WATER RESEARCH COMMISSION

Technical Report

1996

TECHNICAL REPORT 1996

Water Research Commission

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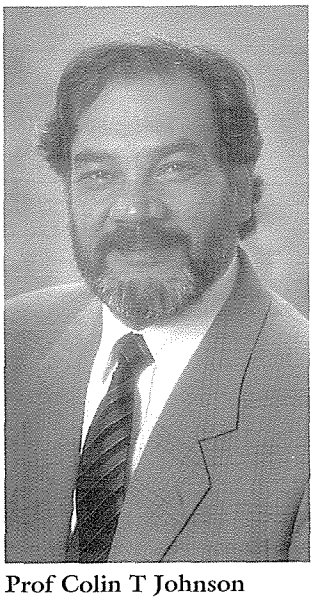
as on 31 December 1996



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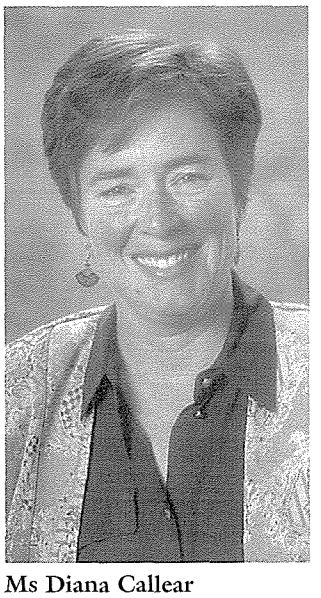

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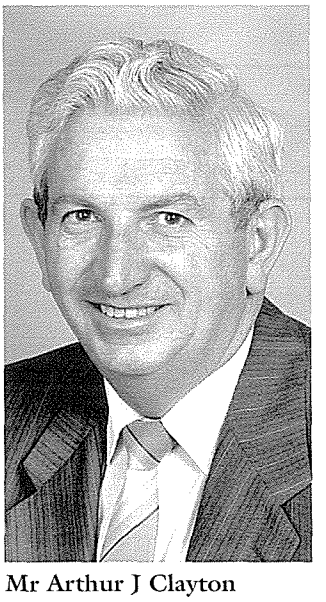

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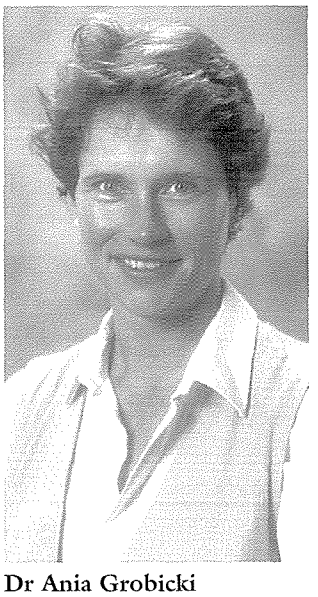

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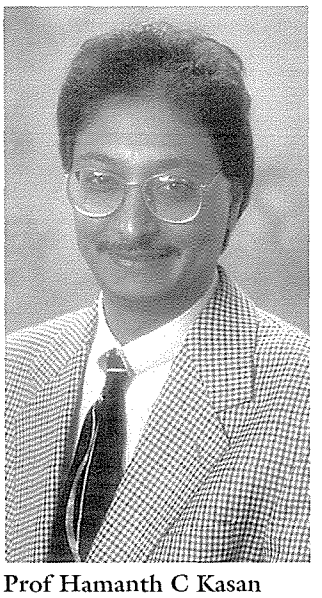

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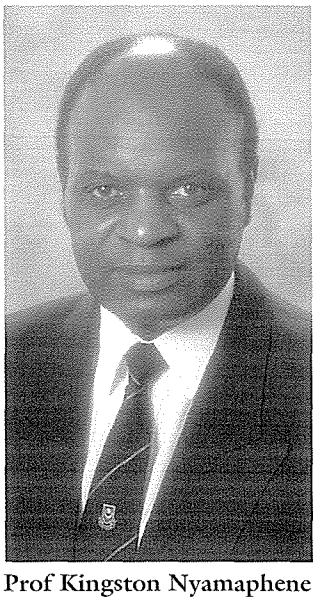

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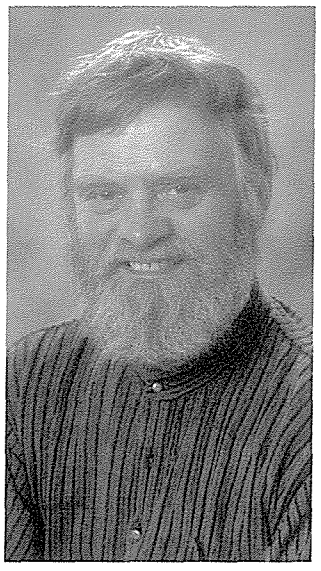

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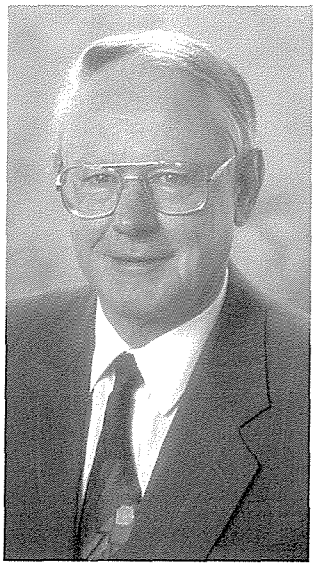

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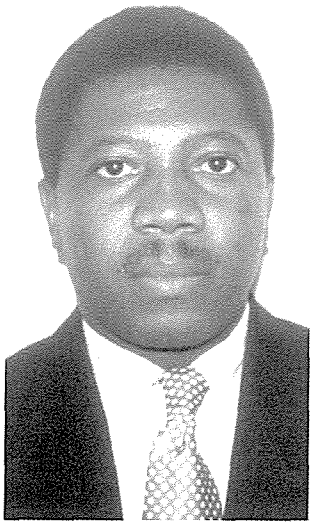

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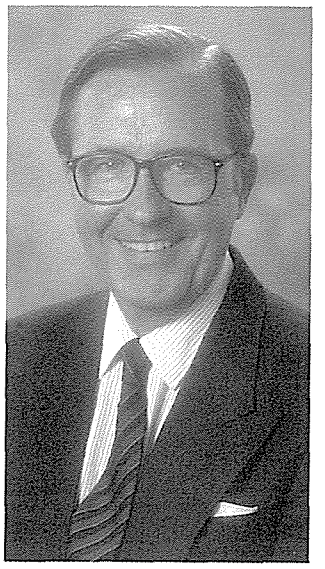

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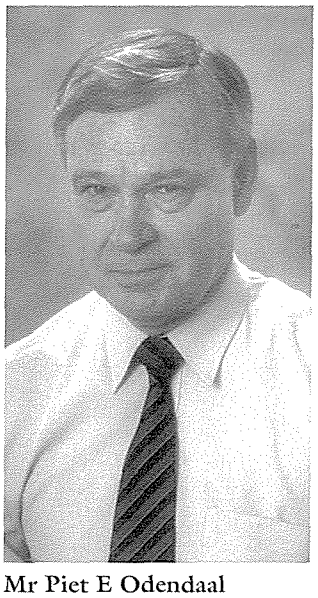

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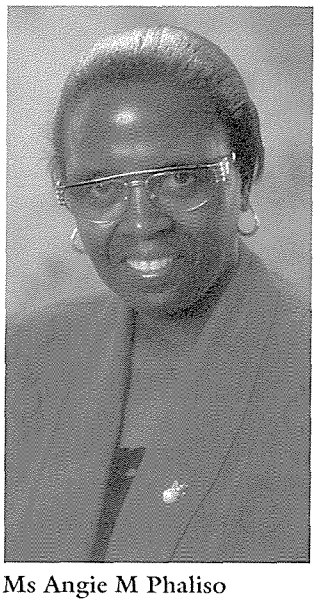

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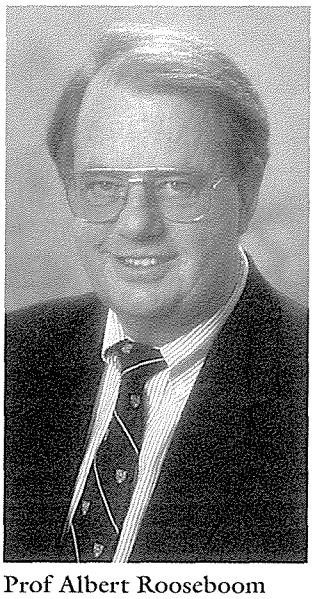

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CONTENTS

1 THE YEAR UNDER REVIEW

The diverse number of research fields supported by the Water Research Commission (WRC) bears testimony to its multidisciplinary approach to water research. The research fields and allocation of funds to the various fields for 1996 are indicated in the accompanying bar chart.

The WRC does not itself undertake research, but enters into agreements with other organisations to carry out the research. In Table 1 the research sectors which are responsible for the research, are listed, as well as the extent of their involvement:

TABLE 1

Research sector	Number of times involved	%
Universities	121	50,8
CSIR	49	20,6
Consultants	32	13,5
Government departments	3	1,3
Local authorities	3	1,3
Water boards	12	5,0
Other organisations	18	7,6
Total	**238**	**100**

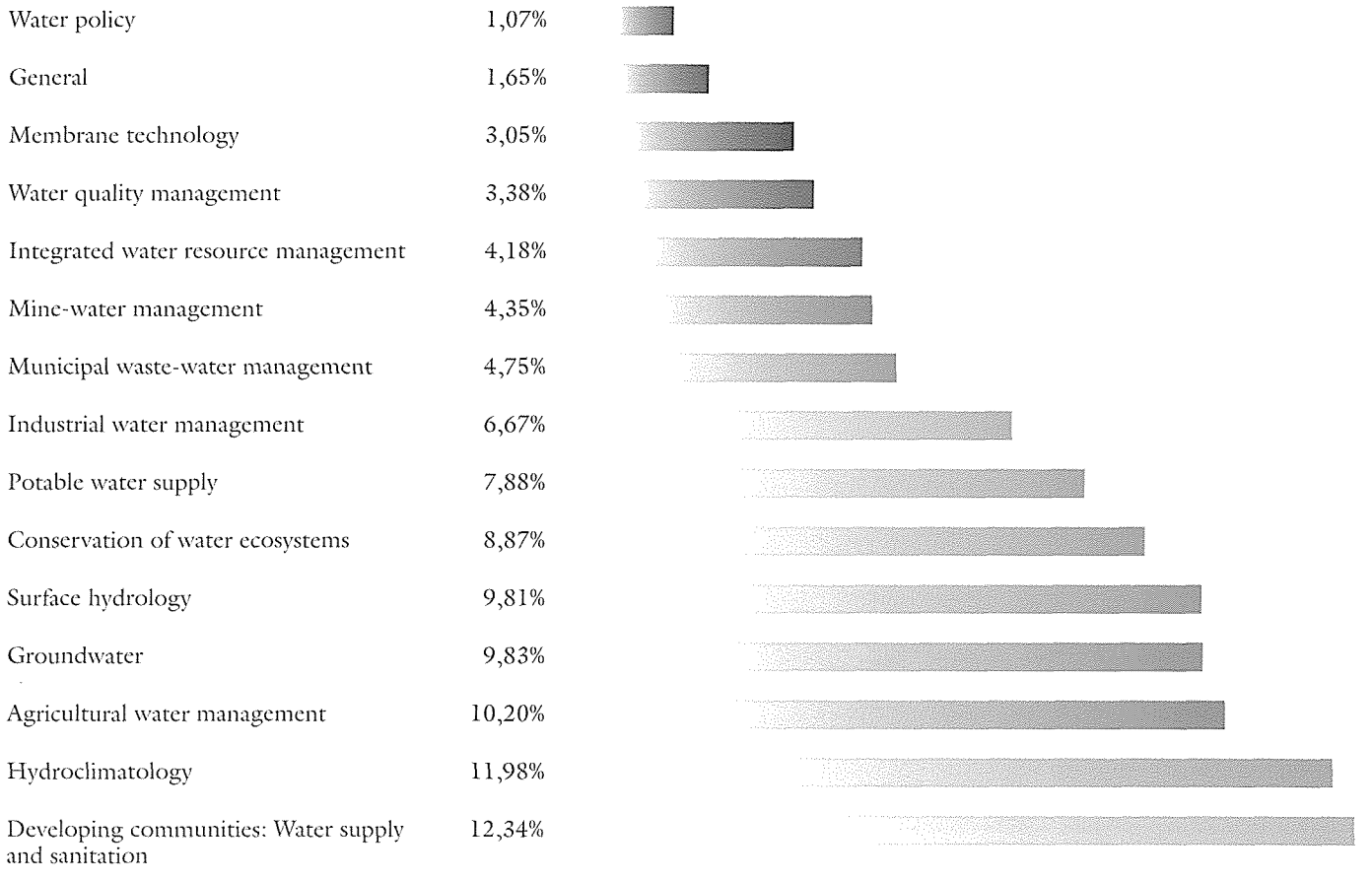
From the figures it is evident that universities are involved in 50,8% of the total number of contracts. The number of times that organisations are involved, namely 238, exceeds the number of projects supported, for the reason that more than one organisation is, in certain cases, involved in the execution of a project. In 1996 the WRC financially supported 235 projects at a budgeted amount of R39 349 300.

In addition to the direct funding of contractual research projects, the WRC also finances two research support services, namely:

- The SA Water Information Centre (SAWIC)
- The Computing Centre for Water Research (CCWR).

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 FIELDS DURING 1996



WRC 25 years old

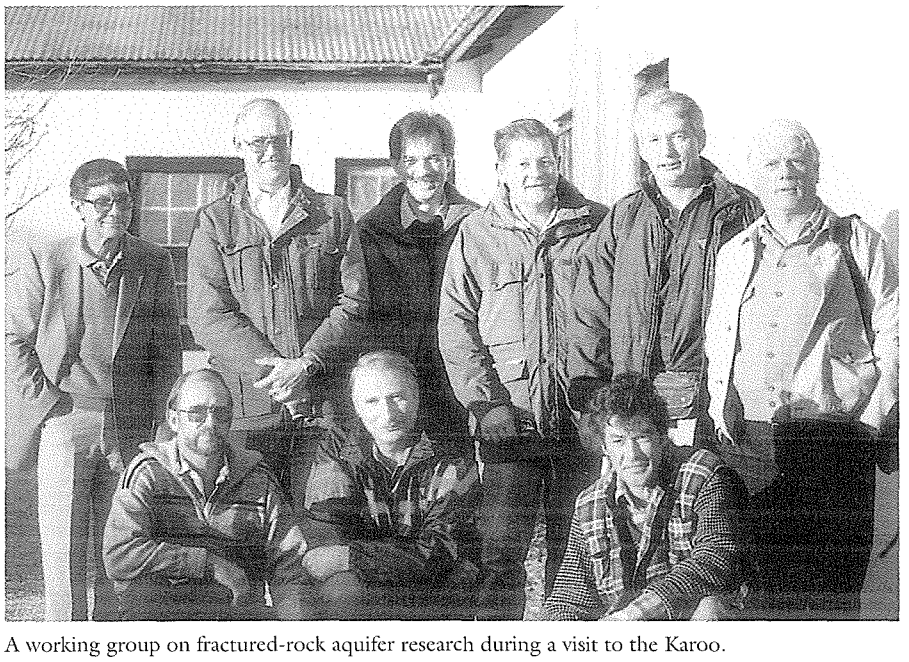
The WRC was established in terms of the Water Research Act (Act 34 of 1971), and began operations on 1 September 1971. To commemorate the WRC's 25th anniversary, a special issue of its news journal *SA Waterbulletin* was published. This special issue reviews the main achievements of the period.

Networks for collaboration and capacity building

The WRC commenced a networking approach for improved capacity building, co-ordination and communication, and for promoting interdisciplinary and interinstitutional research. An essential element is the underpinning of human networking with an Internet-based electronic network. Thus far the WRC has been involved in three successful networking initiatives:

- **EMILY** (**E**lectronic **M**embrane **I**nformation **L**ibrary), developed by the University of Natal on behalf of the WRC, as an information server for membrane technology. This has generated extensive international interest and participation.
- **INTERWATER**, aimed at the water supply and sanitation needs of developing countries. The idea was promoted with the International Association on Water Quality, who funded the University of Natal to pioneer the system, with the WRC providing infrastructure. Key role players in the world have now taken co-ownership of INTERWATER.
- **The KwaZulu-Natal Water Research Network**, initiated in June 1996, in collaboration with the FRD. In this instance the concept tested was the use of electronic networks to promote **human networks**. Positive developments, relating to collaboration and co-ordination, have already taken place.

The WRC now intends to test and demonstrate networking nationally for a few selected water research areas. Information scientists will be appointed during 1997 to promote not only the WRC's technology transfer and co-ordination functions, but also to assist in the development and management of electronic networks.



A working group on fractured-rock aquifer research during a visit to the Karoo.

WRC participates in an international peer-review system

In 1995/96 the WRC participated with four other water research organisations in an international peer-review system, called RECIPRO. The organisations are:

- The American Water Works Association Research Foundation (AWWARF) – USA
- Technologiezentrum Wasser (TZW) – Germany
- Keuringsinstituut van Waterleiding-Artikeln (KIWA) – Netherlands
- Compagnie Generale des Aux – France

RECIPRO involved visits to each organisation by the chief executives of the other organisations, and an evaluation of the organisation's policies and procedures.

Fractured-rock aquifer research programme

It is estimated that some 90 per cent of South Africa's groundwater occurs in secondary aquifers consisting primarily of shallow zones of weathering and fracturing. Considerable attention has been focused on the occurrence, movement and recharge of groundwater in these fractured-rock aquifers. An understanding of the physical nature and behaviour of such aquifers is essential, not only in the correct siting of boreholes and judicious abstraction of groundwater, but also in the protection of such aquifers from the ingress of pollutants. Fractured-rock environments are particularly vulnerable to contamination due to their inherent lower attenuation capacity and higher groundwater flow rates compared to primary or porous flow aquifers.

A fractured-rock aquifer research programme was initiated by the WRC in 1992 and considerable advances in our understanding of these aquifers have been made. A number of projects managed under this programme have recently been concluded. A Phase 2 programme will be initiated during 1997, following a thorough evaluation of the results from

Phase 1. As part of this evaluation, the preparation of a *Handbook on the Hydrogeology of the Karoo Super Group* will be initiated.

International experts advise on groundwater research

Three international groundwater experts visited South Africa in 1996 to participate in the workshop "Groundwater-Surface Water Issues in Arid and Semi-Arid Areas". All were exposed to groundwater research programmes in South Africa, and they made constructive contributions to the following current projects:

- Prof David Lerner, University of Bradford, UK, and Dr Peter Dillon, Centre for Groundwater Studies, Australia: **An assessment of the impact of agricultural practices on the quality of groundwater resources in South Africa; Investigation of the contaminant attenuation capacity of the soil/aquifer system with special emphasis on the vadose zone** (WRC Projects No 641 and No 572).
- Prof Ian Simmers, Vrije Universiteit, The Netherlands: **Groundwater supply assessment and strategy for the Western Karoo, Namaqualand and Bushmanland; Guidelines for the evaluation of water resources for rural development with an emphasis on groundwater** (WRC Projects No 721 and No 677).

An aquifer classification system for South Africa

For both economic and practical reasons it is not possible to accord all aquifers the same high level of protection. Furthermore, subsurface environments differ in their ability to attenuate pollutants. Consequently the CSIR's Division of Water, Environment and Forestry Technology developed a system of classifying aquifers and boreholes for differential protection, so that those supply sources regarded as being valuable or vulnerable to contamination can be accorded the highest level of protection.

Classification systems are usually based on criteria such as economic value, vulnerability to pollution, groundwater potential (yield) and present water quality. The aquifer system management classification developed during the study is based on the British Geological Survey aquifer vulnerability classification, but also recognises the need to consider two important management aspects, namely:

- The high value of sole source aquifers in South Africa
- The need for a pragmatic approach which allows for special factors to be considered.

The single most important use for the classification, at a national scale, is to provide a means of defining the importance of an aquifer in order that sound and consistent decision-making with respect to groundwater management is promoted.

Collaboration with the Australian Geological Survey Organisation

The need to ensure that communities are kept well informed and have access to information on their water supplies, is in line with the current approach that communities be given the responsibility of operating and managing their own water supplies. This is particularly relevant to groundwater resources, which are most effectively managed at a local level. The dissemination of information collated during the Department of Water Affairs and Forestry's ongoing hydrogeological mapping programme, will thus be of utmost importance if this approach is to succeed in rural areas. To ensure that this dissemination takes place effectively, a research project entitled **The development of a strategy for disseminating information from the hydrogeological mapping programme to village water committees** (WRC Project No 734) was initiated.

The Australian Geological Survey Organisation (AGSO) expressed a keen interest to collaborate on the project. They have accumulated considerable experience during their own Land Care Programme, whereby information on the relationship between farming practices and salinisation of water and soils is being conveyed to farming communities. Through funding made available by the Australian Agency for International Development (AusAID), Mr Ray Evans of AGSO has been actively participating in the WRC study.

The hydrological potential of weather radar confirmed by flood event

During the period 8 to 16 February 1996, widespread rain fell over the north-eastern half of South Africa, causing one of the highest flood peaks of the century in the Vaal River. The event provided an excellent opportunity to evaluate hydrometeorological data in terms of current and potential usefulness for operational hydrology.

Part and parcel of the catchment's hydrometeorological instrumentation, is the MRL-5 wavelength radar, recently purchased by the WRC and installed near Bethlehem to promote research into the better quantification of areal rainfall. The radar is being operated by the Weather Bureau's precipitation research team who also maintain a rain-gauge network of high spatial density within a small part of the area of radar coverage. Since installation the radar has undergone extensive upgrading by the research team, which greatly improves accuracy of rainfall measurement.

The accuracy of the MRL-5 radar as a rainfall-measuring device is reflected in results of radar/rain-gauge comparisons over the six days of rain which produced the flood event. The two methods agreed to within 3 per cent. For hourly rainfall comparisons, the correlation coefficient was as high as 0.93.

During the flood event, information on areal rainfall derived from radar data and regularly fed through to the Department of Water Affairs and Forestry (DWAF), was beneficially but not necessarily optimally used for making decisions regarding the operation of the Vaal Dam. The subsequent development of a capability to transmit areal rainfall data electronically and to track storms in real time will help to optimise future hydrological uses of these radar data. Further benefici-

ation will result from interfacing the radar data with predictive river-flow models, which will significantly increase lead times for flood management purposes.

Hygroscopic cloud-seeding technology under international scrutiny

The South African hygroscopic cloud-seeding technology, developed as a result of many years of research into rainfall enhancement, is commanding increasing interest internationally.

The research, jointly sponsored by the WRC and the Weather Bureau, has been carried out by a team of scientists, technicians and pilots attached to the company CloudQuest (Pty) Ltd, the Weather Bureau itself, and the University of South Africa. Scientists at the USA's National Center for Atmospheric Research (NCAR) have, over the years, closely monitored progress and have also ascertained that field results are consistent with numerical model predictions of initial coalescence growth of cloud drops after the introduction of hygroscopic particles into clouds.

The hygroscopic seeding technology, now being adapted for operational use in the Northern Province of South Africa, is also being tested in Arizona and Texas in the USA, with a major programme being mooted for north-eastern Colorado in the near future.

Outside South Africa and the USA, a four-year programme to further test the technology in the Mexican state of Coahuila, commenced in July 1996. The Mexican government, along with agricultural and industrial interests, is sponsoring the research, which is being done by scientists from NCAR working with scientists from several Mexican universities. Members of the South African research team have participated, as advisers, in the initial field operations. There are further prospects being launched in Thailand, Indonesia and Korea.

Guidelines complement water services regulation

Palmer Development Group is being funded by the WRC to prepare management guidelines for the water and sanitation departments in local authorities. These guidelines will be complementary to the new law being drafted for water service regulation. Under this law, the DWAF intends to support local authorities and other providers of water services. The emphasis will be on proper planning and management with the guidelines being seen as an integral part of the supporting documentation.

Private sector participation in water supply and sanitation services

The WRC published a document entitled *Preliminary Guidelines for Private Sector Participation in Water Supply and Sanitation Services.* The guidelines were prepared by the consultant Philip Pybus, under the direction of the project steering committee.

In the *White Paper on Water Supply and Sanitation Policy*, the essential role that could be played by the private sectors in the delivery of water and sanitation services was recognised. The guidelines are intended to promote the establishment of partnerships between the private and public sectors in order to exploit all available resources to the benefit of the country.

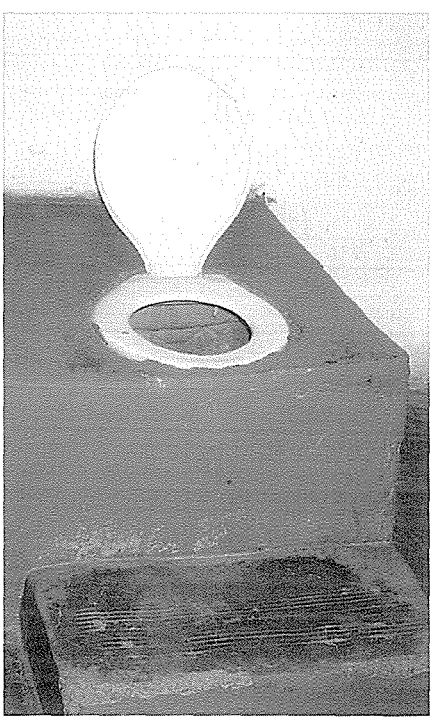
To this end, the document provides information on the variety of services available from the private sector, as well as the options that are available to them for the improvement and upgrading of these services.

Models relating to infrastructure investment planning by local authorities

The WRC, together with the Development Bank of Southern Africa (DBSA) funded a project to develop computer-based models to support local authorities in planning future investment in infrastructure. The Combined Services Model (CSM), which was developed by Palmer Development Group, looks at all services together, including water and sanitation. It is a tool that allows local authorities to test different levels of service, estimate capital and recurrent costs and look at trends with household bills. This model has received wide interest, and the Department of Constitutional Development is proposing its use by all local authorities.

Guidelines for planning on-site sanitation for low-cost housing schemes

The WRC appointed Bernhardt Dunstan and Associates to undertake a research project on the evaluation of on-site sanitation systems for applicability in low-cost housing from a socio-economic perspective. This project will provide guidelines for the planning and implementation of on-site sanitation systems that are cost-effective, appropriate, affordable and sustainable for low-cost housing schemes. The National Sanitation Coordination Office (NASCO) of the DWAF expressed interest in such guidelines.



Guidelines for domestic ventilated pit latrines

The Division of Building Technology of the CSIR is completing a WRC-funded project on the preparation of guidelines for domestic ventilated improved pit (VIP) latrines. The following guidelines will be published early in 1997:

- Design and construction guidelines for domestic VIP toilets
- Guidelines for local water and sanitation committees on domestic VIP toilets
- Guidelines for users of domestic VIP toilets.

These guidelines will be used by the DWAF for the implementation of the national sanitation programme. The guidelines will assist developers and communities in building VIP latrines that meet the basic requirements for health.

Network on irrigation research and extension for small-scale agriculture (NIRESA)

There is increasing realisation that improved multidisciplinary co-operation is essential in order to gain a better understanding of problems experienced by small-scale irrigation farmers. Following a workshop in May 1996, organised by the WRC, it was decided that improved communication between researchers, practitioners and extensionists involved in this field is a priority. To this end it was agreed by participants to establish NIRESA and to invite other interested persons or organisations to take part in the network.

The purpose of the network is, firstly, to compare available research results with the requirements for successful small-farmer settlement and, secondly, to identify information gaps as well as appropriate steps to undertake problem-solving research projects and targeted extension programmes. Tasks which must receive attention include determination of success factors in critical areas such as climate, soil and water resources; crop production; irrigation and drainage; marketing; financing; land tenure and water rights; managerial ability; community participation; development approaches; and training.

Apart from regular interaction through various mediums of communication, it is envisaged that members of the network will meet at least annually to exchange ideas based on case studies in different agricultural regions of South Africa.

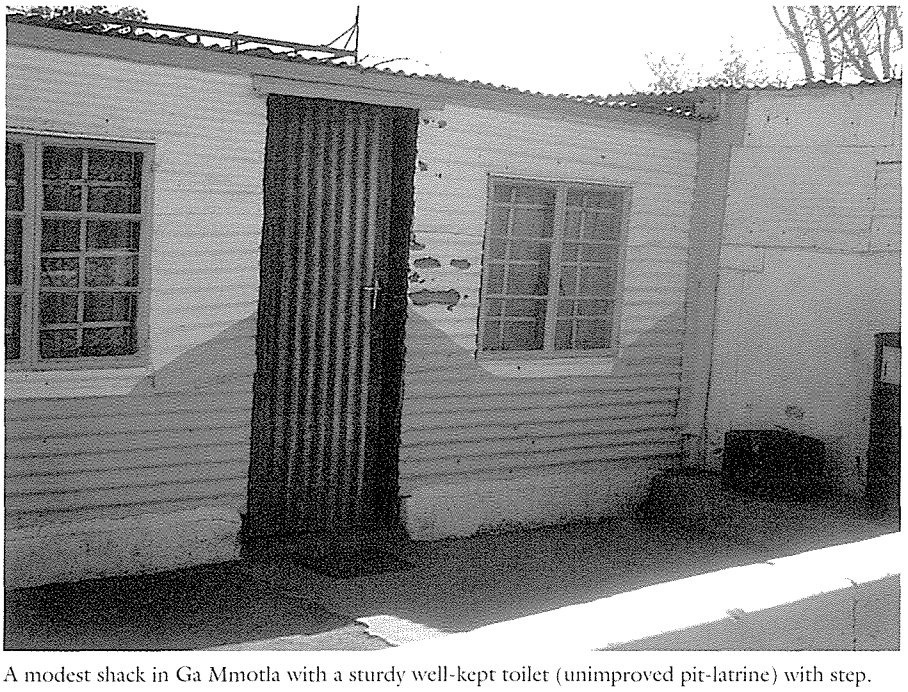
Proposal for collaborative research with the University of New England, on irrigation water management

Dr Norman J Dudley, a University Fellow in the Centre for Water Policy Research, University of New England, Armidale, NSW, Australia, visited South Africa in August 1996, as a guest of the WRC.

The mainstream of Dr Dudley's research is the development and application of computer-based, multi-stage decision models for economic problems in natural resource use in which uncertainty is paramount. Together with Prof Warren Musgrave, Dr Dudley was responsible for developing the concept of capacity sharing, an innovative alternative to conventional water allocation mechanisms.

The purpose of the visit was to hold exploratory discussions on the opportunities for undertaking collaborative research and the feasibility of developing a research proposal for the application of capacity sharing models in South Africa. Orientation visits for Dr Dudley were arranged to the Makhatini Irrigation Scheme on the Pongola River in the KwaZulu-Natal Province, which is being considered as a possible case study area since conflicting interests exist between domestic, irrigation and ecological uses of water.

On conclusion of the visit it was agreed that follow-up actions will be taken with the intention of submitting a research proposal for evaluation and to negotiate funding during 1997.



A modest shack in Ga Mmotla with a sturdy well-kept toilet (unimproved pit-latrine) with step. (Photos by Uhuru Madida).

Co-ordination of mining-related water research

With the co-operation and support of the mining industry, government departments and other interested parties, the WRC established a Co-ordinating Committee for Mining-Related Water Research (CCMRWR) to, *inter alia*, identify research priorities and co-ordinate the national research effort in this field.

At present, research in this field is aimed at improving assessment of the effects of mining – now and in the future – on the water environment. Research is also being conducted on means which can be used to minimise pollution and mitigate or control mining impacts through appropriate treatment methods. As a result of initiatives taken by the CCMRWR, duplication within the national mining-related water research effort has largely been eliminated and research is being conducted more cost-effectively. Several of the current research projects are being funded jointly by more than one funding agency to the benefit of all. The WRC's financial contribution to research in this field represented less than a quarter of the national effort during the past year.

The impact of mining on the water environment

A manual containing guidelines and procedures to assess and ameliorate the impact of gold-mining operations on the water environment, was published towards the end of 1996. This publication emanated from studies at three typical mines, during which a salt-and-water budget was compiled for each mine, the main sources of water quality deterioration identified, and their effect on the receiving water environment determined. From these findings, procedures were identified which are technically and economically viable, to ameliorate the negative impacts of mining operations. The manual describes the approaches and techniques which are available to assess the impact of gold mining, together with strategies and alternatives which are available to manage its consequences for the surface water environment. The manual was developed by the CSIR's Division of Mining Technology.

Survey of mining management and treatment practices

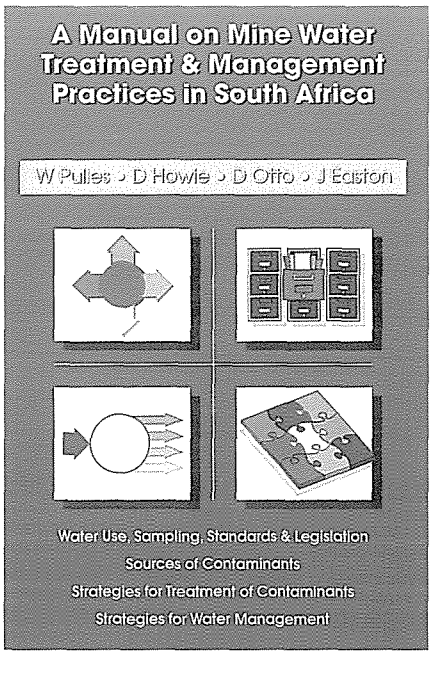
A state of the art report was published which set out the innovative and successful strategies and treatment processes which have been developed and applied at various mines. A total of 12 gold and 17 coal mines were investigated as part of the study. From the findings a manual was compiled which presents:

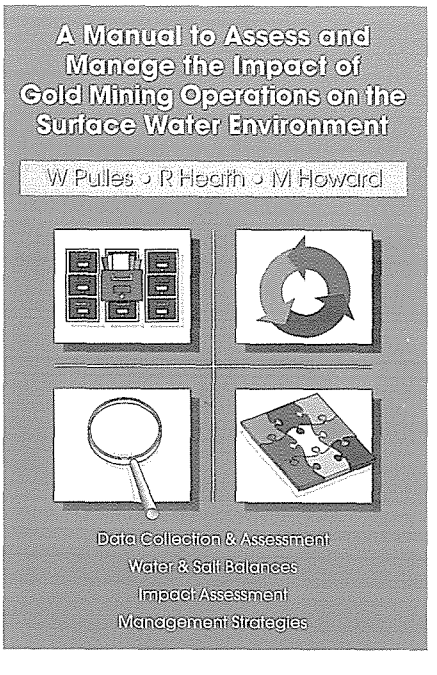
- General information on water use, sampling, standards and legislation
- Sources of contaminants
- Strategies for the treatment of contaminants
- Strategies for water management.

The manual, drawn up by the Chamber of Mines of SA, is structured such that it can be used by water specialists as well as by mining staff with little knowledge of water management issues.

Plastic-bodied water meter perfected

One of the more prominent cost inputs in a low-income house, is the installed cost of a conventional water meter. The most expensive part of such a meter is the brass body. A cheaper, possibly plastic-bodied water meter, would be the ideal solution, also obviating the problem of theft for the scrap value of brass-bodied meters. It was estimated that the potential market in South Africa alone could be as high as three million units. These considerations prompted the WRC to financially support AAB Kent Meters in the development of their latest version of a plastic-bodied water meter. The result is a vastly improved product which is now in great demand, locally and overseas.





Improved method for detection of viruses in water

The Department of Medical Virology, University of Pretoria, has developed user-friendly procedures for the virological analysis of water. The cost of the new method is less than that of the standard coliform tests, and is more specific in identifying the causes of disease. Technology for the isolation of viruses has also been improved.

The combination of cell cultures developed for the analysis is now being used on a routine basis in the Department. This could well be the most sensitive cell-culture system being used for the detection of viruses anywhere in the world.

A health guide for water supplies

The WRC financially supported the first edition of *A Guide for the Health-Related Assessment of the Quality of Water Supplies*, developed by the Inter-Departmental Co-ordinating and Liaison Committee for Water Supply and Sanitation. The guide was officially launched by the Minister of Water Affairs and Forestry, Prof Kader Asmal, and the Minister of Health, Dr N C Dlamini-Zuma.

The document explains the concepts of water quality in such a way that it will be useful not only to highly skilled scientists and engineers, but also at community level. The guide was evaluated and tested at inter-departmental and inter-sectoral provincial forums as well as at the National Environmental Health Forum to ensure an acceptable and high-quality product. Water quality criteria are presented in a simple classification system, based on acceptability of water for domestic use. The guide also indicates the available treatment options relating to each of the criteria, to improve water quality to acceptable levels.

It is anticipated that the guide will play a vital role in the planning of water supply services and in developing an understanding and awareness of water quality, at all levels. Considerable interest in the guide has already been shown by many communities and by consultants, both locally and internationally, including the World Health Organisation.

Treatment technology for Iron

Iron range (mg/l)	Treatment Options		
	Home	Conventional	Advanced
0 - 0.1	Treatment not necessary	Treatment not necessary	Treatment not necessary
0.1 - 0.2	Treatment not necessary	Treatment not necessary	Treatment not necessary
0.2 - 2.0	Treatment not necessary	Normal coagulation and flocculation, sedimentation and filtration	Ion exchange
2.0 - 10.0	Add bleach and filter	Oxidation by aeration and pH adjustment (if required) or addition of chemical oxidants, followed by sedimentation and filtration	Ion exchange
> 10	Add bleach and filter		Ion exchange

NOTE: For particulars on home treatment, consult your local health official or the Department of Water Affairs Officials.

Water quality guidelines for iron and treatment options proposed by the DWAF and the Department of Health (1st edn. 1996).

Iron guideline

Iron range (mg/l)	Effects on domestic uses				Treatment technology		
	Drinking	Laundry	Bathing	Watering plants	Home	Conven -tional	Advanced
							
0 - 0.1	No health or aesthetic effects				O	O	O
0.1 - 0.2	No health effects. Very slight aesthetic effects				O	O	O
0.2 - 2.0	No health effects. Aesthetic effects	Slight staining of clothes appear			O	✓	✓
2.0 - 10	Possibility of health effects in infants. Marked effect on taste	Staining of clothes appear		Slight spots appear on plants	✓	✓	✓
> 10	Chronic health effects in sensitive individuals. Severe aesthetic effects	Unacceptable staining occurs		Unsightly spots appear on plants	✓	✓	✓

BLUE = Suitable for use
GREEN = Rare instances of negative effects
YELLOW = Common instances of negative effects
RED = Unsuitable for use without treatment

O = Treatment not necessary
✓ = Treatment available
✗ = No treatment available

An atlas of potentially water-related diseases in South Africa

In compiling the atlas, the Department of Community Health, University of Cape Town, statistically analysed registered deaths in South Africa for 1990, and presented results in a series of tables and maps in the first volume of the atlas. The main results of the study were that significant overall mortality occurred for the following water-related causes: Intestinal infections (2,87%); accidental drowning (0,6%); viral hepatitis (0,09%); and malaria (0,03%).

In the second volume of the atlas, 14 water-related diseases are described under the following headings: aetiology of the disease; prevalence in South Africa; critical bibliography relating to South Africa; and interventive and/or ameliorative action.

Health effects of water handling in developing communities

The Division of Water, Environment and Forestry Technology, CSIR, studied the effect, in developing communities, of water handling and usage on water quality, with specific reference to health indices.

Water provided to the study population was of good microbiological quality and complied with the SABS guidelines. However, water was significantly more contaminated after handling and storage than at source. In a cross-sectional study, a significantly higher proportion of diarrhoea cases was recorded in areas where communal taps constitute the water supply, compared to areas where taps are available on-site. Other factors such as hygiene practices and knowledge of the causes and prevention of diarrhoea, were shown to be important factors impacting on the health of the population in a developing community.

Operating manual for biological nutrient removal waste-water treatment works

Acting on a proposal by the Nutrient Removal Division of the Water Institute of Southern Africa, the WRC contracted Stewart Scott (CE) Inc. to compile *An Operating Manual for Biological Nutrient Removal (BNR) Wastewater Treatment Works.*

The operating manual is written for managers, staff and owners of BNR plants. Its objective is to assist trained operators to understand the complexities of the BNR process, and so enable them to optimise the control of their plants. Consultants commissioning new works can use the manual as the basis for works management and operation. In addition, it will provide valuable operator training material.

Evaluation of cooling-tower performance

Large quantities of water are presently required for cooling in the power, chemical, petro-chemical, and other industries. For example, approximately 2 *l* of water are evaporated to generate 1 kWh of electrical energy, i.e. to allow 10 bulbs of 100 W each to burn for one hour. For this reason, the Department of Mechanical Engineering, University of Stellenbosch, undertook a study on the performance of wet- and dry-cooling towers, in order to develop decision-support information for selecting the most efficient cooling system for a particular plant, taking into consideration technical, environmental and cost factors.

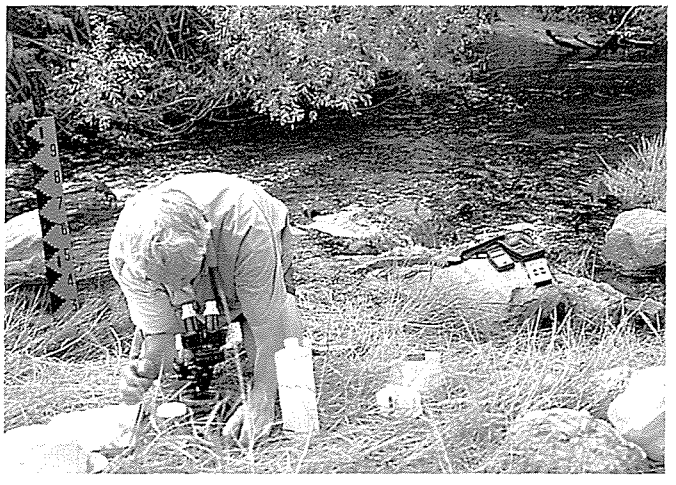
Three computer programs have been prepared for evaluating the performance of three different types of cooling systems: direct dry-cooling; indirect dry-cooling; and wet-cooling. With the information made available, it is possible for an engineer to prepare similar programs for the many types or combinations of industrial air-cooled systems found in practice.

Biomonitoring

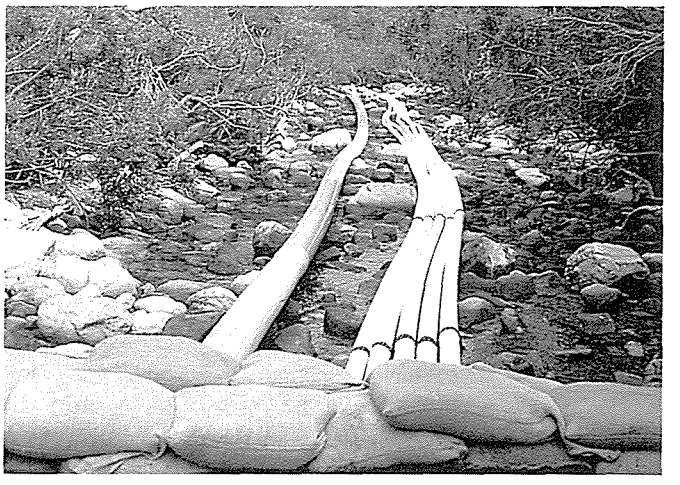
The South African scoring system (SASS), using macro-invertebrates to monitor water quality, is now widely used by government departments, statutory organisations and private bodies, interested in the monitoring of water quality. It also forms the basis of the National Biomonitoring Programme which is currently being initiated by the DWAF.

SASS was originally developed by the CSIR with WRC funding.

Diks Madikizela and G Ngabangani (University of the Transkei) sampling invertebrate fauna on the Tsitsa River, Umzimvubu catchment, Eastern Cape.



Releasing experimental freshes (flow pulses) from Clanwilliam Dam to study spawning response of the Clanwilliam yellowfish: Dr Jim Cambray, Albany Museum at the microscope.



A temporary sandbag diversion weir on Riviersonderend River to investigate the effects of low flow on invertebrate fauna (Dept. of Zoology, UCT).

Method for instream flow assessment

The Department of Zoology, University of Cape Town, developed the Building Block Methodology for instream flow assessment. This constitutes a method for estimating the flow volume and pattern of flow required to maintain a viable ecosystem in a river for which little or no data exist. The assessment may be made in a relatively short time (6 to 9 months).

This methodology is now being widely applied by the DWAF at the prefeasibility stage of planning new impoundments. The existence of a methodology to quantify environmental flow requirements has allowed the concept of an environmental reserve to be included in the present water law review. The methodology is currently being exported to Australia.

International network for drinking-water research

During May 1996 research managers from 16 countries laid the foundations for an international communications network for research on drinking-water treatment and supply.

The occasion was the 7th *Emerging Technologies* summit, which was held in Antwerp. This series of summits has been arranged by the AWWARF since 1984. These meetings are held biennially, each time in a different country, to discuss the latest technologies and research in drinking water. The previous meeting had been held in Cape Town in 1994.

The meeting decided to form international co-ordinating committees for various areas of concern in the drinking-water field. The purpose of the committees is to co-ordinate research efforts internationally in order to leverage limited funds and minimise duplication. This will be achieved by initially creating a structured, international information network, operating mainly by E-mail. However, it is possible that co-operative research programmes may eventually emanate. Co-ordinating committees have initially been formed for the following subjects:

- Protecting consumers of drinking water against *Cryptosporidium*
- Water quality in distribution systems
- Algae and drinking water
- Estrogen and estrogen-mimicking substances
- Membranes in water treatment
- Small water treatment systems
- Minimisation of waste and residuals.

The establishment and maintenance of each of these committees have been assigned to one or more institutions. The WRC has accepted responsibility for the Small Water Treatment Systems Committee.

Technology Transfer Fair on drinking-water research

In November 1996, the WRC, in conjunction with researchers and stakeholders, held a Technology Transfer Fair on drinking-water research. The objective was to bring both researchers and users together with a view to:

- Identify practical problems still being experienced in drinking-water treatment
- Inform those present of the status quo of research in the drinking-water field
- Bring researchers up to date with the work of other researchers in the field
- Incorporate research needs identified, and insights gained at the Fair, into the WRC's Strategic Plan for Research on Drinking-Water Treatment.

Representatives from the research community first presented summary assessments of the status of research products in the field. The users of research products (water utilities, consulting engineers, etc.) then had the opportunity to express their views on the following:

- Who actually uses these research products?
- Were experiences with these products negative or positive?
- Suggestions for improvement and further research and development
- Remaining problems not yet addressed by researchers.

The outputs of the Fair will be incorporated into the Strategic Plan for Research on Drinking-Water Treatment.

Book on water treatment membrane processes

The publication of a book entitled *Water Treatment Membrane Processes* is the culmination of a co-operative effort between the AWWARF, Lyonnaise des Aux (France), and the WRC. The WRC's Executive Director, Mr PE Odendaal, was one of the members of the editorial panel.

Expert researchers supported by these three organisations collaborated in producing an up-to-date manual on the application of membrane processes for the production of potable quality water.

Seven of the 22 contributors to the book are WRC-funded researchers and they contributed to 11 of the 18 chapters. Topics include the principles of membrane processes, performance characteristics of membranes, applications of membranes in the field of potable water production, pressure-driven and electrically driven membrane processes, membrane plant design and operation, and economic evaluations of membrane processes.

Development of a novel capillary membrane

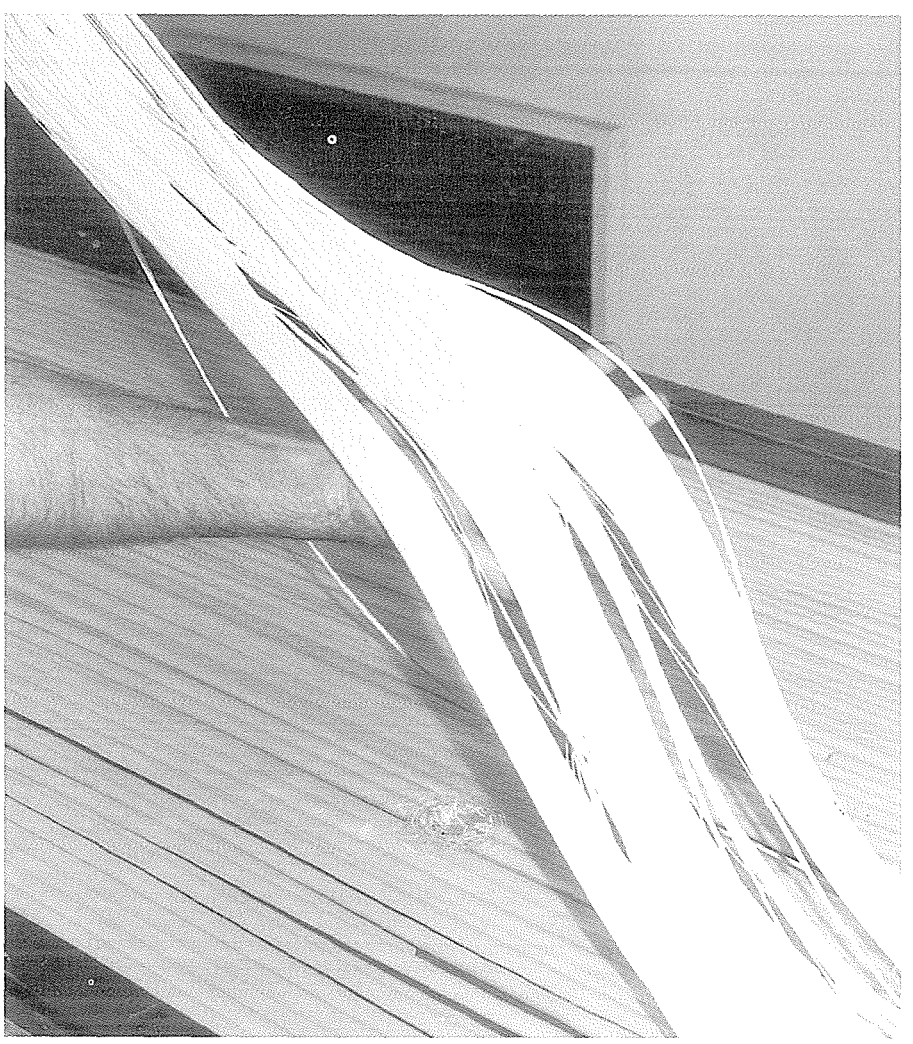
Collaborative research between the Institute for Polymer Science, University of Stellenbosch, and the Department of Microbiology and Biochemistry, Rhodes University, resulted in the development of a unique, multi-purpose polysulphone capillary membrane.

Two patents have been registered in the name of the WRC – one dealing with the development of the outer-skinless polysulphone membrane for potable water production, and the other with its use as a novel bioreactor for the production of enzymes from white rot fungus, used for the removal of intractable pollutants from industrial waste waters.

Dr HM Saayman of the WRC was invited by the Indian Membrane Society to present a paper on this novel multi-purpose membrane system at the 14th Symposium of the Society, held at the Indian Institute of Technology in Delhi, February 1996. Furthermore, Dr Saayman together with Prof PD Rose and Mr WE Leukes from Rhodes University, each presented a paper, highlighting various aspects of this research effort, at the prestigious *International Congress on Membranes and Membrane Processes* in Yokohama, Japan, August 1996.

Launch of a stakeholder forum for water resources assessment research

The WRC has the responsibility of ensuring that water research undertaken in South Africa is effectively co-ordinated. Up to now a number of co-ordinating committees, each concerned with a particular research field, and composed of representatives of both performers and end-users of research in the particular field, have been used to good effect. However, because of the many interacting dimensions of water research, cross-field co-ordination is becoming essential. Furthermore, given the universal interest in water-related matters, it is desirable that the opportunity be given to a more representative cross-section of



A bundle of capillary ultrafiltration membranes.

society to express needs and thereby influence the direction of research.

For this reason the WRC, encouraged by certain major stakeholders, launched a national Stakeholder Forum for Water Resources Assessment Research. Water resources assessment is the first of a number of water-related national concerns for which such fora may ultimately be established.

Assessing the dynamic state of South Africa's water resources is of major concern to ensure equitable, adequate and sustainable provision of water to all users. The situation is complicated by: climate variability and change; spatial variability of resources; population growth and mobility; increasing competition among users; deteriorating water quality as water use intensifies; and socio-economic considerations which affect exploitability of resources, both conventional and non-conventional.

Research thus has a vital role to play in helping to overcome such uncertainties regarding available resources of water, and their adequacy for meeting growing demands.

Stakeholders were approached in October 1996, via letters and advertisements, to apply for membership of the Forum, which will begin functioning in 1997. To qualify, prospective members must have a real interest in water resources assessment and must be prepared to contribute ideas and participate in discussions which would ultimately help to steer research in the most beneficial direction.

South Africa to participate in UNESCO's International Hydrological Programme (IHP)

The Minister of Water Affairs and Forestry established the South African National Committee for the IHP. The secretariat is located at the WRC.

A representative of the Department and one of the WRC attended the 12th council meeting of the IHP in Paris, France. During the meeting it became clear that South Africa could make an important contribution towards the co-ordination and promotion of hydrology in the Southern African region. One of the biggest needs expressed in Africa relates to capacity building in hydrology and water management, and the expertise available in South Africa should be made available in the most effective way.

Groundwater and surface water brought closer together

The ideal of bringing groundwater and surface-water research together has been brought a step closer to reality.

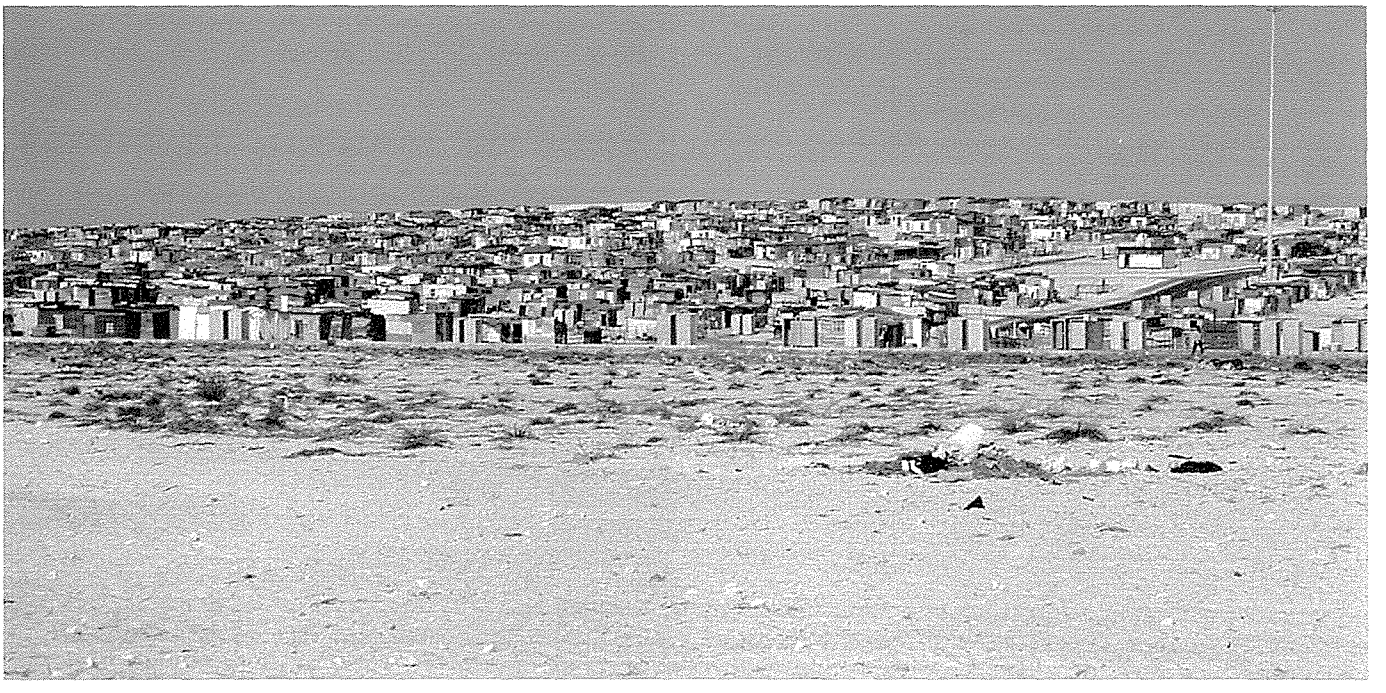
Two workshops, one on "the interaction between vegetation and groundwater", and the other on "groundwater recharge and the interaction between groundwater and surface water", were held in the second half of 1996. Three overseas experts were invited to present keynote papers at the second workshop.

There was significant enthusiasm for closer co-operation, as well as a recognition of much common ground between disciplines that have been separated in the past. One of the issues common to both fields, is the effect that land-use change will have on both the groundwater and surface-water resources of the country, either directly via recharge, or indirectly via saturated flow processes.

Senior staff changes and achievements

- **Mr HC Chapman**, Research Manager, retired in September. He had been with the WRC since 1977
- **Mr PM van der Schyff**, Director Administration, retired in November. He had been with the WRC since 1974
- **Dr GR Backeberg**, Research Manager, was elected President of the Agricultural Economics Association of South Africa
- **Dr SA Mitchell**, Research Manager, was elected President of the Water Institute of Southern Africa
- **Dr NP Mjoli** was promoted to Research Manager. She was also appointed by the Minister as Vice-Chairperson of the National Water Advisory Committee
- **Mr PE Odendaal**, Executive Director, was re-elected Vice-President of the International Association on Water Quality
- **Dr G Offringa** obtained the Ph.D. degree at the University of Pretoria with a thesis titled *A Decision Support Model for the Determination of Water Research Priorities*
- **Mr AG Reynders** was nominated to the Council of the International Association for Geohydrologists
- **Mr DS van der Merwe**, Deputy Executive Director, was appointed Vice-Chairman of the Africa Focus Group of the International Commission on Irrigation and Drainage (ICID), as well as Chairman of ICID's Working Group on the Impacts of Drought on Irrigated Agriculture.

2 DEVELOPING COMMUNITIES: WATER SUPPLY AND SANITATION



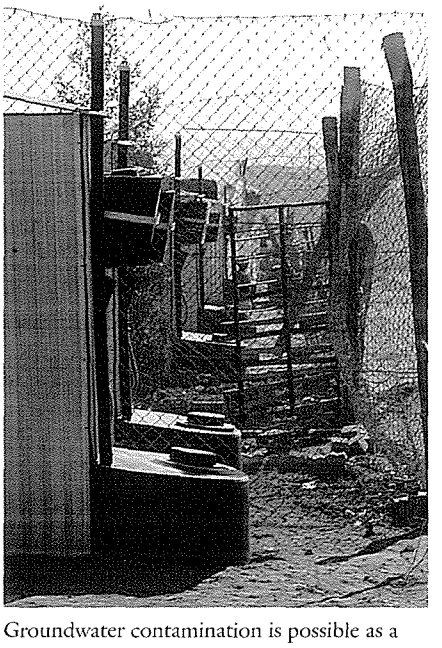
During the year under review, the WRC continued to increase its research budget allocation to this field and all these research projects will provide information that will support the implementation of the government's policies for the provision of basic services to the millions of South Africans who are unserved.

During 1996 the co-operation of a number of agencies and government departments led to the launch of the draft *National Sanitation Policy White Paper* at a National Sanitation Conference held in Cape Town in June. This White Paper provides a foundation on which future sanitation improvement programmes can be built. The major objective of the national sanitation policy is to improve the health and quality of life of all South Africans. This objective can only be achieved by integrating health and hygiene education into all new sanitation projects and community water supply improvement programmes.

It is essential to assess community knowledge and resources and to develop a hygiene programme that builds on what people already know. Research must, therefore, be done in order to establish a regionally or context-based understanding of existing health and hygiene practices, beliefs and knowledge for the different communities.

The Co-ordinating Committee for Research into Water Supply and Sanitation for Rural and Urban Communities (CCRUC) which was formed in 1995, made inputs to the development of a draft strategic research plan. Palmer Development Group (PDG) was appointed by the WRC to prepare a draft strategic research plan, based on contributions from CCRUC workshops. In this document, three research user groups were identified, namely:

- Government (national and provincial levels) has research needs for policy-making, regulations, institutional structures and subsidy mechanisms.
- Rural service agencies: these are organisations which are responsible for the delivery of services. This group will consider research needs of the communities they serve and those of consultants and contractors.
- Urban service agencies (municipalities): this user group will consider research needs of urban communities and project implementers.



Groundwater contamination is possible as a result of Third-World type urbanisation.

The concept of user groups received full support from CCRUC. These user groups will in future play an important role in guiding research in the field of water supply and sanitation for developing communities. The strategic research plan will be available early in 1997 in order to assist researchers in preparing project proposals that address the high-priority areas of research in this field.

Completed projects

Per capita water demand in developing communities

(No 480) Water Systems Management

Water use per household depends on many factors, namely, standard of living, family size, access to the water source, price of water and culture. An analysis of the importance and sensitivity of these factors and their inter-relationship is very important for planning sustainable water supply schemes.

This study assessed water demand patterns of developing communities in the Northern Province.

The following conclusions were drawn:

- Domestic water demand was a function of the value orientation of the community
- Water demand increased with the increase in the standard of living
- Water use was influenced by access to the water source, water quantity and quality
- Paying for water did not significantly reduce water demand for the very poor households; a 30% reduction in water demand was observed for households with a medium to high standard of living
- When planning new water supply schemes, provision must be made for the daily and seasonal variations in water demand.

Cost: *R472 000*
Term: *1992-1994*

Effect of water supply, handling and usage on water quality in relation to health indices in developing communities

(No 562) Division of Water, Environment and Forestry Technology, CSIR

Khayelitsha was chosen as study site as it contains different levels of water and sanitation provision and it has a relatively high incidence of diarrhoea in children.

Water provided to the study population was of good microbiological quality and complied with SABS guidelines but, after collection and storage, it was found to be of a poor quality.

No statistically significant association between poor in-house water quality and diarrhoea was observed, but analysis of questionnaire and observational data of the case-control study identified some risk factors for severe diarrhoea among pre-school children.

An increased risk of diarrhoea was associated with poor knowledge regarding food handling and hygiene, as well as a lower level of knowledge regarding the causes and prevention of diarrhoea and poor kitchen hygiene.

In the cross-sectional study, a comparatively larger proportion of diarrhoea cases was recorded from areas where communal taps were the type of water supply used, compared to areas where a tap was available on site.

Cost: *R868 800*
Term: *1993-1996*

Improving access to clean water supplies through a groundwater information programme.

New projects

Development of a strategy for disseminating information from the hydrogeological mapping programme to village water committees

(No 734) Water Systems Management

Groundwater is an important water source in most rural communities. Incorrect understanding of its nature and properties, however, has led to the poor confidence many communities have in this valuable resource. Because of the scarcity of water, it is of the utmost importance that communities gain confidence in groundwater and use it in a sustainable manner.

The need to ensure that communities are kept well informed and have access to information on their water supplies, is in line with the *White Paper on Water Supply and Sanitation Policy* recently released by the DWAF, which clearly states that communities will be given the responsibility of operating and managing their own water supplies. This is particularly relevant to groundwater resources which are most effectively managed at a local level.

The dissemination of information collated during the Department's now ongoing hydrogeological mapping programme will thus be of utmost importance if government policy on water supply and the water supply goals of the Reconstruction and Development Programme (RDP) are to succeed in rural areas. To ensure that this dissemination takes place effectively, the following objective has been formulated:

- Transfer of hydrogeological knowledge, arising out of the regional hydrogeological mapping programme, to communities so that they can understand and manage their own groundwater sources on a sustainable basis.

A key outcome of this project will be an expectation that communities will start to plan their groundwater resource development more strategically.

Estimated cost: *R200 000*
Estimated term: *1996*

Guidelines for the upgrading of existing rural water treatment plants

(No 738) Division of Water, Environment and Forestry Technology, CSIR

In South Africa many small water treatment plants have been installed in rural areas in an attempt to ultimately provide all households in the country with a supply of safe drinking water. However, a large number of these plants do not produce the quantity or quality of drinking water originally intended, for a variety of different reasons.

This project, therefore, aims to:

- Identify the typical problems experienced
- Investigate practical and affordable means to solve these problems
- Draw up a concise set of practical guidelines for the upgrading of existing rural water treatment plants.

Estimated cost: *R194 000*
Estimated term: *1996-1997*

Health impact of water-borne viruses and methods of control in high-risk communities

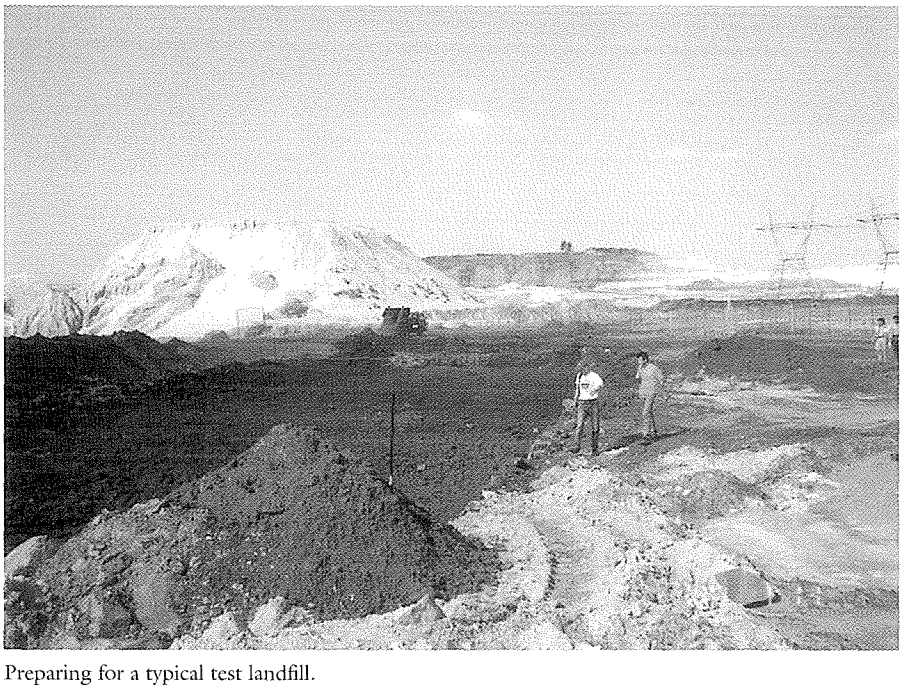
(No 743) Department of Medical Virology, University of Pretoria

Infectious diseases are the most important concerns associated with poor water quality. According to authoritative estimates, some 50 000 people in the world die each day as a result of water-borne and water-related infectious diseases. In addition to mortality, which affects mainly children in impoverished communities, water-borne diseases also have far-reaching socio-economic implications.

Viruses may account for about 75% of water-borne diseases. Some viruses are exceptionally resistant to unfavourable environmental conditions, and their minimum infectious dose may be as low as a single particle.

Information on the incidence and behaviour of enteric viruses in water is limited because the great majority of the viruses are not detectable by conventional laboratory techniques.

The Department of Medical Virology at the University of Pretoria has developed infrastructure and expertise for research on water-borne viruses. It is of utmost importance to establish indicator



Preparing for a typical test landfill.

systems for the practical and reliable monitoring of the virological safety of water supplies and the efficiency of water treatment processes.

The objectives of the research programme are as follows:

- Optimise techniques for the recovery of viruses from water
- Assess the correlation of viruses circulating in a community to viruses detectable in the waste water from the community
- Assess the implications of viruses in waste water from informal settlements for sanitation and the protection of water sources
- Assess the risk of water-borne human viral infections constituted by animal wastes
- Evaluate the reliability of practical indicator organisms for assessment of the virological quality of water
- Formulate recommendations for the control of water-borne viral diseases and practical routine monitoring of the virological safety of water.

Estimated cost: *R999 000*
Expected term: *1996-1998*

Water supply to rural and peri-urban communities using membrane technology

(No 764) Institute for Polymer Science, University of Stellenbosch

In many areas of South Africa people traditionally make use of borehole water to provide for their household needs. Alternative arrangements often need to be made to augment the potable water supplies during the drier months of the year, or when the water consumption exceeds the available water supplies.

The overall objectives of this project are to develop a package capillary ultrafiltration (UF) membrane filtration plant to provide affordable, safe drinking water from substandard surface or subsurface resources for use by rural, farming and/or otherwise deprived communities, schools and medical clinics.

The main aims of the project are to:

- Determine the usefulness of UF as a single-step clarification operation to provide good quality potable water from water which is unfit for direct human consumption
- Improve the productivity, performance and energy-efficiency of the UF membrane system
- Design a package demonstration filtration unit
- Provide a final operating protocol and design manual for a package capillary UF membrane treatment facility to provide potable water to communities of between 50 and 1 000 or more people in rural or peri-urban areas of South Africa.

Estimated cost: *R429 000*
Estimated term: *1996-1998*

Evaluation of on-site sanitation systems for applicability in low-cost housing from a socio-economic perspective

(No 765) Bernhardt Dunstan and Associates (BDA)

Provision of basic services to all South Africans is one of the main objectives of the RDP. These services must be cost-effective, appropriate, affordable and sustainable because the majority of people targeted are in the low-income category or unemployed. There should be emphasis on community participation to ensure that the services provided are a direct response to the needs of the beneficiary communities.

The main objectives of the project are to:

- Evaluate on-site sanitation systems from a socio-economic perspective
- Highlight key points for planning and policy intervention
- Highlight procedures that must be followed to implement viable and sustainable on-site sanitation systems.

The research output will include guidelines for planning and implementation of on-site sanitation systems in low-cost housing schemes.

Estimated cost: *R188 000*
Estimated term: *1996*

A small country town landfill.

Sustainability and affordability of community-based integrated waste and waste-water management for dense, informal urban settlements

(No 767) SRK (CE) Inc.

Rapid urbanisation has resulted in the increase in dense informal settlement areas which lack sewerage facilities. Disposal of greywater and solid waste in these areas poses a major environmental health hazard. This project will evaluate low-cost technology options for integrated solid waste and waste-water management for the dense informal urban settlements.

The main objectives of the project are to:

- Demonstrate the practicability of integrated waste-water and solid-waste management in optimising water quality improvements for environmental health
- Quantify the institutional and community requirements in promoting, establishing and financing community-based integrated waste-water and waste management
- Explore ways of empowering the communities and community-based organisations to operate their own localised sanitation and integrated stormwater management services.

Estimated cost: *R490 000*
Estimated term: *1996-1997*

Handbook of water disinfection processes

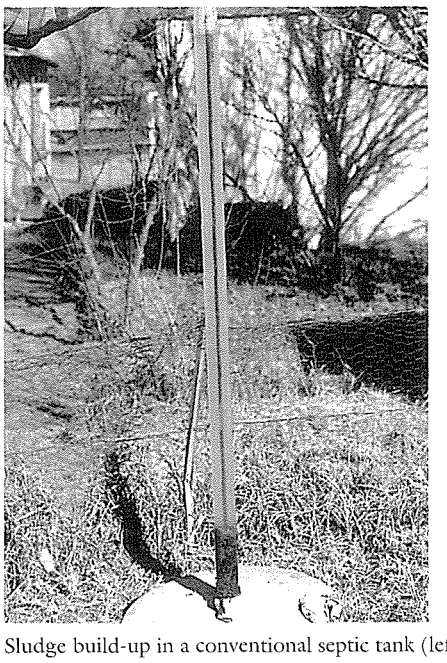
(No 770) Division of Water, Environment and Forestry Technology, CSIR

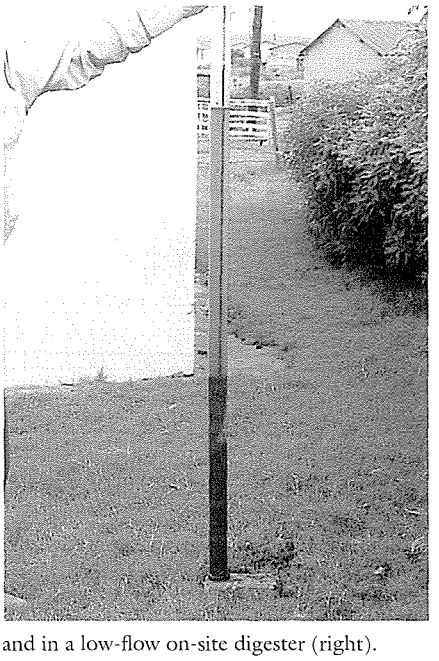
Surface and groundwater intended for drinking and domestic use inevitably has to undergo some form of final disinfection. This is often crucial to rendering it safe and fit for use and to prevent the spread of water-borne diseases. Outbreaks of epidemics of water-borne diseases can frequently be traced back to inadequate, defective or non-existent disinfection practices.

Neglect of adequate water disinfection can often be attributed to lack of knowledge and understanding on the part of plant managers and operator staff, of the importance of water disinfection in safeguarding human health.

In view of the above, the envisaged handbook will prove invaluable in providing essential information and background on disinfection processes in an understandable, assimilable and readily accessible form that can be used in training courses for plant personnel at all levels, as well as serving as a convenient handbook for everyday reference purposes, particularly on small water purification plants and in developing communities where small- to medium-scale disinfection needs to be undertaken.

Estimated cost: *R70 000*
Estimated term: *1996*





Sludge build-up in a conventional septic tank (left) and in a low-flow on-site digester (right).

Preparation of a booklet for new owners of sanitation systems that will contain the essential operation and maintenance requirements of sanitation systems

(No 771) Division of Building Technology, CSIR

One of the main causes of failure of sanitation systems is poor operation and maintenance due to the ignorance of users. The proposed booklet will provide user-friendly information on the operation and maintenance requirements of the different sanitation systems that are used in South Africa. The booklet will be translated into all official languages in South Africa in order to make the information accessible to all South Africans.

Estimated cost: *R76 000*
Estimated term: *1996*

Information booklet on drinking water for creating a greater awareness among the general public

(No 772) Division of Water, Environment and Forestry Technology, CSIR

In many communities, especially in the underprivileged communities, a basic understanding of the important issues that relate to the supply of drinking water is lacking. These communities need information on the various sources of drinking water that can be used, the treatment needed and the importance of ensuring the appropriate water quality. Once an awareness of these issues is created, the community will be empowered to make decisions regarding the level and type of water-supply system they would like to implement in the community.

The aim of this project is to produce an information booklet on drinking water which will hopefully make the general community more aware of their drinking water. The booklet will provide basic information on the possible sources and treatment of drinking water supplied to the community, water quality requirements, as well as the handling and possible pollution of drinking water.

Estimated cost: *R68 000*
Estimated term: *1996*

Application of visual settlement planning (ViSP) computer software in South Africa: Building the capacity of local communities in urban development

(No 786) Department of Civil Engineering, University of Cape Town

Community participation at the local level is an essential component of sustainable development. But it is constrained by several factors, the most important of which is the lack of capacity at this level. In particular, with respect to physical infrastructure and housing provision in urban areas, there is a growing need to develop methodologies to facilitate improvements in local capacity. An important contribution to this process would be the use of user-friendly computer images for interactive decision-making.

A system called visual settlement planning (ViSP) has been piloted successfully in Belo Horozonte in Brazil by the United Nations Centre for Human Settlement (Habitat). South Africa provides an ideal environment for further testing and improvement of such systems.

The project has a number of facets. Firstly, there is a need to adapt the technology to South African conditions. Secondly, there is the social component which explores how the approach might be used to empower communities to get a better insight in future options. Thirdly, it looks at integrated planning and engineering perspectives.

The project is carried out in collaboration with and support by Habitat and builds on an existing project being managed by the City of Cape Town in Ikapa.

Estimated cost: *R437 000*
Estimated term: *1996-1997*

Research projects

Completed

- **480** *Per capita* water demand in developing communities (Water Systems Management)
- **562** Effect of water supply, handling and usage on water quality in relation to health indices in developing communities (CSIR – Division of Water, Environment and Forestry Technology)

Current

- **346** Study of the relationship between hydrological processes and water quality characteristics in the developing Zululand coastal region (University of Zululand – Department of Hydrology)
- **384** Water resources and sanitation systems sourcebook with special reference to KwaZulu-Natal (University of Natal – Department of Economics)
- **386** Development of a cross-flow microfilter for rural water supply (University of Natal – Department of Chemical Engineering, and Umgeni Water)
- **435** Development of a training programme on community water supply management for village water committees (CSIR – Division of Water, Environment and Forestry Technology, and Appropriate Technology Information)
- **514** Groundwater contamination as a result of Third-World type urbanisation (CSIR -Division of Water, Environment and Forestry Technology)
- **519** Development of programmes to combat diffuse sources of water pollution in residential areas of developing communities (Afrosearch CC)
- **520** Guidelines on appropriate technologies for water supply and sanitation in developing communities (CSIR – Division of Water, Environment and Forestry Technology)
- **521** Water scheme cost recovery (Umgeni Water)
- **539** Development of a dynamic cross-flow sand filter for rural water treatment (CSIR – Division of Water, Environment and Forestry Technology)
- **544** Determination of sludge build-up rates in septic tanks, biological digesters and pit latrines in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **586** Development of a decision support system for the selection of the most appropriate sanitation option for developing communities (Umgeni Water)
- **598** Appropriate management of urban runoff in South Africa (University of the Witwatersrand – Water Systems Research Group and CSIR – Division of Water, Environment and Forestry Technology)
- **599** Co-disposal and composting of septic tank and pit latrine sludges with municipal refuse (CSIR – Division of Water, Environment and Forestry Technology, and La Trobe Associates)
- **603** Development of effective community water supply systems using deep and shallow-well handpumps (CSIR – Division of Water, Environment and Forestry Technology)
- **622** Rapid quantitative evaluation of water quality using a modified biological test – Phase 1 (University of the Witwatersrand – Department of Microbiology)
- **629** Evaluation of solid waste practice in developing urban areas in South Africa (Palmer Development Group)
- **630** Community participation and education in water resources management and environmental awareness (Amanzi Esizwe)
- **631** Assignment of a financial cost to pollution from on-site sanitation, with particular reference to Gauteng (University of the Witwatersrand – Department of Civil Engineering)
- **649** Assessment of common problems associated with drinking water disinfection in the developing areas (CSIR – Division of Water, Environment and Forestry Technology)
- **651** Appropriate low-cost sewage treatment using the advanced algal high-rate oxidation pond (Rhodes University – Department of Biochemistry and Microbiology)
- **656** Appropriate low-cost treatment of sewage reticulated in saline water, using the algal high-rate oxidation ponding (AHROP) system (Rhodes University – Department of Biochemistry and Microbiology)

- **670** Graded standards for landfilling in South Africa: Establishing appropriate affordable standards for disadvantaged communities (University of the Witwatersrand – Department of Civil Engineering)
- **671** Fog collection as a supplementary water source for small rural communities (University of the North – Department of Geography)
- **677** Guidelines for the evaluation of water resources for rural development with an emphasis on groundwater (Rhodes University – Institute for Water Research)
- **684** Development of a community-based integrated catchment management programme with special reference to water supply and sanitation in the Ntshongweni catchment (University of Natal – Farmer Support Group)
- **685** Occurrence and survival of protozoan parasites in source water and drinking water used by unserved rural communities (CSIR – Division of Water, Environment and Forestry Technology)
- **698** Land-based effluent disposal and use: Development of guidelines and expert-systems-based decision support (CSIR – Division of Water, Environment and Forestry Technology)
- **708** Guidelines for the operation and maintenance of septic tank effluent drainage (STED) systems by communities in South Africa (CSIR – Division of Building Technology)
- **709** Preparation of standard engineering drawings, specifications and guidelines for ventilated improved pit latrines in South Africa (CSIR – Division of Building Technology)
- **710** Pilot study for the development of a GIS database on water and sanitation in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **712** Biological processes in on-site low-flush volume sanitation systems (CSIR – Division of Water, Environment and Forestry Technology)
- **714** Socio-biological study of the aquatic resources and their utilisation in an underdeveloped rural region, the Mutshindudi River catchment (University of Venda -Department of Zoology)
- **715** Quantitative determination and removal of nitrogenous pollutants from natural waters (University of the Northwest – Department of Chemistry)
- **724** Pollution of domestic water supply and health-related problems in the rural areas of the Molopo region of the Northwest Province (University of the Northwest – Department of Nursing Science, Chemistry and Agriculture)
- **727** Effect of water supplies, handling and usage on water quality and quantity in relation to health indices in the Eastern Cape Province (Prowater Health) (University of Fort Hare – Department of Development Studies)

New

- **734** Development of a strategy for disseminating information from the hydrogeological mapping programme to village water committees (Water Systems Management)
- **738** Guidelines for the upgrading of existing rural water treatment plants (CSIR – Division of Water, Environment and Forestry Technology)
- **743** Health impact of water-borne viruses and methods of control in high-risk communities (University of Pretoria – Department of Medical Virology)
- **764** Water supply to rural and peri-urban communities using membrane technology (University of Stellenbosch – Institute for Polymer Science)
- **765** Evaluation of on-site sanitation systems for applicability in low-cost housing from a socio-economic perspective (Bernhardt Dunstan and Associates)
- **767** Sustainability and affordability of community-based integrated waste and waste-water management for dense, informal urban settlements (SRK (CE) Inc.)
- **770** Handbook of water disinfection processes (CSIR – Division of Water, Environment and Forestry Technology)
- **771** Preparation of a booklet for new owners of sanitation systems that will contain the essential operation and maintenance requirements of sanitation systems (CSIR – Division of Building Technology)
- **772** Information booklet on drinking water for creating a greater awareness among the general public (CSIR – Division of Water, Environment and Forestry Technology)
- **786** Application of visual settlement planning (ViSP) computer software in South Africa: Building the capacity of local communities in urban development (University of Cape Town – Department of Civil Engineering)

CONTACT PERSONS

- **Dr NP Mjoli** (Sanitation and Microbiological Aspects)
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3 POTABLE WATER SUPPLY

The challenges facing South African water utilities – whether large or small, urban or rural – in treating and supplying water cost-effectively to an acceptable potable quality are progressively increasing. A few reasons for this state of affairs seem to be the following:

- Urbanisation is taking place at a rate much higher than the average birth rate. This leads to a higher demand for potable water in the urban areas and increased pollution due to higher return flows of treated sewage effluents into surface water sources used for the production of potable water further down the catchment area.
- Expanding industrial activity adds to the burden.
- Supply of potable water to the previously disadvantaged communities is being stepped up as increased funding becomes available for these projects as a result of the increased priority to supply each citizen with a safe drinking water.
- Settlement of people in the catchment areas and on the banks of surface water sources is on a fairly sharp incline, leading to diffuse pollution which already exceeds point-source pollution of these water resources in many instances.

In order to ensure that all people in the country are provided with safe, wholesome and aesthetically acceptable drinking water under these demanding circumstances, water suppliers require the necessary knowledge and technology to fulfil these requirements.

In the above regard, the WRC supports both technical and sociological research projects pertaining to drinking water in the following main research areas, i.e. **Water Treatment and Reclamation, Drinking-Water Quality and Health Aspects**, and **Urban and Rural Water Supply**.

Water treatment and reclamation

This area of research deals with the development, improvement and selection of cost-effective plants and processes for the supply of drinking water which complies fully with the Department of Health water quality guidelines. The research is guided by the Strategic Plan for Research on Potable Water Treatment.

Water treatment and supply authorities are becoming increasingly concerned about the worsening pollution of surface water sources from both natural and anthropological organic matter. In this regard, the WRC is supporting a number of projects investigating the improvement of taste, odour, appearance and general health aspects of purified water by means of activated carbon, advanced oxidation and enhanced coagulation treatment. Special attention is also being paid to the modelling of algal growth in surface water (see **Water Quality Management**) the effect of algae and their exudates on the water treatment process, as well as the identification of problem algae and the amelioration of their negative effects on final water quality.

As part of the movement toward a "global village", international E-mail linkages have been established on a more formal basis between South African and international researchers in the drinking-water treatment field. Thus far, formal links have been formed in a number of specific areas of concern (see **Year under Review**: "International network for drinking-water research").

In order to provide some practical insights before the following up-date of the Strategic Plan for Research on Potable Water Treatment, as well as to ensure some technology transfer between the researchers in drinking-water treatment and the users of the research, a Technology Transfer Fair was arranged by the WRC. More details on this Fair are provided in the **Year under Review**.

Drinking-water quality and health aspects

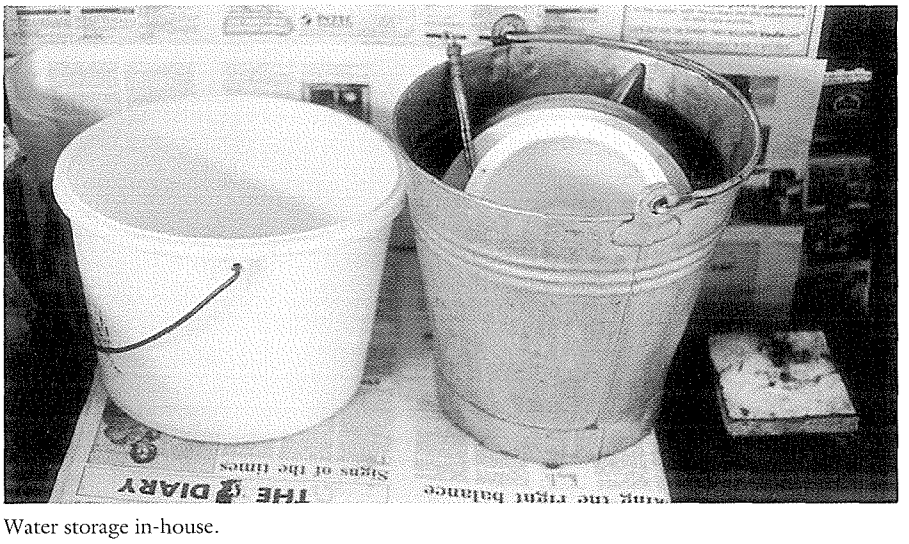
Water-borne diseases are the most important concern related to the quality of water. Differences exist between pathogens, regarding their size, structure, excretion by humans and animals and incidence and behaviour in water environments. This constitutes difficult challenges when monitoring the water to ensure its safety and providing efficient treatment processes. New epidemiological data, progress in technology and expertise, the methods and strategies for quality monitoring and control of water-borne diseases need to be continually revised and updated. Development of simple, economic and rapid methods for high-frequency basic monitoring of water quality and the efficiency of treatment systems is of the utmost importance.

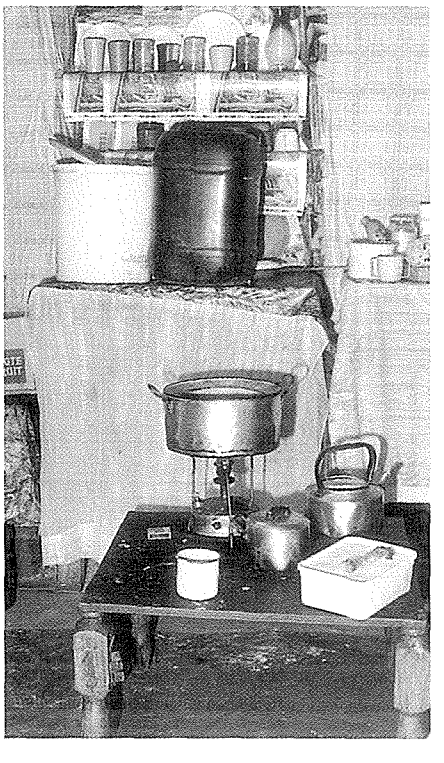
Coupled to this, there is a fundamental need for microbiological quality data in the management of national and regional water resources and supplies.

Therefore, in the near future it is expected that the emphasis will shift toward the monitoring and control of water quality in the interest of improved health for the whole of the population.

Rural and urban water supply

The unrelenting variability of nature is always a major factor in the equation when planning for the future. The 1994/95 rainfall was below average and the spring/summer of 1995 continued the trend. Water restrictions had to be imposed on many consumers throughout the country and large sums of money were spent by the DWAF, by water boards, notably Rand Water, and by local authorities, to promote water conserva-





Water storage in-house.

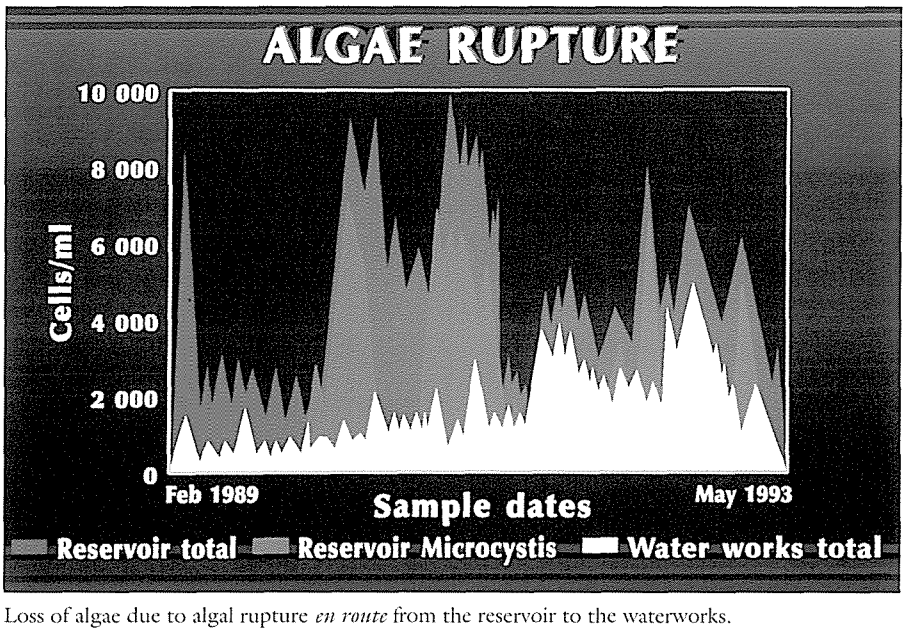
tion in the home, in the water distribution system and in the treatment processes. And then it rained! Within only three weeks all of the major storage facilities had recovered from levels of often less than 20% to in excess of full supply level.

Although the immediate urgency of a drought situation has, for the moment, declined, the challenge of water conservation remains. The main challenge now is to devise ways and means of convincing consumers and suppliers alike of the need to conserve water at a time when the dams are running over. This matter will have to be intensively and even aggressively addressed, to overcome the natural lethargy of consumers.

Droughts will recur, but, because of the increasing population, *per capita* consumption, industrial, commercial and agricultural expansion, what was previously regarded as a "good" year, will in future be regarded as marginal. This means that we can look forward to more frequent drought events (periods when demand exceeds supply long enough to put the supply resources under stress), and the severity of the worst cases will intensify. In Gauteng, full reservoirs today will only supply water for three to four years, whereas previously (only ten years ago), the same storage capacity was anticipated to provide water for seven to eight years.

Resulting from a WRC initiative in the 1980s, National Water Supply Regulations are expected to be published early in 1997. Simultaneously, the SABS has been drafting a Code of Practice (CoP) for the Management of Potable Water Distribution Systems. This is also expected to become available during 1997, initially for comment only. The CoP will include a Water Audit facility which was commissioned by the WRC for this purpose. (In simple terms, the difference between water purchased or put into supply, and water sold, is referred to as unaccounted-for water. Analysing the difference constitutes a water audit).

A third initiative which is now reaching fruition, is the Manual for the Reduction and Control of Unaccounted-for Water (UAW). The manual is a major product emanating from a current WRC project (No 489). Originally, it was anticipated that the manual would be a seed document for the CoP, but due to circumstances, the two documents have reached an advanced stage simultaneously. As a result it was agreed by all of the involved parties, that the two should be merged to form a single, comprehensive document, representing virtually everything that has ever been written on the subject.



Loss of algae due to algal rupture *en route* from the reservoir to the waterworks.

Completed projects

Evaluation of non-conventional disinfection technologies for small water systems

(No 449) Division of Water, Environment and Forestry Technology, CSIR

United Nations agencies like WHO, Pan American Health Organization, UNICEF, etc., usually refer to chlorine disinfection in rural areas as a failure. The reason for this is that the acquisition of the chemicals poses a difficult obstacle in small rural and informal settlement areas. Therefore, support has gone into non-traditional ways of disinfecting water and in recent years new technologies have come into use. The objectives of this project were to identify potential non-conventional disinfection technologies and their comparative disinfection abilities, power consumption (where applicable), reliability, cost and operational needs, in order to be able to select the appropriate system for small water treatment plants.

The researchers selected the following as being the best candidates for small community water supplies: UV radiation, MOGGOD (mixed gases generated on-site for disinfection) systems and on-site hypochlorination production. All three have the required characteristics if they are to be used in small communities (including remote rural areas) with success. However, the researchers have suggested that further field evaluations of the technologies should take place before final recommendations can be made.

Cost: *R130 000*
Term: *1992-1993*

Algal rupture – Further investigations

(No 558) Scientific Services, Umgeni Water

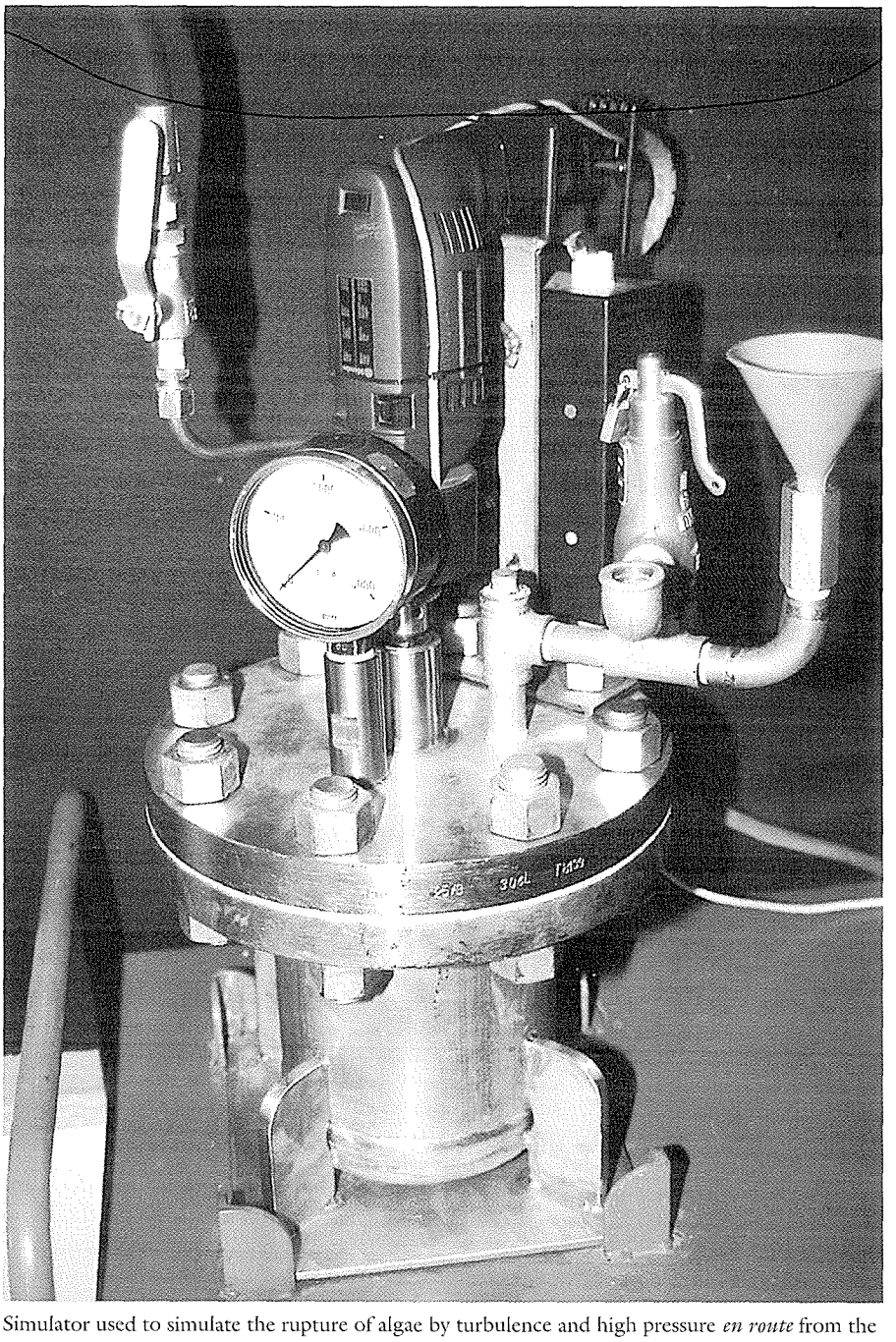
Preliminary investigations have shown that there is a loss of algae (particularly *Microcystis*) during the passage of water from an impoundment to the treatment works. The consequences include increased coagulant demand and increased concentrations of trace organics, such as geosmin, algal toxins and THMs, which are liberated into the water.

The objectives of the project were to

further investigate the effect of algae and algal rupture in abstracted water on the release of organics into the water and its impact on coagulant demand and activated carbon usage.

It was found that between 61% and 72% of *Microcystis* cells ruptured under the conditions experienced (1 300 kPa and 1,6 m/s velocity). Coagulant demand and geosmin release increased by several fold when cells were ruptured. The cost of water treatment was shown to increase significantly with the increase in algal cell numbers, and, especially, with increased rupture of these algal cells. The most important cost increase was in terms of activated carbon, followed by increased coagulant required to produce an acceptable drinking water.

Cost: *R50 000*
Term: *1993*



Simulator used to simulate the rupture of algae by turbulence and high pressure *en route* from the reservoir to the waterworks.

Atlas of potentially water-related diseases in South Africa

(No 584) Department of Community Health, University of Cape Town

An atlas of potentially water-related diseases in South Africa was compiled and the seriousness of these diseases, especially for pre-school children, emphasised.

Volume 1: Registered deaths in South Africa for 1990 were statistically analysed. Statistics excluded the former homelands as data were not available.

Causes of death were analysed for each geographic area and results presented in a series of tables and maps. The tables contain information on the 56 causes of death listed according to the basic tabulation list of the ICD (International Classification of Diseases) and a more detailed list of water-related diseases in South Africa which caused death.

The results of the study showed the following water-related mortalities:

- Intestinal infections
  2,87% of all deaths
- Accidental drowning
  0,60% of all deaths
- Viral hepatitis
  0,09% of all deaths
- Malaria
  0,03% of all deaths

Volume 2: Fourteen water-related diseases are described under the following headings : aetiology of the disease, prevalence in South Africa, critical bibliography relating to South Africa and interventive and/or ameliorative action.

Cost: *R94 000*
Term: *1993-1994*

Removal of invertebrates by sand filtration and the influence thereof on water quality

(No KV76/95) Scientific Services, Rand Water

As the status of invertebrata-related potable water quality was not known in South Africa, the study aimed to investigate the following aspects:

- The relationship between invertebrate population in filtered water and specific properties of filter media
- The effect of invertebrates on water quality determinants such as turbidity and biologically assimilable organic carbon
- The effect of recycling filter backwash water on the occurrence of invertebrates on filters and in filtered water.

It was found that sand particle size and uniformity did not play an important role. Only when using very coarse sand types did invertebrate breakthrough become significant.

Proper filter backwashing at the sand fluidisation point improves invertebrate removal, as does proper disinfection of the filters. Other micro-organisms, mostly bacteria, were found together with the invertebrates, but the micro-organisms identified do not seem to pose a health problem.

A guideline for allowable invertebrate levels in purified water was suggested.

Cost: *R76 000*
Term: *1994*

Development of a plastic-bodied water meter for use in South Africa

(No KV78/95) Kent Measurement (Pty) Ltd.

Many authorities have in the past expressed an opinion that a cheap, possibly plastic-bodied water meter would be ideal for low-cost housing because of the problem of theft for the scrap value of brass-bodied water meters. The concept of using a disposable plastic body with no intrinsic material value hence deserved consideration in this particular type of environment.

Although plastic-bodied meters have been manufactured over the past 15 to 20 years, they have failed to capture a significant market share because of problems caused by structural/chemical failures of the plastic bodies. In this project, several materials were selected and evaluated in terms of their suitability for the manufacture of a plastic-bodied water meter which overcomes the mechanical and chemical stability problems of the plastic raw material under diverse installation conditions.

The final product of the project was a cost-effective plastic-bodied water meter which meets all the requirements of a robust water meter. The project team recommended that this water meter should be manufactured in South Africa and marketed throughout the world.

Cost: *R94 000*
Term: *1992-1994*

New projects

Additional treatment requirements of water abstracted from the Vaal River system following the importation of Lesotho Highland water

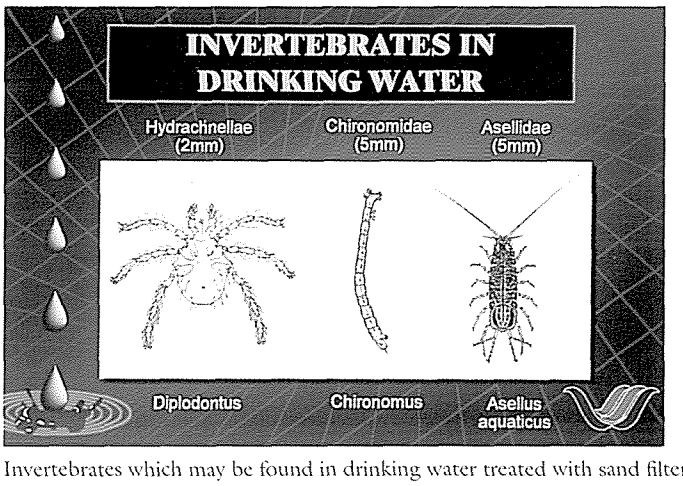
(No 737) Scientific Services, Rand Water

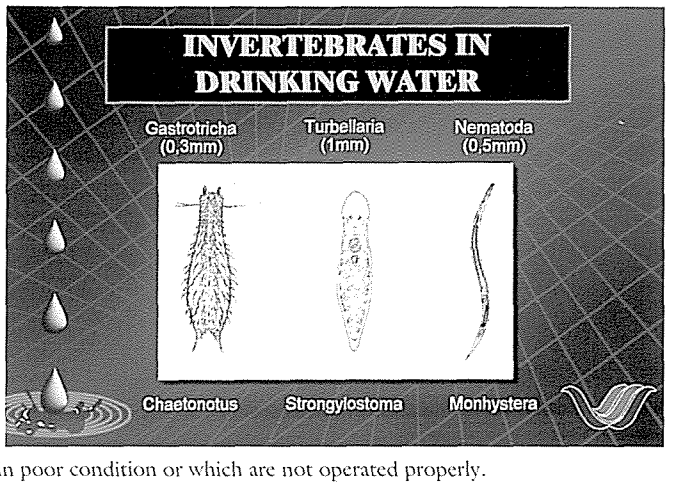
It is envisaged that the importation of water from the Lesotho Highlands Scheme into the Vaal River system could affect the treatment requirements of water which is abstracted and purified for domestic and industrial purposes. The following possible consequences, in particular, are relevant:

- Suspended matter is expected to increase during the initial release of Lesotho Highland water as river courses are carved deeper by the higher flow rates
- Changing mineralogical composition of the suspended matter may require changes in coagulation and flocculation systems presently in use
- Expected changes in algal populations may require alternative treatment methods
- Lower expected alkalinity will result in additional stabilisation requirements.

Therefore, the project aims to:

- Establish the most probable changes of chemical composition of water released from the Vaal Dam





Invertebrates which may be found in drinking water treated with sand filters in poor condition or which are not operated properly.

- Determine how this will affect the future treatment requirements of the water.

Estimated cost: *R236 000*
Expected term: *1996-1997*

Enteropathogens in water; rapid detection techniques, occurrence in South African waters and the evaluation of epidemic risks (health related)

(No 741) Division of Water, Environment and Forestry Technology, CSIR

Epidemics of typhoid fever, cholera and shigellosis are often associated with developing and rural communities with inadequate or non-existent sanitation. Recent outbreaks of typhoid fever in Delmas, cholera outbreaks reported in other parts of South Africa and shigellosis in KwaZulu-Natal showed the importance of addressing the problem.

It is important in the case of an outbreak to be able to establish the cause of the disease as soon as possible. New methods for the detection of enteropathogens in water have been developed and applied lately. Following adaptation of these techniques for South African conditions and the evaluation of the presence of these pathogens in South African waters, a risk assessment relating the numbers of organisms detected to their associated epidemic risk will be possible. This would be valuable in assessing and quantifying the problems associated with the occurrence of these organisms in the South African context.

Estimated cost: *R294 000*
Expected term: *1996-1997*

Qualitative and quantitative evaluation of oestrogen and oestrogen-mimicking substances in the water environment

(No 742) Scientific Services, Rand Water

The issue of environmental oestrogens and claimed "oestrogen-mimicking" substances has been the subject of emotional controversy in recent years. These substances are being accused of wreaking havoc with human and animal reproductive systems.

In general, there is a paucity of information regarding the organic composition of sewage effluent, and of both raw and treated waters in South Africa. This information will assume more significant proportions as South Africa prepares for increased water recycling and reclamation.

This project is not aimed at specific cause-and-effect relationships, but to establish which of the claimed substances are likely to occur in the water environment, the possible sources and how the occurrence of the substances can be reduced. If findings indicate a potential problem, effects of the substances can be further evaluated by the water industry with a view to developing cost-effective treatment methods.

Estimated cost: *R255 000*
Expected term: *1996-1997*

Development of a model to be used for the optimisation of the pumping and design policies of reservoir systems

(No 757) Water Systems Research Group, University of the Witwatersrand

Water pumping costs constitute some 16% of Rand Water's running expenses. As the current model, relating the pumping rate to user requirements, was developed in 1980 it is essential that it be upgraded to accommodate distribution system changes that have since been introduced.

The current project, therefore, aims to:

- Develop a dynamic computer simulation model which can be used by operators of reservoir storage systems to optimally relate the pumping operation to changes in the demand pattern
- Use the dynamic model produced to evaluate existing design parameters relating to normal as well as emergency storage capacity.

Although the model will be based on the distribution set-up and flow data obtained at two reservoirs in Rand Water's distribution system, it will ultimately be generalised for use at other reservoirs and pumping stations.

Estimated cost: *R377 000*
Expected term: *1996-1997*

Enhanced coagulation for the removal of disinfection by-product precursors

(No 773) Scientific Services, Umgeni Water

Expensive treatment options such as ozonation, advanced oxidation and granular activated carbon are gaining popularity, but these options are not always viable, especially at smaller water treatment facilities, where both the capital costs and the need for skilled personnel to operate such processes, preclude them. However, coagulation aimed specifically at optimal organics or disinfection by-product removal ("enhanced" coagulation) may enable treatment facilities to significantly reduce harmful organic contaminants at very little additional cost and may even obviate the need for much more costly and sophisticated treatment processes.

The project aims to assess the reduction in disinfection by-product precursors, pesticides/herbicides and taste and odour compounds achievable using enhanced coagulation on typical, organically polluted surface waters. Using these results, guidelines will be produced for the treatment of different waters typical to South Africa.

Estimated cost: *R60 000*
Expected term: *1996*

Use of chloramination and sodium silicates to inhibit corrosion in mild steel pipelines

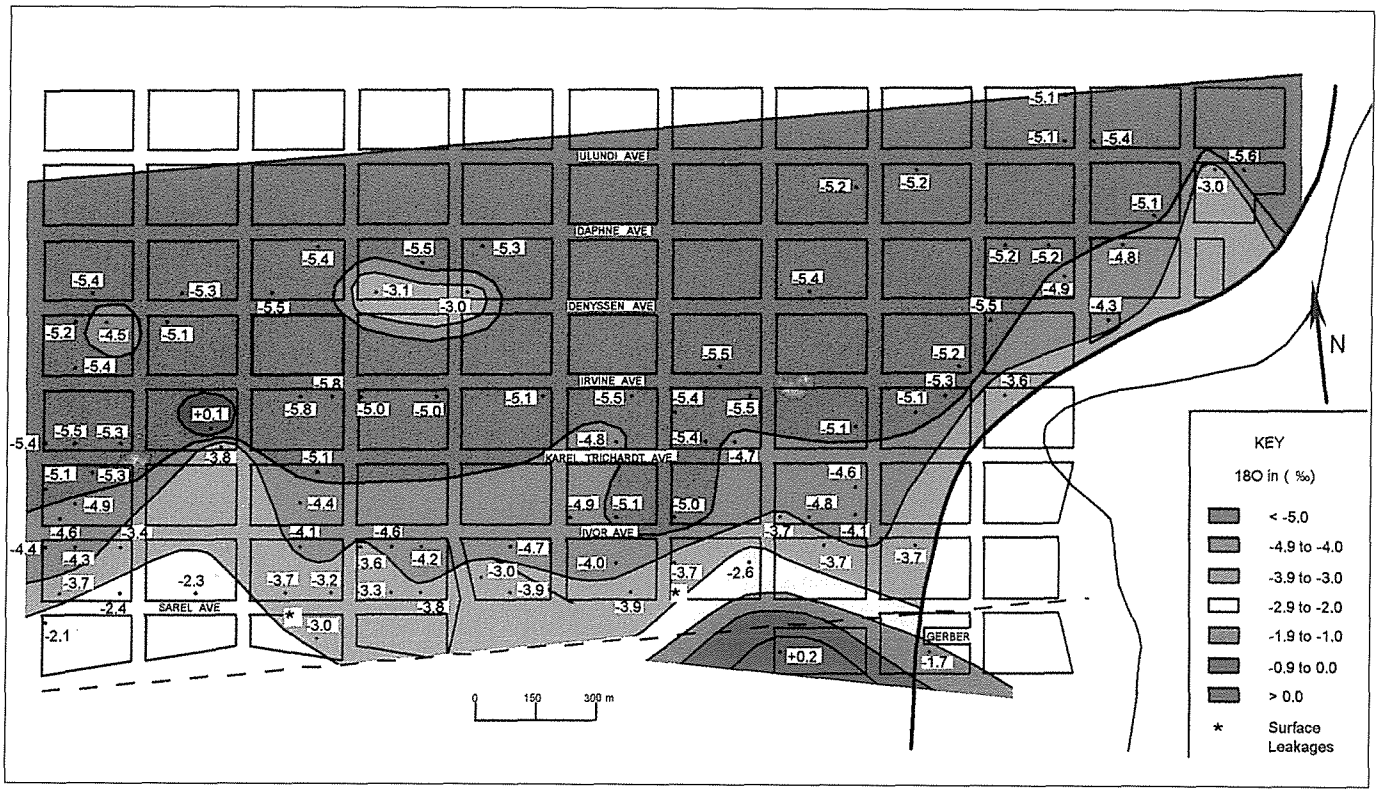
(No 779) Scientific Services, Rand Water

Distribution and reticulation systems are prone to damage by corrosive waters, and this leads to financial losses in the repair of pipelines, as well as water lost from the system.

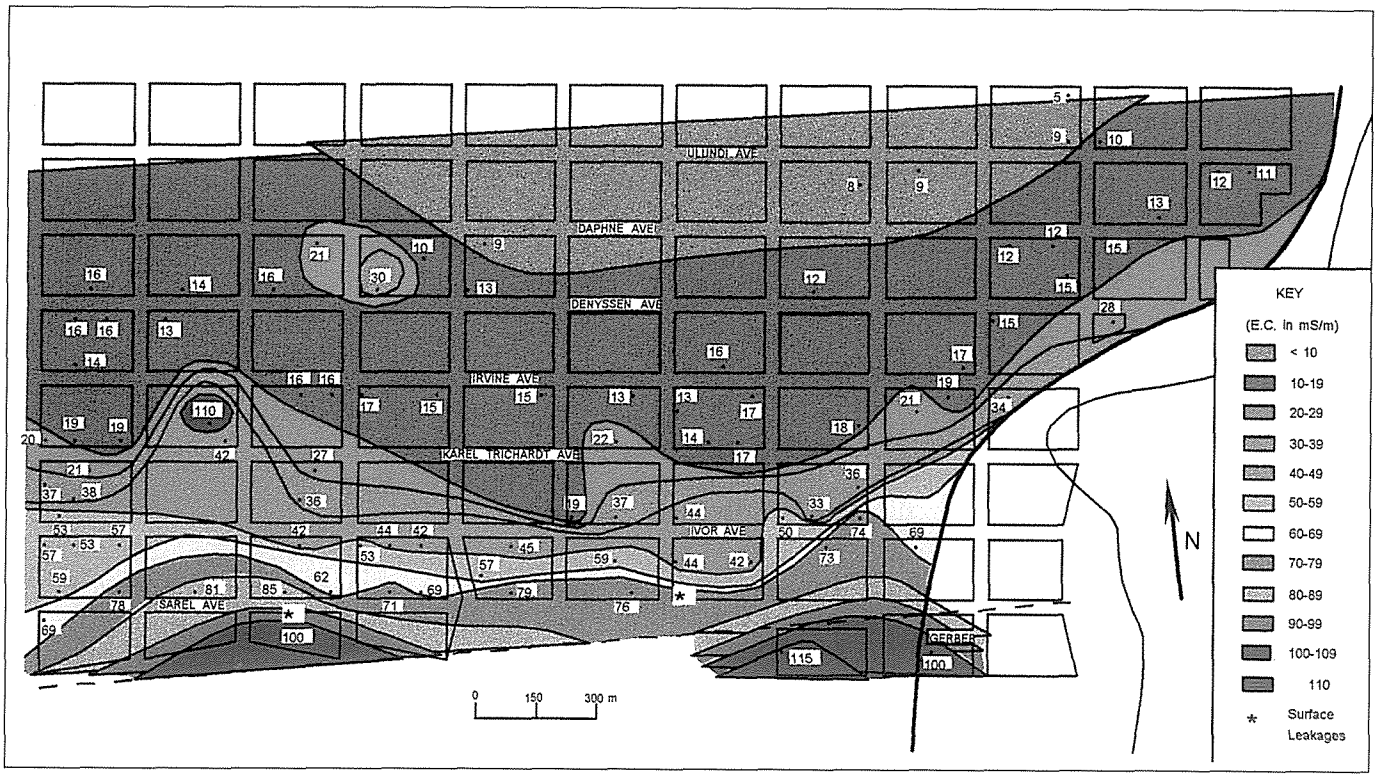
Although the inhibiting action of monochloramine and sodium silicates against corrosion has been described, they are seldom utilised for that purpose in the production and distribution of potable water.

The use of monochloramine could serve a twofold purpose – by protecting pipeline systems against corrosion and at the same time serving as a disinfectant and preventing microbiological deterioration during distribution.

The objectives of the research project are to determine the extent to which cor-



A plan of Mountain View, Pretoria, showing zones of increasingly heavy isotope composition of the underlying groundwater down slope. This shows that near the top, natural groundwater is found, with increasing proportions of mains water lower down.



A plan of Mountain View, showing zones of increasing dissolved solids in the groundwater. Note the similarity with the general distribution of isotopic values, also showing leakage sites. The dissolved solids are partially natural and partially introduced with the mains water.

rosion in steel pipes can be inhibited or reduced by the use of chloramines or sodium silicates; to find the optimal dosages and conditions necessary and to determine health effects of these additives on consumers.

Estimated cost: *R110 000*
Estimated term: *1996*

Production of a corrosion brochure for local authorities

(No 787) Division of Materials, Sciences and Technology, CSIR

Recently completed research has clearly shown that the external corrosion of buried metallic pipelines is a major concern for water supply authorities.

To enable water supply authorities to effectively develop a suitable corrosion protection strategy, a concise guideline brochure, based on the results of the earlier research, will be produced to guide them in the identification of corrosion characteristics of various metallic piping materials and the appropriate remedial measures to inhibit or prevent further corrosion.

The brochure will highlight cost-effective ways in which external corrosion can be minimised and could even be used by repair teams working in the field to identify causes of failure.

This will enable local authorities to build up their own databases, assisting them in implementing appropriate corrosion prevention strategies.

Estimated cost: *R60 000*
Estimated term: *1996*

Research projects

Completed

- **449** Evaluation of non-conventional disinfection technologies for small water systems (CSIR – Division of Water, Environment and Forestry Technology)
- **558** Algal rupture – Further investigation (Umgeni Water – Scientific Services)
- **584** Atlas of potentially water-related disease in South Africa (University of Cape Town – Department of Community Health)
- **KV76/95** Removal of invertebrates by sand filtration and the influence thereof on water quality (Rand Water – Scientific Services)
- **KV78/95** Development of a plastic-bodied water meter for use in South Africa (Kent Measurement (Pty) Ltd.)

Current

- **259** Effect of water quality and chemical composition on the corrosivity in mild steel pipelines (Rand Water)
- **280** Evaluation of full-scale flotation-filtration and chlorine dioxide plants (Orange Free State Gold Fields Water Board)
- **282** Development of a combination of sedimentation, flotation and sand filtration processes for water treatment (SEDIDAFF) (CSIR – Division of Water, Environment and Forestry Technology)
- **354** Evaluation and development of deep-bed filtration for the treatment of South African surface waters (CSIR – Division of Water, Environment and Forestry Technology and Local Government Affairs Council)
- **358** Development of guidelines for toxicity bioassaying of drinking and environmental waters in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **363** Development and evaluation of small-scale potable water treatment equipment (University of Natal – Department of Chemical Engineering and Umgeni Water)
- **381** Corrosion performance of various non-metallic piping materials and coatings in potable water (CSIR – Division of Materials, Sciences and Technology)
- **383** Holistic approach to affordable planning and maintenance of water and sewer systems (Water Management Services)
- **443** Compilation of guidelines for the use of peroxone and other oxidants in the treatment of eutrophic water (CSIR – Division of Water, Environment and Forestry Technology)
- **446** Ozonation in the production of potable water from polluted surface water (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering and Rand Water)
- **450** Performance criteria for package water treatment plants (Umgeni Water and University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **470** Application of health risk assessment techniques to microbial monitoring data (CSIR – Division of Water, Environment and Forestry Technology)
- **488** Optimisation of the Rand Water system (University of the Witwatersrand – Water Systems Research Group)
- **489** Development of procedures for the control of unaccounted-for water in water distribution systems and for the reduction of water loss (De Leuw Cather Inc.)
- **504** Guide for water purification and plant design: Phases 2 and 3 (Dr FA van Duuren)
- **534** Guidelines for the treatment of Eastern and Southern Cape coloured water (CSIR – Division of Water, Environment and Forestry Technology)
- **537** Guidelines to coagulation and flocculation for South African waters (Pavel Polasek Association)
- **540** Evaluation of the use of bacteriophages as indicators for water quality (University of Pretoria – Department of Medical Virology)
- **541** Bio-degradable organic compounds and microbial regrowth in drinking water (Rand Water)
- **549** Algal toxins in drinking-water supplies (CSIR – Division of Water, Environment and Forestry Technology and Umgeni Water)
- **557** Optimal operation of combined flotation/filtration of eutrophic surface water (Rand Afrikaans University – Laboratory for Energy)

- **567** Occurrence and distribution of algal species and related substances in a full-scale water purification plant (University of the Orange Free State – Department of Botany and Genetics)
- **568** Development of an Exxpress unit for the production of potable water and the dewatering of waterworks sludges (Umgeni Water)
- **587** Evaluation of water pipe leaks in the Johannesburg municipal area (CSIR – Division of Materials, Sciences and Technology)
- **591** Study for the provision of point-source water by air-gap membrane distillation (University of Stellenbosch – Institute for Polymer Science)
- **611** Development of procedures for bio-degradability testing of organic chemical compounds (CSIR – Division of Water, Environment and Forestry Technology)
- **613** Stabilisation of aggressive and corrosive waters (CSIR – Division of Water, Environment and Forestry Technology)
- **614** Expert system for water treatment plant design and analysis (Wates, Meiring and Barnard Inc., Sutherland and Ass.)
- **615** Modelling the causes of algal blooms in impoundments of the Umgeni catchment and the consequences for potable water treatment (Umgeni Water)
- **621** Balancing tank control application (Watson Edwards Inc.)
- **628** Leak detection from municipal mains water systems in the PWV area using environmental isotopes (University of the Witwatersrand – Schonland Research Centre for Nuclear Sciences)
- **648** Application of computational fluid dynamics to improving the design and operation of water and waste-water treatment plants (University of Natal – Department of Chemical Engineering)
- **662** Evaluation and optimisation of a cross-flow microfilter for the production of potable water (University of Natal – Pollution Research Group)
- **679** Compilation of a computerised, diagnostic system for algal-related water purification problems (Rand Water – Scientific Services)
- **694** Treatment of eutrophic waters using pre- and intermediate ozonation, peroxone and Pica carbon (Umgeni Water)
- **704** Prediction of chlorine loss from potable water in pipeline systems (Rand Afrikaans University – Department of Civil Engineering)
- **705** Re-evaluation of the existing guidelines for urban and industrial water supply, based on measured water uses Phase 1: Pretoria supply area (University of Pretoria – Department of Civil Engineering)

New

- **737** Additional treatment requirements of water abstracted from the Vaal River system following the importation of Lesotho Higland water (Rand Water – Scientific Services)
- **741** Enteropathogens in water; rapid detection techniques, occurrence in South African waters and the evaluation of epidemic risks (health related) (CSIR – Division of Water, Environment and Forestry Technology)
- **742** Qualitative and quantitative evaluation of oestrogen and oestrogen-mimicking substances in the water environment (Rand Water – Scientific Services)
- **757** Development of a model for the optimisation of the pumping and design policies of reservoir systems (University of the Witwatersrand – Water Systems Research Group)
- **773** Enhanced coagulation for the removal of disinfection by-product precursors (Umgeni Water – Scientific Services)
- **779** Use of chloramination and sodium silicates to inhibit corrosion in mild steel pipelines (Rand Water – Scientific Services)
- **787** Production of a corrosion brochure for local authorities (CSIR – Division of Materials, Sciences and Technology)

CONTACT PERSONS

- **Dr G Offringa** (Water Treatment and Reclamation and Membrane Applications)
- **Mrs APM Oelofse** (Drinking-water Quality and Health Aspects)
- **Mr JN Bhagwan** (Water Supply, Water Loss Control and Corrosion)
- **Dr TC Erasmus** (Cross-flow Microfiltration)
- **Dr SA Mitchell** (Bioassaying)

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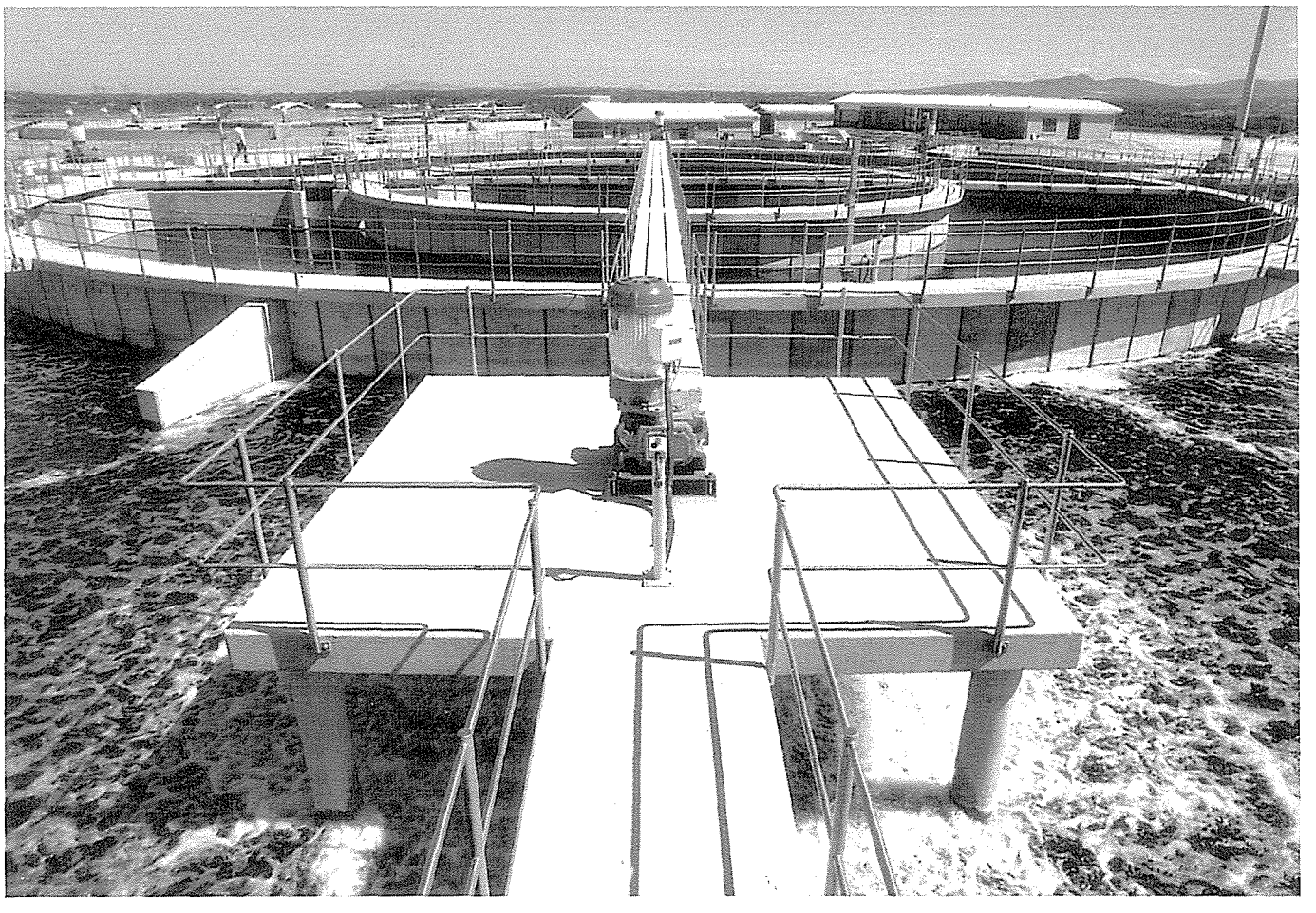


Projected increases in water demand with both the projected population increase and the projected *per capita* increase with increasing sophistication of the consumer economy indicate that the importance of effective effluent treatment will increase. One problem that has beset the municipal waste-water treatment industry for some time is the bulking of sludges in activated sludge systems. The understanding of this has risen to a level where full-scale plants are being investigated to see if bulking sludges can be correlated to the presence of denitrification intermediates in the recycle.

The co-ordinating committee met during the year to review the Strategic Research Plan.

Completed projects

Co-disposal of sewage sludge and refuse

(No 391) City Council of Cape Town

This research was carried out at the Coastal Park landfill site using thickened (2% solids) sludge from the adjacent Cape Flats Waste-Water Treatment Works. Monitoring of the experimental (co-disposal) and control (municipal solid waste only) sites showed that the safe working ratio was 6 parts refuse to 1 part sludge by volume during the winter (wet season) and 4:1 during the summer (dry season). The moisture content of the co-disposal line was less than calculated, and a little leachate was generated from the co-disposal line in winter only. The control line generated very little leachate. The volume of gas production could not be measured, but the gas constituents were similar for both the experimental and control lines. The work concluded that co-disposal is a viable management strategy in suitable circumstances, and that the added moisture in the sludge will enhance the microbial breakdown of the municipal solid waste.

Cost: *R69 000*
Term: *1991-1993*

Human viruses in diffuse effluents and related water environments

(No 496) Department of Medical Virology, University of Pretoria

The primary objective of this research project was to study the impact of rapid urbanisation and squatting on the biological quality of water resources.

There are still many shortcomings in the methods for the recovery and detection of viruses and to be able to get a better understanding and assessment of the health risks in the environment, it was necessary to test and refine the methods first.

A protocol has been developed for user-friendly procedures that cost less than the standard faecal coliform tests and are more specific to identify the cause of the disease. Technology for the isolation of viruses has been improved. The combination of cell cultures is now being used routinely for the virological analysis of water in the laboratories of the Virology Department of the University of Pretoria. This may be the most sensitive cell-culture system being used for the detection of viruses anywhere in the world.

These refined methods were used in two studies during outbreaks of gastro-enteritis and revealed new information on water pollution and related health risks, which is essential for defining appropriate water quality criteria.

The results of the research on the quality of diffuse effluents from two informal settlements showed that diffuse effluents from these settlements with restricted or no sanitation carry heavy loads of faecal organisms, and in at least some cases, also large numbers of viruses to water sources such as receiving streams, rivers and impoundments.

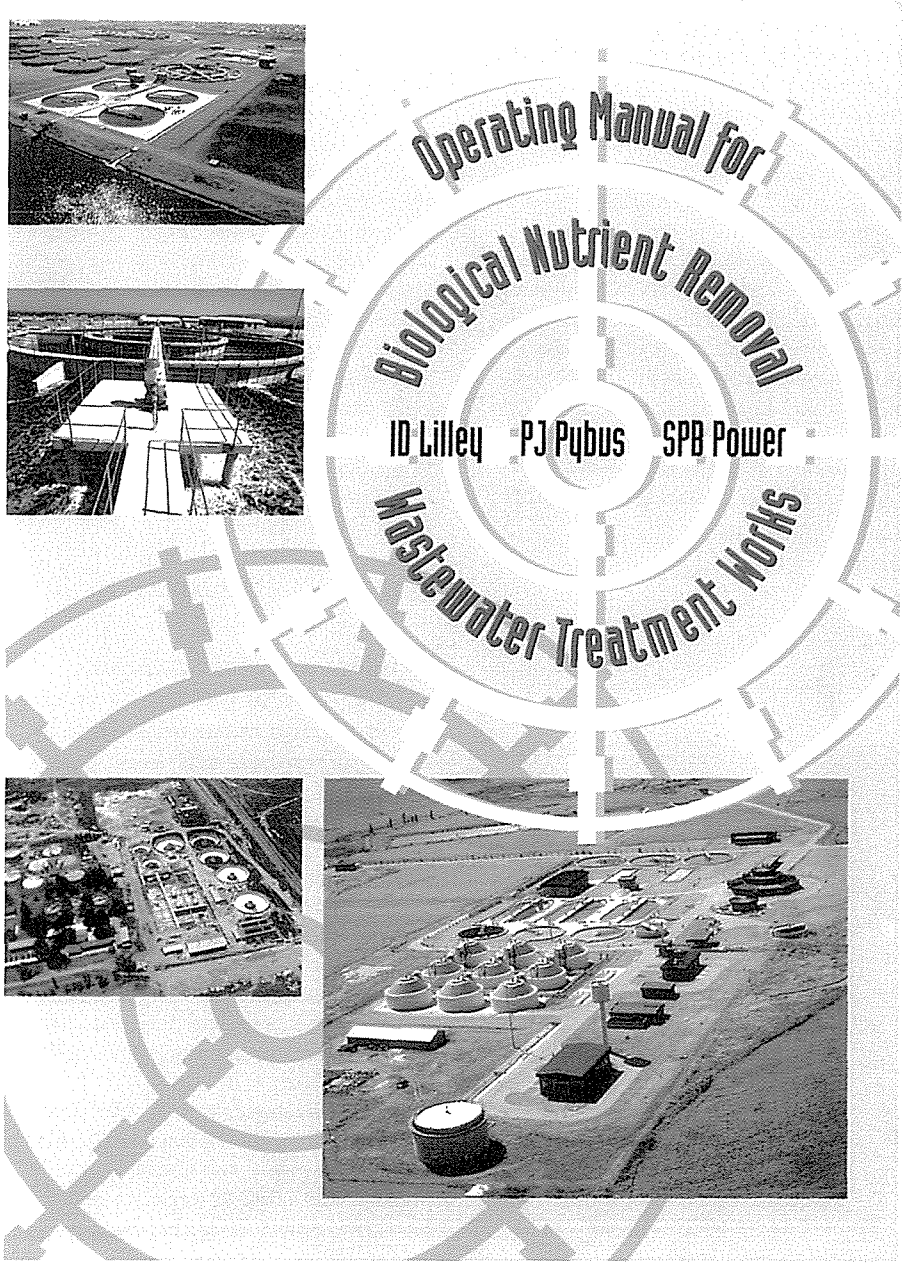
Cost: *R583 000*
Term: *1992-1994*

Compilation of an operating manual for biological nutrient removal waste-water treatment works

(No 607) Stewart Scott (CE) Inc.

The need for an operating manual for biological nutrient removal (BNR) waste-water treatment works had been identified by the Nutrient Removal Division of the Water Institute of Southern Africa. The end-product complements the 1984 manual on the theory and design of these plants, a publication which is in great demand, nationally and internationally.

The operating manual is written for managers, staff and owners of BNR plants. Its objective is to assist trained operators to understand the complexities



of the BNR process, and so enable them to optimise control of their plants. The manual assumes experience in the basic activated sludge process, and covers only those aspects of the process related specifically to the BNR. Consultants commissioning new works can use this manual as the basis for works management and operation, with the addition of items specific to the plant being commissioned. In addition it will provide valuable training material for pupil-operators' training in the operation of BNR works.

Further to covering relevant aspects of the process from the head of works to final clarifiers in a logical way, the manual also covers the operation of the Phostrip, a sidestream P-removal process, the tests that a plant operator needs to perform and the various legal and policy aspects relevant to the running of a plant. The final chapter is an easy-to-follow trouble-shooting table.

The manual, therefore, collates existing information and procedures into a single, logical and easily digestible package with particular emphasis on operational aspects, aimed at the transfer of BNR technology to plant operations staff. This is particularly relevant in the light of the current WRC initiative on the education and training of operators.

Cost: *R114 900*
Term: *1994-1996*

New projects

Disinfection of purified effluent

(No 739) Division of Water Utilisation Engineering, Department of Chemical Engineering, University of Pretoria

All purified waste waters should conform to the General Standard for microbiological quality, i.e. zero faecal coliforms per 100 m*l*. Often exemption permits are allowed. This sometimes results in the disinfection of purified waste waters not being seen as a very high priority. In certain cases uncontrolled disinfection may even cause damage to the water environment.

An example is that the mixing of chlorine and waste water, especially in terms of the contact period, is not always carried out correctly. Much larger chlorine dosages than required are added to the water, which promotes the formation of chlorinated components that may have a damaging effect on the water environment and human health.

The aims of the project are to compile guidelines for the improvement of present practices for the disinfection of purified waste water and in particular to assess the chloramination disinfection process. This would lead to cost savings in the disinfection of treated waste waters accompanied by improvement in the general water quality.

Estimated cost: *R141 000*
Expected term: *1996-1997*

Development of strategies for amelioration of bulking by anoxic-aerobic filamentous organisms in nutrient removal activated sludge systems

(No 775) Stewart Scott (CE) Inc.

The researchers aim to further investigate sludge bulking by conducting a survey of plants and examining the data collected partly in the light of laboratory work which indicated that bulking sludges are the result of incomplete denitrification in the return activated sludge entering the aerobic reactor.

Control strategies will be developed and implemented for plants which show bulking problems, and a manual will be prepared outlining strategies to be followed to control sludge bulking.

Estimated cost: *R388 500*
Expected term: *1996-1998*

Fingerprinting of activated sludge systems using PAGE analysis of total protein extractions for the optimisation of biological phosphorus removal

(No 776) Department of Microbiology and Plant Pathology, University of Pretoria

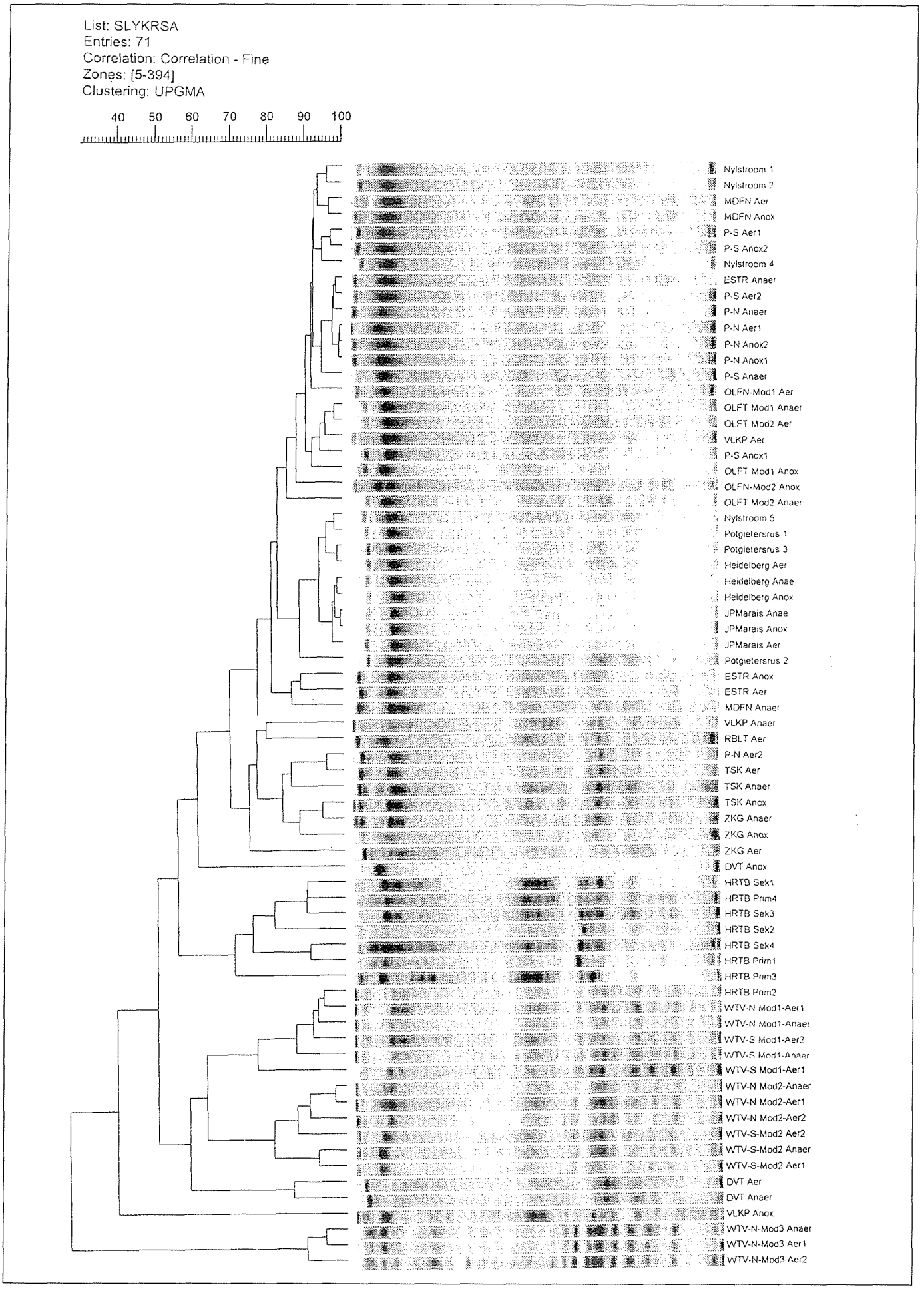
Many biological phosphorus removal activated sludge plants do not remove phosphorus adequately to satisfy effluent discharge standards. Currently ferrous sulphate is added to almost all South African nutrient removal activated sludge plants discharging effluents to sensitive catchments to mitigate potential eutrophication. Improved biological phosphorus removal could significantly reduce chemical and sludge disposal cost.

The main aims of the project are:

- Monitoring a specific activated sludge plant over time using polyacrylamide gel electrophoresis (PAGE) analysis of total cell protein extracts
- Comparison of metabolic zones within the same system using PAGE analysis
- Comparison of different systems according to their design and phosphorus removal using PAGE analysis of cell protein
- Comparison of systems which remove phosphorus to those which do not remove phosphorus using the PAGE method
- Comparing the same system when removing phosphorus and when not removing phosphorus using the PAGE method.

Estimated cost: *R154 000*
Expected term: *1996-1997*

Right: A dendrogram of the protein profiles (after SDS PAGE analysis) representing various activated sludge systems: SLYKRSA represents sludge samples from 21 different sludge systems in Gauteng (Gel Compare 3.1).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Correlation: Correlation - Fine
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Nylstroom 1
Nylstroom 2
MDFN Aer
MDFN Anox
P-S Aer1
P-S Anox2
Nylstroom 4
ESTR Anaer
P-S Aer2
P-N Anaer
P-N Aer1
P-N Anox2
P-N Anox1
P-S Anaer
OLFN-Mod1 Aer
OLFT Mod1 Anaer
OLFT Mod2 Aer
VLKP Aer
P-S Anox1
OLFT Mod1 Anox
OLFN-Mod2 Anox
OLFT Mod2 Anaer
Nylstroom 5
Potgietersrus 1
Potgietersrus 3
Heidelberg Aer
Heidelberg Anae
Heidelberg Anox
JPMarais Anae
JPMarais Anox
JPMarais Aer
Potgietersrus 2
ESTR Anox
ESTR Aer
MDFN Anaer
VLKP Anaer
RBLT Aer
P-N Aer2
TSK Aer
TSK Anaer
TSK Anox
ZKG Anaer
ZKG Anox
ZKG Aer
DVT Anox
HRTB Sek1
HRTB Prim4
HRTB Sek3
HRTB Sek2
HRTB Sek4
HRTB Prim1
HRTB Prim3
HRTB Prim2
WTV-N Mod1-Aer1
WTV-N Mod1-Anaer
WTV-S Mod1-Aer2
WTV-S Mod1-Anaer
WTV-S Mod1-Aer1
WTV-N Mod2-Anaer
WTV-N Mod2-Aer1
WTV-N Mod2-Aer2
WTV-S-Mod2 Aer2
WTV-S-Mod2 Anaer
WTV-S-Mod2 Aer1
DVT Aer
DVT Anaer
VLKP Anox
WTV-N-Mod3 Anaer
WTV-N-Mod3 Aer1
WTV-N-Mod3 Aer2

Research projects

Completed

- **391** Co-disposal of sewage sludge and refuse (City Council of Cape Town)
- **496** Human viruses in diffuse effluents and related water environments (University of Pretoria – Department of Medical Virology)
- **607** Compilation of an operating manual for biological nutrient removal waste-water treatment works (Stewart Scott (CE) Inc.)

Current

- **248** Chemical augmentation of biological phosphate removal (City Council of Johannesburg)
- **316** Aspects of sewage sludge treatment and disposal (City Council of Johannesburg)
- **328** Full-scale study of chemical sludge bulking control (University of Pretoria – Department of Chemical Engineering)
- **356** Consolidation of activated sludge research (University of Cape Town – Department of Civil Engineering)
- **416** The application and performance of full-scale constructed wetlands for waste-water treatment in South Africa (SRK (CE) Inc.)
- **462** Activated fixed and suspended cultures for nitrification (University of Pretoria – Department of Chemical Engineering)
- **491** Pond-enhanced trickling filter operation (PETRO) (Wates, Meiring and Barnard (CE) Inc. and CSIR – Division of Water, Environment and Forestry Technology)
- **542** Causes and control of low A/A filament bulking in nutrient removal activated sludge systems (University of Cape Town – Department of Civil Engineering)
- **554** Study of activated sludge microbial population dynamics for the optimisation of biological phosphorus removal (University of Pretoria – Department of Microbiology and Plant Pathology)
- **555** Limitation of convection currents in clarifiers (University of Pretoria – Department of Chemical Engineering)
- **556** Refinement of design parameters for sludge thickening by dissolved air flotation (Rand Afrikaans University – Energy Laboratory)
- **560** Development of a cross-flow microfiltration unit to improve the performance of anaerobic digesters at waste-water treatment works (University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **569** High-rate recirculation and solids contact optimisation of biological filtration plants (Wates, Meiring and Barnard (CE) Inc.)
- **597** Technology adaption for successful application of septic tank systems in the coastal zone (CSIR – Division of Water, Environment and Forestry Technology)
- **602** Application of chemical equilibrium to the control of struvite and calcite precipitation in waste-water treatment (University of Cape Town – Department of Civil Engineering)
- **604** Compilation of guidelines for the design and operation of sewage sludge drying beds (GFJ (CE) Inc.)
- **605** Municipal sewage sludge disposal: Development of guidelines and expert systems (CSIR – Division of Water, Environment and Forestry Technology)
- **606** Practical application of special waste co-disposal with municipal refuse at the Coastal Park landfill bioreactor (Cape Town City Council – City Engineer's Department)
- **620** Modelling, design and operation of secondary settling tanks (University of Cape Town – Department of Civil Engineering)
- **623** Bioremediation of a river system using the Alpha Biocatalyst (Alpha Biotech CC)
- **668** Determination of dissolved organic loads in raw and other sewage and the termination of the COD and DOC ratios (East Rand Water Care Company)
- **688** Laboratory and pilot-plant bioreactor development for remediation of metal-contaminated waste water using activated sludge as biosorbent (Technikon Natal – Department of Biotechnology)
- **692** Treatment of waste waters with high nutrients (N and P) but low organic (COD) contents (University of Cape Town – Department of Civil Engineering)
- **707** Calibration of open channel flow measuring systems using laboratory calibrated velocity-head electronic measuring instruments, and by applying the continuity principle (East Rand Water Care Company, through Sigma Beta (CE))
- **713** Removal of algal and other biomass from treated waste waters employing the PETRO process (Wates, Meiring and Barnard (CE) Inc.)

New

- **739** Disinfection of purified effluent (University of Pretoria – Division of Water Utilisation Engineering, Department of Chemical Engineering)
- **775** Development of strategies for amelioration of bulking by anoxic-aerobic filamentous organisms in nutrient removal activated sludge systems (Stewart Scott (CE) Inc.)
- **776** Fingerprinting of activated sludge systems using PAGE analysis of total protein extractions for the optimisation of biological phosphorus removal (University of Pretoria – Department of Microbiology and Plant Pathology)

CONTACT PERSONS

- **Dr SA Mitchell** (Nutrient Removal and Sludge Treatment)
- **Mr JN Bhagwan** (Low-cost Sanitation)

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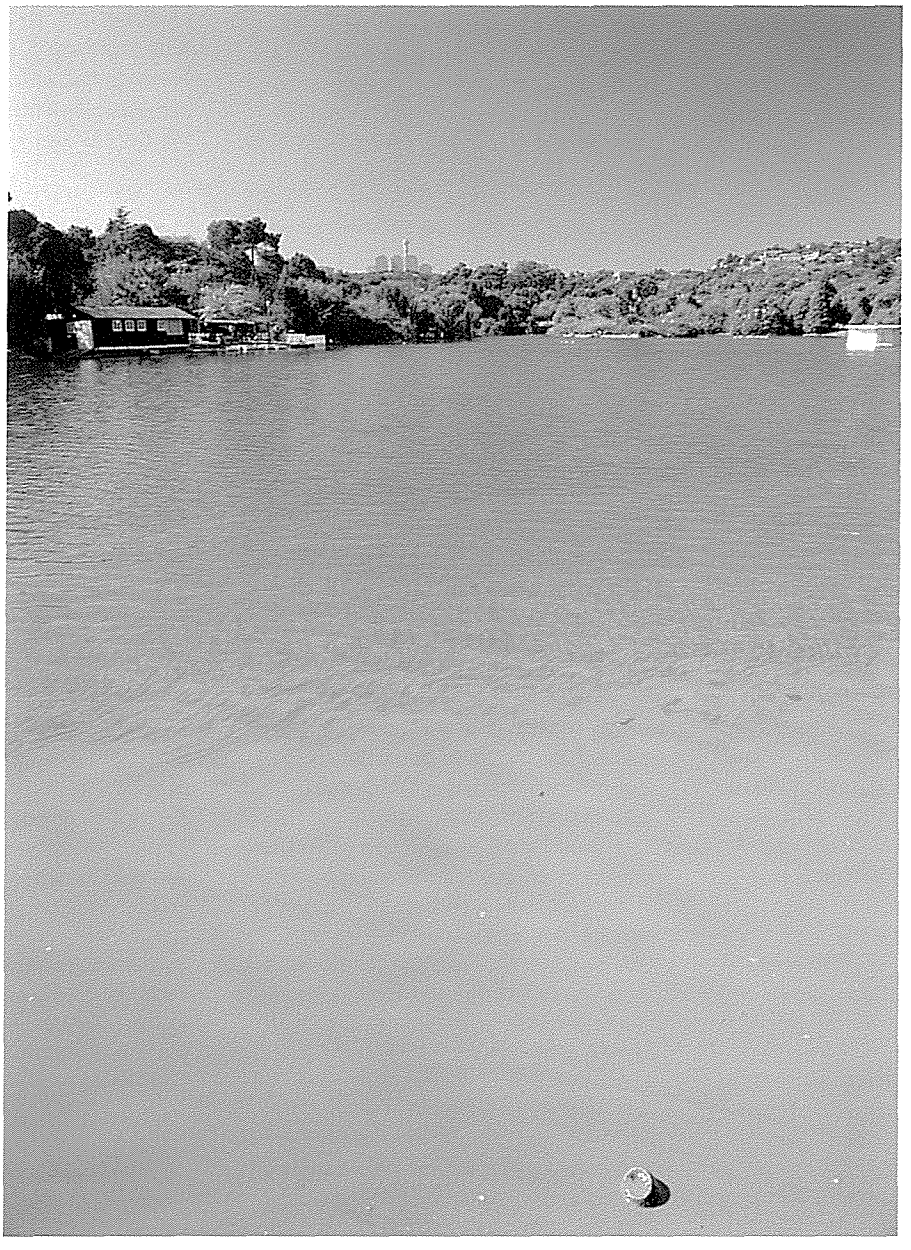
5 WATER QUALITY MANAGEMENT



The quality of water determines its suitability for all uses. Deteriorating water quality, to which a water-scarce country like South Africa is particularly susceptible, poses a threat to sustainable industrial, agricultural and other development. Since humans require fairly high quality water to fulfil their needs, the national aim to meet the basic water needs of our people is likewise threatened by water quality degradation. Unlike water-rich countries which often have the luxury of solving water quality problems by making use of the dilution capacity of surplus water supplies, South Africa has to adopt and develop alternative ways of meeting this challenge. Experts have expressed the opinion that our ability to provide users with water of an acceptable quality may prove to be more difficult to achieve on a sustainable basis than merely providing an adequate supply.

It is an accepted fact, which is also embodied in the *Water Law Principles* which will underpin the new Water Act, that water quality and quantity are interdependent and should be managed in an integrated manner. The DWAF has the responsibility to ensure the fitness-for-use of South Africa's water resources. The WRC's research programme into water quality management therefore seeks to identify and study the long-term strategic issues affecting water quality in South Africa.

A corner-stone of our water quality management approach is the recognition that water bodies have a limited capacity to assimilate waste and that this capacity represents a limited national resource which should be managed in a sustain-

able way. Research conducted in this field is mostly in support of this approach to water quality management. A number of projects are aimed at analysing the water quality situation, its causes and impact on users. Other projects aim to improve our ability to predict system response to natural driving forces, disturbances, pollution incidents and management intervention or obtain a better understanding of the processes which operate in nature.

Poor water quality often manifests itself as specific problems. Projects that address problems in the fields of salinity, eutrophication, other surface water quality studies and marine disposal are being funded by the WRC in this particular field.

Salinisation remains one of the consequences of water pollution which causes widespread problems in South Africa. However, most of these problems go unnoticed, or remain unconnected by consumers. Salinisation is the result of the addition of a variety of salts to the water environment which almost inevitably results from the increasing use and reuse of water associated with development. With increasing salinity the water becomes less fit for most users, thereby incurring additional costs.

Eutrophication is the enrichment of the water environment with plant nutrients and the consequent abundant growth of algae and aquatic plants. Serious problems pertaining to economics of water purification and defacement of the water environment are associated with eutrophication, while certain algae also excrete toxins.

The gradual deterioration of water quality and the growing awareness of water quality as a factor which undermines the utilisation potential of water, have given rise to the identification of a number of research needs. **Water quality studies** are being conducted to address problems associated with microbial pollution, sediments and other water constituents, as well as to improve the means to cope with them.

Marine disposal often is more economical than the land-based treatment of effluents. However, the sea's limited assimilation capacity is increasingly being recognised. Because marine disposal is sometimes used for the disposal of substances detrimental to the marine environment, and because of the unfavourable publicity associated with such abuses and with pipelines which are poorly designed and operated, public resistance to marine disposal is increasingly being experienced world-wide. It is nevertheless a practice which is widely adopted by coastal communities (also in South Africa) to dispose of their effluents. The WRC finances projects in order to establish criteria for using marine disposal as a responsible alternative to land-based disposal of effluents.

Completed projects

Applicability of hydrodynamic reservoir models for water quality management in stratified water bodies in South Africa

(No 304) Ninham Shand Inc.

This project aimed to evaluate existing mathematical models for their ability to predict stratification and related processes in South African impoundments, adapt them as required and demonstrate their application value. After these tasks were successfully completed and reported on, the project was extended in order to demonstrate the use of the models for management and planning purposes. Two models were selected for this purpose, viz. DYRESM and CE-QUAL-W2. The following water bodies were used: Inanda, Roodeplaat, Laing and Rooipoort Dams, as well as the Vaal Barrage. The models provided acceptable simulations of one or more of the following processes for each of the dams: reservoir volume balance, thermal stratification, hydrodynamic mixing, non-conservative constituents (including: nutrients, oxygen regime and algal biomass), conservative constituents, and sediment-water interactions. The combination of predictive ability and model structure allowed the evaluation of a range of reservoir management options, such as destratification by bubble plume aeration, selective abstraction, control of reservoir operating level, hypolimnetic releases, freshening options, and changes to reservoir input loading.

Cost: *R536 979*
Term: *1990-1996*

Occurrence and accumulation of selected heavy metals in freshwater ecosystems affected by mine and industrial polluted effluents

(No 312) Department of Zoology, Rand Afrikaans University

The pollution of water resources by heavy metals, emanating from mining and industrial areas, has a serious impact on freshwater ecosystems in the Gauteng area. Heavy metals occur in relatively high concentrations in the sediments of such water bodies. The overall effects of this on the ecosystems were investigated to locate the most important sources of heavy metal pollution in the respective areas and to quantitatively evaluate their characteristics and effects on plant and animal life.

The uptake of these heavy metals by plants, fish, birds and animals was studied in great detail and it was shown that all these ecosystems are endangered by excessive loads of heavy metals. The water and in particular the sediments pose serious threats to plants and animals and also eventually to humans.

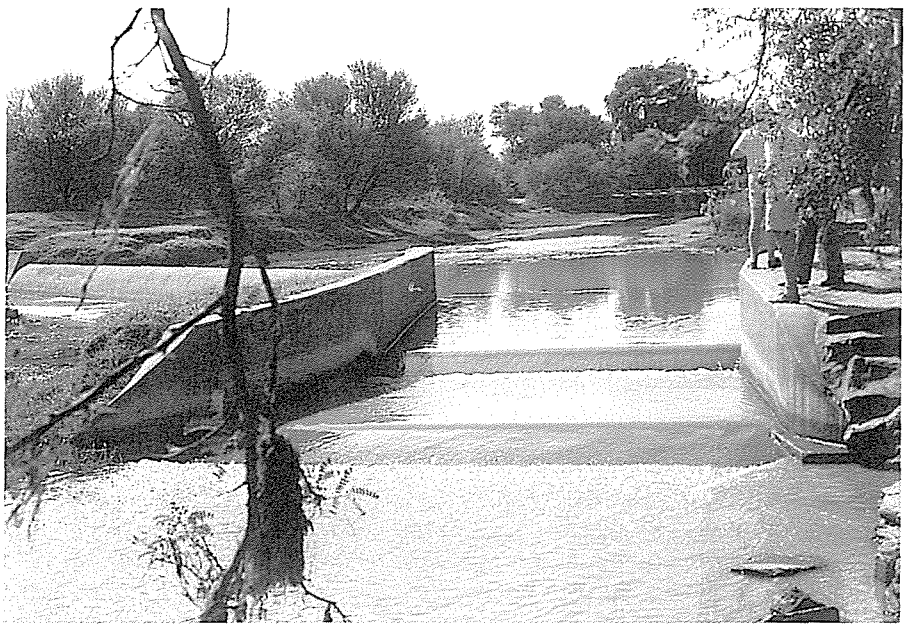
Some plants and animals are able to control the uptake of heavy metals by bioregulation. Wetlands have a beneficial effect on heavy metal pollution, but control and regulation by the responsible authorities of mining and industrial effluent pollution is the only effective way to overcome this pollution of aquatic ecosystems.

Cost: *R198 000*
Term: *1990-1994*

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

(No 380) Division of Water, Environment and Forestry Technology, CSIR and Rand Water

In their management of water quality the DWAF recognises that receiving water bodies have a quantifiable and manageable capacity to absorb some waste before a level is reached where its fitness for recognised uses is exceeded. This project aimed to develop guidelines and tools for the investigation and management of microbial water quality of rivers. Field work and monitoring of microbial water quality was conducted mainly in



Espagsdrift weir on the Harts River downstream of the Vaalharts North canal irrigation area.

the Rietspruit which discharges into Loch Vaal. It transpired that the microbial contamination of Rietspruit water made it unfit for direct domestic use and mostly also for full-contact recreation. Because of their high levels and the short river retention time (3 days), die-off did not reduce faecal coliforms to acceptable levels. Microbial decay rates measured *in situ* were similar to those reported in the literature. The QUAL2E model which was selected as the most appropriate for local conditions was demonstrated to simulate the decay pattern of faecal coliforms well. It is expected that when the model is applied to other rivers, it will give a good indication of travel time and distance required for microbial counts to decrease to acceptable levels.

Cost: *R1 013 025*
Term: *1991-1995*

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, Environment and Forestry Technology, CSIR, in association with the Water Research Institute, Rhodes University

Although several studies have been undertaken previously to address water quality problems in the Buffalo River, Eastern Cape, they were either of an *ad hoc* nature or not detailed enough for use in the development of an overall water quality management programme for the catchment. Because of their previous experience with similar investigations the then Division of Water Technology (now Division of Water, Environment and Forestry Technology) took the lead with this investigation. Most of the actual groundwork was, however, done by Rhodes University. It was found necessary to supplement available information with focused supplementary surveys. The major water quality problems were found to be concentrated between King William's Town and Laing Dam and within Bridle Drift Dam. High salinity, nutrients (eutrophication) and faecal bacteria were identified as the main water quality variables of concern. No long-term trends could be discerned for salinity and phosphate. The limited data for faecal bacteria indicated an increase in Bridle Drift Dam since 1960.

Cost: *R509 241*
Term: *1991-1993*

Long-term salt balance of the Vaalharts irrigation scheme

(No 420) Stewart Scott (CE) Inc.

A study of the Harts River on behalf of the DWAF in 1987 indicated that little of the salt contained in the water supplied to Vaalharts irrigation scheme left the area via surface return flows. Since it is inconceivable that salt can be absorbed indefinitely into a salt sink, it was decided to determine the validity of these findings, to determine what becomes of the salt and what can be expected to happen in future. Updated available information was used to compile a hydro-salinity simulation model and to simulate the long-term behaviour of the systems. This confirmed that Vaalharts is operating as a salt sink and has accumulated two-thirds of the total dissolved salt load contained in the irrigation water since its commissioning in the late 1930s. The hypothesis is that the gradual seepage of water drainage from below the root zone to underlying deeper groundwater storage is the main mechanism by which salt is retained. Although the sparse historical groundwater record lends support to this hypothesis it needs to be confirmed by further investigations.

Cost: *R199 996*
Term: *1992-1993*

Lower Vet River water quality situation analysis with particular reference to the OFS gold-fields

(No 523) Stewart Scott Inc.

A previously completed project presented strong evidence that gold mining is the most likely cause of the contamination of the Sand River in the Free State Province. This could have potentially serious implications for downstream users. The water quality situation analysis reported on here, was undertaken to close the gap between the previous study's results and the information required by the DWAF before they can develop an effective water quality management plan for the catchment. An evaluation was made of the salinity status of the lower Vet River catchment and the main factors affecting it were identified. It transpired that pollution sources in the gold-fields area add significant quantities of salt to the catchment, while salt is

being retained by irrigated lands. Water salinity in the upper reaches complies with user requirements. However, in the lower reaches the limits of several users are exceeded by wide margins for large percentages of time.

Cost: *R303 968*
Term: *1993-1994*

Potential for the use of economic instruments to protect the quality of water resources in South Africa

(No 574) Economic Project Evaluation (Pty) Ltd.

The difficulties which are being experienced with the traditional command-and-control approach to the management of water quality and the apparent benefits associated with an economic approach, have created an extensive world-wide interest in the use of economic instruments to achieve the same objectives. This project aimed to identify those instruments that have been applied in the rest of the world, which hold most promise for local application, and to evaluate their application potential in a local test case. From the international literature a toolbox of instruments relevant to South African conditions was assembled. A combination of green taxes and tradable emission permits was identified as most appropriate to control sulphate pollution of the upper Olifants River catchment, which was selected as test area. The effect that the introduction of these economic instruments would have on water pollution and effective use of available resources was tested with a model. This illustrated the underlying theory of tradable permits as water quality control instruments. The concepts and how they interact were demonstrated to various sectors of the economy at a workshop organised to increase the understanding of how economic instruments operate.

Cost: *R209 765*
Term: *1992-1995*

Development of a laboratory river model to determine the environmental impacts of key xenobiotic compounds

(No 583) International Centre for Waste Technology, University of Natal, and Umgeni Water

Synthetic organic (xenobiotic) compounds have become significant environmental contaminants. Few of them have, however, been tested for their ecotoxicological properties. Because of the important roles micro-organisms play in ecosystem dynamics, their ubiquitous nature, rapid response to changes in the environment and ease of culturing, microbial ecotoxicology is increasingly being used to determine the potential environmental impacts of synthetic compounds. A multi-stage continuous-flow laboratory model system was developed for this project. It was used successfully to determine the environmental impacts of phenol and 2,4-dichlorophenol on a microbial association enriched and isolat-

Mossgas offshore pipeline at Vlees Bay: The spreading of the effluent under moderate to weak current conditions.

ed from an aquatic ecosystem. Practical problems such as the slow rate at which nitrifying populations established within the model, the operational complexity of the model (which increased variability) and the relatively large number of analyses required, did not facilitate numerous impact studies and reduced the anticipated cost-effectiveness of the model that was developed.

Cost: *R107 517*
Term: *1993-1995*

Comparison of predicted secondary dilutions of deep-sea marine outfalls to measured field data and the determination of prototype diffusion coefficients

(No 675) Division of Earth, Marine and Atmospheric Science and Technology, CSIR

The efficiency of an offshore effluent discharge pipeline, of which there are 12 operating along the South African coastline, is largely governed by the initial dilution and to a lesser extent by the secondary dilution. Erroneous estimation of the total dilution could have either financial or environmental implications, depending on whether it is under- or over-estimated. Initial dilution, which was investigated in a preceding study, arises from the entrainment of sea water during the vertical rise of the buoyant effluent from the pipeline's discharge at sea-bed to the surface of the sea.

Turbulence and eddy currents present in the sea currents transporting the surfaced effluent away from the "boil", i.e. the area where the effluent surfaces, cause further ingress of sea water into the effluent to effect the so-called secondary dilution.

This project compared actual secondary dilutions with those predicted by the Brooks' model to establish the applicability of the model at different areas along the South African coast.

The model and suggested parameter values may be used to predict the achievable secondary dilutions and consequent impact of the effluent at distant locations. Greater accuracy is, however, required to enable detailed final design of the outfall. Thus, in view of the diversity of conditions existing along the South African coastline, it is strongly recommended that field measurements be conducted to obtain more accurate site-specific diffusion characteristics.

Cost: *R107 100*
Term: *1995-1996*

Algal scum on Zoo Lake, Johannesburg.

New projects

Rapid quantitative evaluation of water quality using a modified biological test – Phase II

(No 784) Department of Microbiology, University of the Witwatersrand

The development of rapid, sensitive and cost-effective biological tests is essential to ensure adequate water quality monitoring. In a previous study, the project team developed an *in vitro* biological test for the detection of toxins in water. During this study a phenomenon known as hormesis was observed. Hormesis is the stimulation of biological activity by low levels of inhibitors.

The aim of this research project is to investigate the nature of the hormetic response. In preliminary tests, it was shown that hormetic levels of toxins induced the synthesis of a 70 kilodalton (kd) protein in cell cultures. This protein will be analysed for similarities to other stress-induced proteins, for example, the heat shock protein (hsp). The biological test will be used to monitor the quality of effluents from metal-plating industry and other environmental water samples.

Expected cost: *R52 000*
Expected term: *1996-1997*

Validation of the modified MINLAKE model on Roodeplaat Dam

(No 785) Stewart Scott (CE) Inc.

As part of a recently completed project, the University of Cape Town adapted some routines within the hydrodynamic model MINLAKE. This significantly improved the ability of the model to simulate the chemical changes and algae succession in Roodeplaat Dam over the test period. MINLAKE is presently the only model of its kind in South Africa with this capability, which enables it to simulate, for example, the effectiveness of management options aimed at changing blue-green algae dominance to dominance by green algae. The validity of the modified MINLAKE model, however, still needs to be confirmed with other data sets having different input variables before it can be considered validated. This project aims to conduct this validation by using a data set stretching over the period before and after the reduction in phosphate concentration in the inflow into Roodeplaat Dam.

Expected cost: *R95 000*
Expected term: *1996*

Research projects

Completed

- **304** Applicability of hydrodynamic reservoir models for water quality management in stratified water bodies in South Africa (Ninham Shand Inc.)
- **312** Occurrence and accumulation of selected heavy metals in freshwater ecosystems affected by mine and industrial polluted effluents (Rand Afrikaans University – Department of Zoology)
- **380** Investigation techniques for the determination of microbial aspects of water quality of South African rivers (CSIR – Division of Water, Environment and Forestry Technology and Rand Water)
- **405** 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 (CSIR – Division of Water, Environment and Forestry Technology in association with Rhodes University – Water Research Institute)
- **420** Long-term salt balance of the Vaalharts irrigation scheme (Stewart Scott (CE) Inc.)
- **523** Lower Vet River water quality situation analysis with particular reference to the OFS gold-fields (Stewart Scott (CE) Inc.)
- **574** Potential for the use of economic instruments to protect the quality of water resources in South Africa (Economic Project Evaluation (Pty) Ltd.)
- **583** Development of a laboratory river model to determine the environmental impacts of key xenobiotic compounds (University of Natal – International Centre for Waste Technology, and Umgeni Water)
- **675** Comparison of predicted secondary dilutions of deep sea marine outfalls to measured field data and the determination of prototype diffusion coefficients (CSIR – Division of Earth, Marine and Atmospheric Science and Technology)

Current

- **195** Hydrosalinity studies in the Eastern Cape (Rhodes University – Institute for Water Research)
- **266** Extension of the management-orientated models for eutrophication control (CSIR – Division of Water, Environment and Forestry Technology)
- **359** Phytoplankton blooms in the Vaal River and the environmental variables responsible for their development and decline (University of the Orange Free State – Department of Botany)
- **369** Completion of research relating to the DISA model – A daily irrigation and salinity analysis system model (Ninham Shand (Cape) Inc.)
- **411** Coastal pollution: Pathogenic micro-organisms (University of Pretoria – Department of Medical Virology)
- **419** Water quality and quantity assessments in catchments with changing land uses in the Umzinto coastal area (SA Sugar Association Experiment Station)
- **421** Relationship between atmospheric deposition and water quality in a small upland catchment (CSIR – Division of Water, Environment and Forestry Technology)
- **447** Optimising diffuser design for off-shore pipelines – Laboratory experiments (CSIR – Division of Earth, Marine and Atmospheric Science and Technology)
- **465** Detergent phosphorus in South Africa: Impact on eutrophication with specific reference to the Umgeni catchment (University of Natal – Department of Chemical Engineering, and Umgeni Water)
- **498** Collection and evaluation of runoff water quality data from a disused feedlot in Natal (CSIR – Division of Water, Environment and Forestry Technology)
- **522** Pilot study to investigate alternative management options to enhance the use of saline water for irrigation purposes (University of Stellenbosch – Department of Soil and Agricultural Water Science)
- **536** Development of a dynamic model for the growth and bloom of algae in the Vaal River (University of the Orange Free State – Department of Applied Mathematics)
- **633** Management of urban impoundments (Johannesburg City Council and Stewart Scott (CE) Inc.)
- **634** Quantifying the impact of the salinisation of South Africa's water resources with special reference to economic effects. Phase 1: Development of a generic model (DWAF and Urban-Econ, Development Economists)
- **696** Development of a guide to assess non-point source pollution of surface water resources in South Africa (Sigma Beta (CE) Inc. and the DWAF)
- **697** Modelling the long-term effect of atmospheric deposition on the salinity of catchment runoff with special reference to the Vaal Dam catchment (Stewart Scott (CE) Inc.)
- **706** Guidelines for point-source pollution risk assessment as a decision-making tool for water quality management (Corporate Risk Management (Pty) Ltd.)
- **717** The impact of urbanisation and industrialisation on the environment (Vista University – Department of Chemistry (Mamelodi Campus))

New

- **784** Rapid quantitative evaluation of water quality using a modified biological test – Phase II (University of the Witwatersrand – Department of Microbiology)
- **785** Validation of the modified MINLAKE model on Roodeplaat Dam (Stewart Scott (CE) Inc.)

CONTACT PERSONS

- **Mr HM du Plessis** (Salinisation, Eutrophication and Water Environment)
- **Mrs APM Oelofse** (Urban Runoff)
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- **Dr TC Erasmus** (Marine Disposal)

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6 GROUNDWATER

Recent initiatives to accelerate the provision of potable water to rural communities are focusing on the development of local groundwater resources. The results of many years of research, particularly in terms of the portrayal of groundwater resource potential in the form of hydrogeological maps, are making an increasingly important contribution to these efforts. However, the detailed siting of boreholes still requires information on the hydrogeological properties of an area at a local scale.

For this reason, considerable attention has been focused on the occurrence, movement and recharge of groundwater in fractured-rock aquifers which occur over much of South Africa. An understanding of the physical nature and behaviour of such aquifers is essential, not only in the correct siting of boreholes and judicious abstraction of groundwater, but also in the protection of such aquifers from the ingress of pollutants. A fractured-rock aquifer research programme was initiated by the WRC and considerable advances in our understanding of these aquifers have taken place over the past 5 years. Phase 2 of the programme will be initiated following a thorough evaluation of the results from Phase 1 in 1997.

Rehabilitation and treatment of polluted groundwater are costly and may, in certain cases, be technically or practically impossible – this is especially true in rural communities where groundwater has traditionally provided a safe, clean source of drinking water. It is imperative therefore to protect groundwater, thus minimising the likelihood of vulnerable resources being destroyed. A project entitled **Utilisation of tracer experiments for the development of rural water supply management strategies for secondary aquifers** (No 733) has been initiated to ensure that valuable groundwater resources supplying rural communities are protected from the ingress of harmful pollutants.

The National Groundwater Database and groundwater information system resident at the DWAF remain central to the storage, processing and dissemination of groundwater information to scientists, planners and decision-makers. A long-term programme to upgrade the database in order to meet emerging needs and to conform to modern standards in terms of database architecture is essential, and will require the allocation of research funds over the next 5 to 10 years.

Three international groundwater experts visited South Africa in 1996. All were exposed to groundwater research programmes and constructive contributions to the following current projects were made:

- Prof David Lerner, University of Bradford, UK, and Dr Peter Dillon, Centre for Groundwater Studies, Australia:

An assessment of the impact of agricultural practices on the quality of groundwater resources in South Africa (Project No 641); **and Investigation of the contaminant attenuation capacity of the soil/aquifer system with special emphasis on the vadose zone** (Project No 572).

- Prof Ian Simmers, Vrije Universiteit, The Netherlands: **Groundwater supply assessment and strategy for the Western Karoo, Namaqualand and Bushmanland** (Project No 721); and **Guidelines for the evaluation of water resources for rural development with an emphasis on groundwater** (Project No 677 in **Chapter 2**).

Completed projects

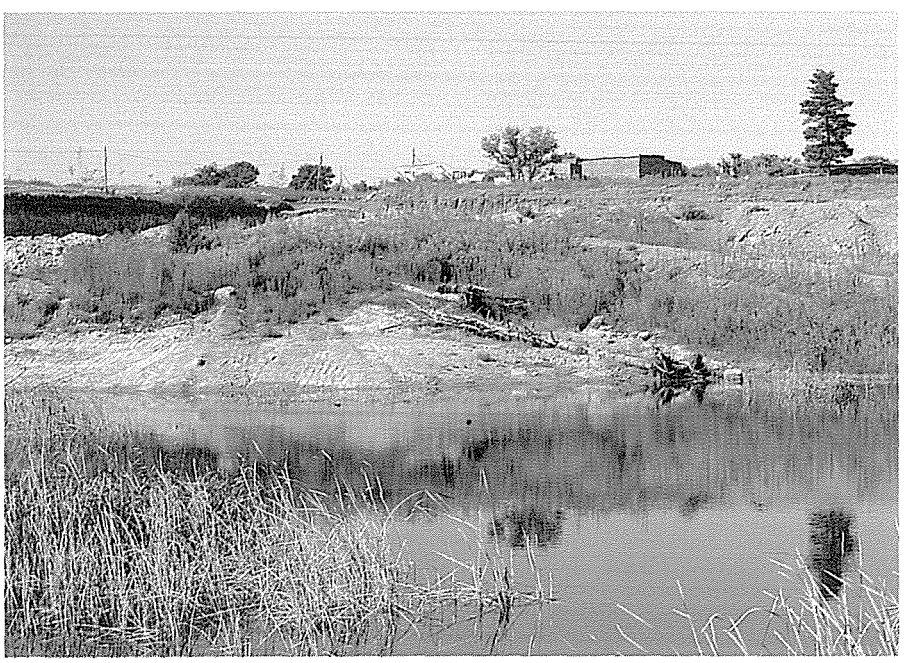
Investigation of the potential use of NOAA satellite remotely sensed data for identification of regional-scale fracture zones for groundwater supply purposes in Southern Africa

(No 273) SRK (CE) Inc.

Groundwater is often the most cost-effective source of water in rural, semi-arid areas. However, approximately 60% of Southern Africa is covered by Karoo formations which characteristically exhibit poor yield potentials for domestic and municipal water supply. The majority of high-yielding aquifers in the Karoo and various other geological formations throughout Southern Africa are associated with fracture zones. It is therefore necessary to identify and evaluate fracture zones on a regional scale in order to optimise the utilisation of groundwater resources with respect to location, quantity and cost. With remote sensing techniques it is possible to obtain structural and lithological information more efficiently and cost-effectively for large areas than can be achieved through ground surveys.

The project demonstrated that regional-scale lineaments can be detected using processed data obtained from the NOAA-AVHRR sensor. When comparing these mapped lineaments to known geophysical and geological lineaments, it was found that some of these did indeed correlate and could be extended by using the satellite data. New lineaments from the satellite data were mapped, but whether these are "real" or merely "artefacts" of the satellite data set could not be ascertained.

Cost: *R67 953*
Term: *1989-1990*



The impact of waste disposal activities on groundwater quality was explored in Project No 311.

Development and evaluation of geohydrological and isotope hydrological methodologies for the identification of areas potentially suitable for waste disposal

(No 311) Schonland Research Centre, University of the Witwatersrand and Atomic Energy Corporation of South Africa Ltd.

Environmental isotopes, as tracers of water, enable the investigation of the transport of groundwater and the contaminants therein. When applied during the initial stage of an investigation, environmental isotope measurements can quite rapidly assess aspects of the geohydrology, such as recharge areas, groundwater flow in relation to depth, discharge points and "turnover" time. Using conventional methods, this type of information could only be obtained after lengthy observations and with detailed information on the existing boreholes.

The intention of this study was to explore the usefulness of environmental isotope techniques in the assessment of groundwater vulnerability to waste disposal. The research effort focused on the situation of Karoo sediments overlying dolomite, where a worked-out quarry was being utilised as a landfill site.

This study has shown the intrinsic power of environmental isotope techniques in assessing various geohydrological settings for the disposal of waste. However, although environmental isotope techniques provide unique information and thus are powerful in themselves, their full power can only be realised when used in a multidisciplinary context. The behaviour of groundwater can be fully described only when the complementary techniques of stable and radioactive isotopes, hydrochemistry and conventional geohydrology are combined in a single, integrated investigation. In terms of the Karoo deposits, their heterogeneity has cast serious doubt on their suitability as potential waste disposal sites, particularly where the protective clay layer has been removed.

Cost: *R460 407*
Term: *1990-1994*

Integrated multidisciplinary geodynamic/geophysical approach to groundwater exploration around the South African coastline

(No 484) Atomic Energy Corporation of South Africa Ltd.

This project proposed the use of a multidisciplinary approach in order to produce a geodynamic analysis of the Algoa Basin for the purpose of locating favourable water-bearing structures.

At the outset it was postulated that in a fractured-rock environment, fractures which are orientated parallel to the neotectonic stress field are the most likely to have a high hydraulic conductivity and thus form the best exploration targets for groundwater development. While this could not be comprehensively demonstrated due to insufficient borehole and fracture data, a number of boreholes provided compelling evidence that this is in fact the case.

Probably the most successful outcome of the project was the recognition of discrete structural geological domains in the study area, within which geohydrological conditions are different and hence require a different exploration strategy. A fundamental understanding of the palaeo- and recent tectonic history of a project area is required prior to attempting this form of domain analysis which, in turn, can increase the probability of locating successful borehole targets.

This project was managed as part of the WRC's Fractured-Rock Aquifer Research Programme, which facilitated the sharing of information across a wide range of disiplines.

Cost: *R610 700*
Term: *1992-1996*

South African aquifer system management classification

(No KV77/95) Division of Water, Environment and Forestry Technology, CSIR

An aquifer classification system is required in order to designate aquifers or parts of aquifers into different categories for differentiated protection. Such a system recognises that because of largely financial constraints, it is neither possible nor for that matter necessary to protect all aquifers to the same degree. Classification systems are usually based on criteria such as economic value, vulnerability to pollution, groundwater potential (yield) and present water quality.

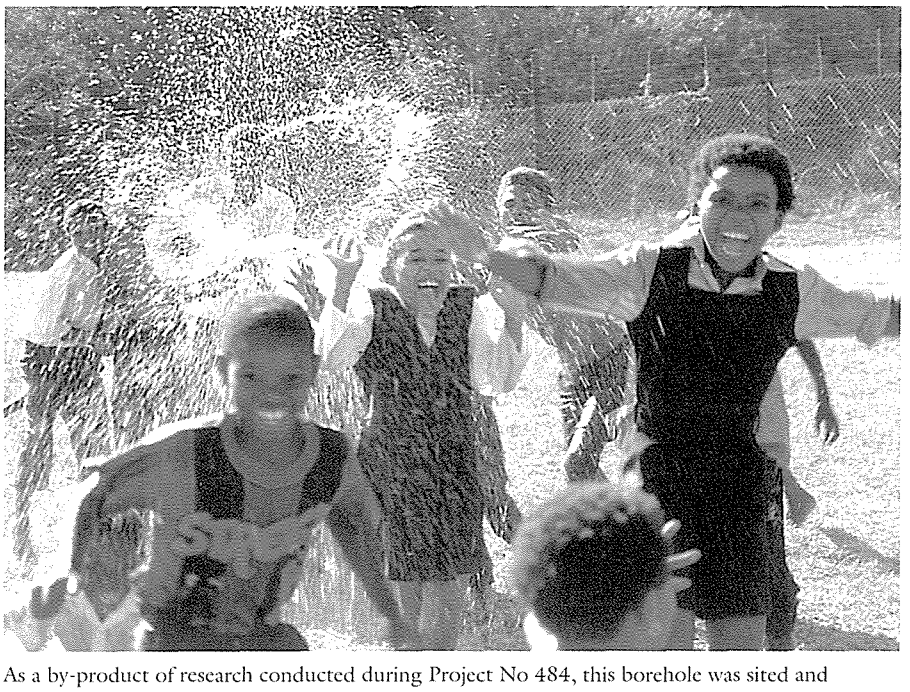
The main aim of the project was to prepare a fully developed proposal for a national aquifer classification system for South Africa which is to be integrated into the groundwater quality management strategy presently under development for the DWAF.

The aquifer system management classification developed during the study is based on the British Geological Survey aquifer vulnerability classification, but also recognises the need to consider two important management aspects, namely:

- The high value of sole source aquifers in South Africa
- The need for a pragmatic approach which allows for special factors to be considered.

The single most important use for the classification, at a national scale, is to provide a means of defining the importance of an aquifer in order that sound and consistent decision-making with respect to groundwater management is promoted.

Cost: *R40 000*
Term: *1995*



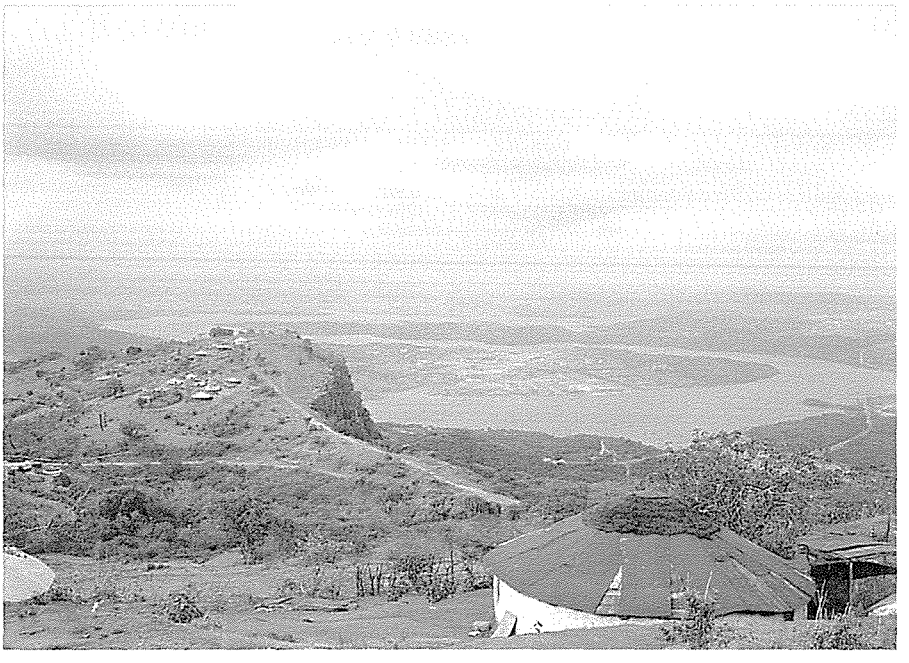
As a by-product of research conducted during Project No 484, this borehole was sited and developed for Bushy Park School near Port Elizabeth.

New projects

Modelling of groundwater flow in the Table Mountain Sandstone fractured aquifer in the Little Karoo region of South Africa

(No 729) Directorate of Geohydrology, DWAF

The Table Mountain Group Sandstone, which outcrops in the southern parts of the Western and Eastern Cape Provinces, is an important aquifer, yet lacks any primary porosity. However, several tectonic events have led to extensive folding and faulting, giving rise to secondary porosity. Although it is generally assumed that water can be found only in shallow local fractures, which are locally recharged, recent research would appear to indicate a far greater reservoir of groundwater present in the fractured aquifer system. As the Little Karoo area is semi-arid, the previous conceptual model meant relatively small quantities of recharge and abstraction. This research proposal rejects this conventional conceptual model, and instead asserts that in addition to the local shallow system, there exists a regional flow system along the



Developing groundwater resources in complex terrain.

regional faults which divide the area into the "table" tectonic blocks characterising this region. These faults are interconnected with secondary faults, which may furthermore be linked to the local shallow fracture system. If these assumptions are found to be correct, then regional underground conduits may be located along the major and secondary fault system, which will enable development of water on a regional scale. The local shallow system can be regarded as the local recharge system, with enhanced recharge over the elevated area, where rainfall is higher.

The proposed project will be carried out within the framework of the Little Karoo Rural Water Supply Scheme, the largest groundwater abstraction scheme from the Table Mountain Group Sandstone. The scheme is very well monitored and offers excellent opportunities for groundwater modelling of fractured aquifer systems.

The main aim is to investigate and develop a conceptual model for the interregional groundwater flow in deeply fractured aquifers of the Table Mountain Group as a basis for a mathematical physical model.

Estimated cost: *R176 000*
Expected term: *1996-1997*

CFCs and groundwater age-dating in South Africa's fractured-rock aquifers

(No 731) Division of Water, Environment and Forestry Technology, CSIR

One of the greatest challenges facing South African groundwater practitioners is the accurate quantification of groundwater resources in fractured-rock aquifers. To this end the WRC has embarked on funding a number of research projects which address this need. Nearly all of South Africa's aquifers are of the fractured-rock type. In contrast, fractured-rock research elsewhere in the world is driven by the need to establish nuclear waste repositories. Thus the needs are different which in turn places a different emphasis on the results required from the research.

Knowledge of the age of groundwater is useful for developing a conceptual flow model and in particular provides important information on water quantity, mixing of different groundwater types, location of recharge and defining recharge rates, sources of pollution and estimation of remediation times.

A newly developed method which holds great promise for resource quantification, is the use of dissolved chlorofluorocarbon (CFC) gases as a groundwater age-dating tool for groundwater younger than 50 years in age. Dissolved CFCs have been used to date post-1946 groundwater accurately to within 5 years of recharge in the United States of America. The above project will assess the applicability of the CFC method for resource evaluation in local fractured-rock aquifers.

Estimated cost: *R200 000*
Expected term: *1996*

Cost-effective development of groundwater in problematic terrain and low-potential areas: The evaluation and assessment of current drilling and groundwater abstraction techniques and the modification of equipment and methods

(No 732) Water Systems Management

The occurrence of groundwater in Southern Africa is restricted mainly to fractured-rock formations and to a lesser extent, alluvial and coastal aquifers. The location of suitable drilling targets in these terrains has, up until now, been limited to the most accessible and obvious targets. As the demand for potable water accelerates into the next decade, the traditionally inaccessible terrains will have to be reached and the drilling or abstraction techniques will have to be developed to exploit all available groundwater sources. Experience in the Northern Province, for example, has led to the belief that a large reserve of groundwater is presently undeveloped due to access problems and difficult drilling conditions.

An evaluation of current drilling techniques and equipment, and the modification of these to better suit the difficult conditions often encountered in rural areas, is expected to result in many benefits, for example savings on drilling costs, provision of labour opportunities and the development of skills.

Estimated cost: *R562 000*
Expected term: *1996-1999*

Utilisation of tracer experiments for the development of rural water supply management strategies for secondary aquifers

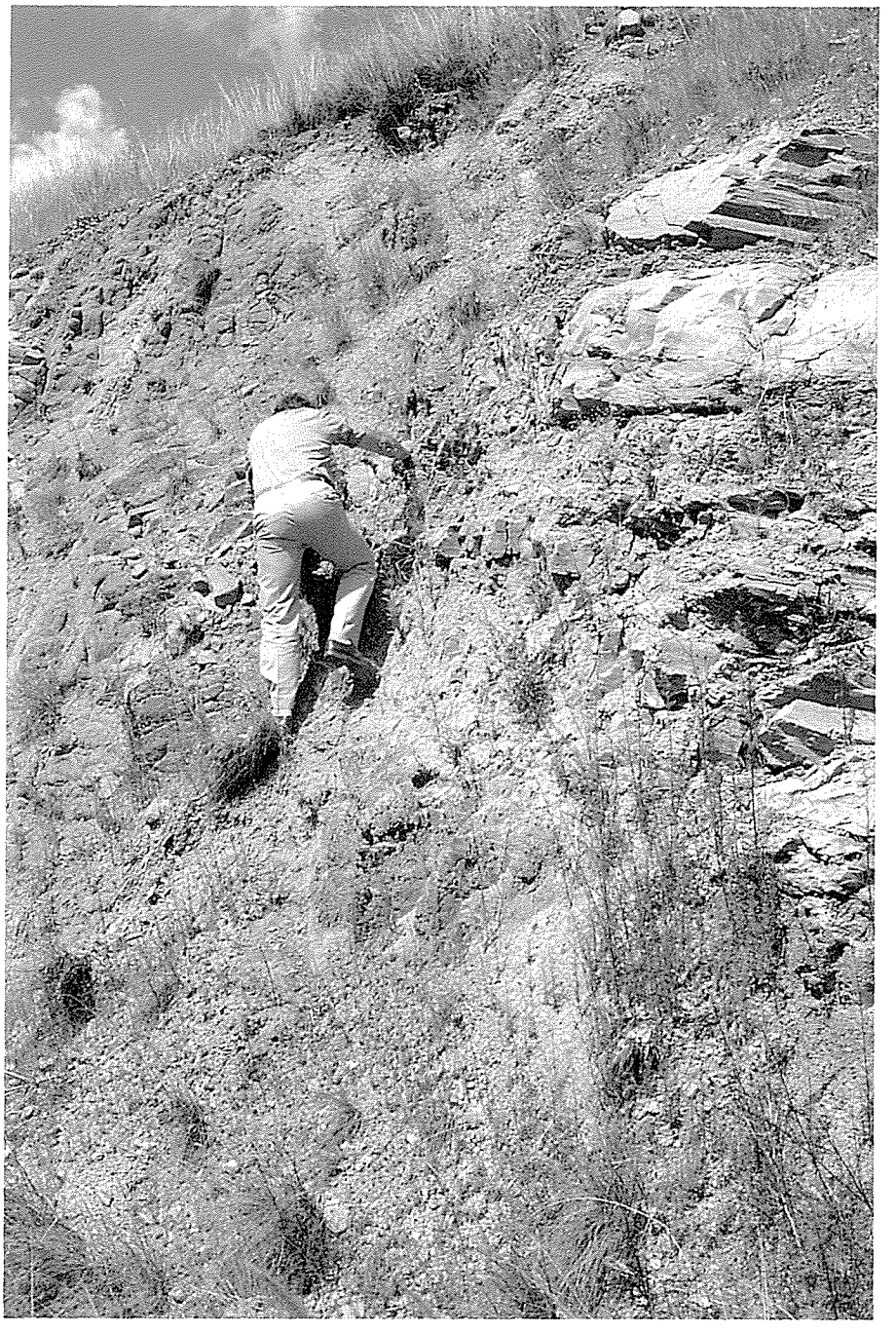
(No 733) Institute for Groundwater Studies, University of the Orange Free State

One of the most striking hydrogeological features of a fractured-rock aquifer is the variability in its physical properties. A parameter such as the hydraulic conductivity determined by classical field methods normally varies by several orders of magnitude within the same rock unit and often within short distances. The reason for this is that the rocks themselves do not transmit much groundwater but rather the fractures and fissures that form the conductive openings through the rock matrix. It thus becomes necessary to know the geometry of groundwater flow in order to delineate groundwater recharge areas and protection zones.

Rational use of this resource requires that the planned abstraction has to stay within the assured yield of the aquifer, and that the catchment areas of boreholes have to be protected from sources of contamination such as inappropriate sanitation systems. Without an understanding of this complex system, sustainable development of groundwater is virtually impossible. A way to know more about the geometry of fractures is through tracer experiments.

In order to develop and test approaches for the sustainable development of rural village water supplies, this project will investigate the use and suitability of artificial and natural tracers in fractured-rock formations to define the catchment area and significant recharge zones which will optimise well-field abstraction rates, and to delineate protection zones around well-heads to minimise the influence of potential pollution sources.

Estimated cost: *R793 000*
Expected term: *1996-1998*



The mapping of fractured-rock aquifers.

Research projects

Completed

- **273** Investigation of the potential use of NOAA satellite remotely sensed data for identification of regional-scale fracture zones for groundwater supply purposes in Southern Africa (SRK (CE) Inc.)
- **311** Development and evaluation of geohydrological and isotope hydrological methodologies for the identification of areas potentially suitable for waste disposal (University of the Witwatersrand – Schonland Research Centre, and Atomic Energy Corporation of South Africa Ltd.)
- **484** Integrated multidisciplinary geodynamic/geophysical approach to groundwater exploration around the South African coastline (Atomic Energy Corporation of South Africa Ltd.)
- **KV77/95** South African aquifer system management classification (CSIR – Division of Water, Environment and Forestry Technology)

Current

- **291** Regional investigation into groundwater quality deterioration in the Olifants River catchment above the Loskop Dam, with specialised investigations in the Witbank Dam subcatchment (University of the Orange Free State – Institute for Groundwater Studies)
- **378** Development of techniques for risk analysis and groundwater management of Southern African aquifers (University of the Orange Free State – Institute for Groundwater Studies and CSIR – Division of Earth, Marine and Atmospheric Science and Technology)
- **481** Geochemistry and isotopes for resource evaluation in the fractured rock aquifers of the Table Mountain Group (CSIR – Division of Water, Environment and Forestry Technology)
- **487** Analysis and interpretation of aquifer tests in secondary aquifers (University of the Orange Free State – Institute for Groundwater Studies)
- **516** Application of seismic tomography and ground-penetrating radar for the detection of fractures and the determination of hydraulic properties of fractured rock aquifers (CSIR – Division of Earth, Marine and Atmospheric Science and Technology)
- **565** Hydrogeological, isotopic and hydrochemical assessment of the response of a fractured multi-layered aquifer to long-term abstraction (University of the Witwatersrand – Schonland Research Centre)
- **572** Investigation of the contaminant attenuation capacity of the soil/aquifer system with special emphasis on the vadose zone (CSIR – Division of Water, Environment and Forestry Technology and the University of Stellenbosch – Department of Soil and Agricultural Water Science)
- **640** Extension and refinement of the AQUAMOD computer software package (University of the Orange Free State – Institute for Groundwater Studies)
- **641** Assessment of the impact of agricultural practices on the quality of groundwater resources in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **653** Regional characterisation and mapping of Karoo fractured aquifer systems – An integrated approach using a geographical information system and digital image processing (DWAF – Directorate of Geohydrology, and the Council for Geoscience)
- **676** Preparation of a monograph on South Africa's groundwater resources (JR Vegter Esq.)
- **701** Relationship between the geotechnical and hydrogeological properties of residual soils and rocks in the vadose zone (University of Pretoria – Department of Geology)
- **702** Development of a Windows-based interpretation system for hydrogeologists (University of the Orange Free State – Institute for Groundwater Studies and the DWAF)
- **720** Geohydrological modelling of the Richards Bay area (University of Zululand – Department of Hydrology)
- **721** Groundwater supply assessment and strategy for the Western Karoo, Namaqualand and Bushmanland (University of the Western Cape – Department of Earth Sciences)

New

- **729** Modelling of groundwater flow in the Table Mountain Sandstone fractured aquifer in the Little Karoo region of South Africa (DWAF – Directorate of Geohydrology)
- **731** CFCs and groundwater age-dating in South Africa's fractured-rock aquifers (CSIR – Division of Water, Environment and Forestry Technology)
- **732** Cost-effective development of groundwater in problematic terrain and low-potential areas: The evaluation and assessment of current drilling and groundwater abstraction techniques and the modification of equipment and methods (Water Systems Management)
- **733** Utilisation of tracer experiments for the development of rural water supply management strategies for secondary aquifers (University of the Orange Free State – Institute for Groundwater Studies)

CONTACT PERSONS

- **Mr AG Reynders** (Groundwater Resource Development and Pollution)
- **Mr HM du Plessis** (Mining Pollution)

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Since the establishment of the WRC, attention in the agricultural sector has mainly been given to initiating, promoting, co-ordinating and funding irrigation research. Based on past achievements and also considering remaining future challenges, the intention is not to reduce the emphasis, but to broaden the research field to include irrigation, rainfed agriculture, livestock watering and aquaculture.

During the annual meeting of the Co-ordinating Committee for Irrigation Research as it is presently constituted, it was decided to change the functions from the relatively narrow confines of irrigation to wider concerns of agricultural water management. This is not merely a superficial name change, but a conscious and fundamental adjustment to a tendency in recent years which is already reflected in the range of research projects which are currently financed. These vary from optimal water use of specific crops to dryland and irrigation water management at farm, irrigation scheme and catchment level; from efficiency of agricultural water use to agroforestry water use and competition with forestry plantations; from technical to economic aspects of water management; from commercial to subsistence farming in rural areas; from laboratory and research station trials to on-farm trials.

An important research area which was embarked upon is water management for sustainable small-scale irrigation farming. Although substantial progress has been made, it is clear that intricate problems are being faced by this subsector and much more research and practical work need to be done.

Strategic plan workshops

In all applied research projects, the goal is to find solutions to problems experienced by water users in agriculture. Renewed efforts have been made to improve communication with representatives of farmer interest groups and the research community. This is necessary to ensure that real-life issues are addressed and a common understanding exists regarding priorities. Apart from addressing meetings and holding individual discussions, two workshops were organised within the framework of the strategic research plan.

The first was on research and extension links for small-scale irrigation farming, with the purpose of taking stock of available research results and determining practical requirements for extension and

advice. Following this meeting a Network on Irrigation Research and Extension for Small-scale Agriculture (NIRESA) was established to improve communication in continued pursuit of the aforementioned goals. It was further agreed that determination of success factors and identification of information gaps regarding small-scale farming be undertaken by working groups within specific disciplines.

The second was on exchange of ideas regarding priorities as defined by researchers who are active in the focus areas of soils, crops, engineering, resource economics and rural sociology. The output included a description of priority research areas, proposals for multidisciplinary co-operation on projects, agreement on the need for a systematic database for all projects, support for follow-up discussion forums with farmers and officials of government departments on a provincial level and recommendation of a revised process for submission and evaluation of project proposals.

When evaluating projects for funding, a balance must be achieved by research management between addressing issues of immediate concern and anticipating issues which are expected to be of concern in future. Consequently there is a commitment towards continuous consultation and liaison through stakeholder forums of national concerns and the co-ordinating committee of this research field. Clients and partners are representatives of farming and research communities who can benefit from and contribute to improved agricultural water management.

Completed projects

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

Irrigation takes place in a dynamic environment and farmers have different attitudes towards risk. The problem experienced in practice is a lack of useful instruments to evaluate the economic efficiency of water and energy use at whole farm level under these circumstances. This refers in particular to the influence of improved irrigation scheduling, alternative crop rotation systems, liability ratios and financing methods on business profitability. The main objective of the research was methodology development and more specifically to estimate water requirements of different crops with the aid of crop-growth simulation models; to identify the most important sources of risk and measure risk preferences; to estimate annual costs of typical farming systems under full and supplemental irrigation and under dryland conditions; to determine the effect of improved water and weather information and alternative pumping restrictions on income; and to develop a decision-support system.

The research was carried out in irrigation areas below the Vanderkloof Dam in the Free State Province and near Winterton in the KwaZulu-Natal Province. Fixed and variable resources of representative farms as well as risk attitudes of farmers were determined empirically. Simulation models were developed to calculate costs and income at enterprise and farming level and to evaluate risk with regard to crop prices and yields, interest rates and hail damage. Optimisation models based on crop-growth simulation were also used to determine the value of information. With the aid of these models, practical and timeous support can be given for management of risk and to increase expected net returns through higher crop yields with simultaneous saving of irrigation water use. Further research is required on risk and information management with emphasis on the farmer as decision-maker.

Cost: *R641 000*
Term: *1991-1994*

Identification of irrigated land in an intensively cultivated agricultural area in the South-Western Cape by means of satellite remote sensing

(No 440) Institute for Cartographic Analysis, University of Stellenbosch

Information on current land-use patterns and trends underlies effective integrated water resource management in drainage catchments. Conventional methods of data collection in land-use inventories are expensive, time-consuming and cumbersome to complete regularly. This project has combined satellite remote sensing and geographic information systems (GIS) to investigate the practicability of such an approach in the intensively cultivated upper Breede River valley. Land parcels planted to single crops are relatively small in this region and this posed the single biggest challenge to the research.

The results of the research showed that irrigated vs. non-irrigated land-use classes could be identified with an accuracy of roughly 80%. This led to the conclusion that digital image analysis enhanced with GIS data is a valid means of obtaining land-cover and land-use information of sufficient accuracy for broad planning and monitoring of catchments and the water requirements for irrigation.

It was also concluded that in considering the use of multi-temporal imagery the gains are not necessarily of such an order of magnitude that it will be financially justified in all applications.

Cost: *R80 400*
Term: *1992-1995*

Transfer of research results on the irrigation of vegetable crops into practice

(No 476) Department of Plant Production and Soil Science, University of Pretoria

Previous investigations into irrigation of vegetable crops showed that a need exists for the application of research results in practice. Thus the objective of this project was to promote the efficient use of irrigation water and to optimise vegetable production by means of the transfer and adaptation of available research results.

A situation analysis in the Loskop irrigation area indicated that uncertainty regarding costs and benefits is the main reason for reluctance to apply sound irrigation scheduling techniques. The point of departure for further research and extension was therefore not only to demonstrate the applicability of scientific irrigation scheduling at farm level, but also to reduce costs and to increase benefits associated with this practice.

In the process, crop factors for beetroot, carrots, cucumbers, sweet-corn and

green peas were either developed or adjusted, effective root depths were determined and a simple computer model was developed to promote the efficient use of tensiometers for those farmers who prefer this type of scheduling instrument. There are clear indications that crop simulation models which are operated by advisers and consultants, will be the most successful instrument in future to transfer advanced irrigation management technology into practice. Consequently a start was also made with the development of a user-friendly, generic, mechanistic crop simulation model which is universally applicable with the necessary adjustment of crop and soil parameters.

Cost: *R559 000*
Term: *1992-1994*

Development of a computerised management system for irrigation projects

(No 513) Department of Civil Engineering, Rand Afrikaans University

Two previous WRC-funded projects related directly to the computerised management of water in irrigation projects. A project by the RAU team developed an optimisation system for minimising distribution losses in irrigation canal systems, whilst a UOFS project addressed maximisation of on-farm irrigation efficiencies. Following these projects, the RAU team was contracted to integrate the canal simulation/administrative data model with the on-farm irrigation scheduling model, thereby allowing comparison of the volume of water requested by farmers with the actual water needed for all the crops on an irrigation scheme.

During the course of the project it was decided rather to use the NewSWB (New soil-water balance) model, mainly for reasons of compatibility with the WAS (water administration system) model. NewSWB is similar to the locally developed PUT-ANYCROP model in that they are both mechanistic, generic crop growth models that simulate a supply-and-demand limited water balance for several soil layers. Their water balances can be driven by Penman-Monteith reference crop evaporation, making them ideal for real-time scheduling using automatic weather station data.

The NewSWB was successfully integrated into the WAS, and ran successfully with climate, soil and crop data collected in the Brits irrigation area. An irrigation scheduling model is, therefore, now part of an optimisation system that can be implemented incrementally, depending on the requirements of the user. Requested and calculated volumes of water are compared, and water loss control optimised, resulting in water savings not only on irrigation scheme scale, but also for individual farms.

Cost: *R107 700*
Term: *1993-1994*

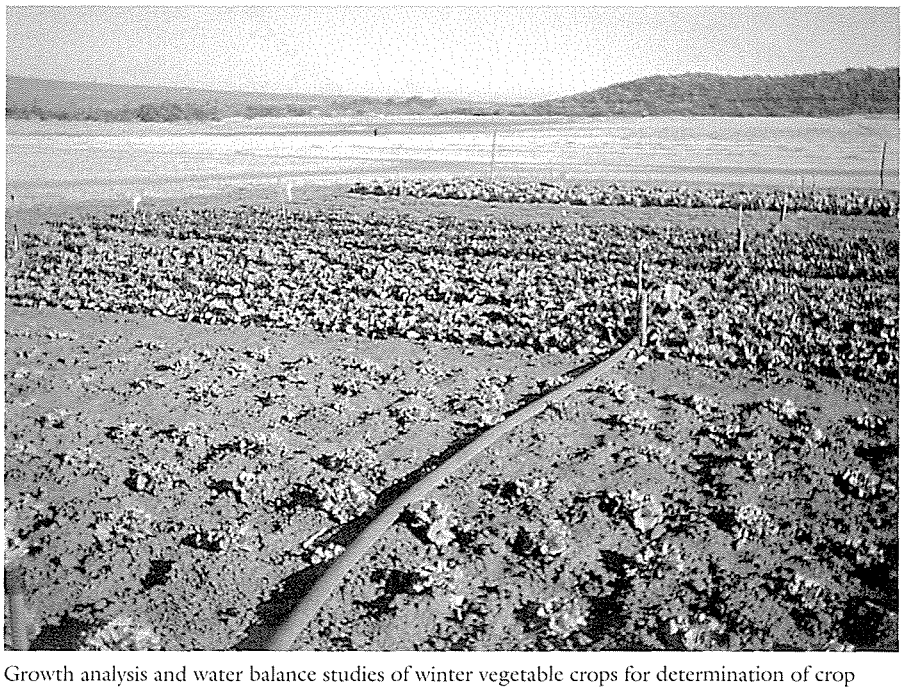
New projects

Facilitating irrigation scheduling by means of the soil-water balance model

(No 753) Department of Plant Production and Soil Science, University of Pretoria

Water can be saved by basing irrigation scheduling decisions on outputs of models, which assess crop water requirements in relation to prevailing weather conditions. The soil-water balance (SWB) model is a mechanistic, generic type of simulation model and has recently been developed and tested for the purpose of scheduling. In order to promote practical application, the objectives of this research are to refine the model in terms of user-friendliness and to determine crop parameters for a range of crops generally grown under irrigation. All available data and information of completed projects at different research organisations will be used to calculate or estimate the needed crop parameters. Co-operation will be requested on the understanding that the source of data will be acknowledged and that the SWB model can be applied by researchers to crops of relevance to them on completion of the project. Compiling a comprehensive set of crop parameters will also enable technical advisers to provide an irrigation scheduling service to farmers who usually cultivate a combination of different crops at the same time.

Estimated cost: *R520 000*
Expected term: *1996-1997*



Growth analysis and water balance studies of winter vegetable crops for determination of crop growth model parameters for the soil-water balance irrigation scheduling model.

Evaluation of the appropriateness and management requirements of micro-irrigation systems in small-scale farming

(No 768) MBB (CE) Inc.

From a very modest beginning in Israel and the USA, the world witnessed a 329% increase in its micro-irrigated area during the decade 1981 to 1991. In South Africa the micro-irrigated area increased by 230% during the same decade, and predictions are that the local micro-irrigated area should reach 250 000 ha by the year 2000.

Research and experience have demonstrated the potential of micro-irrigation as a management tool, and where economically and technically feasible, its utilisation should be promoted. Its general use, however, is hampered by a number of factors which are experienced by both commercial and developing farmers, resulting in the use of these systems being limited to mainly high-income crops.

Appreciating the needs of South Africa's developing irrigated agriculture, the WRC's Co-ordinating Committee for Irrigation Research during 1994 identified the need for local research on the adaptation of and management needs of micro-irrigation under these conditions. Furthermore, reducing the capital cost and maintenance requirements of micro-irrigation systems, and increasing the reliability and longevity of simplified versions with special reference to the needs of developing agriculture, were also identified as high research needs at the 5th International Micro-Irrigation Congress in 1995.

Against this background this project aims to investigate comprehensively all the problems associated with micro-irrigation especially under conditions of small-scale farming in South Africa. Evaluations of possible solutions to these problems and a thorough investigation of the management problems which implementation of these systems may pose, also form part of the project.

Estimated cost: *R725 000*
Expected term: *1996-1998*

New Forest irrigation scheme, Northern Province: Small-plot vegetable farmers tending their crops as part of on-farm trials.

Development of guidelines for appropriate training levels and content in support of sustainable small-scale irrigation development

(No 774) MBB (CE) Inc.

Investment in human capital through education, training and extension is one of the most important factors contributing to the success of farming on irrigation schemes. In a foregoing project, the need for more information and practical training in technical aspects of irrigation was highlighted. It is clear that this training should be "on-the-job" and "how-to-do-it" type of training rather than theoretical lessons. The objectives are, therefore, to identify categories of people such as farmers and project staff who need training; to determine the content of courses in terms of "need-to-know"; and to determine the best way of transferring this knowledge. This information will be gathered through interviews and work sessions with people in real-life situations in selected irrigation areas. Guidelines will be produced covering the principles and details of the training programmes that are required for job and income generation and establishment of sustainable irrigation by small-scale farmers. It is envisaged that these will contribute to more efficient use of water and also build capacity for farmer-managed irrigation development on existing schemes.

Estimated cost: *R150 000*
Expected term: *1996*

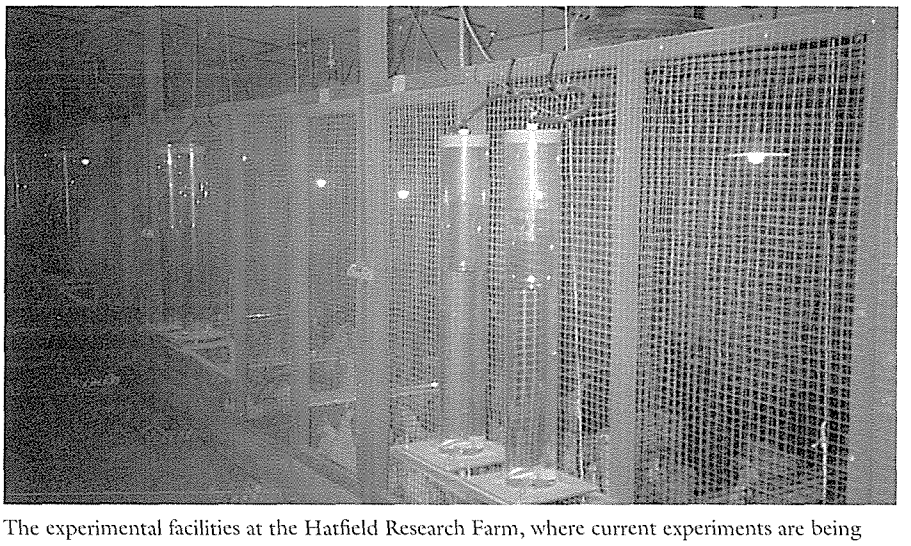
Effect of the introduction of agroforestry species on the soil moisture regime of traditional cropping systems in rural areas

(No 780) Division of Water, Environment and Forestry Technology, CSIR

Growing trees in combination with crops can enhance productive use of soil and water, alleviate the wood fuel crisis and reduce pressure on over-exploited natural grasslands. However, there is a perception that agroforestry will decrease water supply and cause lower crop yields. In addition there is a lack of farmer participation in planning research trials. Participatory rural appraisal workshops were held to investigate the needs of people in communities of the Upper Thukela region with respect to trees and water. This project forms part of the implementation phase and the objectives are to examine agroforestry systems and management systems, to determine the comparative water use and to monitor the effect of moisture competition between roots of trees and crops. On-farm trials will be conducted by planting trees of different species that can provide fodder for livestock. Recommendations will be made on appropriate species of multipurpose trees for agroforestry systems. It will also be demonstrated that introduction of agroforestry in specifically small-scale farming can contribute towards integrated environmental and human resource development in rural areas.

Estimated cost: *R339 800*
Expected term: *1996-1997*

Dohne-Merino incisors after being exposed to fluoride in the drinking water from birth to market weight.



The experimental facilities at the Hatfield Research Farm, where current experiments are being done on water quality. The water system enables the water intake of the chickens to be measured accurately.

The blackfly control programme in action.

CONTACT PERSONS

- **Dr GR Backeberg**
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  (Salinisation)

☎ **(012) 330-0340**

Research projects

Completed

- **347** Global farm approach to enhancing the economic efficiency of water and energy use for irrigation in the central RSA (University of the Orange Free State – Department of Agricultural Economics)
- **440** Identification of irrigated land in an intensively cultivated agricultural area in the South-Western Cape by means of satellite remote sensing (University of Stellenbosch – Institute for Cartographic Analysis)
- **476** Transfer of research results on the irrigation of vegetable crops into practice (University of Pretoria – Department of Plant Production and Soil Science)
- **513** Development of a computerised management system for irrigation projects (Rand Afrikaans University – Department of Civil Engineering)

Current

- **290** Flood and furrow irrigation: A critical evaluation of design procedures and the computerisation of the most suitable approaches (University of Pretoria – Department of Agricultural Engineering)
- **303** Use of saline water for irrigation purposes and an assessment of salt tolerance criteria of crops (University of Stellenbosch – Department of Soil and Agricultural Water Science)
- **348** Root development and water usage of commercial timber species (University of Natal – Department of Agronomy)
- **372** Assessing the impacts of varying rainfall conditions on vegetation dynamics, production and certain hydrological properties of natural grassland, using a system modelling approach (Potchefstroom University for CHE – Department of Plant and Soil Sciences)
- **389** Scheduling irrigation of tuber crops with specific reference to potatoes (Agricultural Research Council – Vegetable and Ornamental Plant Institute)
- **417** Optimal water utilisation by turf (Potchefstroom University for CHE – Department of Plant and Soil Sciences)
- **423** Effect of pre-programmed deficit irrigation on crop reaction (University of the Orange Free State – Department of Soil Science)
- **441** Determination of the relationship between transpiration rate and declining available soil water for Eucalyptus grandis (CSIR – Division of Water, Environment and Forestry Technology)
- **479** Molecular approach to drought tolerance (Agricultural Research Council – Institute for Plant Biotechnology)
- **499** Effect of exchangeable sodium percentage and clay mineralogy on the infiltration capacity of soil already sealed due to cyclic irrigation (Potchefstroom University for CHE – Department of Plant and Soil Sciences)
- **507** Improved estimation of plant and soil evaporation from cropped lands (University of the Orange Free State – Department of Agrometeorology)
- **508** Modelling the water balance on benchmark ecotopes (Agricultural Research Council – Institute for Soil, Climate and Water)
- **573** Water-use efficiency of cultivated subtropical forage and pasture crops (University of Pretoria – Department of Plant and Soil Sciences)
- **578** Evaluation of irrigation techniques used by subsistence and emergent farmers (MBB (CE) Inc.)
- **581** Computerised weather-based irrigation water management system (University of the Orange Free State – Department of Agrometeorology)
- **600** Problem blooms of macro-algae: Investigation of causal factors, seasonality of recruitment and growth, and efficiency of control methods (University of Cape Town – Department of Botany)
- **624** Personal computer-based procedure for the estimation of irrigation requirements of crops in Southern Africa (MBB (CE) Inc.)
- **625** Use of computer models for agricultural water management at farm level (University of the Orange Free State – Department of Soil Science)
- **644** Quality of water for livestock production with emphasis on subterranean water and the development of a water quality guideline index system (University of Pretoria – Department of Animal and Wildlife Science)
- **645** Optimal management of uncertain water availability at farm and regional level with due allowance for risk and the environment (University of the Orange Free State – Department of Agricultural Economics)
- **646** Maximisation of economic water-use efficiency of processing tomatoes (University of Pretoria – Department of Plant Production)
- **650** Integrated control of blackflies along the Orange River (Agricultural Research Council – Onderstepoort Veterinary Institute)
- **689** Irrigation water requirements of small-plot vegetable farmers (Agricultural Research Council – Institute for Soil, Climate and Water)
- **695** Establishing effects of saline irrigation water and managerial options on soil properties and plant performance (University of Stellenbosch – Department of Soil and Agricultural Water Science)
- **719** Investigation into food-plot production on irrigation schemes in the central region of the Eastern Cape Province (University of Fort Hare – Agricultural and Rural Development Research Institute)
- **725** Quantitative evaluation of the hydraulic properties of stony soils by means of laboratory simulations (Potchefstroom University for CHE – Department of Plant and Soil Sciences)

New

- **753** Facilitating irrigation scheduling by means of the soil-water balance model (University of Pretoria – Department of Plant Production and Soil Science)
- **768** Evaluation of the appropriateness and management requirements of micro-irrigation systems in small-scale farming (MBB (CE) Inc.)
- **774** Development of guidelines for appropriate training levels and content in support of sustainable small-scale irrigation development (MBB (CE) Inc.)
- **780** Effect of the introduction of agroforestry species on the soil moisture regime of traditional cropping systems in rural areas (CSIR – Division of Water, Environment and Forestry Technology)

8 INDUSTRIAL WATER MANAGEMENT

Research on industrial water use and effluents is oriented towards developing and promoting integrated water conservation and effluent management strategies through the application of sustainable water pollution prevention practices, and cost-effective water pollution abatement technologies. The implementation of these strategies is expected to result in significant savings in freshwater intake, reduced pollution load discharge to the environment per unit of production, minimisation and elimination of toxic chemical discharges, optimisation of energy use and the utilisation of environmentally friendly technologies for not only the purification of effluents and the implementation of closed-loop systems, but also for the production of high value by-products.

Research undertaken by various industries, e.g. textile, tanning and fellmongering, fish processing, fruit and vegetable processing, mining, pulp and paper, electrical power generation, petroleum processing and large- and medium-sized meat processing, is yielding benefits in terms of increased awareness for the need and importance of total water quantity and quality management, and has resulted in the adaptation of several new and cost-effective biological processes to South African conditions and further development thereof.

Research on the following areas continues to be important, including new research areas involving social impact assessment which have been initiated:

- The development of cost-effective robust industrial effluent treatment systems suitable for small- to medium-sized industries generating effluents rich in organics, e.g. utilisation of earthworm systems and advanced integrated ponding systems (AIPS).
- The development of anaerobic treatment systems for the detoxification of wastes, decolourisation of textile wastes and immobilisation of metals, e.g. adaptation of the AIPS for treatment of metal-laden effluent.
- The development of a novel biotechnological treatment system utilising higher order micro-organisms, such as fungi, and enzymes for the treatment and detoxification of pulp and paper effluents, thus reducing the requirement for extensive use of process chemicals that are toxic, e.g. chlorine and sulphur dioxide.
- The development of biological treatment systems coupled to advanced physico-chemical systems for reuse of treated effluents, e.g. the recycling and reuse of abattoir waste water.
- Social impact assessment studies of pipeline ocean discharges from a chemical industrial complex in

Umbogintwini on the Natal Coast and involving a number of stakeholders including commercial and sports anglers, tourism operators, local communities, local industry and government.

Completed projects

Evaluation and improvement of the anaerobic digestion/ ultrafiltration (ADUF) effluent treatment process

(No 365) Division of Water, Environment and Forestry Technology, CSIR

The ADUF process can be used to reduce the pollution potential of industrial waste waters containing high concentrations of soluble and/or colloidal organic carbon. Its chief advantages include complete biological solids retention, clear effluent, high rates of operation and great flexibility.

During pilot-scale tests, a number of problems arose which needed to be addressed. In an attempt to find practical solutions to these problems, the project addressed the following:

- The reasons for the relatively poor performance of the process
- Changes in the digester sludge characteristics caused by rapid pumping and the possible accumulation of biological debris and indigestible solids in the sludge
- The effect of various feed substrates on the performance of the ADUF system.

The laboratory-scale tests performed did not produce results which could conclusively prove the viability or otherwise of the ADUF process to treat spent wine waste and beer brewery waste. The units were adversely affected by scale effects and the tests were hampered too frequently by disruptions and equipment malfunctions. The following conclusions can, however, be drawn from the study:

- All suspended solids were retained in the digester.
- Short-circuiting of raw or partially treated feed did not occur.
- No build-up of intractable sludge residue was evident from the solids analysis.
- The generation of foam in the ADUF process severely limits the loading rate that the plant can handle. The space load rates as well as the biological load rates that could be maintained were very low when compared with those attained by larger plants.
- The rate of flux loss was uneconomically high, especially when the low load rates are considered.

Cost: *R212 000*
Term: *1991-1992*

Biological approach to the removal of organics from saline effluents

(No 410) Department of Biochemistry and Microbiology, Rhodes University

Saline effluents present intractable problems both in their treatment and disposal. Based on work in the field of algal biotechnology undertaken over a number of years at Rhodes University and LIRI Technologies, the objectives of this project were focused on the development of an integrated system for the treatment, the effective utilisation as a resource and ultimate disposal of saline effluent wastes.

Most desalination processing options produce a concentrated brine stream which must, nevertheless, also be dealt with. An additional complication is the accumulation of organics which cause 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. In the tanning industry large quantities of water are used in the processing of hides and outflows contain highly elevated TDS values.

This project proposed a biotechnological approach to dealing with saline effluents and its purpose was to attempt to demonstrate the feasibility or otherwise, of the application of micro-algal technology to the problem.

The following deliverables, identified as desirable outcomes from the programme, were successfully demonstrated:

- It is a low-technology system for the economic disposal of saline effluents and possibly including the recovery of algal products of value
- It is a process for the co-disposal of refractory organic solids with saline effluents
- It provides a possible solution to the tannery effluent problem of "salting" as a method of preservation for green hides
- It is able to remove nutrients and heavy metals from brine effluents enabling their disposal by dilution where this is appropriate.

Cost: *R76 500*
Term: *1991*

Saving of water with air-cooled heat exchangers

(No 478) Department of Mechanical Engineering, University of Stellenbosch and Eskom

Some 45% of the heat generated during the combustion of coal for power generation needs to be dissipated to the atmosphere. This can be effected by evaporating water in a wet-cooling tower or by means of an air-cooled heat exchanger, or so-called dry cooling. South Africa, a relatively arid country, is fortunate in having three of the world's largest dry-cooled power stations at its disposal. As each of these are more than an order of magnitude larger than any similar station abroad, limited relevant design information and operating experience are available from outside sources. To enable Eskom to improve the efficacy of such large systems, the Mechanical Engineering Department of the University of Stellenbosch was commissioned by the WRC to study the impact of both system and environmental parameters on the performance of dry-cooling systems. This project served as precursor for the development of computer programs to evaluate and improve the performance of dry-cooling systems.

The following three menu-driven computer programs were developed:

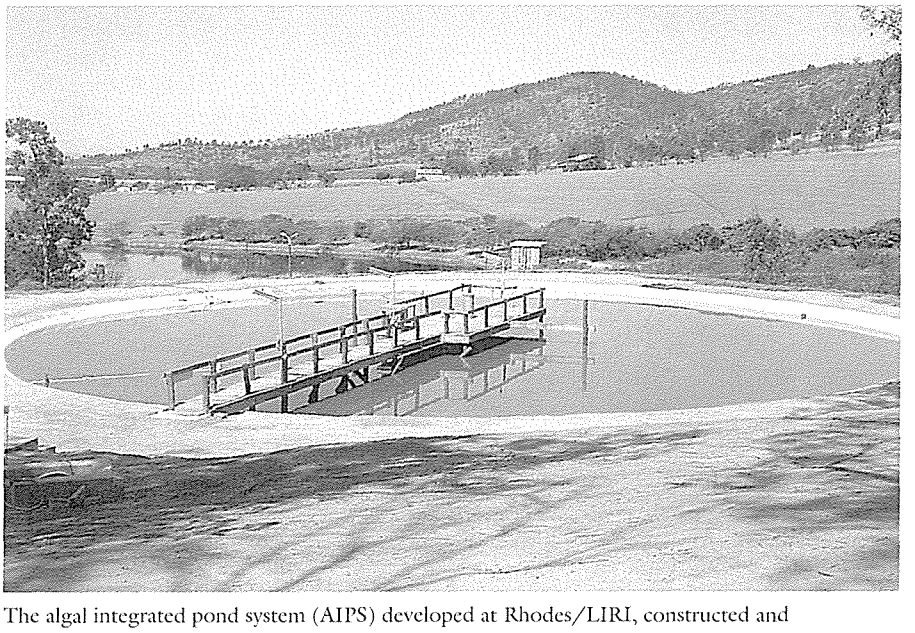
- **Natural draught wet-cooling tower analysis program**

The program enables the user to determine the performance of a natural draught counterflow wet-cooling tower in which the tower packing is arranged

horizontally in the inlet (bottom) cross-section of the tower.

Using the specified ambient conditions, tower dimensions and fill characteristics, the program computes the corresponding air and water outlet temperatures and air mass flow rate to establish the tower capacity and associated water losses.

The effect of altering tower dimensions (including tower support configuration) and fill characteristics on tower performance can be investigated to facilitate optimum design.



The algal integrated pond system (AIPS) developed at Rhodes/LIRI, constructed and commissioned in Grahamstown.
Above: The first stage anaerobic/facultative pond system.
Below: The algal high-rate ponding system.

- **Forced draught, direct condensing, air-cooled heat exchanger analysis program**

The program determines the cooling capacity of an air-cooled heat exchanger under various atmospheric conditions and, given the annual ambient temperature duration profile and net power/condenser heat dissipation characteristics, computes the net effective annual electrical energy generated by the associated turbo-generator.

The program provides a quick method to investigate the influence of certain design parameters on the overall system performance and to identify modifications that could effect major savings in capital and running costs over the effective life of the power station.

- **Natural convection dry-cooling tower analysis programs**

The program, enabling performance evaluation of a natural convection dry-cooling tower, caters for two configurations of heat-exchanger bundles:

- Where the bundles are arranged horizontally in the inlet (bottom) cross-section of the tower
- Where the bundles are arranged vertically and externally around the tower.

Cost: *R650 700*
Term: *1992-1995*

Application of capillary membranes in the biotechnological treatment of industrial effluents

(No 553) Institute for Polymer Science, University of Stellenbosch

In the past the use of biological reactors for effluent treatment has been hindered by a lack of suitable technologies to accommodate the specific requirements of living organisms or enzymic catalysts. Synthetic membranes have the potential to overcome these disadvantages. The main aim of the research project was to establish the potential application of capillary membranes in waste-water bioreaction.

Suitable membranes and modules were developed, allowing good mass transfer at low linear flow rates and easy cleaning of the membrane/feed interfaces.

Cross-flow capillary membrane bioreactors were used to immobilise the enzyme polyphenol oxidase which removed intractable phenols from industrial effluents.

Cost: *R81 200*
Term: *1993-1994*

Evaluation of membrane technology for treatment of industrial effluents

(No 590) Division of Water, Environment and Forestry Technology, CSIR

The salinity levels of combined tannery effluents are on an average four times higher than the recommended maximum of 500 mS/m, laid down by most municipal authorities.

Tannery effluent consists of various streams (soak paddle effluent, liming effluent, deliming effluent, tanning effluent and dye-house effluent) contributing different salinity, organic and ammonia-nitrogen concentration levels to the final combined effluent. The soak paddle and certain parts of the tanning effluent (pickling and vegetable and chrome tanning operations) contribute most to the salinity level of the final effluent.

Attempts were made to reduce the contaminant levels in tannery effluents by using reverse osmosis (RO) in conjunction with ultrafiltration (UF), particularly with regard to the treatment of the combined, soak paddle, dye-house and liming effluents.

Although fouling of the membranes was an initial problem, optimisation of the technique finally allowed good turbidity and COD removals. This proved that combined UF and RO constituted suitable unit processes to treat the various individual effluent streams emanating from tanneries.

Cost: *R99 000*
Term: *1994-1995*

Investigation into the use of biodispersants available for biofouling control in industrial water systems

(No 592) Department of Microbiology and Plant Pathology, University of Pretoria

The project investigated the dispersing activity of biodispersants with regard to bacterial attachment and detachment of established biofilms on surfaces within cooling-water systems used in power stations.

Due to periodic water shortages Eskom is forced to recycle and reuse water in their cooling systems. This leads to concentrations of dissolved and suspended substances in the water, giving rise to microbial growth, biofilm formation and eventually biofouling of such industrial recirculating water systems.

Laboratory experiments were conducted on glass surfaces and 3CR12 stainless steel coupons. It was shown that a non-ionic surfactant, used in combination with isothiazolone biocide, inhibited bacterial attachment to these surfaces by 96% and removed 97% of a mature *Pseudomonas aeruginosa* biofilm.

Cost: *R96 000*
Term: *1994-1995*

Extractive purification of industrial effluents

(No 617) Department of Chemical Engineering, Potchefstroom University for CHE

The main aims of the project were the qualification of supported liquid membrane (SLM) extraction with regard to the concentrations of the feed and strip solutions, their respective acidities, the concentration of the extractant mix, and the effect of temperature variations on these processes.

The technical feasibility of SLM extraction was demonstrated on anions such as HPO_3^{2-} and $H_2PO_2^-$, as well as lactates and acetates. Further positive results were also obtained with Ca, Ni and Cr from a synthetic sulphate medium and extraction of Zn from industrial effluent.

Capsulated membrane extraction (CME), where the extractant is confined in a capsule placed in the feed solution, was shown to achieve extraction rates of an order of magnitude higher than that achieved by SLM extraction.

It was therefore concluded that both SLM and CME are viable techniques for the extraction and recovery of a variety of chemical species from dilute industrial effluents.

Cost: *R266 300*
Term: *1994-1995*

New projects

NATSURV: Water and waste-water management in the petrochemical industry

(No 759) Division of Water, Environment and Forestry Technology, CSIR

A sustainable and healthy socio-economic development can only be ensured by maximising production per unit volume of water used. To control pollution of South Africa's water resources, water must be used judiciously and waste water managed effectively.

The Oil Industry Environment Committee, which is contracted to the major petrochemical industries in an advisory capacity, was recently contacted and they strongly supported the need for a national survey to be conducted on water and waste-water management to evaluate water wastage and possible means to address the pollution loads of various petrochemical effluents. Through such a national and industrial water and waste-water survey (NATSURV), water quality can be improved and water wastage can be minimised.

The main aims are to:

- Determine volumes of water intake and discharge for the major petrochemical industries
- Make recommendations in terms of

water and waste-water management
- Determine pollutant loads in the effluents generated
- Compile a NATSURV publication.

Estimated cost: *R190 000*
Estimated term: *1996-1997*

Waste minimisation and effluent treatment guide for the textile industry

(No 760) Pollution Research Group, University of Natal

Textile industries are water-intensive, using a total of 30 million k*l* of water per year. The effluent produced is ranked second highest with respect to hazardous waste intensity and principally affects water quality. It is therefore important to encourage textile industries to implement water and effluent management strategies and to minimise waste at source. In order for the local textile industry to survive, it must become more export orientated and economically competitive, principally by reducing environmental impacts. Therefore, there is a need for a detailed guide to train the industry and its employees to conduct waste minimisation surveys and implement cleaner production technologies.

Project aims are to:

- Transfer the technology already gained to the South African textile industry in a range of readily accessible media
- Enable the industry to implement its own waste minimisation and pollution prevention programmes
- Enable the industry to be internationally competitive through the implementation of proactive and rational environmental management systems.

Estimated cost: *R345 000*
Estimated term: *1996-1997*

Extraction of ionic and chemical species from water by capsulated membrane extraction

(No 761) Department of Chemical Engineering, Potchefstroom University for CHE

The transport of material through a membrane is always very expensive due to the very high capital investment of reactors with large active areas and the extremely adverse thermodynamic conditions that have to be overcome to produce significant transport rates.

SLM systems are characterised by the extraction of chemical species from a feed solution through a membrane into a strip solution. In order to overcome certain limitations of such SLM systems the idea of an unconfined reactor was conceptualised. This concept comprises a capsule containing the so-called strip solution, impregnated with the correct extractant/diluent, which would effect the desired extraction.

The main aim of this project is the development of a suitable SLM to extract specific ions from boiler feed water and cooling water. This entails the identification and evaluation of suitable substrates; a suitable extractant and strip solution and suitable chemical conditioning of the feed and strip solutions.

Estimated cost: *R100 000*
Estimated term: *1996*

Survey of anaerobic digesters in the KwaZulu-Natal region in order to assess their availability for the treatment of high strength or toxic organic effluents

(No 762) Pollution Research Group, University of Natal

The KwaZulu-Natal region has the potential to attract more industries, due to its relative abundance of water. Certain industries will be from the agro-industrial sector, or those which produce high-strength or toxic organic liquid effluents. Hence there is the need for anaerobic digestion facilities that can accept such industrial effluents.

The region also has a great need for the provision of sanitation because the increasing urban and peri-urban population will require increased sewage treatment capacity. Use of existing but underutilised capacity will assist in financing the additional infrastructure needed.

This survey aims at providing information which will allow the rational location of new industries producing high strength or toxic organic liquid effluents; to assist in the optimal utilisation of effluent treatment facilities in the region; and to identify under-performing digesters. This will allow rational decisions to be taken on safe disposal of effluents and to safeguard the aquatic environment by providing suitable industrial effluent treatment options.

Estimated cost: *R243 000*
Estimated term: *1996-1997*

Biotechnological approach to the management of effluents from the pulp and paper industry

(No 763) Department of Microbiology and Biochemistry, University of the Orange Free State

During the bleaching of paper and pulp a number of chlorinated compounds are produced that are extremely toxic to the environment. Furthermore, sulphur compounds used in the pulping processes also constitute an environmental problem. Therefore, there is a need to reduce such compounds.

Biological treatment of wood and pulp by micro-organisms and enzymes can lead to reduction in the requirements for these toxic compounds thereby reducing their concentration in the effluents. Biological processes would also enable pulp and paper plants to reduce their requirements for process water.

The project is aimed at developing a novel technology for pulp and paper manufacture by using white-rot fungi or lignolytic enzymes and reduced amounts of pulping and bleaching chemicals and improving the quality of the effluents produced as a result of the application of the biopulping and biobleaching technologies and as a result of secondary treatment of the effluents.

Estimated cost: *R288 000*
Estimated term: *1996-1997*

Utilisation of earthworms and associated systems for treatment of effluent from red meat abattoirs

(No 766) Multilog Division, Abakor Ltd.

An assessment of water and waste management practices conducted at small- and medium-sized abattoirs revealed that the overall level of environmental performance of these plants was very poor, which is attributed to the lack of a robust low-cost treatment technology.

Researchers in India have developed a robust treatment system that has successfully used earthworms for processing poultry offal and for conversion of

bones, feathers, blood and dead birds into useful by-products. In South Africa there is expertise on the processing of organic waste using the earthworm, *Eisenia foetida*.

The main aim of the project is the development of a robust system to treat effluent from red meat abattoirs by the utilisation of earthworms and associated systems which will be economically and practically feasible to be applied by small- and medium-sized abattoirs.

Estimated cost: *R520 000*
Estimated term: *1996-1997*

Total recycling of effluent from the protein recovery process appropriate to the red meat and poultry abattoir industries

(No 778) Multilog Division, Abakor Ltd.

This project aims to treat recycled abattoir effluent to potable standards for general reuse in any part of the abattoir including the wash-down of lairages and to monitor the bacteriological and virological quality of the treated effluent. With the successful execution of this project the abattoir industry would be in a position to considerably reduce freshwater use, recover valuable by-products and proteins and save on effluent treatment costs.

The objectives are:

- Construction and operation of a system to treat effluent from the protein recovery process to a reuse quality of drinking-water standards
- To determine the most successful and cost-effective treatment system
- Determination of design and operational parameters.

Estimated cost: *R195 000*
Estimated term: *1996*

Flamingos certify environmental world-first at Mossop Western Leather, Wellington where the first full-scale high-rate oxidation pond treating leather effluent was commissioned recently.

Research projects

Completed

- **365** Evaluation and improvement of the anaerobic digestion/ultrafiltration (ADUF) effluent treatment process (CSIR – Division of Water, Environment and Forestry Technology)
- **410** Biological approach to the removal of organics from saline effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **478** Saving of water with air-cooled heat exchangers (University of Stellenbosch – Department of Mechanical Engineering and Eskom)
- **553** Application of capillary membranes in the biotechnological treatment of industrial effluents (University of Stellenbosch – Institute of Polymer Science)
- **590** Evaluation of membrane technology for the treatment of industrial effluents (CSIR – Division of Water, Environment and Forestry Technology)
- **592** Investigation into the use of biodispersants available for biofouling control in industrial water systems (University of Pretoria – Department of Microbiology and Plant Pathology)
- **617** Extractive purification of industrial effluents (Potchefstroom University for CHE – Department of Chemical Engineering)

Current

- **239** Transfer of waste-water management technology to the meat processing industry (SRK (CE) Inc. and Abakor Ltd.)
- **241** Dewatering of compressible filter cakes (University of Natal – Department of Chemical Engineering)
- **263** Biological treatment of industrial water with the simultaneous production of single-cell protein (University of Pretoria – Department of Chemical Engineering)
- **308** Recovery of water and chemicals from ion-exchange regeneration effluents (University of Natal – Department of Chemical Engineering)
- **315** Utilisation of the fungus *Geotrichum* in waste water (University of Pretoria – Department of Chemical Engineering)
- **331** Improved oxygen transfer for high biosludge concentrations (University of Pretoria – Department of Chemical Engineering)
- **333** Removal of suspended solids from pulp and paper effluents by employing a combined sedimentation, flotation and sand filtration process (CSIR – Division of Water, Environment and Forestry Technology)
- **342** Improvement in water usage control and waste-water treatment in the sorghum beer industry (University of Pretoria – Department of Chemical Engineering)
- **388** Evaluation of various methods for the forming of free radicals for the oxidation of molecules in industrial effluents and potable water (University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **408** Fats and oils in effluents (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering)
- **409** Phenols in the steel industry waste water: Origin, prevention and removal (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering)
- **453** Development of procedures to assess whole effluent toxicity (CSIR – Division of Water, Environment and Forestry Technology)
- **455** Anaerobic digestion of dairy factory effluents (Irene Animal Production Institute, Agricultural Research Council)
- **456** Regional treatment of textile and industrial effluents (University of Natal – Department of Chemical Engineering)
- 457 Monitoring and optimisation study of high-rate biofiltration, aerobic biological treatment processes for tannery and fellmongery waste water (LIRI Technologies)
- **458** Development of an expert systems approach to water management in the fruit and vegetable processing industry (SRK (CE) Inc.)
- **495** Biotechnological approach to the removal of organics from saline effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **535** Use of filamentous micro-organisms for the purification of industrial effluents (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering)
- **546** Development and demonstration of effluent treatment systems appropriate to the needs of the red meat abattoir industry (SRK (CE) Inc.)
- **551** Evaluation of the potential quantity of methane gas from 85 anaerobic household digesters (BE La Trobe)
- **552** Evaluation of immobilised semi-conductor particles for the photo-catalytic oxidation of organic pollutants in industrial and municipal waste water (University of Stellenbosch – Department of Chemistry)
- **589** Development of management strategies and recovery systems for heavy metal wastes (SRK (CE) Inc.)
- **612** Reduction of scaling in industrial water-cooling circuits by means of magnetic and electrostatic treatment (Rand Afrikaans University – Energy Laboratory and Department of Chemistry)
- **616** Use of algal and yeast biomass to accumulate toxic and valuable heavy metals from waste water (Rhodes University – Department of Biochemistry and Microbiology)
- **652** Purification of abattoir effluents by means of the protein reclamation process (Abakor Ltd.)
- **657** Course development for the education and training of industrial waste-water treatment plant operators and managers (Rhodes University – Department of Biochemistry and Microbiology)
- **658** Algal high-rate oxidation ponding for the treatment of abattoir effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **659** Purification of high organic effluent by means of a tent-type anaerobic digester (Abakor Ltd. – Multilog Division)
- **660** Development and implementation of biological cleaning techniques for ultrafiltration and reverse osmosis membranes for industrial effluents with a high organic content (University of Stellenbosch – Department of Biochemistry)
- **661** Role played by *Shewanella* and sulphide-producing bacteria in metallic corrosion in industrial water systems (University of the Western Cape – Department of Microbiology)

- **667** Enhanced granulation in upflow anaerobic sludge-bed digesters (UASB) by process induction and microbial stimulation (University of Stellenbosch – Department of Food Science)
- **673** Complete treatment of dairy factory effluents by means of primary anaerobic digestion and secondary algal protein production (Agricultural Research Council – Animal Nutrition and Animal Production Institute)
- **674** On-site evaluation of an anion-free flocculant for industrial cooling systems (University of Natal – Department of Chemical Engineering (Pollution Research Group) and Eskom)
- **687** Membrane-based biotechnological systems for treatment of organic pollutants (Rhodes University – Department of Microbiology)

New

- **759** NATSURV: Water and waste-water management in the petrochemical industry (CSIR – Division of Water, Environment and Forestry Technology)
- **760** Waste minimisation and effluent treatment guide for the textile industry (University of Natal – Pollution Research Group)
- **761** Extraction of ionic and chemical species from water by capsulated membrane extraction (Potchefstroom University for CHE – Department of Chemical Engineering)
- **762** Survey of anaerobic digesters in the KwaZulu-Natal region in order to assess their availability for the treatment of high strength or toxic organic effluents (University of Natal – Pollution Research Group)
- **763** Biotechnological approach to the management of effluents from the pulp and paper industry (University of the Orange Free State – Department of Microbiology and Biochemistry)
- **766** Utilisation of earthworms and associated systems for treatment of effluent from red meat abattoirs (Abakor Ltd. – Multilog Division)
- **778** Total recycling of effluent from the protein recovery process appropriate to the red meat and poultry abattoir industries (Abakor Ltd. – Multilog Division)

CONTACT PERSONS

- **Dr TC Erasmus** (Cross-flow Microfiltration, Power Stations and Industrial Water and Effluent Management)
- **Dr SA Mitchell** (Bioassaying)
- **Dr G Offringa** (Membrane Applications)

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Synthetic membranes are being used to an increasing extent in the desalination and purification of industrial effluents, for reuse as process water, and also as a cost-efficient method to purify water for potable use. In the latter case membrane technology has been identified as having great potential in the supply of potable water to remote, rural and peri-urban communities.

A novel polysulphone capillary ultrafiltration membrane has been developed by the Institute for Polymer Science, University of Stellenbosch with WRC funding. This dual-purpose membrane, which is characterised by having an outer-skinless construction, may not only be used as an ultrafiltration membrane to produce potable water from surface or subsurface sources, but also as a novel bioreactor to produce fungal enzymes which are very effective in treating intractable organic pollutants found in certain industrial effluents. The latter application has been patented recently in the name of the WRC.

These developments were communicated to membrane technologists at a national conference of the Indian Membrane Society in Delhi, India in February 1996 and also presented as a full paper at the prestigious "International Congress on Membranes and Membrane Processes" in Yokohama, Japan in August 1996.

Completed projects

Mon Villa rural watercare project

(No KV79/95) Institute for Polymer Science, University of Stellenbosch

The project was aimed at optimising modern membrane technology to make it cost-effective in providing potable water to small- and medium-sized rural communities.

The water supply from Theewaterskloof is only intended for irrigation and the quality of this untreated water is such that it cannot be regarded as safe for human consumption. The water has high microbial activity as well as a high colour content and is also extremely corrosive

due to its low carbonate alkalinity.

In order to render this irrigation water suitable for drinking purposes, the Institute for Polymer Science developed a small-scale ultrafiltration (UF) plant to treat 12 m^3 of water on a daily basis, at relatively low cost. This plant has been in successful operation for the past 18 months. The process makes use of a novel capillary UF membrane which only has an inner skin with the outer surface being open-pored. This allows good flux characteristics, but removes all suspended organic materials, including bacteria. Breakpoint chlorination is applied after UF as a final safeguard against viruses.

Cost: *R100 000*
Term: *1995-1996*

Membrane characterisation by electrochemical measurements and membrane optimisation with computational fluid mechanics

(No 529) Department of Chemical Engineering, Potchefstroom University for CHE

The aim of this feasibility study was the quantification of membrane characteristics by means of electrochemical impedance spectroscopy (EIS) and computational fluid dynamics (CFD).

The latter technique made use of iterative convergence of non-linear relationships between viscosity, density, concentration and osmotic pressure with changes in temperature. Trans-membrane variables, such as pressure gradients and permeability; intra-membrane variables, including compaction, tortuosity and porosity; and membrane proximity factors, such as concentration gradients; density, viscosity and velocity profiles were investigated and verified.

EIS studies concentrated on the development of an electrolytic cell to generate impedance spectral data, used for static modelling of a membrane in an electrolyte as a resistance-capacitance electrical circuit.

An attempt was made to relate the results of these two studies to dynamic flow conditions occurring in ultrafiltration and reverse osmosis.

Cost: *R516 000*
Term: *1993-1995*

Development of characterising and cleaning techniques to classify foulants and to remove them from ultra- and microfiltration membranes by biochemical means

(No 531) Department of Biochemistry, University of Stellenbosch

The main objectives of this research project were the identification and classification of membrane foulants occurring in abattoir, wool-scouring and other industrial effluents. Two further aims were the development of methods for the biological removal of such foulants from membrane surfaces and the cloning and large-scale preparation of specialised enzymes to degrade specific foulants.

Proteins and lipids were found to be the main foulants in abattoir effluents, whilst proteins and waxes were predominant foulants in wool-scouring effluents. Lipases and esterases were successful enzymes for the removal of foulants from abattoir and wool-scouring effluents, respectively, and restored the fluxes in fouled membranes.

These promising results indicated that enzyme-based biological cleaning regimes hold great promise for the restoration of fouled ultrafiltration membranes.

Cost: *R150 900*
Term: *1993-1994*

Synthesis of organic precursors for the development of novel tubular membranes for the treatment of industrial effluents

(No 547) Department of Chemistry, University of Stellenbosch

The aims of this project included the following developments: syntheses of substituted benzonoid aromatic di-acids and their derivatives; and the syntheses of soluble polyamides with high molecular masses showing good resistance to both acids and alkalis. Such novel precursors may be used in the manufacture of chemically and thermally resistant capillary membranes for the treatment of industrial effluents. o-Phenylenediamine was cyclised with thionyl chloride to yield 77% of benzothiadiazole. Oxidation of the latter, however, produced the desired di-acid in only 16% yield. A modified approach resulted in a much improved 88% yield of the di-acid.

Polyamides were also synthesised in fairly low yields, 12 to 16%, by reactions of di-acid dichlorides with amino monomers, using solution polymerisation.

Larger-scale production of these precursors will allow their use in novel membrane synthesis.

Cost: *R54 200*
Term: *1993-1995*

New project

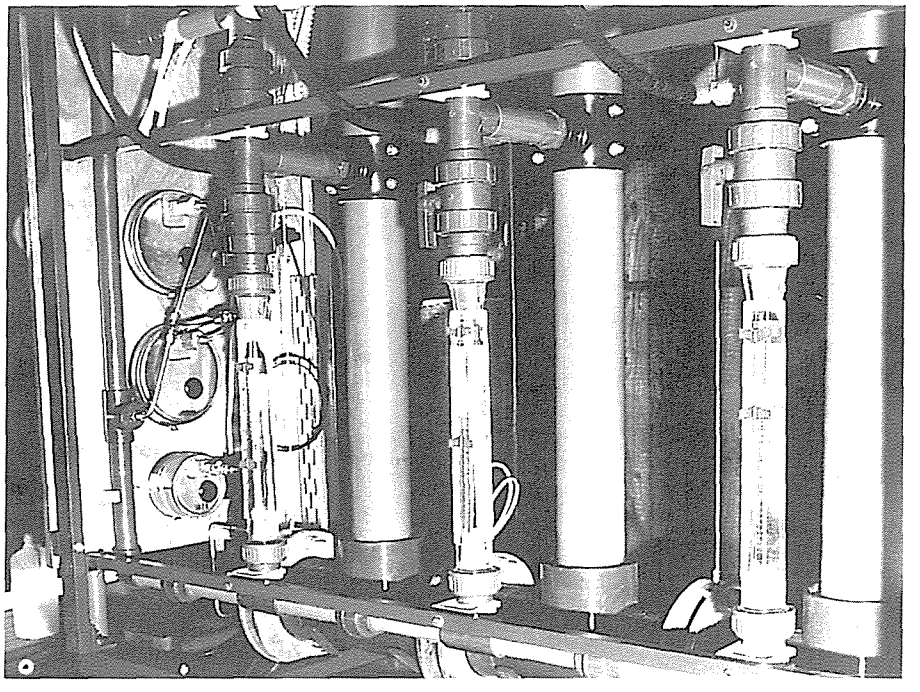
Computer program for cross-flow module and potable water plant design

(No 728) Institute for Polymer Science, University of Stellenbosch

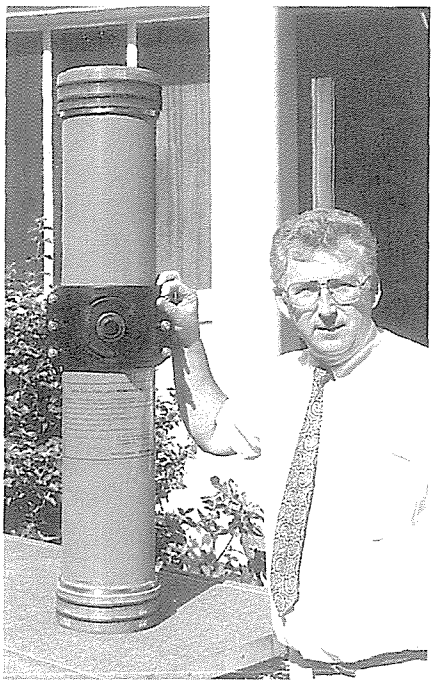
The need for a computer design facility and database program for rapid updating, access, storage and retrieval of information and drawings has been identified, because it will save time and duplication of design work; ensure the success of module manufacture; speed up training of students and personnel in industry; and reduce production cost by using proven designs and concepts. Such a facility is also essential for project planning and for cost estimates. Ultimately this will lead to the production of more reliable equipment to be used in the production of potable water or for recycling of process water in industry.

The main aim of the research and development project is a computer design database for cross-flow capillary membrane modules and plants made from them. This will involve the integration into a computer-aided design and machining (CAD/CAM) system for the production and manufacture of membrane modules and plants.

Estimated cost: *R42 000*
Estimated term: *1996-1997*



Mon Villa ultrafiltration facility for potable rural water supply.



Mr Siegfried Domröse of the Institute for Polymer Science demonstrating a large membrane module.

Research projects

Completed

- **KV79/95** Mon Villa rural watercare project (University of Stellenbosch – Institute for Polymer Science)
- **529** Membrane characterisation by electrochemical measurements and membrane optimisation with computational fluid mechanics (Potchefstroom University for CHE – Department of Chemical Engineering)
- **531** Development of characterising and cleaning techniques to classify foulants and to remove them from ultra- and microfiltration membranes by biochemical means (University of Stellenbosch – Department of Biochemistry)
- **547** Synthesis of organic precursors for the development of novel tubular membranes for the treatment of industrial effluents (University of Stellenbosch – Department of Chemistry)

Current

- **201** Treatment of inorganic brines and concentrates (University of Natal – Pollution Research Group)
- **238** Design criteria for cross-flow microfiltration (University of Natal – Pollution Research Group)
- **548** Investigation into the upgrading of Orange River water and secondary sewage effluent by means of ultra- and nanofiltration (University of Stellenbosch – Institute for Polymer Science)
- **618** Development of specialised cross- and transverse-flow capillary membrane modules (University of Stellenbosch – Institute for Polymer Science)
- **619** Tolerant membranes (University of Stellenbosch – Institute for Polymer Science)
- **632** Capillary membrane production development (University of Stellenbosch – Institute for Polymer Science)
- **723** Designed functionalised polymers by anionic macromolecular engineering for membrane development (Vista University – Department of Chemistry (Port Elizabeth Campus))

New

- **728** Computer program for cross-flow module and potable water plant design (University of Stellenbosch – Institute for Polymer Science)

CONTACT PERSONS

- **Dr G Offringa** (Development and Application of Membranes)
- **Dr TC Erasmus** (Engineering Aspects of Membranes)

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10 HYDROCLIMATOLOGY

Hydroclimatology is the name given to the water research field which incorporates all weather- and climate-based sciences and developing technologies which have an important contribution to make to the assessment and management of South Africa's water resources.

Precipitation enhancement through cloud seeding is one of the developing technologies which has enjoyed the strong research support of the WRC since 1983. What initially started off as two individual WRC and Weather Bureau supported projects, were in 1990 amalgamated into a single, jointly funded research programme. This, the National Precipitation Research Programme (NPRP), focused strongly on understanding precipitation processes in summer convective storms, learning to modify these processes by appropriate seeding of storms, measuring responses to seeding using ground-based radar and airborne cloud microphysical instrumentation, and performing randomised experiments to determine the size and statistical significance of measured cloud responses to seeding. The main product of the NPRP has been a well-researched and highly promising technology based on hygroscopic seeding of convective storms as a means of increasing their precipitation efficiency.

During recent years, but especially during the past year, the focus of the NPRP has shifted progressively from measuring single-storm responses, to assessing area-scale effects of multiple-storm seeding. Acceptance, and consequent operational application of the seeding technology, is dependent upon demonstrating that meaningful benefits to water resources and agricultural production (including forestry production) are both attainable and cost-effective.

The immediate research challenge, thus, is how to objectively assess the benefits of an area-scale seeding programme which necessarily tends to be more operational by nature, than rigorous in meeting the requirements of conventional statistical experimentation. In order to achieve this objective assessment, several promising evaluation techniques are currently being investigated and developed. These include the use of improved, radar-based procedures for tracking storms and measuring rainfall in real time. They also include the complementary use of streamflow data and hydrological models.

Significant advances in the **measurement and monitoring of areal rainfall** with the aid of radar, which have come about as a spinoff from the precipitation

enhancement research programme, are likely to have widespread benefits for water resources management in general. Applications which are likely to benefit most include the use of distributed hydrological models to predict runoff and sediment transport, the monitoring of potential life- and property-threatening situations and the assessment of the extent and intensity of drought conditions. For these applications, the sole use of rain-gauge measurements, being essentially point measurements, has proved to be largely inadequate because of low sampling density and infrequent reporting.

Even with enhanced rainfall monitoring systems, dealing adequately with droughts and floods would undoubtedly be made much easier if reliable forecasts of such conditions were to be available. For this reason it has been important for the WRC to contribute towards research which would lead to the improvement of skills in the **forecasting of precipitation in the Southern African region**. Of special interest are forecasts with lead times ranging from several days to several months. Several contributing projects have already been completed, while ongoing research is currently under way at the University of Cape Town and the University of the Witwatersrand.

Weather and climate forecasts, from short to long range, are already starting to benefit enormously from steady development and improvement in general circulation models or GCMs. However, GCMs operate at global scale, i.e. at large spatial scales and coarse spatial resolution. To be useful predictors of climate variability at sub-country or at catchment scale, GCM outputs need to be "downscaled" to match the scale of the region of interest. In South Africa, development of downscaling techniques is being undertaken as part of WRC-supported research, at the University of Cape Town, into **regionalising GCM forecasts of global climate change** resulting from anthropogenically-induced changes in the earth's atmosphere. There are indications that South Africa's water resources could be strongly impacted by regional climate change, making it necessary, therefore, to establish realistic planning scenarios in order to develop strategies for accommodating likely impacts.

Completed project

Mechanisms of short-term rainfall variability

(No 436) Department of Oceanography, University of Cape Town

This project was initiated in response to a need for a better understanding of mechanisms whereby atmospheric disturbances in the tropical Indian Ocean and in mid-latitude areas propagate and interact to affect Southern African rainfall. The aim of the project was to identify and understand such mechanisms, especially those governing intra-seasonal (15 to 40 day) variability in summer convection over the Southern African plateau. Intra-seasonal oscillations (with a dominant cycle length of about 25 days) in summer convection were identified and causative mechanisms revealed by means of composite analysis of numerical weather data. Intra-seasonal oscillations (ISOs) appear to be influenced by slow, eastward moving "waves" in both tropics and mid-latitudes; the contribution from either source is variable and results in a wide range of ISO characteristics which were able to be classified and described. The research has made a considerable contribution to the characterisation of wet and dry spells in Southern Africa. The better understanding of mechanisms involved should be of practical use in refining techniques for 10 to 30 day rainfall forecasts.

Cost: *R371 000*
Term: *1992-1995*

New projects

Analysis of regional precipitation and water resource impacts from GCM-derived regional climate change scenarios

(No 751) Department of Environmental and Geographical Science, University of Cape Town

Climate change, which is being quantified at a global scale using various general circulation models (GCMs), will impact society in South Africa most directly through changes in precipitation and water resources. In response to this likelihood, the WRC funded a two-year project during 1994 to 1995 to develop downscaling methods to obtain regional climate change scenarios for precipitation and temperature over South Africa.

In order to assess global climate change impacts on water resources, the regional climate change scenarios which this follow-on project aims to produce, will have to take into consideration the following:

- Changes in seasonality of rainfall
- Changes in event persistence, frequency, intensity and extreme events
- The degree of consensus between the different GCMs from which regional climate change scenarios may be derived
- Disaggregation of the regional scenarios to even finer spatial scales such as catchments and even down to individual climate stations.

Scenarios will be used in conjunction with hydrological and crop models to better understand the vulnerability of South Africa's resources and to develop better strategies to adapt to the climate change impacts.

Estimated cost: *R137 100*
Expected term: *1996-1997*

Spatial and temporal modelling of rainfields using fractals

(No 752) Department of Civil Engineering, University of Natal

Much effort has been expended and considerable expense incurred, both locally and overseas, in developing sound hydrological models as tools to be used in the management of river catchments and water resources. It is well-recognised, however, that the greatest limiting factor to the effective use of these models is the quality of the rainfall input information. This is especially true in the South African situation where our predominantly convective (thunderstorm) rainfall tends to be highly variable in both space and time. Consequently, point measurements made with isolated rain gauges are notoriously unreliable.

There is an urgent need to overcome this limitation, both when using hydrological models with historic rainfall information for planning purposes or with current rainfall information to assist with real-time management (e.g. flood warning and control). The challenge is to present rainfall information, not in the form of point data, but as rainfield data, either acquired directly or derived (modelled) in a sound and valid manner. Rainfields are representations of the true areal (spatial) distribution of rainfall, irrespective of where sampling rain gauges may or may not have been positioned.

Two recent developments will assist in meeting this challenge, which the current research aims to address. They are the availability of a suitable weather radar for direct observation of rainfield occurrence in space and time and growing expertise in fractal geometry, which appears to be the most logical and sound basis for characterising rainfields mathematically.

Estimated cost: *R247 000*
Expected term: *1996-1997*

Research projects

Completed

- **436** Mechanisms of short-term rainfall variability (University of Cape Town – Department of Oceanography)

Current

- **349** Evaporation measurements above vegetated surfaces using micro-meteorological techniques (University of Natal – Department of Agronomy)
- **374** Southern Agulhas Current and its influence on the weather and climate of Southern Africa (University of Cape Town – Department of Oceanography)
- **437** Assessment of the potential for using stable carbon isotope ratios of wood charcoal as a climate indicator (South African Museum – Cape Town)
- **550** Development of models to stochastically generate spatially distributed daily rainfields (University of Natal – Department of Civil Engineering)
- **594** Regional climate change scenarios for precipitation and temperature from general circulation models (University of Cape Town – Department of Environmental and Geographical Science)
- **595** Modelling rainfall-producing systems over Southern Africa (University of the Witwatersrand – Climatology Research Group)
- **596** Development of a real-time non-conventional rainfall mapping system for coastal zone cloud systems (University of Pretoria – Department of Civil Engineering)
- **672** Development of an objective system to forecast summer rainfall over Southern Africa (University of Cape Town – Department of Oceanography)
- **693** Weather radar measurement of rainfall as well as hydrological applications of weather radar (University of Pretoria – Department of Civil Engineering)
- **726** National precipitation research programme with a view to rainfall enhancement (Company for Research on Atmospheric Water Supply (CRAWS) and Department of Environment Affairs (Weather Bureau), subcontracting CloudQuest (Pty) Ltd. and Unisa)

New

- **751** Analysis of regional precipitation and water resource impacts from GCM-derived regional climate change scenarios (University of Cape Town – Department of Environmental and Geographical Science)
- **752** Spatial and temporal modelling of rainfields using fractals (University of Natal – Department of Civil Engineering)

CONTACT PERSON

- **Dr GC Green**

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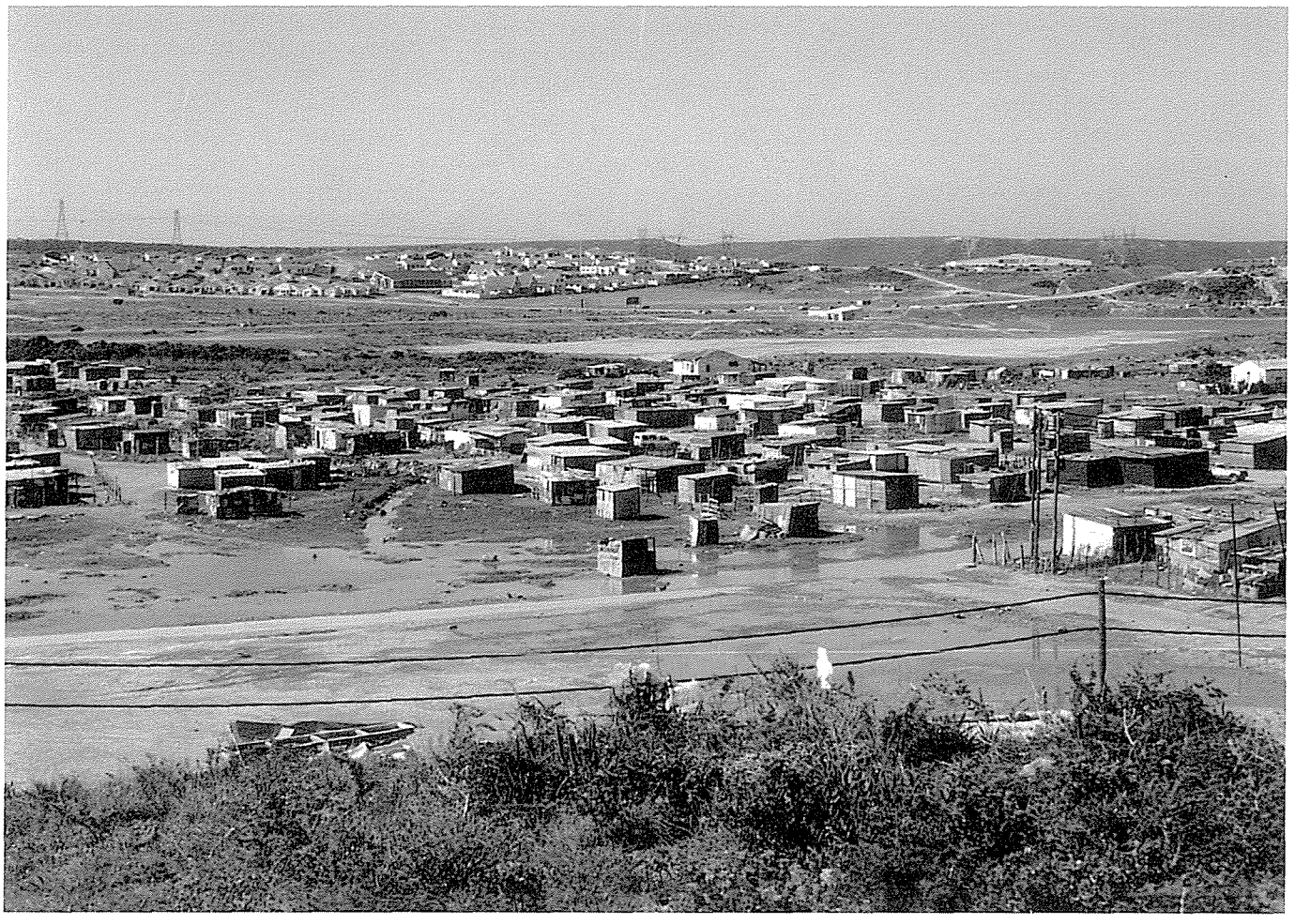


With the present activity to comprehensively review and rewrite our water law, a unique opportunity exists to clarify the philosophy and practice of integrated catchment management (ICM). The WRC initiated research on this issue some years ago but the water law review process rapidly overtook activities and created urgency in the matter. Several workshops and conferences that have been held recently, all clearly showed a lack of common vision in this regard and it will take considerable and ongoing effort from all of us to keep ideas converging.

In its widest sense, ICM recognises the need to integrate all environmental, economic and social issues within a river basin into an overall management policy, process and plan. One of the many important elements in this regard is that consensus must be reached by all stakeholders regarding co-ordinated action plans for different aspects of water resource management by central, provincial and local spheres of government while public participation must be optimised taking into account local capacity.

Empowerment of people to actively take part in the process will hinge to a large extent on scientifically correct, appropriate and comprehensive information. At the same time a lot more research on socio-economic and legal concerns will have to take place in order to promote the process in a systematic fashion.

Comprehensive decision support systems will have to play an important role in the untangling of our extremely complex problem so that we can all learn to distinguish between the wood and the trees but above all provide everybody involved with a better understanding of the other person's viewpoint.

Completed projects

Economics of groundwater usage: The importance of intrinsic value as a basis for sustainable management

(No 639) Economic Project Evaluation (Pty) Ltd.

The overall objective of this project was to develop methodologies for placing a value on groundwater which is proportional to the importance of the use to which it is put. At the outset it was recognised that these values are likely to vary from one groundwater use activity to another, and from one location to another. Such values are critical in that they can indicate and justify the nature and extent of groundwater management systems.

The literature review confirmed that in many regions of the world groundwater has been regarded as a free commodity, and this has led in some instances to over-exploitation of the available resources, as well as uncontrolled releases of pollutants into water resources by households, agriculture and industry.

During the course of the study it became apparent that integral to an economic analysis of groundwater management regimes is an insight into the legal status of groundwater and the rights attached to its use. Consequently the research team examined this issue within the context of the then interim constitution and presented recommendations for policy and legislative reform of groundwater law.

Various methodologies for economically valuing groundwater, based on classical economic theory, were developed for use in the case studies. The researchers found that each of the techniques for estimating the value of groundwater have problems attached to them which makes the application in many instances difficult. Hence caution is recommended when choosing a technique for a particular application. Of these, it was found that the **Residual Imputation Method** of valuing groundwater is probably the most appropriate public or private valuation technique, in that it does represent factual input and output parameters that can be measured.

Economic incentives for groundwater management were considered, and the most promising of these for the South African context appear to be:

- Levies, taxes and charges
- Pricing policies
- Groundwater markets
- Tradable permits.

Recommendations in this regard are made in the report.

Cost: *R170 000*
Term: *1994-1995*

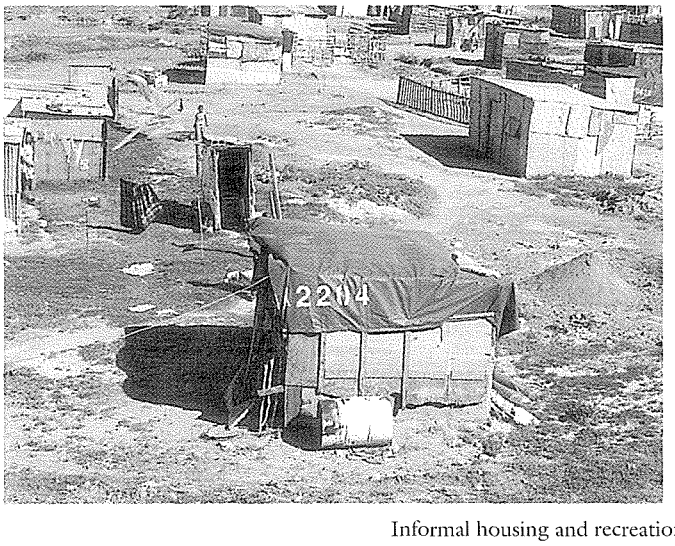
Capacity of catchments to satisfy water requirements of rural areas

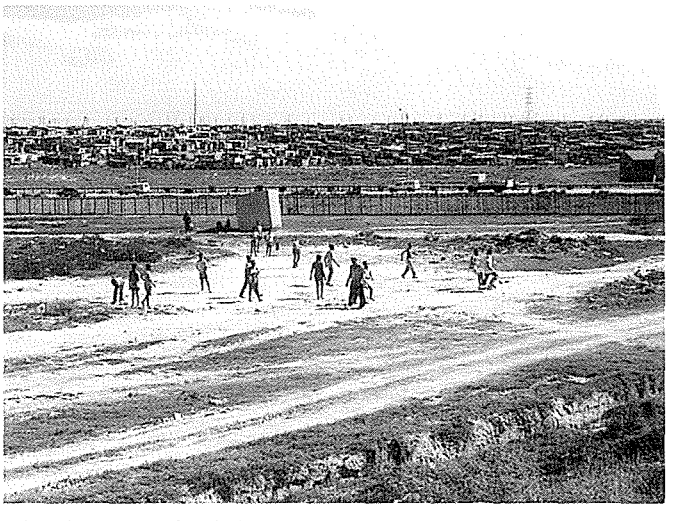
(No 680) Department of Landscape Architecture, University of Pretoria

The historical distribution of the South African population places extreme pressure on the water resources of South Africa. Both the physical presence of excessive concentrations of people and the resulting growing demand on the resource can be detrimental. The ecological state of the catchment can thus have a large influence on the ability of resources to satisfy national requirements.

Two categories of knowledge therefore have a bearing on the assessment of the potential of a water resource. On the one hand there is knowledge of the ecological state of the environment and on the other there is information on human concentrations and land uses.

Quantification of available water resources in South Africa recently received a boost via three WRC-supported projects viz. **Surface water resources of South Africa** (No 298) and the **Groundwater resources mapping programme** (No 483 and No 517). Prior to the start of this project, there was a strong need to combine this spatial information, as well as spatial information on population density and ecological status of catchments within a single GIS coverage. This would greatly facilitate assess-





Informal housing and recreation on the Chatty River flood plain.

ment of the impact of population densities on water resources and the ability of catchments to meet water demands of various communities, especially in the light of the high priority being given by the government to community water supply.

The following data sets have been compiled and brought together in a single coverage called SGPATLAS:

- exp (groundwater exploitability)
- acc (groundwater accessibility)
- mar (mean annual runoff)
- sgpatlas (unioned dataset)
- pop (1993 population data)
- gwpot (groundwater potential)
- swpot (surface water potential).

The GIS database consists of a series of ARC/INFO coverages residing in a dedicated sub-directory called SGPATLAS. One overall unioned coverage exists, called SGPATLAS. A detailed description of item or field names in the attribute (non-geographic) data file is included in the final report. A list of all coverage names and abbreviations is also in the final report.

No data were specifically captured for this study. Existing data sets were combined and manipulated for use on a national scale.

Cost: *R110 000*
Term: *1995*

New projects

Impacts of exotic plants on the water resources of South Africa, with special reference to economics and policy options for effective management of the problem

(No 748) Division of Water, Environment and Forestry Technology, CSIR

Exotic trees, introduced into South Africa for a number of reasons, are known to decrease water yield substantially. They also result in many other impacts, including the impacts on economic development (through excessive use of water), on biodiversity, ecotourism, catchment stability and fire control.

Examples include the invasion of catchment areas in the Western Cape Province, where indications are that up to 30% of the water resources currently used by the city of Cape Town could be lost if exotic trees are not cleared from catchment areas; the dramatic increases in streamflow that are recorded where alien trees are cleared from riparian zones in the Eastern Transvaal; and the damage to soil stability that results from fire in invaded catchments (for example at Cathedral Peak in KwaZulu-Natal or Bosboukloof in the Western Cape).

While these impacts are known to occur, there has to date been no synthesis that has attempted to quantify the overall magnitude and distribution of the problem and to propose approaches that could be adopted to address the problem at a policy level. Such a synthesis would be extremely useful at this stage, given the relevance of the problem to the RDP, the need for rapid solutions to pressing problems in the face of development pressures, and the fact that the results of scientific experiments are already available for some areas of the country.

Against this background, the aims of the proposed project are:

- Special attention will be given not only to rivers and catchments but also to groundwater reserves and aquatic environments
- Estimates of hydrological and economic consequences will be made for the control of the spread of alien invasives as well as for the failure to exercise this control
- Attention will be paid to the nature and responsibility of seed pollution
- Understanding will be obtained of the different permutations in terms of time frames, costs, socio-economic consequences and labour needs
- The benefits of additional water to the user community and the costs thereof will be compared with standard marginal cost of water supply in the region
- Research will be undertaken to understand how best to integrate this programme with community forestry needs.

Close liaison with the existing "Working for Water" programme will be maintained to ensure that the latest experience is taken into account.

Estimated cost: *R390 000*
Expected term: *1996-1997*

Modelling benefits of integrated catchment management

(No 749) Department of Agricultural Engineering, University of Natal

One of the ultimate objectives of WRC-funded programmes on water resources is that the benefits of the technologies generated should feed back to the public and should contribute to formation of catchments-related policy. In this regard, integrated catchment management (ICM) is a structured and credible methodology of formulating policy on holistic management of the interacting natural/social/political/economic systems operating within catchments.

In order to take a holistic approach, to be able to work in partnerships, and to resolve water-related conflicts in a manner which enables water demand and supply issues to be managed in an **equitable and sustainable** way, ICM requires appropriate **modelling tools** to provide answers which facilitate rapid but objective decision-making.

These modelling tools must be able to address the real issues now facing South African catchments including:

- Pressures on water resources by multi-sectoral demands as well as impacts associated with empowerment of previously disadvantaged groups
- Changes in land uses, including those associated on the one hand with the intensification of land use, and on the other with degradation of land
- Claims for an equitable water allocation for environmental purposes (including high flows and low flows for wetlands and natural habitats)
- Assessing trade-offs between economic production from catchments (including mining, industry, afforestation, commercial agriculture, irrigation), subsistence and small-scale production and sustainability of a healthy river system in regard to water quantity and quality
- The vagaries of climatic variability, manifested by exacerbated water resources variability (quantity and quality, over time and space).

It is for the above reasons that the objectives of this research programme include the further development, refinement and application of the advanced and well-established ACRU modelling system for

exploring and assessing the benefits of various ICM options in respect of water quantity and quality, including:

- Drought management
- Veld degradation and rehabilitation
- Small farmer and rural water demands and impacts
- Informal settlements
- Environmental needs
- Afforestation impacts
- Best irrigation practices.

Estimated cost: *R3 360 000*
Estimated term: *1996-1998*

Research projects

Completed

- **639** Economics of groundwater usage: The importance of intrinsic value as a basis for sustainable management (Economic Project Evaluation (Pty) Ltd.)
- **680** Capacity of catchments to satisfy water requirements of rural areas (University of Pretoria – Department of Landscape Architecture)

Current

- **375** Development of a distributed hydrological modelling system to assist with water quantity and quality management in the Mgeni catchment, Phase II (University of Natal – Department of Agricultural Engineering)
- **515** Groundwater abstraction in the Port Elizabeth municipal area (SRK (CE) Inc. and the Municipality of Port Elizabeth)
- **526** Distribution of fluoride-rich groundwater in the eastern and Mogwase regions of Bophuthatswana: Influence of bedrock and soils and constraints on utilisable drinking-water supplies (University of Cape Town – Department of Geology)
- **640** Extension and refinement of the AQUAMOD computer software package (University of the Orange Free State – Institute for Groundwater Studies)
- **642** Development of a water information management database system for data capture and processing at local authority level (University of the Orange Free State – Institute for Groundwater Studies and DWAF)
- **666** Holistic, catchment-scale, comparison of water-use efficiency of crops, focusing on the comparison between forest plantations and key irrigated agricultural crops (CSIR – Division of Water, Environment and Forestry Technology)
- **682** Integrated catchment management approaches in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **690** Continued research on flood damage functions, models and computer programs for irrigation and urban areas in South Africa (University of the Orange Free State – Department of Agricultural Economics and the DWAF)
- **702** Development of a Windows-based interpretation system for hydrogeologists (University of the Orange Free State – Institute for Groundwater Studies and the DWAF)

New

- **748** Impacts of exotic plants on the water resources of South Africa, with special reference to economics and policy options for effective management of the problem (CSIR – Division of Water, Environment and Forestry Technology)
- **749** Modelling benefits of integrated catchment management (University of Natal – Department of Agricultural Engineering)

CONTACT PERSONS

- **Mr H Maaren** (Hydrology and Water Management
- **Mr JN Bhagwan** (Urban Water Balance)
- **Mr AG Reynders** (Groundwater Aspects)
- **Dr GR Backeberg** (Aspects related to Agriculture)
- **Mr HM du Plessis** (Pollution Aspects)

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12 SURFACE HYDROLOGY

The surface of the earth may include all vegetation and the first 2 m of the soil, depending on the discipline it is viewed from. Maintaining this surface will ensure sustainable flow in our rivers. The first land-use map of the country is presently in the process of production, new satellite technology will allow us to see deeper into the soil and generally the prospects for doing useful research in this field are improving all the time. Because surface hydrology is so clearly visible many observations are taken for granted and there is even a sad tendency to consider our present knowledge, especially in terms of hard facts, as close to sufficient.

Hydrological services in sub-Saharan Africa, including South Africa, are strongly under-valued. A World Bank report on the situation in South Africa this year emphasised that hydrological services should be structured so that they can address all aspects of the land phase of the hydrological cycle. It was also stated "that a broad view of integrated environmental monitoring is missing from the existing programmes, and no attempt has been made to describe the sustainability of water usage". It is for these reasons that the WRC has decided to support water resources assessment in the broadest possible sense. Some serious research on the establishment of effective hydrological information systems needs to be undertaken urgently.

Rainfall, plant water use, human consumption patterns, groundwater recharge and the ever-present pollution threat to the fitness-of-use of the available resources now need to be studied and measured in a truly integrated hydrological service. Convincing evidence has to be brought to the attention of our politicians that without these services sustainable reconstruction and development of Southern Africa will be extremely difficult to achieve. It must also be realised that without the broad foundation of well-planned observation networks our expert research results will disappear in a quicksand of ignorance.

Co-operation at the international level within the International Hydrological Programme (IHP) of UNESCO, has now become a reality for South Africa. The establishment of a new Water Sector in SADC may be expected to provide a fresh impetus to co-operative hydrological research provisionally with a focus on surface hydrology.

Completed projects

Urban catchment monitoring

(No 317) SRK (CE) Inc.

The main aims of this project were to obtain rainfall-runoff characteristics of an urban catchment in a semi-arid environment (Welkom) and to evaluate the suitability of the ILLUDAS and WASHMO models to predict flow events under these conditions. The chemical and microbiological quality of runoff was also assessed.

Rainfall distributions and estimates of impervious areas and curve numbers were again the most sensitive model parameters. It was noted that when using the model with actually measured catchment parameters in design mode, the average pipe size recommended was about 27% larger than for a calibrated model using the "best-fit" model parameters. By using the calibrated model for design a capital-cost saving of up to 35% was achieved.

Unfortunately the project could not quantify the increase in flood peaks and volumes due to increased urbanisation, because much longer records are required for this. The estimated recurrence interval of storm events observed varied from 0.5 to 3 years and therefore the runoff characteristics of potentially damaging storms could not be evaluated.

Some useful observations on water quality were made but a more comprehensive long-term monitoring programme needs to be designed carefully.

Cost: *R145 000*
Term: *1990-1993*

Palaeoflood hydrological analysis for selected South African rivers

(No 509) Council for Geosciences, Pretoria

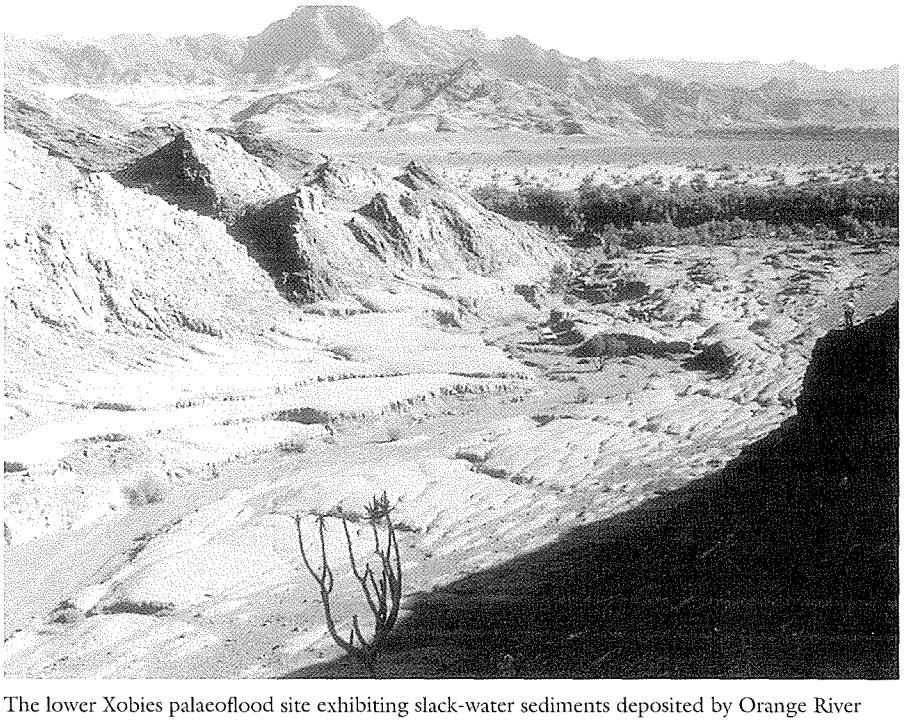
Floods have always posed a threat to man in terms of loss of life and damage to property. This situation is exacerbated by a perception that floods have a random pattern of occurrence with seemingly little hope of predicting their magnitude and spatial and temporal occurrence. In South Africa, the determination of flood-recurrence intervals and corresponding discharges has been the sole concern of the hydrologist, who mainly employs statistical techniques in determining flood recurrence. However, hydrologists concede that problems exist in conventional flood-frequency analysis, particularly with predicting large-scale and catastrophic flood events.

The current practice in selecting design floods requires the use of annual maximum flood-peak records which in South Africa are on average 20 to 30 years in length. A further problem with the use of these flood records is that most of the flow-gauging records are not calibrated for larger flood events.

Palaeoflood hydrology (PFH) is the study of past or ancient flow events which occurred prior to direct measurement by modern hydrological procedures. PFH is a potentially valuable technique as it seeks to identify persistent geological and geomorphological features which are then used to identify past flood events that are not reflected in the conventional flood-flow record. PFH uses sedimentological and stratigraphic principles to identify palaeofloods, and with radiometric dating as well as hydraulic modelling of flood flows, can furnish a flood catalogue of peak discharge and temporal occurrence of past flood events. This flood record can then be used to augment and lengthen the conventional flow record and in this way improve the statistical basis from which flood recurrence intervals can be calculated. In addition, PFH analysis can give an indication of the upper flood limits, information that cannot be obtained from conventional statistical means.

The final report provides an excellent situation analysis for PFH in South Africa.

Cost: *R282 600*
Term: *1993-1996*



The lower Xobies palaeoflood site exhibiting slack-water sediments deposited by Orange River flood waters that back-flooded into the tributary.

New projects

Development of a research strategy on the interaction between vegetation and groundwater

(No 730) Division of Water, Environment and Forestry Technology, CSIR

There is a growing appreciation in South Africa that the separation of surface and groundwater resources is artificial, and that these systems are but expressions of a single limited resource. A better understanding of how these two phases of our water resources interact is consequently required.

A recent study on recharge of groundwater resources in South Africa points to the complexity of the recharge processes and the need for well-planned process studies at the plant-soil-aquifer interface. Furthermore, the considerable contribution of groundwater to streamflow in some eastern catchments, and the potential impact of afforestation on shallow groundwater, is a cause of great concern.

Although there is a scattered body of evidence of plant-soil-aquifer interactions in South Africa, much of it is anecdotal. There is evidence, for instance, of land-use changes affecting groundwater levels in KwaZulu-Natal and suggestions that groundwater exploitation is having a detrimental effect on Karoo veld productivity. A need exists to draw this information, of various forms and from a broad range of sources, together and to subject it to objective scientific assessment, in order to better understand individual cases and to see if there are patterns which can be developed from the information. Wetlands are a special case of this interaction which ought also to be addressed in this project.

With this in mind, the following objectives have been formulated:

- Explore the substance of this subject area, by gathering evidence from the published literature and gathering evidence from South African experience
- Develop hypotheses as a theoretical basis for understanding the processes of vegetation-groundwater interactions for different climatic, geomorphological and vegetation types in South Africa
- Convene a national workshop of a broad cross-section of relevant experts from the various disciplines of, for instance, plant ecology, soil science, hydrology and hydrogeology, to discuss the status of our knowledge, classify vegetation-groundwater situations, and prioritise research topics
- Produce a research strategy for relevant issues in this inter-disciplinary research area.

Estimated cost: *R205 000*
Expected term: *1996*

Experimentation and laboratory measurement for hydrological processes research

(No 744) Department of Agricultural Engineering, University of Natal

The ACRU agrohydrological modelling system, developed over the past 15 years with WRC support, is the foremost and most widely used of its kind in South Africa. It is physically-based, deterministic and designed to make best use of natural resource databases available locally. ACRU's usefulness to water resource planners and managers depends on its ability to simulate land-use and developmental impacts on hydrological systems both accurately and in sufficient detail.

The observation of hydrological processes through experimentation, monitoring and measurement enhances the understanding of the processes and allows modellers to formulate more realistic algorithms to represent the phenomena at appropriate scales in time and space.

The need for this refined representation of specific hydrological and water quality processes in the environment has become vital due to both recent and expected trends in land use. These include:

- An increase in the number of small farming communities which are remote from major water supply sources and are therefore reliant on water generated in local catchments
- The development of forest plantations on hillsides on which certain localised soil water processes may render some portions of the slopes inadequate for sustaining viable growth
- The encroachment of informal communities into areas adjacent to streams and rivers
- The continued use of fertilizers and pesticides in large- and small-scale agriculture
- The spilling or leaking of contaminants into the soil or directly into rivers.

In order to successfully model the effects of the above, and through the use of models to explore and select best management options, specific processes have been identified for investigation. These are:

- Catchment and on-farm soil-water processes
- Two-dimensional hillslope water movement and accumulation
- Wetland and riparian soil-water processes
- Local to catchment-scale water quality processes

Estimated cost: *R550 600*
Expected term: *1996-1999*

Development of a hydrological model of the Upper and Middle Limpopo River

(No 746) Department of Civil Engineering, University of Stellenbosch

The Limpopo River forms the international border between South Africa, Botswana, Zimbabwe and Mozambique. The utilisation of the flow in the Limpopo River is presently restricted to surface abstractions from numerous small weirs along the river or groundwater abstractions from the alluvial aquifers in or adjacent to the main river channel. These abstractions supply water to irrigation schemes on both sides of the river, to settlements and towns (including Messina) and to certain mining operations.

It is important to note that, as an internationally shared water resource, any future large-scale utilisation of the Limpopo River should involve extensive collaboration between the affected states in order to prevent serious water conflict situations from developing. Such collaboration between South Africa and Botswana supported the joint Upper Limpopo basin study (JULBS) during

1990 to 1991, which was aimed at screening the options for large-scale impoundments along the Limpopo River upstream of the confluence with the Shashe River, with a view to the equitable sharing of the resource.

JULBS was, however, hampered by a great number of difficulties. In order to address these difficulties and pave the way for effective water resources planning with regard to the utilisation of the Limpopo River, a project with the following objectives was initiated:

- Development of conceptual understanding of the primary surface flow systems and the interlinked alluvial aquifer/ flood-plain dynamics of the main stem of the Limpopo River downstream of the confluence of the Crocodile and Marico Rivers to immediately downstream of the Crocodile and Luvuvhu Rivers
- Formulation of appropriate improvements to the existing hydrological monitoring systems, both to support the conceptual model, and to aid future water resources planning in the Limpopo Basin as far downstream as the Luvuvhu River
- Configuration and verification of a mathematical rainfall-runoff model, alluvial aquifer model and a river loss model, incorporating the aforementioned conceptual understanding, which can be used to generate flow sequences at points of interest along the main stem of the Limpopo as far downstream as the Luvuvhu River
- Linkage of the aforementioned modelling results and the ARSP water resources yield model to enable integrated system analysis of the Limpopo River system as far downstream as the Luvuvhu River.

Estimated cost: *R346 000*
Expected term: *1996-1998*

Assessment of the MIKE SHE hydrological model for application in South African catchments

(No 747) Institute for Water Research, Rhodes University

MIKE SHE is the commercial version of the distributed, physically-based, surface-groundwater interaction model developed over the last 10 to 15 years by various European hydrological and hydraulic research agencies. It has been tested and validated in a number of different climate and physiographic zones world-wide. There appears to be a perception by some groups of practising hydrologists in South Africa that this type of model should be used in preference to some of the simpler approaches that are currently in use.

It is therefore essential that the usefulness of the model be evaluated in the context of the South African situation before the model is adopted for widespread use. The usefulness should be evaluated not only in terms of its applicability to South African hydrological and water-use conditions, but also in terms of the general availability of the required data and the resources needed to collect such data.

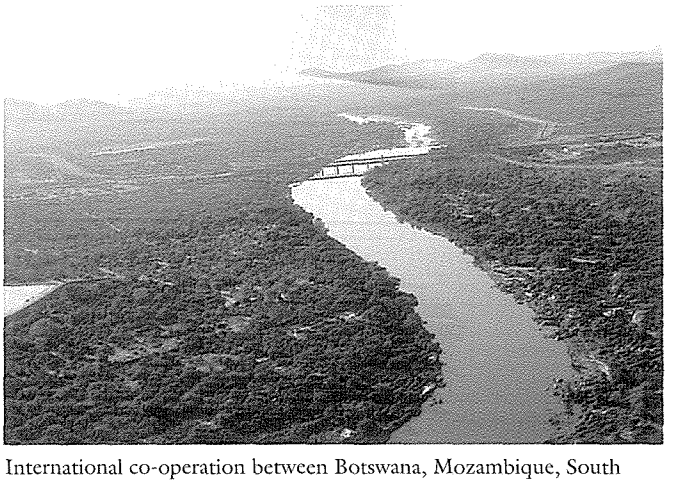
The Institute for Water Research at Rhodes University has a long history of association with various types of model and the current personnel have more than adequate modelling experience (both surface and groundwater) to be confident that they are capable of carrying out a thorough evaluation of the model.

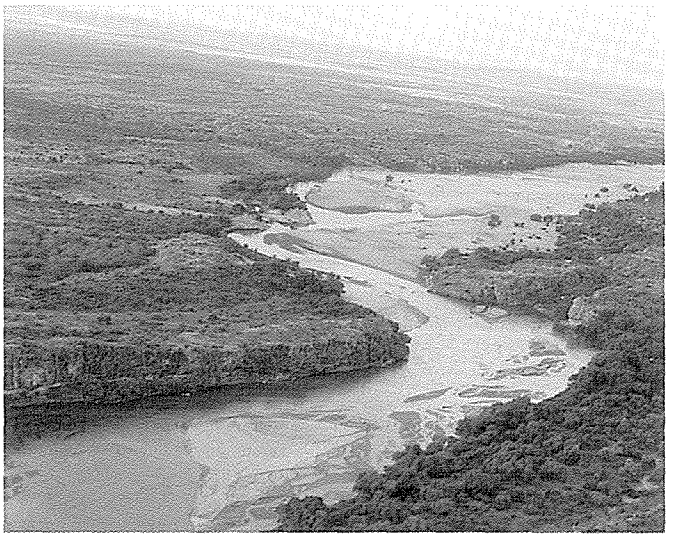
Estimated cost: *R280 000*
Expected term: *1996-1997*

Long-term monitoring of streamflow and weather in the Cathedral Peak catchments

(No 781) Division of Water, Environment and Forestry Technology, CSIR

Long-term data provide major insights into problems such as global warming and predictive management. However, availability of such data is rare due to a number of constraints including funding and continuity. The research catchments at Cathedral Peak have been well designed and have 40 years of uninterrupted data. Lack of funding threatens





International co-operation between Botswana, Mozambique, South Africa and Zimbabwe in research on shared river basins takes place along the Limpopo River.

the continuity of this strategically important research.

The Cathedral Peak data set represents a unique series of long-term monitoring of montane areas of the Natal Drakensberg. The Nanni Curves, which are still used for granting planting permits for afforestation throughout the country, are an example of the national value of this research station. Many of the catchments at Cathedral Peak represent the only undisturbed or pristine catchments in which streamflow is monitored in the summer rainfall area of South Africa. The hydrological monitoring is being complemented with vegetation monitoring.

Increasing evidence of climatic change through global warming, increasing atmospheric and water pollution, and degradation of grassland areas through overgrazing and repeated droughts are strong arguments for maintaining the Cathedral Peak area as a long-term ecological monitoring station.

During this project, a proposal for the maintenance of Cathedral Peak as a national long-term hydrological monitoring site will be developed in co-operation with the DWAF.

Estimated cost: *R87 700*
Expected term: *1996*

Research projects

Completed

- **317** Urban catchment monitoring (Welkom City Council and SRK (CE) Inc.)
- **509** Palaeoflood hydrological analysis for selected South African rivers (Council for Geosciences, Pretoria)

Current

- **319** Monitoring the effect of catchment development on urban runoff and water balance (University of the Witwatersrand - Department of Civil Engineering, Water Systems Research Group)
- **348** Root development and water usage of commercial timber species (University of Natal - Department of Agronomy)
- **424** Development of an urban component for the ACRU model (University of Durban-Westville - Department of Geography)
- **442** Development of improved flow-gauging structures for South African rivers (Sigma Beta CE)
- **492** Effect of the agricultural environment on water resources (University of Natal - Department of Agricultural Engineering)
- **493** Development and testing of a water balance model for a grassland catchment in the summer rainfall area of South Africa (CSIR - Division of Water, Environment and Forestry Technology)
- **494** Classification and hydrological modelling of low flows in Southern Africa (Rhodes University - Institute for Water Research)
- **511** Hydrological implications of afforestation in the North-Eastern Cape (CSIR - Division of Water, Environment and Forestry Technology)
- **580** Control of dam siltation in South Africa (BKS (CE) Inc.)
- **635** Flow regimes from international experimental and network data (FRIEND) for Southern Africa (Rhodes University - Institute for Water Research)
- **636** Hydrological systems modelling research programme: ACRU model development and user support (University of Natal - Department of Agricultural Engineering)
- **637** Hydrological systems modelling research programme: Hydrological process research (University of Natal - Department of Agricultural Engineering)
- **638** Studies on river losses: Phase 2 (BKS (CE) Inc.)
- **643** Development of rigorous engineering methodology for designing vegetative erosion protection systems: Phase 2 (SRK (CE) Inc.)
- **681** Short-duration design rainfall estimates for Southern Africa (University of Natal -Department of Agricultural Engineering)
- **683** Evaporation from the Orange River: Quantifying open water resources (CSIR - Division of Water, Environment and Forestry Technology)

New

- **730** Development of a research strategy on the interaction between vegetation and groundwater (CSIR - Division of Water, Environment and Forestry Technology)
- **744** Experimentation and laboratory measurement for hydrological processes research (University of Natal - Department of Agricultural Engineering)
- **746** Development of a hydrological model of the Upper and Middle Limpopo River (University of Stellenbosch - Department of Civil Engineering)
- **747** Assessment of the MIKE SHE hydrological model for application in South African catchments (Rhodes University - Institute for Water Research)
- **781** Long-term monitoring of streamflow and weather in the Cathedral Peak catchments (CSIR - Division of Water, Environment and Forestry Technology)

CONTACT PERSONS

- **Mr H Maaren** (Hydrology and Water Management)
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- **Mr DS van der Merwe** (Flow Measurement and Sediment)

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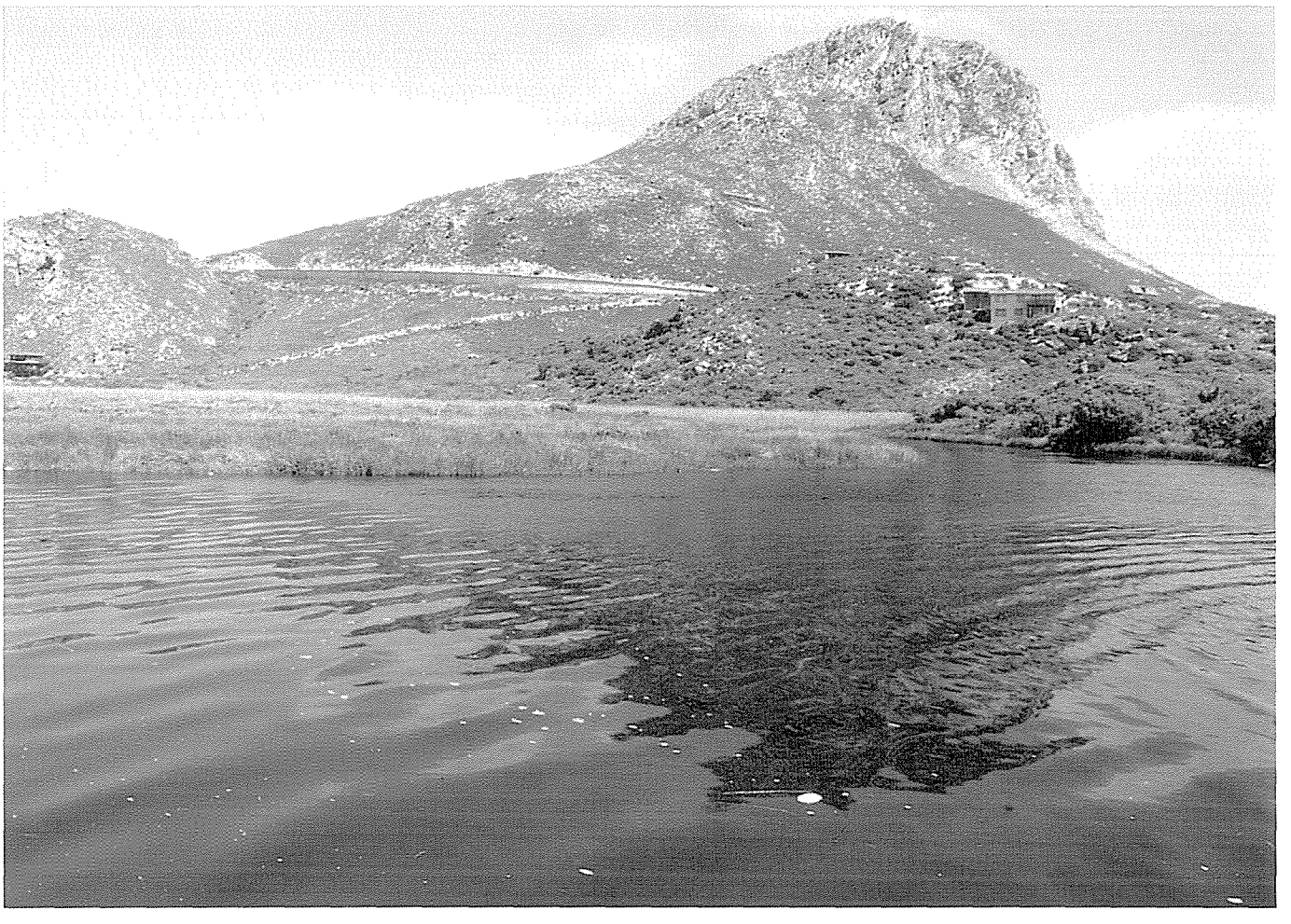
13 CONSERVATION OF WATER ECOSYSTEMS



The acknowledgement in the Water Law Review Process of the aquatic ecosystem being the resource rather than a competing water user, together with the designation of resource base in the *Water Law Principles*, increases the necessity for research which provides support to water managers. There are currently several thrusts, some multidisciplinary, which aim to improve our management capability.

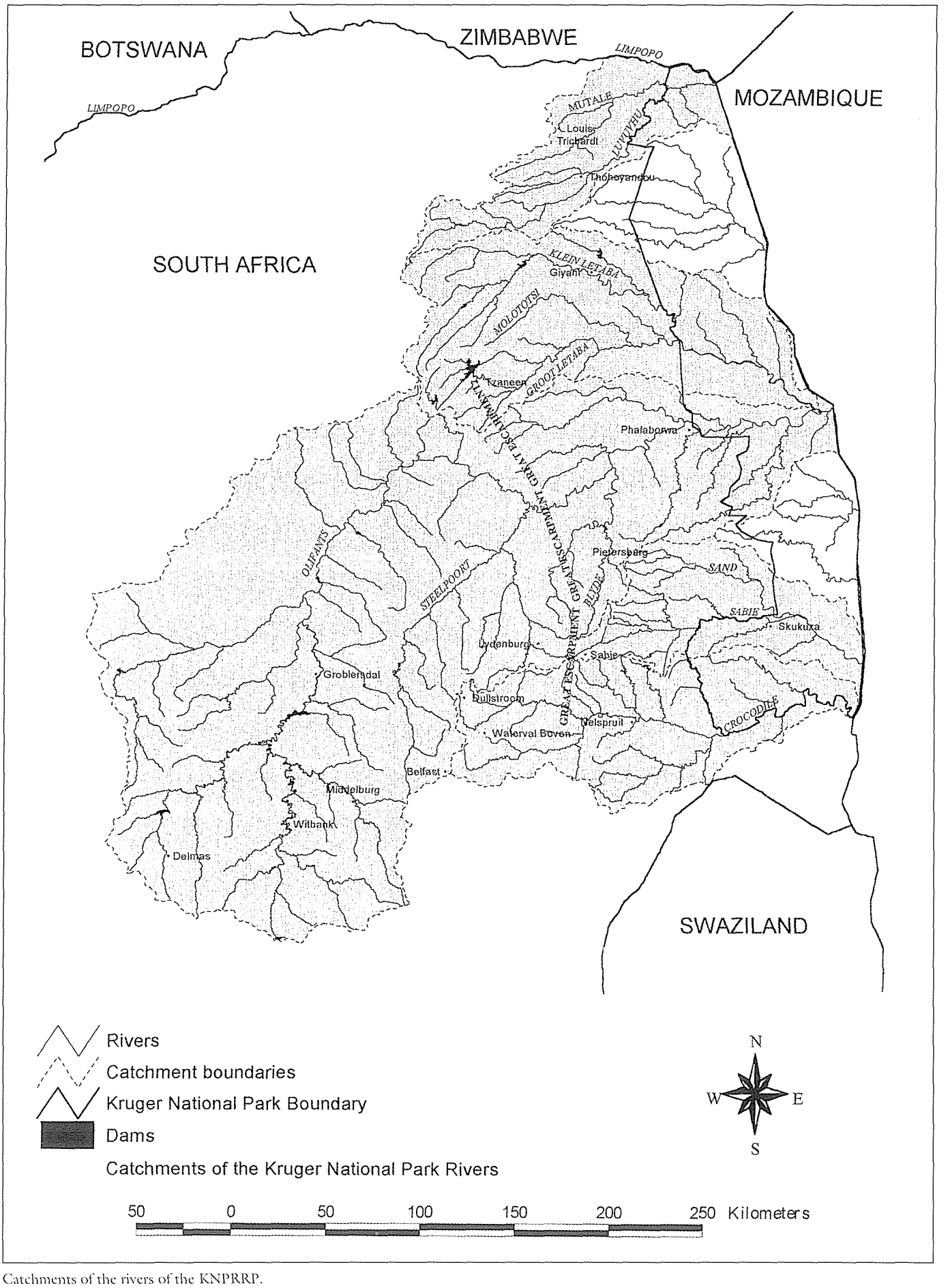
The Kruger National Park Rivers Research Programme, the building-block methodology on which the instream flow assessment workshops are based and the work being done by the Consortium for Estuarine Research and Management are established programmes which have each, in their own fields, increased our ability to manage particular aspects of the aquatic environment.

The Strategic Research Plan for Water Ecosystem Research was reviewed during the year and will be published in the *SA Waterbulletin* early in the new year so that researchers wishing to submit proposals will see it in time for them to use.

The Kruger National Park Rivers Research Programme (KNPRRP)

Background

The KNPRRP is a co-operative undertaking by resource-use managers, funding agencies and researchers, addressing, in an integrative framework, the water quality and water quantity requirements of the natural environments of those rivers flowing through the Kruger National Park (KNP).



Catchments of the rivers of the KNPRRP.

The Programme, conceived at a workshop convened by the DWAF in March 1987, was initiated in December 1988, jointly by:

- The WRC
- The Foundation for Research Development
- The DWAF
- The National Parks Board
- The Department of Environment Affairs and Tourism
- Various research institutions and provincial nature conservation authorities.

During Phase I of the programme (1988 to 1993), first approximations of the water requirements for ecological maintenance were put on the table, but it was very obvious that these approximations needed to be refined through application and research. In Phase II (1994 to 1996) the focus shifted from an emphasis on research to a more holistically conceived programme. Four components were considered essential for the success of the programme, i.e.:

- Development and application of decision support systems
- Research to improve understanding and enhance decision support
- Information management and training
- Information and technology transfer.

Each of these components was attended to under the supervision of a subprogramme manager who operated under the guidance of the Programme Managing Director, Prof CM Breen of the Institute of Natural Resources of the University of Natal.

Public forums on the KNPRRP

During June 1996 the Programme Development and Management Committee of the KNPRRP held a series of three public forums with the overall objective of informing the key stakeholders in the results of the programme about its aims, progress and desired future course. The three forums were attended by politicians, agriculturists, environmentalists, rural developers, researchers and catchment managers – all representatives of those sectors having an interest in the KNP rivers and the environmental, agricultural and anthropogenic developments in their catchments. The objectives and achievements of the various subprogrammes were reviewed by the relevant subprogramme managers, whilst the Managing Director, in addition to his review of the KNPRRP in general, also stressed the point that future programmes of this nature will need to address not only matters such as biodiversity, water allocation and water pricing, but will also have to promote participation of the communities involved, as well as their sense of responsibility for resource management.

Workshop to develop Phase III of the KNPRRP

A workshop was held in July 1996 to lay the foundation for Phase III of the programme. It emerged that while the research during Phases I and II focused on improving the understanding and developing the tools and techniques necessary to meet the programme goals, the research and activities of Phase III (1997 to 1999) should support the translation of this understanding and tools into practical implementation. In addition, beyond strengthening the existing programme components, new challenges are also to be faced. These include *inter alia* the following:

- Improving the understanding and application of scientific, social and economic principles to the management of the natural environment of rivers flowing through the KNP
- Improving the KNPRRP's ability to assist in meeting South Africa's obligations in terms of a number of international conventions and charters, e.g. Ramsar and Agenda 21
- Involvement of previously excluded stakeholders and researchers, thereby enhancing their capacities to participate in achieving the objectives of the KNPRRP.

Completed projects

Pre-impoundment study of the Sabie-Sand River system, Eastern Transvaal, with special reference to predicted impacts on the Kruger National Park

(No 294) Zoology Departments, Universities of Cape Town and Rhodes

This project aimed to:

- Characterise the present chemical, physical and biological conditions prevailing in the Sabie-Sand River system before any of the planned impoundments are built
- Assess the probable ecological disturbances of impoundment (compared to other rivers for which the effects have already been measured) and to recommend management guidelines to minimise impacts by them
- Collect basic data so that instream flow requirements could be determined
- Develop a surveillance method to monitor changes in the system, as well as a method to allow comparisons between this and other river systems in the KNP.

Fortuitously, during the project two unusual events occurred which the researchers were able to monitor. Firstly, Mpumalanga Province experienced a severe drought which allowed the researchers to observe the effects of reduced flow on the ecosystem, and secondly, Zoeknog Dam failed, presenting the opportunity to study the effects of heavy silt deposition in the river.

The three-volume report gives considerable detail on the state of the Sabie-Sand River system prior to the construction of the Injaka Dam and the other proposed impoundments, and the authors make predictions based on their observations on the effects of impoundment on other rivers as well as observations made during a period of very low flow. This was done by characterising the prevailing physical, chemical and biological conditions and their response following specific events. In addition the researchers developed methods to allow comparisons between this and other river systems.

The results of this project have led the authors to predict that, while biotic com-

ponents of the ecosystem can survive in refugia during extreme events, the effects of permanently reduced flow on the river system will lead to a reduction of the diversity which makes the Sabie-Sand system one of the nation's more important rivers.

Cost: *R738 500*
Term: *1990-1993*

Structural analysis of the water allocation mechanism of the Water Act 54 of 1956 in the light of the requirements of competing water user sectors

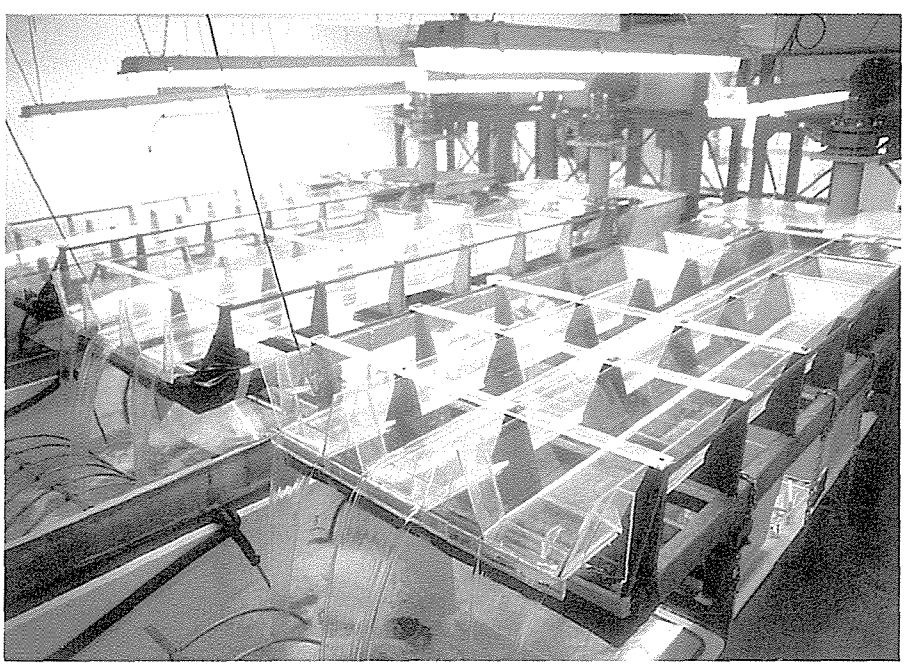
(No 406) Adv M Uys, Consultant

Current water legislation does not provide protection for ecobiotic water requirements, and neither does it contain sufficient measures for the sustainable conservation of water as a scarce resource. This lack of statutory protection can no longer be afforded, because environmental elements are interdependent and neglected conservation measures with respect to one of these elements, may harm the entire environmental cycle.

During a case study of the Letaba River system in Mpumalanga, it was confirmed that very little protection exists for ecobiotic water needs. Measures must be taken to ensure prolonged water supply for natural ecosystems during drought conditions. This necessitated a critical analysis of the legal system in terms of which water rights are allocated in the South African law. The historical development process of the South African water law, the main tendencies followed in the Roman and Roman-Dutch law systems, as well as the principles of water allocation which had been adopted into the South African system by the courts and the legislature, in particular of the Water Act 54 of 1956, were investigated.

The results indicate a lack of basic principles which could form the basis of an allocation system aimed at the protection of the environmental network of interdependency. Proposals are made for fundamental principles to form the basis for revision of the South African water law, in order to create a system of water allocation which accommodates the water requirements of all user sectors in a balanced and equitable way.

Cost: *R439 500*
Term: *1991-1994*



Large artificial stream systems: IWR stream laboratory, Grahamstown.

Development of a recirculating experimental stream system

(No 475) Zoology Department, Rhodes University

Water quality standards set in terms of user needs may bear little relation to the tolerance limits of the biota whose existence is necessary for the healthy functioning of rivers. With this in mind, this project aimed to develop an experimental facility for doing ecotoxicological work on lotic organisms. The first step was to synthesise information on existing artificial streams internationally and to construct a suitable facility in South Africa. After construction, it was necessary to calibrate the facility to enable quantitative comparisons of the physical and chemical conditions to be made between channels. It was also necessary to select appropriate organisms for the work, and this was done through wide consultation with people in the field. Three of the 12 species of organisms recommended were tested and found suitable. Further work on the culture of these is being addressed under a separate project.

Considerable progress had been made in the establishment of test protocols by the end of this project, and this project has set in motion a method for obtaining meaningful results on water quality guidelines for lotic organisms. The research is being continued in a follow-up project.

Cost: *R1 128 000*
Term: *1992-1995*

Effect of land use on water quality of the Gamtoos estuary

(No 503) Department of Oceanography, University of Port Elizabeth

Less freshwater is often available for estuaries as a result of dams being built and abstraction of water for other purposes. This investigation was initiated to determine the input of potential pollutants in runoff from an established intensive agricultural area and whether the flushing processes in the estuary itself were sufficient to inhibit the accumulation of such pollutants. Inputs from surface runoff, groundwater and agricultural drains were determined.

Nitrate, sulphate and potassium from a subsurface irrigation drain were frequently present at very high levels, while

nitrate often exceeded the recommended limit, and all samples had total phosphorus levels above that recommended for the protection of aquatic life. Pesticide screening tests also yielded positive results in all the samples analysed. However, the nutrient content in especially the upper estuary was generally low. Certain nutrient levels at times exceeded limits recommended for the protection of marine life. Overall the estuary was in a healthy condition and because of the resilience of the system, water quality was generally restored within a few days.

Cost: *R94 100*
Term: *1992-1996*

Development of a modelling system which will provide a common currency for integration of the results and data emanating from the Kruger National Park Rivers Research Programme (KNPRRP)

(No 654) Department of Landscape Architecture, University of Pretoria

In a preceding research project, entitled **Geographical information systems (GIS) and the integrated environmental management (IEM) procedure in the planning and management of water resources within river catchments** (No 300), no water quality and no instream processes (essential to river ecologists) were modelled. Only daily flow modelling of selected rivers within the Sabie System had been touched on. This follow-up project attended to both the quality and instream modelling aspects at an untried scale, both temporal and spatial. It was aimed at using GIS, existing modelling systems and interactive graphical displays of spatial and time-series information in a manner which will enhance the level of scientific communication between researchers in the programme. As such it was specifically tailored to provide input to the decision support system approach which was the basis of Phase II of the KNPRRP.

On completion the project formed an integral part of the training, information and technology transfer subprogramme of the KNPRRP, the purpose of which is to ensure that the information and technology developed within the programme are transferred effectively to the appropriate users. The point of departure, therefore, was that the modelling and graphical presentation systems were designed to address communication on major aspects of the KNPRRP, both internally and externally.

In order to provide continuity and cohesion for the time series involved in the abiotic simulation portion of the programme, it became clear that a backbone modelling system needed to be included. A comprehensive set of criteria, to be met by the modelling system, was developed, and based on these criteria the hydrological simulation program Fortran (HSPF) and the ACRU agro-hydrological modelling systems were selected. As far as the time series manipulation and display capability were concerned, the software developed by Ninham Shand Inc. was adopted in accordance with the philosophy of co-operating with existing groups.

The project succeeded in developing the framework of a modelling system for the Sabie River, incorporating *inter alia* ARC/INFO, ACRU, HSPF and the watershed data management system (WDMS). It has also been demonstrated that the product of this development can serve as a catalyst to elicit meaningful interaction, communication and integration amongst researchers in the KNPRRP.

The results, therefore, provide a structured and operational form of communication, both at the conceptual and technical level. This is seen as a significant contribution not only to the objectives of the training, information and technology transfer subprogramme, but also to the KNPRRP as a whole.

Cost: *R103 500*
Term: *1994-1995*

Status report on the Kruger National Park Rivers Research Programme

(No 711) Institute for Water Research, Rhodes University

As is pointed out in the introduction the KNPRRP is being attended to in phases. Phase II (completed in 1996) had the objective to inform policy-makers and resource managers of the water quantities and qualities required to maintain the natural environments of the rivers flowing through the KNP. The intention was to achieve this objective by the development of decision support systems to be utilised by those organisations involved in the natural environments of the KNP rivers.

During the conclusion of Phase II and in preparation for the development of Phase III, this project was launched to examine and summarise the information collected within the KNPRRP to date; to relate the resulting synthesis to the objectives of the Programme and to advise on the remaining priority objectives.

The research team concluded that the Programme contributed substantially to the information base dealing with water quality and quantity requirements to sustain the natural environments of the KNP rivers and also to the development of methods for predicting the responses of rivers to changing flow regimes and water quality. Furthermore, it was very obvious that the process of achieving the objectives of the KNPRRP, and the management of the rivers to achieve acceptable conditions in the rivers, are intimately linked. Since rivers are not static systems, and since the definition of acceptable conditions will change in response to natural and anthropogenic effects in the catchments, management procedures will always be iterative, and there will always be a need for improved and updated information.

The research team categorically stated that their knowledge of the KNP rivers is now far more extensive, as is the fundamental understanding of the processes occurring in the rivers and governing their condition and biota. The consequences of changing flow conditions can now be predicted with far greater confidence. The decision support system has been developed, but this is a dynamic process which will continue to guide and refine the activities of the KNPRRP, also in Phase III which is to be launched in 1997.

Cost: *R68 000*
Term: *1995-1996*

New projects

Linking abiotic and biotic data on South African rivers

(No 754) Department of Zoology, University of Cape Town

There has been sustained development of river research in South Africa together with the recognition that multi-disciplinary input is needed to guide wise river management. However, some of the disciplines involved are more advanced than others, and not all the data are collected at the same level of resolution. This project will investigate the potentially useful data that exist in the various disciplines involved by determining where existing data in a field may be linked to data in another field, developing collaborative research activities and ways of producing usable interfaces between different data sets.

Estimated cost: *R1 000 000*
Expected term: *1996-1999*

Development of a production facility for test organisms to be used in flowing water ecotoxicological research

(No 755) Institute for Water Research, Rhodes University

This project forms a part of the thrust to develop the science of ecotoxicological monitoring in flowing waters at the Institute for Water Research (IWR). During a previous project expertise was developed for the mass culture of invertebrates for use in ecotoxicological testing in the artificial streams, and in this project the mass culture techniques developed will be refined and techniques will be developed for a further organism. An invertebrate production facility to provide test organisms for the artificial stream testing facility will be designed and costed.

Estimated cost: *R450 000*
Expected term: *1996-1998*

Decision support for the management and conservation of estuarine systems: Phase II

(No 756) Institute for Natural Resources, University of Natal

The conservation of estuarine systems is important because estuaries are important refuge and recruitment areas for certain biota, but are also favoured for both recreation and development. This project will draw together estuarine researchers for the development of a decision support system (DSS) which will enable government and local authorities responsible for the management of estuaries to make the most appropriate decisions for the management of specific estuaries. The compilation of a DSS identifies gaps in existing knowledge, and an important part of this project will be to fill those gaps.

Estimated cost: *R1 000 000*
Expected term: *1996-2000*

Abiotic-biotic links in the Sabie River: The responses of riverine biota to changing hydrology and geomorphology

(No 777) Institute for Water Research, Rhodes University

The first phase of the KNPRRP was organised largely as a series of individual research projects aimed at gaining an understanding of different components of the KNP rivers. The second phase provided a set of conceptual models through which research could be directed towards a system understanding of the rivers, and finally a predictive capability which can assist planners and managers to assess the consequences of different options.

This new project represents the culmination of Phase II of the KNPRRP, in which the knowledge and information generated by individual projects are brought together to achieve one of the main goals of the Programme, i.e. "to develop, test and refine methods for predicting the responses of the natural environments of rivers flowing through the KNP to changing water quality and patterns of supply".

The intention is to build a multi-disciplinary model describing the effects of changed flows on the channel morphology of the Sabie River, and extrapolating the consequences to the fish fauna. More specifically this project will focus on the following aspects of the KNPRRP:

- Linking the information collected up to now into a coherent story of the Sabie River
- Pulling the four subprogrammes (i.e. decision support system development, supplementary research, information systems, and training, information and technology transfer) together towards the common goals of Phase II
- Providing information and predictions which will allow the National Parks Board and the DWAF to implement the findings and recommendations of the Programme.

Although this project will be restricted to the Sabie River since it has been the focus of Phase II, there will be a conscious effort to develop general rules for linking biotic and abiotic processes, also applicable to other rivers of the KNP and, in principle, to the rest of the country.

Estimated cost: *R253 000*
Expected term: *1996*

Scenario modelling for the Kruger National Park Rivers Research Programme decision support system

(No 782) Centre for Water in the Environment, University of the Witwatersrand

The demands on the surface water resources of South Africa are such that competition between the various user sectors is inevitable. In the interests of optimal development of South Africa's water resources for all sectors and the credibility of the claim for environmental management, it is essential that ecological water requirements be qualified reliably.

In order to facilitate the contribution of a previous project to the decision support system of the KNPRRP, this follow-up project aims to:

- Refine, verify and test a suite of hydraulic and geomorphological models
- Model the geomorphological change in the Sabie River in order to isolate

effects of past climatic and anthropogenic influences
- Ensure transferability of techniques to other KNP rivers
- Establish procedures for defining the geomorphologically desired state of the natural environment of rivers.

Estimated cost: *R600 000*
Expected term: *1996-1997*

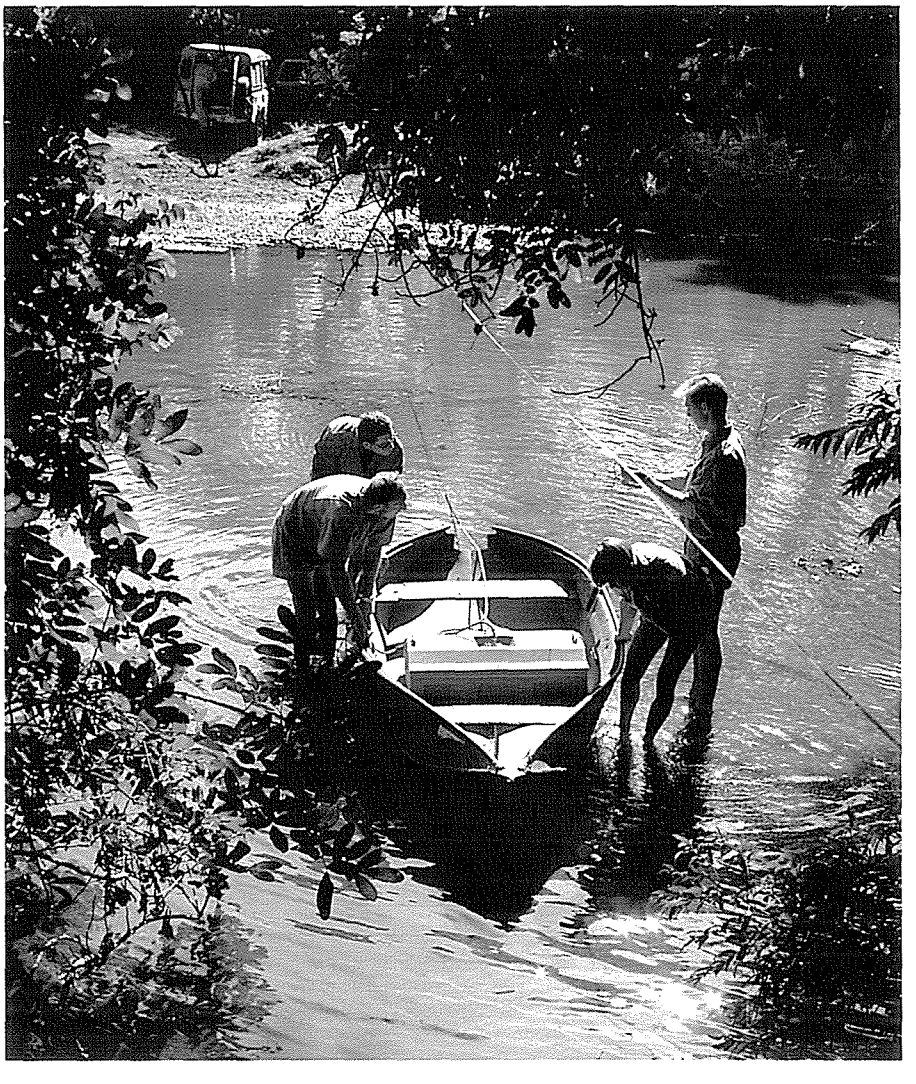
Tolerances of selected macro-invertebrates from the Buffalo River (Eastern Cape, South Africa) to components and dilutions of textile effluent

(No 783) Institute for Water Research, Rhodes University

This project will investigate the acute tolerances of selected riverine macro-invertebrates to textile effluent in the Buffalo River, providing specific information for the management of this and other rivers. In addition, this project will provide information on the tolerances of the selected test organisms which can be compared with the tolerances of organisms from systems such as the Sabie River where the water quality is better.

Estimated cost: *R35 000*
Expected term: *1996-1999*

Surveying riverine vegetation types in relation to base flow in the Kruger National Park.



Right: Guiding a boat containing an antenna across the Sabie River as part of a ground-penetrating radar study to determine the depth to bedrock.

CONTACT PERSONS

- **Dr SA Mitchell**
  (Stream Fauna and Flora and Aquatic Ecosystems)
- **Mr HM du Plessis**
  (Irrigation Return Flow)
- **Mr JN Bhagwan**
  (Natural Wetlands)
- **Mr DS van der Merwe**
  (Facets of the KNP Rivers Research Programme)
- **Dr GR Backeberg**
  (Resource Economics)

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Research projects

Completed

- **294** Pre-impoundment study of the Sabie-Sand River system, Eastern Transvaal, with special reference to predicted impacts on the Kruger National Park (University of Cape Town – Freshwater Research Unit, and Rhodes University – Institute for Water Research)
- **406** 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)
- **475** Development of a recirculating experimental stream system (Rhodes University – Institute for Water Research)
- **503** Effect of soil utilisation on water quality of the Gamtoos estuary (University of Port Elizabeth – Department of Oceanography)
- **654** Development of a modelling system which will provide a common currency for integration of the results and data emanating from the Kruger National Park Rivers Research Programme (KNPRRP) (University of Pretoria – Department of Landscape Architecture)
- **711** Status report on the Kruger National Park Rivers Research Programme : A synthesis of results and assessment of progress (Rhodes University – Institute for Water Research)

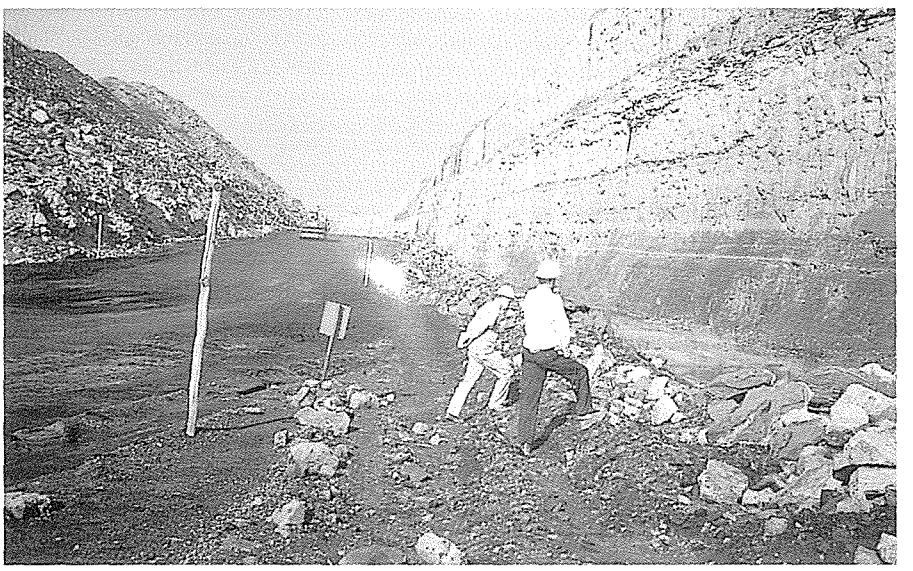
Current

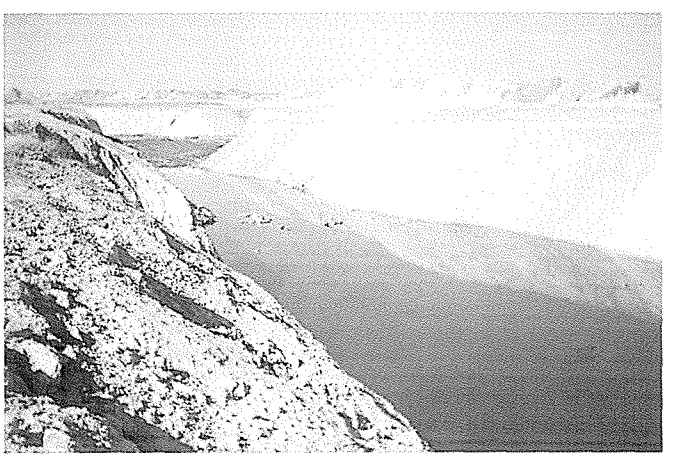
- **376** Geomorphological response to changing flow regimes of the Sabie and Letaba River system (University of the Witwatersrand – Department of Botany)
- **422** Rapid biological assessment of water quality impacts in streams and rivers (CSIR – Division of Water, Environment and Forestry Technology)
- **428** Overview of the pesticide and heavy metal levels present in populations of the larger indigenous fish species of selected South African rivers (CSIR – Division of Water, Environment and Forestry Technology)
- **463** Diversity and productivity of biotic communities in relation to freshwater inputs in Eastern Cape estuaries (University of Port Elizabeth – Department of Zoology)
- **474** Developing an integrated approach to predicting the water use of riparian vegetation (University of the Witwatersrand – Department of Botany)
- **497** Geomorphological classification system for South African river systems (Rhodes University – Department of Geography)
- **505** Environmental status of the Orange River mouth as reflected by the fish community (University of the Orange Free State – Department of Zoology and Entomology)
- **525** Natural and unnatural factors regulating the structure and functioning of estuarine systems (University of Natal – Institute of Natural Resources)
- **545** Standard laboratory organisms for water quality studies (Rhodes University – Institute for Water Research)
- **576** Effects of different magnitude flows on riverine ecosystems (University of Cape Town – Freshwater Research Unit)
- **577** Decision support system for the integrated management and conservation of estuaries (University of Natal – Institute of Natural Resources)
- **601** Freshwater requirements of plant communities in different types of estuaries (University of Port Elizabeth – Department of Botany)
- **608** Lethal and sublethal effects of metals on fish physiology in the Republic of South Africa (Rand Afrikaans University – Department of Zoology)
- **626** Water quality requirements for riverine biotas (University of Cape Town – Department of Zoology)
- **627** Integrated modelling system for predicting the impacts of changes in water quantity and quality brought about by upstream development (Sigma Beta (CE))
- **655** Establishment of an effective information management system for the Kruger National Park Rivers Research Programme (KNPRRP) (National Parks Board in collaboration with the University of Natal – Institute of Natural Resources)
- **663** System-related scale study to determine the function of the riparian vegetation of the Olifants River, Transvaal (Agricultural Research Council – Roodeplaat Grassland Institute)
- **664** Water quality modelling of estuaries (CSIR – Earth, Marine and Atmospheric Science and Technology)
- **665** Assessment of the ecological impacts of inter-basin transfer schemes in dryland environments (University of Cape Town – Department of Zoology)
- **669** Survey for potential biological control agents for the troublesome alga Cladophora glomerata (Agricultural Research Council – Plant Protection Research Institute)
- **686** Application of an artificial stream system to investigate macro-invertebrate water quality tolerances (Rhodes University – Institute for Water Research)
- **716** Water quality and aquatic faunal studies in the Umzimvubu catchment, Eastern Cape, with particular emphasis on species as indicators of environmental change (University of the Transkei – Department of Zoology)
- **718** Tadpoles as bio-indicators of stream quality (University of the Western Cape – Department of Biochemistry)
- **722** Effect of inter-basin transfer on the hydrochemistry, benthic invertebrates and ichthyofauna of the Mhlatuze Estuary and Lake Nseze (University of Zululand – Department of Zoology)

New

- **754** Linking abiotic and biotic data on South African Rivers (University of Cape Town – Department of Zoology)
- **755** Development of a production facility for test organisms to be used in flowing water ecotoxicological research (Rhodes University – Institute for Water Research)
- **756** Decision support for the management and conservation of estuarine systems: Phase 2 (University of Natal – Institute for Natural Resources)
- **777** Abiotic-biotic links in the Sabie River: The responses of riverine biota to changing hydrology and geomorphology (Rhodes University – Institute for Water Research)
- **782** Scenario modelling for the Kruger National Park Rivers Research Programme (KNPRRP) decision support system (University of the Witwatersrand – Centre for Water in the Environment)
- **783** Tolerances of selected macro-invertebrates from the Buffalo River (Eastern Cape, South Africa) to components and dilutions of textile effluent (Rhodes University – Institute for Water Research)

14 MINE-WATER MANAGEMENT





Mining remains the single most important industry in South Africa. The mining sector is very diverse and a large number of minerals are being mined. Water usage patterns and impact on water quality vary tremendously throughout the mining sector so that there are bound to be exceptions to any generalisations that can be made about water in mining. None the less, it can be stated in general that although the mining sector is a relatively minor user of our water supplies, it is a significant contributor to water pollution.

Mining activities account for less than 3% of the national water demand and its share on a national basis is expected to decrease in future. Although the gold-mining industry uses large volumes of water in its operations it has also done much to save water. More than 80% of its water use is actually being recycled or reused internally. This drastically reduces the intake of freshwater.

Most of the geologic formations that are mined in South Africa contain pyrites, which oxidise to form sulphuric acid when exposed to air and humidity. Acid mine drainage is thus almost inseparably linked to mining activities. Acid generated underground in gold and coal mines, and above-ground in the various waste deposits, is the main cause of water pollution originating from mining. Additional pollution originates from the metallurgical refinement and other beneficiation activities on mines. The quality of underground water seeping into mine workings varies geographically. Since these "own" sources are used extensively by mines, its quality largely determines the quality of water they ultimately dispose of.

Mine water discharged from point sources directly to surface waters represents only a small portion of water used by mines. Most mine water is lost inadvertently by seepage to groundwater, is entrained in waste products, or lost to evaporation. As indicated above, much of the pollution from mines is the result of acid mine drainage which is generated over time in waste material above and below ground. Most of the water pollution originating from mining is thus of a diffuse, or non-point, nature. Because it is difficult to measure, control and manage non-point pollution, such pollution in the past received little attention from the regulating authorities. As a result of

the increased awareness of the importance of non-point pollution in general, mining pollution is, at present, receiving more attention.

The mining industry is also increasingly aware of the water quality degradation associated with their activities. Mining sectors are co-operating actively in the WRC's research activities by facilitating access to mining properties, making facilities available and contributing financially to some research projects. They are also funding several research projects of their own.

Research on mine-water management is presently being conducted in order to improve our assessment of the effects of mining on the water environment and improve on predictions of mining's future impact. Research is also being conducted into means which can be used to minimise pollution and mitigate or control its effect through suitable treatment methods. As a result of the initiatives of the WRC's Co-ordinating Committee for Mining Related Water Research (CCMRWR) duplication within the national research effort in this field has largely been eliminated. The CCMRWR has established a structured research framework which is being used to identify and prioritise research needs, as well as to appraise research proposals. Research needs were identified during a workshop held for this purpose in November 1993 and are being updated on an annual basis. Making these research needs known to the research community, helps to ensure that mainly research proposals which address priority needs are prepared with a view to funding.

Completed projects

Guidelines and procedures to assess and ameliorate the impact of gold-mining operations on the water environment

(No 477) Division of Mining Technology, CSIR

This project aimed to establish guidelines and procedures by means of which the impact of gold-mining operations on the water environment could be assessed and ameliorated. Three different gold mines, considered to be representative of typical mines in the Witwatersrand, Carletonville and Klerksdorp mining regions were studied with the full co-operation and support of the respective mines. This involved surveys to characterise the biotic and abiotic components in water samples from the mine itself and surface streams potentially affected by mine effluent. Survey results were used to compile salt and water budgets for each mine, identify the main sources of water quality degradation and determine the effect on the receiving water environment. Results for each mine were different from those of the others. Findings were used to identify procedures which are technically and economically viable for ameliorating the impact of gold-mining operations on the surface water environment. From these a manual was compiled which describes the approaches and techniques available to assess the impact together with strategies and alternatives which are available to manage the impact of gold-mining operations on the surface water environment.

Cost: *R720 000 (WRC)*
(An additional contribution of more than R1 000 000 was made by mining groups)
Term: *1992-1994*

Survey of current water management and treatment practices in the South African gold-and coal-mining industries

(No 527) Chamber of Mines of SA

Of late, mines have endeavoured to reduce both their freshwater intake and the volumes of effluent discharged to the environment. Different mines, therefore, had to develop and implement different strategies in order to deal with their particular problems.

A comprehensive "state of the art" report, setting out the innovative and successful strategies and treatment processes which have been developed and applied at various mines, will be of benefit in enabling individual mines to optimise their water management practices.

The project, therefore, aimed to:

- Establish current water management and treatment practices and developments in the South African gold- and coal-mining industry
- Provide the mines and the DWAF with information relating to current practices as an input into the definition of best available technology not entailing excessive cost
- Identify knowledge gaps with regard to mine-water treatment and management which should be addressed by future research projects.

The final report, covering the visits to 12 gold mines and 17 coal mines, comprises:

- *A Manual on Mine-water Treatment and Management Practices in South Africa*, covering:
  - general information on water use, sampling, standards and legislation
  - sources of contaminants
  - strategies for treatment of contaminants
  - strategies for water management.

- Five *Appendices*, covering the 29 mine-site visit reports, the information gathered during a study tour to Australia, the USA, Canada and the United Kingdom and various literature reviews.

The Manual is structured in such a way that it can be used both by water specialists and mine staff who have only a rudimentary knowledge of water management issues. The Manual itself can be used by all persons, while the different appendices are directed more at mine-water management practitioners and specialists.

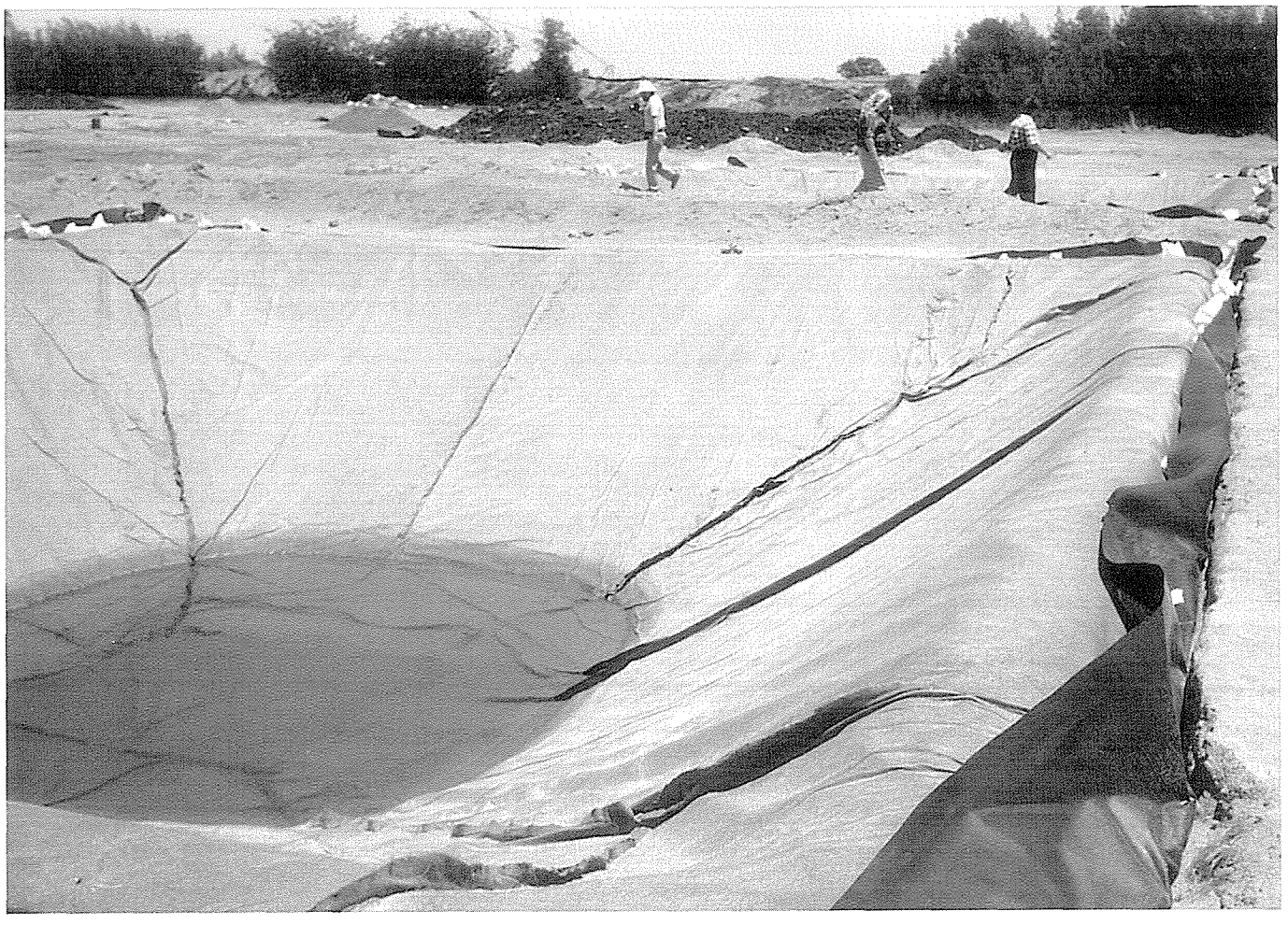
Cost: *R530 000*
Term: *1993-1995*

Underground neutralisation of mine water with limestone

(No 609) Division of Water, Environment and Forestry Technology, CSIR

A latent disadvantage of the use of lime to neutralise acidic effluents is the need for accurate dosing, which is difficult to achieve in the unstable flow conditions prevailing underground. The fluidised-bed limestone neutralisation process, developed in a preceding study, incorporates a number of benefits, such as less expensive neutralisation material and simplified dosage control.

A pilot plant was erected underground



The construction of an integrated passive water treatment system for mine effluent streams.

at the Western Areas Gold Mining Co. to assess the process' suitability for underground application and to determine its economic feasibility.

The study has demonstrated that underground mine water can be effectively and cost-effectively neutralised in a limestone fluidised-bed reactor. The system offers several advantages over conventional neutralisation processes; the main advantage being that, despite the unstable flow conditions encountered underground, all the acid fed is neutralised and only the stoichiometric equivalent amount of limestone is consumed (i.e. no under-/over-dosing of alkali).

Cost: *R446 900*
Term: *1994-1996*

New project

An information transfer, extraction and management system for mine-water management and treatment

(No 750) Pulles, Howard and De Lange

There is increasing pressure on regulators and mine operators to address the negative impacts of mining on the water environment and there is therefore an incr easing demand for access to a wide range of technical information. Although much of this information is presently available, it is usually in written report format and therefore often non-user-friendly. Moreover, mines seldom have the capability to keep up to date with all these developments unless they are assisted.

A computerised system will enable users to get instant and intelligent access to information required to address a specific problem. The primary aim of this research project is to develop a computerised information transfer, extraction and management system (ITEMS) which will enable users to gain access to local and international information on mine-water quality, management, treatment and research.

Having a simple structure, where options are selected by menus, ITEMS will enable users to view extensive lists of information based on specific queries, and will allow them to assess their water quality information scientifically.

Estimated cost: *R248 000*
Expected term: *1996*

Research projects

Completed

- **477** Guidelines and procedures to assess and ameliorate the impact of gold-mining operations on the water environment (CSIR – Division of Mining Technology)
- **527** Survey of current water management and treatment practices in the South African gold- and coal-mining industries (Chamber of Mines of South Africa)
- **609** Underground neutralisation of mine water with limestone (CSIR – Division of Water, Environment and Forestry Technology)

Current

- **413** Use of vegetation in the amelioration of the impact of mining on water quality -An assessment of species and water use (CSIR – Division of Forest Science and Technology)
- **454** Occurrence of bacteria causing acid mine drainage in the outer layers of coal waste dumps (University of Stellenbosch – Department of Microbiology)
- **471** Optimisation of mine service water disinfection (University of Pretoria – Department of Chemical and Environmental Engineering, Division of Water Utilisation)
- **528** Development of an integrated and generic water quality simulation model for open-cast coal mining water circuits (Wates, Meiring and Barnard (CE) Inc.)
- **559** Prediction of pollution loads from coarse sulphide-containing rock materials (SRK (CE) Inc.)
- **575** Calibration of models for the design of covers for open-cast mine and waste dump rehabilitation (Wates, Meiring and Barnard (CE) Inc.)
- **582** Screening of crop, pasture and wetland species for tolerance of polluted water originating in coal mines (University of Pretoria – Department of Plant and Soil Science)
- **647** Application of isotope chemistry to quantify the contribution of gold and coal mines to salt pollution load in groundwater and rivers (CSIR – Division for Earth, Marine and Atmospheric Science and Technology)
- **699** Prediction techniques and preventative measures relating to the post-operational impact of underground mines on the quality and quantity of groundwater resources (Institute for Groundwater Studies, University of the Orange Free State, Chamber of Mines of South Africa and the DWAF)
- **700** Pilot-scale development of integrated passive water treatment systems for mine effluent streams (Pulles, Howard and De Lange, The Chamber of Mines of South Africa, Eskom and Sasol Coal)

New

- **750** An information transfer, extraction and management system for mine-water management and treatment (Pulles, Howard and De Lange)

CONTACT PERSONS

- **Mr HM du Plessis** (Impact Studies and Mitigation of Effects)
- **Dr TC Erasmus** (Acid Mine Water)
- **Mr AG Reynders** (Groundwater Pollution)

☎ **(012) 330-0340**

15 WATER POLICY

The democratic transition to a new political dispensation and acceptance of a bill of rights in the constitution was instrumental in bringing about major public policy reforms regarding water resources. This is illustrated by the recent publication of the *White Paper on Water Supply and Sanitation* (1994), discussion documents on *Water Law Principles* (1995 and 1996) and *Bulk Water Tariffs* (1995) and the holding of a consultation planning meeting for irrigation policy development in August 1996. The opportunity exists to introduce and seek further improvements through timeous and reasoned contributions based on sound research. The target group or clients of research activities are policy-advisers and policy-makers specifically in the executive branch of government. Top managements and ministries of national and provincial departments, as well as local authorities, require decision-support which will improve their bargaining position. At the same time research results must create an awareness amongst members of the public of the expected benefits and costs of proposed policy changes and institutional arrangements. The issues which must be addressed are determined by the content of public policy, i.e. the principles and intentions expressed in policy statements or more importantly the lack thereof and incompleteness or contradictions contained therein.

The focus of water policy research must be on analysis of the water system and on design of appropriate water institutions. Based on experiences gained through studies in several countries by the World Bank (1995) this includes four main issues:

- Articulating a broad natural resource policy incorporating water and land management, food security, health improvement and environmental protection
- Treating water resources in a comprehensive, inter-sectoral framework that recognises interaction within river systems and allows integrated catchment management
- Decentralising functions to self-financing organisations on a local level with stakeholder participation
- Understanding the growing scarcity and economic value of water and changing the emphasis to secure water rights, proper incentives, pricing and regulation of markets.

According to the Food and Agriculture Organisation (1995) the process of policy review essentially consists of the following steps:

- Determining the importance of water
- Constructing a matrix of problems and critical issues
- Quantifying the pressure on water resources
- Formulating objectives and strategies
- Identifying options
- Defining an action programme and implementation schedule.

There is an urgent need for these studies to be done systematically for the important water sectors such as urban and rural water supply and sanitation, forestry, agriculture and irrigation, manufacturing industries, energy and hydropower, ecosystem and natural environmental requirements.

Although a number of research projects have in the past provided support for policy formulation and contributed to policy evaluation, water policy is now for the first time a separate research field. At this stage, therefore, only a few research projects are listed under this heading, but a concerted effort is being made to mobilise existing research expertise and to initiate policy-related projects. In addition to refinement of theoretical principles, various types of empirical investigations need to be undertaken. These include catchment surveys to analyse the current situation, feasibility studies to make estimates and projections of the social, economic and ecological impact of water resource development and reallocation, as well as research projects to find solutions to particular supply-and-demand management problems.

Completed project

Policy proposal for irrigated agriculture in South Africa

(No KV96/96) GR Backeberg, TJ Bembridge, ATP Bennie, JA Groenewald, PS Hammes, RA Pullen and H Thompson

The WRC initiated the compilation of this *Discussion Paper* with the purpose to inform interested and affected parties on relevant issues concerning irrigation policy. This is done within the realities of the new constitution, the mature phase of the water economy, widespread poverty in rural areas and climatic variability. Attention is given to policy principles, water resources, land resources and production, human resources, markets for agricultural products and institutional arrangements. Specific proposals are made regarding policy objectives and strategies, institutional reform in respect of the legal framework, economic pricing and equitable reallocation of available water resources, as well as organisational structures for involvement of water users in water management on a local level. Priorities are indicated in order to improve efficiency of water utilisation in both commercial and subsistence farming on existing irrigation schemes. The *Discussion Paper* will be distributed widely to various interest groups and policy-advisers in support of the ongoing consultation process aimed at formulating a new irrigation policy.

Cost: *R122 000*
Term: *1995-1996*

New projects

Establishment of a research framework for local authorities and the preparation of the first part of a series of management guidelines for water and waste departments in local authorities

(No 758) Palmer Development Group

Research has a vital role to play in supporting local authorities in effectively delivering services to the people. Many local authorities have expressed a desire for information to assist them in managing service provision. The main objectives of the research are to:

- Establish a framework for WRC support for local authorities with emphasis on water and waste services
- Draft the first part of a series of management guidelines for water and waste departments.

The proposed research framework for local authorities will deal with both urban and rural areas, recognising the growing emphasis on local government and service provision in rural areas. One of the objectives of this project will be to produce a set of management guidelines that will set out approaches and procedures to assist local authorities in managing water and waste services with special emphasis on the ongoing finance, planning, operation and maintenance of services.

Estimated cost: *R380 000*
Expected term: *1996-1997*

Arrangements for regulating water services in South Africa

(No 788) Palmer Development Group

The key issue of providing many unserved or underserved communities with water supply is not addressed by the existing water law which is focused almost entirely on water resources, irrigation and bulk water supply. With the current emphasis on reconstruction and development, the issue of water services provision also moved into the limelight. In order to facilitate the effective functioning of the water services sector, new legislation is needed, and this is to be the focus of this project. Within the water sector there are also new private sector service providers who are increasingly active. This development also requires legislation to ensure protection of consumers.

Against this background this project aims to review international experience relating to regulation of water services provision, and to review current arrangements for water service provision in South Africa, at the same time proposing new arrangements for regulating water services.

Estimated cost: *R80 000*
Expected term: *1996*

Research projects

Completed

- **KV96/96** Policy proposal for irrigated agriculture in South Africa (Group of consultants)

Current

- **512** Development of procedures for decision support in water resources management (University of Cape Town – Department of Statistical Sciences)
- **678** Pricing water as an economic resource (Palmer Development Group)

New

- **758** Establishment of a research framework for local authorities and the preparation of the first part of a series of management guidelines for water and waste departments in local authorities (Palmer Development Group).
- **788** Arrangements for regulating water services in South Africa (Palmer Development Group)

CONTACT PERSONS

- **Dr GR Backeberg** (Economics)
- **Mr H Maaren** (Decision Support)

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As in the past, this chapter deals with those research projects which cannot readily or logically be accommodated in the other chapters. The result is that the character of the chapter may vary from year to year, depending on the character of the projects reported on. Originally the chapter dealt mainly with projects on hydraulic and geological aspects, but due to important developments in information technology, the majority of the projects in this chapter now concentrate on this facet.

Completed project

Hydraulic roughness of tunnels bored by machine through various rock-types

(No 579) Department of Civil Engineering, University of Natal

Hydraulic engineers active in the design of tunnels to be excavated by tunnel-boring machines (TBMs), are faced with the problem of the hydraulic resistance of the tunnel walls, especially in situations where head loss is important. In order to address this problem the roughness of the surface inside the tunnel and the relationship between the physical roughness and the hydraulic resistance must be quantified. Although relatively few kilometres of TBM-excavated tunnel were available at the outset of this project, it increased substantially in recent years which provided an ideal opportunity to obtain information on the relevant resistance coefficients. The objective, therefore, was to take actual roughness measurements of the newly bored tunnel walls, and to form the link between these measurements and the hydraulic resistance.

During the course of the project a methodology using a laser scanner was developed to collect accurate roughness data at 0.5 mm intervals over a 1 m base length. These roughness "samples" and accompanying photographs were collected at 100 m intervals in 15 km of freshly bored tunnels in Lesotho and KwaZulu-Natal. Several statistical parameters for quantifying physical roughness of the tunnel wall from the measured data were defined and studied using time series analysis and spectral analysis. By comparing predictions of resistance with those obtainable in the literature, a selection was made between the various roughness statistics as to which was best for predicting hydraulic resistance. In addition theoretical fluid dynamics investigations were made into the nature of flow in large conduits and an improved velocity distribution for turbulent flow in conduits was developed.

Following the procedures developed in this project, it was found, for tunnels excavated by TBMs through hard rock, that the Manning's n value varied within the range of the reported values found in the literature. In particular, the mean n values for cast *in situ* concrete, sandstone, granite and shotcrete surfaces turned out to be as follows:

Surface	Mean	Standard deviation
Cast concrete lining	$n = 0.0119$	0.0009
Sandstone	$n = 0.0154$	0.0010
Granite	$n = 0.0157$	0.0008
Shotcrete	$n = 0.0161$	0.0011

Cost: *R70 000*
Term: *1993-1995*

New projects

Promotion of the Internet as a source of information on water and sanitation

(No 735) Department of Chemical Engineering, University of Natal

The provision of adequate water and sanitation has a high priority with the Government. One of the main constraints, however, in attending to this objective successfully, is the availability of adequate information, especially in terms of non-technical aspects.

The Pollution Research Group of the above Department has been involved in a project funded by the International Association on Water Quality, the objective of which is to provide a water and sanitation information server on the Internet. This project attracted the interest of important organisations in this field, e.g.:

- Water, Engineering and Development Centre, Loughborough University of Technology, which maintains the GARNET databases
- International Reference Centre, The Hague
- United Nations Centre for Human Settlement (Habitat)
- Water Supply and Sanitation Collaborative Council Network of Services for the Urban Poor.

Considerable resources in the form of research results, manuals and educational material are available from these and other organisations. In order to promote the efficient and effective provision of water and sanitation services in South Africa, the available information needs to be disseminated as quickly and efficiently as possible. In this regard electronic communications such as the Internet need to be exploited to their fullest extent.

Against this background this project has the objective of supporting South African policy-makers and organisations involved in the planning, design, financing, implementation and operation of water and sanitation services through the provision of an efficient information service. At the same time it plans to make international information on the topic available to local organisations, and vice versa. All in all the aim is to promote the

use of existing information systems by the full range of end-users, with the emphasis on water and sanitation.

Expected cost: *R250 000*
Expected term: *1996-1997*

Development and implementation of a plan for the WRC, using information technology for the more effective transfer of research results

(No 736) Division of Information Services, CSIR

With the increased emphasis on organisations such as the WRC to make their research results known to a wider group of stakeholders, and with the increased accessibility and user-friendliness of information technology (IT), the possibility of more effectively using IT to assist technology transfer is being explored.

The WRC initiated a feasibility study in 1995 entitled: **A pilot study to develop an information system to improve the accessibility and usability of research results and reports, through the application of information technology** (No 703) which was aimed at developing a multimedia prototype for the more effective transfer of information in the area of water supply and sanitation for developing communities.

This project clearly showed that IT, and in particular the use of multimedia applications, can be used to make research results more accessible and understandable to those who may not have a strong scientific background or who find themselves in areas where highly specialised information needs to be disseminated to much broader groups with little or low levels of scientific understanding.

The feasibility study revealed that there is a need to develop a strategic plan for the more effective use of information technology to aid information and technology transfer, of all the research fields within the WRC; and to develop appropriate software for those fields identified as needing alternative mechanisms for information transfer, and to place appropriate information onto such a system. The above project aims to address these issues.

Expected cost: *R123 000*
Expected term: *1996*

Research projects

Completed

- **579** Hydraulic roughness of tunnels bored by machine through various rock-types (University of Natal – Department of Civil Engineering)

Current

- **433** Engineering properties of important Southern African rock types with special reference to the shearing strength of concrete dam wall foundations (Technikon Pretoria – School for Civil Engineering)
- **502** Plunge pool scour reproduction in hydraulic models (CSIR – Division of Water, Environment and Forestry Technology)
- **691** Removal of floating and suspended materials from streams (University of Stellenbosch – Department of Civil Engineering)
- **703** Pilot study to develop an information system to improve the accessibility and usability of research results and reports, through the application of information technology (CSIR – Division of Information Services)

New

- **735** The promotion of the Internet as a source of information on water and sanitation (University of Natal – Department of Chemical Engineering)
- **736** The development and implementation of a plan for the WRC, using information technology for the more effective transfer of research results (CSIR – Division of Information Services)

CONTACT PERSONS

- **Mr DS van der Merwe** (Hydraulics)
- **Mr AG Reynders** (Information Technology)

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The South African Water Information Centre (SAWIC)

The South African Water Information Centre (SAWIC) was established by the WRC in 1974 as part of the fourth objective in its mission statement, which is to "Promote effective transfer of information and technology". For the past 22 years SAWIC has been managed as an independent unit on behalf of the WRC by the Division of Information Technology, CSIR. During the original planning, it was recommended that SAWIC should operate under its own name and have an identity of its own. In this way it would serve as a national reference centre for both sources of information and services in the water sector.

The aims and responsibilities of the Centre are to:

- Specialise in the provision of information on water and related subject areas
- Act as a central reference centre for enquiries about water and related topics
- Co-ordinate existing and planned information services in the fields of water and related sciences and thereby ensure that optimal use is made of existing facilities, expertise and information skills available at different organisations
- Promote the use of information services
- Keep abreast of the latest developments in the fields of water and related sciences and liaise with similar services in South Africa and overseas
- Maintain alerting services and other publications and adapt these to the changing needs of users
- Co-ordinate the acquisition, processing and building of databases on water and related topics as well as the computerised information services associated with such databases.

The importance of reliable up-to-date and accurate information to policy-makers and planners, trainers, technicians and project staff, and water users, cannot be overemphasised, particularly in a rapidly developing country like South Africa. In many cases the information is not readily available and without well-organised systems it is almost impossible to determine whether the information that is needed exists and how it can be obtained. SAWIC provides the systems and expertise to provide the information required and to assist users to obtain copies of the documents.

Waterlit

Over the years, SAWIC has become synonymous with the WATERLIT database, and the development of the database remains SAWIC's main responsibility. The database continues to grow at a rate of over 1 200 items per month, with the total number of items now standing at 260 000. Journal papers still form the majority of items added to the database. Increased subscription rates of journals has forced SAWIC to investigate alternative methods of gaining access to key sources of information. At present the total number of journals scanned stands at 520.

Database of water-related research projects

This database, which provides details of current and completed water-related research projects in South Africa, serves as an important management tool for the WRC in the co-ordination of its research effort. The whole database is available to researchers free of charge on diskette from SAWIC. It may also be accessed via the SAWIC home page on the Internet.

Bibliographies

Bibliographies which are produced on demand and stored on computer for easy updating, include:

- Selective bibliography on Sanitation for Developing Communities
- Selective bibliography on Water Supply for Developing Communities
- Selective bibliography on Privatisation of the Water Industry
- SAWIC staff also act in an advisory capacity to other organisations producing bibliographies.

Database of water-related information sources

Although WATERLIT is the main source of bibliographic information, SAWIC is becoming increasingly aware of the need for other types of water-related information. A database of the sources of this information is being built as a valuable in-house tool and this will be made freely available on request.

The future of SAWIC

There is no doubt that SAWIC has become an integral part of the research programmes of most water researchers in South Africa. Avoidance of costly duplication of effort due to a lack of awareness of current research trends, provision of a unique and comprehensive Southern African component to the WATERLIT database and the inclusion of "grey literature" are viewed as being essential for effective water research in this country.

The highly professional and competent SAWIC staff are continually investigating ways and means of making the service more accessible and cost-effective. Rapid advances in technology over the past few years, improved access to international databases and the ever-increasing range of sources of published information have resulted in the need to constantly examine the role and future direction to be taken by the Centre.

Various issues, both internal and external, have arisen which have resulted in the need to re-evaluate the functions and location of the Centre. The role of SAWIC has changed over the past 5 years. This has been both as a result of the advent of the CD ROM version of the WATERLIT database and as a result of "on-line" access to the database. In addition, the information needs of the water sector have increased considerably thereby putting greater pressure on the SAWIC staff to meet these needs. It has become clear that the current vision of SAWIC and the perceived needs of the WRC are converging. For example, the WRC has recently been connected to the Internet. The advantages of a dynamic home page, bulletin boards, electronic conferencing and placement of reports/executive summaries on the Internet are enormous. For this reason,

the information technology (IT) staff from SAWIC will be relocating to the WRC to assist the WRC in addressing its IT needs – the building of the WATERLIT database will, however, continue under contract at the CSIR.

The WRC has committed itself to moving into the 21st century using the technological benefits afforded by the Internet, and eagerly anticipates the contribution that will be made by SAWIC staff in this regard.

Computing Centre for Water Research (CCWR)

Mission

The mission of the CCWR is to support collaboration and the dissemination of knowledge, data and information amongst researchers and practitioners through advanced computing and communication technology in order to enhance water resources management.

The value of the services provided by the CCWR is best appreciated in the context of the external driving forces which impact on researchers and practitioners in the water industry.

The two primary forces are outlined below:

- 70% of the land area in the Southern African Development Community (SADC) is covered by shared river basins. The equitable and sustainable management of water in the region therefore requires the integrated efforts of a range of stakeholders, backed by high quality information and communication between scientists and stakeholders.
- The successful application of the new water law principles will enhance the need for integrated and consensual resolution of conflicts. This in turn will drive the need for easy and continuous interaction between stakeholders.

To cope with the needs which these external forces generate the water-related software systems will inevitably have to be developed in an interactive integrated environment. However, the country's intellectual resources to achieve this are limited and widely separated both geographically and in terms of disciplines.

The CCWR is a key strategic service initiated by the WRC to meet the twin challenges posed by these forces and the intellectual resource constraints mentioned above. All of the medium- to long-term projects at the CCWR are focused on serving the above needs.

At the same time the CCWR serves 381 registered users of whom 120 registered for the first time after April 1995. The CCWR staff of 6 professionals serves the on-line, medium- and long-term needs of all these users. These users are based at no fewer than 139 departments within 93 institutions, including 15 overseas institutions in the USA, Britain, Germany, Australia and New Zealand. A further breakdown of users reveals approximately 60% from universities, 20% from private consulting firms and 20% from state and parastatal institutions. These users are working in every conceivable water discipline. Selected initiatives and achievements for 1996 are listed below:

- Internet home page sites were established for the WRC, the Kruger National Park Rivers Research Programme, the Water Resources 90 report series and the Hydrological Information Library (HYDROLIB) for Southern Africa. These pages point *inter alia* to those of a number of institutions whose researchers work extensively on the CCWR system.
- Encouraging trends continued to develop in three major directions, namely, biological and ecological modelling, environmental geochemistry and networking to previously disadvantaged communities.
- The Pollution Research Group (PRG) in the Department of Chemical Engineering, University of Natal, in collaboration with several international agencies, the WRC and the CCWR, established the "Water and Environmental Sanitation Services Electronic Network for Developing Country Needs" (Interwater) on the CCWR system.
- Through the Kruger National Park Rivers Research Programme electronic links have been established with water researchers and practitioners in Mozambique, Swaziland and Zimbabwe.
- Excellent progress has been made in co-operation with key user groups in developing a software shell for integrated catchment information systems and a common standard system for the management of complex time series data within models.
- With regard to the above progress the CCWR has strengthened its international contacts with the US Environmental Protection Agency (EPA), the Water Resources Division of the US Geological Survey and European Union scientists. These contacts, initiated and fostered by the CCWR are

yielding significant benefits for the Southern African water research community.
- Particularly close links have been forged with the historically disadvantaged University of Zululand. The CCWR also assists users from the University of the Western Cape, University of Fort Hare, University of Transkei and University of the North.
- The CCWR has again this year been used as a major platform to assist the Department of Agricultural Engineering, University of Natal to achieve international recognition in Global Climate Change Programmes. Their work on agrohydrology and climatology is currently playing a leading role in international programmes relating to the impacts of drought, climate variability and change in Southern Africa.
- Digital maps of mean annual rainfall and other climate variables for South Africa continue to be the most popular research products distributed through the CCWR.
- CCWR staff serve on 23 Steering and Co-ordinating Committees of the WRC as part of the WRC's strategy to enhance the CCWR's functionality in the valuable integrating tasks which they perform.

The CCWR works in a complementary relationship with the WRC's other major service initiative, namely the South African Water Information Centre (SAWIC). The CCWR's focus in this relationship is on enabling the co-creation of future information. The CCWR strives through the activities outlined above to achieve the productive creation of this information and interactive working relationships in an integrated and co-ordinated fashion throughout Southern Africa. The technology transfer functions outlined above are thus essential to facilitate feedback from practitioners and hence develop focus on the issues of relevance in water research.

18 TRANSFER OF INFORMATION AND TECHNOLOGY

The promotion of information and technology transfer is one of the most important objectives of the WRC. 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 WRC 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 WRC's publications cater for three levels, viz. pure scientific, popular scientific and practical scientific.

Water SA

Water SA is the WRC'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
- 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 1996 and which emanated from research supported wholly or in part by the WRC.

Conferences, seminars, workshops and demonstrations

From time to time the WRC, 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 transfer, 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 WRC has developed various methods to achieve this. Overseas specialists, for example, are engaged as consultants and the WRC 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.

ANNEXURE

Publications emanating from research financed wholly or partially by the WRC.

This **Annexure** contains a list of publications released in 1996, as well as a complementary list of 1995. Requests for articles and papers should be directed to the authors.

DEVELOPING COMMUNITIES

Articles and papers (1996)

- Aphane MJ and Olivier J (1996) The fog water project: Selection of site for project implementation. Paper presented at 13th Annu. Conf. of the S. Afr. Soc. for Atmos. Sci., Cape Town. 31 October – 1 November.
- Astin LM (1996) Septic tank effluent drainage (STED) systems in South Africa. Paper presented at the 22nd WEDC Conf., New Delhi, India. September.
- Buckley CA, Odendaal PE, Kibata N and Dindar MC (1996) Water supply and environmental sanitation services electronic network for developing country needs (WENDY). Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Du Preez M, Gericke M, Bateman B and Kfir R (1996) The occurrence of *Giardia* cysts and *Cryptosporidium* oocysts in South African raw and treated water. Paper presented at the IAWQ Health-related Water Microbiol. Conf., Mallorca, Spain. 6-11 October.
- Gaigher MJ (1996) Water, health and development: A multi-disciplinary approach. Paper presented at a Conf. on Environment, Life Elements and Health Longevity in Beijing, China. 6-10 May.
- Genthe B, Strauss N, Seager J, Vundule C, Maforah F and Kfir R (1996) The effect of type of water supply on water quality in a developing community in South Africa. Paper presented at IAWQ Health-related Water Microbiol. Conf., Mallorca, Spain. 6-10 October.
- Genthe B, Vundule C, Strauss N, Maforah F and Seager J (1996) The effect of type of water supply, handling and storage on diarrhoea in developing communities. Paper presented at WISA, Port Elizabeth. 6-9 May.
- Gericke M, Du Preez M, Bateman B and Kfir R (1996) Occurrence of protozoan parasites in South African source and drinking water. Paper presented at the Bienn. Conf. and Exhibition of WISA, Port Elizabeth. 20-23 May.
- Mjoli-Mncube N (1996) The flush alternative for the women of Soshangove. *Agenda* **30** 26-31.
- Nel C (1996) Meteorological features of orographic clouds along the eastern escarpment of South Africa. Paper presented at 13th Annu. Conf. of the SA Soc. for Atmos. Sci., Cape Town.
- Olivier J (1996) Fog: A source of water for rural communities in South Africa? Paper presented at 28th Int. Geogr. Conf., The Hague, The Netherlands. Also at Conf. on Fulfilling Basic Needs: The Role of Sci. and Technol., S. Afr. R. Soc.
- Venter CA, De Wit, SY and Mostert NL (1996) An investigation into the pathogenic microbial contamination of the Mutshindudi River, Northern Province of South Africa. Paper presented at the Int. Health Water Microbiol. Conf., Mallorca, Spain.

Articles and papers (1995)

- Genthe B, Vundule C, Maforah F, Strauss N and Seager J (1995) The effect of water supply, handling and storage on diarrhoea in a peri-urban community: A case-control study. *Epidemiol.* **6** (4) S30. Also presented at the Annu. Conf. of the Int. Soc. for Environ. Epidemiol. and the Int. Soc. for Exposure Analysis, Noordwijkerhout, The Netherlands. 30 August – 1 September.
- Nel C (1995) Misfrekwensie te Woodbush 1960 – 1995. Referaat gelewer by die 12e Jaarlikse Konf. van die S.-Afr. Ver. vir Atmos. Wet., Pretoria.
- Olivier J (1995) Fog water as a source of supplementary water. In: *Africa – Proc. of the 1994 Spring Lectures.* Unin Press, Univ. of the North, Sovenga. 144-157.
- Olivier J (1995) Fog water extraction. Paper presented at 12th Annu. Conf. of the S. Afr. Soc. for Atmos. Sci., Pretoria.
- Olivier J (1995) The South African fog water collection project. *SA Soc. for Atmos. Sci. Newsletter* **22** 22-28.
- Olivier J (1995) The South African fog water research project. Paper presented at 1st Int. Geogr. Conf., Durban.
- Strauss N, Genthe B, Vundule C, Maforah F and Seager J (1995) The incidence of diarrhoea in a peri-urban community in South Africa: A cross-sectional study. *Epidemiol.* **6** (4) S81. Also presented at the Annu. Conf. of the Int. Soc. for Environ. Epidemiol. and the Int. Soc. for Exposure Analysis, Noordwijkerhout, The Netherlands. 30 August – 1 September.

Reports (1996)

- Palmer Development Group (1995) Evaluation of Solid Waste Practice in Developing Urban Areas of South Africa. WRC Report No. 629/1/96.
- Palmer Development Group (1995) Evaluation of Solid Waste Practice in Developing Urban Areas of South Africa. Executive Summary. WRC Report No. 629/2/96.
- Palmer Development Group (1996) Water and Sanitation Handbook for Community Leaders (in Xhosa). WRC Report No. 78/96.
- Pybus PJ (1996) Preliminary Guidelines for Private Sector Participation in Water Supply and Sanitation Services. WRC Report No. KV 81/96.
- Van Schalkwyk A (1996) Guidelines for the Estimation of Domestic Water Demand of Developing Communities in the Northern Transvaal. WRC Report No. 480/1/96.

Reports (1995)

- Palmer Development Group (1995) Water and Sanitation Handbook for Community Leaders (in Zulu). WRC Report No. 68/95.

Thesis

- Kibata N (1996) Water and Environmental Sanitation for Urban Communities in Developing Countries: Information Server. M.Sc. Thesis, Dept. of Chem. Eng., Univ. of Natal.

POTABLE WATER SUPPLY

Articles and papers (1996)

- Du Preez M and Genthe B (1996) Evaluation of rapid methods for the detection of indicator organisms in drinking water. Paper presented at the Bienn. Conf. and Exhibition of WISA, Port Elizabeth. 20-23 May.
- Du Preez M, Gericke M, Bateman B and Kfir R (1996) The occurrence of *Giardia* cysts and *Cryptosporidium* oocysts in South African raw and treated water. Paper presented at the IAWQ, Health-related Water Microbiol. Conf., Mallorca, Spain. 6-11 October.
- Gericke M, Du Preez M, Bateman BW and Kfir R (1996) Occurrence of protozoan parasites in South African source and drinking water. Paper presented at the Bienn. Conf. and Exhibition of WISA, Port Elizabeth. 20-23 May.
- Grabow WOK (1996) Control of waterborne viral diseases. Invited paper presented at Int. Congr. on Waterborne Pathogens, jointly organised by the German Assoc. of Hygiene and Microbiol. and the World Health Organ., Bonn, Germany. 22-24 May.
- Grabow WOK (1996) Hepatitis E virus – A novel agent for water-borne infection. Invited paper presented at Hong Kong Soc. for Microbiol. and Infect., Hong Kong. 2 July.
- Grabow WOK (1996) New challenges in monitoring water for pathogens. *Water, Sewage and Effluent* **16** 51-54.
- Grabow WOK (1996) Pathogenic and indicator organisms in drinking water. Invited paper presented at Semin. on the Microbiol. of Drinking Water, Spanish Ministry of Public Health, Madrid, Spain. 27-29 November.
- Grabow WOK (1996) Rand Water: Virological Quality of Water, April 1995 to March 1996. Report to Dept. of Virol., Univ. of Pretoria.
- Grabow WOK (1996) Waterborne diseases: Update on water quality assessment and control. *Water SA* **22** (2) 193-202.
- Grabow WOK (1996) Why monitor viruses in water and food? Invited paper presented at Symp. on Ecotoxicol., City Univ., Hong Kong. 4 July.
- Grabow WOK, De Villiers JC, Erasmus B, Erasmus D and Engelbrecht L (1996) Viruses in waste water from an informal settlement. Paper presented at Bienn. Conf. of WISA, Port Elizabeth. 20-23 May.
- Grabow WOK, Taylor MB and Webber LM (1996) Hepatitis E virus in South Africa. *S. Afr. J. of Sci.* **92** 178-180.
- Haarhoff J, Van Beek JC and Van Wyk HJ (1996) Practical application of the Argaman/Kaufman flocculation model. Paper presented at Bienn. Conf. of WISA, Port Elizabeth. 20-23 May.
- Haarhoff J and Van Beek S (1996) Five years of combined flotation/filtration at the Rietvlei water treatment plant. *J. of the S. Afr. Inst. of Civil Eng.* **38** (1) 15-20.
- Jacobs L and Cloete TE (1996) Spectrophotometric method for the monitoring of *Pseudomonas aeruginosa* adhesion to glass and 3CR12 stainless steel surfaces. In: *Proc. of the IAWQ Bienn. Conf.*, Singapore. June.
- Jagals P and Grabow WOK (1996) An evaluation of Sorbitol-fermenting bifidobacteria as specific indicators of human faecal pollution of environmental water. *Water SA* **22** (3) 235-238.
- Manson NJ (1996) Optimising water supply and distribution. *Proc. Int. Assoc. of Hydraulic Res.*, Africa Div., Bienn. Congr. "From Flood to Drought", Sun City. August.
- Marx FE, Taylor MB and Grabow WOK (1996) PCR detection of human astroviruses in environmental water samples. Paper presented at IAWQ Int. Symp. on Health-Related Water Microbiol., Mallorca, Spain. 6-10 October.
- Marx FE, Taylor MB and Grabow WOK (1996) The detection of human astroviruses in stools of patients with diarrhoea using molecular techniques. Poster presentation at Congr. of the Fed. of S. Afr. Soc. of Pathol., Karos Kruger Lodge. 29 June – 3 July.
- Pieterse AJH (1996) Algae and purification processes. Invited paper presented at WISA Meeting, Johannesburg. November.
- Pieterse AJH (1996) Algal cells and coagulation, flocculation and sedimentation processes. Paper presented at Joint Int. IAWQ-IWSA Conf. on the Role of Particle Characteristics in Separation Processes, Jerusalem, Israel. November.
- Pieterse AJH (1996) From river water to drinking water. Paper presented at WISA Semin. for Water Sci., Bothaville. February.
- Pieterse AJH (1996) Man and environment: Friends or foes? Paper presented at Environ. Summit for the Greater Potchefstroom Area, Potchefstroom. February.
- Pieterse AJH (1996) Phytoplankton characteristics and water purification. Paper presented at Congr. of the SA Assoc. of Bot., Univ. of Stellenbosch. January.
- Pieterse AJH (1996) The conflict between environment and development. *Word and Action* (Winter) 14-16.
- Pieterse AJH (1996) The effect of algae on coagulation. Invited paper presented at the 2nd Afr. Water Conf., Johannesburg. September.
- Pieterse AJH (1996) The role of physical and physiological characteristics of algal cells in the coagulation and sedimentation of phytoplankton. Paper presented at Meet. SA Acad. for Sci. and Arts (Div. Biology), Pretoria.
- Pieterse AJH (1996) The role of science and technology in eutrophication and water purification. Paper presented at Annu. Conf. of the R. Soc. of S. Afr., Fulfilling Basic Needs: The Role of Sci. and Technol., Univ. of Cape Town. February.
- Pieterse AJH and Van Vuuren SJ (1996) Algal population succession in the Vaal River at Stilfontein. Paper presented at Annu. Congr. of the Phycol. Soc. of South. Afr., Meerensee, Hermanus. January.

- Roos JC and Pieterse AJH (1966) The impact of flood-waters on Vaal River phytoplankton. Paper presented at Int. Conf. of the South. Afr. Assoc. for Aquatic Sci., Victoria Falls, Zimbabwe. July.
- Roos JC and Pieterse AJH (1996) Seasonal variation of phytoplankton biomass in the middle Vaal River, South Africa. *Water SA* **22** (1) 33-42.
- Stephenson D and Turner K (1996) Water consumption patterns in Gauteng. *IMIESA* **21** (1) 11-16.
- Steynberg MC, Guglielmi MM, Geldenhuis J and Pieterse AJH (1996) Chlorine and chlorine dioxide, pre-oxidants used as algocides in potable water plants. *J. Water S.R.T. Aqua* **45** 1-9.
- Swanepoel A and Pieterse AJH (1996) An ecological study of the Loch Vaal. Paper presented at Annu. Congr. of the Phycol. Soc. of South. Afr., Meerensee, Hermanus. January.
- Swartz CD and De Villiers HA (1996) Guidelines for the treatment of coloured water for potable use in South Africa. Paper presented at WISA Bienn. Conf., Port Elizabeth. May.
- Taylor MB, Parker S, Grabow WOK and Cubitt WD (1996) An epidemiological investigation of Norwalk virus infection in South Africa. *Epidemiol. and Infect.* **116** 203-206.
- Taylor MB, Wolfaardt M and Grabow WOK (1996) Molecular epidemiology of South African strains of hepatitis A virus: 1984-1995. Poster presentation at Int. Congr. of Virol., Jerusalem, Israel. 11-16 August.
- Traut DF and Pieterse AJH (1996) Coagulation and sedimentation of algal cells and associated materials in the Vaal River. Paper presented at Annu. Congr. of the Phycol. Soc. of South. Afr., Meerensee, Hermanus. January.
- Van der Walt AM and Pieterse AJH (1996) A reedbed for secondary treatment of small-volume effluent. Paper presented at Annu. Congr. of the Phycol. Soc. of South. Afr., Meerensee, Hermanus. January.
- Van der Walt AM, Pieterse AJH and Wood A (1996) A reedbed system for secondary treatment of a mixed effluent. Paper presented at 9th Bienn. Congr. of the S. Afr. Soc. of Microbiol., Pretoria. July.
- Van Vuuren S and Pieterse AJH (1996) Environmental variables, abundance and seasonal succession of phytoplankton populations in the Vaal River at Balkfontein. Paper presented at Annu. Congr. of the Phycol. Soc. of South. Afr., Meerensee, Hermanus. January.
- Venter A and Pieterse AJH (1996) Isolation of *Oscillatoria simplicissima* from the Vaal River in artificial growth medium. Paper presented at Meet. SA Acad. for Sci. and Arts (Div. Biology), Pretoria.
- Vermeulen A and Pieterse AJH (1996) The ecology of phytoplankton populations of the Vaal Dam. Paper presented at Annu. Congr. of the Phycol. Soc. of South. Afr., Meerensee, Hermanus. January.
- Visser R and Pieterse AJH (1996) Algal species penetrating unit processes in the Balkfontein water purification plant. Paper presented at Annu. Congr. of the Phycol. Soc. of South. Afr., Meerensee, Hermanus. January.
- Webber LM, Grabow WOK and Favorov MO (1996) Assessment of techniques for the detection of hepatitis E antibodies. Paper presented at Faculty Day, Faculty of Medicine, Univ. of Pretoria. 27-28 August.

Articles and papers (1995)

- Govender S, Pillay VL and Buckley CA (1995) Woven-fibre cross-flow filtration. Paper presented at Appl. Pollution Res. Symp., WISA Water Scientists, Technikon Natal. 24 August.

Reports (1996)

- Bourne DE and Coetzee N (1996) An Atlas of Potentially Water-related Diseases. Vol 1 – Mortality 1990 in South Africa. WRC Report No. 584/1/96.
- Coetzee N and Bourne DE (1996) An Atlas of Potentially Water-related Diseases in South Africa. Volume 2 – Bibliography. WRC Report No. 584/2/96.
- Dickens CWS, Graham PM and Freese S (1996) Algal Rupture during Abstraction from Reservoirs and the Consequences for Water Treatment. WRC Report No. 558/1/96.
- Genthe B and Seager J (1996) The Effect of Water Supply, Handling and Usage on Water Quality in Relation to Health Indices in Developing Communities. WRC Report No. 562/1/96.
- Grabow WOK, Taylor MB and Wolfaardt M (1996) Research on Human Viruses in Diffuse Effluents and Related Water Environments. WRC Report No. 496/1/96.

Reports (1995)

- Solsana F and Pearson I (1995) Non-Conventional Disinfection Technologies for Small Water Systems. WRC Report No. 449/1/95.
- Steynberg MC, Kok M, Chale B, Grundlingh JA, Joubert JHB and Geldenhuys JC (1995) The Removal of Invertebrates by Sand Filtration and the Influence Thereof on Water Quality. WRC Report No. KV 76/95.

Theses

- Barnett JL (1995) Residence Time Methods for Modelling and Assessing the Performance of Water Treatment Processes. M.Sc. Thesis, Dept. of Chem. Eng., Univ. of Natal.
- Chemaly BSF (1996) Point-source Water Provision through Solar Distillation. M.Sc. (Eng.) Thesis, Univ. of Stellenbosch.
- Janse van Vuuren SM (1996) Environmental Variables and Seasonal Succession of Phytoplankton Populations in the Vaal River. M.Sc. Thesis, Potchefstroom Univ. for CHE.
- Potgieter N (1996) The Recovery of Small Numbers of Viruses from Large Volumes by Affinity Chromatography. M.Sc. (Medical Virology) Thesis, Univ. of Pretoria.
- Van der Veen A (1996) Research on Methods for the Enumeration of Enteric Viruses and Related Indicators in Shellfish. M.Sc. (Medical Virology) Thesis, Univ. of Pretoria.
- Vermeulen A (1996) Ecology of Phytoplankton Populations in the Vaal Dam. M.Sc. Thesis, Potchefstroom Univ. for CHE.
- Viljoen OJ (1996) The Prediction of Chlorine Decay from Potable Water in Pipeline Systems. M.Sc. Thesis, Rand Afr. Univ.
- Wolfaardt M (1996) Detection and Characterisation of Human Caliciviruses. Ph.D. (Medical Virology) Thesis, Univ. of Pretoria.

MUNICIPAL EFFLUENTS

Articles and papers (1996)

- Cloete TE, Allison P and Poulton WIJ (1996) Control of Biofouling in Industrial Water Systems. NACE Special Publication on Biofouling Control.
- Jacobs L, De Bruyn EE and Cloete TE (1996) Spectrophotometric monitoring of biofouling. Paper presented at 9th Bienn. Congr., S. Afr. Soc. for Microbiol., Pretoria. July.
- Jacobs L, De Bruyn EE and Cloete TE (1996) Spectrophotometric monitoring method for the adhesion of *Pseudomonas aeruginosa* to a glass surface. Paper presented at IAWQ Conf., Singapore. June.
- Momba MNB and Cloete TE (1996) Biomass relationship to growth and phosphate uptake of *Pseudomonas fluorescens, Escherichia coli* and *Acinetobacter radioresistens* in mixed liquor medium. *J. of Ind. Microbiol.* **16** 364-369.
- Momba MNB and Cloete TE (1996) The relationship of biomass to phosphate uptake by *Acinetobacter junii* in activated sludge mixed liquor. *Water Res.* **30** (2) 364-370.
- Naidoo V, Pillay VL, Senior E and Buckley CA (1996) The effects of higher solids concentrations in anaerobic digesters treating sewage. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Odendaal PE (1996) Emerging technologies for wastewater treatment in South Africa. Paper presented at the Special Seminar on Int. Trends in Water Environ. Manage., Tokyo, Japan. 23 April.
- Pietersen B, Brözel VS and Cloete TE (1996) Response of *Pseudomonas aeruginosa* PAO following exposure to hydrogen peroxide. *Water SA* **22** (3) 239-244.
- Pietersen B, Brözel VS and Cloete TE (1996) The response of *E. coli* K12 upon exposure to hypochlorous acid and hydrogen peroxide. *Water SA* **22** (1) 43-48.
- Pillay VL, Govender S and Buckley CA (1996) Utilising crossflow microfiltration for potable water production. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Pillay VL, Naidoo V, Hilditch J and Buckley CA (1996) The coupled crossflow microfiltration/anaerobic digestion process: Progress on the full-scale unit. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.

Articles and papers (1995)

- Ballard RH and Petrie JG (1995) An experimental study of heavy metal sorption in landfill biomass. Poster presentation at S. Afr. Inst. of Chem. Eng. (Western Cape Branch), Chem. Eng. R & D '95, Cape Technikon. November.
- Ballard RH and Petrie JG (1995) Heavy metal immobilisation in domestic landfills: An experimental study. Paper presented at Coastal Park Semin., Inst. of Waste Management and Cape Town City Council, Muizenberg Pavillion. October.

Report (1996)

- Novella PH, Ross WR, Lord GE, Greenhalgh MA, Stow JG and Fawcett KS (eds.) (1996) The Co-disposal of Waste-water Sludge with Refuse in Sanitary Landfills. WRC Report No. 391/1/96.

Report (1995)

- Smollen M and Kafaar A (1995) Development of Electro-osmotic Sludge Dewatering Technology. WRC Report No. 427/1/95.

Theses

- Jacobs L (1996) Anionic and Nonionic Surfactants Used for Controlling the Attachment of *Pseudomonas aeruginosa* to Glass and 3CR12 Metal Surfaces. M.Sc. Thesis, Dept. of Microbiol. and Plant Pathol., Univ. of Pretoria.
- Naidoo V (1995) A Laboratory Scale Study to Investigate the Effects of Solids Concentration on the Efficiency of Anaerobic Digester. M.Sc. Thesis, Dept. of Chem. Eng., Univ. of Natal.

WATER QUALITY MANAGEMENT

Articles and papers (1996)

- De Clercq WP en Moolman JH (1996) Effek van besproeiing met brakwater op wingerdproduksie. Referaat gelewer by Besproeiingsboeredag, Noordwes Landbou-ontwikkelingsentrum, Vredendal. 12 Junie.
- Eigenhuis BE and Moolman JH (1996) The prediction of sustainable contaminant disposal in soils using computer models: Model selection criteria and sensitivity analysis. Paper presented at the 20th Congr. of the Soil Sci. Soc. of S. Afr., Bloemfontein. 25-27 June.
- Johnston MA, Savage MJ, Moolman JH and Du Plessis HM (1996) Calibration models for interpretation of soil salinity measurements using an electromagnetic induction technique. *S. Afr. J. Plant and Soil* **13** 110-114.
- Jovanovic NZ, Annandale JG, Rethman NFG and Barnard RO (1996) A mechanistic water balance-salt movement model for management of irrigation with lime treated acid mine drainage. Paper presented at the 20th Congr. of the Soil Sci. Soc. of S. Afr., Bloemfontein. 25-27 June.
- Ketley D, Freeman MJ and Wiechers HNS (1996) The management of urban impoundments. *Chem. Technol.*, September/October.
- Rykaart EM (1996) Experiments on recharge through soil covers to coal spoils. *Proc. of the One-day Course on Hydrol. of Made Ground*, Indaba Hotel, Fourways. 9 October.
- Rykaart EM (1996) Performance of soil covers to minimise infiltration and reduce oxygen migration into coal spoils: A review. *Proc. of the Young Water, Environ. and Geotechn. Eng. Festival*, Botha's Hill, KwaZulu-Natal, South Africa. 17-19 July.
- Van Zyl E en Moolman JH (1996) Seisoenale verspreiding van soute in die plant-opname van *Vitis vinifera* L. (cv. Colombar) wat met soutryke water besproei word. Referaat gelewer by die 20e Kongres van die Grondkundever. van S.-Afr., Bloemfontein. 25-27 Junie.
- Venter SN, Steynberg MC, De Wet CME, Hohls H, Du Plessis G and Kfir RA (1996) A situational analysis of the microbial water quality in the Rietspruit catchment. Paper presented at WISA Monthly Meeting. 19 September.

- Venter SN, Steynberg MC, De Wet CME, Hohls H, Du Plessis G and Kfir RA (1996) A situational water quality in a peri-urban catchment in South Africa. Paper presented at Conf. on Health Related Water Microbiol., Mallorca, Spain. 6-10 October.
- Wiechers HNS and Ketley D (1996) The management of urban impoundments. Paper presented at WISA Monthly Meeting. April.
- Wiechers HNS, Freeman MJ, Howard M and Lötter L (1996) Guidelines for the management of urban impoundments in Southern Africa. Paper presented at the Vic Falls Conf. on Aquatic Systems, Zimbabwe. 15-19 July.

Articles and papers (1995)

- Botes WAM and Kapp JF (1995) Dilution studies on three marine outfalls in South Africa. *Water Sci. Technol.* **32** (2) 297-304.
- Shamrock JR (1995) The Pollution Potential of Waste from Developing Communities in South Africa. Report to the Univ. of the Witwatersrand.

Reports (1996)

- Botes WAM and Taljaard S (1996) Comparison of Predicted Secondary Dilutions to Measured Field Data and the Determination of Prototype Diffusion Coefficients. WRC Report No. 675/1/96.
- Herold CE and Bailey AK (1996) Long Term Salt Balance of the Vaalharts Irrigation Scheme. WRC Report No. 420/1/96.
- Herold CE, Pitman WV, Bailey AK and Taviv I (1996) Lower Vet River. Water Quality Situation Analysis with Special Reference to the OFS Goldfields. WRC Report No. 523/1/96.
- Pulles W, Heath H and Howard M (1996) A Manual to Assess and Manage the Impact of Gold Mining Operations on the Surface Water Environment. WRC Report No. TT 79/96.
- Venter SN, Steynberg MC, Du Plessis C, De Wet CME, Hohls D, Rodda N and Kfir R (1996) Tools for Microbial Water Quality Assessment of South African Rivers. WRC Report No. 380/1/96.
- Wiechers HNS, Freeman MJ and Howard M (1996) The Management of Urban Impoundments in South Africa – Volume 1: Status Quo Report. WRC Report No. TT 77/96.

Theses

- Hunter C (1996) Development of a Laboratory River Model to Determine the Environmental Impacts of Point- and Diffuse Source Pollution Discharges. M.Sc. Thesis, Univ. of Natal.
- Pillay M (1995) Detergent Phosphorus in South Africa: Impact of Eutrophication with Specific Reference to the Umgeni Catchment. M.Sc. Thesis, Dept. of Chem. Eng., Univ. of Natal.

GROUNDWATER

Articles and papers (1996)

- Botha JF, Van Tonder GJ, Verwey JP and Kinzelbach W (1996) Analysis of hydraulic test data from Karoo aquifers. In: Kovar K and Van der Heide P (eds.) *Proc. of the ModelCare '96 Conf. on the Calibration and Reliability in Groundwater Modelling*, Golden, Colorado. IAHS Publication No. 237.
- Botha JF, Vivier JJP en Verwey JP (1996) Grondwaterondersoeke te Philippolis. Verslag opgestel vir die Firma Cahi De Vries. Inst. vir Grondwaterstudies, Univ. van die Oranje-Vrystaat, Bloemfontein.
- Bredenkamp DB (1996) Perspectives on groundwater recharge estimation in South Africa. Paper presented at Workshop on Groundwater-Surface Water Issues in Arid and Semi-arid Areas, Mabalingwe. 16-17 October.
- Butler MJ and Verhagen BTh (1996) Urban isotope hydrology. Paper presented at Africa Groundwater Resources '96, 1st Int. Conf. of the Hydrogeol. Assoc. of Afr., Abidjan. 9-15 August.
- Conrad JE (1996) Is fertilizer contaminating groundwater? Poster presentation at the Annu. Fertilizer Soc. of S. Afr. Symp., Midrand Volkswagen Conference Centre. 22 August.
- Pitman WV and Vegter JR (1996) Recharge and stream flow. Paper presented at the Workshop on Groundwater-Surface Water Issues in Arid and Semi-arid Areas, Mabalingwe. 16-17 October.
- Verhagen BTh (1996) Saturated zone recharge studies. Working paper. Workshop on Groundwater-Surface Water Issues in Arid and Semi-arid Areas, Mabalingwe. 16-17 October.

Articles and papers (1995)

- Weaver JMC, Talma AS and Brunke E (1995) Dating of Groundwater using CFCs. Paper presented at Groundwater '95, Groundwater Recharge and Rural Water Supply Conf., Midrand. September.

Report (1996)

- Economic Project Evaluation (Pty) Ltd (1996) The Economics of Groundwater Usage: The Importance of Intrinsic Value as a Basis for Sustainable Management. WRC Report No. 639/1/96.

Reports (1995)

- Lukas E, Fourie G and Hodgson F (1995) The Use of Geographic Information Systems and Other Computer Aided Drafting Facilities for the Production of Geohydrological Maps. WRC Report No. 377/1/95.
- Parsons R (1995) A South African Aquifer System Management Classification. WRC Report No. KV 77/95.
- Van Schalkwyk A, Jordaan JM en Dooge N (1995) Die Erodeerbaarheid van Verskillende Rotsformasies onder Variërende Vloeitoestande. WNK Verslagno. 302/1/95.

Theses

- Van der Voort I (1995) The Influence of the Geometry of Karoo Aquifers on their Ability to Yield Water. M.Sc. Thesis, Dept. of Geohydrol., Univ. of the Orange Free State, Bloemfontein.
- Vivier JJP (1996) The Influence of Geology on the Geohydrology of Karoo Aquifers. M.Sc. Thesis, Dept. of Geohydrol., Univ. of the Orange Free State, Bloemfontein.

AGRICULTURAL WATER MANAGEMENT

Articles and papers (1996)

- Anderson JJ, Botha JJ, Hensley M en Van Staden PP (1996) Waterbalansmetings en simulasies met koring op die Bultfontein/Clovelly en Petrusburg/Bloemdal ekotope 1993-1995. Referaat gelewer by die Gewasmodellering-werksessie by die LNR se Kleingraaninst. Maart.
- Annandale JG and Savage MJ (1996) Sensitivity of Penman-Monteith reference crop evaporation to input measurement errors. Paper presented at SASCP Annu. Congr., Bloemfontein. January.
- Backeberg GR (1996) Constitutional change and natural resource policy reform in South Africa: Conducive or obstructive to sustainable economic growth of agriculture? *Agrekon* **35** (4).
- Backeberg GR (1996) The challenge of irrigation policy reform in the mature water economy of South Africa. *Proc. of an Int. Workshop on Security and Sustainability in a Mature Water Economy: A Global Perspective.* Water and Resource Economics Consortium, Univ. of Melbourne, Australia.
- Booysen HJ, Viljoen MF en De Villiers GduT (1996) Konstruering van vloedskadefunksies vir die residensiële sektor van Upington. *Water SA* **22** (1) 1-6.
- Booysen HJ, Viljoen MF en De Villiers GduT (1996) The need for and the importance of adequate hydrological data for the accurate calculations of potential flood damage. Paper presented at Bienn. Congr. "From Flood to Drought". 5-7 August.
- Botes JHF, Bosch DJ and Oosthuizen LK (1996) A simulation and optimization approach for evaluating irrigation information with limited and unlimited water supplies. *Agric. Systems* **51** 165-183.
- Breytenbach P, Meiring JA en Oosthuizen LK (1996) Die belangrikheid van elektrisiteitskoste by besproeiingsboerdery. *Water SA* **22** (4) 333-338.
- Breytenbach P, Meiring JA en Oosthuizen LK (1996) Die generering en gebruik van kumulatiewe waarskynlikheidsverdelings vir die evaluering van diversifikasie as risikobestuurswyse in die Wintergebied. Referaat gelewer tydens die Jaarlikse Konf. van die Landbou-ekon. Ver. van S.-Afr., Midrand. 25-27 September. Ook in *Agrekon* **35** (4).
- Casey NH, Meyer JA and Coetzee CB (1996) An investigation into the quality of water for animal production. *Proc. 2nd All Afr. Conf. on Animal Agric.*
- Casey NH, Meyer JA and Coetzee CB (1996) Livestock Watering, South African Water Quality Guidelines, Vol 5: Agricultural Use. Dept. of Water Affairs and Forestry Report.
- De Jager JM and Mottram R (1996) Saving water using a weather based water management system. *Trans. of the 16th ICID Spec. Session on "The Future of Irrigation under Increased Demand from Competitive Uses of Water and Greater Needs for Food Supply"*, Cairo. September. Vol 1-E. 153-165. Also presented at 47th Int. Executive Council, Cairo.
- De Ronde JA (1996) HPLC-analysis in cotton leaves. Poster presentation at Plant Breeders Symp., Potchefstroom.
- Du Plessis LA and Viljoen MF (1996) A flood damage simulation model for irrigation areas in South Africa: A GIS-approach. Paper presented at Bienn. Congr. "From Flood to Drought". 5-7 August.
- Dye PJ (1996) Response of *Eucalyptus grandis* trees to soil water deficits. *Tree Physiol.* **16** 233-238.
- Hensley M (1996) A meaningful upper limit of available water, and a problem case. Paper presented at the Biol. Modelling Forum, Potchefstroom. October.
- Hensley M (1996) Improving neutron water meter measurements in wet soils. Paper presented at the 1996 Soil Sci. Soc. of S. Afr. Congr., Bloemfontein.
- Hensley M (1996) Using drainage curves to determine crop modified drained upper limit values. Paper presented at the 1996 Soil Sci. Soc. of S. Afr. Congr., Bloemfontein.
- Jovanovic NZ and Annandale JG (1996) Measurement of radiant interception by crop canopies. Paper presented at SASCP Annu. Congr., Bloemfontein. January.
- Jovanovic NZ, Annandale JG, Rethman NFG and Barnard RO (1996) A mechanistic water balance-salt movement model for management of irrigation with lime treated acid mine drainage. Paper presented at Soil Sci. Soc. of S. Afr. Congr., Bloemfontein. June.
- Jovanovic NZ, Annandale JG, Rethman NFG and Barnard RO (1996) Crop growth simulations under saline soil conditions. Paper presented at SASCP Annu. Congr., Bloemfontein. January.
- Le Roux PAL, Van Staden PP, Hensley M en Botha JJ (1996) Pedoverskynsels en versadigde hidrouliese geleivermoë van enkele plintiese gronde. Referaat gelewer by die 1996 Kongr. van die Grondkundever. van S.-Afr., Bloemfontein.
- Marais D, Rethman NFG and Annandale JG (1996) Water use efficiency and nutritive value of corn, pearl millet and fodder sorghum. Paper presented at 5th Int. Conf. on Desert Dev., Texas, USA. August.
- Marais D, Rethman NFG and Annandale JG (1996) Water use efficiency of corn and cowpeas in terms of dry matter (WUE^{DM}) and crude protein production (WUE^{CP}). Paper presented at 5th Int. Conf. on Desert Dev., Texas, USA. August.
- Marais D, Rethman NFG and Annandale JG (1996) Water use efficiency of maize and soybean at four irrigation levels. Paper presented at 31st Congr. of the Grassland Soc. of South. Afr., Nelspruit. January.
- O'Reagan BP and Cress WA (1996) Gene expression in response to water stress. Paper presented at Plant Breeders Symp., Potchefstroom.
- Palmer RW (1996) Blackfly control, using *B.t.i.*, in the Orange River, South Africa. Paper presented at Conf. on the Bacterial Control of Insect Pests and Vectors of Human Diseases, Ben Gurion Univ. of the Negev. En Gedi.12-16 August.

- Palmer RW, Edwardes M and Nevill EM (1996) Control of pest blackflies (Diptera: Simuliidae) along the Orange River, South Africa. *Onderstepoort J. of Vet. Res.* **63** (4) x-xx.
- Palmer RW, Edwardes M and Nevill EM (1996) Downstream carry of larvicides used in the control of pest blackflies (Diptera: Simuliidae) in the Orange River, South Africa. *J. of Vector Ecol.* **21** (1) 37-47.
- Palmer RW, Edwardes M and Nevill EM (1996) Timing of larvicide treatments for the control of the pest blackflies (Diptera: Simuliidae) in a semi-arid environment in South Africa. *J. of Vector Ecol.* **21** (1) 48-59.
- Rethman NFG, Venter PS and Lindeque JP (1996) Influence of water stress on the mass and distribution of roots of Buffelbrass selections. Paper presented at 2nd Int. Symp. on the Biol. of Root Formation and Development, Israel. June.
- Rethman NFG and Tanner PD (1996) The potential use of gypsiferous water for irrigation. Paper presented at Olifants River Forum – Water Management Day, Middelburg, Mpumalanga. October.
- Van der Mescht A (1996) Drought tolerant crops for South Africa? A biotechnological approach. Paper presented at Plant Breeders Symp., Potchefstroom.
- Van der Mescht A and Rossouw FT (1996) Changes in CuZn superoxide dismutase, glutathione reductase and perioxidase concentration during drought stress in potato. Poster presentation at Plant Breeders Symp., Potchefstroom.
- Van der Mescht A and Rossouw FT (1996) Drought tolerant potatoes for South Africa – A strategy for the development of a screening method. Poster presentation at 5th Congr. of the S. Afr. Genetics Soc., Stellenbosch.
- Van der Westhuizen AJ and Annandale JG (1996) Demand-driven transfer of irrigation scheduling technology. Paper presented at SASCP Annu. Congr., Bloemfontein. January.
- Van der Westhuizen AJ en Annandale JG (1996) Simulasie van vars opbrengs en kwaliteit van fabriekstamaties. Referaat gelewer by SAVG Jaarlikse Kongr., Bloemfontein. Januarie.
- Van der Westhuizen AJ en Annandale JG (1996) TOM-MAN: 'n Bestuurshulpmiddel vir die optimisering van besproeiingsbestuur by fabriekstamaties. Referaat gelewer by SAVG Jaarlikse Kongr., Bloemfontein. Januarie.
- Venter PS and Rethman NFG (1996) Comparing various parameters to study the drought tolerance of subtropical grasses. Paper presented at 31st Congr. of the Grassland Soc. of South. Afr., Nelspruit. January.

Articles and papers (1995)

- Botes JHF, Bosch DJ and Oosthuizen LK (1995) The value of irrigation information for decision-makers with neutral and non-neutral risk preferences under conditions of unlimited and limited water supply. *Water SA* **21** (3) 221-230.
- De Jager JM and Kennedy JA (1996) Weather based irrigation scheduling for numerous farms, commercial and small scale. Paper presented at 46th ICID Int. Executive Council and Spec. Tech. Session. Workshop on Irrigation Scheduling: From Theory to Practice, Rome, Italy. 11-16 September.
- De Ronde JA and Steyn HSF (1995) Proline accumulation during drought and heat stress in cotton. Poster presentation at Biochem. Congr., Bloemfontein.
- De Ronde JA, Van der Mescht A and Cress WA (1995) Synthesis of late heat shock proteins and acquisitions of thermotolerance in six cotton cultivars. *S. Afr. J. Plant and Soil* **12** (4) 177-179.
- De Ronde JA, Van der Mescht A and Cress WA (1995) The biochemical responses of six cotton cultivars to heat stress. *S. Afr. J. Sci.* **91** 363-366.
- Jovanovic NZ, Annandale JG, Barnard RO and Rethman NFG (1995) Crop response to irrigation with lime treated acid mine drainage. Paper presented at Combined Conf. SASCP, SSSSA, SAWSS, SASHS and SAPBA, Stellenbosch. January.
- O'Regan BP and Cress WA (1995) Gene expression in maize in response to water stress. Poster presentation at Int. Congr. on Integrated Studies on Drought Tolerance of Higher Plants, Montpellier, France.
- Van der Mescht A (1995) A biotechnology approach to drought tolerance. Drought Discussion Group, Univ. of the Witwatersrand.
- Van der Mescht A and Rossouw FT (1995) Changes in CuZn superoxide dismutase glutathione reductase and peroxidase concentration during drought stress in potato. Poster presentation at Int. Congr. on Integrated Studies on Drought Tolerance of Higher Plants. Montpellier, France.

Reports (1996)

- Annandale JG, Van der Westhuizen AJ en Olivier FC (1996) Die Fasilitering van Tegnologie-oordrag deur Verbeterde Besproeiings-riglyne vir Groente en 'n Meganistiese Gewasmodellerings-benadering. WNK Verslagno. 476/1/96.
- Backeberg GR, Bembridge TJ, Bennie ATP, Groenewald JA, Hammes PS, Pullen RA and Thompson H (1996) Policy Proposal for Irrigated Agriculture in South Africa. WRC Report No. KV 96/96.
- Booysen HJ en Viljoen MF (1996) Die ontwikkeling van Vloed-skadefunksies en 'n Rekenaarprogram om die Voordele van Vloedbeheer- en Vloedskadebeheermaatreëls te Bepaal: **Vol 3**: Stedelike Gebied. WNK Verslagno. 490/3/96.
- Casey NH and Meyer JA (1996) Interim Water Quality Guidelines for Livestock Watering. WRC Report No. TT 76/96.
- Casey NH, Meyer JA, Coetzee C and Van Niekerk WA (1996) An Investigation into the Quality of Water for Animal Production. WRC Report No. 301/1/96.
- Crosby CT (1996) SAPFACT 1.0: A Computer Program for Qualitative Evaluation of Irrigation Farming. WRC Report No. 382/1/96.
- Crosby CT (1996) SAPWAT 1.0: A Computer Program for Estimating Irrigation Requirements in Southern Africa. WRC Report No. 379/1/96.
- Du Plessis LA en Viljoen MF (1996) Die Ontwikkeling van Vloed-skadefunksies en 'n Rekenaarprogram om die Voordele van Vloed-beheer- en Vloedskadebeheermaatreëls te Bepaal: **Vol 2**: Besproeiingsgebied. WNK Verslagno. 490/2/96.
- Mkhize SS, Vanassche FMG and Laker MC (1996) The Response of Citrus Seedlings to Soil Compaction and Variations in Soil Water Potential in the Upper Range of Plant Available Water. WRC Report No. 261/1/96.

- Oosthuizen LK, Botes JHF, Bosch DJ and Breytenbach P (1996) Increasing Economic Efficiency of Water and Energy Use for Irrigation at Whole Farm Level in the Winterton Area. WRC Report No. 347/2/96.
- Oosthuizen LK en Meiring JA (1996) Die Ontwikkeling van 'n Besluitnemingsondersteuningstelsel vir die Ekonomiese Evaluering van Risiko-bestuur op Plaasvlak en die Toepassing Daarvan in die Halfdroë Gebied Benede die PK Le Rouxdam. WNK Verslagno. 347/3/96.
- Oosthuizen LK, Meiring JA, Botes JHF, Bosch DJ and Breytenbach P (1996) Development of a Decision Support System for Increasing the Economic Efficiency of Water and Energy Use for Irrigation at Whole Farm Level in Central RSA, Taking Risk into Account. WRC Report No. 347/1/96.
- Viljoen MF, Du Plessis LA en Booysen HJ (1996) Die Ontwikkeling van Vloedskadefunksies en 'n Rekenaarprogram om die Voordele van Vloedbeheer- en vloedskadebeheermaatreëls te Bepaal: **Vol 1**: Samevattende Verslag. WNK Verslagno. 490/1/96.

INDUSTRIAL WATER AND EFFLUENT

Articles and papers (1996)

- Barclay SJ, Carliell CM and Buckley CA (1996) Treatment of exhaust reactive dyebath effluent using anaerobic digestion. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Bell CJ, Barclay SJ, Carliell CM and Buckley CA (1996) Decolorisation of textile effluent using a modified 5-stage Bardenpho nutrient removal process. Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Carliell CM, Barclay SJ and Buckley CA (1996) Treatment of exhausted reactive dyebath effluent using anaerobic digestion: Laboratory and full-scale trials. *Water SA* **22** (3) 225-234.
- Coetzee PP (1996) The role of metal surfaces in physical water treatment. Paper presented at Int. Symp.: Antiscale Magnetic Water Treatment, Cranfield Univ., Bedford, UK. 14 March.
- Coetzee PP, Howell SS and Yacoby M (1996) Magnetic water treatment for the prevention of scale: Myth or fact? Paper presented at 33rd Conv. of the S. Afr. Chem. Inst., Cape Town. January.
- Coetzee PP, Yacoby M and Howell SS (1996) The role of zinc in magnetic and other physical water treatment methods for scale prevention. *Water SA* **22** (4) 319-326.
- Gordon P, Brouckaert CJ and Buckley CA (1996) An investigation into the fouling of heat exchangers. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Gravelet-Blondin LR, Carliell M, Barclay SJ and Buckley CA (1996) Management of water resources in South Africa with respect to textile industry. Paper presented at 2nd IAWQ Specialised Conf. on Pretreatment of Industrial Wastewaters, Divani Caravel Hotel, Athens, Greece. 16-18 October.
- Jewnarain SR, Schwikkard GW, Winship SJ and Buckley CA (1996) Investigation of the ultrasonic kinetics of hydrogen peroxide. Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Reeves JA and Buckley CA (1996) Chemical speciation modelling of cooling-water circuits. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Rencken GE, Mullan DJ and Buckley CA (1996) Modelling of the tubular filter press process. Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Schwikkard GW, Winship SJ and Buckley CA (1996) Design of a sonochemical reactor. Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Schwikkard GW, Winship SJ and Buckley CA (1996) Sonochemical degradation of hydantoin compounds. Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Schwikkard GW, Winship SJ and Buckley CA (1996) The use of ultrasound for the degradation of biorefractory compounds in industrial effluent. Poster presentation at 5th Meet. of the Eur. Soc. of Sonochem., St John's College, Cambridge, UK. 7-11 July.
- Winship SJ, Cerisier S, Hanekom D, Gericke G, Smit J and Buckley CA (1996) The pilot-plant evaluation of an anion-free flocculant. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.

Articles and papers (1995)

- Barclay SJ (1995) Anaerobic treatment of textile effluent. Intensive and advanced course: Biochem. Eng. Applications in Environ. Biotechnol. and Cleaner Production, Gautemala. 18-29 September.
- Brouckaert BM (1995) Introduction to MINTEQA2, a geochemical speciation program. Paper presented at Appl. Pollution Res. Symp., WISA Water Scientists, Technikon Natal. 24 August.
- Brouckaert CJ, Baddock LAD and Buckley CA (1995) The application of computational fluid dynamics to water treatment equipment. Paper presented at Appl. Pollution Res. Symp., WISA Water Scientists, Technikon Natal. 24 August.
- Buckley CA (1995) Applications of bioprocessing in South Africa. Plenary lecture at UNESCO-FRD Biotechnol. Regional Workshop Programme, Univ. of Durban-Westville. 18 September.
- Buckley CA (1995) Water conservation reportback power generation, mining and industrial sector. Paper presented at Natl. Conf. on Water Conservation, The World Trade Centre, Kempton Park. 2-3 October.
- Gordon P (1995) Investigation into the fouling of process cooling water. Paper presented at Appl. Pollution Res. Symp., WISA Water Scientists, Technikon Natal. 24 August.

Reports (1996)

- Kröger DG (1996) Cooling Tower Performance Evaluation. WRC Report No. 478/1/96.
- Schoeman JJ and Steyn A (1996) Electrically Driven Membrane Separation Processes for the Treatment of Industrial Effluents. WRC Report No. 532/1/96.
- Schoonbee HJ, Adendorff A, De Wet LM, De Wet LPD, Fleischer CL, Van der Merwe CG, Van Eeden PH and Venter AJA (1996) The Occurrence and Accumulation of Selected Heavy Metals in Freshwater Ecosystems Affected by Mine and Industrial Polluted Effluents. WRC Report No. 312/1/96.

Report (1995)

- Nell JH and Kafaar A (1996) The Evaluation and Improvement of the Anaerobic Digestion/Ultrafiltration (ADUF) Effluent Treatment Process. WRC Report No. 365/1/95.

Theses

- Canbulat S (1996) Measurement of Calcium Carbonate Precipitation in an Experimental Heat Exchange Circuit. M. Eng. Thesis, Dept. of Eng., Rand Afr. Univ.
- Chetty S (1995) The Evaluation of the Cavitation Process to Produce Radical Species Capable of Oxidising Organic Pollutants in Industrial Wastewaters and Potable Water. M.Sc. Thesis, Dept. of Chem. Eng., Univ. of Natal.
- Howell SS (1996) A Critical Evaluation of Physical Water Treatment for the Prevention of Scale. M.Sc. Thesis, Dept. of Chemistry, Rand Afr. Univ.
- Naidoo N (1995) Chemical Treatment and Structural Elucidating of Textile Dyes. M.Sc. Thesis, Dept. of Chem. Eng., Univ. of Natal.
- Schwikkard G (1995) An Investigation of the Sonochemical Degradation of Hydantoin Compounds. M.Sc. Thesis, Dept. of Chem. Eng., Univ. of Natal.
- Simpson AE (1995) The Recovery of Sodium Hydroxide from Cotton Scouring Effluents. Ph.D. Thesis, Dept. of Chem. Eng., Univ. of Natal.
- Yacoby M (1996) The Effect of Magnetic and Constant Electric Field Antiscaling Devices on the Mechanism of $CaCO_3$ Scale Formation. M.Sc. Thesis, Dept. of Chemistry, Rand Afr. Univ.

Patent

- Process for Treatment of Water: Prevention of Scale Deposits. Patent No. 95/6807.

MEMBRANE TECHNOLOGY

Articles and papers (1996)

- Allie Z, Maartens A, Swart P and Jacobs EP (1996) Optimisation of biological cleaning of ultrafiltration membranes fouled in abattoir effluent. Poster presentation at 2nd Afr. Water Conf., Midrand. 2-5 September.
- Bessarabov DG, Sanderson RD and Jacobs EP (1996) Use of membrane contactors with nonporous membranes for improved gas and liquid separations. Paper presented at 8th Annu. Meet. of the North Am. Membrane Soc., Citadel Inn, Ottawa, Ontario, Canada. 18-22 May.
- Brouckaert BM, Brouckaert CJ and Buckley CA (1996) Prediction of conductivity from equilibrium speciation. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Brouckaert CJ, Baddock LAD and Buckley CA (1996) The application of computational fluid dynamics for modelling of water treatment systems. Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Brouckaert CJ, Buckley CA and Jacobs EP (1996) Common pitfalls in the design and operation of membrane plants – or how I should have done it! Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May. Also at 2nd Afr. Water Conf., Midrand. 2-5 September.
- Brouckaert CJ, Simpson AE, Baddock LAD and Buckley CA (1996) Modelling of nanofiltration of sodium carbonate solution. Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Brouckaert CJ (1996) The application of computational fluid dynamics for modelling of treatment systems. Paper presented at WISA, KwaZulu-Natal Branch, 3rd Gen. Meet., Durban. 5 June.
- Domröse SE, Jacobs EP and Sanderson RD (1996) Capillary membrane module design and manufacture. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Edwards W, Boshoff A, Leukes WD, Jacobs EP, Sanderson RD, Burton SG and Rose PD (1996) A comparison between two parallel transverse-flow membrane bioreactor modules in terms of bioremediation efficiency using immobilised tyrosinase. Paper presented at 2nd Afr. Water Conf., Midrand. 2-5 September.
- Edwards W, Boshoff A, Leukes WD, Jacobs EP, Sanderson RD, Burton SG and Rose PD (1996) A comparison between two parallel transverse-flow membrane bioreactor modules in terms of bioremediation efficiency using immobilised tyrosinase. Poster presentation at 2nd Afr. Water Conf., Midrand. 2-5 September.
- Edwards W, Boshoff A, Leukes WD, Jacobs EP, Sanderson RD, Saayman HM, Burton SG and Rose PD (1996) Continuous treatment of phenol-polluted waters in a novel capillary membrane bioreactor. Paper presented at ICOM '96, Yokohama, Japan. August.
- Edwards W, Leukes WD, Burton SG, Jacobs EP and Sanderson RD (1996) Dephenolization of waste water using immobilised polyphenol oxidase in a hollow-fibre membrane transverse-flow biological contactor. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Engelbrecht J, Bellstedt DU, Swart P and Jacobs EP (1996) The use of ultrafiltration for the purification of industrial waste waters with a high organic content: Membrane fouling and clean-up. Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Engelbrecht J, Bellstedt DU, Swart P and Jacobs EP (1996) The use of ultrafiltration for the purification of industrial waste waters with a high organic content: Membrane fouling and clean-up. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Gilfillan C, Barclay SJ, Law S and Buckley CA (1996) An assessment of the environmental performance of the textile industry in South Africa. Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Jacobs EP, Barnard JP and Saayman HM (1996) Capillary and nanofiltration membranes in waste-water management. Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Jacobs EP, Botes JP, Bradshaw S and Saayman HM (1996) Membrane filtration in potable water production. Paper presented at ICOM '96, The Int. Congr. on Membranes and Membrane Processes, Yokohama, Japan, 18-23 August.

- Jacobs EP, Botes JP, Burton SG, Leukes WD, Edwards W and Saayman HM (1996) Novel capillary membranes for waste-water bioremediation or potable water production. Paper presented at XIV IMS Natl. Symp. on Membranes in Chem. and Biochem. Industries, New Delhi. 16-17 February.
- Jacobs EP, Botes JP, Saayman HM, Bradshaw SM and Sanderson RD (1996) Crossflow ultrafiltration: A single-step approach to small and medium-scale rural watercare. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Jacobs EP, Pillay VL and De Villiers HA (1996) Ultrafiltration in potable water production. Paper presented at 2nd Afr. Water Conf., Midrand. 2-5 September.
- Leukes WD, Burton SG, Edwards W, Jacobs EP, Sanderson RD and Rose PD (1996) A critical investigation into the use of *Phanerochaete chrysosporium* in a hollow-fibre bioreactor for the degradation of aromatic pollutants. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Leukes WD, Jacobs EP, Burton SG, Edwards W, Sanderson RD and Rose PD (1996) Continuous production of lignin peroxidase by *Phanerochaete chrysosporium* in a capillary membrane bioreactor for the degradation of aromatic pollutants. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Leukes WD, Jacobs EP, Sanderson RD, Saayman HM, Burton SG and Rose PD (1996) Continuous production of lignin peroxidase by *Phanerochaete chrysosporium* in a novel capillary membrane bioreactor for the degradation of aromatic pollutants. Paper presented at ICOM '96, Yokohama, Japan. August.
- Rose PD, Burton SG, Sanderson RD, Jacobs EP, Leukes WD and Edwards W (1996) Membranes and biotechnology. Plenary lecture at 23rd SACI Conf., Cape Town.
- Rose PD, Edwards W, Leukes WD, Sanderson RD, Jacobs EP and Burton SG (1996) The application and integration of membrane processes in biotechnology. Paper presented at 2nd Afr. Water Conf., Midrand. 2-5 September.
- Sanderson RD (1996) Newer membrane materials and processes presently under investigation in South Africa. Paper presented at 33rd Conv. of the S. Afr. Chem. Inst., Univ. of Cape Town. 29 January – 2 February.
- Sanderson RD and Paul D (1996) The use of SPM in the manufacturing of membranes. Paper presented at 2nd S. Afr. SPM Workshop, Latest Developments in Scanning Probe Microscopy, Univ. of Stellenbosch. 6-9 February.
- Smith SPJ, Jacobs EP and Sanderson RD (1996) Preparation of novel composite zealite membranes. Paper presented at 2nd Afr. Water Conf., Midrand. 2-5 September.
- Swart P, Maartens A and Jacobs EP (1996) Fouling and the role of enzymes in membrane cleaning. Paper presented at 2nd Afr. Water Conf., Midrand. 2-5 September.
- Van der Walt A, Jacobs EP and Bradshaw SM (1996) A model for the performance of cellulose acetate tubular nanofiltration membranes. Poster presentation at 2nd Afr. Water Conf., Midrand. 2-5 September.
- Van der Walt A, Jacobs EP and Bradshaw SM (1996) A model for the performance of cellulose acetate tubular nanofiltration membranes. Paper presented at 2nd Afr. Water Conf., Midrand. 2-5 September.
- Van der Walt A, Jacobs EP and Bradshaw SM (1996) Optimization of cellulose acetate tubular nanofiltration membranes. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Van Zyl PW, Sanderson RD, Du Toit FJ and Jacobs EP (1996) Surface modification of fluoropolymer membranes. Paper presented at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May. Also at 2nd Afr. Water Conf., Midrand. 2-5 September.
- Van Zyl PW, Sanderson RD, Du Toit FJ and Jacobs EP (1996) Surface modification of fluoropolymer membranes. Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.

Articles and papers (1995)

- Burton SG, Edwards W, Leukes WD, Rose PD, Jacobs EP and Sanderson RD (1995) The effects of immobilisation of the activity of polyphenol oxidase in a hollow-fibre membrane bioreactor. Paper presented at Enzyme Eng. XIII, Meet. of the Eng. Foundation, San Diego.
- Burton SG, Leukes WD, Rose PD, Jacobs EP, Sanderson RD and Cross R (1995) A cytochemical method for localisation of lignin peroxidase in *Phanerochaete chrysosporium* biofilm immobilised on a hollow fibre membrane. Paper presented at 13th Congr. of the S. Afr. Biochem. Soc., Bloemfontein.
- Morkel CE, Sanderson RD and Jacobs EP (1995) Cellulose acetate membrane regeneration. Poster presentation at 1st Natl. Polymer Sci. Res. and Graduate Training Interest Group Workshop, Gordon's Bay. 22-24 November.
- Sanderson RD and Jacobs EP (1995) Environmental solutions for potable water. Paper presented at Seminar at the Peninsula Technikon, Cape Town. 15 September.

Report (1996)

- Swart P, Maartens A, Swart AC and Jacobs EP (1996) The Development of Characterising and Cleaning Techniques to Classify Foulants and to Remove them from Ultra- and Microfiltration Membranes by Biochemical Means. WRC Report No. 531/1/96.

HYDROCLIMATOLOGY

Articles and papers (1996)

- Ansorge I, Lutjeharms JRE, Cooper J, Roberts M and Rouault M (1996) Variability of the eastern Agulhas bank cell. Paper presented at 9th South. Afr. Marine Sci. Symp., Cape Town. 21-23 November.
- Crimp SJ (1996) Simulating sea-surface temperature effects on Southern African rainfall using a mesoscale numerical model. Paper presented at the 13th Annu. Conf. of the SA Soc. for Atmos. Sci., Cape Town. 30 October – 1 November.
- D'Abreton PC (1996) Lagrangian kinematic and isentropic trajectory models for aerosol and trace gas transport studies in Southern Africa. *S. Afr. J. of Sci.* **92** 157-160.

- D'Abreton PC and Tyson PD (1996) Three-dimensional kinematic trajectory modelling of water vapour transport over Southern Africa. *Water SA* **22** (4) 297-306.
- Fletcher L and Steffens FE (1996) Outcome of the National Precipitation Research Programme. Paper presented at SASA Conf., Stellenbosch. 6-8 November.
- Fletcher L and Steffens FE (1996) The use of permutation techniques in evaluating the outcome of a randomized storm seeding experiment. *J. of Appl. Meteorol.* **35** (9) 1546-1550.
- Hewitson BC (1996) Climate change scenarios: Short-term variability over South Africa. Paper presented at the 13th Annu. Conf. of the SA Soc. for Atmos. Sci., Cape Town. 30 October – 1 November.
- Hewitson BC (1996) Downscaling for regional climate change impacts. Paper presented at the 13th Annu. Conf. of the SA Soc. for Atmos. Sci., Cape Town. 30 October – 1 November.
- Hewitson BC (1996) Seminar on regional climate change implications for Southern Africa, Univ. of Northern Colorado. Paper presented at the 13th Annu. Conf. of the SA Soc. for Atmos. Sci., Cape Town. 30 October – 1 November.
- Hewitson BC (1996) Seminar on downscaling regional climate change scenarios, UK Meteorological Organization. Paper presented at the 13th Annu. Conf. of the SA Soc. for Atmos. Sci., Cape Town. 30 October – 1 November.
- Joubert A and Tyson PD (1996) Equilibrium and coupled GCM simulations of future Southern African climates. *S. Afr. J. Sci.* **92** 471-484.
- Jury MR (1996) Regional teleconnection patterns associated with summer rainfall over South Africa, Namibia and Zimbabwe. *Int. J. Climatol.* **16** 135-153.
- Jury MR and Levey KM (1996) Vertical structure of the wet spells over southern Africa and contribution by westerly waves. Paper presented at the 13th Annu. Conf. of the SA Soc. for Atmos. Sci., Cape Town. 30 October – 1 November.
- Jury MR, Pathack BMR, Rautenbach CJdeW and Van Heerden J (1996) Drought over South Africa and Indian Ocean SST: Statistical and GCM results. *Global Atmos. and Ocean System* **4** 47-63.
- Lee-Thorp A, Rouault M and Lutjeharms JRE (1996) Air-sea interaction in the Agulhas current system. Paper presented at 9th South. Afr. Marine Sci. Symp., Cape Town. 21-23 November.
- Majodina M, Raouault M and Jury MR (1996) Tropical air-sea interactions during a cruise in the Central Indian Ocean. Paper presented at 9th South. Afr. Marine Sci. Symp., Cape Town. 21-23 November.
- Mather GK and Terblanche DE (1996) Hygroscopic seeding – The development of a new convective cloud seeding technology. Paper presented at the Workshop on Theoretical and Practical Aspects of a Regional Precipitation Enhancement Programme for the Middle East and Mediterranean, Bari, Italy. 11-15 November.
- Mather GK, Dixon MJ and De Jager JM (1996) Assessing the potential for rain augmentation – The Nelspruit randomised convective cloud seeding experiment. *J. Appl. Meteor.* **36**.
- Mather GK, Terblanche DE and Steffens FE (1996) Results of the South African cloud seeding experiments using hygroscopic flares. *Proc. 13th Conf. on Planned and Inadvertent Weather Modification*, Atlanta, Georgia. 121-128.
- Nel C, Van Heerden J and Olivier J (1996) Meteorological features of orographic clouds along the eastern escarpment of South Africa. Paper presented at the 13th Annu. Conf. of the SA Soc. for Atmos. Sci., Cape Town. 30 October – 1 November.
- Rautenbach CJdeW (1996) The CSIRO-9(T63) GISST run and the rainfall of South Africa. Paper presented at the 13th Annu. Conf. of the SA Soc. for Atmos. Sci., Cape Town. 30 October – 1 November.
- Rautenbach CJdeW and Van Heerden J (1996) The characteristics of the anomalous rainfall and sea surface temperature fields that occurred over the Southern African region during the 1995/96 summer season. Paper presented at the 13th Annu. Conf. of the SA Soc. for Atmos. Sci., Cape Town. 30 October – 1 November.
- Rouault M, Lee-Thorp A and Lutjeharms JRE (1996) Air-sea interaction above the Agulhas current. *Proc. 8th Conf. on Air-sea Interaction*, 76th Am. Meteorol. Conf., Atlanta. 28 January – 2 February. 1-6.
- Rouault M, Lee-Thorp A and Lutjeharms JRE (1996) Boundary layer modification above the Agulhas current. *Proc. of Conf. on Meteorol. and Oceanogr. of the Coastal Zone*, 76th Am. Meteorol. Conf., Atlanta. 28 January – 2 February.
- Rouault M, Lee-Thorp A, Ansorge I and Lutjeharms JRE (1996) The Agulhas Current air-sea exchange experiment. Paper presented at 9th South. Afr. Marine Sci. Symp., Cape Town. 21-23 November.
- Steffen FE and Fletcher L (1996) Finding a basis of comparison in operational seeding programmes. Poster presentation at the Workshop on Rainfall Enhancement, Bari, Italy. 11-15 November.
- Steffens FE and Fletcher L (1996) Statistical aspects of the evaluation of an operational cloud seeding project. Paper presented at the 13th Conf. of the SA Soc. for Atmos. Sci., Cape Town. 31 October – 1 November.
- Stuart JF (1996) Observed drop size distributions (DSDs) for convective and stratiform precipitating cloud over the northern Free State using a RD-69 disdrometer and AD-96 analyser. Paper presented at the 13th Annu. Conf. of the SA Soc. for Atmos. Sci., Cape Town. 30 October – 1 November.
- Terblanche DE (1996) A simple digital signal processing method to simulate linear and quadratic responses from a radar's logarithmic receiver. *J. Atmos. Ocean Technol.* **13** (2) 533-538.
- Terblanche DE, Mittermaier MP, Kroese NJ and Adam BF (1996) The February 1996 flood event: A radar, rain-gauge and streamflow perspective. Paper presented at the 13th Conf. of the SA Soc. for Atmos. Sci., Cape Town. 31 October – 1 November.
- Van Heerden J (1996) Prediction of the summer rainfall over South Africa. *J. of Clim.* **8** (6).

Report (1996)

- Jury MR, Levey KM and Makarau A (1996) Mechanisms of Short Term Rainfall Variability over Southern Africa. WRC Report No. 436/1/96.

Thesis

- Van den Heever S (1996) Modelling Tropical-Temperate Troughs over Southern Africa. M.Sc. Thesis, Climatol. Res. Group, Univ. of the Witwatersrand.

SURFACE HYDROLOGY

Articles and papers (1996)

- Basson GR and Rooseboom A (1996) Flushing channel deformation during high flow drawdown flushing. *Proc. of Int. Conf. on Reservoir Sedimentation*, Colorado State Univ., Fort Collins, USA.
- Basson GR and Rooseboom A (1996) Reservoir Sedimentation Engineering Handbook. Chapter 7.3: Remedial Measures and Impacts. *Proc. of Int. Conf. on Reservoir Sedimentation*, Colorado State Univ., Fort Collins, USA.
- Basson GR, Rooseboom A and Olesen KW (1996) Mathematical modelling of reservoir flushing. *Proc. of Int. Conf. on Reservoir Sedimentation*, Colorado State Univ., Fort Collins, USA.
- Campbell LA (1996) Comparison of the trends predicted by QUALZE and WITQUAL water quality models with observed Jukskei River instream data. *Proc. 7th Int. Conf. on Urban Storm Drainage*, Hannover.
- Coleman TJ (1996) Description of an expert system for the management of urban runoff. *Proc. 7th Int. Conf. on Urban Storm Drainage*, Hannover.
- Coleman TJ, MacKay HM and Campbell LA (1996) Development of a tool for the management of urban runoff in South Africa. Paper presented at 2nd Conf. of Environ. Management Technol. and Develop., Environ. Eng. Div., SAICE.
- Downing TE, Kiker GA and Schulze RE (1996) Climate Change and Agriculture in Southern Africa. Final Report to Climate Research Unit, Univ. of East Anglia, UK. 27 pp.
- Esprey IJ and Lorentz SA (1996) Hillslope soil moisture budgeting experiment in the North East Cape: Phase 1. Paper presented at Symp. of SA Inst. of Agric. Eng., Pretoria.
- Herpertz D, Flügel WA and Schulze RE (1996) Application and validation of the ACRU agrohydrological modelling system in Germany. Paper presented at Symp. of the Eur. Geophys. Soc., Den Haag, The Netherlands.
- Hughes DA (1996) Groot River Basin, Eastern Cape, Republic of South Africa. In: *Water Resource Management and Desertification: Problems and Challenges.* World Meteorol. Organ., Geneva, Switzerland. 169-180.
- Hughes DA (1996) The rainfall-runoff modelling sub-programme of the southern African FRIEND project. Paper presented at the 12th Journees Hydrologiques de L'ORSTOM, Montpellier, France. October.
- Hughes DA and Smakhtin VY (1996) Daily flow data time series patching or extension, a spatial interpolation approach based on flow duration curves. *Hydrol. Sci. J.* **41** (6) 851-871.
- Joubert A and Leiman A (1996) Multi-criteria and cost-benefit analysis in the developing world: A critical evaluation. Paper presented at the Int. Conf. on Ecol., Soc., Econ., Paris. May.
- Kelbe BE and Rawlins BK (1996) Specialist Study on Hydrology and Water Quality. Iscor Heavy Minerals Environmental Impact Assessment, CSIR Environmental Services, Pretoria.
- Kiker GA and Schulze RE (1996) Using Savanna ecosystem models to explore alternatives to the concept of carrying capacity. Paper presented at the Grassland Soc. of South. Afr. Congr. 31, Nelspruit, Mpumalanga.
- Lecler NL (1996) A crop yield rainfall prediction interface. Paper presented at a Univ. of Zimbabwe and Wageningen Agric. Univ. Workshop on "Water for Agriculture", Harare, Zimbabwe.
- Lecler NL (1996) Generation of maize yield forecasts from seasonal, categorical rainfall forecasts. Paper presented at Symp. of SA Inst. of Agric. Eng., Pretoria.
- Lecler NL (1995) The *ACRU* agrohydrological modelling system. Paper presentated at the Int. Res. Inst. for Climate Prediction Pilot Project Training Course, Columbia Univ., New York, USA.
- Lecler NL, Pike AP and Schulze RE (1996) Seasonal forecast weather builder for generating agricultural and hydrological forecasts from rainfall forecasts. Paper presented at NOAA Workshop on Applications of Seasonal Forecasts in South. Afr., Victoria Falls, Zimbabwe.
- Lorentz SA, Ballim F and Pretorius JJ (1996) Estimation of Soil Water Flux in Forest Soils in the Sabie Region. *ACRUcons* Report **10** to CSIR Forestek, Nelspruit.
- Lorentz SA, Hughes GO and Schulze RE (1996) Various techniques for estimating groundwater recharge at different scales in Southern Africa. Paper presented at the WRC Workshop on Groundwater-Surface Water Issues in Arid and Semi-Arid Areas, Warmbaths.
- Lynch SD and Schulze RE (1996) Digital agrohydrological atlas for southern Africa. Paper presented at 1996 ESRI User Conference, Palm Springs, CA, USA. (Available from http://www.ccwr.ac.za/~lynch2/p308.html).
- Lynch SD, Lecler NL and Schulze RE (1996) Using real-time hydrological data. Paper presented at 1996 ESRI User Conf., Palm Springs, CA, USA. (Available from http://www.ccwr.ac.za/~lynch2/p307.html).
- McKenzie RS and Craig AR (1996) Suitability of Tracers for Estimating Irrigation Return Flow Residence Times. Report by BKS (Inc.)
- Moreira P (1996) Flood calculations using a spreadsheet to generate hydrographs. *SAICE Journal* **38** (2) 29-32.
- Pike A and Schulze RE (1996) Low flow analysis. Addendum to the report *Hydrological Impacts Assessment of Proposed Afforestation in the Franklin Area.* Report to Venter Forestry Services, Pietermaritzburg.
- Rooseboom A and Basson GR (1996) Lessons learned from case studies on reservoir sedimentation in Southern Africa. *Proc. of Int. Conf. on Reservoir Sedimentation*, Colorado State Univ., Fort Collins, USA.
- Schulze RE (1996) Agrohydrological modelling across a range of scales for integrated catchment management applications. Paper presented at Potsdam Inst. for Climate Impact Res., Berlin, Germany.
- Schulze RE (1996) Coping with conflict, or "The future is not what it used to be". Keynote address to Natal Ten Ton Maize Soc.
- Schulze RE (1996) Managing an uncertain future: An agro-hydrologist's perspective on possible impacts of climate change in Southern Africa. Invited keynote address, Zool. Soc. of SA Symp.
- Schulze RE (1996) Techniques for mapping hydrometeorological and ecological interactions at varying scales in the Drakensberg mountain range of South Africa. Paper presented at Int. Conf. on Ecohydrol. of High Mountain Areas, Kathmandu, Nepal.
- Schulze RE (1996) Transcending scales of space and time in agro-hydrological modelling under conditions of present and perturbed climates. Invited opening address at SA Soc. of Atmos. Sci. Symp., Cape Town. 31 October – 1 November.

- Schulze RE and Kiker GA (1996) Crop and biomass modelling in mountainous terrain: Considerations, problems, challenges. Invited keynote address at IGBP-BAHC/GCTE Workshop on Global Change Impacts on Mountain Hydrol. and Ecol., Kathmandu, Nepal.
- Schulze RE, Kienzle SW and Lorentz SA (1996) Simulating the impacts of land use and cover change on hydrological responses in the Mgeni catchment of South Africa with the *ACRU* modelling system. Paper presented at IGBP-LUCC Open Science Meeting Land-Use and Land-Cover Change, Amsterdam, Netherlands.
- Schulze RE, Kiker GA, Howe BJ and Meier KB (1996) Water resources hindcasts: A spatial study over South Africa of hydrological responses in El Niño, La Niña and "average" years. Paper presented at NOAA Workshop on Applications of Seasonal Forecasts in South. Afr., Victoria Falls, Zimbabwe.
- Schulze RE, Kiker GA and Kunz RP (1996) Global climate change and agricultural productivity in Southern Africa. Thought for food and food for thought. In: Downing, TE (ed.) *Climate Change and World Food Security.* Springer Verlag, Berlin. 421-448.
- Schulze RE, Pike A and Fourie A (1996) Assessment of Hydrological Impacts of Proposed Afforestation in the Nyambathi Catchment. *ACRU*cons Report **9** to Venter Forestry Services, Pietermaritzburg. 35 pp.
- Schulze RE, Pike A, Lecler NL, Esprey IJ, Howe BJ and Zammit RM (1996) Hydrological Impacts of Land Use Practices in the Pongola-Bivane Catchment. *ACRU*cons Report **11** to Forest Ind. Assoc., Pietermaritzburg. 49 pp.
- Scott L (1996) Water policy planning through scenario analysis. Paper presented at 14th Trienn. Conf. of the Int. Fed. of Oper. Res. Soc., Vancouver, Canada. July.
- Smithers JC (1996) An Initial Assessment of SWAT as a Hydrological Modelling Tool for the Mid-western USA. Report to Agric. and Biol. Eng. Dept., Purdue Univ., West Lafayette, Indiana, USA.
- Smithers JC (1996) Indian Pine Watershed Project: Data Assessment, Adjustment, Processing and Monitoring Procedures. Report to Agric. and Biol. Eng. Dept., Purdue Univ., West Lafayette, Indiana, USA.
- Smithers JC (1996) Short-duration rainfall frequency model selection in Southern Africa. *Water SA* **22** (3) 211-217.
- Smithers JC and Engel BA (1996) An initial assessment of SWAT as a hydrological modelling tool for the Mid-West USA. ASAE Paper No. 96-2065, St Joseph, Michigan, USA.
- Smithers JC and Schulze RE (1996) Modelling the Impacts of Grassland, Forestry and Sugarcane on Runoff at the Umzinto Research Catchments. *ACRU*cons Report **12** to SA Sugar Assoc. Experiment Station, Mt. Edgecombe. 24 pp.
- Stephenson D (1996) Evaluation of the effects of urbanization on storm runoff. *Proc. 7th Int. Conf. on Urban Storm Drainage*, Hannover.
- Stewart TJ (1996) Relationships between data envelopment analysis and multicriteria decision analysis. *J. of the Oper. Res. Soc.* **47** 654-665.

Reports (1996)

- Coleman TJ and Simpson DE (1996) Adaptation and Calibration of an Urban Runoff Quality Model. WRC Report No. 299/1/96.
- Department of Water Affairs and Forestry and the Water Research Commission (1996) The Philosophy and Practice of Integrated Catchment Management: Implications for Water Resource Management in South Africa. WRC Report No. TT 81/96.
- Van Riet WF and Slabbert SA (1996) The Ability of Catchment Basins to Supply the Water Demands of Rural and Urban Areas. WRC Report No. 680/1/96.
- Zawada PK, Hattingh J and Van Bladeren D (1996) Paleoflood Hydrological Analysis of Selected SA Rivers. WRC Report No. 509/1/96.
- Zietsman HL, Vlok AC and Nel I (1996) The Identification of Irrigated Land in an Intense Cultivated Agricultural Area in the South-Western Cape by Means of Satellite Remote Sensing. WRC Report No. 440/1/96.

Theses

- Basson GR (1996) Hydraulics of Reservoir Sedimentation. Ph.D. Dissertation, Univ. of Stellenbosch.
- Campbell LA (1996) A study of Stormwater Runoff from Alexandra Township in the Jukskei River. M.Sc. Thesis, Dept. of Civil Eng., Univ. of the Witwatersrand.
- Lotriet HH (1996) River Discharge Measurement at South African Compound Weirs in Rivers with High Sediment Loads: An Improved Method of Measurement. Ph.D. Thesis, Dept. of Civil Eng., Univ. of Stellenbosch.
- Salberg DB (1996) An Improved System for the Cost Effective Removal of Storm Water from the Surface of Roads on Steep Gradients. M.Sc. Thesis, Dept. of Civil Eng., Univ. of the Witwatersrand.
- Savo R (1995) Soil Water Content Evaluation Through Time Domain Electromagnetics. M.Sc. Thesis, Dept. of Electronic Eng., Univ. of Natal, Pietermaritzburg.
- Savvas AC (1996) Assessment of the Bowen Ratio Method for Catchment Water Balance. M.Sc. Thesis, Dept. of Civil Eng., Univ. of the Witwatersrand.
- Summerton MJ (1996) Process and Modelling Studies in Forest Hydrology. M.Sc. Dissertation in Hydrology, Dept. of Agric. Eng., Univ. of Natal, Durban.
- Wessels P (1996) The Calibration of Compound Crump and Sharp-crested Weirs in South Africa. Ph.D. Thesis, Dept. of Civil Eng., Univ. of Stellenbosch.

WATER ECOSYSTEMS

Articles and papers (1996)

- Adams JB and Bate GC (1996) Are microalgae important in marine dominated estuaries? Paper presented at the 13th Congr. of the Phycol. Soc. of South. Afr., Meerensee, Hermanus. 21-24 January.
- Adams JB, Coetzee JC and Bate GC (1996) Saltmarshes – A threatened habitat. Poster presentation at the ECSA 26 and ERF 96 Symp., Middelburg, The Netherlands.
- Alcock PG (1996) Sources of environmental information in South Africa. Paper presented at Environ. History Workshop, Univ. of Natal, Pietermaritzburg. 8-10 July.
- Bate GC and Adams JB (1996) The interpretation of microalgal distribution in Cape estuaries. Paper presented at the 13th Congr. of the Phycol. Soc. of South. Afr., Meerensee, Hermanus. 21-24 January.
- Biggs HC, O'Keeffe JH and Görgens AHM (1996) Information systems management in overall programme function – A case study from the Rivers Research Programme. Paper presented at Victoria Falls Int. Conf. on Aquatic Systems, Victoria Falls, Zimbabwe. 15-19 July.
- Birkhead AL, Heritage GL, White H and Van Niekerk AW (1996) Ground-penetrating radar as a tool for mapping the phreatic surface, bedrock profile and alluvial stratification in the Sabie River, Kruger National Park. *J. of Soil and Water Conserv.* **51** (3).
- Birkhead AL, Van Coller AL and James CS (1996) Modelling water availability to riparian vegetation in an impacted river system. *Proc. of the 2nd IAHR Symp. on Habitat Hydraulics, Ecohydraulics 2000.* A121-A132.
- Coetzee JC, Adams JB and Bate GC (1996) A botanical importance rating system for estuaries. *J. of Coastal Conserv.* December.
- Davies BR, O'Keeffe JH and Snaddon CD (1995) River and stream ecosystems in Southern Africa: Predictably unpredictable. In: Cushing CE, Cummins KW and Minshall GW (eds.) *River and Stream Ecosystems*, Elsevier Press, New York.
- Davies BR, Snaddon K and Wishart M (1996) Some implications of inter-basin water transfers for river functioning and water resources management in Southern Africa. Paper presented at SASAQS Vic Falls Conf. on Aquatic Systems. July.
- Heritage GL and Van Niekerk AW (1995) Drought conditions and sediment transport in the Sabie River. *Koedoe* **38** (2).
- Heritage GL, Van Niekerk AW and Weeks D (1996) A model of fish assemblage response to hydraulic and fluvial geomorphological change in a pool-rapid channel type. *Proc. of the 2nd IAHR Symp. on Habitat Hydraulics, Ecohydraulics 2000.* A355-A366.
- James CS, Nicolson CR, Van Niekerk AW and Heritage GL (1996) Modelling the response of river geomorphology and riverine vegetation to water resources development in the Sabie River, South Africa. *Proc. of the 2nd IAHR Symp. on Habitat Hydraulics, Ecohydraulics 2000.* A331-A342.
- King J and Louw D (1996) Assessment of instream flow requirements for regulated rivers in South Africa using the Building Block Methodology. Paper presented at SASAQS Vic Falls Conf. on Aquatic Systems. July.
- Nortjè I and Van Vuren JHJ (1996) The use of hepatic variables as biological indicators of stress in an aquatic environment. *Proc. of Vic Falls Conf. on Aquatic Systems*, Zimbabwe. 15-19 July.
- Nortjè I en Van Vuren JHJ (1996) Die gebruik van hepatiese veranderlikes as biologiese indikatore van stres in 'n akwatiese omgewing. Referaat gelewer by Jaarkongr., S.-Afr. Akad. vir Wet. en Kuns, Afdeling Biol., Pretoria. 18-19 Junie.
- Nussey G en Van Vuren JHJ (1996) Die effek van koper en sink op die hematologie van die bloukurper, *Oreochromis mossambicus.* Referaat gelewer by Jaarkongr., S.-Afr. Akad. vir Wet. en Kuns, Afdeling Biol., Pretoria. 18-19 Junie.
- Nussey G, Van Vuren JHJ and Du Preez HH (1996) Acute toxicity tests of copper on juvenile Mozambique tilapia, *Oreochromis mossambicus* (Cichlidae) at different temperatures. *S. Afr. J. Wildl. Res.* **26** (2) 47-55.
- Nussey G, Van Vuren JHJ and Du Preez HH (1996) The effect of copper and zinc on the haematology and osmoregulation of the Mozambique tilapia (*Oreochromis mossambicus*). *Proc. of Vic Falls Conf. on Aquatic Systems*, Zimbabwe. 15-19 July.
- Nussey G, Van Vuren JHJ and Du Preez HH (1996) The effect of copper and zinc on the blood coagulation of the Mozambique tilapia. (*Oreochromis mossambicus*). *Proc. of Vic Falls Conf. on Aquatic Systems*, Zimbabwe. 15-19 July.
- O'Keeffe JH (1996) Review of Phases I and II, KNPRRP. Paper presented at the Strategic Planning Workshop for Phase III of the Kruger National Park Rivers Research Programme, Broederstroom. 4 July.
- O'Keeffe JH (1996) Southern hemisphere methods of assessing conservation status for natural freshwaters. In: Boon P (ed.) *Water Quality, Defining the Indefinable*, Wiley and Sons, Chichester.
- O'Keeffe JH (1996) The benthic invertebrates of the Sabie-Sand River system. Paper presented at the Sabie-Sand Instream Flow Requirement Workshop, Aan de Vliet, Mpumalanga. 18-22 August.
- Rowntree KM and Wadeson RA (1996) A geomorphological framework for sustainable management of South African Rivers. Paper presented at SASAQS Vic Falls Conf. on Aquatic Systems. July.
- Rowntree KM and Wadeson RA (1996) Translating channel morphology into hydraulic habitat: Application of the hydraulic biotope concept to an assessment of discharge related habitat changes. *Proc. 2nd IAHR Int. Symp. on Hydraulics and Habitats*, Quebec City. 11-14 June.
- Rowntree KM, Wadeson RA and McGregor GK (1996) Geomorphology. In: Brown C (ed.) *Towards A Spatial Framework to Facilitate the Selection of Monitoring and Reference Sites for A National Biomonitoring Programme.* CSIR and Department of Water Affairs and Forestry, Pretoria.
- Sanders MJ, Du Preez HH and Van Vuren JHJ (1996) The freshwater river crab, *Potamonautes warreni*, as a biological indicator of metal pollution. *Proc. of Vic Falls Conf. on Aquatic Systems*, Zimbabwe. 15-19 July.
- Seymore T, Du Preez HH and Van Vuren JHJ (1996) Concentration of chromium and nickel in *Barbus marequensis* A Smith, 1841 from the lower Olifants River, Mpumalanga. *SA J. Zool.* **31** (3).
- Seymore T, Du Preez HH and Van Vuren JHJ (1996) Concentrations of zinc in *Barbus marequensis* from the lower Olifants River, Mpumalanga, South Africa. *Hydrobiol.* **332** 141-150.

- Slinger J, Adams J, Bate G, Boroto J, Busse J, Hearne J, Huizinga P and Quinn N (1996) A linked modelling system as a predictive tool for estuarine management. Paper presented at Vic Falls Conf. on Aquatic Systems, Victoria Falls, Zimbabwe. 15-19 July.
- Slinger JH and Taljaard S (1996) Water Quality Modelling in the Management of Estuaries. Paper presented at Vic Falls Conf. on Aquatic Systems, Victoria Falls, Zimbabwe. 15-19 July.
- Slinger JH and Taljaard S (1996) Water Quality Modelling of Estuaries. Field Data Collection for Calibrating the Mike 11 Water Quality Module on the Great Berg Estuary. CSIR Report EMAS-D 96002. 25 pp.
- Tharme R (1996) Effects of low flows on benthic macroinvertebrates inhabiting the upper reaches of perennial Cape rivers. Paper presented at SASAQS Vic Falls Conf. on Aquatic Systems. July.
- Tharme R (1996) Synopsis of international methodologies for the quantification of the instream flow requirements of rivers. Paper presented at SASAQS Vic Falls Conf. on Aquatic Systems. July.
- Uys MC and O'Keeffe JH (1996) Simple words and fuzzy zones: Early directions for temporary river research in South Africa. *Environ. Manage.*
- Uys MC and O'Keeffe JH (1996) Trials of life in temporary streams in the eastern Cape. An assessment of the effects of flow variability. Paper presented at Victoria Falls Int. Conf. on Aquatic Systems, Victoria Falls, Zimbabwe. 15-19 July.
- Van der Molen J, Adams JB and Bate GC (1996) Diatoms as indicators of water quality in a riverine/estuarine system. Poster presentation at the 13th Congr. of the Phycol. Soc. of South. Afr., Meerensee, Hermanus. 21-24 January.
- Van Vuren JHJ (1996) Fish haematology and the refinement of water quality guidelines. Paper presented at 2nd Afr. Water Conf., Midrand. 2-5 September.
- Van Vuren JHJ, Du Preez HH and Deacon AR (1996) Assessment of river pollution in a national park. Technical delegation on the Environment, People to People Ambassador Programme, USA, Peoples Republic of China. June.
- Wadeson RA and Rowntree KM (1996) The development and testing of a standardised technique for the classification of hydraulically distinct instream flow environments. Paper presented at SASAQS Vic Falls Conf. on Aquatic Systems. July.

Articles and papers (1995)

- Bate JB, Coetzee JC and Adams JB (1995) A botanical importance rating system for estuaries. Paper presented at the 25th Annu. Symp. of the Estuarine and Coastal Sci. Assoc., Trinity College, Dublin, Ireland.
- Coetzee JC, Adams JB and Bate GC (1995) A botanical importance rating system for Cape estuaries. Paper presented at the ZSSA and SASAQS Symp., Rhodes Univ., Grahamstown.
- Home IF (1995) The use of microalgae as indicators of eutrophication by urban runoff at the Motherwell canal on the Swartkops estuary. Unpublished third-year project, Dept. of Botany, Univ. of Port Elizabeth. 34 pp.
- Van Niekerk AW, Heritage GL and Moan BP (1995) River classification for management: The geomorphology of the Sabie River. *S. Afr. Geogr. J.* 77 (2).

Reports (1996)

- O'Keeffe JH and Coetzee Y (1996) Status Report on the Kruger National Park Rivers Research Programme: A Synthesis of Results and Assessment of Progress to January 1996. WRC Report No. 711/1/96.
- O'Keeffe JH, Weeks DC, Fourie A and Davies BR (1996) A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with Special Reference to Predicted Impacts on the Kruger National Park. Vol 3: The Effects of Proposed Impoundments and Management Recommendations. WRC Report No. 294/3/96.
- Palmer CG, Goetsch PA and O'Keeffe JH (1996) Development of a Recirculating Artificial Stream System to Investigate the Use of Macro-invertebrates as Water Quality Indicators. WRC Report No. 475/1/96.
- Weeks DC, O'Keeffe JH, Fourie A and Davies BR (1996) A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with Special Reference to Predicted Impacts on the Kruger National Park. Vol 1: The Ecological Status of the Sabie-Sand River System. WRC Report No. 294/1/96.

Reports (1995)

- Allanson BR (1995) An Introduction to the Management of Inland Water Ecosystems in South Africa. WRC Report No. TT 72/95.
- King JM, O'Keeffe JH, Pollard S, Tharme RE and Weeks D (1995) Assessment of Environmental Water Requirements for Selected South African Rivers: Problems and Possible Approaches. WRC Report No. KV 72/95.
- Pearce K, Snyman H, Van Heerden H, Greben H and Oellermann RA (1995) Bioremediation Technology for the Treatment of Contaminated Soil in South Africa. WRC Report No. 543/1/95.
- Van der Heever JA and Grobbelaar JU (1995) The Use of Algae in Bioassays to Detect the Presence of Toxic Compounds in Natural Waters. WRC Report No. 393/1/95.
- Whitfield AK (1995) Available Scientific Information on Individual South African Estuarine Systems. WRC Report No. 577/1/95.

Theses

- Coetzee JC (1995) Classification of South African Estuaries Based on Plant Communities. M.Sc. Thesis, Dept. of Bot., Univ. of Port Elizabeth. 117 pp.
- Coetzee L (1996) Bioaccumulation of Metals in Selected Fish Species and the Effect of pH on Aluminium Toxicity in a Cichlid *Oreochromis mossambicus*. M.Sc. Thesis, Rand Afr. Univ.

MINE-WATER MANAGEMENT

Reports (1996)

- Maree JP, Van Tonder GJ and Millard P (1996) Underground Neutralisation of Mine Water with Limestone. WRC Report No. 609/1/96.
- Pulles W, Howie D, Otto D and Easton J (1996) A Manual on Mine Water Treatment and Management Practices in South Africa. WRC Report No. TT 80/96.
- Pulles W, Howie D, Otto D and Easton J (1996) A Manual on Mine Water Treatment and Management Practices in South Africa. Appendix Volume 1. Literature Reviews. WRC Report No. 527/1/96.
- Pulles W, Howie D, Otto D and Easton J (1996) A Manual on Mine Water Treatment and Management Practices in South Africa. Appendix Volume 2. Coal Mine Site Visit Reports. WRC Report No. 527/2/96.
- Pulles W, Howie D, Otto D and Easton J (1996) A Manual on Mine Water Treatment and Management Practices in South Africa. Appendix Volume 3. Gold Mine Site Visit Reports. WRC Report No. 527/3/96.
- Pulles W, Howie D, Otto D and Easton J (1996) A Manual on Mine Water Treatment and Management Practices in South Africa. Appendix Volume 4. Overseas Study Tour Report. WRC Report No. 527/4/96.
- Pulles W, Howie D, Otto D and Easton J (1996) Management Practices in South Africa. Appendix Volume 5. Catalogue of Relevant WRC Report. WRC Report No. 527/5/96.

GENERAL

Articles and papers (1996)

- Buckley CA (1996) Interwater – An electronic information server for water supply and environmental sanitation in developing countries. Paper presented at Int. Symp. on Environ. Technol.: Applications in Principle and Practice, Merdeka Univ., Melang, Indonesia. 1-3 July.
- Buckley CA and Hurt QE (1996) Why water scientists and engineers need to use the Internet. Poster presentation at WISA Bienn. Conf. and Exhibition, Port Elizabeth. 20-23 May.
- Buckley CA and Loveday BK (1996) Legislation on water pollution in South Africa and an overview of research work on water and mineral processing in the Department of Chemical Engineering, University of Natal. Tech. presentation at Gen. Meet. of the S. Afr. Inst. of Mining and Metallurgy, Natal Branch, Westville, Durban.
- Offringa G and De Wet G (1996) A quality of life-based decision support model for the determination of water research priorities. *Water SA* 22 (4) 359-372.

Articles and papers (1995)

- Barnett JJ (1995) Residence time distribution. Paper presented at Appl. Pollution Res. Symp., WISA Water Scientists, Technikon Natal. 24 August.

Reports (1996)

- Uys M (1996) A Structural Analysis of the Water Allocation Mechanism of the Water Act 54 of 1956 in the Light of the Requirements of Competing Water User Sectors with Special Reference to the Allocation of Water Rights for Ecobiotic Requirements and the Historical Development of the South African Water Law: Volume I. WRC Report No. 406/1/96.
- Uys M (1996) A Structural Analysis of the Water Allocation Mechanism of the Water Act 54 of 1956 in the Light of the Requirements of Competing Water User Sectors with Special Reference to the Allocation of Water Rights for Ecobiotic Requirements and the Historical Development of the South African Water Law: Volume II. WRC Report No. 406/2/96.

Thesis

- Offringa G (1996) Decision Support Model for the Determination of Water Research Priorities. Ph.D. Thesis, Univ. of Pretoria.

MISSION STATEMENT 1996

To contribute effectively to the best possible quality of life for the people of South Africa, by promoting water research and the application of research findings.

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- Promote co-ordination, communication and co-operation in the field of water research
- Establish water research needs and priorities
- Fund water research on a priority basis
- Promote effective transfer of information and technology.