establishment of an information service, it is also of considerable academic and practical value since various methods for the determination of evapotranspiration will be investigated during the project. By using these various methods the soil moisture content can be calculated and the specific method producing the best correlation between soil moisture results and gauged soil moisture will be used in the water balance model.

Development of effective irrigation methods for application to steep lands, with special reference to micro-methods

(Existing project: Contract with the University of Stellenbosch — Department of Civil Engineering, Chair of Irrigation Engineering)

The aims of the project are the improvement of gauging equipment, the investigation of the uniformity of application of different application methods and the critical comparison of different irrigation methods on steep lands. The information will be of particular value in the development of irrigation in the Western Cape.

During the year an hydraulic model of an automatically controlled water supply system was completed. The system has a flow rate capacity of 250 ℓ/s and consists of various flow measuring components placed in series in order to facilitate the comparison of methods. The control system, together with the supply canals, balancing ponds and secondary piping, will be immediately capable of meeting the combined demand of irrigation farmers at irrigation schemes where it is applied. This model investigation will provide the principles for the design of a larger system with all its components.

Simultaneously with the abovementioned laboratory study, four irrigation test areas on steep land on the farm Welgevallen near Stellenbosch were provided with the required water supply under controlled pressure and the electrical power for the control equipment. A start has already been made with the irrigation of cabbage crops in order to determine the accuracy of application and water demand in a practical situation where irrigation is carried out according to a specific scheduling procedure. These tests serve a further purpose in that they provide information for assessing the design principles for the supply system in order that the best possible results may be obtained for the users, within the limits of economic design.

Research on the soil factors affecting the optimal utilization of irrigation water in the Black States

(Existing project: Contract with the University of Fort Hare — Department of Soil Science)

Due to the problems associated with dry land crop production, the production of agricultural products under irrigation plays an important role in the food requirements of the Black States.

During the year studies on the two main aspects of this project continued:

- Studies on the profile available water capacity (PAWC) soils.
  PAWC, with wheat as test crop was determined in undisturbed profiles (1 000 to 1 200 mm deep). As in the case with maize these determinations also gave very high PAWC values, ranging between 107 and 126 mm. These values, obtained with young wheat plants, were slightly lower than the average of 144 mm obtained with mature wheat plants in field experiments.

  The feasibility of using the very high PAWC values as a basis for irrigation planning was tested in field experiments with wheat, maize, sorghum and soy beans on a soil of the Jozini series. The results were very promising and indicated that it is possible to use PAWC as basis for irrigation scheduling, apparently without detrimental effect to the test crops.

- Studies on infiltration.
  For the strongly crusting soils of the Jozini series at the Fort Hare farm, the infiltration rates determined for the dynamic state (water flowing over a bed) were much higher than those determined for the static state (in a dam).

  This observation is confirmed by a comparison of steady hydraulic conductivity values. K_{steady} was 1 820 mm/d for dynamic data and only 200 mm/d for static data. The difference between dynamic and static data is most probably due to surface breakdown and sealing.

Research during the following year will concentrate mainly on the possible water savings when PAWC for irrigation scheduling is used and on cooperative experiments to collect PAWC values through a simplified technique. For the infiltration aspect of the project, the emphasis will be on the effects of different irrigation bed slopes and the development of a reliable dynamic infiltration measurement technique.

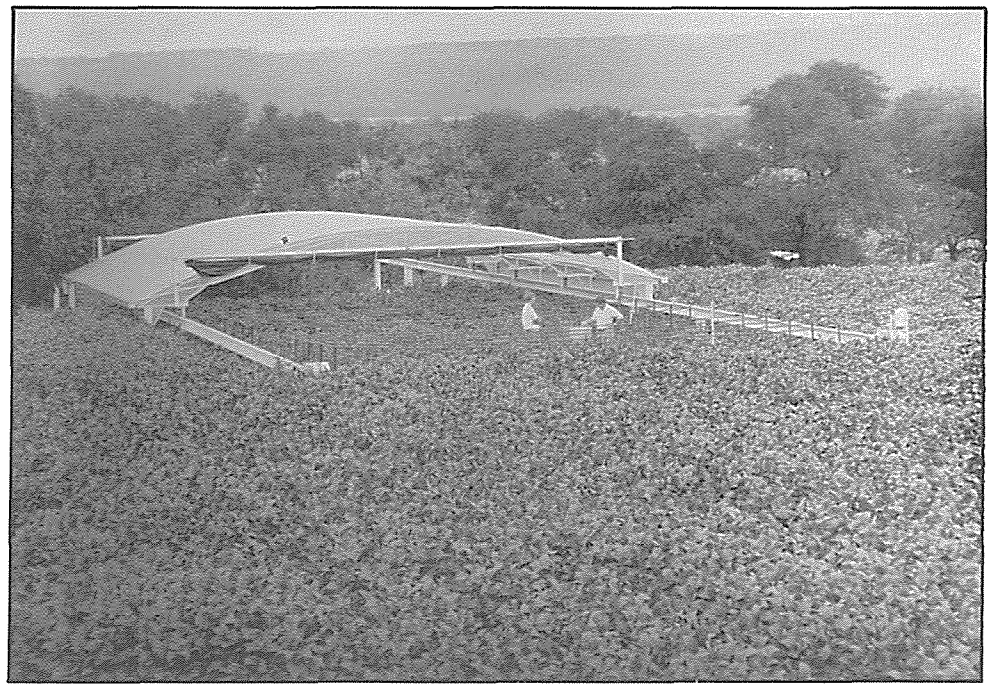
Evapotranspiration and water use studies by means of weighing lysimeters: Evapotranspiration as a function of soil, plant and atmospheric factors

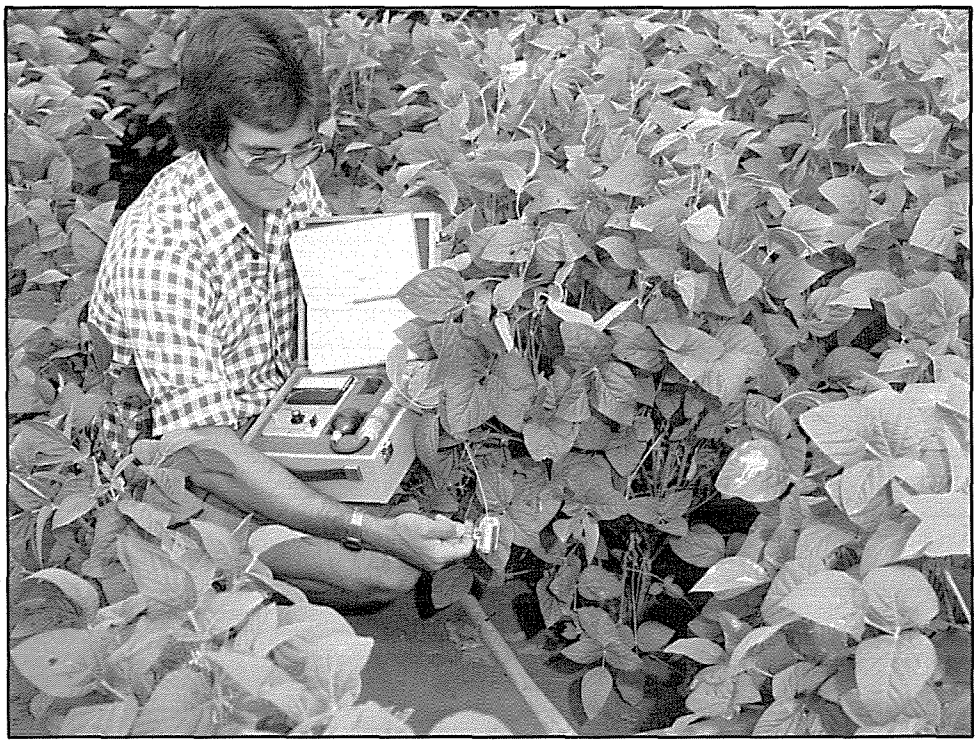
(Existing project: Contract with the Department of Agricultural Technical Services — Soil and Irrigation Research Institute)

Weighing lysimeters at Roodeplaat near Pretoria were again used to obtain precise measurements of water use by wheat during winter and spring, and by soy beans during summer. These measurements satisfied the need for detailed reference data which are indispensable for testing and refining models for simulating the process of water movement through the soil-plant-atmosphere system. Several computer models which simulate the water balance and predict irrigation requirements of the wheat crop have been tested. These models initially tended to underestimate water loss by evapotranspiration. Generally the models failed to account for the large quantities of advective energy which supplement solar radiation energy during the arid winter months when irrigated areas are surrounded by much larger non-transpiring dry land areas. A temperature-based correction factor for advection, when introduced into the Ritchie water balance model, improved the performance of the model considerably. The United States Department of Agriculture irrigation scheduling model, when calibrated for Roodeplaat conditions, also performed well.

The response of wheat and soy beans to the onset of water stress was examined in some detail. Plant responses considered in the case of wheat were the ratio between evapotranspiration and potential evapotranspiration, predawn leaf water potential and the growth rate of leaves. The evapotranspiration ratio and predawn leaf water potential both started to decline rapidly once 80 per cent of the plant available water (PAW) had been depleted from the profile. However, leaf growth showed signs of a much earlier decline near 50 per cent of

The removable rain shield which is used in evapotranspiration studies on soy beans in order to eliminate the influence of rainfall on moisture stresses caused by differing levels of irrigation





A diffusion porometer is used to measure the rate with which water vapour moves through the stomata of a leaf and this indirectly indicates the internal moisture status of the plant

PAW. Closer examination showed that contrary to expectation, very little leaf growth took place at night, probably because of the low night temperatures. In this way daytime sensitivity to turgor pressure and therefore declining soil water status, may begin to dominate the overall growth pattern when temperatures are low.

For soy beans, leaf growth, evapotranspiration, predawn leaf water potential and daytime diffusive conductance all appeared to decline when about 75 per cent of PAW had been depleted.

Considerable attention was paid to the observation of phenological growth stages and to the analysis of yield components associated with the various irrigation treatments. This served to demonstrate certain probable effects of stress at different stages of crop development.

According to an electrical analogy, it should be possible to calculate water movement through plants from measured potential differences if appropriate values of plant conductances can be ascertained. A start has been made with the evaluation of such conductances using measured rates of water loss and potential gradients based on measurements of predawn, covered and exposed leaf water potentials.

This year's results have opened up many potentially fruitful avenues of research which will be further pursued in the coming year.

Chapter 7

Surface hydrology

South Africa is dependent mainly upon runoff reaching rivers and streams for its water requirements, so much so that approximately 90 per cent of the total water consumption is derived from this source. It is estimated for South Africa as a whole, that the total mean annual runoff amounts to approximately 53 milliard m^3 (almost 8,6 per cent of the rainfall), of which an estimated one-third originates in the Black States. Between 50 and 60 per cent of this runoff can be made available for use by means of existing techniques.

In view of the importance of this water resource, it is clearly of cardinal importance for the planning of further development, that estimates of water resources be continuously updated. The accuracy of such estimates will play an increasingly important role in future. It is essential, therefore, that techniques for the calculation of runoff be continuously improved and that hydrological research should continue to enjoy a high priority.

The nature of hydrological research however, is such that it is influenced by several factors over which the research scientist has no control. This usually has the result that research, for example on rainfall-runoff ratios, must be conducted over the long term, since dependable results can only be obtained if adequate opportunity exists for the investigation of all variables to the required degree of accuracy.

An example of such a variable which, together with rainfall and the nature of the catchment, plays a decisive role, is catchment utilisation (for industrial, residential and agricultural purposes) and its effect on the runoff. Human activity in the form of utilisation and management of the catchment can markedly affect the flow in rivers.

With the expected development in various catchments, the need for accurate estimates of the effect of catchment utilisation on river flow has become of great importance. Rivers, impoundments and marshes can be detrimentally affected by human activity such as the extraction of water for irrigation purposes, farming malpractices and township development, to such an extent that its recovery is not that easy. There are normally several methods which may be used to rectify such conditions but the application of incorrect measures is not only a futile expense, it may also result in irreparable damage. It is therefore important that the effect of remedial measures be predicted in advance.

In addition to the detrimental effect on water quality, runoff quantities can also be affected. The best-known example of the latter is the effect of afforestation on runoff. This has led to an amendment of the Water Act to the effect that a permit must be obtained from the Minister of Water Affairs and Forestry before afforestation or deforestation is allowed.

It is clear therefore, that with increasing critical evaluation of water conservation as the demand for water increases, much attention will have to be given to predictions of the effects of changes in land-use and management practices on stream flow, erosion and water quality. Available research data and methods of prediction do not meet with all the requirements, with

the result that further research is necessary. This aspect is receiving attention in the research projects supported by the Commission.

Completed hydrological research projects

During 1978, the first hydrological research projects in which the Commission was involved were completed and the reports ensuing from work were published during 1979. Each of these reports represent a significant contribution to hydrological knowledge in South Africa, and are of considerable value at both operational as well as research level. The reports are the following:

- *The Runhydrograph: Theory and Application for Flood Predictions,* by LAV Hiemstra and DM Francis, Department of Civil Engineering, University of Natal.

  For the development of the runhydrograph of a river containing flow gauging structures, existing hydrographs of the river are mathematically and statistically processed in order to identify important parameters for the runhydrograph. This information can then be used to develop runhydrographs for streams without gauging structures. Families of composite flood hydrographs for any desired return period can then be compiled and which would have great value from a design point of view. For this reason the report has been compiled in the form of a manual in which the use of the technique is presented in such a way as to greatly facilitate its use.

- *A Comparison of the Performance of Selected Conceptual Models of the Rainfall-Runoff Process in Semi-Arid Catchments near Grahamstown,* by PJT Roberts, Department of Geography, Rhodes University.

  This report describes a variety of simulation models tested in the catchments of the Ecca River and its tributaries and which led to the formulation of tentative guidelines for the use of the models for the determination and prediction of the rainfall-runoff relationship. These guidelines are particularly useful for the selection of a suitable model for a specific application. A simple model which can compete with more complicated models with respect to accuracy has been developed. Several of the models tested have been modified to enhance their applicability under general South African conditions. The report, therefore, has made a significant contribution to the use of simulation models in South Africa. Research which led to this report is being continued under a new agreement between the Commission and the University, with a view to further refinements and further investigation of the transfer model parameter values, and will also be extended to the Wilderness catchments.

- *Field Studies, Data Processing, Techniques and Models for Applied Hydrological Research,* by RE Schulze, Department of Agricultural Engineering, University of Natal.

  The report deals with the optimization of input parameters in the development of simulation models, and centres mainly around adaptation of the hydrograph generation technique of the *Soil Conservation Service* (SCS) for application under South African conditions. By means of the SCS technique the expected runoff intensity may be predicted for different frequencies in different catchments. Indications are that the technique will be used on an increasing scale in South Africa and also with respect to studies in connection with soil losses. In conjunction with this work, the kinetic energy of rain (as an important factor in soil erosion and sediment transport) was investigated, as well as rains that cause floods in Natal. To a large extent this report can be regarded as a manual for future research of a similar nature.

  This research is also being continued in terms of a new agreement with the University with a view to further data collection, improvement of techniques and more sophisticated data manipulation.

- *Hydrological Investigations of Small Catchments in the Natal Coastal Belt, and the Role of Physiography and Land-use in the Rainfall-Runoff Process,* by AS Hope and GJ Mulder, Department of Geography, University of Zululand.

  The research work reported in this publication dealt with the collection of hydrological data in and around the experimental catchments in Zululand and the role of physiography in the rainfall-runoff process. The results form the basis for detailed rainfall-runoff process modelling in Zululand, especially with respect to the estimation of model parameters. In this respect the establishment of a hydrological unit map (based on land use, soil type and slope) provides basic catchment data for the area which also has value from other points of view. This research is being continued in terms of a new agreement with the University in order to expand the data base and to allow further testing of the influence of the physiography.

Coordination of hydrological research

Since the establishment of the Coordinating Research Committee for the Hydrological Cycle (CRCHC) in 1977, coordination of hydrological research is being placed on a very sound basis. This Committee, which functions under the control of the Department of Water Affairs, is

responsible for the overall initiation and coordination of research with respect to the hydrological cycle.

One of the first tasks undertaken by the CRCHC was a survey of all current hydrological research work being done in South Africa. All universities, government departments and other organizations having an interest in hydrology, were involved in the survey. For the purpose of the survey, research associated with the hydrological cycle was catagorised as atmospheric processes, catchment processes, surface runoff, mathematical modelling of hydrological processes, and data banks of hydrological data.

The survey showed that there are currently 53 research projects being undertaken in these fields. Of these, 34 are undertaken by government departments — mainly the Departments of Water Affairs, Forestry and Transport (Weather Bureau) — and the remainder by different universities, mainly the Universities of the Witwatersrand and Natal. The Water Research Commission supports 14 of these projects directly or indirectly by providing either funds or personnel. More details of the projects in which the Commission is directly involved are given later in this chapter. The CRCHC is also aware of 19 other projects which touch on the hydrological cycle.

In addition the CRCHC also attempted to identify shortcomings in hydrological research. The general conclusion was that the following fields were in need of attention, *viz* droughts — their frequency, intensity and distribution; methods for the estimation of rainfall distribution (including rainfall in mountainous catchments); the effect of catchment utilisation and management of runoff; and sediment load of catchments and factors which influence it.

At this stage the highest priority is being awarded to the effect of catchment utilisation and management of runoff, and during the course of 1980 specific problems and gaps in this field will be identified.

RESEARCH PROJECTS

Research on water resources

(Existing project: Contract with the University of the Witwatersrand — Hydrological Research Unit)

Faced with the problem of developing a water supply from a river which has never been gauged, or for which measurements of flow are available for only a short period, the engineer is obliged to rely on procedures for estimates of run-off and flood occurrences as outlined in the Hydrological Research Unit's Water Resources Survey of 1969 (HRU Report 2/69) or on some other similar technique. The aim of the current project is to improve on the information provided in the 1969 survey.

If a series of flow data is available, several problems can be solved, such as, establishing the volume of storage required to meet a desired draft from surface waters, predicting the wash-off of pollutants from a catchment or any of a wide variety of problems in which a knowledge of the fluctuations of streamflow is needed. Where this cannot be provided from observations it must be generated synthetically. It is also aimed at providing long hydrographs (covering at least 50 years) at many places on rivers throughout the Republic; other statistics relevant to the study of water resources will also be reported. In this regard it is expected that information in respect of the Vaal and the Limpopo Rivers (including the Olifants), will shortly become available.

Hydrological investigation of rural catchments in Natal with specific reference to flood events

(New project: Contract with the University of Natal — Department of Agricultural Engineering)

In June 1979 a first five-year phase of the hydrological investigation into rural catchments came to an end and a second five-year project with similar aims commenced in order to extend the available data base for more accurate statistical analysis. Important research findings to have emanated from the previous project include applications of, and suggested improvements to, the Huggins and the Soil Conservation Service (SCS) rainfall-runoff models; the areal distribution of rainfall by trend surface analysis; the influence of topography and vegetation on soil moisture distribution; hydrological studies of soil loss with particular emphasis on rainfall erosivity; and a study of potential flood producing rainfall in Natal. The present work envisages refinement of the established relationships. On the technological side computer programs with wide application in hydrological studies, particularly in regard to data processing, have been developed. Five research reports and seven scientific papers have resulted from this research project.

Research into the SCS and other models and extreme rainfall events in South Africa, both of which are applied in day-to-day decision-making in hydrology, is continuing in the present phase of this project.

The development of a data bank of autographic rain-gauge records in South Africa

(New project: Contract with the University of Natal — Department of Agricultural Engineering)

Many engineering design and control problems centre around depth-duration-frequency information, i.e. the expected magnitude of a storm event of a given duration and for a given return period. In South Africa the basic data for such calculations are not yet readily available in computer-compatible, i.e. digitized form, and this project is making a contribution towards meeting this need. Computer facilities in the Department of Agricultural Engineering at the University of Natal in Pietermaritzburg have therefore been extended and a start has been made at digitizing data from autographic rain gauges at key stations. An important by-product of this research project will be the information obtained on the kinetic energy of rainfall, a most significant factor in the estimation of soil losses, and the production of sediment from catchments which will eventually be deposited in storage dams.

This project is relevant to the project on the digitization of autographic rainfall data carried out by the Weather Bureau. The digitization of the Natal data will be done by the University of Natal and the results will be incorporated in the rainfall databank of the Weather Bureau.

A part of the computer facilities of the Department of Agricultural Engineering at the University of Natal which is used in the project on a data bank for autographic rain gauge data

An agrohydrological study of Natal

(New project: Contract with the University of Natal — Department of Agricultural Engineering)

As a result of the intensive agricultural activities in Natal it is imperative that the province's water resources should be carefully managed and therefore be thoroughly assessed. Since this includes research into the agricultural use of water, a study of the agrohydrology of Natal commenced in June 1979.

The first task to be undertaken in this regard has been a detailed and distributive long-term water balance of Natal. At each of over 1 000 grid points over the Province the potential evapotranspiration for selected crops and actual evapotranspiration for given soil depths and textures, as well as soil moisture deficits and irrigation requirements have been calculated by the water balance approach. Forthcoming results will be of use in irrigation scheduling and crop planning.

Other work to be undertaken in this project will include probabilistic studies of rainfall and of drought occurrences.

Hydrological research in Zululand

(New project: Contract with the University of Zululand — Department of Geography)

A previous contract with the University of Zululand concerning hydrological research in the Natal coastal area terminated in May 1979. In that project the rainfall-runoff process in catchments of the Natal coastal belt, was investigated, as well as the role of physiography and land-use. Other catchments were also used in the investigation of physiography and land-use in the rainfall-runoff process.

Detailed pedological, vegetal, geological, hydrometeorological and hydrological data have been collected and processed for the Zululand Research Catchments. These data will provide the foundation for a Hydrological Response Unit model which is to be developed in the next five years of the new project.

The investigations relating to the importance of physiography and land-use in the rainfall-runoff process will make a significant contribution towards water resources engineering in Natal. A procedure was developed whereby parameters for the Pitman Monthly Model could be determined from catchment physiography, thus enhancing the reliability of this Model in ungauged areas.

The following two aspects will also be investigated:

- The development of procedures for predicting catchment antecedent moisture conditions for application in storm flow simulation models.
- The monitoring of water quality in terms of its chemical and/or sediment load of the Zululand catchments and its relation to agricultural practices, land-use and hydrometeorological phenomena.

Research during the year under review has been focused on the antecedent moisture component of the SCS Model. This component of the Model is regarded as being second only to rainfall in importance for predicting storm flow volumes. A refined procedure for estimating antecedent moisture conditions has been developed and preliminary investigations based on catchments in Zululand have revealed significant improvements in the prediction of storm flow volumes.

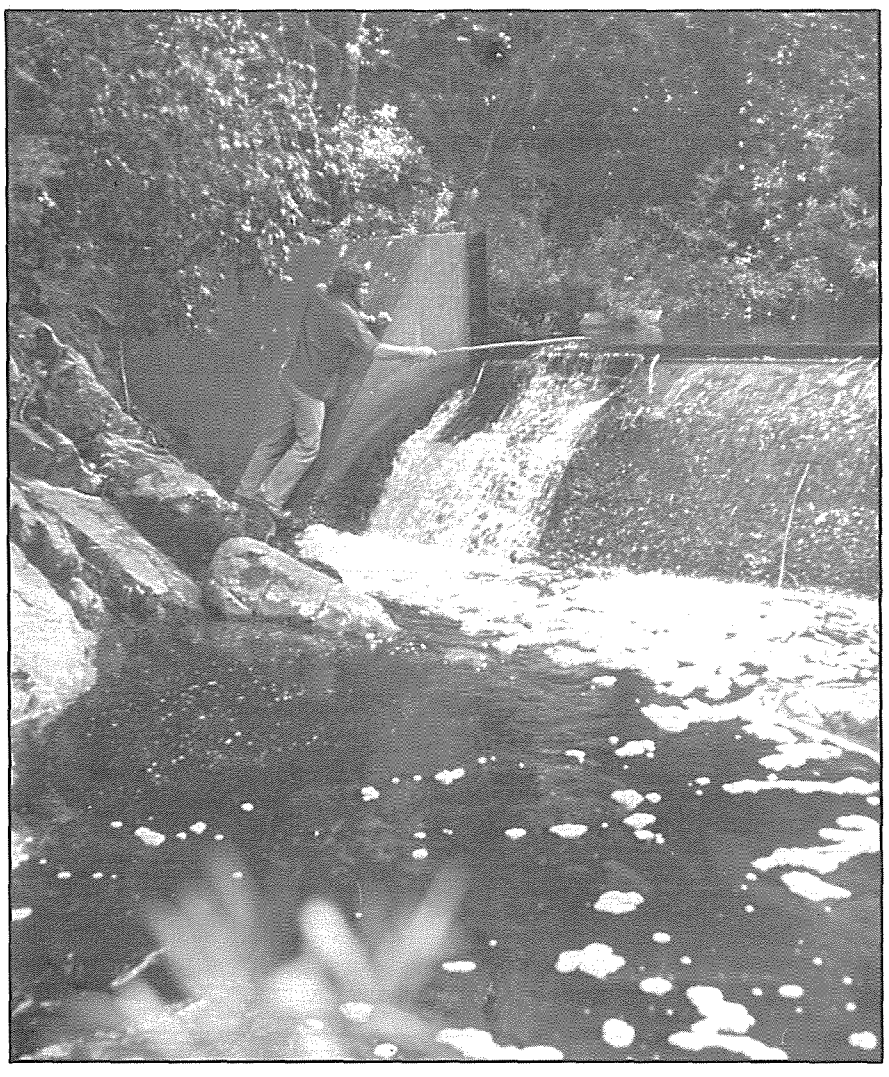
Hydrological research in the Ecca and Wilderness catchments

(New project: Contract with Rhodes University — Department of Geography)

The routine collection of hydrometeorological data in the Ecca catchment, started during a contract with similar aims, *viz.* modelling of rainfall-runoff relationships, has been continued. By September 1979 a total of 8 discrete flood events had been recorded. The most severe of these events were caused by two storms of several days' duration during the third weeks of July and August. The first storm produced twin flood peaks of 36 m^3/s, as well as lower ones, while the second storm produced a highest peak of 39 m^3/s, followed by lower ones. The gauging structures withstood the floods without any sign of strain. The floods caused heavy deposition of sediment and heavier materials in the weir-pools of the three weirs.

Data collection in the catchment has been extended to salinity monitoring by regular sampling of discharge at the five flow gauging points, as well as groundwater monitoring at 10 boreholes, both in terms of water levels and salinity of groundwater. These programmes are in the process of being extended with the installation of an electrical conductivity recorder at the main weir and autographic water level recorders on at least three boreholes. Furthermore, two additional rain gauges and an additional evaporation pan are being installed in the catchment.

In the Wilderness catchment a start was also



A research worker is seen removing an obstruction at a weir on a river in the Wilderness catchment area

made with the acquisition, coding and processing of rainfall records for about 30 Weather Bureau rainfall stations, 7 Department of Water Affairs flow gauging stations and 4 evaporation stations.

The data processing and storage system has been improved with the purchase of a new digitizer and a powerful supporting microcomputer system, which will make break-point digitizing possible.

Further research work included the loading of all existing programsl for the catchment models tested during the previous contract, as well as some additional model programs, on to on-line computer files for future testing and use. Comprehensive literature surveys on topics related to the research programme have also been completed.

The research programme for 1980 reflects the continuation of the trend established during 1979 namely a primary emphasis on additional catchment model testing, as well as on salinity monitoring and testing in the Ecca catchment, and a secondary emphasis on sediment monitoring.

The 1980 research programme for the Ecca catchment comprises the following:

- The continuing collection, manipulation and storage of hydrometeorological, salinity and groundwater data for the catchment together with maintenance of the gauging network.
- Development and testing of both types of deterministic rainfall-runoff models, and data collection programmes to meet any specific requirements of these models.
- Development and testing of models describing catchment mineralization.

- Acquisition and processing of hydrometeorological data from other semi-arid catchments for future parameter transfer investigations.

- Pilot studies of erosion and sedimentation processes.

The 1980 research programme for the Wilderness catchment is as follows:

- Continuation of the processing of hydrometeorological and physical data for the area.

- Modelling studies for the provision of hydrological data to the National Research Institute for Oceanology of the CSIR estuary/lake model of the Lakes system, as well as the initiation of parameter transfer investigations.

Digitizing of autographic rainfall data

(New project: Contract with the Department of Transport — Weather Bureau)

Autographic rainfall records contain considerable information which is best utilised only when digitized in computer-readable form. In this respect there is an urgent need amongst hydrologists, agriculturalists, engineers and meteorologists (attached to organizations such as the Department of Water Affairs, Forestry and Agricultural Technical Services and various universities) for digitized data in computer-readable form for use in research projects.

The Weather Bureau is responsible for the project since it already has a network of stations throughout the country and because it is a function of the Weather Bureau to collect, store and disseminate meteorological data. The aim is firstly to digitize, and correct and make the information on approximately 163 000 cards in the possession of the Weather Bureau available to users. Because various other organisations are also in possession of similar digitized data, the project will also be aimed at bringing together all available autographic rainfall data in a central data base in order to ensure that:

- the data from the various organizations will, whenever possible, be of a similar quality;

- there will be no unnecessary duplication of work;

- the digitized data is included in the data base at the Weather Bureau so that it can be made available to any user at any time; and that

- basic processing of general importance can be done according to a standard method so that processed data can be made generally available so as to eliminate unnecessary processing by different users.

Chapter 8

Flood occurrences and flood damage

During the past decade disastrous floods have not been an uncommon occurrence in the Republic. Enormous damage can be caused in terms of loss of life, damage to property, and disruptions of communications, transport links and essential services.

Increasing utilization of flood plains of rivers for agricultural, industrial and residential purposes will lead to future drastic increases in damage in flood plains if injudicious flood plain utilization is not limited and flood control measures are not applied.

In 1975 the Commission, at the request of the Department of Water Affairs, initiated support for research into flood damage. Agreements were entered into between the Commission and the Universities of the OFS and Stellenbosch in terms of which the Institute for Social and Economic Research (ISER) and the Bureau for Economic Research (BER), respectively, would determine the damage resulting from the 1974 floods in certain stretches of the Orange, Vaal, Riet, Seekoei, Hartbees, Sondags, Vis and Sak Rivers.

These investigations dealt with the development of surveying techniques and methodology for the determination of damage which had already resulted as well as with the prediction of future damage. The work included the identification of different flood damage categories and the relationship between flood duration and extent of damage. Actual flood damage resulting from the 1974 floods has also been determined.

In 1977 ISER, with financial support by the Commission, also commenced with an investigation into the flood damage of the 1975 flood in the Vaal River.

The research on the 1974 floods has progressed well and four reports, discussed in the previous annual report, have already been made available to interested organizations. Copies are available on request. Part V which deals with the 1975 flood damage in the Vaal River is expected to be released early in 1980. In the meantime ISER is in the process of compiling Part VI which will serve as a manual for the determination of flood damage. A manual of this nature will be of great value to the Department of Water Affairs and other organizations for the determination of future flood damage.

The Hydrological Research Unit of the University of the Witwatersrand has for some years now been engaged in research into flood occurrences in terms of an agreement with the Commission. Investigations have been carried out in respect of the Vaal River (Vaal Dam), Crocodile River (Hartbeespoort Dam), Pongola River (Pongola flood plain) and with respect to rainfall and flood occurrences in the SWA/Namibia area. The following two interim reports, which are available for distribution have appeared:

- *A Numerical Hydraulic Model of the Pongola Flood Plain* by WV Pitman and HW Weiss. Report No 2/79 of the Hydrological Research Unit of the University of the Witwatersrand; July 1979.

  This publication reports on a mathematical hydraulic model which may be used to predict the hydrology of the Pongola flood plain below the Pongolapoort Dam. It relates to the water levels and recharge of the water in the pans in the flood plain below the dam and which play an important role in the ecology of the plain. It can be used to determine the quantity and rate of release of the water from the dam in order to maintain existing ecological conditions of the plain. The ecological investigation is being done by the University of Natal as part of the CSIR's programme in connection with Inland Water Ecosystems.

- *An Analysis of SWA/Namibia Rainfall Data* by BFC Richardson and DC Midgley. Report No 3/79 of the Hydrological Research Unit of the University of the Witwatersrand; August 1979.

A characteristic flood scene after a severe storm. The Water Research Commission supports projects on flood damage and occurrences

This report consists of an analysis of all available daily rainfall data for the area with respect to the probable maximum precipitation and the duration and frequency of such downpours. These data will be very useful in predictions and estimates of floods for the area. Accurate predictions of flood levels are of the greatest importance in the design of flood control measures and the prevention of flood damage.

RESEARCH PROJECTS

Research on flood occurrences

(Existing project: Contract with the University of the Witwatersrand — Hydrological Research Unit)

The main aim of this project is to obtain information which could be used for routing the runoff as a result of floods in a catchment through the river system and through the downstream flood plain, in such a way as to minimize damage. As mentioned in the introduction, investigations to this end were done at Vaal Dam, Hartbeespoort Dam, Pongola flood plain and SWA/Namibia.

Procedures and computer programs were devised and developed for aiding floodgate operation at Vaal Dam so as to minimize downstream damage. These techniques were also applied at the Hartbeespoort Dam, where the much smaller catchment responds within hours rather than days. A survey of downstream flood damage was undertaken at the Hartbeespoort Dam so that the economics of flood control by means of the proposed techniques could be studied.

Revised flood peaks of various return periods for Vaal River floods have also been calculated and routed through the Barrage reach to establish the probable flood contours. This information will be valuable in flood damage studies.

As far as investigations with regard to the Pongola flood plain are concerned, a numerical model has been successfully devised for simulating the behaviour of the water levels in the pans. Although not fully calibrated

the model permits a first estimate to be made of the probable quantity of water that would have to be released from the Pongolapoort Dam to preserve the ecology of the pan system.

In the daily rainfall data investigations for SWA/Namibia for use in flood estimates, all obtainable information has been committed to edited tapes and copies given to the Weather Bureau, Pretoria, and to the Department of Water Affairs in Windhoek and Pretoria.

As part of this agreement a promising start has also been made in the field of urban hydrology and a storm water management model is being tested.

Research on flood damage

(Existing project: Contract with the University of the Orange Free State — Institute for Social and Economic Research)

During the year the fourth report on flood damage research appeared under the title "'n Evaluering van die problematiek rondom vloedskadebepaling in die Republiek van Suid-Afrika". The report was compiled in cooperation with the Bureau for Economic Research (BER) of the University of Stellenbosch and marked the closure of the joint research effort between ISER and BER in this respect. The report offers a resumé of the problems encountered during determination of flood damage; recommendations with regard to a possible future *modus operandi* in the investigation of flood damage and further research which may be done; as well as a discussion of the applicability of the research results. A few of the recommendations are discussed here.

It has been recommended, *inter alia,* that the method developed for damage classification during the investigation, should be employed in future investigations. On the whole, damage is divided into tangible and intangible damage, whilst the former is further subdivided into primary (direct and indirect) and secondary damage.

As far as intangible damage is concerned (loss of life, damage to historic buildings, etc.), it was found that as long as there were no clear norms for the measurement of damage a complete description, classification and quantification of only those facets of non-tangible damage which lent themselves to such a description, would have to suffice.

Care must be exercised in measuring tangible damage and during each investigation careful consideration must be given to that damage which should be included and that which should not. The approach to the determination of flood damage (national, regional or individual) plays an important role in this respect.

A recommendation was made that secondary (second and higher order effects) damage should be ignored for several reasons.

The complete determination of indirect damage is an almost impossible task and must, of necessity, be limited geographically. With respect to farming, for example, it is recommended that the determination of indirect damage be limited to persons who also suffered direct damage.

Specific recommendations have been made with respect to incomplete or unfinished information. In particular accurate information on the topographic, hydrological and even pedological characteristics of flood plains is required for predictions of expected flood damage.

For those stretches of river where meaningful loss functions were obtained it will be possible to make use of these functions in future floods. It remains desirable however, to verify results obtained in this way on a small scale within river stretches.

When the approach is to determine flood damage without the occurrence of an actual flood, it will be necessary to compile detailed maps of the topography and land use patterns in the relevant flood plains. The reliability of such flood damage results will naturally only be determined when tested against an actual flood. The stage has now been reached where, for the development of flood damage prediction models, the *ex post* and *ex ante* approaches should be applied together.

From research on the Vaal River with reference to the 1975 flood, it was found, contrary to general expectations, that the agricultural information collected during these surveys did not render much information. Except for numerous smallholdings along certain stretches of the river and which are more residential in nature, the rest of the agricultural usage of the flood plain is quite extensive and diversified and it would appear that little can be expected in terms of meaningful loss functions in the area. The investigation into the Vaal River flood damage of 1975 will probably further refine the residential damage functions determined in the Orange River investigations and could allow for more accurate predictions in this regard.

As far as flood damage control is concerned, the accent was placed mainly on structural aspects (dams, emergency weirs, etc.). It is advisable that attention should now be given to non-structural aspects (statutory limitations on flood plain utilisation, improvements to warning systems, etc.) as an integrated component of flood control planning within the broader context of flood plain planning, where some of the flood plains may be identified as sub-national areas and treated as such.

Chapter 9

Rainfall stimulation

At the current rate of economic, agricultural and social development it is anticipated that the Republic will experience a severe water shortage shortly after the turn of the century. In view of these circumstances the Commission deems it essential to investigate, in cooperation with the Department of Water Affairs, all possible alternative sources of water. In this respect, increased rainfall by means of artificial stimulation, should this be possible, would probably be the best method. It is, therefore, of the utmost importance for the future of South Africa to establish whether this is possible and to what extent it will influence runoff.

Reports from various parts of the world such as Israel, the USA and Russia, indicate that precipitation can be increased with a reasonable degree of success, by means of cloud seeding with substances such as silver iodide and dry ice. Statistically, however, it is difficult to provide absolute proof of these claims. As a result of research conducted over a period of 17 years in Israel it is claimed that under certain circumstances rainfall can be artificially increased by between 15 and 23 per cent.

A report entitled *The Management of Weather Resources* (1978) of the American Weather Modification Advisory Board contains the following statement about weather modification in the USA in general:

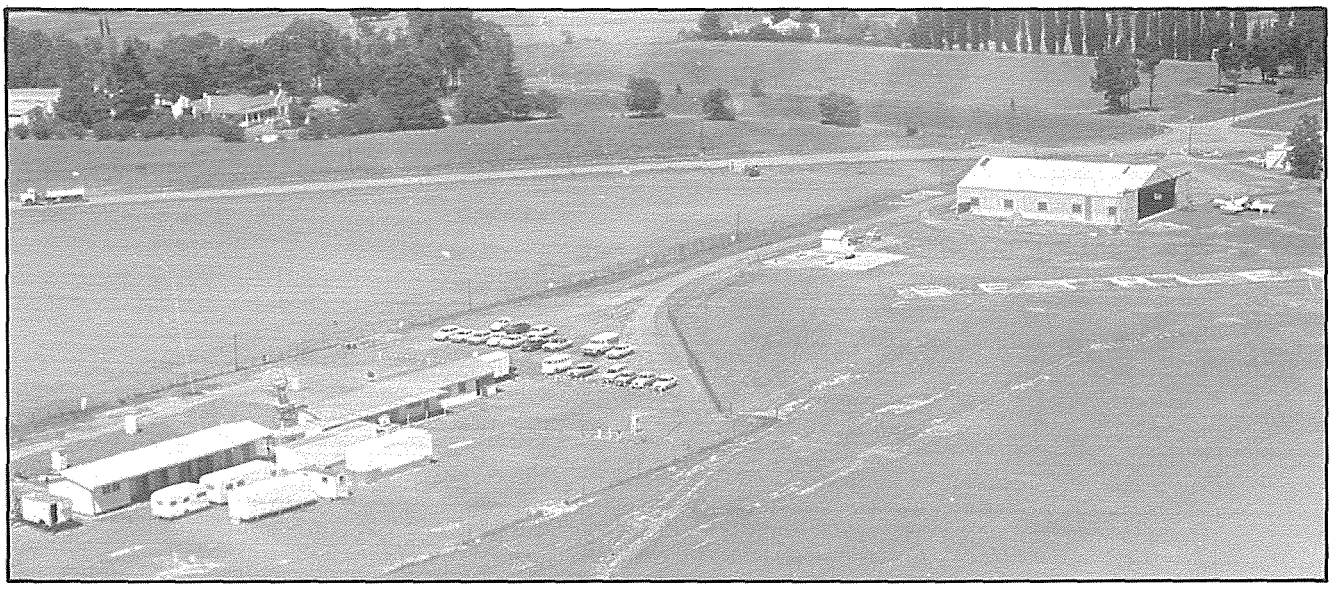
"It seems probable that a much intensified and steady programme of scientific inquiry over the next two decades will yield regionally-important increases in mountain snowpack in the 1980's, increased rainfall in areas like our High Plains and Midwest by the late 1980's, reduced hurricane winds and hail damage by the 1990's. The margins of man-produced weather change would be 10 to 30 per cent increases for snow and rain, wind reduction of 10 to 20 per cent in certain hurricanes, and hail reduction up to 60 per cent", and further; "The case for hastening progress along these lines is very strong. The economic benefits of delivering more water in the right places ... for farming, including irrigated crops, for hydroelectric power and for municipal and industrial water supply ... seem very likely to outweigh the costs by impressive amounts."

The same report mentions, that at the time of reporting, experiments with respect to rainfall stimulation and hail suppression have been carried out in 74 countries, but that these experiments were generally initiated without intensive prior scientific investigation into the cloud physics and dynamics and the precipitation mechanism of the relevant region. Results obtained were therefore not very meaningful.

The Department of Water Affairs and the Commission are at this stage only interested in the hydrological effects of rainfall stimulation, i.e. in the possible increase of water yield (in the form of river flow) in the relevant catchments. In view of the possibilities offered by rainfall stimulation as an additional source of water, the Commission deems it advisable that even now, background information should be collected and that the expertise in the field should be developed in the Republic. In the process, overseas expertise and data will have to be used intensively. To this aim the Commission supports two separate projects.

One project is being executed at Bethlehem by the Weather Bureau (in terms of a contract with the Department of Transport) in cooperation with the Department of Water Affairs and consists of two phases *viz.* rainfall stimulation and the effect of any increase in rainfall, as a result of cloud seeding, on the hydrology of the experimental catchments. Both facets are being investigated simultaneously but a routine cloud seeding programme will not be commenced until the background information pertaining to climatological and meteorological circumstances has been obtained.

The other project is being undertaken at Nelspruit in terms of an agreement with the Laeveldse Koöperasie



An aerial photograph of the Weather Bureau's research station for artificial rainfall stimulation at Bethlehem in the Orange Free State

Beperk and deals with the potential for rainfall stimulation in the Lowveld. For the execution of the project the Co-operative has employed the services of a specialist group of research scientists from the USA. Mention should also be made of the fact that the Co-operative maintains an operational hail suppression project in the Lowveld, but that the research sponsored by the Commission does not deal with hail suppression, but with the effect of cloud seeding for hail suppression on the local rainfall and in general with the rainfall stimulation potential of the Lowveld.

RESEARCH PROJECTS

Research on the artificial stimulation of rainfall at Bethlehem

(Existing project: Contract with the Department of Transport)

This project which has now seen two complete seasons has a twofold objective, firstly, basic scientific research in connection with cloud physics and dynamics and the mechanism of precipitation of the particular area, followed by specific operational cloud seeding tests to determine the possibility of artificially increasing the rainfall in the North Eastern Free State. Secondly, it is proposed that the effect of any increase in rainfall on the hydrology of the experimental catchments will be determined, for which purpose a detailed investigation of the current rainfall-runoff pattern will be made in order to serve as basis for the quantitative evaluation of the effects of the seeding programme.

As far as the first aspect is concerned, progress was impeded to some extent by the lack of an aeroplane that could be used in all weather conditions, but nevertheless, important results were forthcoming and research direction has become clearer. Some of the more important preliminary results include:

- Clouds with a high liquid water content at approximately −10°C occur frequently and are a prerequisite for successful cloud seeding.
- Natural ice crystals occur in relatively high concentrations at a temperature of −10°C. If this preliminary result is verified it will mean that seeding, with the aim of promoting ice formulation, cannot be applied successfully.
- First radar echoes occur frequently in areas where the temperature is higher than freezing point. This means that the coalescence process probably plays an important role in the precipitation process in the project area.
- In the precipitation from stratiform clouds almost no liquid water is present at heights where the temperature is below 0°C. This would indicate that no method of cloud seeding will yield results under these conditions.

Subject to the verification of these preliminary results, it may be concluded that in the design and execution of a routine cloud seeding programme it is desirable to concentrate on the seeding of cumulus clouds in order to obtain best precipitation results. This means that an effort should be made to increase the depth and cross-sectional area of the clouds by seeding rather than augmenting a shortage of ice nuclei. A high priority will be afforded to the identification of weather conditions in which clouds will react favourably to such seeding.

The rainfall observation network is still being extended. By the end of winter in 1979 a network of more than 100 recording rain gauges had been erected, 22 of which are completely automatic weather stations. In this respect excellent cooperation has been received from the farming community and the local authorities in that they regularly reported rainfall figures.

The second aspect of the project also progressed well, *viz,* the effect of any increase in precipitation (as a result of cloud seeding) on the hydrology of the experimental catchments. This task is being undertaken by the Department of Water Affairs.

Research on the stimulation of rainfall at Nelspruit

(Existing project: Contract with the Laeveldse Koöperasie Beperk)

The main objectives of this project are to obtain additional scientific information on the effect of cloud seeding for hail suppression on rainfall and to assess the potential of the Nelspruit area for rain augmentation. The Laeveldse Koöperasie Beperk has for several years been involved in a cloud seeding programme for hail suppression in this area, and information resulting from this programme, is also used in the project financially supported by the Commission.

To achieve the project goals, it is necessary to conduct a detailed study of the climatology of the area. The study can be divided into three categories according to order of magnitude:

- Synoptic scale studies designed to reveal the synoptic scale control mechanisms which give rise to significant rain and/or hail events in the area.
- Meso or cloud-scale studies in which the characteristics (area, height, directions of movements, etc.) of the dominant precipitation-producing clouds are determined.
- Microscale measurements of the processes of cloud physics that lead to the production of precipitation-size elements which reach the ground as usable moisture.

The research is being conducted by a team of scientists at the University of Virginia USA and contracted by the Co-operative. The team's efforts are divided between field work at Nelspruit and studies at the University of Virginia.

During the year under review significant progress was achieved.

As far as the synoptic scale studies are concerned, records of South African rainfall, surface climatologies and rawinsonde (from radio windsonde), generously provided by the South African Weather Bureau, have been transferred to the research team at the University of Virginia. Data from a total of 350 rainfall stations within and surrounding the target area have been extracted. Initial analyses indicate high monthly correlations between rainfall in the target area and surrounding segments. This suggests that large (synoptic) scale events are responsible for the significant rainfall events within a 200 km radius of Nelspruit. Computer programs

A Lear jet equipped with special instruments to determine cloud properties in the investigation of rainfall stimulation in the Nelspruit area

are being used to analyse the complete set of historic data from the Nelspruit recordings. Different techniques (total moist static energy and convective storm indices) are being used to determine whether one or more convective storm indices can be used to describe the hail and/or storms in the Nelspruit area.

A two-dimensional synoptic model has been operated for a cross-section which runs at right angles to the escarpment through Nelspruit. It is hoped that this model may be used as an aid in stratifying the synoptic conditions that produce the important precipitation events in the region.

With respect to mesoscale studies the set of radar records gathered at Nelspruit since November 1974 will be studied to determine cloud dimensions and movements, areas favouring storm generation and subsequent life cycles associated with the synoptic classifications defined by the studies in the previous section.

In connection with the cloud physics studies a cloud physics instrumentation package was purchased and installed in one of the Nelspruit Learjets. This system is built around a Particle Measurement System's 2-D cloud probe and data acquisition system. The 2-D probe captures images of cloud droplets and ice crystals in a size range between 0,05 and 1 mm in diameter and is of great importance in the investigation since in-cloud precipitation-forming mechanisms are active within this range.

Additional equipment has been designed to analyse the outputs from the airspeed, altitude, temperature and liquid water sensors also installed in the Learjet. Initial results obtained from flights during the last rainy season suggests that only about 20 per cent of the moisture or water vapour involved in some of the storms reaches the ground in the form of rain. The reasons for this low precipitation efficiency will be further investigated.

The cloud physics measurement programme will be speeded up next season so that a representative sample of the cloud microphysical processes active in the local precipitation process can be obtained.

Chapter 10

Desalination

The Commission continues to regard the development and evaluation of desalination techniques under local conditions as a very important component of the national research effort to ensure a sufficient supply of fresh water of suitable quality for the future.

The Commission currently supports four research projects with regard to desalination. Three of these are existing projects and deal with the desalination of sea water by means of reverse osmosis at Swakopmund (South West Africa), the development of membrane support systems and modules and the desalination of treated sewage by means of reverse osmosis and ultrafiltration. These projects made good progress during the year under review.

As far as reverse osmosis as desalination technique is concerned, the importance of effective pretreatment of the feed water and its influence on the utilization of membranes were very clearly illustrated. Especially in the case of the project on the desalination of sea water at Swakopmund, problems were experienced by the end of 1978, namely that the conventional pretreatment system could not produce water to satisfy the requirements of membrane suppliers. These problems caused a considerably delay in the evaluation of the performance of the various reverse osmosis units and membranes. A solution to the problem was however found by the National Institute for Water Research (NIWR) of the CSIR by applying the so-called UVOX process (chlorination and exposure to sunlight) which could supply water of excellent quality in a pilot scale plant. It is expected that the final report on the findings and a manual for design and operating criteria for the desalination of sea water will be finalised by the end of 1980.

The project on the development of membrane support systems which is being undertaken by the NIWR in collaboration with the University of Stellenbosch made good progress during the year. An important development in this regard is that a local firm intends to evaluate the membranes which were produced by the University in a locally produced desalination unit.

A fourth project dealing with desalination by means of ion exchange was commenced during the year. The project arose from an earlier investigation on the treatment of waste water which was financially supported by the Commission, the contract for which came to a close at the end of 1978. The feasibility of the process will now be tried out on a larger scale. This research is being done on a partnership basis in terms of an agreement between the Commission, the University of Cape Town and an industrial enterprise. It provides for the planning, design, construction and operation of a 100 m^3/d pilot plant for the desalination and tertiary treatment of secondary purified sewage. The pilot plant will be constructed on the new site of the sewage works on the Cape Flats and the same purified sewage used for the reclamation plant (reported on in Chapter 2) will be used. This will allow comparison on an equal basis of physical-chemical reclamation with ion exchange for the production of potable water.

Although the Commission does not currently support any research on other desalination processes, contact is nevertheless maintained on various levels thereby keeping abreast of developments and their applications in the technology.

Research on and development of desalination of sea water at reverse osmosis pilot plant, Swakopmund

(Existing project: Contract with the Department of Water Affairs (South West Africa) and the CSIR — National Institute for Water Research).

In view of projections of water requirements indicating a need for additional water sources in the coastal area of South West Africa in the early 1980's, a project on a pilot plant scale was instigated with the aim of obtaining vital data for the design of a full-scale sea water desalination plant on the coast.

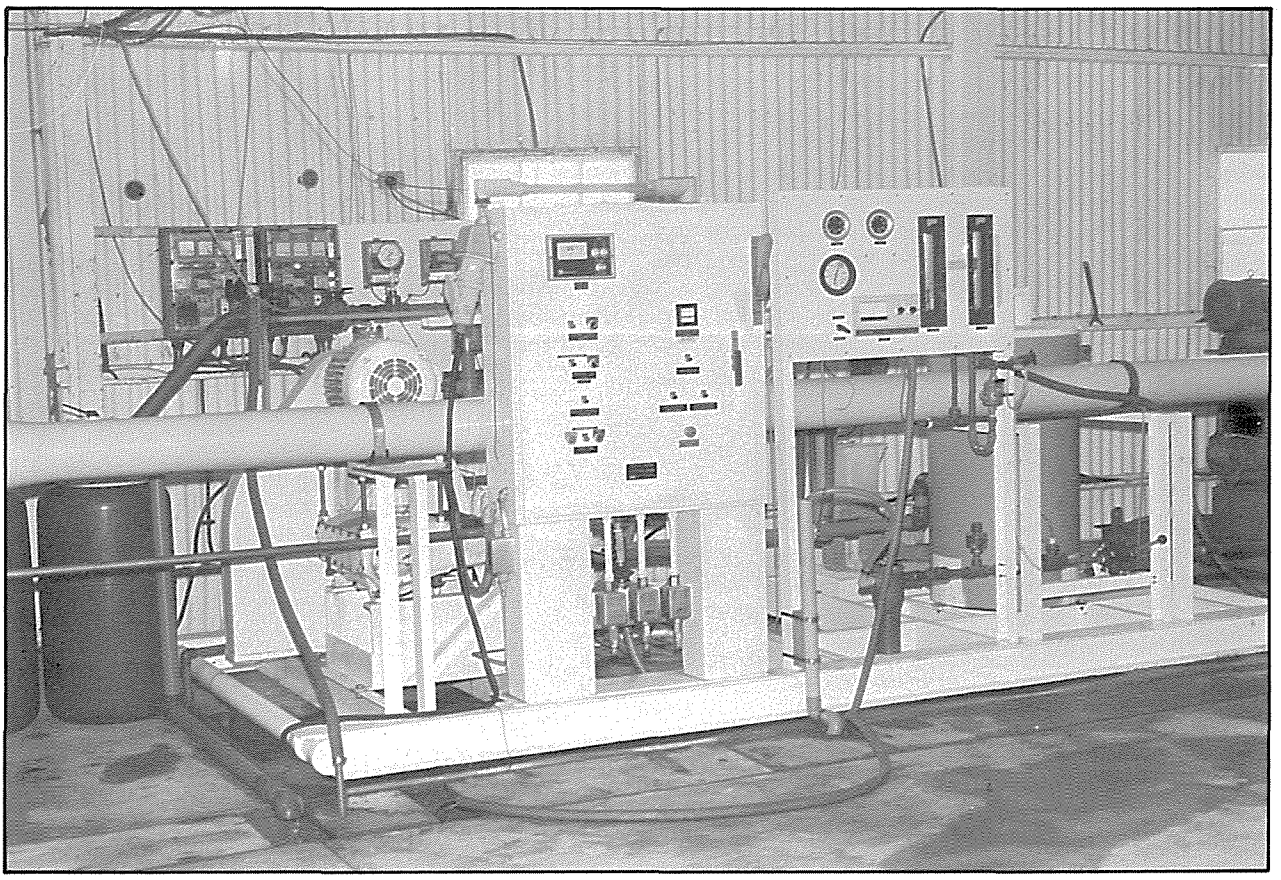
The main objectives of the research programme are to establish design criteria for a simple and inexpensive pretreatment method for raw sea water and to evaluate the performance and lifetime of various commercially available sea water reverse osmosis (RO) membrane systems.

Pretreatment tests were initiated in March 1978 and concentrated mainly on the application of known coagulation/flocculation and subsequent sedimentation/filtration or flotation/filtration procedures. The sea water was subjected to dosages of chlorine (5 mg/ℓ), aluminium sulphate (25 mg/ℓ) and polyelectrolytes (0,1 mg/ℓ) in attempts to remove plankton and other suspended solids. Both pretreatment procedures produced satisfactory results during the months July to October 1978, a period noted for low water temperatures along the west coast.

From October 1978 onwards and for unknown reasons the methods applied no longer achieved the quality standards laid down for feed water to the membranes by the suppliers of RO systems. Despite intensive investigation and numerous modifications to the test parameters, the applied pretreatment failed to produce a water of satisfactory quality. It seemed obvious that the coastal waters had undergone a change, probably related to "up-welling", for which the area is well-known.

A solution to the problem was finally found by chlorinating sea water and exposing it to sunlight (the UVOX process) for a period of 3 days during which it was found that the quality improved to such an extent that simple filtration produced an acceptable feed water

Pretreatment of sea water that has to be desalinated comprises chlorination and exposure to sunlight. In the picture two of the dams constructed at Swakopmund for the pretreatment of sea water can be seen



A reverse osmosis unit which is used at Swakopmund in the research on the desalination of sea water

quality. Two large ponds were constructed to allow for the radiation of sufficient water supplies to keep the RO units operating on a continuous basis. The system which has been in operation since February 1979 has proved to be simple and inexpensive. A paper based on the experience and data obtained with this pretreatment method was presented at a conference in Nice during October 1979.

Three RO units, operating on different principles, have to date been tested in parallel. Running times have been adversely affected by pretreatment and mechanical problems and a fair evaluation of performance and lifetime will therefore only be possible in 1980.

Product water from all three units, which was of a high quality, was pumped into the water distribution system of the Swakopmund municipality after minor adjustments.

Research on the development of membrane support systems and modules

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

During the year under review the most important aspect of the project was the emphasis placed on the construction and completion of a number of important process units and which enhanced the membrane production capability.

The tube winder and continuous casting facility for tubular membranes has been rebuilt and is now

mounted vertically, thereby overcoming a number of technical casting problems and enabling air drying and leaching operations to be more satisfactorily controlled. It is now possible to produce cellulose acetate membranes continuously and achieve consistent results. Locally produced membranes have been fitted into a commercially available tubular membrane support system and tested under field conditions on reclaimed sewage effluents. Initial results are promising and the work is continuing.

The batch casting of 'second generation' composite membranes in tubular supports has also been successful, but many problems remain to be overcome in this area.

A computerized optimization technique for controlling the multitude of operating variables during the casting of cellulose acetate membranes has been developed. This should prove to be of considerable use in reducing the number of trial runs required to assess the effects of making progress changes.

Research on the desalination of treated sewage

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

Processes for the reclamation of sewage effluents are finding application in many parts of the world. However, they all suffer from the disability that inorganic salts present in the sewage effluents are not removed and tend to build up within the cycle of use, reclamation and reuse. This build-up of salts impairs the reuse potential of the reclaimed water. In terms of the contract the National Institute for Water Research has been evaluating the application of reverse osmosis and ultrafiltration for the desalination and simultaneous quality improvement of purified and reclaimed sewage effluent.

Results achieved with the reverse osmosis process have been satisfactory. The product water quality is excellent, with salt concentrations reduced by 90 per cent and chemical oxygen demand (COD) down to less than 5 mg/ℓ. A persistent problem with this process is that of fouling of the membranes, due to organic material present either in colloidal form or even through solution in the feed. The investigation has shown that tubular membrane systems that can be cleaned by the circulation of plastic foam swabs are more practical than other systems such as spiral wrapped membranes, which are, however, considerably cheaper in initial cost. These spiral membranes require a much more effective pretreatment system to keep the fouling problem within limits. Cleaning methods for the membranes have been investigated and several of these produced acceptable results.

Attention is now being concentrated on pretreatment processes for the feedwater to reduce its tendency to foul the membranes.

Technological development of ion exchange for the desalination and tertiary treatment of effluents: Planning, design, construction and operation of a 100 kℓ/d pilot plant and evaluation of its performance

(New project: Contract with the University of Cape Town — Department of Chemical Engineering — and a local chemical company).

The initial ion-exchange contract, between the Commission and the University of Cape Town, was entered into to establish the feasibility of ion exchange as a desalination process in wastewater treatment. It was established that, in addition to desalination, the combined cation-anion treatment removed most of the residual chemical oxygen demand (COD) material, together with nitrates, phosphates and other eutrophying constituents, as well as decolourizing and deodorizing the wastewater. The details of the development of this process, using a continuous countercurrent ion-exchange (CCIX) operation, and with nitric acid and ammonia as regenerants, were submitted to the Commission in a final contract report.

A new contract has been entered into for the design, erection and operation of a 100 m^3/d demon-

stration plant on the Cape Flats, to establish the feasibility of the process on a larger scale. At present, the alternative, and less expensive, regenerant system utilizing lime and sulphuric acid is being studied on a laboratory-scale pilot plant. Final engineering design of the demonstration plant was completed during the year and construction will begin early in 1980. The pilot plant will be situated at the site of the new Cape Flats Sewage Works and investigations will initially be conducted on effluent from this plant. Two separate regeneration systems will be investigated to establish the cost of the product water and to finalize design details for a full-scale plant.

The Department of Chemical Engineering of the University of Cape Town will be responsible for the basic design and for the ongoing research into the desalination and tertiary treatment process, while a chemical company will be responsible for the engineering and operation of the plant.

Chapter 11

Water economy measures

Realising the important role that water economy plays in the optimal utilization of the Republic's limited water resources, the Commission has already initiated several measures in this regard. While other chapters contain discussions on research projects relating to the optimal utilisation of water, this chapter deals with two new projects which could lead to large direct savings in water use, *viz* the projects on water economy measures in urban areas and dry cooling in power stations.

During the year a tripartite agreement was entered into between the CSIR (through its National Building Research Institute — NBRI), the South African Bureau of Standards (SABS) and the Commission, in terms of which research will be done on water economy measures in urban areas. The project is the result of action taken by the Coordinating Research and Development Committee (CRD committee) for Water Economy in Urban Areas, established by the Commission. This CRD committee held its first meeting in 1975 and the NBRI was requested to compile a master plan in this regard. The master plan approved by the CRD committee is based mainly on a report by Mr M Kantor, an Israeli specialist on water economy and former consultant to the Commission. The programme of research is based on the master plan.

The main aims of the project are to effect significant water economy by means of the design and utilisation of water supply appliances, and to establish criteria which may be used to up-date the relevant parts of the National Building Regulations.

As far as dry cooling at power stations is concerned, the Commission has entered into a tripartite contract with ESCOM and the CSIR for research to be done in this regard. As mentioned in Chapter 1, large volumes of water are used daily for cooling purposes at power stations. It is estimated that two-thirds of the water used by industry in South Africa (excluding the mining industry), is needed for cooling purposes, especially at power stations. The substitution of conventional wet cooling by dry or dry-wet cooling will result in considerable savings in water consumption at power stations. This method of cooling differs from the conventional wet method in that cooling is effected by means of the movement of air over cooling elements and not by means of evaporation as is the case in the wet method.

Dry cooling, however, has not yet found large scale application because of considerably higher capital costs and lower efficiency. ESCOM, however, has already erected two full scale 200 MW dry units at its Grootvlei power station in order to obtain operational experience of this type of cooling before it is applied at larger units.

As a result of the increasing demand for water on the Eastern Transvaal Highveld where ESCOM's most recent power stations are being built, and the contribution that dry cooling can make in order that water be set free for other purposes, it has long been felt that research should be directed at the optimisation of dry cooling systems under local conditions. The Commission therefore started negotiations with ESCOM to develop a project with the aim of optimising and improving existing dry cooling systems.

As a result of the experienced gained by ESCOM in operation of two dry cooling towers, certain factors have been identified which could have an important effect on the efficiency of such towers. These factors, as well as aspects such as corrosion and scale formation on the cooling elements due to spraying, will be investitated in the project undertaken in conjunction with the CSIR.

As a precursor to the compilation of the research

programme, a fact-finding mission with representation from the relevant organizations, visited the USA and Europe during the year and also established contact with research groups abroad.

RESEARCH PROJECTS

Research on economy measures for water distribution systems in urban areas

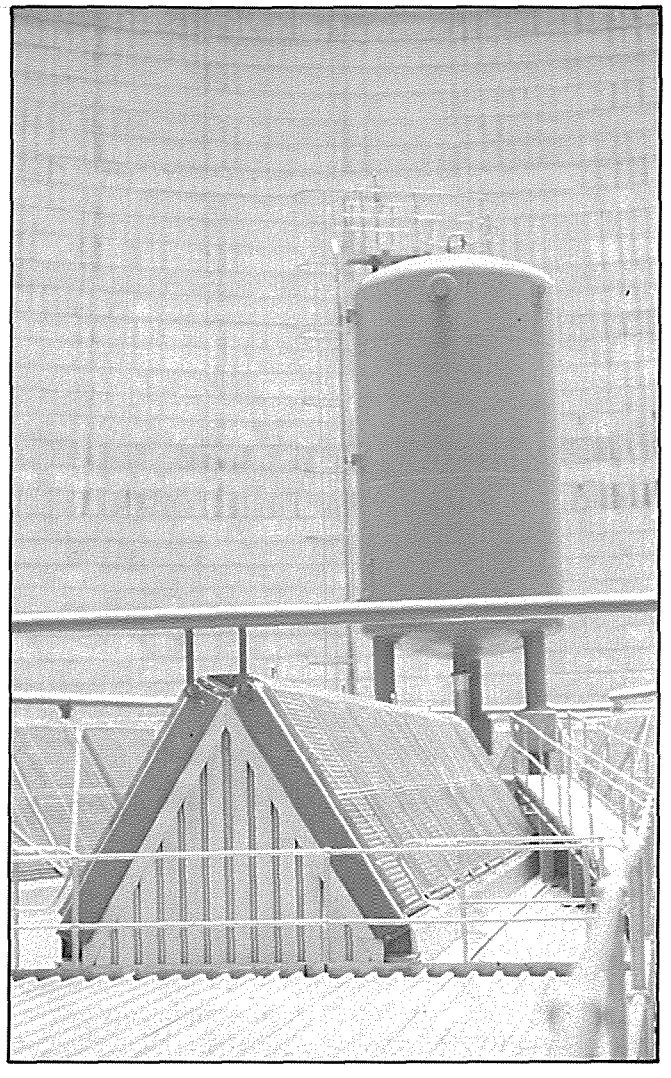
(New project: Contract with the South African Bureau of Standards and the CSIR — National Building Research Institute)

The overall objectives of this new tri-partite agreement are to achieve a meaningful saving of water in the design and usage of water supply fittings, and to establish criteria which can be used in future up-dating of the relevant parts of the National Building Regulations as compiled by the South African Bureau of Standards (SABS).

To ensure standardization of fittings and appliances used in water supply installations, it is anticipated that a list of such fittings and appliances, including water meters, will be drawn up by the National Building Research Institute (NBRI) of the CSIR, in conjunction with all branches of the plumbing industry.

The SABS will take the necessary steps towards drawing up specifications for those items which are not covered by existing specifications and, if necessary, the up-dating of specifications already in existence.

To ensure that only fittings and appliances of an acceptable standard are used in water supply installations, an approval system will be instituted whereby all fittings supplied in South Africa, whether manufactured locally or not, will be marked or certified as complying with the functional requirements of the abovementioned specifications.



A typical dry cooling element in the foreground in a cooling tower at a power station

It is not only within the home that water saving is sought but outside the home as well. To ensure the correct installation of approved components and design of water supply systems in general, codes of practice are to be drawn up by the SABS to cover the following:

- Plumbing and drainage in buildings
- Garden, parks and recreational facility watering
- Municipal water distribution systems (This item does not form part of this project)

The project envisages full participation of many of the major local authorities and those already contacted have indicated a willingness to participate even when water quantity is no problem *per se*.

Metering, especially, appears to have created some problems as a result of difficulties encountered in guaranteeing the accuracy of domestic metering equipment. It is widely felt that the meters now accepted by the assize authorities are not up to the long term accuracy standards of some alternative types of meter now in use overseas, and this will also be investigated.

For a long time water supply authorities have been aware of the problem of water wastage by automatic flushing devices. At last there is an air of optimism that a solution to this problem can be found. Reduced pres-

sures and low volume flushing devices are also to be investigated and in this regard the NBRI have already carried out preliminary tests and published a report on water-closet and urinal flushing requirements, an aspect which has from the outset been recognised as the number one priority with possibly the greatest potential for reducing water consumption in buildings.

The manufacturing industry is also showing a keen interest in the project and preliminary discussions have indicated that it is even prepared to take the initiative in some respects, if this should be necessary.

Research on the optimisation of dry and dry-wet cooling systems at power stations in South Africa

(New project: Contract with ESCOM and the CSIR — Air Pollution Research Group and Corrosion Research Division)

During the year under review a tripartite agreement was entered into between the Commission, the Electricity Supply Commission (ESCOM) and the CSIR to do research on the optimisation of systems for dry and dry-wet cooling at power stations. This agreement came into being due to the fact that significant savings in water consumption can be effected by substituting dry or dry-wet cooling for wet cooling methods. This technique has not found general application yet as a result of the considerably higher capital costs and lower efficiency.

ESCOM, however, has gained experience with the operation of two full scale dry cooling towers and certain factors, which could have an important effect on the efficiency of dry cooling systems, have been identified. Some of these factors relate to the atmospheric conditions such as stable air layers (inversions) which occur generally on the Eastern Transvaal Highveld (where ESCOM is erecting new power stations), and have wind velocities of more than 10 m/s. Preliminary investigations have indicated that these conditions have a detrimental effect on the performance of dry cooling towers. The project therefore, will attempt to quantify the effect of these factors on the performance of the existing dry cooling towers.

Improved cooling at a slightly higher water consumption can also be obtained by spraying the cooling elements of a dry cooling tower with water during periods of peak demand which occur simultaneously with unfavourable atmospheric conditions. The danger of corrosion and scaling of the cooling elements is ever-present and this could adversely affect performance. The investigation of these aspects constitutes the second part of the project.

In terms of the tripartite agreement the Air Pollution Research Group of the CSIR will undertake the investigations into the effect of the atmospheric conditions and the Corrosion Research Division of the CSIR the investigations into the effect of spraying on the physical condition of the heat exchanger elements. ESCOM has appointed a project coordinator who will lead and coordinate the investigations and the various activities.

Chapter 12

Transfer of information and technology

In terms of the Water Research Act, one of the important functions of the Commission is to collect, assimilate and disseminate knowledge with respect to water research and the application thereof and to promote development work for such application. The task of the transfer of information and technology continues to enjoy a high priority at the Commission and several activities have been developed for its promotion.

During the year the information and technology transfer (TT) activities of the Commission were closely compared with those of overseas organizations involved in the field of water. The opportunity for such a comparison arose from a visit by a Senior Adviser of the Commission to water research organizations and information centres in the USA, UK and Europe. On the whole, progammes for information and technology transfer of the various organizations visited consisted mainly of the publication of different types of publications (at purely scientific, practical scientific and popular scientific levels); maintenance of information centres with on-line computer facilities with data-base distributors; the arrangement of demonstrations, courses, seminars and simposia; promotion of contact between persons; and the exchange of scientists. From this comparison it would appear that the Commission's methods compare favourably with those of the relevant overseas organizations.

Publications

Commission publications provide for three levels *viz.* pure scientific, popular scientific and practical scientific levels and in this respect *Water SA, SA Waterbulletin* and practically orientated publications (e.g. manuals) respectively, are published.

Water SA

Water SA is a scientific journal which contains original research articles and review articles on all aspects of the water science. The first edition was launched by the Commission in April 1975 and the journal appears quarterly. Currently there are more than 1 400 subscribers of whom more than a quarter are located overseas and requests to be placed on the mailing list are still regularly received.

Water SA also enjoys world-wide coverage by means of abstracting services. Abstracts of articles from this journal currently appear in the following abstracting services: Chemical Abstracts; Biological Abstracts; Engineering Index; Pollution Abstracts; Oceanic Abstracts; Current Contents; Water Resources Abstracts (American Water Resources Association); Hydata; Selected Water Resources Abstracts; Desalination Abstracts; Waterlit; Water Research Centre Information; Aqualine; Abstracts Journal (Institute of Scientific Information of the USSR Academy of Sciences); and Soils and Fertilizers (incorporating Irrigation and Drainage Abstracts).

SA Waterbulletin

This bilingual newsletter which was launched by the Commission in August 1975 contains articles, news snippets and items of interest on local as well as overseas aspects of water. Activities of various institutions in the field of water in South Africa are emphasized in the bulletin. Good cooperation has been built up with producers and distributors of new equipment and processes connected with the promotion of water affairs, and information on equipment and processes now appear on a regular basis in *SA Waterbulletin.* The mailing list is steadily growing; currently there are more than 1 300 subscribers.

It is also envisaged to promote technology transfer through the bulletin. For this purpose a special column will be initiated in which regular announcements will be made on publications, simposia and other events of a practical nature which can assist in bridging the gap between research and application.

Manuals and reports

When a project is concluded and also whilst research is being done, results are evaluated in respect of application possibilities and depending on the nature of the results a decision is taken on their publication, dissemination and application. It may be that the final report has been compiled in such a way that it could be selectively distributed in that format. However, a decision may also be taken to package the results in the form of a manual in order to enhance the application possibilities. Interim reports and results are handled in the same way.

With regard to publications intended for practical application a complete list of those already published and those which are still in preparation appears in Chapter 1.

As mentioned in Chapter 1 a monthly column on the Commission has appeared since January 1979 in *Imiesa* (official journal of the Institution of Municipal Engineers of Southern Africa). This is specifically aimed at regular feedback of information to local authorities in order to keep them informed on activities and research done on their behalf.

The South African Water Information Centre

The South African Water Information Centre is operated by the CSIR under contract and on behalf of the Commission as an independent unit and provides different types of information services regarding water and related fields. During the year the number of users of the services and the extent of the services showed exceptional growth.

The Centre added 26 per cent more items to the computerized bibliographic data base *Waterlit* than in the previous year. This brings the total number of references on the data base to more than 25 000. Articles from more than 400 scientific journals are currently being indexed for inclusion in *Waterlit.* During the year 407 retrospective searches (42 per cent more than in the previous year) were undertaken on the data base while 157 persons (45 per cent more than in 1978) receive literature profiles on a regular basis. The increased use of the information services can partly be attributed to the contact the Centre has initiated with scientists and engineers as part of its "marketing programme".

The Centre maintains close liaison with similar information centres overseas and exchanges information with these centres. The stage has now also been reached where the possible exchange of data base and/or inclusion of *Waterlit* in overseas services is under consideration. This possibility was further discussed during visits by the Head of the Centre to information centres in the USA, UK and Europe. In this connection an organization in the USA, which offers comprehensive online information retrieval services, is interested in the inclusion of *Waterlit* in its services. Negotiations in this regard are currently under way.

The current awareness services of the Centre were also well supported. These services include the following journals: *Selected Journals on Water, Water Patent Bulletin* and *SA Waterabstracts.* A new system of text preparation has been developed for the latter and this has led to a substantial saving in time as well as in improved method for the compilation of the publication.

TT Seminar

One of the best methods to promote technology transfer is to hold simposia and seminars where specific technology can be transferred to a selected audience. In this manner the necessary contact between the scientists involved and user is accomplished. In May 1979 the Commission, in collaboration with the Institute of Water Pollution Control, the National Institute for Water Research, the Institution of Municipal Engineers of Southern Africa and the SA Institution of Civil Engineers organized a first TT Seminar. The seminar dealt with the removal of nutrients from municipal sewage and was aimed at providing local authorities and consultants with the latest state of art.

Utilization of overseas expertise

In order to execute its duties successfully the Commission deems it necessary to keep abreast of the latest developments in the field of water and to this end makes use, *inter alia* of the following methods:

- The exchange of publications between the Commission and overseas organizations has been in progress for several years.
- The Commission is a member of several international and overseas organizations from which recent information is regularly received. These organizations are the International Association on Water Pollution Research; the International Water Supply Association;

the Water Research Centre in the United Kingdom; the American Water Works Association; the Research Foundation of the American Water Works Association's Information-Coordination Programme on Water Reuse, and the Water Pollution Control Federation in the USA.

- Visits by officials of the Commission to institutions and participation in conferences overseas.

- Entering into contracts with overseas specialist consultants in order to advise the Commission in specific areas.

Partnership Research

As stressed in previous annual reports as well as in Chapter 1 of this report, the involvement of operational organizations in the planning and executing of research is an effective method in promoting technology transfer. For this reason it is the Commission's declared policy to support research as far as possible on a partnership basis. The extent to which local authorities, industries and government departments have been involved is obvious from the previous chapters.

Chapter 13

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 1 January 1979 to 31 December 1979.

The Commission derives its income from rates and charges on water usage and on scheduled irrigation land. 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 1979 financial year in Government Notice No 333 of 2 March 1979.

"(a) 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), or in respect of which an allocation has been made in terms of section 56(3) of the said Water Act, 1956, to be irrigated at any time during the period 1 January 1979 to 31 December 1979 with water supplied or made available from a Government dam and distributed by means of an aqueduct, irrespective of whether or not such aqueduct belongs to or is controlled by the Government, an irrigation board or other statutory body. This rate shall be recovered by or by direction of the Secretary for Water Affairs simultaneously with any rate or charge which I may levy in respect of the land concerned during the said period in terms of section 66 of the said Water Act, or, if no such rate or charge is levied, the rate levied hereby shall be payable to the Secretary for Water Affairs upon demand.

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

"(c) Twenty (20) cents in respect of each hectare of land scheduled in terms of section 88 of the aforementioned Water Act, to be irrigated, at any time during the 1979—80 or, as the case may be, the 1979 financial year of any irrigation board or other statutory body, with water supplied or made available from a water work 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.

"(d) Two-tenths of a cent (0,2c) per cubic metre in respect of metered water supplied or made available during the period 1 January 1979 to 31 December 1979 from a Government water work for purposes other than the irrigation of land. This charge shall be recovered by the Secretary for Water Affairs simultaneously with any charge I may levy in terms of section 66 of the aforesaid Water Act during the said period.

"(e) Two-tenths of a cent (0,2c) per cubic metre in respect of the quantity of water supplied or made available for the use of urban, industrial or domestic purposes during the period 1 January 1979 to 31 December 1979 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 said 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 abovementioned public supplier during the said period the quantity of water supplied or made available from the Government water work in terms of paragraph (d) 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:

(i) In respect of the period 1 January 1979 to 30 June 1979, not later than 30 September 1979, and

(ii) in respect of the period 1 July 1979 to 31 December 1979, not later than 31 March 1980.

"The audited statements prescribed under section 11(3)(b) of the said Water Research Act shall be submitted together with the payment mentioned in subparagraph (ii).

"If such rates and charges remain wholly or partly unpaid after the due date, interest at a rate which at the due date applied in respect of loans granted by the State out of the State Revenue Fund under section 26(1) of the Exchequer and Audit Act, 1975 (Act 66 of 1975), will be charged in respect of the amount outstanding as from that date.

"For the purposes of this notice one cubic metre shall be equal to one kilolitre."

In terms of section 11 of the Water Research Act as amended, the Administrator-General for the Territory of S.W.A. has announced the following rates and charges for South West Africa in respect of the 1979/80 financial year in Government Notice No AG57 of 1979 (The rates and charges for the period 1 January 1979 to 30 June 1979 were the same as for the 1979/80 financial year):

"1. Forty (40) cents in respect of each hectare of land to be irrigated at any time during the period 1 July 1979 to 30 June 1980 with water supplied or made available from a Government water work. This rate, recoverable by the Secretary for Water Affairs, shall be payable simultaneously with any other 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 1979 to 30 June 1980 from a Government water work for purposes other than the irrigation of land. This charge, recoverable by the Secretary for Water Affairs shall be payable simultaneously with any other 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, including water referred to in paragraph (2), supplied or made available for urban, industrial or domestic purposes during the period 1 July 1979 to 30 June 1980 by the Municipalities of Windhoek and Tsumeb. The rates recoverable by the said Municipalities shall be paid over to the Secretary for Water Affairs, c/o the Director of Water Affairs, Private Bag 13193, Windhoek, 9100 —

(a) in respect of the period 1 July 1978 to 31 December 1979 not later than 31 March 1980; and

(b) in respect of the period 1 January 1980 to 30 June 1980 not later than 30 September 1980.

"The audited statements prescribed under section 11(3)(b) of the said Water Research Act shall be submitted to the Secretary for Water Affairs, as aforesaid, together with the payment for the period mentioned in subparagraph (b).

"For the purposes of this notice one cubic metre shall be equal to one kilolitre.

"In respect of any rates and charges which are due and payable but unpaid, interest shall be charged as from the date fixed for payment thereof under subsection (5) of section 11 of the Water Research Act, 1971, as inserted by section 1 of the Water Research Amendment Act, 1977 (Act 106 of 1977), at the standard interest rate which at that date applies in respect of loans granted by the State out of the State Revenue Fund under section 26(1) of the Exchequer and Audit Act, 1975 (Act 66 of 1975)."

WATER RESEARCH COMMISSION

STATEMENT 1
BALANCE SHEET AS AT 31 DECEMBER 1979

1978	Liabilities	1979		1978	Assets		1979	
R		R	R	R		R	R	R
	Sundry creditors —				*Capital assets —			
133 946	Revenue paid in advance		96 299,46	5 000	Land (Cost)		5 000,00	
	Fund account —				Motor vehicles	18 359,54		
5 294 695	Balance at 31/12/78	5 294 695,02			*Less:* Depreciation	5 201,98		
	Plus: Excess of income over expenditure 1979	285 906,19		6 426			13 157,56	
			5 580 601,21		Office equipment	39 567,53		
					Less: Depreciation	1 978,38		
				31 289			37 589,15	
					Office furniture	30 632,73		
					Less: Depreciation	1 531,64		
				29 335			29 101,09	
								84 847,80
				3 970 981	**Investments			4 681 488,00
					Current assets —			
					Sundry debtors —			
					Outstanding revenue:			
					Prior to 1979	8 422,06		
					1979	327 959,73		
				542 466			336 381,79	
				847 492	Project advances (Statement 3)	488 231,59		
				11 964	Subsistence and transport advances	6 125,00		
				250	Deposits	300,00		
							494 656,59	
				150	Cash on hand		150,00	
				82 288	Cash in bank		79 376,49	
								910 564,87
R5 428 641			R5 676 900,67	R5 428 641				R5 676 900,67

*Capital assets purchased by research organisations by means of research grants are not included.
**Includes accrued interest
Pretoria, 28 March, 1980

(sgd.) M.R. HENZEN
Chairman

The above Balance Sheet has been audited in accordance with the provisions of section 42(4) 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.

Pretoria, 2 May 1980
Department of the Auditor-General

(sgd.) W G. SCHICKERLING
Auditor-General

WATER RESEARCH COMMISSION

STATEMENT 2

INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD 1 JANUARY 1979 TO 31 DECEMBER 1979

1978	Expenditure		1979
R			R
474 303	Salaries and allowances		492 494,99
13 644	Subsistence		14 313,33
4 978	Motor transport		5 091,05
121 275	General transport		78 034,98
475	Commission members' allowances		475,00
4 112	Postal and telegraph services		2 748,65
11 109	Telephone services		10 669,93
9 706	Printing and stationery		10 797,94
2 841	Advertisements		1 002,05
25 457	Publications and Information		30 694,66
6 688	Lease and maintenance of office equipment		10 521,78
6 740	Entertainment		5 186,22
25 915	Office rental		26 715,81
3 197	Maintenance of and alterations to offices		3 250,10
1 492	Electricity		1 418,36
1 978	Typing services		2 053,23
4 942	Insurances and licences		5 010,32
34 884	Collection fees		40 175,33
844	Audit fees		883,00
165	Legal costs		167,00
7 329	Registrations and subscriptions		4 909,90
2 402	Miscellaneous petty expenses		2 611,06
7 038	Depreciation		8 712,00
2 622 947	Research projects (Statement 3)		2 429 251,96
	Contracting of researchers and expertise:		
168 259	Weather modification at Bethlehem	165 117,78	
16 477	Evapotranspiration and water use studies by means of weighing lysimeters	22 669,42	
—	Digitizing of autographic raingauge data	8 046,41	
7 866	Instrumentation and automation of flood irrigation systems	2 236,15	
			198 069,76
178,728	Research and other grants		166 439,00
220 099	Specialist and consultation services		219 607,94
—	Excess of income over expenditure		285 906,19

1978	Income			1979	
R		R	R		R
	Rates:				
	Government irrigation schemes with canal systems:				
	Received	42 568,21			
	Less: Adjustment in respect of previous years	36,30			
			42 531,91		
	Plus: Outstanding 1979		36 265,92		
73 474					78 797,83
	Government irrigation schemes without canal systems				
	Received	3 013,46			
	Less: Adjustment in respect of previous years	24,00			
			2 989,46		
	Plus: Outstanding 1979		3 093,10		
3 306					6 082,56
	Irrigation Board Schemes:				
	Received	26 284,55			
	Less: Adjustment in respect of previous years	54,20			
			26 230,35		
	Plus: Outstanding 1979		2 148,19		
26 756					28 378,54
	Charges:				
	Metered water from Government Schemes:				
	Received	2 406 309,86			
	Plus: Adjustment in respect of previous years	12 760,06			
			2 419 069,92		
	Plus: Outstanding 1979		249 712,29		
2 469 131					2 668 782,21
	Municipalities:				
	Received	950 637,90			
	Less: Adjustment in respect of previous years	2 030,39			
			948 607,51		
	Plus: Outstanding 1979		10 499,65		
971 798					959 107,16
	S.W.A.:				
	Received		53 983,13		
	Plus: Outstanding 1979		26 240,58		
73 211					80 223,71

1978	Expenditure (continued)	1979
R		R
R3 987 890		R4 057 211,54

1978	Income (continued)			1979
R		R	R	R
	Unallocated rates and charges ...			22 499,31
1 397	Interest on rates and charges in arrear			1 838,21
286 149	Interest on investments			211 218,23
200	Sundry income			283,78
82 468	Excess of expenditure over income			—
R3 987 890				R4 057 211,54

WATER RESEARCH COMMISSION

STATEMENT 3

STATEMENT OF PROJECT EXPENDITURE AND ADVANCES FOR THE YEAR 1979

Project	Expenditure		Total advances outstanding as at 31/12/79
	1978	1979	
	R	R	R
Development of research on the reclamation of water at the Athlone Sewage Works, Cape Town	41 935	24 814,06	40 449,80
Technological development of water reclamation on the basis of the Windhoek plant	19 465	18 292,08	2 808,97
Eutrophication of rivers and dams	134 914	68 899,00	*(15 899,00)
Technological development of water reclamation and pollution control — Daspoort	122 212	2 500,00	—
Reclamation, storage and abstraction of purified sewage effluents in the Cape Peninsula	372 041	90 146,80	99 077,59
Research on the treatment of waste water by ion exchange	75 604	—	—
Research on the activated sludge process	64 755	—	41 760,00
The removal of metal ions from dilute solutions in an electrolytic precipitator	38 919	724,34	—
The role of aquatic macrophytes in Swartvlei, Wilderness, in maintaining trophic conditions	46 105	23 115,49	—
Hydrological investigation of small catchments in the Grahamstown area	—	16 036,40	—
Hydrological investigation of small rural catchments with specific reference to flood events	43 344	25 993,56	*(,56)
Hydrological investigation of small catchments in the Mtunzini district	34 548	21 552,16	19 247,84
Biological denitrification and the removal of phosphate	75 205	—	7 369,88
An investigation on the optimal utilization of water from the Eerste River by means of storage in sand beds or other methods	—	114 421,94	15 373,05
Development of the WAT-process for the desalination of sea water	3 918	—	—
South African Water Information Centre	206 861	121 477,63	*(35 282,51)
The development and evaluation of techniques for the determination of the exploitation potential of ground water resources in the Southern Orange Free State and Northern Cape	140 846	173 901,90	18 598,10
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	276 456	98 743,40	*(14 696,17)
Research on water consumption patterns in urban areas	—	18 071,67	—
Research on the removal of sludge and wash water at water purification installations	—	6 953,17	—
Research on water losses in pipe networks	—	3 418,23	—
Geohydrological studies in the Gamagara catchment using environmental isotopes and complementary techniques	129 758	11 534,32	—
The development of the concept of the runhydrograph in the analysis of flood hydrographs	11 264	—	—
Research on flood damage — Bureau for Economic Research	—	477,55	—
An investigation into soil compaction under irrigation at the Vaalharts State Irrigation Scheme	9 374	6 968,09	—
An investigation into the influence of internal plant moisture stress on the growth and production of certain agronomic crops	11 358	1 576,57	39,24
Research on flood damage — Institute for Social and Economic Research	56 255	33 562,95	14 318,81
Research on the microbiological quality and health aspects of water for re-use	—	165 571,98	104 095,37
Research on the soil factors affecting the optimal utilization of irrigation water in Bantu homelands	22 692	68 038,52	*(6 091,56)
Research on water requirements of certain agronomic and vegetable crops	—	25 831,60	22 499,20
Research on the purification and re-use of effluents from the hides and skin curing, fellmongery and tanning industries	62 831	58 019,05	3 388,09
Research on and development of desalination of sea water by reverse osmosis on the pilot plant at Swakopmund	31 521	35 153,00	*(7 153,001)
Research on desalination of treated sewage	48 426	49 792,00	2 191,42
Research on development of membrane support systems and modules	39 947	32 409,00	4 936,00

Research on the technological application of the anaerobic digestion process for the purification of spent wine residue	5 924	7 930,00	*(23,00)
Water management and effluent treatment in the Textile Industry	151 242	213 955,43	2 082,56
Research on the development of effective irrigation methods for application on steep lands, with special reference to micro-methods	—	8 746,12	22 503,88
Research on flood occurences	54 704	46 768,96	4 576,86
Research on water resources	52 571	34 167,33	*(558,34)
Research programme for studying conditions in Hartbeespoort Dam before and after full scale spraying of the water hyacinths	10 709	—	—
Water pollution and effluent reclamation in the Pretoria-Witwatersrand-Vereeniging-Sasolburg Complex	145 762	151 685,23	21 835,47
Research on the scheduling of irrigation of wheat in the irrigation area of the Orange Free State	9 791	27 084,96	3 915,04
The artificial replenishment and abstraction of purified sewage effluent in the Cape Flats	57 833	77 346,00	*(4 779,00)
Research on rainfall stimulation at Nelspruit	—	63 365,67	77 134,33
The geohydrology of the sand deposits in the Cape Flats	13 857	22 535,00	708,00
Research related to the purification and reuse of tannery effluent	—	6 055,97	4 053,06
Research on the development and application of aspects of equilibrium chemistry and precipitation kinetics to water stability problems encountered in water reclamation	—	—	5 965,00
Evaluation of the performance of a horizontal decanter centrifuge on the removal of sludge from liquid scouring wastes	—	9 700,00	—
The removal of nitrogen and phosphate from biofilter effluents	—	11 191,00	3 209,00
Hydrological research in the Ecca and Wilderness catchments	—	46 796,83	11 703,17
Research on the optimization of dry and dry-wet cooling systems at power stations in South Africa	—	19 576,36	*(19 576,36)
Research on the optimization of the modified activated sludge process for nutrient removal (Johannesburg City Council)	—	109 291,68	708,32
Research on the optimization of the modified activated sludge process for nutrient removal (NIWR)	—	81 091,00	709,00
Hydrological investigation of rural catchments in Natal with specific reference to flood events	—	22 709,34	*(2 709,34)
An agro-hydrological study of Natal	—	2 197,12	302,88
The development of a data bank of autographic raingauge records in South Africa	—	24 372,88	5 627,12
The efficiency of water extraction from fine sandy irrigation soils by different root systems	—	28 348,98	1 141,02
Technological development of ion exchange for the desalination and tertiary treatment of effluents: Planning, design, construction and operation of a 100 kl/day pilot plant and evaluation of its performance	—	—	44 415,00
Operation of the Stander Water Reclamation Plant and related investigations into certain health aspects	—	54 097,00	—
Research on economy measures for water distribution systems in urban areas	—	26 742,64	*(11 742,64)
Research on water reclamation and pollution control: Operation of Stander Water Reclamation plant by the City Council of Pretoria, the implementation of surveillance programmes relevant to health aspects and the application of catchment quality control	—	15 500,00	—
	R2 622 947	R2 429 251,96	R488 231,59

*Excess expenditure over advances for projects

WATER RESEARCH COMMISSION
STATEMENT 4
BUDGET 1980

	R	R
ESTIMATED INCOME		
Rates and charges in terms of Section 11 of the Water Research Act		3 648 700
Interest on Investment		200 000
		3 848 700
Appropriation from accumulated funds		1 213 000
TOTAL ESTIMATED INCOME		5 061 700
ESTIMATED EXPENDITURE		
Administrative expenses:		
Salaries and allowances	543 000	
Subsistence and travelling expenses	107 600	
Postal, telegraph and telephone	18 000	
Printing, stationery, advertisements and publications	64 000	
General expenditure	129 000	
		861 600
Research Projects:		
Approved projects		
Development of research on the reclamation of water at the Athlone Sewage Works, Cape Town	38 000	
Technological development of water reclamation on the basis of the Windhoek plant	58 000	
An investigation on the optimal utilization of water from the Eerste River by means of storage in sand beds or other methods	2 500	
The development and evaluation of techniques for the determination of the exploitation potential of ground water resources in the Southern Orange Free State and Northern Cape	203 500	
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	32 000	
An investigation into the influence of internal plant moisture stress on the growth and production of certain agronomic crops	1 500	
Research on flood damage – Institute for Social and Economic Research	25 000	
Research on the microbiological quality and health aspects of water for re-use	138 400	
Research on the soil factors affecting the optimal utilization of irrigation water in the Bantu homelands	45 000	
Research on water requirements of certain agronomic and vegetable crops	25 600	
Research on the purification and re-use of effluents from the hides and skin curing, fellmongery and tanning industries	87 300	
Research on and development of desalination of seawater by reverse osmosis on the pilot plant at Swakopmund	60 000	
Research on desalination of treated sewage	4 500	
Research on development of membrane support systems and modules	40 000	
Water management and effluent treatment in the Textile Industry: Sizing and desizing effluent	54 500	
Research on the development of effective irrigation methods for application on steep lands, with special reference to micro-methods	41 000	
Research on flood occurrences	37 700	
Research on water resources	53 200	
Water pollution and effluent reclamation in the Pretoria-Witwatersrand-Vereeniging-Sasolburg Complex	135 000	
Research on the scheduling of irrigation of wheat in the irrigation area of the Orange Free State	35 500	
Research on rainfall stimulation at Nelspruit	59 500	
Research on the development and application of aspects of equilibrium chemistry and precipitation kinetics to water stability problems encountered in water reclamation	15 700	
The removal of nitrogen and phosphate from biofilter effluents	56 000	
Hydrological research in the Ecca and Wilderness catchments	61 000	
Research on the optimization of dry and dry-wet cooling systems at power stations in South Africa	116 000	
Research on the optimization of the modified activated sludge process for nutrient removal (City of Johannesburg)	34 000	
Research on the optimization of the modified activated sludge process for nutrient removal (NIWR)	93 500	
Hydrological investigation of rural catchments in Natal with specific reference to flood events	55 300	
An agro-hydrological study of Natal	5 500	
The development of a data bank of autographic raingauge records in South Africa	17 500	
Hydrological research in Zululand	20 700	
The efficiency of water extraction from fine sandy irrigation soils by different root systems	26 900	
Technological development of ion exchange for the desalination and tertiary treatment of effluents: Planning, design, construction and operation of a 100 kℓ/d pilot plant and evaluation of its performance	253 000	
Research on economy measures for water distribution systems in urban areas	115 900	
Research on water reclamation and pollution control: Operation of Stander Water Reclamation Plant by the City Council of Pretoria, the implementation of surveillance programmes relevant to health aspects and the application of catchment quality control	224 000	
Epidemiological studies pertaining to the reclamation and reuse of purified sewage effluent in the Cape Peninsula	55 000	
	2 327 700	

	R	R
Possible projects		
Proposed	1 038 200	
Tentative	50 000	
		3 415 900
Contracting of researchers and expertise		314 200
Research and other grants		220 000
Specialist and Consultation Services		250 000
TOTAL ESTIMATED EXPENDITURE		5 061 700