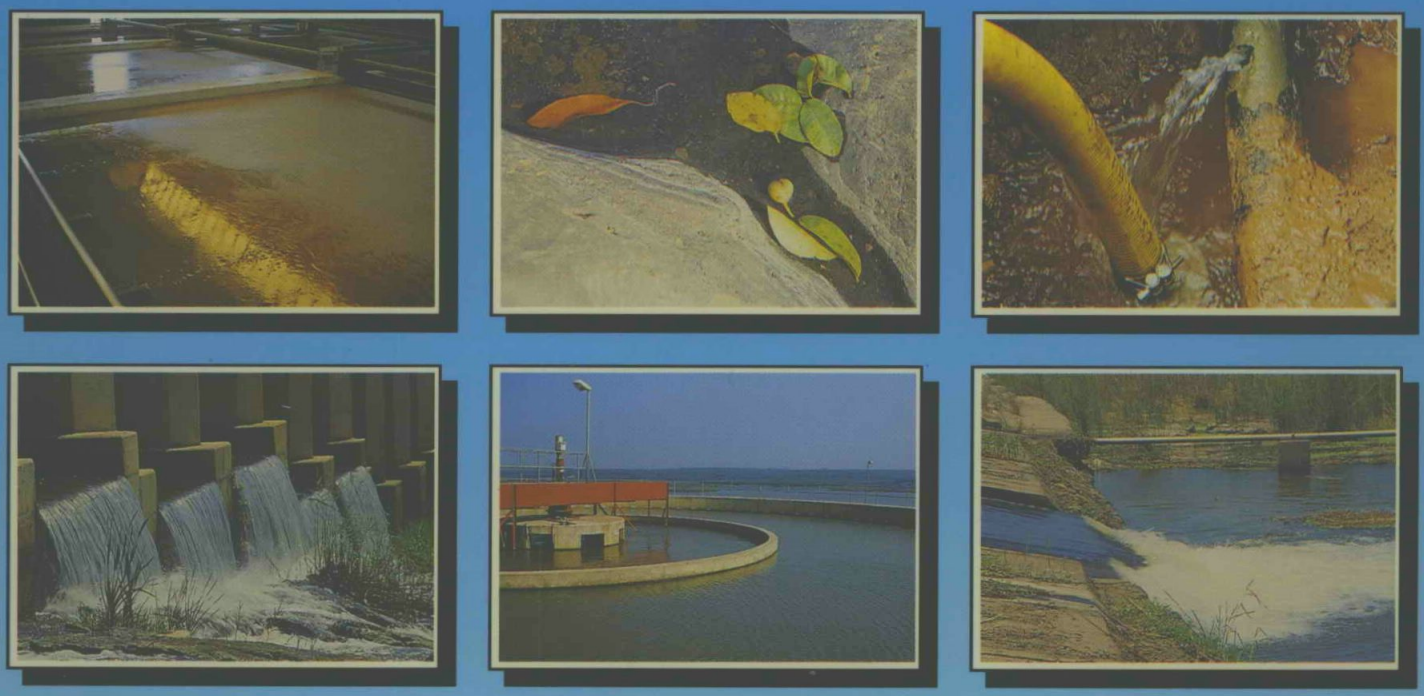

1991

ANNUAL REPORT

WATER RESEARCH COMMISSION

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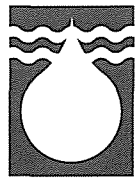
1991

ANNUAL REPORT

WATER RESEARCH COMMISSION



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WATER RESEARCH COMMISSION
PO BOX 824
PRETORIA
0001
20 MARCH 1992

Dear General Malan

We take pleasure in submitting to you, herewith, the report of the Water Research Commission for the period 1 January to 31 December 1991.

The balance sheet and statement of revenue and expenditure for the financial year to 31 December 1990, as certified by the Auditor General, as well as a receipts and payments account for the year ended 31 December 1991 and a budget for 1992, are furnished under ***Financial Statements*** *of this report.*

Yours respectfully

AJ Raubenheimer
CHAIRMAN

PE Odendaal
EXECUTIVE DIRECTOR

General MA de M Malan, MP
Minister of Water Affairs and Forestry
Private Bag X9052
CAPE TOWN
8000

CONTENTS

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Dr MJ Pieterse
(Municipal effluents; industrial water and waste water; drinking water; treatment technology)

Research managers

Dr TC Erasmus
Dr OO Hart
Mr G Offringa
Dr HM Saayman
Dr SA Mitchell

DEPUTY EXECUTIVE DIRECTOR

Mr DS van der Merwe
(Water sources; urban water reticulation; water utilisation for agricultural and ecological purposes)

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Mr HC Chapman
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Dr GC Green
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Deputy research manager

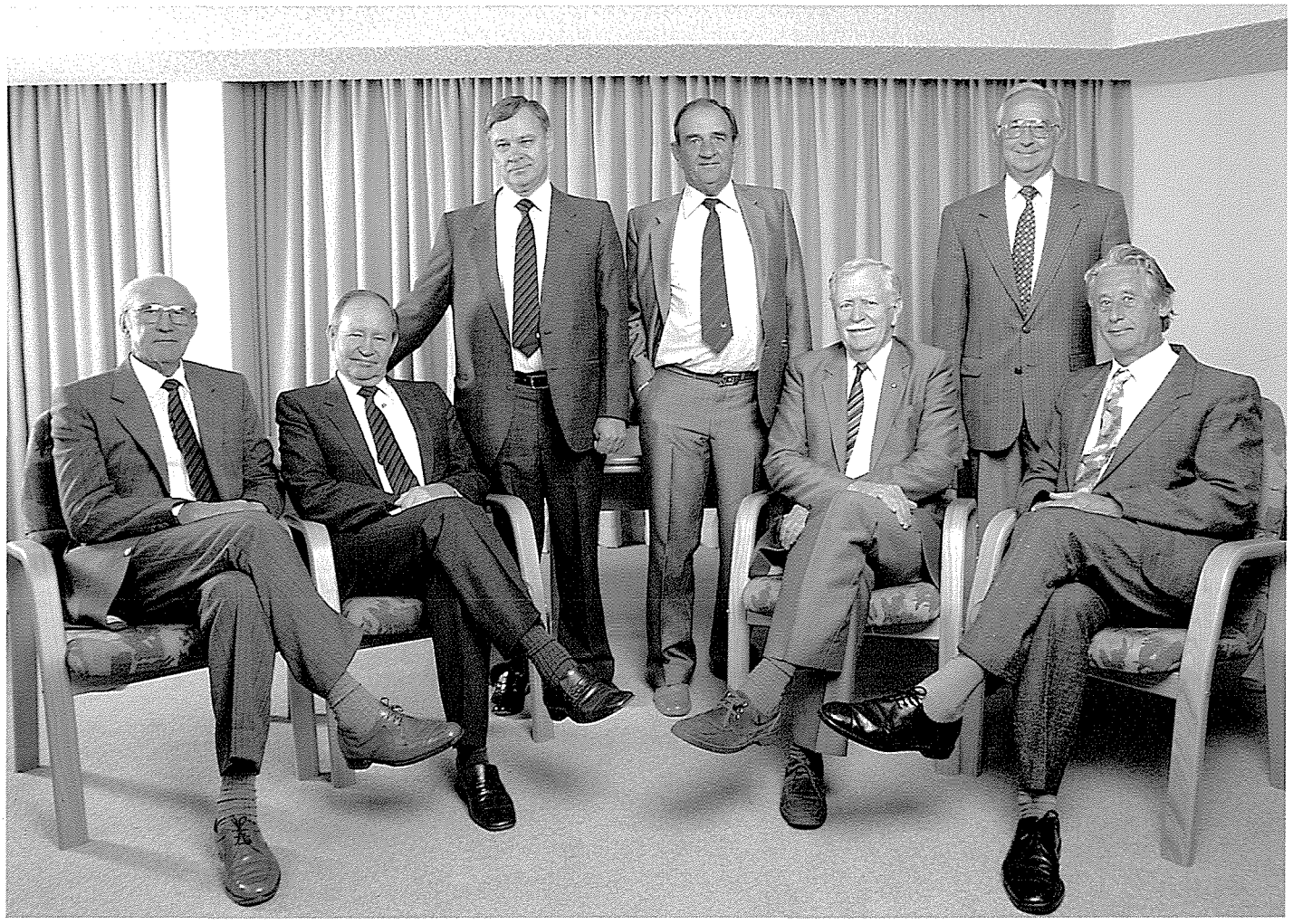
Mr AG Reynders

ADMINISTRATIVE

DIRECTOR: ADMINISTRATION

Mr PM van der Schyff

MEMBERS OF THE WATER RESEARCH COMMISSION AS ON 31 DECEMBER 1991



FROM LEFT TO RIGHT:

Mr DH Marx - Chairman: Magalies Water Board and former city engineer of Pretoria.

Dr WL van Wyk - Former deputy director-general: Department of Mineral and Energy Affairs.

Mr PE Odendaal - Executive director: Water Research Commission.

The Honourable AJ Raubenheimer (DMS) (Chairman) - Former Minister of Water Affairs.

Mr EJ Hall - Member: Council for the Environment and former city engineer of Johannesburg.

Mr DW Steyn - Former Minister of Economic Affairs and Technology; chairman: Roadfix Africa Ltd; and chairman: Prisma Food CC.

Dr AJ Heyns - President: Agricultural Research Council.

ABSENT:

Mr GCD Claassens (Vice-chairman) - Director-general: Department of Water Affairs and Forestry.

Prof PD Tyson - Vice-principal: University of the Witwatersrand.

Mr M Erasmus (Co-opted member) - Deputy director-general: Department of Water Affairs and Forestry.

THE OBJECTIVES OF THE WATER RESEARCH COMMISSION

In terms of section 2(3) of the Water Research Act 1971 (Act No 34 of 1971) the objectives of the Commission are "to co-ordinate, to promote, to encourage or to cause to be undertaken, as determined by the Minister specifically or in broad outline, research in respect of

- the occurrence, preservation, conservation, utilization, control, supply, distribution, purification, pollution or reclamation of water supplies and water;

- the use of water for

  - agricultural purposes;

  - industrial purposes; or

  - urban purposes".

Section 3(1) of the above-mentioned Act describes the functions of the Commission and stipulates *inter alia* that the Commission shall "accumulate, assimilate and disseminate knowledge in regard to the results of such research and the application thereof, and promote development work for the purpose of such application".

THE YEAR UNDER REVIEW

The multidisciplinary approach to water research is evidenced by the variety of research areas supported by the Water Research Commission (WRC):

- Hydrometeorology
- Rainfall stimulation
- Surface hydrology
- Ground water
- Agricultural water utilisation
- Water pollution
- Municipal effluents
- Industrial water and effluents
- Drinking water
- Membrane technology
- Aquatic ecosystems
- Developing communities

The allocation of funds to the various areas is reflected in the accompanying pie chart.

The WRC does not itself undertake research, but enters into agreements with other organisations to carry out the research. In the following table the research sectors responsible for the research are listed, as well as the extent of their involvement:

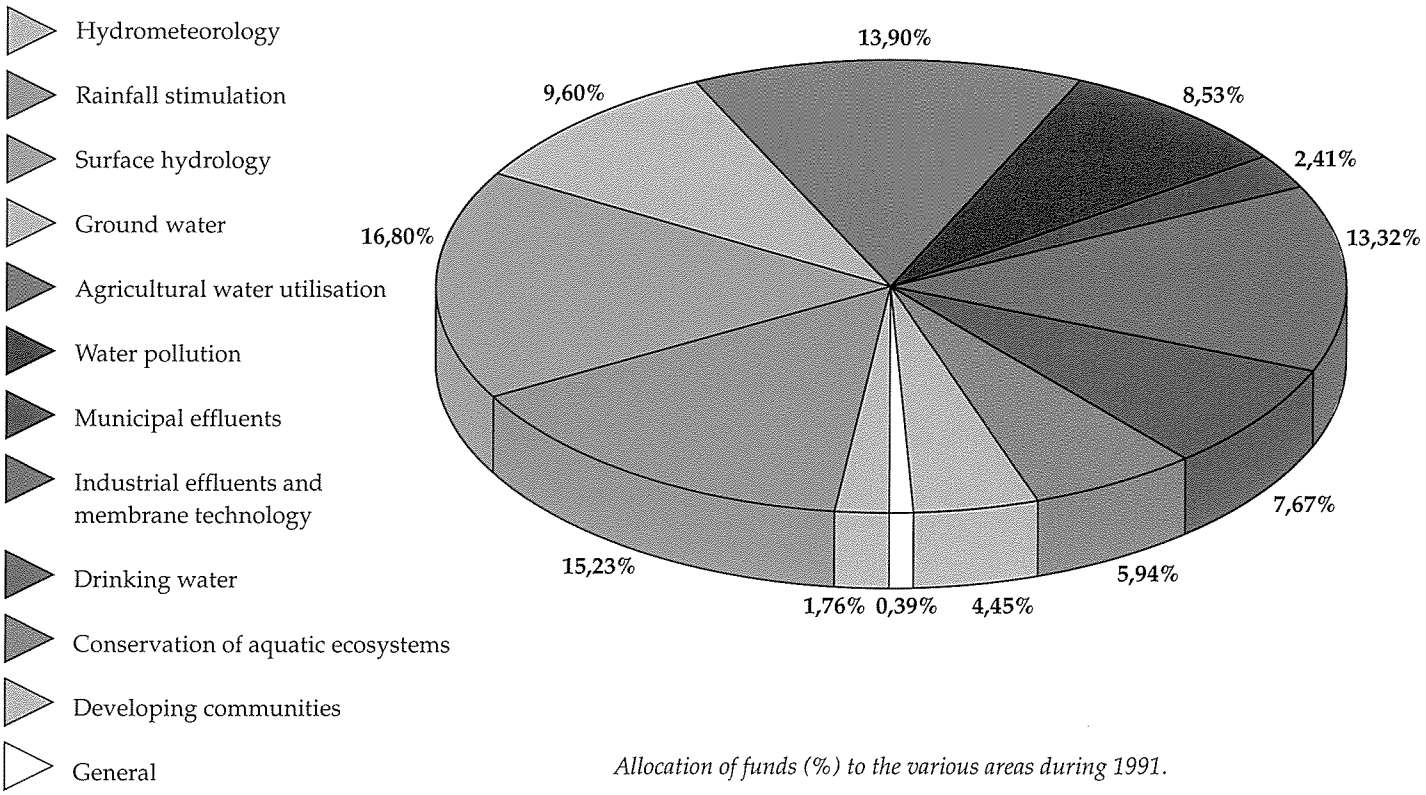
RESEARCH SECTOR	NUMBER OF TIMES INVOLVED	%
Universities	101	50
CSIR	45	22
Consulting engineers	18	9
Government departments	9	4
Local authorities	8	4
Water boards	7	3
Private companies	10	5
Other organisations	5	3
Total	**203**	**100**

From the figures it is evident that universities are involved in 50% of the total number of contracts. The number of times that organisations are involved, namely 203, exceeds the number of projects supported, for the reason that more than one organisation is, in certain cases, involved in the execution of a project. In 1991 the WRC financially supported 177 projects at a budgeted amount of R24 122 888.

In addition to the direct funding of contractual projects, the WRC also supports 3 research support services:

- The South African Water Information Centre (SAWIC)
- The Computing Centre for Water Research (CCWR)
- The Hydrological Information System (HIS)

While the activities pertaining to the past year will be reported on in the various chapters, certain highlights will be singled out in this chapter.



Allocation of funds (%) to the various areas during 1991.

WATER SUPPLY AND SANITATION FOR DEVELOPING AREAS

The rapid development of informal residential areas around our cities and towns has highlighted the problems associated with water supply and sanitation for developing areas. A related problem is the serious degree of storm-water pollution emanating from these areas.

Consequently, WRC funding of research in this regard has rapidly increased during the past 2 years. A shortcoming at this stage is, however, that a proper research plan with designated priorities has yet to be developed. This will receive attention in 1992.

Experience, both locally and overseas, and verified by an exploratory report

A meaningful research programme not only has to focus on technological aspects, but also has to address the socio-economic problems

drawn up for the WRC by the Human Sciences Research Council (HSRC), has clearly shown that a meaningful research programme not only has to focus on technological aspects, but also has to address thoroughly the socio-economic problems associated with water supply and sanitation in developing communities.

MASTER PLAN FOR RESEARCH ON MUNICIPAL WASTE-WATER MANAGEMENT

The WRC's Co-ordinating Committee for Research on Municipal Waste-water Management worked through a series of workshops to produce a research master plan.

The main thrust areas identified in order of priority, are the following:

- Development of affordable and acceptable technologies for developing communities
- Development of treatment strategies and technologies to address diffuse pollution
- Development of improved, acceptable and affordable high technology
- Improved sludge handling and utilisation
- Recovery of resources from sewage sludge

The plan has been made available to the research community.

Uncontrolled storm-water pollution creates health hazards for developing communities.

COMPUTER PROGRAMS FOR SIMULATING ACTIVATED SLUDGE WASTE-WATER TREATMENT

Two computer programs for simulating the behaviour of single activated sludge systems on personal computers have been released by the WRC. The 2 programs, UCTOLD and IAWPRC, are based on what are arguably the 2 most up-to-date mechanistic models of the activated sludge system in the world today.

In the past, design, operation and control of activated sludge systems were based on relatively simplistic ideas about the behaviour of the systems, and on experience acquired in running such systems. Not only have the system configuration and its operation increased in complexity, but more stringent standards for effluent quality have to be complied with. With such complexity it is no longer possible to make a reliable quantitative, or sometimes even qualitative, prediction as to the effluent quality to be expected from a design, or to assess the effect of modifications, without some model of the system behaviour.

UCTOLD is based on the model developed by the Department of Civil Engineering at the University of Cape Town (UCT) over the past 15 years, while IAWPRC is based on a model proposed by a task group of the International Association on Water Pollution Research and Control, incorporating some modifications by the UCT group.

The models have found application in the development of optimal design procedures, identification and solution of operational problems, the development of plant control strategies and in operator training.

ADVANCES IN MEMBRANE TECHNOLOGY

The application of membrane technology for water and waste-water treatment in South Africa holds exciting possibilities. A local membrane manufacturing industry has already been established, and a number of membranes and membrane systems developed through WRC-funded research have found application in practice.

A local membrane manufacturing industry has already been established

Two notable advances have emerged from WRC projects at the Institute for Polymer Science (University of Stellenbosch) during 1991. The first was the successful development of a capillary ultrafiltration membrane system. Capillary membranes are narrow diameter hollow tubules and have the advantage that they are self-supporting at moderate pressures. Bundles of these capillary tubes are placed in a plastic shroud and the end pieces are sealed with epoxy resins to produce elegant modular membranes. Prototypes of these capillary ultrafiltration membranes are being evaluated in field studies by the Institute and also in collaboration with Membratek (Pty) Ltd.

The second development concerns the production of cost-effective low molecular-mass cut-off (MMCO) ultrafiltration membranes. The availability of these membranes will promote the broader application of the low-cost tubular ultrafiltration system developed by Membratek with WRC support.

Three types of low MMCO membranes were developed, with performance characteristics comparable to, and often better than, similar commercially available products from overseas. Application studies have already shown that the new membranes are effective in removing colour in the treatment of natural waters and certain industrial waste-water streams.

COMPUTER PROGRAM FOR THE SOFTENING AND STABILISATION OF WATER UPGRADED

The computer program of the University of Cape Town (UCT) for the stabilisation and softening of water, known as *Stasoft*, has recently been upgraded by the University and Eskom.

The program was modified to enable it to handle water containing dissolved solids of up to 15 000 mg/*l*. The previous version of *Stasoft* was limited to salinities of approximately 1 000 mg/*l*. At the same time the user-friendliness of the program was improved.

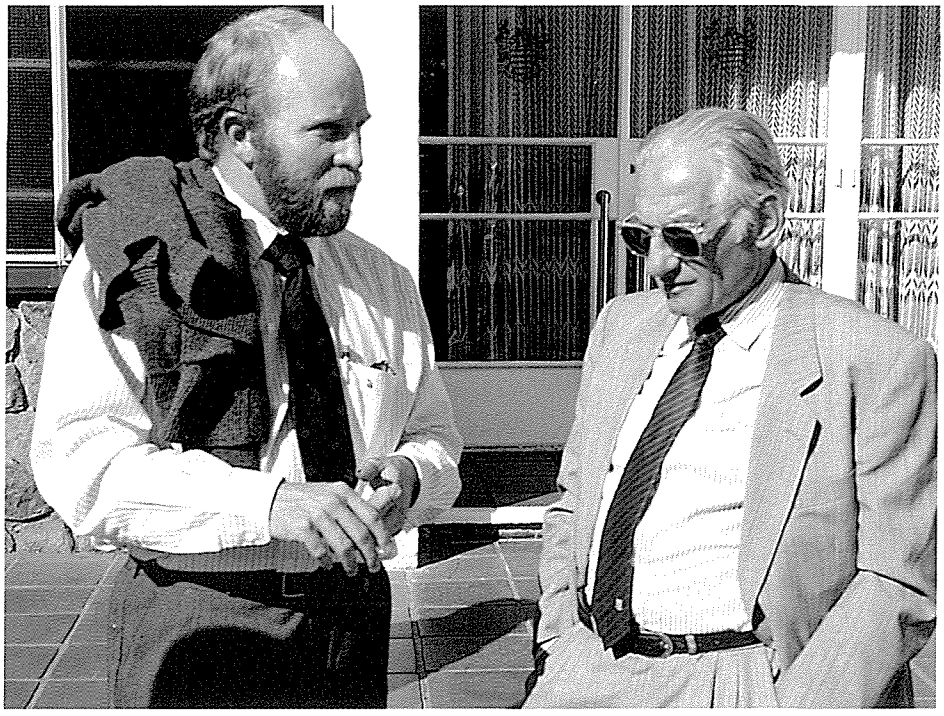
Although the original *Stasoft* development was funded by the WRC, the upgraded version was a collaborative effort between UCT and Eskom. However, the WRC assisted in finalising the program and will act as main distributor of the program.

The original *Stasoft* enjoyed wide application, particularly by consultants, and the upgraded version should see even more extensive use.

OVERSEAS CONSULTANT ON DRINKING-WATER TREATMENT

Professor H Bernhardt, the technical director of the Wahnbachtal Reservoir Society in Germany, visited South Africa from 13 to 24 May 1991 on the invitation of the WRC. Professor Bernhardt is a world-renowned expert on the treatment of eutrophic water to drinking water. He serves on a number of European committees concerned in drinking-water matters and is the scientific editor of *Aqua*, the journal of the "International Water Supply Association".

The purpose of his visit was to advise various organisations concerned in the design and operation of drinking-water plants, as well as the WRC, on the latest European expertise concerning the treatment of eutrophic waters. To this end Professor Bernhardt visited various waterworks and other organisations and gave several lectures on aspects such as algae and colour removal, ultraviolet disinfection and the "finer points" of water treatment. The group visits and discussions



Mr MC Steynberg (left) of the Rand Water Board in conversation with Prof H Bernhardt of the Wahnbachtal Reservoir Society, Germany, during a technical visit to a drinking-water plant.

undertaken together with Professor Bernhardt by a number of South African experts in this field, were particularly informative and successful.

On invitation Professor Bernhardt also read a paper at the WRC, as well as 2 papers at the 2nd Biennial Conference of the Water Institute of Southern Africa, held in Kempton Park from 13 to 16 May 1991.

FLOTATION DESIGN GUIDELINES

South African guidelines for the design and application of dissolved air flotation in water treatment were drawn up by engineers of the consulting firms BS Bergman and Partners Inc. and GFJ Inc. A brief, historical review of flotation in South Africa has also been incorporated in the manual mentioning among others, that South Africa had pioneered this process.

The guidelines were drawn up after conducting a country-wide, detailed survey of the design and operational performance of 26 flotation plants, and incorporating local and overseas literature on the design of such plants.

In recent years the flotation process showed its mettle in the application of the process for the treatment of eutrophic water. A few existing conventional water purification works were successfully converted to flotation or a combination of flotation and sand filtration, with several new works being built. Design information was, however, not freely available, there also being a shortage of feedback regarding efficacy and problem aspects.

This manual consolidates the valuable experience already gained in practice, for use by the designers, planners, decision-makers and owners involved in the flotation process.

A MASTER PLAN FOR RESEARCH ON HEALTH-RELATED WATER QUALITY

The WRC's Co-ordinating Committee for Health-related Water Quality held a strategy session during the year and has now finalised its master research plan. The mission of this Committee is to minimise human health risks related to water quality and use, through effective co-ordination and promotion of research and through effective information and technology transfer.

The primary goal of the master plan is to assess the impact (actual or potential) of water quality and use on human health for specific user sectors (domestic, recreational, industrial, irrigation and aquaculture), with a view to establishing research needs in this field. The Committee has also established secondary and tertiary goals and has assigned priorities to all the goals.

Strategies have also been developed to address the primary, secondary and ter-

Flotation plant for the treatment of eutrophic water to drinking water.

tiary goals. These strategies mainly refer to guidelines for water quality, analytical methodology, surveys and information and technology transfer. Another strategy is assessing the efficiency of water treatment technology with reference to human health. A separate Co-ordinating Committee will develop a master plan for treatment technology.

WATER QUALITY MONITORING STRATEGIES

A water quality monitoring strategy has been formulated and submitted to the Department of Water Affairs and Forestry as a tool to assess water quality on a national scale. The strategy resulted from a research project carried out in terms of a tripartite agreement between the WRC, CSIR and the Department of Water Affairs and Forestry.

The project objectives were to make water quality information, which is required for regulatory and research purposes and for water resource development, more accessible and reliable. The recommended strategy included specifications for the variables to be measured, sampling frequency, sampling site locations and a statistical protocol to analyse the data for trend identification. Accurate trend assessment is particularly valuable as a decision support input in allocating resources for purposes of water quality management.

A water quality monitoring strategy has been formulated as a tool to assess water quality on a national scale

DESIGN GUIDE FOR WASTE-WATER TREATMENT IN THE TEXTILE INDUSTRY

Two publications dealing with effluent management in textile mills, viz. a final report entitled: *Water Management and Effluent Treatment in the Textile Industry: Scouring and Bleaching Effluents* and *A Guide for the Planning, Design and Implementation of Waste- water Treatment Plants in the Textile Industry,* have been released by the WRC.

Both publications emanate from a research project carried out by the Pollution Research Group at the University of Natal and contain full experimental details and analytical results together with theoretical aspects and design data relating to the treatment of bleach and scour effluents in the textile industry.

Textile processing plants utilise a wide variety of dyes and other chemicals such as acids, bases, salts, detergents, wetting agents, sizes and finishes. Of these, many are not retained in the final product and are discharged in the effluent. Textile effluents are in general relatively non-biodegradable and hence present problems in terms of discharge, both to sewage systems and the environment. Pretreatment of these effluents is therefore desirable, and technology for this purpose is addressed by the publications.

TECHNOLOGY FOR TREATMENT OF ABATTOIR EFFLUENTS

Abattoir effluents are considered to be one of the problematic industrial effluents in municipal areas. Apart from high organic loads and high discharge costs they are also relatively non-biodegradable.

After conducting pilot-scale studies at the Maitland Abattoir in Cape Town, during which it was found that this type of effluent can indeed be purified with ultrafiltration and reverse osmosis (UF/RO) membranes, it was decided to transfer the technology to the meat processing industry.

An agreement was entered into with the South African Abattoir Corporation (ABACOR) with a view to the practical application of the process by personnel of ABACOR. A modular UF/RO plant was installed at the Cato Ridge Abattoir and

Dr Oliver Hart (WRC) (left) presents an award to Mr Frans van der Vyfer, Managing Director of ABACOR in recognition of services rendered by ABACOR for the development of technology to combat water pollution. (Photo: Johan Stander, Beeld*)*

A UF/RO plant is capable of purifying the abattoir effluent to various degrees of quality

operated for more than a year. The plant is capable of purifying the abattoir effluent to various degrees of quality, depending on the reuse needs of the abattoir and the economic implications. In excess of 90% of the organic content and 80% of the phosphate content of the abattoir effluent can be removed.

A successful demonstration of the process to illustrate its viability was held during the year at the Cato Ridge Abattoir.

WATER AND WASTE-WATER MANAGEMENT IN THE PAPER AND PULP INDUSTRY

A secondary objective of the WRC's survey of industrial water and waste water (NATSURV) which was completed in 1990, was the publication of a series of manuals for water management in specific industrial sectors. A further publication in this series, which appeared in 1991, is directed at the paper and pulp industry.

The proposed objectives for water intake and pollution load per unit product which are stated in the guides, provide a basis for both regulation and action within the industry as a valid basis of comparison has been established. The proposed objectives have been discussed in detail with representatives of the industry to ensure that the objectives are attainable and can have a considerable impact in order to reduce the water intake and pollution load of the industry.

A MANIFOLD FOR THE UNIFORM DISTRIBUTION OF FLUIDS

In the water industry the uniform distribution of fluids is often necessary in equipment where a number of similar sections are arranged in parallel, e.g. in heat exchangers, tubular chemical reactors, tubular reverse osmosis modules, crossflow microfiltration tubes, filter press tubes, and flow splitter boxes. In a consultancy agreement with the WRC, the Pollution Research Group of the University of Natal successfully developed a manifold for the uniform distribution of fluids through a number of outlets.

Results obtained with the manifold showed that the division of flow between parallel elements could be controlled to within 5% of the predicted value. This novel manifold was patented by the WRC after experimental work had indicated that one version of the manifold could be used for feeding a single vessel, such as a flocculator, whilst a different version could be adapted for feeding a bank of parallel elements, such as those found in tubular crossflow filters.

ENHANCING THE MEASUREMENT OF RAINFALL

Rainfall is traditionally measured by having rain gauges located at sites which are often many tens of kilometres apart. Given the convective nature of most of South Africa's rainfall, the determination of the areal or spatial distribution of rainfall amounts with rain gauges is obviously subject to enormous sampling errors. Yet there are a growing number of applications for which improved knowledge of areal rainfall is a necessity. These include the modelling of runoff, the assessment of the potential for floods, monitoring of developing droughts and crop forecasting for dryland agriculture.

In March 1991 a workshop was held to assess the feasibility of using remote sensing (radar and satellite) data to supplement rain gauge data in providing better areal rainfall measurements. This work-

There are a growing number of applications for which improved knowledge of areal rainfall is a necessity

shop, organised by the Co-ordinating Committee for Research on Hydrometeorology, was led by Professor GL Austin, the director of the McGill Radar Weather Observatory attached to McGill University in Canada. Attending the workshop were hydrologists, meteorologists, agriculturists and remote sensing specialists from government departments, universities and the private sector. Two representatives from neighbouring states were also present.

The workshop confirmed both the priority and the potential feasibility of integrating rain gauge, radar and satellite measurements, but also emphasised the urgent need to develop appropriate procedures to be able to capitalise on current satellite coverage and prospective radar coverage to be provided by the growing Weather Bureau radar network.

A blueprint for a pilot project in this connection was devised by the workshop. Resulting from this, the WRC has received a formal proposal for such a pilot project, in which the Weather Bureau, Department of Water Affairs and Forestry and the University of Pretoria plan to participate jointly.

INNOVATIONS WITHIN THE NATIONAL PRECIPITATION RESEARCH PROGRAMME (NPRP)

Team members of the NPRP, which is jointly funded by the WRC and the Weather Bureau, continue in the course of their investigations to be exceptionally innovative in developing advanced research tools and cloud seeding approaches. Recent examples include a PC-based aircraft data acquisition system that records data from on-board meteorological and navigational sensors and also laser probes for counting and imaging cloud particles. Both the system hardware and the software for acquiring, analysing, displaying and storing the data have been developed in-house. The same applies to a PC-based system for controlling the operation of meteorological radars and for acquiring, displaying and recording radar reflectivities and aircraft positions.

Cloud seeding to enhance rainfall has traditionally been done with either dry ice or silver iodide. Evidence of inadvertent modification of cloud properties through the industrial emission of hygroscopic particles has, however, led to the development and testing of a hygroscopic seeding flare. This flare, which is used at cloud base, is now being evaluated in terms of its ability to increase the efficiency of rainfall processes in naturally inefficient convective clouds.

GEOHYDROLOGICAL MAPPING

The systematic quantification and evaluation of ground-water resources on the basis of geohydrological provinces and drainage regions, was assigned a very high priority by the ground-water research community. In this regard a recommendation was made that South Africa should embark on a national ground-water mapping programme without delay; that the ground-water information should be as far as possible in a quantifiable form; and that the mapping programme should be supported by a fully operational National Ground-water Data Base which covers all sources of ground-water data in South Africa.

Given this mandate by the ground-water user community, 4 task groups were established to investigate various aspects of developing a mapping strategy:

- The development of a mapping concept - including information to be mapped, scale, representation of information and data sources required
- Availability of data and data capture
- Geographic Information System (GIS) link and mapping technology
- Resources for mapping - e.g. man-power, equipment, financial implications, possible inputs from various organisations and phasing of the project.

A workshop to integrate the findings of the different task groups and to formulate a proposal for a national mapping programme and strategy was held during 1991. Dr Wilhelm Struckmeier, chairman of the International Association for Hydrology (IAH) Commission on Geohydrological Maps, participated in the workshop and through his vast experience provided invaluable insight into the development of a geohydrological mapping strategy for South Africa.

GROUND-WATER QUALITY

The deterioration in ground-water quality has emerged world-wide as one of the most problematic environmental issues. Surface pollution may manifest in ground water only after many years and, once polluted, aquifers can only be cleaned up at vast cost - if at all.

The problem ranges from toxic chemical wastes - particularly wide-spread in the USA - to increased nitrate levels, mainly derived from the use of fertilisers in agriculture.

The master plan for geohydrological research, developed by the WRC's Co-ordinating Committee for Geohydrological Research, indeed identified the investigation of ground- water contamination as a priority research requirement.

The WRC is already funding a number of projects dealing with ground-water pollution. In addition, this need was addressed by the initiation of a situation assessment to identify the major groups of

Fog formation through burning of hygroscopic cloud seeding flares in conditions of high humidity.

The master plan for geohydrological research identified the investigation of ground-water contamination as a priority

industries and activities contributing to the problem and to evaluate the magnitude of these contributions. This study was funded jointly by the WRC, the Department of Water Affairs and Forestry, and the CSIR. It culminated in a draft document, entitled *Ground-water Quality Management Policies and Research Needs for South Africa*. In order to proactively encourage researchers to address these needs, the report has been distributed to ground-water researchers even prior to publication.

The role of coal mining and power generation as possible sources of ground-water pollution is currently being investigated.

FLOW MANAGEMENT IN IRRIGATION CANALS BY MEANS OF A COMPUTERISED SYSTEM

A research team at the Systems Laboratory at the Rand Afrikaans University under contract with the WRC developed a computerised management program which can be used successfully to optimise irrigation canal system management.

The computer package which was developed over a period of more than 4 years, showed that it could minimise the losses in distribution canals and facilitate canal management.

The new program is a major improvement on the techniques which are at present applied to manage irrigation canal systems. Currently all procedures are conducted by hand, ranging from the calculation of input hydrographs to the preparation of water accounts. Such a manual system leaves room for mistakes, since it is time-consuming and can seldom be adequately controlled.

The WRC's new computer package will enable the manager of an irrigation scheme and the personnel of the water office who are responsible for apportioning the water, to reduce operational losses and to increase the general productivity of the scheme.

The simulation model was successfully tested on the basis of flow conditions in the left-bank canal of the Loskop Irrigation Scheme.

NEW FLOW CONTROL MECHANISM FOR FLOOD IRRIGATION

The Department of Agricultural Engineering of the University of Pretoria developed a low-pressure flow control mechanism for balancing dams, thereby alleviating one of the problem areas in effective flood irrigation. The flow control mechanism, or irrigation stream regulator, ensures a constant flow rate from an irrigation dam during irrigation irrespective of the depth of the water in the dam, and can be manufactured by farmers themselves on the farms.

Flood irrigation plays a major role in the water economy of South Africa. A national survey conducted in 1986 indicated that approximately 30% of the total water consumption in South Africa is utilised for flood irrigation purposes. The general standard of flood irrigation in South Africa is, however, unsatisfactory as confirmed by the relatively low application efficiencies observed in practice. By regulating the irrigation flow strength effectively, the situation can be significantly improved.

FIRST PHASE OF THE HYDROLOGICAL INFORMATION SYSTEM COMPLETED

During 1991 the development of the Hydrological Information System (HIS) reached a stage where the project could be handed over to the Department of Water Affairs and Forestry.

The project was started in 1985 with the following objectives:

- To improve existing data banks and to create new ones
- To link various data banks including the ones for ground water and rainfall
- To load all applicable data into HIS.

The project had 2 major components: firstly the development and maintenance of system software and, secondly, data capture and processing.

The original goal was to capture and process all historical hydrological data from 1900 to 30 September 1980, while the Department would keep all recent and incoming data up to date. This goal has been achieved.

Various options for data extraction have been developed and are in the process of being fully integrated via user-friendly menus. The HIS can also be accessed via the Computing Centre for Water Research (CCWR).

Right: The sampling of river water in the Eastern Transvaal.

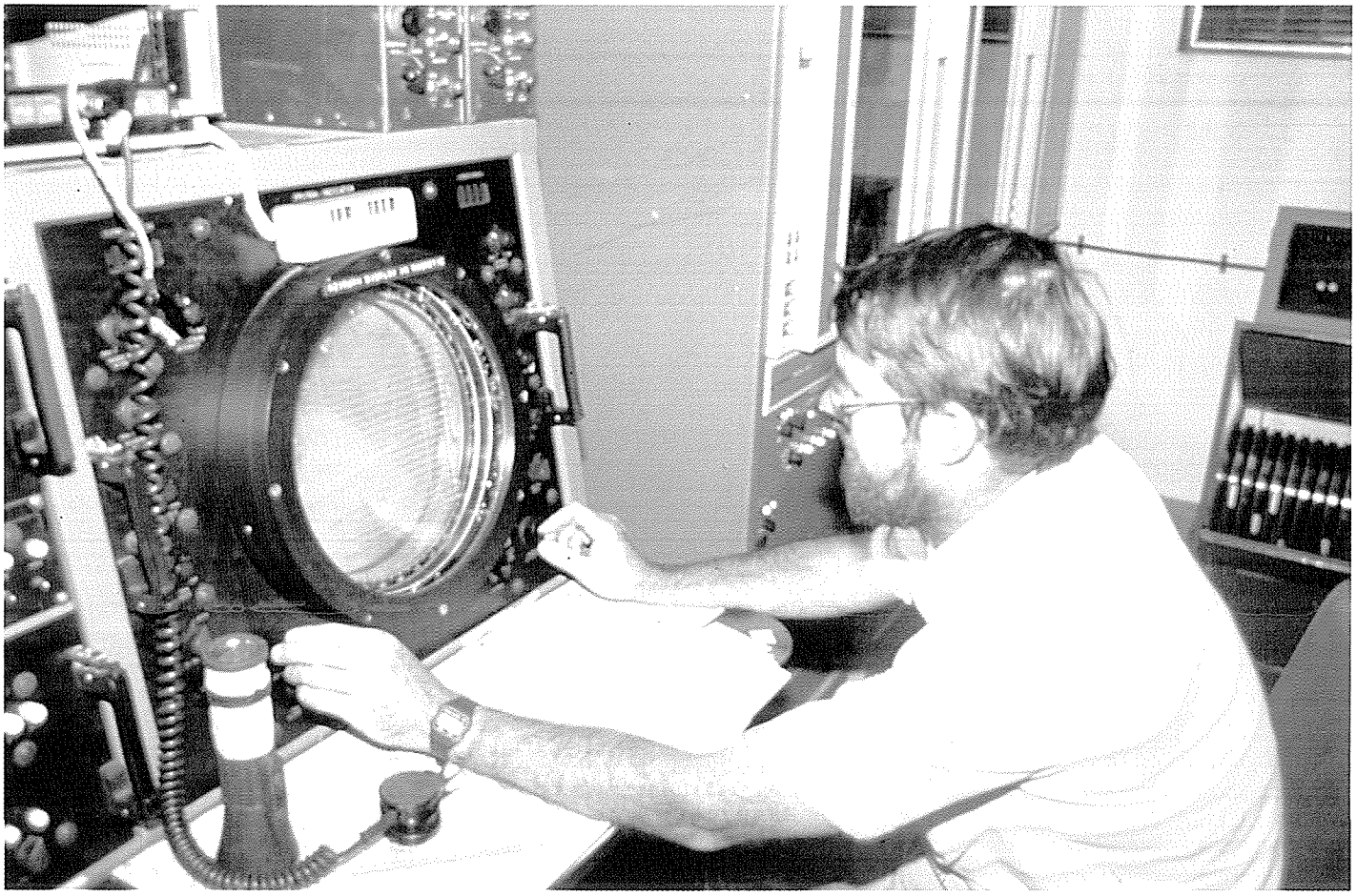
HYDROMETEOROLOGY

Hydrometeorology is the study of weather and climate in relation to the hydrological cycle and also the availability, use and conservation of water resources. Since the water resources of South Africa are almost totally dependent on highly variable and poorly distributed rainfall for replenishment, hydrometeorological investigations supported by the Commission have largely comprised studies of rainfall variability in space and time, techniques for medium- and long-range rainfall forecasting and the potential for rainfall augmentation. The potentially large influence of the surrounding oceans on rainfall patterns over the subcontinent has been recognised and is being addressed as part of the Commission's overall hydrometeorological research initiative.

The Commission, through the Co-ordinating Committee for Research on Hydrometeorology (CCRH), continually strives to assess and update research needs and to co-ordinate research on a national basis. In response to an expressed need, a workshop organised by the CCRH was held to assess the potential of enhancing the measurement of rainfall by using satellite and radar data in conjunction with conventional rain-gauge data. This approach has great potential for reducing the very large sampling errors inherent in using gauge data alone to draw conclusions concerning the spatial distribution of daily rainfall. The workshop was led by Professor Geoff Austin of the McGill Radar Weather Observatory attached to McGill University in Canada. The major outcome of the workshop was a comprehensive plan for launching a co-operative, multi-organisational pilot project designed to develop the methodology for integrated use of rain-gauge, radar and satellite data in producing digital maps of spatially distributed rainfall in near-real time. These maps will be of great benefit in the prediction of runoff and sediment transport to rivers, detection of imminent flooding events and monitoring the progression of hydrological and agricultural drought conditions.

The potentially large influence of the surrounding oceans on rainfall patterns has been recognised and is being addressed

During 1991, the Commission financially supported 9 hydrometeorological projects. Of these, 2 were new research agreements, while the final reports on 2 completed projects were accepted by the Commission.



Radar observations will be used to complement rain-gauge measurements to provide better rainfall information.

COMPLETED PROJECTS

A stochastic daily climate model for South African conditions

(No 200) Department of Mathematical Statistics, University of Cape Town

In 1987 a research project was initiated to develop a stochastic model for the simultaneous description of climatic variables on a day-to-day basis at a fixed location. The aim was to preserve all the important properties of such variables, these being seasonal behaviours, short-term persistence, interrelationships between different variables, variances and boundedness. The researchers succeeded in developing a family of stochastic models which met the stated objectives. Although based on complex mathematical theory, these models have been presented in a form which makes them accessible to users with only limited mathematical experience. The ability of the models to generate realistic daily climatic records stochastically has great value for both water resources and agricultural planning and risk analysis when reliable long-term climatic observations are unavailable.

Costs: R158 393
Term: 1987-1990

Precipitation and airflow in cumulus clouds

(No 223) Division of Earth, Marine and Atmospheric Science and Technology, CSIR

In 1987 the then National Physical Research Laboratory acquired the necessary hardware to develop a triple Doppler radar system to investigate relationships between:

- the spatial distribution of precipitation and internal airflow within convective clouds;
- the surface precipitation patterns and three-dimensional airflow in clouds; and
- rainfall intensities as measured by rain gauges and radar reflectivities.

Unfortunately, only one of the 3 Doppler radars was successfully brought on-line before the end of the WRC contract in support of this research. The objectives reliant on the use of multiple Doppler radars could therefore not be met. Despite this, the capability of a single Doppler radar in revealing kinematic storm properties could be assessed. Furthermore, useful results were obtained concerning rainfall drop size distributions and area-time integrals of radar echoes as factors in the successful measurement of rainfall volumes using radar.

Costs: R520 258
Term: 1988-1991

NEW PROJECTS

Evaporation measurements above vegetated surfaces using micro-meteorological techniques

(No 349) Department of Agronomy, University of Natal

Evaporation from vegetated land surfaces is a major component of the hydrological cycle and directly affects both the biomass production of the vegetation, and the runoff from such surfaces. Evaporation depends on numerous atmospheric, plant and soil factors and is extremely difficult to estimate with precision, even though the process is well understood. While the equations (e.g. the Penman-Monteith equation) which describe the evaporation process are sound, the problem is to obtain correct values of all the input variables needed to calculate evaporation rates with the help of such equations. In terms of this contract the feasibility will be investigated of using micro-meteorological techniques, notably the Bowen ratio technique and the eddy correlation technique, to obtain direct measurements of evaporation from natural grassland and afforested surfaces. Should these techniques prove successful, they would greatly enhance our ability to quantify the water budget of surfaces associated with different forms of land use.

The southern Agulhas Current and its influence on the weather and climate of Southern Africa

(No 374) Department of Oceanography, University of Cape Town

Both locally and internationally, there is increasing recognition of the important role oceans play in determining the weather and climate of the continents. This particularly applies to Southern Africa, which is bordered by ocean on three sides. This project will focus on the southern Agulhas Current, the Agulhas retroflection region and the subtropical convergence zone, where ocean-atmosphere heat and vapour fluxes are among the highest in the world. These fluxes will be quantified and studied with a view to obtaining better insight into the effect of the southern Agulhas Current on the weather and climate of Southern Africa.

RESEARCH PROJECTS

Completed projects

- **200** The development of a stochastic daily climate model for South African conditions (The University of Cape Town - Department of Mathematical Statistics)
- **223** Precipitation and airflow in cumulus clouds (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology)

Current projects

- **222** The reconstruction of the climatic history of the last 2 000 years in the summer rainfall regions of Southern Africa (The South African Museum)
- **278** The prediction of South African summer rainfall variability from ocean surface temperatures (The University of Cape Town - Department of Oceanography)
- **279** Relationships between lightning and precipitation (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **305** Interpolation and mapping of daily rainfall model parameters for South Africa (The University of Cape Town - Department of Mathematical Statistics)
- **306** Techniques for seasonal and long-term rainfall forecasting in South Africa (The University of Pretoria - Department of Civil Engineering (Chair of Meteorology))

New projects

- **349** Evaporation measurements above vegetated surfaces using micrometeorological techniques (The University of Natal - Department of Agronomy)
- **374** The southern Agulhas Current and its influence on the weather and climate of Southern Africa (The University of Cape Town - Department of Oceanography)

RAINFALL STIMULATION

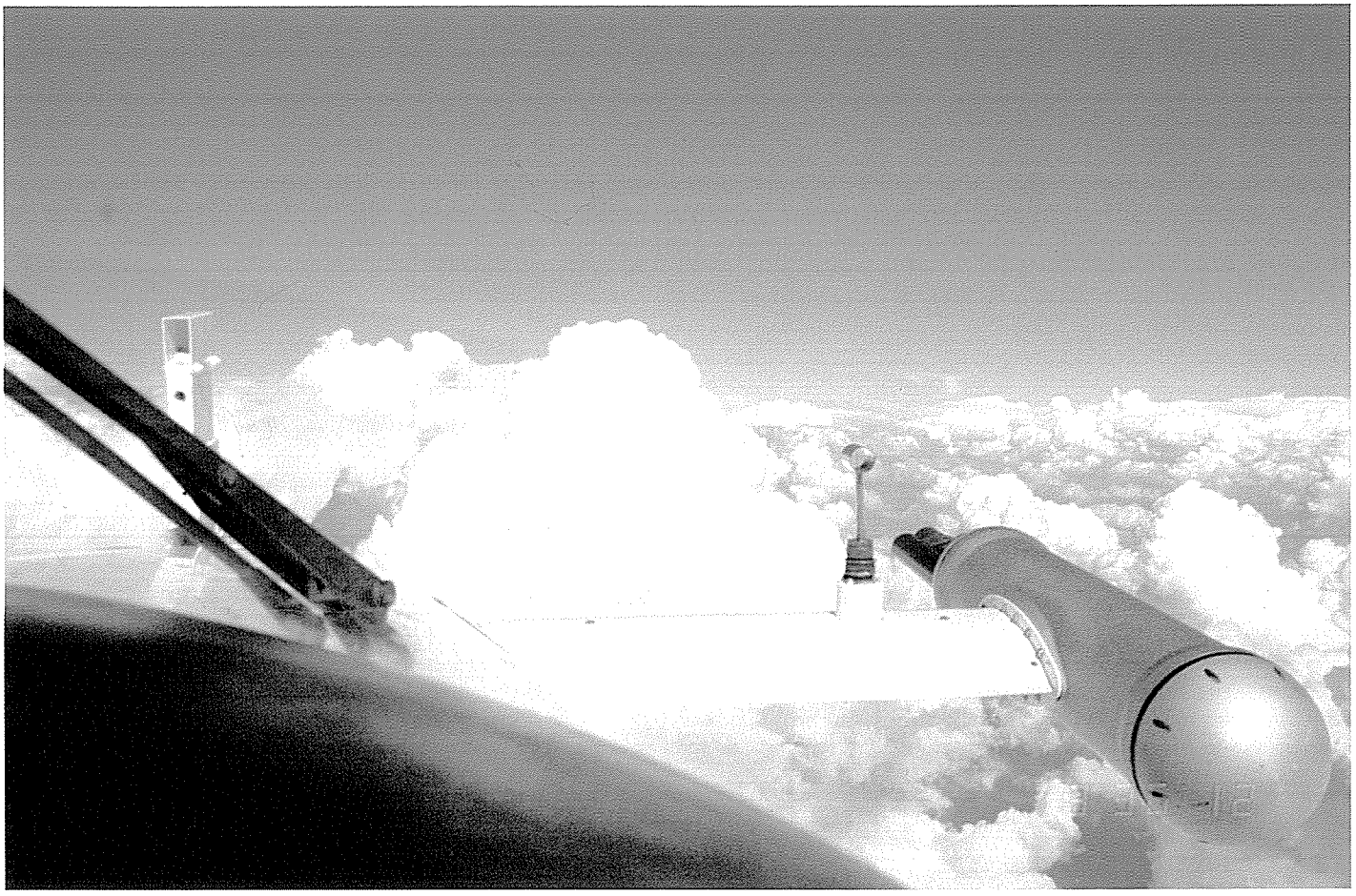
Rainfall stimulation represents a potential option for augmenting South Africa's scarce water resources at fairly modest cost. For this reason, research into rainfall stimulation has been strongly supported by the WRC for the past 9 years. During the past 2 years research has been undertaken in partnership with the Weather Bureau of the Department of Environment Affairs under the umbrella of the National Precipitation Research Programme (NPRP).

There have been some notable achievements since the inception of the NPRP. The programme's two research radar installations at Bethlehem and Carolina have been systematically upgraded and have been placed under control of computer systems which also process and store the incoming radar signals reflected from clouds and aircraft. The NPRP's four research aircraft have been equipped with state-of-the-art instrumentation packages. This includes hardware and software systems for the control of sophisticated instrumentation and the in-flight acquisition, processing, display and storage of data. Most of these developments have been undertaken in-house, at considerable savings in cost.

Important natural precipitation formation mechanisms active in a corridor stretching from Nelspruit in the Eastern Transvaal to Bethlehem in the north-eastern Orange Free State have been documented. Factors contributing to inefficiency of precipitation formation have been identified and hypotheses concerning the appropriate treatment of clouds to enhance their natural efficiency have been developed. Previous findings that dry ice seeding of convective clouds produced considerable and statistically significant increases in cloud size and precipitation rate in the time interval from 20 to 40 min after seeding are being confirmed. Recent findings suggested that certain clouds should respond even more favourably to seeding with hygroscopic materials. Flares for hygroscopic seeding have therefore been developed and are now under investigation.

Flares for hygroscopic seeding have been developed and are now under investigation

The planning of area-wide rainfall augmentation will receive attention in the near future. In anticipation, steps have been taken to assess public attitudes to large-scale artificial rainfall enhancement practices, and to initiate several studies designed to assess potential impacts on agriculture, forestry, water resources and the environment.



Rainfall stimulation instrumented aircraft approaching a cloud to make observations of microphysical characteristics.

COMPLETED PROJECT

Information strategies for rainfall stimulation *(No 394) Information Dynamics Group, Human Sciences Research Council*

Should research results provide justification for an operational rainfall stimulation programme for South Africa, it is likely that authorities would wish to see such a programme implemented. Negative public perceptions could, however, make implementation difficult. In terms of this research project a survey was carried out to assess the extent to which various strata of South African society were either informed or uninformed about artificial rainfall stimulation and to what extent being uninformed could be responsible for negative perceptions. The results of this study have provided guidance on what steps to take to ensure an adequately informed public.

Costs: R79 000
Term: 1991

NEW PROJECT

A spatially distributed daily rainfall data base for various weather modification scenarios *(No 373) Hydrological Research Institute, Department of Water Affairs and Forestry*

The aim of this project is to develop a suite of computer programs to simulate the response of a sequence of rainfall events to a rainfall stimulation programme. These programs will then be used to generate plausible data sets of modified rainfall sequences using various scenarios for both the operational aspects of a rainfall stimulation programme and for the seeding effect on rainfall.

An analysis of the potential impact of rainfall stimulation on water resources, forestry and agriculture depends on the availability of rainfall maps representing the various possible effects of the seeding programme, for example the increased storm intensity and area. Once the various scenarios have been simulated, these data sets, together with the original unmodified data set, can be routed through hydrological and crop production models, thereby quantifying the likely impact of rainfall stimulation on the end-users.

RESEARCH PROJECTS

Completed project

- **394** The development of information strategies for rainfall stimulation (The Human Sciences Research Council - Information Dynamics Group)

Current project

- **H1/133** National precipitation research programme (NPRP) with a view to rainfall enhancement (The Company for Research on Atmospheric Water Supply and the Department of Environment Affairs - Weather Bureau, subcontracting CloudQuest (Pty) Ltd, UNISA and others)

New project

- **373** The generation of a spatially distributed daily rainfall data base for various weather modification scenarios (The Department of Water Affairs and Forestry - Hydrological Research Institute)

SURFACE HYDROLOGY

The focus in this field is now clearly divided between 2 main components:

- **Hydrology**; and
- **Water resources management.**

In reconstituting the Co-ordinating Committee for Hydrological Research (CCHR) representation has therefore been broadened.

Hydrology is the scientific foundation for sound water resources management. It seeks to explain the water balance dynamics of any defined spatial (from a point to global) and temporal scale (from seconds to years) and their relationships with the physical and chemical transport of matter through the hydrologic cycle and with ecology.

Understanding of the quantitative aspects of the catchment water balance is slowly improving, but the more the complexity of the management problem is faced the more it is realised where new knowledge and innovative solutions are needed.

Forest hydrology will receive special attention in the near future and 2 short-term research planning studies have been initiated. One study by Ninham Shand Inc. will evaluate research on forest hydrology which has been carried out in South Africa up to now and will present an objective assessment of research needs. The other study will specifically assess research needs and opportunities in the Eastern Cape where large-scale afforestation is now taking place.

Forest hydrology will receive special attention in the near future

The interaction between ground- and surface-water resources is not yet clearly understood and as the increasing shortage of water resources focuses attention on the higher rainfall areas it is realised that the management of mountain catchments not only affects surface water, but ground water as well.

In an age where computing facilities can be used to simulate the real world and produce fascinating results one must be careful to realise that real observation, measurement and experimentation should not be neglected.

During 1991 the Commission financially supported 16 hydrological research projects; of these, 2 were new research agreements and 2 were completed.

COMPLETED PROJECTS

The hydrological response to Third World settlements in peri-urban areas of Natal/KwaZulu

(No 233) Department of Hydrology, University of Zululand

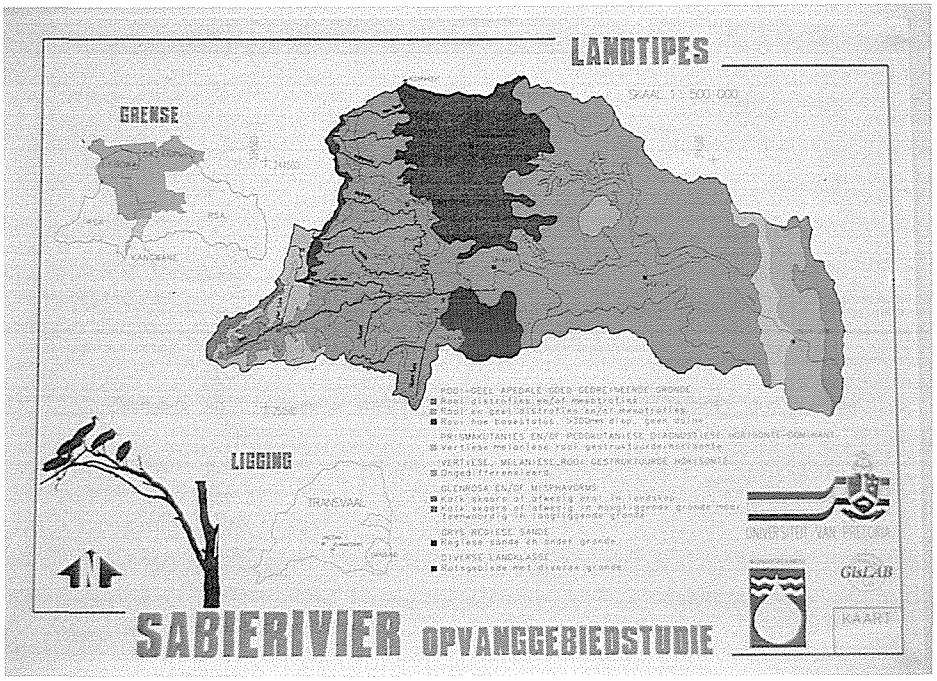
The research was carried out in the catchments of the Ntuze River which are characterised mainly by grassland on fairly deep granitic soils. These catchments are physiographically similar to the urban fringe areas surrounding other Natal coastal centres, consequently the results of this research should be directly applicable to many other similarly affected areas.

The objective of the research was to relate observed land-use changes in one catchment with hydrological response. An undisturbed natural catchment was used for baseline comparison.

The conclusion of the work at this point, where the population density has increased to 300 people/km^2, is that there is no significantly different response in runoff regimes. By the turn of the century the population is expected to increase to 900 people/km^2 and then the picture may be different.

However, marked differences were found in most of the water quality parameters studied - such as pH, conductivity, turbidity, suspended solids, nitrates and phosphates. Turbidity and total phosphate were linearly related to suspended solids which tend to increase with increasing discharge and which increased almost fourfold due to increased population density.

Costs: R43 126
Terms: 1988-1990



Geographic information systems start to play an increasingly important role in hydrology and water resources management.

A systems model for the Mgeni catchment *(No 234) Department of Agricultural Engineering, University of Natal*

In the first phase of this project attention was focused mainly on the development and testing of a physical conceptual systems model to represent the water quantity components of the hydrologic system.

The systems model developed makes use of existing, generally available data on land type (soils), rainfall and 1:50 000 topographical maps. Special surveys were carried out to provide data on land use and land cover, storage reservoirs and irrigation abstractions.

Simulations of the systems model are verified against observed flow data and the results are generally highly acceptable. The models can address the effect of afforestation in certain parts of the catchment or the effect of farm dams, etc.

Costs: R303 788
Term: 1988-1991

NEW PROJECTS

A distributed hydrological modelling system to assist with water quantity and quality management in the Mgeni catchment: Phase II *(No 375) Department of Agricultural Engineering, University of Natal*

Development of the distributed modelling system will continue, to enable simulation of, and to provide initial information on selected critical water quality parameters required by those responsible for planning and managing the Mgeni River catchment water resources.

Research will focus on the incorporation of selected dominant water quality components and subroutines into the modelling system developed in Phase I (See **Completed projects**). Initially conservative determinands such as conductivity and possibly chloride or sodium ion concentrations will be modelled. Ultimately the modelling system will be expanded to cater for the simulation of non-conservative determinands such as phosphates, nitrates, *E. coli*, chlorophyll *a*, turbidity and dissolved oxygen to enable representation of water quality in terms of, *inter alia*, the national water quality index.

The modelling system will be developed in collaboration with researchers and institutions working in water quality, specifically the Department of Water Affairs and Forestry; Umgeni Water; the CSIR's Division of Water Technology; and the University of Zululand. Collaborators' research findings will be incorporated into the hydrological modelling system, where beneficial to the project.

The application of resource economics to water management decision-making in South Africa *(No 415) Institute of Natural Resources, University of Natal*

As a natural resource, water has been the subject of study within the specialised field known as resource (or environmental) economics. This discipline is relatively new in South Africa, and has as yet not been widely applied to facilitate decision-making in situations characterised by scarcity of resources.

It will, for example, be particularly useful in decision-making affecting the allocation of water to users such as conservation, rural communities, irrigation and recreation. Not everyone will always agree with the role that resource economics could play, but the advantages are that decisions can be reached in a logical, transparent and objective manner.

The theoretical aspects of this research and the usefulness of the approach will be tested with the aid of a limited number of presently popular case studies.

RESEARCH PROJECTS

Completed projects

- **233** The investigation of the hydrological response to Third World settlements in the peri-urban areas of Natal/KwaZulu (The University of Zululand - Department of Hydrology)
- **234** The development of a systems model for the Mgeni catchment (The University of Natal - Department of Agricultural Engineering)

Current projects

- **183** The effects of urbanisation on catchment water balance (The University of the Witwatersrand - Department of Civil Engineering, Water Systems Research Group)
- **198** Development of methods to assess the impact of agricultural practices on water resources in Southern Africa (The University of Natal - Department of Agricultural Engineering)
- **235** Hydrological modelling studies in the Eastern Cape (Rhodes University - Department of Geography)
- **236** Development of a model to simulate flow in alluvial rivers (A firm of consulting engineers: Bruinette Kruger and Stoffberg Inc.)
- **270** Hydrological systems model development (The University of Natal - Department of Agricultural Engineering)
- **296** The quantitative structuring of national water planning objectives for use in decision support systems in South Africa (The University of Cape Town - Department of Mathematical Statistics)
- **297** The preparation of a review document on sediment transport in Southern Africa, including revision of the sediment production map of Southern Africa (Sigma Beta Consulting Engineers)
- **298** The surface water resources of South Africa 1990 (Consortium of consulting engineers)
- **299** The adaption and calibration of an urban runoff quality model (The CSIR - Division of Water Technology)
- **300** The utilisation of geographic information systems (GIS) and integrated environmental management (IEM) in the planning and management of water resources within river catchments (The University of Pretoria - Department of Landscape Architecture)
- **317** Urban catchment monitoring (Welkom City Council and a firm of consulting engineers: Steffen Robertson and Kirsten Inc.)
- **319** Monitoring the effect of catchment development on urban runoff and water balance (The University of the Witwatersrand - Department of Civil Engineering, Water Systems Research Group)

New projects

- **375** The development of a distributed hydrological modelling system to assist with water quantity and quality management in the Mgeni catchment: Phase II (The University of Natal - Department of Agricultural Engineering)
- **415** The application of resource economics to water management decision- making in South Africa (The University of Natal - Institute of Natural Resources)

GROUND WATER

As increased stress is placed on South Africa's limited ground-water resources, there is no doubt that the demand for ground water will intensify in the future. Significant measures need to be taken today to ensure that both the quality and quantity of this resource will adequately meet future requirements.

The preparation of a geohydrological map of South Africa is viewed as an important means for managing ground water

The preparation of a geohydrological map of South Africa is viewed as an important means of achieving this end, as a prerequisite for managing ground water and as an educational tool in protecting this valuable resource. A workshop on the development of a geohydrological mapping strategy was held on 20 and 21 March this year. Under the guidance of Dr W Struckmeier, chairman of the International Commission on Hydrogeological Maps, it was decided that the compilation of a national-scale map should commence without delay.

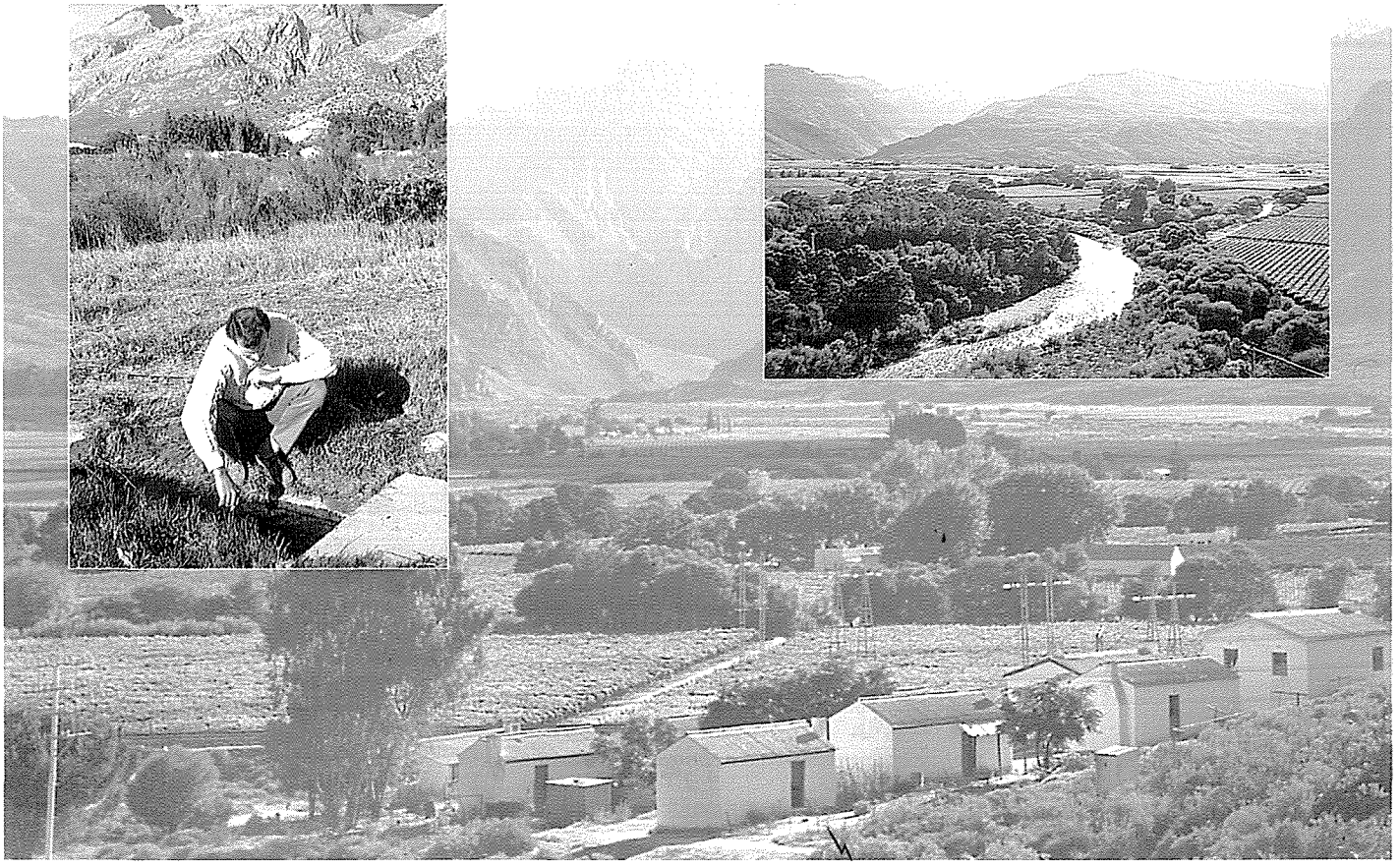
In terms of identifying ground-water quality research needs, significant progress was made during 1991 on the compilation of a situation assessment of the threats to ground-water quality. In collaboration with the Department of Water Affairs and Forestry a document outlining these threats together with ground-water quality management policies and strategies and the need for further research, has been prepared and will be published early in 1992.

During 1991 the Commission supported 21 projects related to ground water of which 7 commenced during the year.

NEW PROJECTS

A method for the selection of suitable landfill sites, and of guidelines for sanitary landfill in municipal areas *(No 352) Division of Water Technology, CSIR*

In many countries, South Africa being no exception, prime land for the expansion and development of urban areas is becoming scarce. Consequently, there is an ever-increasing pressure for the location of municipal solid waste landfill sites in zones considered unsuitable or uneconomical for other kinds of development.



Sampling of drain- and shallow ground water to assess pesticide levels in the Hex River valley.

Many such zones are, however, highly unsuitable for landfill.

Landfill site selection and evaluation studies involve complicated procedures which are dependent upon a number of interrelated factors. In order to help regulatory bodies determine types and depths of studies required and to guide them through the decision-making process, there is a need for a decision support system. The main objectives of this study are to investigate existing landfill site selection and evaluation methodologies, to develop a suitable methodology for South African conditions, and to incorporate this into a decision support system.

A manual on quantitative estimation of ground-water recharge and aquifer storativity *(No 353) Department of Water Affairs and Forestry*

It is well documented that reliable estimation of ground-water recharge and aquifer storativity is a difficult exercise. This is due largely to problems in separating the effects of recharge, storage, and inflow and outflow of ground water which interactively determine the ground-water level response. This project aims to overcome these problems by collating new technological and methodological developments regarding estimation of ground-water recharge and aquifer storativity in the form of a manual. The simplistic water balance and lumped parameter approach will be tested using several case studies and will result in more effective management of South Africa's limited ground-water resources.

A preliminary investigation of the nitrate content of ground water and limitation of the nitrate input *(No 368) Division of Water Technology, CSIR*

A marked increase in ground-water nitrate levels is being reported world-wide, resulting in certain ground waters being progressively less suitable for human use, especially infants. Little is known regarding the situation in South Africa. It is, however, to be expected that the trend would be similar, but hopefully less pronounced than in some developing countries. This short-term project is aimed at carrying out a preliminary evaluation of the situation in South Africa, using available information, both as regards the extent and the seriousness of nitrate contamination. An attempt will be made to identify the main sources of contamination qualitatively and to undertake a preliminary evaluation of the possibilities of managing nitrate contamination.

A compilation of information on the magnitude, nature and importance of coastal aquifers in Southern Africa *(No 370) Coastal Research Institute, University of Port Elizabeth*

Coastal sand aquifers are important, not only as sources of fresh water for many small villages and resorts along the coastline, but also as an important source of nutrients for surf-zone ecosystems. Very little is known concerning the possible impact of ground-water abstraction from coastal sand aquifers on foredune vegetation systems, surf zones and estuaries. Before any research is undertaken on these and other aspects of coastal aquifers, it is essential that all available information on the nature and extent of coastal aquifers be collated and documented, this being the major aim of this project.

Feedlots are being included in the preliminary survey of possible nitrate pollution sources.

Health aspects of the impact of domestic and industrial waste disposal activities on ground-water resources *(No 371) Division of Water Technology, CSIR*

Ground water is vulnerable to contamination from many sources, including agricultural practices, mining, and domestic and industrial waste disposal activities. In order to protect ground water it is important that the risk associated with various disposal practices be assessed, and where possible, quantified.

An important aspect of risk is the effect on human health associated with drinking contaminated ground water. Prior to initiating full-scale research on the subject, this project aims to undertake a comprehensive literature survey to ascertain international findings on the impact of domestic and industrial waste disposal on ground-water resources and to relate this to current waste disposal practices in South Africa.

The use of geographic information systems and other computer-aided drafting facilities for the production of geohydrological maps *(No 377) Institute for Ground-water Studies, University of the Orange Free State*

Ground-water resources are generally less well documented than surface water, resulting in its utilisation being far from optimal in the national context. The lack of such documentation on the location, potential and quality of ground water can be held partly responsible for the fact that millions of rands are wasted annually on poorly sited, constructed and completed boreholes.

The increasing significance of ground water and the emerging problems surrounding its utilisation coupled with the large number of institutions involved in the planning, development and implementation of this resource demand that information on ground water at a regional scale should be readily available. Geohydrological maps offer a singularly effective means of satisfying this demand. This project aims to develop the technology base for the production of such maps by establishing links between ground water and other hydrological data bases and a geographic information system. It will be co-ordinated as part of the national geohydrological mapping strategy for South Africa.

Techniques for risk analysis and ground-water management of Southern African aquifers *(No 378) Institute for Ground-water Studies, University of the Orange Free State and Division of Earth, Marine and Atmospheric Science and Technology, CSIR*

South Africa's water resources, limited both by unfavourable climatic conditions and poor geographic distribution, are being further stressed by the impact of industrial, mining and agricultural activities. It is becoming increasingly important to manage, distribute and control water resources in a more efficient manner.

Although considerable time and money have been expended on mathematical models to describe the physical nature and behaviour of ground water in South Africa, linking these to management models will make effective ground-water management a reality. This project aims not only to investigate the availability and usefulness of ground-water management models under South African conditions, but also to use risk analysis techniques for determining the potential of an aquifer during periods of below normal rainfall.

The relationship between ground water and the lake system on the Zululand coastal plain is being investigated.

RESEARCH PROJECTS

Current projects

- **212** The use of electromagnetic exploration techniques for the development of ground-water resources (The University of Pretoria - Department of Geology)
- **216** The evaluation and development of techniques for the determination of geohydrological parameters by using geoelectrical methods (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **221** A geohydrological investigation and evaluation of the Zululand coastal aquifer (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **224** The development of techniques for the evaluation and effective management of surface and ground-water contamination in the Orange Free State goldfields (The University of the Orange Free State - Institute for Ground-water Studies)
- **225** The enhancement of the National Ground-water Data Base facilities (The University of the Orange Free State - Institute for Ground-water Studies)
- **267** The evaluation and development of geophysical techniques for characterising the extent and degree of ground-water pollution (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology and Division of Water Technology)
- **268** A preliminary survey of pesticide levels in ground water from a selected area of intensive agriculture in the Western Cape (The CSIR - Division of Water Technology)
- **271** A comparative study of two- and three-dimensional ground-water models (The University of the Orange Free State - Institute for Ground-water Studies)
- **272** An investigation into the oscillation method for the determination of aquifer transmissivity (The University of the Orange Free State - Institute for Ground-water Studies)
- **273** An investigation of the potential use of NOAA satellite remotely sensed data for identification of regional-scale fracture zones for ground-water supply purposes in Southern Africa (A firm of consulting engineers: Steffen Robertson and Kirsten Inc.)
- **291** A regional investigation into ground-water quality deterioration in the Olifants River catchment above the Loskop Dam, with specialised investigations in the Witbank Dam subcatchment (The University of the Orange Free State - Institute for Ground-water Studies)
- **310** The integration of remote sensing, digital image processing and geographical information systems technologies for regional-scale ground-water resources assessment in South Africa (A firm of consulting engineers: Steffen Robertson and Kirsten Inc.)
- **311** The development and evaluation of geohydrological and isotope hydrological methodologies for the identification of areas potentially suitable for waste disposal (The University of the Witwatersrand - Schonland Research Centre, and the Atomic Energy Corporation of South Africa)
- **339** The compilation of a comprehensive guide for ground-water sampling in South Africa (The CSIR - Division of Water Technology)

New projects

- **352** Development of a method for the selection of suitable landfill sites, and of guidelines for sanitary landfill in municipal areas (The CSIR - Division of Water Technology)
- **353** Preparation of a manual on quantitative estimation of ground-water recharge and aquifer storativity (The Department of Water Affairs and Forestry)
- **368** A preliminary investigation of the nitrate content of ground water and limitation of the nitrate input (The CSIR - Division of Water Technology)
- **370** A compilation of information on the magnitude, nature and importance of coastal aquifers in Southern Africa (The University of Port Elizabeth - Institute for Coastal Research)
- **371** An assessment of health aspects of the impact of domestic and industrial waste disposal activities on ground-water resources (The CSIR - Division of Water Technology)
- **377** The use of geographic information systems and other computer-aided drafting facilities for the production of geohydrological maps (The University of the Orange Free State - Institute for Ground-water Studies)
- **378** The development of techniques for risk analysis and ground-water management of Southern African aquifers (The University of the Orange Free State - Institute for Ground-water Studies and the CSIR - Division of Earth, Marine and Atmospheric Science and Technology)

AGRICULTURAL WATER UTILISATION

Over the past number of years there has been a subtle, but definite, shift away from basic research to more practical on-farm orientated research. This shift can be attributed to the fact that not only have sufficient data been collected through the years, but also that the research community itself is now more at ease with the on-farm situation.

Initial research in this regard concentrating on the correct irrigation scheduling of field crops, has already indicated the importance of this approach

Initial research in this regard, centred mainly in the Pietersburg and Winterton areas, and concentrating on the correct irrigation scheduling of field crops, has already indicated the importance of this approach - not only in ensuring the effective on-farm implementation of research results, but also of the most important aspect of technology transfer between all parties involved, namely the researcher, the farmers, irrigation boards and organised agriculture. This approach has been expanded so as to include research in the fields of soil science, agricultural meteorology, agricultural economics and the irrigation of vegetables. It is to be expected that insufficiencies in current basic research results will be identified during field testing. These insufficiencies can then be rectified, if required, by further basic research.

The number of agriculturally related research projects financed by the Commission in 1991 came to 28. Of these 5 were completed while 7 new research agreements were entered into.

MASTER PLAN FOR IRRIGATION RESEARCH

The development of the prioritised master plan for irrigation research, the initiation of which was reported on in the *1990 WRC Annual Report*, continued during 1991 to the stage where the master plan was finalised and accepted by the Co-ordinating Committee for Irrigation Research.

The overall objective of the master plan is the optimum development, management and conservation of irrigation resources in South Africa. In terms of the plan the following have been identified as the primary irrigation research objectives in South Africa for the immediate future:

- Refinement of data bases and planning methods for optimising irrigation development.
- Optimisation of efficiencies for storing, distributing and applying irrigation water.
- Optimisation of crop yield and quality per unit of water used.

COMPLETED PROJECTS

The quantification and limitation of water losses associated with centre- pivot irrigation systems

(No 153) Department of Agricultural Engineering and the Department of Agronomy, University of the Orange Free State

The research has been conducted over a period of 6 years. As a result of problems experienced with the use of the conventional uniformity index in the case of centre-pivot systems, a new approach, known as the emitter index, was defined and tested. This is based on emitter yield and a 10% variation in yield is accepted as the norm. This implies a minimum emitter index of 95%. The project showed that this is feasible in practice using the correct design approach.

The project showed further that, in order to limit wind and evaporation losses, drop sizes under centre-pivot systems must be of the order of 1 to 3 mm in diameter. A mathematical relationship between evaporation losses, wind speed, vapour-pressure deficit and the depth of application for each irrigation was established as a result of the project observations. The project made a further contribution to irrigation practice by formulating a set of recommendations on the design, construction and management of centre-pivot irrigation systems.

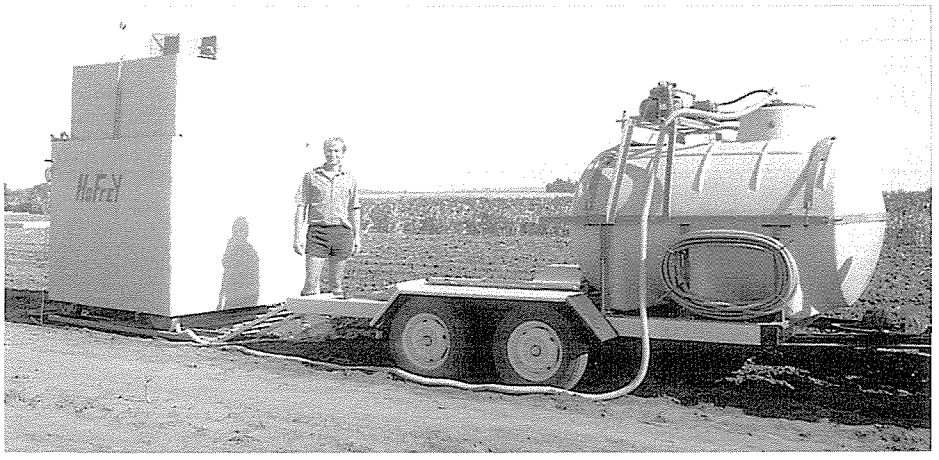
Costs: R299 886
Term: 1984-1991

An adjustable low pressure flow-rate control valve for flood irrigation

(No 207) Department of Agricultural Engineering, University of Pretoria

The project was executed over a period of 4 years. The objective was to develop a simple flow control mechanism by means of which flow for flood irrigation purposes could be maintained within approximately 10% of a pre-selected value.

The outcome of the project, which



The mobile mini rainfall simulator built by the Department of Soil Science, UOFS.

meets all the requirements regarding accuracy and cost, was an immersed spout which is held under the water surface by means of a float at a chosen depth. The spout is connected to the dam outlet with the aid of a sturdy pipe and flexible coupling. By changing the spout size and/or its depth under the water surface, the delivery rate can be varied to the required value to suit particular circumstances. The design procedures and the necessary design graphs which will ensure that the mechanism complies with the requirements of the circumstances are set out in the final report on the project.

General use of the mechanism in irrigation dams for flood irrigation purposes will make a significant contribution to the standard of flood irrigation in South Africa.

Costs: R47 375
Term: 1987-1989

Methods of developing operational rules for individual irrigation systems *(No 209) Department of Civil Engineering, University of Stellenbosch*

The project aimed at providing a methodology which would enable the informed irrigator to develop his own operating rules for a particular irrigation system for a given set of situation data. As these operating rules are influenced by a great number of parameters, an optimisation process is being envisaged by means of which the recommended observations could be processed in order to provide the practical operating rules for the irrigation system and crop under consideration. Although the proposed approach to the development of the operating rules is a healthy one from a theoretical point of view, the project experienced such problems in the execution thereof that the original objectives could not be attained within the available time and funds. Nevertheless some useful information, especially regarding data collection for management purposes, is contained in the final report.

Costs: R458 634
Term: 1987-1990

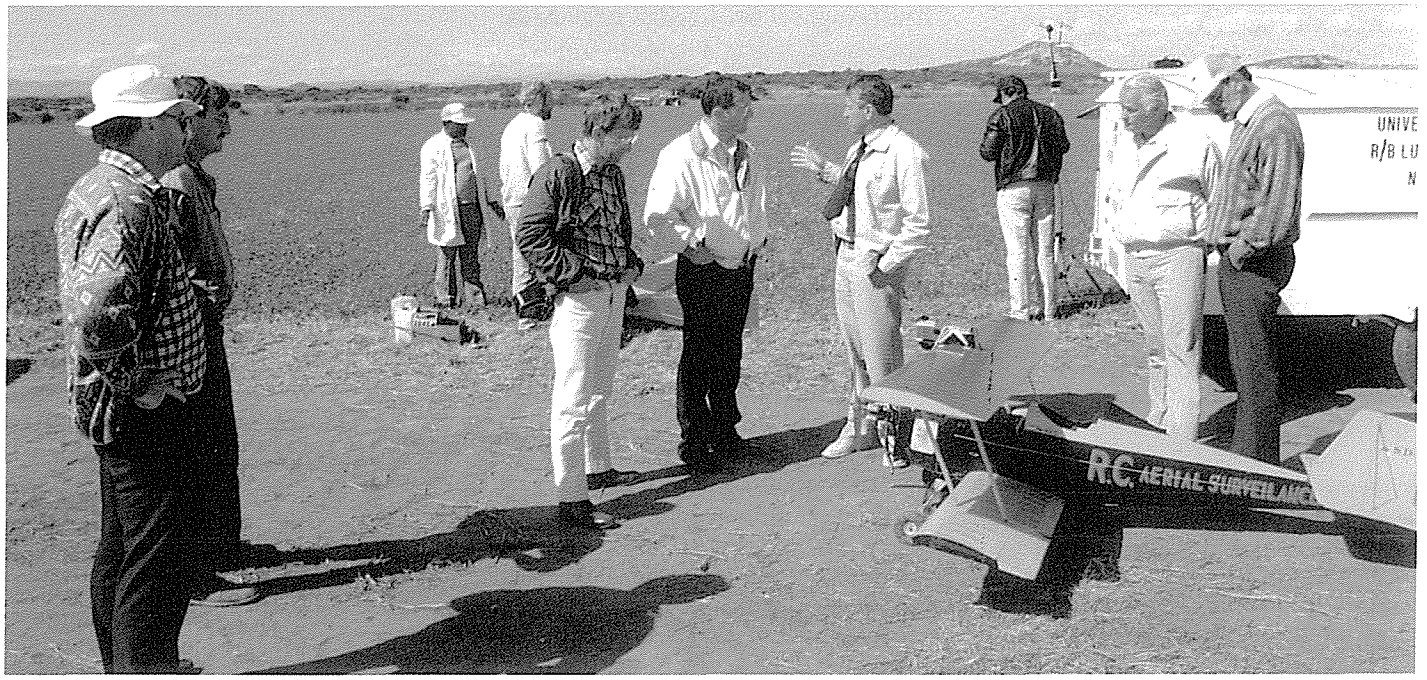
The economic evaluation of alternative irrigation scheduling strategies for wheat in the irrigated area of the Orange Free State *(No 218) Department of Agricultural Economics, University of the Orange Free State*

This project was carried out over a period of three and a half years. The results of the project indicate clearly that size, static head and delivery rate of a centre-pivot system are the major factors affecting the economic viability of the system. The research also showed, albeit via theoretical analysis, that irrigation scheduling practices not only resulted in a saving of water but also increased the nett income of the farmers. The researchers concluded that, given the increase in nett income, farmers should be in a position to pay for an irrigation scheduling service.

Costs: R300 784
Term: 1987-1991

A manual to be used with the IDES computer programs for the design of irrigation systems *(No 230) MBB Inc.*

During the execution of a previous WRC research project the consulting engineering company MBB Inc. had developed computer-based procedures for the selection of a suitable irrigation method for a given set of circumstances, as well as for the design of the chosen irrigation method in order that it may be the most suitable in terms of the efficient use of water and energy. With a view to promoting these computerised procedures the WRC, in consultation with MBB, decided to commercialise them. A marketing prerequisite was, however, that the computer program package had to be refined, and that a suitable manual for the judicious use thereof had to be made available. The development of the manual was successfully completed by the same consulting



Prof Paul Fouche (University of the North) explains to visiting scientists Drs Rob Reginato and Wayne Meyer the operation of the aerial surveillance unit.

engineering firm. The provision of a manual was basically a technology transfer action through which the results of a previous research project could be presented to users in a digested form.

Costs: R64 000
Term: 1988

NEW PROJECTS

A global farm approach to enhancing the economic efficiency of water and energy use for irrigation in the central RSA *(No 347) Department of Agricultural Economics, University of the Orange Free State*

In a previous project methods had been developed and demonstrated to evaluate irrigation efficiency at operational branch level economically. To fully utilise the qualitative and quantitative value of the research, it has to be extended to improve the economic efficiency of irrigation at a global farm level. Thereby the possibility of crop substitution and reallocation of water between different farming operations can be included in the methodology when adjustments have to be made with regard to limited water supplies and higher energy costs at global farm level.

On the one hand the research is directed at improving the economic efficiency of water and energy usage and on the other hand it is aimed at evaluating risk management strategies. Risk management has become a necessity but it is a difficult task as the evaluation of different strategies with regard to operation expansion, irrigation scheduling and pump limitations is unknown or complicated. This project can make a substantial contribution towards improving the water-use efficiency at micro- as well as macro-level during high-cost limited water periods.

Root development and water usage of commercial timber species *(No 348) Department of Agronomy, University of Natal*

With the forestry industry due to expand considerably within the next 20 years, there can be no doubt about the potential impact on water resources. In the course of this expansion, afforestation of marginal sites will take place despite a lack of knowledge concerning the long-term sustainability of production and the effect on water yield of such sites. The manner in which roots develop in soil profiles with varying physical and hydraulic properties is likely to be a key factor in sustaining water extraction and production as soil drying progresses. Consequently, the Department is undertaking a 4-year research project to investigate root development and soil water usage of commercial timber species on a range of soils. Investigations, which will take place under partly controlled conditions, will initially focus on various *Eucalyptus* species.

A consolidated computer software package for the management of an irrigation scheme *(No 367) Systems Laboratory, Rand Afrikaans University*

This project follows a similar project which was completed in 1989 by the Laboratory. During the course of that project a computer package was developed for the simulation of inconstant, non-uniform water flow in canal systems. Simultaneously an office or administrative data base was also created to perform functions such as the computerised handling of water demands, accounts, etc. The current project is aimed at merging the above-mentioned 2 separate packages in a single marketable package.

Assessing the impacts of varying rainfall conditions on vegetation dynamics, production and certain hydrological properties of natural grassland, using a system modelling approach *(No 372) Department of Plant Sciences, Potchefstroom University for CHE*

While hydrological and agricultural responses of natural grassland (veld) to rainfall are conditioned by the current state of the veld, this veld condition in turn responds, in terms of its vegetation dynamics, either beneficially or deleteriously to each rainfall event. Vegetation dynamics are manifested by species compositional changes within postulated limits of ecological resilience, largely determined for a given habitat by recent management practices. The interactions between rainfall, habitat, veld condition, runoff, phytomass production and veld management are thus extremely complex, but must be addressed if important questions concerning water use, water-use efficiency and runoff production of natural veld are to be answered. In view of this complexity, a system modelling approach to this investigation has been adopted.

Decision-making procedures for the determination of crop water requirements *(No 379) MBB Inc.*

Irrigation system design, based on incorrect assumptions and decisions regarding crop water requirements, results in ineffective and uneconomic systems which may have an adverse impact on the environment. These assumptions and decisions are further complicated by the level of system management, the target yield, the acceptable risk levels, the reliability of water supply and the importance of abnormal climatological factors e.g. heat waves. In this regard a well-founded procedure, based on a "management support system" approach, mobilising research results presently not generally utilised, could make a major contribution.

- The primary objective of the research is thus to establish techniques for developing decision-making procedures for the estimation of crop moisture requirements by irrigation system designers. These procedures must be suitable for use by commercial designers with limited experience and training and can only be considered successful if they are accepted as an industry standard.
- The secondary objective of the research is to fully exploit and incorporate diverse research results and to mobilise the extensive practical insight of irrigation scientists, designers and farmers in arriving at acceptable decision-making procedures.

The interdependent factors which determine the viability of irrigation farming *(No 382) MBB Inc.*

Financial analyses and economic evaluations of new irrigation developments, or the upgrading of existing schemes, do not paint a very positive picture. Indications are that in the long term only limited and specialised irrigation will be economically viable in South Africa. A drastic reappraisal of the future allocation of the Republic's water resources is, therefore, imperative. The many well-established and successful irrigation farmers in the RSA, however, could signify that there may be indirect factors which influence analyses, but are difficult to incorporate in these analyses.

Against this background the main objective of the project is to establish characteristic profiles of irrigation farms which could form the basis of case studies on the evaluation of irrigation projects. The profiles and subsequent case studies will integrate the influences of agricultural, technical, human and financial factors within the limitations of available natural resources. This pilot project will be limited in scope and is intended to develop the techniques of undertaking surveys, and of assessing the validity and applicability of results.

Scheduling irrigation of tuber crops with specific reference to potatoes *(No 389) Vegetable and Ornamental Plant Research Institute, Department of Agricultural Development*

Knowledge of the water requirements of tuber crops is still lacking. Potatoes in particular are extensively cultivated under irrigation, but there is great uncertainty about the optimal levels of water supply and soil water abstraction for different soil types and climatic circumstances. Experience has shown that injudicious water supply is the most important factor which not only affects the yield, but also the grade and keeping quality of potatoes. The main aim of the project is to develop a mathematical model with a view to optimal scientific scheduling of water applications.

The effect of different irrigation scheduling practices on the growth and yield of pasture crops.

WATER QUALITY STUDIES

The greater awareness of quality as a factor determining the utilisation potential of water, and the observation that water quality is gradually deteriorating, have created the need to devise a strategy according to which the most important aspects of water quality can be monitored and managed. New research needs identified as a result of the new approach to water quality management by the Department of Water Affairs and Forestry, resulted in various new projects being initiated in this field of research during the past year. The Commission currently finances 10 projects regarding water quality studies, of which 5 commenced and 1 was completed.

MARINE DISPOSAL

The main appeal of this practice is economical and it was viewed largely positively in the past as it was accepted that the sea had a great capacity for assimilating specific waste products. Although world-wide increasing resistance is being encountered to marine disposal it remains a practice which is widely used (also in South Africa) by coastal communities to dispose of their effluents. The Commission currently finances 2 projects pertaining to marine disposal, both having commenced during the year.

COMPLETED PROJECTS

Water quality monitoring strategies and procedures for water quality data interpretation *(No 204) Division of Water Technology, CSIR, and the Department of Water Affairs and Forestry*

This project was carried out in terms of a tripartite agreement. The objectives of the project were to improve water quality information for water resources development, and regulatory and research purposes by developing practical monitoring strategies and procedures for analysing water quality data to provide reliable information for decision-making.

The project produced a strategy to satisfy the information requirements for trend detection in river water quality. Principal features of the strategy were the use of a small number of variables to be measured at carefully selected sites and a focus on ensuring a consistent record over time. A statistical protocol to provide reliable data analysis procedures was developed to complement the data collection activities.

Costs: R439 000
Term: 1987-1991

The management of phosphate concentrations and algae in Hartbeespoort Dam *(No 289) Division of Water Technology, CSIR, and the Department of Water Affairs and Forestry*

The main objective of this project was to identify and quantify the mechanisms by which large quantities of phosphate have been lost since 1987/88, and the mechanisms which resulted in the virtual absence of *Microcystis* in 1988/89. The major cause of the low phosphorus concentration was that the dam filled up, resulting in a very much larger percentage of the incoming phosphorus load being sedimented. The disappearance of the *Microcystis* was associated with the greatly altered nitrogen to phosphorus ratio. It is recommended that the phytoplankton should be managed by maintaining the total nitrogen to total phosphorus ratio at least at present levels. Should the total phosphorus concentration tend to rise relative to the total nitrogen concentration, more nitrogen could be made available by relaxing the nitrogen standard for effluents or by destratifying the dam.

Costs: R153 683
Term: 1989-1991

NEW PROJECTS

Phytoplankton blooms in the Vaal River and the environmental variables responsible for their development and decline *(No 359) Botany Department, University of the Orange Free State*

Phytoplanktonic algal growth is stimulated by the presence of nutrients in the water, and dense populations (blooms) make water purification difficult. This project aims to identify the factors responsible for the onset and decline of algal blooms by the various species assemblages in the river. This will be done by relating the phytoplankton present to current and recent physical and chemical environmental variables. Results will be incorporated in a predictive mathematical model for use by water resource managers. This project will also indicate which algae are responsible for nuisance conditions in the waterworks, and therefore which nutrients should be controlled in order to limit algal growth.

Field dilution studies on large off-shore pipelines *(No 364) Division of Earth, Marine and Atmospheric Science and Technology, CSIR*

Only 2 of the 12 off-shore pipelines discharging effluent to the sea have been field-tested for their diluting capability, revealing that the design calculation methods used to predict the diluting capabilities of pipelines are rather conservative. This needs further substantiation not only because of the inherent cost implications, but also because the physical processes controlling the dilution/ dispersion characteristics of a pipeline are site-specific.

This project will thus investigate the performance of some of the other pipelines, not only to aid in the planning of new and more cost-effective disposal schemes, but also to minimise the impact of disposal practices on the marine environment and on human recreational activities.

The completion of research relating to the DISA model - A daily irrigation and salinity analysis system model *(No 369) Ninham Shand (Cape) Inc.*

Irrigation return flow has been identified as one of the major non-point sources of the salinisation of rivers. This project aims to further refine and test the DISA model, developed by the Department of Water Affairs and Forestry in collaboration with Ninham Shand for the prediction of salinisation due to irrigation in the Breë River, by using flow and salinity data collected during the preceding year. The findings of complementary projects will also be used. Steps will, furthermore, be taken to convey the application of the DISA model and supporting research finding to interested parties.

Investigation techniques for the determination of microbial aspects of water quality of South African rivers

(No 380) Division of Water Technology, CSIR and the Rand Water Board

In order to improve on water quality management the Department of Water Affairs and Forestry adopted a new approach, namely that of receiving water quality objectives, which they combine with the prevention of pollution. In terms of this approach it is accepted that receiving water bodies have a quantifiable and manageable capacity to absorb waste products without deteriorating to such a degree that its quality is unfit for recognised uses.

In order to apply this approach the relationship between pollution loads and the resulting quality of the receiving water needs to be understood. The ability to determine microbiological waste load allocations has not yet been achieved locally. This project aims at acquiring the expertise still lacking with regard to the microbiological aspects of water quality and to establish such guidelines and tools.

Revised water quality criteria for the South African coastal zone

(No 401) Division for Earth, Marine and Atmospheric Science and Technology, CSIR

The water quality criteria (WQC) of 1984 provide guidelines on the "limits" which must not be exceeded if a specified end use for that water is to be sustained. While the criteria have served an important role in the past 6 years, applications have made it clear that there are certain shortcomings, the most notable of which concern the microbial parameters relating particularly to human health aspects.

The aim of the current project is to re-evaluate the 1984 WQC for the South African coastal zone with the objective of establishing a revised WQC. The revised criteria will incorporate new overseas developments and research findings applicable to the South African context.

A manual for waste load allocations in South Africa

(No 404) Marketing and Business Development, Environmental Services, CSIR

The concept of waste load allocation is central to the new approach to water quality management followed by the Department of Water Affairs and Forestry. A shortage of manpower skilled in the application of these concepts is, however, delaying the implementation of this approach. The intention with this project is to alleviate this shortage by summarising the available expertise in one authoritative document. The focus of the manual will be on the finding of techniques for the solution of local problems and will provide guidance on the specific tasks expected of regulators, the industry and consultants.

A situation analysis of water quality in the Buffalo River, Eastern Cape with special emphasis on the impact of low-cost, high-density urban development on water quality

(No 405) Division of Water Technology, CSIR and Institute of Water Research, Rhodes University

Several water quality problems in the Buffalo River catchment area have already been identified. Although a number of *ad hoc* studies have already been carried out to address specific problems, these have not been sufficient to develop an overall water quality management plan. One of the problem areas yet to be addressed is to determine what the effect will be of non-point source phosphates originating from low-cost, high-density urban developments on the quality of the dam water downstream. This situation analysis of water quality in the Buffalo River catchment area will address the above aspects.

Coastal pollution: Pathogenic micro-organisms

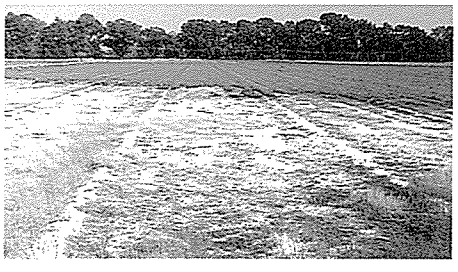
(No 411) Department of Medical Virology, University of Pretoria

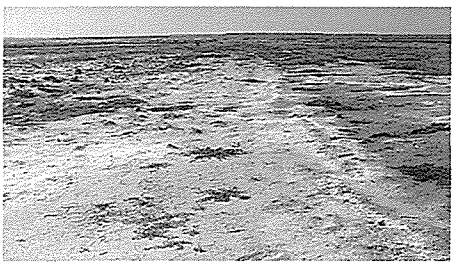
Research in this regard is jointly sponsored by the Department of National Health and Population Development, the Foundation for Research Development and the WRC. This project will address the discharge of pathogenic micro-organisms to the sea and aims at formulating appropriate quality criteria and policies for the management of waste water and storm water in coastal areas. Epidemiological/microbiological surveys and general practitioner surveillance studies (e.g. case-control studies) in selected areas will be carried out, to investigate the relationship between morbidity among bathers, consumers of shellfish and contaminated sea water/seafood.

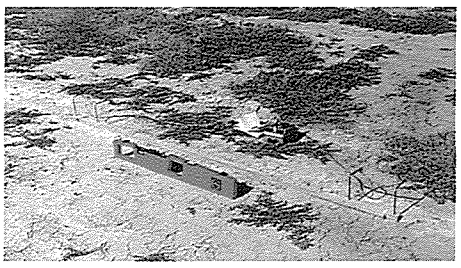
The use of vegetation in the amelioration of the impact of mining on water quality - An assessment of species and their water use

(No 413) Division of Forest Science and Technology, CSIR

Mining activities often give rise to a deterioration in the quality of underground







A surface salt crust is clearly visible on heavily salinised soils. Instruments with which soil salinity is measured are shown below right.

and surface waters. This deterioration is mostly the result of the disturbance of surface soil, the breaking up of the underlying rocks and the concomitant increase in through-flow of water and the exposure of unweathered surfaces. The possibility will be investigated of limiting the deterioration in the water quality due to mining by reducing the flow of water through the disturbed material. It is expected that trees with a deep root system and a high water demand will achieve this by intercepting percolating water before it drains below their root zone.

Soil buffering of rain-water salinity in the Vaal Dam catchment

(No 414) Department of Agronomy, University of Natal

The relatively high saline content of rain water in the Vaal Dam catchment area which is presumably due to air pollution can in the course of time lead to the doubling of the saline load from the Vaal Dam catchment area. The extent to which salts in the rain water will be retained by soil is one of the uncertainties which makes it difficult to make a prediction of the extent to which the saline content of the Vaal Dam will increase as well as over how long a period this will occur. This project will determine the ability of the major soil groups to retain salt, thereby enabling predictions to be made with greater confidence.

RESEARCH PROJECTS

Completed projects

- **204** Water quality monitoring strategies and procedures for water quality data interpretation (The CSIR - Division of Water Technology and the Department of Water Affairs and Forestry)
- **289** The management of phosphate concentrations and algae in Hartbeespoort Dam (The Department of Water Affairs and Forestry and the CSIR - Division of Water Technology)
- **326** Assessment of the feasibility and impact of alternative water pollution control options on TDS concentrations in the Vaal Barrage and Middle Vaal (A firm of consulting engineers: Steffen Robertson and Kirsten Inc.)
- **344** The contribution of ground water to the salt load of the Breë River using natural isotopes and chemical tracers (The University of the Orange Free State - Institute for Ground-water Studies)

Current projects

- **195** Hydrosalinity studies in the Eastern Cape (Rhodes University - Department of Geography)
- **196** The abilities of several solute and water transport models to predict the quantity and quality of water leaving the root zone (The University of Stellenbosch - Department of Soil and Agricultural Water Science)
- **197** Phosphate export models for catchments (The CSIR - Division of Water Technology)
- **237** The effects of land use on runoff quality in selected catchments in Natal (The CSIR - Division of Water Technology)
- **256** The design and use of irrigation systems in the Breë River with a view to the control of potential drainage losses (A firm of consulting engineers: MBB Inc.)
- **264** The harvesting of algal drift from Hartbeespoort Dam water for the reclamation of fine chemicals (The CSIR - Division of Water Technology)
- **266** The extension of the management-orientated models for eutrophication control (The CSIR - Division of Water Technology)
- **269** The four-electrode electrical conductivity and electromagnetic induction techniques of soil salinity measurement for use under South African conditions (The University of Natal - Department of Soil Science and Agrometeorology)
- **304** The applicability of hydrodynamic reservoir models for water quality management in stratified water bodies in South Africa (A firm of consulting engineers: Ninham Shand Inc. and the University of Cape Town - Department of Civil Engineering)
- **312** The occurrence and accumulation of selected heavy metals in freshwater ecosystems affected by mine and industrial polluted effluent (Rand Afrikaans University - Department of Zoology)
- **313** The concentration ratios of selected radionuclides in aquatic ecosystems affected by mine drainage effluents (Rand Afrikaans University - Department of Zoology)

New projects

- **359** Phytoplankton blooms in the Vaal River and the environmental variables responsible for their development and decline (The University of the Orange Free State - Department of Botany)
- **364** Field dilution studies on large off-shore pipelines (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **369** The completion of research relating to the DISA model - A daily irrigation and salinity analysis system model (A consulting engineering firm: Ninham Shand (Cape) Inc.)
- **380** Investigation techniques for the determination of microbial aspects of water quality of South African rivers (The CSIR - Division of Water Technology)
- **401** Revised water quality criteria for the South African coastal zone (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **404** A manual for waste load allocations in South Africa (The CSIR - Marketing and Business Development, Environmental Services)
- **405** A situation analysis of water quality in the Buffalo River, Eastern Cape, with special emphasis on the impact of low-cost high-density urban development on water quality (The CSIR - Division of Water Technology and Rhodes University - the Institute of Water Research)
- **411** Coastal pollution: Pathogenic micro-organisms (The University of Pretoria - Department of Medical Virology)
- **413** The use of vegetation in the amelioration of the impact of mining on water quality - An assessment of species and water use (The CSIR - Division of Forest Science and Technology)
- **414** Soil buffering of rain-water salinity in the Vaal Dam catchment (The University of Natal - Department of Agronomy)

MUNICIPAL WASTE WATER

South Africa, in common with other countries situated just outside the tropics, is predominantly semi-arid and susceptible to droughts. In addition to the potential water shortages resulting from an unpredictable climate, the largest urban and industrial development in the country is centred on the watershed between the Limpopo and Vaal Rivers in the Southern Transvaal where water is not only scarce, but any effluents discharged must be of a standard which is both suitable for reuse downstream and will minimise eutrophication downstream in impoundments. Thus, it is imperative that municipal effluents are treated to a high standard before discharge.

Any effluents discharged must be of a standard which is suitable for reuse downstream

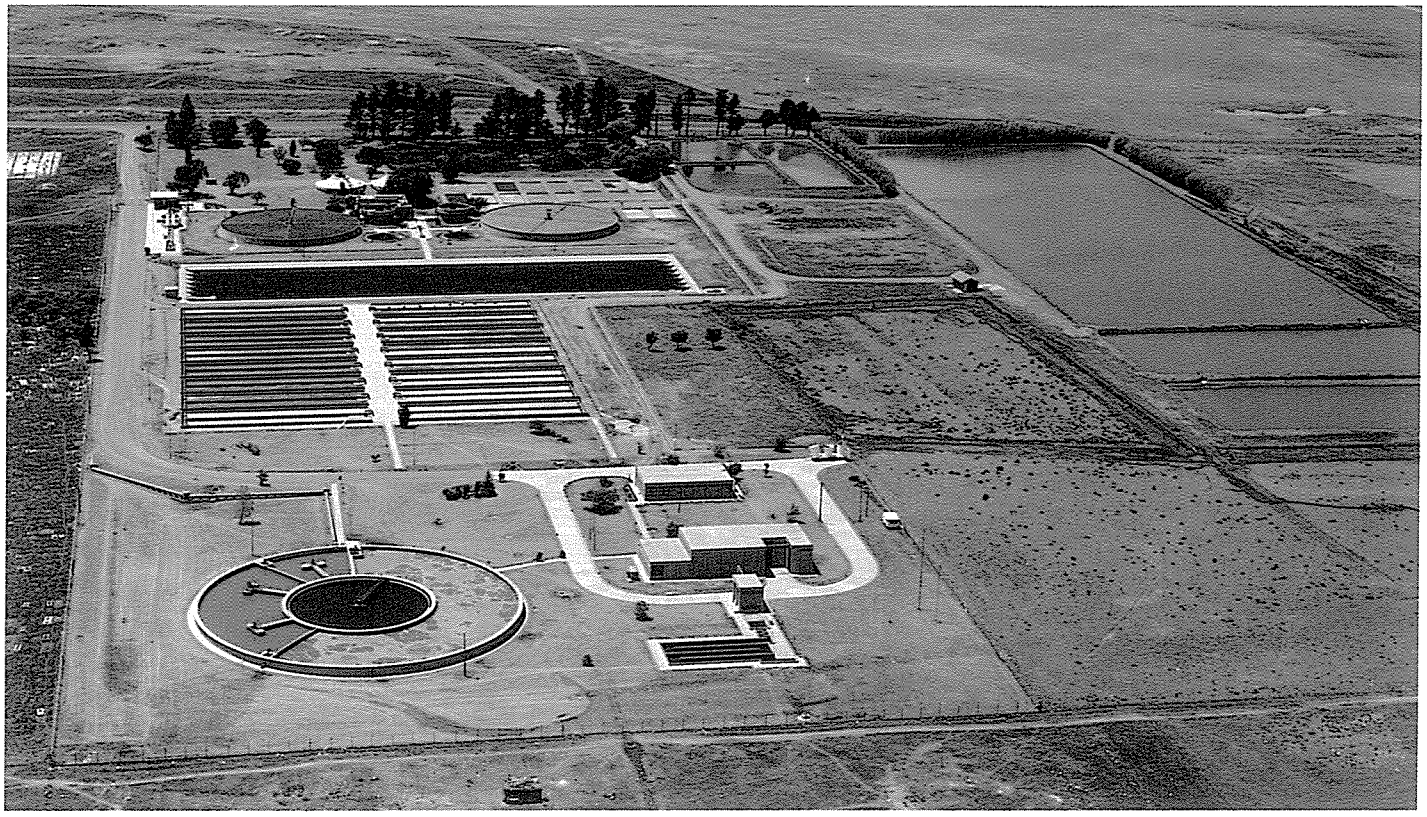
Research on municipal waste-water treatment sponsored by the WRC is aimed at:

- producing effluents of adequate quality for direct or indirect reuse;
- protecting public health; and
- combating pollution of the water environment.

Much effort has been focused on the removal of nutrients, particularly phosphates, from effluents, as this is what causes increased plant growth, primarily algae, in impoundments. Excessive algal build-up not only causes aesthetic problems for the water bodies affected, but the difficulty in treating these waters to potable standards is increased. While the effective treatment of municipal effluents remains important, it was rated third priority in the master plan for sanitation. The top priorities identified by the master plan are the development of acceptable sanitation for developing communities, and of technologies to address diffuse pollution. It is anticipated that these areas will be receiving increased attention in the future. The fourth thrust area identified for research was sludge handling and utilisation which remains one of the major problems facing authorities which run treatment works. The final area identified as needing attention was the recovery of resources from the waste-water treatment process.

A list of secondary and tertiary goals was identified for each of these 5 thrust areas during a series of one-day workshops. These goals are presented in the master plan.

In this field which encompasses **Sewage Treatment, Sewage Sludge Treatment and Disposal** and **Wetlands** the WRC supported 14 projects during 1991, of which 4 commenced during the year, 9 are current, and 1 was completed.



One of the first nutrient removal plants in South Africa.

COMPLETED PROJECT

Consolidation of activated sludge and water chemistry research

(No 251) Department of Civil Engineering, University of Cape Town

This project addressed various topics concerning activated sludge and its related water chemistry which had been identified by earlier research on activated sludge systems as needing further attention. Specifically, the following research topics have been completed:

- The data on nitrification and nitrification/denitrification in activated sludge systems have been incorporated into a simulation model which is now available. This simulation is intended as an aid for plant design and as an educational aid in plant operation.
- While it has been known that acid fermentation of primary sludge enhances biological excess phosphate removal, the dynamics have been poorly understood.
- Research carried out during this project has led to a more effective method for the characterisation of the weak acid/base system encountered in activated sludge.
- This project indicated that disposal of waste alum sludge from water purification works into municipal sewage not only provided a satisfactory method for the disposal of the alum sludge, but that it assisted in phosphate removal.

Costs: R191 407
Term: 1988-1990

NEW PROJECTS

The consolidation of activated sludge research *(No 356) Department of Civil Engineering, University of Cape Town*

The following aspects of research on activated sludge systems which could not be dealt with in the project discussed above (No 251) will be addressed in terms of this agreement:

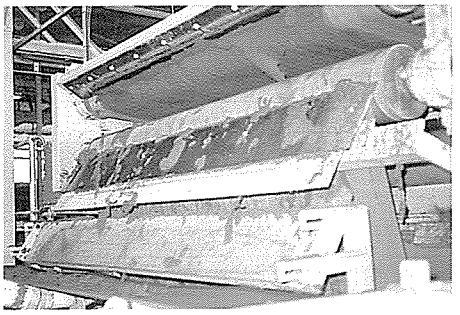
- Develop a general kinetic model for nitrification/denitrification biological excess phosphate removal (NDBEPR) activated sludge systems.
- Complete the calibration of the nitrification/denitrification kinetic model and compile a user manual.
- Revise the 1984 NDBEPR design manual to incorporate recent research.
- Evaluate the effects of fixed media in the aerobic zone of NDBEPR systems so that the sludge age may be reduced while maintaining complete denitrification.

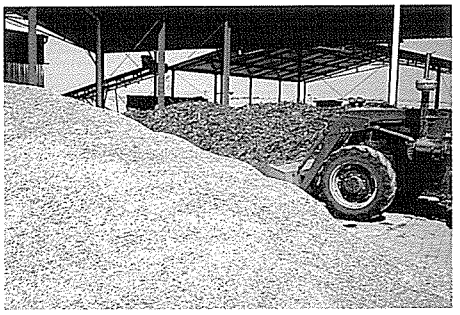
Full-scale pilot-plant studies on phosphate crystallisation in biological systems *(No 366) Division of Water Technology, CSIR and the Pretoria City Council*

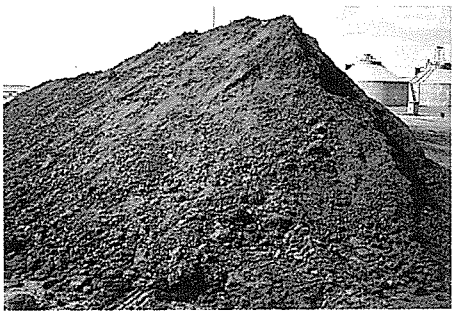
At present the standard method to remove phosphate from municipal effluents is activated sludge plants. An alternative method for phosphate removal is integrated crystallisation technology. The technological feasibility of the integrated process which, *inter alia*, produces no sludge or unwanted anions and does not need filtration, has already been confirmed at laboratory scale.

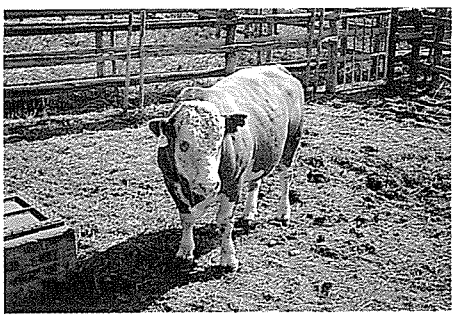
The aim of this study is to install a phosphate crystallisation reactor at a full-scale activated sludge module of the City Council of Pretoria and to put it into operation, evaluate and adapt it where necessary over a period of 3 years. Aspects which will receive pertinent attention are:

- the determination of the critical design and operational aspects;
- the compilation of comparative cost data; and
- the establishment of guidelines for the wider application of phosphate crystallisation in municipal effluent treatment.









The sludge-compost cycle at Johannesburg Northern Works.

Compilation of an operators guide on anaerobic digestion of sewage sludge *(No 390) Ross Consultancy*

During this project a guide will be compiled on the anaerobic digestion of sewage sludge which is written specifically for process operators. Care has been taken to cover the subject in such a way as to make the guide applicable to all situations, as well as to approach the subject in a manner that will make this guide easy for all to use.

Aspects of the treatment process which affect anaerobic digestion, such as pretreatment of sewage, primary settling and sludge thickening will also be covered, as no suitable text on these aspects is currently available.

The co-disposal of sewage sludge and refuse *(No 391) Cape Town City Council*

This project will examine aspects concerning co-disposal of sewage sludge and municipal refuse. The project is based at the Coastal Park Landfill Site, adjacent to the Cape Flats Sewage Works. The project aims to develop practically designed criteria for integrated treatment and disposal of both municipal refuse and sewage sludge in landfill. In order to maximise the cost-effectiveness of the sludge disposal, unthickened digested sludge of approximately 2% will be used.

The landfill will be designed as a bioreactor so that biogas can be extracted for utilisation.

Co-disposal of municipal waste and sewage sludge at Coastal Park Landfill Site, Cape Town.

RESEARCH PROJECTS

Completed project

- **251** Consolidation of activated sludge and water chemistry research (The University of Cape Town - Department of Civil Engineering)

Current projects

- **189** The evaluation and optimisation of the process of dual digestion of sewage sludge (The Town Council of Milnerton and the CSIR - Division of Water Technology)
- **215** Phosphate crystallisation in activated sludge systems (The CSIR - Division of Water Technology)
- **232** The preparation of engineering design guidelines for artificial wetlands for wastewater treatment (The CSIR - Division of Water Technology and Stewart Scott Inc.)
- **248** Chemical augmentation of biological phosphate removal (The City Council of Johannesburg)
- **250** Phosphate fixation in waste water by means of controlled struvite formation (The CSIR - Division of Water Technology)
- **286** The development and evaluation of specific control methods for ameliorating low F/M bulking (The University of Cape Town - Department of Civil Engineering)
- **314** Biological phosphate removal mechanisms in the activated sludge process (The University of Pretoria - Department of Microbiology and Plant Pathology)
- **316** Aspects of sewage sludge treatment and disposal (The City Council of Johannesburg)
- **328** Full-scale study of chemical sludge bulking control (The University of Pretoria - Department of Chemical Engineering)

New projects

- **356** The consolidation of activated sludge research (The University of Cape Town - Department of Civil Engineering)
- **366** Full-scale pilot plant studies on phosphate crystallisation in biological systems (The CSIR - Division of Water Technology and the City Council of Pretoria)
- **390** Compilation of an operators guide on anaerobic digestion of sewage sludge (Ross Consultancy)
- **391** The co-disposal of sewage sludge and refuse (The City Council of Cape Town)

INDUSTRIAL EFFLUENTS

Should the expected inflow of investment capital into this country materialise, this could signify economic growth with concomitant additional provision of employment. There is a direct connection between economic growth and industrial growth which means increased water usage in the industrial sector and a resultant increase in industrial waste water. By implication research in this regard should therefore be developed dynamically and also sustained. It has already been emphasised repeatedly that WRC policy regarding research on the treatment of industrial effluents is aimed at the creation of norms with a view to minimum water intake, coupled with minimum pollution load discharged into the environment per unit product produced. In order to have an indication of the boundaries of such norms a national survey of industrial water and waste water has been conducted over a period of 5 years. During this period 539 industries were surveyed and an extensive industry-related data base was created. Fourteen industries with high water consumption were intensively investigated and guides were compiled with recommendations regarding water intake and load discharge aims. Although comprehensive guides which describe water management and treatment processes are available there is, unfortunately, as mentioned previously, still not much full-scale application.

In the light of this "application problem" the time has maybe come to start playing an active part to incorporate proven treatment processes into factory production units rather than regarding it as a "separate" part of the plant. This concept has to be brought to the attention of decision-makers as well as factory personnel by means of information and education programmes.

Fortunately there are signs that this concept has become established in some industries.

The time has maybe come to incorporate proven treatment processes into factory production units

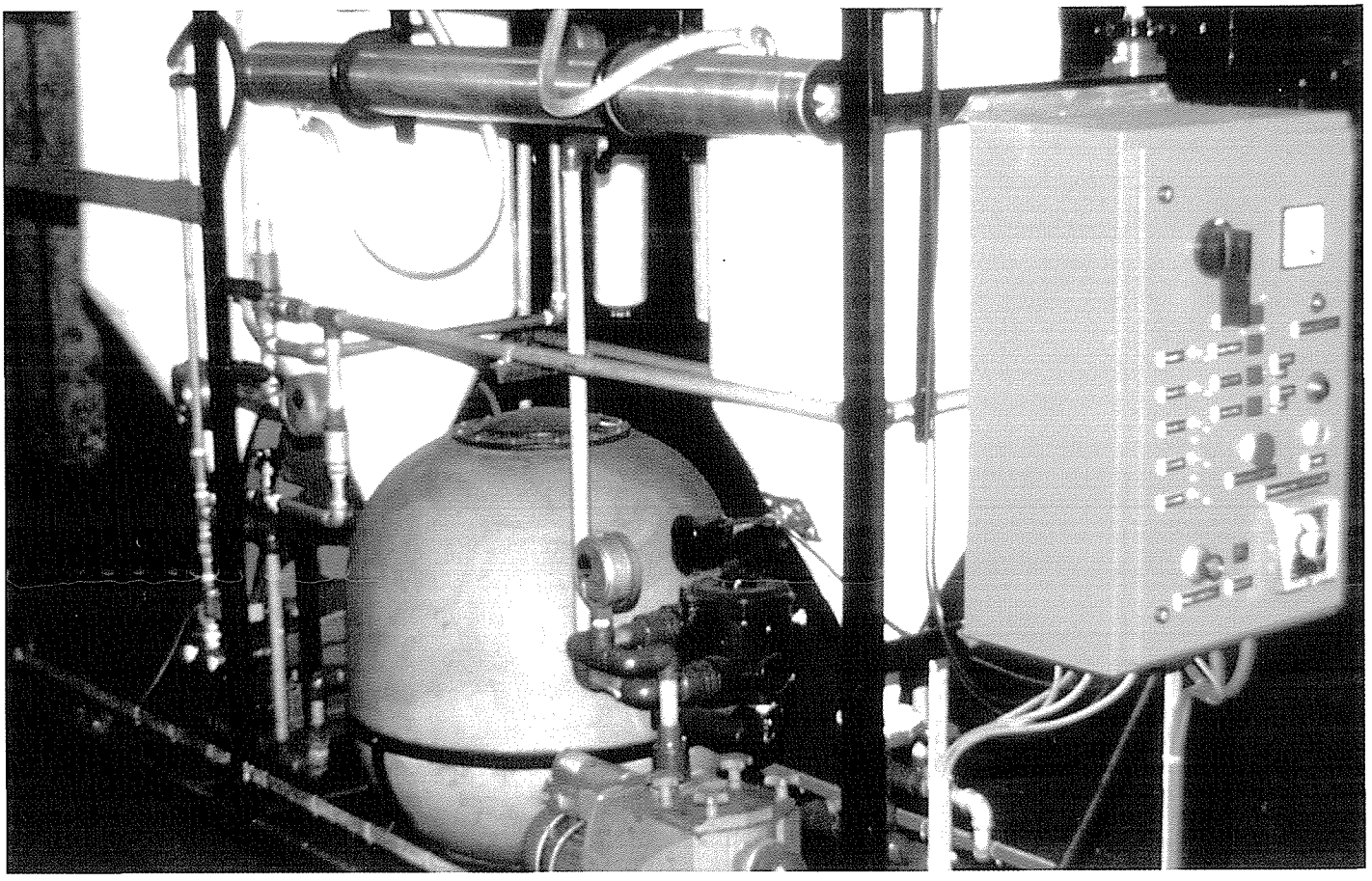
COMPLETED PROJECT

A national industrial water and waste-water survey (NATSURV)

(No 145) Steffen Robertson and Kirsten Inc.

This project was carried out with 2 main objectives in mind. These were:

- to establish a data base (containing information on water intake, raw materials used, products, waste-water quality and quantity and industrial



Nanofiltration pilot plant for the recovery of sugar liquor ion-exchange resin regeneration effluent.

waste) which can be used to determine targets for water intake and pollution loads reasonably achievable by industry; and
- to establish areas where research is needed to assist industry in improving its water and waste-water management at minimum cost or even to its own advantage.

During the course of the project, some 539 industries were surveyed and an extensive data base of industry-related information has been compiled. Some 34 potential research projects have been identified, the details of which have been circulated to all the universities and technikons in South Africa.

To assist further with the dissemination of this information, 12 industry-specific guides on water and waste-water management have been produced. The industries for which guides have been produced are the malt brewing, metal finishing, soft drink, dairy, sorghum malt and beer, edible oil, red meat, laundry, poultry, tanning and leather finishing, pulp and paper and sugar industries. Two more guides, on the textile and wine industries, will be published shortly.

These are aimed at the industries themselves, and at other interested parties such as municipalities, administrators, researchers and consultants in the water and waste-water fields.

Targets proposed in the NATSURV guides for water intake and pollution load per unit of product provide a basis both for legislation and for action within industries by providing like-industries with a valid basis for comparison. In each case the target figures proposed have been discussed in detail with representatives of that industry to ensure that the targets are both readily achievable and are likely to have significant impact in reducing industrial water intake and pollution load.

Costs: R3 485 000
Term: 1984-1990

NEW PROJECTS

A study on a mine-water reclamation test plant *(No 322) Chamber of Mines Research Organisation (COMRO)*

The gold mining industry uses large quantities of mine service water underground and as a result consumes about 220 M*l* of water/d. To reduce costs COMRO has developed, refined and tested various unit processes for treating spent mine service water for reuse underground. However, implementation of these new or refined water treatment technologies has not taken place to any major extent, largely due to a lack of suitable information.

The current project aims to obtain reliable data to establish the cost benefits associated with each water treatment unit process. This, together with existing COMRO-developed water management software, will then allow each mine to determine the optimum water treatment process configuration appropriate to its situation.

The neutralisation of water containing high concentrations of sulphuric acid with calcium carbonate *(No 355) Division of Water Technology, CSIR*

In this new project the focus is on an alternative process whereby effluents containing sulphuric acid could possibly be neutralised more cost-effectively than with the currently used lime process.

The project investigates the use of a fluidised bed to enable the neutralisation with calcium carbonate pellets to take place at a constant rate.

The microbiological transformations of metal contaminated effluents *(No 357) Department of Microbiology, University of Durban-Westville*

This project aims to treat effluents high in heavy metals using waste sludge to capture the metal ions biologically. The project will initially characterise available sludges in terms of the microbial population and the metal contents. The adsorption and desorption capacities of the various sludges will then be ascertained for a range of effluents, and appropriate methods for the recovery of metals from the sludges will be investigated. Once the best performing sludges have been identified, management parameters will be optimised in batch-fed bioreactors.

This technology could be applied in e.g. metal-plating industries for the on-site treatment of heavy-metal containing effluents.

The evaluation and improvement of the anaerobic digestion/ultrafiltration (ADUF) effluent treatment process *(No 365) Division of Water Technology, CSIR*

The advantages of the ADUF process, which comprises anaerobic digestion followed by ultrafiltration phase separation, include complete biological solids retention, clear effluent, high rate of operation and great flexibility.

The process has been evaluated at a number of industries and although reasonable results were obtained its full potential was generally not achieved. It is proposed that the causes be investigated on a large-scale laboratory plant. Specific objectives of the project include improvements to overall plant design and digester performance, and investigation of the effect of digester sludge characteristics on the digestion process.

Long-term semi-pilot scale studies will also be undertaken at selected sites to study the effects of feed substrates on the performance of the anaerobic process and on fouling of the ultrafiltration module.

Evaluation of various methods for the forming of free radicals for the oxidation of molecules in industrial effluents and potable water *(No 388) Department of Chemical Engineering, University of Natal*

The oxidation of organic chemicals present in industrial effluents or potable water is becoming increasingly important. Techniques available include the use of chlorine, chlorine dioxide, ozone, oxygen and hydrogen peroxide. In order to promote the oxidation or breaking of chemical bonds ultraviolet (UV) radiation is sometimes used in conjunction with oxidants in order to promote the formation of free radicals (atoms, or diatomic or polyatomic molecules which possess at least one unpaired electron).

The aims of this project are to investigate:

- the oxidation rate and daughter products of various advanced oxidation processes, or combinations thereof, on a sequence of model organic compounds;
- the disinfection properties of various advanced oxidation processes on model microbiological indicators; and
- the effectiveness of these processes on a selected number of process streams such as coloured textile effluent and toxic organic chemical streams.

The use of yeast biomass and yeast products to accumulate toxic and valuable heavy metals from waste water *(No 392) Department of Microbiology and Biochemistry, Rhodes University*

The aim of this project is to use yeast biomass (either living or dead) to accumulate metal ions. The final preparation of biomass should make it suitable for industrial use, either for the removal of heavy metals from effluents, or for the recovery of valuable metals. This project also seeks to identify the components of the biomass responsible for the metal accumulation, and to immobilise these components to determine whether they are more efficient at metal accumulation than the biomass itself.

This technology will have an application for the on-site treatment of metal containing effluents.

The use of algae to bioassay for toxic substances in water *(No 393) Department of Botany and Genetics, University of the Orange Free State*

This project will use the rate of certain physiological reactions in algae as a measure of toxins in the environment. The aim is to develop a bioassay which is both cost-effective and reliable. If possible, tests will be automated, or proposals for the automation of tests will be made. An advantage of using measurements of the physiological rates, as proposed in this project, is that reactions such as photosynthesis respond quickly to variations in the environment. This short response time makes tests based on these organisms potentially useful.

The envisaged application of this technology is in the monitoring of effluent quality before it is allowed to return to the receiving water body.

The degradation of mortar linings and concrete by micro-organisms in industrial water systems *(No 398) Eskom*

In the past mild steel, covered with organic coatings, has been used extensively for the fabrication of pipework in industrial water systems. Microbially influenced corrosion has, however, caused numerous failures with consequent down-time for repair and maintenance.

Replacement materials, such as austenitic stainless steel, have proved to be too expensive for industrial water systems. From an economic viewpoint cement and mortar lining of mild steel pipes may prove to be a viable alternative. Various bacteria, which are commonly found in industrial water systems, may, however, degrade such cement-based lining materials.

This study will evaluate the effects of micro-organisms and the concentration of aggressive chemical species on the mortar linings and concrete used to protect the mild steel pipework.

Reassessment of the strategy with respect to industrial effluent discharge with special reference to advanced technology treatment methods: Phase 1 *(No 407) Department of Chemical Engineering, University of Natal*

In 1974 a report entitled *Industrial Discharges into Public Sewers* was prepared for the WRC. The objectives of the survey were to identify areas in which problems arose due to discharges of industrial effluents and the industries responsible for the problems, and to consider *inter alia*, means by which these problems could be solved.

The aims of the present project are to:

- identify and assess current problems in regard to treatment of industrial effluents;
- attempt to identify reasons for continued failure to meet standards for effluents from long-established industries;
- identify problems in connection with effluents resulting from new industrial developments;
- recommend research into those areas where modern advanced technologies may be applicable; and
- encourage management to practise waste minimisation as a business strategy.

Fats and oils in effluents *(No 408) Department of Chemical Engineering, University of Pretoria*

Fats and oils end up in water which is used in industrial processes. Insufficient treatment leads to the discharge of fats and oils together with waste water either in sewers or they end up together with factory effluents in rivers. At sewage treatment plants these fats and oils cause deposits which foul and clog the purification plant. Water-bourne oils can be detrimental to the environment as plants may be killed and oxygen transfer may be impeded, which in turn can contribute to aquatic animal mortalities.

The fats and oils problem in South African waste waters has never been properly quantified. Oils and fats also have a distinct value and better waste-water purification practices may lead to better resource utilisation. More effective fat separation at sewage treatment plants before secondary treatment may have economical advantages.

Phenols in the steel industry waste water: Origin, prevention and removal *(No 409) Department of Chemical Engineering, University of Pretoria*

Phenols are generally found in the steel and stainless steel production industry, especially where coking is used. Phenols end up in the water during slaking and from slag dumps they find their way into storm and ground water. Phenols are detrimental to the environment as a result of their biocidal action and can import a bad taste to water at low concentrations, causing problems in mainly water purification, as chlorination aggravates the taste problem. It is of great importance that phenolic pollution should be prevented in view of South Africa's limited drinking water sources.

Phenols are also valuable and if these substances could be effectively extracted out of ovens and slags, they may be sold to the chemical industry as useful raw materials. By using this procedure water pollution could then be totally avoided.

The objectives of this project are:

- to quantify the problem regarding phenols in the steel industry;
- to create a management programme which will prevent phenols from ending up in effluents; and
- to launch an investigation into the most suitable waste-water purification methods for the removal of phenols from effluents.

A biological approach to the removal of organics from saline effluents *(No 410) Department of Biochemistry and Microbiology, Rhodes University*

Saline effluents present a particularly intractable problem. In South Africa increased amounts of dissolved solids in water supplies pose a severe economic threat to the water economy as a whole. Disposal options for these effluents are rather limited. The broad aim of the programme is the development of a biotechnological approach to the treatment and handling of saline effluents.

Most desalination processing options produce a concentrated brine stream which must, nevertheless, also be dealt with in one of the above ways. An additional complication is the accumulation of organics which causes odour problems and also the concentration of heavy metal pollutants. Membrane technology now offers cost-effective desalination, but organics must be removed to prevent fouling, reduced fluxes, shorter membrane life and increased costs.

The project will examine a biological approach to the removal of organics from saline effluents using halophilic algae and will evaluate membrane desalination of the resultant stream. It will assess the financial benefit that will accrue from the yield of high value metabolites.

RESEARCH PROJECTS

Completed project

- **145** A national industrial water and waste-water survey (NATSURV) (The Department of Water Affairs and Forestry, and a firm of consulting engineers: Steffen Robertson and Kirsten Inc.)

Current projects

- **158** Thermal feedback caused by dry cooling at power generating stations (Eskom and the CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **161** The treatment of wool scouring effluents (The University of Natal - Department of Chemical Engineering; a firm of consulting engineers: Steffen Robertson and Kirsten Inc.; and Gubb and Inggs (Pty) Ltd)
- **239** The transfer of waste-water management technology to the meat processing industry (A firm of consulting engineers: Steffen Robertson and Kirsten Inc.; and the South African Abattoir Corporation)
- **241** The dewatering of compressible filter cakes (The University of Natal - Department of Chemical Engineering)
- **249** Pelletisation in upflow anaerobic sludge bed (UASB) systems (The University of Cape Town - Department of Civil Engineering)
- **253** The effect of biocorrosion in water systems (The CSIR - Division of Water Technology)
- **263** The biological treatment of industrial water with the simultaneous production of single cell protein (The University of Pretoria - Department of Chemical Engineering)
- **276** Biological techniques for the treatment of pulp bleaching effluent (Sappi Management Services)
- **277** Abattoir solid waste: Development and implementation of a treatment system (The South African Abattoir Corporation)
- **284** The interaction between the atmospheric boundary layer and the natural draught cooling towers at Kendal Power Station (Eskom and the CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **285** Evaluation of various factors affecting dry-wet cooling (Eskom and the University of Stellenbosch - Bureau of Mechanical Engineering)
- **308** The recovery of water and chemicals from ion exchange resin regeneration effluents (The University of Natal - Department of Chemical Engineering)
- **309** Phase diagrams of complex precipitants (The University of Natal - Department of Chemical Engineering)
- **315** The utilisation of the fungus *Geotrichum* in waste water (The University of Pretoria - Department of Chemical Engineering)
- **318** The optimisation of biofouling control programmes (The University of Pretoria - Department of Microbiology)
- **331** Improved oxygen transfer for high biosludge concentrations (The University of Pretoria - Department of Chemical Engineering)
- **333** The removal of suspended solids from pulp and paper effluents by employing a combined sedimentation, flotation and sand filtration process (The CSIR - Division of Water Technology)
- **342** Improvement in water usage control and waste-water treatment in the sorghum beer industry (The University of Pretoria - Department of Chemical Engineering)

New projects

- **322** A study on a mine water reclamation test plant (Chamber of Mines Research Organisation)
- **355** The neutralisation of water containing high concentrations of sulphuric acid with calcium carbonate (The CSIR - Division of Water Technology)
- **357** The microbiological transformations of metal contaminated effluents (The University of Durban-Westville - Department of Microbiology)
- **365** The evaluation and improvement of the anaerobic digestion/ultrafiltration (ADUF) effluent treatment process (The CSIR - Division of Water Technology)
- **388** Evaluation of various methods for the forming of free radicals for the oxidation of molecules in industrial effluents and potable water (The University of Natal - Department of Chemical Engineering, Pollution Research Group)
- **392** The use of yeast biomass and yeast products to accumulate toxic and valuable heavy metals from waste water (Rhodes University - Department of Biochemistry and Microbiology)
- **393** The use of algae to bioassay for toxic substances in water (The University of the Orange Free State - Department of Botany and Genetics)
- **398** The degradation of mortar linings and concrete by micro-organisms in industrial water systems (Eskom)
- **407** Reassessment of the strategy with respect to industrial effluent discharge with special reference to advanced technology treatment methods: Phase I (The University of Natal - Department of Chemical Engineering, Pollution Research Group)
- **408** Fats and oils in effluents (The University of Pretoria - Department of Chemical Engineering, Division of Water Utilisation Engineering)
- **409** Phenols in the steel industry waste water: Origin, prevention and removal (The University of Pretoria - Department of Chemical Engineering, Division of Water Utilisation Engineering)
- **410** A biological approach to the removal of organics from saline effluents (Rhodes University - Department of Biochemistry and Microbiology)

DRINKING WATER

Pollution is increasingly affecting the surface water sources of South Africa and this places the burden on the supplier to provide water cost-effectively, while still complying with the prescribed quality criteria.

The water consumer needs to be sure that the drinking water which reaches him, does not pose a health risk

The water consumer needs to be sure that the drinking water which reaches him, does not pose a health risk and will therefore comply with all the required quality criteria. In addition to this the consumer obviously wishes to pay an acceptable price for the water. The drinking water supplied is firstly judged by means of the consumer's own senses which normally include: smell, taste, temperature, colour and turbidity. Because the water consumer is unable to judge the other quality criteria, such as microbiological quality, and inorganic and organic quality, he is in this respect dependent on the water supplier and the organisations which are in control of the quality.

On the one hand the increasing threat of pollution makes certain demands while on the other hand authorities world-wide are laying down ever more stringent quality criteria. Although legal quality standards for drinking water do not exist in South Africa, guidelines do. The water supplier has to develop the necessary technology to ensure that the treated water complies with the guidelines, while the Department of National Health and Population Development is the organisation responsible for matters relating to water quality with regard to human health.

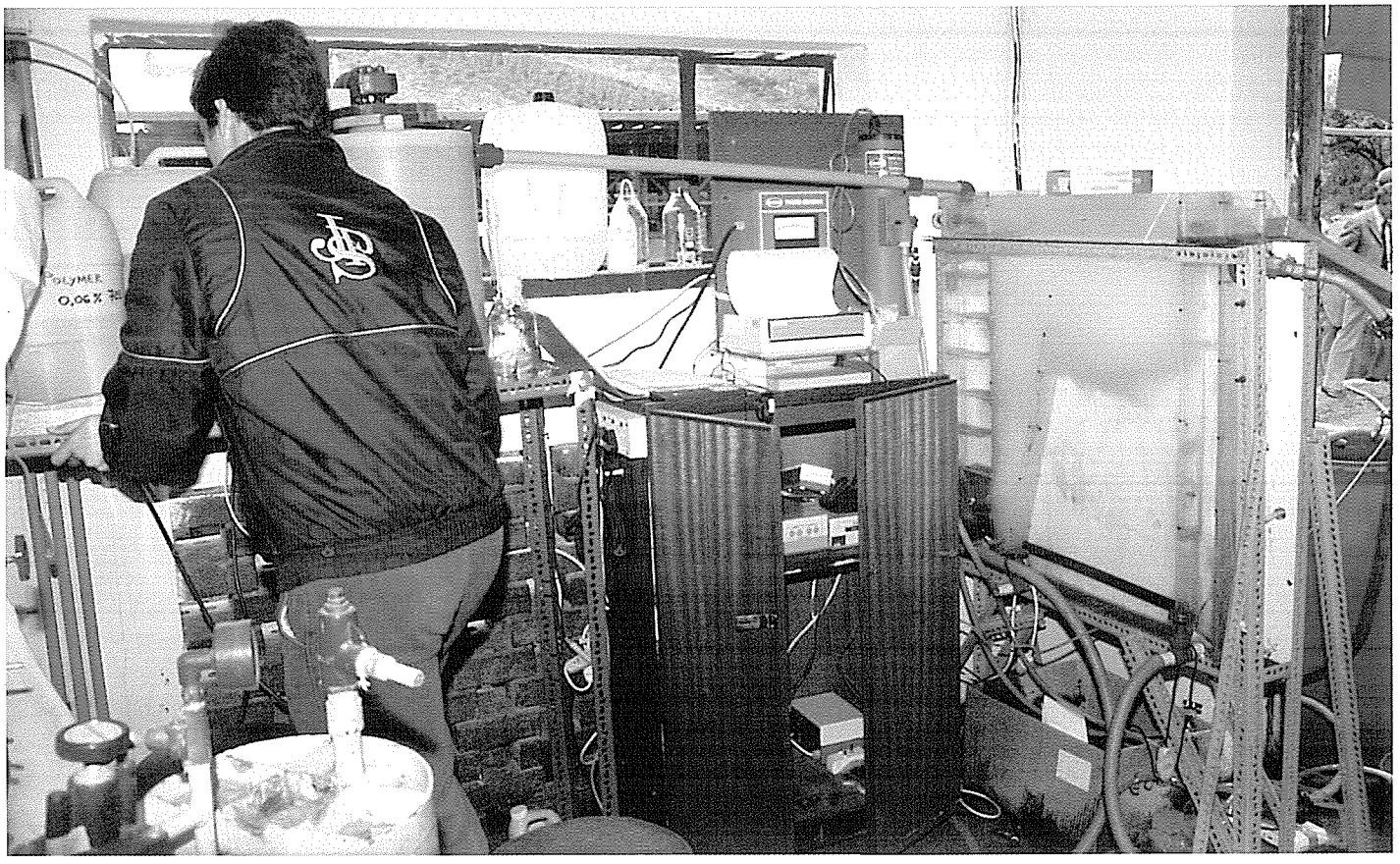
In the above regard the WRC supports various research programmes and projects pertaining to drinking water.

The main research areas in this regard are as follows:

WATER TREATMENT AND RECLAMATION

A Co-ordinating Committee for Drinking-water Treatment was founded towards the end of the year. Shortly after the inaugural meeting a three-day strategy session was held during which the main objectives for research in this field were identified and prioritised. Further strategy sessions will, however, be necessary in order to finalise the plan.

During the year the WRC supported 10 projects in the field of water treatment technology. Of these 3 projects were completed and 2 commenced.



Pilot plant used in flotation tests at Hartbeespoort Dam.

DRINKING-WATER QUALITY AND HEALTH ASPECTS

The Co-ordinating Committee for Health-related Water Quality finalised a master plan during the year which identifies priority areas for research. This is discussed in greater detail in **Chapter 1**.

The WRC during the year supported 7 projects which address drinking-water quality and health aspects as such. Of these 3 projects were completed and 3 commenced.

URBAN WATER SUPPLY

The direction of research in this field is fourfold:

- Firstly, as potable water becomes all the more expensive to acquire, treat, distribute and deliver, so the importance of cost recovery increases. This in turn has accentuated the need for more accurate metering, which in turn implies more costly metering devices.
- Secondly, the materials used in the distribution networks are changing rapidly and research is needed to improve corrosion protection for metallic materials and to enable the correct selection of non-metallic materials. The performance of non-metallic coatings and linings exposed to various internal and external conditions needs to be predictable.
- Thirdly, the amount of non-revenue earning water needs to be quantified for the extent of the problem to become known. If unaccounted-for water is high, then large investments in finding cures are justified.
- Finally, in order to optimise the efficiency of a water distribution network one not only needs to know the historical growth patterns, but also to be able to predict fairly accurately what the growth patterns of per capita consumption are likely to be in the medium to long term.

These directions are all reflected in the project portfolio listed in this section.

COMPLETED PROJECTS

The effects of reduced water consumption on domestic sewer systems *(No 199) Division of Building Technology, CSIR*

Householders are continually looking for ways to reduce water consumption. One possibility is the reduction of the flushing capacity of toilet cisterns. Over the years this volume has been reduced to the current norm of 9 *l* and a figure of 6 *l* or less has been proposed. Local authorities, however, are concerned that, during times of severe water restrictions when waste flows from baths, showers, washing machines and other appliances are drastically reduced or eliminated completely, coupled with the use of non-approved sanitary materials, sewers will be unable to cope and severe blockages will occur with disastrous health consequences. The project aimed to gather reliable scientific data regarding the performance of sewers under these conditions.

The results indicated that 6 *l* flushes would not cause undue blockages, provided that sewers were regular and at the prescribed gradients. Sewage treatment plants are able to handle the consequent increase in biological concentrations due to the reduced hydraulic loads without problems. Some benefits in the form of reduced pumping and chemical dosing costs were reported.

Costs: R112 783
Term: 1987-1990

Dissolved air flotation as pre-treatment to make enriched surface water potable *(No 202) Division of Water Technology, CSIR*

This two-year study was carried out by a visiting Canadian professor, Professor R Gehr, assisted by the personnel of the Division of Water Technology. The main objective of the study was to determine to what extent the dissolved air flotation process could be optimised to remove trihalomethane precursors (THMP) from a eutrophic water.

Findings indicate that a lower pH and a higher alum or ferric chloride dosage are required to remove THMP effectively than would normally be used for turbidity removal. Approximately 80 per cent of the THMP could thus be removed. It was also found that dissolved carbon analyses give a very poor indication of the THMP levels present.

Costs: R99 500
Term: 1987-1988

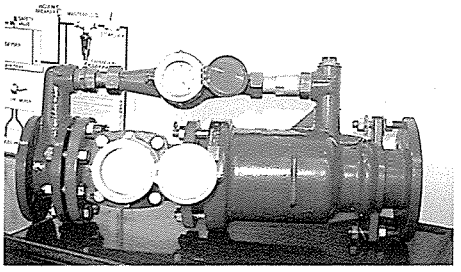
The flow rates and patterns of water consumption and unaccounted-for water in urban areas *(No 206) Department of Civil Engineering, University of Pretoria and Pretoria City Council*

The main aim of this project was to determine the flow rate and pattern of domestic water consumption under various conditions. Secondary aims were to determine the most suitable size of water meter to use for domestic applications by testing meters at high, intermediate and low flow rates and thereby to establish an optimum maintenance and replacement programme. This would also lead to answers regarding the amount of water presently unaccounted for, and recommendations regarding the assize requirements would be proposed.

Although all the aims could not be achieved, the results determined that over 90 per cent of the flow through a domestic meter occurred at less than 75 per cent of the flow capacity of the meter and that 55 per cent of the flow occurred at less than 50 per cent of the meter capacity. The conclusion arrived at was that generally domestic water meters were oversized.

The results indicated the need for performance standards for "meters in use" so that local authorities could determine the point at which meters should be replaced. As a result the SABS has agreed to incorporate such a clause into its new SABS Standard for domestic water meters.

Costs: R117 000
Term: 1987-1990



Bulk-flow water meter used for determining unaccounted-for water.

A combined flotation-powdered carbon process for potable water treatment *(No 244) Division of Water Technology, CSIR*

The main objective of the study was to determine whether a eutrophic water could be purified more effectively by means of an integrated counter-flow process of activated carbon adsorption and dissolved air flotation. This study was carried out over 2 years.

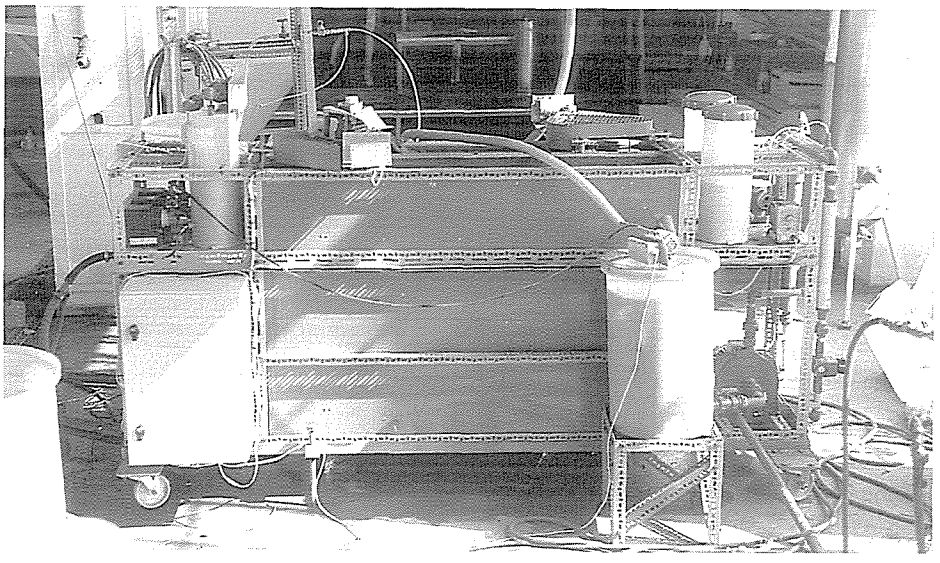
The most important finding of the study was that 2 process steps (flotation cells), applied as usual, were in reality unnecessary since one flotation cell could adequately remove organic material and powdered carbon. The other important finding was that coagulation and flocculation of the water to which the powdered carbon had already been added, had an omissible effect on the adsorption capacity of the powdered carbon.

Costs: R65 749
Term: 1988-1989

Water quality problems due to microbial growth in drinking-water distribution systems *(No 252) Division of Water Technology, CSIR*

Potable water contamination resulting from the breakthrough and aftergrowth of micro-organisms remains one of the difficulties faced by providers of potable water throughout the world. In this project biofilm formation (due to microbial aftergrowth) and the microbiological quality of the potable water in the distribution system of a major South African metropolitan area were studied. Water samples were collected from private houses, apartment buildings and other public institutions. Total coliform bacteria were isolated from 33 per cent of the samples of which 10 per cent exceeded the South African recommended guidelines. Bacterial numbers counted in the distribution system of apartment buildings were found to be higher than in private houses. Substantially higher bacterial counts were found in water samples collected from older buildings.

Costs: R306 000
Term: 1988-1991



Pilot plant used for combined flotation-powdered carbon process experiments.

Human viruses in water *(No 265) Department of Medical Virology, University of Pretoria*

This research was conducted during the past 3 years, the global aim being to develop expertise and technology for the evaluation of the virological water quality. This was achieved and the expertise and technology thus developed can now be applied to research and quality monitoring at a level and cost not previously possible. The successes achieved also open the door to improved technology, especially in regard to viruses such as hepatitis A, rota, adeno types 40 and 41 and gastroenteritis viruses which cannot be determined by cell cultures, gene probes or by immunological methods.

Costs: R243 118
Term: 1989-1991

Visiting fellow Professor Juan Jofre (Dept of Microbiology, University of Barcelona, Spain) and M.Sc. student Rina Holtzhausen (Dept of Medical Virology, University of Pretoria) assessing the efficiency of a newly designed glass powder column for the simple and inexpensive on-site recovery of viruses from water supplies.

Guidelines for the design and application of dissolved air flotation/filtration processes *(No 332) BS Bergman and Partners Inc. and GFJ Inc.*

The aim of this project was to analyse and consolidate the available information on the applications of the flotation process in South Africa in a practical, useful manual for designers, planners and operational personnel. The project was carried out over a 2-year period by engineers of the above-mentioned firms by means of a country-wide survey of flotation plants for water purification and sludge thickening. A historical review of flotation in South Africa, as well as the theoretical aspects of flotation, has also been included in the manual.

Costs: R75 000
Term: 1990-1991

The liquid consumption patterns among the black population of Cape Town *(No 334) Department of Community Health, University of Cape Town*

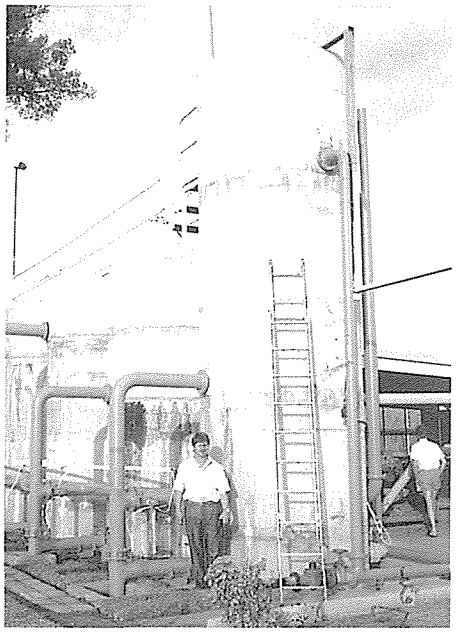
This project followed on a previous project on liquid consumption for other population groups. Information on the water consumption patterns is used as part of epidemiological studies. This study examined the type of water supply, the sources of water, whether consumed at home or away, according to the age and sex of the population. A survey of dietary and liquid consumption intake by means of 24-h recall was undertaken during 1990 among a representative sample of 1 513 black residents of Cape Town aged 3 years or more.

Costs: R11 000
Term: 1990

NEW PROJECTS

Deep-bed filtration for the treatment of South African surface waters *(No 354) Division of Water Technology, CSIR and the Local Government Affairs Council (LGAC)*

In terms of this new agreement LGAC's unique deep-bed, coarse-medium series filtration process will be evaluated for the cost-effective treatment of eutrophic waters, in order to draw up design guidelines.



Deep-bed series filtration is being evaluated for the treatment of eutrophic waters.

This process only employs 2 consecutive filters in which the depth of the bed, sand particle sizes and backwash method play a decisive role. Positive results are obtained at turbidity units of up to a few hundred. As a result of the excellent flocculation experienced in the first coarse-medium filter, no additional flocculation systems are necessary and less coagulants are also used than in a conventional water purification process.

Guidelines for toxicity bioassaying of drinking and environmental waters in South Africa *(No 358) Division of Water Technology, CSIR*

A number of bioassay tests exist worldwide. Some are more sensitive than others to particular pollutants or toxins, and some are easier to use than others. This project will assess bioassays currently used in South Africa for their ability to detect toxicity in water, and their potential applications will be evaluated in the light of literature findings.

The research findings will be presented as guidelines for the use of various tests with the object of allowing users to identify the best test for their specific application and to present standardised methods so that results from different laboratories will be comparable.

This technology can be applied in the monitoring of water quality at the intakes of installations such as water purification works.

The mutagenicity of drinking water produced with conventional treatment methods of surface water sources *(No 360) Rand Water Board*

The aim of this project is to investigate the incidence of mutagens which can be formed in drinking water (Mutagens are compounds which can increase the frequency of the DNA molecules and can, in certain instances, be carcinogenic). Samples are taken after various stages of the treatment process in order, on the one hand, to ascertain whether an increase in the incidence of mutagens has taken place, and on the other hand, by means of which process the mutagens could be removed. It will further be investigated whether an increase takes place in the mutagenicity in the distribution system after the water has left the plant.

The development and evaluation of small-scale potable water treatment equipment *(No 363) Department of Chemical Engineering, University of Natal and Umgeni Water*

The planning of extensions to a potable waterworks, or the need to optimise its operation, frequently requires investigative trials to be undertaken. These trials are usually carried out sequentially on the assumption that the water quality remains reasonably constant. It would be very advantageous if small-scale waterworks processes were available so that side-by-side trials could be undertaken.

This project aims to design and construct a small-scale plant which, when fed from the same water source, would behave in a similar fashion to Umgeni Water's Wiggins Waterworks. The small-scale unit will be used to investigate performance - affecting parameters such as water blends, flocculants and coagulants, the effect of pre-ozonation or chlorine dioxide addition and the need and efficiency of granular or powdered activated carbon processes. The experience gained will be incorporated in a guide to be issued so that other water authorities can build their own plants.

The corrosion performance of various non-metallic piping materials and coatings in potable water *(No 381) Division of Materials Science and Technology, CSIR*

In an earlier project the Mine Hoisting, Metallurgical and Corrosion Services Programme of the above Division investigated the corrosion of metallic pipelines. This follow-up project aims to evaluate the performance of non-metallic piping materials, linings and coatings by determining which water parameters are important when selecting piping materials and recommending candidate coatings and piping materials to reduce internal corrosion of pipes.

It is anticipated that through the correct selection of piping materials, less water will be lost unnecessarily due to leaks and that water quality will not deteriorate due to products of corrosion entering the water column. The effect of raw dam waters on generic coatings will also be investigated to provide information required by the Department of Water Affairs and Forestry.

COMPLETED PROJECTS

The development of low-cost ultrafiltration modules *(No 243) Bintech (Pty) Ltd*

In the RSA the process of ultrafiltration is used mainly for the clarification of fruit juices. Ultrafiltration (UF) may, however, be used far more widely if tubular modules can be produced more cheaply.

Bintech (Pty) Ltd, now Membratek (Pty) Ltd, developed low-cost UF modules which do not require the traditional support structure of tubular membranes. The cost of materials alone for these new membranes amounts to approximately 25 per cent of that of conventional membranes, thus allowing their use in many new fields of application.

Costs: R60 000
Term: 1988

The development of seeded reverse osmosis technology *(No 245) COMRO, Iscor and Bintech (Pty) Ltd*

The slurry precipitation and recycle reverse osmosis (SPARRO) process is one of the most promising technologies available for the desalination of calcium sulphate scaling mine waters. The process is based on the principle that precipitation will rather take place on seed crystals than on membranes, should such crystals be present. A slurry of very fine crystals is therefore circulated in the tubular reverse osmosis system to prevent scale formation and to enhance desalination.

Pilot-plant tests conducted at the ERPM gold mine by COMRO indicated the ability of the SPARRO process to successfully desalinate calcium-scaling mine water, achieving a water recovery of 85 to 90 per cent and salt rejections of 90 to 95 per cent. Moreover, relatively simple feedwater pretreatment was required to ensure membrane lifetimes of at least 2 years.

It was also possible to estimate realistically the capital and operating costs of a SPARRO plant with a 20-year lifespan and producing 500 kl/d of desalinated water as R2,58 million and R1,34/kl, respectively.

Costs: R400 000
Term: 1988-1990

The development of low-cost ultrafiltration systems *(No 283) Bintech (Pty) Ltd*

Ultrafiltration (UF) has to be made more economical before this process can be used more widely in the RSA. UF may for instance find application in the pretreatment of water used in textile dyeing, in ion exchange, in reverse osmosis, in boilers and in the polishing of condensates during power generation.

Bintech (Pty) Ltd, now Membratek (Pty) Ltd, successfully developed a tubular UF system which is cheaper than conventional systems that are currently in use. The system may be used at low pressure, hence pumps are not necessary, because tap-water pressure is sufficient for operation.

The combination of UF and anaerobic digestion, "ADUF", was successfully evaluated on an industrial scale.

Costs: R60 000
Term: 1989

The improvement of present polyether-sulphone ultrafiltration membrane technology *(No 336) Membratek (Pty) Ltd*

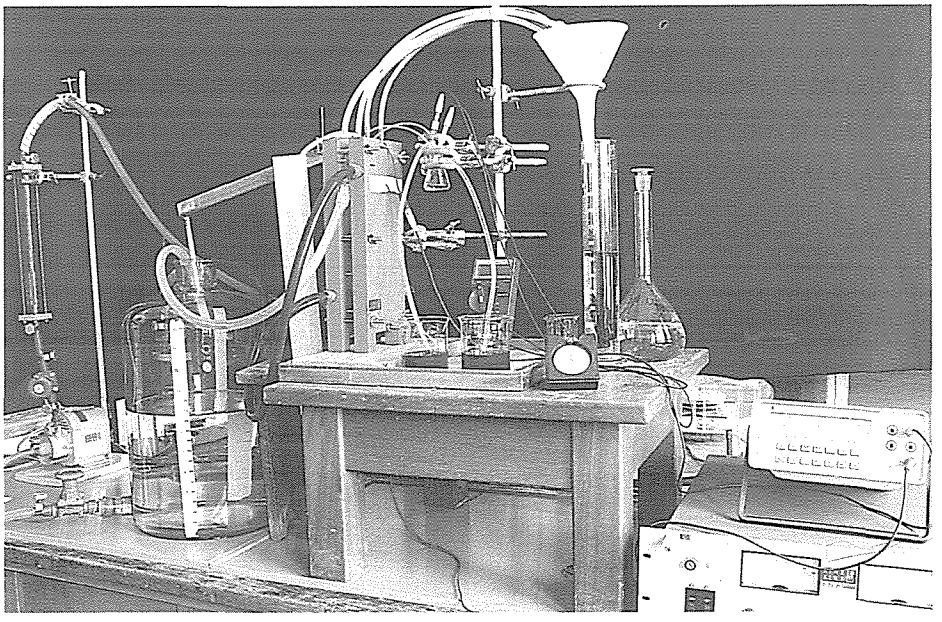
Low-molecular-mass cut-off ultrafiltration membranes was developed at the Institute for Polymer Science of the University of Stellenbosch as the first step towards commercial production by Membratek (Pty) Ltd. Changes in polymer solution formulations, to compensate for differences in production conditions, allowed Membratek to produce membranes whose performance duplicated that of membranes produced in the laboratory.

Three types of low-molecular-mass cut-off ultrafiltration membranes were developed with performance characteristics comparable to, and often better than those of similar imported membranes. These membranes showed economical productivity and useful retention characteristics in application studies concerning colour removal from natural waters and process waters from the sugar industry.

Costs: R39 000
Term: 1990

The application of the anaerobic digestion-ultrafiltration (ADUF) process to brewery effluents *(No 338) Membratek (Pty) Ltd*

The treatment of brewery effluent by the ADUF process has the advantage of not only retaining the biomass, but also of improved digester load rates when compared to conventional clarigesters. Laboratory investigations showed that at space load rates of up to 17,76 kgCOD/m^3.d and hydraulic retention times of 0,5 to 0,8 days COD removal efficiencies of 91,1 to 99,6 per cent were achievable. At more

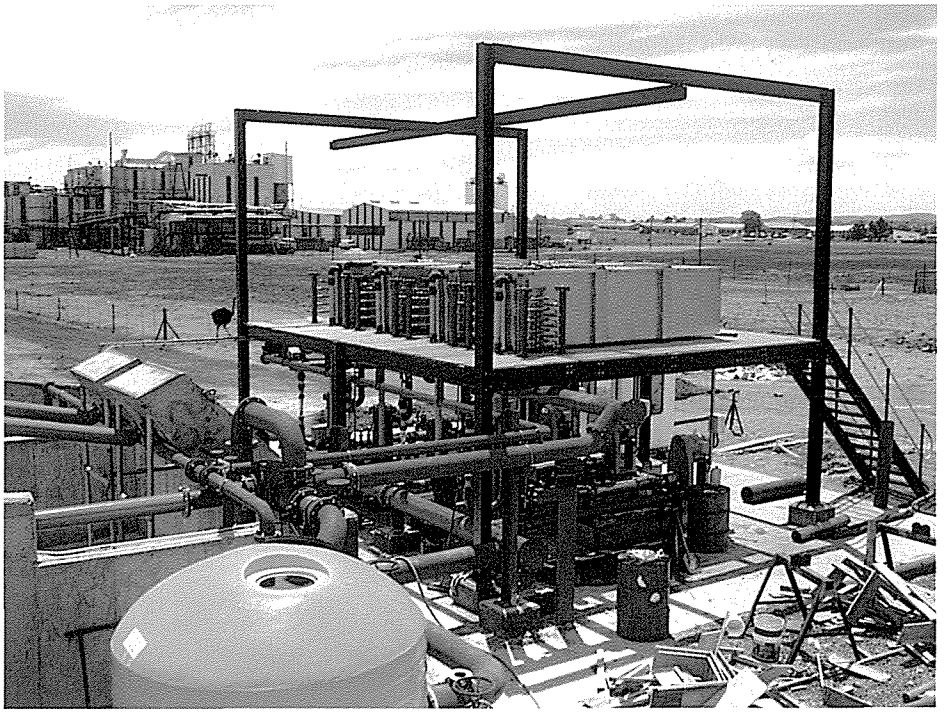


Sealed-cell electrodialysis unit (bench scale) for the concentration of industrial effluents.

conservative load rates and retention times the final effluent COD could be reduced to below the current legal limit for discharge into rivers. Membrane flux values remained stable and fouling was not experienced. Linear flow velocity, sludge concentration and chemical conditions within the digester, were found to have a significant effect on membrane flux.

Design criteria for full-scale application were developed.

Costs: R65 000
Term: 1990



ADUF water treatment plant: Construction phase.

NEW PROJECTS

The development of tolerant membranes *(No 361) Institute for Polymer Science, University of Stellenbosch*

Thin-film membranes play an important role in reverse osmosis, where they generally provide a high flux at reasonably low operating pressures. However, most commercial membranes of this type show a limited tolerance of chlorine.

The objective is to develop a new family of low-pressure thin-film membranes, which are tolerant of chlorine and which should offer a distinct advantage over currently available membranes. Two types will be considered: a medium- to high-sodium chloride (salt) retaining reverse osmosis membrane and a low- to medium-salt-retention nanofiltration membrane.

Industrial application of membranes *(No 362) Institute for Polymer Science, University of Stellenbosch*

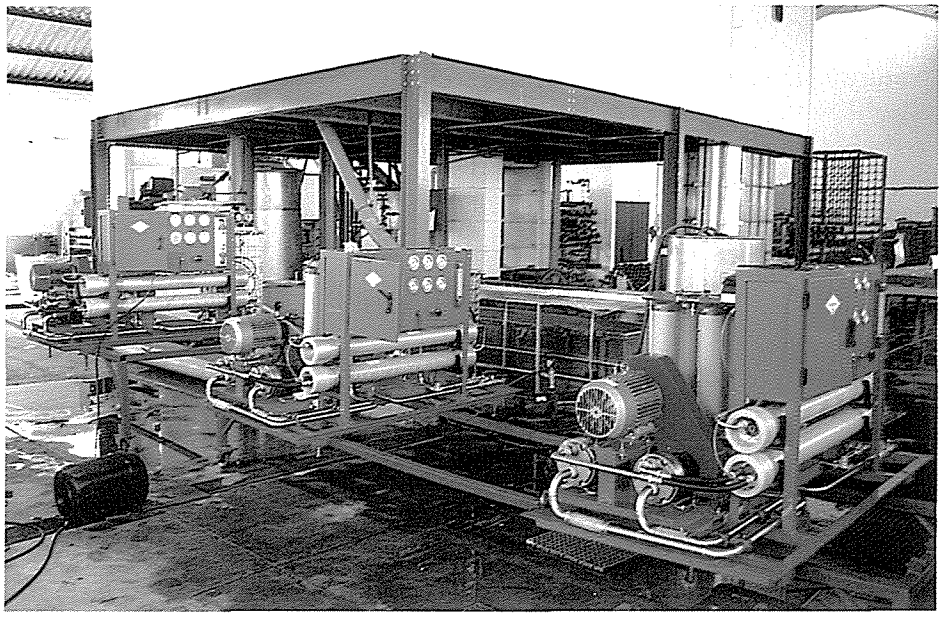
This project involves the small-scale laboratory evaluation of various membranes on real or simulated effluents, as well as at industrial sites. The work will be conducted in close co-operation with Membratek (Pty) Ltd in order to create specially selected membranes for specific markets, as well as to ensure that the required production technology falls within the scope of their production capability. The work will involve pretreatment studies with experimental ultrafiltration or nanofiltration membranes and will make use of pilot-plant studies to gain hands-on experience in effluent treatment situations.

The development and production of membrane systems *(No 387) Institute for Polymer Science, University of Stellenbosch*

Ultrafiltration (UF) membranes, commonly produced from polyether-sulphone (PES) or polysulphone (PS), have found widespread use in the form of spiral-wrap, tubular and capillary forms in the medical, food-processing and water purification fields.

Microfiltration (MF) membranes are produced from polyethylene or polypropylene, usually in the form of self-supporting capillaries, and are generally used in the fields of water and sewage purification.

The proposed work will endeavour to develop novel, supported tubular UF membranes with extended molecular cut-off ranges in the case of PES and PS membranes. New materials will also be used.



Reverse osmosis units for the treatment of brackish water in remote locations.

A South African electrodialysis membrane system *(No 395) Division of Water Technology, CSIR*

Electrodialysis (ED) uses ion-exchange membranes to separate and concentrate ionic impurities from water under the influence of a direct electric current. It is presently used overseas in a wide variety of water desalination applications.

Since there is no producer of ED in the RSA at present, the project is directed at developing and constructing a wholly South African made ED membrane system for use in industrial effluent treatment and brackish water desalination for smaller communities.

The close co-operation of National Chemical Products (Pty) Ltd will be invaluable for the supply of ion-exchange resins which will be used in the construction of the ED system.

Organic fouling of ion-exchange membranes *(No 396) Division of Water Technology, CSIR*

This project will be conducted in co-operation with Eskom. The main aims of the research will be:

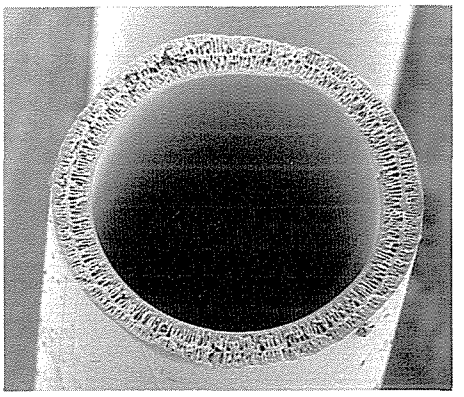
- to identify organic materials with the potential of fouling ion-exchange membranes used for the purification of industrial effluents;
- to study the surface characteristics of organically fouled membranes;
- to identify pretreatment methods to prevent such fouling; and
- to determine effective cleaning methods for ion-exchange membranes.

Prototype capillary micro- and ultrafiltration membranes for industrial application *(No 397) Membratek (Pty) Ltd*

Process and design parameters which influence capillary membrane and module performance will be evaluated in various process applications and the findings will be relayed to the Institute for Polymer Science of the University of Stellenbosch to assist them in the development and design processes.

The modelling of flow through porous membranes *(No 402) Department of Applied Mathematics, University of Stellenbosch*

This project is aimed at improving the effectiveness of membrane research and development by means of mathematical modelling and numerical simulation of flow through porous membranes. Geometrical structural modelling of the microstructure of porous materials may lead to the design of a new tensiometer-type soil moisture meter.



The micrograph shows a cross-section of a capillary ultrafiltration membrane.

RESEARCH PROJECTS

Completed projects

- **243** The development of low-cost ultrafiltration modules (Bintech (Pty) Ltd)
- **245** The development of seeded reverse osmosis technology (The Chamber of Mines Research Organisation (COMRO); Iscor; and Bintech (Pty) Ltd)
- **283** The development of low-cost ultrafiltration systems (Bintech (Pty) Ltd)
- **336** The improvement of present polyethersulphone ultrafiltration membrane technology (Membratek (Pty) Ltd)
- **338** The application of the anaerobic digestion - ultrafiltration (ADUF) process to brewery effluents (Membratek (Pty) Ltd)

Current projects

- **172** Membrane development and fabrication for reverse osmosis and ultrafiltration (The University of Stellenbosch - Institute for Polymer Science)
- **187** The development of polymers for the formation of dynamic membranes and the evaluation thereof for the treatment of industrial effluents (The University of Natal - Department of Chemical Engineering; The University of Stellenbosch - Institute for Polymer Science; and the CSIR - Division of Water Technology)
- **192** The feasibility of reverse osmosis for water reclamation on large scale (The Municipality of Port Elizabeth; the CSIR - Division of Water Technology; and Membratek (Pty) Ltd)
- **201** The treatment of inorganic brines and concentrates (The University of Natal - Department of Chemical Engineering)
- **219** The development of fixed and dynamic membrane systems for the treatment of brackish water and effluents (The University of Stellenbosch - Institute for Polymer Science)
- **238** Design criteria for crossflow microfiltration (The University of Natal - Department of Chemical Engineering)
- **246** The concentration of industrial effluents with sealed-cell electrodialysis (The CSIR - Division of Water Technology)
- **274** Technical support for the application of dynamic membrane plants for the treatment of industrial effluents (The University of Natal - Department of Chemical Engineering)
- **275** The evaluation of membrane technology for electroplating effluent treatment (The CSIR - Division of Water Technology)
- **325** Modelling of tubular reverse osmosis systems (The University of Natal - Department of Chemical Engineering)
- **345** Pilot-scale desalination of sea water by means of reverse osmosis (Membratek (Pty) Ltd)

New projects

- **361** The development of tolerant membranes (The University of Stellenbosch - Institute for Polymer Science)
- **362** Industrial application of membranes (The University of Stellenbosch - Institute for Polymer Science)
- **387** The development and production of membrane systems (The University of Stellenbosch - Institute for Polymer Science)
- **395** The development of a South African electrodialysis membrane system (The CSIR - Division of Water Technology)
- **396** An investigation into the organic fouling of ion-exchange membranes (The CSIR - Division of Water Technology)
- **397** The evaluation of prototype capillary micro- and ultrafiltration membranes for industrial application (Membratek (Pty) Ltd)
- **402** The modelling of flow through porous membranes (The University of Stellenbosch - Department of Applied Mathematics)

CONSERVATION OF AQUATIC ECOSYSTEMS

This relatively new research field continued to increase in that 5 new projects are being supported. The new projects will all address issues of importance and/or weakness in existing projects, and as such will assist in the final evaluation of water requirements for the conservation of aquatic ecosystems.

New projects will assist in the final evaluation of water requirements for the conservation of aquatic ecosystems

The Co-ordinating Committee for Water Ecosystems Research (CCWER) met once during the year and the first steps toward the compilation of a relevant research master plan were taken.

The researchers of the Kruger National Park (KNP) Rivers Research Programme held their first annual meeting in March. All the Programme participants, having backgrounds as diverse as mathematical statistics, civil engineering through to zoology, reported on research progress in the 27 registered projects. The meeting presented participants with the opportunity of integrating with the Programme as a whole. A few problem areas were identified, which will receive attention in the coming year.

Prof Angela Arthington, Director of the Centre for Catchment and Instream Research at Griffith University, Brisbane visited South Africa during November. During her stay she reviewed the KNP Programme and, *inter alia*, visited various centres at which WRC projects are being undertaken. Her opinions and recommendations regarding future work directions will prove invaluable in the long-term planning of water ecosystems research.

The number of ecologically related research projects financed by the Commission in 1991 came to 10. Of these 1 was completed, while 5 research agreements were entered into.

COMPLETED PROJECT

The water rights of nature conservation *(No 340) Advocate M Uys*

What started out as a broad spectrum analysis of the South African Water Act in relation to nature conservation, was redirected, on advice of the Steering Committee, to an in- depth study of the legal aspects of the development of the Letaba River water resources, with specific reference to water apportionment to the various user sectors. Based on the findings of

The Seekoei estuary in flood (17 November 1989).

this study a further in-depth study, of the water apportionment mechanisms contained in the Water Act, was approved - the results of this study therefore acting as input to the new investigation (See notes on Project No 406, given under **New projects**).

Costs: R60 000
Term: 1990

NEW PROJECTS

The effect of pollution on the physiology of fishes in the Olifants River *(E.Tvl.) (No 350) Department of Zoology, Rand Afrikaans University*

Up to the present most of these studies were aimed at determining the results of acute exposures of fish to pollutants. Under these conditions the death of the organism was the only measurable variable. It is, however, accepted that an organism ceases to function physiologically normally and effectively long before dying. For this reason the project aims at determining the effect of pollutants on the physiology of, in this case, fish, from exposure to such substances to serious physiological disturbance.

The effect of pollution on the physiology of fish in the Olifants River, Eastern Transvaal, is being studied.

The effect of water quality variables on riverine biota *(No 351) Department of Zoology, University of Cape Town*

Water quality determines the numbers and types of aquatic species and communities in aquatic ecosystems and the functioning thereof. One method of assessing water quality impact on a water body is to construct a rating curve of the concentration of each quality variable against some measure of "harmfulness". This project will determine the effects of the concentration of a number of water quality variables on riverine biota in order that the necessary rating curves may be constructed.

Geomorphological response to changing flow regimes of the Sabie and Letaba River systems *(No 376) Department of Botany, University of the Witwatersrand*

The form of a river channel, which defines the physical environment for aquatic biota, is determined by water and sediment supply from upstream. Changes in these supply rates result in significant modification of the river form and habitat. Specifications of water allocations for the conservation of aquatic environments therefore require understanding of the river response to these changes in a quantitative and predictive sense. The objectives of this study have been formulated to develop such understanding and predictive capability.

A structural analysis of the water apportionment mechanisms in the Water Act 54/1956, in view of the requirements of competing user sectors *(No 406) Advocate M Uys*

The rapidly increasing competition for the RSA's limited water resources could lead to conflict of interest between the various user sectors. The project will research the historical development of the SA Water Act with the aim of re-evaluating the efficiency of the Water Act's express acknowledged and unacknowledged mechanisms of water apportionment between competing user claims. Out of this, guidelines will be drawn up for possible incorporation in future relevant amendments to the Water Act.

Contribution to the estuaries research programme *(No 412) Institute for Natural Resources, University of Natal*

This study is scheduled for an initial one-year period. It will concentrate on the impact of disturbances in river flow patterns and flooding frequencies, on the natural spatial and temporal scales of change within estuarine systems. The results of the study will assist in the formulation of plans and strategies for remedial action in the case of such disturbances. This study is funded within a Special Programme of the Foundation for Research Development (FRD) and is a joint venture between the FRD, the WRC, the Department of Environment Affairs, Portnet and the Natal Provincial Administration.

RESEARCH PROJECTS

Completed project

- **340** The water rights of nature conservation (Advocate M Uys)

Current projects

- **292** The freshwater requirements of estuarine plants (The University of Port Elizabeth - Department of Botany)
- **293** The relationship between low flows and the river fauna of the Letaba River (The CSIR - Division of Water Technology)
- **294** A pre-impoundment study of the Sabie-Sand River system, Eastern Transvaal, with special reference to predicted impacts on the Kruger National Park (The University of Cape Town - Freshwater Research Unit, and Rhodes University - Institute of Freshwater Studies)
- **295** The assessment of the instream flow requirements of rivers (The University of Cape Town - Freshwater Research Unit)

New projects

- **350** The effect of pollution on the physiology of fishes in the Olifants River (E.Tvl.) (The Rand Afrikaans University - Department of Zoology)
- **351** The effect of water quality variables on riverine biota (The University of Cape Town - Department of Zoology)
- **376** The geomorphological response to changing flow regimes of the Sabie and Letaba River systems (The University of the Witwatersrand - Department of Botany)
- **406** A structural analysis of the water apportionment mechanisms in the Water Act 54/1956, in view of the requirements of competing user sectors (Advocate M Uys)
- **412** Contribution to the estuaries research programme (The University of Natal - Institute for Natural Resources)

The Seekoei estuary in dry conditions resulting in die-back of macrophytes (4 April 1991).

DEVELOPING COMMUNITIES

Water supply, sanitation and pollution control in developing communities constitute a problem of rapidly growing proportions which a number of organisations, both government and non-government, have to cope with. Despite the fact that sufficient technology exists for the construction of rural water supply and sanitation facilities, implementation of these schemes is fraught with unique difficulties. Countless examples have been cited of well-planned schemes which have failed simply because insufficient attention was given to factors that apply in developing communities.

As far as sanitation is concerned, facilities are mostly inadequate because of severe overcrowding, and together with the large number of homeless and semi-homeless people making up the population of a developing community, surface pollution problems of great concern are being created. Surface runoff carries the pollution load into local streams and rivers and eventually into a public recreational facility such as a lake, reservoir or the sea. Where local ponding takes place the most severe concentration of faecal pollution occurs and this inevitably seeps down into the soils and often reaches the ground water. In the sand areas of the Cape Flats, for instance, the winter water table actually rises above the ground level, exacerbating the problem.

Because of the national importance of the problem, the WRC is actively involved in the funding of projects addressing these problems. During 1991 the Commission supported 10 projects directly related to developing communities of which 5 commenced during the year and 2 were completed.

Because of the national importance of the problem, the WRC is actively involved in the funding of projects addressing developing communities

COMPLETED PROJECTS

Guidelines on cost-effectiveness of rural water supply and sanitation projects

(No 231) Division of Water Technology, CSIR, and Sviridov De Waal and Associates

It became apparent that there was an urgent need to develop a set of guidelines to assist both governmental and non-governmental organisations to maximise the cost-effectiveness of their work. The objectives of this project therefore were to develop guidelines on how to maximise

The absence of an adequate waste disposal system transfers the pollution load to the water supply.

the cost-effectiveness; to develop procedures for quantitatively determining the objectives of rural development projects; to develop procedures and norms for evaluating their achievements; and to provide guidelines for future projects which would avoid past mistakes and increase the probability of success of future projects.

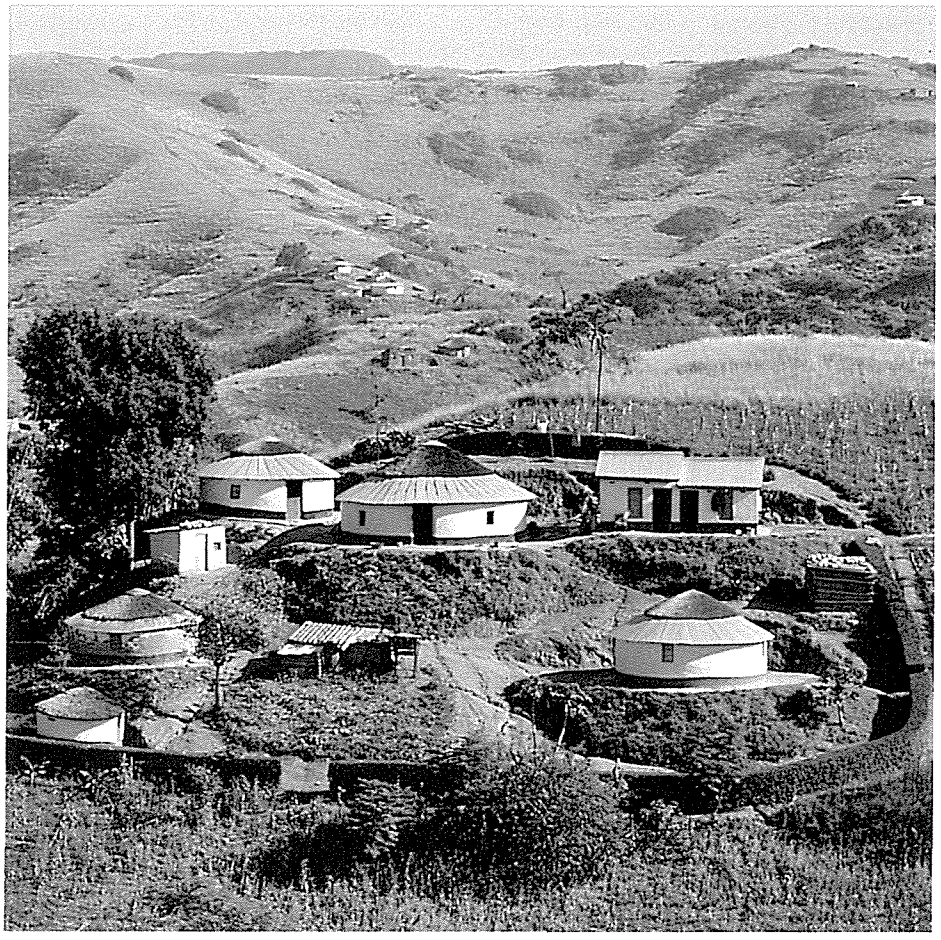
The results are contained in the following 2 reports: *Guidelines on the Cost-effectiveness of Rural Water Supply and Sanitation Projects*, and *Guidelines on the Technology for and Management of Rural Water Supply and Sanitation Projects*.

The first guideline document focuses primarily on the methodologies for the selection of the appropriate rural water supply or sanitation system. The important factors of sustainability, cost recovery and community participation are stressed. The related costs and benefits of various water supply systems are dealt with, and a table of general service levels is provided. Estimates of capital and operation costs are given for the various components of water supply schemes, and the steps recommended for the selection of a suitable technology for a particular application are listed.

The second guideline document on the technologies and management aspects of rural water supply and sanitation projects deals mainly with the various appropriate technology solutions for the provision of water supplies and sanitation to rural areas. The document highlights technologies which have been successfully applied in Southern Africa, and in some cases in other parts of the world, but which would be applicable for use in Southern Africa.

Guidelines emanating from this research are not intended to prescribe to the organisations involved with rural development, or to reduce their autonomy, but to provide a basis for objective self-evaluation and improvement and by so doing to contribute to the overall development of rural areas in Southern Africa.

Costs: R265 000
Term: 1988-1991



A typical rural settlement.

Pollution loads, dispersion and effects of urban runoff from the Motherwell township into the Swartkops River, Eastern Cape

(No 324) Department of Oceanography, University of Port Elizabeth

Pollution carried by rainfall events into canals and rivers eventually lands up in some or other water body and in this instance, the Swartkops Estuary.

The project had two aims: the first was to control the high pollution load associated with low flows from the area; and the second to determine the fate of the pollutants once they reached the estuary. Unfortunately both the project leader and the researcher left the employ of the university at the end of 1990 before the second aim could be addressed. However, as the first aim had been successfully completed, the WRC agreed to terminate the project at the end of 1990, the balance of the unutilised funds returning to the WRC.

The problem of high-concentration low flows in the canal was solved by constructing a sump in the canal floor and installing a sump pump which transferred the low-flow liquor to the nearest sewer manhole for treatment at the sewage works. At higher flows the capacity of the pump was exceeded, the sump filled and the now adequately diluted storm water runoff discharged into the estuary.

The importance of the second aim is still recognised and it is therefore envisaged that the aspect of the fate of pollutants entering a water body will be incorporated in another project in the near future.

Costs: R199 950 (budgeted amount)
Term: 1990-1991

NEW PROJECTS

A study of the relationship between hydrological processes and water quality characteristics in the developing Zululand coastal region

(No 346) Department of Hydrology, University of Zululand

The Zululand coastal region is experiencing a large influx of people which, together with pressure from agricultural development, particularly sugar-cane and afforestation, places a heavy burden on this area's water resources. The study will compare a natural system (Ngoye Nature Reserve) with a rural catchment experi-

encing an increase in population.

Emphasis will be placed on the identification of hydrological processes and their relationship to water quality. Not only will processes be identified and studied, but an effort will be made to investigate possible management options and land management practices in order to counteract some of the expected negative effects.

Water resources and sanitation systems source book with special reference to Natal/KwaZulu

(No 384) Department of Economy, University of Natal

The aim is to present a considerable array of information relating to a variety of water resource and sanitation systems, including a comprehensive bibliography of published and unpublished material relating to the various topics. The book represents a unique concept in the field of water and sanitation in South Africa and can therefore serve as a source of data, information and expertise.

The importance of water and sanitation information will be emphasised and indications will be given as to how, through the use of available knowledge, the best possible utilisation of water resources may be achieved.

Relevant data on water and sanitation equipment manufactured in South Africa will enable the selection of the most appropriate products for the development in question. Readers will also be alerted to the increasing proportion of material in the form of "grey" literature, namely unpublished or internal reports. This is necessary to avoid repeating an investigation or to provide historical and background information to others with similar interests.

Technical, socio-economic and environmental evaluation of sanitation systems for developing urban areas in South Africa *(No 385)*

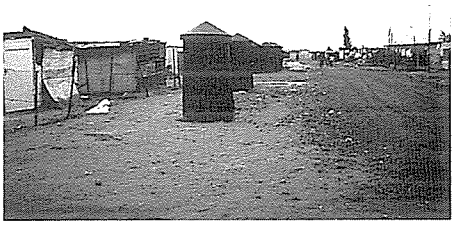
Department of Civil Engineering, University of Cape Town and the Palmer Development Group

During the next decade some 11 million people are likely to migrate to the cities of South Africa. The challenge of providing these people with services will place a great burden upon the economic and manpower resources of the country.

The capital cost of providing fully sewered sanitation to 11 million people has been estimated at R3,9 billion, and the annual operating, maintenance and water costs at R350 million. It is therefore essential to look at simpler, less costly, yet adequate systems for sanitation. Such an approach would result in a high proportion of the capital expenditure being retained in the local economies where systems suitable for construction by small local contractors using labour-intensive methods are provided.

However, before a start can be made with any such scheme, a study must be made of the impact that each scheme will have on the ground water and on the environment in general, as the characteristics of each and every region are different.

Information concerning the costs and operation of alternative options needs to be gathered and methods to upgrade and improve such systems still have to be published.



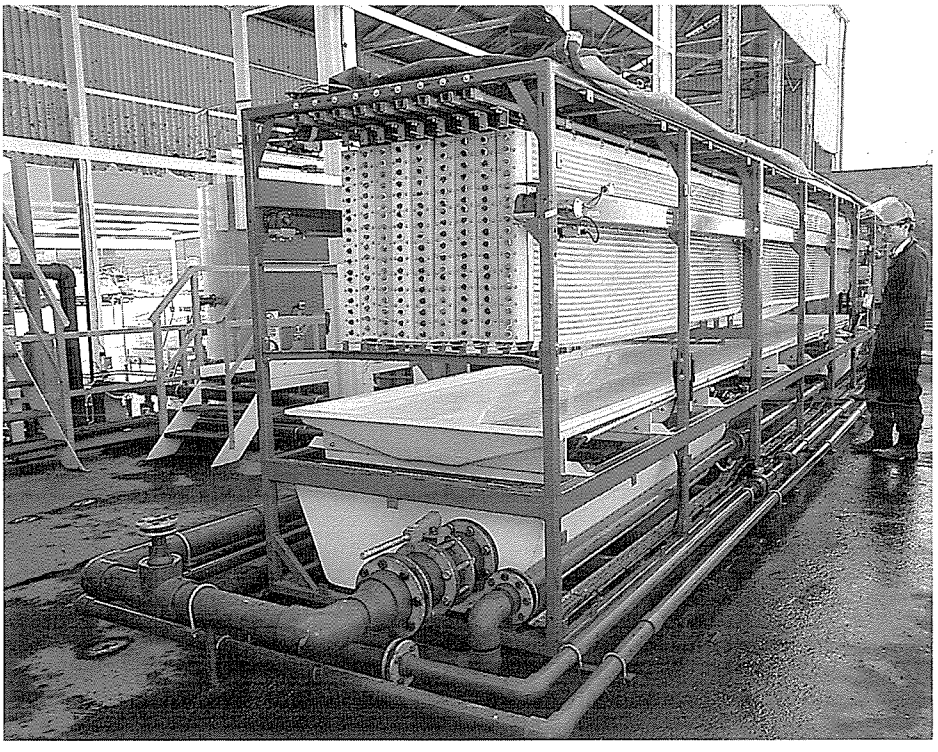
As the density of developing communities increases, provision has to be made for upgraded sanitation facilities.

A crossflow microfilter for rural water supply *(No 386)*

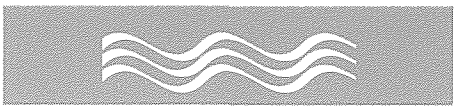
Umgeni Water and Department of Chemical Engineering, University of Natal

A new agreement has been signed whereby the Pollution Research Group will develop and evaluate a crossflow microfiltration-based water treatment system for rural areas.

Both the chemical and microbiological quality of the water produced will be monitored and aspects such as costs and manpower requirements for operation will also be assessed.



A crossflow microfilter for rural water supply.



Nitrate removal from potable water *(No 403) Department of Chemical Engineering, University of Pretoria*

In a number of rural areas ground water can be found with nitrate levels exceeding the SABS maximum allowable concentration of 10 mg/*l*. Consequently a one-year agreement was entered into in order to develop possible suitable, practical and inexpensive methods for removing these nitrates. Too high nitrate levels in drinking water causes a disease of the blood known as methemoglobinaemia especially in babies and young children.

RESEARCH PROJECTS

Completed projects

- **231** The preparation of guidelines on cost-effectiveness of rural water supply and sanitation projects (The CSIR - Division of Water Technology, and Sviridov De Waal and Associates)
- **324** Pollution loads, dispersion and effects of urban runoff from the Motherwell township into the Swartkops River, Eastern Cape (The University of Port Elizabeth - Department of Oceanography)

Current projects

- **323** A hydrological investigation of storm-water runoff from the Khayelitsha urban catchment in the False Bay area, South-Western Cape (The CSIR - Division of Water Technology)
- **341** Forced aeration composting of sewage sludge for rural communities (The City Council of Grahamstown)

New projects

- **346** A study of the relationship between hydrological processes and water quality characteristics in the developing Zululand coastal region (The University of Zululand - Department of Hydrology)
- **384** Water resources and sanitation systems source book with special reference to Natal/KwaZulu (The University of Natal - Department of Economy)
- **385** Technical, socio-economic and environmental evaluation of sanitation systems for developing urban areas in South Africa (The University of Cape Town - Department of Civil Engineering, and the Palmer Development Group)
- **386** Development of a crossflow microfilter for rural water supply (Umgeni Water and the University of Natal - Department of Chemical Engineering)
- **403** Nitrate removal from potable water (The University of Pretoria - Department of Chemical Engineering)

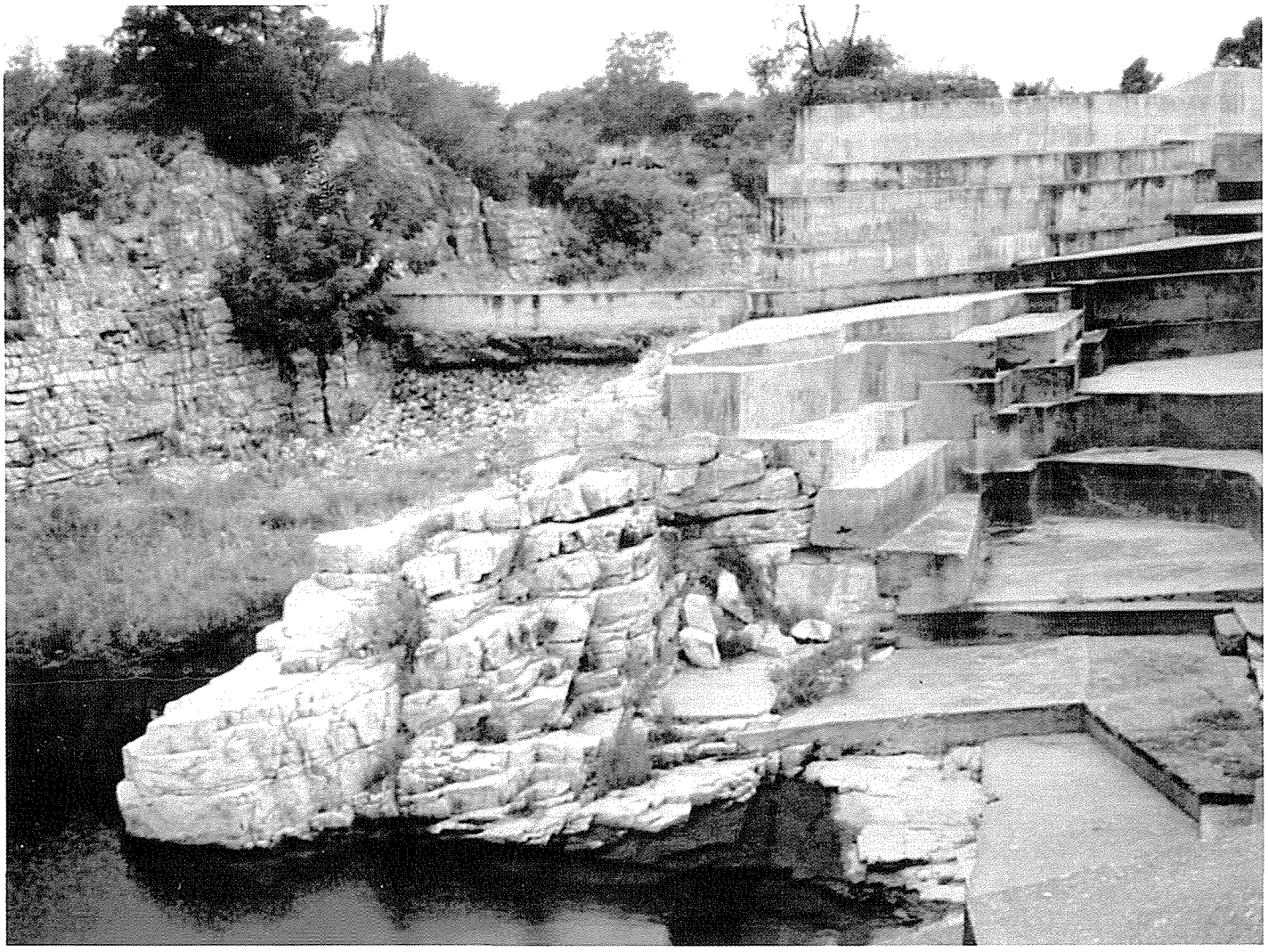
GENERAL

SOCIO-ECONOMIC EFFECTS OF WATER RESTRICTIONS

Three previous WRC-financed projects partially researched the socio-economic effects of the water restrictions which were in force from March 1983 to September 1987 in large areas of the RSA as a result of intense drought conditions. The projects covered the period March 1983 to March 1985 but further research was needed for the period April 1985 to September 1987 (i.e. the month in which the restrictions were lifted). In order to ensure that future restrictions would not have an unacceptable socio-economic and financial impact, the WRC took the view that the effects should be determined for the full period of drought (i.e. 1983 to 1987); that a qualified exposition should be given of the global nature and extent of the tangible and intangible effects of the restrictions; and that relationships between the nature and extent of the restrictions and the effects thereof should be ascertained for the various sectors. An agreement was entered into with the Department of Agricultural Economics of the University of the OFS to carry out this task.

The financial effects of water restrictions for the period 1983 to 1987 *(No 288) Department of Agricultural Economics, University of the Orange Free State*

The first 2 objectives of the research were attained in 1991 and the reports were published. A suitable methodology was developed to determine the directly tangible effects and was applied to the following sectors/establishments: agricultural, mining and industrial sectors, local authorities, households and public institutions. In addition the indirect tangible effects were determined by means of an input-output technique.



Marico Bosveld Dam: New spillway after failure of original spillway as a result of erosion.

The direct financial effects of the water restrictions over the above-mentioned term are indicated in **Table 1**. This amounted to a total of R1 514,15 million in nominal value of which households and industries contributed the major portion. It is further evident that the major impact occurred during the first 2 years of the restrictions.

Table 1: DIRECT FINANCIAL EFFECTS (R) OF WATER RESTRICTIONS ACCORDING TO YEAR AND SECTOR, VAAL RIVER AND RIET RIVER WATER SUPPLY AREA, 1983 TO 1987

SECTOR	1983	1984	1985	1986	1987	TOTAL
AGRICULTURE:						
Vaal River system	18 672 482	16 473 594	11 254 606	12 243 652	11 617 232	70 261 566
Vaalharts State Water Scheme	26 189 480	21 176 509	16 880 043	20 616 196	14 110 079	98 972 307
Riet River State Water Scheme	6 769 699	5 353 173	4 573 030	5 346 536	-	22 042 339
TOTAL AGRICULTURE	51 631 562	43 003 276	32 707 679	38 206 384	25 727 311	191 276 212
Mining	26 006 743	32 290 503	13 098 377	12 929 034	14 861 021	99 185 678
Industry	60 330 346	77 563 286	38 867 755	37 121 180	37 192 913	251 075 480
Households	140 918 518	166 767 929	57 108 542	54 254 390	54 085 899	473 135 278
PUBLIC INSTITUTIONS:						
WRC	31 037	450 324	120 886	325 733	769 262	1 697 242
Department of Water Affairs	14 836 000	11 288 500	9 923 000	7 114 500	-18 828 000	24 334 000
Rand Water Board	34 573 190	31 489 160	32 955 651	54 875 581	55 504 221	209 397 803
OFS Gold Fields Water Board	-2 507 089	-5 043 370	-6 547 449	581 643	7 510 983	-6 005 282
Western Transvaal Regional Water Co	2 489 496	3 046 171	4 104 331	4 692 069	5 019 005	19 351 072
Local authorities	59 730 372	15 259 933	-3 797 756	38 294 751	70 172 832	179 660 132
Eskom	71 043 969	-	-	-	-	71 043 969
GRAND TOTAL	**459 084 144**	**376 115 712**	**178 541 016**	**248 395 265**	**252 015 447**	**1 514 151 584**

In **Table 2** the directly tangible effects are indicated of the restrictions on certain components of agricultural activities in the 3 areas, namely the Vaal River system and the Vaalharts and Riet River State Water Schemes. The table clearly reflects the consequences for livestock production on cultivated grazing under irrigation.

The total directly tangible effects of the restrictions on the other sectors are indicated in **Table 3**.

Table 2: TOTAL DIRECTLY TANGIBLE EFFECT OF WATER RESTRICTIONS ON CERTAIN COMPONENTS OF IRRIGATION AGRICULTURE, VAAL RIVER AND RIET RIVER WATER SUPPLY AREAS, 1983 TO 1987

TOTAL TANGIBLE EFFECT (NOMINAL)

AREAS	Irrigation crop income (R'000 000)	Livestock income (R'000 000)	Exploitation and development of new water resources (R'000 000)	TOTAL (R'000 000)
Vaal River	75,73	14,58	3,01	93,32
Vaalharts	97,05	3,80	4,96	105,81
Riet River	31,54	3,51	1,46	36,51
TOTAL	**204,32**	**21,89**	**9,43**	**235,64**

Table 3: TOTAL DIRECTLY TANGIBLE EFFECT OF WATER RESTRICTIONS ON THE MINING, INDUSTRIAL, LOCAL AUTHORITY AND HOUSEHOLD SECTORS, VAAL RIVER WATER SUPPLY AREA, 1983 TO 1987

TOTAL TANGIBLE EFFECT (NOMINAL)

SECTOR	Transferred loss (R'000 000)	Additional expenses and losses (R'000 000)	Net revenue loss (R'000 000)	Total (R'000 000)
Mining	54,40	44,77	-	99,17
Industry	147,95	103,12	-	251,07
Local authority	-	15,77	163,88	179,65
Households	221,93	251,20	-	473,13
TOTAL	**424,28**	**414,86**	**163,88**	**1 003,02**

With the completion of this facet the nature and extent of the effects were quantified. Furthermore the relative degree of effect on the different sectors and components of economic activity within each sector was indicated. Consequently these components can be placed in perspective with regard to the relative impact on them, and information is supplied by means of which the financial extent of the consequences of water restrictions can be compared with the consequences of other natural disaster situations.

The results of the research now provide a more rounded off answer as to how future restrictions have to be managed to minimise their impact. It has become clear that the extent of the restriction measures has to be determined in consultation with those affected and not one-sidedly.

The research also proved that an assessment of only the direct consequences to a large degree underestimates the global impact. The interrelationships between the different sectors have to be taken into account in order that the indirect consequences may also be calculated.

The last objective of this project, namely to establish the relationships between the nature and extent of the restrictions and the concomitant effects, is currently being finalised and will be reported on in 1992.

GEOLOGICAL ASPECTS

The erodibility of different rock formations under varying flow conditions *(No 302) Department of Geology, University of Pretoria*

The erodibility of rock formations is a problem especially at dam spillways where reverse erosion or pot-hole formation can cause the structure to yield or be damaged. A rock formation can be compared to mason-work consisting of solid boulders with different characteristics, shapes and sizes, which are separated from each other by joints with or without filling material. Field studies and back analyses of eroded rock formations at dam spillways showed that the removability of boulders is determined by the slab formation and topography, while the rate of erosion is influenced by the firmness and permeability of the joint filling material.

The objectives of the project are:

- identification of the engineering geological and hydraulic parameters influencing the erodibility of a rock formation;
- development of a procedure to characterise a rock pile in terms of erodibility; and
- development of a correlation between flow speed (or water gauge) and the degree as well as the rate of erosion which can be expected.

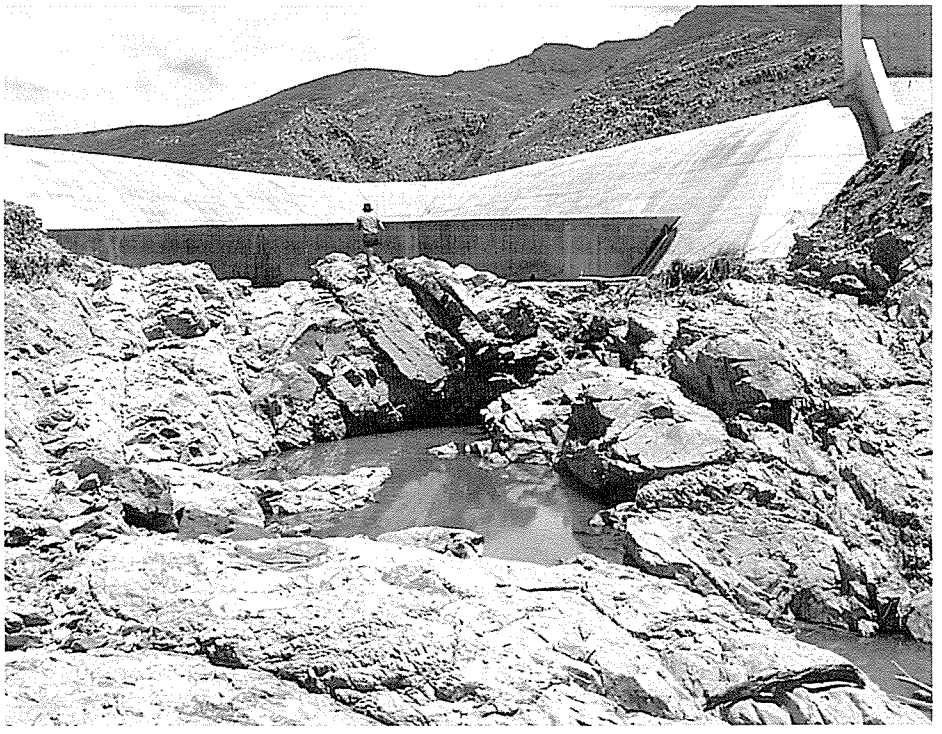
A flow canal for model studies, donated by the CSIR's Division of Earth, Marine and Atmospheric Science and Technology, was commissioned at the University of Pretoria. Various modelling tests were carried out to determine a relationship between the characteristics of artificially manufactured joint filling material, flow speed and the rate of erosion. In addition, a series of indicator tests were developed to compare the artificial filling material with natural material.

RESEARCH PROJECTS

Current projects

- **288** Determination of the socio-economical and financial implications of the water restrictions in force from 1983 up to its annulment in 1987 (The University of the Orange Free State - Department of Agricultural Economics)
- **302** The erodibility of different rock formations under varying flow conditions (The University of Pretoria - Department of Geology)

Hans Strydom Dam: Erosion along the fault zone, in the spillway channel.



Prinsrivier Dam: New spillway after undercutting of original structure by erosion.

RESEARCH SUPPORT SERVICES

SOUTH AFRICAN WATER INFORMATION CENTRE

The South African Water Information Centre (SAWIC) is funded by the WRC and operated by the Division of Information Services of the CSIR.

SAWIC serves as a central reference centre for enquiries about water and related subject areas and specialises in the provision of references to publications on these topics. To this end the staff are expected to keep up to date with information on the latest developments in the fields of water, waste water and sanitation and to ensure that this information is distributed as widely as possible.

WATERLIT, the bibliographic data base developed and run by SAWIC, has been in existence since 1975. Its reputation as one of the best water data bases in the world was confirmed recently when the American firm, Cambridge Scientific Abstracts, approached SAWIC with a proposal to produce the data base in CD-ROM form for the international market. WATERLIT contains more than 190 000 references to books, reports, conference proceedings and theses as well as to articles from more than 450 local and international scientific and technical journals.

Information from the data base is invaluable when background information is required for the design of new projects, when new research is being undertaken and when problems are encountered in the water field. Literature searches are usually requested either at the planning stage of new projects, where a specific problem has arisen and background information is required about work already done on the topic or where information is required for the preparation of articles for publication or presentations. For continuing projects and for users who need to be kept up to date on the latest developments in their field, the alerting service provides a monthly list of the newest references.

New technology in the field of information science is also being introduced. At present searches can be provided through the CSIR's Division for Information Services at Pretoria, Durban and Stellenbosch, and the library of the Department of Water Affairs and Forestry in Pretoria (for staff of this department). By 1992 it is hoped to have the facilities in place to enable users to access the data base from their own personal computers. A system of menus will make it easy for a user to search the data base without requiring special training. Users will also be able to request the output from the monthly alerting service on diskette, to be stored on their personal computers.

As a result of a marketing campaign, awareness of the services offered is increasing, especially in the industrial sector. More than 200 clients subscribe to the monthly alerting service. The demand for literature searches fluctuates. The change in the price structure is expected to have an impact on the demand for searches, but this will probably be offset by the increasing awareness of WATERLIT in the industrial sector and the availability of direct access to the data base. Many of the current users have indicated an interest in being able to search the data base themselves.

HYDROLOGICAL INFORMATION SYSTEM (HIS)

The HIS project was started in 1985 as a joint venture between the WRC and the Department of Water Affairs and Forestry with the following objectives:

- to improve existing data banks and to create new ones;
- where feasible, to link the various data banks and also create links with data banks for ground water and rainfall that have been created separately; and
- to load all applicable data into the HIS.

The project had 2 major components, viz. system development and software maintenance, and data capture and processing.

During 1991 the HIS project was completed and handed over to the Department of Water Affairs and Forestry. The main achievements with regard to system development during the past 6 years have been the establishment of systems for:

- HIS security
- Station catalogue
- Geometric design of measuring weirs
- Flow data
- Evaporation data
- Processed flow data (old Reservoir data bank)
- Water quality
- Patched and extended flow data
- Publications
- Digitising of data
- Integrated data extraction

A great number of user manuals and background documentation have been produced.

The National Ground-water Data Base coupled with the Hydrocom software are part of HIS which allows for data loading via a PC. Further integration can be expected in the future.

The original goal with data capture was to process all historical hydrological data from 1900 to 30 September 1980, while the Department would process all recent and incoming data. This object has been achieved.

Calibration of flow-measuring weirs has progressed well and during the project 1 450 surveys were carried out; 1 700 visits were made to measuring points; 650 new rating tables were produced; and 1 050 rating tables were improved or replaced.

Especially towards the end of the project more attention was paid to data quality which resulted in a shift in emphasis away from production rate *per se* towards improved data quality and better trained personnel.

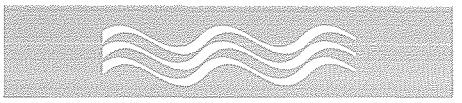
Because of the decentralisation of the data capture function within the Department a start has been made with decentralising the digitising system.

COMPUTING CENTRE FOR WATER RESEARCH (CCWR)

In 1986 the Computing Centre for Water Research (CCWR) was established jointly by IBM SA (Pty) (later ISM (Pty) Ltd), the WRC and the University of Natal.

The CCWR supports collaboration and disseminates knowledge, data and information among researchers and practitioners through advanced computing and communication technology in order to enhance water resources management. It has a staff of 7 people.

During this year the number of users has not grown very much but several have extended their usage considerably. The future of the CCWR has been planned further following the WRC deci-



sion in principle to support the CCWR for another 5 years beyond 1991.

A start has been made to change over to the IBM RISC System 600 which allows the CCWR users to enjoy the privilege of advanced computer technology. Through the kind donation of ISM the CCWR now also has available a multi-user version of ARC/Info.

Hydrological modelling for the purpose of effective integrated catchment management plays a central role in our research effort. To enhance co-operation between researchers a start has been made to pursue the Watershed Data Management System approach now adopted by the Environmental Protection Agency (USA) and the US Geological Survey. In this way the CCWR hopes to provide more common ground between the different hydrological modellers in the country.

The CCWR is now able to provide users with direct access to the large governmental data bases such as the Weather Bureau, the Department of Water Affairs and Forestry and the Soil and Irrigation Research Institute.

The CCWR realises that first-class technology constitutes only the first step in the fulfilment of its mission and more attention will therefore be paid to user-interaction as the key to success lies in assisting users "to fish" rather than "doing the fishing for them".

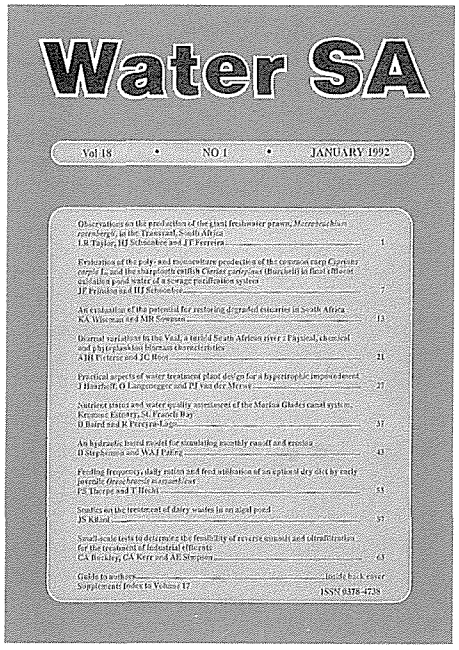
TRANSFER OF INFORMATION AND TECHNOLOGY

The promotion of information and technology transfer is one of the most important objectives of the Commission. This is very clearly defined in the Water Research Act, namely to "accumulate, assimilate and disseminate knowledge in regard to the results of such research and the application thereof, and promote development work for the purpose of such application".

For the promotion of its programme of information and technology transfer, the Commission has developed a number of activities. Although some of these activities are directed at the transfer of information, the emphasis falls mainly on technology transfer, i.e. the application of research results, since this will always represent the final dividend of the research investment.

PARTNERSHIP RESEARCH

Partnership research is regarded as a very effective method of enhancing technology transfer. The partnership principle is incorporated, as far as possible, in research projects, and means that the end user of the results participates in the planning and execution of the research.



PUBLICATIONS

The Commission's publications cater for three levels, viz. pure scientific, popular scientific and practical scientific.

WATER SA

Water SA is the Commission's scientific journal which contains original research articles and review articles on all aspects of water science, technology and engineering. The journal appears quarterly and the first edition was launched in April 1975.

Water SA has a strict refereeing system whereby all articles submitted for publication are first referred to referees, whereafter a decision is taken on publication.

Water SA has an extensive local as well as overseas readership. It also enjoys world-wide coverage in the sense that it is covered by more than 20 international abstracting services who publish and distribute summaries of articles which appear in *Water SA*.

SA WATERBULLETIN

SA Waterbulletin is a bilingual bi-monthly periodical. Within the broad spectrum of water research it aims to:

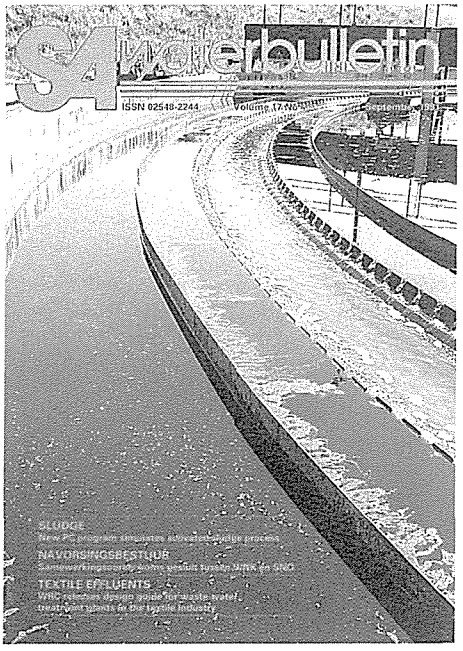
- furnish information on water and water research in a popular scientific manner to the different interest groups in the water field;
- promote the transfer of technology by announcing the availability of reports, manuals, guides etc. which emanate from water research;
- promote communication between the WRC and authorities and individuals, such as researchers, engineers, technicians, government departments, local authorities and the industrial and agricultural sectors; and
- convey social news and matters of interest (e.g. about conferences and personalities) to the water research community.

MANUALS, GUIDELINES AND REPORTS

At the conclusion of a project, and also while research is still under way, results are evaluated in respect of possible use and application and depending on the nature of the results a decision is taken on publication, dissemination and application thereof. More information on these publications appears in the relevant chapters and in the **Annexure**.

LIST OF COMMISSION PUBLICATIONS

The **Annexure** to this annual report contains a list of publications (articles, papers and published reports) which appeared during 1991 and which emanated from research supported wholly or in part by the Commission.



CONFERENCES, SEMINARS, WORKSHOPS AND DEMONSTRATIONS

From time to time the Commission, on its own or in co- operation with other organisations, arranges such meetings. These afford ideal opportunities for promoting personal contact between research scientists or between research scientists and the users of research results. In this way the transfer of information and technology is greatly enhanced. More information on meetings held during the year is contained in the individual chapters.

MASS MEDIA

In this regard the accent falls on information tranfer, and press releases, radio and television are used to this end.

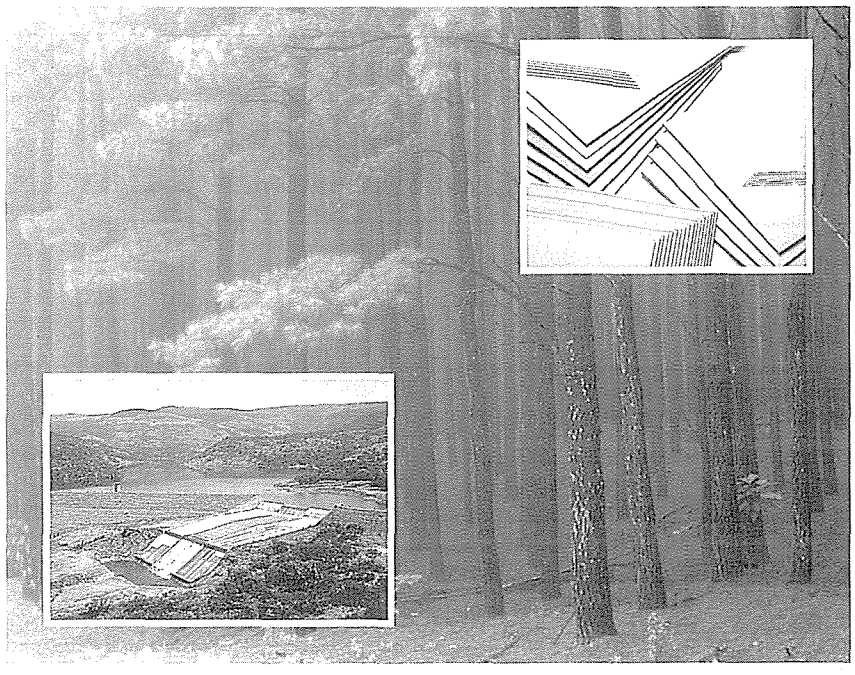
UTILISATION OF OVERSEAS EXPERTISE

It is in the national interest that overseas expertise and knowledge be used where these are not available locally, and the Commission has developed various methods to achieve this. Overseas specialists, for example, are engaged as consultants and the Commission from time to time sends personnel and other experts overseas in order to obtain information on a particular problem area. More information in this regard appears in the individual chapters.

COMMERCIALISATION

In the future the WRC will focus increasingly on a further aspect of technology transfer, which is in progress already, viz. the commercialisation of research results by e.g. the private sector. The patenting of research results and the sale of publications and computer programs would be classified as such. In this way the WRC earns royalties, locally as well as abroad.

WATER AND WASTE-WATER MANAGEMENT IN THE PAPER AND PULP INDUSTRY



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 1990 to 31 December 1990.

The Commission derives its income from rates and charges on water usage and on scheduled irrigation land. The tariffs for the 1991 financial year were 1,30c/m^3 for water supplied for urban, industrial or domestic use, and 141c/ha of land scheduled for irrigation.

STATEMENT 1

BALANCE SHEET AS AT 31 DECEMBER 1990

1989	LIABILITIES	1990	
R		R	R
	Accumulated funds -		
	Balance at 31/12/89	30 177 429,03	
30 177 429	Plus: Income over expenditure, 1990	17 212 335,92	47 389 764,95
	Current liabilities -		
	Sundry creditors -		
298	Revenue paid in advance		86 564,17
R30 177 727			R47 476 329,12

1989	ASSETS	1990		
R		R	R	R
	*Capital assets -			
5 000	Land (Cost)		5 000,00	
	Motor vehicles	117 666,40		
117 666	Less: Depreciation	30 566,98	87 099,42	
	Office equipment	319 777,30		
285 493	Less: Depreciation	14 710,53	305 066,77	
	Office furniture	162 455,70		
152 890	Less: Depreciation	7 892,72	154 562,98	551 729,17
18 406 108	Loans			21 371 767,10
	Investments -			
	Cash investment	12 008 775,44		
	Plus: Accrued interest	464 785,72	12 473 561,16	
7 120 667	Unlisted shares		755 938,74	13 229 499,90
	Current assets -			
	Sundry debtors -			
1 713 952	Outstanding revenue		9 331 453,74	
1 927 983	Net project advances	2 315 900,62		
5 594	Subsistence and transport advances	550,05		
16 894	Motor financing	253 386,00		
600	Deposits	600,00	2 570 436,67	
150	Cash on hand		150,00	
424 730	Cash in bank		421 292,54	12 323 332,95
R30 177 727				R47 476 329,12

* Capital assets purchased by organisations by means of research grants are not included.

Pretoria, 26/4/91

(Signed) DS van der Merwe
Acting Executive Director

The accounts of the Water Research Commission have been audited in terms of Sections 5 and 18(2) of the Auditor-General Act, No. 52 of 1989, read with Section 14(1) of the Water Research Act, No. 34 of 1971, and in my opinion the annual financial statements are a fair representation of the financial position of the Commission as at 31 December 1990 and the result of its operations for the year then ended.

Pretoria, 9/12/91

(Signed) JAJ Loots
Acting Auditor-General

STATEMENT 2

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31 DECEMBER 1990

1989	EXPENDITURE	1990
R		R
3 046 402	Salaries and allowances	3 263 368,17
96 059	Subsistence	115 952,73
11 913	Motor transport	16 622,57
221 062	General transport	302 431,65
7 670	Commission members' allowances	11 526,00
17 296	Postal and telegraph services	19 401,74
58 558	Telephone services	58 695,59
72 633	Printing and stationery	64 686,93
19 914	Advertisements	16 950,07
333 207	Publications and information	374 569,47
36 508	Technology and information transfer	86 193,48
72 941	Lease and maintenance of office equipment	90 169,40
3 540	Computer software	13 678,76
17 796	Entertainment	25 180,57
492 498	Office rental	565 073,01
-	Maintenance of and alterations to offices	830,71
48 399	Electricity	52 874,36
1 695	Maintenance and lease of furniture	4 634,24
3 101	Typing and translation services	15 202,39
27 632	Insurance and licenses	25 284,90
223 259	Collection fees	286 553,90
9 751	Audit fees	34 378,49
77 868	Legal costs	85 013,12
33 160	Registrations and subscriptions	30 226,43
33 121	Miscellaneous petty expenses	18 574,76
51 917	Depreciation	54 187,29
10 675 114	Research projects and research support services	15 281 359,58*
345 695	Contracting of researchers and expertise	-
100 000	Research and other grants	9 000,00
496 688	Specialist and consultation services	479 909,54
2 562 842	Income over expenditure	17 212 335,92
R19 198 239		R38 614 865,77

1989	INCOME	1990	
R		R	R
	Rates		
243 382	Government irrigation schemes with canal systems		236 020,90
227 135	Irrigation board schemes		325 586,06
	Charges		
13 096 488	Metered water from Government schemes		29 259 122,15
4 206 140	Municipalities		6 329 255,39
12 228	Interest on rates and charges in arrears		36 748,82
	Interest on investments		
	Received	1 097 958,00	
697 327	Accrued	464 785,72	1 562 743,72
74 328	Sundry income		188 969,12
	Interest on loan		
641 211	Erf Sewe-Nul-Ses Rietfontein (Pty) Ltd		676 419,61
R19 198 239			R38 614 865,77

* Only includes expenditure for which audited statements are received

STATEMENT 3

STATEMENT OF EXPENDITURE AND ADVANCES OUTSTANDING IN RESPECT OF RESEARCH PROJECTS AND RESEARCH SUPPORT SERVICES AS AT 31 DECEMBER 1990

PROJECT	EXPENDITURE		TOTAL ADVANCES OUTSTANDING AS AT 31/12/90
	1990	TOTAL TO 31/12/90	
1. RESEARCH PROJECTS	R	R	R
Research on the inhibition of bacterial oxidation of pyrite and the concomitant acid mine drainage	5 380,00	207 569,29	-
A national industrial water and waste-water survey (NATSURV)	577 209,86	3 177 812,98	16 875,14
An investigation into rainfall recharge to ground water	-	576 804,82	1 062,69
Research on correction factors for the evaporimeter coefficients used in the irrigation scheduling of wheat	2 545,52	249 000,00	-
Research on the practical scheduling of irrigation in the Northern Transvaal	40 888,15	334 172,30	*(8 193,15)
Research on the quantification and limitation of water losses associated with centre pivot irrigation systems	5 369,69	299 508,95	4 827,93
Research into the treatment of wool scouring effluents	-	1 199 907,63	150 378,79
Research on improving irrigation management based on soil water monitoring and detailed knowledge of profile available water capacities	10 693,77	297 793,10	-
Research on the socio-economic effects of water restrictions on industries and local governments	-	98 234,63	4 223,03
The development of a computer program to simulate water flow in distribution canals	-	143 258,25	3 033,73
Research on the effects of urbanisation on catchment water balance	193 936,64	733 605,80	266 063,36
Research on drip irrigation of tomatoes	144 309,32	655 261,60	74,10
Research on epidemiological surveillance of potential changes in drinking-water quality	-	369 283.77	7 084,35
Research on the evaluation and optimisation of the process of dual digestion of sewage sludge	165 247,04	550 273,03	*(999,21)
Research on the feasibility of reverse osmosis for water reclamation on large scale	22 900,78	639 777,60	*(7 393,60)
Hydrosalinity studies in the Eastern Cape	227 834,36	979 904,16	46 105,84
Research on the evaluation of the abilities of several solute and water transport models to predict the quantity and quality of water leaving the root zone	79 045,00	317 199,17	-
Development of phosphate export models for catchments	131 800,00	199 983,30	*(34 733,30)
The development of methods to assess the impact of agricultural practices on water resources in Southern Africa	202 935,00	755 795,10	100 404,90
Research on the effects of reduced water consumption on domestic sewer systems	20 000,00	112 783,54	*(14 073,54)
Research on the development of a stochastic daily climate model for South African conditions	10 108,72	153 384,76	17 469,81
Development of water quality monitoring strategies and procedures for water quality data interpretation	96 823,85	289 442,63	11 557,37
Research on the isolation and identification of mutagens in drinking water	56 959,00	139 402,68	*(9 661,68)
Research into water consumption rates and patterns and unaccounted-for water in urban areas	33 388,00	116 999,70	0,75
Research on the development of criteria for sprinkler irrigation systems to combat surface sealing of soils	116 400,00	282 183,94	*(14 348,94)
An investigation into methods of developing operational rules for individual irrigation systems	12 078,74	478 634,46	21,26
Research on ground-water abstraction in residential areas	9 000,00	185 289,64	15 710,36
Research on the use of electromagnetic exploration techniques for the development of ground-water resources	94 634,34	204 165,85	*(49 973,28)
Research on economic evaluation of alternative irrigation scheduling strategies for wheat in the irrigated area of the Orange Free State	112 330,00	274 983,42	-
The development of fixed and dynamic membrane systems for the treatment of brackish water and effluents	638 328,00	1 751 260,11	*(265 596,11)
Research on geohydrological investigation and evaluation of the Zululand coastal aquifer	190 091,00	357 945,30	105 474,70
Research on the reconstruction of the climatic history of the last 2 000 years in the summer rainfall regions of Southern Africa	42 300,00	129 843,00	823,31
Research on precipitation and airflow in cumulus clouds	209 294,00	520 258,11	*(58,11)

STATEMENT 3

CONTINUED

PROJECT	EXPENDITURE		TOTAL ADVANCES OUTSTANDING AS AT 31/12/90
	1990	TOTAL TO 31/12/90	
	R	R	R
Research on the development of techniques for the evaluation and effective management of surface and ground-water contamination in the Orange Free State Gold Fields	363 989,81	917 712,99	-
Research on the enhancement of the national ground-water data base facilities	189 800,00	431 947,55	52,45
Research on maximising irrigation project efficiency in different soil-climate-irrigation situations	-	253 650,54	199 212,10
Research on the storage and utilisation of rain water in soil for the stabilisation of plant production in semi-arid regions	168 560,00	520 760,53	*(16 060,00)
Research on the factors affecting the water-use efficiency of irrigated crops, with special reference to the physiological responses of these crops	243 000,00	712 712,83	23 315,01
Research on the estimation and evaluation of moisture stress in crops by means of remote control aerial surveillance	77 847,28	140 179,28	31 465,72
Research on the preparation of guidelines on cost-effectiveness of rural water supply and sanitation projects	75 346,33	230 842,02	*(3 142,02)
Research on the preparation of engineering design guidelines for artificial wetlands for waste-water treatment	36 000,00	50 000,00	-
An investigation of the hydrological response to third-world settlements in peri-urban areas of Natal/KwaZulu	10 272,00	43 145,00	12 018,00
The development of a systems model for the Mgeni catchment	89 334,00	169 688,11	48 811,89
Hydrological modelling studies in the Eastern Cape	318 312,15	644 319,66	57 430,34
The development of a model to simulate flow in alluvial rivers	107 179,83	211 733,10	-
Research on the quantification of the effects of land-use runoff quality in selected catchments in Natal	79 927,34	208 346,71	27 926,29
Research on the design criteria for crossflow microfiltration	182 047,89	562 621,40	*(8 547,89)
Transfer of waste-water treatment management technology to the meat processing industry	18 096,91	18 096,91	62 761,73
Research on the filtration of compressible cakes	39 932,50	63 485,18	*(10 432,50)
The development of seeded reverse osmosis technology	200 000,00	400 000,00	-
Research on the concentration of industrial effluents with sealed-cell electrodialysis	19 500,00	115 183,58	*(13 010,50)
A comparative study of chlorine dioxide and other oxidants in potable water treatment	89 891,00	182 334,73	*(15 334,73)
Research on chemical augmentation of biological phosphate removal	-	9 393,41	54 606,59
Research on pelletisation in upflow anaerobic sludge bed (UASB) systems	105 000,00	174 284,92	14 057,78
Research on phosphate fixation in waste waters by means of controlled struvite formation	84 599,00	177 699,40	*(4 799,40)
Consolidation of activated sludge and water chemistry research	54 728,91	191 407,15	8 271,09
Research on the assessment of water quality problems due to microbial growth in drinking-water distribution systems	168 499,86	295 966,27	*(35 566,27)
Research on the effect of biocorrosion in water systems	56 266,56	127 779,84	23 020,16
Research on the effects of varying water quality on the corrosion of different pipe materials in the PWV/Klerksdorp areas	-	223 695,67	*(16 796,57)
Research on the development and testing of data logging equipment for the monitoring of water consumption patterns	-	86 120,77	12 379,23
Research on the evaluation of the design and use of irrigation systems in the Breë River with a view to the control of potential drainage losses	142 186,50	410 324,71	97 764,62
Research on the water-use efficiency of certain irrigated temperate pasture species	62 700,00	267 578,39	12 221,61
Model studies on the minimisation of dry and dry-wet cooling systems	70 988,49	155 581,32	-
Research on the effect of water quality and chemical composition on the corrosivity in mild steel pipelines	6 799,38	6 799,38	9 700,62
Research on the relationship between climate and crop factors	-	53 567,51	100 432,49
Research on soil-plant-water relations in the upper reaches of plant available soil water	109 700,00	232 003,25	*(3,25)
Research on moisture sensors to facilitate water management	138 100,00	223 098,50	*(66 629,50)
Research on the biological treatment of industrial water with the simultaneous production of single cell protein	24 000,00	24 000,00	64 500,00
Research on harvesting Hartbeespoort Dam algal scums for fine chemicals	47 784,00	72 999,27	*(47 784,00)

STATEMENT 3

CONTINUED

PROJECT	EXPENDITURE		TOTAL ADVANCES OUTSTANDING AS AT 31/12/90
	1990	TOTAL TO 31/12/90	
	R	R	R
Research on human viruses in water	75 281,52	114 117,79	52 219,21
Research on the extension of the management orientated models for eutrophication control	80 943,49	123 997,37	7 002,63
Research on the evaluation and development of geophysical techniques for characterising the extent and degree of ground-water pollution	96 075,00	302 902,00	48 649,00
Research on a preliminary survey of pesticide levels in ground water from a selected area of intensive agriculture in the Western Cape	53 104,31	85 451,39	14 087,61
Research on the evaluation of the four-electrode electrical conductivity and electromagnetic induction techniques of soil salinity measurement for use under South African conditions	39 400,00	89 587,00	2 963,00
Research on hydrological systems model development	498 130,00	648 409,00	132 291,00
A comparative study of two- and three-dimensional ground-water models	169 959,81	331 458,12	86 041,88
An investigation into the oscillation method for the determination of aquifer transmissivity	33 300,00	84 947,38	52,62
An investigation of the potential use of NOAA satellite remotely sensed data for identification of regional-scale fracture zones for ground-water supply purposes in Southern Africa	11 000,00	67 953,15	2 046,85
Technical support for the application of dynamic membrane plants for the treatment of industrial effluents	211 030,91	350 086,18	*(22 030,91)
The investigation into the evaluation of membrane technology for electroplating effluent treatment	22 000,00	83 916,11	13 083,89
Research on abattoir solid waste: Development and implementation of a treatment system	-	-	33 000,00
Research on the prediction of South African summer rainfall variability from ocean surface temperatures	109 280,73	142 869,98	23 820,02
Research on relationships between lightning and precipitation	81 000,00	150 941,00	59,00
The evaluation of full-scale flotation-filtration and chlorine dioxide plants	71 029,00	71 029,00	*(43 529,00)
Research on the effect of water quality on the effectiveness of chlorine dioxide in drinking-water treatment	30 807,70	30 807,70	2 992,30
The development of a combination of sedimentation, flotation and sand filtration processes for water treatment (SEDIDAFF)	21 238,70	22 204,40	7 795,60
Research on low-cost ultrafiltration systems	60 000,00	60 000,00	-
Research on the interaction between the atmospheric boundary layer and the natural draught cooling towers at Kendal Power Station	59 803,00	126 000,00	-
Research on and evaluation of various factors affecting dry-wet cooling	234 130,00	535 299,24	38 418,76
Research on development and evaluation of specific control methods for ameliorating low F/M bulking	109 200,00	141 626,29	96 743,71
Research on phosphate removal by means of electrochemically formed iron ions	13 709,85	34 560,95	14 439,05
Determination of the socio-economic and financial implications of the water restrictions in force from 1983 up to its annulment in 1987	54 076,96	80 007,87	4 492,13
Research on the management of phosphate concentrations and algae in Hartbeespoort Dam	88 545,02	143 682,07	4 479,93
Research on flood and furrow irrigation: A critical evaluation of design procedures and the computerisation of the most suitable approaches	68 603,59	68 758,59	15 396,41
A regional investigation into ground-water quality deterioration in the Olifants River catchment above the Loskop Dam, with specialised investigations in the Witbank Dam subcatchment	-	-	443 000,00
Research on the freshwater requirements of estuarine plants	55 551,22	55 551,22	14 448,78
Research on the relationship between low flows and the river fauna in the Letaba River	146 597,33	146 597,33	12 402,67
Research on a pre-impoundment study of the Sabie-Sand River system, Eastern Transvaal, with special reference to predicted impacts on the Kruger National Park	202 938,82	202 938,82	*(5 503,82)
Research on assessment of the instream flow requirements of rivers	123 926,71	123 926,71	*(1 635,74)
Research on the quantitative structuring of national water planning objectives for use in decision support systems in South Africa	54 636,88	54 636,88	58 820,70

STATEMENT 3

CONTINUED

PROJECT	EXPENDITURE		TOTAL ADVANCES OUTSTANDING AS AT 31/12/90
	1990	TOTAL TO 31/12/90	
	R	R	R
Research on the preparation of a review document on sediment transport in Southern Africa including revision of the sediment production map of Southern Africa	-	-	49 763,87
Research on the surface water resources of South Africa 1990	300 000,00	300 000,00	11 890,39
Research on the adaptation and calibration of an urban runoff quality model	70 850,40	70 850,40	*(1 350,40)
Research on the utilisation of geographical information systems (GIS) and integrated environmental management (IEM) in the planning and management of water resources within river catchments	180 000,00	180 000,00	-
An investigation into the quality of water for animal production	74 179,59	74 179,59	820,41
Research on the erodibility of different rock formations under varying flow conditions	56 153,59	56 153,59	33 846,41
Research on the use of saline water for irrigation purposes and an assessment of salt tolerance criteria of crops	157 755,59	157 755,59	46 344,41
Research on the applicability of hydrodynamic reservoir models for water quality management in stratified water bodies in South Africa	81 831,00	81 831,00	*(4 894,85)
Research on interpolation and mapping of daily rainfall model parameters for South Africa	18 232,28	18 232,28	32 767,72
Research on techniques for seasonal and long-term rainfall forecasting in South Africa	58 000,00	58 000,00	45 000,00
Research on the influence of different water-nitrogen regimes on crop canopy development, water flow resistance and crop yield, with a view to improvement of irrigation models	109 471,42	109 471,42	10 636,72
Research into the recovery of water and chemicals from ion exchange regeneration effluents	52 000,00	52 000,00	*(14 500,00)
Research on phase diagrams of complex precipitants	47 060,92	47 060,92	*(28 560,92)
Research on the integration of remote sensing, digital image processing and geographical information systems technologies for regional scale ground-water resources assessment in South Africa	37 283,03	37 283,03	*(12 974,57)
Research on the development and evaluation of geohydrological and isotope hydrological methodologies for the identification of areas potentially suitable for waste disposal	-	-	50 000,00
Research on the occurrence and accumulation of selected heavy metals in freshwater ecosystems affected by mine and industrial polluted effluent	15 241,77	15 241,77	6 008,23
Research on the concentration ratios of selected radionuclides in aquatic ecosystems affected by mine drainage effluents	6 476,62	6 476,62	3 523,38
Research on biological phosphate removal mechanisms in the activated sludge process	51 000,00	51 000,00	-
Research on the utilisation of the fungus *Geotrichum* in waste water	24 216,60	24 216,60	45 783,40
Research on aspects of sewage sludge treatment and disposal	-	-	17 000,00
Research on urban catchment monitoring	82 008,34	82 008,34	23 991,66
Research on the optimisation of biofouling control programmes	89 500,00	89 500,00	-
Research on monitoring the effect of catchment development of urban runoff and water balance	-	-	-
Research on taste- and odour-forming micro-organisms occurring in South African surface waters	60 463,95	60 463,95	4 036,05
Research on bacteriophages as water quality indicators	64 924,48	64 924,48	675,52
Research on a hydrological investigation of stormwater runoff from the Khayelitsha urban catchment in the False Bay area, Southern Cape	156 924,70	156 924,70	75,30
Research on pollution loads, dispersion and effects of urban runoff from the Motherwell township into the Swartkops River, Eastern Cape	57 005,54	57 005,54	9 644,46
Research on modelling of tubular reverse osmosis systems	137 414,32	137 414,32	*(414,32)
Research on assessment of the feasibility and impact of alternative water pollution control options on TDS concentrations in the Vaal Barrage and Middle Vaal	300 000,00	300 00,00	13 883,80
Evaluation of the active sewage pasteurisation (ASP) process for sewage sludge treatment	-	-	-
Full-scale study of chemical sludge bulking control	3 920,68	3 920,68	35 079,32

STATEMENT 3

CONTINUED

PROJECT	EXPENDITURE		TOTAL ADVANCES OUTSTANDING AS AT 31/12/90
	1990	TOTAL TO 31/12/90	
	R	R	R
Research on removal of orthophosphate from water by the direct use of scrap iron	20 000,00	20 000,00	-
Research on improved oxygen transfer for high biosludge concentrations	-	-	-
The development of guidelines for the design and application of dissolved air flotation/filtration processes	37 500,00	37 500,00	-
Research on the removal of suspended solids from pulp and paper effluents by employing a combined sedimentation, flotation and sand filtration process	10 200,00	10 200,00	-
Research on the liquid consumption patterns among the black population of Cape Town	11 000,00	11 000,00	*(5 500,00)
Studies on hot air recirculation in draught air cooling systems	159 951,94	159 951,94	48,06
Research on the improvement of present polyethersulphone ultrafiltration membrane technology	39 000,00	39 000,00	*(7 800,00)
Research on removal of algae from water by ultrafiltration	35 000,00	35 000,00	*(7 000,00
Research on the application of the anaerobic digestion ultrafiltration (ADUF) process to brewery effluents	65 000,00	65 000,00	*(13 000,00)
The compilation of a comprehensive guide for ground-water sampling in South Africa	46 500,00	46 500,00	*(500,00)
Research on the water rights of nature conservation	60 000,00	60 000,00	*(8 000,00)
Research on forced aeration composting of sewage sludge for rural communities	20 000,00	20 000,00	*(4 000,00)
Research on improvement in water usage control and waste-water treatment in the sorghum beer industry	23 040,76	23 040,76	21 759,24
Research on the development of an effective and environmentally safe larviciding programme for the control of the blackfly, *Simulium chutteri*, along the Orange River	781,60	781,60	-
An investigation into the contribution of ground water to the salt load of the Breede River using natural and chemical tracers	49 500,00	49 500,00	44 000,00
Pilot-scale desalination of sea water by means of reverse osmosis	40 000,00	40 000,00	*(40 000,00)
TOTAL	12 616 910,19	32 774 435,16	2 382 132,16
2. RESEARCH SUPPORT SERVICES			
South African Water Information Centre	637 000,00	2 419 501,01	-
The establishment of a National Hydrological Information System	1 767 696,39	5 520 705,16	-
The establishment of a Computing Centre for Water Research	259 753,00	1 194 824,51	*(66 231,54)
TOTAL	2 664 449,39	9 135 030,68	*(66 231,54)
GRAND TOTAL	15 281 359,58	41 909 465,84	2 315 900,62

* Excess expenditure over advances for projects

STATEMENT 4

BUDGET 1992

	R	R
ESTIMATED INCOME		
Rates and charges in terms of Section 11 of the Water Research Act		38 800 000
Loan		-
Interest on investment		1 820 000
Erf Sewe-Nul-Ses Rietfontein (Pty) Ltd		650 000
Sundry income		-
		41 270 000
Appropriation from accumulated funds		4 298 378
TOTAL ESTIMATED INCOME		R45 568 378
ESTIMATED EXPENDITURE		
Administrative expenses:		
Salaries and allowances	4 140 000	
Subsistence and travelling expenses	698 500	
Postal, telegraph and telephone	110 500	
Printing, stationery, advertisements and publications	867 000	
General expenditure	2 188 000	8 004 000
Research expenses:		
Research projects:		
Hydrosalinity studies in the Eastern Cape	198 000	
The development of methods to assess the impact of agricultural practices on water resources in Southern Africa	196 500	
Research on geohydrological investigation and evaluation of the Zululand coastal aquifer	195 580	
Research on the reconstruction of the climatic history of the last 2 000 years in the summer rainfall regions of Southern Africa	30 050	
Research on maximising irrigation project efficiency in different soil-climate-irrigation situations	238 500	
Research on the storage and utilisation of rain water in soil for the stabilisation of plant production in semi-arid regions	297 400	
Research on the factors affecting the water-use efficiency of irrigated crops, with special reference to the physiological responses of these crops	326 998	
Research on the estimation and evaporation of moisture stress in crops by means of remote control aerial surveillance	80 397	
Hydrological modelling studies in the Eastern Cape	388 500	
Research on the design criteria for crossflow microfiltration	500 000	
Research on the effects of varying water quality on the corrosion of different pipe materials in the PWV/Klerksdorp areas	4 800	
Research on water-use efficiency of certain irrigated temperate pasture species	82 900	
Research on the effect of water quality and chemical composition on the corrosivity in mild steel pipelines	36 000	
Research on the relationship between climate and crop factors	63 134	
Research on soil-plant-water relations in the upper reaches of plant available soil water	120 500	
Research on the evaluation of the four-electrode electrical conductivity and electromagnetic induction techniques of soil salinity measurement for use under South African conditions	72 100	
Research on hydrological systems model development	550 000	
Technical support for the application of dynamic membrane plants for the treatment of industrial effluents	26 000	
Research on the prediction of South African summer rainfall variability from ocean surface temperatures	80 000	
Research on relationships between lightning and precipitation	55 000	
Research on development and evaluation of specific control methods for ameliorating low F/M bulking	70 000	
Research on flood and furrow irrigation: A critical evaluation of design procedures and the computerising of the most suitable procedures	115 000	
A regional investigation into ground-water quality deterioration in the Olifants River catchment above the Loskop Dam, with specialised investigations in the Witbank Dam subcatchment	530 000	
Research on the freshwater requirements of estuarine plants	88 600	
Research on the relationship between low flows and the river fauna in the Letaba River	20 000	
Research on a pre-impoundment study of the Sabie-Sand River system, Eastern Transvaal, with special reference to predicted impacts on the Kruger National Park	191 735	
Research on assessment of the instream flow requirements of rivers	163 506	
Research on the quantitative structuring of national water planning objectives for use in decision support systems in South Africa	131 600	
Research on the surface water resources of South Africa 1990	730 000	
Research on the adaptation and calibration of an urban runoff quality model	181 600	
Research on the utilisation of geographical information systems (GIS) and integrated environmental management (IEM) in the planning and management of water resources within river catchments	200 000	

STATEMENT 4

CONTINUED

	R	R
An investigation into the quality of water for animal production	124 000	
Research on the erodibility of different rock formations under varying flow conditions	70 000	
Research on the use of saline water for irrigation purposes and an assessment of salt tolerance criteria of crops	357 200	
Research on the applicability of hydrodynamic reservoir models for water quality management in stratified water bodies in South Africa	47 000	
Research on interpolation and mapping of daily model parameters for South Africa	111 000	
Research on techniques for seasonal and long-term rainfall forecasting in South Africa	98 700	
Research on the influence of different water-nitrogen regimes on crop canopy development, water flow resistance and crop yield, with a view to improvement of irrigation models	150 000	
Research into the recovery of water and chemicals from ion-exchange regeneration effluents	116 500	
Research on phase diagrams of complex precipitants	66 500	
Research on the development and evaluation of geohydrological and isotope hydrological methodologies for the identification of areas potentially suitable for waste disposal	130 000	
Research on the occurrence and accumulation of selected heavy metals in freshwater ecosystems affected by mine and industrial effluents	71 300	
Research on the concentration rates of selected radionuclides in aquatic ecosystems affected by mine drainage effluents	43 100	
Research on biological phosphate removal mechanisms in the activated sludge process	51 000	
Research on the utilisation of the fungus *Geotrichum* in waste water	70 000	
Research on aspects of sewage sludge treatment and disposal	16 000	
Research on urban catchment monitoring	10 000	
Research on the optimisation of biofouling control programmes	117 090	
Research on monitoring the effect of catchment development on urban runoff and water balance	310 000	
Research on taste- and odour-forming micro-organisms occurring in South African surface waters	100 000	
Research on bacteriophages as water-quality indicators	73 700	
A study on a mine-water treatment and monitoring plant: The Aquarius Plant	81 100	
Research on hydrological investigation of stormwater runoff from the Khayelitsha urban catchment in the False Bay area, South-western Cape	115 000	
Research on pollution loads, dispersion and effects of urban runoff from the Motherwell township into the Swartkops River, Eastern Cape	NIL	
Research on modelling of tubular reverse osmosis systems	203 500	
Full-scale study of chemical sludge bulking control	13 000	
Research on the development of an effective and environmentally safe larviciding programme for the control of the black fly, *Simulium chutteri*, along the Orange River	115 200	
A study of the relationship between hydrological processes and water quality characteristics in the developing Zululand coastal region	168 100	
A global farm approach to enhancing the economic efficiency of water and energy use for irrigation in the central RSA	173 300	
Root development and water usage of commercial timber species	148 000	
Evaporation measurements above vegetated surfaces using micrometeorological techniques	139 600	
The effect of pollution on the physiology of fishes in the Olifants River (E.Tvl.)	74 000	
The effect of water quality variables on riverine biotas	152 800	
Development of a method for the selection of suitable landfill sites, and of guidelines for sanitary landfill in municipal areas	79 500	
Preparation of a manual on quantitative estimation of ground-water recharge and aquifer storativity	35 200	
Research on the evaluation and development of deep-bed filtration for the treatment of South African surface waters	71 000	
Research on the neutralisation of water containing high concentrations of sulphuric acid with calcium carbonate	125 000	
The consolidation of activated sludge research	190 000	
Research on the microbiological transformations of metal contaminated effluents	104 100	
The development of guidelines for toxicity bio-assaying of drinking and environmental waters in South Africa	140 000	
An investigation into phytoplankton blooms in the Vaal River and the environmental variables responsible for their development and decline	102 000	
Research on the mutagenicity of drinking water produced with conventional treatment methods of surface water sources	75 000	
Research on the development of tolerant membranes	188 000	
Research on industrial application of membranes	139 000	
The development and evaluation of small-scale potable water treatment equipment	184 000	
Research on field dilution studies on large off-shore pipelines	8 200	
Research on the evaluation and improvement of the anaerobic digestion/ultrafiltration (ADUF) effluent treatment process	117 500	
Research on full-scale pilot plant studies on phosphate crystallisation in biological systems	129 895	
The development of a consolidated computer software package for the management of an irrigation scheme	25 000	
A preliminary investigation of the nitrate content of ground water and limitation of the nitrate input	10 000	

STATEMENT 4

CONTINUED

	R	R
An assessment of health aspects of the impact of domestic and industrial waste disposal activities on ground-water resources	25 993	
Assessing the impacts of varying rainfall conditions on vegetation dynamics, production and certain hydrological properties of natural grassland, using a system modelling approach	145 500	
The Southern Agulhas current and its influence on the weather and climate of Southern Africa	184 000	
The development of a distributed hydrological modelling system to assist with water quantity and quality management in the Mgeni catchment, Phase II	503 400	
The geomorphological response to changing flow regimes of the Sabie and Letaba River systems	219 000	
The use of geographic information systems and other computer-aided drafting facilities for the production of geohydrological maps	363 000	
The development of techniques for risk analysis and ground-water management of Southern African aquifers	362 000	
Decision-making procedures for determination of crop water requirements	96 000	
Techniques for microbial aspects of water quality investigation of South African rivers	351 700	
The corrosion performance of various non-metallic piping materials and coatings in potable water	223 500	
The evaluation of the interdependent factors which determine the viability of irrigation farming	60 000	
A holistic approach to affordable planning and maintenance of water and sewer systems	40 500	
A water resources and sanitation systems source book with special reference to Natal/KwaZulu	150 600	
Technical, socio-economic and environmental evaluation of sanitation systems for developing urban areas in South Africa	97 200	
Research on development of a crossflow microfilter for rural water supply	260 000	
Research on the development and production of membrane systems	487 000	
Evaluation of various methods for the forming of free radicals for the oxidation of molecules in industrial effluents and potable water	215 000	
Scheduling irrigation of tuber crops with specific reference to potatoes	125 700	
Co-disposal of sewage sludge and refuse	25 000	
The use of algae to bio-assay for toxic substances in water	27 500	
The degradation of mortar linings and concrete by micro-organisms in industrial water systems	50 000	
Establishing revised water quality criteria for the South African coastal zone	31 600	
Research on the modelling of flow through porous membranes	38 000	
The preparation of a manual for waste load allocation in South Africa	593 700	
A situation analysis of water quality in the Buffalo River, Eastern Cape, with special emphasis on the impact of low-cost, high-density urban development on water quality	255 900	
A structural analysis of the water apportionment mechanisms in the Water Act No. 54/1956, in view of the requirements of competing user sectors	149 500	
Marine pollution: Pathogenic micro-organisms	60 000	
Contribution to the estuaries research programme	50 000	
The use of vegetation in the amelioration of the impacts of mining on water quality - An assessment of species and water use	218 500	
Soil buffering of rain-water salinity in the Vaal Dam catchment	74 600	
The application of resource economics to water management decision-making in South Africa	253 000	
The application and performance of full-scale artificial wetlands for waste-water treatment in South Africa	66 500	
Expected projects	11 580 800	
	25 589 178	
Research and other grants	60 000	
Specialist and consultation services	920 000	
Loan (Company for Research on Atmospheric Water Supply)	3 881 000	
Research support services	4 114 200	37 564 378
TOTAL ESTIMATED EXPENDITURE		R45 568 378

STATEMENT 5

STATEMENT OF RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 31 DECEMBER 1991

RECEIPTS	1991	
	R	R
Balance on 1 January 1991 -		
Investment at Corporation for Public Deposits	10 812 686,49	
Cash on hand	150,00	
Cash in bank	421 292,54	**11 234 129,03**
Rates -		
Government irrigation schemes with canal systems		**294 771,46**
Irrigation Board Schemes		**311 832,38**
Charges -		
Metered water from Government schemes		**26 059 316,26**
Municipalities		**6 010 310,30**
Interest on rates and charges in arrears		**14 973,56**
Interest on investments		**2 122 588,94**
Sundry income		**173 543,96**
Subsistence and transport advances recovered		**148 842,42**
		R46 370 308,31

PAYMENTS	1991	
	R	R
Salaries and allowances		**3 756 038,19**
Motor transport		**17 842,72**
Subsistence		**220 494,72**
Subsistence and transport advances		**123 594,48**
Own transport: Purchases		**2 825,00**
General transport		**271 151,78**
Commission members' allowances		**15 031,00**
Postal and telegraph services		**21 900,05**
Telephone services		**72 249,81**
Printing and stationery		**62 178,95**
Advertisements		**6 448,18**
Publications and information		**463 191,34**
Technology and information transfer		**176 065,23**
Office equipment: Purchases		**150 994,62**
Office equipment: Computer software		**65 586,64**
Lease and maintenance of office equipment		**87 771,98**
Entertainment		**28 499,51**
Office rental		**653 662,48**
Electricity		**46 135,01**
Office furniture: Purchases		**2 612,24**
Maintenance and lease of furniture		**70,55**
Typing, translation and services rendered		**8 577,88**
Insurance and licenses		**28 175,68**
Collection fees		**315 517,86**
Audit fees		**36 383,10**
Legal costs		**102 925,14**
Registrations and subscriptions		**49 428,82**
Miscellaneous petty expenses		**29 624,89**
Project advances		**18 119 970,00**
Research projects		**6 062,59**
Research and other grants		**7 095,27**
Specialist and consultation services		**593 493,65**
Loans		**2 260 015,57**
Research support services		**498 856,35**
Balance as at 31 December 1991 -		
Investment at Corporation for Public Deposits	17 591 364,38	
Cash on hand	150,00	
Cash in bank	478 322,65	**18 069 837,03**
		R46 370 308,31

WATER RESEARCH COMMISSION Pretoria, 26 February 1992

(Signed) PE ODENDAAL **EXECUTIVE DIRECTOR**

ANNEXURE

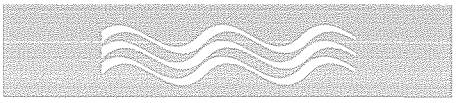
PUBLICATIONS EMANATING FROM RESEARCH FINANCED WHOLLY OR PARTIALLY BY THE COMMISSION

This **Appendix** contains a list of publications released in 1991.
Requests for publications should be directed, as far as possible, to the authors.

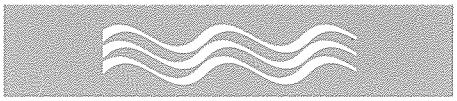
PUBLICATIONS FOR 1991

ARTICLES AND PAPERS

- Adam, BF and Loftus, E (1991) Microphysical measurements at cloud base. Paper presented at the 8th Annu. Conf. of the S. Afr. Soc. for Atmos. Sci., Pretoria. 23-24 October.
- Adams, JB (1991) Estuarine macrophytes. Paper presented at the Annu. Inst. for Coastal Res. Symp., Univ. of Port Elizabeth. March.
- Adams, JB and Bate, GC (1991) The distribution of macrophytes in relation to salinity and elevation. Poster presentation at the Mar., Estuarine and Freshwater Ecosyst. Conf., Rhodes Univ. July.
- Adams, JB, Knoop, WT and Bate, GC (1991) The distribution of estuarine macrophytes in relation to freshwater in four Eastern Cape estuaries. Paper presented at the 17th Annu. Congr. of the S. Afr. Assoc. of Bot., Univ. of Natal. January.
- Auguostinos, MT (1991) Health aspects of potable water. Paper presented at Corrosion Semin. : Water and Gas Dep., City of Johannesburg, Johannesburg Civic Centre. 27 November.
- Auguostinos, MT, Kfir, R and Venter, SN (1991) Assessment of water quality due to microbial growth in drinking water distribution systems. Paper presented at the Pretpath Conf., 31st Annu. Congr. of the Fed. of S.Afr. Soc. of Pathol., Warmbaths Overvaal. 30 June-3 July.
- Bellstedt, MO and Kröger, DG (1991) Flooding at the inlet of an air-cooled condenser tube operating in the upflow mode. Paper presented at Natl. Symp. on Heat Transfer and Thermal Techn., S. Afr. Inst. of Mech. Eng., Univ. of Pretoria. January.
- Bennie, ATP (1991) Effek van grondbewerkingspraktyke op sekere grondeienskappe en oesopbrengs. Referaat gelewer tydens die Interdissiplinêre Seminaar oor Minimum-bewerking en Grondgedraagde Siektes, Navorsingsinstituut vir Plantbeskerming, Stellenbosch.
- Bennie, ATP (1991) Growth and mechanical impedance. In : Waisel, Y, Eshel, A and Kafkafi, U (eds.) *Plant Roots, the Hidden Half.* Marcel Dekker, New York. 393-414.
- Booysen, J and Bosch, OJH (1991) An integrated computer system for assessment and optimisation of condition and grazing capacity of Southern African rangeland. Paper presented at the 4th Int. Rangeland Congr., Montpellier, France. 22-26 April.
- Booysen, J and Bosch, OJH (1991) ISPD - an integrated system for plant dynamics. Paper presented at the Int. Conf. on Decision Support Systems for Nat. Resour. Manage., College Station, Texas. 15-18 April.
- Booysen, J and Bosch, OJH (1991) Monitor - a statistically justified point sampling apparatus for use in veld condition assessment. Paper presented at the Int. Conf. of the Grassland Soc. of South. Afr., Pretoria. 6-10 May.
- Bosch, M and Cloete, TE (1991) Protein profile analysis of *Acinetobacter* strains exhibiting variations in phosphate accumulation. Paper presented at 2nd Bienn. WISA Conf., Kempton Park. 13-16 May.
- Bosch, OJH and Booysen, J (1991) Rangeland condition and grazing capacity assessment as a basis for management decisions on farm level. Paper presented at the 4th Int. Rangeland Congr., Montpellier, France. 22-26 April.
- Bosch, OJH and Gauch, HG (1991) The use of degradation gradient for the assessment and interpretation of range condition index. Paper presented at the Int. Conf. of the Grassland Soc. of South. Afr., Pretoria. 6-10 May.
- Botes, JHF en Oosthuizen, LK (1991) 'n Ekonomiese winsgewendheidsontleding van alternatiewe besproeiingskedu-leringstrategieë vir koring in die Suid-Vrystaat substreek. Referaat gelewer tydens Suider-Afrikaanse Besproeiing-simposium, Durban. 4-6 Junie.
- Botes, JHF en Oosthuizen, LK (1991) 'n Vergelyking van die winsgewendheid van 'n minder-as-volle-besproeiingskedu-leringstrategie met die vier tipiese besproeiingskedulering-strategieë in die Suid-Vrystaat substreek. Referaat gelewer tydens Suider-Afrikaanse Besproeiingsimposium, Durban. 4-6 Junie.
- Brouckaert, CJ (1991) Simulation of tubular reverse osmosis. Paper presented at 6th Natl. Meet. of the S.Afr. Inst. of Chem. Eng., Elangeni Hotel, Durban. 7-9 August.
- Buckley, CA (1991) Environmental ethics and water. Paper presented at 2nd Bienn. WISA Conf./Exhib., World Trade Centre, Kempton Park. 13-16 May.
- Buckley, CA, Brouckaert, CJ and Kerr, CA (1991) RO application in brackish water desalination and in the treatment of industrial effluents. In : Amjad, Z(ed.) *Reverse Osmosis : Membrane Technology, Water Chemistry and Industrial Application.* Van Norstrand Reinhold Publishing Company, New York.
- Bux, F, Ishwarlall, AD and Kasan, HC (1991) Identification of filamentous bacteria in activated sludge plants in Natal. Paper presented at the Annu. Symp. of the Natal Branch of the S. Afr. Soc. for Microbiol., Pietermaritzburg. October.
- Bux, F, Ishwarlall, AD and Kasan, HC (1991) Survey of filamentous bacteria in activated sludge plants in Natal. Paper presented at the Annu. Congr. of the Electron Microsc. Soc. of S. Afr., Cape Town. December.
- Buys, J, Messerschmidt, HJ and Botha, JF (1991) Including known discontinuities directly into a triangular irregular mesh for automatic contouring purposes. *Comput. and Geosci.* **17** (7).
- Calvert, B and Jacobs, ED (1991) Poly (ether sulphone) UF membranes : A study of cleaning techniques. Poster presentation at Mini-symp., Membrane Technol. Div. (WISA), Johannesburg. 22-23 October.
- Chetty, S (1991) Evaluation of hydrogen peroxide and ultraviolet radiation to oxidise organic molecules in industrial effluents and potable water. Paper presented at 2nd Bienn. WISA Conf./Exhib., World Trade Centre, Kempton Park. 13-16 May.
- Clayton, JA, Ekama, GA, Wentzel, MC and Marais, GvR (1991) Denitrification kinetics in biological nitrogen and phosphorus removal systems treating municipal wastewaters. *Water Sci. Tech.* **23**(4/6-2) 1025-1035.
- Cloete, TE, Mienie, NJJ and Steyn, PL (1991) A cell immobilisation technique for studying pure cultures in wastewater treatment plants. Paper presented at 2nd Bienn. WISA Conf., Kempton Park. 13-15 May.
- Coetsee, VdA and Meyer, R (1991) Hydraulic aquifer characteristics from resistivity sounding parameters using empirical formulae - Part one. Extended Abstract, 6th Bienn. Ground Water Conf., Johannesburg.
- Cogho, VE and Hodgson, FDI (1991) Assessment of groundwater pollution in the Orange Free State Goldfields. Paper presented at WISA Mine Water Techn. Div. Open Day, November.
- Cogho, VE, Van Niekerk, LJ and Pretorius, HPJ (1991) Groundwater quality management options for the Orange Free State Goldfields. Paper presented at Bienn. Groundwater Conv., August.
- Conradie, TA and Kröger, DG (1991) Enhanced performance of a dry- cooled power plant through air precooling. Paper presented at the Int. Power Generation Conf., San Diego, California. October.
- Coyle, AJ, Kelbe, BE, Reed, DW and Stewart, EJ (1991) A temporal look at hydrological extremes. Paper presented at 3rd Natl. Hydrol. Symp., Southhampton.
- Cronje, C, Taylor, MB and Grabow, WOK (1991) Determination of detection levels of seven commercial diagnostic rotavirus kits. Poster presentation at 31st Annu. Congr. of the Fed. of S. Afr. Soc. of Pathol., Warmbaths Overvaal. 1-3 July.
- Dent, MC (1991) Spatial estimation of rainfall in Southern Africa. Paper presented at 5th Natl. Hydrol. Symp., SANCIAHS, Stellenbosch.
- Dent, MC (1991) The role of geographic information systems in assessing irrigation water requirements in developing regions of Southern Africa. Paper presented at South. Afr. Irrig. Symp., Durban. 4-6 June.
- Dent, MC, Lynch, SD and Schulze, RE (1991) Mapping long-term rainfall using SAS and other procedures. Paper presented at 9th Annu. Conf. SAS Users Group, SUGISA 9.
- Dent, MC and Smithers, JC (1991) Quantification of high intensity rainfall : An important input to environmental impact assessment. *Agric. Eng. in S. Afr.* **23** 60-66.
- Du Plessis, HM (1991) Researching and applying measures to conserve natural irrigation resources. Paper presented at the South. Afr. Irrig. Symp., Durban. 4-6 June.
- Du Plessis, HM and Reynders, AG (1991) The potential impact of mining on chemical water quality. *Proc. of the Mine Safety and Health Congr.*, Johannesburg. 31 October-1 November. 570-583.
- Du Plessis, HM and Van Veelen, M (1991) Water quality : Salinisation and eutrophication time series and trends in South Africa. *S.Afr. J. Sci.* **87** 11-16.
- Du Preez, CC and Bennie, ATP (1991) Concentration, accumulation and uptake rate of macronutrients by winter wheat under irrigation. *S. Afr. J. Plant Soil* **8** 31-37.



- Du Toit, CG and Kröger, DG (1991) Numerical modelling of recirculation in mechanical-draught heat exchangers. Paper presented at ICHMT Int. Numerical Heat Transfer Conf. and Software Show, Guildford, England. July.
- Easton, J and Versfeld, D (1991) The use of vegetation to retard leachment movement in waste sites. Poster presentation at the Waste Manage. Symp., Johannesburg. 22-24 October.
- Elphinstone, CD, Coetsee, VdA and Watson, A (1991) Geostatistical techniques applied to geophysical data. Extended Abstract, SAGA 2nd Techn. Meeting, Johannesburg.
- February, EC (1991) Climatic reconstruction using wood charcoal from archaeological sites. Paper presented at the 10th Bienn. Conf. of the S.Afr. Soc. for Quaternary Res., Port Elizabeth. 1-4 July.
- Fischer, HH (1991) Scheduling of deficit irrigation for improved water-use efficiency. Poster presentation at the South. Afr. Irrig. Symp., Durban. 4-6 June.
- Fischer, HH en Nel, PC (1991) Die invloed van waterstremming op blaargroei by marktamaties (*Lycopersicon esculentum* Mill cv. Flora Dade). Referaat gelewer by die 20e Kongr. van die S.-Afr. Ver. vir Gewasprod., Stellenbosch. 29-31 Januarie.
- Fouché, PS and Booysen, NW (1991) Remotely piloted aircraft for low altitude aerial surveillance in agriculture. *Appl. Plant Sci.* 5 53-59.
- Gabb, DMD, Still, DA, Ekama, GA, Jenkins, D and Marais, GvR (1991) The selector effect on filamentous bulking in long sludge age activated sludge systems. *Water Sci. and Technol.* 23(4/6-2) 867-877.
- Gerber, S, Van Reenen, AJ and Sanderson, RD (1991) Dynamically formed hydrous zirconium (IV) oxide-polyelectrolyte membranes. X. Crosslinked poly(acrylic acid-co-hydroxyethyl acrylate) and poly(acrylic acid-co-hydroxyethyl methacrylate) membranes. *Water SA* 17 (3) 203-210.
- Gomes, AM and Held, G (1991) The first case study of a thunderstorm in South Africa based on dual Doppler radar observations. Paper presented at the 8th Annu. Conf. of the S. Afr. Soc. for Atmos. Sci., Pretoria. 23-24 October.
- Grabow, WOK (1991) Human viruses in water. Paper presented at Monthly WISA Meeting, Johannesburg. 17 October.
- Grabow, WOK (1991) New trends in infections associated with swimming pools. *Water Res.* 17 173-177.
- Grabow, WOK (1991) Omgewingsbesoedeling en die verspreiding van siektes. Interne Simp. oor Omgewingsnavorsing, -bewaring en -bestuur aan die Univ. van Pretoria. 31 Oktober.
- Grabow, WOK (1991) Virological dangers of sewage effluents. Paper presented at Public Health Semin., South. Cape Public Health Advisory Board, Civic Centre, George. 19 June.
- Grabow, WOK, De Villiers, JC and Prinsloo, N (1991) An assessment of methods for the microbiological analysis of shellfish. *Water Sci. and Technol.* 24 413-416.
- Grabow, WOK, Kfir, R and Slabbert, JL (1991) Microbiological methods for safety testing of drinking water directly reclaimed from wastewater. *Water Sci. and Technol.* 24 1-4.
- Grabow, WOK, Morris, P and Botzenhart, K (eds.) (1991) Proc. of the 1990 Int. IAWPRC Symp. on Health-related Water Microbiol., Tübingen, West Germany. 1-6 April. *Water Sci. and Technol.* 24/2 1-433.
- Greeff, H and Jacobs, EP (1991) Poly (ether sulphone) and polysulphone UF membranes : Differences in membrane morphology. Poster presentation at Mini-symp., Membrane Technol. Div. (WISA), Johannesburg. 22-23 October.
- Green, GC (1991) Irrigation research and development for field crops. Paper presented at the South. Afr. Irrig. Symp., Durban. 4-6 June.
- Harris, J (1991) National river water quality assessment in the Republic of South Africa. Paper presented at the 27th Annu. Am. Water Resour. Ass. Conf., New Orleans, Louisiana, USA. 8-13 November.
- Haywood, RW and Schulze, RE (1991) Comparison of hydrological model performances on small sugarcane catchments. *Agric. Eng. in S. Afr.* 23 181-191.
- Held, G and Swanepoel, DJ de V (1991) Cloud merger mechanisms observed on the Southern African Highveld by single-Doppler radar. Paper presented at the 8th Annu. Conf. of the S. Afr. Soc. for Atmos. Sci., Pretoria. 23-24 October.
- Herald JR (1991) GIS : A tool for hydrological modellers. *Proc. of 5th S. Afr. Natl. Hydrol. Symp.*, Stellenbosch.
- Herald JR (1991) The need for a standard hydrological data processing system within South Africa. Paper presented at Workshop on Time Series Data Management within Models, Computing Centre for Water Research, Pietermaritzburg.
- Herald, JR (1991) The hydrosalinity of a small stream within an area of irrigated citrus orcharding. Paper presented at the XVI Gen. Assem. of the Eur. Geophys. Soc., Wiesbaden, Germany. 22-26 April.
- Herald JR (1991) Using stable isotopes to determine the irrigation return flow component of a small stream within an area of irrigated citrus orcharding. *Proc. of 5th S. Afr. Hydrol. Symp.*, Stellenbosch.
- Hilmer, T (1991) Estuarine phytoplankton. Paper presented at the Annu. Inst. for Coastal Res. Symp., Univ. of Port Elizabeth. March.
- Hilmer, T and Adams, JB (1991) Macrophyte response to extremes in freshwater input in two small East Cape estuaries. Poster presentation at the Mar., Estuarine and Freshwater Ecosys. Conf., Rhodes Univ. July.
- Hilmer, T and Bate, GC (1991) Covariance analysis of chlorophyll distribution in the Sundays River estuary, eastern Cape. *South. Afr. J. of Aquat. Sci.* 16 37-59.
- Hilmer, T and Bate, GC (1991) Flagellate blooms in East Cape estuaries : 1. Sundays River. Poster presentation at the Mar., Estuarine and Freshwater Ecosys. Conf., Rhodes Univ. July.
- Hilmer, T and Bate, GC (1991) Flagellate blooms in East Cape estuaries : 2. Gamtoos. Poster presentation at the Mar., Estuarine and Freshwater Ecosys. Conf., Rhodes Univ. July.
- Hilmer, T and Bate, GC (1991) Flagellate blooms in East Cape estuaries : 3. Some conclusions. Poster presentation at the Mar., Estuarine and Freshwater Ecosys. Conf., Rhodes Univ. July.
- Hilmer, T and Bate, GC (1991) Vertical migration of a flagellate-dominated bloom in a shallow South African estuary. *Bot. Mar.* 34 113-121.
- Holden, A and Stephenson, D (1991) A continuous model of catchment runoff. *Proc. 5th S.Afr. Natl. Hydrol. Symp.*, Stellenbosch.
- Holtzhausen, CS, Jofre, J and Grabow, WOK (1991) The incidence of *Bacteroides fragilis* and *Escherichia coli* bacteriophages in human and animal faeces. Poster presentation at 31st Annu. Congr. of the Fed. of S. Afr. Soc. of Pathol., Warmbaths Overvaal. 1-3 July.
- Hughes, DA (1991) Catchment hydrological modelling : Where are we and where do we go from here? Paper presented at the 5th S. Afr. Natl. Hydrol. Symp., Stellenbosch. November.
- Hughes, DA and Murdoch, KA (1991) The development of a flexible, PC based hydrological modelling system. Computer software demonstration presented at the 13th Annu. Symp. on Comput. in Civ. Eng., Port Elizabeth. May.
- Hughes, DA and Murdoch, KA (1991) The development of a flexible, PC based hydrological modelling system. Paper presented at the XVI Gen. Assem. of the Eur. Geophys. Soc., Wiesbaden, Germany. April.
- Human, JJ, De Bruyn, LP and Pretorius, JP (1991) Research on crop water stress as a key to increased water-use efficiency. Paper presented at the South. Afr. Irrig. Symp., Durban. 4-6 June.
- Human, JJ, Pretorius, JP and Pieterse, NM (1991) The influence of agronomic practices on water use and yield of irrigated wheat. Paper presented at the South. Afr. Irrig. Symp., Durban. 4-6 June.
- Hurndall, MJ, Jacobs, EP and Sanderson, RD (1991) New composite RO membranes made from poly-2-vinylimidazoline. *J. Appl. Polymer Sci.*
- Hurt, QE (1991) Improving the performance of membrane systems by mass transfer enhancement. Paper presented at 2nd Bienn. WISA Conf./Exhib., World Trade Centre, Kempton Park. 13-16 May.
- Ishwarlall, AD, Bux, F and Kasan, HC (1991) Survey of algae and protozoa in activated sludge plants in Natal. Paper presented at the Annu. Symp. of the Natal Branch of the S. Afr. Soc. for Microbiol., Pietermaritzburg. October.
- Jacobs, EP (1991) Synthetic membrane application in treating industrial effluents. Paper presented at Western Province Branch of WISA monthly meeting, CSIR, Stellenbosch. June.
- Jacobs, EP and Sanderson, RD (1991) Low cut-off UF membranes : Technology transfer and availability in the RSA. Paper presented at Mini-symp., Membrane Technol. Div. (WISA), Johannesburg. 22-23 October.
- Jewitt, GPW and Schulze, RE (1991) A decision support system for assessing hydrological impacts of afforestation. *Proc. 5th S.Afr. Natl. Hydrol. Symp.*, Stellenbosch. 5B-1-1 to 5B-1-9.
- Johnston, MA (1991) Measurement of soil salinity using the four- electrode probe. Poster presentation at the South. Afr. Irrig. Symp., Durban. 4-6 June.
- Jury, MR and Gourtney, S (1991) A transition in weather over the Agulhas Current. *S. Afr. J. Mar. Sci.* 10 159-171.
- Jury, MR and Pathak, BMR (1991) Tropical climate and weather variability over the SE Africa-SW Indian Ocean region. Paper presented at the 19th Conf. on Hurricanes and Trop. Meteorol. of the Am. Meteorol. Soc., Miami, Florida. 5-10 May.
- Jury, MR, Pathack, BMR, Courtney, S and Nassor, A (1991) A circulation mechanism for summer rainfall variability. Paper presented at the 8th Annu. Conf. of the S. Afr. Soc. for Atmos. Sci., Pretoria. 23-24 October.
- Kasan, HC (1991) Biotechnological options for metal-ion removal from effluents. Paper presented at the 6th Natl. Meeting of the S. Afr. Inst. of Chem. Eng., Durban. August.
- Kasan, HC (1991) The use of micro-organisms for metal reclamation from industrial effluents. Paper presented at the Int. Symp. on Environ. Biotechnol., Ostend, Belgium. April.
- Kelbe, BE, Bodenstein, B and Mulder, GJ (1991) An investigation of the hydrological response to informal settlements on small catchments in South Africa. In : *Sediment and Stream Water Quality in a Changing Environment : Trends and Explanations (Proc. of the Vienna Symp.)*, August. IAHS Publ. No 203.
- Kerr, CA, Buckley, CA and Kohler C (1991) Speciation as an aid to understanding the chemistry of water treatment. Paper presented at 6th Natl. Meeting of the S. Afr. Inst. of Chem. Eng., Elangeni Hotel, Durban. 7-9 August.
- Kerr, CA, Trusler, KGE, Loewenthal, RE and Buckley, CA (1991) Chemical speciation as an aid to understanding the precipitation kinetics of industrial effluents. Paper presented at 2nd Bienn. WISA Conf./Exhib., World Trade Centre, Kempton Park. 13-16 May.
- Ketley, DA, Casey, TG, Ekama, GA, Wentzel, MC and Marais, GvR (1991) The effect of fully anoxic conditions and frequency of exposure to anoxic and aerobic conditions on the growth of low F/M filaments in nitrogen removal systems. UCT Report W68.



- Kfir, R and Slabbert, L (1991) Health aspects of wastewater reclamation for potable use. Paper presented at Am. Water Resour. Ass. Symp. on Water Supply and Water Reuse : 1991 and Beyond, San Diego, California. 2-6 June.
- Kienzle, SW (1991) Evaluation of the influence of the sampling frequency on the representation of water quality of streams and rivers in a semi-arid catchment. *Agric. Eng. in S. Afr.* **23** 198-206.
- Kienzle, SW (1991) Hydro-geochemical characterization of surface water as a means of identifying irrigation induced hydro-chemical changes of surface water. Paper presented at the Workshop on Irrigation Induced Physical and Chemical Changes in Soil, Groundwater and Surface Water, XX General Assembly IUGG, IAHS Scientific Program, Vienna. 11-24 August.
- Kienzle, SW and Schulze, RE (1991) Assessment of the impact of afforestation on the water resources in the Mbazwana area, northern Zululand. Report to INR, Pietermaritzburg. 26 pp.
- Kienzle, SW and Schulze, RE (1991) A simulation model to assess the effect of afforestation on ground water resources in deep sandy soils. *Proc. 5th S. Afr. Natl. Hydrol. Symp.*, Stellenbosch. 5B-2-1 to 5B-2-9.
- King, JM and Rowlston, WS (1991) Modelling river flow : Differences between engineering and environmental hydraulic models. *Proc. 5th S. Afr. Hydrol. Symp.*, Stellenbosch.
- King, JM and Tharme, RE (1991) An ecological perspective on river flow in South Africa. Paper presented during the WRC/FRD sponsored working tour of Australia, November-December.
- King, JM, De Moor, FC and Chutter, FM (1991) Alternative ways of classifying rivers in Southern Africa. In : Boon, P, Petts, G and Calow, P (eds.) *River Conservation and Management*. John Wiley & Sons, Chichester, UK.
- Koen, D and Jacobs, EP (1991) Poly (ether sulphone) and polysulphone UF membranes : Differences in performance. Poster presentation at Mini-symp., Membrane Technol. Div. (WISA), Johannesburg. 22-23 October.
- Kröger, DG (1991) Thermische Strömung in trockengekühlten Systemen für Kraftwerke. *VGB Kraftwerkstechnik* **11**(71) 1013-1016.
- Kruger, M, Van Vuren, JHJ en Du Preez, HH (1991) Die fisiologiese effek van besoedelingstowwe op die hematologie en metabolisme van *Clarias gariepinus*. Vorderingsverslag, NKW 1990 - Junie 1991.
- Kruger, M, Van Vuren, JHJ and Du Preez, HH (1991) The bioconcentration of heavy metals in *Clarias gariepinus* in the Olifants River. Poster presentation at 1st Annu. Res. Meeting, KNP Rivers Research Programme, Roodevallei Country Lodge. 19-20 March.
- Lambourne, J, Coleman, T and Stephenson, D (1991) Water balance compar of urban and rural catchments. *Proc. 5th S. Afr. Natl. Hydrol. Symp.*, Stellenbosch.
- Lecler, NL and Schulze, RE (1991) Hydrological research for the Cathkin Park area : An assessment of the available water resources in the Cathkin Park area of the Natal Drakensberg. Report to Bradford Conning and Partners, Pietermaritzburg. 65 pp.
- Lilley, ID, Wentzel, MC, Loewenthal, RE, Ekama, GA and Marais, GvR (1991) Acid fermentation of primary sludge at 20°C. Paper presented at 2nd Bienn. WISA Conf., Kempton Park. 13-16 May.
- Loewenthal, RE, Wentzel, MC, Ekama, GA and Marais, GvR (1991) Mixed weak acid/base systems Part II : Dosing estimation, aqueous phase. *Water SA* **17**(2) 107-122.
- Lötter, LH (1991) Chemical removal of phosphate in nutrient removal activated sludge plants. Paper presented at 2nd Bienn. WISA Conf., Kempton Park. 13-16 May.
- Lynch, SD and Dent, MC (1991) Estimating areal mean monthly time series of rainfall. *Proc. 5th S. Afr. Natl. Hydrol. Symp.*, Stellenbosch. 4A-1-1 to 4A-1-6.
- Malherbe, GF, Jacobs, EP en Sanderson, RD (1991) Behandeling van uitvloeisels met behulp van membraanprosesse. Referaat gelewer by die SASOL Tegnologie-simp., RAU, Johannesburg. 26 Julie.
- Maree, JP, Du Plessis, P and Mackintosch, G (1991) Neutralisation of acid mine water with calcium carbonate. *Proc. of the 6th Natl. Meeting of the S. Afr. Inst. of Chem. Eng.*, Durban. 7-9 Aug.
- Mather, GK (1991) Coalescence enhancement in large multicell storms caused by the emissions from a Kraft paper mill. *J. Apppl. Meteorol.* **30** 1134-1146.
- Mather, GK and Terblanche, DE (1991) A new cloud seeding device. Paper presented at the 8th Annu. Conf. of the S. Afr. Soc. for Atmos. Sci., Pretoria. 23-24 October.
- Meintjies, E (1991) Research on the feasibility of reverse osmosis for water reclamation on large scale from secondary effluent : Chemical aspects. Paper presented at Am. Water Resour. Ass. Symp. on Water Supply and Water Reuse : 1991 and Beyond, San Diego, California. 2-6 June.
- Meiring, JA en Oosthuizen, LK (1991) Die beraming van die geweegde gemiddelde koste van kapitaal met verwysing na besproeiingsboere in die Vanderkloof Staatswaterskema. *Agrekon* **30** (2) 82-88.
- Meiring, JA en Oosthuizen, LK (1991) Die ontleding van die jaarlikse koste van tipiese spilpuntstelsels in die Suid-Vrystaat substreek. *Water SA* **17** (4) 249-254.
- Meiring, JA en Oosthuizen, LK (1991) Ontleding van die ekonomiese winsgewendheid van alternatiewe spilpuntstelsels met inagneming van produksie- en prys-risiko. Referaat gelewer tydens Suider-Afrikaanse Besproeiingsimposium, Durban. 4-6 Junie.
- Meyer, DH and Harris, J (1991) Prediction of phosphorous load from non-point sources to South African rivers. *Water SA* **17** (3)211-216.
- Meyer, R and Du Plooy, B (1991) A DC resistivity investigation of a ground water pollution plume - Field survey and mathematical modelling. Extended Abstract, SAGA 2nd Techn. Meeting, Johannesburg.
- Moerdyk, MR and Schulze, RE (1991) Impacts of forestry site preparation on surface runoff and soil loss. *Agric. Eng. in S. Afr.* **23** 319-325.
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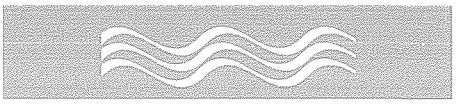

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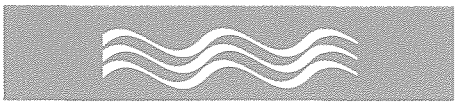

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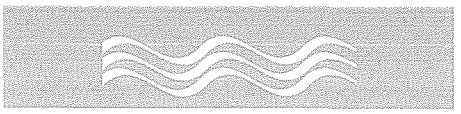

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